General Command of Mapping
National Mapping Agency

Semi-Dynamic Reference Frame Realization in Turkey: Towards an Improved Velocity Field Model
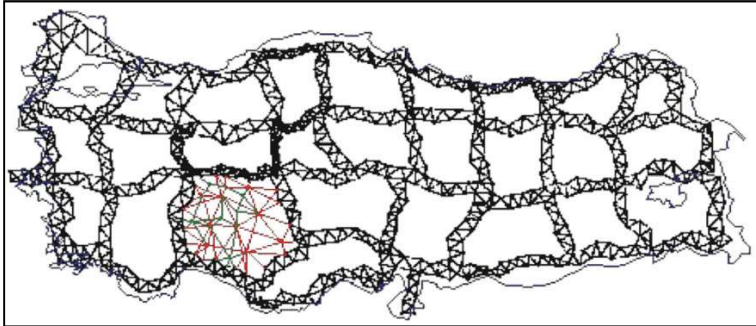
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OUTLINES

❖ National Geodetic Datum Evolution

❖ Geodetic Datum Realization- TNFGN

❖ Location Based Services: CORS-TR

❖ GPS Re-processing Strategies

❖ Velocity Field Model Determination

❖ Future Plans and Outlook

GEODETIC DATUM EVOLUTION IN TURKEY

Classical Triangulation Datum: ED 50
Realized by observations to and from
8 sites in Bulgaria and Greece
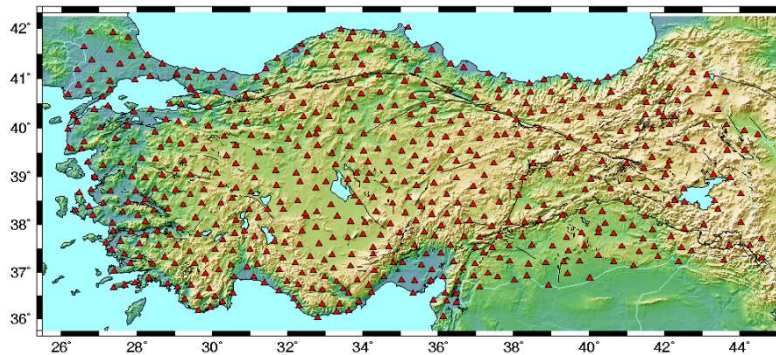
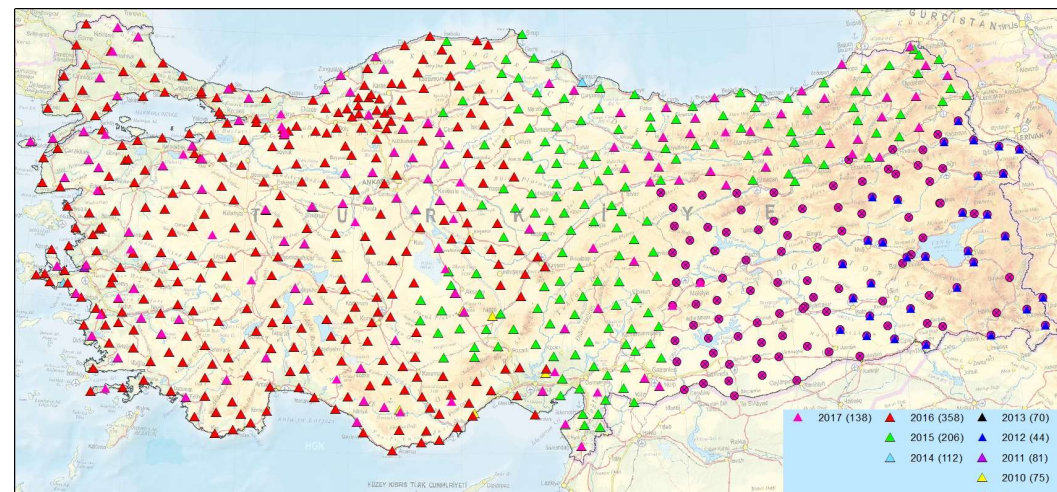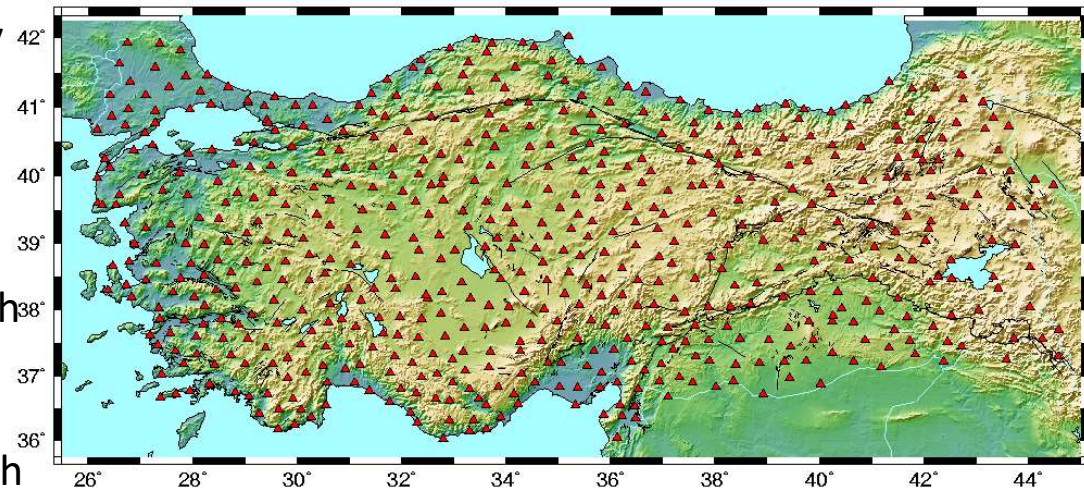In 2001: ED50 => TUREF (Turkish Reference Frame)

TUREF: ITRF96 Epoch 2005

Data processings are made with the latest ITRF version and then coordinates and velocities are transformed to TUREF to provide unification.

Vertical Datum: TNVD99

TURKISH NATIONAL FUNDAMENTAL GNSS NETWORK- TNFGN (TUTGA)

- First fundamental geodetic network based on GPS technology
- 594 sites established through campaign type GPS surveys between 1997 and 1999
- 664 sites at the moment
- Velocities interpolated at sites with 1 epoch observation
- Sites observed with GNSS (permanent sites, tide gauge bench marks, classical network points, geodynamic points) contribute to velocity field
- Revision surveys are done annualy (usually parallel with GCP works) and after the main earthquakes
- 3D coordinates and velocities are computed in latest ITRF, transformed into ITRF-96 epoch 2005

CAMPAIGNS SURVEYED RECENT YEARS

# Tripod ➜ Tech 2000 Surveying Kit (UNAVCO)

- Due to vandalism and other effects pillars are destroyed more than benchmarks.

- More accurate antenna height measurement and centering.

