

Laser Ranging Contributions to Earth Rotation Studies

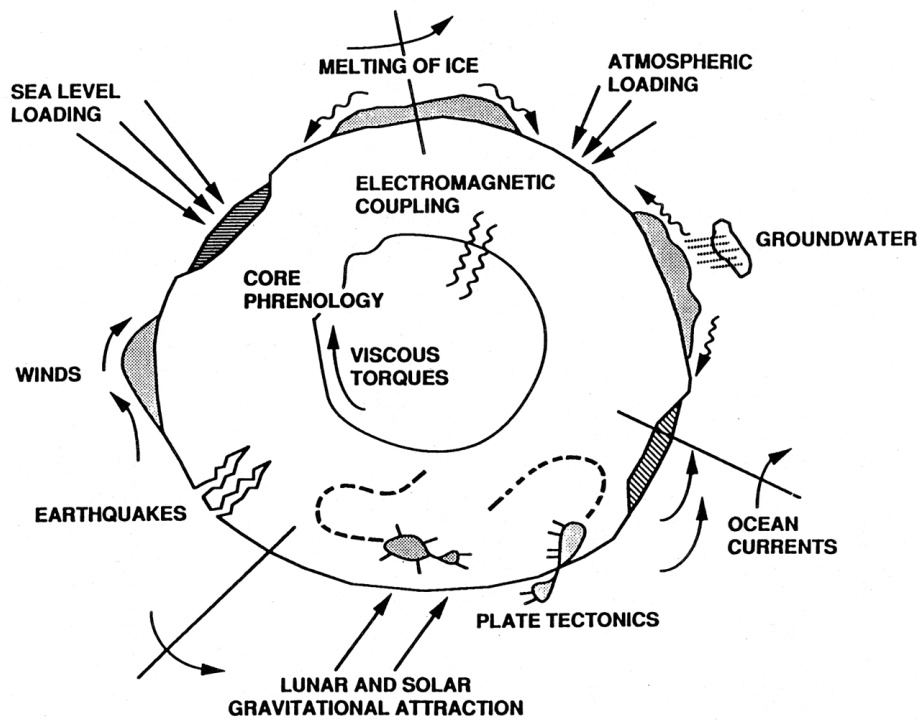
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Earth Rotation Dynamics



Sources of Earth Rotation Variations

Rotation of Earth changes

Length of day by few milliseconds

Wobbles by few hundred milliarcsec
(10 meters at North Pole)

Nutation and precession

Rotation changes caused by

External torques — tidal phenomena

Internal deformation — earthquakes,
glacial isostatic adjustment

Angular momentum exchange with
bounding fluids — atmosphere,
oceans, core

Studying Earth's rotation improves knowledge of

Rheology and dissipation processes of solid Earth

Interior figure of Earth

Core-mantle coupling

Laser Ranging Contributions

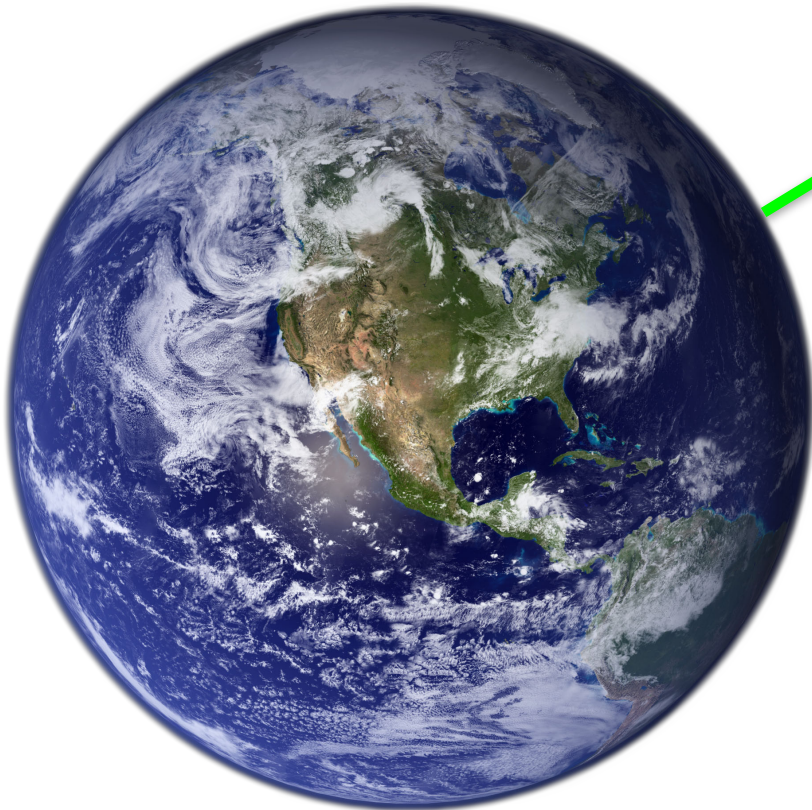
- Longest available space-geodetic series of Earth orientation parameters
 - LLR measurements since 1970
 - SLR measurements since 1976
- Needed for studying long-period variations in Earth's rotation
 - Polar motion
 - Interannual to decadal variations of unknown (?) origin
 - Length-of-day
 - Secular decrease caused by tidal dissipation
 - Interannual variations primarily caused by atmospheric winds
- Provides backbone for combining EOPs from different space-geodetic techniques
 - Geophysical interpretation of observed EOPs usually done using combined series

