# WEGENER 2010
# 15th General Assembly of Wegener

## Programme and Book of Abstracts


September 14-17, 2010, Istanbul, Turkey

WEGENER 2010 is organised by the Geodesy Department of Kandilli Observatory and Earthquake Research Institute of Bogazici University

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# 1 Welcome Address

Dear Colleagues,

On behalf of the scientific and the organizing committee we like to welcome and introduce your contributions to the 15th general Assembly of WEGENER in Istanbul, Turkey. Istanbul has been designated by the European Union the 2010 European Capital of Culture. The conference will take place in the Albert Long Hall Conference Center of the Bogazici University. This building, built in 1891, was designed by Alfred Hamlin, son of Cyrus Hamlin, the founder of the Robert College.

WEGENER is the acronym for **W**orking Group of **E**uropean **G**eoscientists for the **E**stablishment of **N**etworks for **E**arth-science **R**esearch. It was founded in March 1981 in response to an appeal delivered at the Journées Luxembourgeoises de Geodynamique in December 1980 to respond with a coordinated European proposal to a NASA Announcement of Opportunity inviting participation in the Crustal Dynamics and Earthquake Research Program. WEGENER was organized as voluntary coordinating body with membership open to any organization actively engaged in research aiming to achieve a better understanding of kinematics, crustal dynamics and of processes leading to earthquakes in Europe and the Mediterranean area. With this 15th general Assembly, we celebrate the 30$^{th}$ anniversary of the project. Within WEGENER, the MEDLAS project (MEDiterrenean LASer), addressing the kinematics of the plate boundary region extending from the central Mediterranean to eastern Turkey and the Jordan Rift, was one of the most important developments involving field activities as well as data analysis and interpretation. Satellite Laser Ranging (SLR) from a selected number of field stations, several of them in Turkey, made it possible to determine reliably the rate of plate movements in this area characterized by high risks of natural disasters.

WEGENER has evolved through the years both as regards science and technology. The development of GPS led to the densification of the large-scale SLR network in the central-eastern Mediterranean allowing to achieve new fundamental insights in the knowledge of the deformations occurring in the interior of the plates, in particular as regards the eastern Mediterranean in Greece and Turkey.

At present, WEGENER is established as the Inter-commission Project 3.2, between Commission 1 and Commission 3, of the International Association of Geodesy (IAG). The mission of WEGENER is the development of interdisciplinary work for the integration of space and terrestrial techniques in the study of the Eurasian/African plate boundary deformation zone and adjacent areas, including the establishment of an European velocity field, by promoting international cooperation and by being a Forum for European and other Earth-Scientists interested in the Eurasian/African plate boundary zone.

Nowadays, the awareness on the status of the Earth and on the environmental changes taking place, have made it clear that our capability to observe the planet needs significant improvements. GEOSS, the Global Observing System of Systems, presently being developed and coordinated by the intergovernmental program GEO (Group on Earth Observations) is the major effort in this context. IAG contributes to GEOSS by developing its Global Geodetic Observing System (GGOS) and WEGENER, on a regional scale, will provide all the necessary support to this endeavor. In fact, WEGENER during the past 30 years has always

kept a close contact with the Agencies and Institutions responsible for the development and maintenance of the global space geodetic networks with the aim to make them aware of the scientific needs and outcomes of the project which might have an influence on the general science policy trends. In this 15th Assembly of the project, the session focusing on "International Organization of Geodetic Initiatives Contributing to Earth Sciences" is intended to be a contribution to the key aspects of planning and management of major geodetic initiatives as well as to the development of forward looking integrated technological and scientific approaches.

Regional studies are a main subject of WEGENER and they will be dealt with in the special sessions on "Current Plate Motions, Inter- and Intraplate Deformation with a Focus on Europe, the Mediterranean, Northern Africa and the Middle East", and "The Mediterranean: A geohazards focus area". The aim is to stimulate high-level scientific discussions on these topics and to renew the spirit of cooperation for new initiatives by following the well established tradition within WEGENER. The session on the "Evolution of our Knowledge about the Africa-Eurasia Plate Boundaries" besides celebrating 30 years of WEGENER activities and participation, covers contributions addressing how and through which means the evolution of our knowledge of the Africa-Eurasia plate boundaries has been accomplished.

This WEGENER conference will bring together from all over the world experts in a wide range of Earth-science disciplines thus providing a major opportunity for presentations on state of the art results focusing on the European-Mediterranean and Northern African regions.

We are most glad that the meeting can take place in Istanbul, a crossroad of cultures and civilizations with its 8,000-year past. Istanbul, with thirty-five universities and many institutions, is the most important centre of Turkish science, culture and history.

We like to gratefully acknowledge the support received by three major Space Agencies, ASI, CNES and NASA, by IAG and by the Bogazici University. All these Institutions generously contributed and made the organization of this conference possible.

Finally, today as well as 30 years ago, we like to wish all participants a successful meeting where presentations and alive and interesting discussions will make it possible to open the way for new ideas and exciting results concerning geosciences of the European and Mediterranean area.

Istanbul, September 2010

Prof. Susanna Zerbini
President of WEGENER
Department of Physics
University of Bologna

Prof.Dr.Haluk Ozener
Local Organizing Committee
Geodesy Department of KOERI
Bogazici University

# 2 Programme

## 14TH SEPTEMBER 2010

08:30 Registration desk opened

**Opening Session**

09:45 Welcome address, Haluk Ozener, Chair of WEGENER 2010 General Assembly

10:00 Welcome address, Tevfik Ozludemir, President of Istanbul Branch of Chamber of Survey and Cadastre Engineers

10:10 Welcome address, Susanna Zerbini, Chair of WEGENER Project

10:20 Welcome address, Mustafa Erdik, Director of Kandilli Observatory and Earthquake Research Institute

10:30 Welcome address, Yesim Arat, Vice President of Bogazici University

*10:40 Coffee break*

**Session 1**
**30 Years of WEGENER - The Evolution of our Knowledge about the Africa-Eurasia Plate Boundaries**

~~11:00 Invited talk: *Mediterranean Geodynamics and Present-day Surface Deformation*~~
~~**Spakman W., Tanasescu G., Ambrosius B.** **(NOT PRESENTED)**~~ (Abstract: page 29)

11:30 Invited talk: *Subduction Drives Arabia/Africa Plate Convergence with Eurasia and Provides a Unifying, Dynamic Mechanism for Mediterranean/Middle East Tectonics*
**Reilinger R., McClusky S.** (Abstract: page 30)

12:00 *Crustal Deformation in the Patras Gulf, Greece, from GPS Data Analysis*
**Anastasiou D., Marinou A., Mitsakaki C., Papazissi K., Papanikolaou X., Paradissis D.** (Abstract: page 31)

12:20 *Monitoring of Geodynamic Activity in the Western Anatolia: Preliminary Results from Repeated Gravity&GPS and PsInSAR Studies*
**Ergintav S., Dogan U., Cakir Z., Cakmak R., Arslan, G.** (Abstract: page 32)

*12:40 Lunch break*

## Session 2
## Current Plate Motions, Inter- and Intraplate Deformation with a Focus on Europe, the Mediterranean, Northern Africa and the Middle East

### General Session

14:00 *Comparison of a Geodetically-derived Velocity Field from the Permanent NOANET-GPS Network (2007-2010) with a Model of Microplate Tectonic Motion in Greece*
**Ampatzidis D., Kotsakis C., Katsambalos K., Rossikopoulos D.** (Abstract: page 34)

14:20 *Update from Central Europe - The Improved Velocity Field from CEGRN Campaigns till 2009 and New Central European Research Initiatives*
**Becker M., Caporali A., Stangland G., The CEGRN Team** (Abstract: page 35)

14:40 *Postseismic Deformation of the Mw=6.9, 21 May 2003 Zemmouri (Algeria) Earthquake Deduced from PsInSAR*
**Cakir Z., Meghraoui M., Belabbes S., Akoglu A.** (Abstract: page 36)

15:00 *Static Stress Drop as Determined from Geodetic Strain Rates and Statistical Seismicity*
**Caporali A., Barba S., Carafa M.C., Devoti R., Pietrantonio G., Riguzzi F.** (Abstract: page 37)

15:20 *GPS Derived Interseismic Strains Resolved on the North Anatolian Fault in Marmara Sea*
**Evren E., Cakir Z.** (Abstract: page 38)

*15:40 Coffee break*

### Session 2.1. The Mediterranean: A Geohazards Focus Area

16:00 *Deviatoric Stresses in Eastern Mediterranean Region*
**Ozeren M.S., Holt W.** (Abstract: page 39)

16:20 *Deformation Studies in the Kaparelli Area, Central Greece*
**Marinou A., Ganas A., Papanikolaou X., Bosy J., Papazissi K., Anastasiou D., Paradissis D., Drakatos G., Kontny B., Cacon S., Papanikolaou M.** (Abstract: page 41)

16:40 *Analysis of Earthquake Parameters by Utilizing AHP and GIS*
**Erden T., Karaman H.** (Abstract: page 42)

~~17:20 *Strike-slip Faulting in the Aegean Sea Region and the Surrounding Lands*~~
~~**Kiratzi A. (NOT PRESENTED)**~~ (Abstract: page 43)

17:40 *A Critical Review of Geodetic Studies on the Preparation of the Active Fault Map of Marmara and Surrounding Region*

**Komut T.** (Abstract: page 44)

19:00-21:00 **Ice Breaker Evening** at South campus of Bogazici University (Roof of Eng.Faculty)

## 15TH SEPTEMBER 2010

### Session 2
### Current Plate Motions, Inter- and Intraplate Deformation with a Focus on Europe, the Mediterranean, Northern Africa and the Middle East

### General Session

~~09:00 *Horizontal Motions in Bulgaria and Northern Greece by GPS Spanning 1993 – 2008 and the Eurasia Present-day Plate Boundary*~~

~~**Georgiev I., Zagorchev I., Dimitrov D.** **(NOT PRESENTED)**~~ (Abstract: page 45)

09:20 *Active Tectonics and Kinematic Modeling at the Triple Junction between the East Anatolian Fault, the Dead Sea Fault and the Cyprus Arc*

**Meghraoui M., Cakir Z., Masson F., Ferry M., Ergintav S., Inan S., Alchalbi A., Daoud M., Karabacak V., Altunel E.** (Abstract: page 46)

09:40 *GPS Characterization of the Triple Junction between Arabia, Africa and Anatolia: New Measurements in SE Turkey and in NW Syria*

**Masson F., Mahmood Y., Cakir Z., Yavasoglu H., Meghraoui M., Alchalbi A., Daoud M., Ergintav S.** (Abstract: page 47)

10:00 *Global Deformations of the Eurasian Plate and Variations of the Earth Rotation Rate*

**Milyukov V., Kravchuk V., Mironov A., Latinina L.** (Abstract: page 48)

10:20 *Interferometric Synthetic Aperture Radar (InSAR) imaging of crustal deformation associated with the May 2009 earthquake sequence in Harrat Lunnayir, northwestern Saudi Arabia*

**Gomez F., Abdallah C., Bollin B., Cochran W.** (Abstract: page 49)

10:40 *Surface Deformation along the Carmel Fault System, Israel*

**Reinking J., Philipp H. S., Even-Tzur G.** (Abstract: page 50)

*11:00 Coffee break*

## Poster Introduction Session

11:30 Short introductions to posters (No. 1, 2, 4, 8, 9, 10, 11, 13) See page 17-19.

*12:30 Lunch break*

## Session 5

### Open Session with Proposed Focus on International Organization of Geodetic Initiatives Contributing to Earth Sciences

14:00 Invited talk: *The Global Earth Observation System of Systems (GEOSS): Observe, Share, Inform*
**Cripe D.** (Abstract: page 51)

14:30 Invited talk: *Facilitating Scientific Research through Open Data Sharing: Experience at the UNAVCO GNSS Archive*
**Boler F., Meertens C., Miller M.** (Abstract: page 52)

15:00 *GPS Geodesy for AfricaArray: Infrastructure to Support Multidisciplinary Science*
**Nyblade A., Calais E., Meertens C., Miller M., Semazzi F.** (Abstract: page 53)

*15:20 Coffee break*

## Session 4

### Earth Observation Systems and Reference Frames, Observation Techniques, Methods and Data Analysis

15:40 *Long-period, Non-linear and Seasonal Variability Observed in GPS Station Positions and Environmental Parameters over Europe and the Mediterranean*
**Zerbini S., Errico M., Ferri S., Raicich F.** (Abstract: page 54)

16:00 *Radar Interferometry for Measuring Regional-scale Processes*
**Hooper A., Arikan M., Bekaert D.** (Abstract: page 56)

16:20 *InSAR Time Series Analysis of Slow Slip Events on the Guerrero Subduction Zone, Mexico*
**Bekaert D., Hooper A., Yun S.** (Abstract: page 55)

16:40 *UNAVCO Event Response Capabilities: Three Great Earthquakes in the Americas in Early 2010*
**Miller M., Blume F., Borsa A., Normandeau J.,Walls C.** (Abstract: page 57-58)

17:00 *Investigating the Noise Properties of GPS Stations in Iberia*
**Bos M.S., Bastos L., Fernandes R.M.S.** (Abstract: page 59)

17:20 *Orbit Tuning for GOCE Measuring Phases and for Planetary Orbiters to Maximize Accuracy Gain in the Gravity Field Mapping*
**Klokocnik J., Bezdek A., Kostelecky J.** (Abstract: page 60)

18:30 **WEGENER Governing Board Meeting** (board members only)

## 16TH SEPTEMBER 2010

### Session 2
### Current Plate Motions, Inter- and Intraplate Deformation with a Focus on Europe, the Mediterranean, Northern Africa and the Middle East

### General Session

09:00 *Velocity Field in Mediterranean Area from ASI-CGS GPS, SLR and VLBI Solutions; the ASIMed Solution*
**Lanotte R., Luceri V., Pacione R., Sciarretta C., Pace B., Iacovone D., Bianco G., Vespe F.** (Abstract: page 61)

09:20 *Kinematics of Azerbaijan and surroundings through GPS Observations*
**Meherremov E., Aktug B., Parmaksiz E., Kurt M., Esedov N., Kilicoglu A., Ozdemir S., Seymen S.** (Abstract: page 62)

09:40 *Slow Deformation in the Western Alps from a Decade of Continuous GPS Measurements*
**Nocquet J.M., The RENAG Team** (Abstract: page 63)

10:00 *Slip Rates Near Karliova Triple Junction by GPS Observations*
**Ozener H., Aktug B., Dikmen U.** (Abstract: page 64)

10:20 *Intra-Eurasia Plate Motions based on CODE-EPN, IVS-Europe, and IVS-combined Solutions*
**Teke K., Bohm J., Nilsson T., Spicakova H., Schuh H.** (Abstract: page 65)

10:40 *Coffee break*

## Session 2.1. The Mediterranean: A Geohazards Focus Area

11:00 *Establishing a Tsunami Warning System in Turkey*
**Necmioglu O., Ozel N.M., Yalciner A.C., Kalafat D., Erdik M.** (Abstract: page 66)

11:20 *Determination of the Displacements along the Tuzla Fault (Izmir) and Surroundings by GPS and Precise Leveling Techniques*
**Sabuncu A., Ozener H.** (Abstract: page 67)

11:40 *Determination of the Kinematic Structure of Izmir and Surrounding Using Repeated GPS/GNSS Observations: Preliminary Results*
**Pamukcu O., Kahveci M., Ersay E.Y., Yurdakul A., Salk M., Sozbilir H.** (Abstract: page 68-69)

12:00 *Static Stress Changes and Fault Interactions in the Lefkada Island (Ionian Islands-Western Greece)*
**Mitsakaki C., Anastasiou D., Marinou A., Papazissi K., Paradissis D., Sakellariou M.** (Abstract: page 70)

~~12:20 *Strain Analysis on the Neo-tectonic Basin of Saronikos Gulf: Preliminary Results*~~
~~**Papageorgiou E.** **(NOT PRESENTED)**~~ (Abstract: page 71)

12:40 *Lunch break*

## Session 2.2. The Seismotectonics and the Earthquake Cycle of the Marmara Region

14:00 Invited talk: *Short-term and Long-term Slip Rate along the Westernmost Segment of the North Anatolian Fault*
**Aksoy M. E., Meghraoui M., Cakir Z., Ferry M., Ucarkus G.** (Abstract: page 72)

14:20 *Crustal Deformation from 15 Years Space-based Geodetic Data on the Inactive Fault Branch of Western North Anatolian Fault Zone*
**Ozener H., Gurkan O., Turgut B., Yilmaz O., Unlutepe A., Dogru A., Halicioglu K., Sabuncu A., Havazli E., Altin A.** (Abstract: page 73)

14:40 *Present-day Vertical Crustal Deformations in the Marmara Region, Turkey from Repeated Absolute Gravity and GPS Observations*
**Dogan U., Ergintav S., Karaboce B., Arslan G., Aydin C., Sadikoglu E., Oz D., Cakmak R., Selendi A., Direnc A., Turkezer A., Lenk O.** (Abstract: page 74)

15:00 *Seismotectonic Setting of the Karadere-Duzce Branch of the North Anatolian Fault Zone between the 1999 Izmit and Duzce Ruptures from Analysis of Izmit Aftershock Focal Mechanisms*

**Gorgun E., Bohnhoff M., Bulut F., Dresen G.** (Abstract: page 75)

*15:20 Coffee break*

**Session 4**

**Earth Observation Systems and Reference Frames, Observation Techniques, Methods and Data Analysis**

15:40 Invited talk: *High Rate GPS for Earthquake Source Study*

**Nocquet J.M., Ueno M., Vallee M., Delouis B., Guihua C., Klinger Y., Xiwei X.** (Abstract: page 76-77)

16:00 *Monitoring the Kinematics of Anatolia through Continuous GPS Observations*

**Aktug B., Parmaksiz E., Kurt M., Cingoz A., Ozdemir S., Erkan Y.** (Abstract: page 78)

~~16:20 *Additional Improvements in Geoid Determination in Algeria Using the New EGM2008 and the Satellite Altimetry-derived Marine Gravity Anomalies*~~

~~**Benahmed Daho S. A. (NOT PRESENTED)** (Abstract: page 79)~~

16:20 *The Two Maradja Surveys (Maradja I and II) Along the Algerian Margin: a Better Improvement in the Knowledge of the African-Eurasian Plate Boundary in the Western Mediterranean Region*

