

Time-Variation Gravity and Ocean Connections

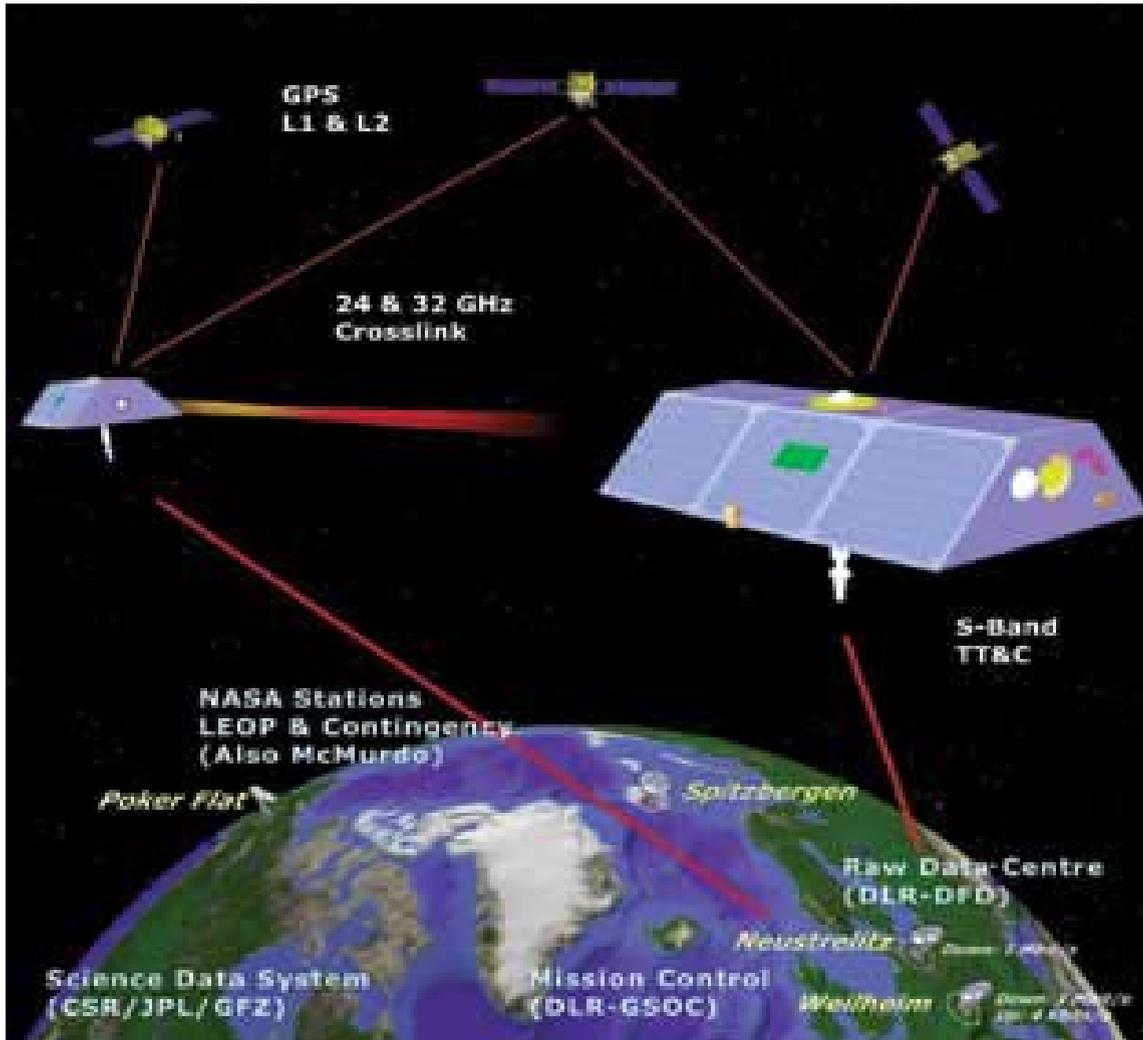


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Measuring time-variable gravity with GRACE

