

Atmospheric and Oceanic Gravity Field De-Aliasing for GRACE Science Data Processing

Th. Gruber, J. Wunsch
GeoForschungsZentrum Potsdam (GFZ), Division 1

S. Bettadpur, T. Pekker
**Center for Space Research at University of Texas in Austin
(CSR)**

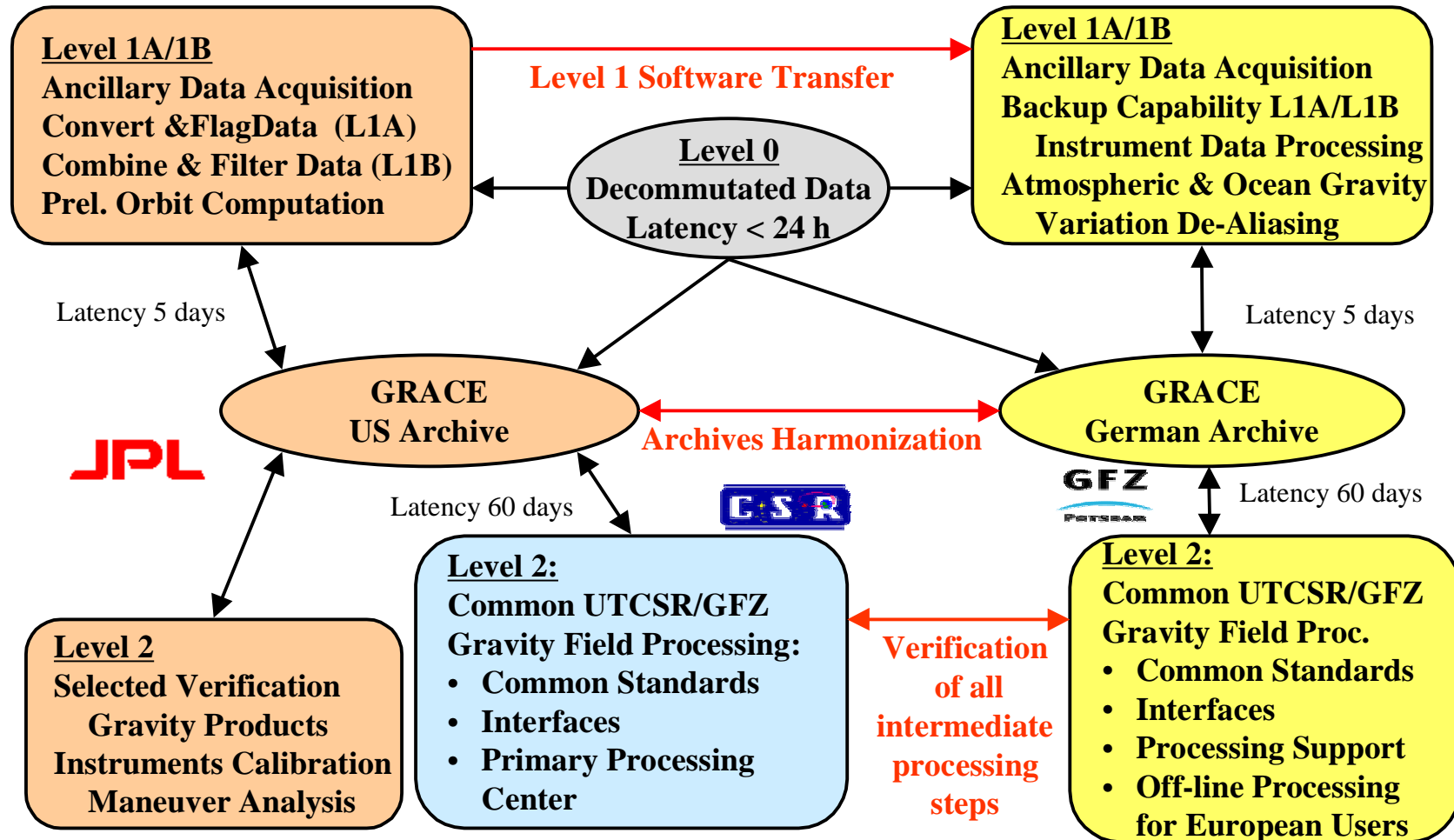
**e-mail: gruber@gfz-potsdam.de
srinivas@csr.utexas.edu
<http://op.gfz-potsdam.de/grace>
www.csr.utexas.edu/grace**



