Integration of space geodetic observations and geophysical models

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Geodetic Week 2006, Munich, 12. October 2006

Earth rotation and global dynamic processes

Overview

- Combination of **space geodetic observations** and **geophysical models**
- **Interactions** between the subsystems of the Earth + **mass conservation**
- **Adapting** of geophysical models to gravimetric observations
- Outlook

Geometric observations

GPS → Intra-technique NEQ

SLR → Intra-technique NEQ

VLBI → Intra-technique NEQ

DORIS → Intra-technique NEQ

↓

Addition of NEQs and weighting

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Addition of local ties and datum realization

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Inter-technique combination

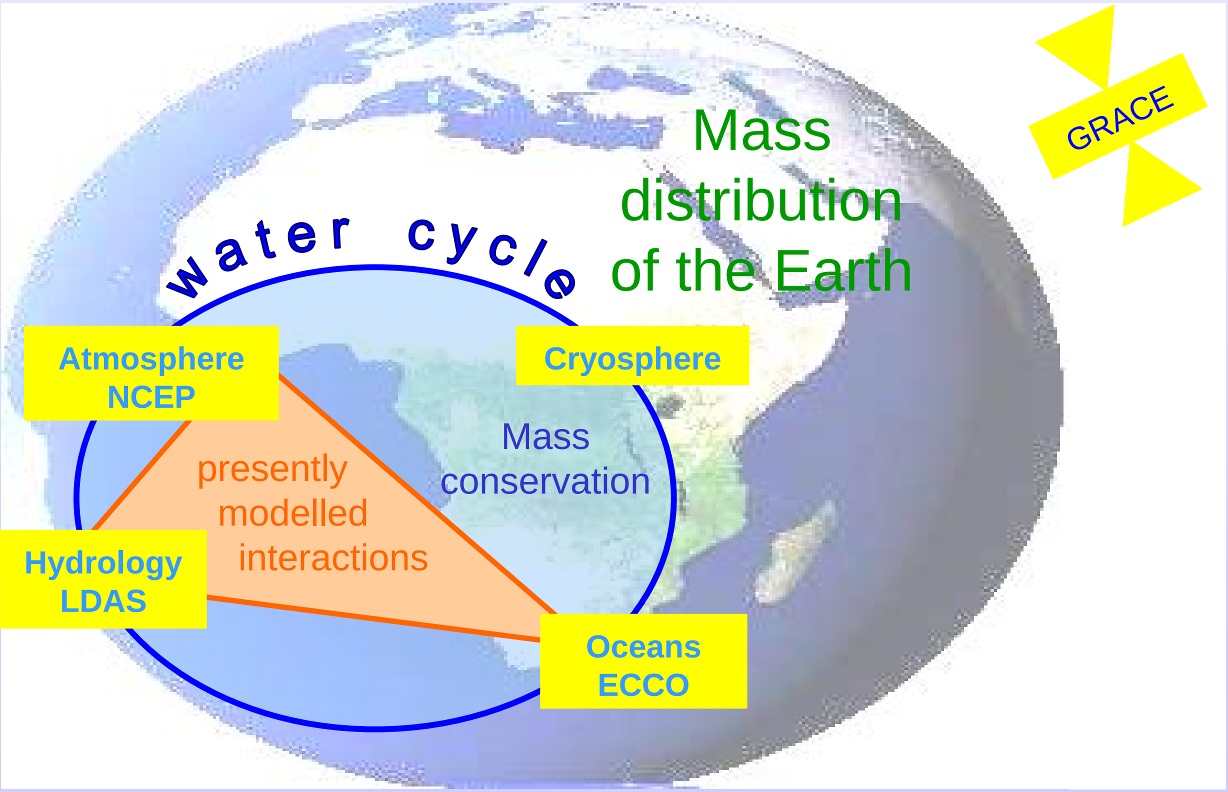
$$b + v = f\,(TRF\,(x, v, \ldots), ERP, low\ degree\ C_{nm}\ u.\ S_{nm})$$

Site displacements influence the estimation of the “observed” ERP
$\Rightarrow$ “observed” ERP reflect the rotation of the observation-network!

Geophy. models / gravimetric observations

GRACE → gravity field changes → reflect mass redistributions in the Earth

Atmosphere | Oceans | Hydrology | Cryosphere | Mantle, Core



NEQ-System of the geophysical models

Mass redistribution in the subsystems of the Earth

Atmosphere | Oceans | Hydrology | Cryosphere | Mantle, Core

Excitation functions of the subsystems

$$\chi_i = \chi_i^{matter} + \chi_i^{motion}$$

Conditions for a consistent combination of the excitation functions are the description of the interactions and the fulfillment of mass conservation

$$\chi = \sum_{i=1}^{n} \chi_i$$ equivalent to quasi-observation

Liouville equation is equivalent to quasi-observation-equation

$$\chi + v = f(x_{Pol}, y_{Pol}, \dot{x}_{Pol}, \dot{y}_{Pol}, \Delta LOD)$$

Mass displacements and motions influence the estimation of the "modelled" ERP $\Rightarrow$ "modelled" ERP reflect the rotation of the Earth!