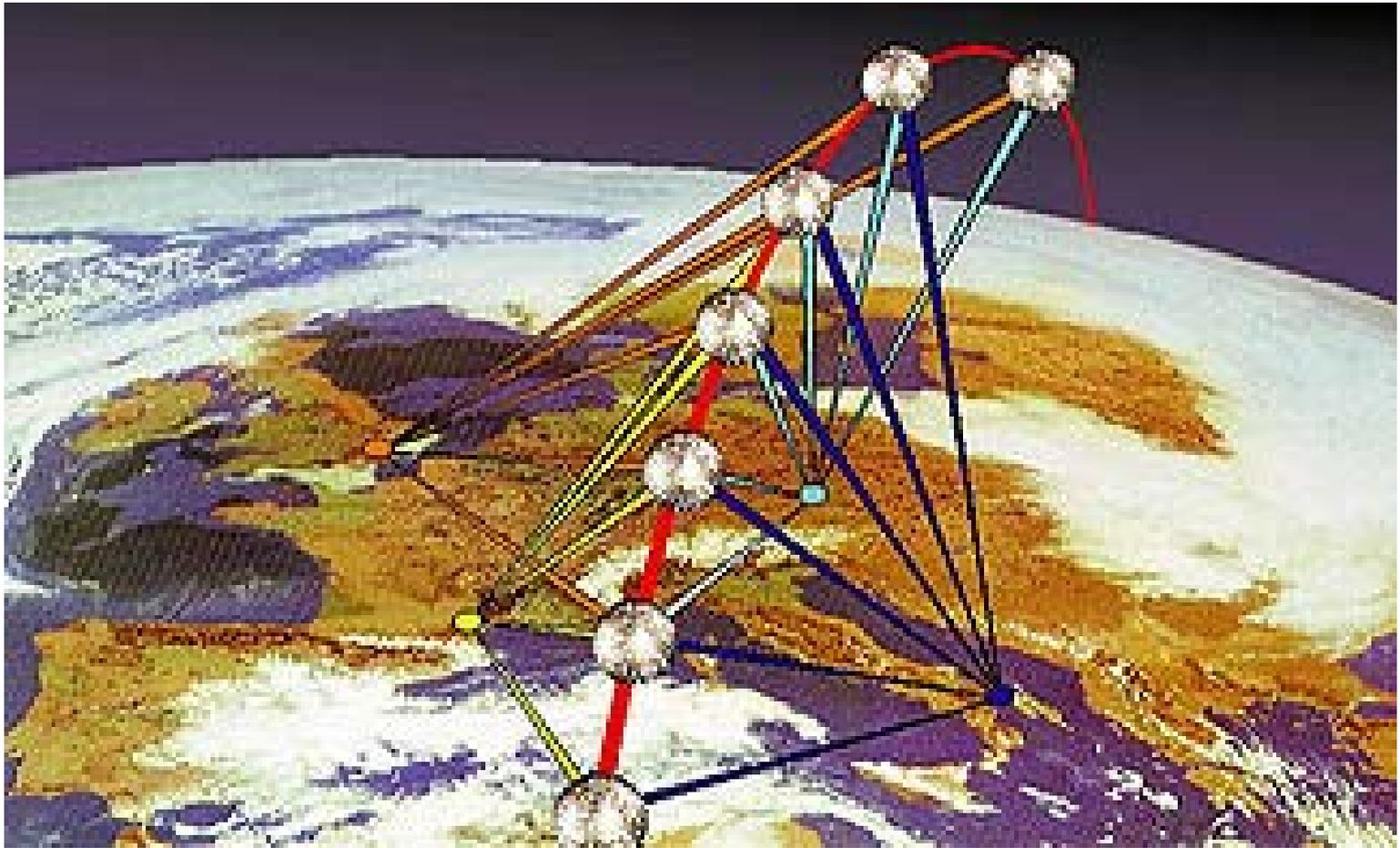


Better gravity field for
Precise Orbit Determination

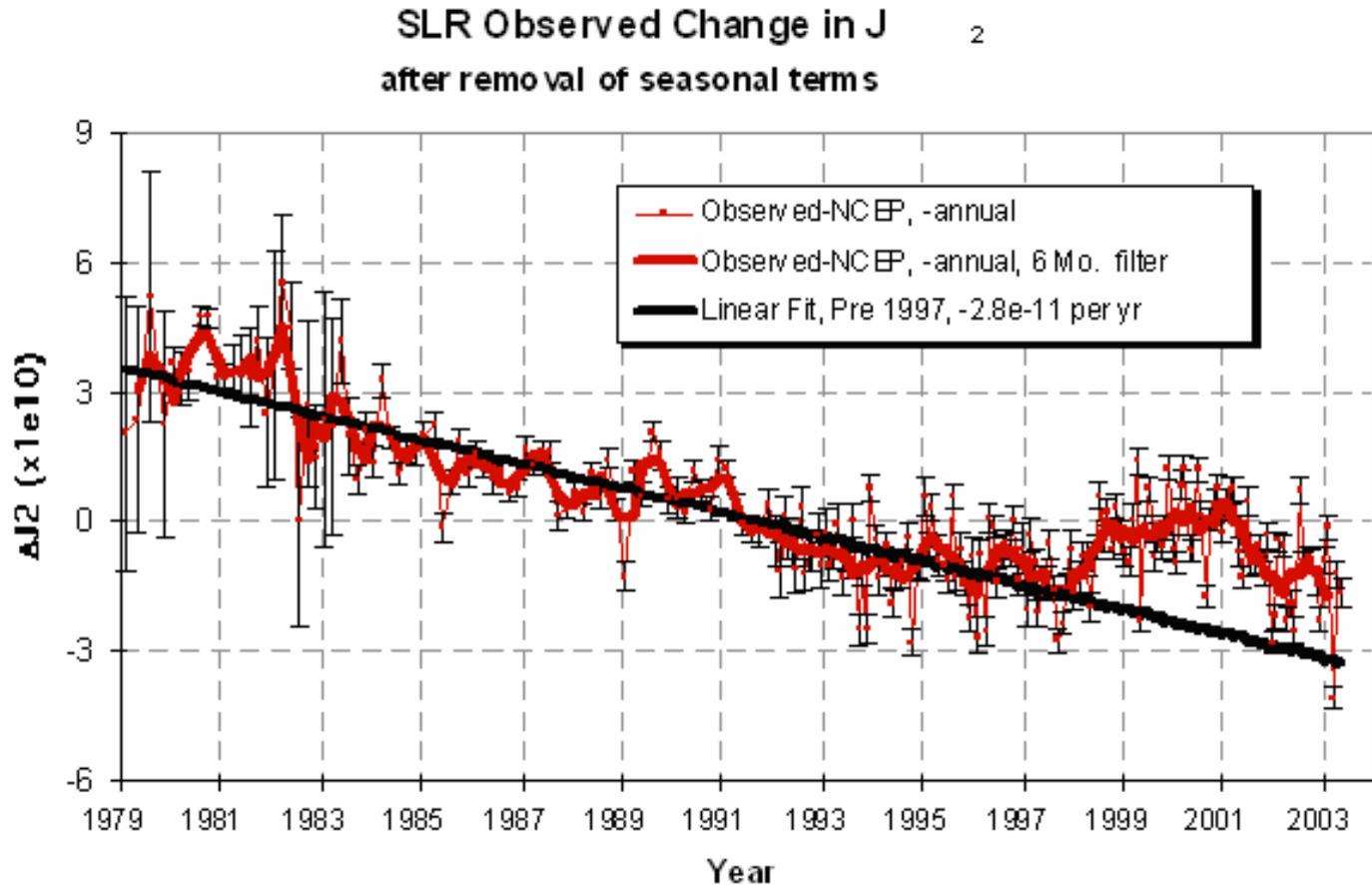
Better geoid for dynamic height

Time-variable gravity signal

Satellite Laser Ranging SLR

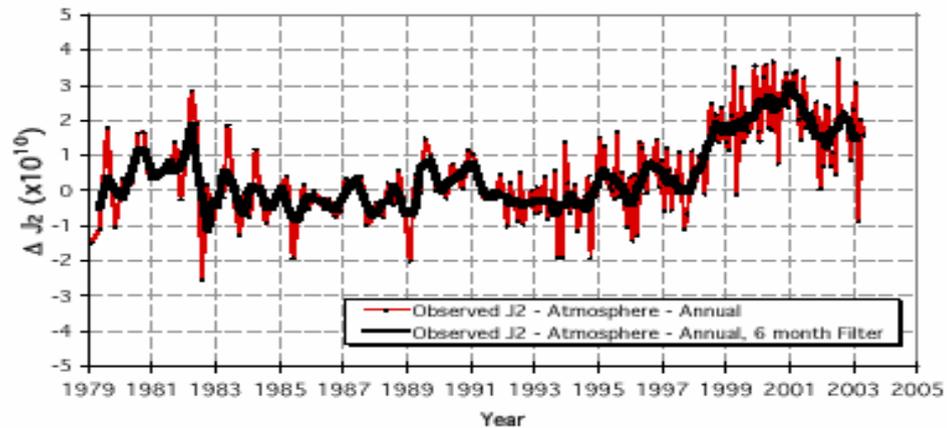
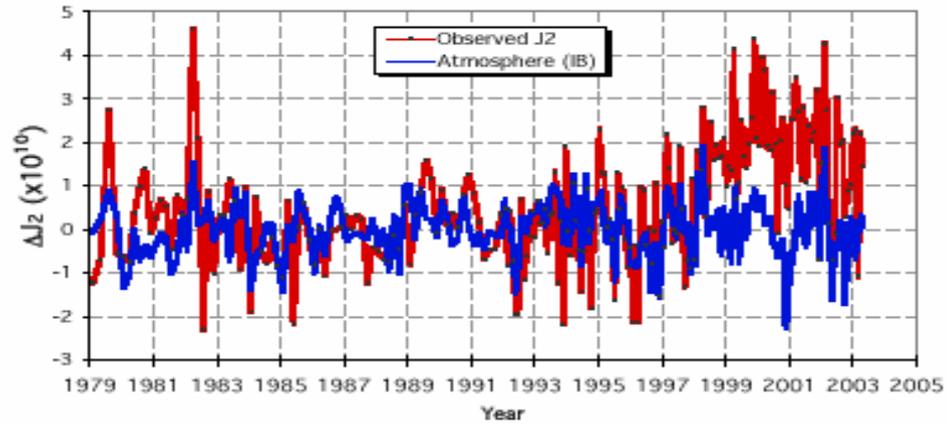


SLR observed J_2 (non-seasonal, non-atmosphere, non-tidal)

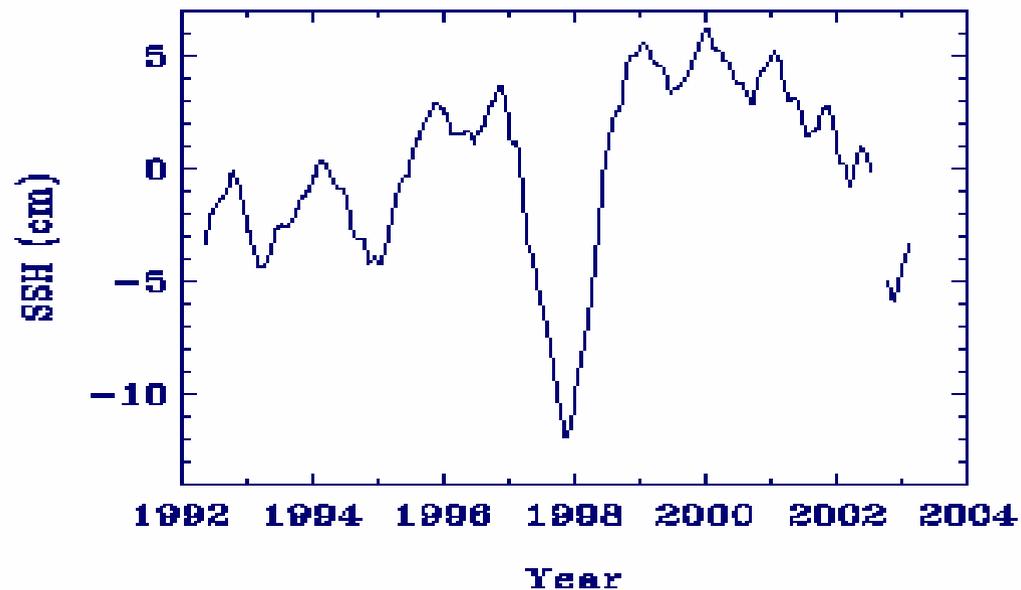
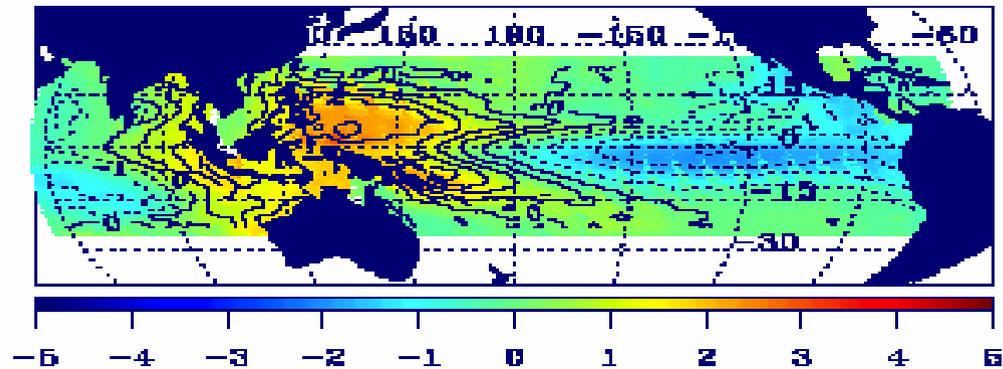


Cox and Chao (2002)

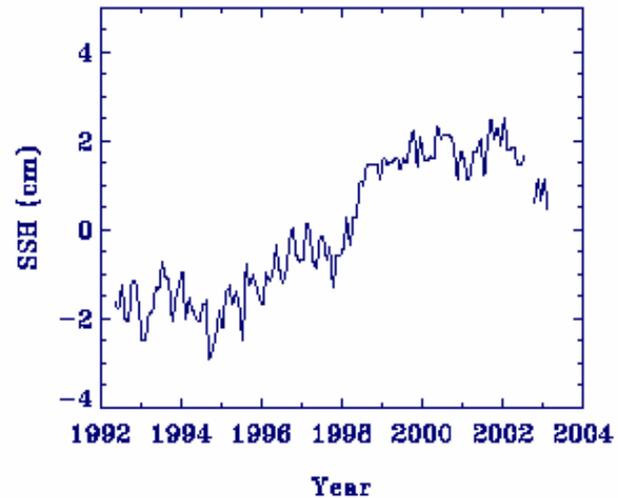
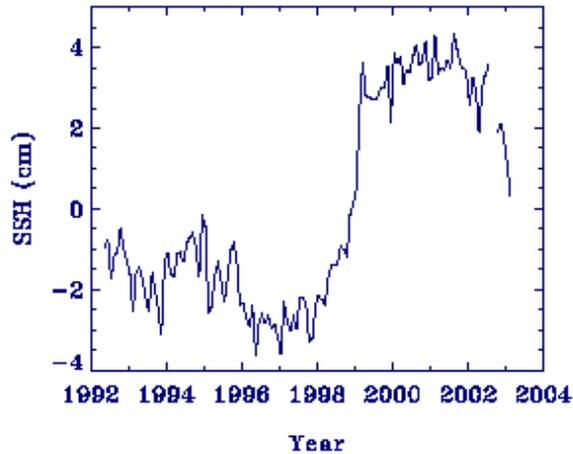
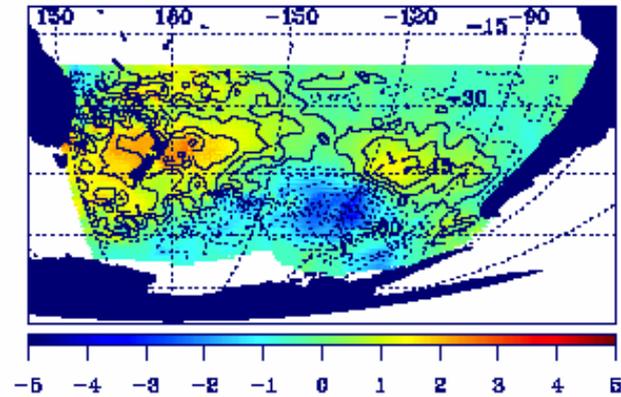
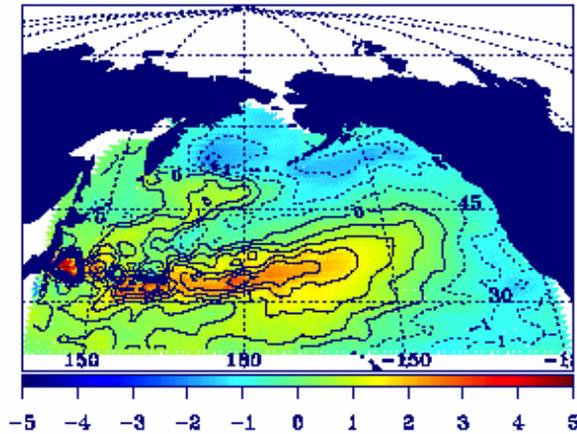
Removing atmosphere contribution in J_2