Lunar Recession

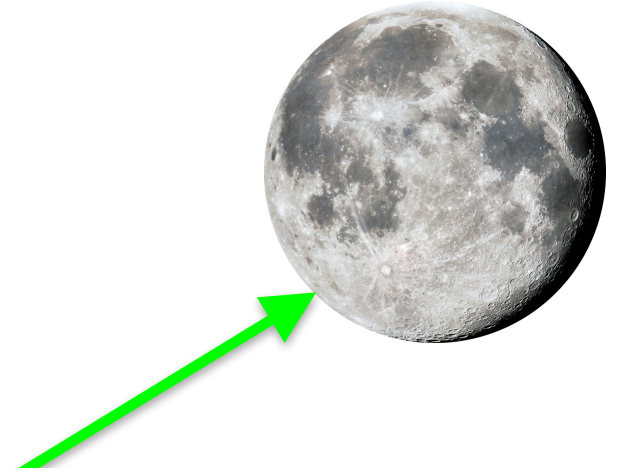


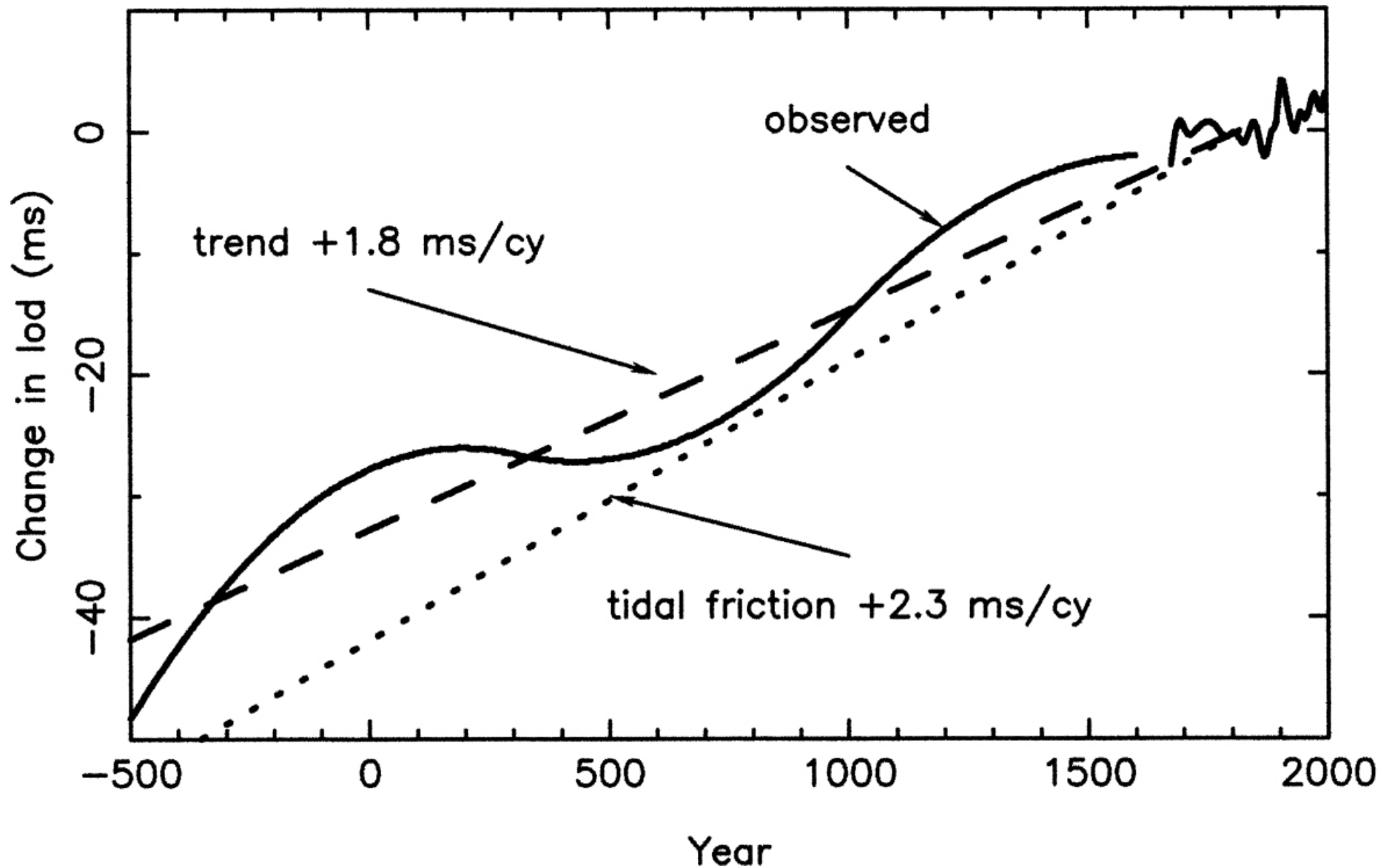
APOLO station ranging to Moon. Source: Dan Long

