

The Impact of Uncertainties of Global Atmosphere Models on the Gravity Field Determination with GRACE

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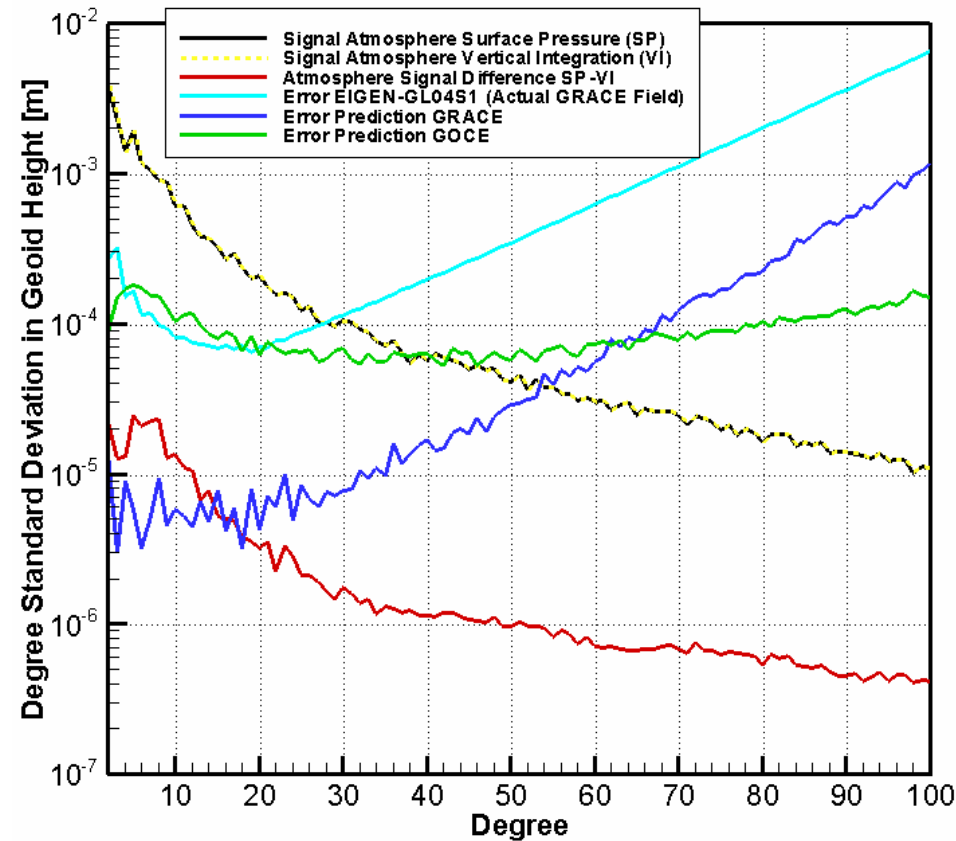
³GeoForschungsZentrum Potsdam

SPP Project: IDEAL-GRACE – Improved De-aliasing for Gravity Field Modelling with GRACE



Motivation

- The **De-Aliasing** process seems to be one of the main remaining uncertainty source in the GRACE data analysis.
- Specifically atmospheric mass variations play a major role!
- Uncertainties in atmosphere models have direct impact on GRACE
(c.p. fig: Degree-Variances of atmosphere signal is „above“ the error of GRACE)



