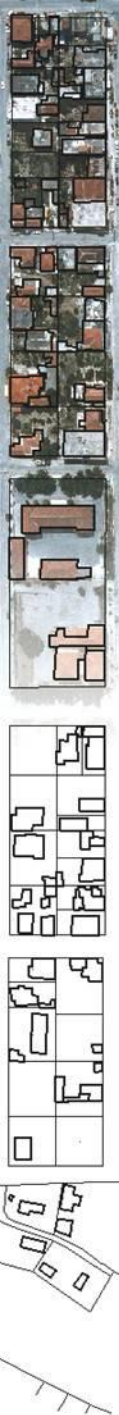


Realizing a geodetic reference frame using GNSS in the presence of crustal deformations: The case of Greece

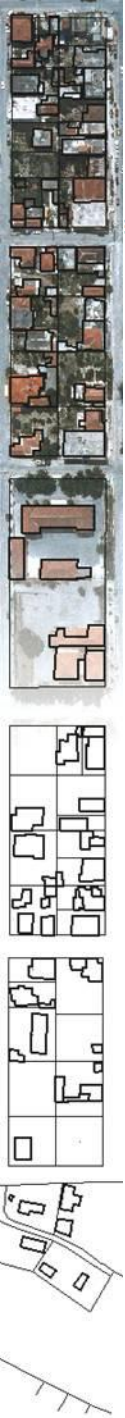
M. Gianniou

National Cadastre and Mapping Agency S.A.



Outline

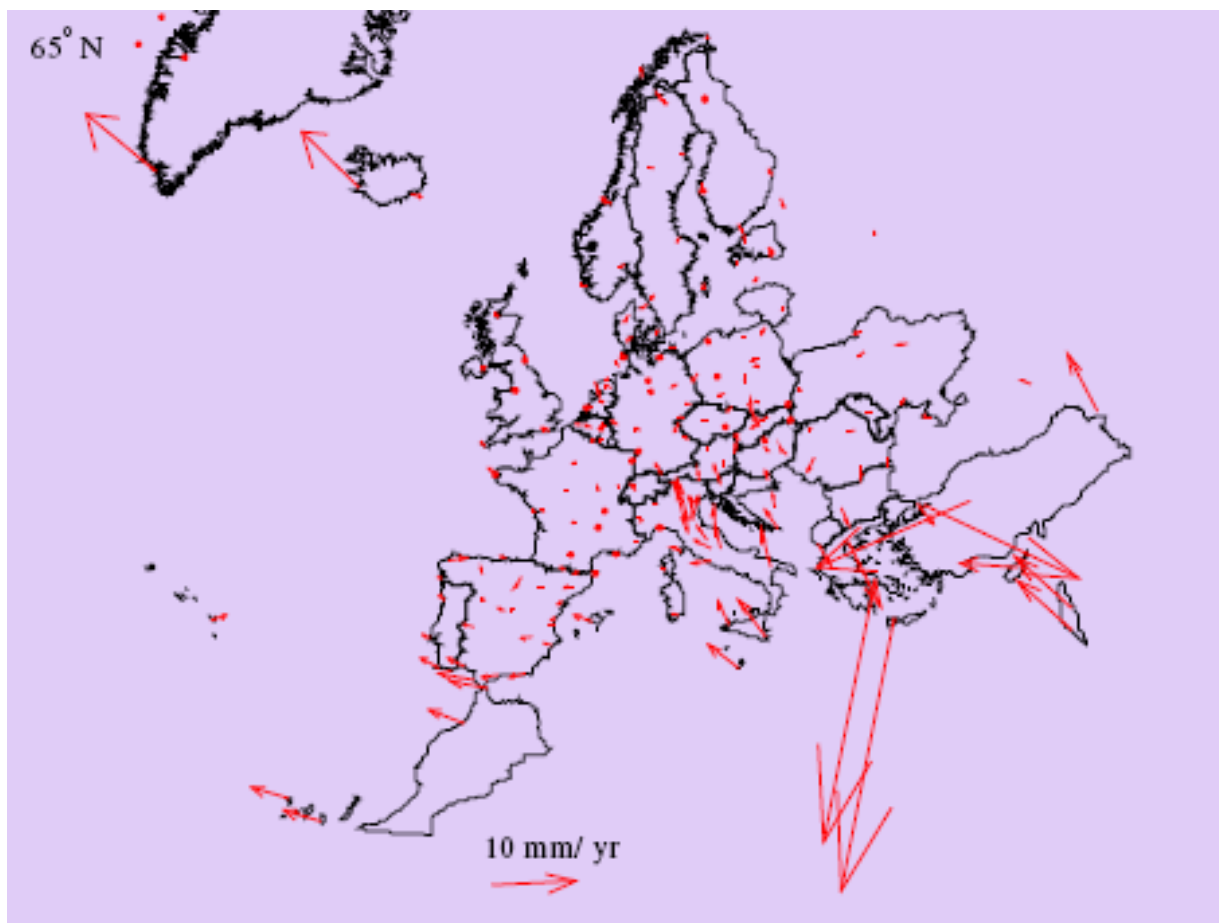
1. Introduction
2. Deformation field in Greece
 - Constant plate motions
 - Earthquakes etc.
3. Deformations and HEPOS
4. Discussion



1. Introduction

EPN stations Velocities

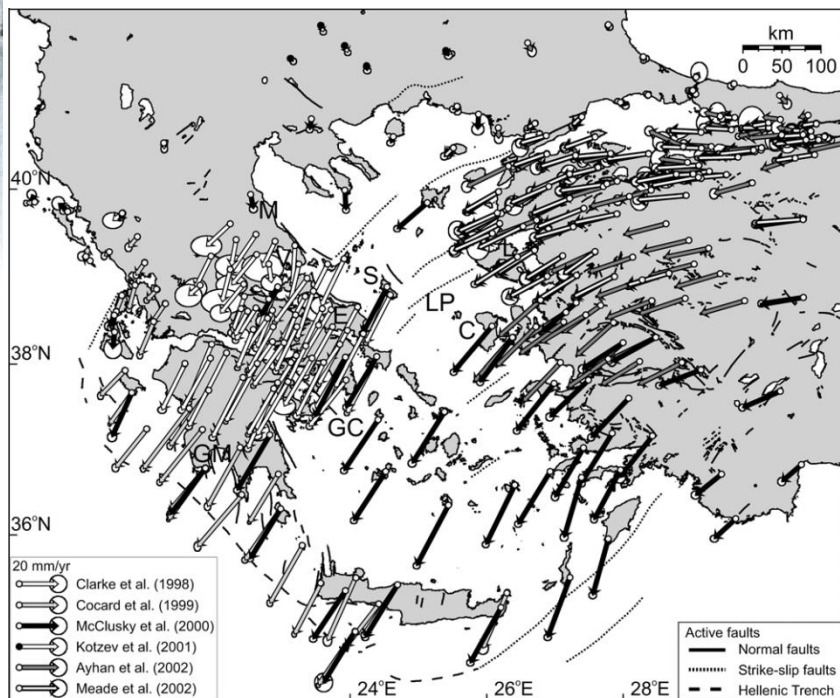
Horizontal ETRF2000 velocities of Class A EPN stations (*Caporali et al., 2011*)