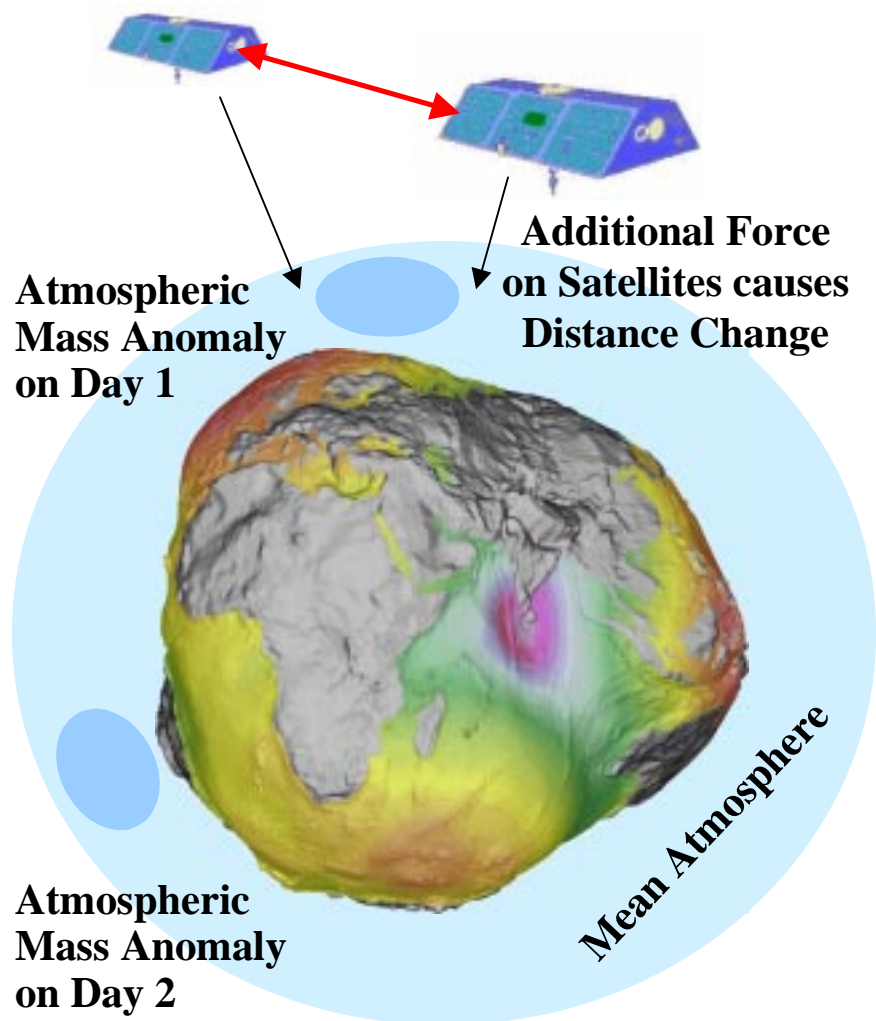
Outline

- *GRACE Science Data System*
- *Introduction & Problem Definition*
- *Atmospheric Gravity Field De-Aliasing*
 - *Surface Pressure Analysis*
 - *Vertical Structure of Atmosphere*
- *Oceanic Gravity Field De-Aliasing*
- *Conclusions & Future Work*

