

# *Science Overview*

*2021 Virtual TOW Meeting*

*Karine Le Bail*

*Onsala Space Observatory*

*Chalmers University of Technology*



# *Science Overview*

*2021 Virtual TOW Meeting*

*Karine Le Bail*

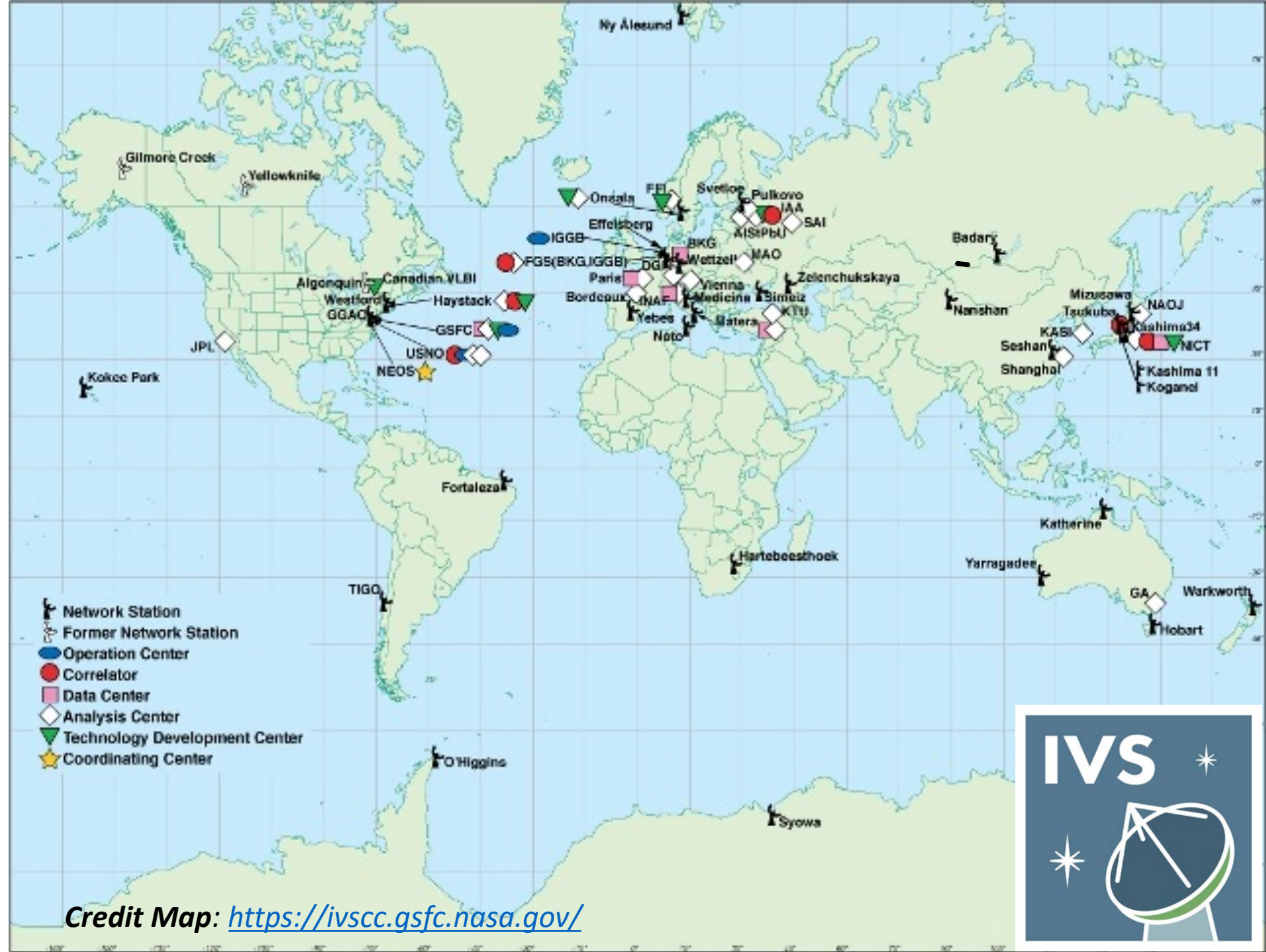
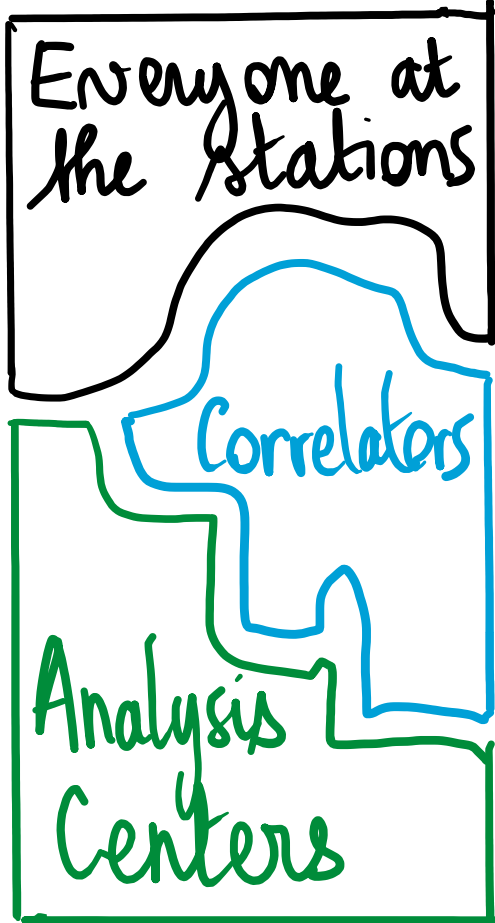
*Onsala Space Observatory*

*Chalmers University of Technology*

*Credit Video:* Onsala Space Observatory  
Roger Hammargren

**CHALMERS**

# The actors of the IVS



Credit Map: <https://ivsc.gsfc.nasa.gov/>



# *IVS products*

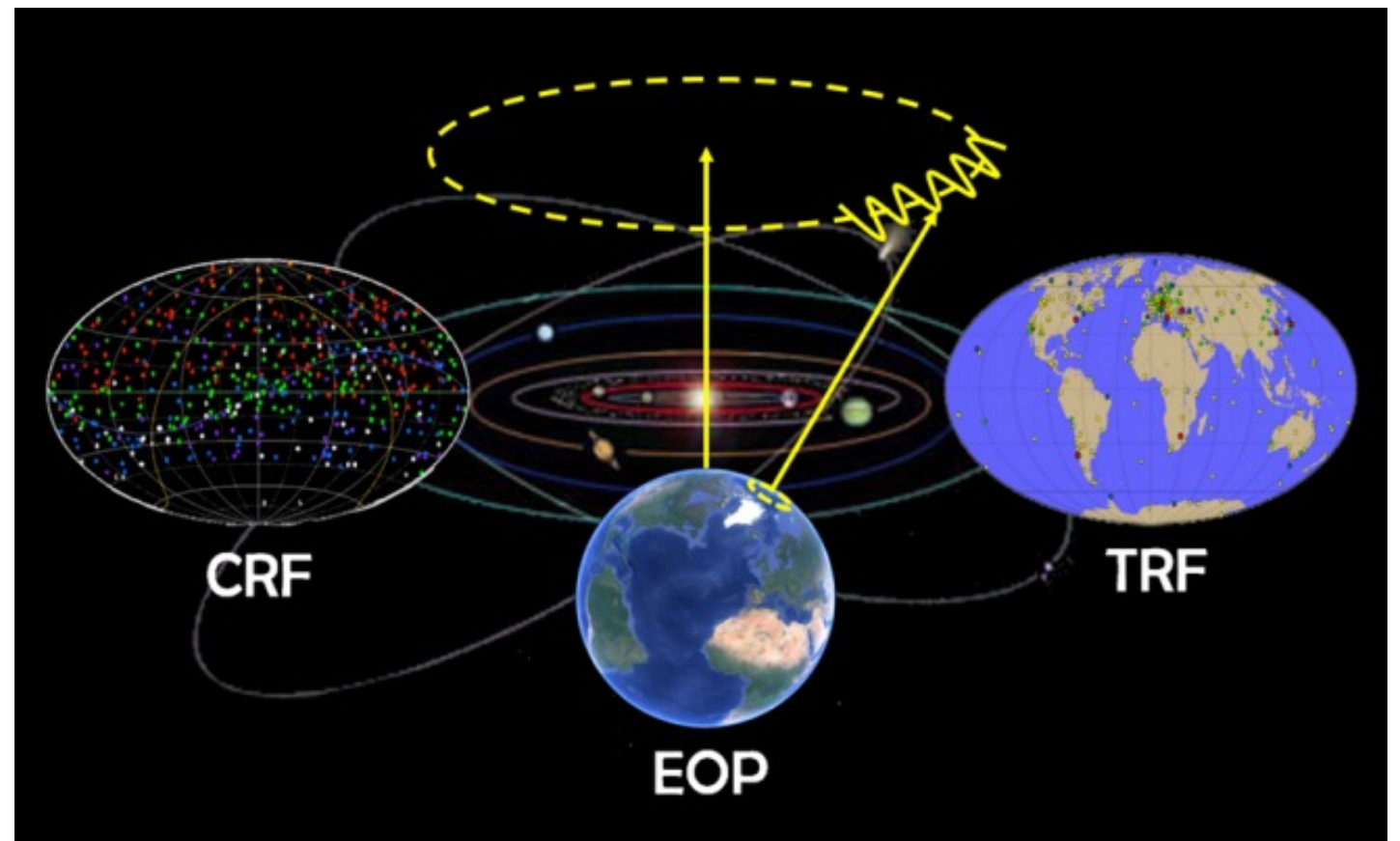
Terrestrial Reference Frame

Celestial Reference Frame

Earth Orientation Parameters



*International Earth Rotation and  
Reference Systems Service*



*Soja, 2019 IUGG General Assembly*

3849 3849803000 0939841123890 347834619  
2788 28171878 5726531486937  
7-267227678264238  
376482233793248