2. Deformation field in Greece

The Aegean Plate



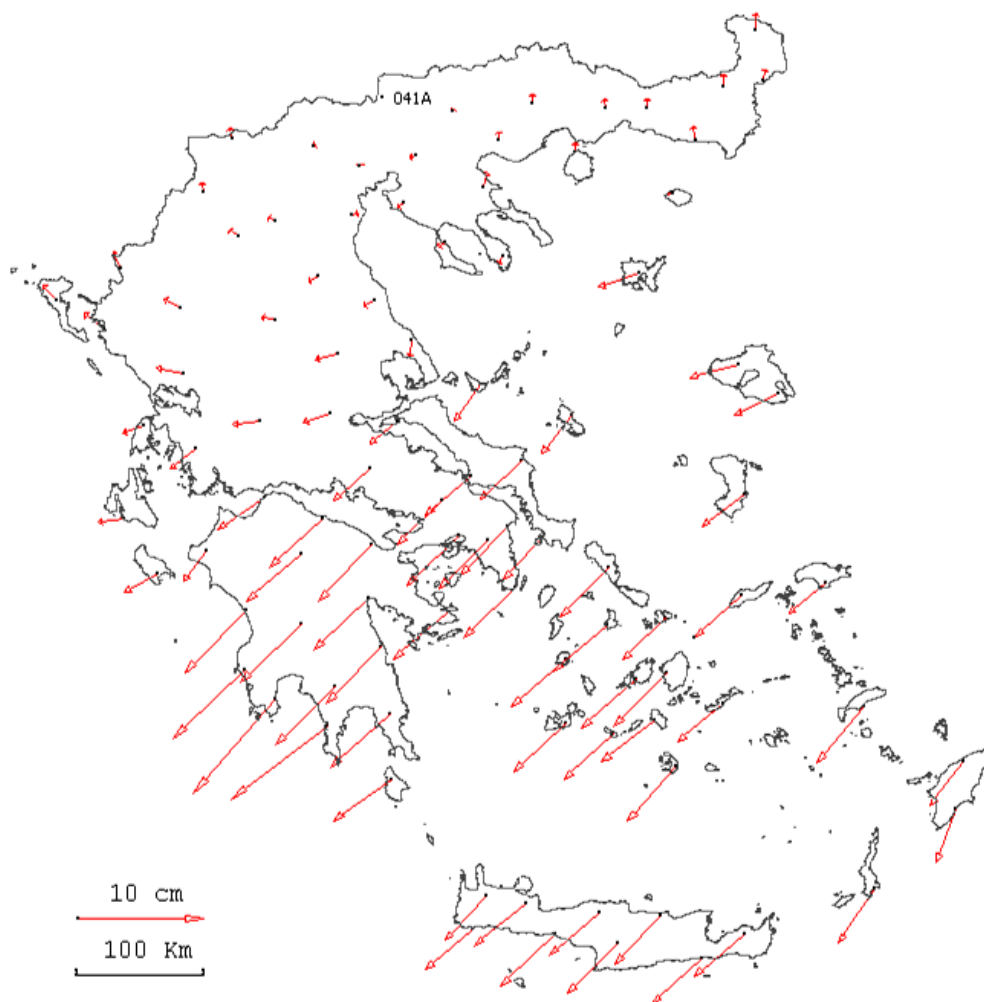
Geodetically derived velocities relative to Eurasia
(Nyst and Thatcher, 2004)





2. Deformation field in Greece

Constant plate motions

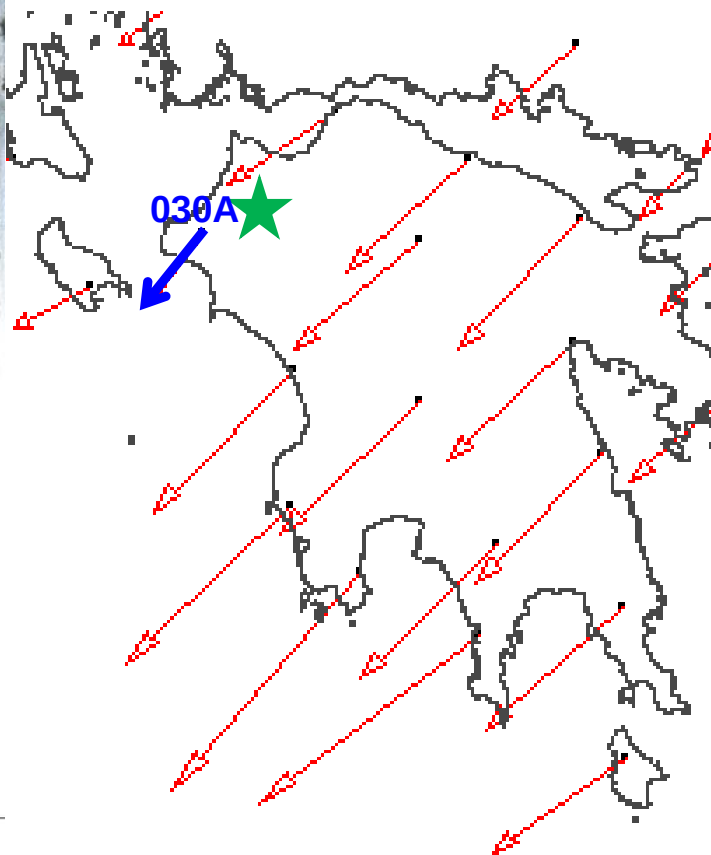


**Differential
displacements of the
HEPOS stations over
a two-years period
(w.r.t. station 041A,
11/2007 - 11/2009)**
(Gianniou, EUREF 2010)