Project Goals

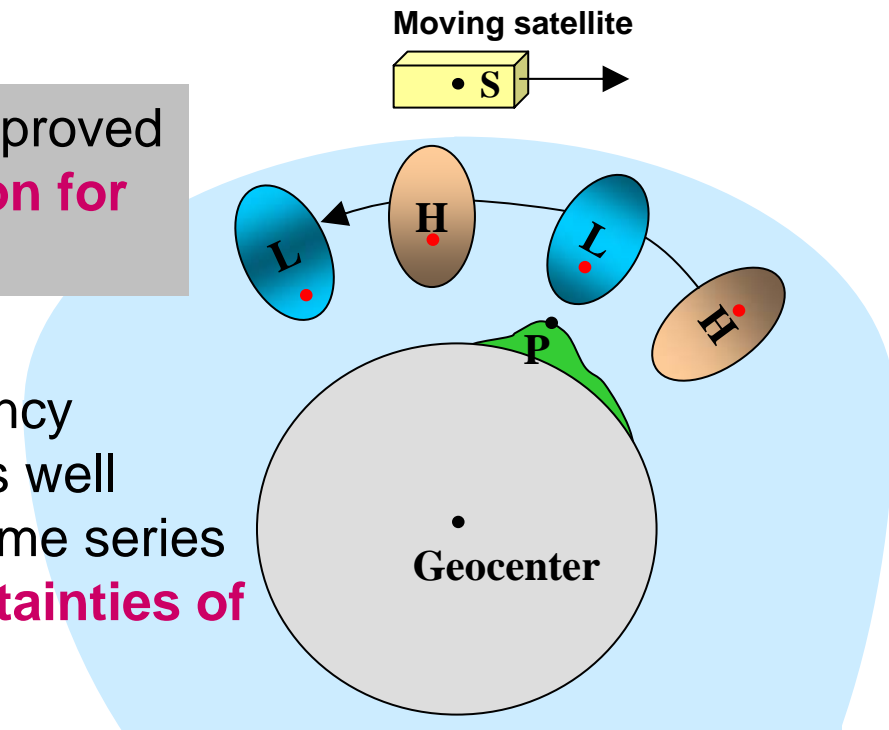
'IDEAL – GRACE'

(Improved **De-AL**iasing for Gravity Field Modelling with GRACE)

1. **Representative error measures** for atmospheric and oceanic parameters shall be determined (*comparison between different atmospheric models, radio occultation, remote sensing data, etc.*).

2. The de-aliasing concept shall be improved by developing an **error propagation for the de-aliasing**.

→ improved modelling of high frequency atmospheric and oceanic effects as well as improved GRACE gravity field time series **by taking into account the uncertainties of these models**.



— Atmospheric De-Aliasing Concept —

- Vertical Integration -

Input – Parameter from ECMWF/NCEP:

Temperature T , Specific Humidity S , Surface Pressure P_s , Surface Geopot. Height H_s

Fundamental Formulas:

$$T_v = (1 + 0.608S)T \quad \Rightarrow \quad H_{k+1/2} = H_s + \frac{1}{g} \sum_{j=k+1}^{N_{level}} R_{dry} T_v \ln \frac{P_{j+1/2}}{P_{j-1/2}}$$

$$P_{k+1/2} = a_{k+1/2} + b_{k+1/2} P_s$$

$$C_{nm} = -\frac{a^2(1+k_n)}{(2n+1)Mg} \iint_{Earth} \left[\int_{P_s}^0 \left(\frac{a}{a-H_{k+1/2}} + \frac{\xi}{a} \right)^{n+4} dP \right] P_{nm}(\cos \theta) \cos m\lambda \sin \theta d\theta d\lambda$$

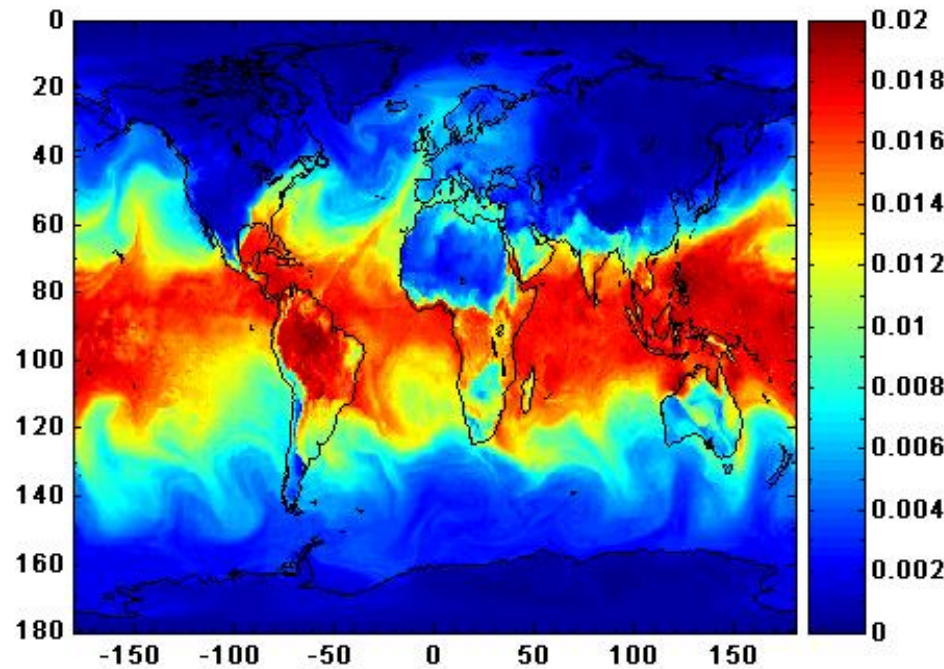
$$S_{nm} = -\frac{a^2(1+k_n)}{(2n+1)Mg} \iint_{Earth} \left[\int_{P_s}^0 \left(\frac{a}{a-H_{k+1/2}} + \frac{\xi}{a} \right)^{n+4} dP \right] P_{nm}(\cos \theta) \sin m\lambda \sin \theta d\theta d\lambda$$