Combination of all "observations"

Inter-technique combination of the geometric observations
NEQ

Combination of the geophysical quasi-observations
NEQ

Addition of NEQs and weighting

Datum realization

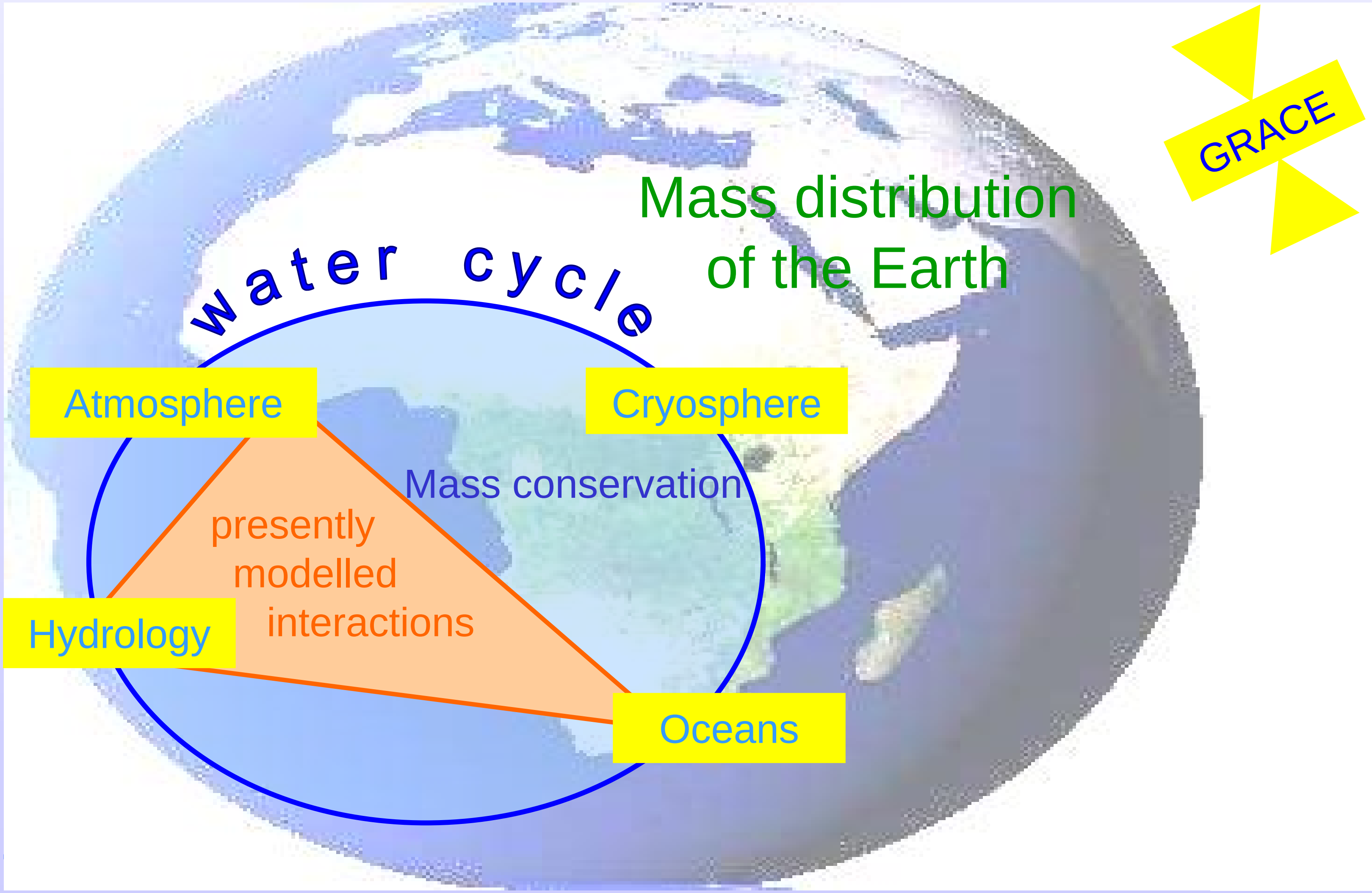
Inter-technique combination of all "observations"

$$b + v = f\,(TRF\,(x, v, \ldots), ERP, low\ degree\ C_{nm}\ u.\ S_{nm})$$

Network uncertainties do not appear in the ERP, but could under circumstances identified as „outliers" in the TRF!