**Yelles A.K., Deverchère J., Boudiaf A., Bracene R., Cattaneo A., Gaullier V., Geli L., Graindorge D., Kherroubi A., Djellit H., Klingelhoefer F., Mercier de Lepinay B., Sage F., Strzerzynski P., Abtout A.** (Abstract: page 33)

16:40 *Evaluation of Recent Global Geopotential Models with Turkish Local GPS/Levelling Geoid*

**Yilmaz N.** (Abstract: page 80)

17:00 *Comparing Conventional Stochastic Model with Helmert Variance Component Estimation in Geodetic Nets*

**Yavuz E., Coskun M.Z., Sahin M., Baykal O.** (Abstract: page 81)

17:20 *Continuous and Semi-Permanent GPS Networks in Northern Algeria*

**Lammali K., Bellik A., Yelles-Chaouch A., Bougrine A., Bacha W., Mahsas A.** (Abstract: page 40)

19:00-22:00 **Conference Dinner (Social Facilities Area of Istanbul University in Baltalimani)**

## 17TH SEPTEMBER 2010

### Session 2
### Current Plate Motions, Inter- and Intraplate Deformation with a Focus on Europe, the Mediterranean, Northern Africa and the Middle East

### General Session

09:00 *Current Red Sea and Gulf of Aden Rifting and Motion of Arabia*
**ArRajehi A., McClusky S., Reilinger R., Ergintav S., Gomez F., Sholan J., Bou-Rabee F.** (Abstract: page 82)

09:20 *VLBI Estimates of Vertical Crustal Motion in Europe*
**Tanir E., Teke K., Schuh H.** (Abstract: page 83)

09:40 *Investigation of the Stability of IGS Station Points: TRAB IGS Station as a Case Study*
**Ulukavak M., Yalcinkaya M., Bayrak T.** (Abstract: page 84)

10:00 *Deformation of Central Anatolia by GPS Data*
**Aktug B., Parmaksiz E., Kurt M., Kilicoglu A., Gurdal M.A., Ozdemir S.** (Abstract: page 85)

10:20 *Understanding of Aseismic Creeping Process in the Ismetpasa Region of North Anatolian Fault Zone by GPS Data*
**Ozener H., Dogru A., Turgut B., Yilmaz O., Ergintav S., Cakmak R., Cakir Z.** (Abstract: page 86)

10:40 *Coffee break*

### Session 4

### Earth Observation Systems and Reference Frames, Observation Techniques, Methods and Data Analysis

11:00 *CORS-TR Network and its Application to Crustal Deformation*
**Eren K., Uzel T.** (Abstract: page 87)

11:20 *RTK Application for Levelling Network Deformation Control*
**Balodis J., Caunite M., Janpaule I., Rubans A., Silabriedis G., Zarinsjh A.** (Abstract: page 88)

~~11:40 *Deformation Monitoring with TUSAGA-AKTIF System*~~
~~**Bakici S., Yildirim O.** **(NOT PRESENTED)**~~ (Abstract: page 89)

12:00 *San Fernando Naval Observatory High Rate GPS Data Processing*
**Mendoza L., Garate J., Davila J.M., Becker M., Drescher R.** (Abstract: page 90)

12:20 *Mapping Strain Tensors Errors for a Realistic Representation of Crustal Deformations*
**Eissa L., Kasser M.** (Abstract: page 91)

*12:40 Lunch break*

14:00-17:00 **Excursion to Kandilli Observatory & Eq. Res. Ins. of Bogazici Uni.**
Travel by bus.

## POSTER

Posters will be exhibited during the conference from Wednesday morning until Friday noon. Poster authors are requested to give a short introduction to their posters in a dedicated poster session on Wednesday, 11:30 o'clock.

### List of Posters

1. *Relation Between Sensitivity and Observing Session Duration in GPS Monitoring Networks*

   **Aydin C., Dogan U., Oz D.** (Abstract: page 92)

2. *Geodetic Observations from a Semi-Permanent Network Around the Constantine Active Faulting*

   **Bellik A., Lammali K.** (Abstract: page 93)

3. *Estimating Strain Accumulation Rates in the Northern part of Marmara Region, Turkey*

   **Deniz I., Ozener H.** (Abstract: page 94)

4. *The Establishment of a Gravity Calibration Baseline in the Marmara Region, Turkey*

   **Dogan U., Ergintav S., Karaboce B., Arslan G., Aydin C., Sadikoglu E., Oz D., Direnc A., Turkezer A., Lenk O.** (Abstract: page 95)

~~5. *Review of Leveling Comparisons and Combination of Triangulation and GPS Data in the Upper Rhine Graben to Estimate Tectonic Deformation*~~

   ~~**Ferhat G. (NOT PRESENTED)** (Abstract: page 96)~~

6. *Crustal Deformation of Broader Athens (Greece) by GPS Measurements*

   **Foumelis M., Fountoulis I., Lagios E. (presented by Marinou A.)** (Abstract: page 97)

7. *Summary Study on Seismogenic Faults in the Region of Boumerdes and Seismotectonic Context of the Earthquake (May 21, 2003 Mw = 6.8)*

   **Mabrouk D., Mohand A.** (Abstract: page 98)

8. *Modern Geodynamical Motion of the Northern Caucasus from Data of GPS/GLONASS Observations*

   **Milyukov V., Zharov V., Kaufman M., Mironov A., Myasnikov A.** (Abstract: page 99)

9. *GPS Antenna Monuments and Mounts Supported by UNAVCO*

   **Normandeau J., Meertens C., Bartel B., Blume F., Jackson M. (presented by Miller M.)** (Abstract: page 100)

10. *An Automated Processing Scheme Designed for All Available Permanent GPS Stations in Greece*

    **Papanikolaou X., Marinou A., Mitsakaki C., Papazissi K., Paradissis D., Zacharis V., Anastasiou D.** (Abstract: page 101)

11. *GPS Networks for Deformation Monitoring in the Canary Archipelago*

    **Sevilla M. J., Martin A. M., Zurutuza J.** (Abstract: page 102)

~~12. *Determination of Active Tectonic Movements of South West Anatolia*~~

    ~~**Tiryakioglu I., Erdogan S., Gulal E., Ergintav S., Cakmak R., Reilinger R., McClusky S., Sahin M. (NOT PRESENTED)** (Abstract: page 103)~~

13. *Geodetic Survey of Global Climatic Changes in the Mediterranean Area*

    **Valty P., Viron O., Panet I.** (Abstract: page 104)

14. *Techniques and Methods for the Sea Level Observation in the Lanzarote Geodynamics Laboratory*

    **Velez E., Vieira R. , Martin Hernandez A.** (Abstract: page 105)

15. *The Lanzarote Geodynamics Laboratory: a Natural Laboratory for Multidisciplinary Investigation in Geodynamics and Global Change*

    **Vieira R., Velez E., Weixi C., Van Ruymbeke M., Sevilla M. J., Arnoso J., Martin Hernandez A.** (Abstract: page 106)

16. *Adaptive Filtering of GPS Time Series in Crustal Deformation Studies*

    **Yalvac S., Ustun A.** (Abstract: page 107)

17. *Deformation Measurements on the Western Marmara, Turkey*

    **Yavasoglu H., Tari E.** (Abstract: page 108)

18. *Comparison of Variance Component Estimation Methods for Horizontal Control Networks*

    **Yavuz E., Coskun M.Z., Ersoy N.** (Abstract: page 109)

19. *Deformation between African and Eurasian Plate Estimated from the European and the Egyptian GPS Geodetic Networks*

    **Zeman A., Hassan K., Holesovsky J., Mohamed A.S., Novotny Z., Salah M.M., Kostelecky J., Ali M.R.** (Abstract: page 110)

# List of Abstracts

Abstract list (oral and poster presentations) ***sorted alphabetically*** by first author.

# 4 Abstracts

## 1.1 Abstracts of oral presentations by session

Abstracts are **sorted chronologically** according to the programme.

### Mediterranean Geodynamics and Present-day Surface Deformation

Wim Spakman[1], Gabriela Tanasescu[1], Boudewijn Ambrosius[2]

[1.] Department of Earth Sciences, Utrecht University, Netherlands
[2.] DEOS, Delft University of Technology, Netherlands

The geodynamics of the Mediterranean region are being driven by subduction processes within a land-locked basin setting between the converging African, Arabian and Eurasian plates. Evidence of subduction processes comes predominantly from mantle structure imaged by seismic tomography and has given rise to elaborate models of slab roll back, slab detachment and other lithosphere rupture processes. The present-day surface response to these processes is being observed by geodetic techniques which allow for a construction the European-Mediterranean velocity-gradient field and crustal flow field. Linking observed surface deformation to deep processes is not trivial. In this presentation we will review mantle structure, models of subduction evolution and possible correlations between deep processes and present-day surface deformation.

# Subduction Drives Arabia/Africa Plate Convergence with Eurasia and Provides a Unifying, Dynamic Mechanism for Mediterranean/Middle East Tectonics

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To constrain plate driving forces and the dynamics of inter-plate deformation, we use geodetic and plate tectonic observations to determine the tectonic evolution of the Africa (AF)-Arabia (AR)-Eurasia (EU) plate system. In the Late Oligocene/Early Miocene (~25 Ma), the initiation of continental rifting, and the separation of AF from AR along the Red Sea and Gulf of Aden caused an ~50% slowing of AF-EU convergence, presumably due to a reduction in the slab-pull force transferred from the Bitlis-Zagros-Makran subduction system to the AF Plate. The rate of AR - EU convergence remained constant as determined from plate tectonic reconstructions, and is indistinguishable from the present-day rate determined from GPS observations. A second major change occurred in the configuration and rate of motion across the AF-AR plate boundary at 11 ± 2 Ma, including an additional ~50% increase in the rate of AF-AR motion, and a corresponding decrease in the rate of AF-EU convergence. We relate these changes in plate rates and the configuration of the Red Sea (AF-AR plate boundary) at 11 ± 2 Ma to the initiation of ocean spreading in the Gulf of Aden that completely severed the continental lithosphere at this time, causing a further reduction in the N-S component of the slab-pull force transferred to the AF Plate. The timing of the initial slowing of AF-EU convergence (~25 Ma; Late Oligocene/Early Miocene) corresponds to the initiation of extensional tectonics in the Mediterranean Basin (Alboran, Central Mediterranean [Tyrrenian, Balearic], and Aegean basins), and the second phase of slowing to changes in the character of Mediterranean extension reported at ~ 11 Ma (Tortonian). Based on theoretical considerations indicating that, all else being equal, buoyancy forces on the subducted lithosphere are proportional to the rate of subduction, we hypothesize that the slowing of AF-EU convergence caused an imbalance in the dynamic equilibrium of the subducting Neotethys oceanic lithosphere beneath the Mediterranean segment of the plate boundary, resulting in foundering of the subducted plate, and associated southward migration of the trench system. Southward trench migration resulted in contemporaneous ~N-S extension within the Mediterranean Basin. The detailed configuration of these extensional basins likely reflects the segmentation and geometry of the subducted lithosphere. Furthermore, all plates converging with EU along its > 15,000 km long southern margin (AF, AR, India, Australia) rotate counterclockwise in a roughly coherent manner with rates increasing from west to east, corresponding to an increase in the width of the subducted Neotethys lithosphere since 150 Ma. We conclude that pulling by the subducted ocean lithosphere is the dominant force driving plate convergence with EU, and provides a unifying, and conceptually simple, dynamic mechanism for post-Late Oligocene (~30 Ma) tectonic deformation in the Mediterranean/Middle East zone of plate interaction.

# Crustal Deformation in the Patras Gulf, Greece, from GPS Data Analysis

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The Gulf of Patras, a very active seismotectonic region which lies at the west end of Corinth and Rio rifts, is associated with the active subduction in the Western Hellenic Arc. Several GPS campaigns, from 1989 until 2002, took place in the area. GPS data for a total of 31 points, occupied during three epochs (1998, 1999, and 2000) were processed with Bernese V.5 software. Twelve IGS stations were used for the realisation of the reference frame ITRF 2005. Averaged positions computed from these campaigns as well as from all available positional information from past research work were used to estimate the tectonic field in the area together with the respective statistical evaluation. Taking into account appropriate mathematical and physical assumptions, strain tensors were calculated for various deformation models.

# Monitoring of Geodynamic Activity in the Western Anatolia: Preliminary Results from Repeated Gravity and Space Geodetic Techniques

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The aim of this study is to determine the crustal motion in the area of Western Anatolia by the help of relative gravity surveys and space geodetic measurements, like GPS and PSİnSAR. Our gravity and GPS network has been estbalished and operated by TUBITAK under the multilateral "Multi-Disciplinary Earthquake Researches in High Risk Regions of Turkey Representing Different Tectonic Regimes" (TURDEP) project. The GPS network consists of 16 campaign sites and 10 continuous GPS stations. The sites of GPS network, also, survey with relative gravitymeters. PSInSAR data covers the Menderes Basin which shows the main active part of our study region.

We present here the first results of these surveys in order to understand the geodynamical processes of this region between the 2006 and 2010 time interval. We investigate the relationship between gravity changes and GPS motions during the time interval. PSInSAR data, also, densify the deformation field between the survey sites in space and time All data sets shows high corrrelation in space&time and help to constrain the 3-dimensions crustal deformations and hence expand our knowledge of the geophysical process in the region.

# The two Maradja surveys (Maradja I and II) along the Algerian margin: a better improvement in the knowledge of the African-Eurasian plate boundary in the Western Mediterranean region

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The African-Eurasiatic boundary in the Western part of the Mediterranean region remained until recently poorly known as the Algerian margin was not covered.

In the last seven years, two marine surveys, a fruit of the Algerian-French cooperation was conducted in 2003 and 2005 to investigate this region from Oran in the western part of Algeria to Annaba in the eastern part.

From these investigations, the recent tectonic deformation process along the margin was outlined. It indicates that seismicity from the central part to the eastern part of the margin is triggered by a series of active north verging reverse faults and folds located mainly in the foot of the margin in a flat-to ramp overall geometry. In the western part, transcurrent movements are predominating.

Evidence of contractional reactivation of the Algerian margin is supporting the hypothesis of an initiation of a subduction of the neogene oceanic lithosphere under the African plate. The contact of these two domains occurred along the foot of the margin, precising the geometry of the African-Eurasiatic plate boundary. In order to further assess the way the process of the convergence is occurring and since how long it is developing, the Algerian-French Project SPIRAL was conducted in November 2009 consisting of five deep seismic transects from the shore to onshore along a distance of about 100 km. These new crustal investigations will allow us to better understand the recent tectonic evolution of the margin and to discuss the hypothesis of the incipient subduction zone and precise the African-Eurasiatic plate boundary.

# Comparison of a Geodetically-derived Velocity Field from the Permanent NOANET-GPS Network (2007-2010) with a Model of Microplate Tectonic Motion in Greece

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The Hellenic area is one of the most geodynamically active regions in the European continent, a fact that is reflected explicitly in the crustal velocity field derived from space geodetic data such as differential GPS measurements. In general, the northern part of the country follows closely the Eulerian motion of the Eurasian plate, while the southern parts seem to have a southern-eastern apparent motion with respect to Eurasia at an approximate rate of 3 cm/yr. This inhomogeneous situation was already known in the pre-GPS era (*McKenzie et al 1972*), leading to a number of geodetic and geophysical studies that have proposed the division of the Hellenic area into a small number of tectonic microplates in order to better describe the regional variations in the GPS-based crustal velocity field obtained in Greece. The latest one of these studies (*Nyst and Thatcher 2004*) was based on several GPS campaigns that were performed throughout the eastern Mediterranean region, including Greece and the western part of Turkey, and it proposed a four microplate model: central Greece, southern Greece, southern Marmara region and Anatolia. Each of these microplates is described by an estimated Euler pole which, in turn, can be used for predicting the 3D velocity vectors at terrestrial points that are included within the respective microplate boundaries. The purpose of this study is to investigate the validity of the aforementioned microplate model for the Hellenic area based on recent GPS data from the permanent GPS-NOANET network. Our test network consists of eleven permanent GPS stations in Greece (including three EPN/EUREF stations and eight stations from the GPS network of the National Observatory of Athens) and five additional EPN/EUREF stations that are located in central Europe. The GPS data cover a time period of almost three years, and they have been analyzed in terms of separate 3-day sessions via the Bernese software program (ver. 5.1). The results indicate a good agreement level (in the order of a few mm/yr) for the crustal velocity vectors that were derived from the recent GPS data with the corresponding velocities that are predicted by the Eulerian motion of the corresponding microplate of each permanent station, except for the case of Ionian islands (Kefalonia and Lefkada).

# Update from Central Europe - The Improved Velocity Field from CEGRN Campaigns Till 2009 and New Central European Research Initiatives

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The GPS stations forming the CEGRN network in Central Europe are regularly observed since 1994. The Central European Geodynamic Refernce Network CEGRN is developed as a a densification of the EPN velocity field especially in the regions of the Carpathians, Dinarides, the Pannonian Basin and the Balkans. The time series of permanent stations of the network plus those of the Eastern Mediterranean give an overview of the movements of Eastern and South-Eastern Europe. Reprocessed CEGRN campaigns between 1994 and 2009 have been added. We report on the results of the systematic processing of the available data up to 2009. The analysis work has yielded the velocities of some 60 sites. We present the latest developments in view of the combination of epoch and permanent sites and the plans for future extensions and joint research activities in the Central European region. New initiatives for the participation of the CEGRN consortium in European geodynamical research programmes will be outlined.

# Postseismic Deformation of the Mw=6.9, 21 May 2003 Zemmouri (Algeria) Earthquake Deduced from PsInSAR

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We study the postseismic deformation following the disastrous 2003 Zemmouri earthquake (Mw=6.9) that occurred near the capital Algiers using Permanent Scatterers Synthetic Aparture Radar Interferometry (PsInSAR) techniques. 28 Advance SAR images of the Envisat (ESA) satellite acquired between 2003 and 2009 were processed using the StaMPS software package (Hooper, 2006). The processing with both the Single Master and Small Baseline methods show that while the epicentral region (mainly Boumerdes and Zemmouri area) has subsided with up to 7-8 cm, the Cap Matifou region has been uplifted up to 6-7 cm with an inflection point immediately west of Boumerdes city. This also suggests that the NE trending coseismic fault rupture is located near Boumerdes and a few km north of the coastline, aligning with the Blida thrust fault system.