Input-Parameter

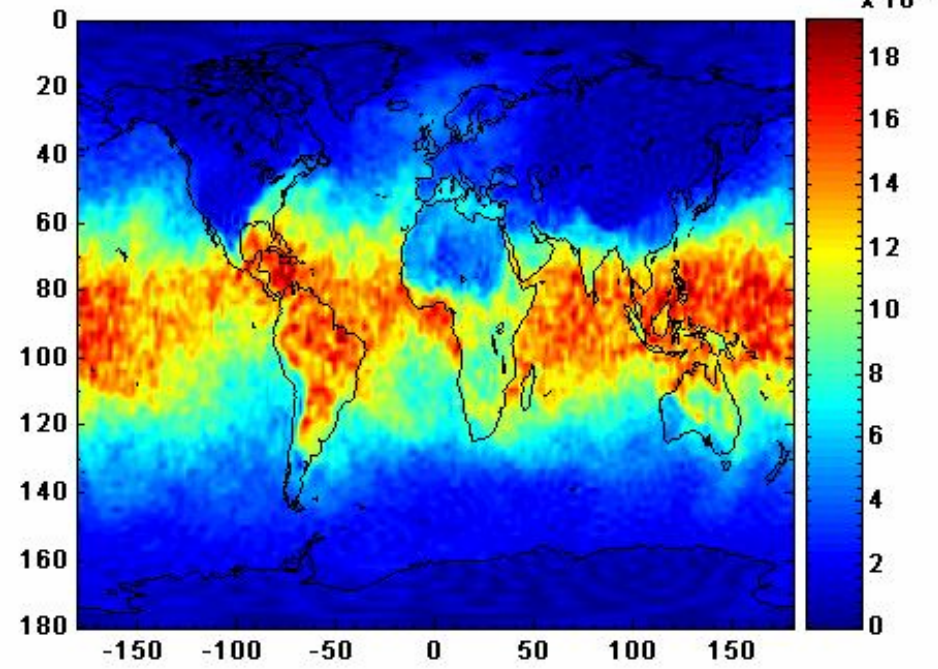
Atmospheric De-Aliasing (I)

01. December 2006 - 0h

Surface Specific Humidity [kg/kg]



Error Surface Specific Humidity [kg/kg]

