Introduction to 3D Reference Frames

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Introduction

- ITRS
- ITRF
- Observing techniques of space geodesy
- Regional reference frames
- Local reference frames

International Terrestrial Reference System (ITRS)

- An internationally-agreed set of prescriptions and conventions to define a Conventional Terrestrial Reference System
- Realised through creating a reference frame – ITRF
- Connected to International Celestial Reference System (ICRS) via Earth Orientation Parameters (EOP)

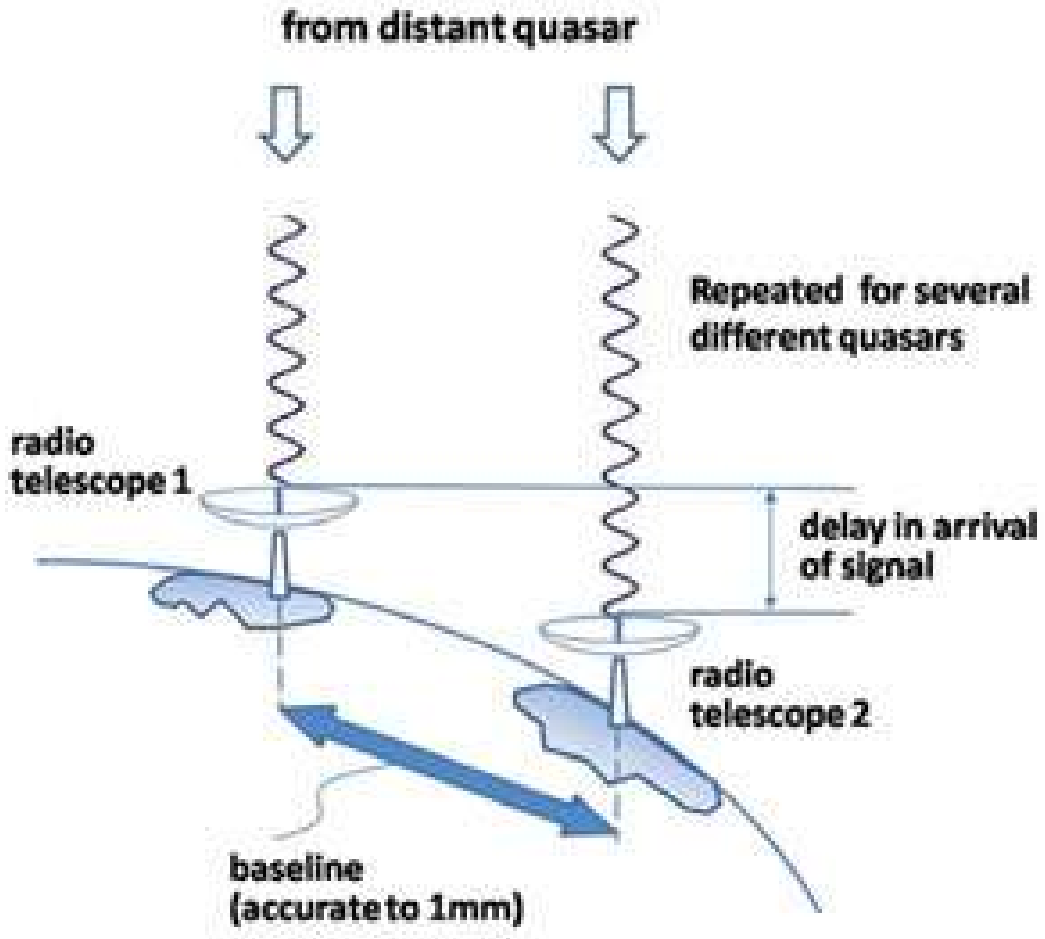
International Terrestrial Reference System (ITRS)

- An ITRS meets the following conditions:
  - Geocentric (origin is Earth centre of mass)
  - Uses the metre as the unit of length
  - Initial orientation given by BIH orientation at 1984
  - The time evolution of the orientation is ensured by using a no-net-rotation condition with regards to horizontal tectonic motions over the whole earth.
- The ITRS is of very little use to the practitioner – we need a realisation (some coordinates)

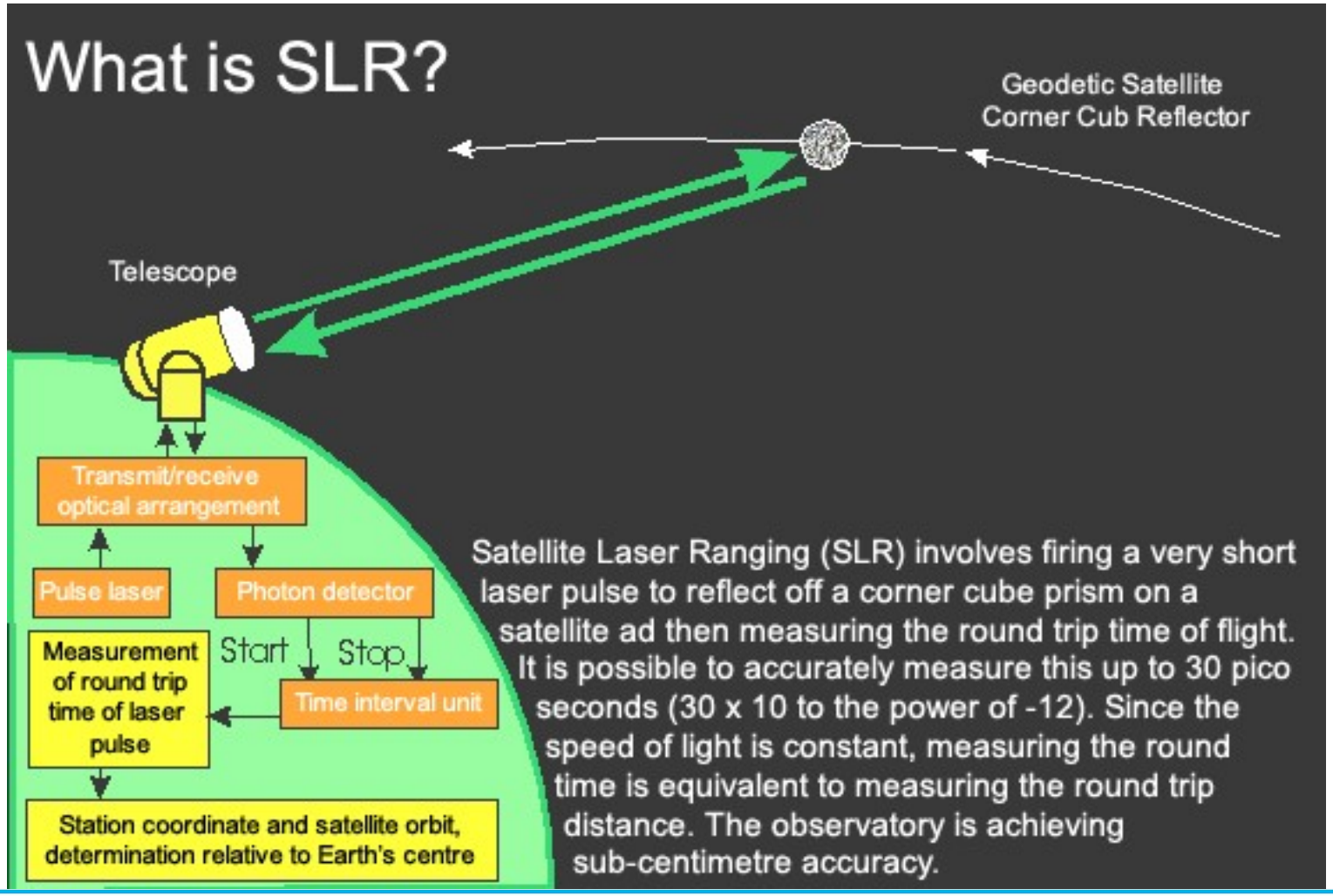
International Terrestrial Reference Frame (ITRF)