TURKISH NATIONAL PERMANENT GPS (TUSAGA) AND CORS-TR NETWORKS

- TUSAGA: Established particularly to monitor geodynamical activities in the country and to serve as a reference network. (2002-2006)
- In this network, ANKR (Ankara) GNSS station continues to send its hourly and daily data to IGS and EPN while no real-time data streaming at the moment. Also ISTA GPS (Istanbul Technical University) and TUBI GPS (TUBITAK Marmara Research Center) are in operational as well.
- TUSAGA-Active or CORS-TR: RTK network consisting of 146 sites to serve real-time positioning information for a variety of applications such as mapping, GIS and cadastral applications.
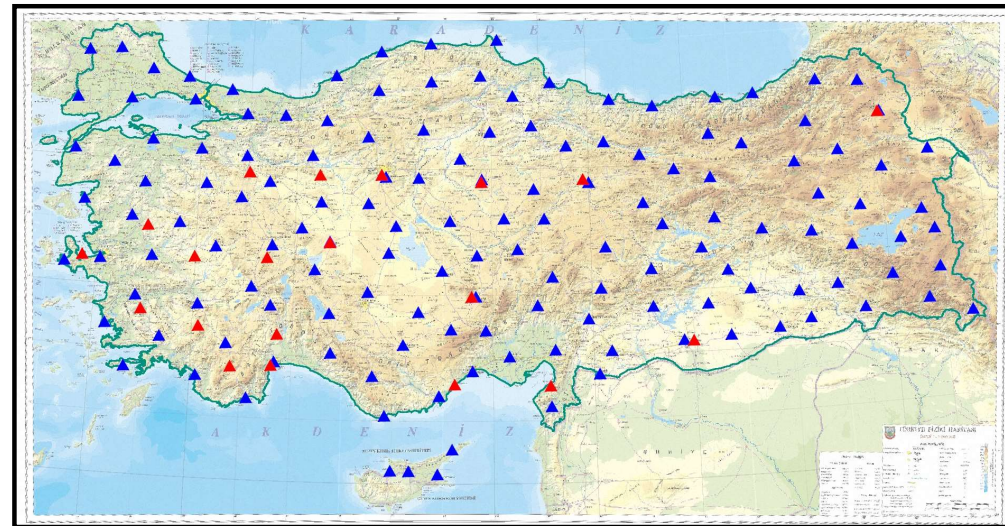
✓ **10 TUSAGA Stations replaced by new MultiGNSS receivers in 2017.**

✓ **10 Stations will be modernized within this year.**

▲ **TUSAGA-Active Stations (146)**

▲ **TUSAGA Stations (21)**

CORS-TR NETWORK

- An RTK Network of 146 sites,
- Finance: Turkish National Scientific and Technological Council
- Executor: Istanbul Culture University,
- Supervision: General Command of Mapping (GCM) and General Directorate of Land Registration and Cadastre.

- Fully operational.
- For the applications ranging from large-scale mapping,GIS and cadastral surveys.
- Serve on real-time kinematic basis.
- Time-series analysis on a daily basis to monitor unexpected movements.
- Utilized as geodetic control and for monitoring crustal movements.
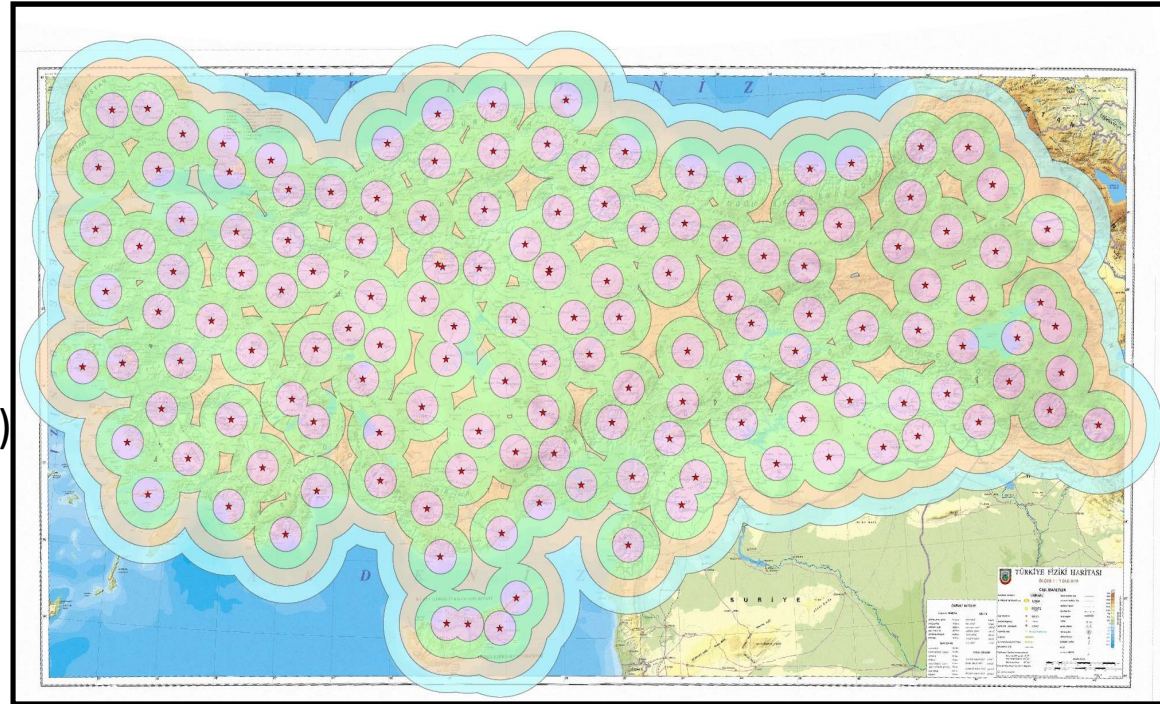
Structure of CORS-TR NETWORK
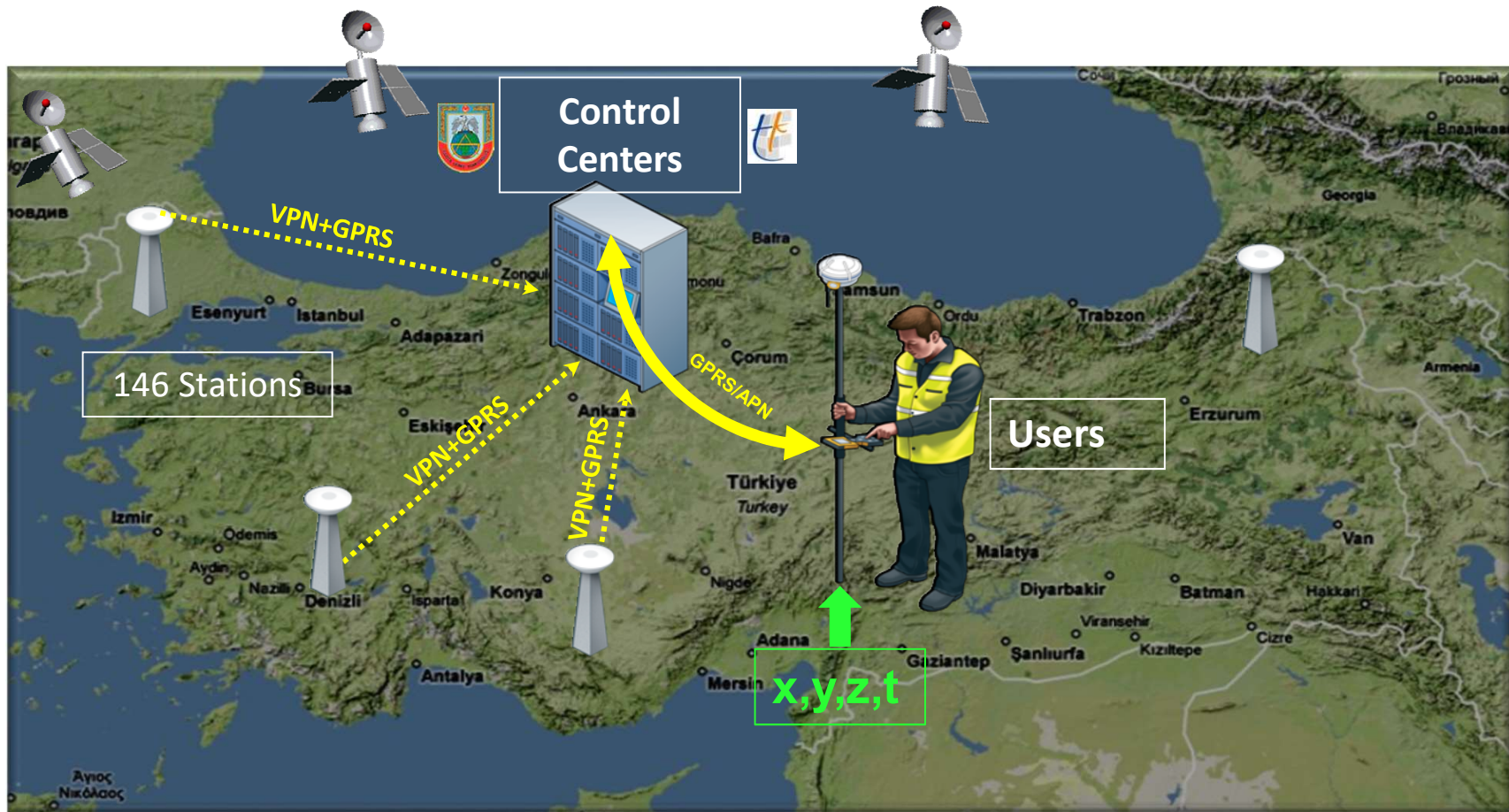
CORS-TR NETWORK