Lunar Recession



Moon receding from Earth
at rate of 3.79 ± 0.07 cm/yr
(Williams et al., 2001)





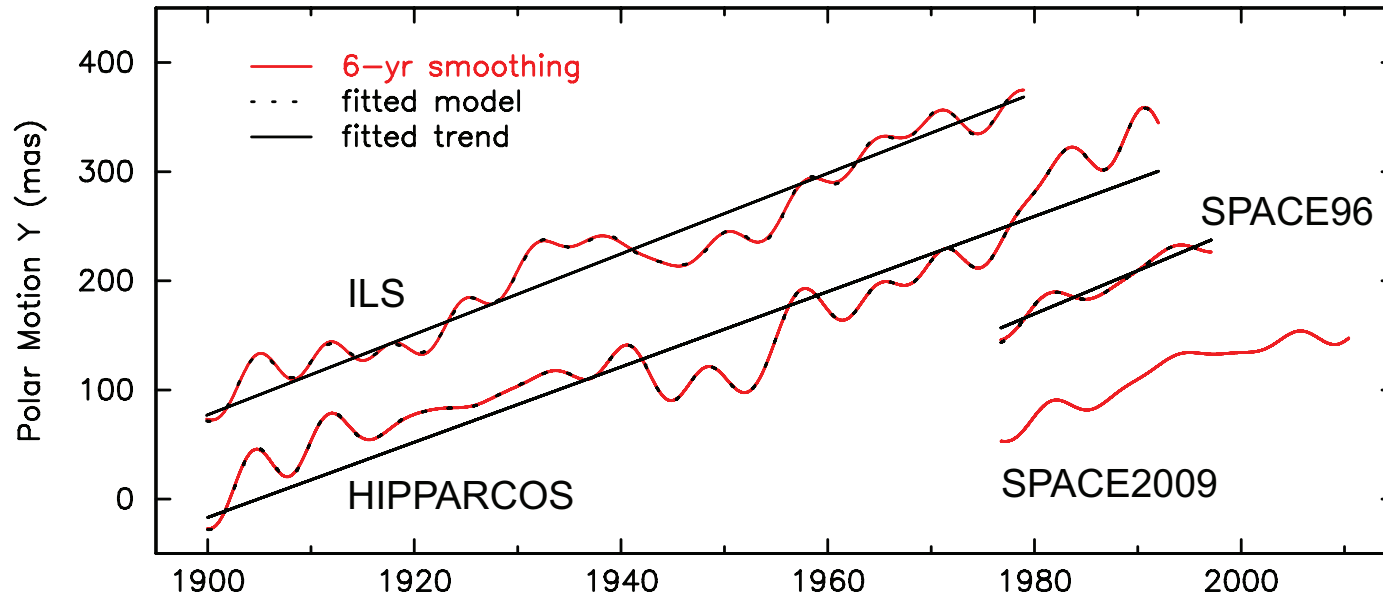
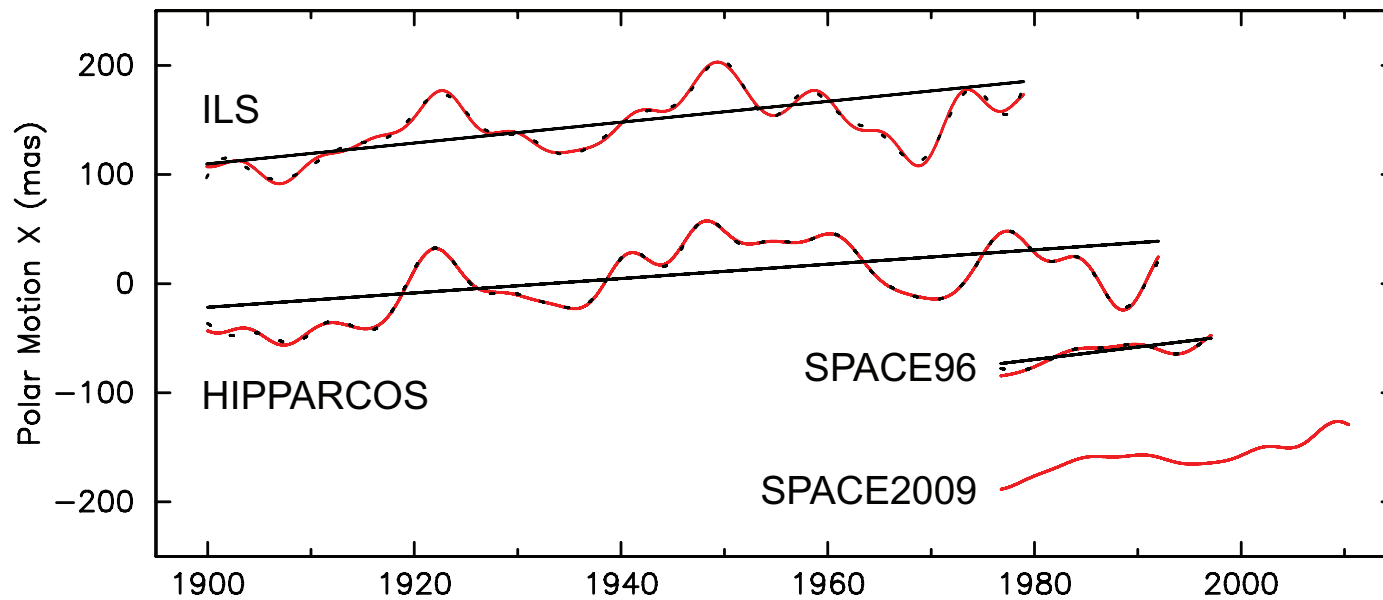
Secular change in the length-of-day during the past 2500 years estimated from lunar and solar eclipse, lunar occultation, optical astrometric, and space-geodetic observations. The difference between the observed secular trend and that caused by tidal friction is due to the effects of glacial isostatic adjustment and other processes such as ice sheet mass change and the accompanying nonsteric change in sea level.
 Source: Morrison and Stephenson (2001).