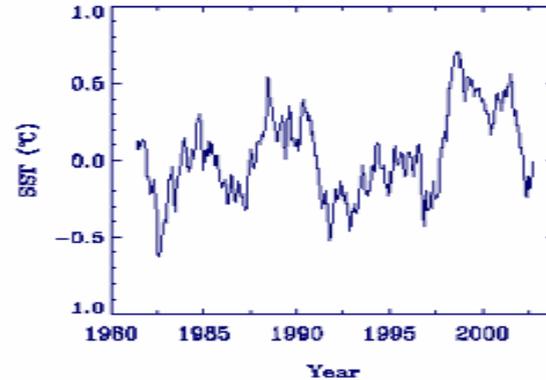
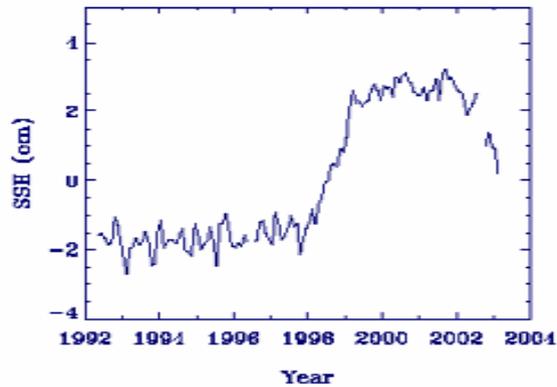
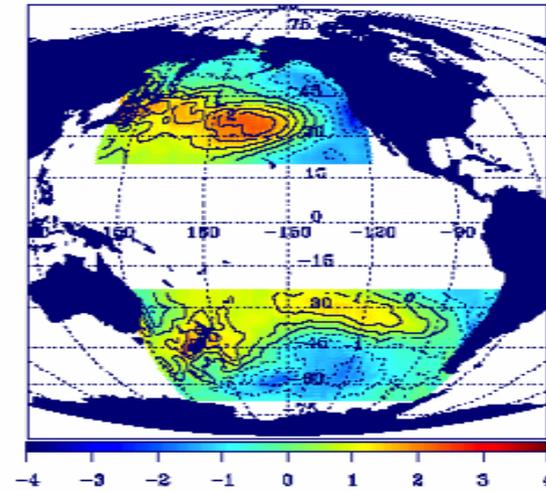
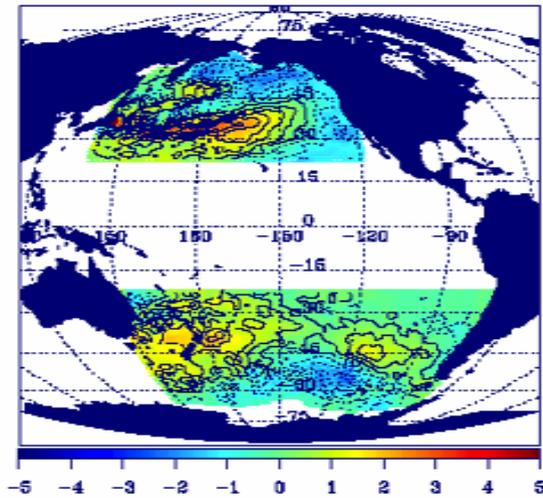
Equatorial Pacific + Indian SSH from T/P (1st EOF/PC)



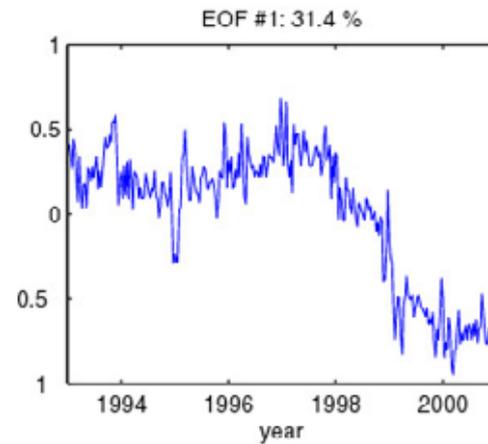
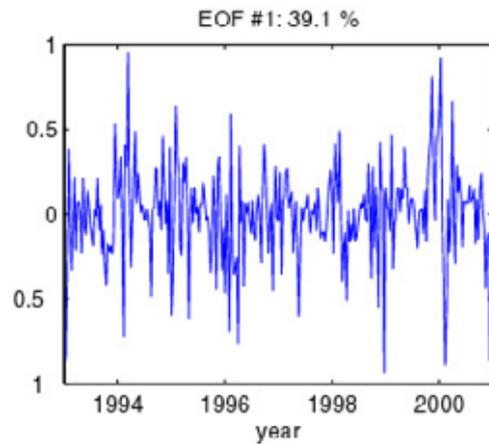
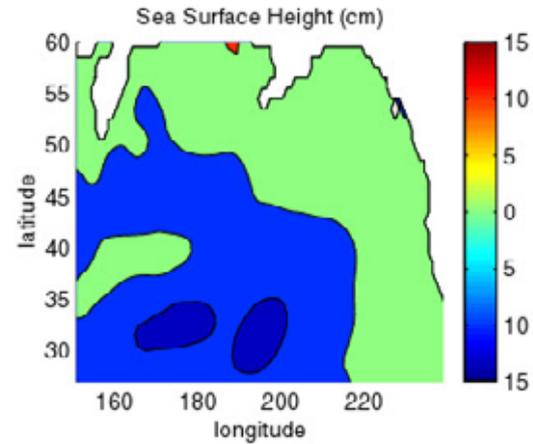
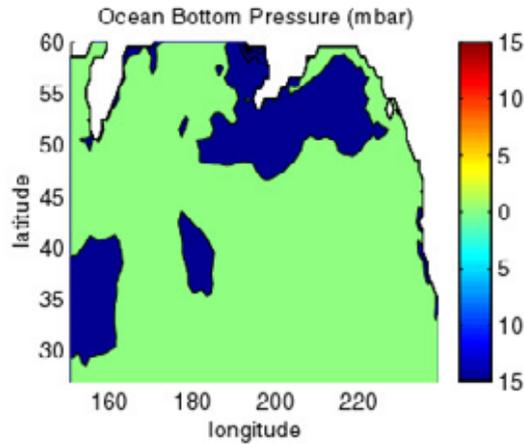
Extratropical North and South Pacific SSH (1st EOF/PC)



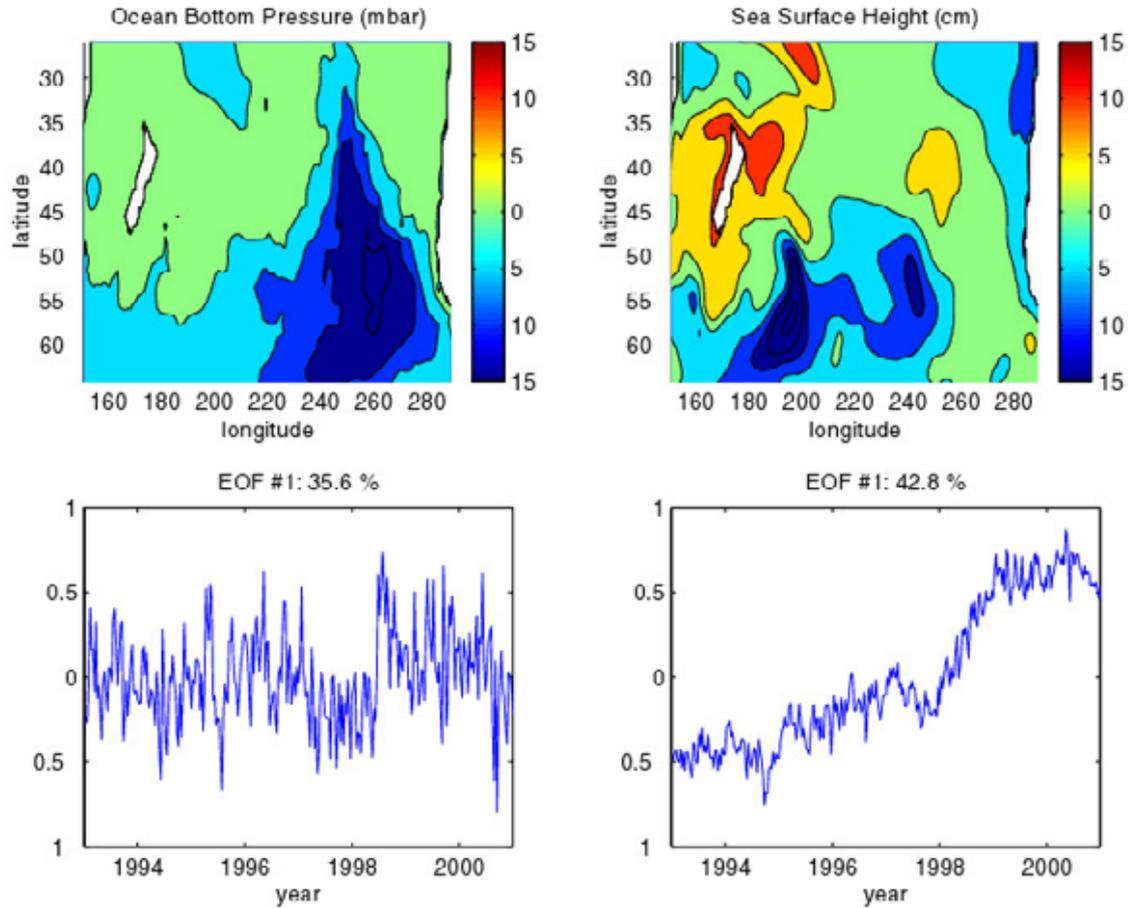
Extratropical North+South Pacific SSH and SST (1st EOF/PC)