# Static Stress Drop as Determined from Geodetic Strain Rates and Statistical Seismicity

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Two critical items in the energetic budget of a seismic province are the strain rate, which is measured geodetically on the Earth's surface, and the yearly number of earthquakes exceeding a given magnitude. Our study is based on one of the most complete and recent seismic catalogues of Italian earthquakes and on the strain rate map implied by a multi-year velocity solution for permanent GPS stations. For each of 36 homogeneous seismic zones we use the appropriate Gutenberg Richter relation, which is based on the seismicity catalogue, to estimate a seismic strain rate, which is the strain rate associated with the mechanical work due to a co-seismic displacement. We show that, for each seismic zone, the volume storing most of the elastic energy associated with the long-term deformation, and hence the seismic strain rate, is inversely proportional to the static stress drop. The GPS-derived strain rate for each seismic zone limits the corresponding seismic strain rate, and an upper bound for the average stress drop is estimated. We show that the implied regional static stress drop varies from 0.1 MPa to 5.7 MPa for catalogue earthquakes in the moment magnitude range [4.5 - 7.3]. The stress drop results are independent of the regional a and b parameters, and heat flow, but are very sensitive to the assumed maximum magnitude of a seismic province. The data do not rule out the hypothesis that the stress drop positively correlates with the time elapsed after the largest earthquake recorded in each seismic zone.

# GPS Derived Interseismic Strains Resolved on the North Anatolian Fault in Marmara Sea

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Calculation of local strain in a particular area is one of the key issues to identify possible seismic risks in that region. In this study, we have used observed geodetic velocities for the interseismic period to calculate the Coulomb stresses and related secular strain rates on main the submarine fault segments of the North Anatolian fault in the Sea of Marmara (NW Turkey). This is achieved by resolving systematically the GPS velocity field on to the nodes of important submarine fault segments. Unlike previous studies in the region, we have minimized the velocity interpolation errors by using a new and improved weighting algorithm for the GPS network. The GPS derived interseismic strain components are calculated as continuous functions over the region and they are resolved on evenly distributed fault nodes. Resulting GPS derived secular strain rates are consistent with the transtensional tectonic characteristics of the North Anatolian Fault in the Marmara region.

# Deviatoric Stresses in Eastern Mediterranean Region

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In this work we use geodetic observations (GPS) and gravitational potential energies to approach the deviatoric stress field in the region that incompasses Anatolia, Aegean Sea, Greece and parts of Bulgaria and Albania. We use linear force balance equations to parametrize the inverse problem and then use an approach based on calculus of variations to calculate stresses. We calculate the strain rates using GPS data from a variety of sources, these strain rates then become the "data" style of which (constraints on the eigenvectors and eigenvalues of the locally defined strain rate tensor) are to be matched by the stress tensors. Rather than imposing boundary conditions, we solve for them as part of the inverse problem algorithm. We finally make a power-law assumption for the constitutive relation for a simplified, one-layer lithosphere to make a first-order approach to the effective viscosities.For both values of n=1 and n=3 for the power law, we determine two high viscosity zones in the region (apart from obvious ones such as the Black Sea). One high-viscosity zone appears in eastern Turkey where the tectonics is dominated by the collision-related boundary conditions. The other is a NW-SE trending region between the almost-rigid Central Anatolian Block and western Turkey.

# Continuous and Semi-Permanent GPS Networks in Northern Algeria

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Northern Algeria, located along the Eurasiatic-African boundary plate is characterised by a moderate to strong seismic activity. During History, some violent earthquakes occurred mainly in the Atlas region, particularly in the Tellian area, leading sometimes to destruction of major cities of Algeria (Algiers, 1716; Oran, 1790; Blida, 1825; El Asnam, 1980; Constantine, 1985; BOUMERDES, 2003…). In order to improve the knowledge of the deformation pattern of the Atlasic region, and more globally of the African-Eurasiatic plate boundary along the Algerian margin, the Research Center of Astronomy, Astrophysics and Geophysics (CRAAG) started since six year to implement two major projects:

1) The REGAT (REseau Geodesique de l'Atlas), consists on a set of 14 continuous GPS stations deployed in the Atlas region, from the coastal area to the Sahara Platform. At this time, eleven stations have been already installed. The first stations (Algiers-Bouzareah, Tamanrasset…) of this basic network are producing data since 2004. First time series are analysed. In 2010, it is projected to extend this network by another set of 50 stations.

2) The second project consists in deployment of semi permanent GPS networks around four seismogenic basins and active fault areas which are: the Oran region, west Algeria; the Chelif basin (El Asnam region), the Mitidja basin (from Tipaza to Dellys), the Ain Smara fault system (Constantine region).

# Deformation Studies in the Kaparelli Area, Central Greece

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The Kaparelli area in central Greece became famous in 1981 when a surface rupture was created after a strong, shallow earthquake (Ms=6.4, 4 March 1981). This is a region of tectonic interest since it is undergoing extension as suggested by both seismological and geological data that indicate normal faulting with the downthrown side to the south. The slip rate of the fault is about one-order of magnitude less than the active faults inside the Gulf of Corinth Rift, but no reliable slip rate data exist for the faults to the east of Kaparelli. Also the strain pattern may change as we enter a low-strain area between two marine rifts (Corinth to the west, Evia to the East). Four GPS campaigns from 2004 until 2008 took place in the area in order to estimate the tectonic motion, and seven IGS stations were used for the realisation of the reference Frame ITRF 2005. The GPS data were processed with Bernese V5 software. Velocity field was estimated as well as two dimensional surface strain tensors in order to evaluate the deformation of the region.

# Analysis of Earthquake Parameters by Utilizing AHP and GIS

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Definition of the earthquake includes parameters with respect to the region of interest. Many of those parameters also include uncertainties. Each of those parameters has different weights on the earthquake ground motion and effect. This study, examines the weight of broad parameters which are accepted all over the world. All of the parameters discussed with the professional judgement. The Analytic Hierarchy Process (AHP) is used for factor weighting of each parameter and Geographic Information Systems (GIS) are used for simulating the results of the AHP on a spatial environment.

AHP is a method that solves multi-criteria decision making problems involving objective as well as subjective criteria. Following four steps of AHP are used in this study. As the first step, the decision making problem is decomposed and the criteria, sub-criteria and alternatives of the problem are exposed. Then linear hierarchy is constructed consisting of a finite number of levels and elements. In step 2, pairwise comparison matrices of all criteria are constructed. In step 3, individual weights of the criteria are determined from the pairwise comparison matrices obtained by using the eigenvalue method. At the end of the process, whole set of weights are synthesized by using the principle of hierarchical composition and then overall or global weights for the alternatives are obtained as the fourth step.

In this study, it is aimed to generate a hierarchical structure of the model for the simulation of an earthquake hazard map. The parameters of the earthquake hazard map are selected by the criterion of non-correlated factors. Selected parameters are topography, distance (type and quantity), soil classification, liquefaction, and fault mechanism. Following the selection of the parameters, a pairwise comparison matrix is formed by comparing the parameters each other. As a result of the study, weights of the parameters that affect the earthquake ground motion on a study area are determined based on the attenuation relations.

# Strike-slip Faulting in the Aegean Sea Region and the Surrounding Lands

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The distribution of pure strike-slip motions in the Aegean Sea and the surrounding lands reveals interesting features in terms of plate kinematics. Four main regions of extensive strike slip motions can be identified and from east to west have as follows: **A)** ***North Aegean Sea strike-slip zone***: this area extends from western Anatolia in the east up to the coastal central Greece (Evia Island) and takes up the shear motion from the westward escape of the Anatolian plate. Within this zone the NE-SW trending structures exhibit dextral strike-slip motions while the NW-SE trending structures (e.g. 2003 Skiros island earthquake sequence) exhibit sinistral strike-slip motions. The shear motion from the east does not cross mainland Greece, at least as indicated by the absence of strike-slip focal mechanisms, and ends abruptly across Evia Island. ***B) Eastern Hellenic Arc strike-slip zone:*** This zone extends from central western Crete, east of Rodos Island up to the mainland of western Anatolia. This zone is characterized by sinistral strike-slip faulting along NE-SW trending structures, related to the Pliny and Strabo trenches south of Crete and the Fethiye – Burdur fault zone in western Anatolia. **C)** ***Cephalonia-Lefkada Strike-slip Zone:*** This zone previously identified, runs close to the western coasts of Cephalonia and Lefkada and clearly affect the geomorphology of the coasts. The sense of motion well documented from strong recent earthquakes is dextral. **D)** ***Western Peloponnese strike-slip zone:*** This zone was mainly identified after the occurrence of the 8 June 2008 Mw6.5 Movri Mt earthquake which clearly showed the operation of a NE-SW striking strike-slip fault. This fault zone is parallel to the Cephalonia-Lefkada strike-slip zone, however it operates at a depth greater than 20 km. Thus, this is a case of a blind strike-slip fault at depth while at the surface the deformation appears to be accommodated as extensional, with complex patterns and absence of fault scarps. The distributed strike-slip faulting in the broader Aegean region defines the limits of coherent blocks, like the central Aegean and Peloponnese block with earthquake slip vectors pointing towards SW, the deformation zone of SE Aegean Sea and the zones affected by the propagation of the North Anatolian Fault into the Aegean. The strike-slip faulting observed along western Peloponnese might be connected to the westward propagation of the North Anatolian Fault, through the Gulf of Corinth. Taking into consideration the operation of the sub-parallel strike-slip faults of western Peloponnese and of Cephalonia-Lefkada a decoupling is possible of the small block bounded by the Ionian Islands and the western coast of Peloponnese, which also exhibits low internal deformation evident by the low level of seismicity.

# A Critical Review of Geodetic Studies on the Preparation of the Active Fault Map of Marmara and Surrounding Region

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Since 1995, a consistency has been tried to find out between fault networks suggested by active tectonic researchers and GPS velocities. Geodetic models related to active faults of Marmara were critically reviewed by considering measurement properties of station networks and modelling methods. According to GPS velocity models, a clear inconsistency is obvious between GPS measurements and generally accepted active fault network and its simplified variations based on pull-apart model. Geodesists insistently point out that in the Marmara, most of the deformation occurs in the north and along a narrow ~E-W oriented single dextral fault trace from İzmit to North Aegean Trough. This simple continuous fault trace delineates the boundary between Anatolia and the Eurasian plate with ~25mm/yr velocity. On the other hand, dilatation rates have inconsiderable amounts based on GPS velocity fields. So extensive extension constructing a basin in any way is lack in the Marmara region. No extension related to the Aegean region is needed to explain opening of the Marmara basin with pull-apart model but any extension produced by the model is expected to be observed around the basin at least in İzmit bay. In addition, an acceptable consistency in a model should be available between pull-apart fault network and GPS velocities. For this reason, the pull-apart model that is used for explaining the active formation of the Marmara basin and draw active fault lines should be critically questioned.

# Horizontal Motions in Bulgaria and Northern Greece by GPS Spanning 1993 – 2008 and the Eurasia Present-day Plate Boundary

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The paper outlines results for horizontal motion of the crust in Bulgaria and Northern Greece obtained by processing and analyzing of GPS campaigns spanning 1993 – 2008. Estimates of horizontal velocities of 98 points in Bulgaria are obtained including points from National GPS Network and a special geodynamic network in South Bulgaria. Velocities of 21 GPS sites located in Northern Greece are also obtained. The horizontal velocity field along with the tectonic and seismotectonic information gives the opportunity to draw inferences about the recent tectonic activity in this area and its position in the East Mediterranean geodynamic processes. In Southwest Bulgaria a few tectonic blocks with homogenous motions are outlined. Their relative rotations exhibit a continuation of former (Neogene) rotation tendencies. The velocities in Bulgaria and Northern Greece exhibit a clear increasing tendency from north to south. The obtained results suggest that the transition zone between the Eurasia and the Aegean extensional province has a complex block structure and is situated south of the Maritsa fault belt (lineament).

# Active Tectonics and Kinematic Modeling at the Triple Junction between the East Anatolian Fault, the Dead Sea Fault and the Cyprus Arc

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We investigate the kinematics and slip rates of active faults at the Maras-Antakya triple junction in southern Turkey (where the Anatolian, Arabian, African plates and Iskenderun microplate meet) using GPS measurements, active tectonics, paleoseismology and block modeling. Repeated GPS surveys between 1991 and 2004 allow us to determine horizontal velocities at 22 stations located across the East Anatolian Fault (EAF), the Dead Sea Fault (DSF) and the Cyprus Arc (CA). Field observations indicate that toward the southwest at Maras the EAF branches into the SW-NE trending Karatas – Osmaniye Fault segment (KOFS) and the SSW-NNE Karasu Fault (KF) that meets the DSF and the CA around Hatay to the south. The tectonic and geodetic field investigations indicate the existence of the Iskenderun block between the Anatolian and African plates. By using a simple kinematic model, we estimate that the relative left-lateral plate motion is 8.9±0.4 mm/yr across the EAF, 5.6±1.7 mm/yr across KOFS and 3.8±2 mm/yr across the Karasu fault. We also determine 1.8±1.1 mm/yr for the Karasu normal-component. However, modeling suggests that additional GPS benchmarks are required and in consequence we have recently installed 25 new GPS points (4 permanent and 21 campaigns) at the triple junction. Geomorphological and paleoseismic studies yield left-lateral slip rates of 10.8±1 mm/yr and 6.0±0.3 mm/yr, respectively for the EAF and DSF, comparable with those obtained from GPS and deduced from block modeling. The kinematic modeling that combines GPS and tectonic results reveals the predominance of the westward movement of the Anatolian block with the Karasu Valley acting as a large pull-apart basin. Furthermore, we observe that the DSF transforms the Cyprus arc subduction into transpressive tectonics on the East Anatolian fault.

# GPS Characterization of the Triple Junction Between Arabia, Africa and Anatolia: New Measurements in SE Turkey and in NW Syria

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The triple junction area located between SE Turkey and NW Syria is tectonically complex because it is at the intersection of three main fault systems, the left-lateral East Anatolian Fault Zone (EAF), the left-lateral Dead Sea Fault (DSF) and the Cyprus Arc. Previous GPS results indicate 9.7+0.9 mm/yr along the EAF and 2.5-6 mm/yr along the DSF (McClusky et al., 2003; Reilinger et al., 2006; Alchalbi et al., 2009). This zone of active deformation is at the boundary between the Arabian, African, and Anatolia-Eurasia plates. The tectonic complexity results from the existence of several tectonic blocks limited by individual fault segments (DSF, EAF, Osmaniye fault, Karasu fault, Latakia fault, Jisr-al-shuggur fault, Idleb fault and Afrin fault) whose kinematics and related fault-slip rates are poorly constrained. Main issues to address in this region are: What are the velocities (geodetic) and slip rates (geologic) along the three main strike-slip fault systems? What is the role of individual tectonic blocks in the regional deformation?

In order to answer these questions we established a network of 59 campaign GPS points in NW Syria and in SE Turkey. The sites are distributed in 4 main profiles (35 points) in Syria with an extension of 2 profiles (24 points) in Turkey. The compatibility between all profiles in Syria and in Turkey is taken into account for a better assessment of velocity field and physical parameters of fault branches along the three major fault systems. The first campaign was carried out in 2009. The second campaign is planned for September 2010. Data gathered will be processed together with previously collected data from a set of 10 permanent sites in Turkey and 6 others in Syria using GAMIT/GLOBK program.

The velocity field vectors derived from all sites in the region will provide some constraints on the active deformation and its distribution at the triple junction. In addition, our study will provide a better understanding on how the geodetic strain cumulates and can be released in this region.

# Global Deformations of the Eurasian Plate and Variations of the Earth Rotation Rate

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The relation of deformation processes in the lithosphere and global geodynamics of the Earth on the short time scale (order of month) has been studied on the base of the original strain data from two space separated (2000 km) observation stations, equipped by geophysical laser interferometer-strainmeter (the Northern Caucasus) and quartz strainmeter (Moscow region) and time series of the variations of the Earth rotation rate (the Length Of the Days, LOD) from the IERS catalogue.

Existence of interrelated perturbations of the deformation fields on large spatial scales, an order of the lithosperic plates size (in this case, the Eurasian plate) is proved at the statistically significant level (95%), i.e. existence of the global component of the deformation field of the Earth with the characteristic "life time" till 3-4 weeks. The analysis at the same significance level has revealed the relation between local deformation fields and variations of the Earth rotation rate.

We have theoretically demonstrated, that a rotational effect of the lithospheric loading, associated with LOD variations, cannot cause the observable correlated changes of the deformation field, it is an effect of the second order of smallness. The global mechanism causing both the global deformation component, and the correlation of the local deformation fields and LOD in the tidal low-frequency range is the powerful and regular long periodical tidal loading (the groups of $M_f$ and $M_{tm}$ waves), having the direct influence on the lithospere and LOD. The global mechanism causing the correlation of the analyzed processes in the non tidal range demands the further studying. As the candidates can be considered the influence of the atmospheric loading, the strongest earthquakes and the coupling mechanism in the Earth interior. For the further study of the relation between the global geodynamics and the global deformation field of the Eurasian plate, with the behaviour features in the Mediterranean area, the observation data of the Gran Sasso deformation station (Italy) will be involved in the analysis.

