What can GGFC get from the Gravity Missions?

Status and Prospect of the GRACE **A**tmosphere and **O**cean **D**ealiasing Level-**1B R**elease 04 (AOD1B RL04) Product

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- The current AOD1B RL04 product for CHAMP/GRACE
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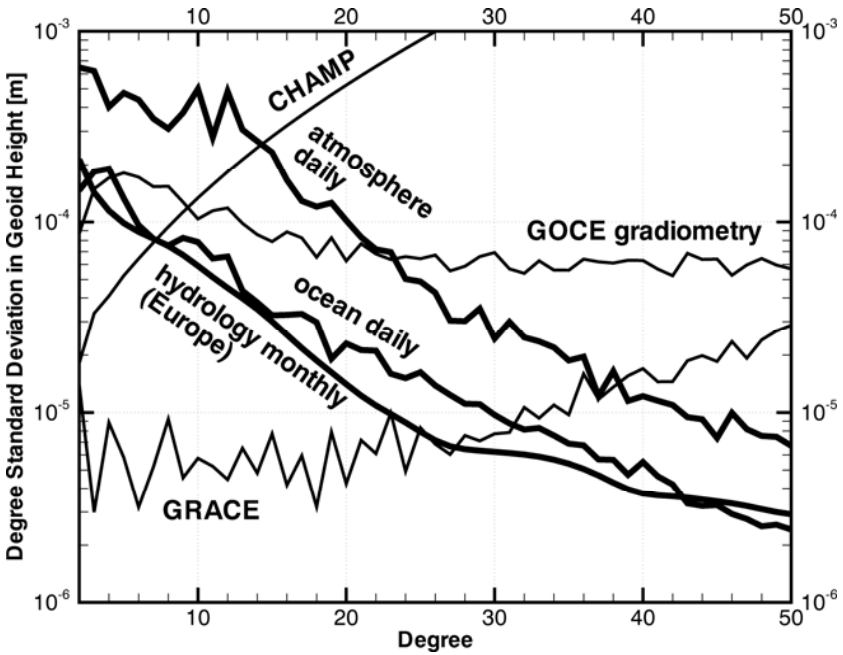
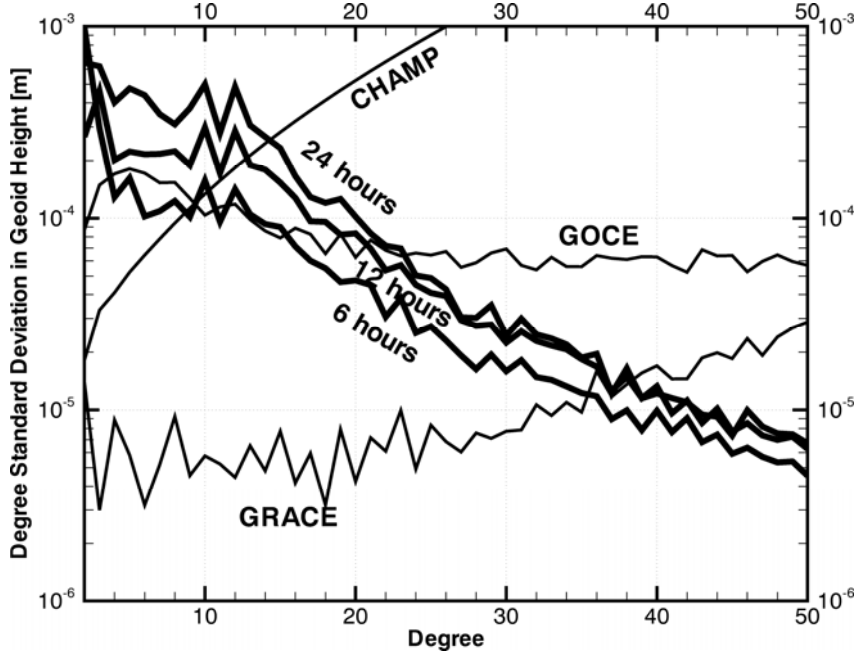
- Some remarks on hydrological mass variations and atmospheric loading

Sensitivity of missions to short-term mass signals





Gravity variation signals from different sources in different time scales compared to gravity mission sensitivities: Comparison of daily atmosphere, daily oceanic and monthly hydrological signals (left) and comparison of 6, 12 and 24 hourly ECMWF signals (right).

Models to correct short-term mass variations

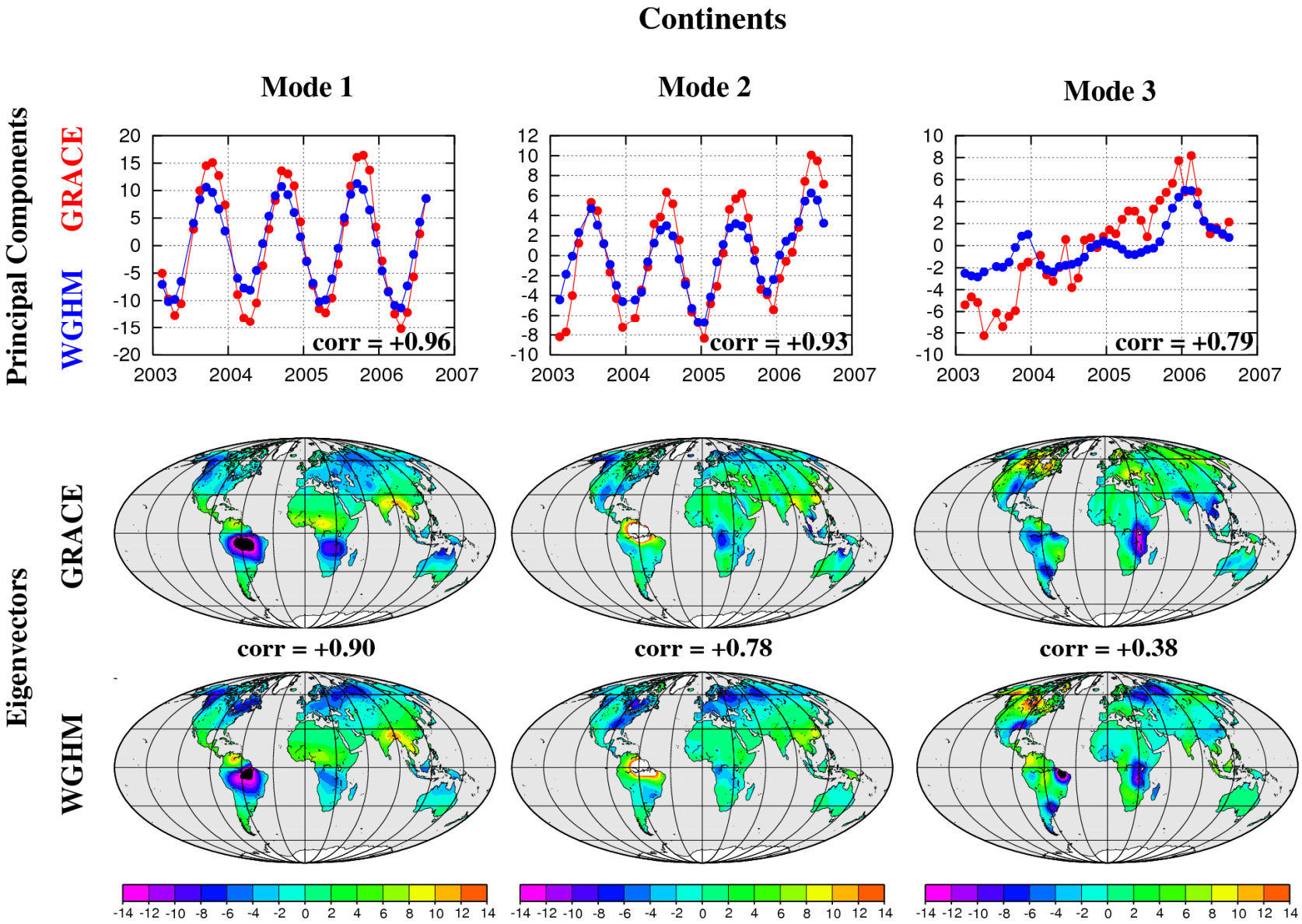
- Short-term mass variations on sub-daily to annual time scales caused by mass redistributions in the Earth's subsystems, i.e. the atmosphere, the oceans, the lithosphere, the hydrosphere and the cryosphere are aliased into the monthly GRACE gravity field solutions if not corrected properly.

- To eliminate short-period non-tidal atmospheric and oceanic mass anomalies from monthly mean GRACE gravity estimates the AOD1B product was developed at GFZ which is based on 6-hourly ECMWF Operational Analysis meteorological data and an ocean model forced with ECMWF data, too.

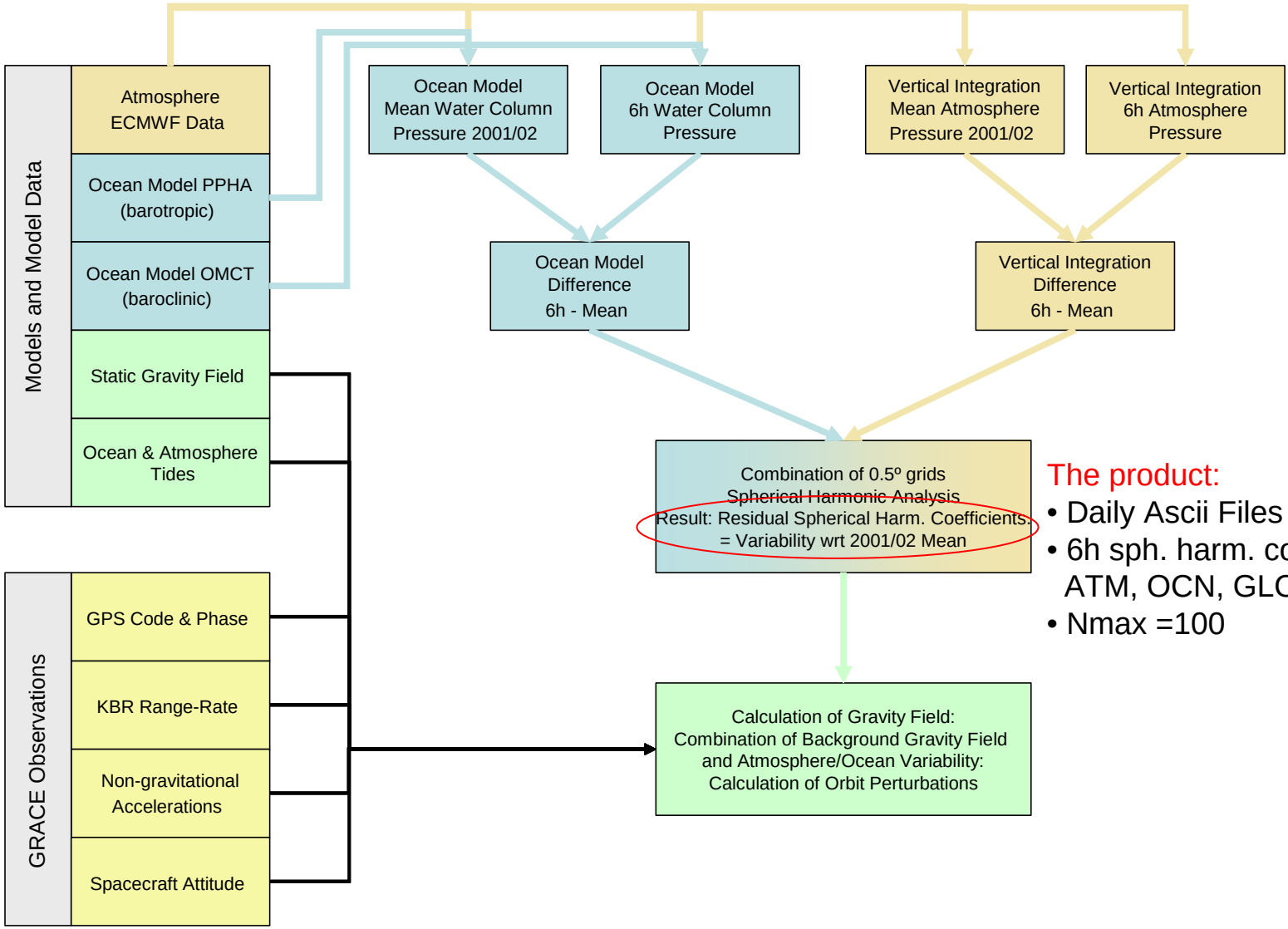
- Tidal atmospheric/oceanic mass variations corrected by models (FES2004…).