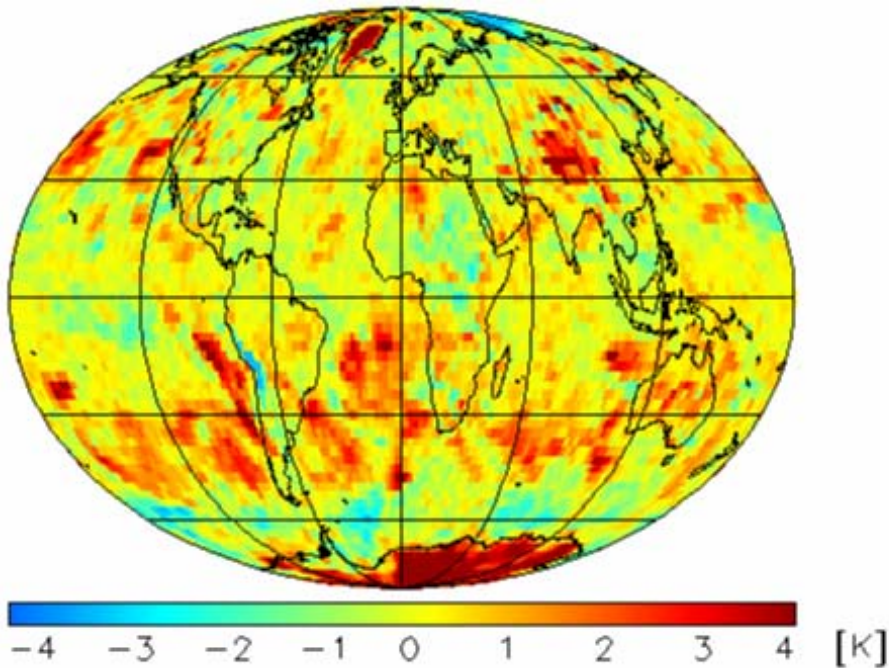


Input-Parameter

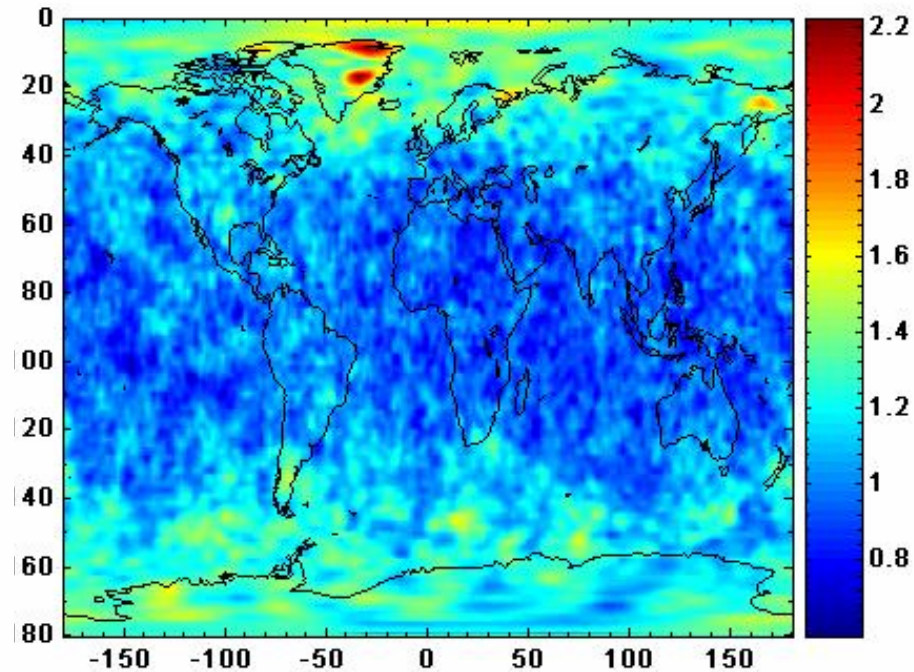
Atmospheric De-Aliasing (II)

01. December 2006 - 0h

Difference ECMWF – NCEP



Error Surface Temperature [K]