Five different correction data are broadcasted by the control centers

- ✓ VRSRTCM3.1
- ✓ VRSCMR+

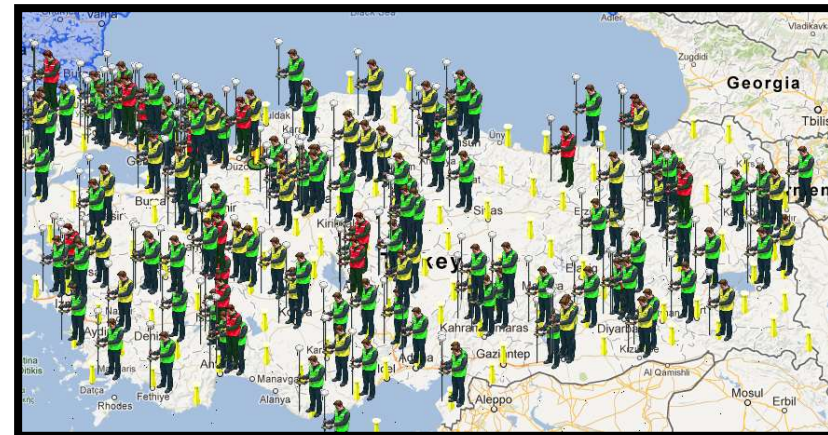→ VRS Technique
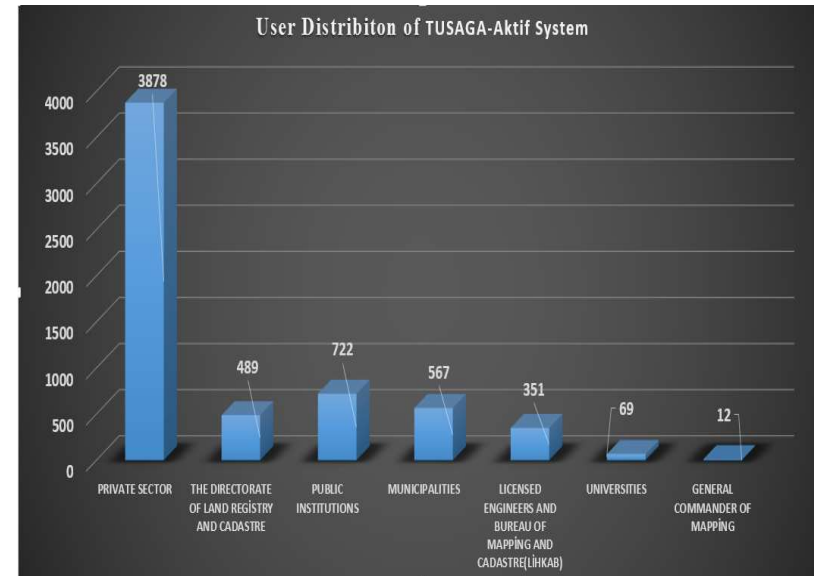
- ✓ RTCM3NET

→ MAC Technique

- ✓ SAPOS (FKP_RTCM3.1)

→ FKP Technique

- ✓ DGPS

USERS OF CORS-TR SYSTEM

- Supports all brand GNSS receiver

- Supports NTRIP protocol

- with GPRS/EDGE modem

- User registration exceeded 10.000 in the beginning of 2018

User Distribiton of TUSAGA-Aktif System
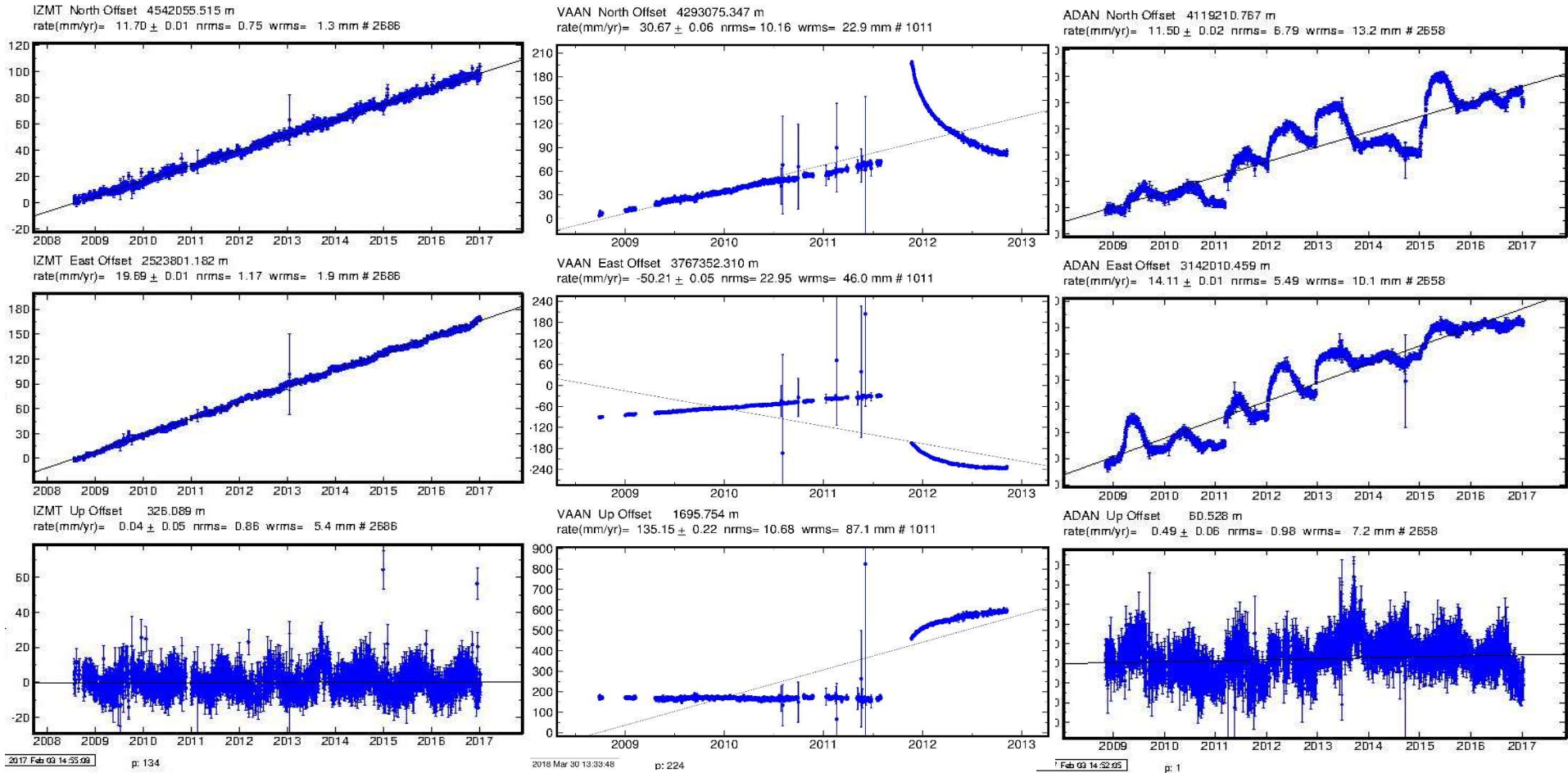
CORS-TR NETWORK
Control Centers & Software

- CORS-Tr Control Centers founded in late 2008.