DGFI

Improvement of geophysical models



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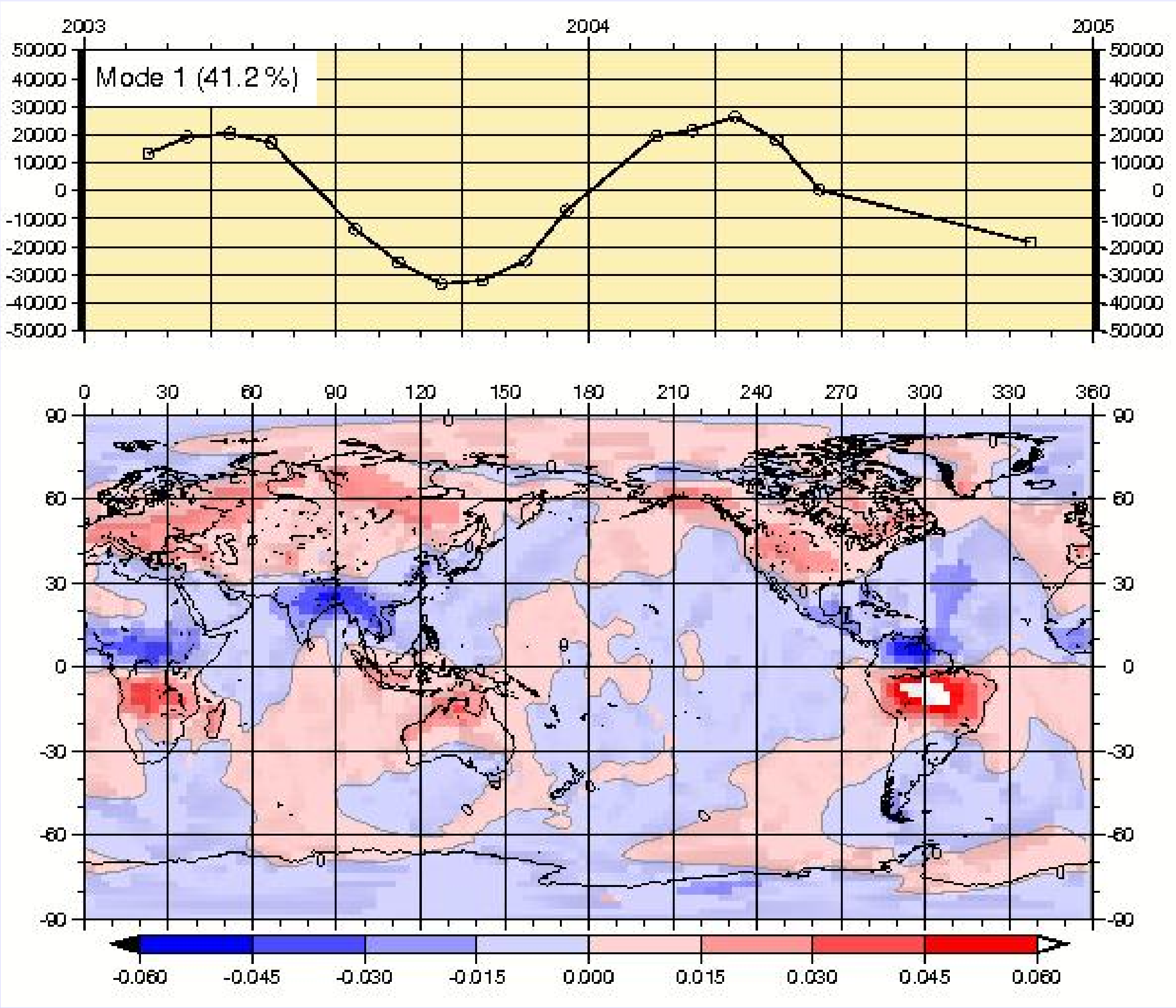
Principal Component Analysis PCA



Principal components:
Represent the temporal evolution of the intensity

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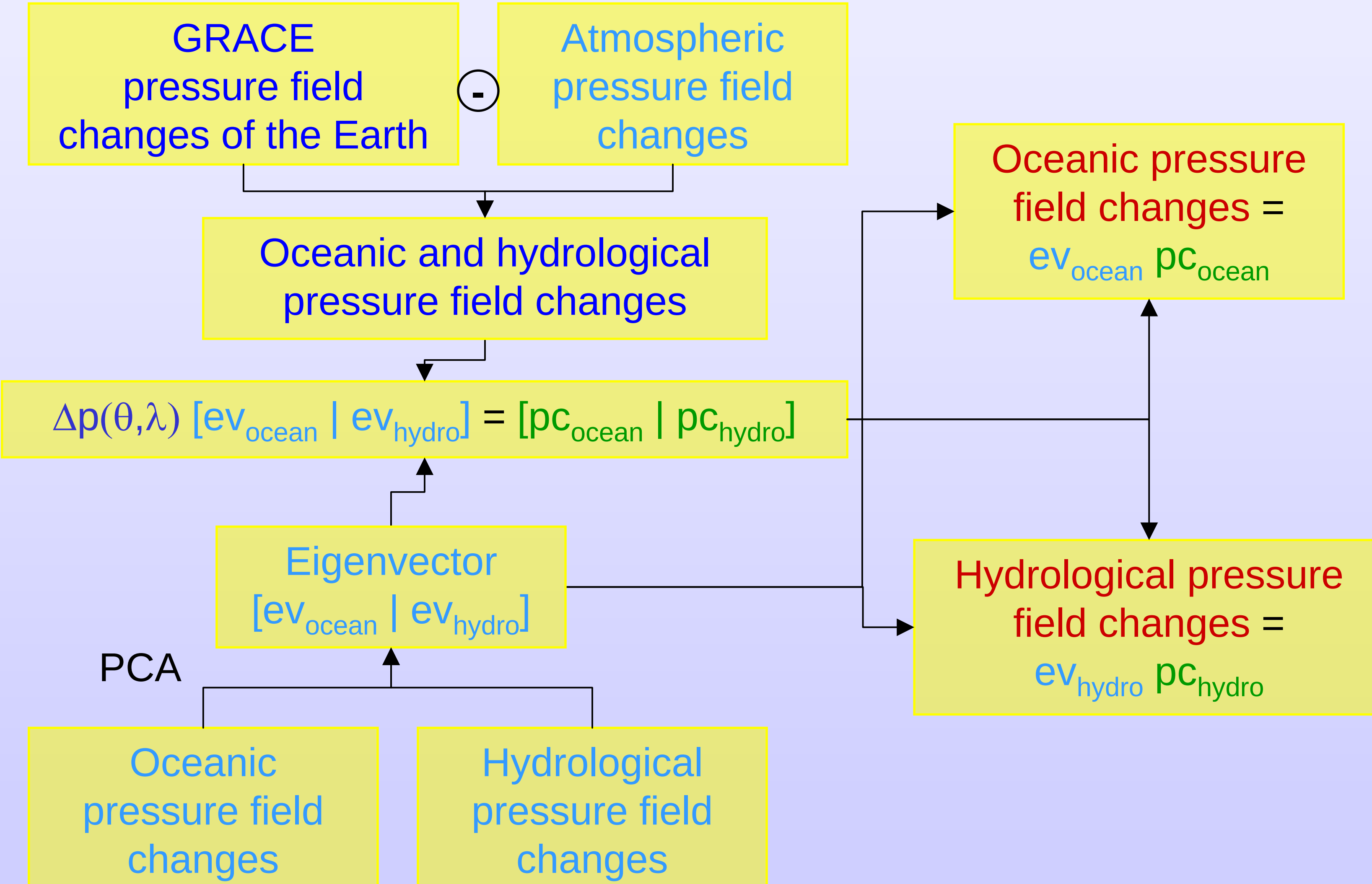
Eigenvector:
Represents dominant spatial patterns of variability