- Follows the conventions set out for the ITRS
- Is re-realised every few years (ITRF89, ITRF90, ITRF91, ITRF92, ITRF93, ITRF94, ITRF95, ITRF96, ITRF97, ITRF2000, ITRF2005, ITRF2008, ITRF2014)
- Provides a set of coordinates and velocities for several hundred stations worldwide
- Uses a geocentric coordinate system (XYZ)
- Data from four space geodesy observing systems
- Most recent is ITRF2014

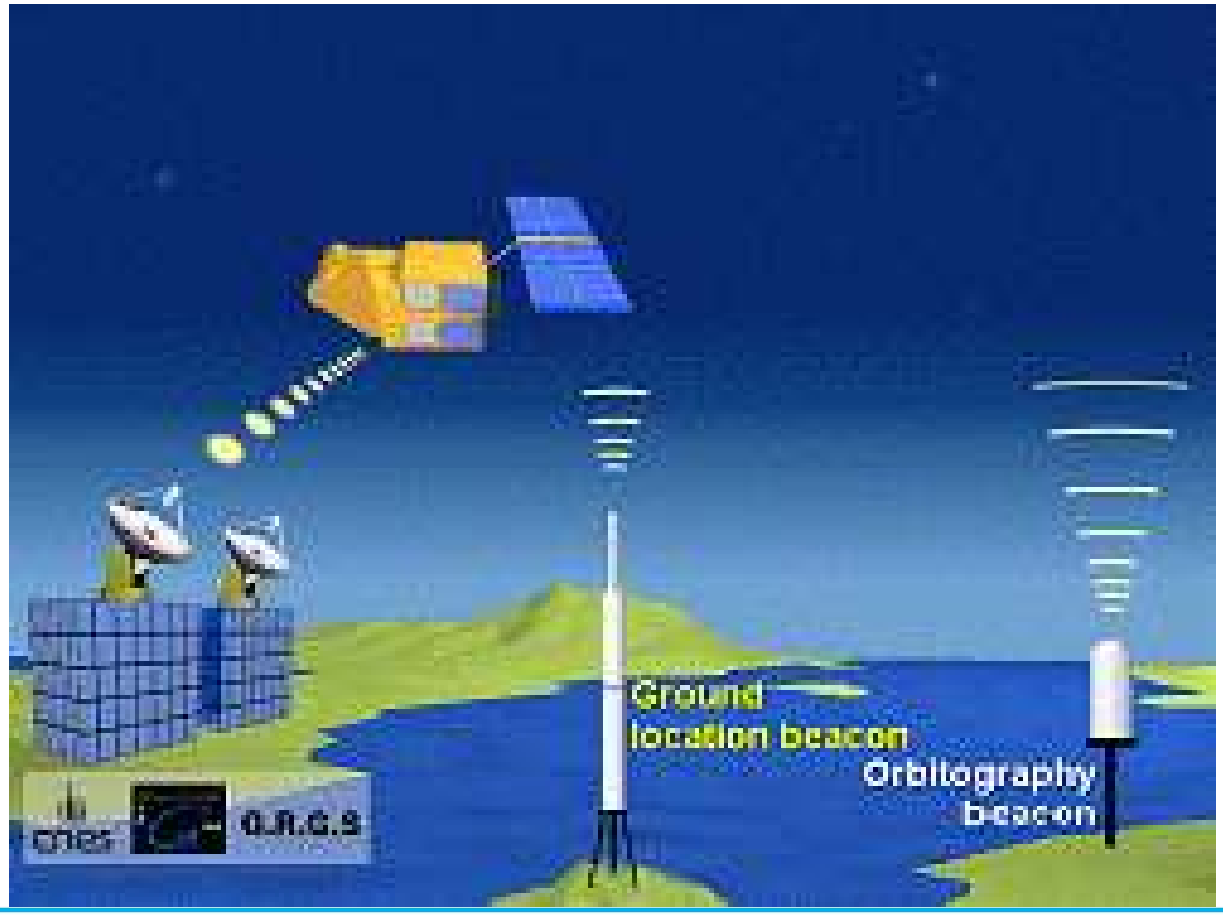
Very Long Baseline Interferometry (VLBI)