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# Interferometric Synthetic Aperture Radar (InSAR) Imaging of Crustal Deformation Associated with the May 2009 Earthquake Sequence in Harrat Lunnayir, Northwestern Saudi Arabia

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An earthquake swarm that occurred in May 2009 in the Harrat Lunnayir volcanic province of NW Saudi Arabia provides an opportunity to study faulting and magmatic mechanisms that may characterize rifting-related processes associated with the northern Red Sea region. The earthquake sequence culminated in the shallow, Mw 5.7 earthquake on May 19, and the reported moment tensor solutions depict NW-SE striking normal faulting. Surface faulting and fracturing resulted, although volcanic eruption did not. This study uses Interferometric Synthetic Aperture Radar (InSAR) to assess surface deformation associated with the earthquake swarm. Using a combination of data from Envisat ASAR and ALOS PALSAR, a sparse time series of deformation spanning the earthquake swarm and the subsequent four months is constructed. Interferograms image two distinct signatures: (1) A broader, symmetric deformation associated with intrusion, and (2) localized faulting associated with a surface-rupturing graben. The results demonstrate that minimal deformation occurred in the area during the preceding two years, and that approximately 0.80 m of vertical displacement was associated with the earthquake swarm in May 2009. During the subsequent two months, an additional ~0.15 m of vertical displacement occurred. Using elastic dislocation models to infer fault parameters, the broader pattern of displacements is best fit using a dilatational crack– i.e., fault parameters more characteristic of a dike intrusion, rather than shear faulting. According to the model, the fracture extends from about 1 – 10 km depth with peak opening of about 3.5 meters. Total moment associated with the dike is consistent with a moment magnitude of 6.0. Modeling deformation associated with the faulting in the graben zone above the dike demonstrate that normal faulting extended from the surface to a depth of about 5 km. The total slip on the normal faults indicates a moment magnitude of 5.7 – i.e., it is consistent with the seismological solution. The implication is that the greater moment associated with diking occurred aseismically and was likely triggered by the shallower faulting, owing to the cross-cutting relationship of the dike and faults. Later interferograms in the time series also demonstrates that dike intrusion continued for approximately 3 months following the main even, and the rate of opening decays exponentially with time. Hence, the 2009 earthquake sequence in Harrat Lunnayir appears to demonstrate a passive role of magmatic intrusion in the late-stage of continental rifting in the northern Red Sea.

# Surface Deformation along the Carmel Fault System, Israel

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The Carmel Fault (CF) is the north-western part of Carmel-Tirtza Fault System in Northern Israel and a generally north-western branch of the Dead Sea Fault System. It is one of the major geological structures of northern Israel and composed of a southern and northern NW-SE striking segments and a short central N-S striking segment in between. The fault crosses the city of Haifa and passes close to the petrochemical factories of the industrial area of Haifa bay. Any damage to these factories which are located in the vicinity of the city of Haifa could cause a very severe environmental disaster. Although this hazardous situation is well known the existing knowledge about the CF is poor and to a certain degree ambiguous.

Studies of geological and geophysical data assume that the CF is potentially active supposing a dominating left-lateral motion. Analysis of GPS measurements along the fault structure show controversial sinistral [2], [3] or dextral [4] movements with velocities ranging from 1 mm/y up to 4 mm/y. Latest investigations using PSInSAR [5] did not show any evidence for differential surface displacement along the CF while a vertical slip of up to 1 mm/y, or horizontal slip of up to 4 mm/y along the NW-SE segments of the CF cannot be totally rejected.

In this study we investigated GPS data from a regional network that has also been used in [2], [3] and [4] and that was collected between 1999 and 2006. Data from a new GPS observation campaign in 2009 was additionally introduced. All data sets were re-calculated using the latest version of the Bernese GPS Software based on a common set of IGS and additional permanent sites that ensure the consistency of the datum definitions in the GPS analysis.

Resulting horizontal site velocities are superposed by the tectonic movements of the greater area, particularly by the movement along the Dead Sea Fault System. To check for the orientation of the movement along the CF, we defined the datum according to [2] based on three sites on the west of the CF. The velocities reach significant values of up to 4 mm/y showing dextral movements along the fault. The overall velocity field is not very clear but somewhat complex.

This velocity field was introduced into an elastic dislocation model based on a geological and geophysical defined set of fault parameters (location, strike, dip, and dimensions) with respect to the geodetic datum definition which can be introduced by a simple S transformation. The slip and rake and its distribution over the fault planes were calculated by means of a least squares adjustment with respect to the covariance matrix of the velocity vectors. The resulting slip field can be compared with expectations from slip rate analysis of seismicity parameters [6] and used to derive a fault-related velocity field.

# The Global Earth Observation System of Systems (GEOSS): Observe, Share, Inform

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Earth observations can help reduce the loss of life and property from natural and human induced disasters through increasing our understanding of complex environmental systems. In this context, the Global Earth Observation System of Systems (GEOSS) is being built through the coordination of efforts within the international Group on Earth Observations (GEO), comprised of 80 Member States, the European Commission and 58 Participating Organizations, established in February 2005. The 10-Year Implementation Plan defines a visionstatement for GEOSS, its purpose and scope, expected benefits for nine "Societal Benefit Areas" (SBAs) (disasters, health, energy,climate, water, weather, ecosystems, agriculture and biodiversity), technical and capacity building priorities, and the GEO governance structure. The full value of GEOSS lies in its ability to integrate information across disciplines. Thus, GEOSS is concerned with: interlinking weather forecasting systems with other Earth observation systems; supporting efforts to advance sustainable energy; and devising end-to-end information services and sustained observing systems essential for addressing climate variability and change. The international collaborative framework of GEO allows: water experts todefine the data and systems needed for improved water-cycle forecasting; international teams to monitor ecosystems and generate maps and other decision support tools; development of an Agricultural Monitoring System of Systems that will integrate in-situ and space data from multiple fields; and comprehensive monitoring critical to the conservation and sustainable use of the world's biological diversity. In particular, in the field of water, unique regional cooperative approaches are now on-going and under planning for making maximum use of, and contributing to, GEOSS. The current GEO Work Plan furnishes the blueprint for activities to implement GEOSS, and provides concrete examples of how decision makers can use the data and services available through GEOSS to address major global opportunities and challenges. This is why GEO strives to develop a GEOSS that would serve the needs of all SBAs through interconnectingexisting and future Earth observation systems, interlinking observation systems, and promotion of open data sharing.

# Facilitating Scientific Research through Open Data Sharing: Experience at the UNAVCO GNSS Archive

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UNAVCO is a non-profit membership-governed academic consortium that facilitates geoscience research and education using geodesy. UNAVCO has operated a Global Navigation Satellite System (GNSS) data archive since 1992 and has hosted the Western United States InSAR consortium (WInSAR) since 2006. Presently, the GNSS archive holds four million GNSS data files, taken principally at a large and growing set of globally-distributed permanent high precision GNSS stations. Each day on average 2,500 new files are archived and 33,000 files are distributed. Campaign data sets, typically consisting of spatially dense sets of observations over multi-day day time frames, form an important component of the UNAVCO Archive that is complementary to the permanent station data. High rate data (1 sample per second and higher) available either as near real time streams or as aggregated daily files, are forming an increasingly important subset of the data that are available from UNAVCO. UNAVCO's GNSS Data Policy provides for immediate open access to most data from continuously operating GNSS stations; UNAVCO is transitioning to a similar immediate access Data Policy for campaign GNSS data.

Space geodetic science and other disciplines using geodetic products have benefited immensely from open sharing of data and metadata from global and regional archives. The International GNSS Service (IGS) is an example of coordinated sharing of data to enable the production of orbit and other products that benefit nearly all civilian users of GNSS data. UNAVCO has partnered with other US archives in the GNSS Seamless Archive Centers (GSAC) initiative as a means of facilitating data sharing. The next generation of the GSAC, utilizing modern metadata exchange methods based on web services, is now under development under NASA sponsorship. The underlying GSAC technology and software is openly available to all archives and broad participation is welcome.

# GPS Geodesy for AfricaArray: Infrastructure to Support Multidisciplinary Science

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A geographic and instrumental expansion of the AfricaArray (AA) network has begun that will provide critical data sets needed for addressing first-order questions about plate boundary tectonics and the rifting cycle, the hydrological cycle and climate change in Africa. Instrumentation for making co-located continuous GPS (CGPS) and meteorological observations is being added to 15 existing AA seismic stations and installed at 5 new stations across eastern, southern and western Africa, forming a 20-station multidisciplinary community facility that will provide continuous high-quality data sets and support unique educational programs serving American and African students alike. The new instruments will contribute to the currently limited GPS infrastructure in Africa, a continent facing critical environmental issues but largely under-sampled with modern geophysical instrumentation. They will also help to fill in a significant gap in global GPS data coverage with a direct benefit to the scientific community worldwide. Over a period of 10 or more years, data from this network will not only lead to major advances in our understanding of continental-scale Earth processes affecting the African environment, but also global ones.

In particular, data from the expanded AfricaArray network will be used to 1) advance our understanding of plate boundary tectonics and the rifting cycle in Africa, including the nature of long-term, steady-state tectonic plate or block motions, the role of magmatism in continental rupture, and the associated hazards, 2) investigate key components of the African hydrological cycle, such as secular changes in groundwater storage and soil moisture, and 3) distinguish and quantify seasonal, intraanual and interannual climate variability in Africa, examine influences on African climate from external factors such as ENSO, and validate regional climate models.

The instrumentation that is being added to the existing AfricaArray seismic network includes an integrated dual-frequency GPS receiver and automatic weather station that measures wind speed and direction, liquid precipitation, barometric pressure, temperature, and relative humidity. The twenty new CGPS/met station locations have been selected to optimize science needs while accounting for the practical challenges of installing long-lasting geophysical instrumentation in Africa. The CGPS and met data will be archived at UNAVCO and openly distributed. Operations and management responsibilities and costs will be distributed amongst AA station operators in each country, plus the Council for Geoscience (South Africa), The University of the Witwatersrand (South Africa) and Penn State University.

# Long-period, Non-linear and Seasonal Variability Observed in GPS Station Positions and Environmental Parameters over Europe and the Mediterranean

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Long-term, non-linear signals in addition to seasonal variability are being observed in the position components of GPS stations located in Europe and the Mediterranean area. The seasonality of the vertical component has been the subject of many publications and it has been associated to the superposition of multiple loading effects on the Earth's crust. The horizontal seasonal variability still requires in-depth studies to identify and explain the responsible physical mechanisms. The position time series of a number of GPS stations distributed across the European-Mediterranean area are now long enough to allow also identifying non-linear, long-period signals. In this region, over the period 1999-2010, we have analyzed the time series of the north, east and up components of 20 GPS station positions, either all together or each component separately, by using the Empirical Orthogonal Functions (EOF) technique. This was done in order to identify the main variability modes common to the selected ensemble of stations. In each analysis, the first principal component is always characterized by a long-period signal with slope inversion around 2003. Seasonality is also well identified. We have also analyzed several series of environmental variables such as the GLDAS water storage data (NASA's Global Land Data Assimilation System), atmospheric pressure and pressure-related indexes such the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO), and the sea surface temperature-related Atlantic Multidecadal Oscillation (AMO). These latter variables are indicators of atmospheric and ocean variability which, in turn, may be connected with position variations. All the EOF analysis results show a long-period signal with slope inversion around 2003 and a marked seasonal component. Moreover, the GRACE surface mass anomalies were investigated by using the EOF methodology and they also exhibit similar behaviours. Finally, the coupled variability between the GPS position components and some of the environmental data sets has been analyzed by means of the Singular Value Decomposition (SVD) approach.

# InSAR Time Series Analysis of Slow Slip Events on the Guerrero Subduction Zone, Mexico

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Guerrero is a province in the southern part of Mexico adjacent to the Pacific Ocean. In the past, large thrust earthquakes have occurred along the interface between the subducting and overriding plates. However, there is a region with a "seismic gap" where no earthquakes have occurred since 1911. It is estimated that a rupture of the gap would result in a Mw 8.0 to 8.4 earthquake. In the past few years it has become apparent that the subduction zone is also very active in terms of slow slip events (SSEs). At least one event every four years has been observed since 1995. The area affected by the associated deformation of these SSEs is rather large, with the highest deformation near the coast and reaching as far as Mexico City, 300 km inland.

Up until now, most geodetic observations of the SSEs have been made using GPS techniques only. By using radar imaging, spatial resolution can be considerably increased, allowing subduction interface models to be much better constrained. Regular radar interferometry (InSAR) fails due to spatial and temporal decorrelation. We apply a time series InSAR technique that searches for pixels, or "persistent scatterers", that have stable phase characteristics in all interferograms. With this time series analysis, we are able to extract the mean interseismic velocity and displacement of the 2006 SSE. In our processing the effect of atmosphere and DEM errors were estimated and subtracted. Continuous GPS data were used to constrain the long wavelength components of both secular motion and the SSE. Current GPS observations indicate a new SSE occurring. This SSE started in the summer of 2009. We are investigating this event using ALOS PALSAR (L-band) data. The ionosphere obscures the data, but first results indicate slow slip signal to be present.

# Radar Interferometry for Measuring Regional-Scale Processes

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Despite the multiple successful applications of InSAR for measuring surface displacements, its use remains limited for the measurement of regional scale processes. In many instances the signal over much of an image either decorrelates too quickly to be useful, or is swamped by atmospheric noise. Time series InSAR methods seek to address these issues by increasing the signal-to-noise ratio (SNR) through the use of more data. These techniques are particularly useful for applications where the strain rates detected at the surface are low, such as postseismic/interseismic motion.

Our previous developments in this field have included a persistent scatterer algorithm based on spatial correlation, a full resolution small baseline approach based on the same strategy, and a procedure for combining the two [Hooper, GRL, 2008]. This combined method works well on small areas (up to one frame) at ERS or Envisat strip-map resolution. However, computer resource problems can arise when applying it to larger areas, such as western Anatolia in Turkey and the Guerrero region of Mexico, or when processing data at higher resolution, e.g. TerraSAR-X. We have therefore altered the processing strategy to involve smarter use of computer memory. Further improvement is achieved by resampling of the selected pixels (whether persistent scatterers or distributed scatterers) to a coarser resolution – usually we do not require a resolution on the scale of individual resolution cells for geophysical applications. Aliasing is avoided by summing the phase of nearby selected pixels, weighted according to their estimated SNR. This is akin to smart multilooking, but better results can be achieved than by starting the analysis with low-resolution (multilooked) data.

In order to address long wavelength errors, due to variation in atmospheric refractivity and orbit inaccuracies, we have developed integration strategies that take advantage of other geodetic data acquired in the region of interest, such as GPS. We demonstrate our improved techniques for measuring interseismic motion in western Anatolia and the 2006/2010 subduction slow-slip events in Guerrero, Mexico.

# UNAVCO Event Response Capabilities: Three Great Earthquakes in the Americas in Early 2010

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As part of the 2008 and 2009 Shake Out earthquake drills in southern California, UNAVCO's organizational event response capabilities were tested and refined to ensure robust protocols for decision-making and geodetic observations in the wake of a natural disaster, where geodetic observations were likely to strengthen hazards science studies undertaken by the UNAVCO Community.

UNAVCO, a university consortium and NSF/NASA-funded geodesy facility, also supports the research community in the study of significant geophysical events such as earthquakes, volcanic activity, landslides, glacial and ice-sheet movements, unusual uplift or subsidence, and extreme meteorological events. UNAVCO resources include field engineering support; permanent, real-time/high rate, and campaign GPS deployment; data communications and power systems; borehole tiltmeter, strainmeter, and seismometer deployments; ground-based LiDAR measurements and airborne LiDAR project management; InSAR data acquisition; assistance with education and outreach activities; and data archiving and processing services.

In early 2010 three significant earthquakes have tested this capability, requiring adaptive management of response protocols. These include the January 12, 2010 Mw=7.0 Haiti, February 27, 2010 Mw=8.8 Maule (Chile), and April 4, 2010 Mw=7.2 El Mayor – Cucapah (Baja California, Mexico) earthquakes. For the ShakeOut drills and each of these earthquakes, a different Event Response Coordinator was appointed to manage communications, support requests, logistics and decision-making both within UNAVCO and the community at-large.

For the Haiti earthquake, community scientists requested support for short-term field deployments and to download high-rate buffers from continuously observing networks in the region. A response coordinator was appointed, a central web page was created, special GPS, borehole strainmeter, and borehole seismometer data sets were posted, a new discussion forum devoted to the event was created, a GEO Event Supersite was created and hosted, and a Science Highlight was posted with contributions from community scientists. Field deployments included campaign and the installation of continuous GPS stations. A full debrief and adaptive refinement of response protocols was implemented prior to the occurrence of the February event in Chile.

For the Maule earthquake, four UNAVCO member institutions sought support to build 25 post-seismic GPS deployments in Chile and Argentina. UNAVCO supported these projects with a shipment of 25 complete GPS systems less than a week after the event. UNAVCO then submitted a successful proposal to develop and install telecommunications using a combination of three different systems at the 25 CGPS stations: (1) the satellite-based Inmarsat Broad Global Area Service (BGAN), (2) Iridium systems, and (3), ground based cellular internet services provided by telecom companies in Chile and Argentina. This deployment will allow for daily downloads of daily 15-second files and of 1 Hz data for up to 10 aftershocks over a 1-year period. This effort will serve as the type example in the geodetic community for rapid CGPS data communications following a destructive earthquake and the hardware purchased will become part of the UNAVCO Facility's equipment pool.

The El Mayor – Cucapah earthquake occurred close to the Mexico – U.S. border, at the edge of the EarthScope – Plate Boundary Observatory (PBO) footprint. UNAVCO was one of several community organizations to support event response, providing co-seismic observations from PBO's CGPS stations, borehole strainmeters and seismometers, the shipment of a Terrestrial LiDAR Scanner, and the acquisition of InSAR data through the UNAVCO-hosted WiNSAR consortium. In addition, UNAVCO participated in a successful University of Arizona-led proposal for the deployment of continuous GPS stations for post-seismic observations. These stations will be installed, maintained and data analyzed by UNAVCO/PBO in coordination with CICESE, an Associate Member institution in Mexico.

# Investigating the Noise Properties of GPS Stations in Iberia

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Continuous GPS is nowadays the best technique to observe neotectonic motions. Analyses of these GPS time-series clearly show a linear motion of the permanent GPS that is assumed to correspond to the motion due to tectonic processes. However, the position of the permanent station can also be affected by local motions e.g., ground subsidence (due to variation in ground water level) or small displacements due to seismic events that are not removed during the analyses. It is also possible that the orbit of the GPS satellite constellation produces variations in the accuracy of the GPS solutions from place to place.

We have investigated if the noise of the GPS time-series made at around 80 permanent GPS stations in Iberia shows a spatial pattern. These GPS data were analysed with GIPSY and mapped into ITRF2005 to produce daily solutions. Afterwards, the daily solutions were analysed with the Maximum Likelihood Estimation (MLE) method to estimate the linear motion, a seasonal signal and offsets when they were clearly visible in the data. It is well known that a power-law noise plus white noise model is a good description of the noise in real GPS time-series and, during the MLE, also the values of these three noise parameters were estimated. These three noise parameters show a weak spatial correlation.