# *IVS products*

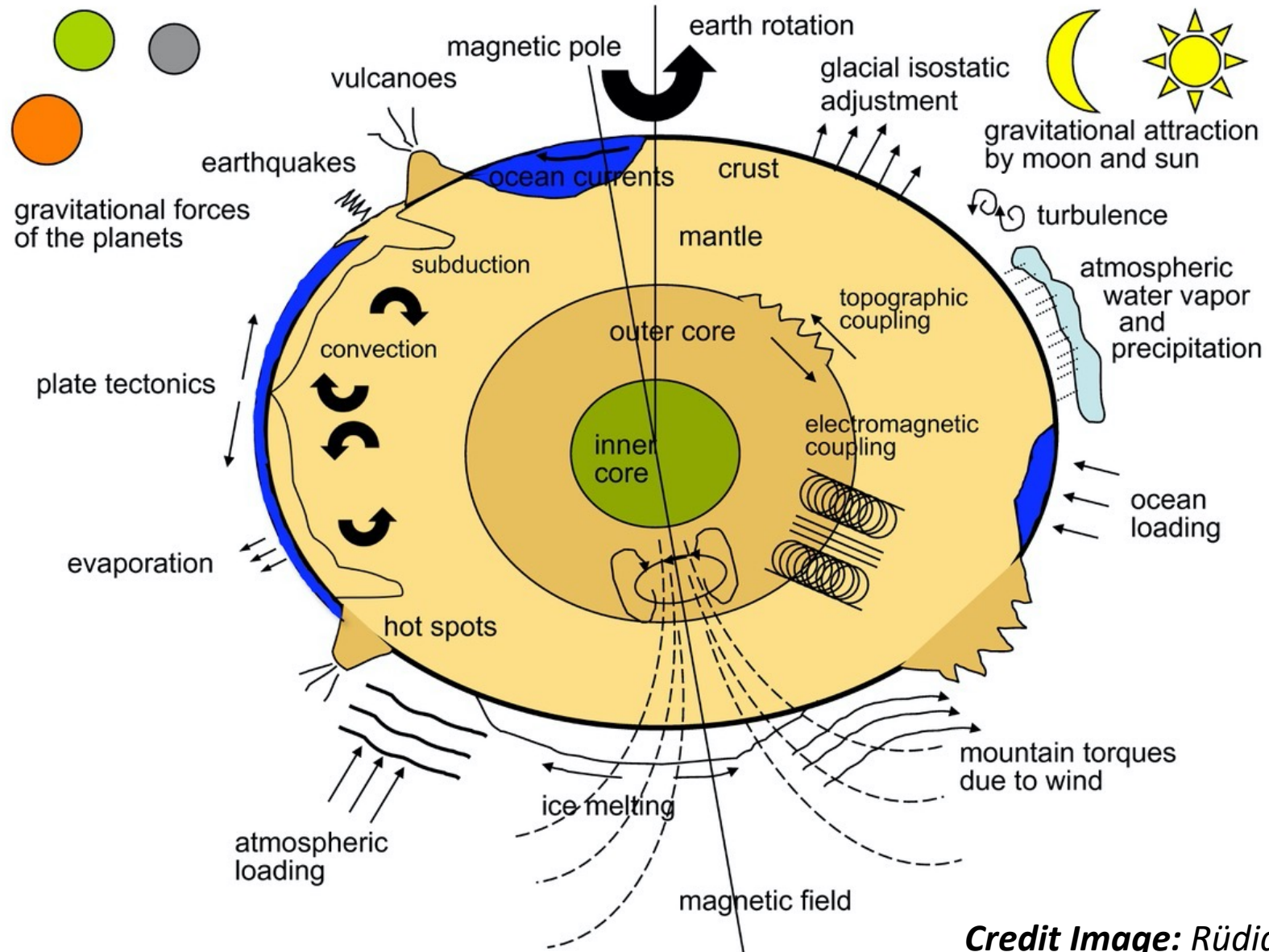
Terrestrial Reference Frame *IVS-T2, RDV*

Celestial Reference Frame

Earth Orientation Parameters

# Terrestrial Reference Frame

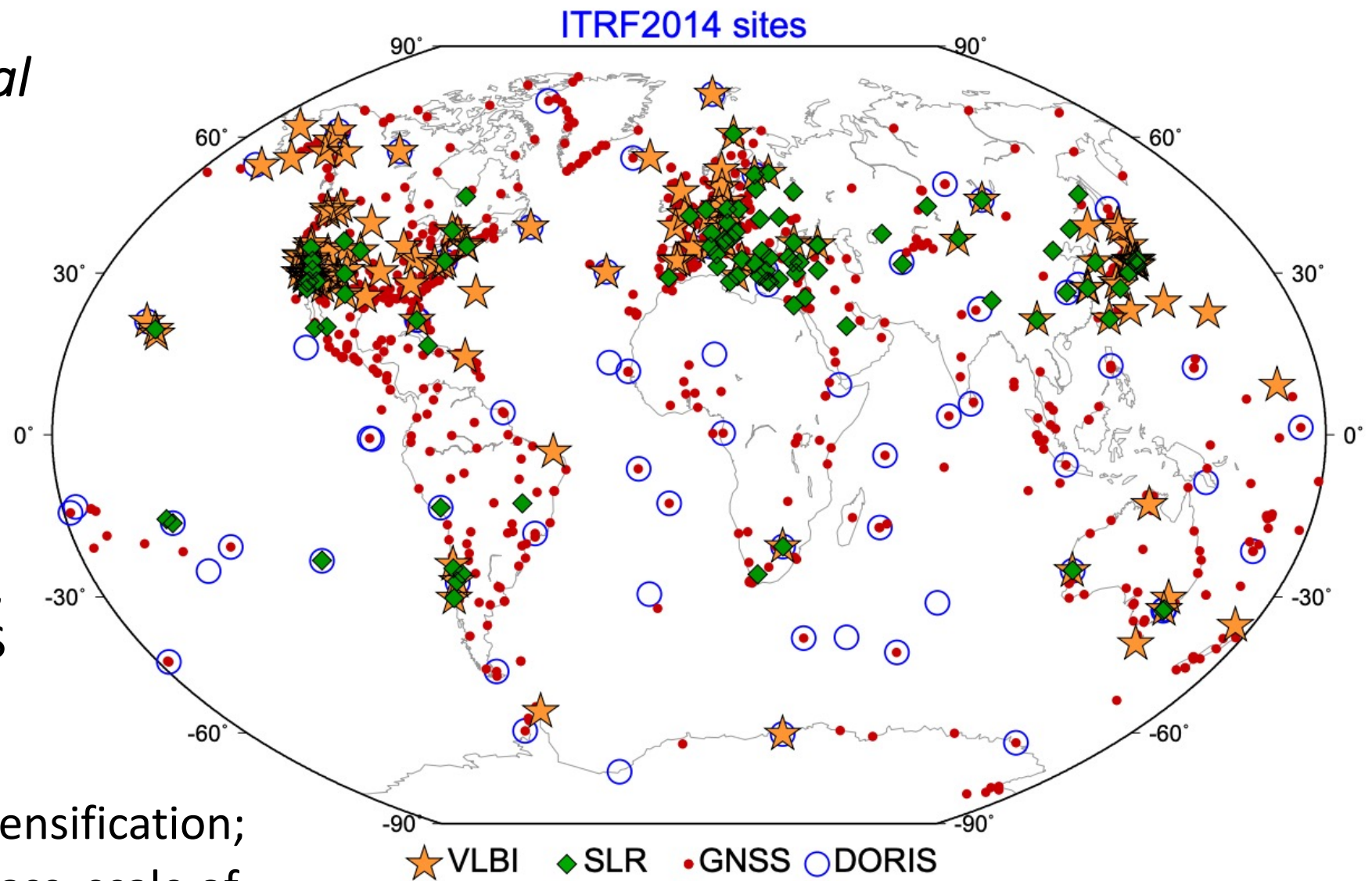
## Factors that affect Earth's shape



*Credit Image: Rüdiger Haas*

# International Terrestrial Reference Frame ITRF2014

- Positions and velocities **1499** stations located at **975** sites (**158** VLBI sites **204** VLBI stations)
- Contributions from VLBI, GPS, SLR/LLR, and DORIS
  - **VLBI: scale of TRF, nutation, UT1-UTC;**
  - GPS: polar motion, densification;
  - SLR/LLR: center of mass, scale of TRF;
  - DORIS: global coverage.

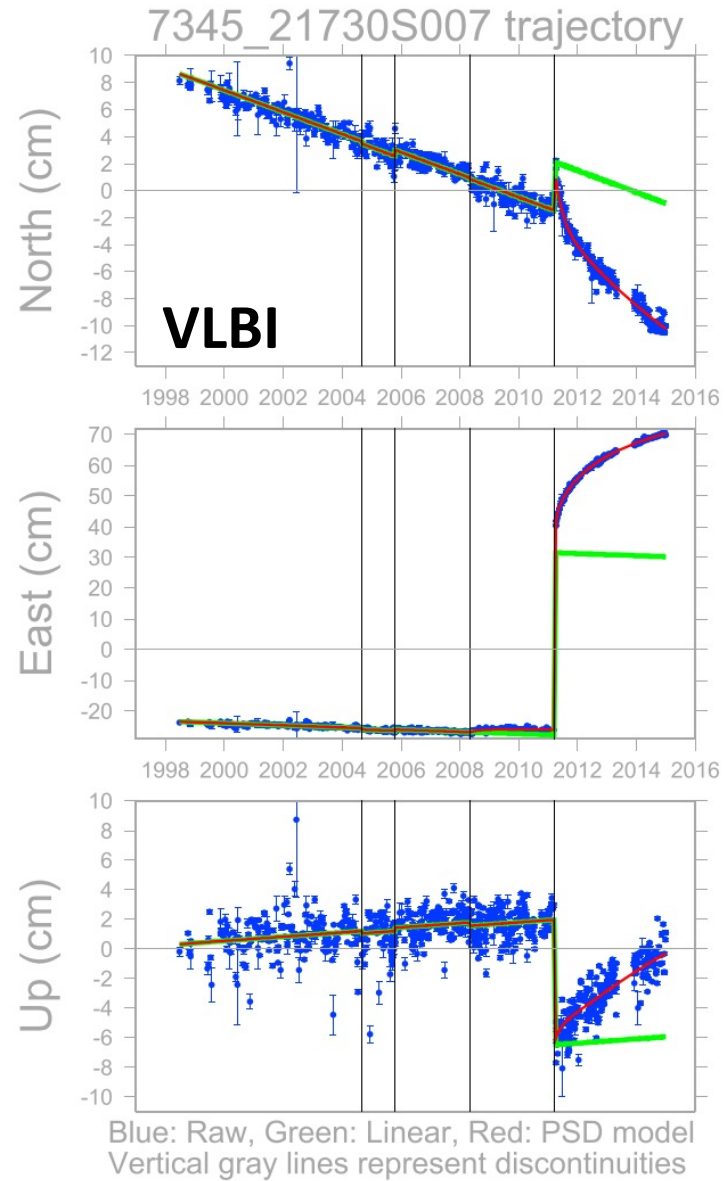
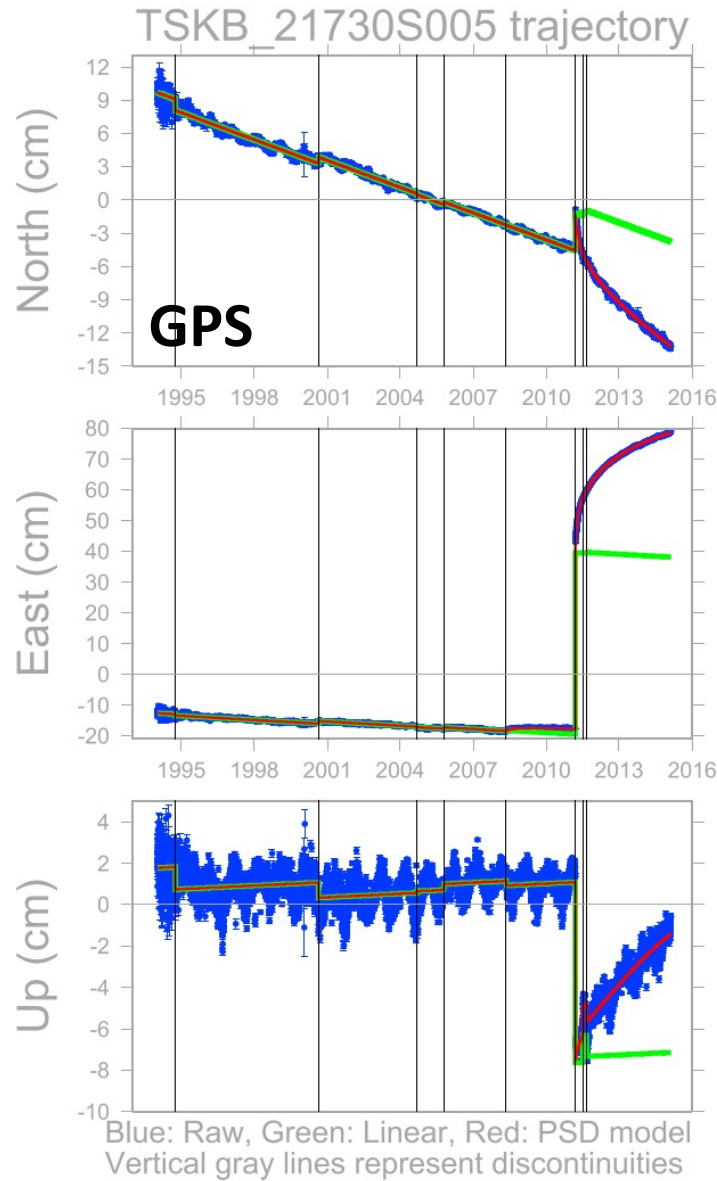