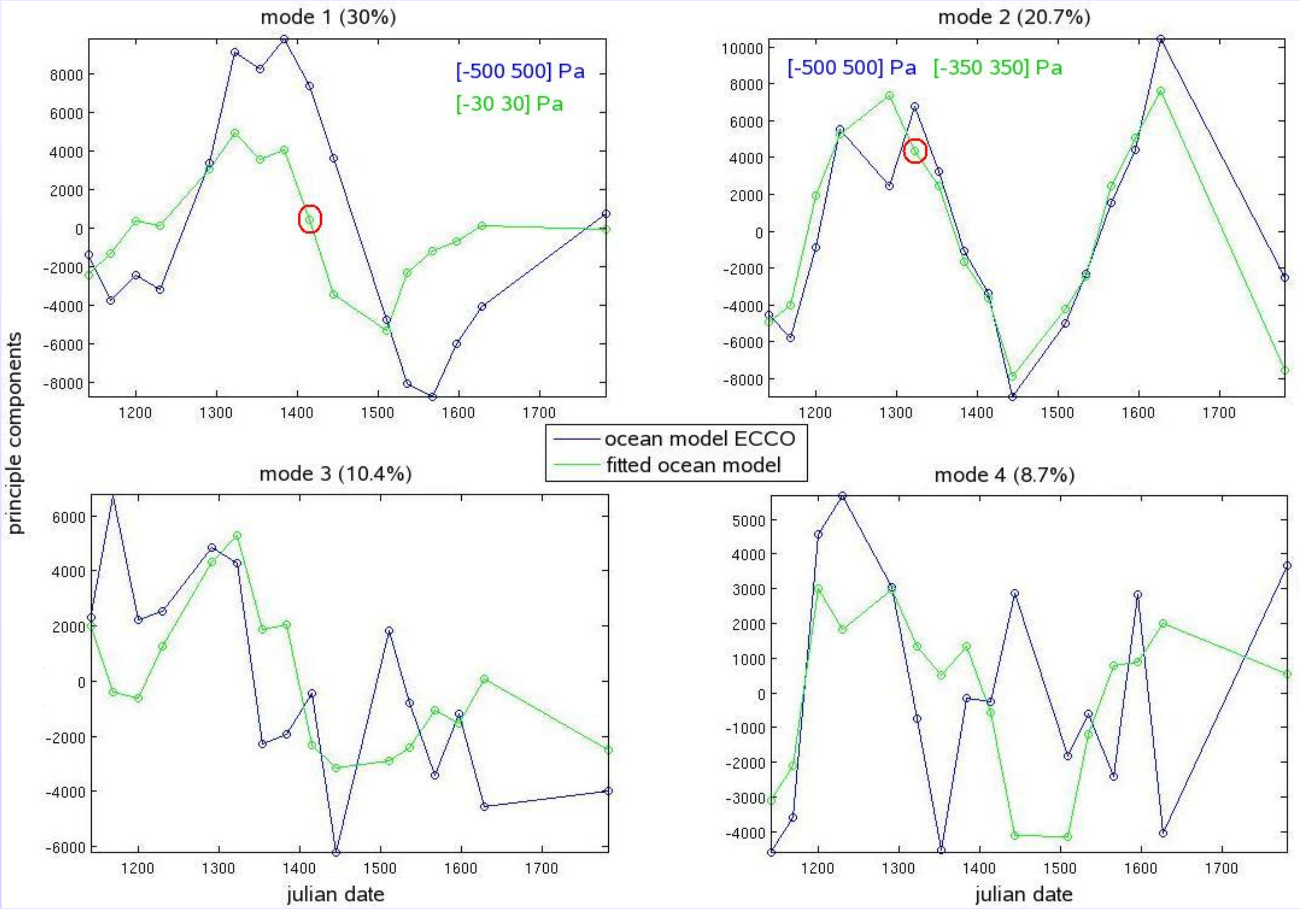
=

Signal:
Represents spatial and temporal patterns

Adapting of geophy. models to GRACE-obs.



Comparison of principal components



Pressure field changes of the ocean model ECCO are smaller than of the adapted ocean model!