- Hydrological mass variations are not yet taken into account. Therefore the prime output from GRACE are monthly maps of the continental hydrological cycle. Nevertheless projects started to assimilate GRACE and to provide hydrological mass variations on daily basis (e.g. TIVAGAM).

Hydrological Mass Variations from WGHM and GRACE



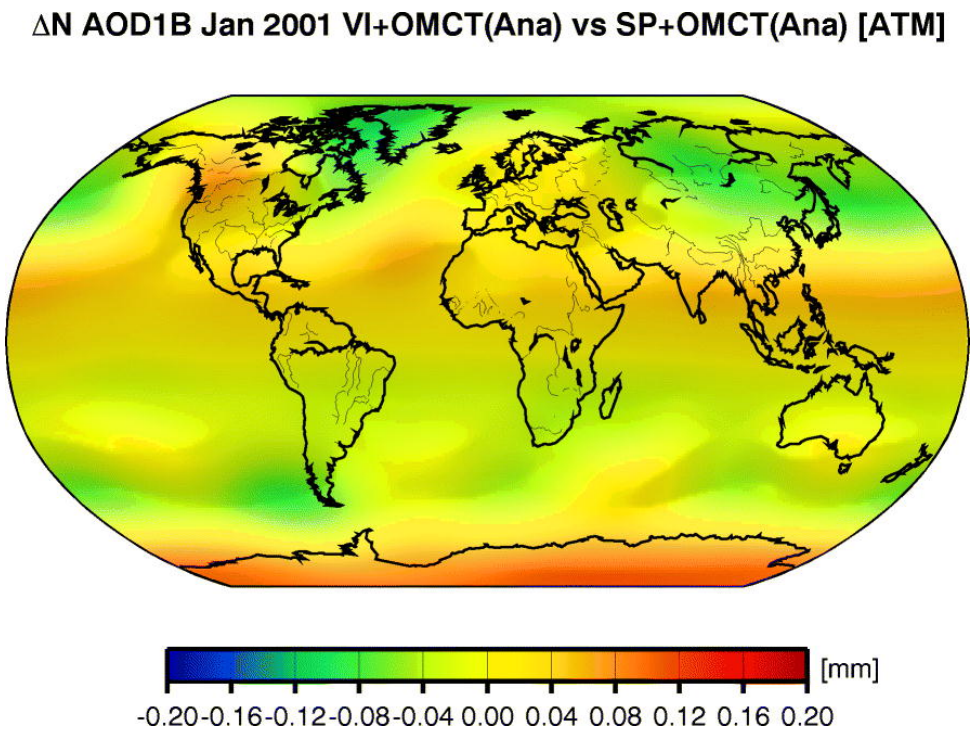
De-aliasing Principle for Atmosphere & Oceans



The product:

- Daily Ascii Files with Header Info
- 6h sph. harm. coefficients for ATM, OCN, GLO (and OBP)
- Nmax =100

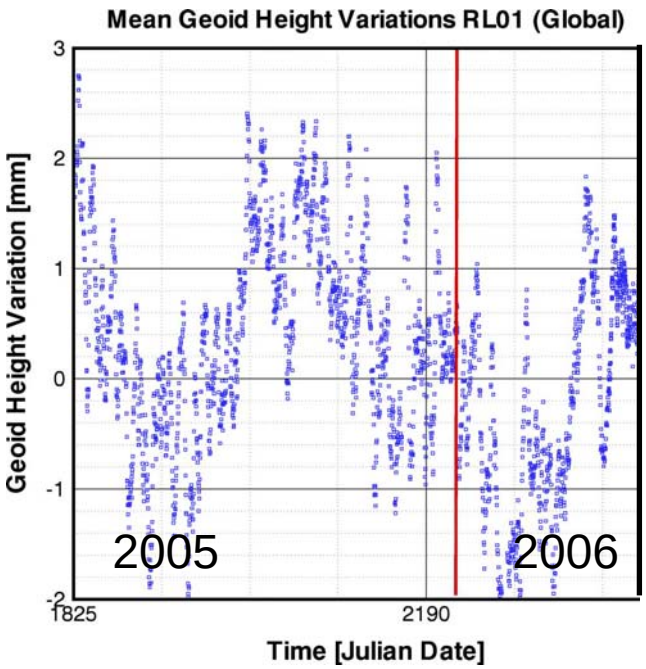
Atmospheric Geoid Height Differences: VI vs. SP

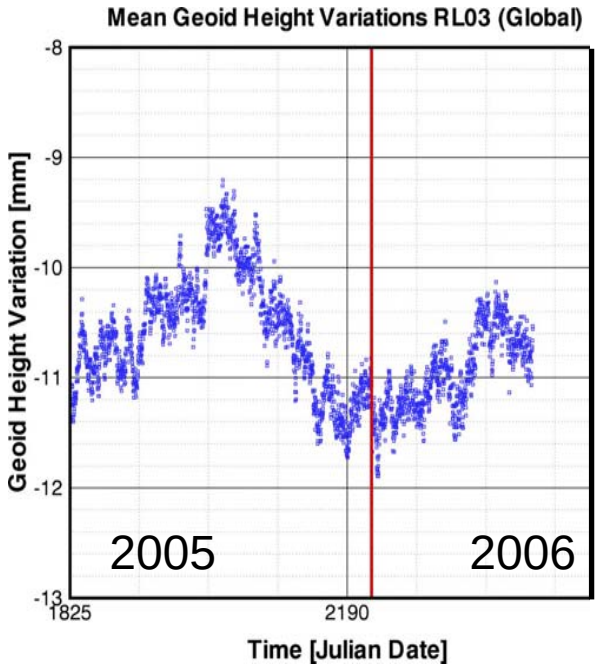


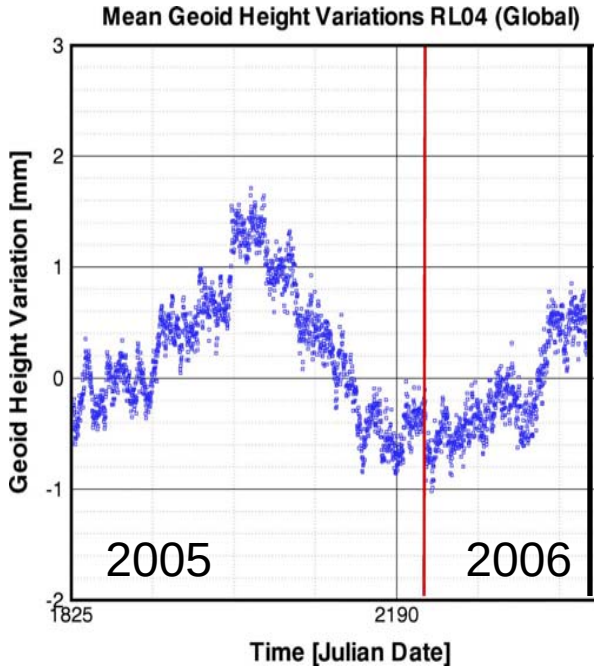
Differences between ECMWF Vertical Integration and Surface Pressure are small, but have to be taken into account for GRACE!
(Requirement: Cumulative Geoid Error < 0.42 mm for n<70)

ECMWF upgrade February 1, 2006

Vertical resolution changed to 91 instead of 60 levels
No influence on mean geoid variation







Mean: 2001
Ocean Model: PPHA

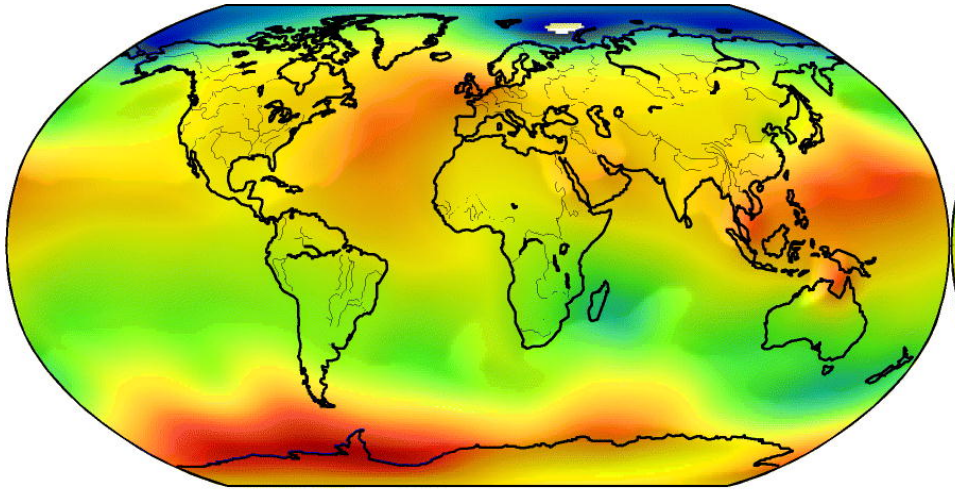
Mean: 2001+2002
Ocean Model: OMCT

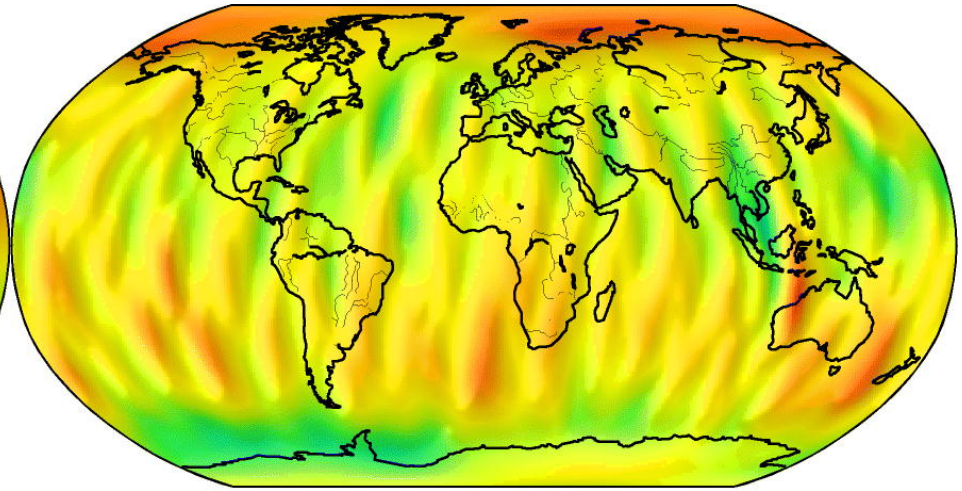
Mean: 2001+2002
Ocean Model: OMCT

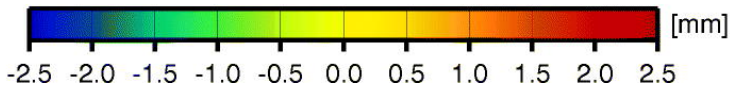
Test of Oceanic Models

- 3 different ocean models tested for 05/03, 08/03, 11/03 and 02/04
  - PPHA (JPL, barotropic, polar gaps)
  - MOG2D (CNES, barotropic, global output)
  - OMCT (TUD, baroclinic, global output)
- Atmosphere: Vertical Integration (identical for all tests)
- Mean Field: 2001+2002
- S_2 atmospheric tide removed from surface pressure before forcing (no double book-keeping with ocean tide model)
- Main Results (see poster presented at EGU 2005 Vienna):
  - Mean AOD geoid heights differ by ± 1.5 mm (max. in the Arctic, S. Ocean)
  - Gravity field solution differences reflect 1:1 the AOD differences
  - GPS phase and K-band residuals nearly identical (MOG2D 1-2% smaller)
  - Striping (especially over the oceans) is still visible
  - Comparisons with NIMA gravity anomalies and CLS01-ECCO oceanic geoid heights show a better agreement (2-8%) at short (2.5°, 5°) wavelengths when using OMCT or MOG2D
- GRACE project decided to use OMCT (under control of SDS)

Oceanic Geoid Height Differences: PPHA vs. MOG2D







Mean geoid height differences [mm] between the barotropic PPHA and the barotropic MOG2D AODs (left) and derived gravity field products (right) for February 2004 (Figures smoothed by Gaussian filter of 500 km radius, C20 variations removed)

Available AOD Releases

Release	Period	Ocean Model	Mean Field	S2 Tide Atmosphere	S2 Tide Ocean
RL01	June 2000 - today	PPHA (barotropic, mass conserving)	2001	Included	Included
RL02	(1)	PPHA (barotropic, mass conserving)	2001+2002	Included	Filtered(2)
RL03	July 2002 - today	OMCT (baroclinic, non mass conserving)	2001+2002	Included	Filtered (2)
RL04	January 2001 - today	OMCT (baroclinic, mass conserving)	2001+2002	Included	Filtered (2)

Comments:

(1) Only available for May, July, August, September, November 2003, February, December 2004 and January 2005 (Tests of ocean models).

