# Monitoring Plate Tectonics and Subsidence in Turkey by CORS-TR and InSAR

By

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(Istanbul Kultur University)

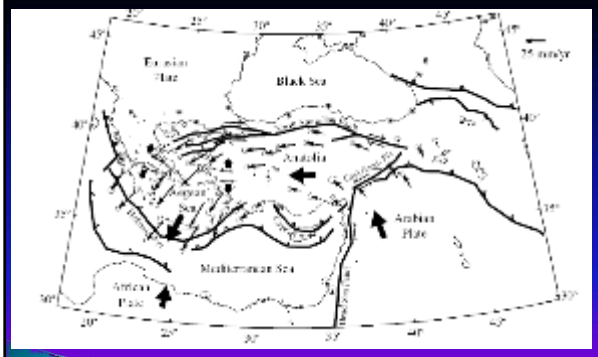
(FIG Conference, Sydney, 11-16 April 2010)

## 1. Overview

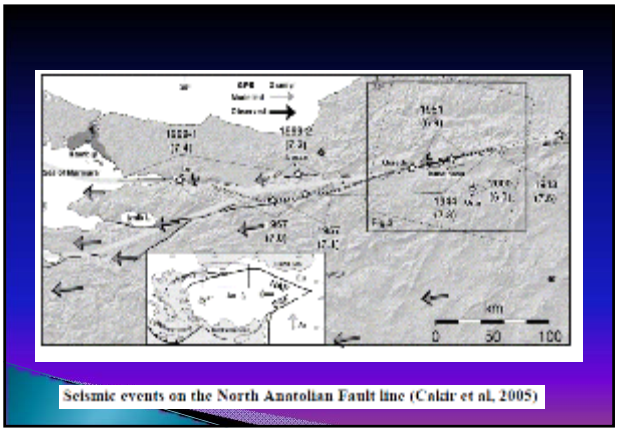
Major faults in Turkey

## TOPICS





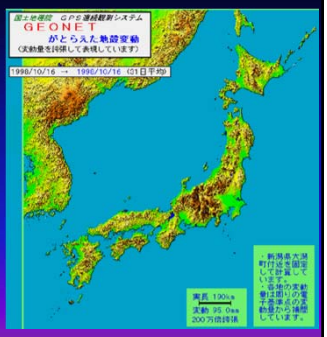

Tectonic setting of Turkey McClusky et al (2000)



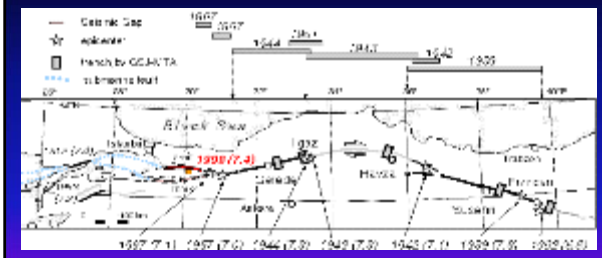

Seismic events on the North Anatolian Fault line (Cakir et al, 2005)

## Deformation in Japan

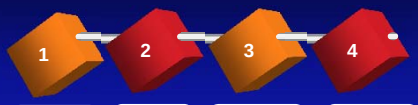
- Animation of horizontal deformation blown 1 to 2,000,000
  - Repeats one – year deformation
  - There is compression of east – west for Tohoku and Kanto




## North Anatolian Fault Zone and Earthquakes




## 2. Objectives

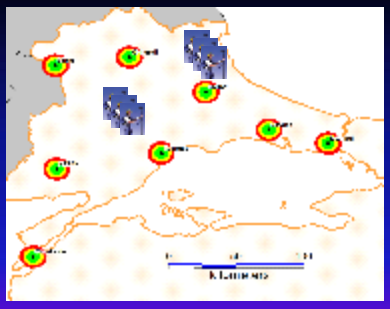



| 1 | 2 | 3 | 4 |
|---|---|---|---|
| 7/24 precise positioning throughout Turkey (mm-precision) using CORS-TR | Monitoring mm-level vertical deformation using InSAR techniques | Combining GNSS and InSAR techniques for studying plate tectonics and deformations | Using the results of the study for early warning and diaster management |