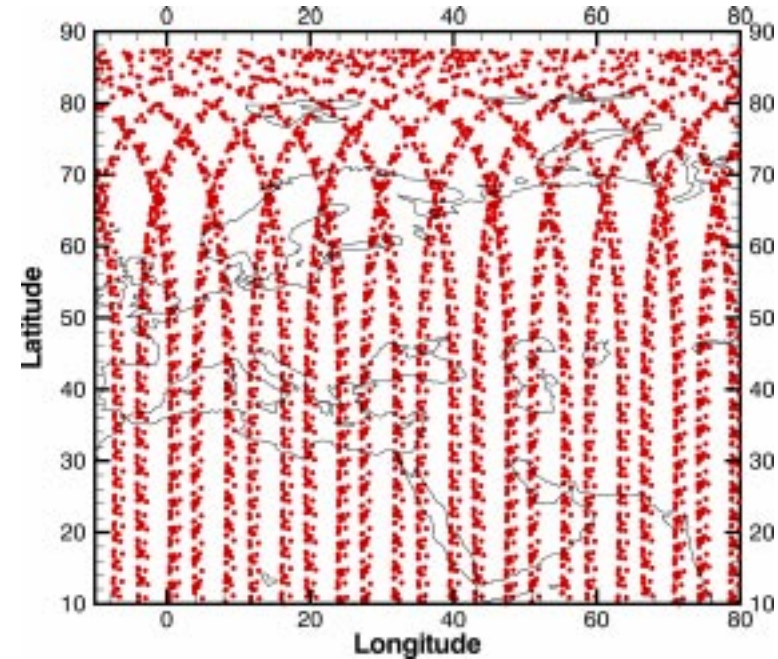
GRACE Science Data System



Introduction & Problem Definition



30 Days Sample Track Pattern

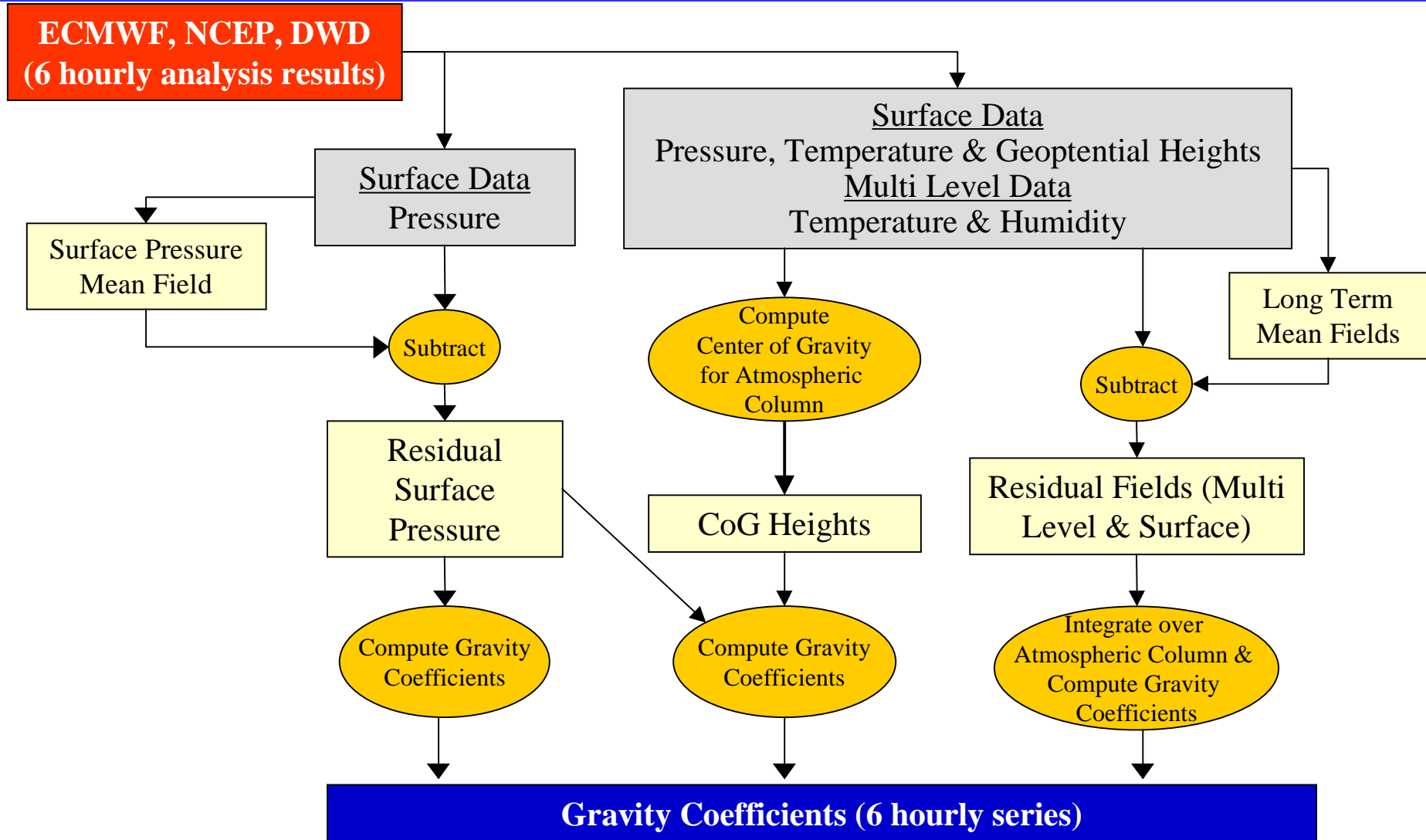


Due to variations in satellites space-time sampling no elimination of time dependent mass anomalies by repeated observations possible (e.g. altimetry). Correction during gravity field determination process necessary.

Introduction & Problem Definition

- **Mass variations cause time variant gravity field forces acting on the satellites**
- **Time varying gravity field forces have to be taken into account during orbit integration.**
- **Approach: Provision of gravity harmonics correction coefficients computed from external data to be applied to mean gravity field.**
- **Primary task: Computation of gravity coefficients corrections from different sources.**
- **Secondary task: Definition of mean gravity field with inclusion of mean atmosphere, ocean, ice and continental water.**

Atmospheric Gravity Field De-Aliasing



Atmospheric Gravity Field De-Aliasing

$$V = \frac{kM}{r} \sum_{n=0}^{\infty} \sum_{m=0}^n \left(\frac{a}{r}\right)^n P_{nm}(\cos \theta) (C_{nm} \cos m \lambda + S_{nm} \sin m \lambda)$$

$$C_{nm} = \frac{1}{(2n+1)Ma^n} \iiint_{Earth} r^n P_{nm}(\cos \theta) \cos m \lambda dM$$

$$dM = \rho dV = \rho r^2 dr \sin \theta d\theta d\lambda = r^2 q \sin \theta d\theta d\lambda = r^2 q dS \quad q = \frac{P_s}{g} = \rho h \quad (\text{hydrostatic equation})$$

Surface Pressure: (on Earth surface $r=a$; k_n : load Love numbers for elastic deformation of Earth)

$$C_{nm} = \frac{a^2(1+k_n)}{(2n+1)Mg} \iint_{Earth} P_s P_{nm}(\cos \theta) \cos m \lambda dS$$

Center of Gravity & Surface Pressure: ($r=a+z$ with z = center of gravity height)

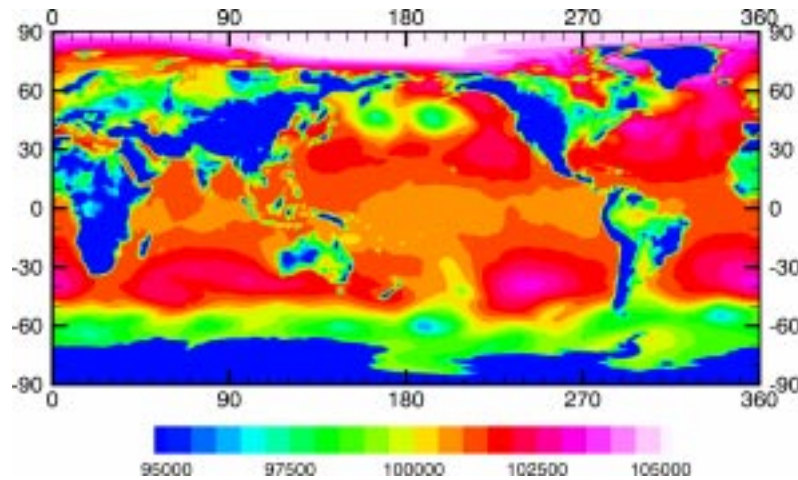
$$C_{nm} = \frac{(1+k_n)}{(2n+1)Ma^n g} \iint_{Earth} r^{n+2} P_s P_{nm}(\cos \theta) \cos m \lambda dS$$

Vertical Integration of Atmospheric Density:

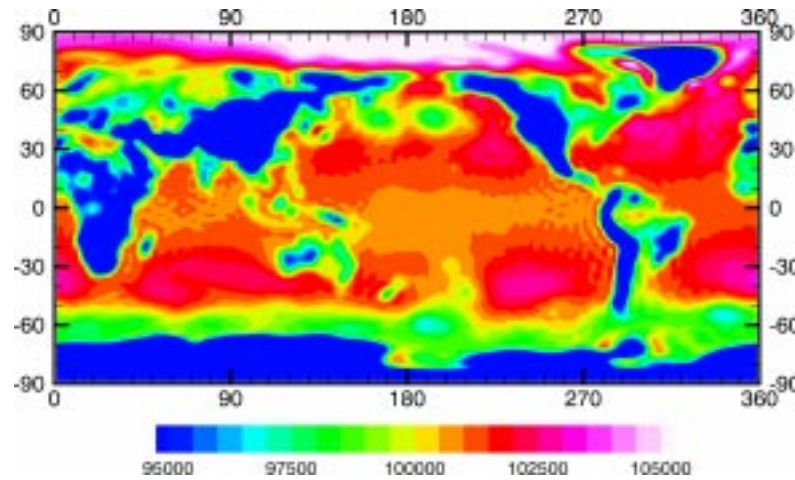
$$C_{nm} = \frac{(1+k_n)}{(2n+1)Ma^n} \iint_{Earth} \left[\int_{P_s}^0 \frac{r^{n+2}}{g} dP \right] P_{nm}(\cos \theta) \cos m \lambda dS$$