(2) The S2 atmospheric tide filtered from surface pressure before forcing PPHA or OMCT using a strategy described in Ponte and Ray (2002).

The AOD1B RL04

AOD1B RL04 Modifications (Overview)

- AOD1B RL03 based on OMCT with non mass conserving parameterization (time-varying freshwater run-offs).

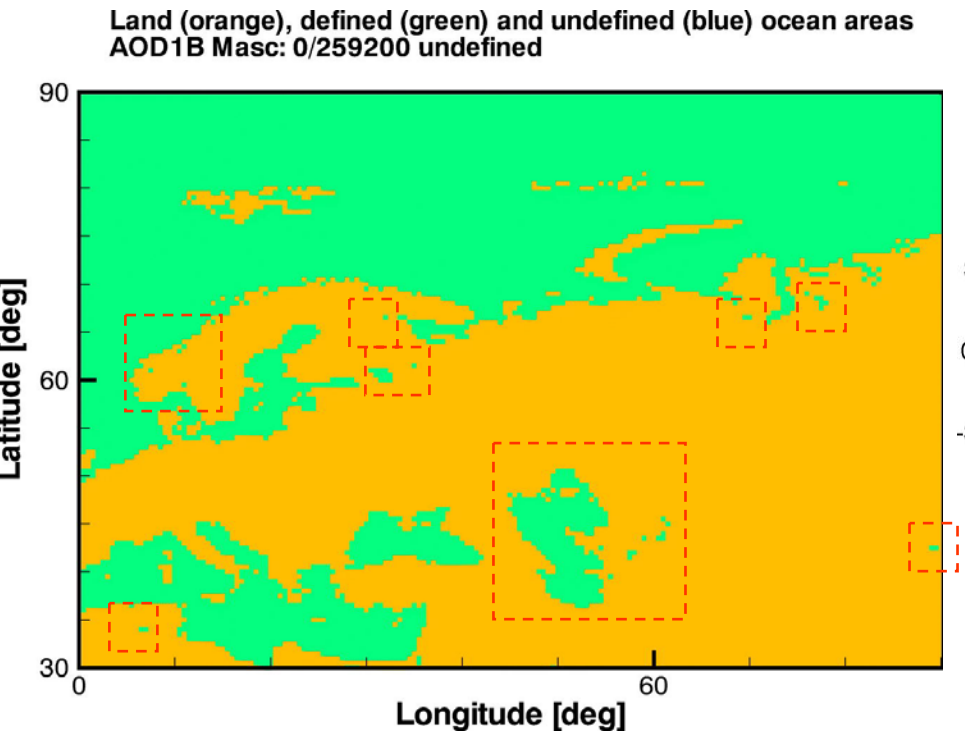
- Caused artificial slopes over land in GFZ RL03 and JPL RL02 monthly geoids which may result in improper interpretation of hydrological mass variations.

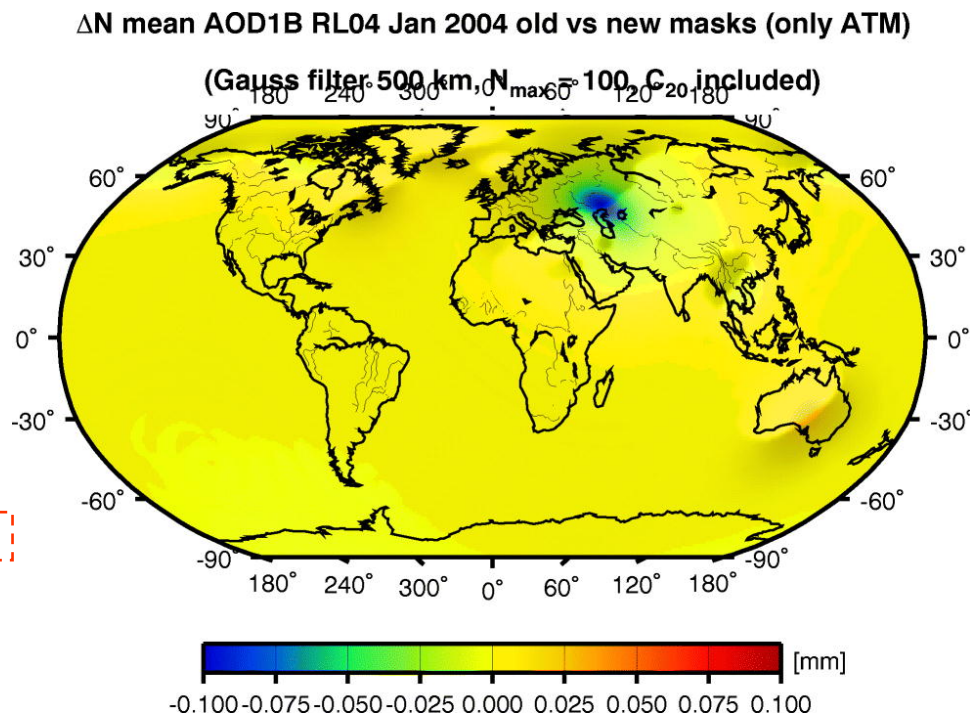
- Solution (TN04): Restoring of GAB product (mean of the 6-h OMCT products).

- AOD1B RL04 based on
  - OMCT with mass-conserving approach,
  - bathymetry adjusted to the AOD1B land-ocean mask,
  - updated thermodynamic sea ice model and
  - new data set for surface salinity relaxation.

AOD1B RL04 Modifications (Land/Water Mask)

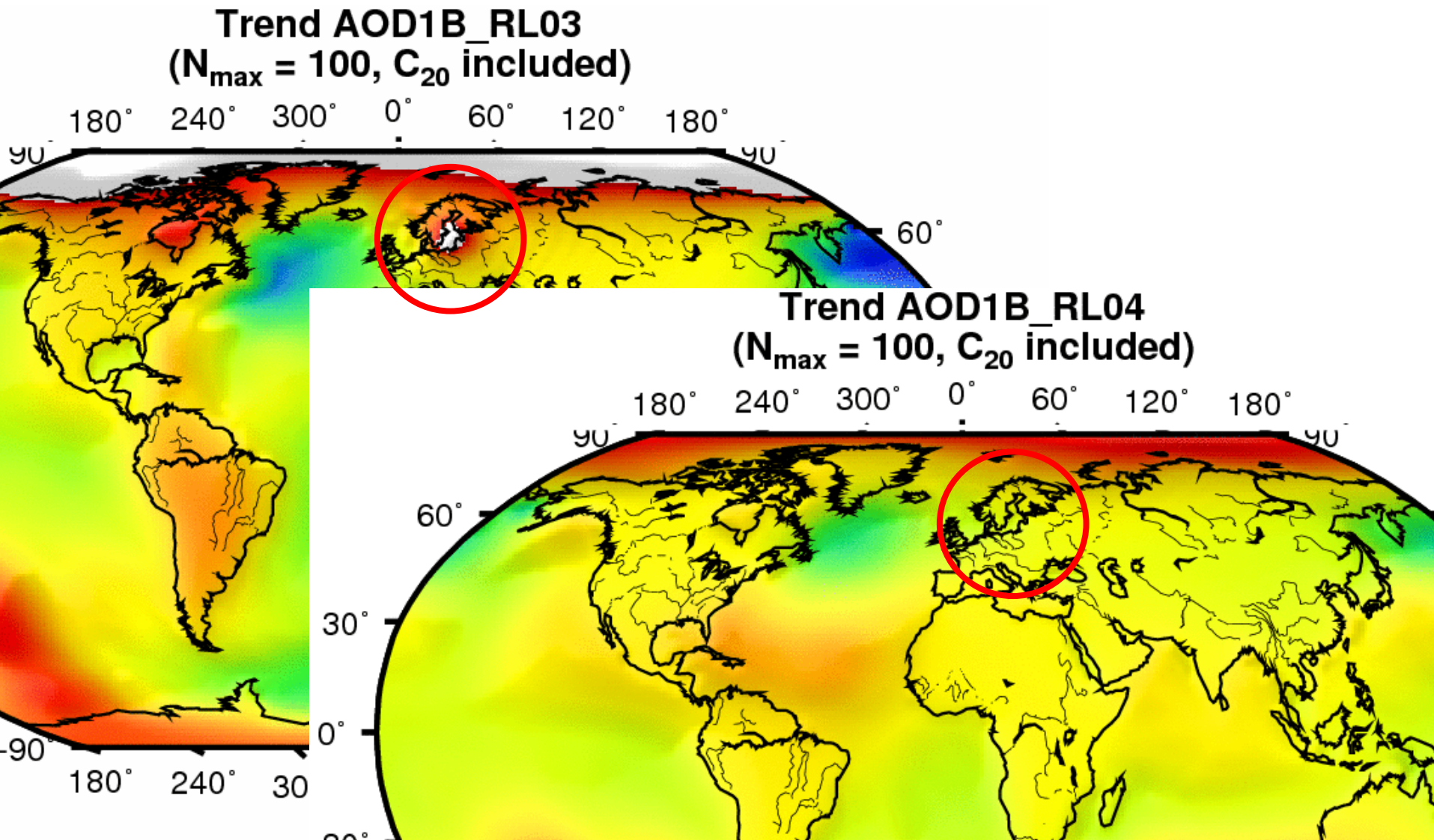
- Some larger area lakes and seas (e.g. Caspian Sea, Aral Lake) and some smaller lakes are now treated as land since horizontal gradients in atmosph. surface pressure on such length scales are too small to allow for an IB-response.
- Number of undefined OMCT pixels reduced from 4313 to 1741 (total 259200)
- => OMCT and AOD1B masks now identical!



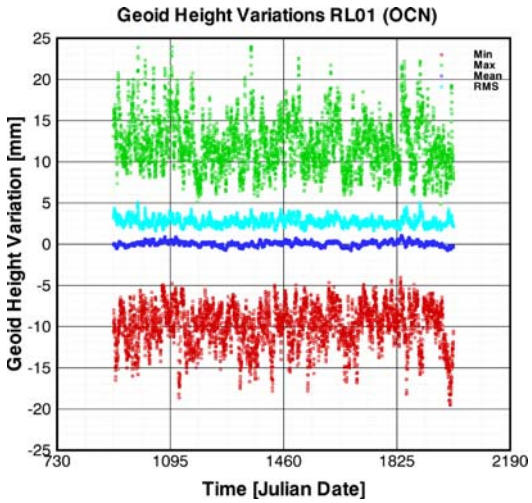


AOD1B RL04 Modifications (East Sea)

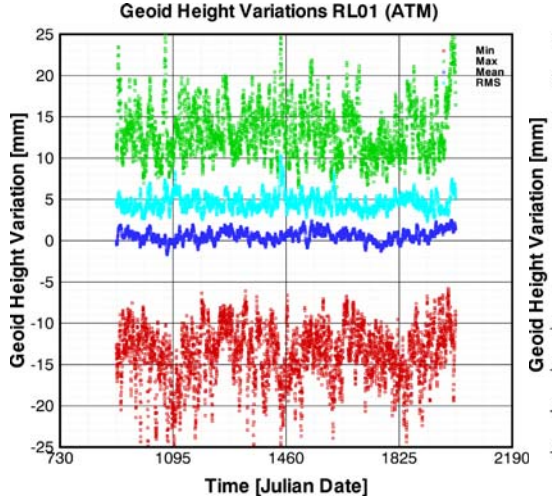
Result of adjusted bathymetry: Improved East Sea (now NIB instead of IB)



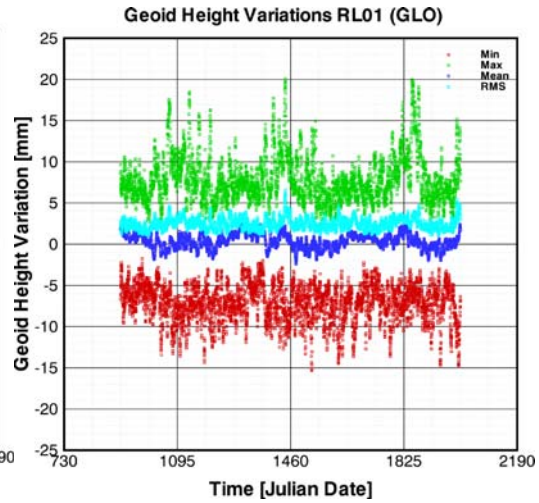
AOD1B RL04 Modifications (Slopes in RL03)