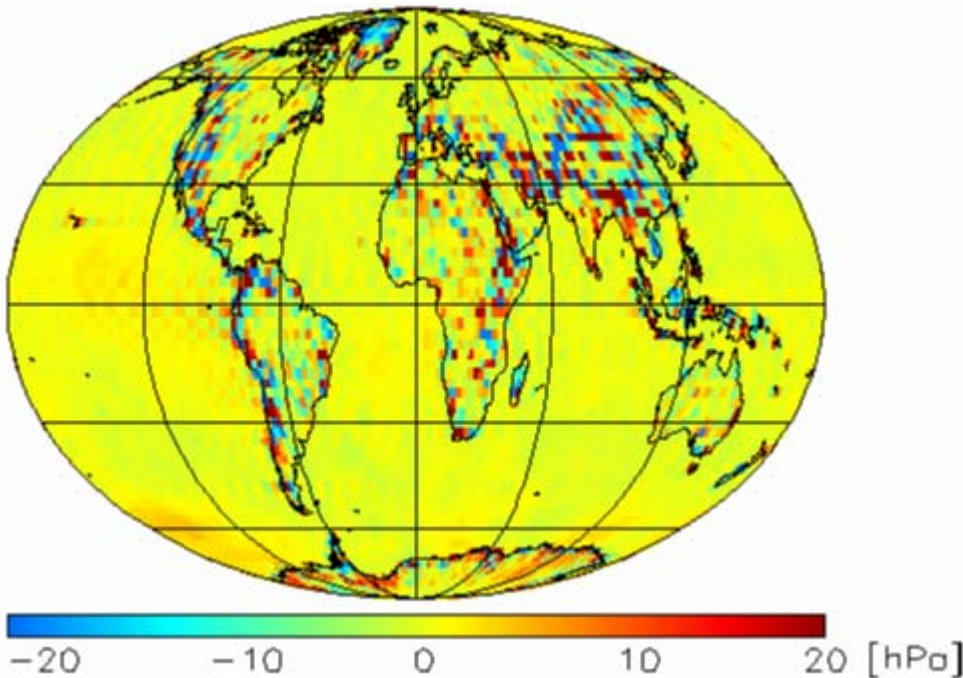


Input-Parameter

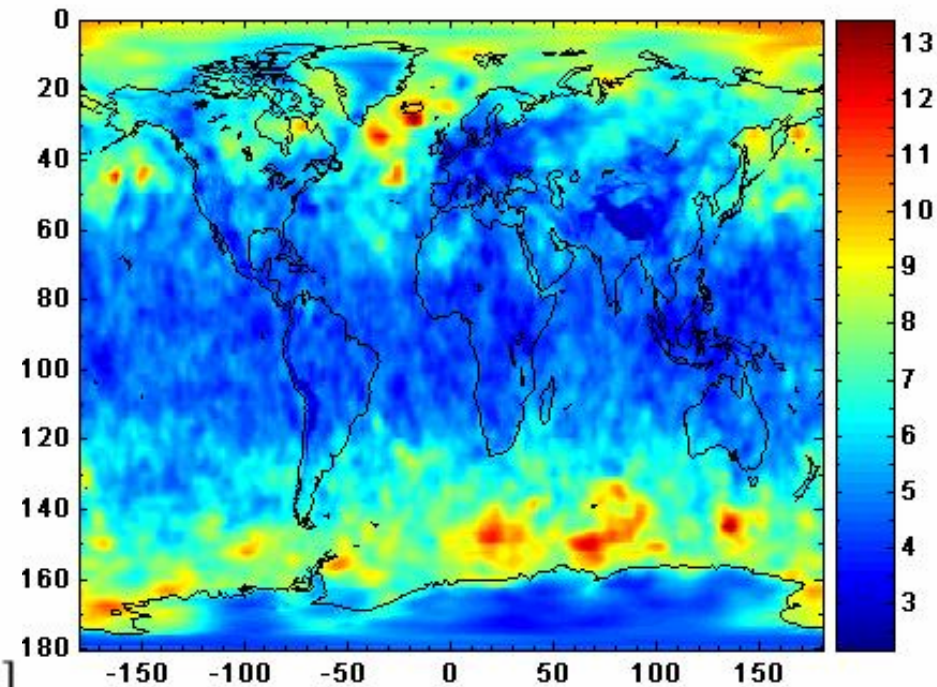
Atmospheric De-Aliasing (III)

01. December 2006 - 0h

Difference ECMWF – NCEP



Error Surface Pressure [hPa]



Mathematical Model - Error Propagation (I)

Law of error propagation (no covariances):

$$f(x, y) \Rightarrow \sigma_f = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 \cdot \sigma_x^2 + \left(\frac{\partial f}{\partial y}\right)^2 \cdot \sigma_y^2}$$

Error of virtual temperature:

$$T_v = (1 + 0.608S)T \Rightarrow \sigma_{T_v} = \sqrt{\left(\frac{\partial T_v}{\partial T}\right)^2 \cdot \sigma_T^2 + \left(\frac{\partial T_v}{\partial S}\right)^2 \cdot \sigma_S^2}$$

Error of „half-level“ pressure:

$$P_{k+1/2} = a_{k+1/2} + b_{k+1/2} \cdot P_s \Rightarrow \sigma_{P_{k+1/2}} = \sqrt{\left(\frac{\partial P_{k+1/2}}{\partial P_s}\right)^2 \cdot \sigma_{P_s}^2}$$

Error of geopot. Height in „half-levels“:

$$H_{k+1/2} = H_s + \sum_{j=k+1}^{k \max} \frac{RT_v}{g_{45}} \cdot \ln\left(\frac{P_{j+1/2}}{P_{j-1/2}}\right) \Rightarrow \sigma_{H_{k+1/2}} = \sqrt{\left(\frac{\partial H_{k+1/2}}{\partial T_v}\right)^2 \cdot \sigma_{T_v}^2 + \left(\frac{\partial H_{k+1/2}}{\partial P_{j+1/2}}\right)^2 \cdot \sigma_{P_{j+1/2}}^2 + \left(\frac{\partial H_{k+1/2}}{\partial P_{j-1/2}}\right)^2 \cdot \sigma_{P_{j-1/2}}^2 + \sigma_{H_s}^2}$$