# Orbit Tuning for GOCE Measuring Phases and for Planetary Orbiters to Maximize Accuracy Gain in the Gravity Field Mapping

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When measurements from the Earth artificial satellites GRACE A/B (devoted to the study of Earth's gravity field) were analyzed, it was discovered that there is a direct relationship between the density of satellite ground tracks *D* and the accuracy *A* of the gravity field parameters derived from the satellite orbit(s), in particular of the monthly solutions for variable geopotential; the lower *D*, the lower *A*. This is due to passage of the satellite orbit through a low order orbital resonance.

A lesson learned from GRACE was applied to GOCE, namely the necessity of avoiding close proximity of its orbit (kept in this case at constant altitudes for the measurement phases with gradiometer on board) to the 16:1 resonance. To avoid the decrease in *A*, we have to choose the orbit in such a way that order *B* of the lowest order resonance which will occur will be higher than the highest degree $L_{max}$ of spherical harmonic expansion of the potential already known for the particular body. For the Earth, $L_{max}$ is now 150 (EIGEN-5S) for satellite-only solutions and 2190 (EGM 2008) for combination models.

Furthermore, the orbit tuning of GOCE for maximum gain of accuracy of products derived from relevant orbits led us to suggest to select high order resonances with very small differences in the orbit height (or semimajor axis) with respect to a lower order resonances – for example the 61-day repeat orbit with subcycles near 40 and 20 days, and to investigate them in a detail. Such orbits have a higher density of ground tracks in longitude but enable, in case of temporary failure of measuring system or orbit keeping system, to save gradiometer data with a lower density. Additional criterion to have as regular ground track density at the equator as possible inspired us to another suggestion, to a 62-day orbit with the height higher by about 200 meters than has the relevant 61-day orbit. For the $4^{th}$ measuring phase of gradiometer on board of GOCE, ESA considers to select a 145-day orbit with 62-day subcycle. We are ready to create various orbit tuning scenarios on request of user.

We extend our findings outside the Earth, for a hypothetical future low flying Mars orbiter; small changes in the semimajor axis can result in a dramatic improvement in accuracy of the derived gravity field parameters, without any additional costs. The situation for Mars is similar to that of Earth. However, slowly rotating bodies like the Moon, Mercury or Venus do not yet suffer from similar problems, because for them we obtain $L_{max} < B$.

# Velocity Field in Mediterranean Area from ASI-CGS GPS, SLR and VLBI Solutions; the ASIMed Solution

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Continuous GPS data processing has been performed at Matera ASI-CGS since 1995 to support EUREF EPN products (EUREF) and, more recently, meteorological applications (e.g. EGVAP), monitoring a large amount of permanent Italian GPS sites. Moreover, ASI-CGS SLR and VLBI global solutions are issued regularly since the very beginning of the data analysis activities at ASI-CGS, contributing since 90's to the international geodetic services official products.

The ASImed solution is a combined velocity field, covering mainly the Central Mediterranean area. The combination of the three geodetic technique solutions allows framing the ASI-CGS GPS estimates, covering densely the Mediterranean area, in the terrestrial reference frame realized by the ASI-CGS SLR and VLBI global solutions.

The ASIMed solution is issued twice a year (http://geodaf.mt.asi.it/) to benefit of the dense and continuous GPS data analysis, as provided by the daily ASI-CGS European solutions: a hundred of GPS sites in the European/Mediterranean area are included in the ASIMed solution.

The availability of two different GPS solutions, a network solution (based on the Microcosm SW) and a PPP solution (Gipsy/OASIS SW) allows a continuous comparison for the sites included in both the solutions useful to detect stations with ambiguous behaviour or disturbed time series and to mitigate these effects in order to recover a stable, as much as possible, velocity field.

This work summarizes the features of the ASI-CGS ASIMed solution, with emphasis on the velocity results for the Mediterranean area, given in terms of residual velocities w.r.t. Eurasian plate and strain rates.

# Kinematics of Azerbaijan and Surroundings Through GPS Observations

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While located in a region surrounded by strike-slip and thrust fault systems, time-dependent variations occur in the site coordinates due to the deformation and sismicity through tectonic movements in Azerbaijan. Maintenance of the national geodetic networks requires determining and modelling of so-called variations. In this respect, periodical GPS measurements were carried out in 2000, 2001, 2002, 2003 and 2008 by Azerbaijan Devlet Toprak ve Harita Cekme Komitesi to determine time-dependent coordinate variations with high precision. Following the completion of the measurements in 2008, velocity field of Azerbaijan has been determined upon a joint work between General Command of Mapping and Azerbaijan Devlet Toprak ve Harita Cekme Komitesi, and velocity estimations have been made even at the points that have no periodical measurements.

Azerbaijan and surroundings are subjected tectonically by Main Caucasian Thrust Zone in the north, lower Caucasian in the south, west Khazar Fault in the east and Kura cave-in in the middle and there have been no GPS studies with a sufficient spatial resolution up to this study that can describe the deformational domain and its magnitude.

In this study, deformational domain in the region has been analyzed and current strike amounts at the main fault systems have been acquired by using repetitive GPS measurements. Results show that, Azerbaijan is under the effect of deformation more than 1 cm per year and Kura cave-in region displays scattered deformation which is assumed stationary in previous studies.

# Slow Deformation in the Western Alps from a Decade of Continuous GPS Measurements

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The western Alps is a collisional belt, part of the plate boundary between the Nubia and Eurasian plate. Its present-day tectonic activity is characterized by a moderate seismicity and sparse geological and geomorphological observations of recent deformation. There, previous GPS studies have concluded that horizontal velocities with respect to stable Europe do not exceed 2 mm/yr, and that the present-day crustal deformation is consistent with a model where strain is essentially controlled by the counterclockwise rotation of the Adriatic micro-plate with respect to Eurasia (Calais et al., 2002, Nocquet et al., 2003). We revisit these results, now benefiting from a higher density of sites and time series exceeding 10 years of duration. We base our results on a homogeneous reprocessing of the whole data set, using reprocessed orbits from the IGS, and a weekly combination of solution using CatRef (Altamimi et al., 2002). Obtained weekly repeatabilities are better that 1mm on the horizontal components and around 1.5 mm in average for the vertical component. Using the approach of Williams (2003), we find that the noise content of the time series is best characterized by a power-law noise model with spectral index of -0.7 for the horizontal components, leading to velocity determined at the level of 0.2 mm/yr. Vertical component time series show noise characteristics different from one site to another, with spectral indices ranging from -0.4 to -2.0. However, even accounting for the time-correlated noise, most sites show vertical rates uncertainties better than 0.5 mm/yr. Residual horizontal velocities with respect to stable Europe do not show any motion larger than 0.5 mm/yr, with a wrms of 0.19 mm/yr. Sites located in the western part of the Pô plain, do not show any significant motion with respect to Eurasia. As an example, the relative velocity of Torino with respect to Lyon is 0.1 ± 0.1 mm/yr. No deformation is found to be statistically significant within the Alps. Vertical velocity ranges from 0.0 to 2.5 mm/yr and show a clear pattern of uplift within the Alps with respect to their surroundings, increasing with the average topography. Although the mechanisms driving the observed GPS velocity field has yet to be proposed, our new analysis rules out the idea that kinematic boundary conditions imposed by the counter-clockwise rotation of the Adriatic micro-plate controls the present-day deformation. The observed vertical velocities also preclude crustal/lithospheric scale gravitational spreading as being the main driving force.

# Slip Rates near Karliova Triple Junction by GPS Observations

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While East Anatolian Fault System (EAFS) is seismically less active, historical evidence suggests that it is capable of producing earthquakes of Mw7.0. On the other hand relatively less urbanized region and buildings and the engineering structures of lower quality in the region also increase the losses and the intensity of the earthquakes as revealed by the recent seismicity. Karliova Triple Junction (KJT) is believed to be the easternmost boundary of westward transport of Anatolia.

The ongoing deformation in the region was already investigated earlier by Reilinger et al. (2006) and more recently Ozener et al. (2010). The latter study provided unpredented spatial coverage through a project performed by Geodesy Department of Kandilli Observatory and Earthquake Research Institute (KOERI) of Bogazici University. This study also enabled the quantification of the ongoing deformation at a much denser network. Both studies provide invaluble data to contribute our understanding of the deformation in this region. However, a detailed study of the region, specifically the current slip rates of the main faults is still needed.

In this study, we homogenously combined the micro network of the Geodesy Department of Kandilli Observatory and Earthquake Research Institute with the results of Reilinger et al. (2006) through estimating a rotation rate. In this respect, most densest GPS network was obtained in the region to allow for better interpretation and modeling. The triple junction and its surroundings were discretized into four blocks corresponding to main tectonic frameworks of the region and block rotations and slip rates on the boundaries are simultaneously estimated throuh minimizing the misfit between the observed velocities and model velocities.

The most segment of the region was found to be Yedisu Segment with more than 11 mm/yr right lateral strike-slip. Similarly, about 10 mm/yr normal slip also exists on this segment. As opposed to common view, the left-lateral slip component on the northern part of East Anatolian Fault System is less than 5 mm/yr. The results also show that thrusting is the dominant component in the deformation of the region. The slip rates over the Ovacik fault segment is about 1.5 mm/yr nearly at the noise level of the measurements.

# Intra-Eurasia Plate Motions Based on CODE-EPN, IVS-Europe, and IVS-Combined Solutions

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Plate motions, inferred from the velocity vectors of geodetic reference points, can be precisely estimated through the analyses of space geodetic measurements, e.g. the Global Navigation Satellite Systems (GNSS), or Very Long Baseline Interferometry (VLBI). Homogenous distribution and high spatial resolution of the geodetic sites, as well as high temporal resolution of precise coordinate estimates have utmost importance for geodynamical studies. In this study, Eurasia plate motions with respect to southern Mediterranean neighbouring micro-plates, e.g. western and central Mediterranean regions, Adria plate, Alpine region, Iberian Peninsula, the Corsica-Sardinia micro-plate, Balkans, and Aegean regions were determined. The data used in this study are based on three different sources. The first is the IVS-Europe VLBI sessions, scheduled and carried out by the International VLBI Service for Geodesy and Astrometry (IVS), in order to determine European VLBI antenna coordinates and their evolutions in time. These daily sessions (day long sessions which are carried out four to six times per year) were analysed from January 1990 to 2010 May with the Vienna VLBI Software (VieVS). The second data set are daily intra-technique combined IVS antenna coordinates from all sessions from 1980 to 2007 (unevenly distributed carried out approximately one to three times per week). The third data set are weekly solutions by the Center for Orbit Determination in Europe (CODE), which contribute to the EUREF permanent GNSS network (EPN) from 1996 to 2010 (evenly weekly solutions). The velocity vectors and low frequency harmonic motions were estimated from the coordinate time series of the GPS and VLBI sites spread over whole Europe and neighbouring regions based on 14 years of CODE-EPN weekly, 20 years of IVS-Europe daily, and 27 years of IVS-combined daily solutions. The coordinate time series of CODE-EPN, IVS-Europe, and IVS-combined were compared at the co-located sites as well as the velocity vectors and periodic motions of the station coordinates.

# Establishing a Tsunami Warning System in Turkey

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Tsunami mitigation, preparedness and early warning initiatives have begun at the global scale only after the tragic event of Sumatra in 2004. Turkey, as a country with a history of devastating earthquakes, has also been effected by Tsunamis in its past. KOERI, as the leading Earthquake Research Institute of Turkey, is setting up a Tsunami Warning Center which is expected to act also as a regional center under the UNESCO Intergovernmental Oceanographic Commission – Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS) initiative. The necessary technical and administrative work has been undertaken by all related national authorities under the coordination of KOERI with the financial support of o the State Planning Organization. NAMI_DANCE Tsunami Simulation / Visualization Code and SeisComp3 have been installed in KOERI to increase the operational capability of the National Earthquake Monitoring Center, which will host the Tsunami Warning Center. Intensification of the coastal seismometer network, obtaining real time seal level data, tsunami modeling, preparation of inundation maps based on model driven scenarios, estimation of tsunami hazard and risk are among the major components of this initiative. KOERI is also starting a new era in its observational capabilities by installing 5 sea bottom observatories in the Sea of Marmara within the Sea Bottom Observatory Project supported by Turkish Telecom, including broadband seismometer and differential pressuremeter, pressure transducer, strong-motion sensor, hydrophone, temperature measurement device and flow meter. One of the sea bottom observatories was installed in December 2009 and already transmitting continuous data to KOERI.

# Determination of the Displacements along the Tuzla Fault (Izmir) and Surroundings by GPS and Precise Leveling Techniques

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Both seismological and geodynamic research studies emphasize that the Aegean region is mainly under pure shear stress from an internally deforming anti-clockwise direction of the Anatolian Plate relative to the Eurasia Plate. The Aegean region is the most seismically active domain in Western Anatolia which comprises the Hellenic Arc, Greece and Western Turkey. Izmir is the third largest and populated city in Turkey which the population has been reached about 2,7 million that is a great risk from big earthquakes. The Tuzla Fault has a significant importance in terms of its proximity to the city of Izmir and seismic activity. The Tuzla Fault is lying between the town of Menderes and Cape Doganbey which has NE-SW lineament trending.

This study is intended to investigate the crustal deformation and relative displacements along the Tuzla Fault and Izmir Bay by two different geodetic techniques. These techniques are GPS and Precise leveling. For this aim a micro-geodetic network with 15 points has been established. The study area covers 30km*50km. Observation of first GPS campaign and leveling measurements were performed at 2009 and subsequent year, 2010, the second GPS campaign and leveling measurements were performed. In order to process collected data by GPS campaigns, GAMIT/GLOBK software was used. As a result of two GPS campaigns, the velocity vectors of points are rated between 21mm/yr to 25mm/yr. In addition, 6.6 mm vertical displacement was observed between two leveling benchmarks which seems critical and needs further investigation.

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# Determination of the Kinematic Structure of Izmir and Surrounding Using Repeated GPS/GNSS Observations: Preliminary Results

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Aegean Region, including Western Turkey and Central Greece, is one of the regions in which the earth's continental crust has been rapidly deformed. There is also a very effective seismic activity in this region. It is commonly thought that the crustal movement in this area has a very large-scale. These crustal movements in Turkey are the reasons of the subduction zones to the south direction along the Hellenic Arc, the right lateral slips along the East-West directional Northern Anatolian Fault and the North-South extension of the Western Turkey, Aegean Sea and Western Turkey were separated by the effect of strain tectonic regime which had started at the end of Middle-Miocene and it took its recent shape due to neotectonic vertical movements. Characteristics of the deformation in the continental crust observed in Aegean Region have a very complex structure. The wide fault blocks in this complex mechanism turn around on both horizontal and vertical axis and the energy conserved because of the deformation along these active faults has been released by the earthquakes we observed in this region. The main reason for this very fast extension movements are related to the active fault zones that are clearly detected by the seismological and geological studies in the region. The active normal faults also control the geomorphology of the region. The graben systems are the key points for understanding of the general deformation system and deep structures of the Aegean region. There are various suggestions about the type of the deformation, the amount of extension and the formation of grabens. Detailed and reliable knowledge about the velocity of the extension was obtained through the studies in which the satellite geodesy methods have been used in recent years. Studies about mapping the active normal faults in Izmir and surround are very rare. Several approaches have been developed about the area based on the GPS/GNSS studies carried out in Western Anatolian region. The three moderate earthquakes that occurred in this area in the last fifteen years show that the area changes its shape under the control of the strike-slip faults (the line: 1992-Doganbey, 2003-Urla and 2005-Seferihisar). The faults observed in western of this line up to Karaburun should be regarded in the same fault system and the earthquake potential of this area should be considered by taking into account of the existence of this fault zone. In this project, the kinematic structures of the faults which control the seismic hazard in Izmir and its surroundings are attempted to estimate by using GPS/GNSS data of the region. For this aim, GPS/GNSS observations were made for three days in two, 10-hour sessions in 20 GPS/GNSS stations in the south of Izmir. In order to process data, twelve stations from International GNSS Service (IGS) of which has a good processing and measurement history as well as which can be used to calculate the velocity vectors was chosen to circulate the network area. Also, the

stable stations of TUBITAK (The Scientific and Technological Research Council of Turkey) in Western Anatolian region had been used.GAMIT/GLOBK software package which was generated by Massachusetts Institute of Technology was used for processing the GPS/GNSS data. The evaluations were carried out and daily solutions were obtained by using GAMIT software. These daily solutions were combined by GLOBK software and the compensated point result coordinates are computed with the result of this combination. Also, the Bernese software was used to process 20 stations of network in order to compare the results obtained from GAMIT/GLOBK software and to explore the differences between these two softwares if there is any. On the other hand, because of one period observation is not enough for obtaining the velocity vectors of the area; GPS/GNSS observation campaigns in 2010 and 2011 which was previously planned will be done. In this study, the preliminary results of 20 stations for first period GPS/GNSS observation have been presented. The results showed that the first period GPS/GNSS observation and calculation are as it was expected. In this ongoing project the structural elements and tectonic system of Izmir and its surrounding in the Western Anatolian tectonic system are investigated in detail.

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# Static Stress Changes and Fault Interactions in the Lefkada Island (Ionian Islands-Western Greece)

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The complicated tectonics of the Mediterranean region, dominated by the collision of the Arabian and African plates with Eurasia, affects the whole of Greece. In Western Greece, the tectonic behaviour is characterised by transcurrent fault systems one of which is the transform fault of the Cefallonia Island with right-lateral slip and a slip rate of about 3cm/yr; the fastest fault slip observed so far in the Hellenic region. The Ionian Islands are situated in a transitional zone characterized by a high crustal deformation rate as revealed by the high shallow seismicity of this zone, which is the highest in Greece.

Repeated GPS campaigns have been carried out covering the broader area of the Ionian Islands. So far, the analysis of these data has provided estimates of the secular motion of the free surface.

In the present work an attempt is made to assess the Coulomb stress change associated with well documented earthquake activity in Western Greece (Ionian Islands) and especially the island of Lefkada which has suffered several times from the occurrence of earthquakes with magnitudes of 6.0-6.5. The efficiency of the earthquake modeling is further evaluated by comparing the free surface displacement fields corresponding to the Coulomb stress changes with the ones derived from the GPS observations.

