Recovery of the Three-Gorges Reservoir (TGD) Impoundment Signal from ICESat altimetry and GRACE

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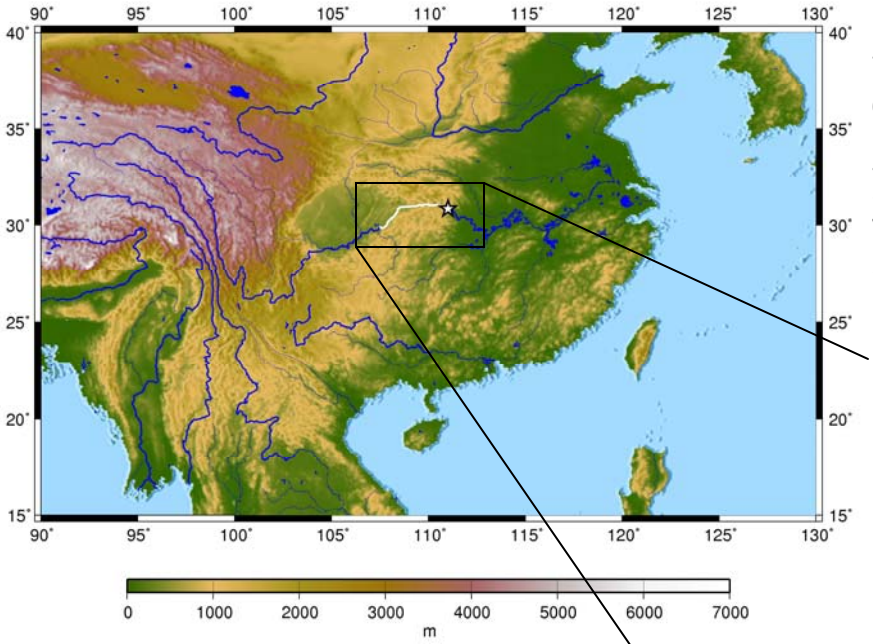
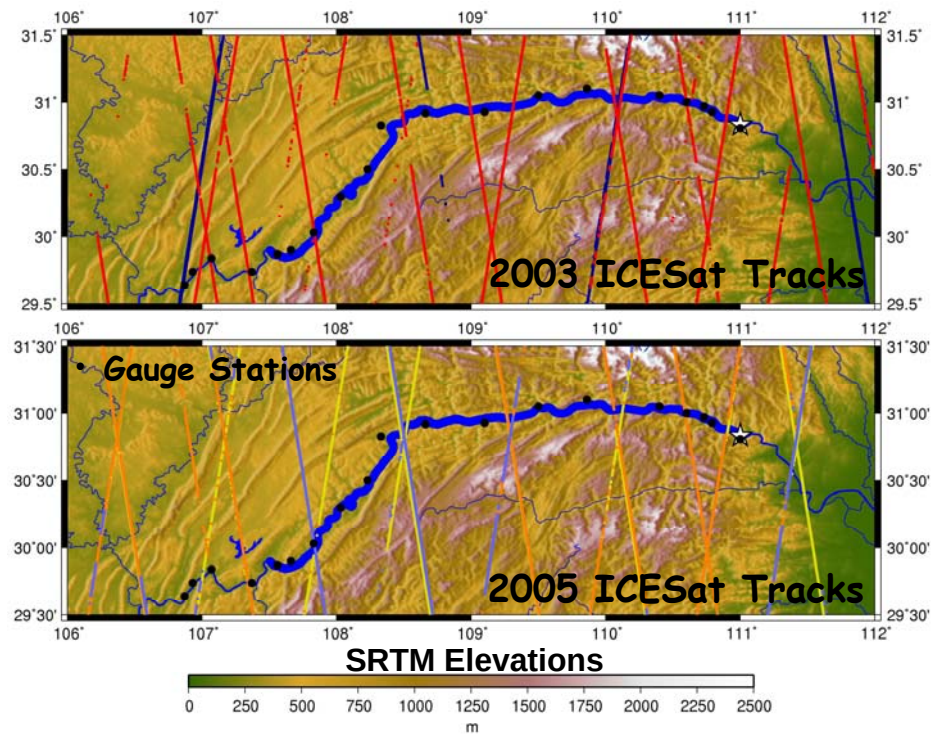
Yangtze River - Three Gorges Dam

Water impoundment in major artificial reservoirs induces significant variations of global geodetic measurements, such as the low degree gravity field (Boy & Chao, 2002) that can be observed by GRACE.