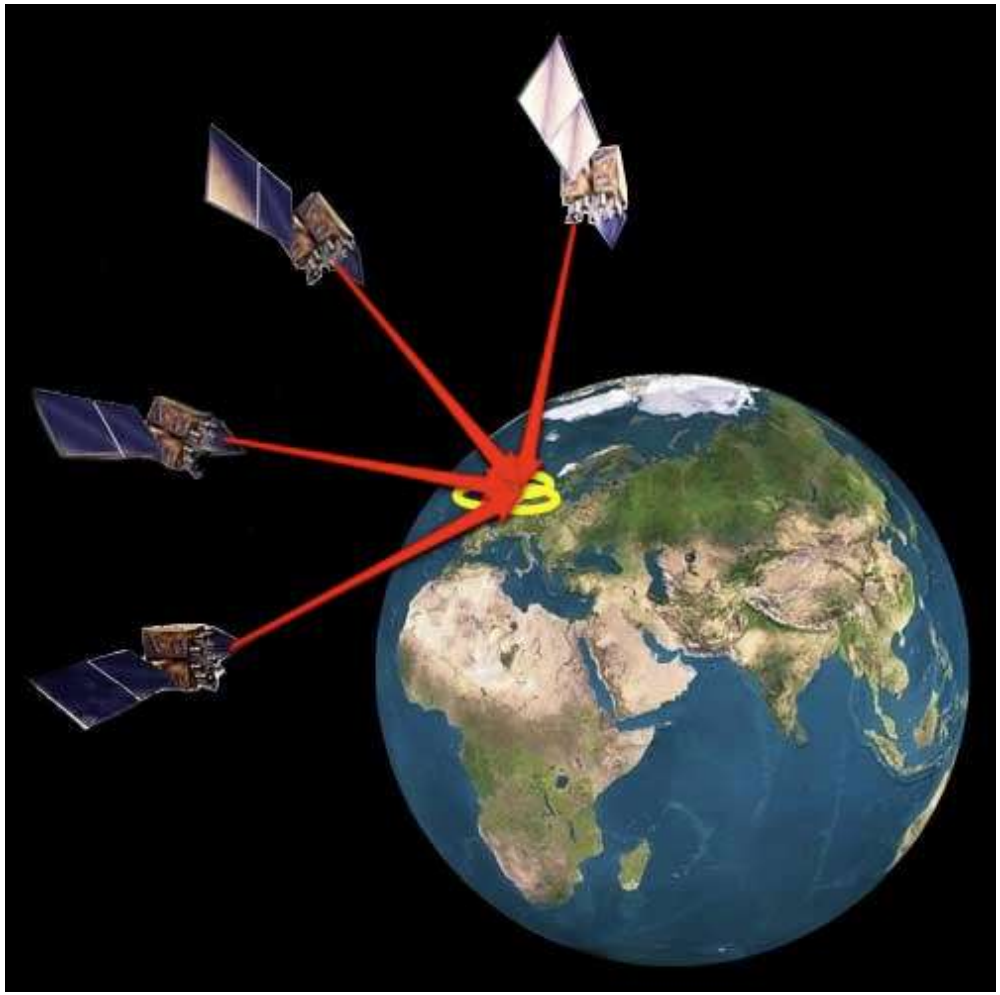
Satellite Laser Ranging (SLR)



Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)



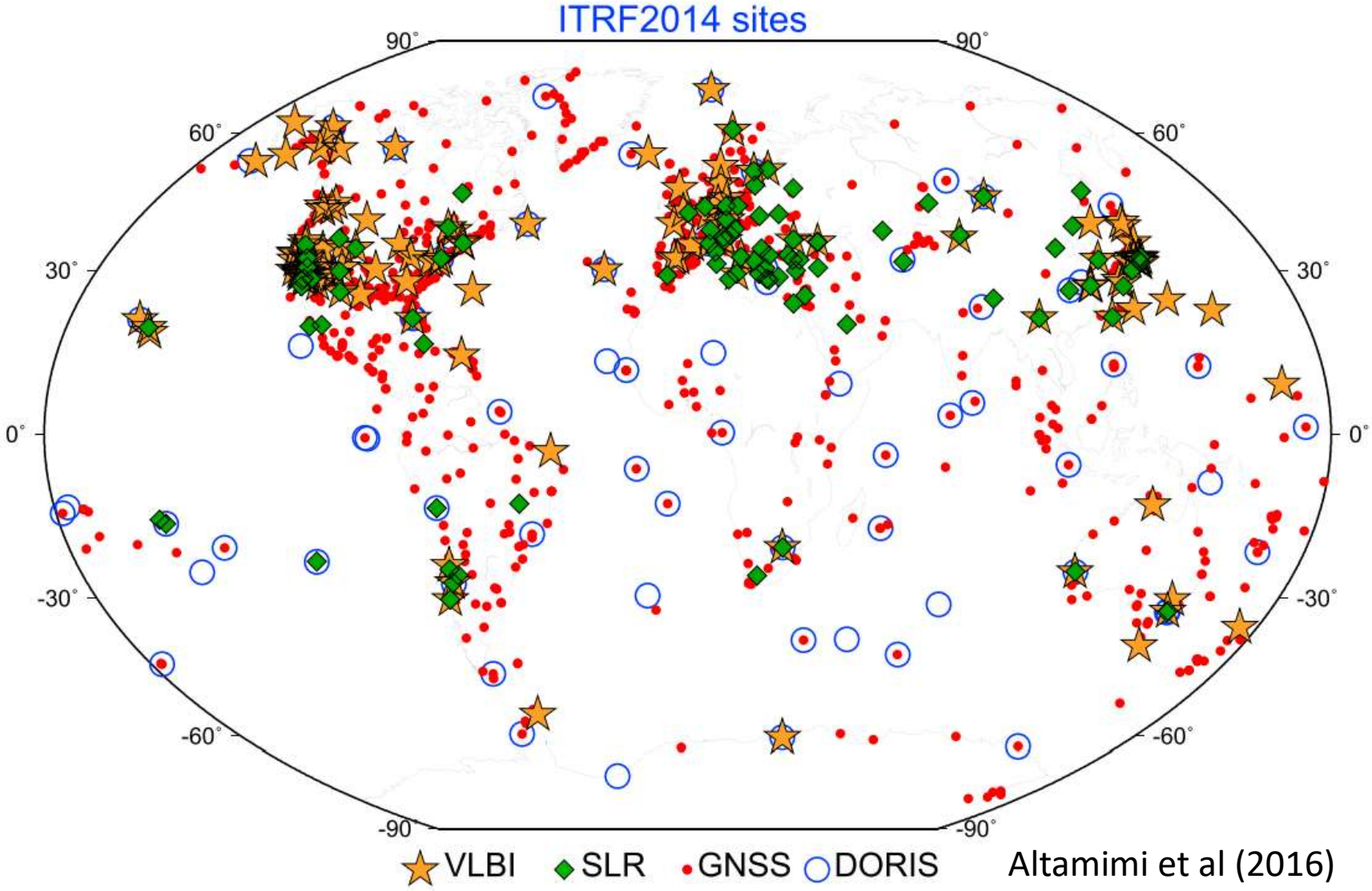
Global Navigation Satellite Systems (GNSS)