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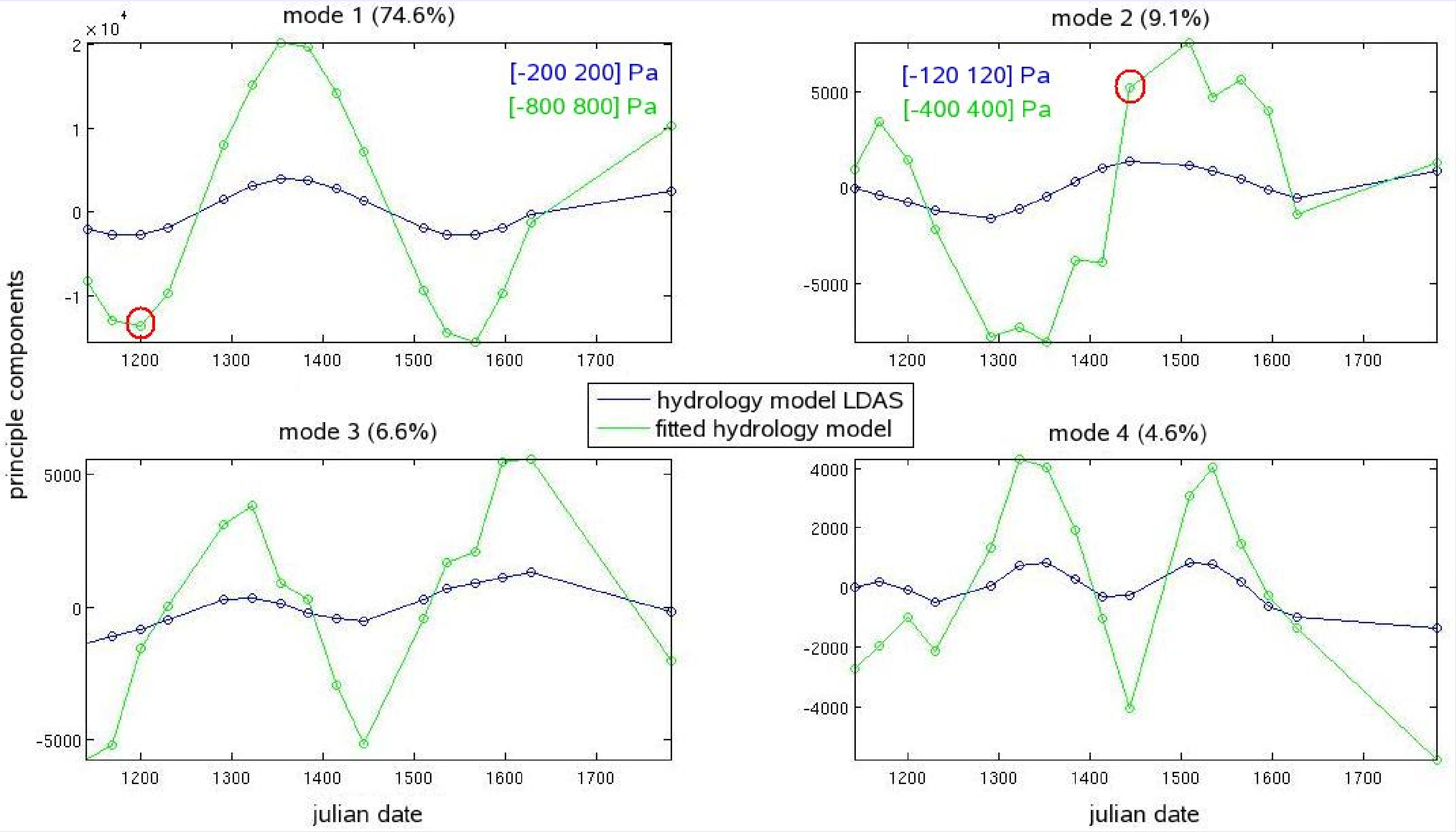
Comparision of principal components



Pressure field changes of the hydrology model LDAS are much smaller and smoother than of the adapted hydrology model!