Atmospheric Gravity from Surface Pressure

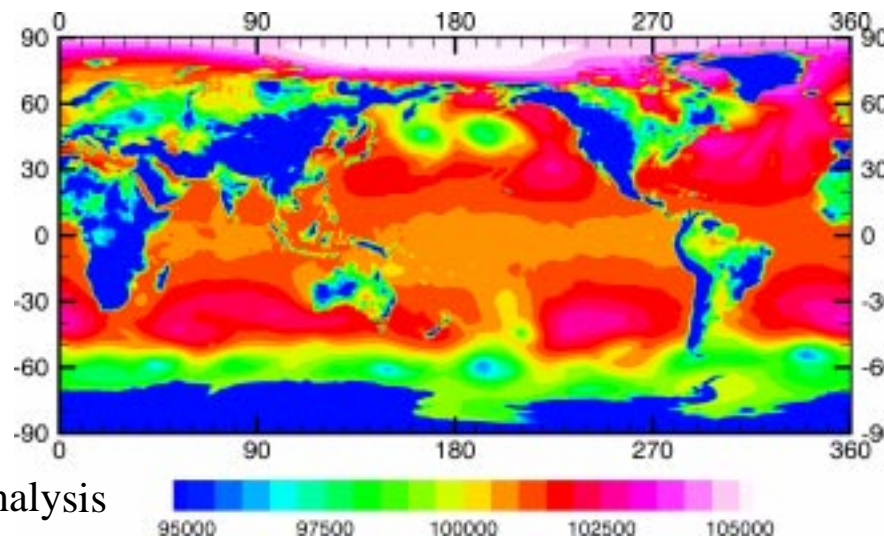
Surface Pressure from Different Analysis (23. Feb. 2001 00h)



DWD Analysis



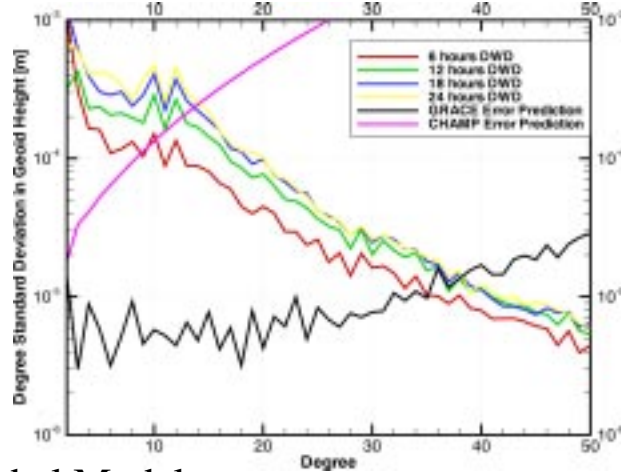
NCEP Reanalysis



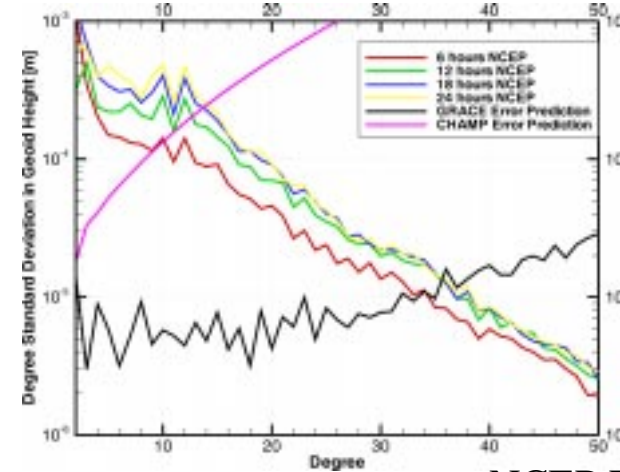
ECMWF Analysis

Atmospheric Gravity from Surface Pressure

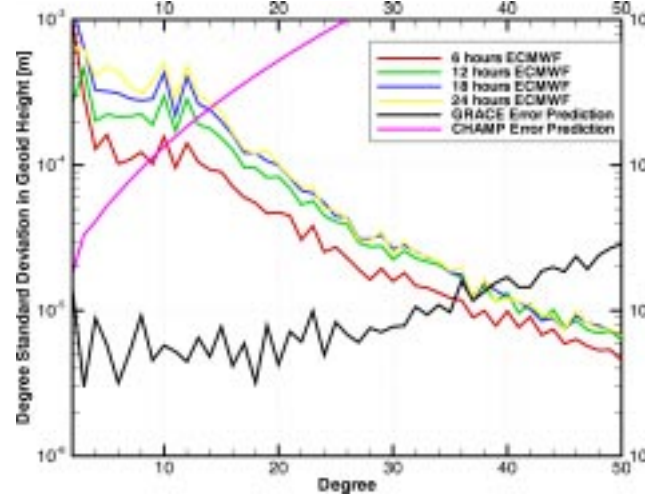
*Gravity Variations for Different Time Intervals (6, 12, 18, 24 hours)
for Different Atmospheric Analysis (23.Feb. 2001)*