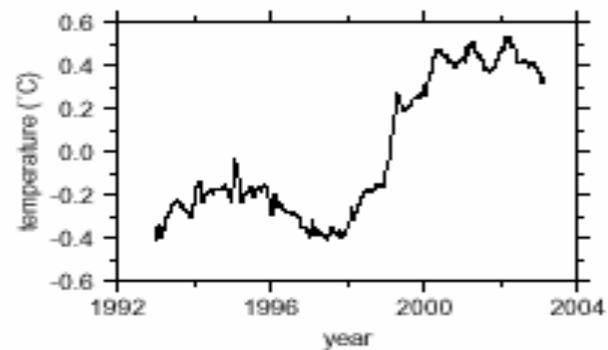
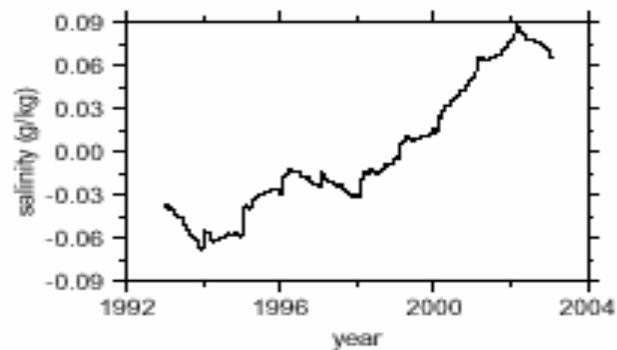
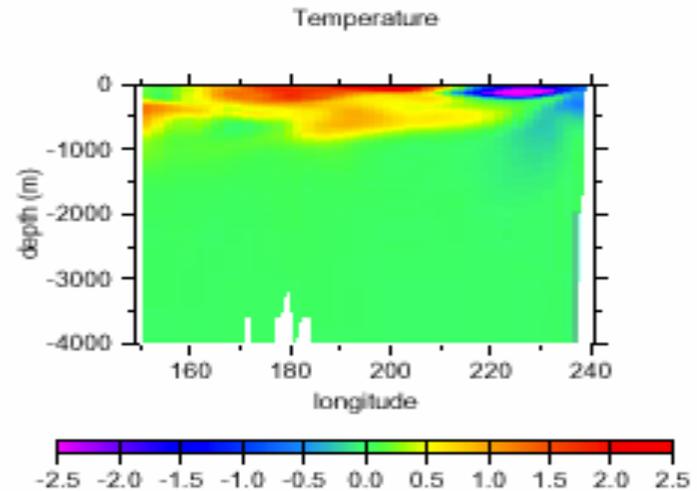
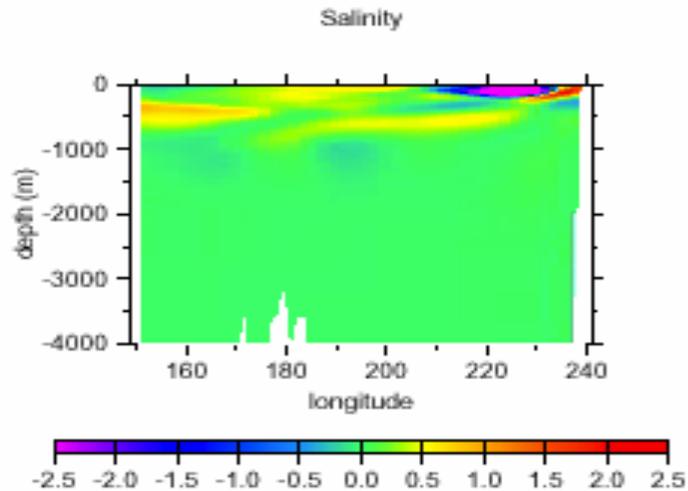
ECCO model - North Pacific EOF/PC Analysis



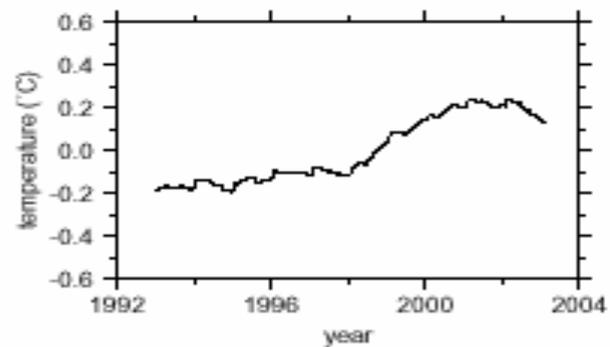
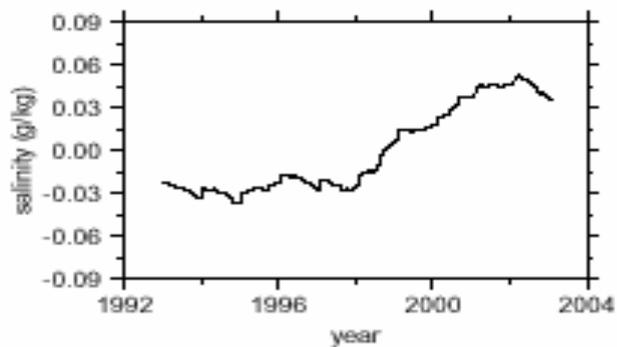
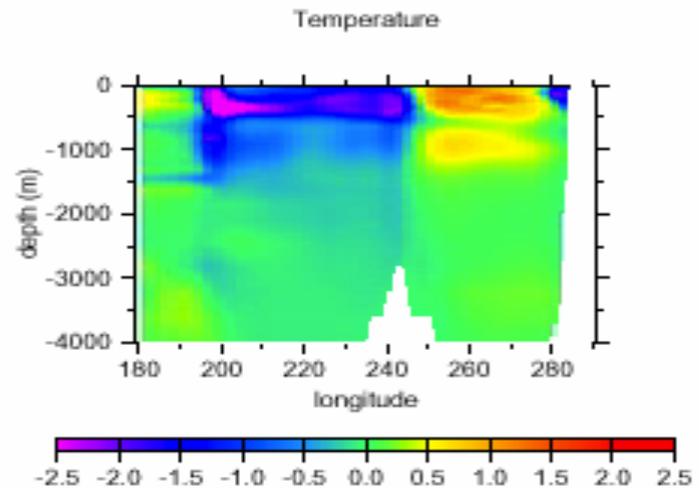
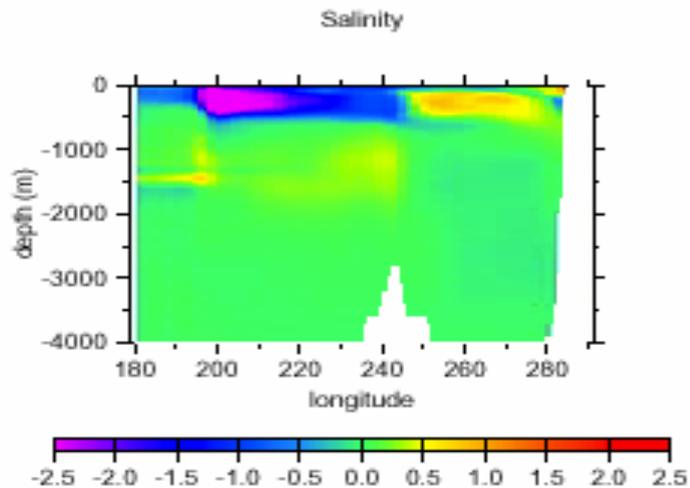
ECCO model - South Pacific EOF/PC Analysis



