Estimating Present-Day True Polar Wander

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Introduction

- Glacial isostatic adjustment
  - Changes figure of Earth
    - Causes rotation pole to drift
- Estimate trend in pole path over last century
  - Optical astrometric observations of star positions
    - Homogeneous International Latitude Service polar motion series
    - More recent Hipparcos polar motion series
  - Space-geodetic observations
    - SPACE96 & SPACE2007 combinations of LLR, SLR, VLBI, & GPS observations
- Compare and contrast estimated trends
  - Search for recent change in trend
    - Possibly caused by change in present-day ice melting

Polar Motion Observations

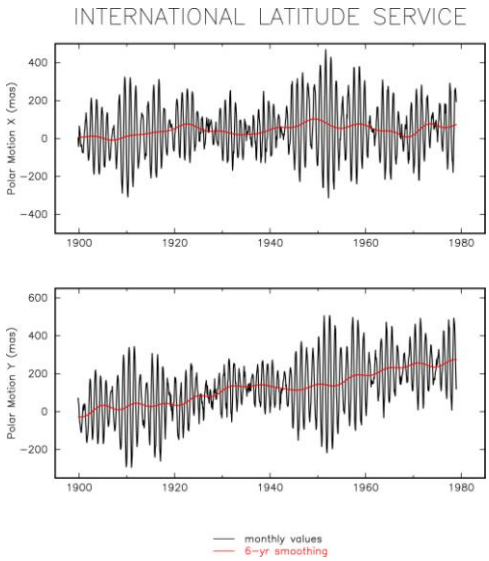
- Optical astrometric estimates of polar motion
  - Based on latitude observations
    - Determined from measurements of star positions
    - Taken at globally distributed network of observing stations
  - Susceptible to local errors
    - Seasonal component of polar motion known to be corrupted by systematic errors
    - Other components, like decadal-scale variations, may also be corrupted
  - Available since 1899
- Space-geodetic estimates of polar motion
  - Based on independent LLR, SLR, VLBI, & GPS observations
    - Taken at globally distributed network of observing stations
  - No evidence of systematic errors
    - By comparing observations taken by independent space-geodetic techniques
  - Available since 1976

EOPs and TRFs

- Earth orientation parameters (EOPs)
  - Determined from observations taken at a network of stations
  - Specify the time varying orientation of that network in space
- Terrestrial reference frames (TRFs)
  - Determined from observed positions of stations in network
  - Orientation and orientation-rate of TRF must be specified
    - Conventional choice for orientation (Greenwich meridian, CIO)
    - No net rotation (NNR) of network with respect to Earth's surface (plate motions)
- EOPs are degenerate with orientation of TRF
  - Change in pole location <=> change in TRF orientation
    - Positive change in PMX equivalent to left-handed rotation of TRF about y-axis
    - Positve change in PMY equivalent to left-handed rotation of TRF about x-axis (PMY defined to be positve towards 90ºW longitude)
- To compare different EOPs, must know their TRFs

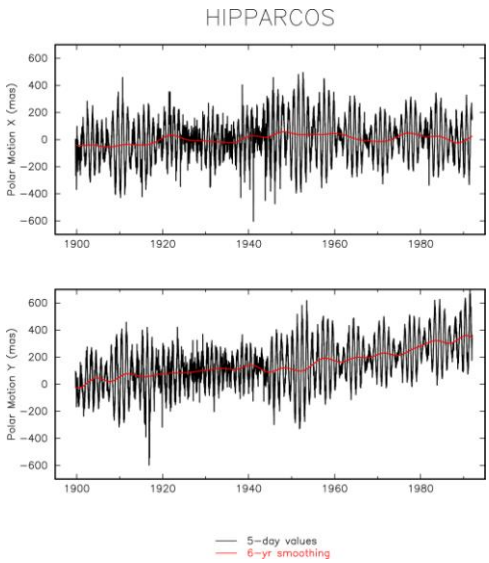
International Latitude Service

- International Latitude Service
  - Established in 1895 by IAG
  - Dedicated to monitoring polar motion by optical astrometric observations of latitude variations
    - Observing stations located at 39° 8' N latitude
    - All stations observe same star pairs
- Homogeneous ILS polar motion series
  - Re-reduction of ILS latitude observations (Yumi and Yokoyama, 1980)
    - Done for express purpose of removing inconsistencies evident in prior reductions
  - Used 772,395 latitude observations from the 7 ILS observing stations
  - Reference frame defined by fixing mean latitude of observing stations to their CIO values
    - Latitudes NOT corrected for plate tectonic motions
  - Resulting polar motion series spans 1899.8 to 1979.0 at monthly intervals
    - 10–20 mas uncertainty