ICESat inland water measurements are of great value, helping define space-based laser altimeter capabilities and constraints for measurements of inland surface water hydrolic properties.

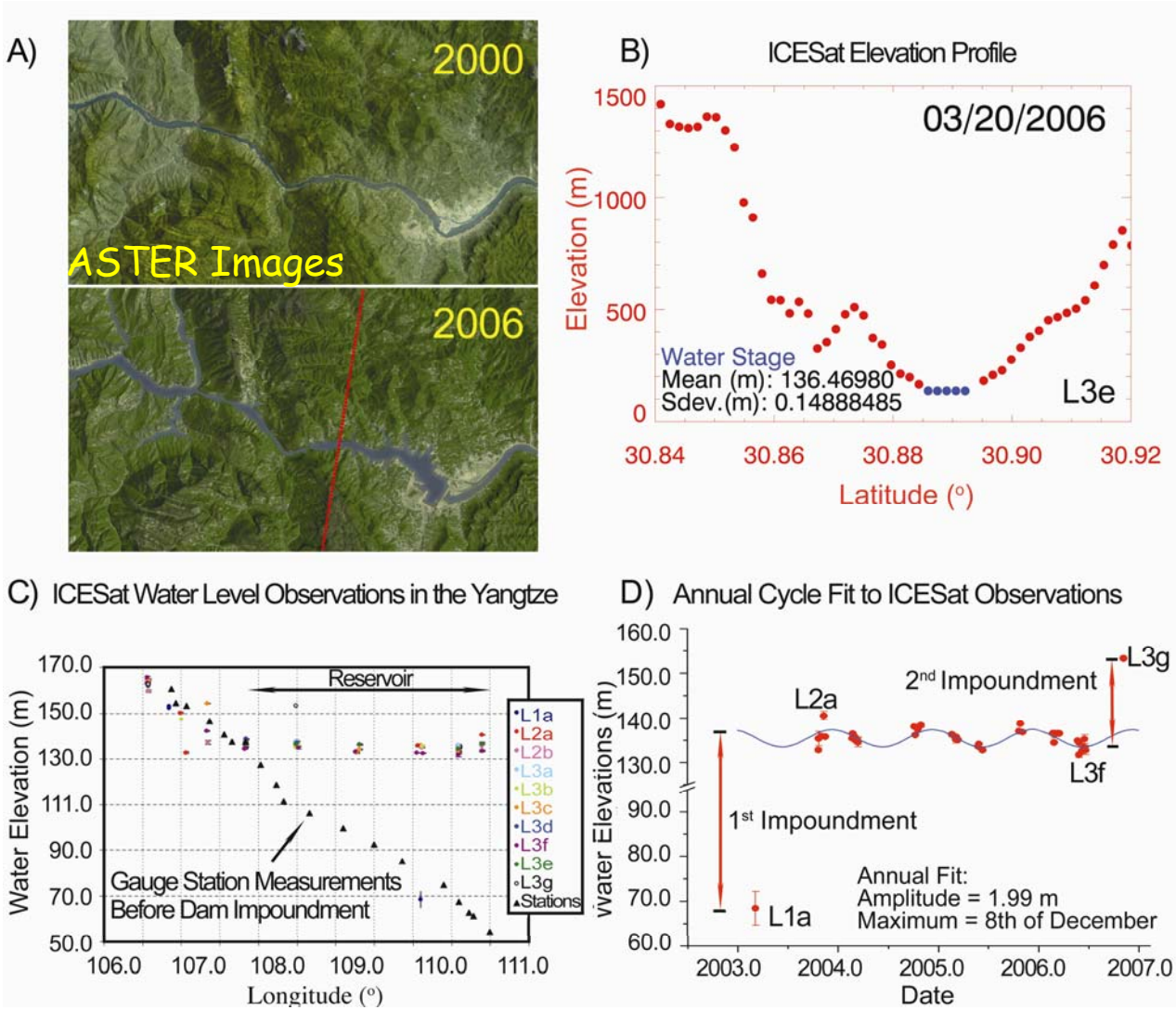




Three Gorges Dam
(water level & volume)
1998: 55 m
2003: 135m, 17.15 km^3
2006: 156m, 22.8 km^3
2009: 175m, 39.3 km^3

from Yang et al. (2005)
Boy & Chao (2002) & Wang (2000)