*Altamimi et al. 2016, JGR-SE*

ITRF2014

# Post-seismic deformation models

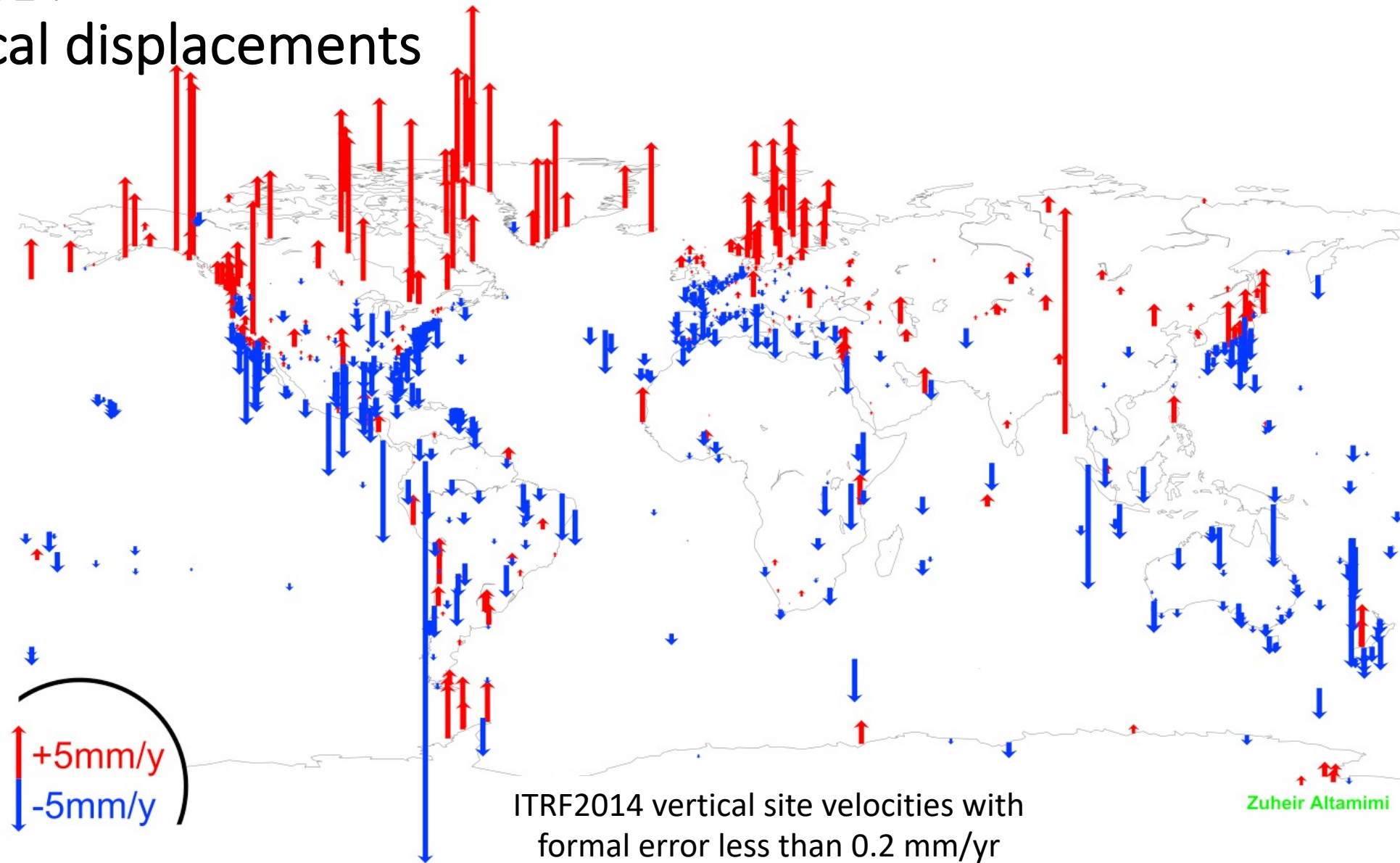
Tsukuba example





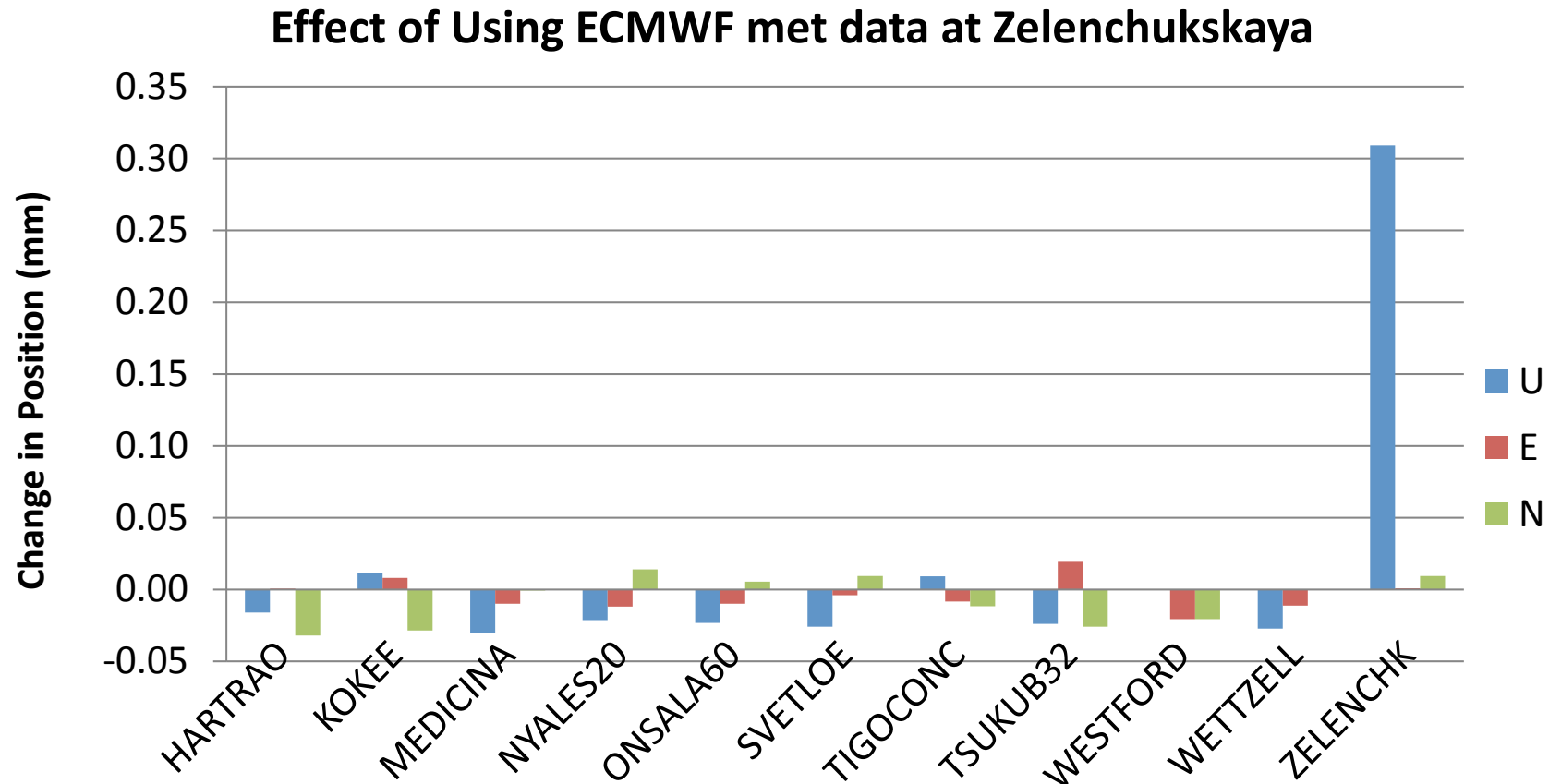
ITRF2014

# Vertical displacements



## Analysis

# Impact of missing meteorological data IVS station Zelenchukskaya during CONT08



# The IVS contribution to ITRF2020 in numbers

- **11** institutions

- **8** countries

Italy, Germany, USA, Russia, Norway, France, Sweden, Austria

- **7** software packages

Calc/Solve, DOGS-RI, PORT, QUASAR, Where, ASCOT, VieVS

- More than **6,500** S/X 24-hr sessions

August 1979 to December 2020

- Up to **38** VGOS sessions

December 2017 to October 2020

Institution	Contacts	Software	S/X	VGOS
ASI CGS	Roberto Lanotte	Calc/Solve	6466	38
BKG	Anastasiia Girdiuk	Calc/Solve	6084	38
DGFI-TUM	Matthias Glomsda	DOGS-RI	6456	38
GFZ Potsdam	Kyriakos Balidakis	PORT	6514	38
NASA GSFC	Dan MacMillan John Gipson	Calc/Solve	6469	38
IAA	Sergey Kurdubov Svetlana Mirinova Elena Skurikhina	QUASAR	6490	23
Norwegian Mapping Authority	Ann-Silje Kirkvik	Where	6468	38
Paris Observatory	Sebastien Lambert	Calc/Solve	6481	38
Onsala Observatory	Rüdiger Haas	ASCOT	6519	38
TU-Wien	Johannes Böhm	VieVS	6391	38
USNO	Megan Johnson	Calc/Solve	5931	-

This list was last updated on 2021Feb10. It reflects the session list as of 2021Jan15.

**Credit:** [https://ivscc.gsfc.nasa.gov/IVS\\_AC/IVS-AC\\_ITRF2020.htm](https://ivscc.gsfc.nasa.gov/IVS_AC/IVS-AC_ITRF2020.htm)