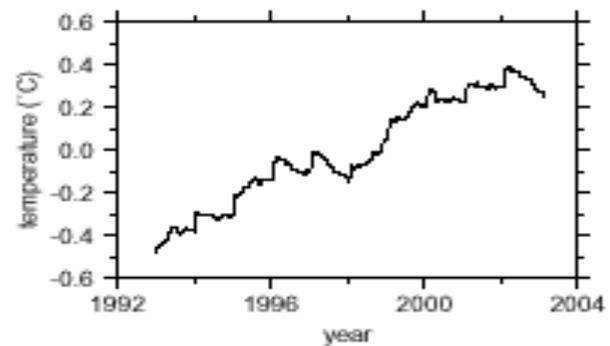
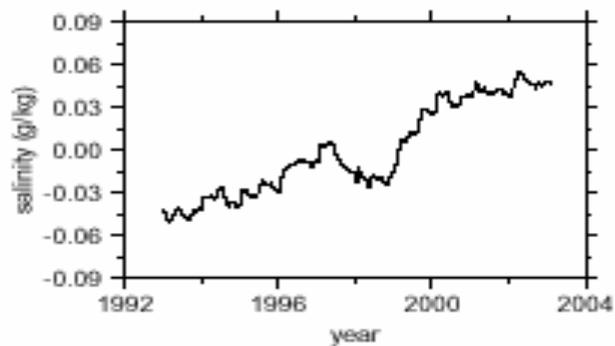
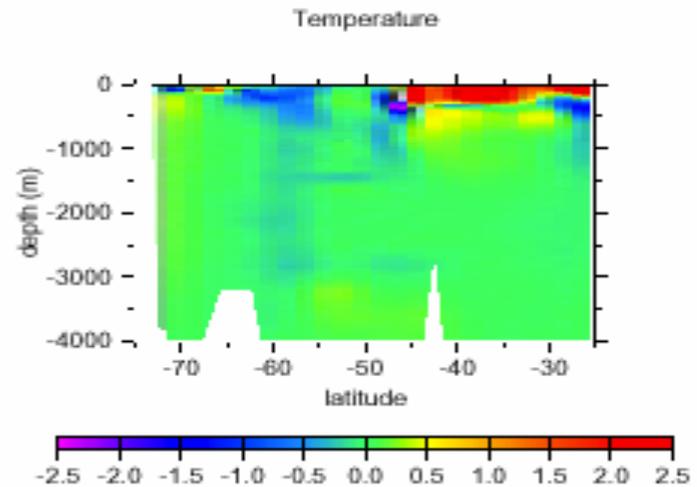
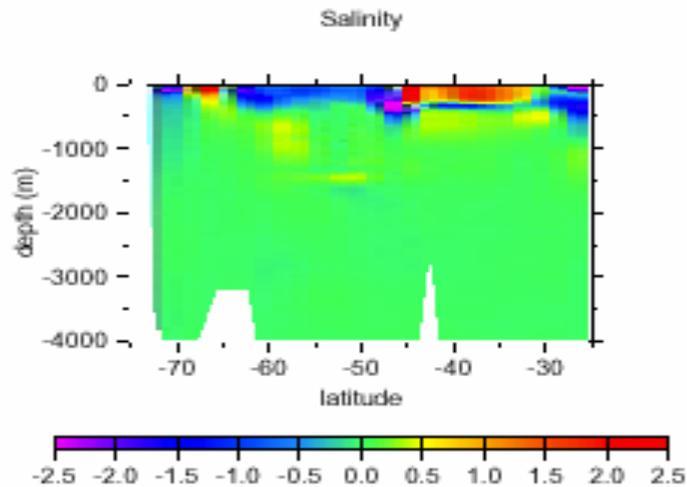
ECCO vertical profiles EOF/PC, E-W 35°N in N. Pacific



ECCO vertical profiles EOF/PC, E-W 50°S in S. Pacific

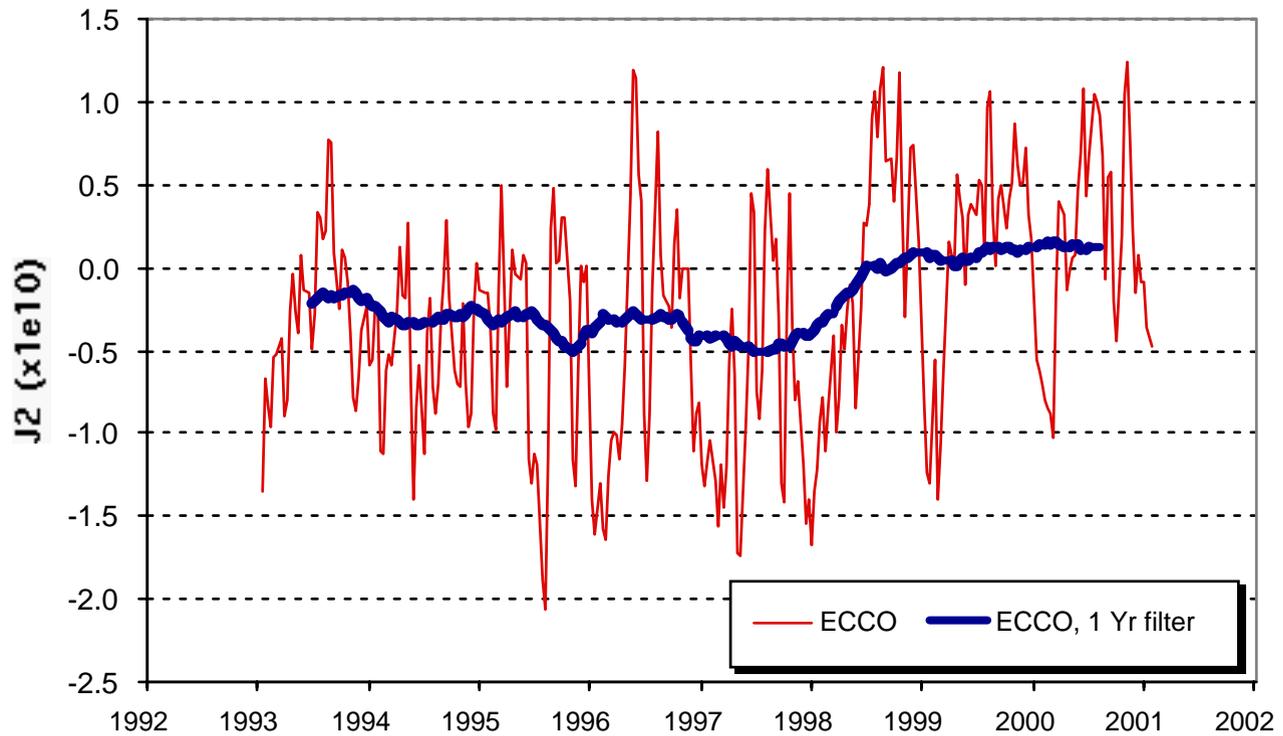


ECCO vertical profiles EOF/PC, N-S 190°E in S. Pacific

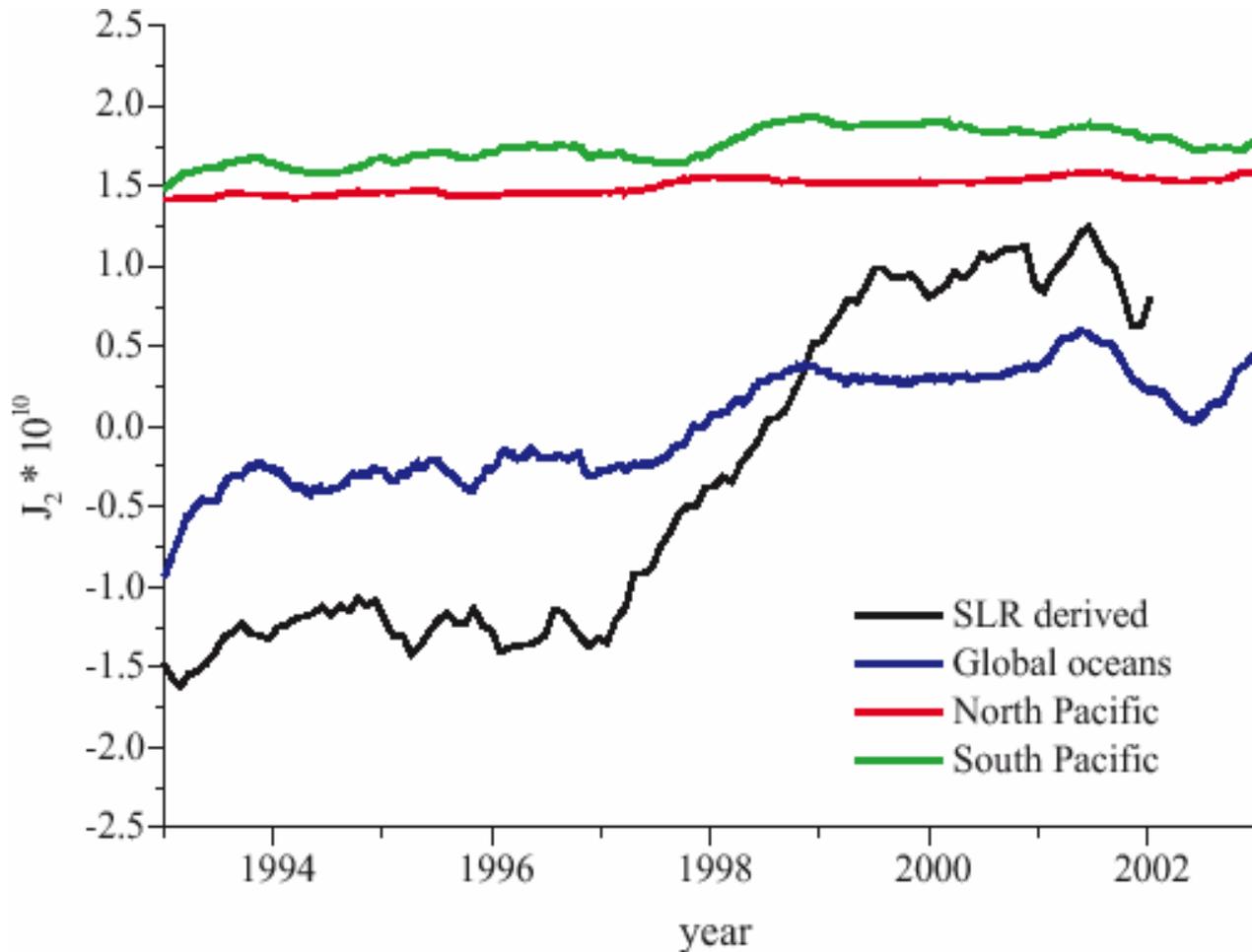


J₂ Variation According to ECCO model...