Water level during impoundment phases, from Wang (personal communication)

Three Gorges Dam (TGD)



When the reservoir is filled in 2012, water will rise to a height of 175 meters and extend 600 kilometers.

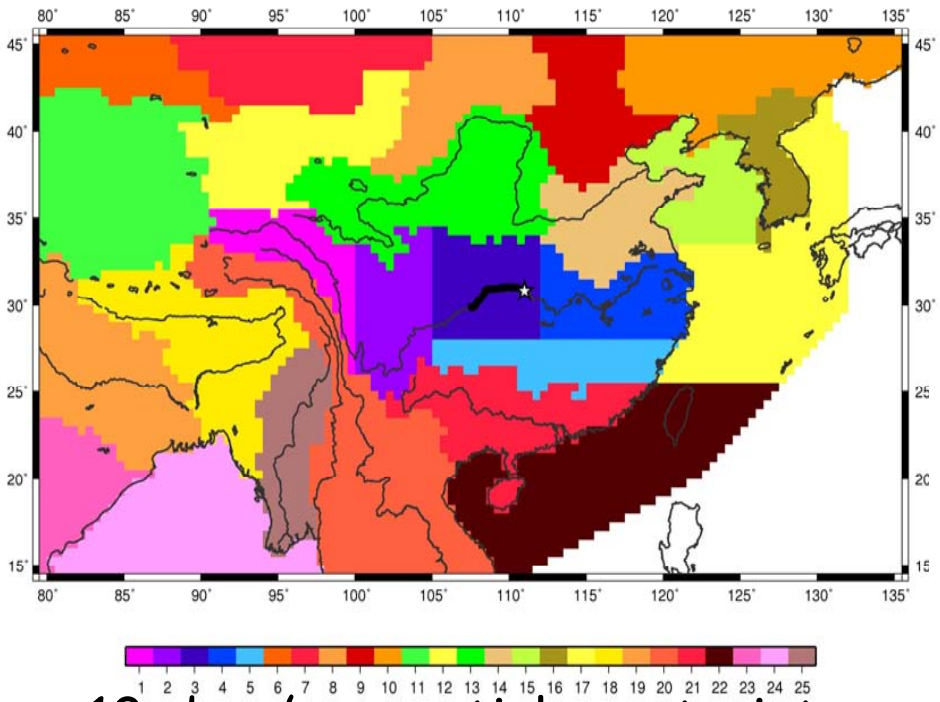
ICESat observations lack the short scale temporal resolution to retrieve all intra-seasonal variations.
(min. in Summer, before the monsoon)

Seasonal variations in water levels within 5 m observed.