## 3. CORS-TR Project

1. CORS-TR Establishment
2. National Datum Transformation

## Classical RTK Base Stations (5, 7.5 and 10 km radius)



Precise, Reliable, Economic

Good — Bad

## GNSS SATELLITES

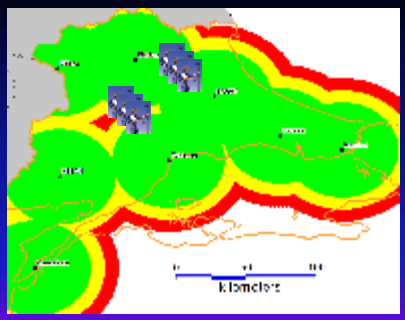
GPS, GLONASS AND GALILEO


- Launched: 1978
- 24 Satellite Constellation

- Launched: 1982
- Current Satellite Constellation: 16
- Planned Constellation: 24

- Planned Launch: Early 2006
- Planned Constellation: 30 Satellites

## CORS-TR Reference Stations (40 and 50 km radius)

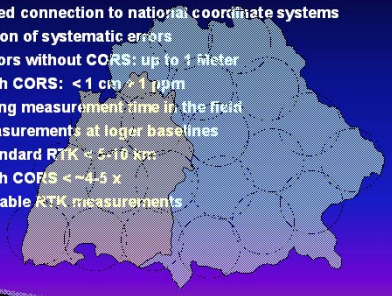


Precise, Reliable, Economic

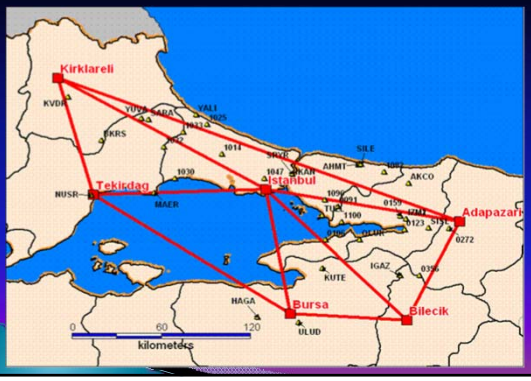
Good — Bad

## CORS and Advantages

- Automated connection to national coordinate systems
- Elimination of systematic errors
  - Errors without CORS: up to 1 meter
  - With CORS: < 1 cm + 1 ppm
- Shortening measurement time in the field
- RTK measurements at longer baselines
  - Standard RTK < 5-10 km
  - With CORS < ~4-5 x
- More reliable RTK measurements



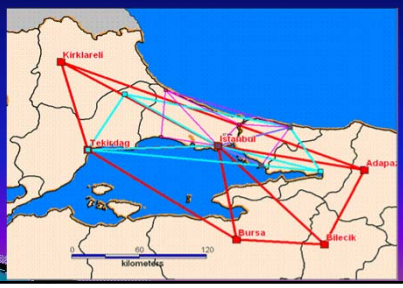
## NET-120 and Existing Stations (Check Points)




## Benchmark Test (2 September – 31 October 2006)

- Testing GNSS receivers and antenna
- Testing Control Center Software packages
- Determining the most optimum spacing between CORS points
- Testing existing communication, Internet and other infrastructure
- Studying atmospheric activities

BM Test Networks
- 120 km,
- 90 km,
- 60 km




## System Design

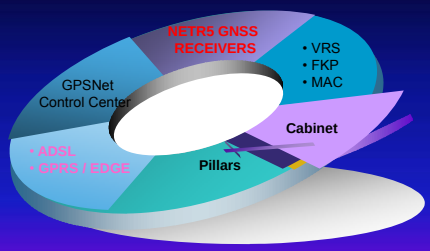
- 24 hours broadcasting (RTK ve post-process)
- 80 - 100 km spacing between CORS stations
- Selection of points on solid and logistically suitable places
- Selection of points with the consideration of plate tectonics in Turkey
- Modeling atmosphere over the entire country