Decadal Polar Motion



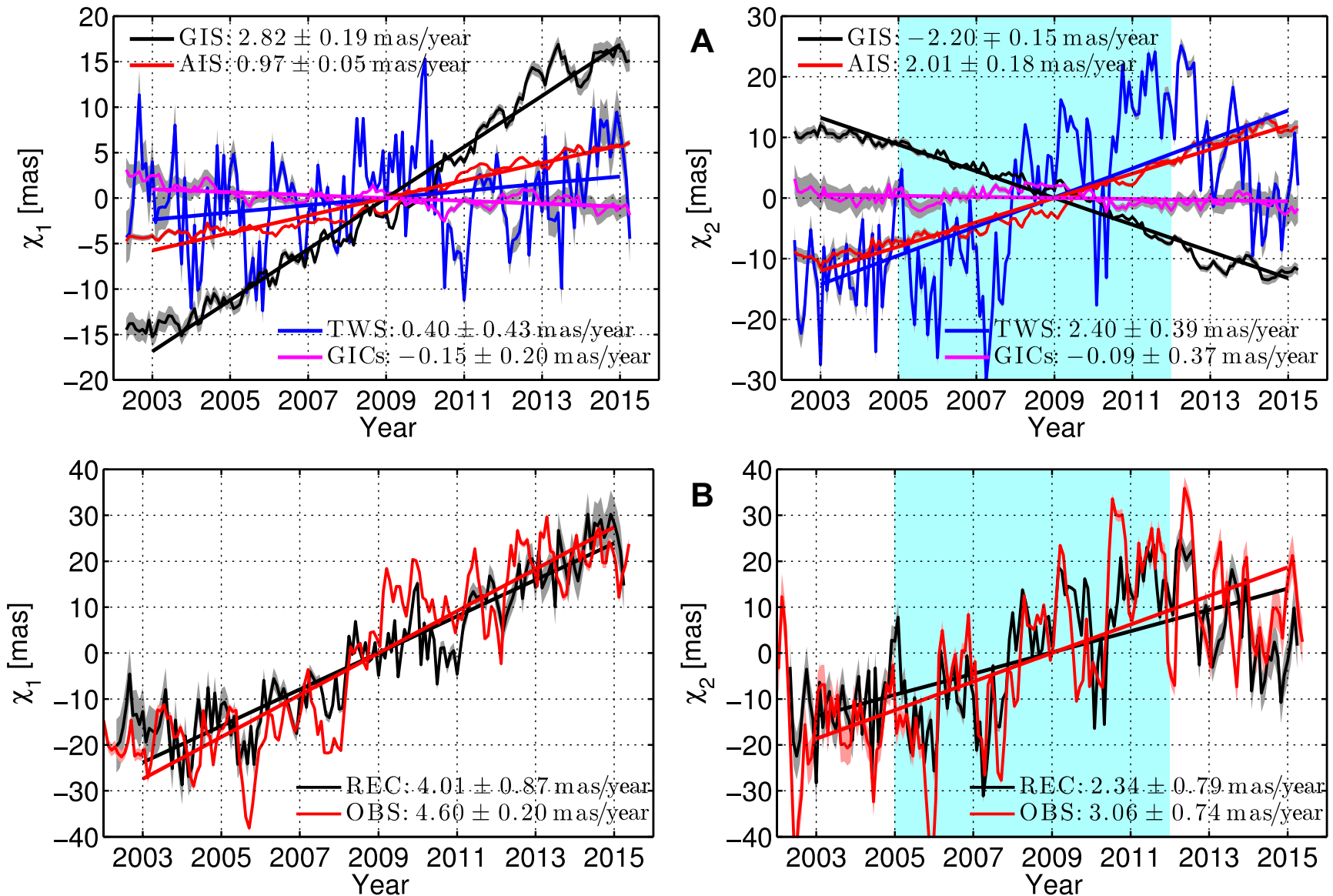
Potsdam laser ranging station

Decadal polar motion variations



Observed decadal-scale polar motion variations from the ILS optical astrometric series, the HIPPARCOS optical astrometric series, and the SPACE96 and SPACE2009 combined space-geodetic series. For clarity of display the curves have been offset from each other by an arbitrary amount. Source: Gross (2015)

Interannual Polar Motion Excitation