Mascon Grid Definition

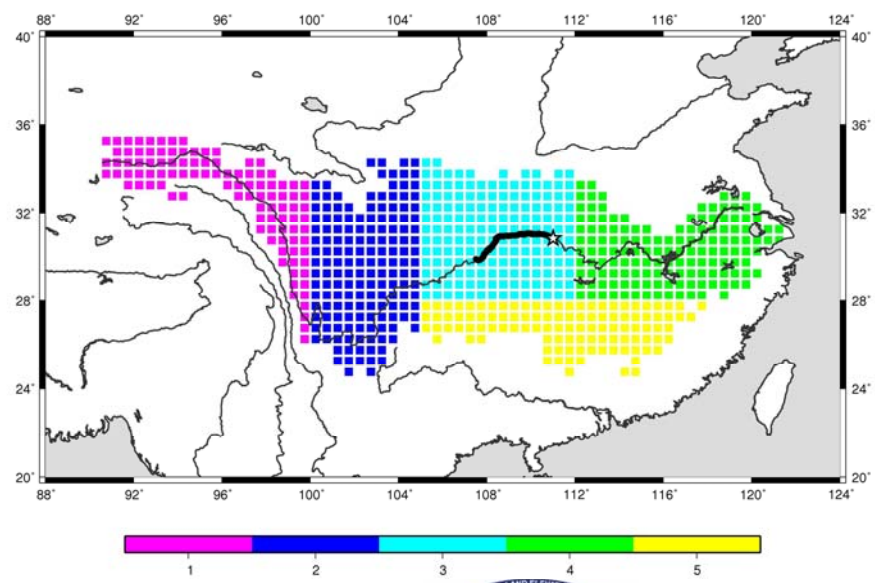
Mascons solve for local mass concentrations rather than globally as with the Spherical Harmonic solutions, minimizing errors from global contamination sources.

Rowlands, D.D. et al.,, GRL, 32, L04310l, doi:10.1029/2004GL021908, 2005. Luthcke, S.B. et al., Science.1130776, 2006.



10-day / no spatial constraints

~500 by 500 km regions, boundaries defined based on River basins from the **Total Runoff Integrating Pathways (TRIP)** *(T. Oki and Y. C. Sud, Earth Interactions, 1998)*