2002 2003 2004 2005



2002 2003 2004 2005

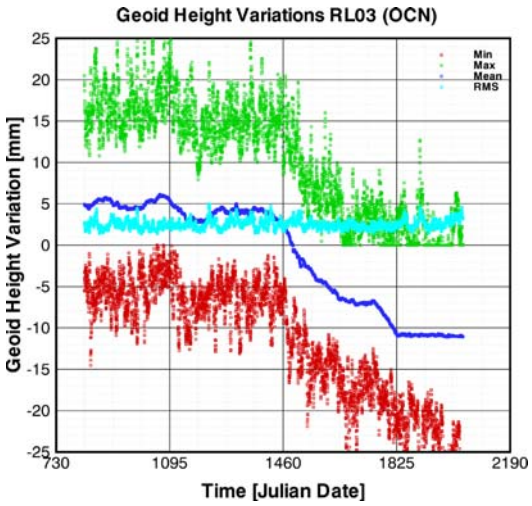


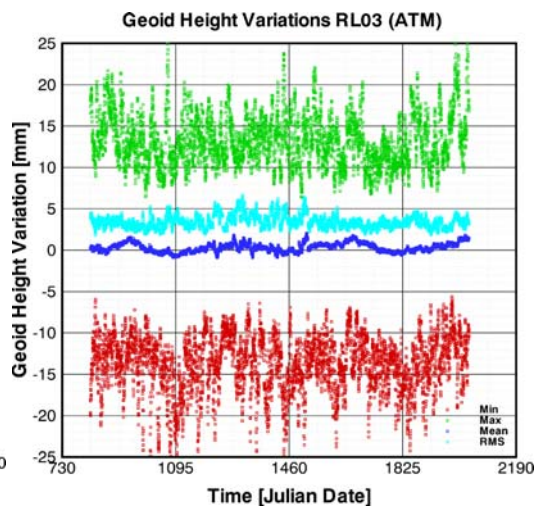
2002 2003 2004 2005

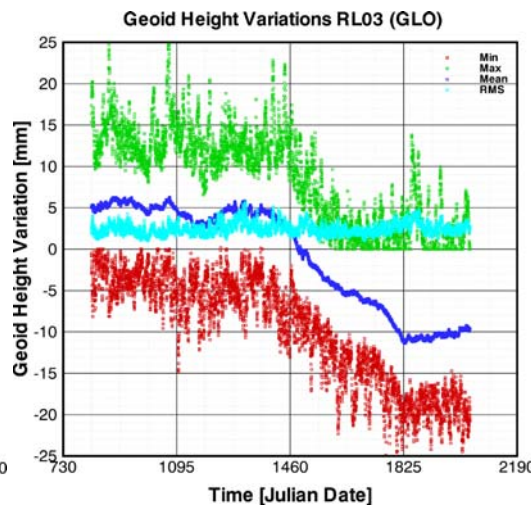
OMCT conditions:

2002-2004:
Salt conservation
(vanishing net fresh water fluxes)

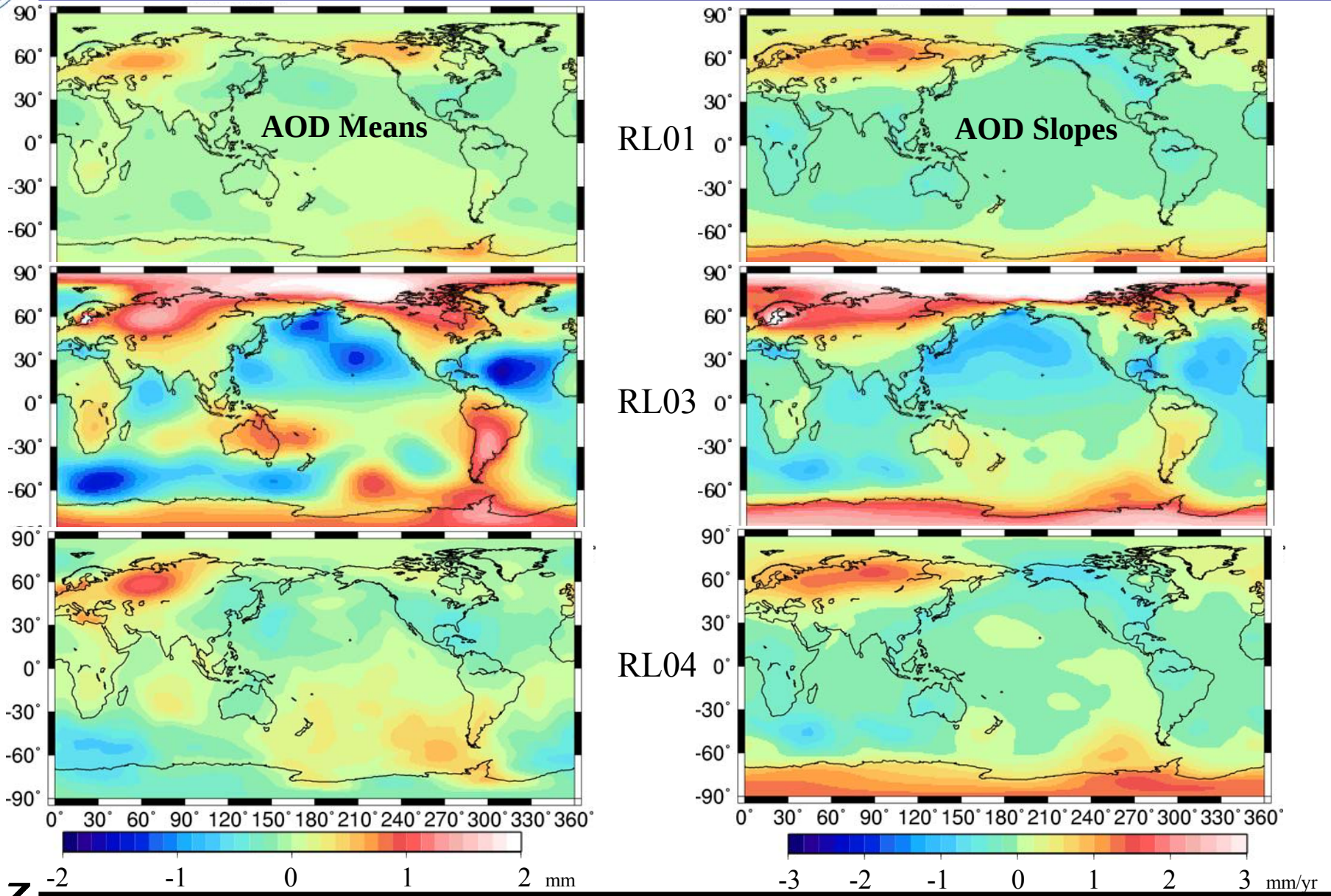
2005:
Mass conservation







AOD1B RL04 Modifications (Mean & Slopes for 2004-2005)



AOD1B RL04 Modifications (OBP Product)

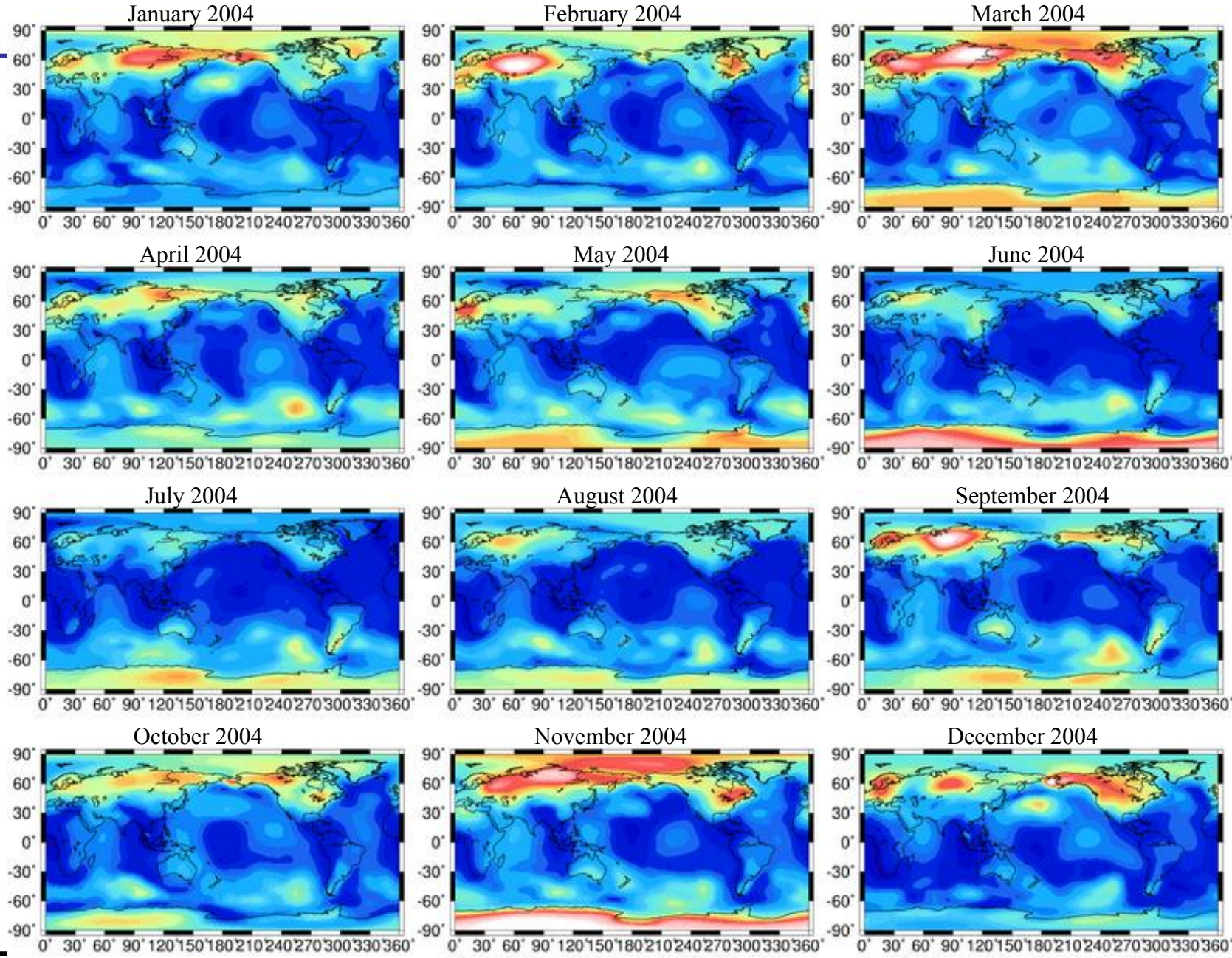
- So far, the oceanographic users had always to re-store the GAC product to the monthly GSM gravity field solutions to compare with e.g. in-situ ocean bottom pressure data.