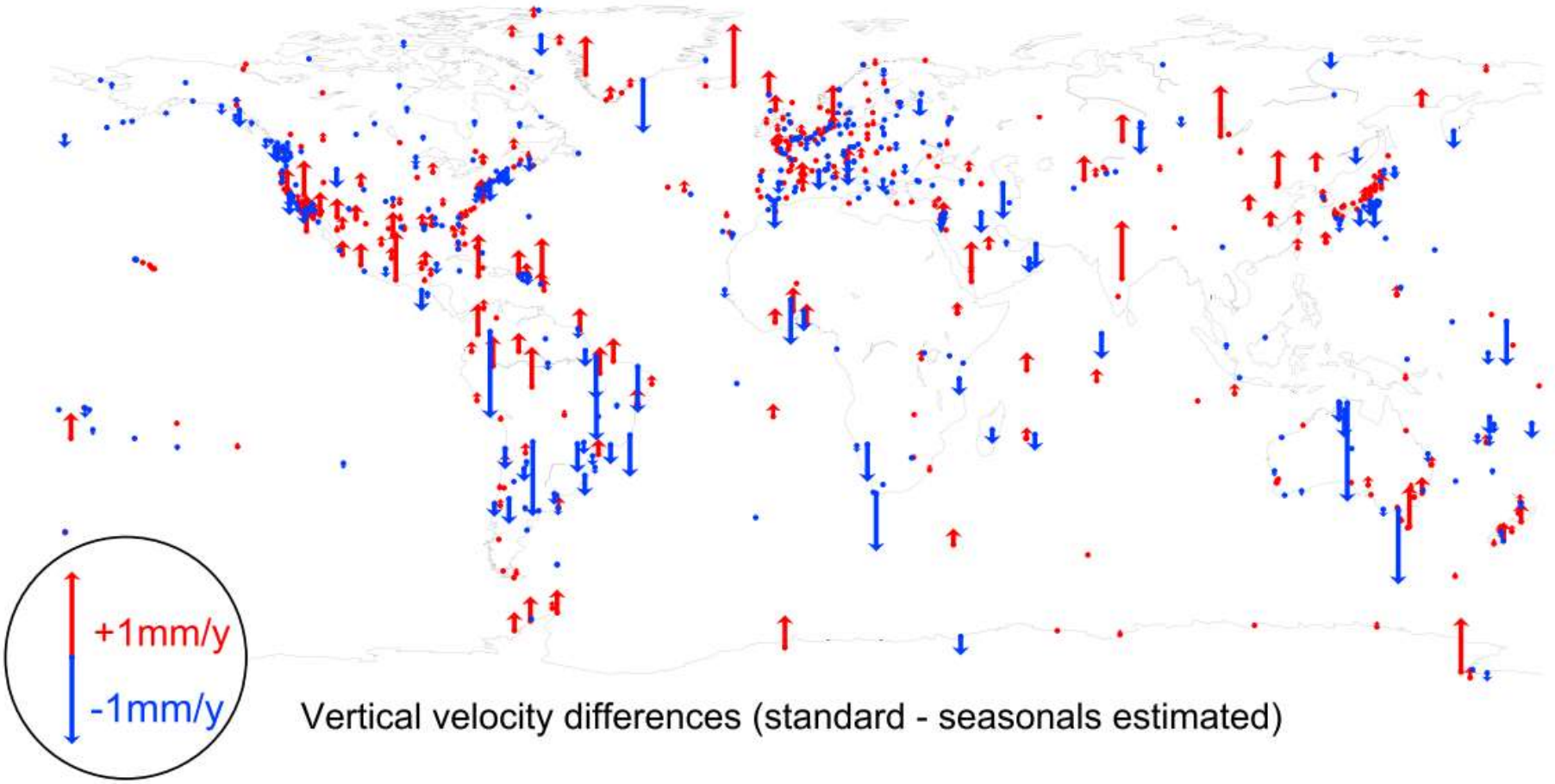
Global Navigation Satellite Systems (GNSS)

ITRF2014

- Based on all 4 space geodesy techniques
- Observations from 1980.0 to 2015.1 (but only a few stations have observations over the entire period)
- Accounts for annual and semi-annual signals
- Includes post-seismic deformation models for sites affected by significant earthquakes
- Products include coordinates, velocities and transformation parameters