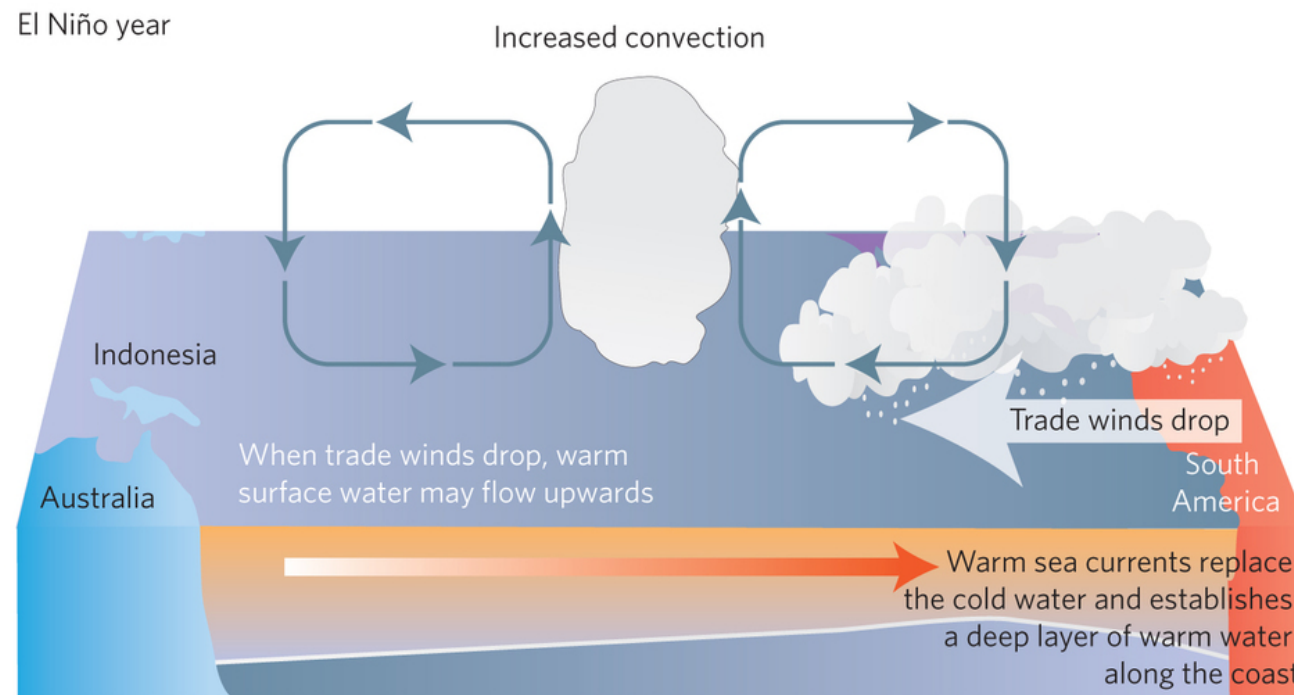
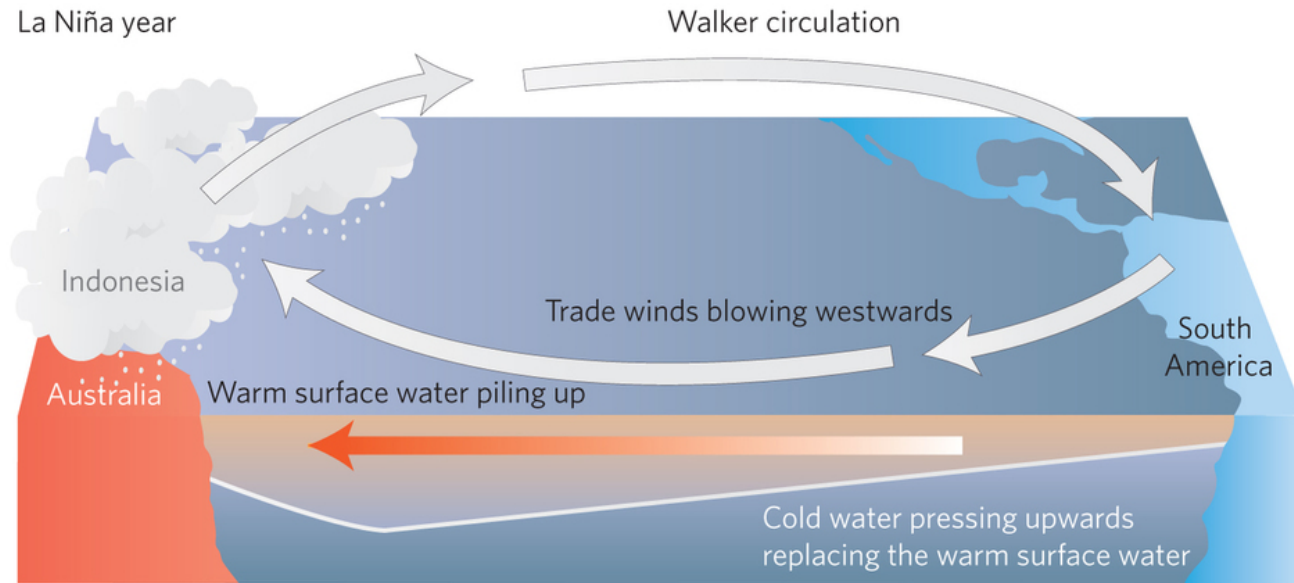
Climate-induced polar motion. (A) Polar motion excitations caused by four climate-related sources. (B) Total reconstructed (REC) and observed (OBS) excitations. Large positive gradients during 2005–2012 (cyan shadow), followed by negative trends, are apparent for $\chi_2(t)$, and it may be explained by analogous trends associated with TWS. Source: Adhikari and Ivins (2016)