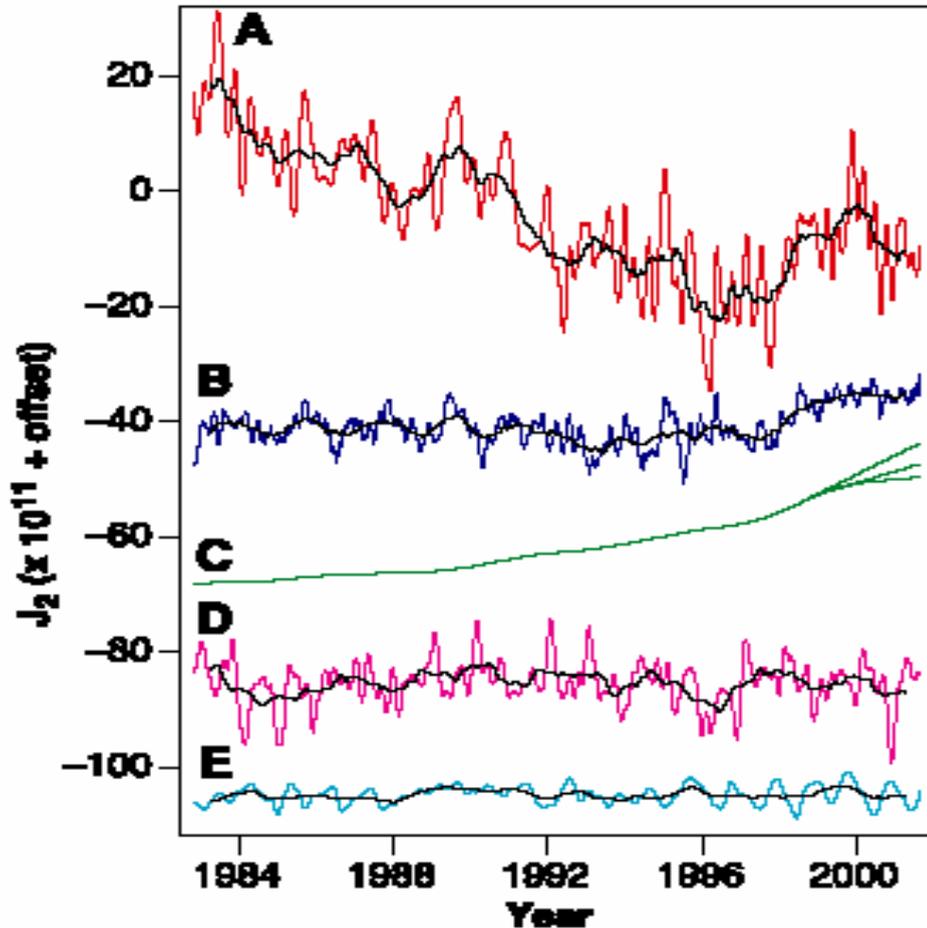
ECCO Assimilation



J₂ Variation According to ECCO model...



J_2 Anomaly (Dickey et al., 2002, Scenarios)



A: SLR-observed

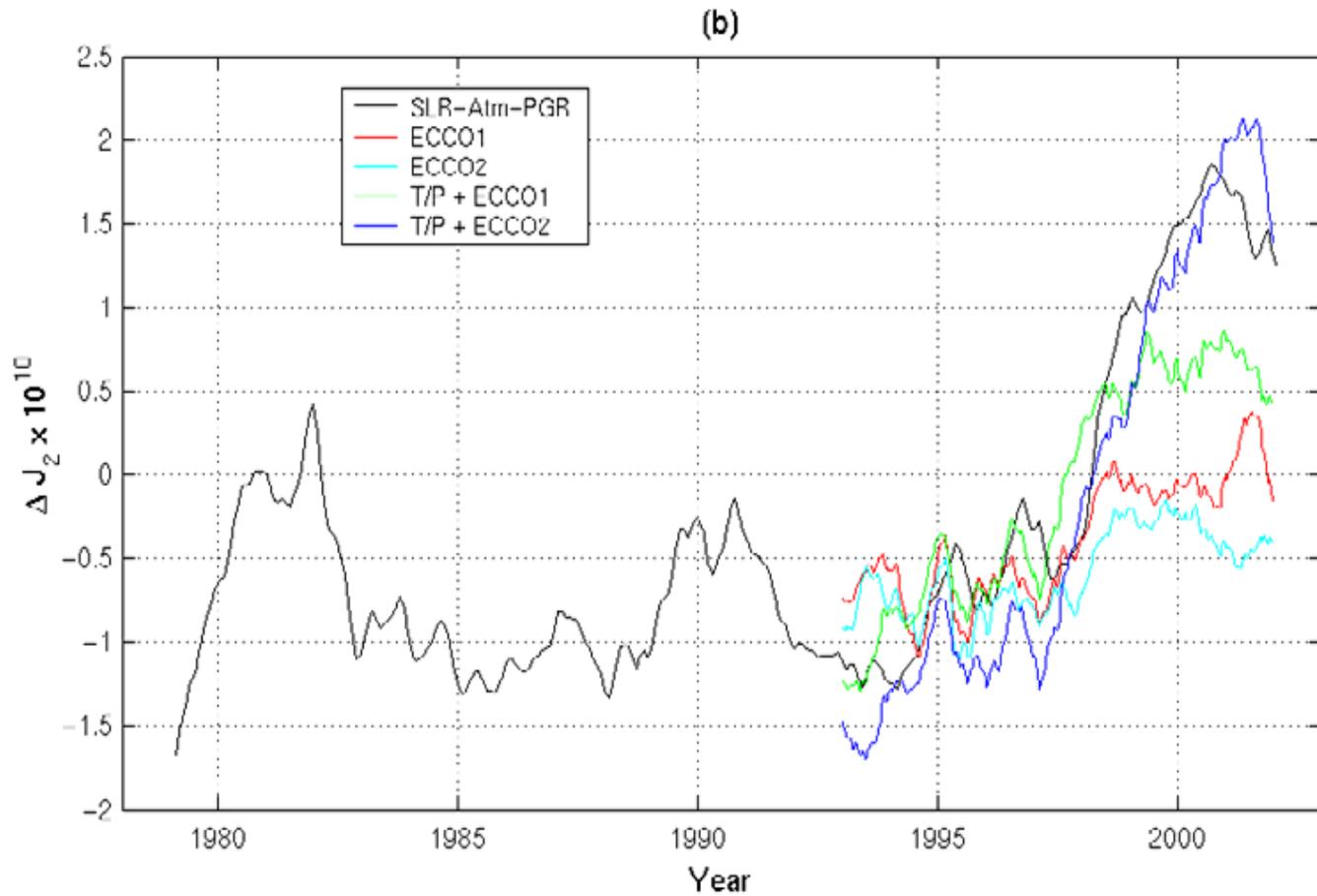
B: ECCO ocean

C: Glaciers extrapolated

D: NCEP atmosphere

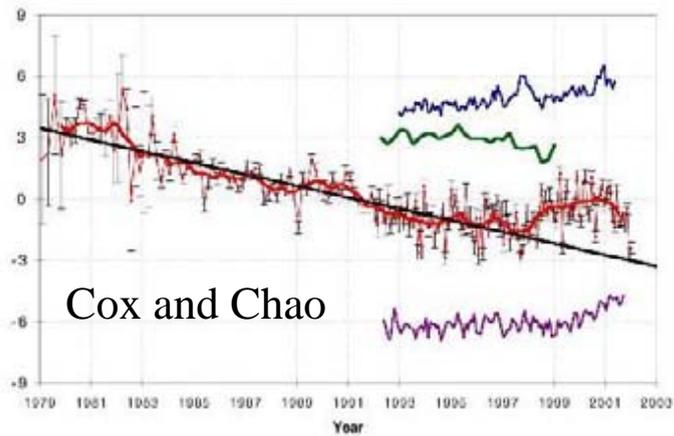
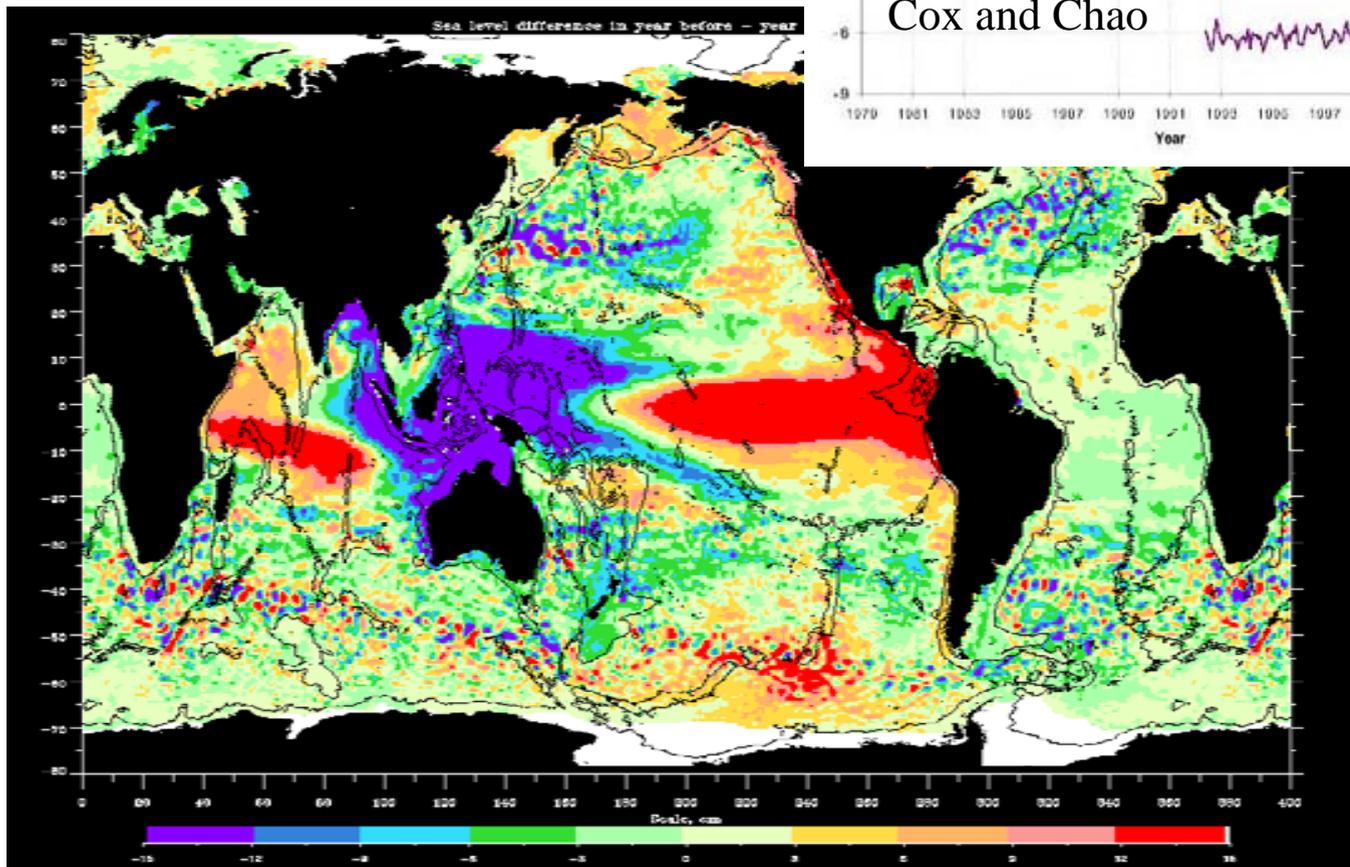
E: NCEP soil moisture