## Communication

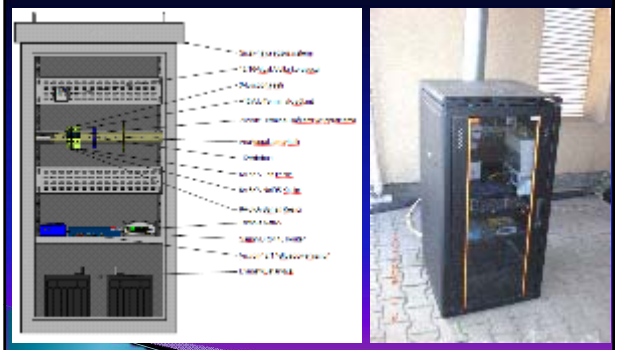
CORS – Control Center Communication
- ADSL
- GPRS / EDGE

Control Center – Rovers Communication
- GSM GPRS / EDGE – NTRIP
- GSM, RADIO

## CORS-TR AND TRIMBLE NETR5 SYSTEM




## CORS – TR Cabinets



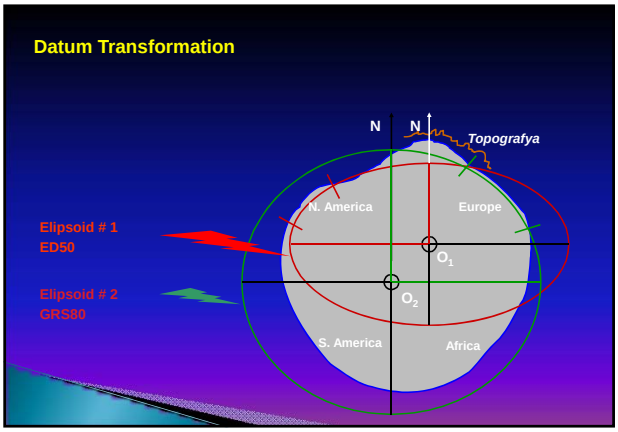
## Installation of CORS Points

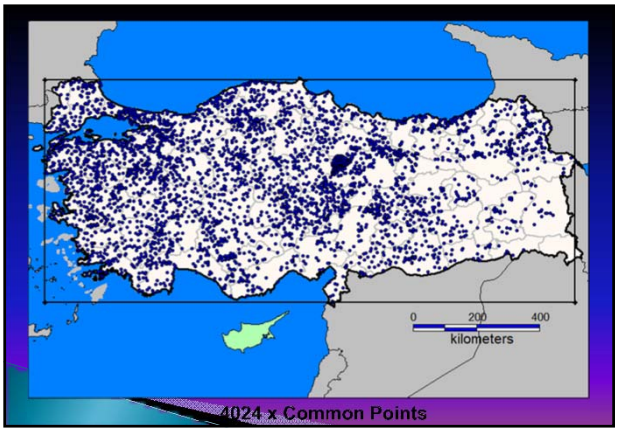
- Concrete pillar on soil,
- On Roof and Terraces: steel pillars (galvanized).

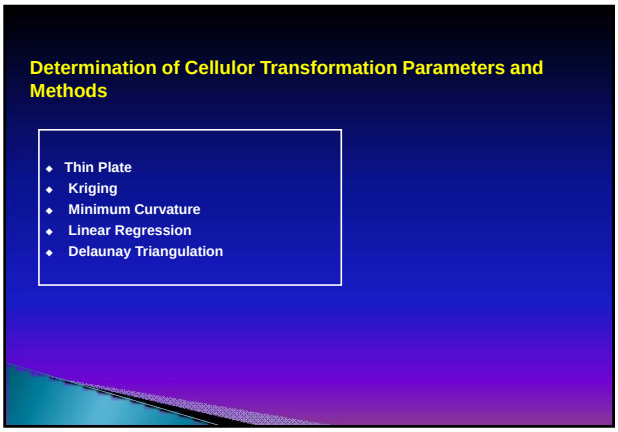
- **85 x 2 m pillars (including soil)**
- **58 x 3 m pillars**
- **3 x 4 m pillars**

