Current challenges of monitoring station height with GPS

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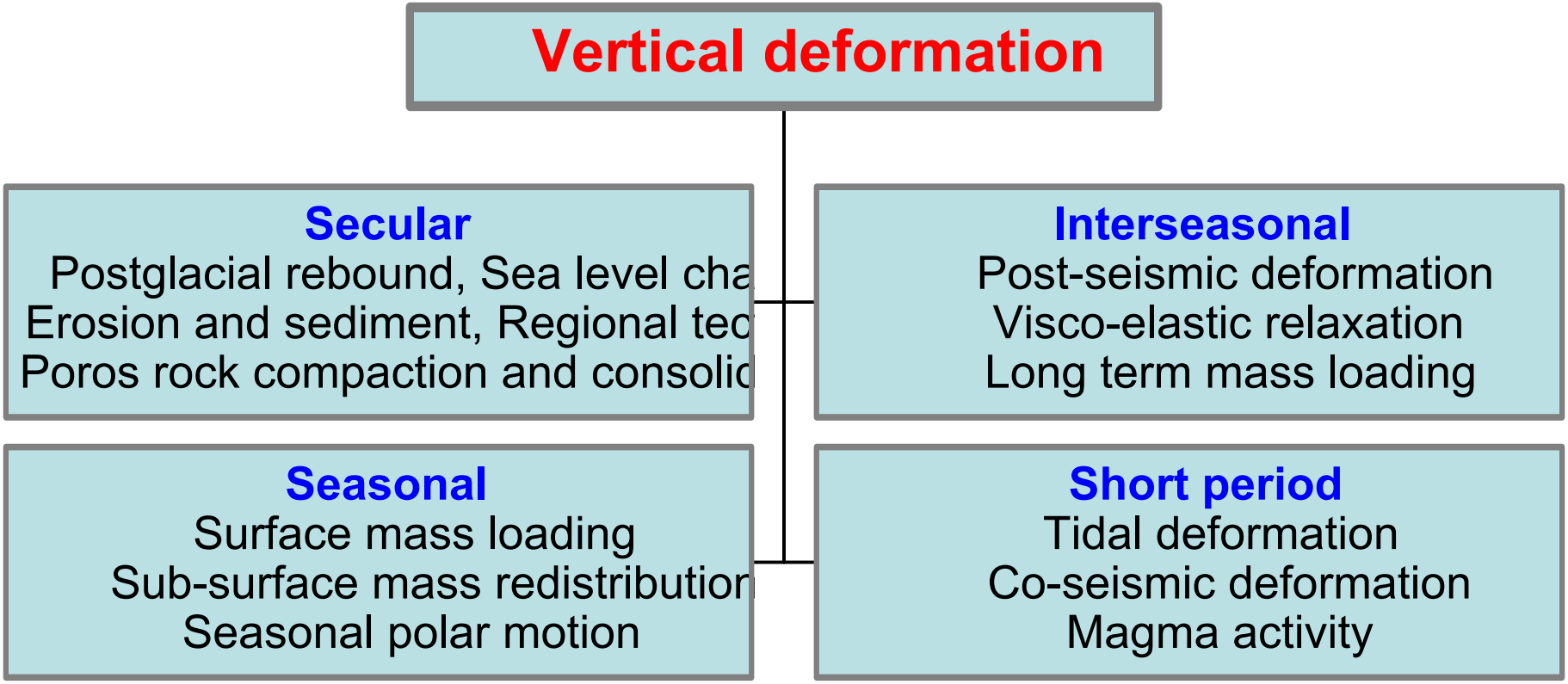
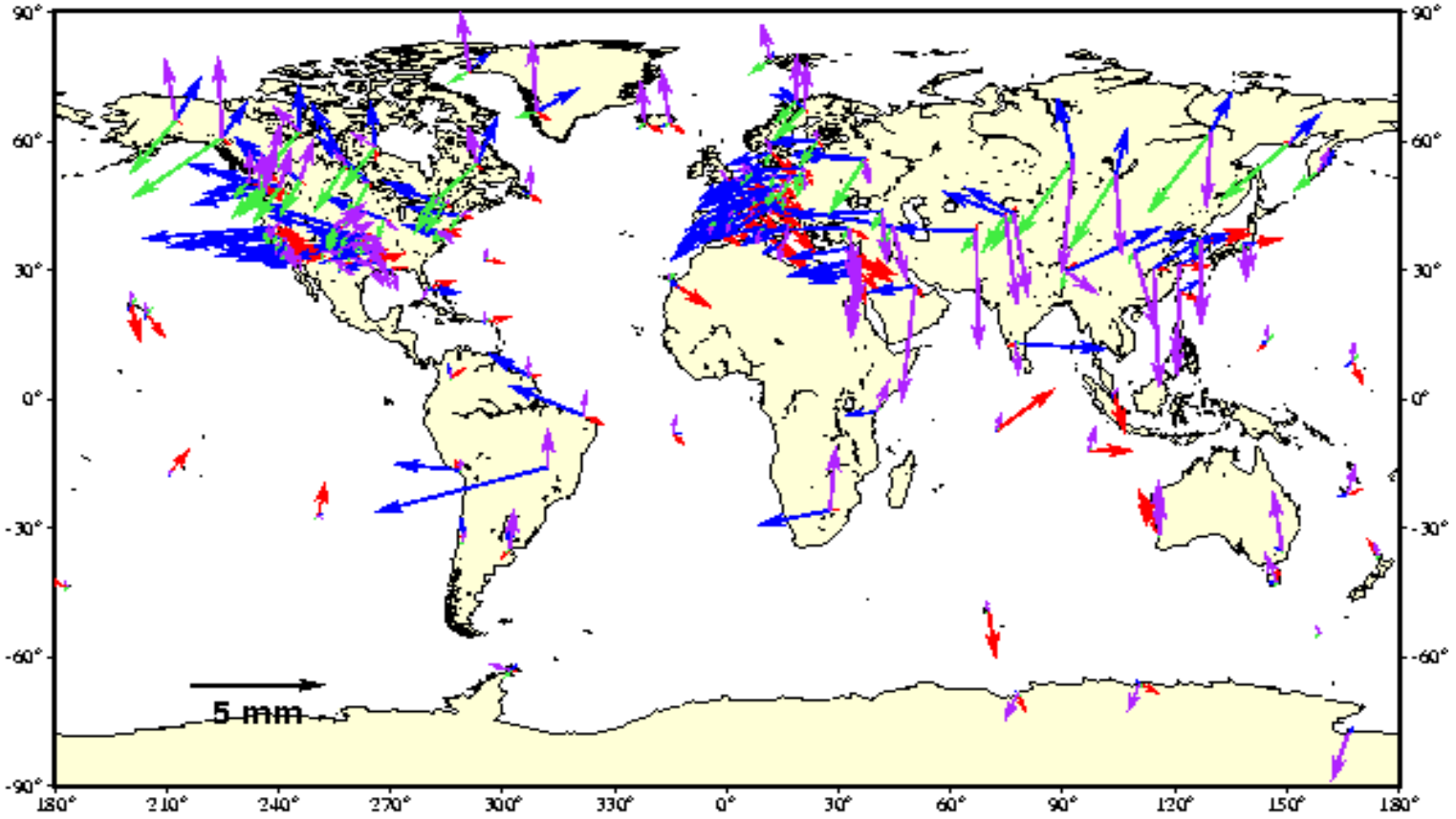
- **Geophysical signals at various time scales in vertical site position time series**
- **Unknown systematic errors exist in GPS station height solutions**
- **Efforts of reducing the systematic errors are complicated due to the high correlation among the vertical parameters**
- **Interpretation of the observed vertical displacement field must consider various contributors**