2. Deformation field in Greece

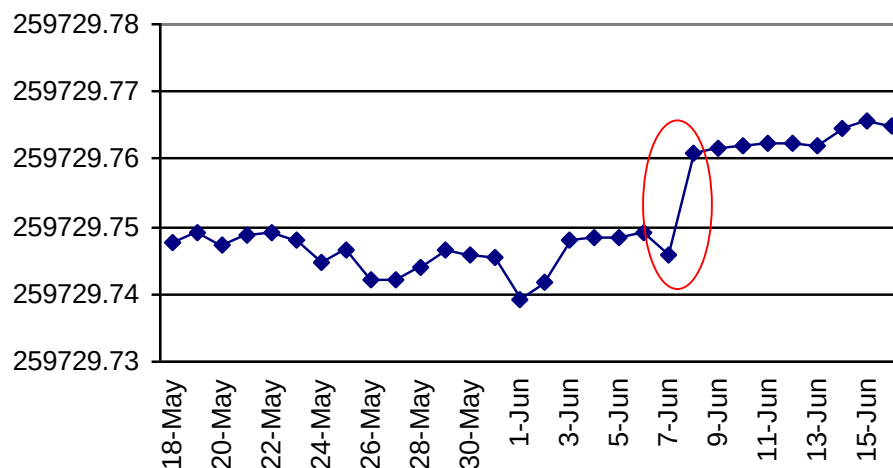
Deformations due to Earthquakes



The Andravida 2008 EQ

- Day: June 8, 2008
- Magnitude (L): 6.5
- Depth: 25 Km

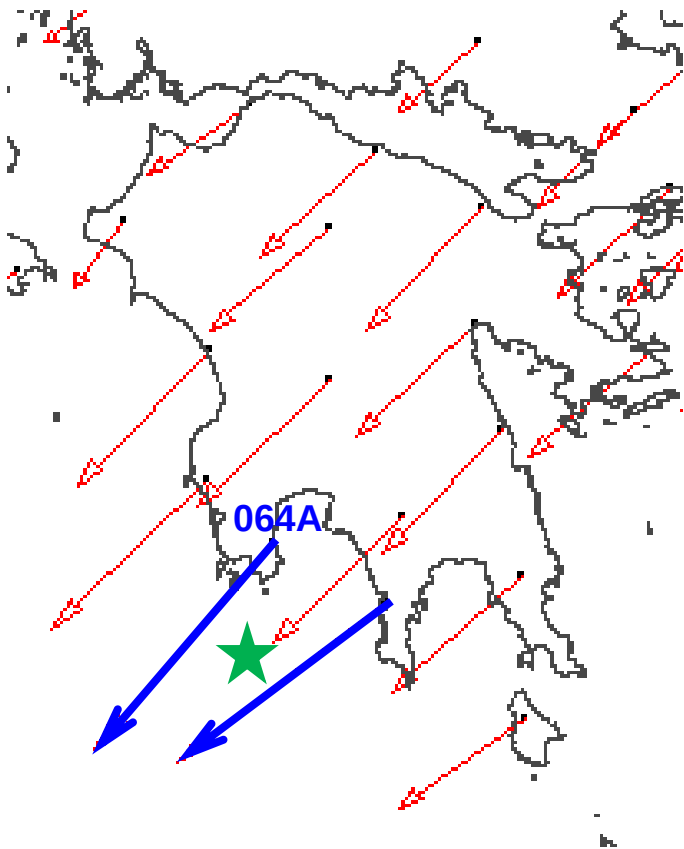
Variation of Easting (RS 030A)





2. Deformation field in Greece

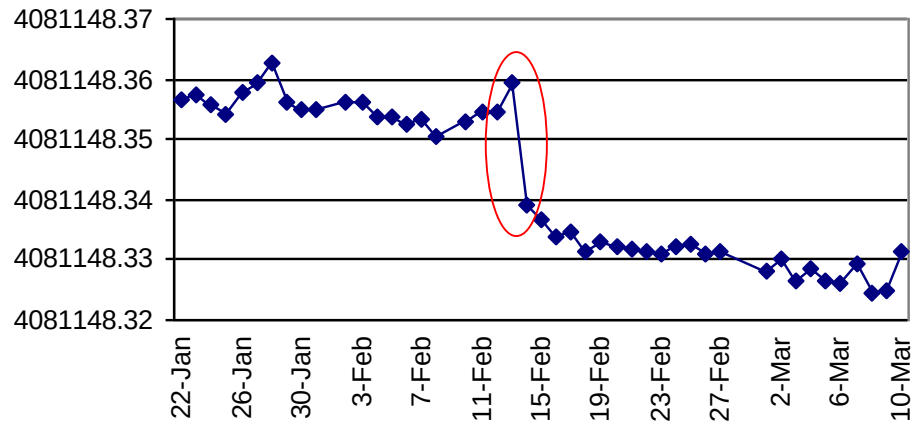
Deformations due to Earthquakes



The 2008 offshore South Peloponnese EQ

- Day: Feb. 14, 2008
- Magnitude (L): 6.2
- Depth: 41 Km

Variation of Northing (RS 064A)



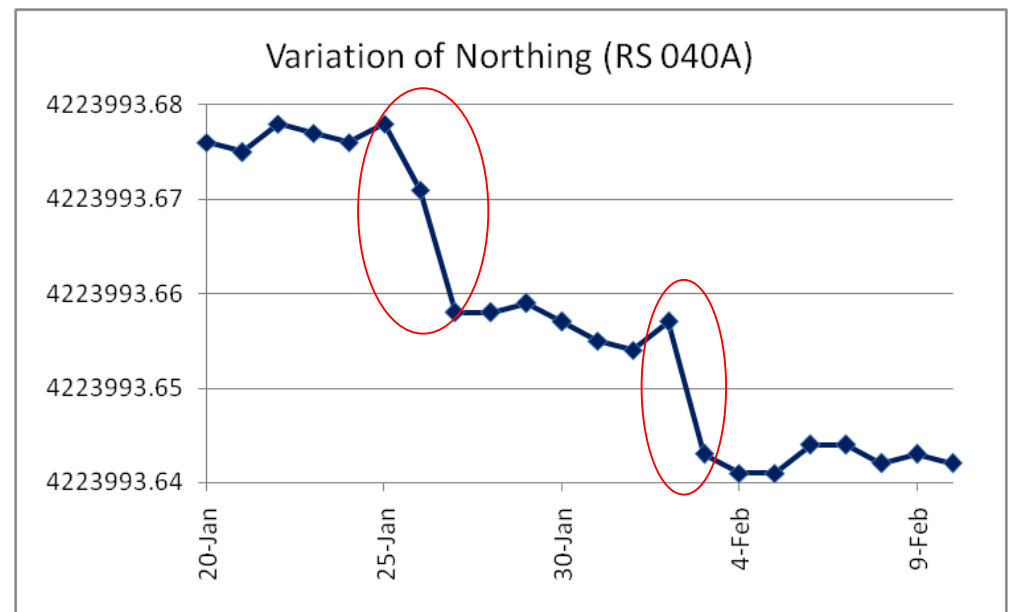
2. Deformation field in Greece

Deformations due to Earthquakes



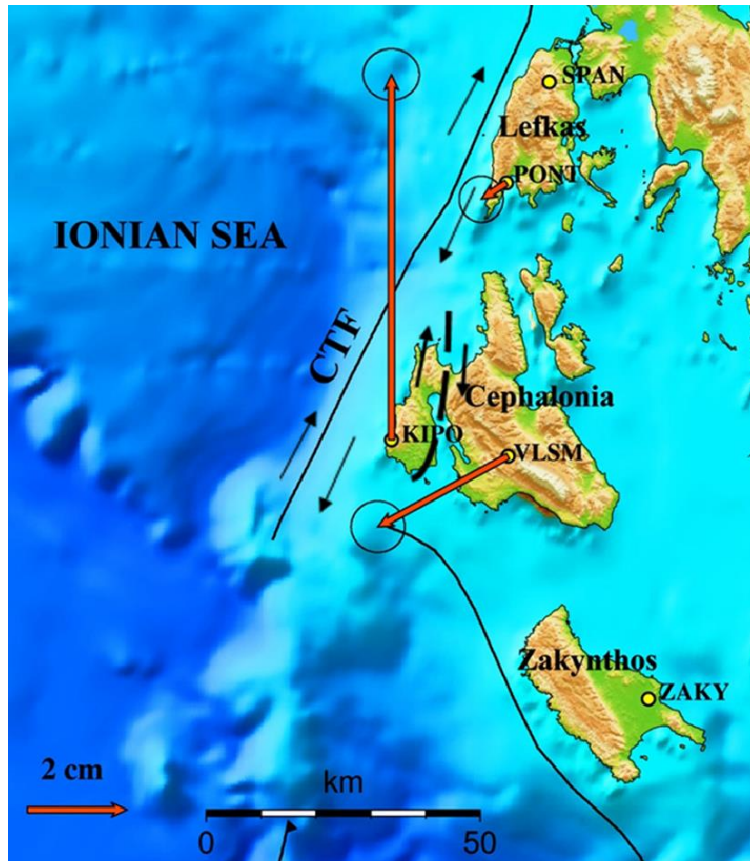
The Cephalonia 2014 EQs (strongest events)