Earth rotation and global dynamic processes

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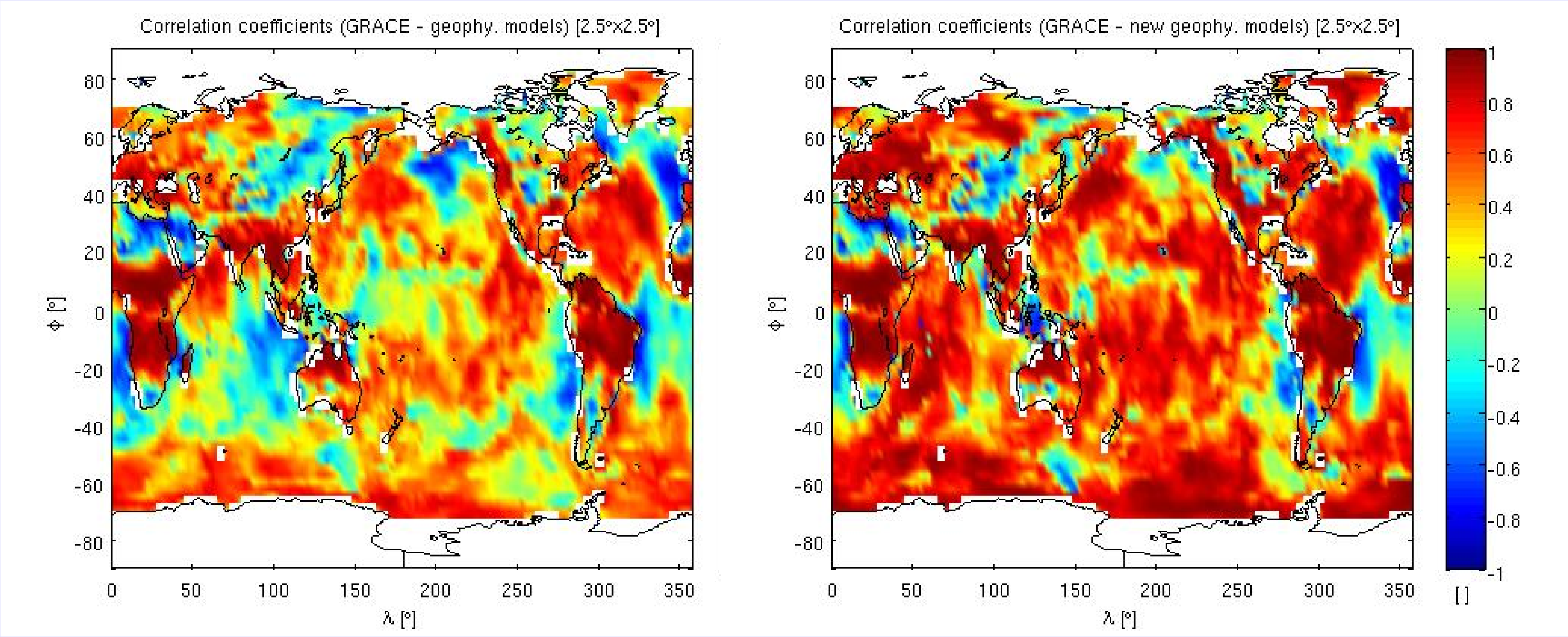
Comparision of correlation-coefficients



mean value = 0.2871	**mean value = 0.4751**
standard deviation = 0.4046	**standard deviation = 0.4105**

Outlook

- Computation of the **excitation functions** (matter-term)
- **Combination** of the “modelled” excitation functions of all relevant subsystems
- **Comparision** with the “observed” excitation function
- Estimation of the **accurancy** of the “modelled” excitation functions

Thank you

for your attention!

GRACE data processing

Level 2 product GSM
monthly static gravity field
exclusive non-tidal atmospheric
and oceanic gravity field part

Level 2 product GAC
monthly non-tidal atmospheric
and oceanic static gravity field