Vertical deformation on different time scales has different geophysical contributors

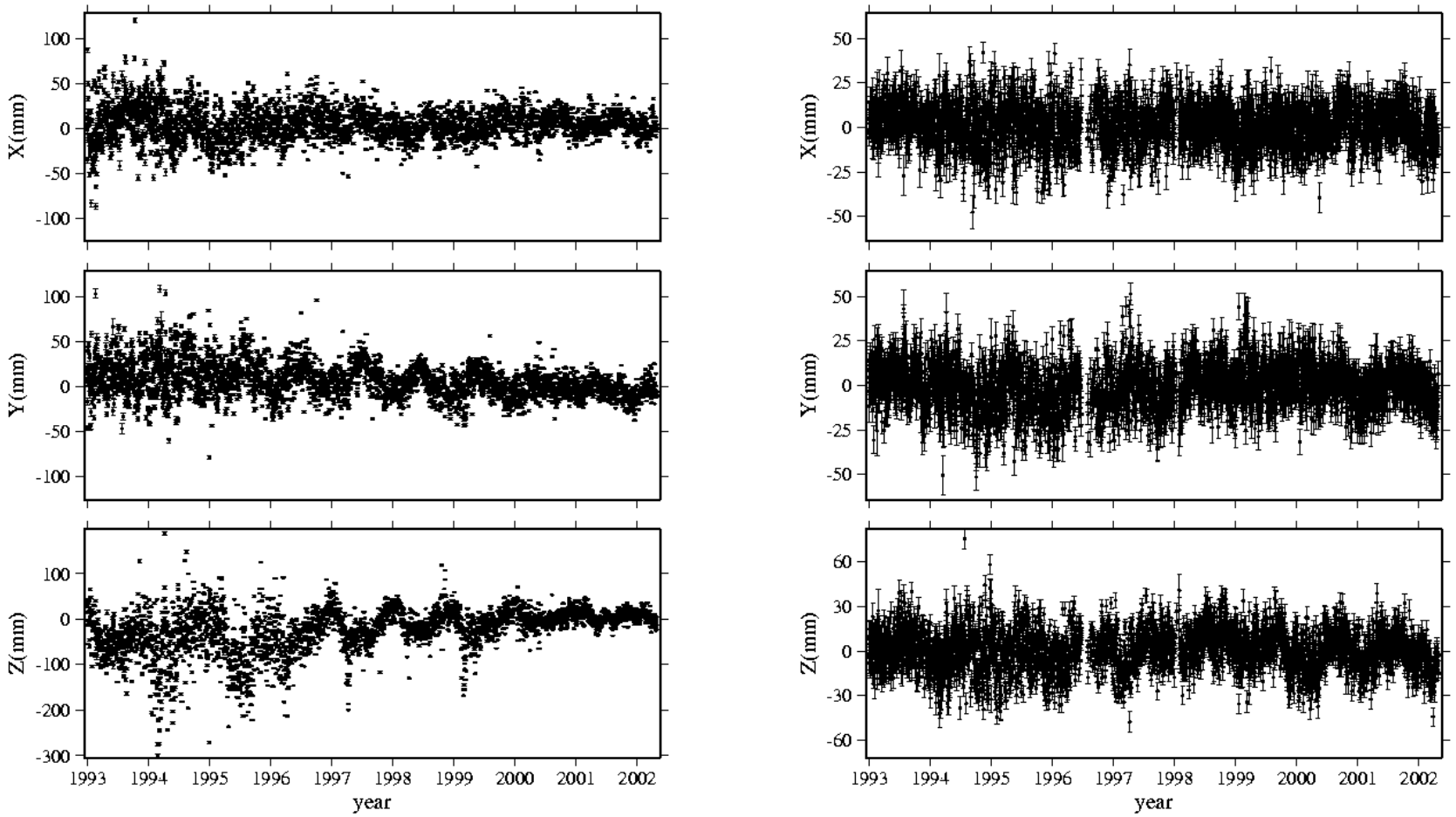


Current GPS vertical solutions are able to detect many vertical deformation signals

- Daily vertical relative coordinate accuracy: 10 mm (Heflin et al., 2002)
- Mass loading caused seasonal vertical displacement: ~5 mm