- Days: Jan 26 / Feb 3 2014
- Mw: 6.0 / 5.9
- Depths: 16 / 11 Km



2. Deformation field in Greece

Deformations due to Earthquakes



The Cephalonia 2014 EQs:

Displacements at non-HEPOS stations for the period before Jan 26 and after Feb 3, 2014.

(Ganas *et al.*, 2015
Acta Geodyn. Geomater, Vol 12)

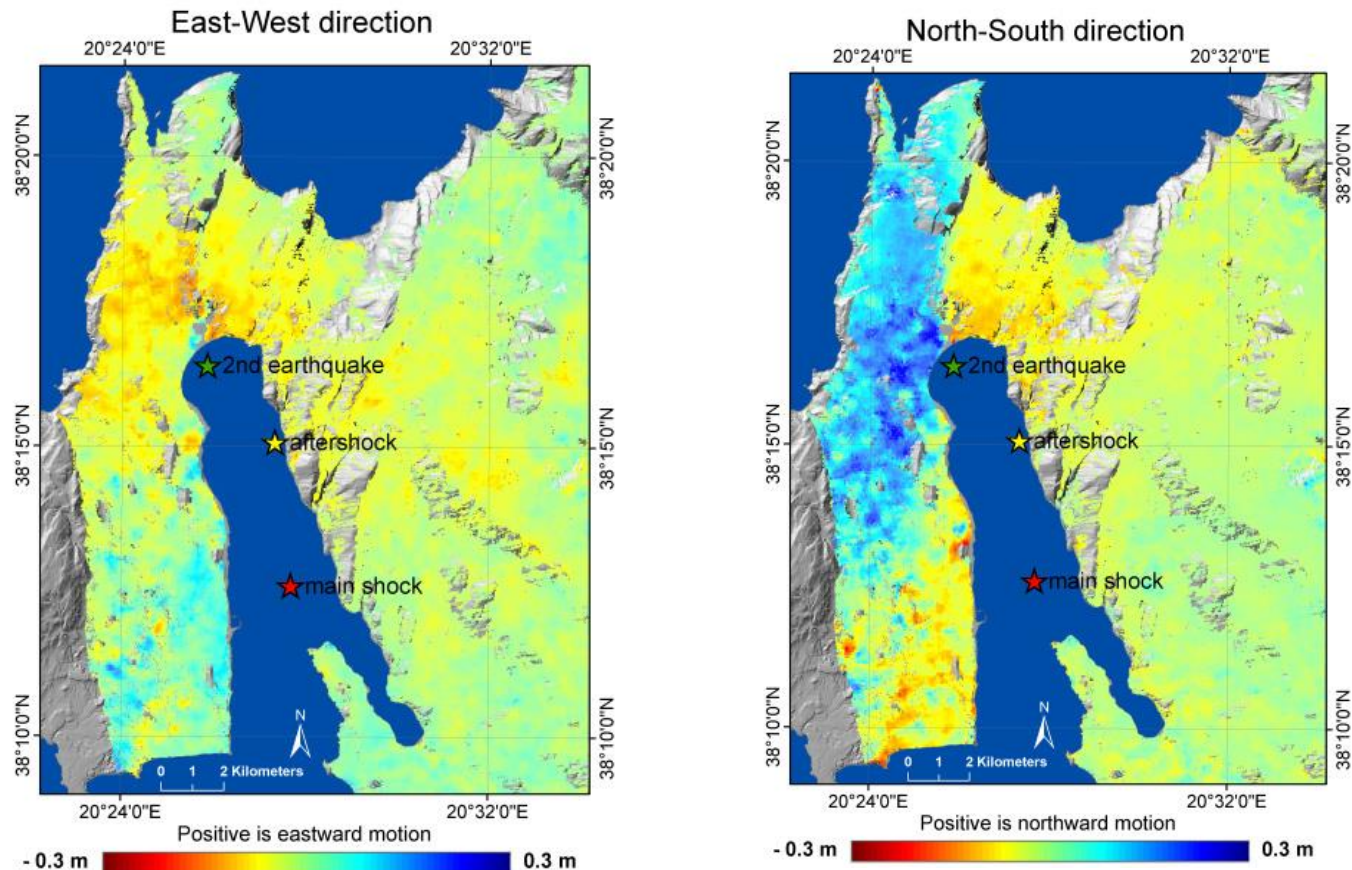


2. Deformation field in Greece

Deformations due to Earthquakes

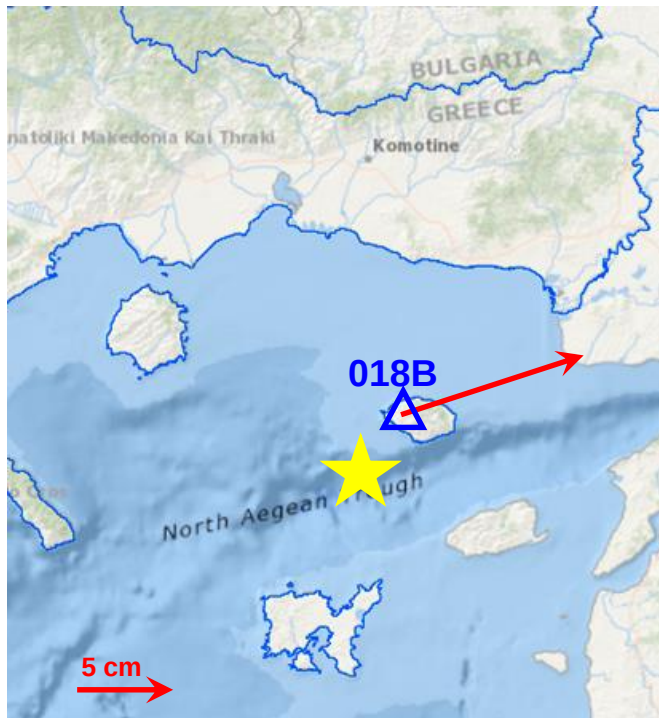