$$\Delta CnmSnm = (GSM - \overline{GSM}) + (GAC - \overline{GAC})$$

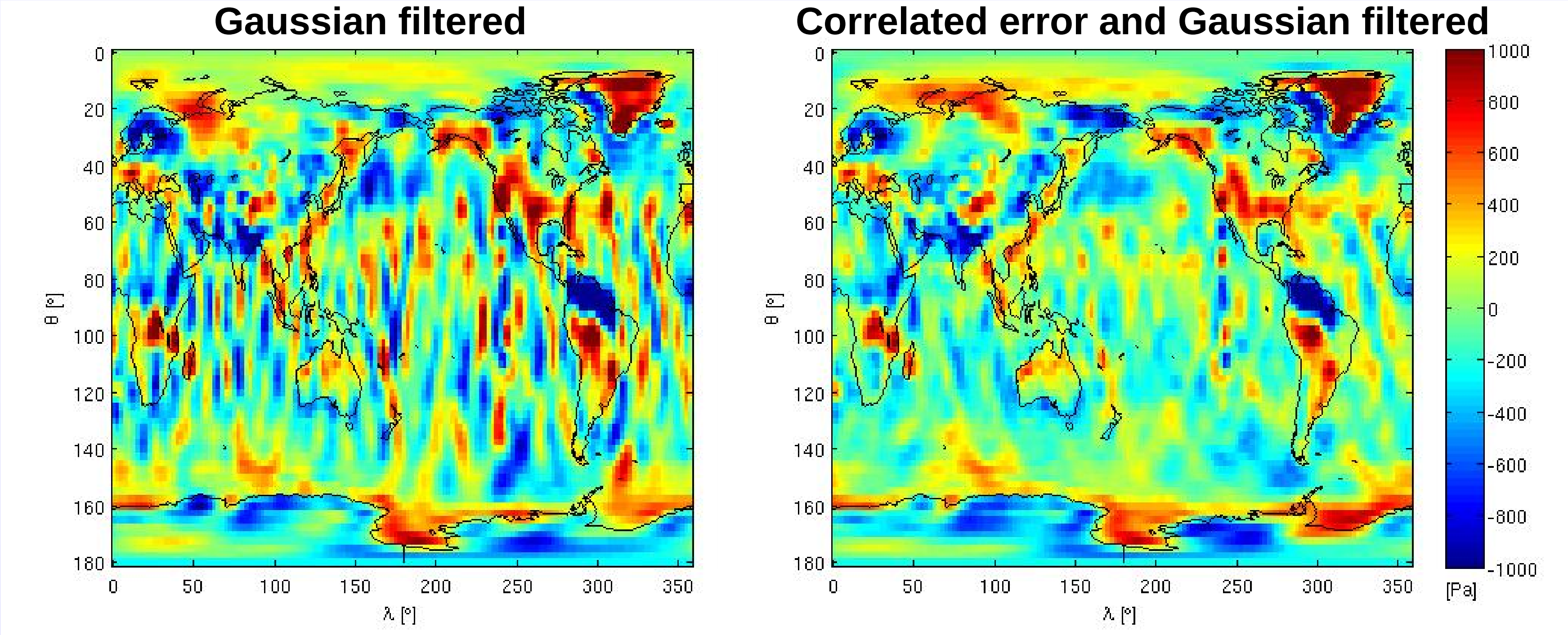
Correlated error filter form DON CHAMBERS

Gaussian filter (r = 500km) form JOHN WAHR

Pressure field changes of the Earth

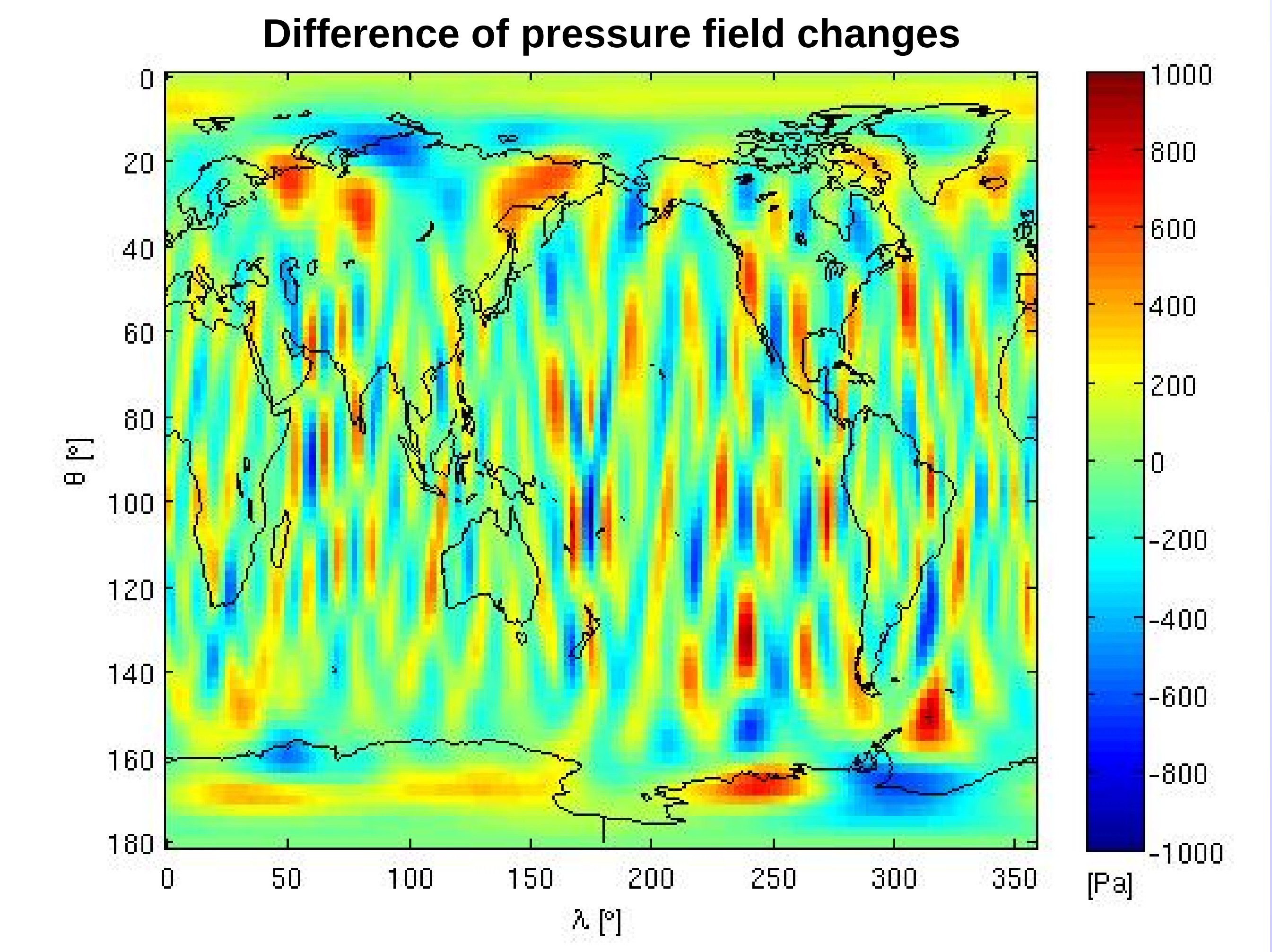
$$\Delta p(\theta,\lambda) = \frac{a_E g \rho_E}{3} \sum_{n=0}^{60} \sum_{m=0}^{n} \frac{2n+1}{1+k_n} \overline{P}_{nm}(\cos\theta)\left[\Delta C_{nm}\cos(m\lambda) + \Delta S_{nm}\sin(m\lambda)\right]$$