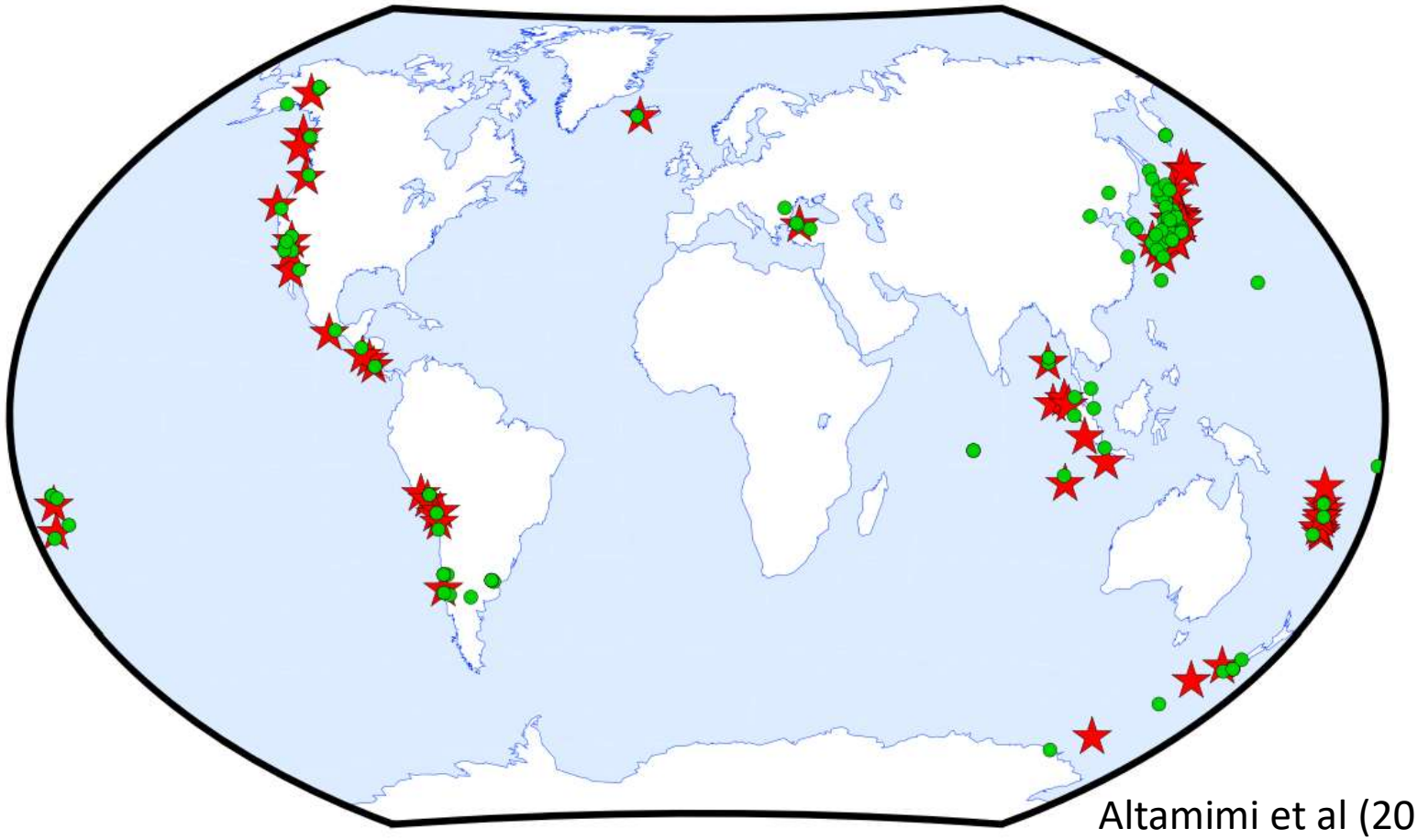
Altamimi et al (2016)



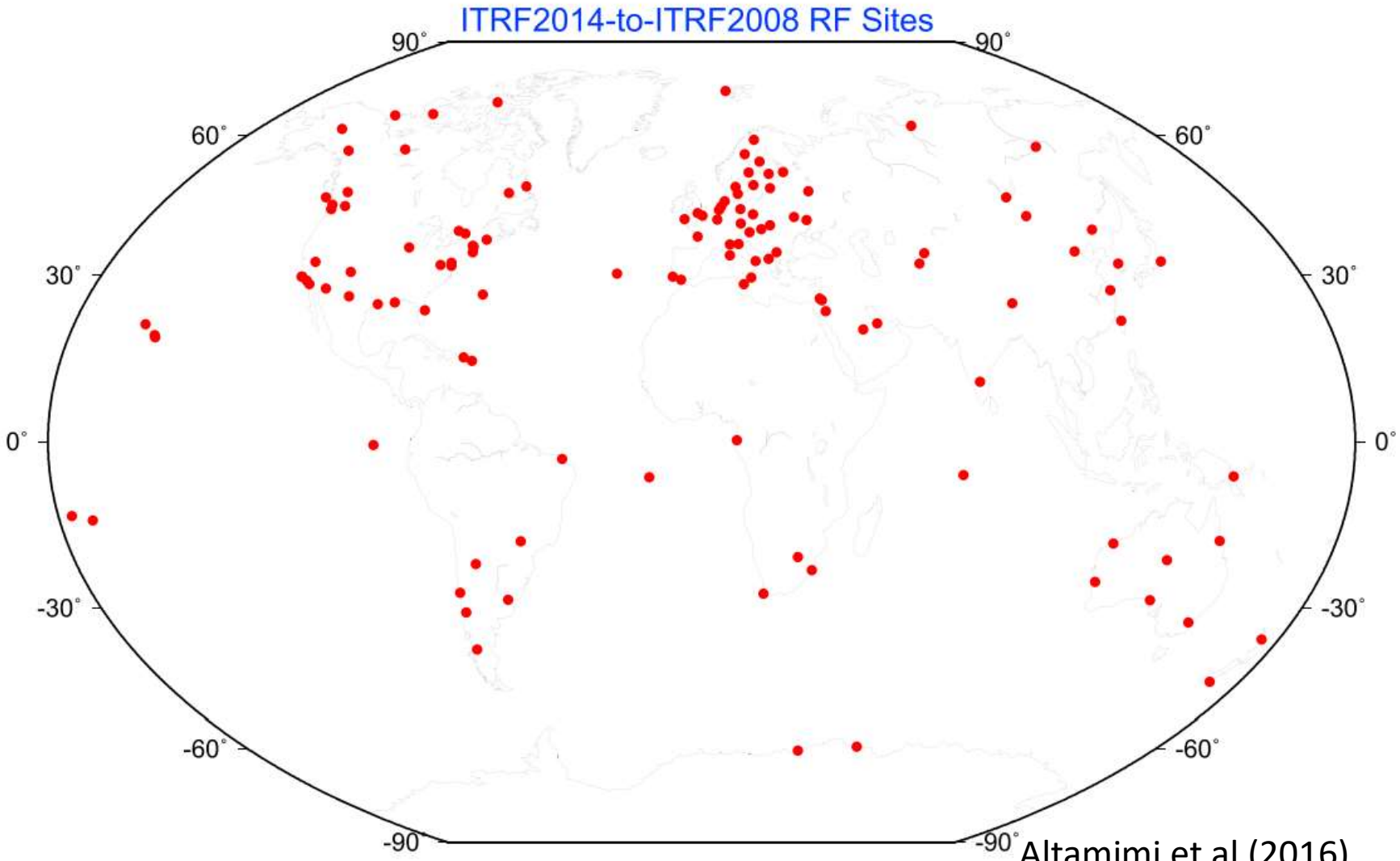
Vertical velocity differences (standard - seasonals estimated)