The Cephalonia Feb. 3, 2014 EQ

Source: Kontoes et al, (2015), BEYOND, EGU 2015 Splinter Session



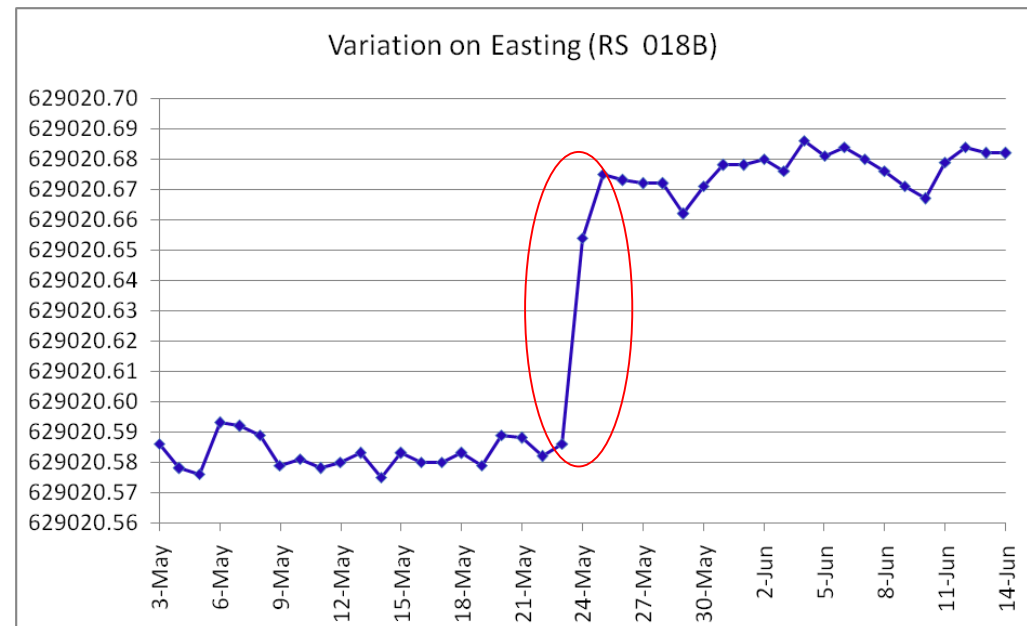
2. Deformation field in Greece

Deformations due to Earthquakes



The North Aegean Sea 2014 EQ

- Day: May 24, 2014
- Mw: 6.9
- Depth: 28 Km

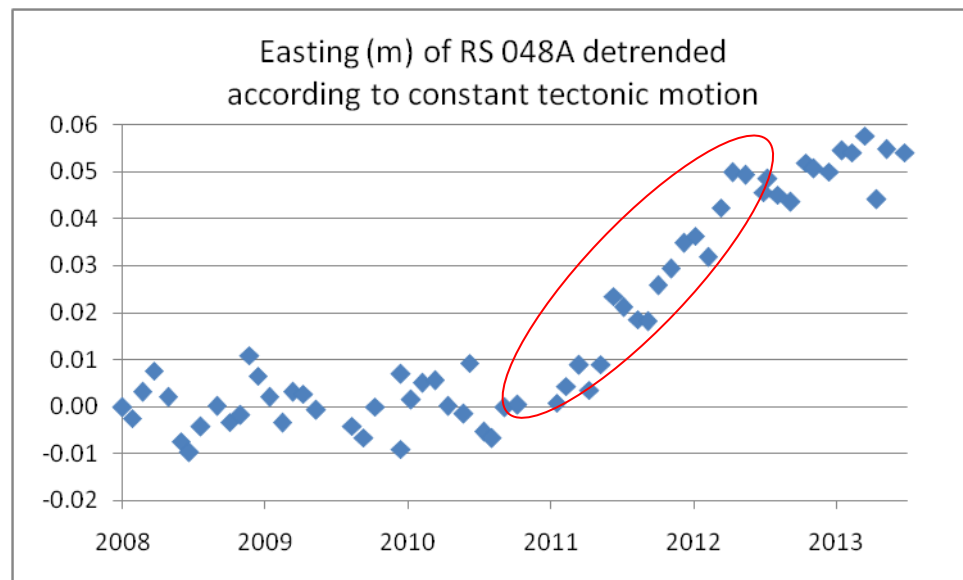




2. Deformation field in Greece

Deformations due to volcanic activity

The 2011-2012 Santorini volcano inflation
(effect on HEPOS station)