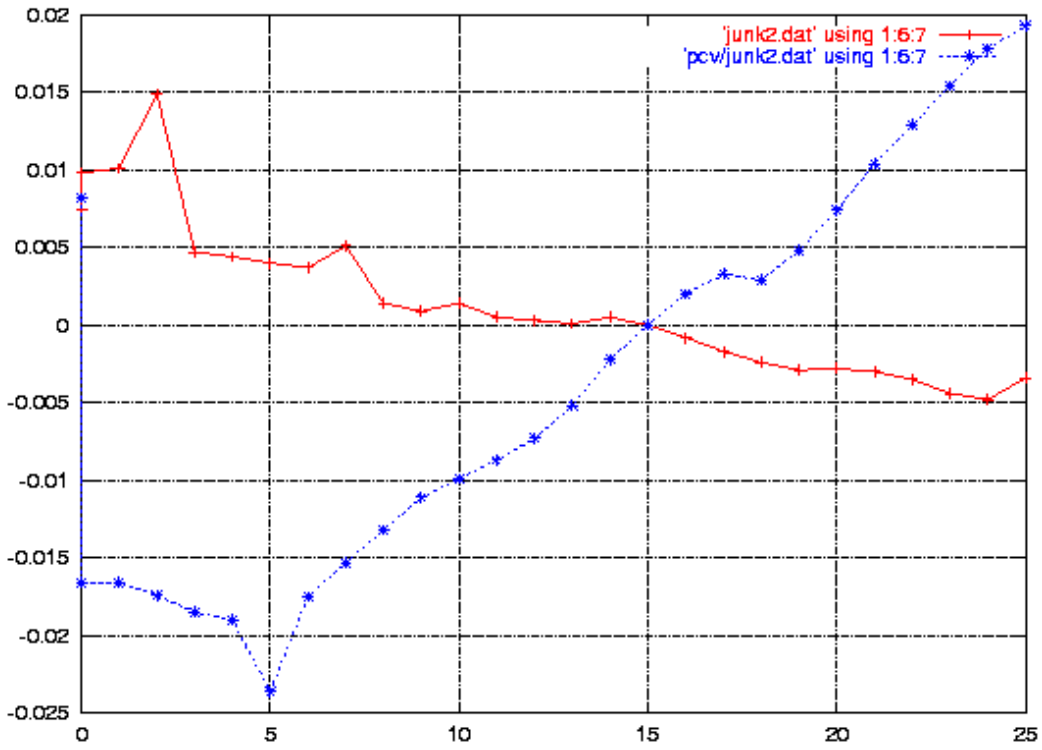


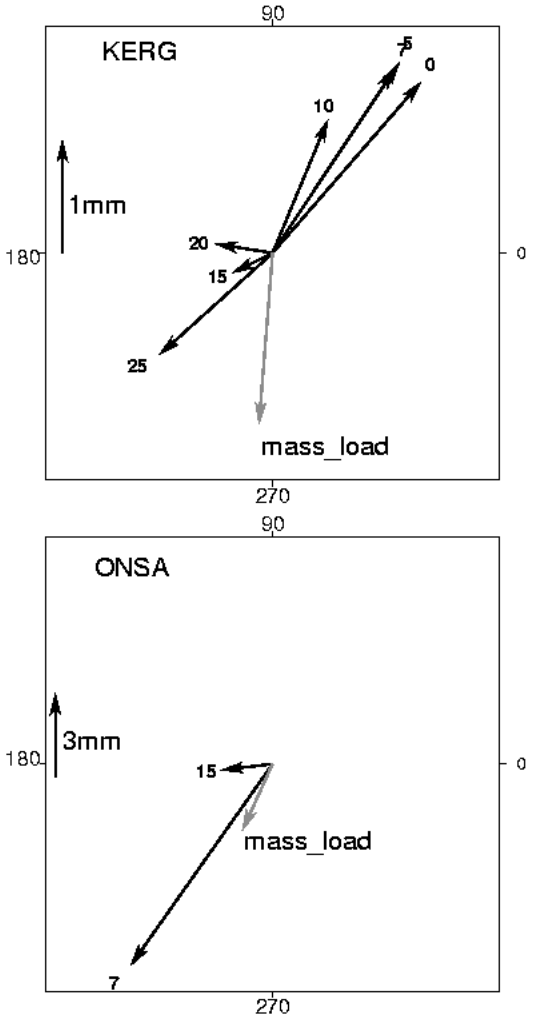
Unresolved systematic errors (1)