# *IVS products*

Terrestrial Reference Frame

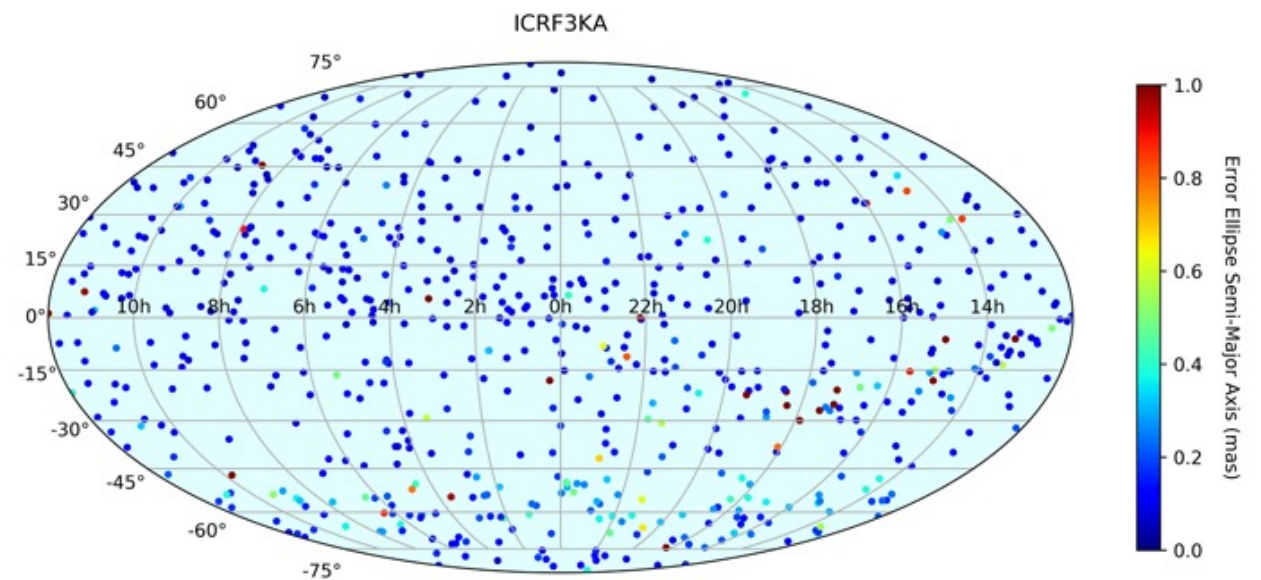
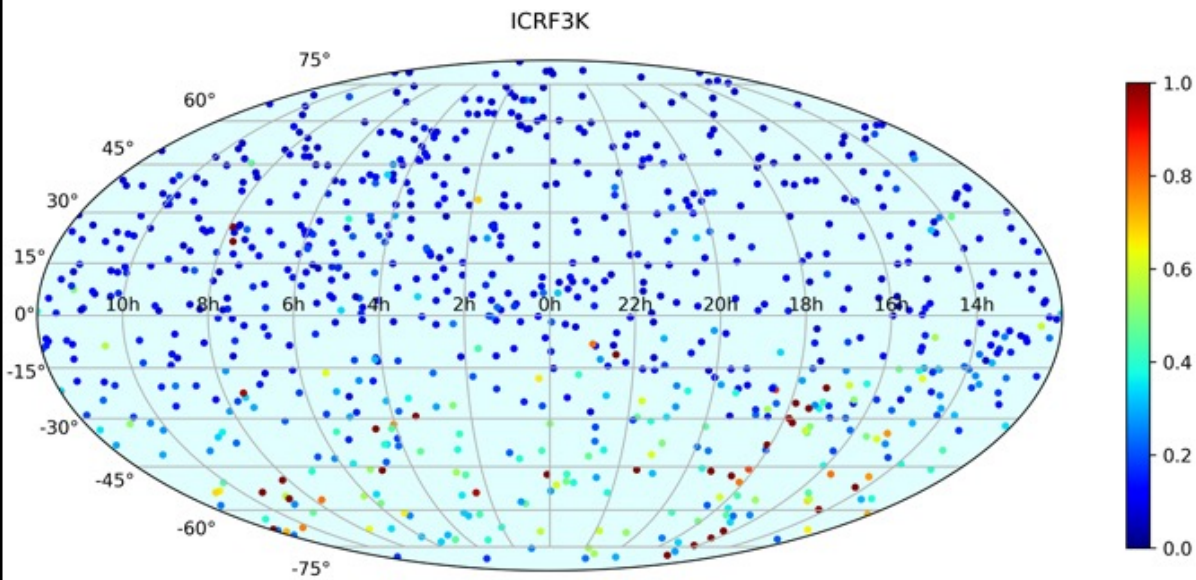
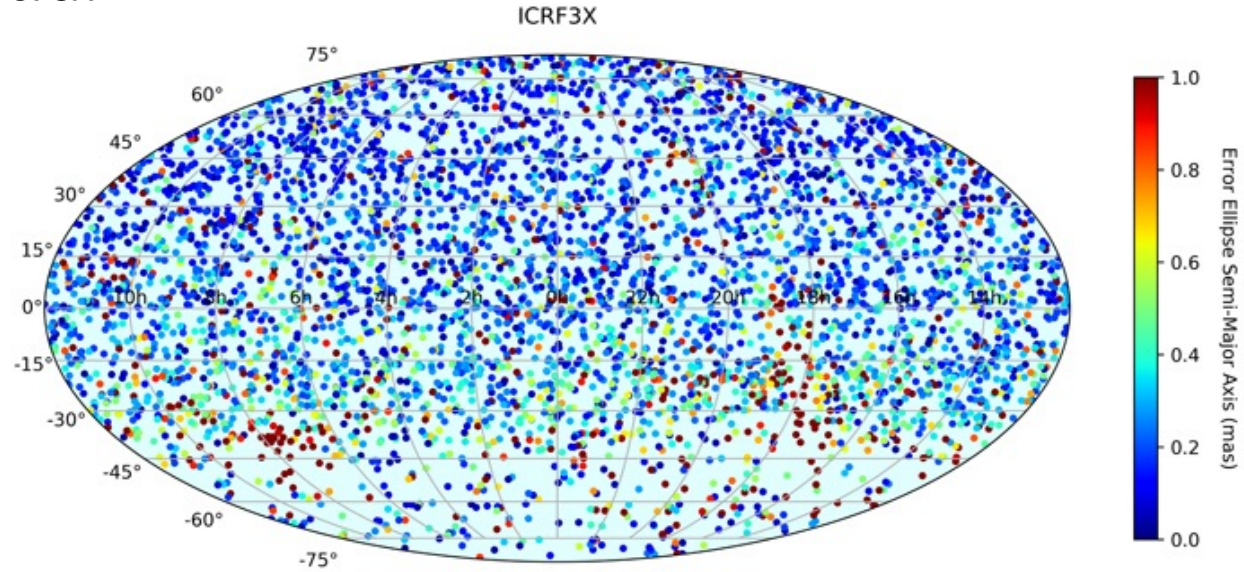
Celestial Reference Frame *IVS-CRF, IVS-CRDS, RDV*

Earth Orientation Parameters

# International Celestial Reference Frames ICRFs

Parameter	ICRF1 (1997) Replace FK5 optical frame	ICRF2 (Jan 1, 2010)	ICRF3 (January 1, 2019)		
			S/X-band	K-band	X/Ka-band
Observation Dates	08/1979 – 07/1995 (16 years)	08/1979 – 03/2009 (29.5 years)	08/1979 – 03/2018 (38.5 years)	05/2002-05/2018	07/2005-01/2018
# Observations	1.6M S/X group delays	6.5M S/X group delays	~15M S/X group delays		
# Defining Sources	212	295	303	193	176
Total Sources	608	3,414	4,536	824	678
Noise Floor	~250 $\mu$ as	~40 $\mu$ as	~30 $\mu$ as	30-50 $\mu$ as	~30 $\mu$ as

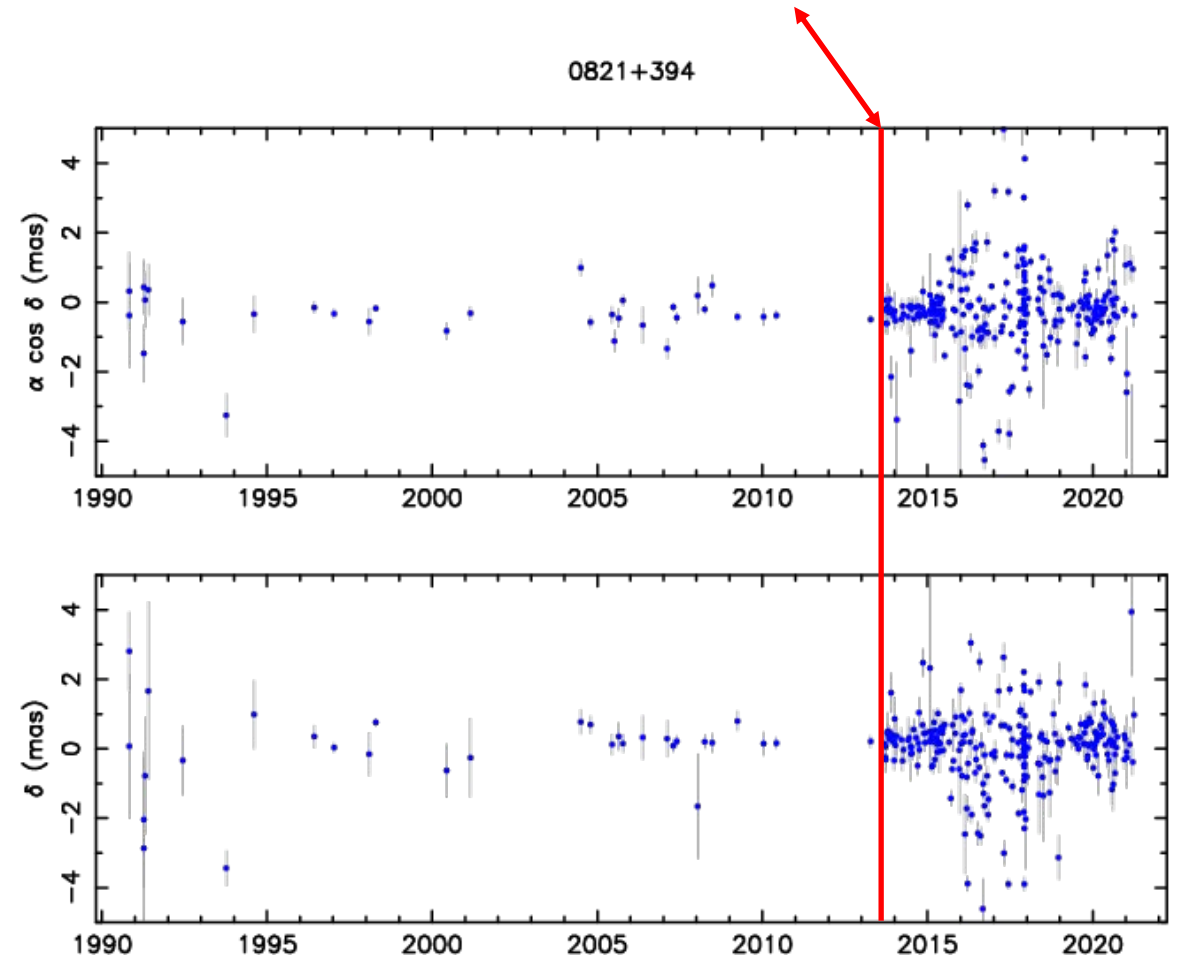
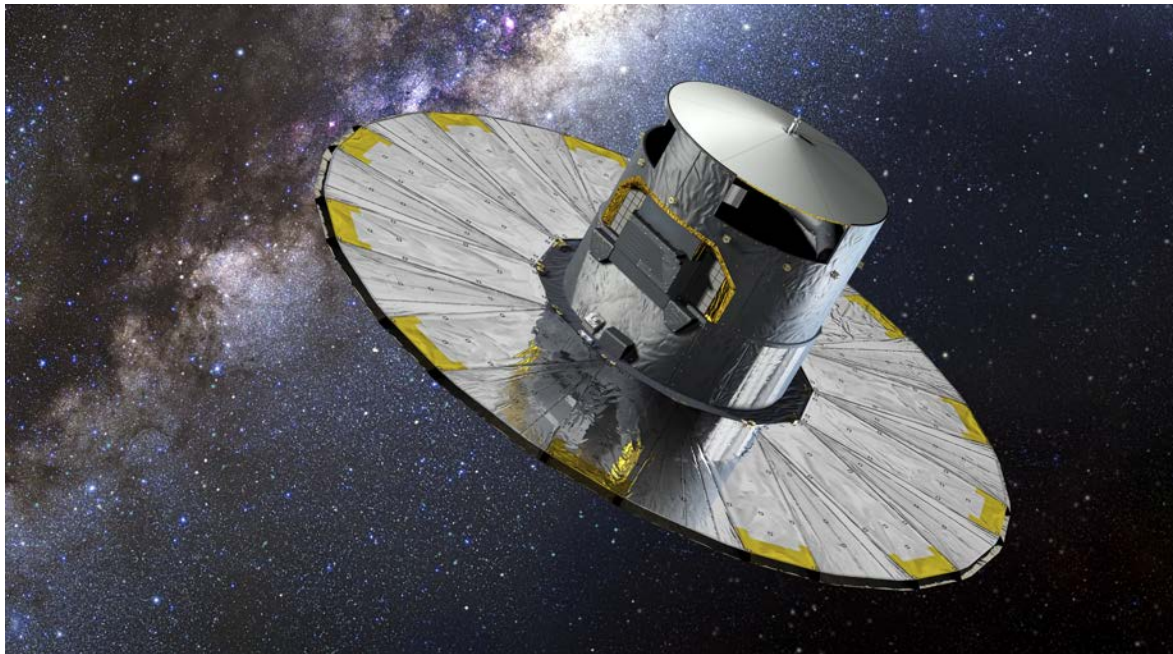
# International Celestial Reference Frame ICRF3