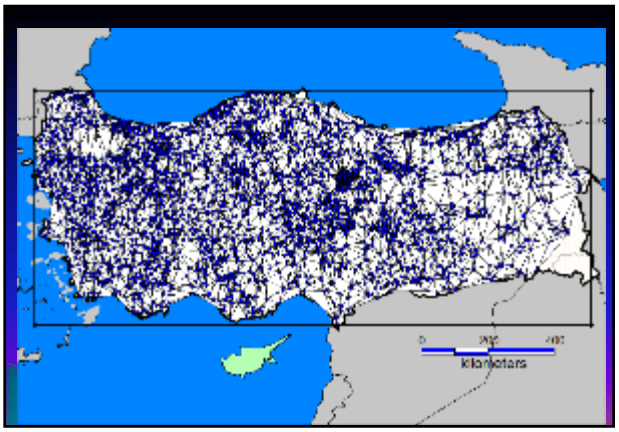
## CORS TR Distribution (146 Stations)

**Average spacing of 80 km, maximum spacing of 100 km Between CORS**


Datum Transformation
N
N
Topografya
Elipsoid # 1
ED50
Elipsoid # 2
GRS80
N. America
Europe
O1
O2
S. America
Africa


0
200
400
kilometers
4024 x Common Points

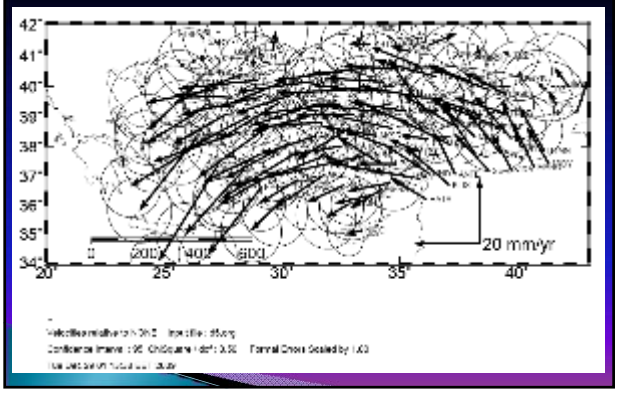

Determination of Cellulor Transformation Parameters and Methods
Thin Plate
Kriging
Minimum Curvature
Linear Regression
Delaunay Triangulation



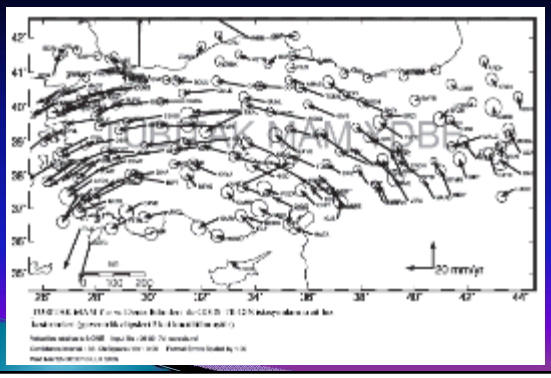
## Results

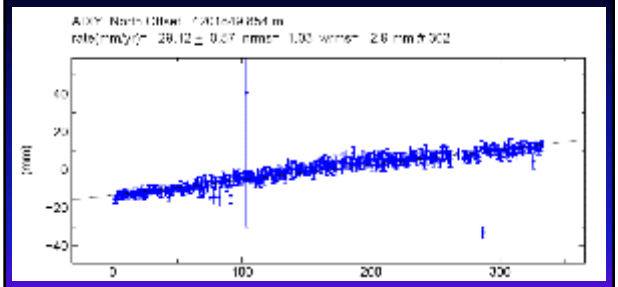
| | Multireg Latititude Residuals | Multireg Longitude Residuals | Kriging Latitude Residuals | Kriging Longitude Residuals | Min Curv Latitude Residuals | Min Curv Longitude Residuals |
|---|---|---|---|---|---|---|
| Min (") = | -0.0568 | -0.0832 | -0.0358 | -0.0794 | -0.0513 | -0.0757 |
| Max (") = | 0.0569 | 0.0939 | 0.0460 | 0.0569 | 0.0452 | 0.0609 |
| RMS (") = | 0.0124 | 0.0172 | 0.0058 | 0.0082 | 0.0061 | 0.0087 |
| RMS (m) = | 0.30 | 0.41 | 0.18 | 0.20 | 0.15 | 0.27 |