- The GAC products are the mean of all AOD1B products used to generate the gravity field solutions

- GAC have the disadvantage that they a) contain atmosphere leakage at the continental borders and b) do not represent true ocean bottom pressure:
  - Land pixels: VI
  - Ocean pixels: VI + WC

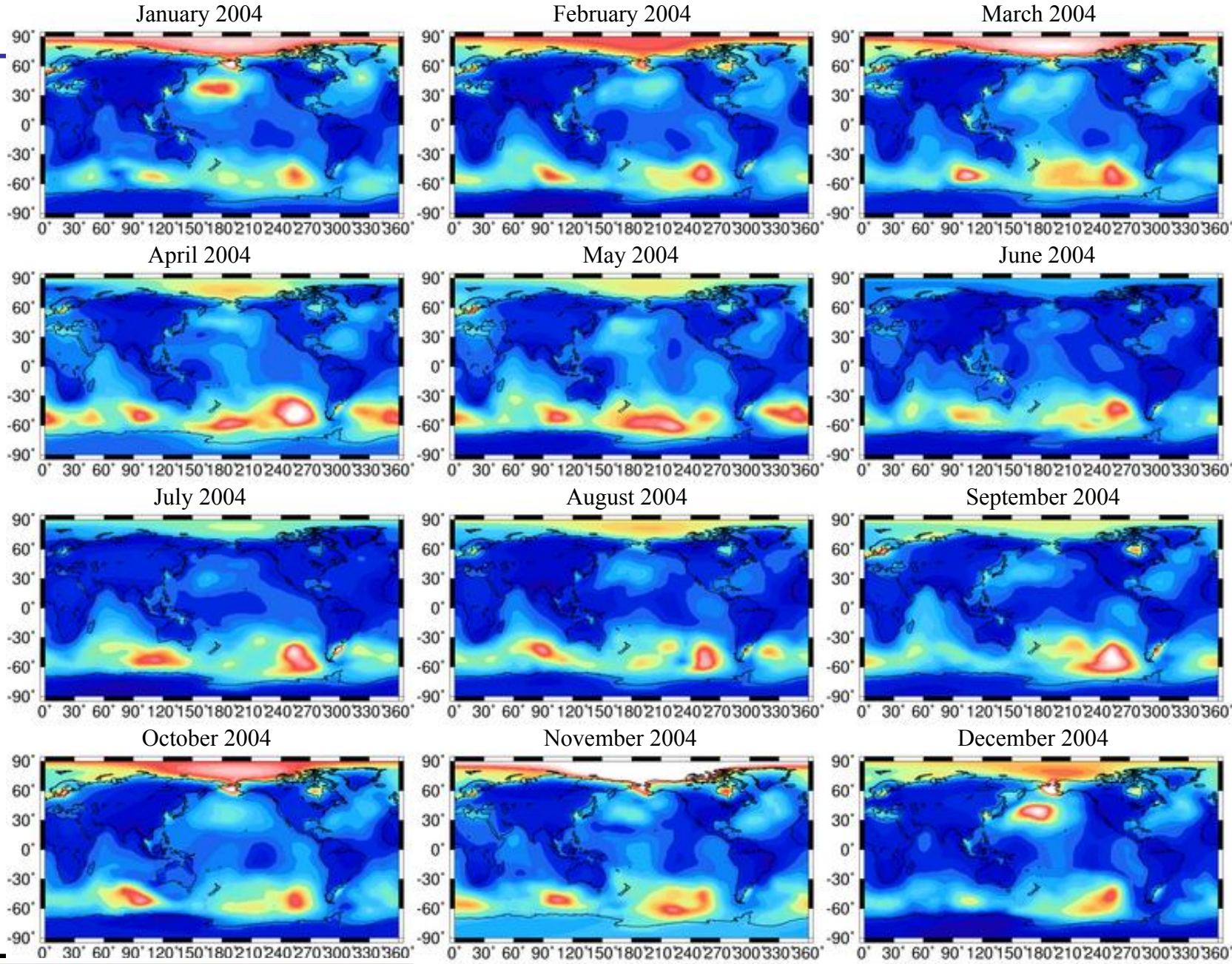
- AOD1B RL04 will provide OMCT ocean bottom pressure (GAD):
  - Land pixels: 0.
  - Ocean pixels: SP + WC

AOD RL04 "GAC" Monthly Standard Deviations for 2004



Courtesy by Jennifer Bolin (CSR)

AOD RL04 “GAD” Monthly Standard Deviations for 2004



Courtesy by Jennifer Bolin (CSR)

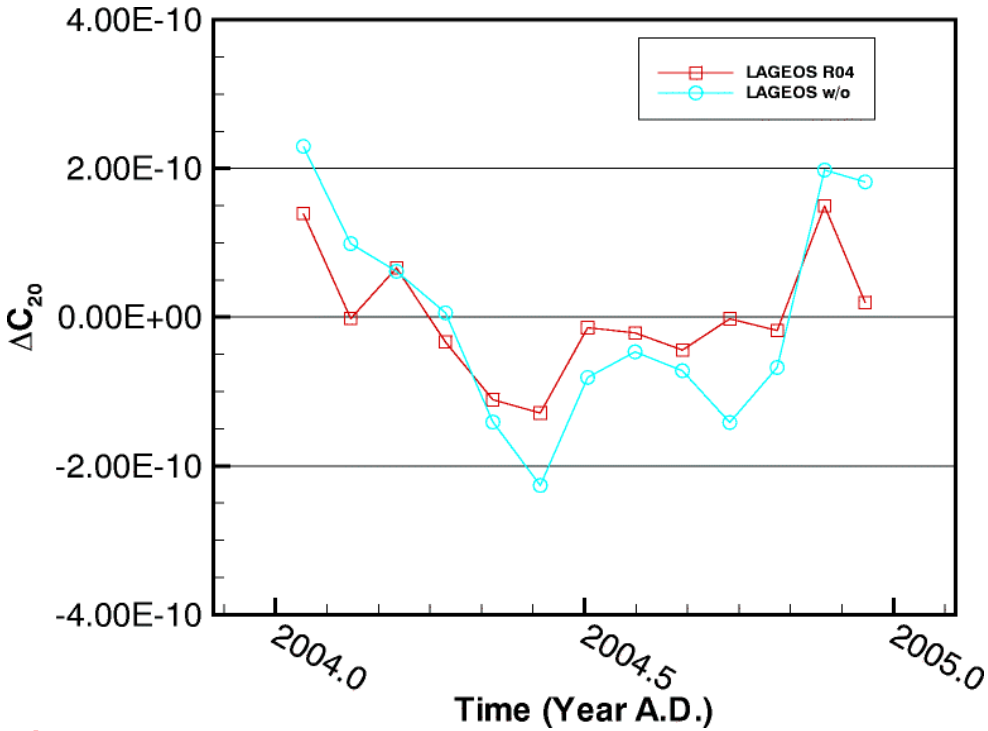
AOD1B RL04 available for 2001 – today:
Used to de-aliase CHAMP and GRACE data

What is the influence on Lageos?

AOD1B RL04 Further Plans (Extension back to 1976)

Q1: Is there an influence of AOD1B on Lageos-derived C20?

Yes!



Three problems to process AODs back to 1976:

1.) VI needs lot of processing time, data acquisition & data storage

Q2: Can we use simple Surface Pressure (SP) instead of VI approach?

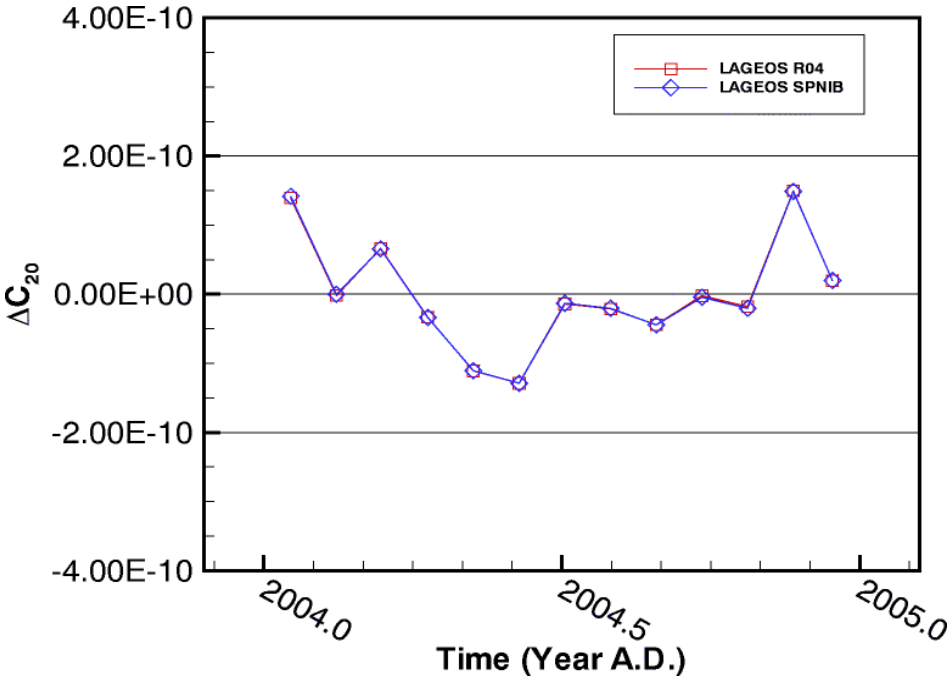
2.) OMCT to be reprocessed for many years

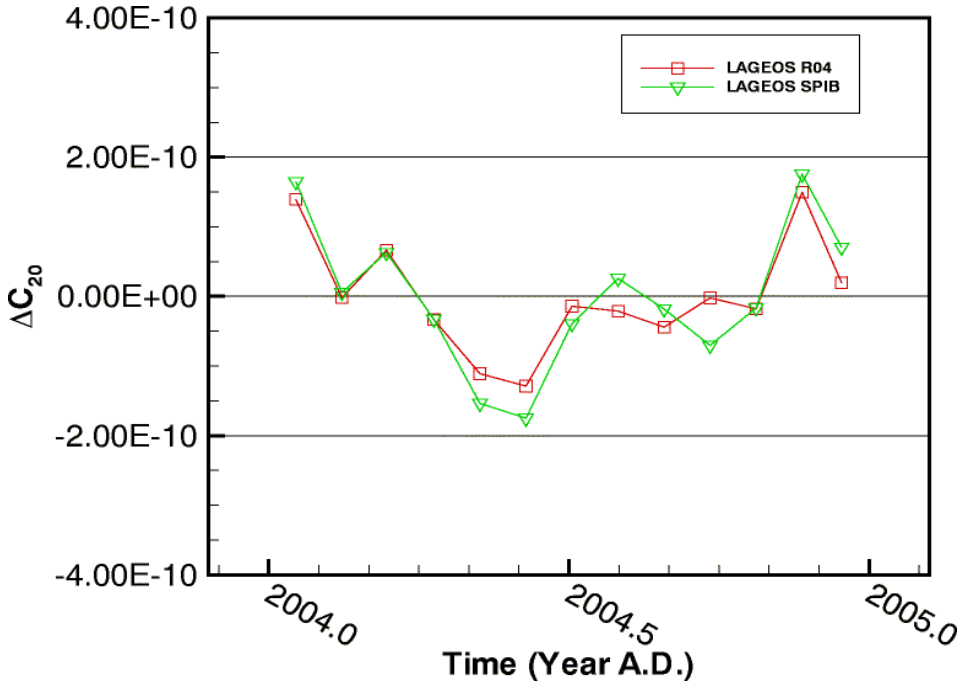
Q3: Can we use IB instead of OMCT?

3.) ECMWF analysis data not consistently available back to 1976

Q4: Can we use ERA40 instead of analysis data for period 1976 – 2000?

AOD1B RL04 Further Plans (Extension back to 1976)