- **GPS derived geocenter time series from network shift and degree-1 deformation approaches.**

Unresolved systematic errors (2)





- **Elevation cutoff angle related site height change (GGN) and seasonal term change (courtesy F. Webb, D. Morken & S. Nerem)**

Unresolved systematic errors (3)

- Satellite antenna phase center offset (Bar-Sever, 1998; Zhu et al., 2003)
- Receiver antenna elevation-angle dependent phase center variation (anechoic chamber test and short baseline GPS measurement) and “15 ppb dilemma” (Rothacher et al., 1995; Springer, 2000; Hatanaka et al., 2001; Rothacher, 2001)
- Scale errors (1 ppb, 0.1 ppb/year) (Heflin et al., 2002; Zhu et al., 2003)
- Multipath and environment effect

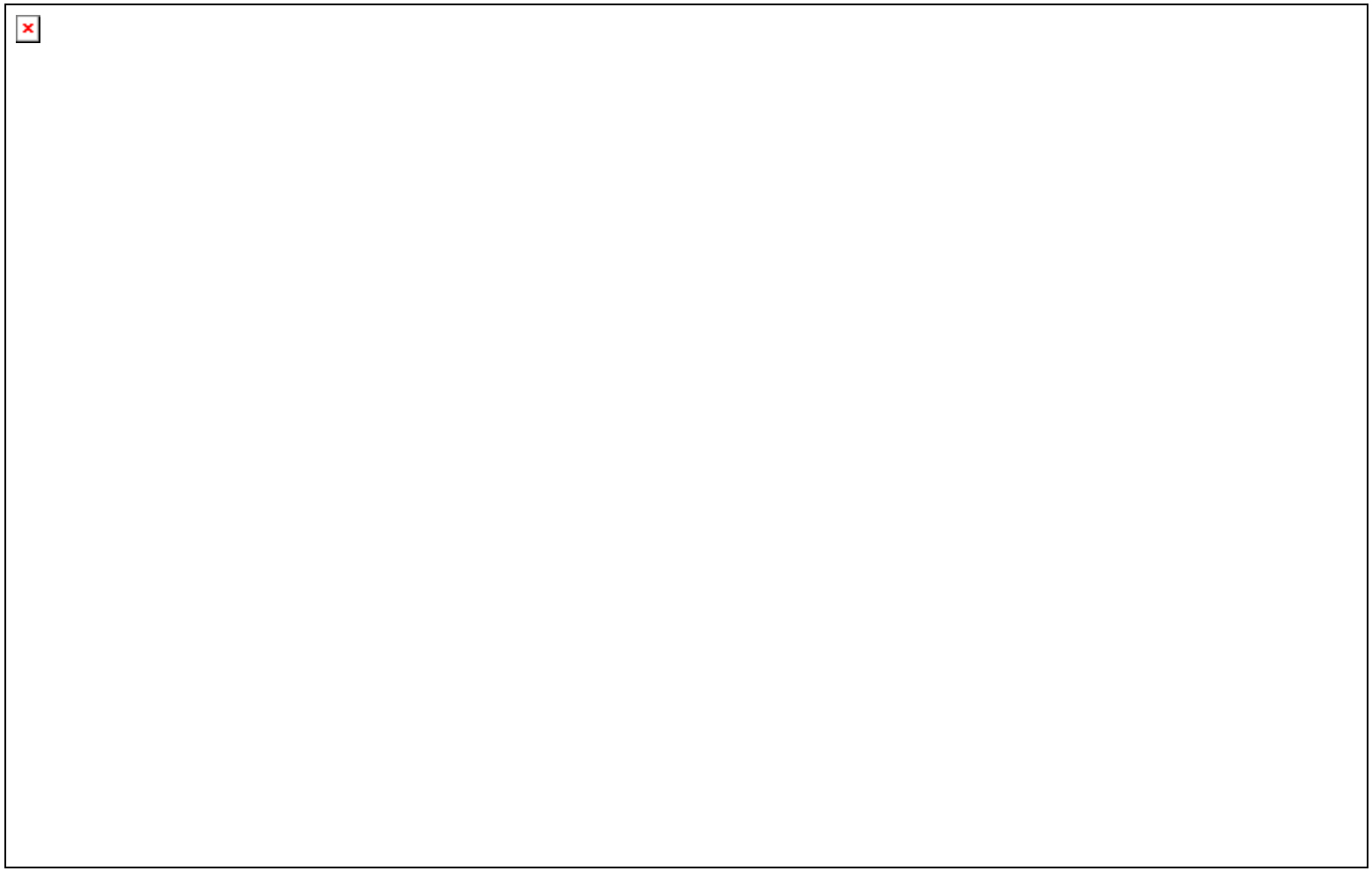
High correlation among estimated parameters