Since the tectonics of the region are controlled by more than one type of faults a comparison is carried out regarding the behaviour of the different types of faulting to static stress changes.

# Strain Analysis on the Neo-tectonic Basin of Saronikos Gulf: Preliminary Results

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Saronikos Gulf was studied by Differential GPS measurements in an attempt to investigate the regional deformation of the area. The GPS network (SARNET) involving stations in Athens (UOA1, OBSV), Aegina Island (AEGI), Methana Peninsula (MET1, MET2) and Soussaki (SUSA) was established in February 2006 and since then it was reoccupied twice. The GPS measurements were primarily referred to World-fixed reference frame (ITRF2000) and then to Europe and Athens as well. The observed velocities for the overall three-year spanning period, independently of the reference frame, indicate the differentiation of AEGI site, at the center of the basin, defining a transitional zone between Western and Eastern Saronikos Gulf. This zone seems to be correlated with the major detachment fault that cross Attica region to the north, and probably continues until Southern Saronikos. Strain analysis proved the different deformation pattern between the two sub-basins of the gulf, implying the continuation of the Attica detachment fault along the Saronikos. The results indicate both extensional and compressional deformation field along the Saronikos Gulf, whereas higher rates of extension are observed at Western Saronikos, conversely to the compression occurring at Eastern Saronikos. It may well be assumed that a fault fraction at Eastern Saronikos deform at least partially aseismically, when interpreting the observed strain rate.

# Short-term and Long-term Slip Rate along the Westernmost Segment of the North Anatolian Fault

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We investigate the cumulative and co-seismic offsets of the Ganos fault, the westernmost segment of the right-lateral North Anatolian Fault System that ruptured during the 9 August 1912 Murefte earthquake (Ms = 7.3). The earthquake size requires a minimum 120 km fault rupture length. Right-lateral coseismic offsets are measured at 45 sites along the 45-km-long onland section of the fault (from Gazikoy to Saros Bay). The maximum co-seismic slip reached 5.5 m at Guzelkoy and Yorguc and the average displacement was inferred as 2-3 m. Using paleo-channel and stream offsets combined with dated units from trenches we obtain slip rates for the Guzelkoy and Yenikoy sites. At Guzelkoy, two paleo-channels display 16 ± 0.5 m and 21 ± 0.5 m offset and yield 22.3 ± 0.5 mm/yr for the last ~700 years and 26.9 ± 0.5 mm/yr for the last 781 years. Furthermore, the dating of the lowermost sedimentary units of the 46 ± 1 m dextral offset stream at Yenikoy provided a maximum 17 mm/yr slip rate for the last 2840 years. Cumulative displacements determined at 69 localities and tectonic reconstructions provide insight on the long term deformation of the Ganos fault segment. A classification of the stream incisions, related offsets and correlations with climatic events deduced from Black Sea sea level curves indicate the correlations of consecutive 5 groups of deflections (from 70 to 300 m) with subsequent sea level rise periods at 4 ka, 10.2 ka, 12.5 ka, 14.5 ka and 17.5 ka. Slip rate estimations yield a constant slip rate of 17.9 mm/yr for the last 20 ka and a variable slip rate from 17.7 mm/yr to 18.9 mm/yr for the last 17.5 ka. These long term slip rates obtained from cumulative stream offsets are comparable to the paleoseismic rates (17 - 27 mm/yr) obtained for the last ~800 years. We discuss the signification of our results and their small variability in comparison with 22 - 26 mm/yr GPS velocities that suggest strain accumulation along the Marmara segment of the North Anatolian Fault.

# Crustal Deformation from 15 Years Space-based Geodetic Data on the Inactive Fault Branch of Western North Anatolian Fault Zone

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Space-based tectonic studies on the western part of North Anatolian Fault Zone (NAFZ) have been carried out for two decades. After the August 17, 1999 Izmit Earthquake (Mw= 7.4) this region attracted more of interest and the collected data became invaluable. Geodesy Department of Kandilli Observatory and Earthquake Research Institute (KOERI) of Bogazici University established three microgeodetic networks at east of Akyazi, east of Iznik, and west of Lake Sapanca in the eastern part of Marmara region and continually collected GPS data since 1994. NAFZ splays into two branches around Mudurnu Valley and the dispersed branches extend up to Aegean Sea. Branches passing through Marmara Sea are thought as active and increase the concerns of the imminence of earthquake danger. However, in the southern branch is in very long sleep for ages. 4-year terrestrial geodetic measurements on this seismically low active region showed that terrestrial instruments are not capable of monitoring such little movements. GPS has played a very important role on detecting immeasurable deformations on fault zones. Iznik network with 10 points are bilaterally located on the fault. This study is the evaluation of almost 15 years of GPS data collected for the monitoring crustal deformation.

# Present-day Vertical Crustal Deformations in the Marmara Region, Turkey from Repeated Absolute Gravity and GPS Observations

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We present a comparison of the gravity changes and Global Positioning System (GPS) vertical velocities in the Marmara Region. The comparison of observations of geometric data by GPS and measurements of absolute and relative gravity helps to separate the two effects, which may be involved: vertical displacement and mass variations in depth. Gravity and GPS data collected at the same location and observations realzied between the 2006–2010 years.

Study area covers the western part of ruptue zone of 17 August 1999 Izmit earthquake in the Marmara Region, Turkey and focus the next expected earthquake area. To increase the observation quality, a gravity calibration baseline stations which was established in the region for the purposes of the calibration of the relative gravimeters. The observations evaluated here demonstrate that the joint analysis of GPS, absolute and relative gravity data help to understand better the vertical component of the postseismic deformations of the 1999 earthquakes and hence expand our knowledge of the geophysical process in the Marmara Region.

# Seismotectonic Setting of the Karadere-Duzce Branch of the North Anatolian Fault Zone between the 1999 Izmit and Duzce Ruptures from Analysis of Izmit Aftershock Focal Mechanisms

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We investigate aftershock focal mechanisms along the eastern part of the Izmit $M_w$ = 7.4 August 17, 1999 rupture zone during the time period August 22, 1999 - October 17, 1999. Two spatial clusters of aftershock activity are analyzed representing the Karadere Fault (KF) and the Duzce Area (DA). Based on an aftershock hypocenter catalogue restricted to events with horizontal and vertical errors < 2 km, we determine fault plane solutions for 221 events. The high number of focal mechanisms at the eastern Izmit rupture zone could be determined only due to the low magnitude-detection threshold of the seismic network and allows resolving the local deformation pattern with unprecedented precision. Focal mechanisms along the Karadere Fault allow us to identify dominantly dextral strike-slip mechanisms with normal faulting components on NE-SW trending fault planes. Focal mechanisms in the Duzce Area predominantly exhibit NE-SW extensional normal faulting but also a substantial part of strike-slip faulting. Further subdivision of the data set slightly decreases for the misfit for deeper (z > 10 km) events. North and east of the easternmost end of the Karadere Fault we observe a high variance in stress field orientation correlated with lower *b*-values. While the Karadere Fault reflects a predominant dextral strike-slip regime with normal faulting components, the Duzce Area further to the East that also hosted the forthcoming $M_w$ 7.2 mainshock 87 days after the Izmit earthquake can be subdivided into a dominantly NE-SW extensional normal faulting regime below the Duzce Basin (DB) and a first-order strike-slip regime along the western Duzce Fault (DF). We conclude that the Duzce Basin was set under tension by the Izmit rupture and partly released the slip deficit by extensional faulting on Karadere Fault parallel to the coseismic displacement. At the same time this area and in particular the Duzce Fault that bounds the Duzce Basin to the south reflects mostly strike-slip events representing a major asperity along the North Anatolian Fault Zone (NAFZ) before initiating the Duzce rupture 87 days after the Izmit event.

# High Rate GPS for Earthquake Source Study

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The increasing number of Continuous GPS networks recording at high-frequency (High Rate GPS, HRGPS), together with improvement of kinematics analysis techniques now enable us to monitor the kinematic surface deformation generated by earthquakes. As a consequence, HRGPS now becomes a new tool for seismology, whose range of application has yet to be explored. So far, three types of applications have been investigated. First, HRGPS was used as near field data to study the earthquake rupture kinematics (Ji et al. 2004, Miyazaki et al., 2004). Secondly, GPS was used to monitor the surface deformation induced by rapid slip immediately following earthquakes (Langbein et al., 2006, Miazaki & Larson, 2008). Finally, Davis and Smalley (2009) quantified the surface waves generated at teleseismic distance by the Sumatra-Andaman 2004 earthquake to determine the Love wave phase velocity dispersion curve in central North America. In this study, we investigate the use of HRGPS at regional distance (250-1000 km) to constrain the earthquake rupture evolution. We first test the use a network located at 250-700 km of the Mw=8.8 2010 Maule (Chile) Earthquake, publicly available from the National Geographical Institute of Argentina (http://www.ign.gob.ar/ramsac). Kinematics processing shows maximum seismic waves amplitude reaching 50 cm peak-to-peak on the east component and co-seismic static displacements reaching 20 cm. However, HRGPS displacement seismograms include long-period noise (>50-100s), which is only partly removed by sidereal filtering. Best results are obtained in the 0.005-0.03Hz range for which sub-centimeter agreement with the waveform predicted by the earthquake kinematic source model can be obtained. HRGPS complement existing data to better constrain the rupture history. Our model finds that the rupture initiated at about 32 km depth and propagated bilaterally resulting in two main slip zones located SSW and NNE of the hypocenter. Average overall rupture velocity is 2.6 km/s, but during the first 30s, slip propagated predominantly and more rapidly (3.2 km/s) southwards. Eventually, the rupture evolved more symmetrically, but the northern slip zone finally shows 20% of seismic moment larger than the southern one. There, maximum slip reaches about 20 m. Down-dip, rupture stopped at about 50 km depth, in agreement with the downdip limit of the locked zone inferred by Ruegg et al. (2009) from pre-seismic GPS data. In a second study, we investigate a new application, which aims at using a local HRGPS network as a small-aperture seismic array to track the earthquake source at intermediate distance (~1000 km). We use a data set of 7 HRGPS sites located ~950km northeast of the Wenchuan (China) Mw=7.9 2008 earthquake. We show that displacement seismograms derived from 1Hz GPS kinematic analysis are accurate enough in the frequency range of 0.02-0.04 Hz to correctly retrieve the back-azimuth of the Wenchuan earthquake. We further identify two zones of coherent highly energetic surface waves emission showing a minimum rupture length of 250km and duration of 90s and confirming the unilateral northeastwards propagation of the rupture. A third source of coherent surface waves radiation is found around 55s after the rupture initiation, ~75km from the epicentre, suggesting an acceleration of rupture velocity. Because HRGPS do not saturate in case of strong

motion, array techniques can always be applied at regional distance using HRGPS networks, providing an additional tool to study earthquake rupture properties.

# Monitoring the Kinematics of Anatolia Through Continuous GPS Observations

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Turkish National Permanent GPS Network (TNPGN) consisting of 27 stations, 4 of which are also included in EPN and IGS networks, is serving for long-term maintenance of TNFGN and provides the integration of national control networks to the global networks. Although TNPGN was preliminarily conceived as a static continuous network, intensive cadastral demands have led to establishing a denser RTK GNSS network which covers the whole country. TNPGN has been currently operated by the General Command of Mapping. Establishment of a new RTK GNSS Network, along with TNPGN, consisting of 150 stations is still under progress and expected to be full functional by the end of 2008 and will provide the basis for various applications and scientific researches. More than half of the stations were installed in meteorological parks of General Directorate of State Meteorology.

TNPGN will function as a fundamental tool for geodynamics, tropospheric ionospheric research as well as surveying and cadastral works. While permanent GNSS networks offer the utmost precision obtainable from GNNS studies, they still lack the sufficient spatial resolution required in high-deformation regions. Turkey is located within the boundary of Eurasia, Arabia and African plates and TNPGN forms the southeastern boundary of European Continues Network. TNPGN has the importance of a continuous monitoring and detecting the rigid and deforming boundaries of Turkey. In this respect, TNPGN will provide an indispensable geodetic control for monitoring the crustal movements as well as addressing the issues of southeastern boundary in reference frame definition.

In this study, we introduce real-time Turkish National Permanent GPS Network (TNPGN) which also provides high temporal and spatial coverage and present the preliminary results of deformation through the continuous stations.

# Additional Improvements in Geoid Determination in Algeria Using the New EGM2008 and the Satellite Altimetry-derived Marine Gravity Anomalies

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The main objective of this paper is to investigate the possibility of improving the accuracy of the latest geoid model for Algeria employing the new Global Gravitational Model EGM2008 and the satellite altimetry-derived marine gravity anomalies. For this purpose, a new gravimetric geoid model for Algeria has been computed using data from the EGM2008 global geopotential model, the land gravity data supplied by the BGI, a nationwide digital elevation model, and satellite altimeter-derived marine gravity anomalies. The geoid heights are on a 5 by 5 arc-minute grid with respect to the GRS ellipsoid, and residual geoid heights were computed using the 1-D fast Fourier transform technique. This solution and latest geoid model are compared to the geoid undulations corresponding to 51 GPS/levelling points located in northern part of Algeria and based upon the international TYRGEONET, ALGEONET projects and some local GPS networks. The collocation technique has been used to determine the relationship between the GPS/levelling and gravimetric geoids. Different models for the corrector surface have been assessed, and the approach has also been used to detect outliers in the GPS/levelling data. According to our numerical results, the new geoid shows an improvement in precision and reliability, fitting the geoidal heights of these GPS/levelling points with more accuracy than the previous geoid. Its standard deviations fit with GPS/levelling data are 17.0cm and 3.0cm before and after fitting using the seven-parameter similarity transformation model. Moreover, the analysis of the results shows that the signals in benchmarks are dominated by errors in the geoid due to the bad gravimetry, while the noise level indicates of the presence of errors in our height datum. This new geoid model will be used to support Levelling by GPS at least for the low order levelling network densification. It is an important contribution to Geophysics, because it can provide a constraint for density distribution, thermal state of the lithosphere and viscosity in the mantle. Such details can be inferred from the geoid and the seismic structure of the study area.

In addition to these more general investigations, special GPS campaign has been performed for altimetric auscultation of a storage tank in which we wanted to test the possibilities to replace levelling by GPS measurements. The comparison between the computed orthometric heights and observed ones allowed to affirm that the alternative of levelling by GPS is attractive for this auscultation.

# Evaluation of Recent Global Geopotential Models with Turkish Local GPS/Levelling Geoid

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In order to determine the outer gravitational field of earth, global potential models which consist of spherical harmonic coefficients ($C_{nm}$, $S_{nm}$) are used. The coefficients are obtained from terrestrial gravity anomalies, satellite orbit perturbations and altimetry data. Generated global geopotential models are always in development to evaluate the gravitational potential and it's functionals which mean gravitational field of earth. The number of data, developments of measurement and evaluation techniques depending on the time comprise the foundation of improvement in models.

In this study, the performances of recent global potential models (GRACE01S, GRACE02S, EIGEN-CHAMP03S, EIGEN-CG01C and EIGEN-CG03C) which computed with CHAMP and GRACE satellites data have been evaluated in Turkey. The purpose of the study is to investigate the improvement in the long-wavelenght component of gravity field in Turkey with different global geopotential models. Therefore, geoid heights computed by using potential models which expressed by spherical harmonic equations from different maximum degrees have been compared and tested with geoid heights obtained by Turkish local GPS/Leveling geoid.

# Comparing of Conventional Stochastic Model with Helmert Variance Component Estimation in Geodetic Nets

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In conventional geodesy , triangulation nets for coordinates of points and leveling nets for heights of points are formed (heights are needed for calculation of the triangulation nets). Different instruments and measurement methods are used in geodetic networks which are named leveling and triangulation nets. The new measurement technologies are also used with conventional measurements. It is known that it is too difficult to define a stochastic model in geodetic networks which are measured by different instruments and measurement methods. In this study, "Variance Estimation by Helmert Type" is introduced and the adjustment results are given for both leveling net and triangulation net.

# Current Red Sea and Gulf of Aden Rifting and Motion of Arabia

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The Arabian plate or "Arabia" is located adjacent to the Red Sea ridge and thereby offers a rare opportunity to study crustal movements at a young, divergent plate boundary. Arabia is not only characterized by the divergence of the Arabian and African plates, as several active volcanoes are located on the Arabian Peninsula. Moderate size earthquakes occur in the transform zones associated with recent volcanism, causing measurable crustal deformation. In 2009 a number of towns near Medina, Saudi Arabia were evacuated due to land unrest in these areas caused by volcanic activity. Around five years earlier, in 2002, the installation of a permanent network of continuous GPS stations (CGPS) was initiated in order to observe deformation due to an ever expanding [Red] sea and unrest in the Medina volcanic system especially around the Al-Eace system of volcanoes. The CGPS network has been enlarged over the years and consists today of more than eight CGPS stations. Most of the stations are located along the Arabia-Africa plate boundary, where most of the active deformation takes place. Red Sea rifting due to continued motion throughout the period of measurements has now been detected and quantified by the CGPS network. This study presents results from analysis of eight years of data from the CGPS network, in the global reference frame ITRF05, which has been evaluated by processing GPS data at both King Abdulaziz City for Science and Technology (KACST), K.S.A and Massachusetts Institute of Technology (MIT), U.S.A. We thus present estimates of the horizontal velocities in Arabia with respect to neighboring regions and combine them with results from a number of networks around it. Hence, estimates of the local vertical motion or land uplift in a global frame are not presented here. The horizontal station velocities clearly show Red Sea spreading across the plate boundary that increases from the northern most Red Sea (~7 mm/yr at ~27°N) to the south reaching a maximum rate of ~ 15.5 mm/yr near 16°N. Further south the rift bifurcates with extension being distributed between the Danakil Depression and the central Red Sea Rift. Moreover, Estimates of current Arabia plate motion is shown to be consistent with geologic plate motion estimates since the early Miocene when Arabia separated from Nubia within uncertainties (i.e., ± 10%).