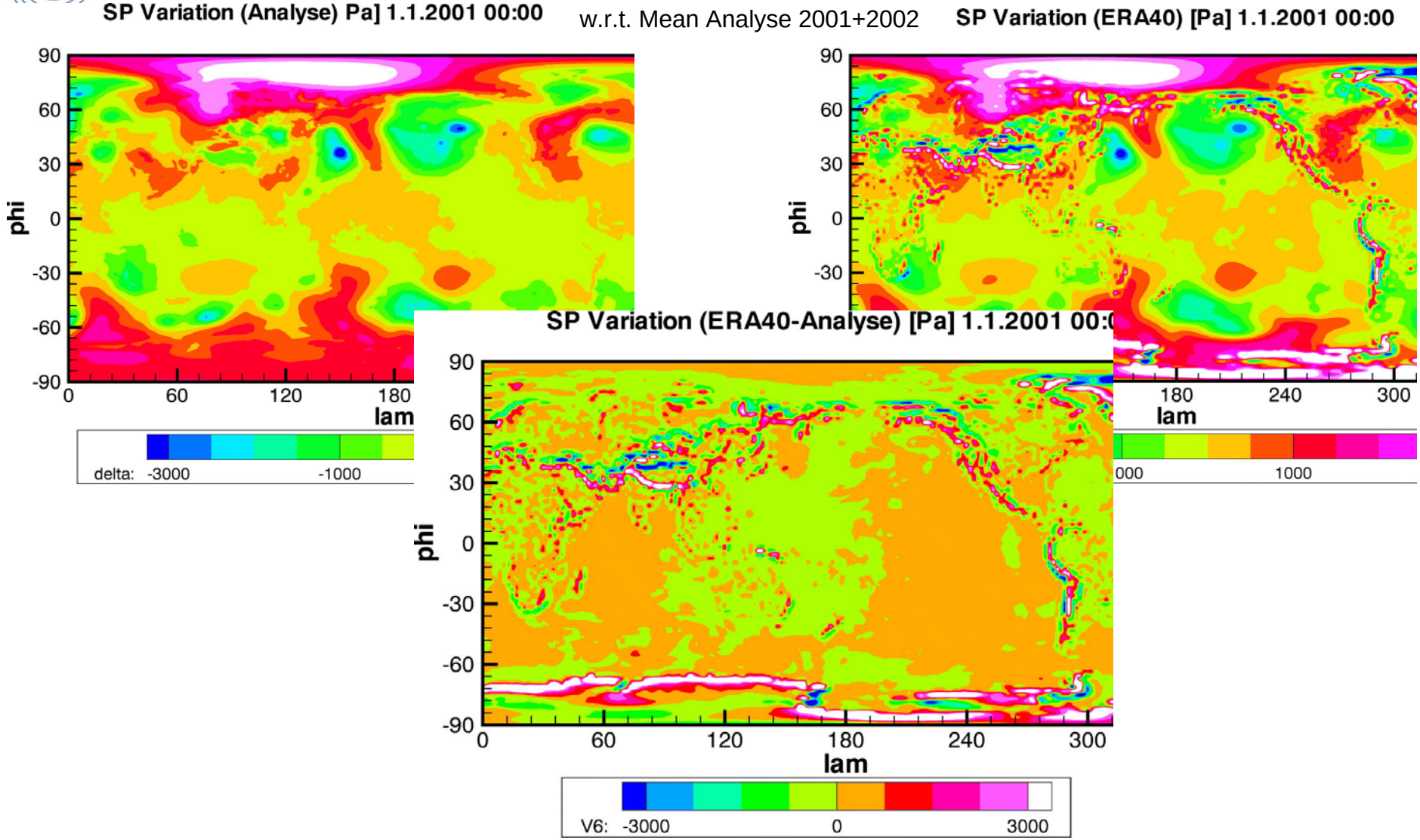




Q2: Can we use simple Surface Pressure (SP) approach? Yes!

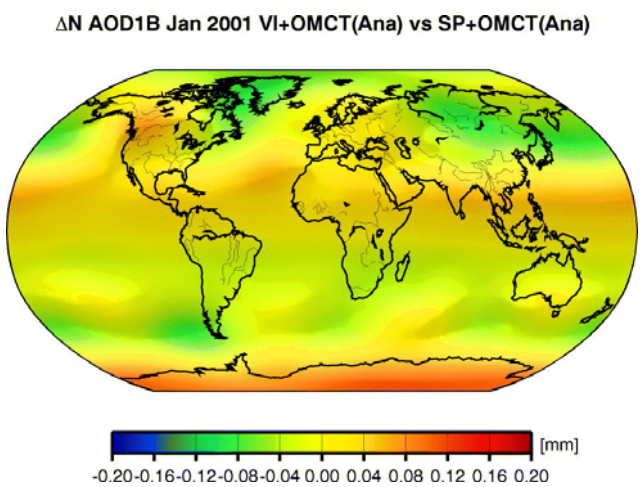
Q3: Can we use IB instead of OMCT? No!

AOD1B RL04 Further Plans (Extension back to 1976)

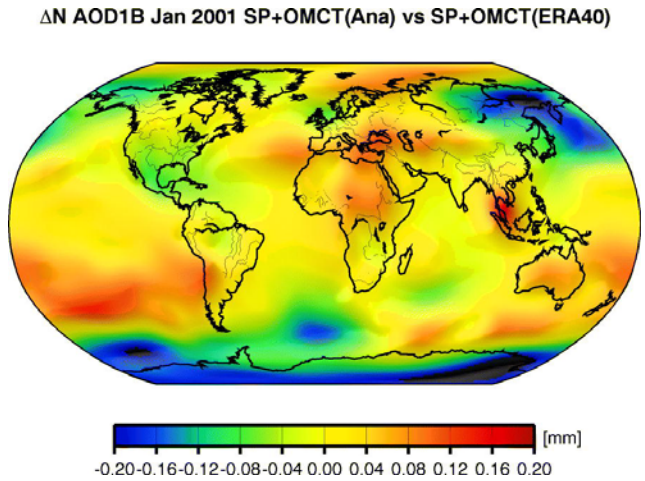


ΔMean to avoid jumps: ERA40 (2001) – Analyse (2001) -> Min

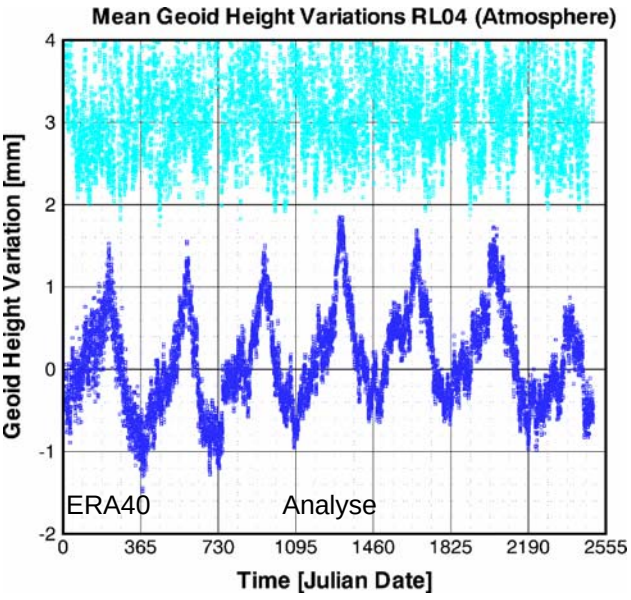
AOD1B RL04 Further Plans (Extension back to 1976)

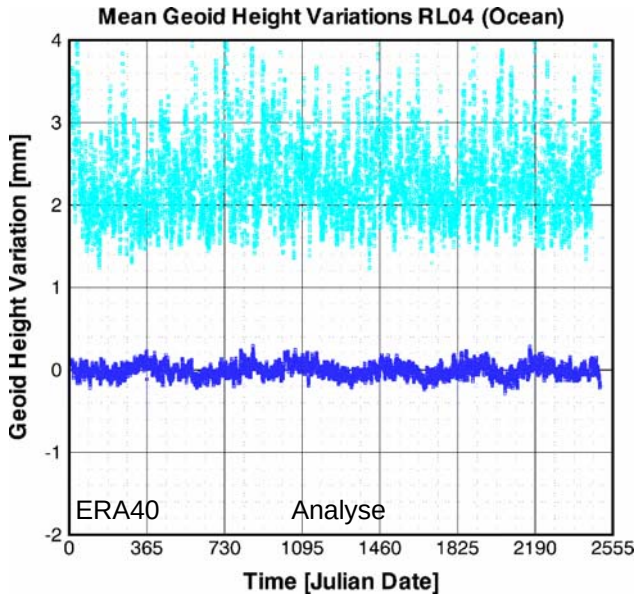


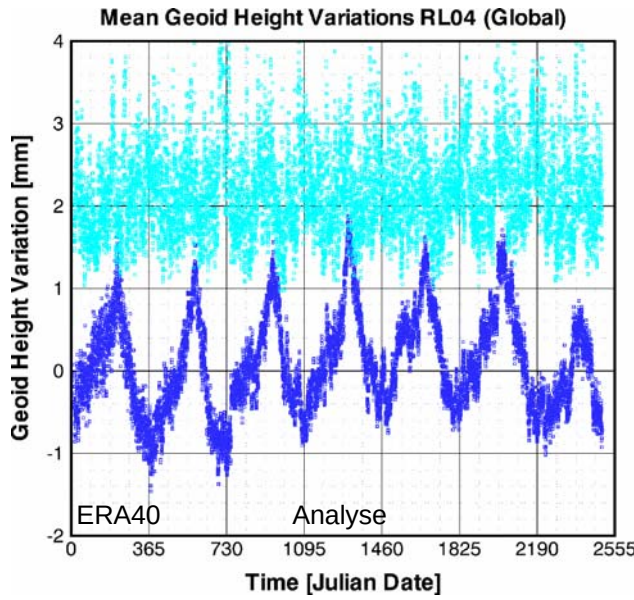
min = -0.093 mm, max = 0.112 mm, RMS = 0.037 mm



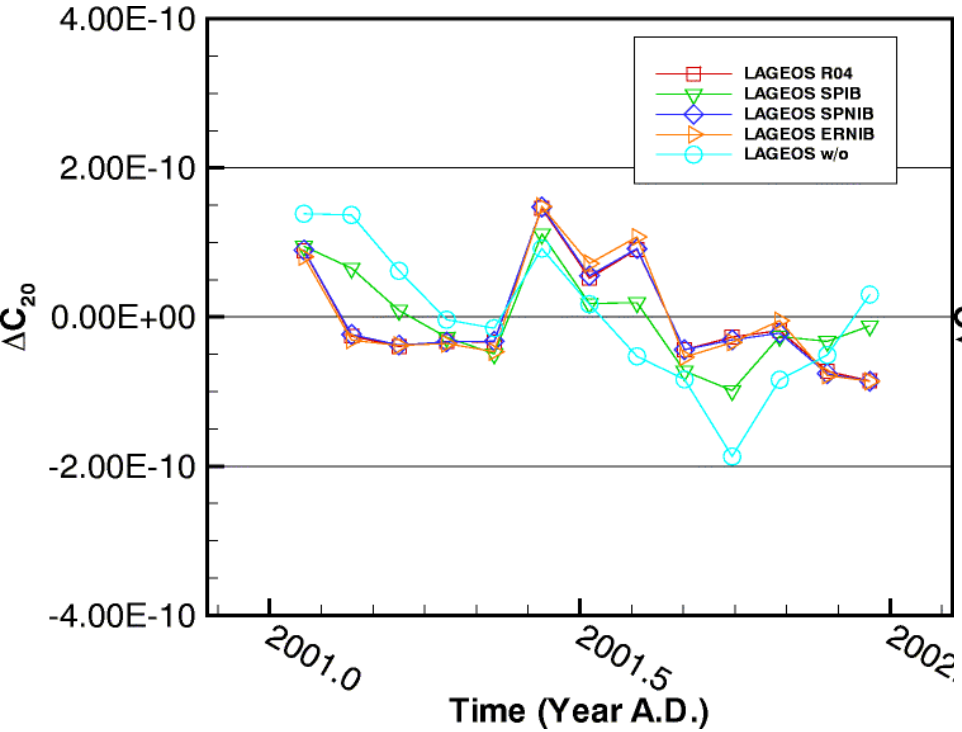
min = -0.252 mm, max = 0.172 mm, RMS = 0.064 mm

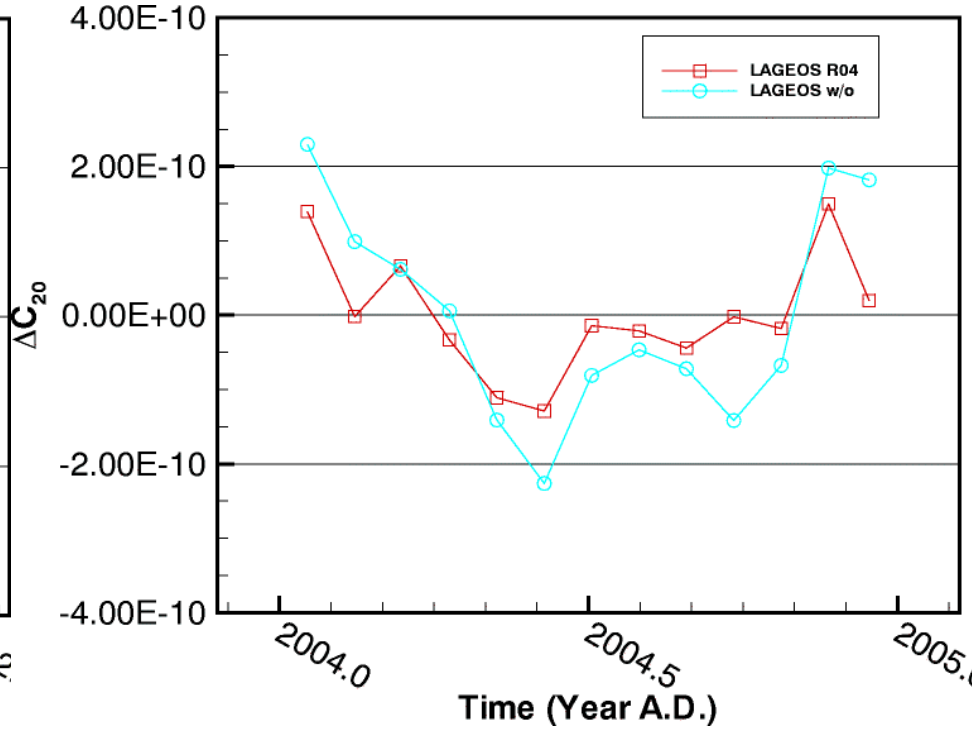






AOD1B RL04 Further Plans (Extension back to 1976)





Q4: Can we use ERA40 instead of analysis data for period 1976 – 2000? Yes!