# Celestial Reference Frames – Radio vs. optical Link between the VLBI CRF (ICRF3) and Gaia CRF (GCRF)

Beginning of the dedicated  
Gaia transfer **R&D** sessions  
and introduction of the sources in the  
Goddard monitoring program

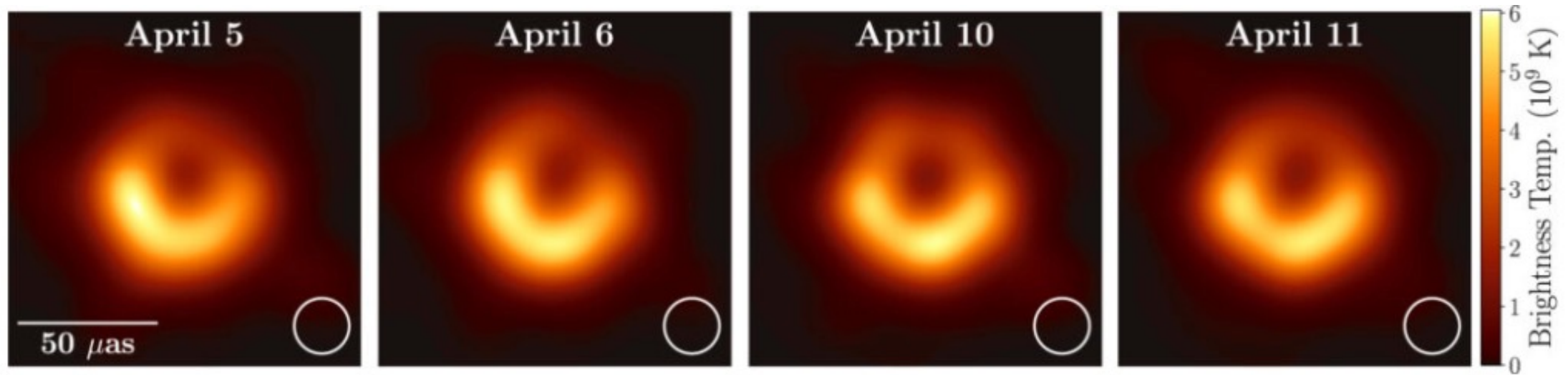
Credit Image: <https://sci.esa.int/web/gaia>



Credit image: Paris Observatory Geodetic VLBI Center

## *VLBI in the news*

# The Event Horizon Telescope (EHT) and the black hole in M87



Images of M87 obtained by the Event Horizon Telescope Collaboration

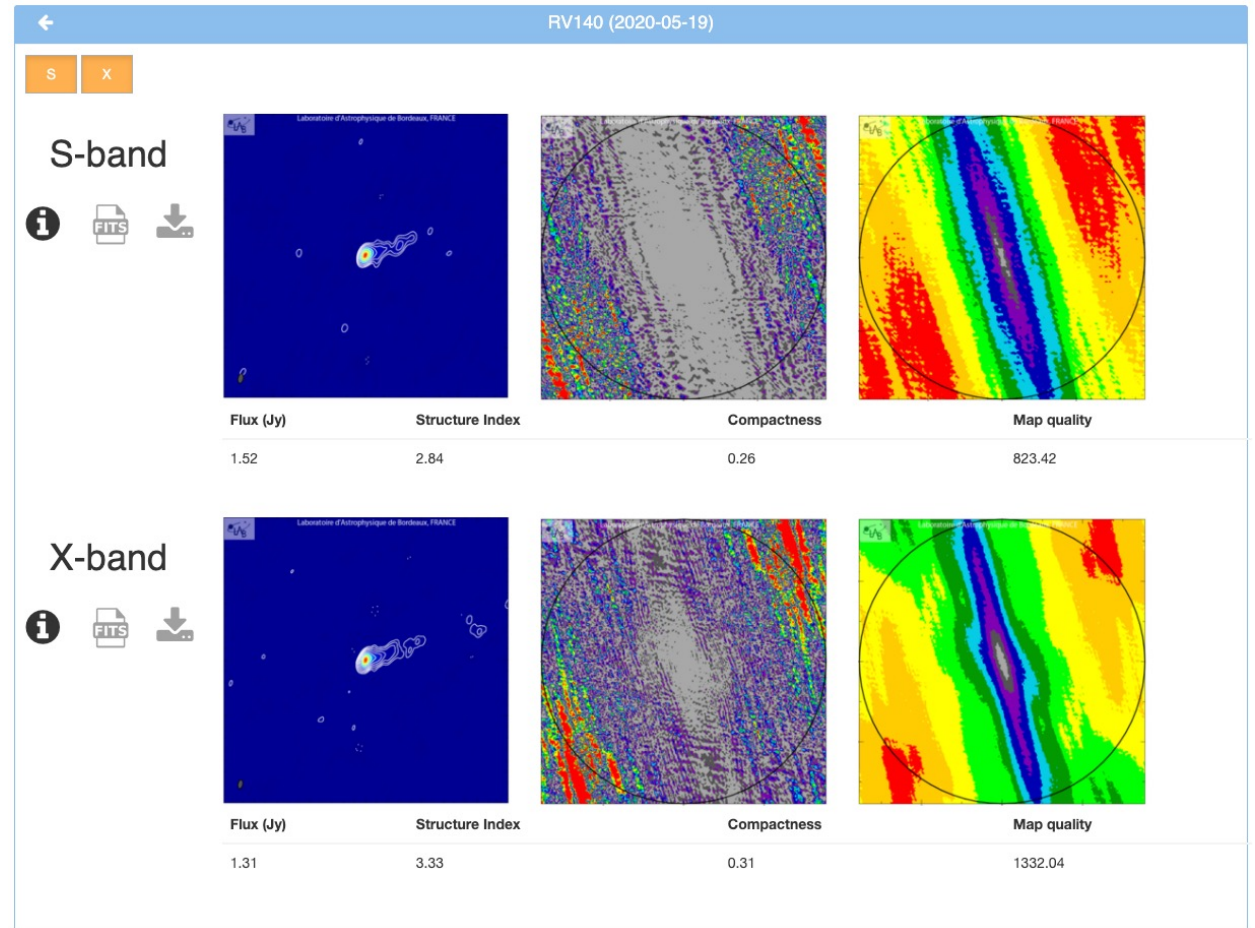
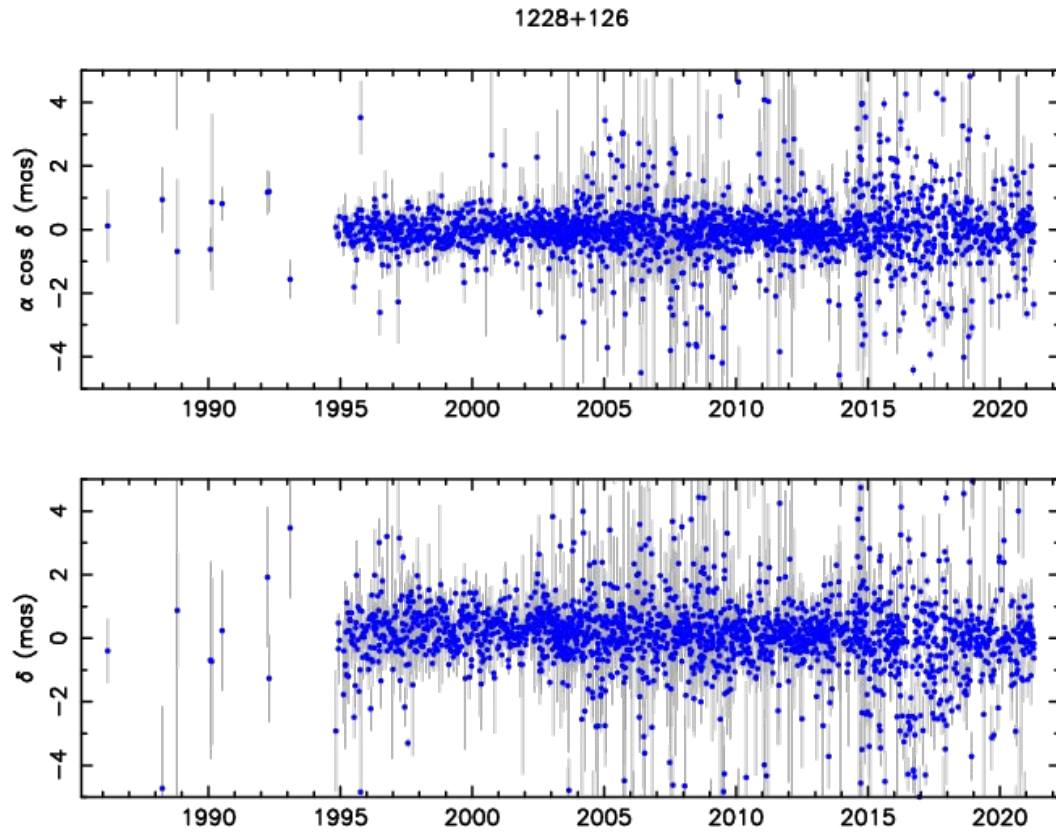
2019

**Credit Image:** MIT Haystack Observatory website

<https://www.haystack.mit.edu/astronomy/astronomy-projects/event-horizon-telescope/>



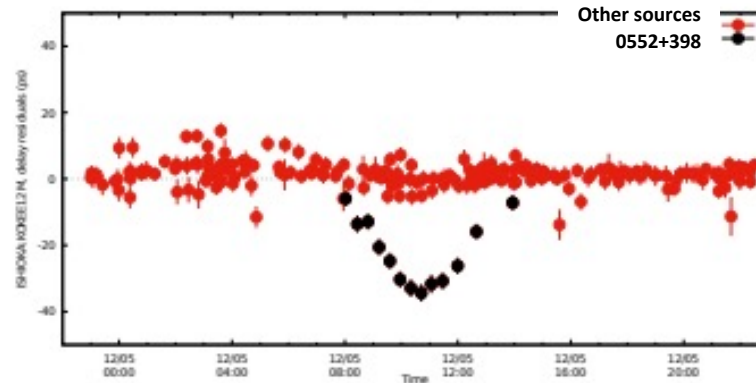
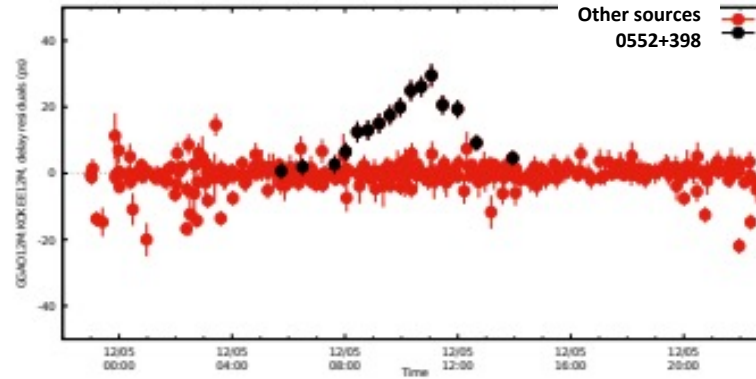
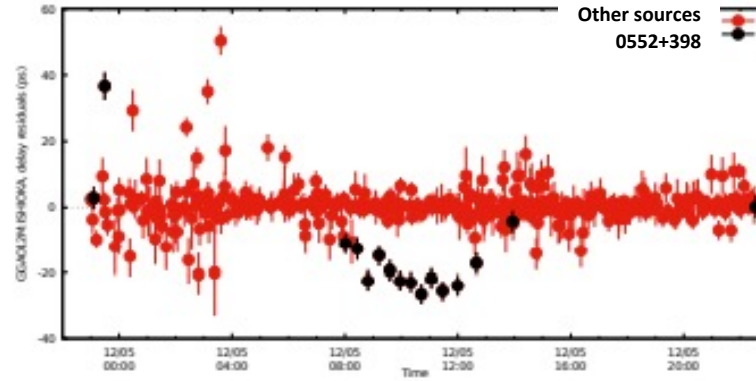
# VLBI IVS observations of M87 (1228+126)