DWD Global Model



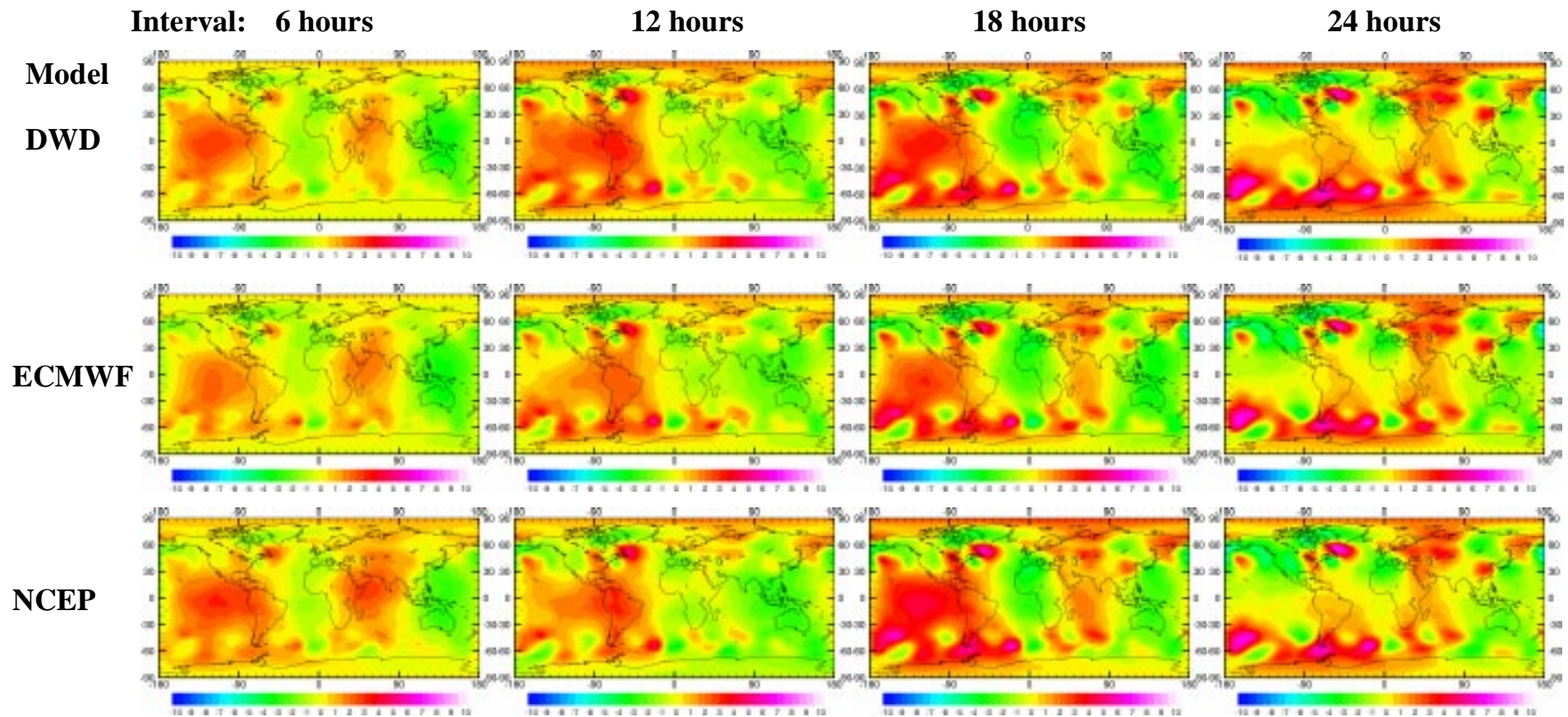
NCEP Reanalysis



ECMWF Model

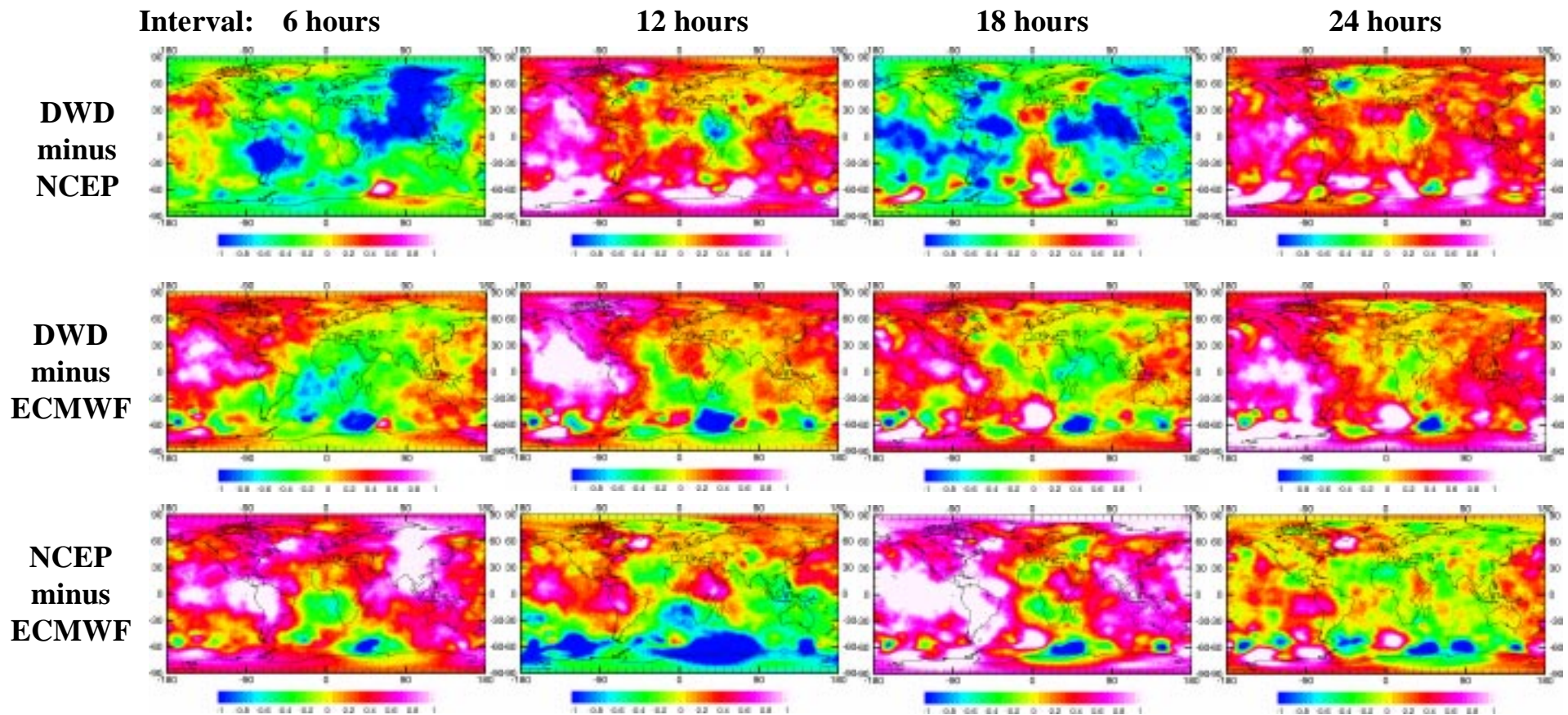
Atmospheric Gravity from Surface Pressure