What can GGFC get from the Gravity Missions today?

- 6-hourly and monthly-mean (corresponding to the GRACE gravity field solutions) atmospheric, oceanic and combined as well as ocean bottom pressure mass variations (AOD1B RL04) based on
  - ECMWF forcing
  - Mean field 2001+2002
  - Mass-conserving OMCT (avoids artificial slopes on land)
  - Vertical integrated pressure, surface pressure (for OBP)
  - Harmonized land/water mask and L1/L2 standards

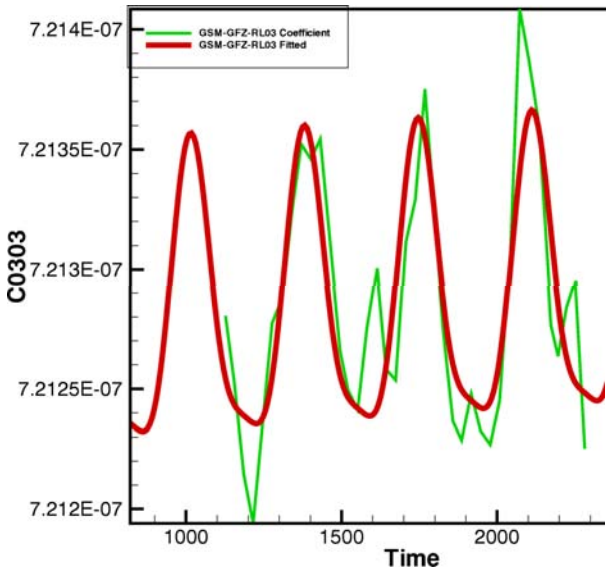
- 2001-today products and AOD1B Product Description Document will be available after release of SDS RL04 GRACE gravity field time series (beginning of 2007) at http://isdc.gfz-potsdam.de/grace

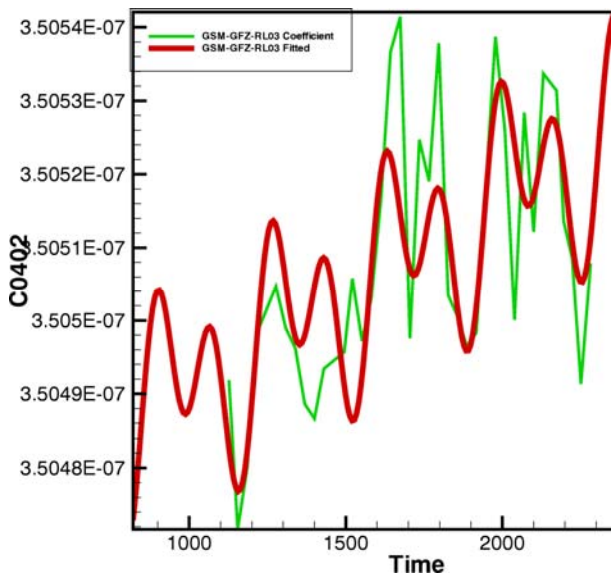
What can GGFC get from the Gravity Missions mid 2007?

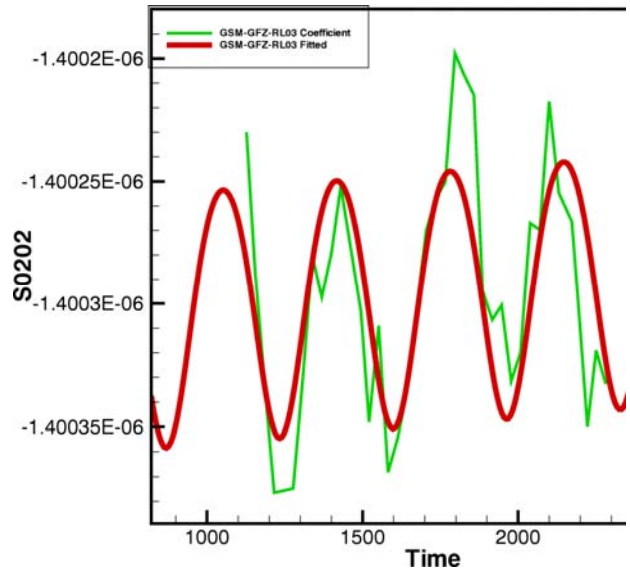
- Extended AOD1B RL04 time series back to 1976 based on ERA40 for Lageos data processing in order to improve long-term C20 time series.

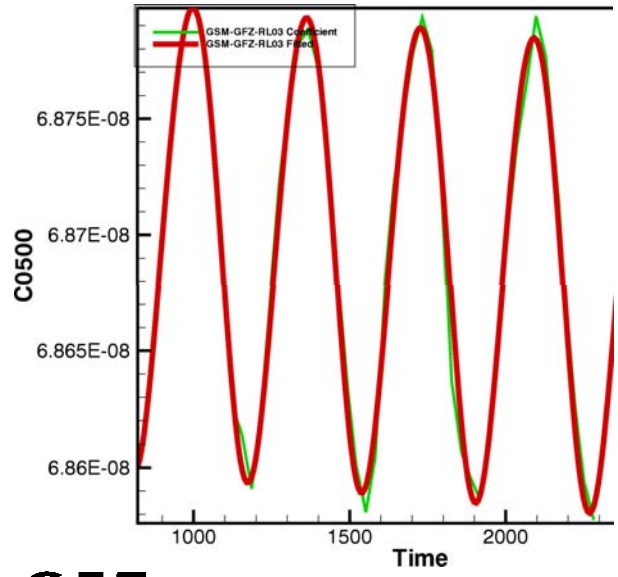
- Products and AOD1B Product Description Document will also be available at http://isdc.gfz-potsdam.de/grace

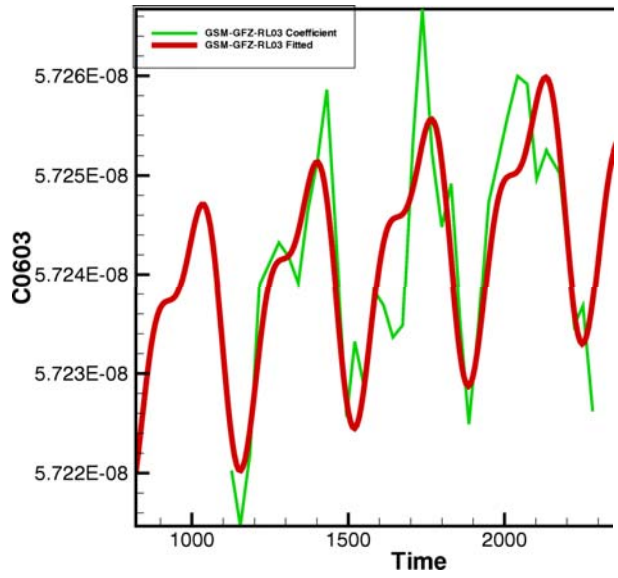
What can GGFC get from the Gravity Missions tomorrow?

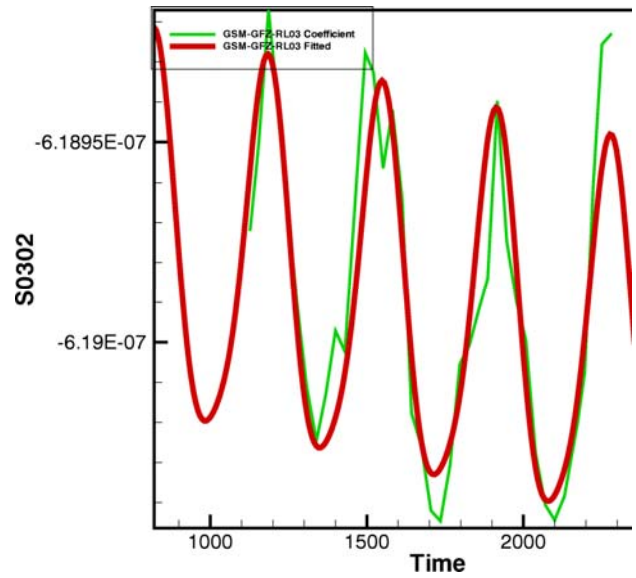






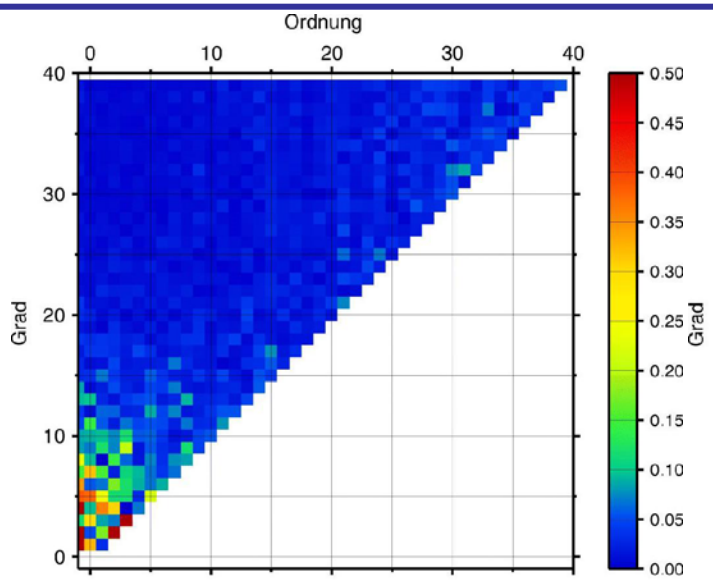


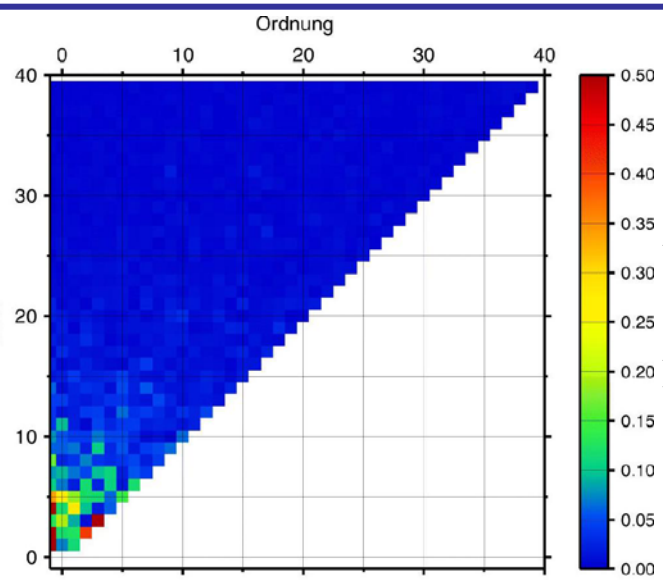




What can GGFC get from the Gravity Missions tomorrow?