Interannual Length-of- Day

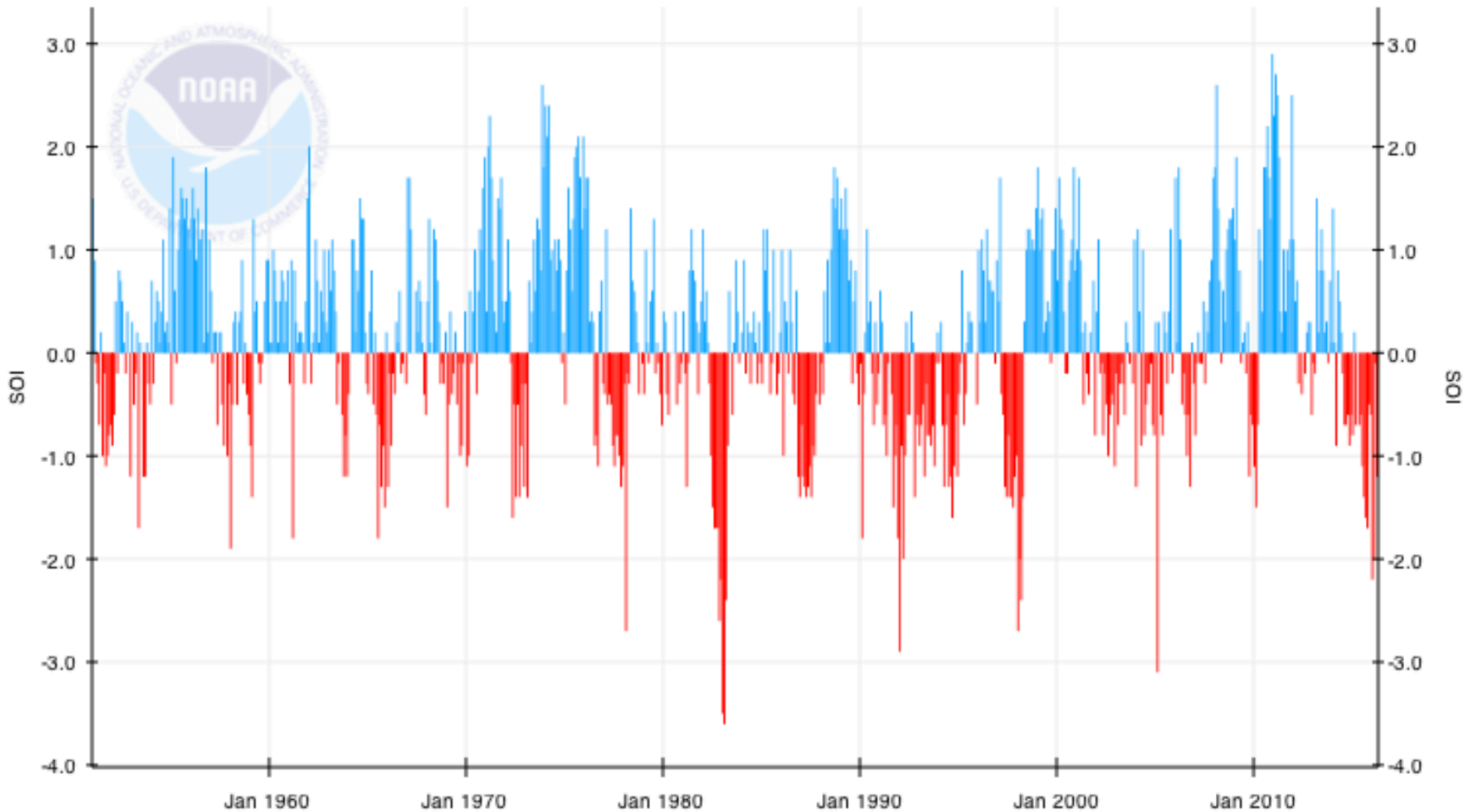


Wettzell laser ranging station

The El Niño / Southern Oscillation



Southern Oscillation Index (SOI)