Gravity Variations for Different Time Intervals for Different Atmospheric Analysis in Terms of Geoid Height Differences in mm (23. Feb. 2001)



Atmospheric Gravity from Surface Pressure

Differences of Gravity Variations for Different Time Intervals for Different Atmospheric Analysis in Terms of Geoid Height Differences in mm (23. Feb. 2001)

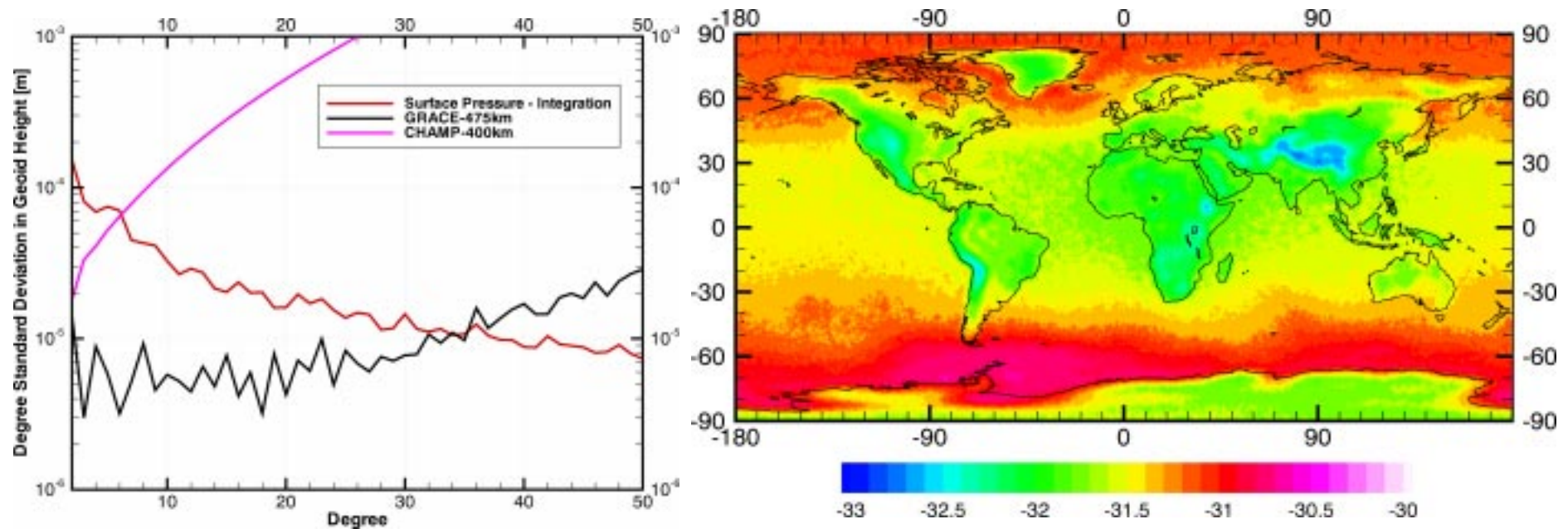


Atmospheric Gravity - Vertical Integration

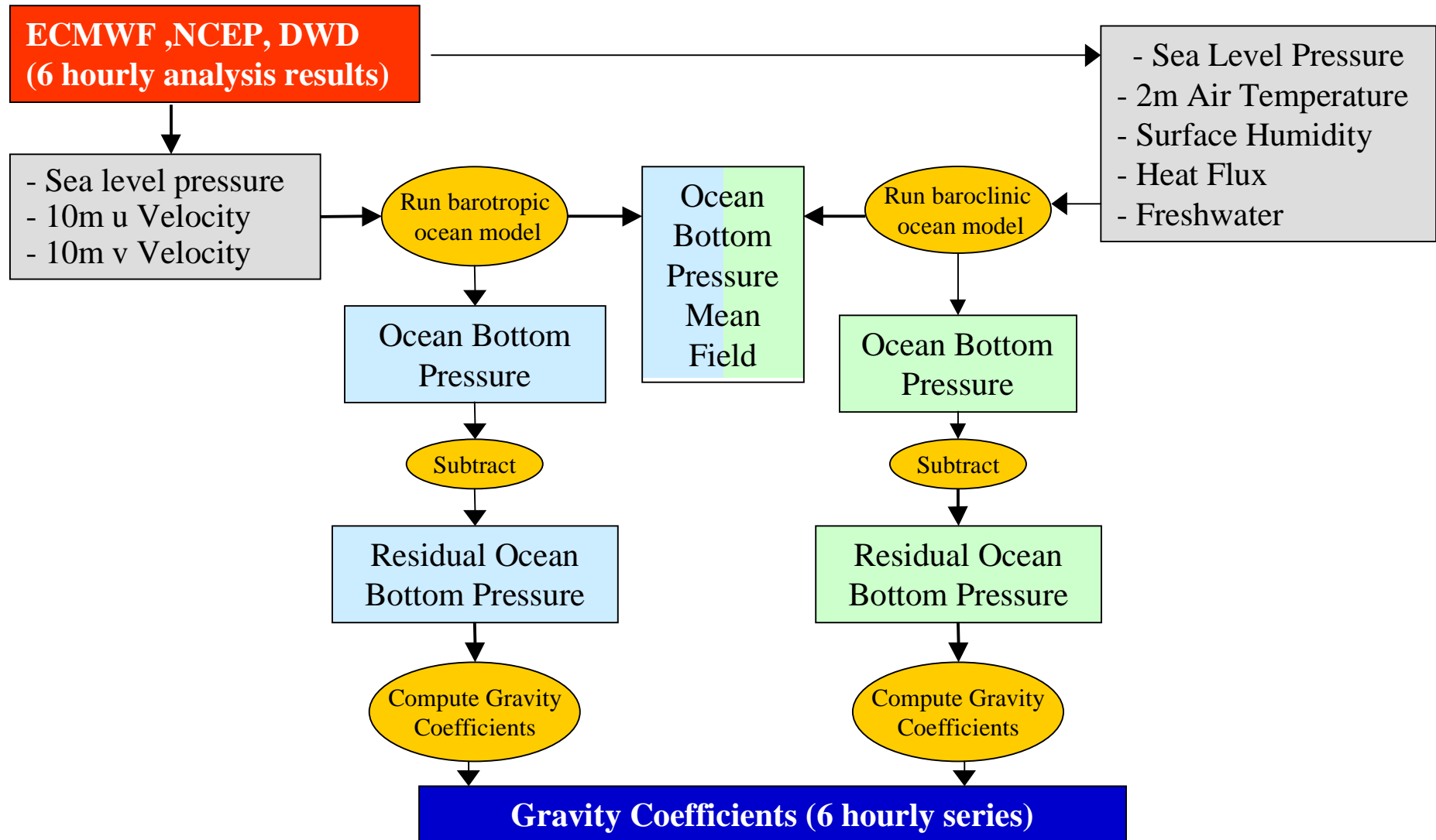
Difference Surface Pressure - Vertical Integration

GFZ Computation:

- Surface Pressure versus Vertical Integration (degree variances and geoid differences)