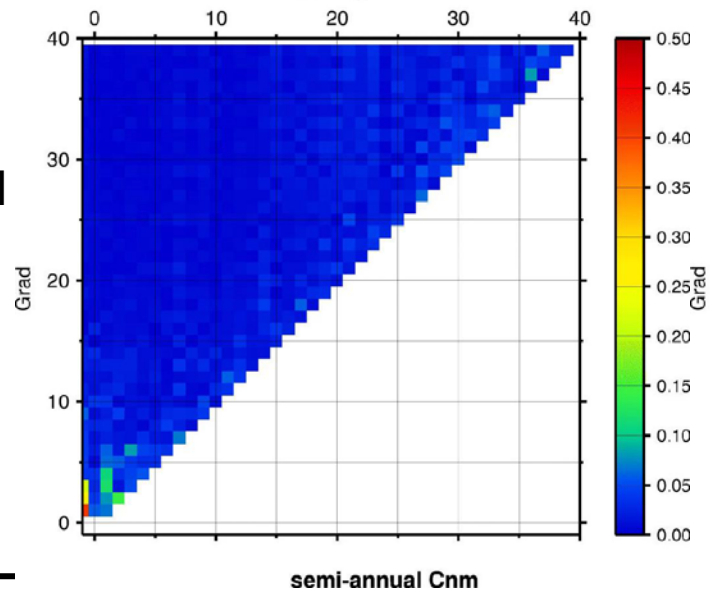
Annual Cnm Amplitudes GFZ RL03

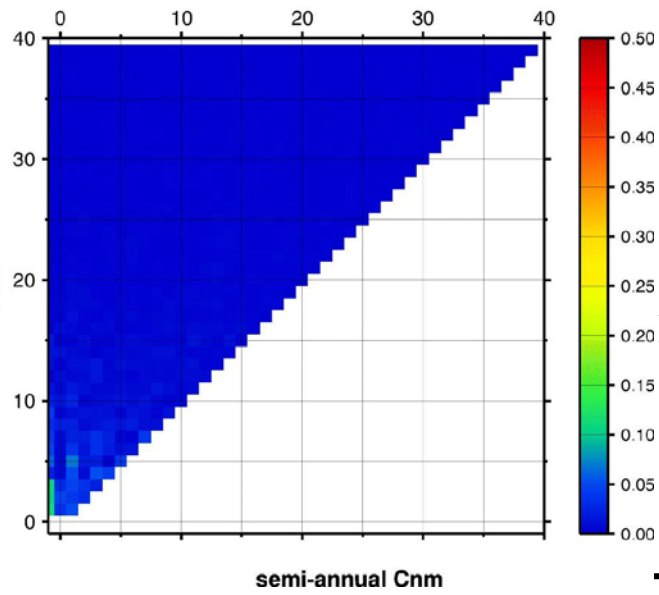




Annual Cnm Amplitudes WGHM

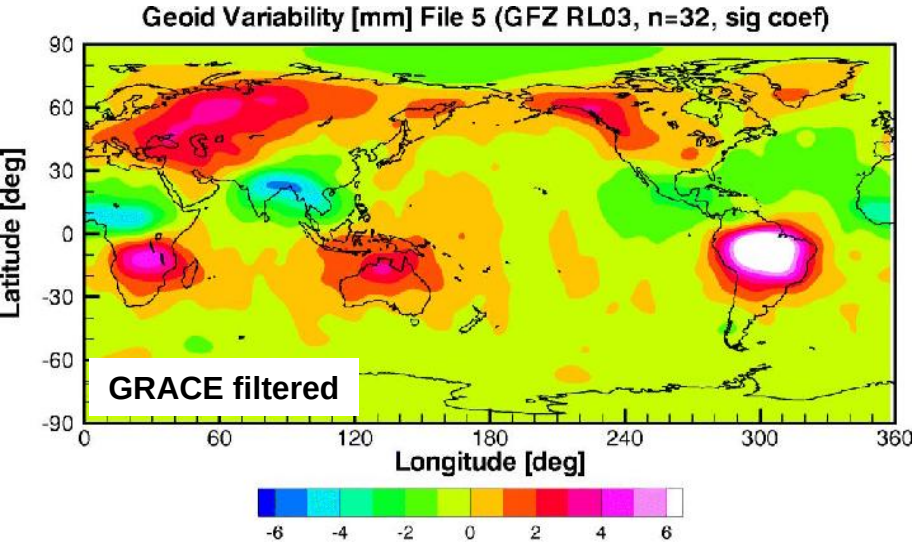
Semi-annual Cnm Amplitudes GFZ RL03

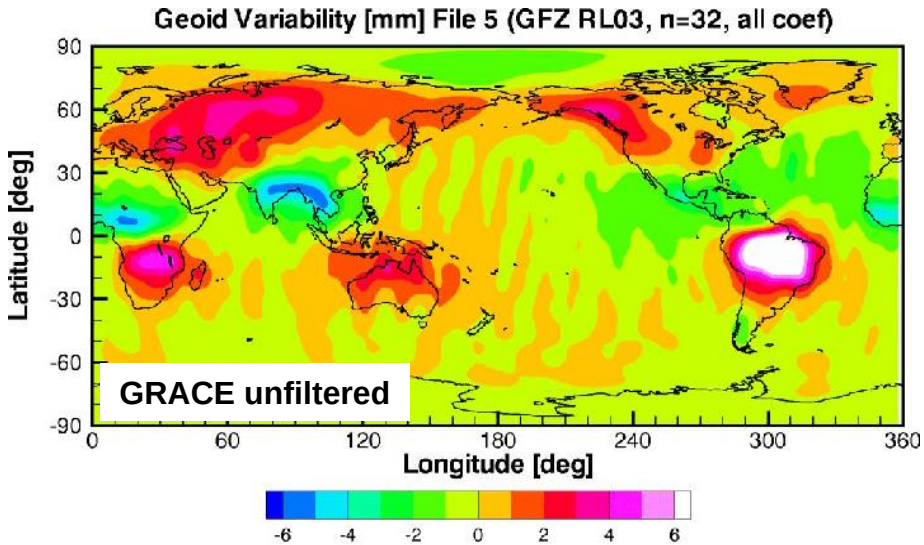


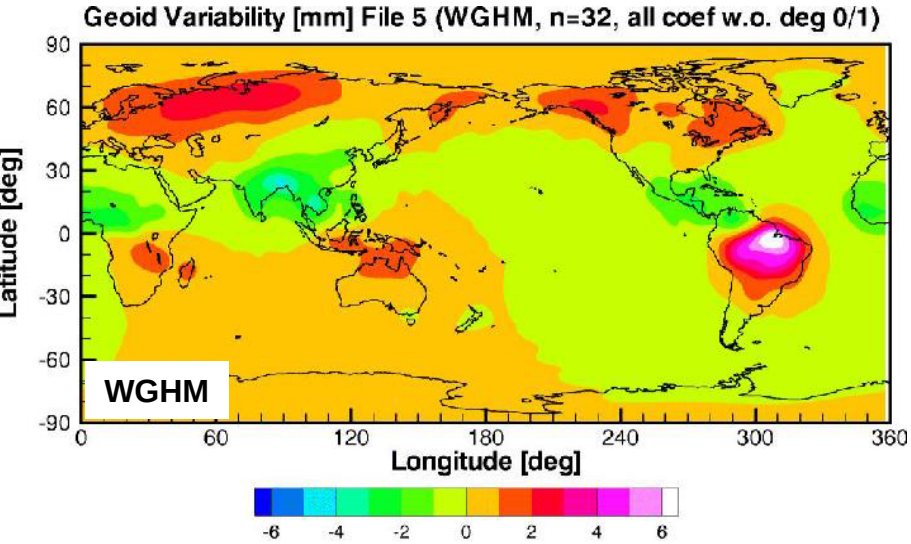


Semi-annual Cnm Amplitudes WGHM

What can GGFC get from the Gravity Missions tomorrow?



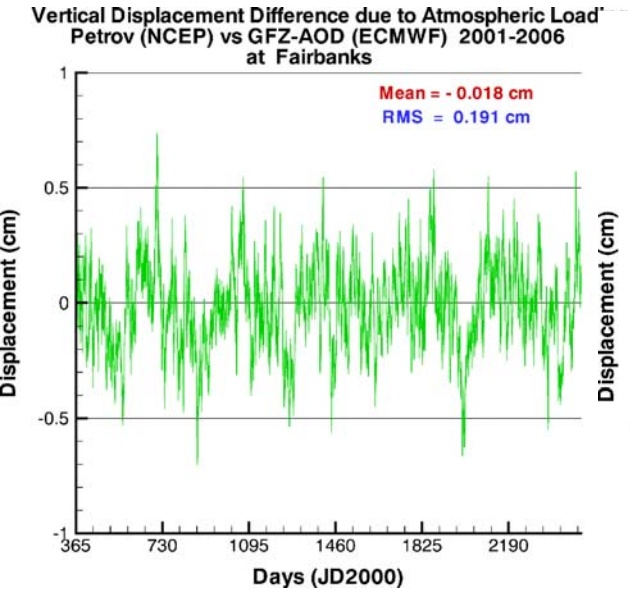


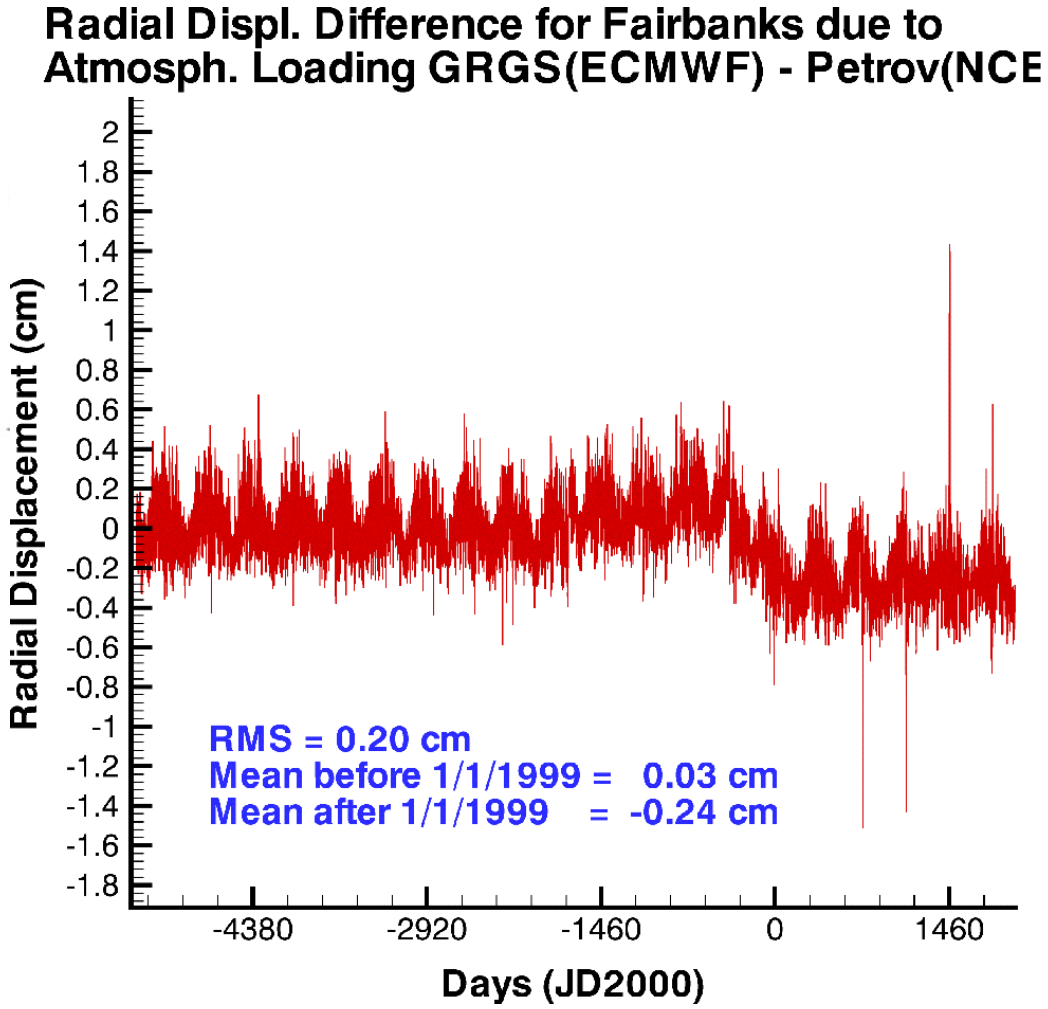


Assimilation of GRACE data into hydrological models (WGHM, TIVAGAM-project) will help to get daily hydrological mass variations!

What can GGFC get from the Gravity Missions tomorrow?

Precise Atmospheric Loading Corrections necessary for GPS ground data processing used to define the High-Low GPS CHAMP/GRACE reference frame.





What can GGFC get from the Gravity Missions tomorrow?

- Daily and monthly-mean (corresponding to the GRACE gravity field solutions) hydrological mass variations based on GRACE assimilation into WGHM (TIVAGAM project). Probaby another set of coefficients in the daily AOD1Bs.

- In principle another 6-hourly set of spherical harmonic coefficients could be generated for atmospheric loading based on
  - ECMWF analysis surface pressure over land (2001-today)
  - ERA40 surface pressure over land (1976-2000)
  - IB over the oceans

  But:
  - Results depend (as well as the AOD1Bs) on the analysed meteorological centers (e.g. ECMWF, NCEP).
  - Special care has to be taken on jumps due to modifications in the met center processing strategy.