Altamimi et al (2016)

Post-seismic Deformation Sites



Altamimi et al (2016)



Altamimi et al (2016)

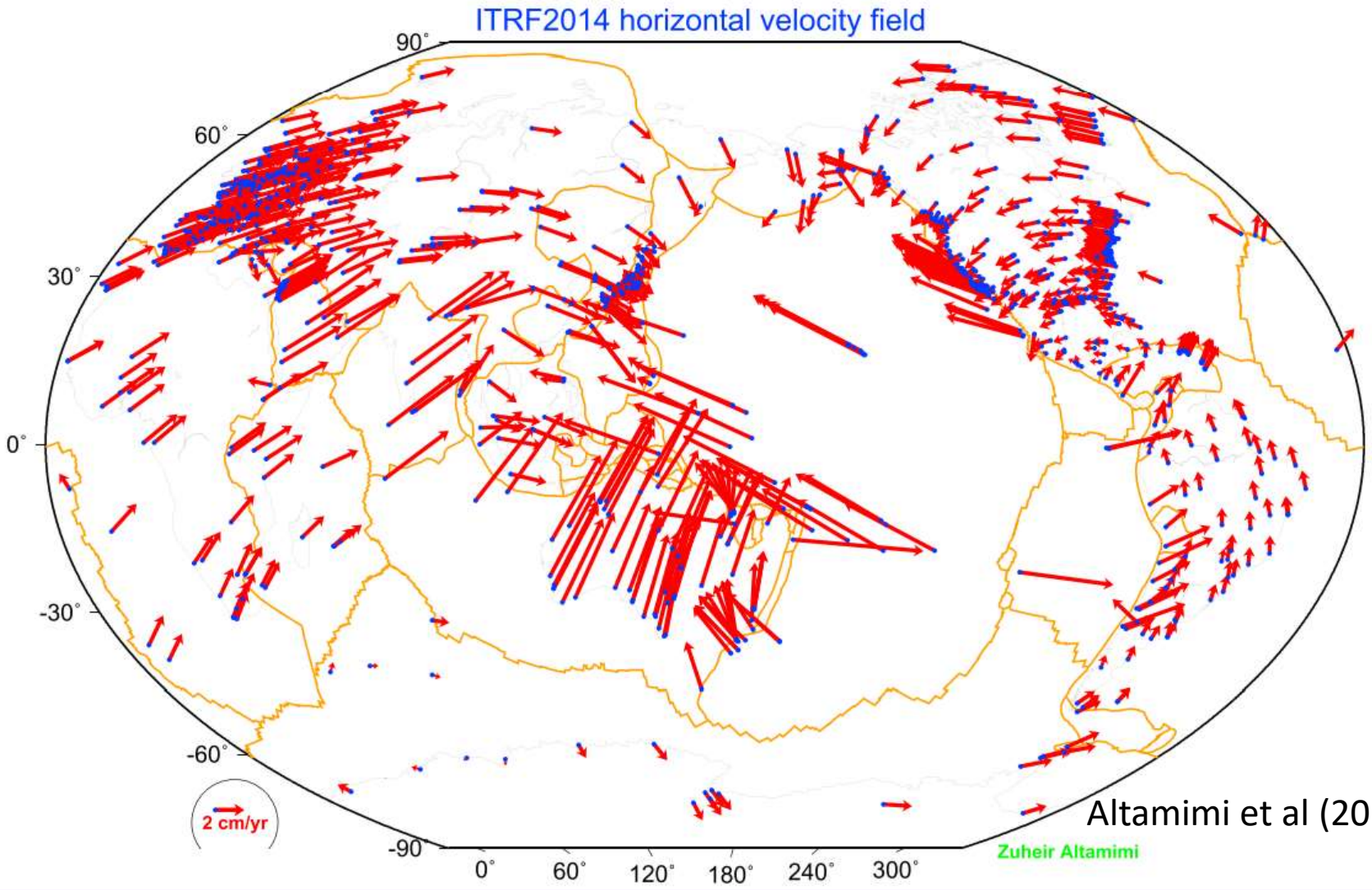
ITRF2014 to ITRF2008

Altamimi et al (2016)