Oceanic Gravity Field De-Aliasing



Oceanic Gravity Field De-Aliasing

Ocean Models available for GRACE Science Data System

Barotropic Model: Ponte-Hirose-Ali Version 1.1

Implemented at JPL by V. Zlotnicki

- 1.125 degree resolution, 1 hour time interval
- Global from 75S to 65N incl. Mediterranean. & smaller closed seas
- Forcing: Atm.pressure and 100 mbar winds converted to wind stress; Atm. thermal tides removed by filter.
- Bathymetry: ETOPO5 with modifications in shallow sea

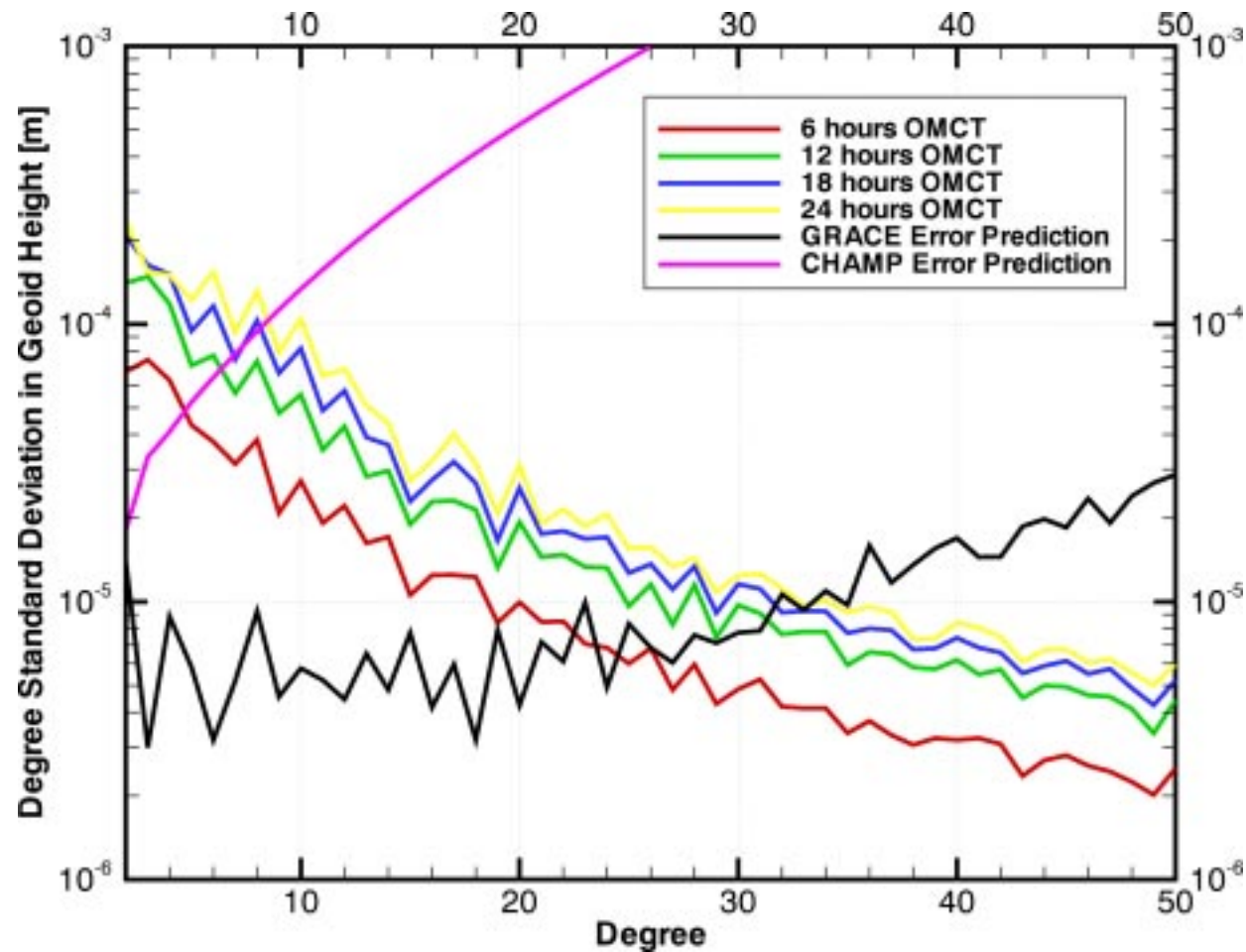
Baroclinic Model: Hamburg Ocean Model for Circulation and Tides