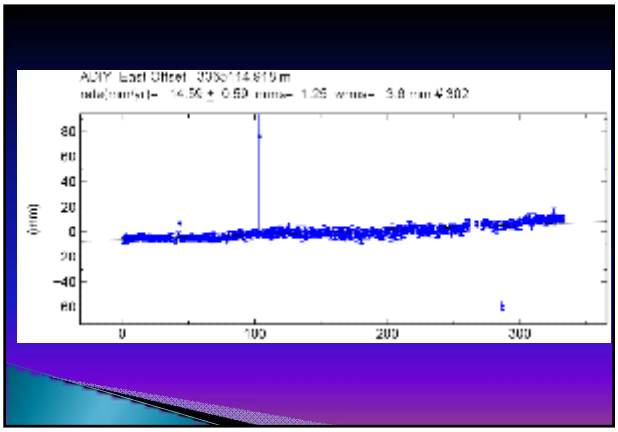
## Plate tectonics from February 2009 to January 2010

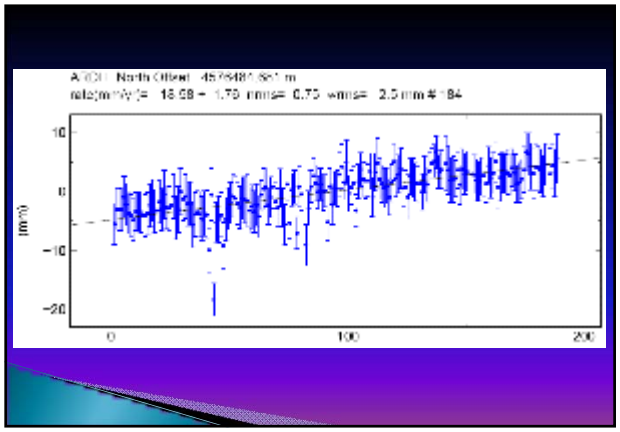


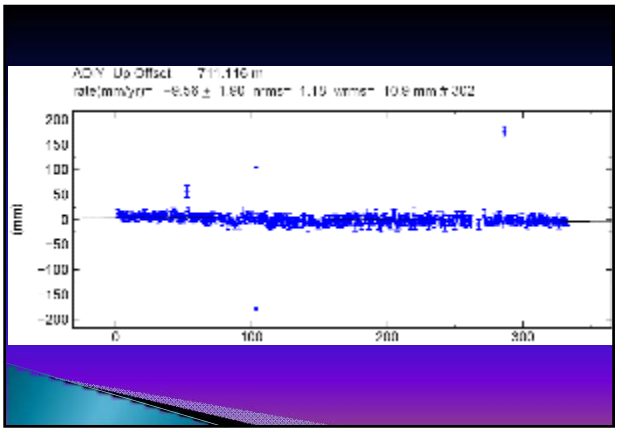

## Plate tectonics in 6 months

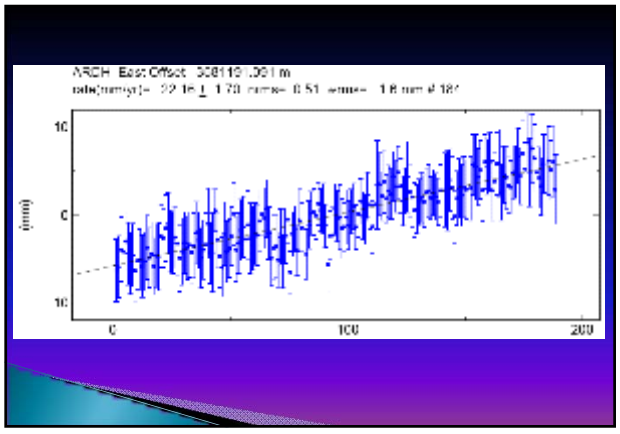


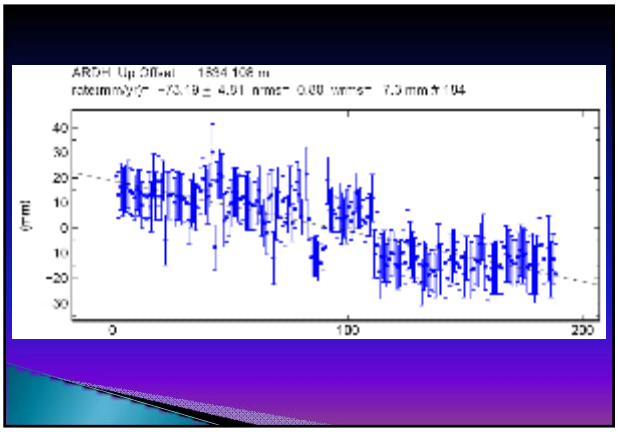














## SAR Satellites

- ERS-1/-2,
- ENVISAT
- Sentinel-1
- Advanced Land Observing Satellite (ALOS)
- RADARSAT-1/-2
- JERS
- IRS

- Cloud-free, Day/Night observation, High vegetation penetration
- Large scale surface deformation detection capability is well known (Crustal deformation due to earthquake)
- Can be focused to small scale surface deformation detection capability (Subsidence, Landslide)

## 4. InSAR Applications

Syntetic Aperture Radar (SAR) interferometric techniques, which uses images acquired with two repeat passes over the same scene, are being used increasingly to monitor landslides and horizontal & vertical deformation.

InSAR stands for Interferometric Synthetic Aperture Radar. This is thus a remote sensing technique that uses radar satellite images. Those radar satellite (ERS1, ERS2, JERS, IRS or Radarsat) shoot constantly beams of radar waves towards the earth and record them after they bounced back off the Earth's surface.

Recent research has shown that differential SAR interferometry (DIFSAR) is being used to monitor deformations and landslide motion.

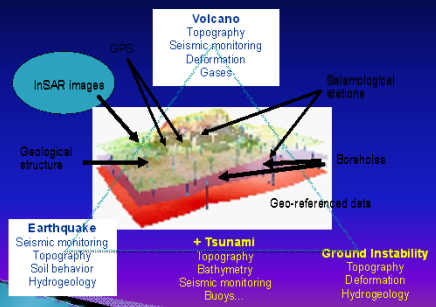
Earthquakes & Tectonics

| | |
|---|---|
| Fault permeability and poroelastic triggering in the January 9-22, 2008 Nima-Gaize (Tibet) earthquake sequence | Gilles Peltzer (University of California Los Angeles) |
| Inferences of normal fault structure and properties for six earthquakes in Tibet from InSAR | Isabelle Ryder (University of Liverpool) |
| Visco-elastic rebound of the lithosphere around the lake Siling Co in Tibet : An InSAR study | Marie-Pierre Doin (Ecole Normale Supérieure) |