# VLBI Estimates of Vertical Crustal Motion in Europe

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Geodetic Very Long Baseline Interferometry (VLBI) observations of European VLBI network (EVN), have been scheduled as IVS-Europe VLBI sessions and carrried out by International VLBI Service for Geodesy and Astrometry (IVS) since 1990 in order to establish a stable and accurate geodetic reference frame covering Europe. The aim of this study is to detemine the vertical crustal motion in Europe by means of analysing the IVS-Europe VLBI sessions over along period of 20 years. Firstly, the IVS-Europe VLBI sessions of EVN from 1990 till 2010 May were analyzed with Vienna VLBI Software (VieVS). Several parametrization options within the analysis of the IVS-Eurpoe VLBI sessions were selected typically for a regional VLBI network. Then, correlations between VLBI antenna reference point height errors, and zenith wet delay estimates were produced and examined for several EVN sites. At the last stage of this study, estimated vertical position time series of VLBI reference points in Europe were compared with those of the corresponding co-located Global Navigation Satellite Systems (GNSS) sites. After reducing the local ties, the agreement between height time series of VLBI and GNSS co-located sites were figured out in terms of descriptive statistics.

# Investigation of the Stability of IGS Station Points: TRAB IGS Station as a Case Study

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Nowadays, deformation measurements has became a conspicuousare discipline for different fields. With the improvements of measurement devices and combined use with the statistical analyses, deformation measurements and analysis has gained a place in many application fields. Increasingly improvement in deformation measurements methods has been entered into space and satellite measurement techniques and permanent GPS (Global Positioning System) stations will continue to be used for deformation analysis purposes.

At the time of going to press, the International GNSS Service (IGS), formerly the International GPS Service collects, archives, and distributes observation data from total 421 permanent IGS stations which of 377 are active stations around the world. At some of these stations, measurements are collected from the observations of not only from satellite but also from quasar, galactic and radar. IGS stations can better determine deformation movements of their constructed area than other types permanent GPS stations.

Within this study, the investigation of stability of TRAB IGS station which is constructed on roof of department of Geomatics Engineering at Karadeniz Technical University (KTU) Kanuni Campus Area, determination of deformation on building of department of Geomatics Engineering and its surroundings, comparison of results with the geologically determined active fault kinematic of research area and interpretation of all results are conducted.

# Deformation of Central Anatolia by GPS Data

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Taking place between North Anatolian and East Anatolian mega shear zones, neotectonics of seismically less active Central Anatolia is often regarded as tectonic escape or extrusion tectonics. Although previous published GPS studies dating back to early 1990's report coherent rotation, they were mostly focused on seismically more active and more populated Western Anatolia and lack spatial resolution in quantifying second-order structures within such as Tuz Golu Fault Zone, Central Anatolia Fault Zone comprising Ecemis Fault and Erciyes Fault, Ezinepazarı Fault, related basins and associated processes. However, new dense GPS velocity field of Central Anatolia exhibit systematic local patterns of internal deformation inconsistent with either coherent rotation or translation. Velocity gradients computed along rotation profiles of Central Anatolia show nearly smooth westward increments which can not be explained through a simple rotation/transport of Central Anatolia Basin. Moreover estimating and removing a rigid-body rotation represented by an Euler Pole computed from sites lying in the middle absorbs the velocity discrepancies between the Eastern and Western part of Central Anatolia down to a few millimetres leaving out systematic residuals.

Upon completion of Turkish National Fundamental GPS Network (TNFGN) in 2002, further observations were carried out in Central Anatolia which results in a velocity field of unprecedented spatial density with average inter-station distance of 30-50 km. We computed horizontal velocity field with respect to ITRF2000, to Eurasia, and to a computed Anatolia Euler Pole as well. Two distinct models of Anatolia neotectonics, microplate and continuum deformation were tested through rigid-body Euler rotations and strain analysis, respectively. Results show that decomposition of the Eurasia-fixed velocity field into rigid rotations and residuals reveals systematic residuals up to 5 mm/yr with respect to a computed best-fit Euler Pole located at 31.682°N±0.05, 31.613°E±0.02 with 1.380°/Myr ±0.01 rate. Relative velocities computed along rotation paths exhibit westward increasing linear gradients of 0.7 mm to 1.3 mm per 100 km depending on the latitude which is mechanically inconsistent with the assumptions of a coherent transport or rotation due to an extrusion in the east. Moreover, strain analysis results show that up to 100 nanostrain/yr E-W extension rates are observed along approximately N-S striking faults within the region from west of Karliova to Isparta Angle which is another indication of partitioned extensional strain across the Central Anatolia.

# Understanding of Aseismic Creeping Process in the Ismetpasa Region of North Anatolian Fault Zone by GPS Data

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In 1972, a six point-network was established by General Directorate of Mapping in Gerede-Ismetpasa. This region is relatively quiet segment of western NAF which is creeping along steadily. This network was surveyed by terrestrial techniques in 1972 and 1973. The Ismetpasa Network was re-measured in 1982 and in 1992 by the Geodesy Working Group of Istanbul Technical University.

Although the same network (with five points) was observed in 2002 and 2007 by Zonguldak Karaelmas University applying GPS technique, with 1-hour site occupation, the characteristics of movement has not been detected implicitly. This type of movement still raises a question about the accumulation of tectonic movements in the region.

Geodesy Department of Kandilli Observatory and Earthquake Research Institute (KOERI) of Bogazici University has been re-surveyed the network by campaign-based static GPS surveying (10-hour site occupation) since 2005. The GPS velocities data coming from geodynamic GPS networks of the crustal deformation studies and the analysis of repeated geodetic observations give us significant information about the elastic deformation. Therefore, data gathered in this study is processed using GAMIT/GLOBK software and analyzed together with previously collected data to obtain velocity field and strain accumulation in the study area.

# CORS-TR Network and its Application to Crustal Deformation

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Recently, a national CORS network, called CORS-TR (or TUSAGA AKTIF) network has been established by Istanbul Kultur University in Turkey and Northern Cyprus. The project was sponsored by Scientific and Technological Research Council of Turkey (TUBITAK). The network was designed to fulfill several important tasks ranging from geodetic measurements in crustal deformation studies to the modeling the atmosphere (troposphere and ionosphere) over Turkey. The network consists of 147 reference stations and three control centers collecting the GNSS data and broadcasting Real Time Kinematic (RTK) corrections.

In Turkey, earthquakes have been natural hazards affecting the country socially and economically. It is of utmost importance to get the knowledge of the characteristic and dynamics of the tectonic plates, including fault lines to mitigate the earthquake hazard. With this goal in mind, in conjunction with InSAR techniques, this paper deals with the monitoring capability of the CORS-TR network in tectonic plate and subsidence in Turkey. The countrywide GNSS data of 141 stations collected in 2009 was processed. The data belonging to 2010 is being processed at the moment. The results are being presented and analyzed in this paper.

Lately, Istanbul was selected as one of the Geohazard Super sites by a membership-based consortium of universities, research institutions, national agencies responsible for geohazard observations, and space agencies. The Geohazard Supersites provide a cyber-infrastructure platform allowing fast, easy and free of charge access to complete satellite and ground-based geophysical datasets derived from different sources and different disciplines. This inter-disciplinary approach of using satellite radar data (SAR interferometry), seismology, and other earth science domains, provides the unique potential in making scientific steps in narrowing down the uncertainty of future disastrous events and providing information to policymakers for urbanization in geohazards endangered areas. Together with InSAR, CORS-TR shall play a key role in studies for Istanbul region. This paper also discusses the use of these techniques for crustal deformations in Istanbul region.

# RTK Application for Levelling Network Deformation Control

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Last 2nd order levelling campaign in Riga city was performed at 1975-77. Mainly negative vertical movement was discovered at several places comparing with levelling results of 1949-54. There were no levelling networks neither controlled nor developed in Riga city after 1977. However, the high accuracy levelling network is still important for many civil engineering tasks and for geodetic and geophysical research purposes.

The deformation of Riga levelling network may be caused by the vertical movement of local earth surface. The tectonic continental and intercontinental movement of the earth core is available as well. There are several effects of vertical movement in urban environment. Development of the new building construction, increase of traffic intensities and both the geologic and hydrogeologic conditions in upper layers of ground are additional sources of the up or down movement of earth surface. The vertical movement could be controlled by height determination of levelling benchmarks.

Application of Global Navigation Satellite Systems (GNSS) in geodesy discovers a powerful tool for the verification and validation of the historically long time ago established geodetic levelling benchmarks. The differential GNSS and RTK methods appear very useful to identify the vertical displacement of landscape by means of inspection of the deformation of levelling networks.

The criteria of Mean Sea Level not always are highly useful. The mean Baltic Sea level has risen by 26 cm during 100 years according the records of Riga tide gauge station. It is placed near the Daugava river estuary where the water level changes depending of the work regime at the Riga hydroelectric power station placed on the Daugava River at a distance of about 20 km. Therefore it is rather difficult to fix the real value of mean sea level. It is influenced by the artificially changing water level of river Daugava.

Additional tool for the independent height determination is the application of Satellite Laser Ranging System (SLR) recently developed at the University of Latvia. The laser ranging accuracy of LAGEOS and other LEO satellites appears at the subcentimeter level. The SLR is located at the centre of *EUPOS*® – *Riga* base station network at a distance of 20 m from GNSS antenna. The relevant volume of SLR ranging data will be collected and the proper height determination tests will be performed.

The control measuring campaign using *EUPOS*® – *Riga* RTK network has been carried out recently. Preliminary results have discovered a land downlift at the bank of Riga Bay. The additional test measurements are planned for summer 2010. The results of the GNSS based control will be reported at the WEGENER Workshop in Istanbul.

# Deformation Monitoring with TUSAGA-AKTIF System

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TUSAGA-Aktif System (CORS-TR) has been proposed by Istanbul Kultur University (IKU), jointly with the General Directorate of Land Registry and Cadastre (GDLRC) and the General Command of Mapping (GCM). The project has been started at May 2006 and completed at May 2009.

The main goals of the project are; to provide RTK GNSS data corrections, determine real time precise coordinates throughout Turkey via establishing 146 TUSAGA-Aktif stations, to determine datum transformation models and computations between different coordinate systems (ED50/WGS-84) and serve data for geodetic, terrestrial mapping and cadastre applications and determine earthquake shift and plate deformation monitoring with RTK Coordinates of 146 stations.

Computations of coordinate correction parameters are being held in main control center established in GDLRC. GNSS data collected at all stations are transferred to the control centers via ADSL or GPRS/EDGE and correction parameters are transferred to the users in the field after computed in these centers. RTK correction parameters which are in current RTCM and CMR+ communication formats are transferred to the rovers via one of GSM, GPRS and NTRIP.

GNSS data collected at each site are processed via BERNESE 5.0 and GAMIT/GLOBK V10.34 software in daily basis and coordinate time series are created. RTK Coordinates for all stations are also computed via RTK.Net Software and stored. After that, these time series and RTK coordinates differences of stations are examined for daily positional variations which can be caused by deformations including plate tectonics, earth's crust or other reasons.

In these paper results of two main earthquake events after establishment of TUSAGA-Aktif System has been investigated.

# San Fernando Naval Observatory High Rate GPS Data Processing

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San Fernando Naval Observatory, (Real Instituto y Observatorio de la Armada, ROA), is located at the southern part of Spain, in the broad plate boundary zone accommodating the relative motion between the Eurasian and the African Tectonic Plates. We are interested in the behavior of this area, limited to the North by the 'Cadiz – Alicante' Fault, and the Betic Mountains, to the South by the Atlas Cordillera and the Maghrebides Mountains and including the Gulf of Cadiz and the Alboran Sea. The seismic pattern in the area might be considered as diffuse, with frequent and superficial earthquakes, which magnitudes are below 5.But there are also stronger episodic events, as Mw 6.4 of the February 24 2004 Alhoucemas Earthquake. An extreme event was the Mw 8.5 earthquake originated in the active zone located at the SW of Saint Vincent Cape (Portugal) with the associated highly destructive tsunami which devastated the coast of the Gulf of Cádiz and Huelva, causing more than 1,300 casualties in the Spanish territory

Since the mid 90's, the Observatory has been developing a geodynamical network, installing Very Broad Band seismometers collocated, in most of the places with Continuous GPS network was deployed. Today there are up to ten CGPS recording data in Southern Spain, and Northern Africa, including the Averroes Rabat Scientific Institute Observatory located close to Casablanca. Because of the risk of tsunamis and earthquakes, the usual 30 second sample data record is complemented by 1Hz data files. In this way we are developing a near-real time high rate processing for quick earthquake magnitude determination, once the network is completed by IGS and EUREF stations.

Bernese 5.0 software is being used to compute relative movements, in order to detect horizontal, but also vertical, surface deformations in the case of large magnitude earthquakes and eventually the vertical loading due to tsunamis. Some UNIX scripts built in Perl make Bernese to run batch processes every 15 minutes: CGPS network stations data files are downloaded, in order to be analyzed automatically. The process output is a new set of coordinates for each station which is compared with those computed in the previous time batch, looking for deformations in near real time. Accuracy is expected at millimeters level.

# Mapping Strain Tensors Errors for a Realistic Representation of Crustal Deformations

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In this paper, our goal is to display in an intuitive mode strain tensors and their related errors. We compute these elements from geodetic data in a geological active region of interest (for example: western Turkey). Then we represent these tensors and their errors by means of a mapping method based on new cartographic specifications. The step of analysing strain tensors errors is established from two points of view: for the first one, we calculate errors using a Monte Carlo method (this part is derived from errors existing on the velocity field measurements), and for the other one we evaluate constraints coming from the network geometry (independently from the measures themselves), and their influences on the strain tensors significance level. The total error estimation to be displayed is then a combination of these two errors sources. We present the resulting errors on the same map, showing e. g.: places where the measurement errors are correct or too high, when compared with the amplitude of the deformations, places where even with quasi perfect measurements, no significant movement will be observable because of the geometry of the network itself, etc.

Our approach is to test and compare different mapping sets. Thus our choice is the one which gives the most intuitive representation of the tensors and their significance level. Then we will realise an opinion survey to choose our final representation model within several possibilities, by asking their preferences to a set of users.

This new mapping method will provide an additional geophysical tool to the existing ones for detecting and interpreting crustal motions.

## 4.2 Abstracts of poster presentations

Abstracts are **sorted alphabetically** by first author.

### Relation Between Sensitivity and Observing Session Duration in GPS Monitoring Networks

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Three days solutions of Marmara Permanent GPS Network (MAGNET)-Turkey were used to determine how the sensitivity of a GPS monitoring network against horizontal movements is correlated with the duration of observing session. For this aim, we considered five different session duration classes (T=4, 6, 8, 12 and 24 hours) and their cofactor matrices in computation of non-centrality parameter (denoted $\lambda$), which is a measure for the sensitivity of a network against pre-assumed movements. From 33,000 randomly produced velocity field models, it is obtained that the rate between two non-centrality parameters $\lambda(T_1)$ of duration $T_1$ and $\lambda(T_2)$ of duration $T_2$ is approximately $T_2/T_1$. In other words, if we increase the observing duration from $T_1$ to $T_2$ hours for a GPS monitoring network, the detectability of the movements will increase $T_2/T_1$ times. Additionally, we deduced that the observing session duration of a monitoring network configured as MAGNET in the region should be more than 4 hours for detecting the expected horizontal velocities.

# Geodetic Observations from a Semi-Permanent Network Around the Constantine Active Faulting

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The seismicity distributed along the Tellian Atlas, North of Algeria, suggests that it is consequent to the tectonic deformation activity, mainly due to the convergence of Africa and Eurasia plates.The seismic activity in the eastern part of this atlasic structure seems to show a low to moderate tectonic activity. In this region, the Ain Smara fault, which is considered as active, have produced the Constantine earthquake of 27 October 1985 (Ms=6.0). For a better comprehension of the deformation distribution and a good knowledge of the slip rate on the active structures, CRAAG started in 2008 the installation a network of 20 semi-permanent GPS sites in the region around the Ain Smara fault. Each site has been measuring during 3 to 5 days within a 30s sampling 24h session in 2008 and 2010. This network is linked to the local Permanent GPS Station of Ain Smara (SMRA) which belongs to the REGAT (REseau Gps de l'Atlas). We show here the result of a first data processing using the GAMIT-GLOBK software. The long term observations of Ain Smara semi-permanent GPS network will contribute to quantify the deformation rate around the Constantine area.

# Estimating Strain Accumulation Rates in the Northern part of Marmara Region, Turkey

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For the purpose of analyzing strain accumulation in Marmara Region, densification network in Kirklareli, Tekirdag, Bursa, Bilecik, and Adapazari were measured by GPS technique by institutions such as Geodesy Department of Kandilli Observatory and Earthquake Research Institute of Bogazici University, Istanbul Metropolitan Municipality, General Command of Mapping (GCM), General Directorate of Land Registry and Cadastre, and TUBITAK- Marmara Research Center (MRC) in 1999. Another GPS campaign were realized by three different GPS manufacturers (Leica, Topcon, and Trimble) on the Turkish Continuously Operating Reference Stations (CORS-TR) test networks in 2006. Then, the displacements of the network stations were estimated by means of analyzing the GPS measurements. For the assessment of the datum differences between 1999 and 2006 on the station coordinates, 3D Helmert transformation was applied to the coordinates of each 1999 and 2006 datum. Strain accumulation with finite element model was then computed.
Maximum values of strain accumulation were found out around the surroundings of Marmara Ereglisi and Izmit as -7.5μs, whereas minimum values are around Istanbul as 0.25 μs.

# The Establishment of a Gravity Calibration Baseline in the Marmara Region, Turkey

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For the purposes of the calibration of the relative gravimeters, we established a gravity calibration baseline which consist of five absolute gravity stations in the Marmara region. A gravity difference of 415 mGal is to be found along the Marmara gravimetric calibration line. The first time absolute gravity measurement with A10 absolute gravity meter has been carried out at the all stations in the Marmara Region after 17 August 1999 Izmit earthquake. Using A10 absolute gravimeter and two Scintrex CG-5 relative gravimeters repeated measurements were carried out three campaigns during the period June 2009 - June 2010. Also, a precise determination of vertical gravity gradients with two Scintrex CG-5 relative gravimeters were carried out at the all absolute stations for the reduction of measured gravity from the reference height of an instrument to the bench mark.

The location of the calibration line was selected in the Marmara region in order to help the on-going projects, related with dynamic properties of the branches of North Anatolian Fault Zone, after the devating 1999 earthquakes in the Marmara.