Chen et al. (2003) Scenarios using T/P SSH + ECCO steric

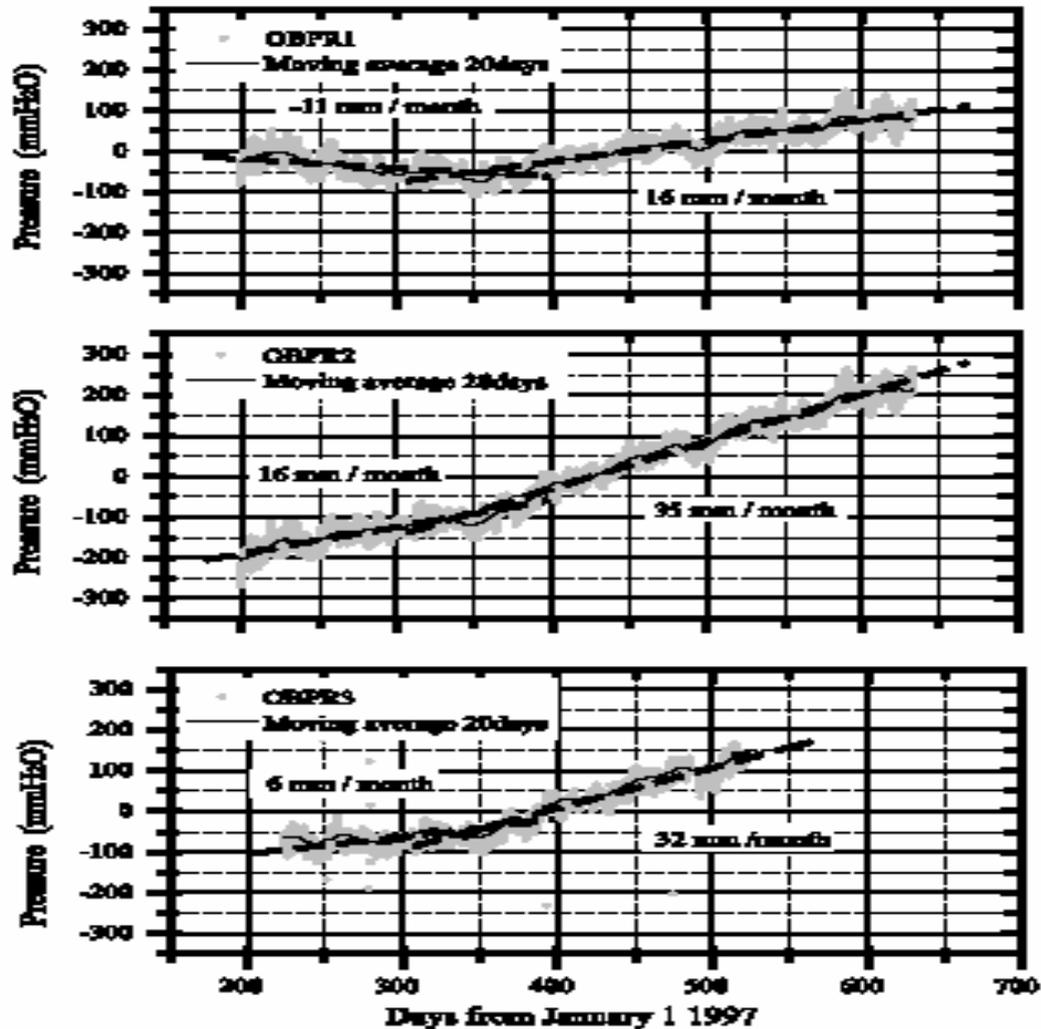


Hughes, 2003

Sea level before - after



Fujimoto et al. (2003) Ocean Bottom Pressure, SE Pacific



Earth Rotation vs Ocean Angular Momentum

Earth Rotation (3-D)

= LOD (1-D) + Polar motion (2-D)

Like time-variable gravity, (oceanic) angular momentum also reflects global mass transport (in ocean).

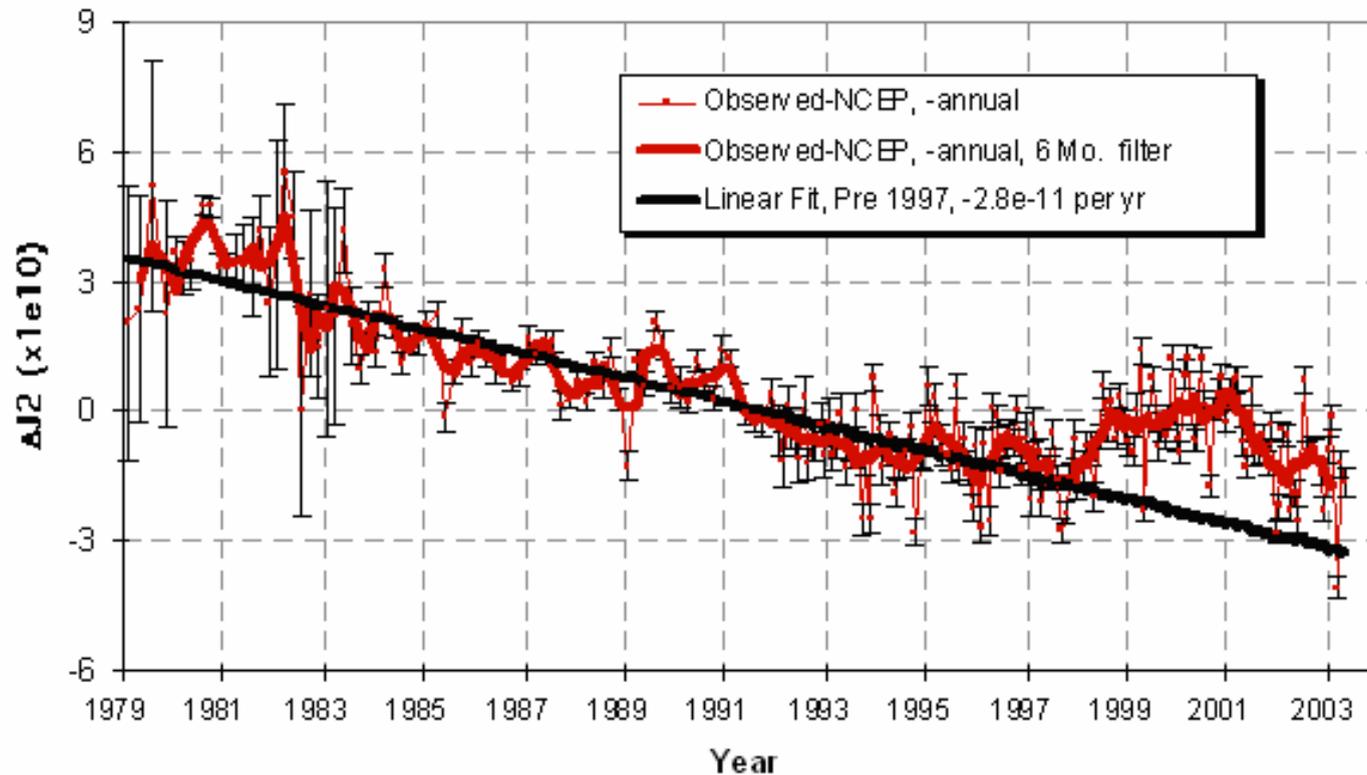
Good correspondence, but relatively small amplitude of OAM reported:

Johnson et al. (2001; 2002) for POCM_4B

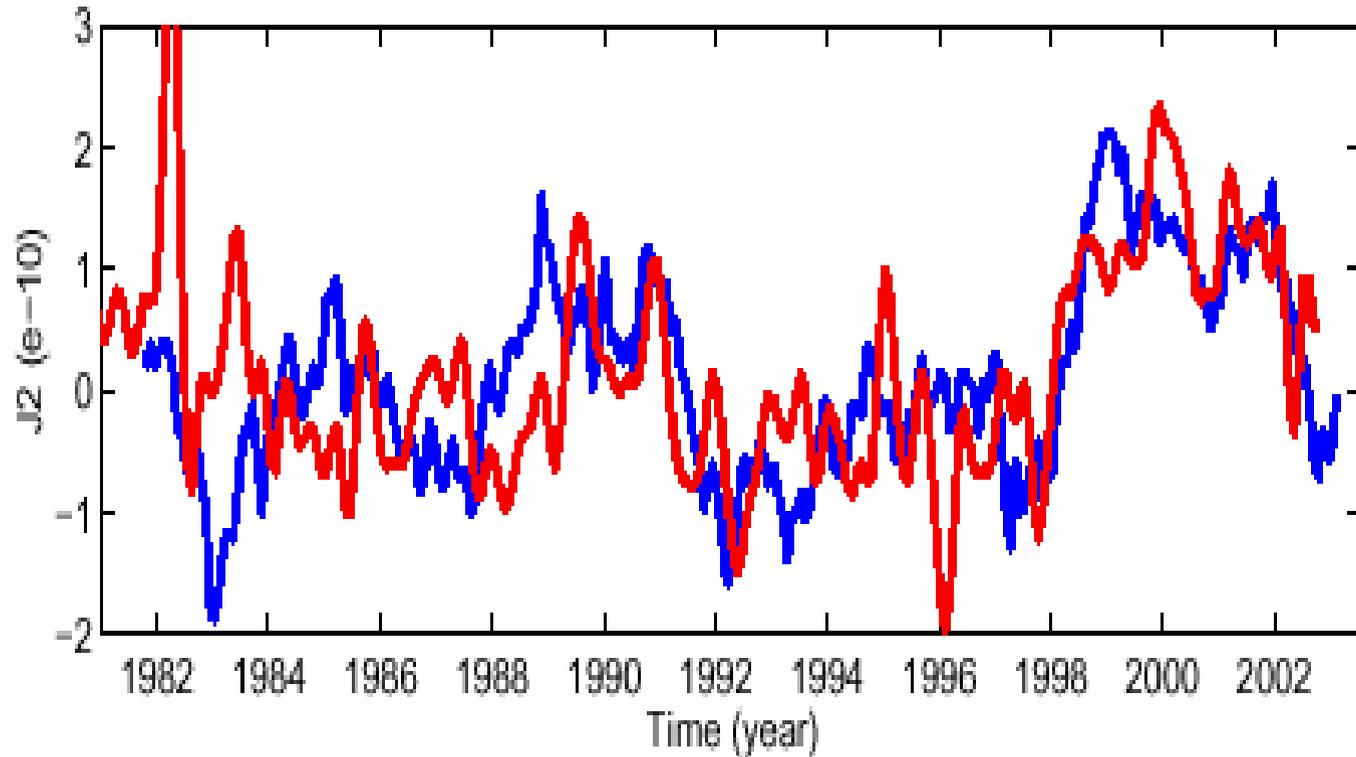
Gross et al. (2003, poster) for ECCO

SLR observed J_2 (non-seasonal, non-atmosphere, non-tidal)