Earthquakes & Tectonics

| | |
|---|---|
| Large-scale crustal velocity field of western Tibet determined by InSAR | Hua Wang (Guangdong University of Technology) |
| Was the February 2008 BUKAVU seismic sequence associated with magma intrusion? | Nicolas d'Oreye (National Museum of Natural History) |
| Extension in Tibet: Recent Normal Faulting measured by InSAR & Body-Wave Seismology | John Elliott (University of Oxford) |
| Seismic slip of the décollement beneath the Kohat Plateau in Pakistan: InSAR constraints from the 20th May 1992, Mw6.0 earthquake | Satyabala S. P. (National Geophysical Research Institute) |
| Mapping the extent of fault creep along the Hayward-Rodgers Creek-Maacama fault system using PS-InSAR | Gareth Funning (University of California, Riverside) |
| Mapping terrain deformations after the 20 and 27 December 2007 Bala (Ankara, Turkey) earthquakes with SAR interferometry | Magdalena Niemiec (Wroclaw Univ. of Environmental and Life Sciences) |
| Postseismic deformation monitoring and modeling of the 2008 Mw7.9 Wenchuan, China earthquake, constrained using GPS and InSAR measurements | Jianbao Sun (Institute of Geology,China Earthquake Admin) |
| Kinematic Fault Slip Model for the 12 May 2008 Wenchuan-Beichuan Mw 7.9 earthquake in Sichuan, China from ALOS, Envisat, GPS and Teleseismic Data | Eric Fielding (Jet Propulsion Lab/Caltech) |
| Intersismic deformation along the Messina normal fault, measured by means of SBAS ERS/ENVISAT time series | Cristiano Tolomei (Istituto Nazionale di Geofisica e Vulcanologia) |
| Asperities, barriers and transition zone in the North Chile seismic gap: State of the art after the 2007 Mw 7.7 Tocopilla earthquake inferred by GPS and InSAR data | Marta Bejar-Pizarro (Institut de Physique du Globe) |
| Comparison of Monte Carlo Methods for Model Probability Distribution Determination from SAR Interferometry | Andrew Hooper (Delft University of Technology) |