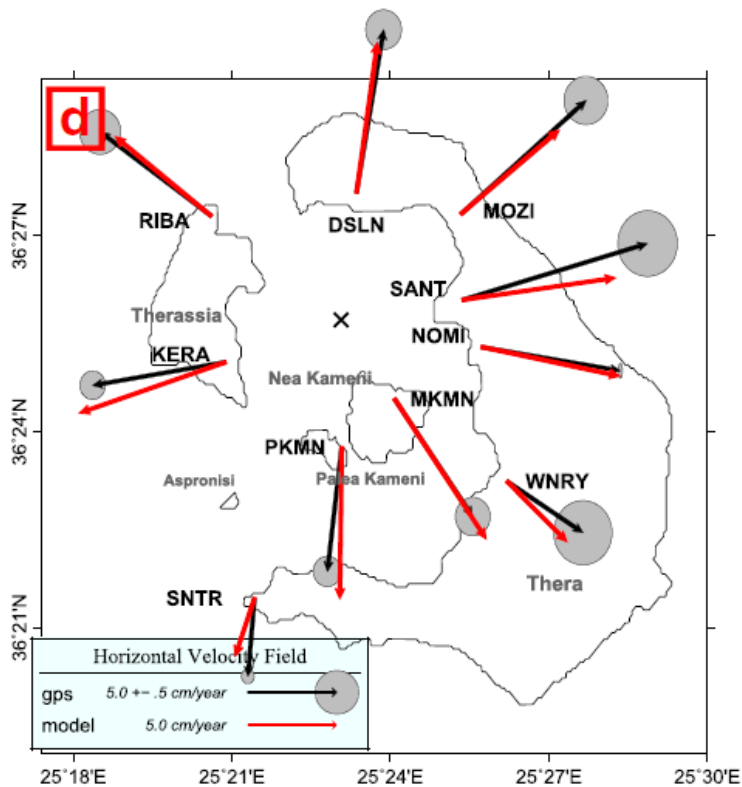




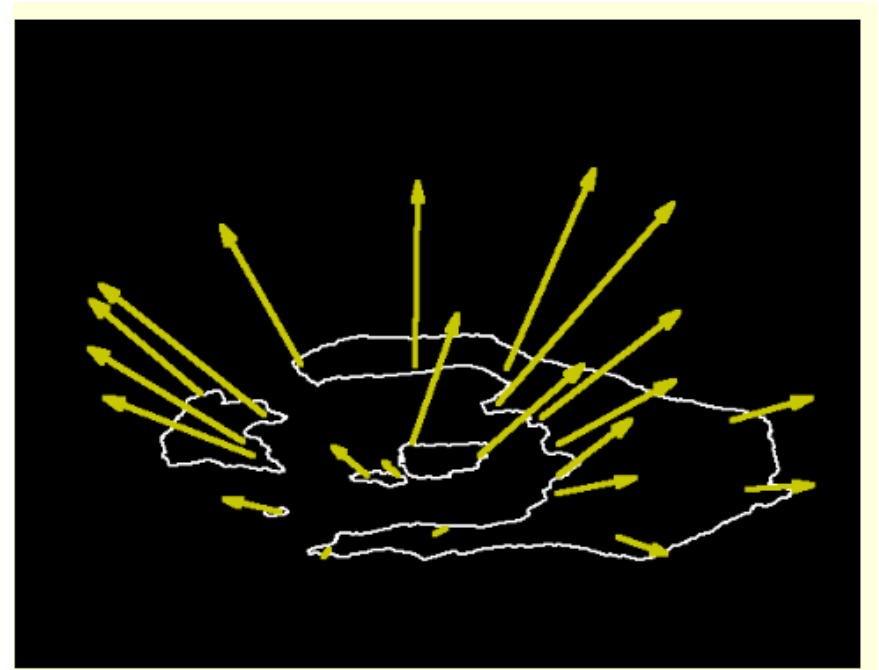
2. Deformation field in Greece

Deformations due to volcanic activity

The 2011-2012 Santorini volcano inflation
(overview)



Source: I. Papoutsis et al. 2013, GRL, Vol 40, 267-272



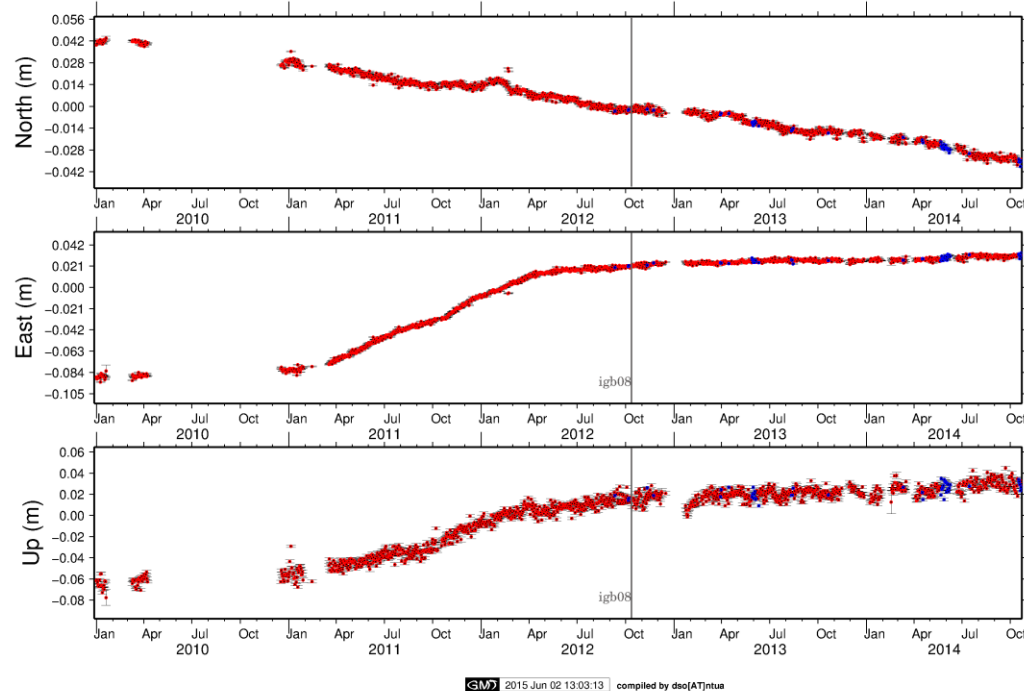
Source:
<http://geophysics.eas.gatech.edu/anewman/research/Santorini>

2. Deformation field in Greece

Deformations due to volcanic activity

The 2011-2012 Santorini volcano inflation
(Station Nomi)

cGPS station nomi

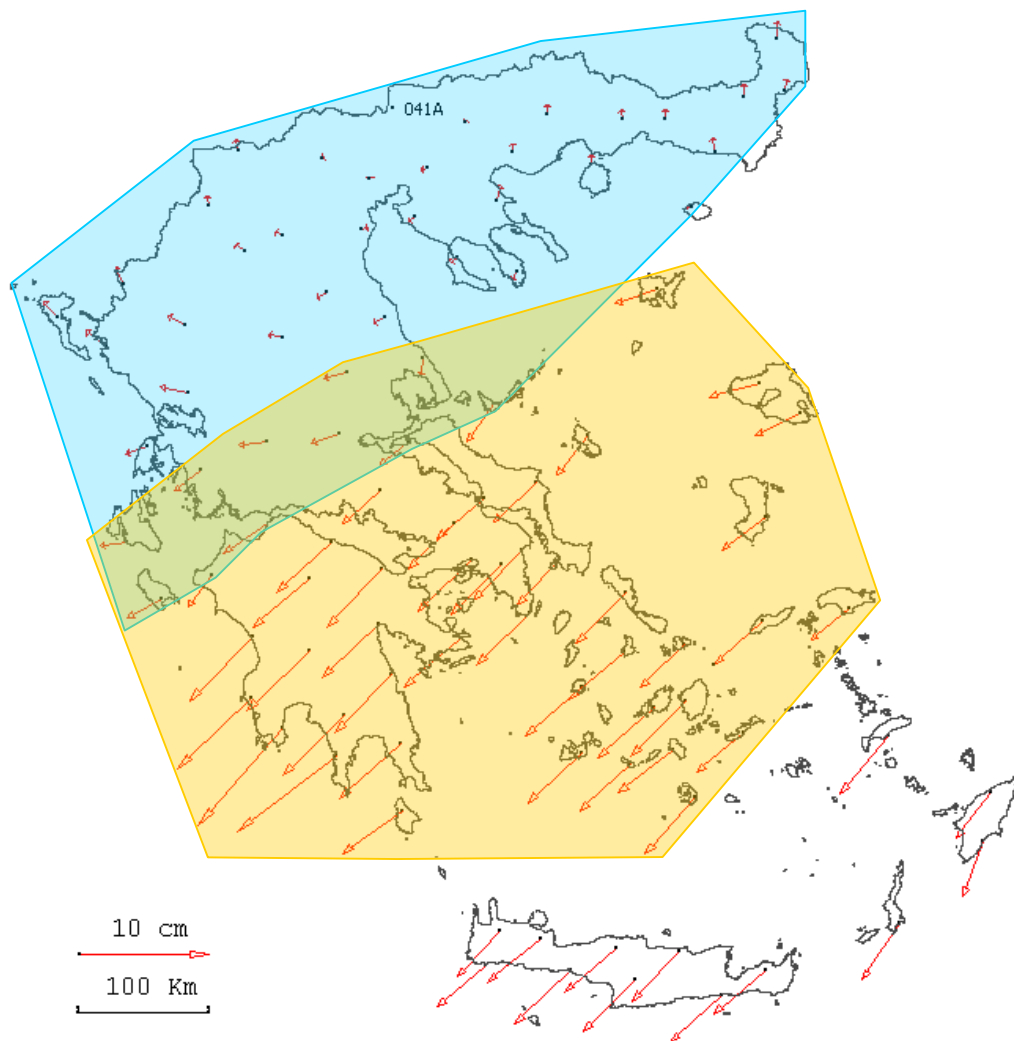


Source: <http://dionysos.survey.ntua.gr/>



3. Approach currently followed in HEPOS

The two sub-networks considered in HEPOS



Based on the tectonic characteristics of the stations, two sub-networks* (with an overlap zone) have been formed.