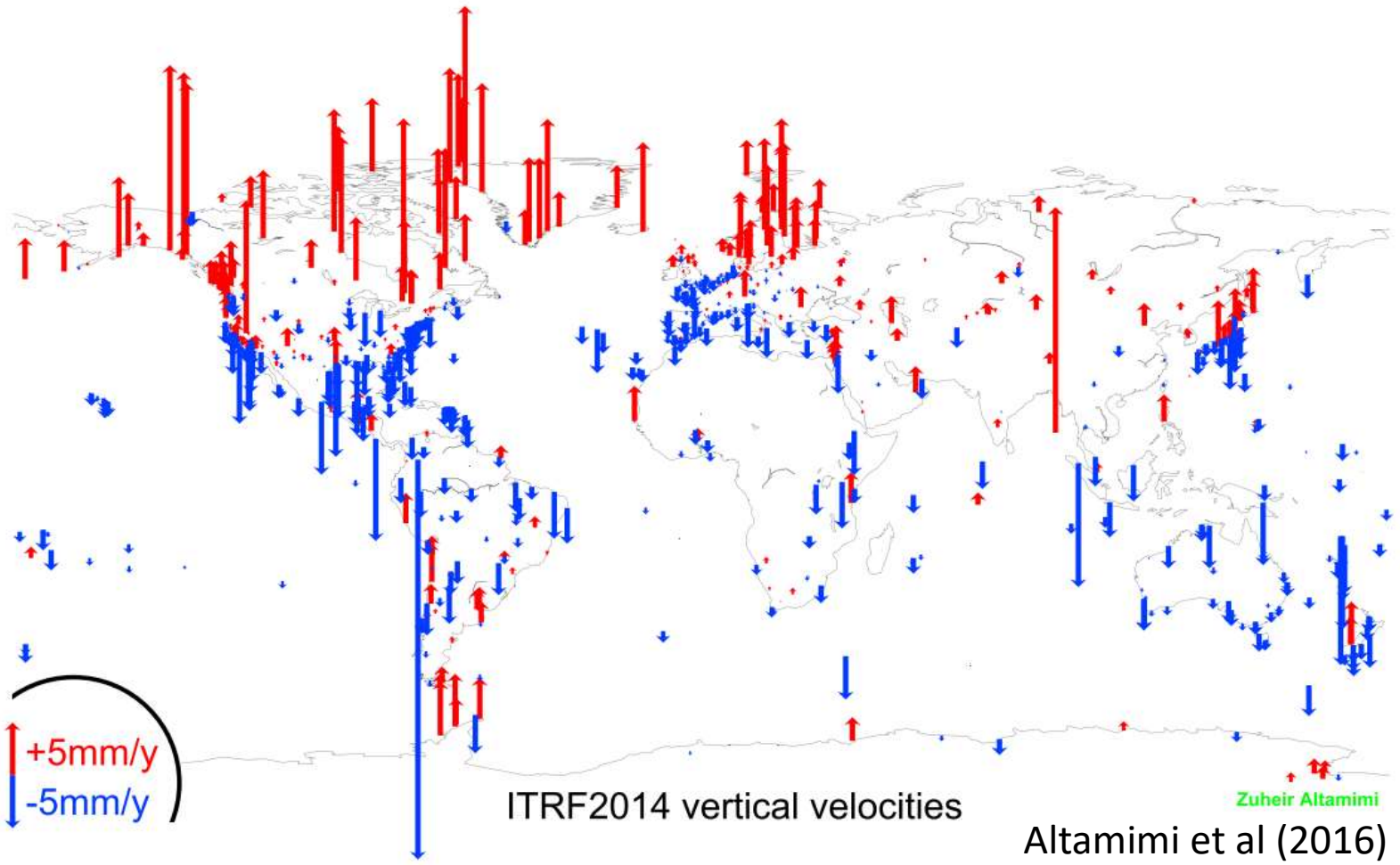
$$\begin{cases} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i08} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + T + D \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + R \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} \\ \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix}_{i08} = \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix}_{i14} + \dot{T} + \dot{D} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + \dot{R} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} \end{cases} \quad (4)$$

Table 4. Transformation Parameters at Epoch 2010.0 and Their Rates From ITRF2014 to ITRF2008, to Be Used With Equation (4)

	T_x (mm) $\dot{T}_x$ (mm/yr)	T_y (mm) $\dot{T}_y$ (mm/yr)	T_z (mm) $\dot{T}_z$ (mm/yr)	D (ppb) $\dot{D}$ (ppb/yr)	R_x (mas) $\dot{R}_x$ (mas/yr)	R_y (mas) $\dot{R}_y$ (mas/yr)	R_z (mas) $\dot{R}_z$ (mas/yr)
	1.6	1.9	2.4	−0.02	0.00	0.00	0.00
±	0.2	0.1	0.1	0.02	0.06	0.06	0.06
	0.0	0.0	−0.1	0.03	0.00	0.00	0.00
±	0.2	0.1	0.1	0.02	0.06	0.06	0.06



Altamimi et al (2016)