Pressure field changes



N-S-stripes disappear!

Difference of pressure field changes



Calculation of excitation function

$$\chi_1^{matter} = -\frac{a^2}{(C-A)\left(1-\frac{k_2}{k_f}\right)} \int_\lambda \int_\varphi \rho\xi \cos\varphi \sin\varphi \cos\lambda \; a^2 \cos\varphi \, d\varphi \, d\lambda$$

$$\chi_2^{matter} = -\frac{a^2}{(C-A)\left(1-\frac{k_2}{k_f}\right)} \int_\lambda \int_\varphi \rho\xi \cos\varphi \sin\varphi \sin\lambda \; a^2 \cos\varphi \, d\varphi \, d\lambda$$

$$\chi_3^{matter} = -\frac{a^2}{C_m} \int_\lambda \int_\varphi \rho\xi \cos^2\varphi \; a^2 \cos\varphi \, d\varphi \, d\lambda$$

Calculation of excitation function

$$\chi_1^{matter} = -\frac{M_E a^2}{(C - A)\left(1 - \frac{k_2}{k_f}\right)} \Delta C_{21}$$

$$\chi_2^{matter} = -\frac{M_E a^2}{(C - A)\left(1 - \frac{k_2}{k_f}\right)} \Delta S_{21}$$

$$\chi_3^{matter} = -\frac{2}{3} \frac{M_E a^2}{C_m} \Delta C_{20}$$

Calculation of excitation function

$$\chi_1^{motion} = -\frac{1}{\Omega(C-A)\left(1-\frac{k_2}{k_f}\right)} \int\limits_r \int\limits_\lambda \int\limits_\varphi \rho r \left(u \sin\varphi \cos\lambda - v \sin\lambda\right) r^2 \cos\varphi \, d\varphi \, d\lambda \, dr$$

$$\chi_2^{motion} = -\frac{1}{\Omega(C-A)\left(1-\frac{k_2}{k_f}\right)} \int\limits_r \int\limits_\lambda \int\limits_\varphi \rho r \left(u \sin\varphi \sin\lambda - v \cos\lambda\right) r^2 \cos\varphi \, d\varphi \, d\lambda \, dr$$

$$\chi_3^{motion} = -\frac{1}{\Omega C_m} \int\limits_r \int\limits_\lambda \int\limits_\varphi \rho u r^2 \cos\varphi \, d\varphi \, d\lambda \, dr$$

NEQs

$$\chi_1(t) = x(t) + \frac{1}{\frac{2\pi}{T_C}\left(1 + \frac{1}{4Q^2}\right)}\left(\frac{1}{2Q}\dot{x}(t) + \dot{y}(t)\right)$$

$$\chi_2(t) = -y(t) + \frac{1}{\frac{2\pi}{T_C}\left(1 + \frac{1}{4Q^2}\right)}\left(\dot{x}(t) - \frac{1}{2Q}\dot{y}(t)\right)$$

$$\chi_3(t) = -\frac{\Delta LOD(t)}{LOD}$$

Correlated error filter

- N-S-strips are a result of systematic errors in the coefficients.
- Coefficients up to order and degree 7 do not show syst. errors.
- For higher orders the systematic errors are estimated by fitting polynomials p(x) of degree 7 by least square adjustment.

Observationequation: $p(x)=ax^7+bx^6+cx^5+dx^4+ex^3+fx^2+gx+C$

Unknowns: a, b, c, d, e, f, g, C

Observations: $C_{9,8}$, $C_{11,8}$, $C_{13,8}$, ... $C_{81,8}$

Filtered coefficients: $C_{n,8}^{filtered} = C_{n,8} - p(n)$

- To estimate the fitting polynomials for orders higher than 40 you have to use coefficients with degrees up to 40+order.
- Coefficients higher than order and degree 50 are not filtered by the correlated error filter.

Isotropic Gaussian filter

$W_n = \exp[-(n\ r_S/a_E)^2/(4\ \ln 2)]$