## Relevant "Super Site" data set




## 5. Super Sites

**"Geohazard Supersite" Initiative to ….**

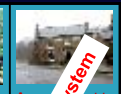
*"stimulate an international effort to study selected sites by establishing open access to relevant datasets according to GEO principles fostering the collaboration between all partners and end-users"*


***Wolfgang LENGERT***
*ERS & ADM-Aeolus Mission Manager*

***Falk AMELUNG***
*Univ. Miami*

***Marc PAGANINI***
*ESA responsible for CEOS task: "Vulnerability Mapping and Risk Assessment" on Supersite*

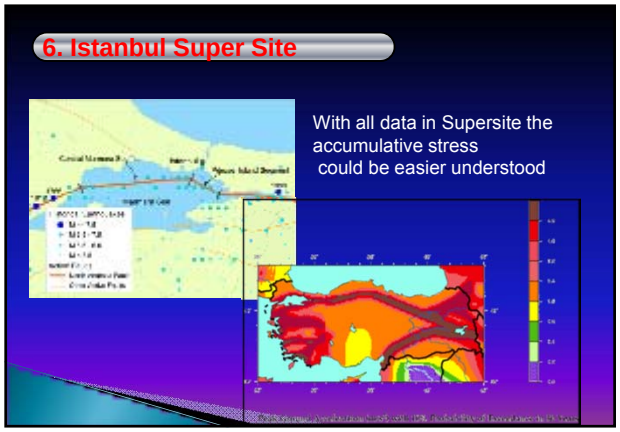

## Potential Geo-hazard Super Sites

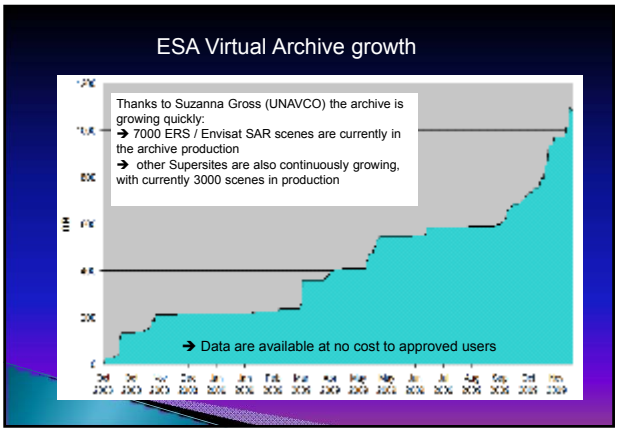
| Geohazards SuperSites |  Active Volcanoes |  c Faults |  Landslide prone Areas |  Areas ect to nce |
|---|---|---|---|---|
| Best Candidates | •Mauna Loa, Kilauea , Hawaii (USA)<br>•Etna (I)<br>•Vesuvius / C… Flegrei (I) | …s (Japan)<br>…nbul (Turkey)<br>…s Angeles, US<br>…ancouver (CA) | Landslides prone areas in:<br>• Ecuador<br>• Japan<br>• Italy<br>• Pakistan (Quett…<br>• India | Citi… …am<br>… …o<br>…arta<br>…ing sites (2):<br>• Poland<br>• Loraine (France) |
| Other Candidates | •Nyirag… …go)<br>•Yellowsto… …S)<br>•Piton de la Fournaise (Fr)<br>•Iceland volcanoes<br>•Sakurajima, Miyake-Jima (Japan) | • Main Japanese Islands<br>• African Rift Valley<br>• San Francisco (US)<br>• Bam (Iran)<br>• Sumatra (Indonesia)<br>• full Italy / Greece | •….suggestions? | •….suggestions? |