ΔPhase = (receiver clock offset) – (satellite clock offset)

– height*sin(elev) + bias + (troposphere zenith delay)/sin(elev)

–(sat phase center offset)*sqrt(1-0.0576*cos(elev)**2)

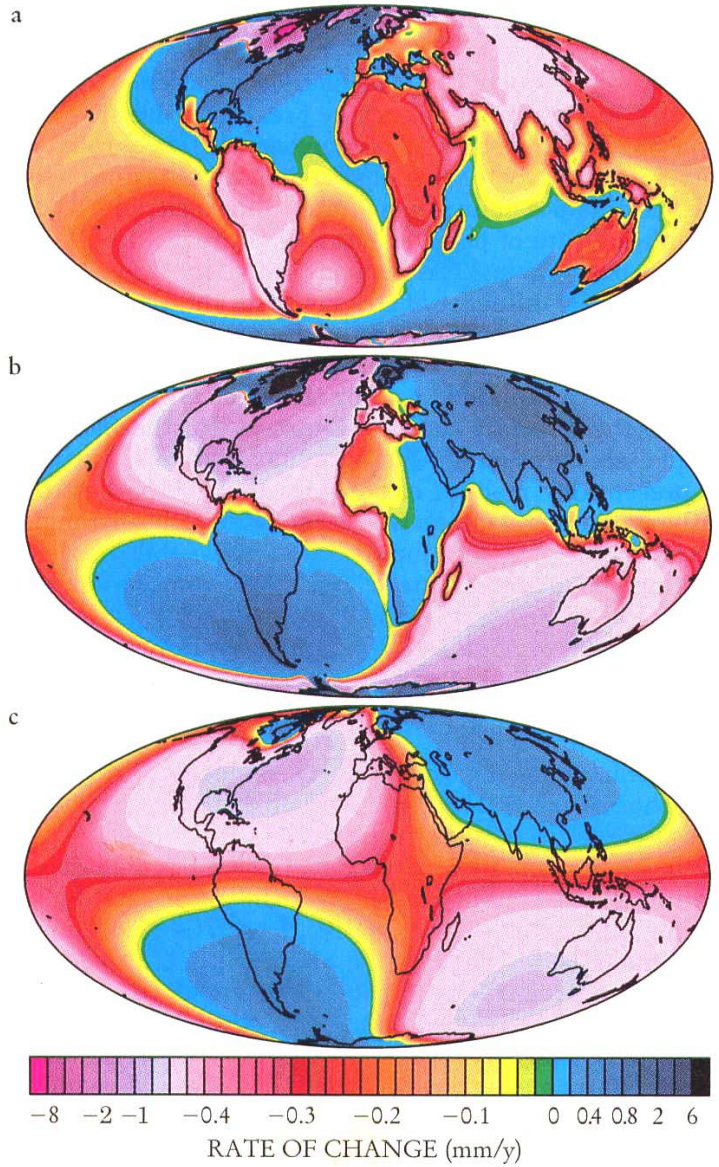
(troposphere gradient terms are not included)