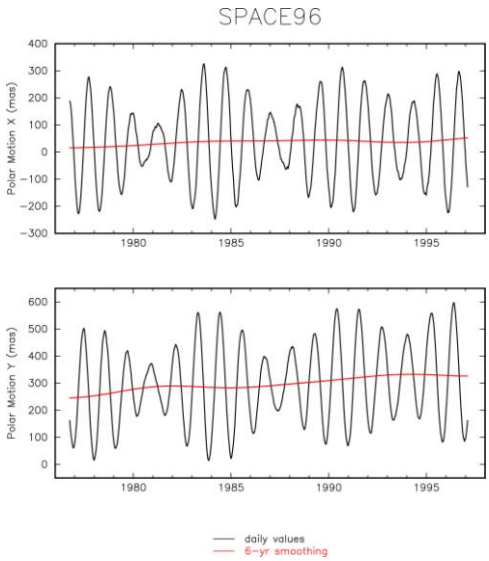
Hipparcos

- Hipparcos Earth orientation series
  - Re-reduction of optical astrometric observations (Vondrák et al., 1998)
    - 4,315,628 latitude, longitude, and zenith distance observations from 48 instruments
    - Includes ILS latitude observations
  - Based on final Hipparcos star catalog and then-current astronomical standards
    - Including plate tectonic motion model (NNR-NUVEL-1)
  - Mean geographic coordinates of individual instruments adjusted in order to place solution in then-current IERS TRF
    - Coordinate rates NOT adjusted
  - Resulting polar motion series spans 1899.7 to 1992.0 at 5-day intervals
    - 10–30 mas uncertainty



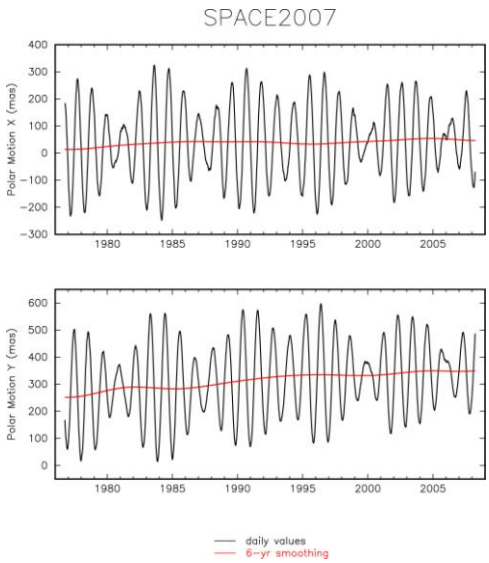
SPACE96

- Combined EOP Series
  - Combination of space-geodetic EOP measurements
    - Lunar and satellite laser ranging (LLR & SLR), very long baseline interferometry (VLBI), global positioning system (GPS)
  - Prior to combination, individual LLR, SLR, VLBI, and GPS series are adjusted so that they are consistent with each other
    - Median polar motion rate adjustment was 0.11 mas/yr
  - Combined solution placed within then-current IERS TRF
    - ITRF94
  - Resulting polar motion series spans 1976.7 to 1997.1 at daily intervals
    - 0.1 to 3 mas uncertainty



SPACE2007

- Combined EOP Series
  - Combination of space-geodetic EOP measurements
    - Lunar and satellite laser ranging (LLR & SLR), very long baseline interferometry (VLBI), global positioning system (GPS)
  - Prior to combination, individual LLR, SLR, VLBI, and GPS series are adjusted so that they are consistent with each other
    - Median polar motion rate adjustment was 0.018 mas/yr
  - Combined solution placed within current IERS TRF
    - ITRF2005
  - Resulting polar motion series spans 1976.7 to 2007.1 at daily intervals
    - 0.05 to 3 mas uncertainty



Trend Recovery

- Besides trend, polar motion consists largely of
  - Annual and Chandler wobbles
  - Decadal-scale variations
- Problem
  - Must estimate trend in presence of these other signals
- Solution
  - Remove annual and Chandler wobbles by low-pass filter
    - 6-year cutoff period
  - Recover trend by simultaneous weighted least-squares fit for
    - Mean, trend, and
    - Periodic terms at frequencies of peaks in spectrum of 6-yr smoothed series (3 periodic terms for SPACE96; 3 for SPACE2007; 12 for ILS; 14 for Hipparcos)
- This should produce an unbiased estimate of trend

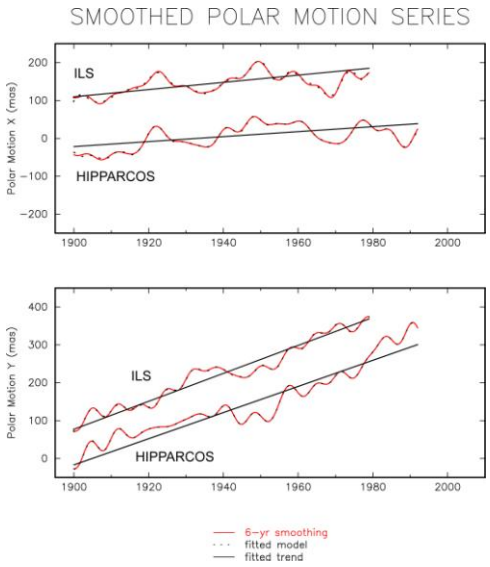
Estimated Trends

Int Lat Service (1899.8 – 1979.0)
(Gross & Vondrák, 1999)
3.81 mas/yr towards 75.5ºW