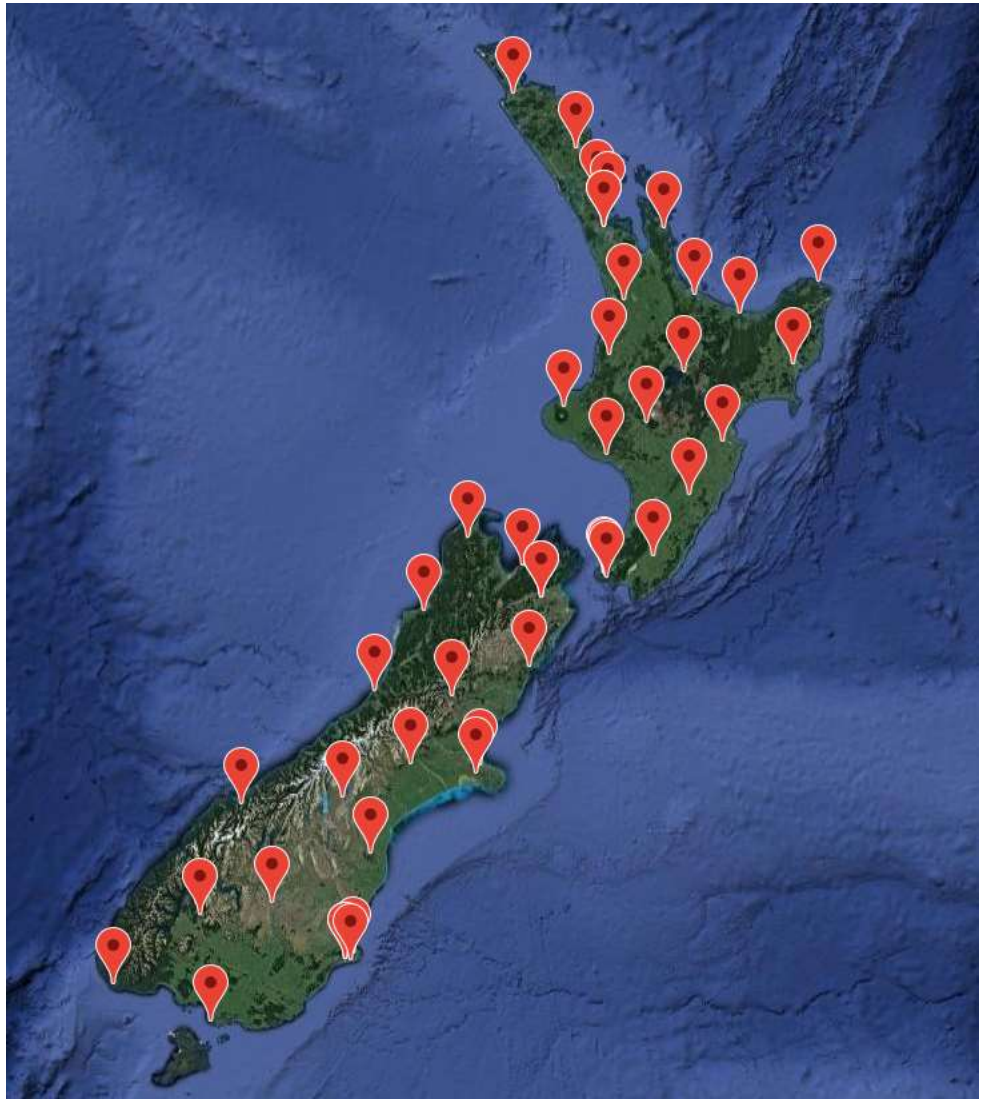


Altamimi et al (2016)

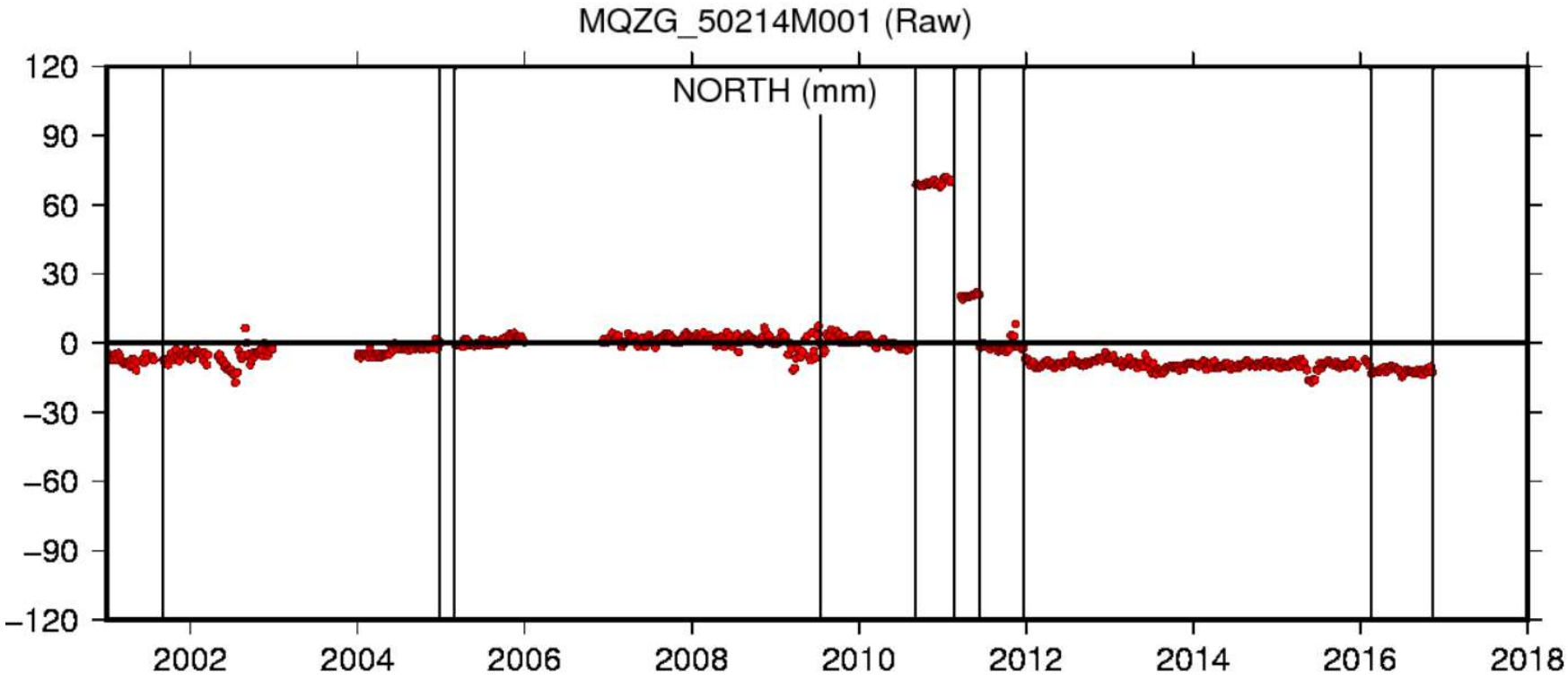
Regional Reference Frames

- Cover large regions of the globe
- Greater densification of stations
- Easier (but slightly indirect) link to the ITRF
- Consists solely of GNSS stations (including ITRF GNSS stations)
- Coordinates, velocities and time series plots produced
- Africa – AFREF
- Asia-Pacific – APREF
- Europe – EUREF
- North and South America - SIRGAS

APREF Example: Stations



APREF Example: Time Series



Local Reference Frames

- Aim is to provide accurate spatial references
- Typically cover an entire country
- Traditionally defined using astronomy
- Modern frames defined through alignment to one of the ITRFs
- Reference Frame vs Datum
- Static vs dynamic/kinematic
- Semi-dynamic

Reference

Open access journal article:

- Altamimi, Z., P. Rebischung, L. Métivier, and X. Collilieux (2016), ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, *J. Geophys. Res. Solid Earth*, 121, 6109–6131, doi: 10.1002/2016JB013098.