Approaches to reduce vertical systematic errors

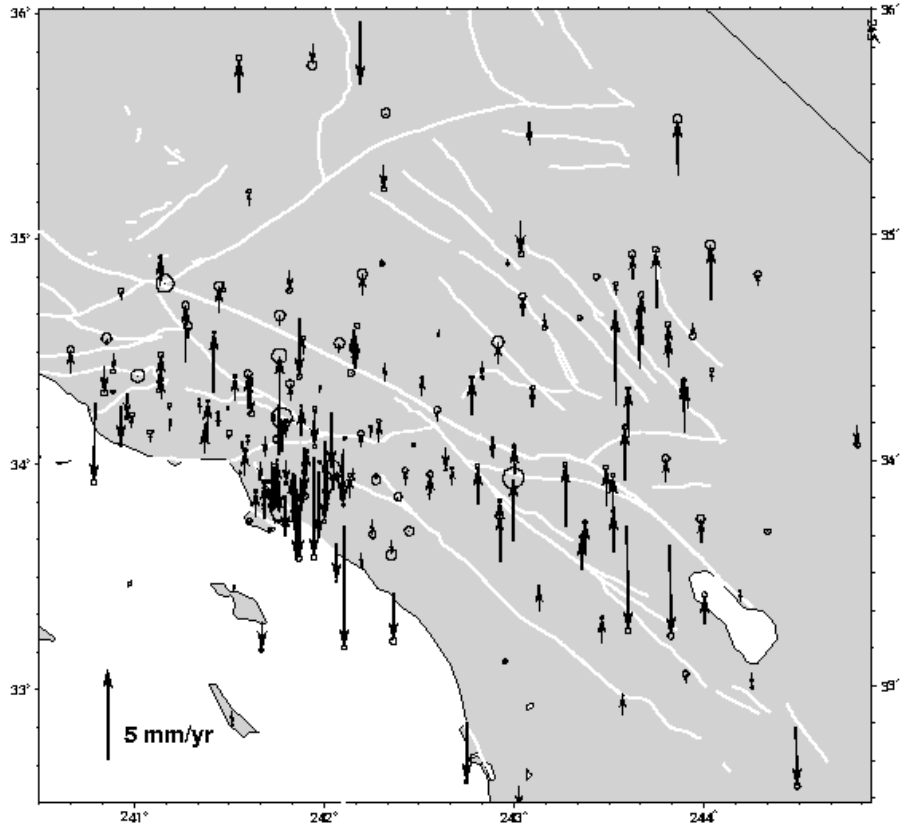
- **Correction:**
  - **Absolute correction**
  - **Adoptive correction**
  - **Elevation angle dependent weighting**
- **Reduce parameter correlation:**
  - **Ambiguity resolution**
  - **Using external atmospheric information**

Sea surface topography (SST) and global sea level (GSL)variation measured from space geodesy



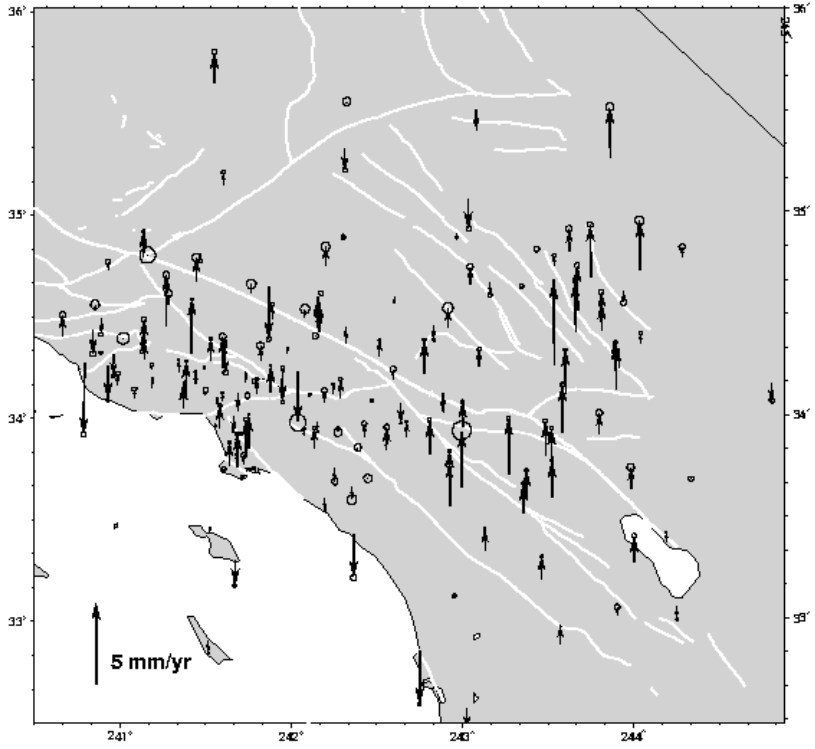
- Signal at 1-2 mm/yr level
- Related to center of mass (CM), while tide gauge records relative sea level
- Reliable vertical motion reference frame to sub-mm/yr level
- Sea floor vertical motion from ICE deglaciation model
- Steric correction
- Role of TIGA
- Courtesy Douglas & Peltier, 2002.