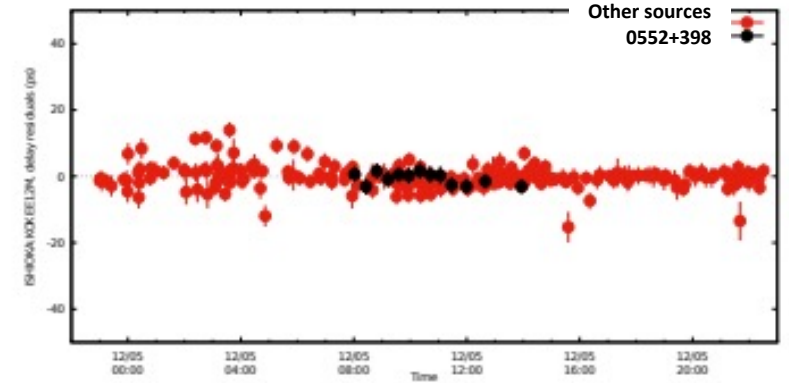
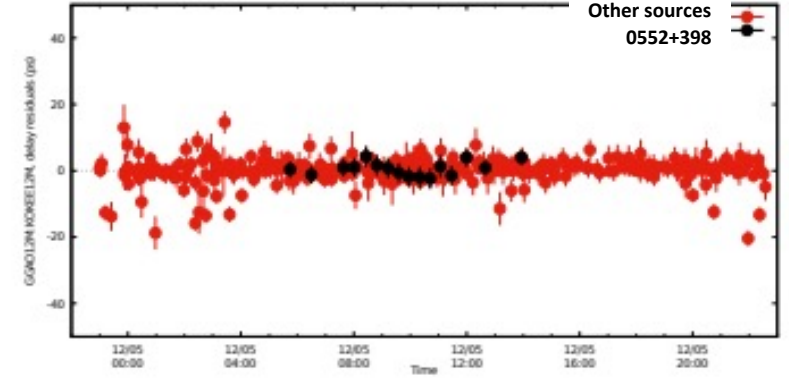
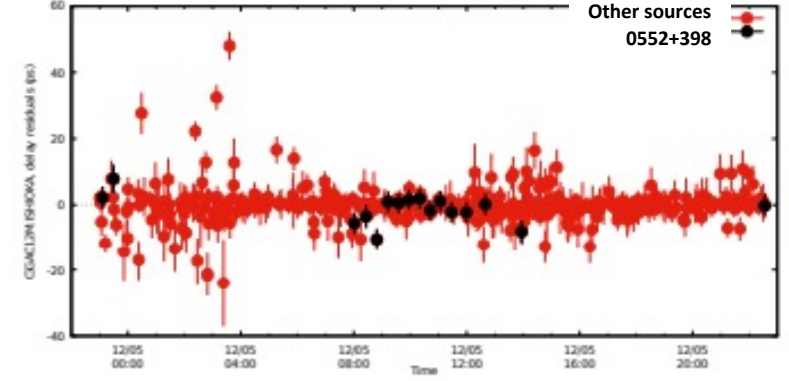
*Credit image: Paris Observatory Geodetic VLBI Center*

*Credit image: The Bordeaux VLBI Image Database*

# Source structure effect in broadband observations



Residuals without the source structure model.



Residuals after the model was applied.

# *IVS products*

Terrestrial Reference Frame

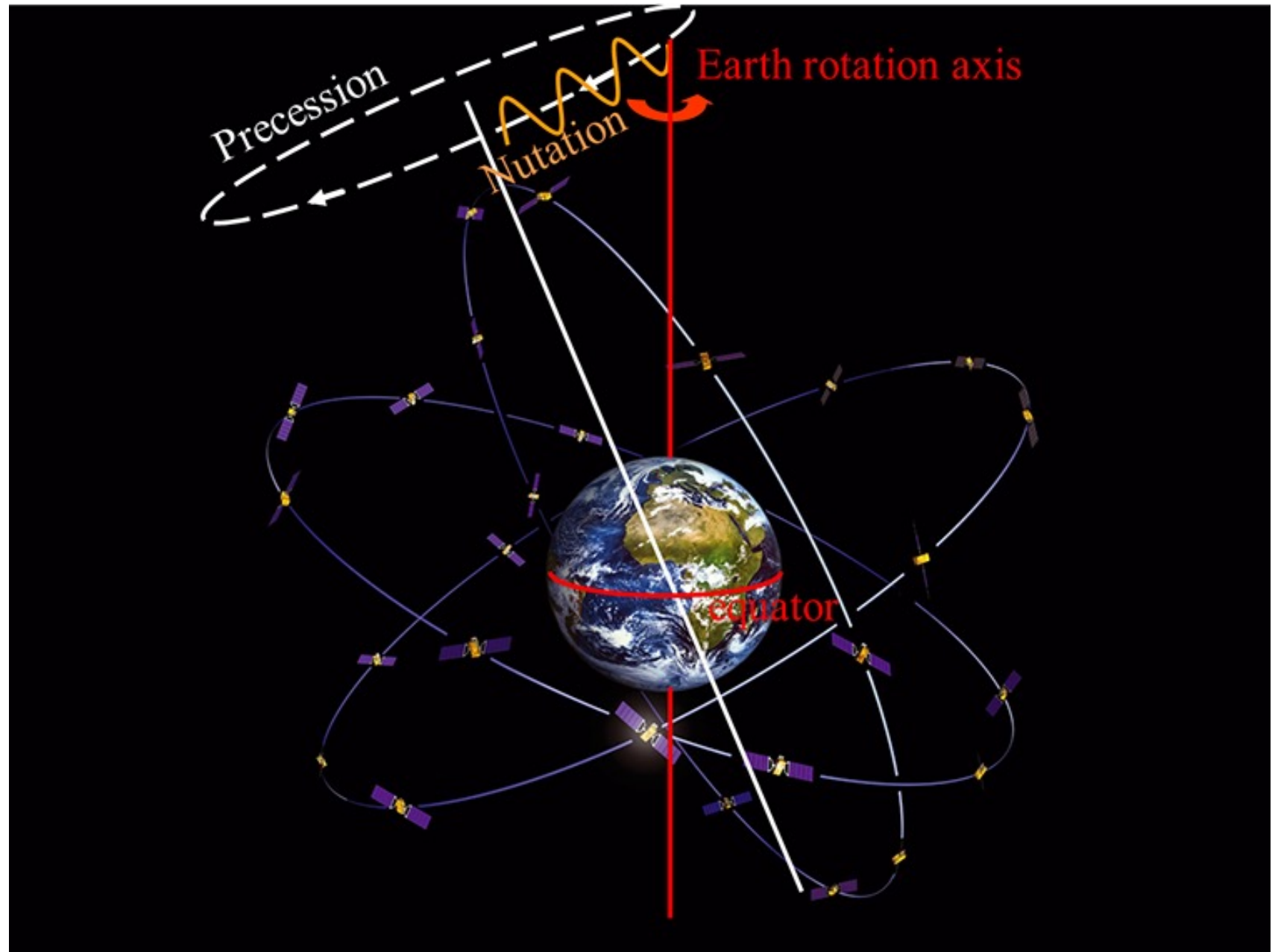
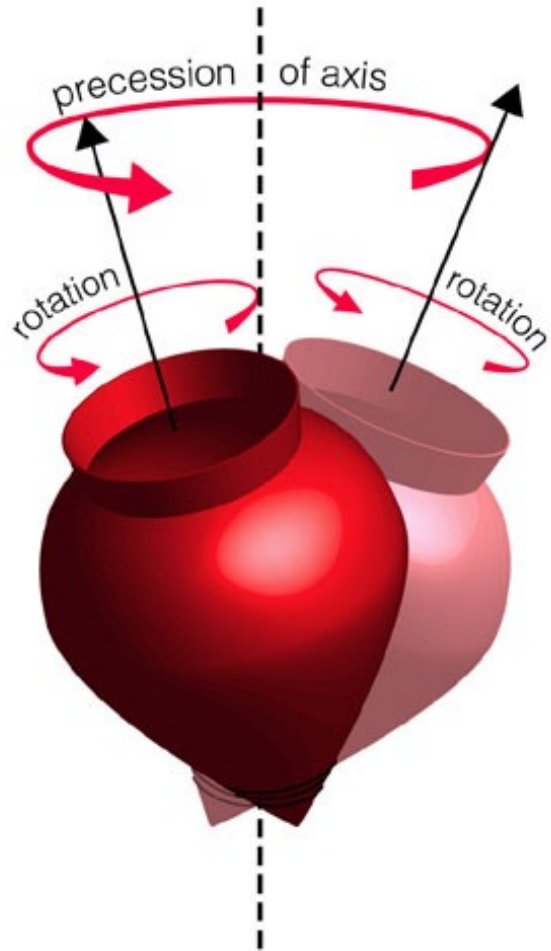
Celestial Reference Frame

Earth Orientation Parameters: precession-nutation, polar motion,  $d(\text{UT1-UTC})$

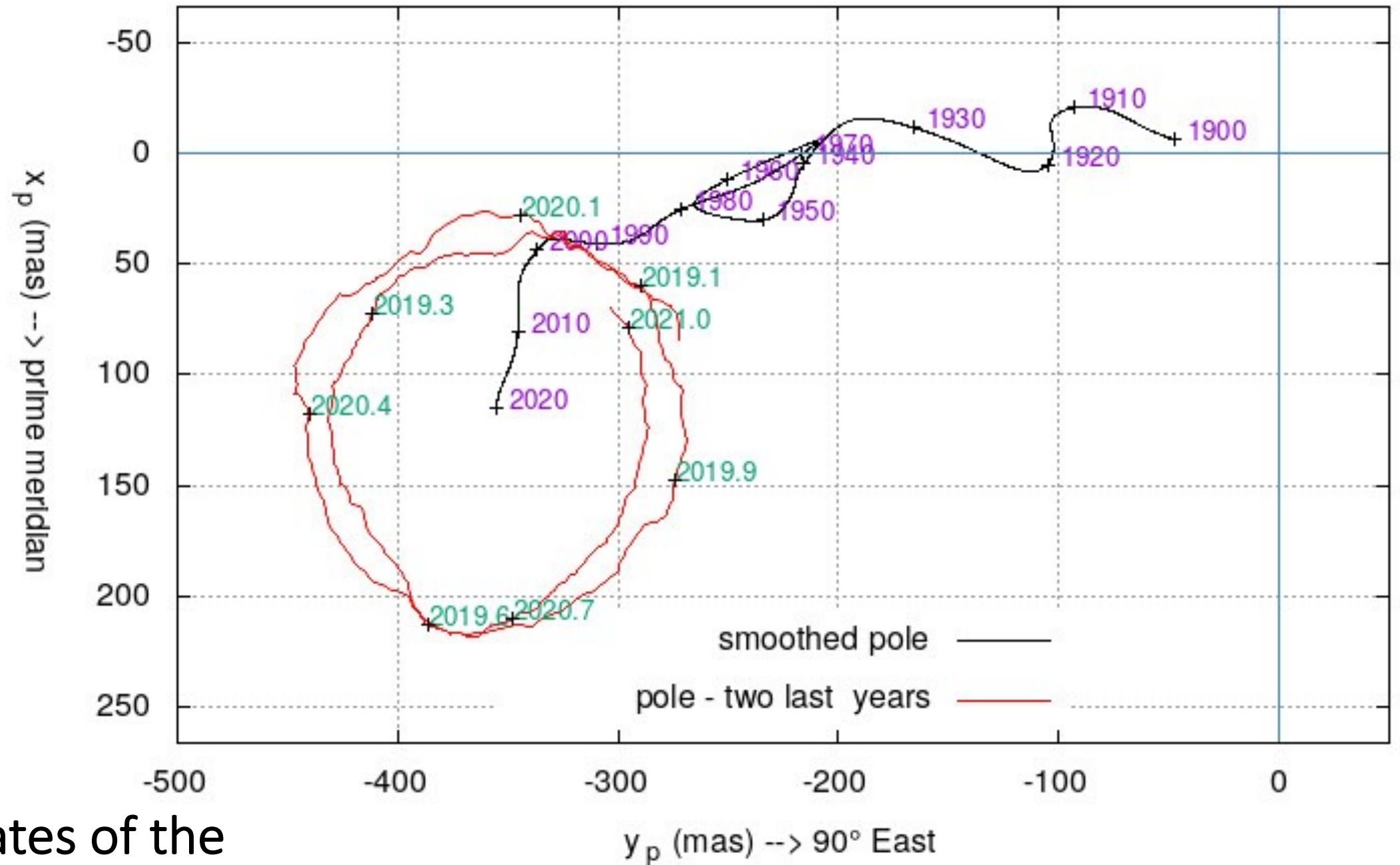
*IVS-R1, IVS-R4, RDV, IVS-INT1, IVS-INT2, IVS-INT3*