Error „vertical Integral“:

$$I_n = -\frac{1}{g_0} \int_{P=P_s}^{P_k \max} \left(\frac{a}{a - H_{k+1/2}} + \frac{N'}{a}\right)^{n+4} dP \Rightarrow \sigma_{I_n} = \sqrt{\left(\frac{\partial I_n}{\partial H_{k+1/2}}\right)^2 \cdot \sigma_{H_{k+1/2}}^2 + \left(\frac{\partial I_n}{\partial dP}\right)^2 \cdot \sigma_{dP}^2}$$

Mathematical Model - Error Propagation (II)

- Full error propagation up to the „inner Integral“ is realized.

$$C_{nm} = -\frac{a^2(1+k_n)}{(2n+1)Mg} \iint_{Earth} \left[\int_{P_S}^0 \left(\frac{a}{a-H_{k+1/2}} + \frac{\xi}{a} \right)^{n+4} dP \right] P_{nm}(\cos\theta) \cos m\lambda \sin\theta d\theta d\lambda$$

$$S_{nm} = -\frac{a^2(1+k_n)}{(2n+1)Mg} \iint_{Earth} \left[\int_{P_S}^0 \left(\frac{a}{a-H_{k+1/2}} + \frac{\xi}{a} \right)^{n+4} dP \right] P_{nm}(\cos\theta) \sin m\lambda \sin\theta d\theta d\lambda$$

- Simplified approach for the spherical analysis (error propagation for the spherical harmonic analyses not yet implemented)

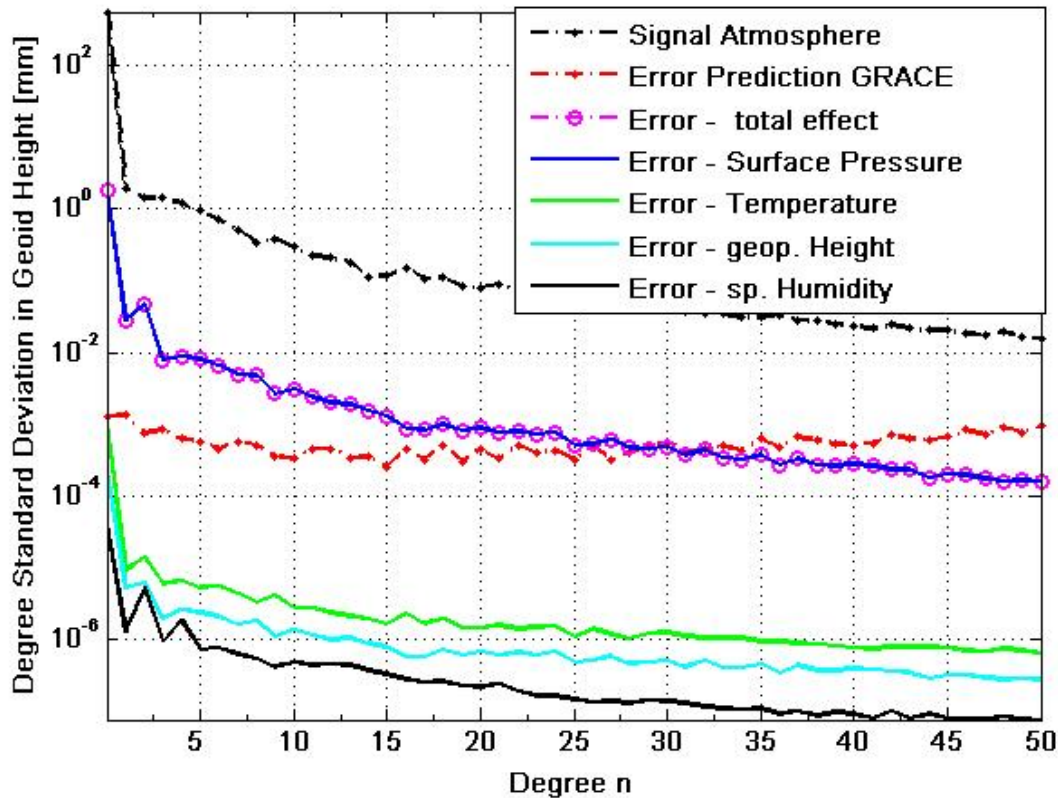
→ Error of the potential coefficients

C_{nm} , S_{nm}

due to uncertainties in the atmosphere model.