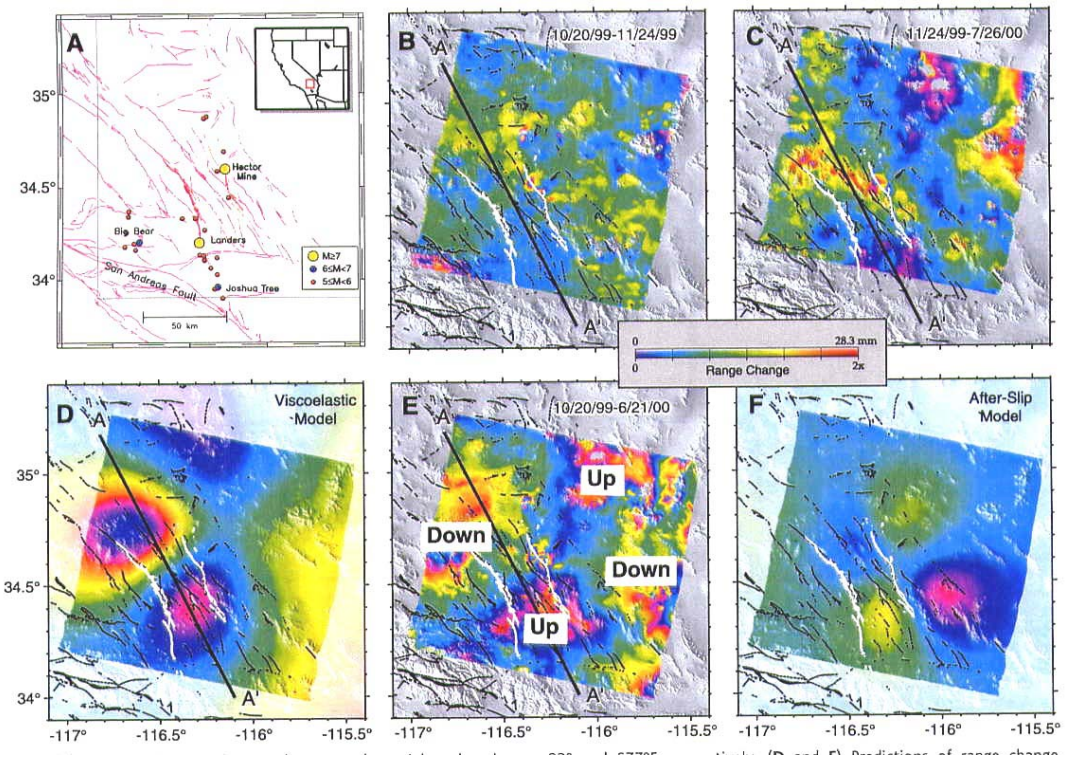
Interpretation of observed vertical deformation field (1)



- Multiple contributors
- Historical and contemporary effects co-exist
- Many local variations
- Example

Interpretation of observed vertical deformation field (2)





- Courtesy Pollitz et al., 2001

Summary

- Systematic errors exist in current GPS analysis, in particular the satellite elevation-angle dependent errors
- Errors could be amplified in vertical direction due to high correlation among estimated parameters in vertical direction
- The request for reliable vertical motion reference frame has been raised
- Open question awaiting for further studies