This study gives additional details about the calibration baseline and presents the adjustment process carried out for the gravity data obtained from repeated absolute and relative measurements and first results are presented.

# Review of Leveling Comparisons and Combination of Triangulation and GPS Data in the Upper Rhine Graben to Estimate Tectonic Deformation

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The Upper Rhine Graben (URG) is a north-northeast trending rift system, which belongs to the European Cenozoic Rift System. This area is of low instrumental seismicity, even if some few magnitude 5 events occurred recently. This region has experienced a major historical earthquake (intensity IX-X event in Basel, 1356). We seek to quantify the present-day deformation in the URG using different kind of geodetic data. A review of leveling comparisons shows vertical movements due to tectonic subsiding/lifting processes but also due to other effects such as water-table drawdown and surface subsidence due to pumping. To estimate horizontal deformation, we use heterogeneous geodetic data, i.e. old triangulation and trilateration data combined with recent GPS campaigns performed in the Vosges, Jura and Black Forest mountains.

# Crustal Deformation of Broader Athens (Greece) by GPS Measurements

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A geodetic determination of the crustal deformation in the broader area of Athens is presented, using GPS data from a newly established network, measured on a yearly basis between 2005 and 2008. The Athens Geodetic NETwork (AGNET) covering the central part of Attica consists of 39 observation sites with an average distance at approx. 5 km. The geological framework of the region was taken into consideration during setup and monumentation of the network, in order to facilitate the identification of relative motions of primarily tectonic origin. The network (about 25×25 $km^2$) was tied to the ITRF2000 through the coordinates and the velocities of the continuous GPS station in Dionysos (DION C), which was also selected as the reference point for the examination of the local displacement field. Displacement velocity vectors were computed at each station from the slope of each coordinates time series by least-squares adjustment. Considering the difficulties involving the accurate estimation of the vertical component of motion over short time intervals, herein only the horizontal solutions are reported. Despite the short observation period, the relatively high density of the network and the spatial consistency of the velocity field, they were proven essential for the recognition of the present day kinematics. The results were generally in agreement with what expected from the regional tectonics. The observed deformation pattern enabled the definition of the high fragmentation of the area with numerous tectonic blocks of small dimension, controlled by fault systems of complex kinematics. Crustal movements are mainly accommodated at Parnitha Mt. and Thriassion Basin to the west of the Athens, with the highest rates of approximate 10 mm/yr observed at the central part of Parnitha. One of the most interesting features of the displacement field is the significantly higher rates at the western than the eastern part, where almost negligible motion occurs. The large scale discontinuity coincides with the location of the NNE-SSW trending detachment fault bounding the metamorphic and non-metamorphic alpine basement of the area. Finally, a unique strain tensor was calculated for the whole area, showing a roughly north-south extension, which implies strain accumulation mainly on normal faults with almost E-W strike.

# Summary Study on Seismogenic Faults in the Region of Boumerdes and Sismotectonic Context of the Earthquake (May 21, 2003 Mw = 6.8)

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The present contribution intends to briefly work done on the earthquake of Boumerdes - Zemmouri of May 21, 2003 in geology, geophysics offshore (gravimetric, aeromagnetic seismic) of seismo-tectonics and seismology (magnitude, seismic moment, mechanisms etc. at home.). The results refer mainly to different work on the study of the earthquake of May 21, 2003 of Boumerdes, Algeria Mw = 6,8.

The focal mechanism indicates a reverse fault oriented NE-SW with a dipping 43°. In the Algiers-Boumerdes region, moderate but continuous and shallow seismicity and the presence of blind active faults involve a high level of seismicity hazard. A synthesis of seismotectonic data indicate the presence of seismically potential active fault such as those of Sahel, of South Mitidja , of Thenia and the supposed offshore faults.

# Modern Geodynamical Motion of the Northern Caucasus from Data of GPS/GLONASS Observations

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The northern part of the Greater Caucasus is one of the most geodynamically active regions of Russia. This is a zone of complex tectonics resulting from interaction between two of the Earth's major lithospheric plates, Arabia and Eurasia. Therefore, the region as a whole is characterized by a complex system of faults, with meridional and diagonal structures. The first GPS and absolute gravity campaign in the Black Sea and Northern Caucasus regions was carried out between 1993 and 1994 as part of the SELF project. One of the points of the GPS measurements was transformed in the stationary station. This station is located in Karatchay-Cherkessia Republic of the Russian Federation. Since 1997 the Zelenchukskaya station has been part of the European Reference Frame (EUREF) GPS network with a code ZECK. Within the last few years we have established three new stationary GPS/GLONASS stations in the Northern Caucasus. The first (site code TRSK) is located in the Kabardino-Balkaria Republic, near the Elbrus volcano. It began to operate in 2005. The second one is located in Karatchay-Cherkessia Republic (site code KISL). This station has been in operation since 2006. The third is located in Vladikavkaz, the capital of North Ossetia Republic (site code VLAD). The continuous GPS measurements began in 2008. These four stationary stations form the base for the regional Northern Caucasus GPS network, which can be called the Northern Caucasus Deformation Array (NCDA). In this study, results obtained from NCDA observations are presented.

The striking aspect of the velocity field of the Northern Caucasus derived from the NDCA stations is the rapid motion in the north–east direction with almost equal velocities of about 28 mm/yr. The motion of the feducial site MDVJ (Moscow region) is characterised by a similar velocity value (25 mm/yr) in the same direction. Therefore the motion of the Northern Caucasus region is mainly defined by the general tectonic movement of the Eurasian plate with respect to ITRF. At the same time the analysis defines excess NE movement of stations in the NCDA with respect to Eurasia (as defined here by the Moscow station) at rates of 3-4 mm/yr. Apparently the excess velocities of NCDA reflect tectonic activity of this region.

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# GPS Antenna Monuments and Mounts Supported by UNAVCO

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Many different monumentation types and antenna mounts have been used in UNAVCO-supported projects for campaign, semi-permanent and long-term continuous GPS sites. We summarize advantages and disadvantages of nine monuments and mounts currently in popular use in UNAVCO-supported projects. The designs range in height from 0 to 3 meters and are intended for installation into a range of substrates including soil, bedrock, and concrete. Costs range from approximately $30 for a simple threaded rod to $15,000 for a deep drilled-braced monument. In many places outside the U.S. logistical, economical, and material restraints make installation of deep- and shallow-drilled braced monuments at best difficult and at worst impossible. Simpler single-mast or concrete monuments offer less expensive, more portable installation options but which may come at the cost of long-term stability. UNAVCO provides extensive technical information, including monumentation documentation, through its online Knowledgebase (http://facility.unavco.org/kb/, or directly at http://facility.unavco.org/kb/questions/104/UNAVCO+Resources%3A+GNSS+Station+Monumentation).

# An Automated Processing Scheme Designed for all Available Permanent GPS Stations in Greece

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During the last decade several Greek institutions have established permanent GPS sites around the country, a number of which is part of the EUREF network. The acquisition of daily data is processed by the Bernese V.5 automatic processing engine.

In this work nine IGS reference stations were used for the realization of the reference frame IGS05 and nineteen local stations spread out all around Greece were processed. The time series duration varies from a few months up to nearly four years per station.

Both precise point positioning (PPP) and triple differences ambiguity resolution (QIF strategy) techniques were applied to process the data, using IGS and/or CODE final products. Discrepancies in the accumulated point positions are computed and compared in order to evaluate the most appropriate technique regarding the processing time consumed and the precision of the products.

The purpose of this work is the comparison between the use of the global reference frame and the estimated regional one, as well as a reliable estimation of tectonic motions on a regular basis.

# GPS Networks for Deformation Monitoring in the Canary Archipelago

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The Canary archipelago is the emerged part of an important volcanic formation located on the oceanic-continental limit of the African plate, at 100 km of the northwest coast of Africa. The study of seven GPS observations campaigns carried out in the years 2001 to 2009, by staff from the Faculty of Mathematics of the Complutense University of Madrid (UCM), to monitor possible deformations in this region is shown in this poster. Three geodetic networks with different purposes have been designed: the micro network of Jameos del Agua, around a permanent GPS station, the network of the island of Lanzarote and the network of the Canary Archipelago covering all the seven islands. The stations of the networks are located at strategic points for the study of possible deformations, there are included a permanent station in Lanzarote (LACV), established in 1999, stations from the IGS network (MAS1 y LPAL) as well as stations from REGCAN95 network of the Instituto Geográfico Nacional (IGN). The GPS data have been computed with two scientific packages: Bernese V 5.0 and AutoGNSS. The results show that the region remains stable and there are no deformations; being one of the most reliable indicators the stability of the distances between LACV and the stations of the three networks, over the various years of the campaigns. To be consistent with the precise ephemeris Reference System, observations carried out in 2009 are referred to the IGS05 solutions, whereas the previous solutions are referred to the former IGb00, so that it has been possible to perform a Helmert transformation to avoid shifts due to the Reference-Frame upgrade. The individual station velocities are consistent with the published velocities from the IGS and ITRF solutions of permanent stations in the area like Maspalomas (MAS1) and La Palma (LPAL). Therefore it can be concluded that the observed changes in the coordinates, between the first and last campaign, mainly obey to the station velocities, since the distances between them stays steady.

# Determination of Active Tectonic Movements of South West Anatolia

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This paper gives evaluation of the GNSS data collected to identify the crustal movements and deformation anomalies around the faults in Southwestern Anatolia. Southwestern Anatolia is located in a tectonically critical region. It incorporates Fethiye-Burdur fault zone, which is of transform nature, and divides two different tectonic regimes and various graben extension zones. Although several geologists acknowledge the extensional tectonics in the N–S direction, different models formulated for the mechanisms of extension in question are still controversial. Like many other parts of Turkey, the region of Southwestern Anatolia is located in a tectonically active region. With 33 earthquakes in the Aegean graben system and 13 earthquakes in the Hellenic-Cyprus trench during the last century, all of which were of M > 5.5, the region constitutes one of the most seismic zones of Turkey. To determine the tectonic characteristics of the region a network of 25 sites was established and GNSS measurements were performed in 1994 and 2009 years. GNSS campaigns were processed using GAMIT/GLOBK software.

# Geodetic Survey of Global Climatic Changes in the Mediterranean Area

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The monitoring of the global changes concerning the sea level and the oceanic circulation has become a major challenge nowadays. Moreover, the Earth shape and gravity field is being continuously monitored by means of geodetic instruments. The climate parameters sensitive to the environmental changes will impact geodetic measurements. On the other hand, geodetic data can be used in order to improve the knowledge about the global changes and be taken into account in the oceanic and hydrological models.

Geodetic data consist in satellite altimetry measurements (JASON, ENVISAT), but also GNSS (Global Navigation Satellite System) data, such as GPS, which give the crustal deformations, tide-gauges measurements, and gravity data from the GRACE mission (Gravity Recovery and Climate Experience). This satellite mission has been launched in 2002 and provides information about the mass distribution inside the Earth system and its temporal variations, allowing to detect the deformations and the global mass transfers.

It has become a crucial need to develop methods to combine and jointly analyze all these data coming from different and independent sources. We also want to know how these geodetic measurements can be assimilated into the oceanic and hydrological models. Here, we focus on the Mediterranean area, where our first aim is to understand how climatic and environmental phenomenon will effect the geodetic measurements.

As a first step, we analyzed the GRACE data. We tested several post-processing methods, in order to get the best estimates of mass changes in our area. Then, we compared the GRACE-based mass variations to Ocean Bottom Pressure estimates from models, and, in terrestrial areas, with GPS time-series of crustal deformation and loading models. Using several time-series analysis methods, we extracted common modes of spatial and temporal variations between each dataset. In this way, we analysed the consistency and the differences between models and each geodetic dataset. Several modes can be extracted, but the seasonal cycle appears to be a common mode to all observations and models.

# Techniques and Methods for the Sea Level Observation in the Lanzarote Geodynamics Laboratory

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To evaluate and quantify the causes of the changes in the sea level is one of the most interesting scientific goals. Global studies of its variations can be indicative of geodynamics processes as tectonic movements or phenomena of mass redistribution. More recently, the study of the mean sea level variations as parameter of the state and possible evolution of the Global Change has gained greater relevance.The Lanzarote Geodynamics Laboratory has an observation module especially dedicated to the research in the field of the sea level. It is located at the north part of the island, in the Jameos del Agua, where the volcanic tube of La Corona Volcano go down under the sea level several times, forming small lakes, until it's submerged definitively. This singular situation confers to it of ideal characteristics for the sea level observation.Obtaining the geoid , the determination of a local datum for altitudes, the absolute variations of the mean sea level in a global reference frame, the study of the perturbations in the sea level observations of geodetic, meteorological and oceanographic character, and the medium and long term studies about the sea level variations, combining terrestrial and space methods and techniques, are some of the scientific goals established.The module is equipped with different types of tide gauges, one geodetic GPS permanent station, one meteorological station with register of atmospheric pressure, temperature, humidity, solar radiation, speed and direction of the wind, pluviometer, several water temperature sensors and a water quality probe (pH, salinity, ORP, $O_2$, $CO_2$, Cl, conductivity and turbidity) To separate the sea level variations from the vertical movements of the crust the GPS station is linked with the reference mark of the tide gauge. For the study of the stability of the place, a geodetic network of leveling has been designed with 13 geodetic signals around the GPS station.In this presentation we do a review of the actual state of the Laboratory and future strategy with the objective to contribute valid information integrated in a global geodetic monitoring system.

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# The Lanzarote Geodynamics Laboratory: a Natural Laboratory for multidisciplinary investigation in Geodynamics and Global Change

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The Natural Laboratories are geographic areas used globally to the study and the investigation through the accomplishment of observations in field that contribute to the real information of the event, its state, development and possible evolution.

Lanzarote Geodynamics Laboratory (LGL) is a multidisciplinary research laboratory located in various outbuildings of the Cabildo of Lanzarote. Created in 1986, it has been developed as a result of the collaboration between the Cabildo and the Spanish Council for Scientific Research (CSIC), Universities and other National and International Institutions in the framework of projects carried out up till now.

Phenomena as the Global Change or Geohazards must be studied under the assumption of the Earth as a global system, where exist a permanent interaction between Lithosphere, Hydrosphere, Atmosphere and Biosphere, and the analysis of long time series of data. In this conceptual framework, LGL combines all the conditions to be a Natural Laboratory in the field of Earth Sciences, where it's possible to develop multidisciplinary investigations in relation with the searching of possible Global Change indicators and the identification of geodynamics processes associated with the activity in an active area of the crust, as the Canary Islands are.

In this presentation we show an overview of the evolution and current state of the LGL, as well as the prospect of research for the coming years.

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# Adaptive Filtering of GPS Time Series in Crustal Deformation Studies

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Adaptive filters designed for noise cancelling are capable of decomposing correlated part of data sets. This kind of filters which optimize itself using Least Mean Square (LMS) algorithm is a powerful tool for the geosciences. In case of adaptive filtering of Continuous Global Positioning System (CGPS) stations' time series, results may show relative displacements between two stations as result of tectonic movement or fault slip and noise related with local monument characteristics, such as multipath and atmospheric effects.In this study, it is aimed to analyze several CGPS stations located in Turkish territory and its surrounding areas using an adaptive finite impulse response (FIR) filters. The FIR filter is used to decompose the time series of baseline solutions of five stations located on both sides of the North Anatolian Fault Zone into the fault movements and noise components. From the various baseline combinations at different years, the estimated fault movement rates are consistent with each others when taking into consider the active fault kinematics of Turkey. The results are in good agreement with the velocity field estimates of the previous studies.

# Deformation Measurements on the Western Marmara, Turkey

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The one of the most important faults of world is the North Anatolian Fault (NAF) which range from Bingol to Aegean Sea. There are a lot of destructive earthquakes occur in the last century along the NAF. This study has been focused on the Gulf of Saros located at the northwestern of Turkey. The study area is seismically active and occasionally destructive earthquakes are observed where there is the 1912 Murefte-Sarkoy earthquake (M=7.4) occurred along the Gazikoy-Saros and the 1975 Saros earthquake (M=6.7) occurred at the western part of the gulf.

In the study area, 14 GPS stations on characteristic part of the region were established as a project funded by The Scientific and Technical Research Council of Turkey (TUBITAK) and Istanbul Technical University (ITU) Research Fund. The GPS campaigns were carried out consecutive three years, 2003, 2004, 2005 and processed by GAMIT/GLOBK software using IGS precise parameters and its core sites. The GPS derived velocity field was calculated.

In this study, the velocity field is modelled by DEFNODE software. The results obtained by modelling will be presented. These results will give important information to scientists interested in this region.

# Comparison of Variance Component Estimation Methods for Horizontal Control Networks

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In this study, some well-known variance component estimation methods, called conventional, Helmert, MINQUE, AUE, and Forstner, developed to determine the stochastic model, for the adjustment of geodetic networks, have been compared. In doing so, concrete deciding criteria, using statistical tests, have been defined and the determination of superior model has been studied. For the validation of the models, numerical experiments using data, from a part of the Istanbul Metropolitan Triangulation Network (Asian side), have been performed.

# Deformation between African and Eurasian Plate Estimated from the European and the Egyptian GPS Geodetic Networks

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The contribution deals with estimating deformation between the African and the Eurasian Plate in the Eastern Mediterranean on the basis of GPS coordinate time series. Two sources of velocities were used for processing. The first was the freely available site velocities from the European Permanent Network (EPN). The second was the Egyptian GPS permanent network velocities. Their values were determined by the following technique. Firstly, the Egyptian site coordinates were computed from GPS daily observations, using the fiducial EPN stations. The daily site coordinates at a given time interval result in coordinate time series, which were analysed and used on velocity estimation of the Egyptian stations. Then the apparatus of the mechanics of continuum was applied to all resultant velocities. The regions of possible mutual interactions between the Eurasian and the African Plate in the Eastern Mediterranean were detected. The basic idea of this contribution is the common processing of GPS daily measurements from the Egyptian permanent network together with the EPN data. The available Egyptian GPS data cover the period from December 2006 to March 2009, which represents a sufficient time interval for velocity estimation. The formerly presented results from preliminary processing are completed by this study and the new results are compared with other published long-term values of horizontal velocities (comparison is available only for the permanent station PHLW). Introducing the measurements from 4 Egyptian permanent GPS stations into processing enables a better estimate of deformations in the Eastern Mediterranean