(Gianniou et al., 2013)

* Crete has always been treated as a separate network.



4. Discussion

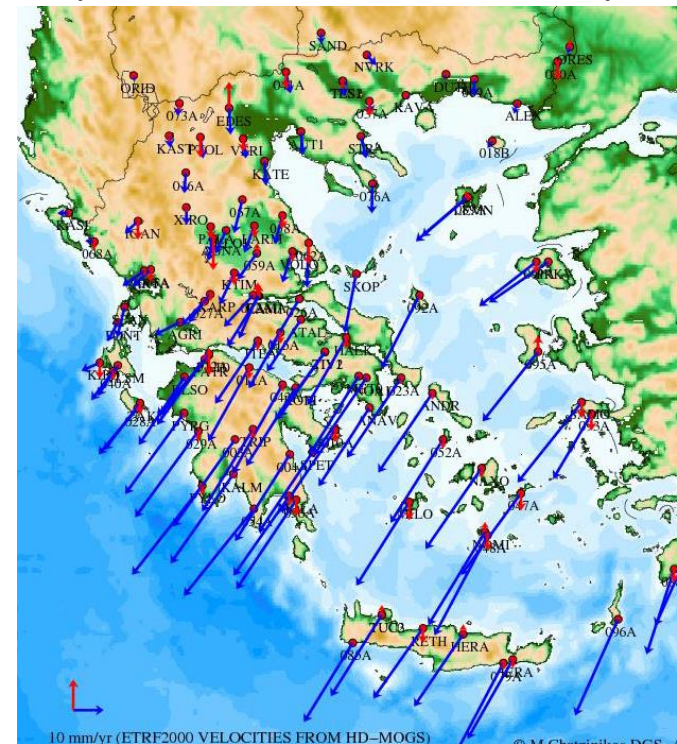
Choosing a reference frame

- Provided that the velocity field is homogeneous, a reference frame can always be defined to ensure practically zero-velocities.
- This is not possible in the case of inhomogeneous velocity field.

IGS08 Velocities
(Chatzinikos et al., EUREF 2013)



ETRF2000 Velocities
(Chatzinikos et al., EUREF 2013)





4. Discussion

Semi-dynamic datum

In a semi-dynamic datum coordinates remain fixed at a reference epoch.

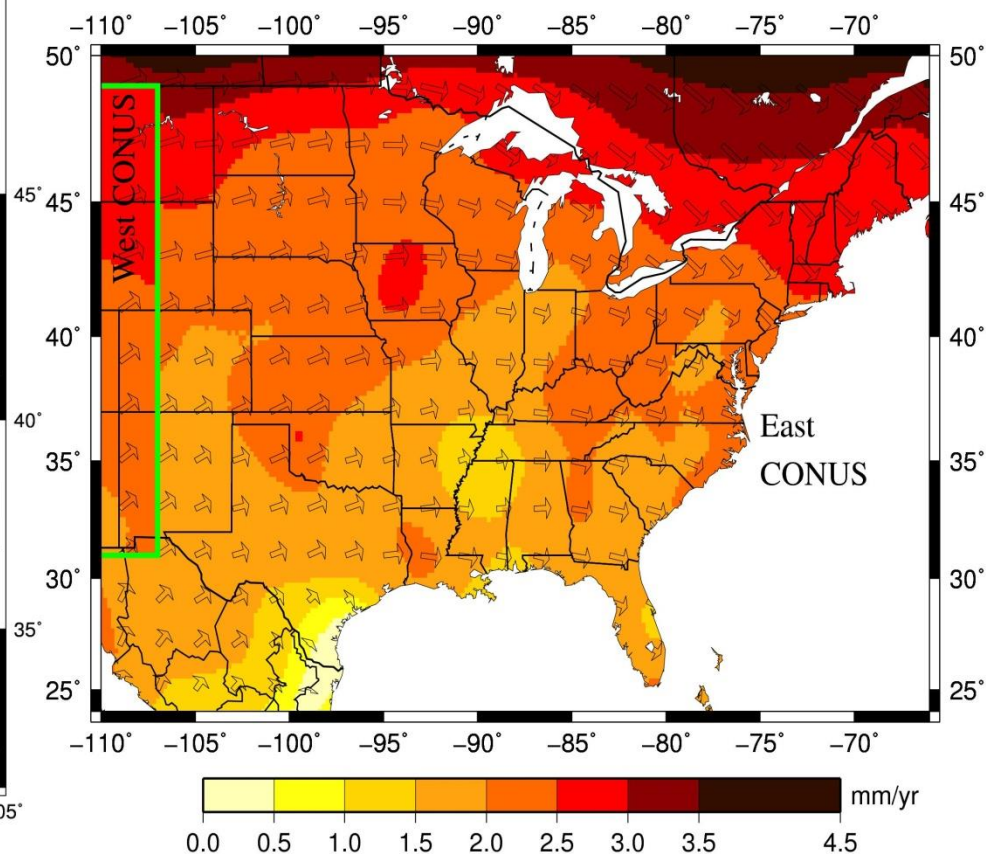
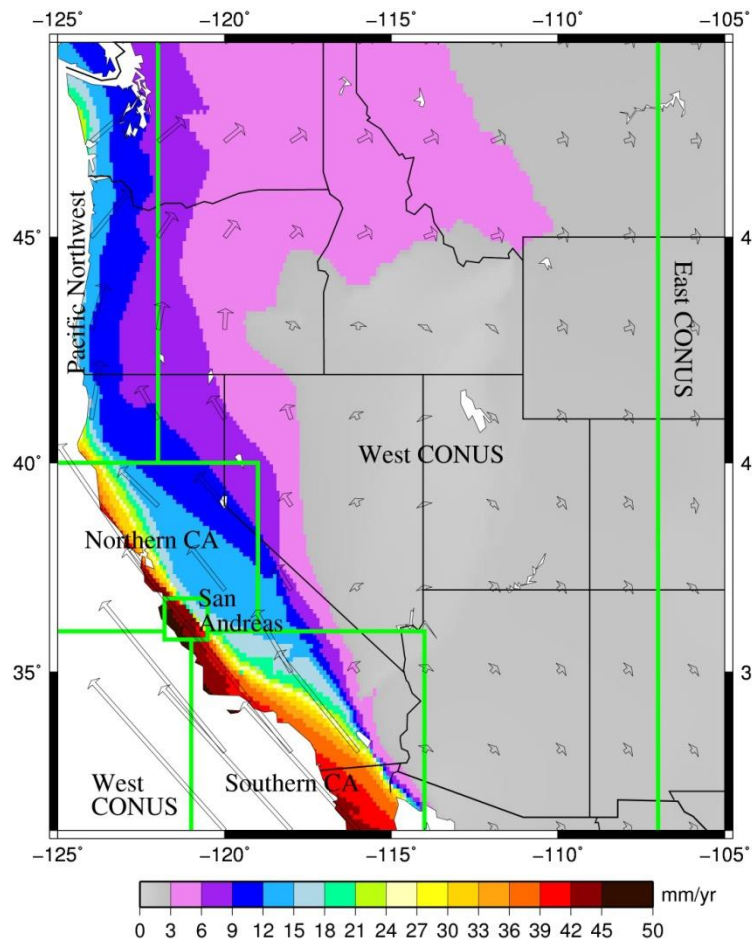
Coordinates computed at time of observations, are being 'transformed' (backdated) to the coordinates that would have been measured at the reference epoch.