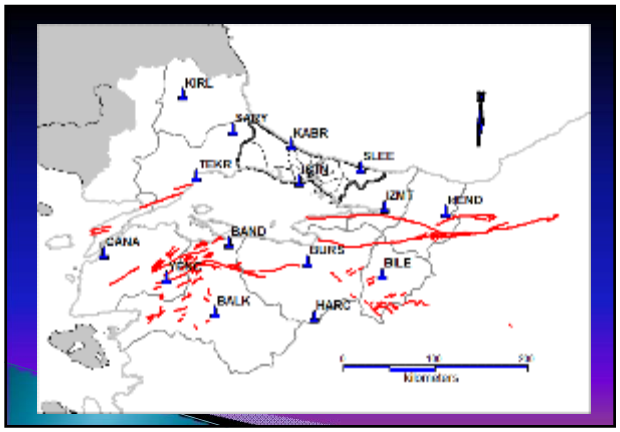
Initial system

Envisaged enlarged system

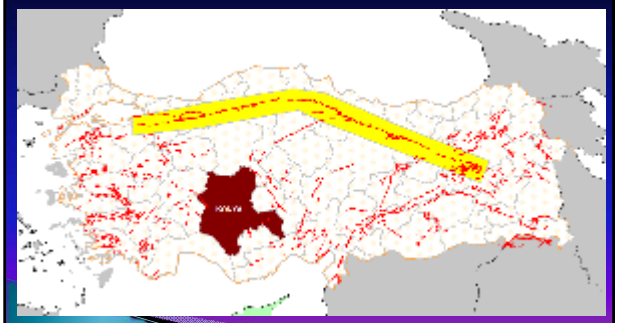

Supersites
SUPERSITES
PHASE1


6. Istanbul Super Site
With all data in Supersite the accumulative stress could be easier understood

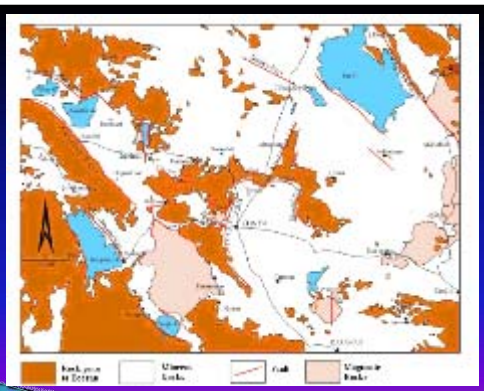

ESA Virtual Archive growth
Thanks to Suzanna Gross (UNAVCO) the archive is growing quickly:
➔ 7000 ERS / Envisat SAR scenes are currently in the archive production
➔ other Supersites are also continuously growing, with currently 3000 scenes in production
➔ Data are available at no cost to approved users


IORL
SARY
KABR
TEKR
SLEE
IZNT
HEND
CANA
BAND
BILE
BALK
HARO

## 7. Other Sites in Turkey



PITS (Obruk) are deep holes / caves caused by melting of liquefaction of calker and gyps type of formations.



The geology of Konya Region

- Pits in Turkey are mainly located in Konya Province spreading to an area of about 4000 km². Forst pits were discovered around 1930. But there is great increase in pits in last 10 years.



## 8. Conclusions

- GNSS and InSAR bring excellent results of detection of small scale surface deformation / tectonic movement as well as large scale surface deformation tectonic movement.
- They are effective to detect deformations and landslide movements
- Continuous monitoring is necessary to mitigate small scale disaster with surface deformation but also detect new risk due to small scale surface deformation.
- **GNSS and InSAR techniques will be extensively used in**
  - **Istanbul**
  - **North Anatolian Fault**
  - **Dams**
  - **Konya pits**

**THANKS**
**FOR**
**YOUR ATTENTION**