Developed and implemented by M. Thomas, J. Sündermann

- 1.875 degree resolution, 1 hour time interval, 13 layers
- Forcing: Atm. Pressure, wind vectors/wind stress, surface temperature, surface humidity, heat flux and freshwater desired
- Prognostic variables: Sea surface elevation, horizontal velocities, temperature, salinity, sea ice thickness and compactness

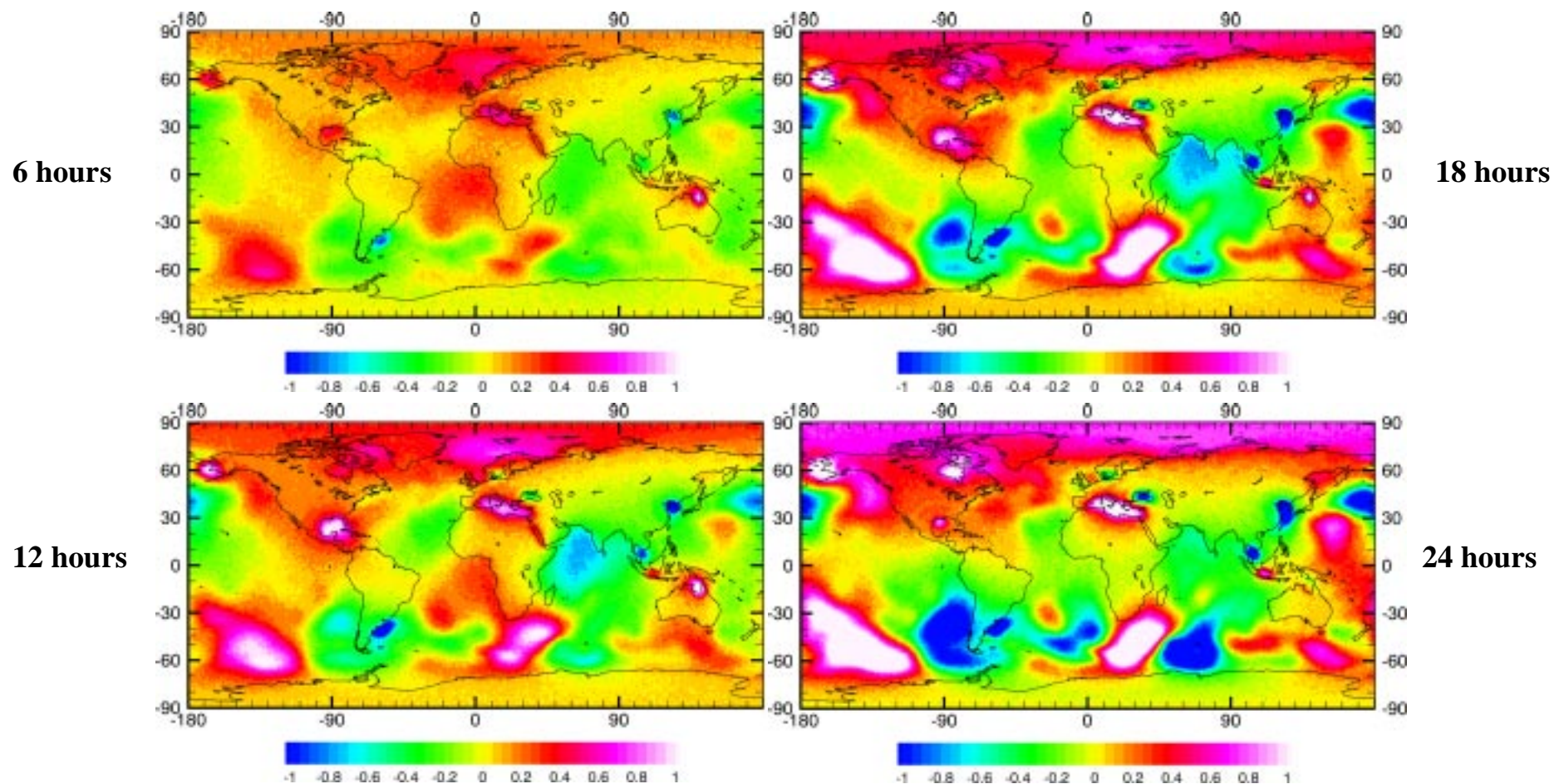
Oceanic Gravity Field De-Aliasing

Gravity Variations for Different Time Intervals based on Hamburg OMCT Model (24. June 1994)



Oceanic Gravity Field De-Aliasing

*Gravity Variations for Different Time Intervals based on
Hamburg OMCT Model*



Conclusions and Future Work

- GRACE will be sensitive to degree 40 (500 km half wavelength) to short term atmospheric & oceanic mass variations.
- ECMWF operational analysis fields will be used for computation of atmospheric gravity effect and forcing the ocean model.
- Uncertainties (based on model differences) of short term atmospheric gravity variation estimates are above prospected GRACE mean gravity field accuracy.
- 2 ocean models available for determination of ocean mass variations (barotropic and baroclinic). Further analysis and comparisons of resulting oceanic gravity variations necessary.
- Question: Is a combined analysis of surface pressure over continents and bottom pressure over oceans possible or necessary ? What assumption for inverse barometer effect ? Full or delayed oceanic response on atmospheric mass ?