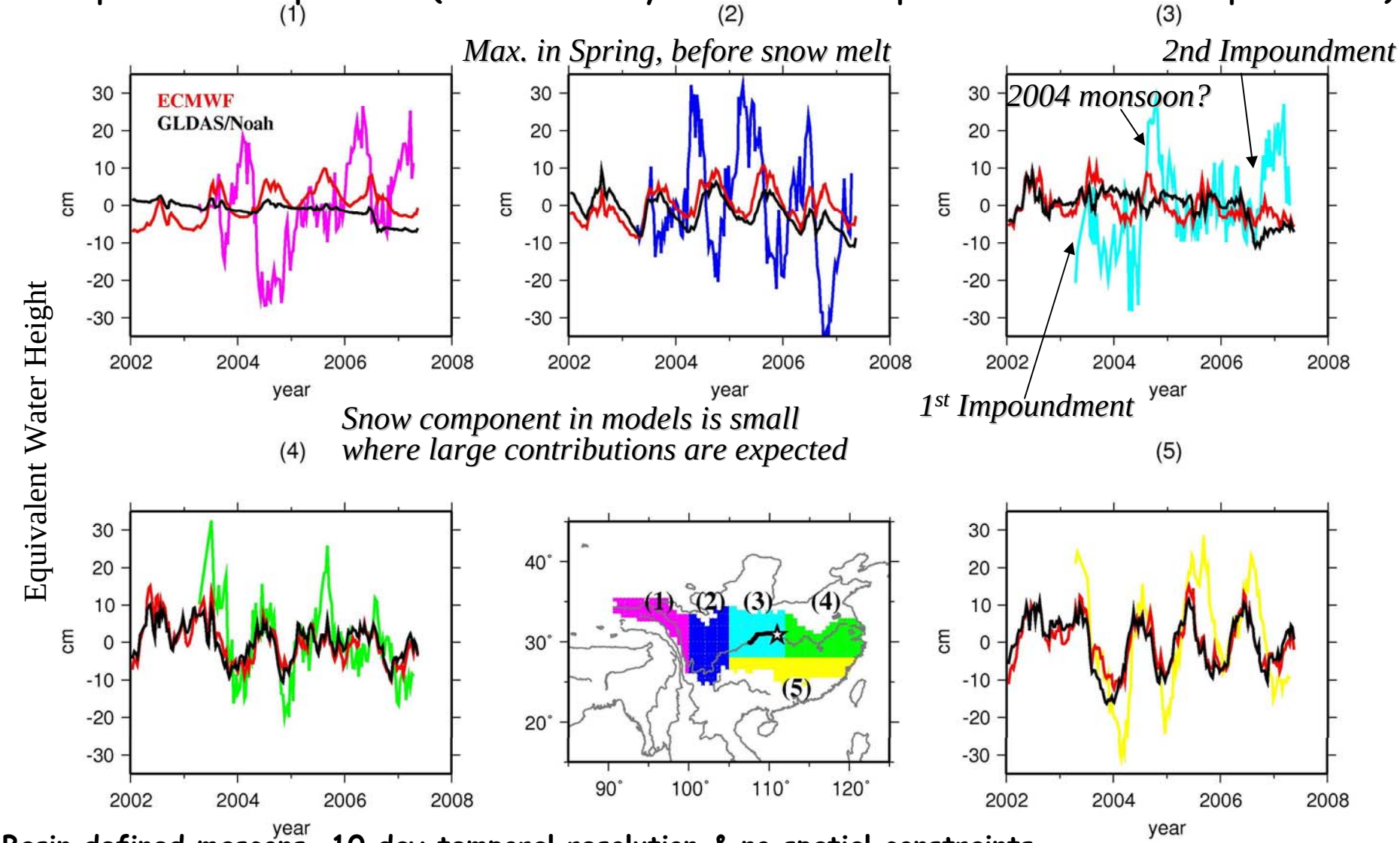


Yangtze Basin divided in 5 regions

(2 upstream/higher relief, 1 including the reservoir, 1 downstream, 1 to the South, sized to allow for no spatial constraints)

Mascon Solutions Over the Yangtze Basin

April 2003 to April 2007 (include the May/June '03 and September/October '06 impoundments)