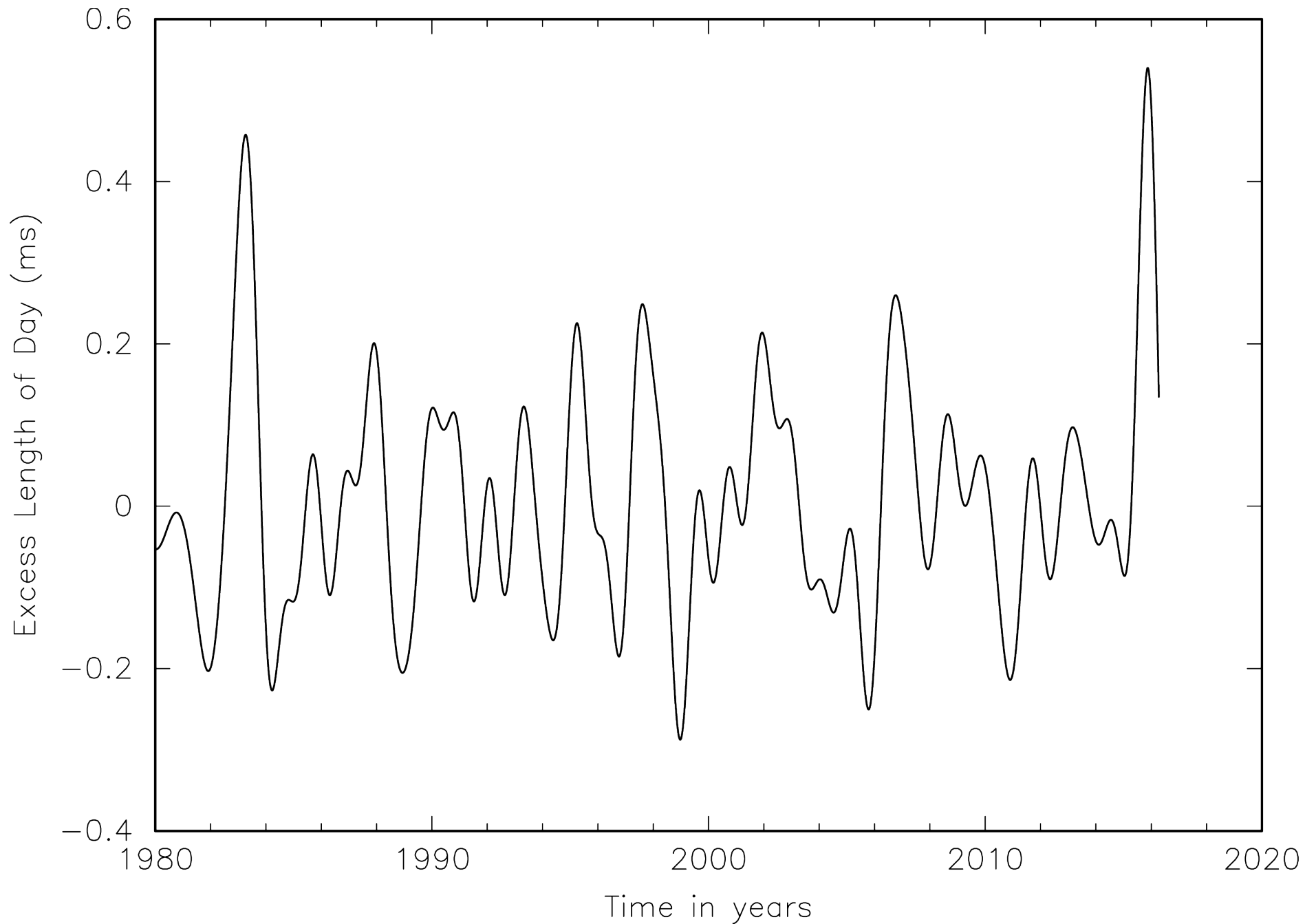
Source: <http://www.cpc.ncep.noaa.gov/data/indices/soi>