ILS corrected for plate motions
(NNR-NUVEL-1A; Argus & Gross, 2004)
3.53 mas/yr towards 79.9ºW

HIPPARCOS (1899.7 – 1992.0)
(NNR-NUVEL-1; Gross & Vondrák, 1999)
3.51 mas/yr towards 79.2ºW

HIPPARCOS (NNR-NUVEL-1A)
3.51 mas/yr towards 78.4ºW



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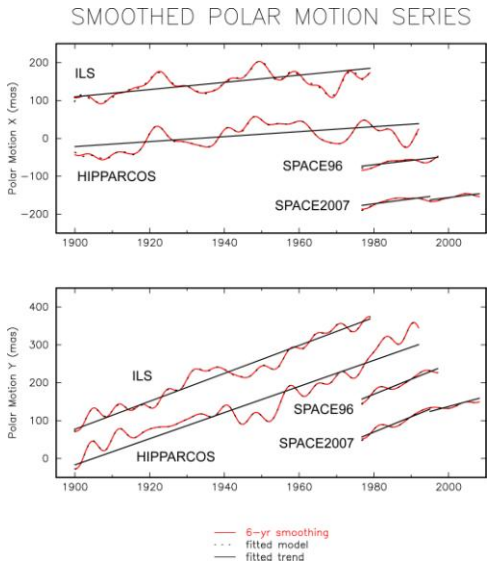
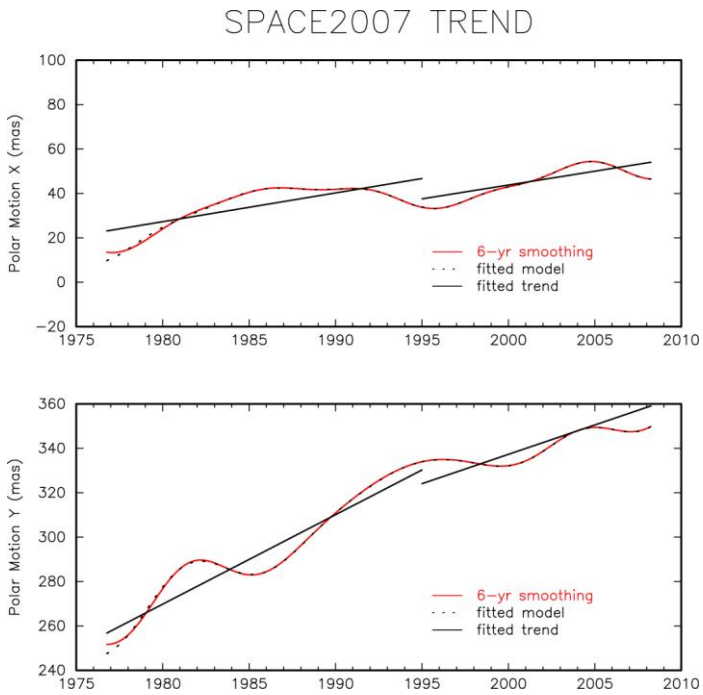
SPACE96 (1976.7 – 1997.1)
(Gross & Vondrák, 1999)
4.12 mas/yr towards 73.9ºW

SPACE2007 (1976.7 – 1995.0)
4.23 mas/yr towards 72.2ºW

SPACE2007 (1995.0 – 2007.1)
2.92 mas/yr towards 64.8ºW





Summary

- Trend in pole path estimated from
  - Optical astrometric observations spanning last century
    - Trends evident in ILS & HIPPARCOS series are consistent with each other when both series are corrected for same plate motion model (NNR-NUVEL-1A)

      ILS: 3.53 mas/yr towards 79.9ºW Hipparcos: 3.51 mas/yr towards 78.4ºW
  - Space-geodetic observations spanning last 3 decades
    - Trends in SPACE96 & SPACE2007 are consistent with each other before 1995

      SPACE96: 4.12 mas/yr towards 73.9ºW SPACE2007: 4.23 mas/yr towards 72.2ºW
    - Smaller trend in SPACE2007 after 1995 (2.92 mas/yr towards 64.8ºW)
- Decadal variations in pole path (Markowitz wobble)
  - Cause differences in trends estimated from different intervals
    - Responsible for differences seen in above trend estimates (?)
  - Caused by changes in present-day ice mass (?)