# Celestial Pole Offsets

## Precession and nutation



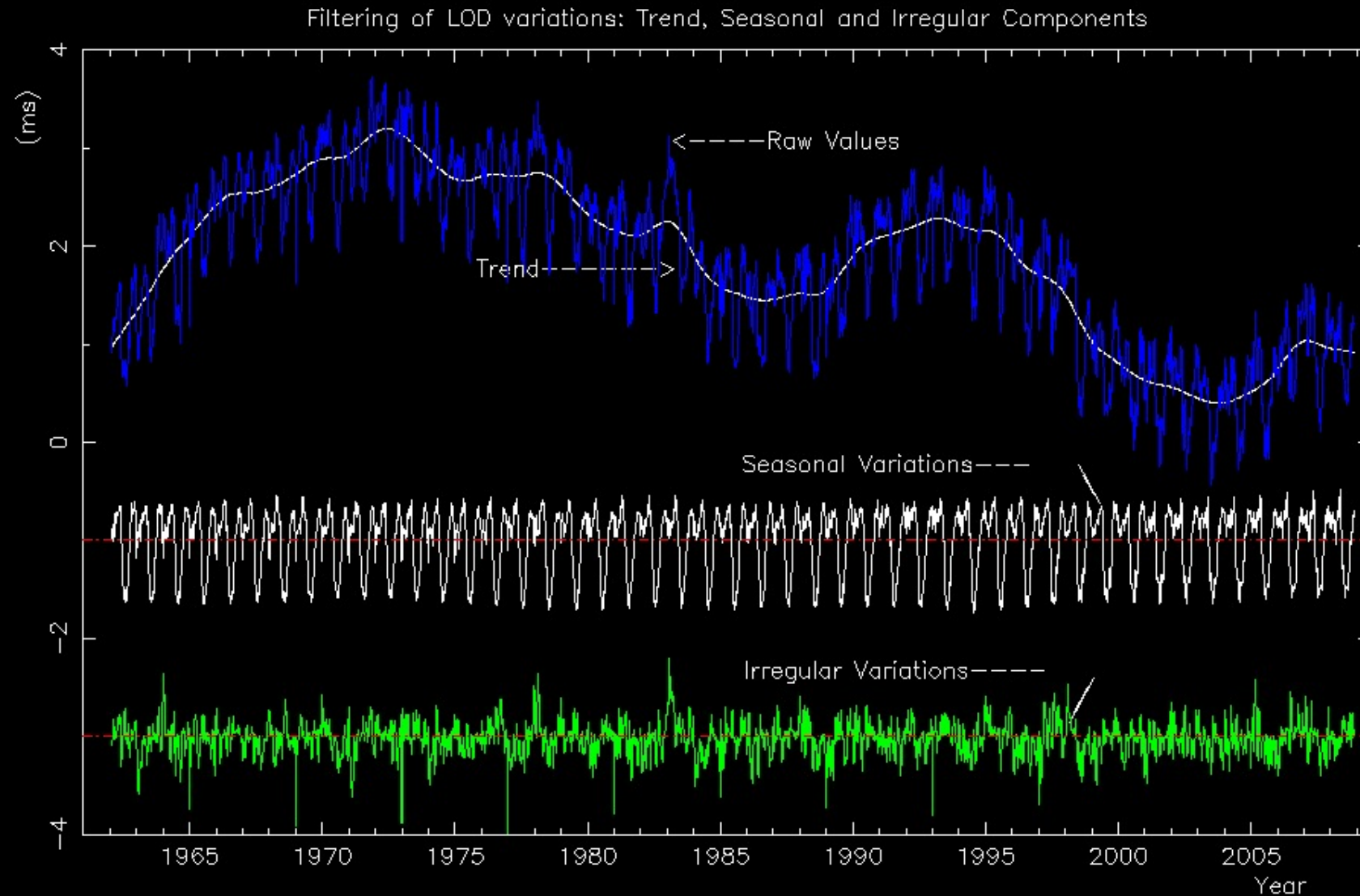
Source: <https://eos.org/> adapted from J. Huart, European Space Agency



Coordinates of the  
Celestial Ephemeris Pole (CEP)

Source: <https://hpiers.obspm.fr/eop-pc/earthor/>

# UT1 Length Of Day (LOD)

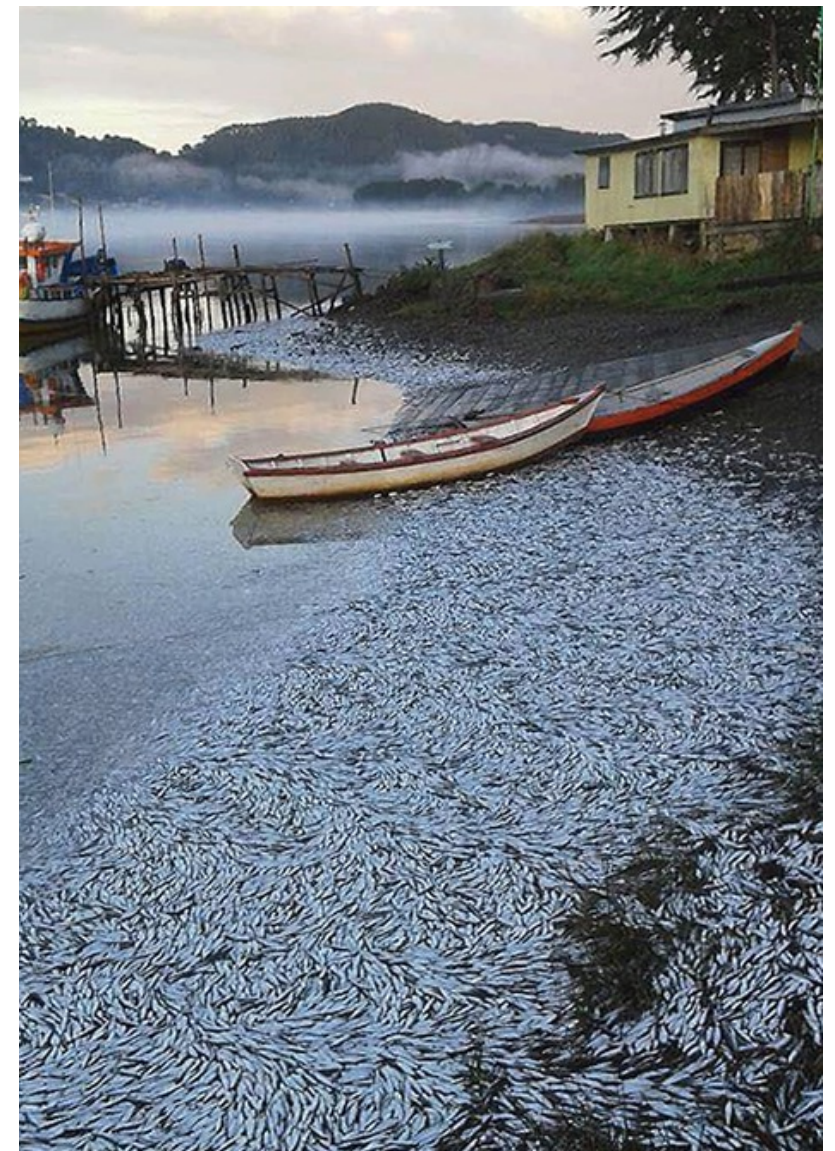


**Pedro Elosegui, 2021 Virtual TOW**  
**“Climate change is the defining challenge of our time.”**



Swollen with the rains of the 1983 El Niño, the Santa Cruz River roils near Tucson, Arizona. (Photograph courtesy of Peter L. Kresan, University of Arizona/U.S. Geological Survey.)

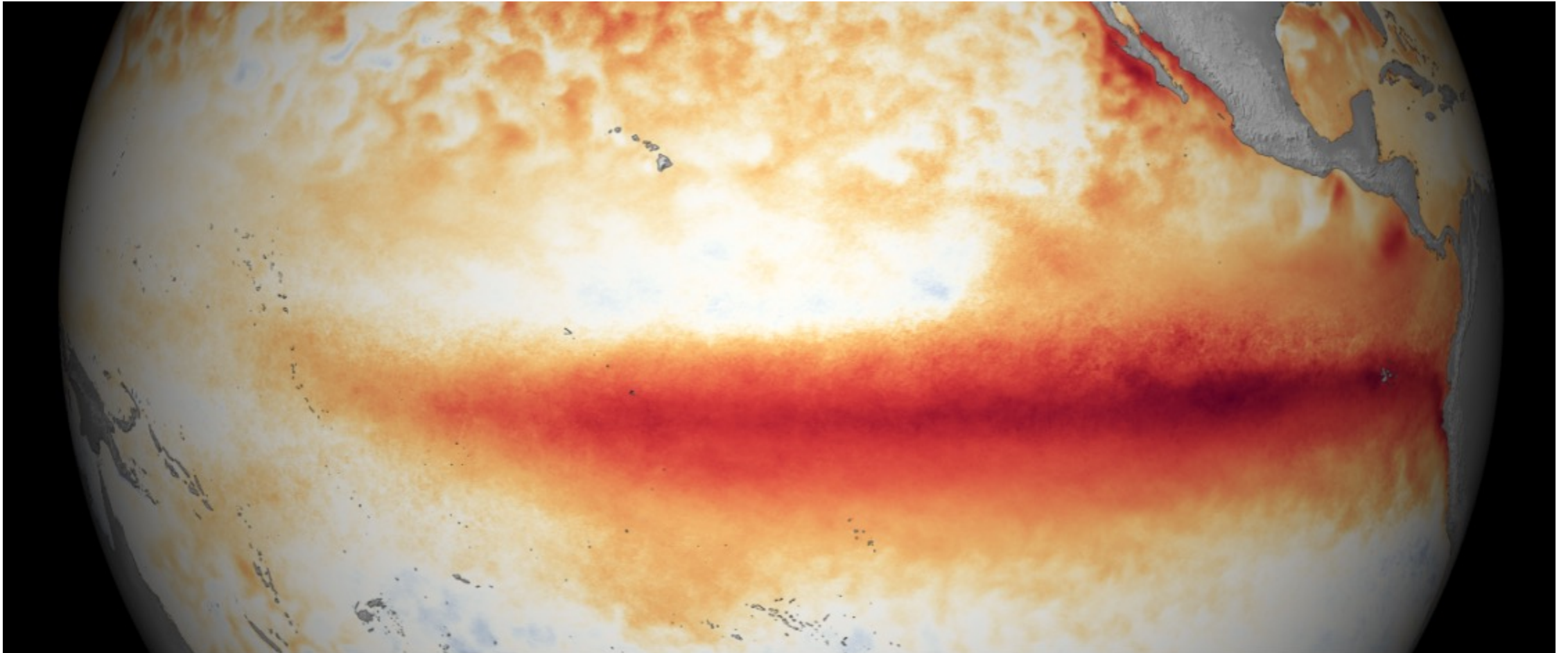
**Credit:** <https://earthobservatory.nasa.gov/features/ElNino>



In April 2016, nearly 8,000 tons of sardines died and washed up along the coast of Chile, likely the result of El Niño related changes in the ocean. (Photographs courtesy of Armada de Chile.)