Propagated Errors on potential coefficients

Square root of degree variances in terms of geoid heights [mm]



Error in terms of geoid heights because of uncertainties in the atmosphere model (simplified approach!):

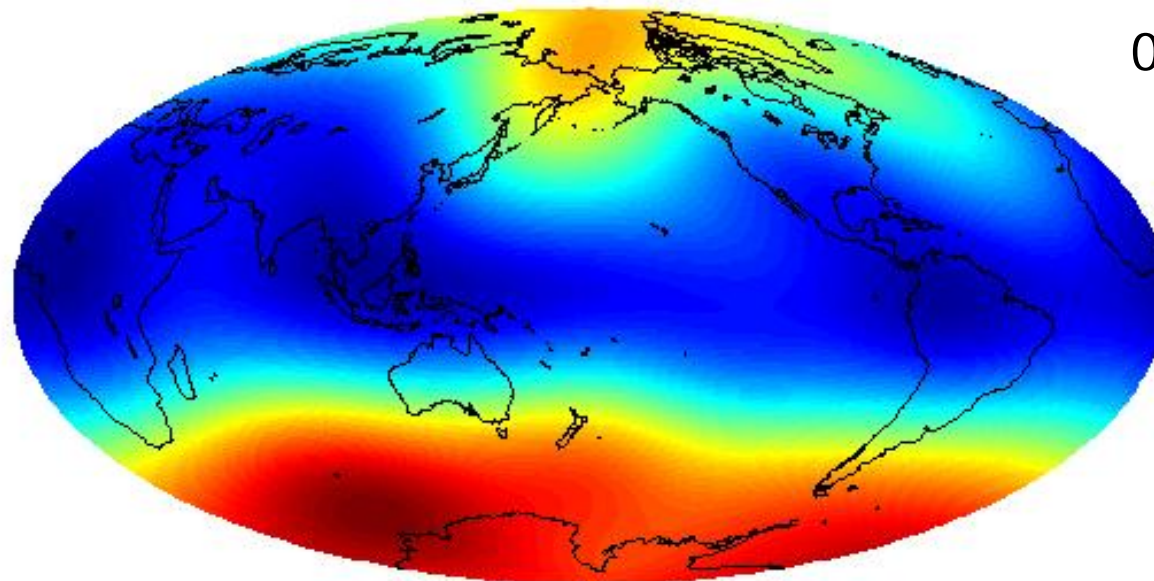
„Error – Parameter“	Global Mean [cm]
all parameter	1.8
surface pressure	1.8
temperature	1.1 e-3
geopotential. height	2.2 e-4
specific humidity	4.1 e-5

GRACE is SENSITIVE to Uncertainties in Atmosphere Models!

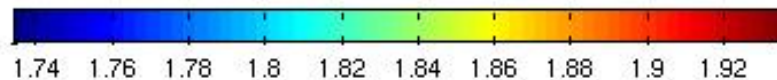
Effects of the Uncertainties on the Geoid

Propagated Error of all atmospheric input parameter (*temperature, surface pressure, specific humidity, geopotential height*) on the geoid.

01. December 2006 - 0h



[cm]



Min	1.73 cm
Max	1.94 cm
Mean	1.81 cm
RMS	0.0055 cm

Conclusions

Until now, the input parameters for atmospheric de-aliasing are regarded as **error-free!**

BUT:

Uncertainties in Atmospheric Models have **significant impact** on GRACE (for the long wavelengths up to degree 30)

- most significant: *surface pressure*
- almost negligible: *temperature, specific humidity, geopotential height*

THEREFORE:

- ➔ To get more reliable homogenous potential coefficient series, **error propagation should be included in the standard GRACE – De-Aliasing process** (AOD1B-Product).
- ➔ **Representative error measures** for atmospheric and oceanic parameters have to be determined.

Thank you for your attention!

Visit our poster:

The Sensitivity of Satellite Gravity Field Determination to Uncertainties in Atmospheric Models

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Poster Session B, Tuesday (Today!) 16/10 at 6 p.m