SOI: Standardized difference in (Tahiti – Darwin) sea level pressure anomalies

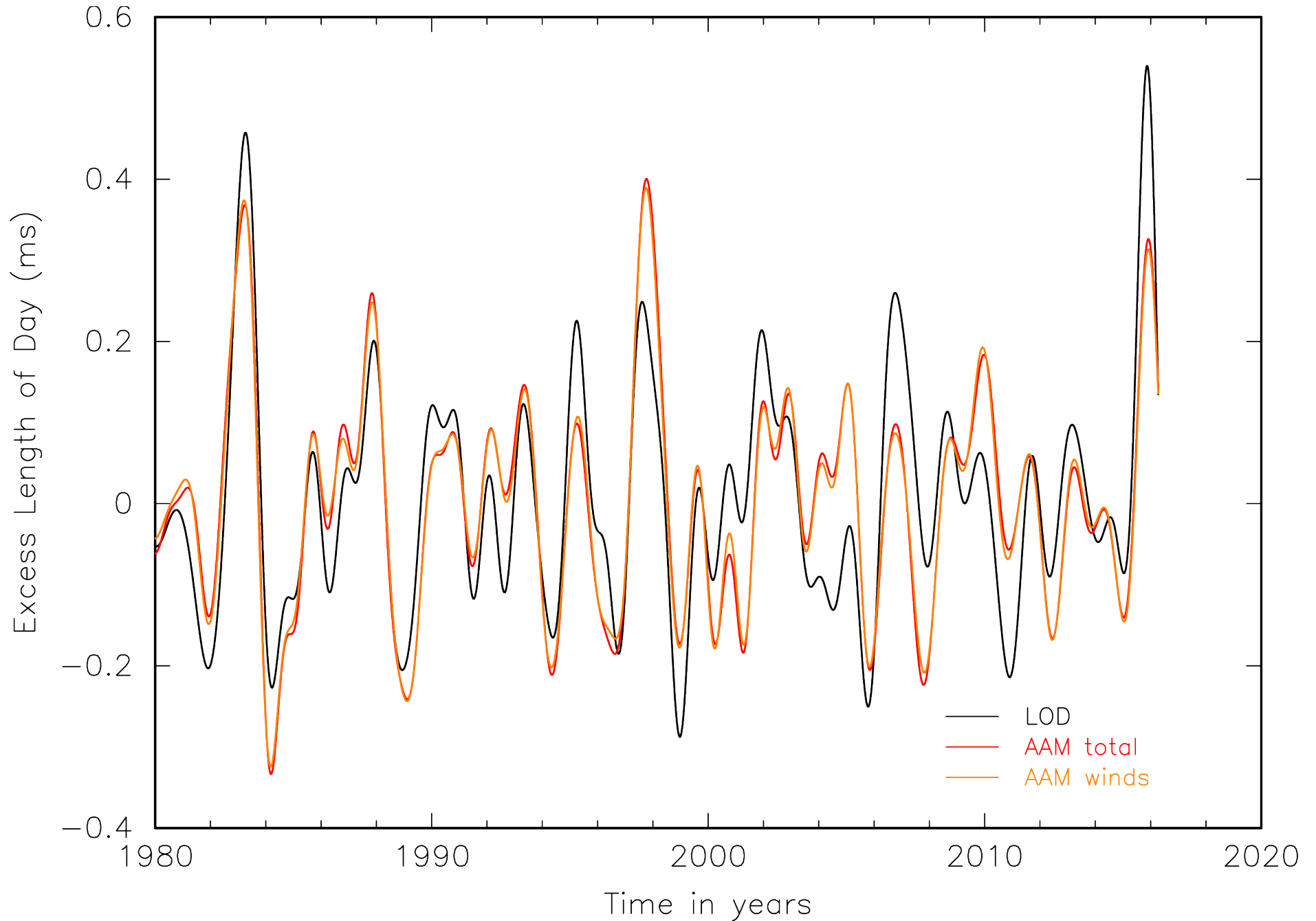
ENSO and LOD

- During an ENSO event
 - Southern Oscillation Index decreases
 - Standardized difference in (Tahiti – Darwin) sea level pressure anomalies decreases
 - Tropical easterlies collapse
 - Atmospheric angular momentum due to winds increases
 - Solid Earth's angular momentum decreases
 - Length of day increases
- Investigate effect of 2015–2016 ENSO on LOD
 - Compare observations of LOD to models of AAM
 - In interannual frequency band
 - After removing tidal signals from LOD

Interannual Length-of-Day



Interannual Length-of-Day



Summary

- Lunar laser ranging
 - Directly measures recession of Moon due to tidal dissipation
 - 3.79 ± 0.07 cm/yr
 - Associated secular change in length-of-day
 - +1.8 ms/cy
- Satellite laser ranging
 - Longest available series of observed EOPs
 - Is the backbone used when combining EOPs from different techniques
 - Needed when studying long-period changes in Earth's rotation
 - Interannual to decadal changes in polar motion possibly caused by changes in terrestrial water storage
 - Interannual changes in length-of-day caused by interannual changes in winds
- Observations must continue in order to gain better understanding of long-period changes in Earth's rotation

<https://www.youtube.com/watch?v=RBZmLzv9NKQ>