- At the end of 2014, CORS-TR system software and hardware have been updated

- Data are stored in RAID5 Storage Control System that provides security

- 64 bit servers provide more stability

- RTK Software is now PIVOT2

The main functions of RTK Control Software;

- ✓ Transferring of links and observations of all reference stations

- ✓ Calculation of the coordinates of the point CORS-TR permanent GNSS stations

- ✓ Modelling of errors

- ✓ Calculation and broadcast of corrections to the rovers

- ✓ WEB services

- ✓ Monitoring of rovers

- ✓ Data storage and etc.

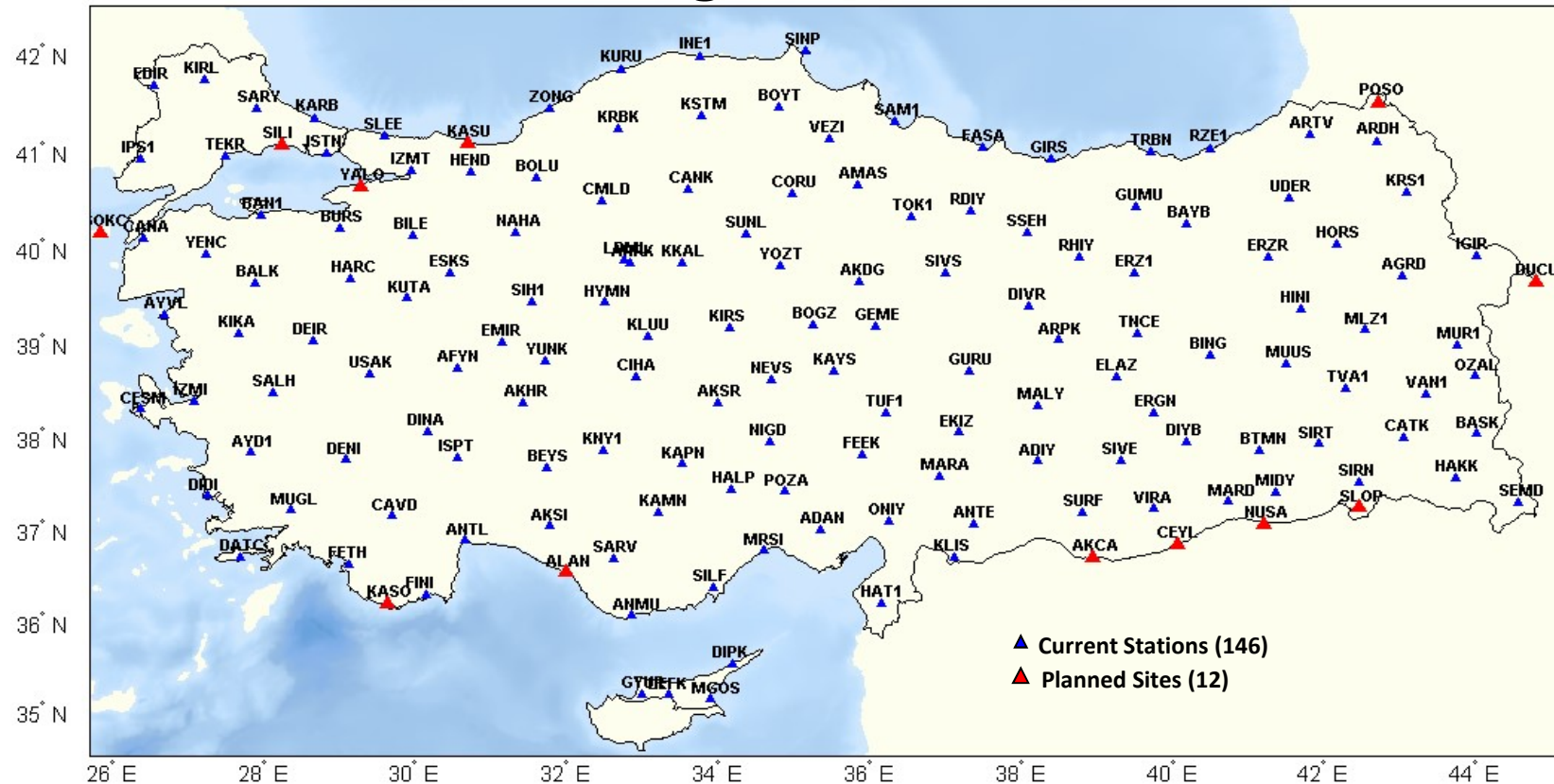# Daily GPS Processings and Time Series Analysis

We provide 1 Hz static data after the main earthquakes for geophysical studies

TUSAGA and CORS-TR

Coordinates and velocities of all stations are reprocessed and published at the GCM web site.

Extending CORS-TR Network

- 12 new stations are planned to be established to increase the efficiency of CORS-TR especially at the borders and coastlines.

- Receivers and antennas are procured, planned to be installed within this year.

New IGS Sites from Turkey
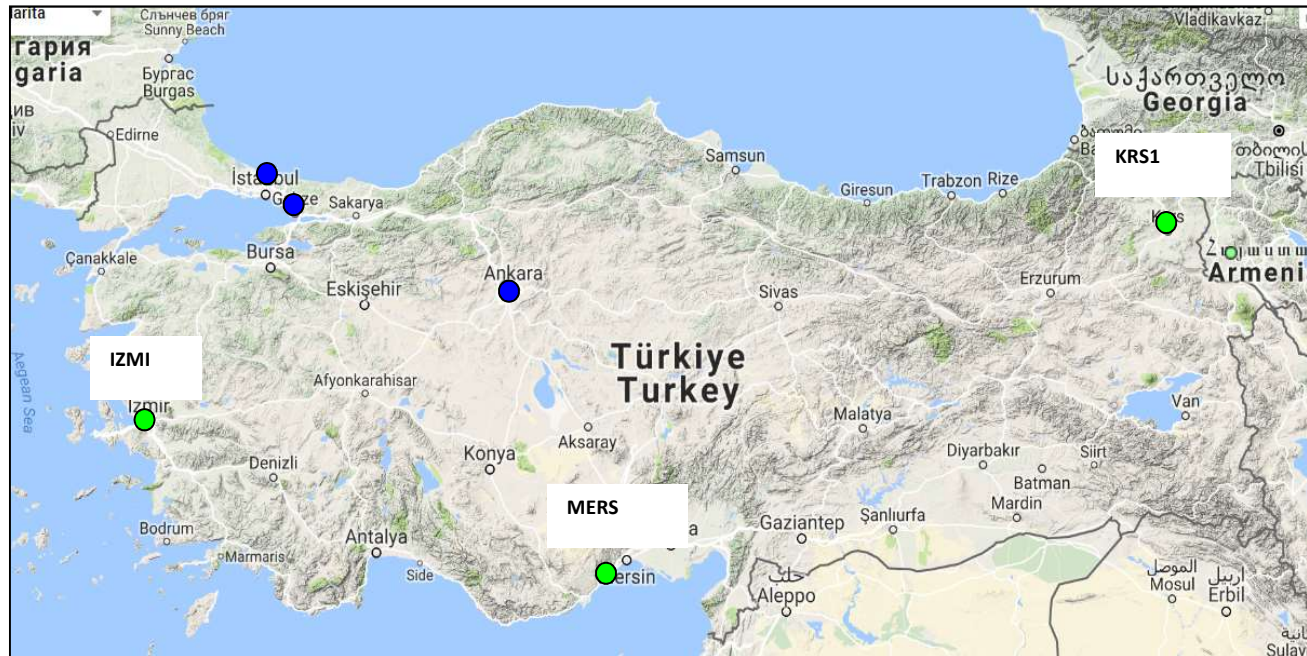
MERS : Multi GNSS

IZMI   : GPS+GLO

KRS1 : GPS+GLO

ANKR : Replaced
with MultiGNSS

[IGSMAIL-7518] New IGS Stations: IZMI, KRS1, MERS

(06 September 2017)

IZMI and KRS1 receivers will be upgraded to MultiGNSS (Receivers are ready)

We will have the chance that these sites will be included in the next ITRF solutions for datum definition.