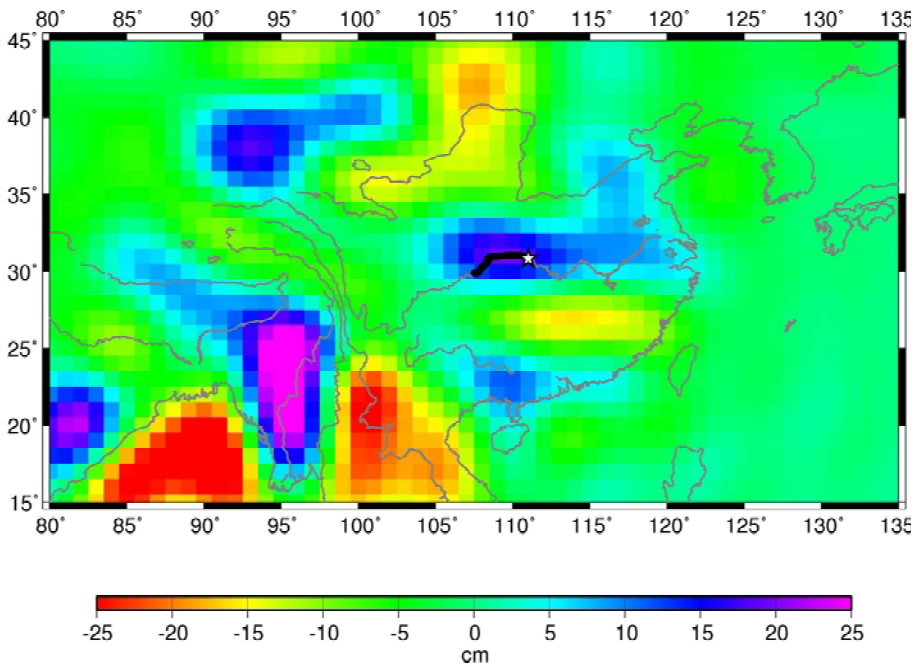


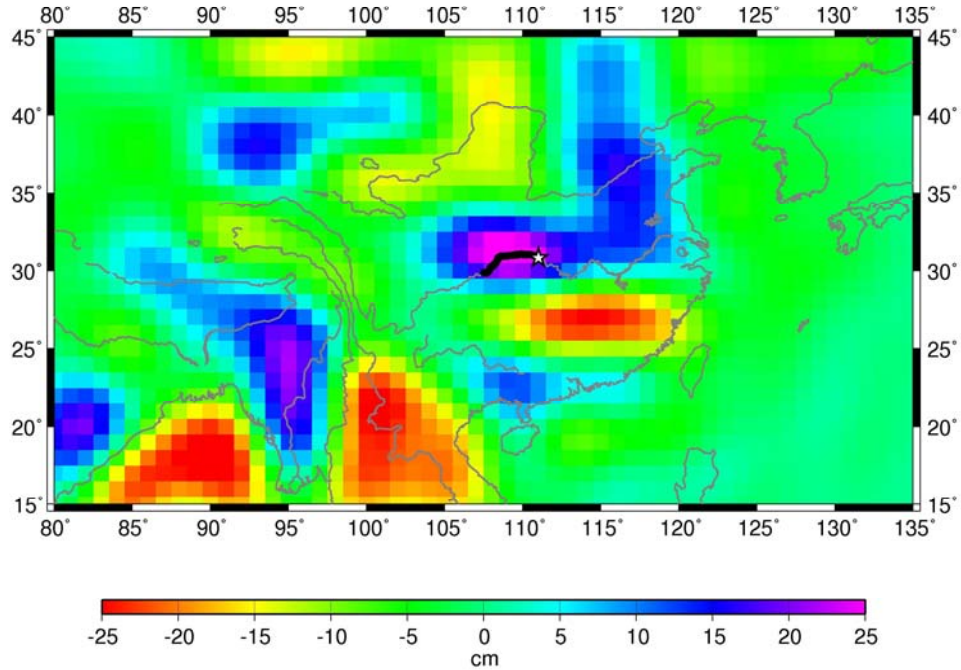
Basin defined mascons, 10 day temporal resolution & no spatial constraints.
No annual signal removed.

GRACE senses monsoon in late Summer, and snow-melt in Spring (up-stream).

Observation of the TGD Water Impoundment Differences between July–April, 2003

(GLDAS, mean annual & trend removed) **(mean annual & trend removed)**





Total volume of water: 10.60 km^3 (17.15 km^3)

Total volume of water: 13.72 km^3 (17.15 km^3)

(differences are due to non-seasonal GLDAS)

Conclusions

- We take advantage of nominal-track observations collected 3 times a year by ICESat to obtain information on impoundment levels in the TGD.
- ICESat is able to recover water levels with a precision of a few centimeters. The smaller footprint of the laser altimeter provides observations in steep terrain, as in the case of the Yangtze.
- Seasonal variations within 5 m in water levels can be observed, corresponding to equivalent water height variations of a few centimeters for GRACE.
- Only GRACE Mascon solutions can recover the Three Gorges Dam (TGD) water impoundment, in **Amplitude** and **Location**.
- Large annual variations observed in Mascon solutions, especially in high relief regions, not present in hydrology models (but, snow small in models).

(However, there is good agreement between Mascon solutions and ECCO and MERCATOR bottom pressure models for ocean regions).

- Impoundment in 2006 of 5.6 km^3 (compared to 17.15 km^3 in 2003) was observed by ICESat. ICESat observations and GRACE processing allow us to continue capturing the evolution of the impoundment, including 2009.
  - Tested sensitivity of amplitude to of other grid configurations with similar results.
  - Will try to assess the snow component for up-stream regions (invert for all water components, through the mass balance equation)

$$[d(SM+SNOW_{MODIS,AMSR-E})_{GRACE}/dt = (P_{rain-fall}-ET)_{atm.\ model}-R_{basin}]$$