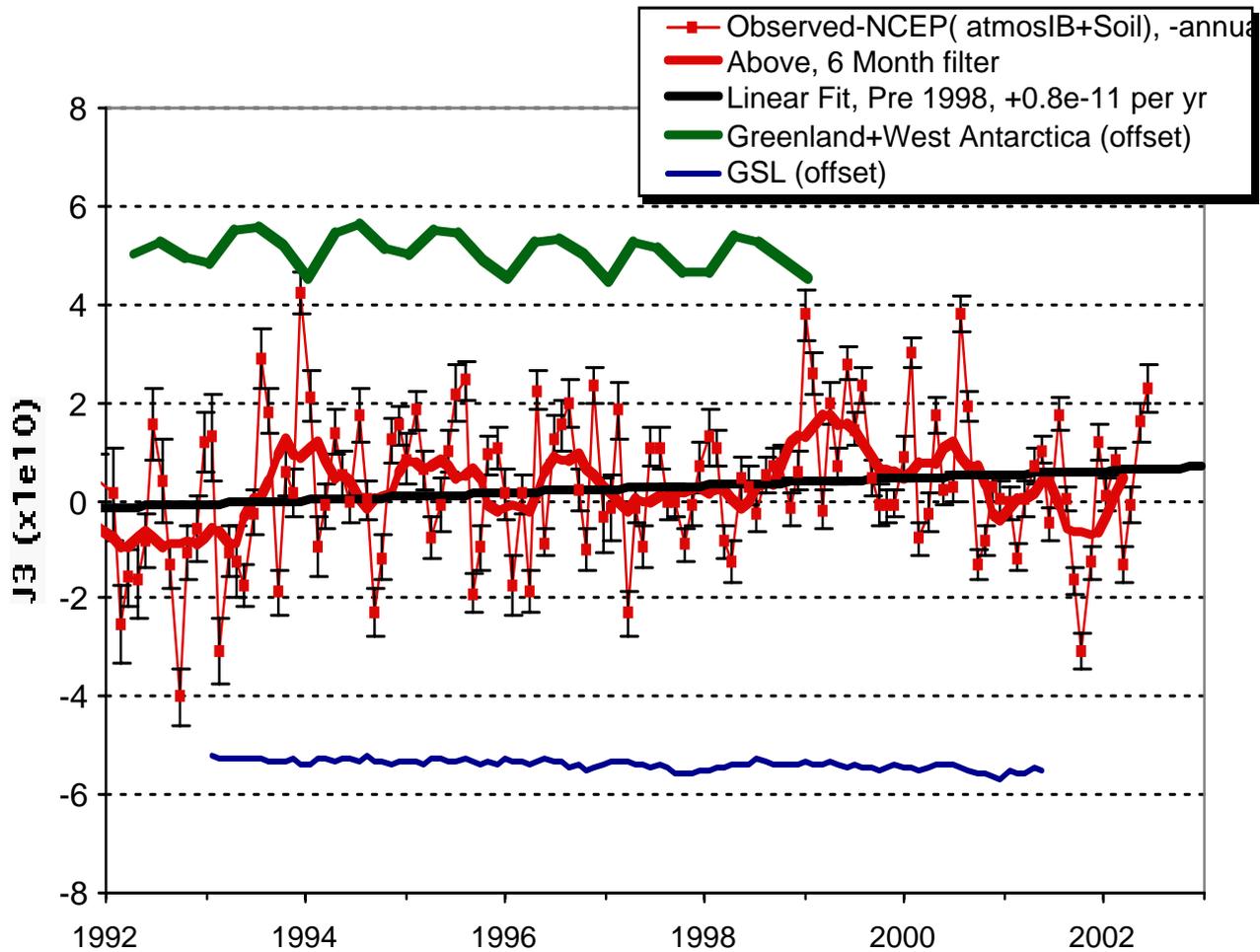
SLR Observed Change in J_2 2
after removal of seasonal terms



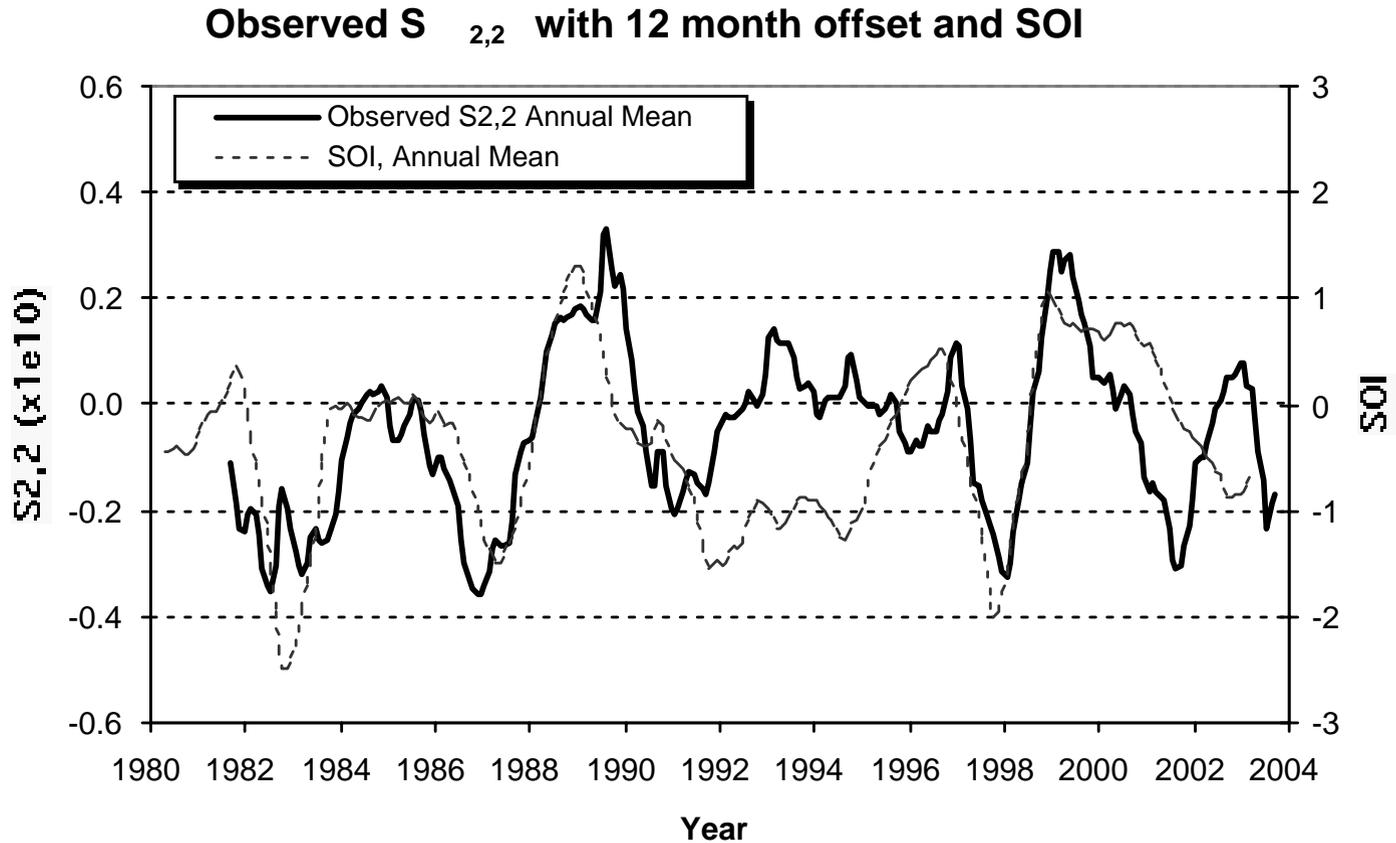
interannual J_2 variation (red) vs. Pacific Decadal Oscillation Index (blue)



SLR-observed J3 variation (non-atmospheric)



SLR-observed $S_{2,2}$ vs. ENSO Index (non-seasonal)



“Conclusions”

- Large 1998-2002 anomaly in J_2 rate
 - Short term deviation or something more?
 - ⇒ *Appears to be short term - returning to “normal” (prior trend)*
- Not atmosphere
- Ice melting scenarios have issues:
 - Needs several hundred km³ of ice melting per year!
 - Implying too much GSL change - Where does the water go?
 - J_2 returning to “normal” - Implies rapid ice *accumulation*
 - Conversely, they can’t be ruled out entirely
 - ⇒ The Greenland and West Antarctica data imply fairly rapid changes
- Ocean?
 - Extratropic Pacific 1998-2002 anomaly
 - ⇒ Following the big 1997-98 El Nino (tropical) but manifesting in extratropic North and South
 - ⇒ Consistent with timing of PDO and extratropic SST, salinity, and SSH changes
 - Recent changes in SSH implied J_2 commensurate in magnitude
 - ECCO model only explains 1/4 to 1/3 of the J_2 anomaly
- Open issues: Ocean steric effects, Mass conservation, Hydrology, Polar Sea influences, Core mass flow, Other gravity harmonics, Earth rotation...