Contribution to EPN Velocity Field Densification Network

- EPN Densification WG will provide a unique control option for the national network operators to crosscheck their ITRFyy/ETRS89 coordinates, not only at the EPN sites but for all stations for which solutions have been submitted to EUREF
- The estimated station velocities will be the basis for the generation of a continental velocity model. This velocity model is especially relevant in countries, where the ETRS89 coordinates, due to tectonic activity, change with more than 3-5 mm/year.

- ➢ GCM is the national representative of EUREF
- ➢ 41 CORS-TR stations
- ➢ 6 years of weekly sinex files (2009-2015) were supplied to EUREF last year.
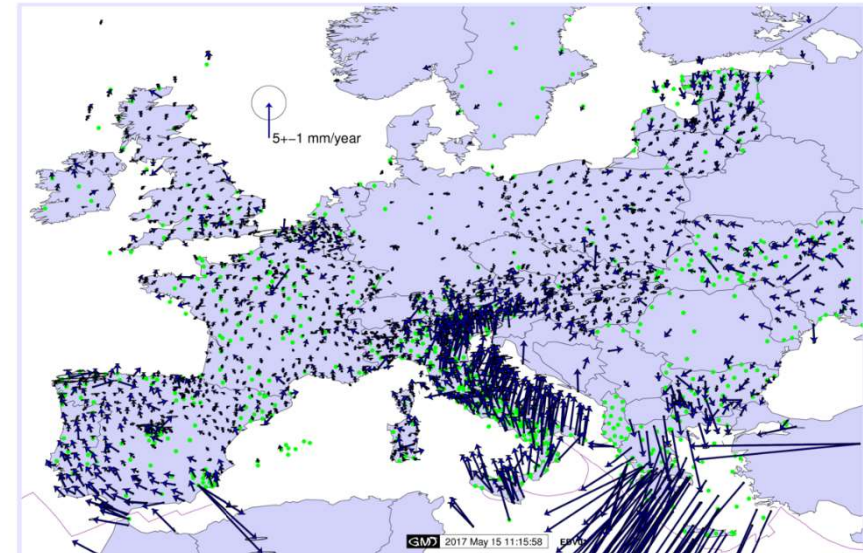
Reprocessing of all Historical GPS Data
Purpose and Motivation

- Homogeneous processing strategy and unique software: Previously daily solutions were done by BERNESE and sinexes were combined with globk and glorg

- Using improved products (repro orbits and erp)

http://www.iapg.bgu.tum.de/gps_repro/

http://www.iapg.bgu.tum.de/gps_repro/
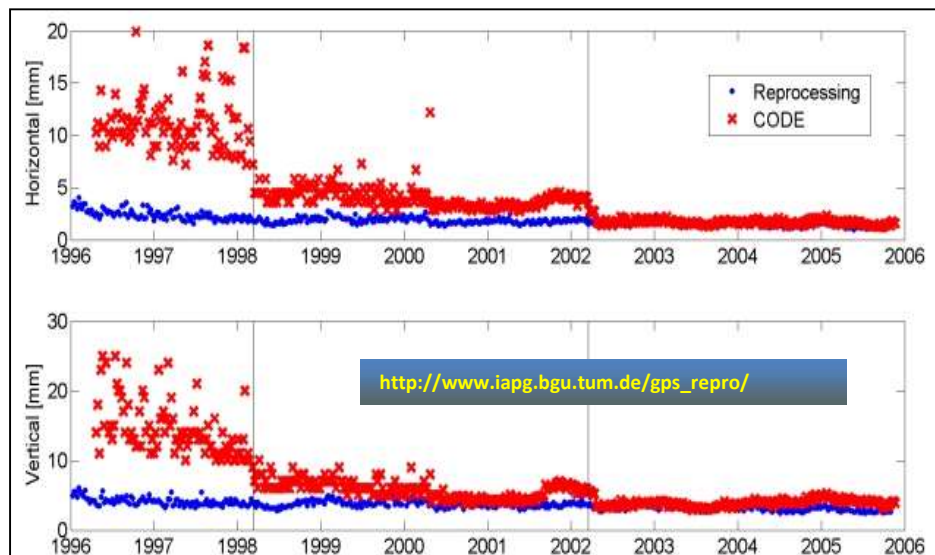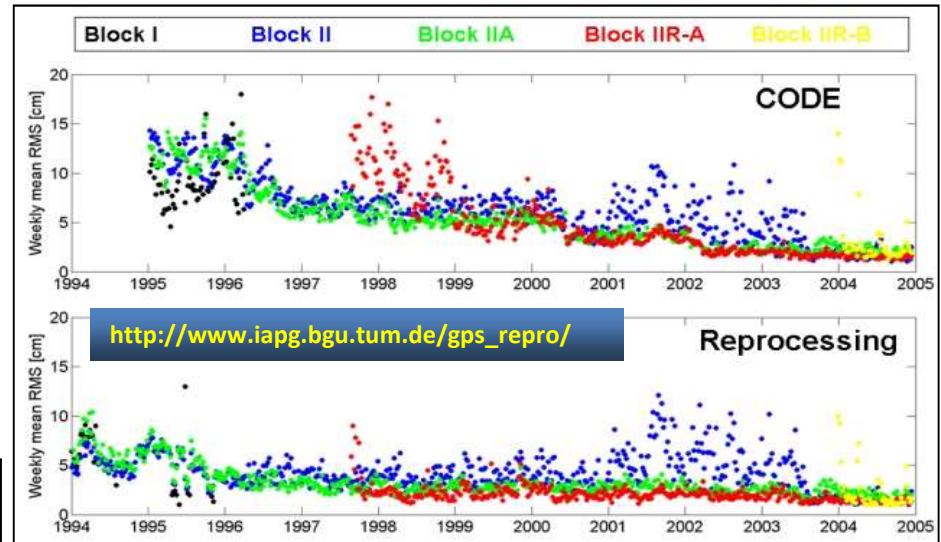
- Improved models (Viennas, higher order ionos)
- Expecting consistency between solutions
- More stable time series and velocities

Reprocessing of all Historical GPS Data

Main Differences and Advantages:

- Include sites not belonging to a specific campaign. Provides more epochs

- Organizations and universities provide data to GCM

- Campaign are splitted to   15 days

- Due to computer capabilites 6-7 IGS sites were used previously. Using more IGS stations than before (33).
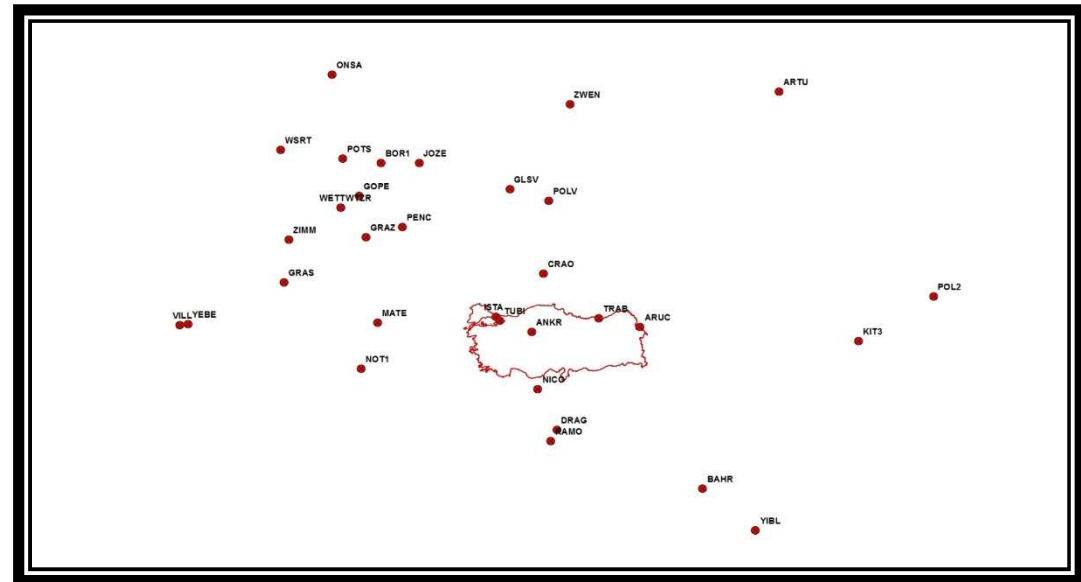
- Vienna Mapping Functions for troposphere (VMF1)

- More epochs (min.2-3)

- Longer data span

- ~170 CGPS sites data span nearly 9.5 years, some of them more than 15 years

GAMIT Daily Data Analysis Strategies Used

Software Version	Version 10.61
Modelled Observables	Double-differences
Elevation angle cutoff	3 degrees, Sites collect at 0 degrees
Orbits and ERPs	IGS Final orbit and ERP (sp3), Bull B
Ocean Loading Corrections	From OSO for stations
IGS Sites	33 Sites are included to the Daily process
Troposphere	Vienna Mapping Function (VMF1) for dry and wet
Met obs source	Global Pressure and Temperature (GPT 50)
Number of Troposphere par.	ZPD at 2 hours intervals
Antenna Phase Center Corrections	Absolute APC corrections based on IGS08 model
Apriori coordinates	ITRF2014
Ionospheric Correcitons	2nd and 3rd Order, IGRF12

Reference Frame Realization

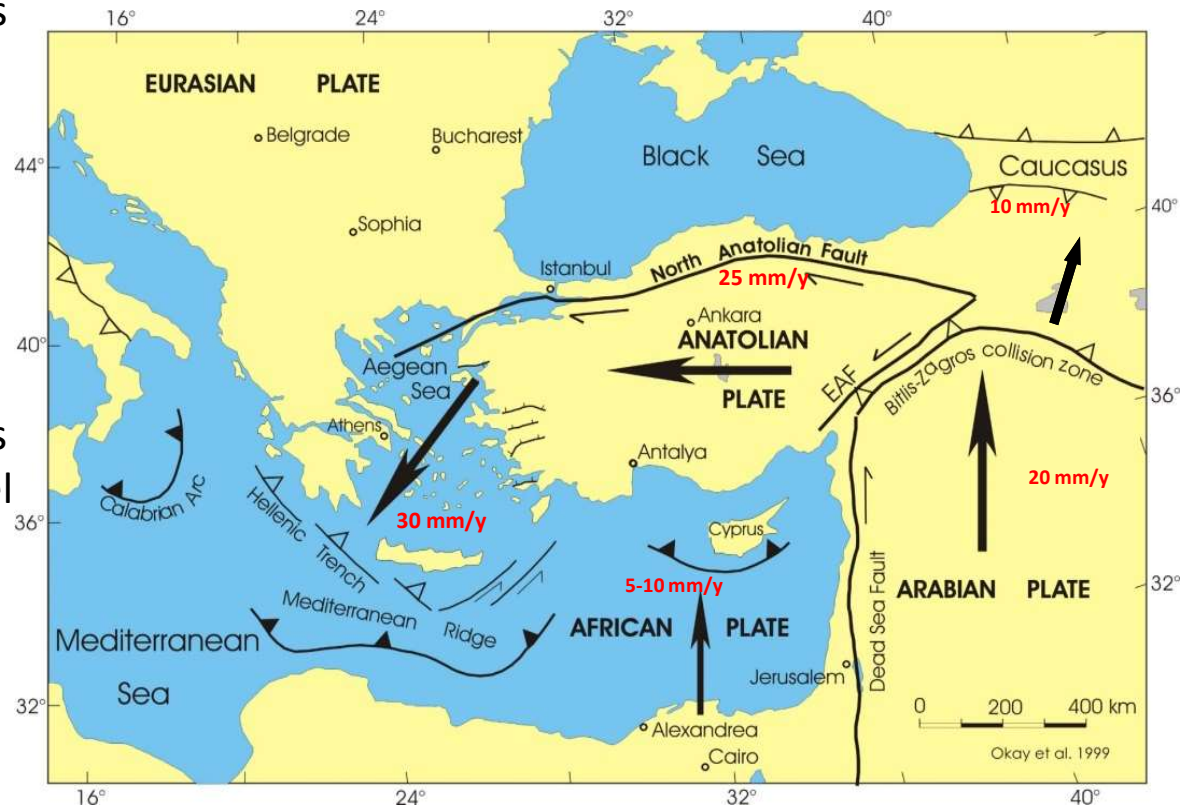| Software Module	glorg
Renames	Earthquake definition file
Stabilization	Regional
Number of IGS Sites Used	33 Stations
Transformation	6 Parameters 3 Tranlations, 3 Rotations
Reference Frame	ITRF2014
National Datum	TUREF (ITRF96 Epoch 2005.0)
Solutions	Daily (TS, noise analysis, monitoring stations)
	Monthly (For combination with campaigns and estimating velocity field)
	Weekly (For EUREF)

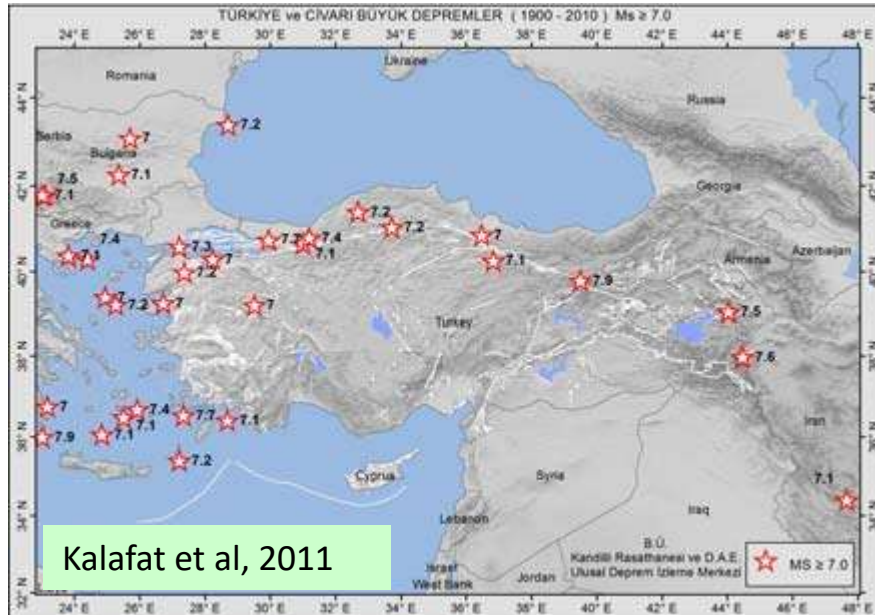# Geodetic Velocity Field Modelling Project