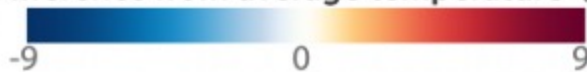
# *El Niño-Southern Oscillation (ENSO)*

## Strong El Niño event in November/December of 2015



December 2015  
compared to 1981-2010

Difference from average temperature (°F)



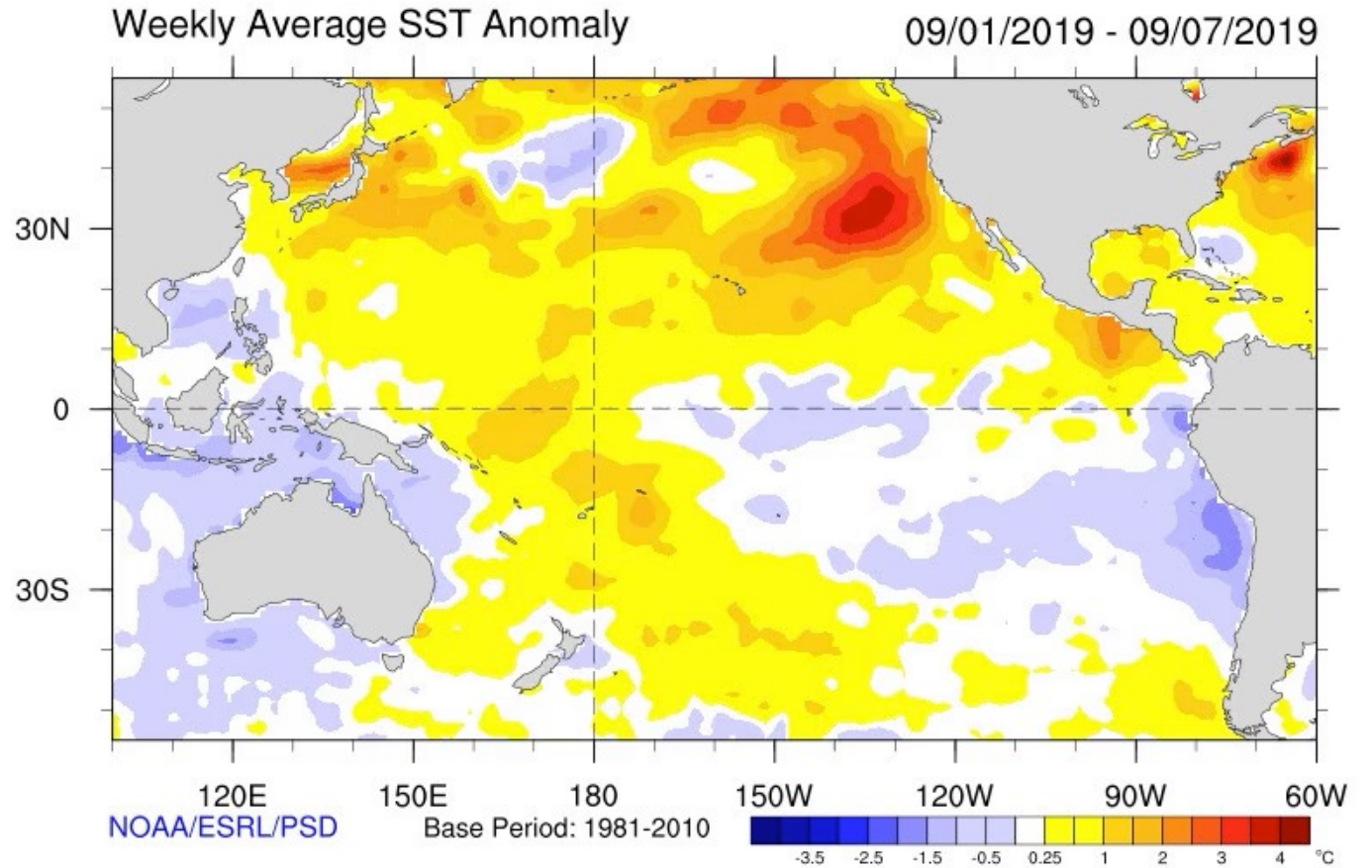
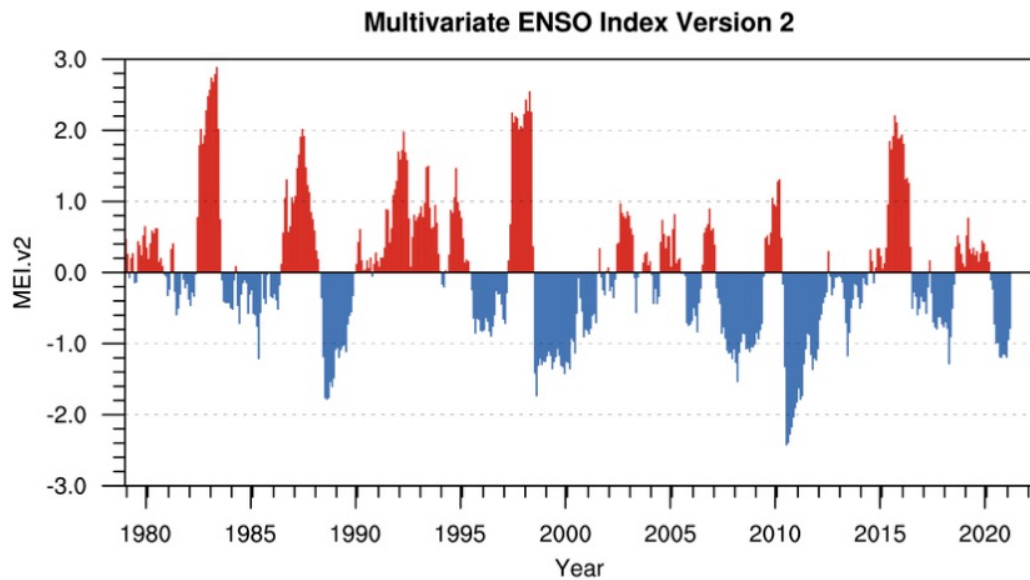
Climate.gov/NNVL  
Data: Geo-Polar SST



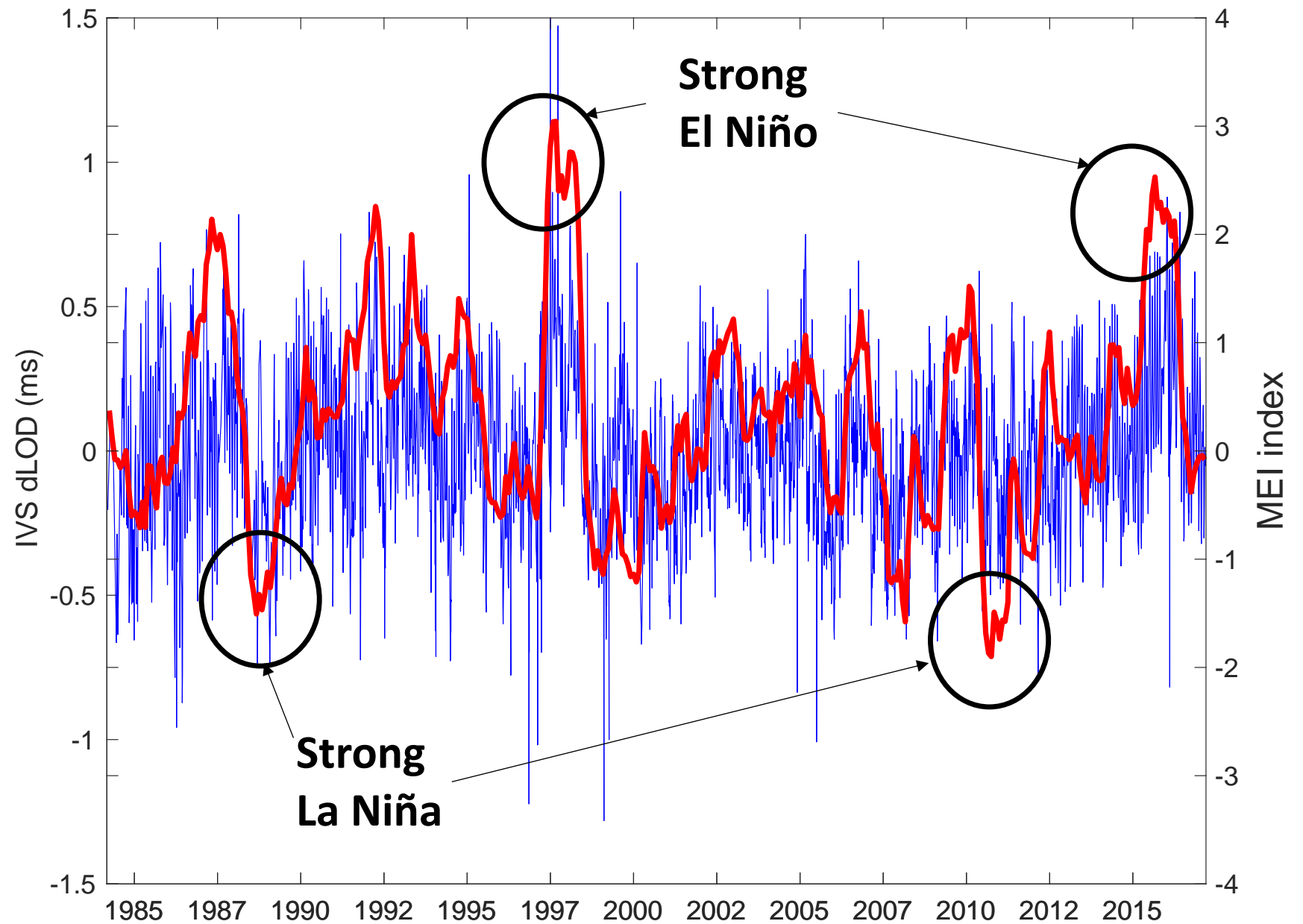
# El Niño-Southern Oscillation (ENSO) and the Multivariate ENSO Index (MEI)

Sea Surface Temperature (SST)  
over the tropical Pacific

Source: <https://psl.noaa.gov/enso/>



# Comparison of the Length Of Day measured by VLBI and the El Niño-Southern Oscillation



*Credit: Rüdiger Haas*

## Summary

Better understanding of our planet  
VLBI as a reference

## Future

VGOS ICRF, source structure, source flux density monitoring,...

**Tack så mycket!**

More videos?

SGP @GSFC/NASA

[https://space-geodesy.nasa.gov/multimedia/videos/vlbi\\_quasars/VLBIQuasarsVideo.html](https://space-geodesy.nasa.gov/multimedia/videos/vlbi_quasars/VLBIQuasarsVideo.html)

Quest for the Exact Position

<https://vimeo.com/324592652>

**Credit Image:** Onsala Space Observatory  
Roger Hammargren

This presentation uses contents from previous Science Overview talks.