4. Discussion

Examples of deformation areas

US - California





4. Discussion

Examples of deformation areas

US - California

HTDP (Horizontal Time Dependent Positioning) software

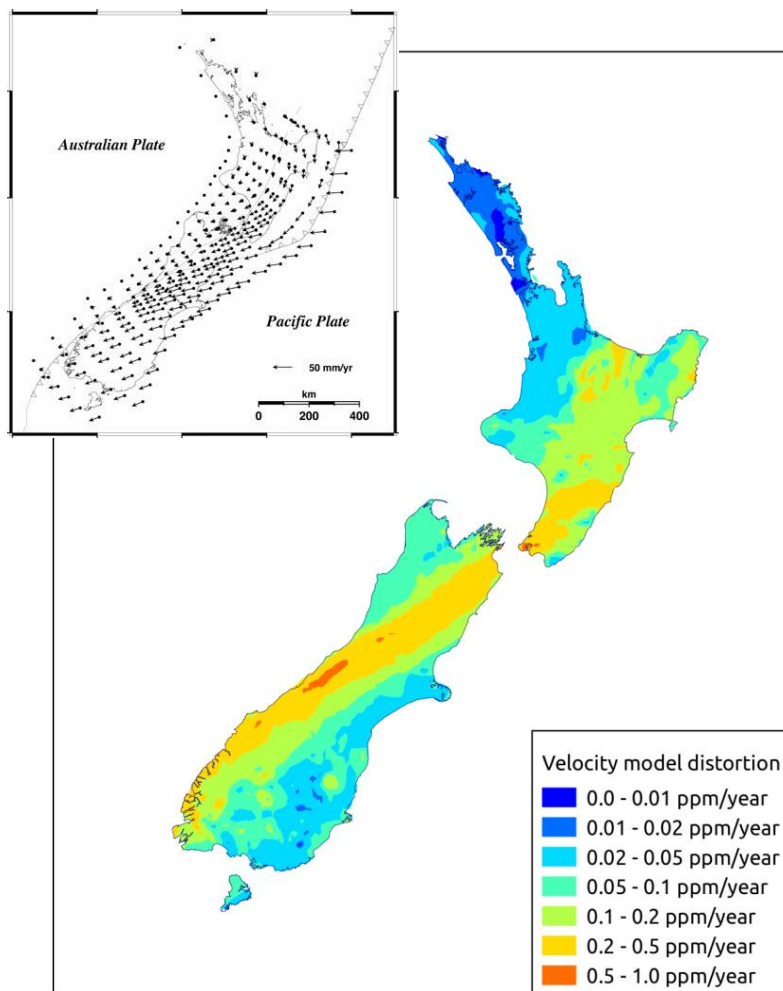
- Estimates horizontal crustal velocities
- Estimates crustal displacements from one date to another
- Updates (or backdate) positional coordinates from one date to another
- Transforms positional coordinates from one reference frame to another and/or from one date to another
- Transforms certain types of geodetic observations from one reference frame to another and/or from one date to another
- Transforms crustal velocities from one reference frame to another



4. Discussion

Examples of deformation areas

New Zealand



Introduction of NZDG2000

- ITRF96 based
- Reference epoch 2000.00
- Use of deformation model
 - Constant deformation
 - Localized patches for EQs



4. Discussion

Examples of deformation areas

New Zealand

Implications-Limitations

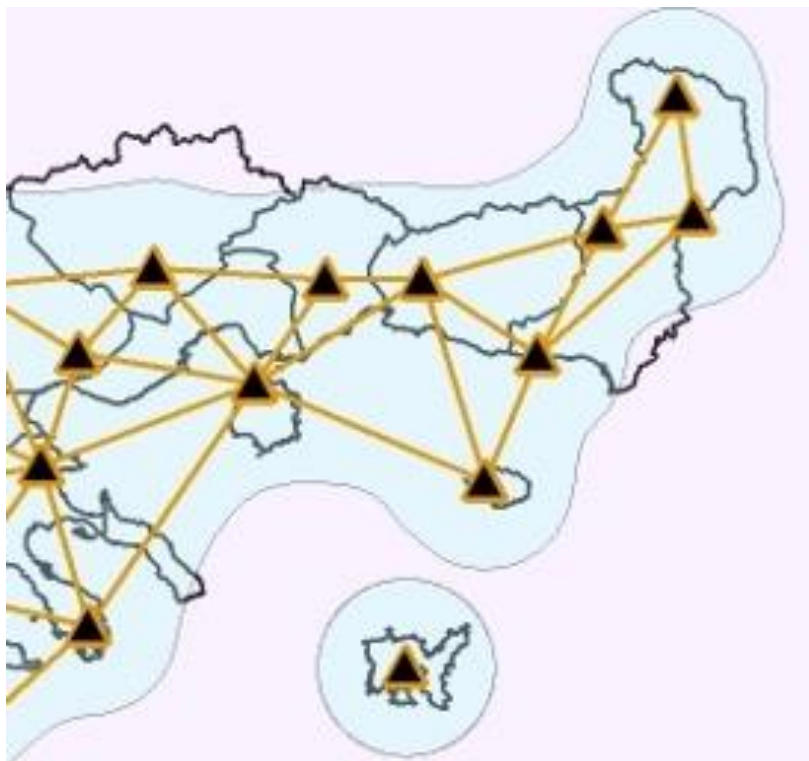
- complexity, annoyance ¹
- coordinates of CORS change ¹
- the deformation model becomes more complex as patches accumulate ¹
- successful use of the deformation model requires thorough understanding of its principles ¹
- incorporation of the deformation model in market software, is complicated especially due to the numerous patches.

(1) : Blick et al., IAG Symp. 2006



4. Discussion

Coordinate changes and Network-RTK



Network-based techniques (VRS, MAC, FKP) facilitate daily surveying.

However, these techniques presume consistent station coordinates, which was not necessary for the classical Single-Base approach.



4. Discussion

Concluding remarks

- The maintenance and realization of a reference frame in regions of active, complex deformations (constant term plus earthquakes) is particularly demanding.
- The approach currently used in HEPOS cope to a large extend with the problem of different velocities between the northern and southern part of the country, but cannot face localized deformation.
- Local deformations due to EQs, volcanic activity etc. should be considered, taking into account the national and international experience (US, New Zealand etc.) .
- The 2014 EQs of Cephalonia and Samothrace can be used as pilot studies.

Acknowledgments



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