STEPS

- Re-processing of all campaigns and permanent stations with modern strategies and products
- Rigorous Inspection of time series that will be used for velocities
- Cross validation of velocities for incompatible site velos
- Determination of blocks using cluster analysis described by Simpson et al. and adding geophysical interpretation to the solutions
- Block modelling for strain analysis
- Determining a deformation model based on the pre-defined blocks
- Publishing this velocity model to users and use this in the CORS-TR system
- Users will have velocity of the points along with coordinates

Protocol signed with Yıldız Technical University (05 October 2017)

Challenges

Kalafat et al, 2011

- Turkey is a big country
- We have fault zones that produce many earthquakes
- Along boundries or within the plate

Kalafat et al, 2009

Kalafat et al, 2009

- 1-2 epochs of observation, afterwards an earthquake or destruction of sites
- Sites destroyed by vandalism as in many countries
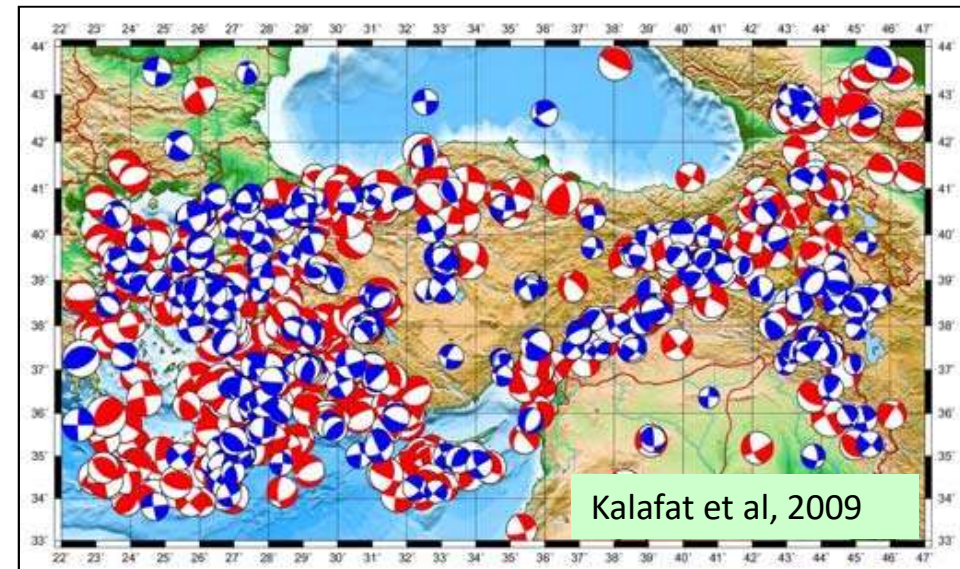
Statistics

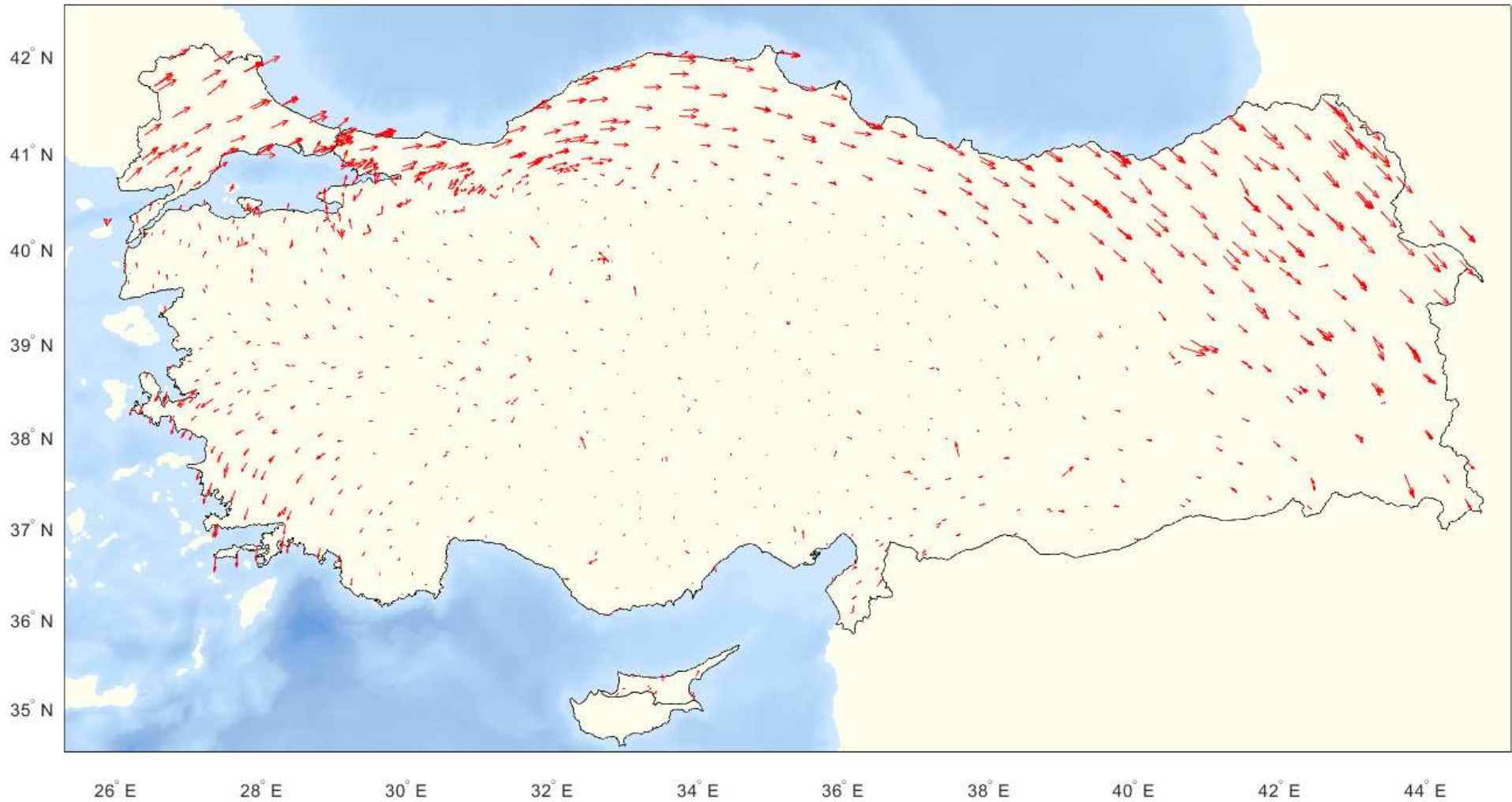| Sites	TUTGA 2009	TUTGA 2018
Sinex Files	84	279
		Globk run takes 4 hours! Every year 12 more sinex
Total Sites	**1547**	**1790**
1 Epoch	723	475
2 Epoch	323	204
3 Epoch	180	263
4 Epoch	112	210
5 Epoch	62	130
> 5 Epoch	147	508

Preliminary Results– wrt ITRF Reference Frame
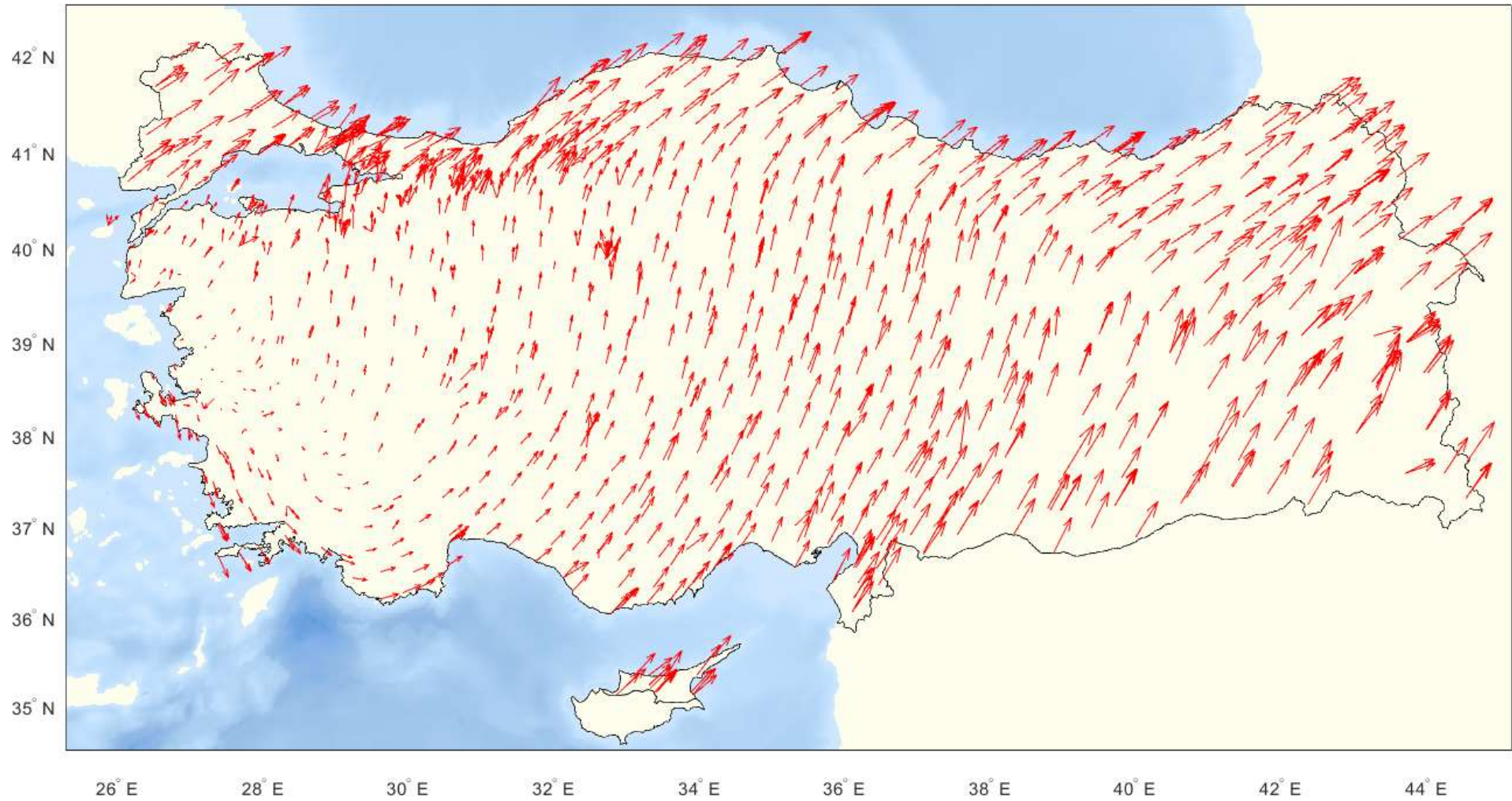
Preliminary Results– wrt Eurasia Fix Reference Frame
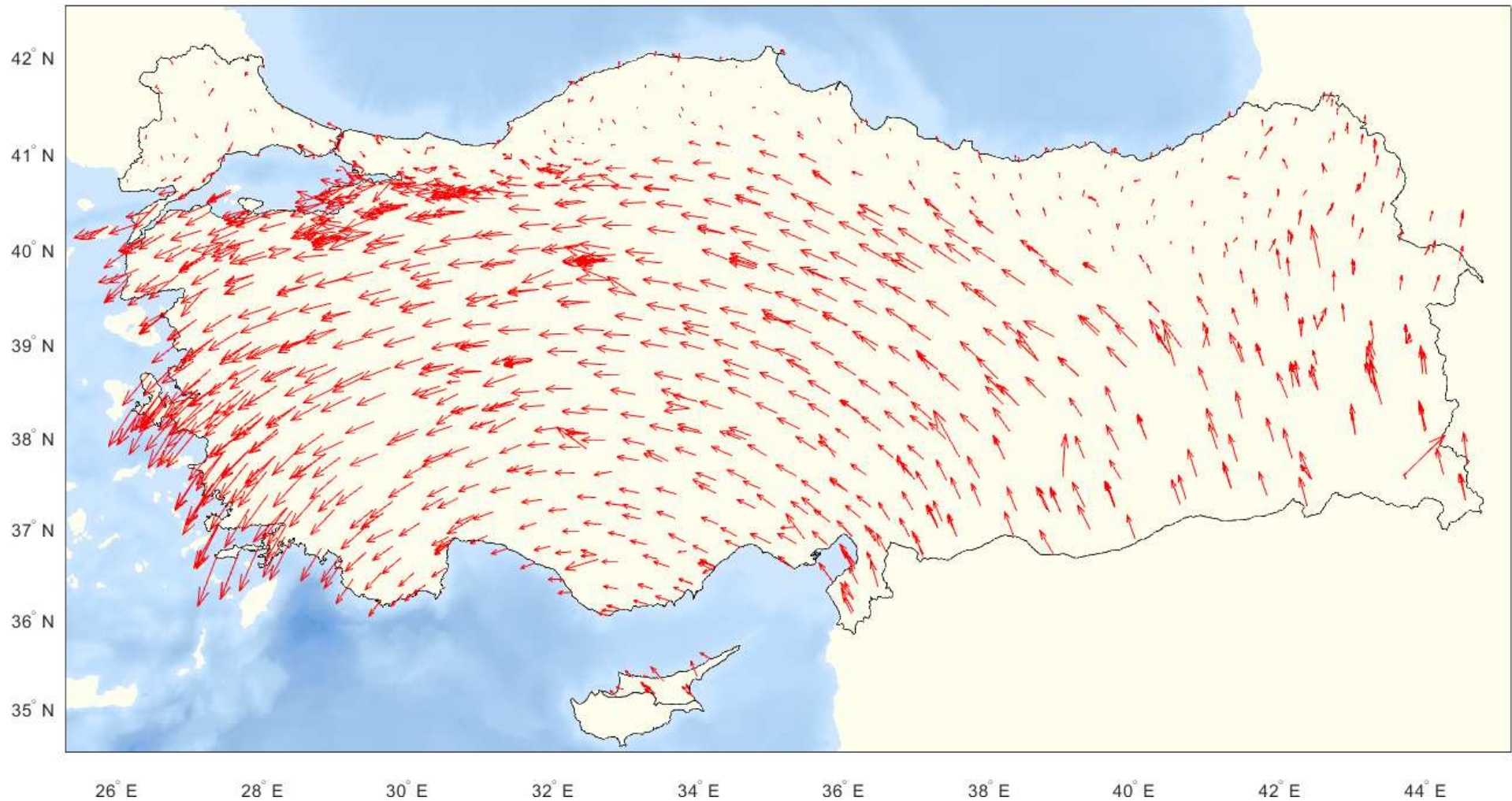
Preliminary Results– wrt Anatolian Fix Reference Frame

FUTURE PLANS AND OUTLOOK

- Implementing parallel re-processing with BERNESE for GPS+GLONASS

- TUTGA- Minimum 4-5 epoch survey

- Define a smooth velocity field model for users and geophysical studies

- Receivers to be replaced with multiGNSS ones

- Publish CGNSS sites time series for noise analysis and other studies

- Defining Anatolian Reference Frame?

General Command of Mapping
National Mapping Agency

Thank you for your attention