Integration of space geodetic observations and geophysical models

Franziska Göttl
Deutsches Geodätisches Forschungsinstitut

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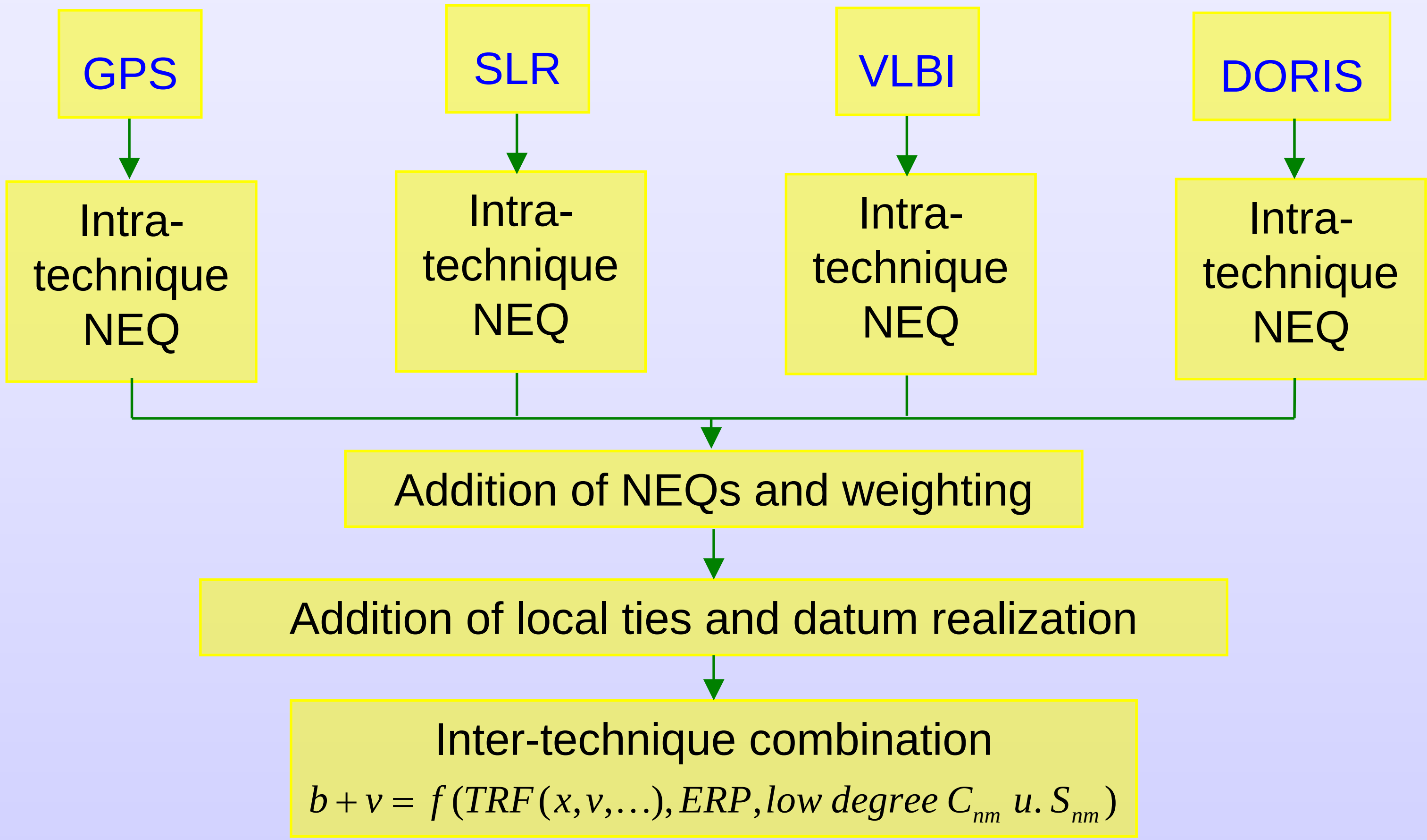
Overview

- 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

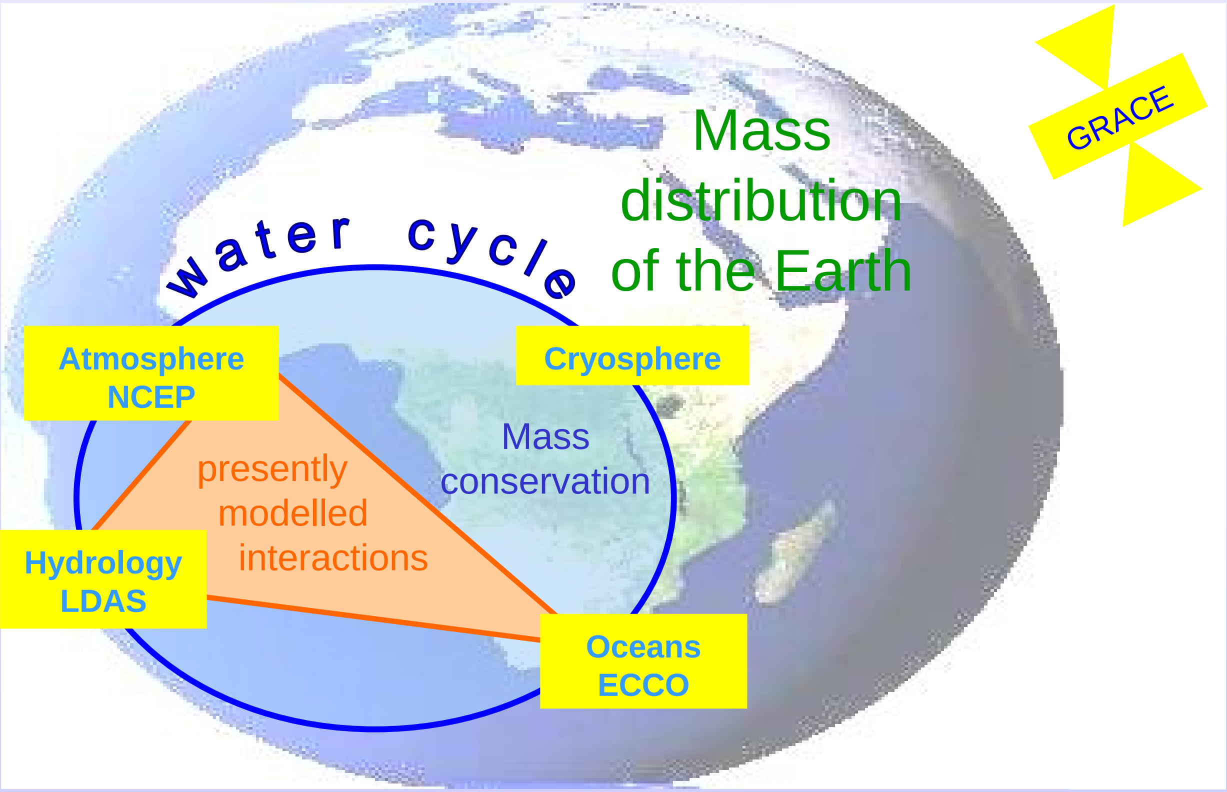


Site displacements influence the estimation of the "observed" ERP
⇒ "observed" ERP reflect the rotation of the observation-network!

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

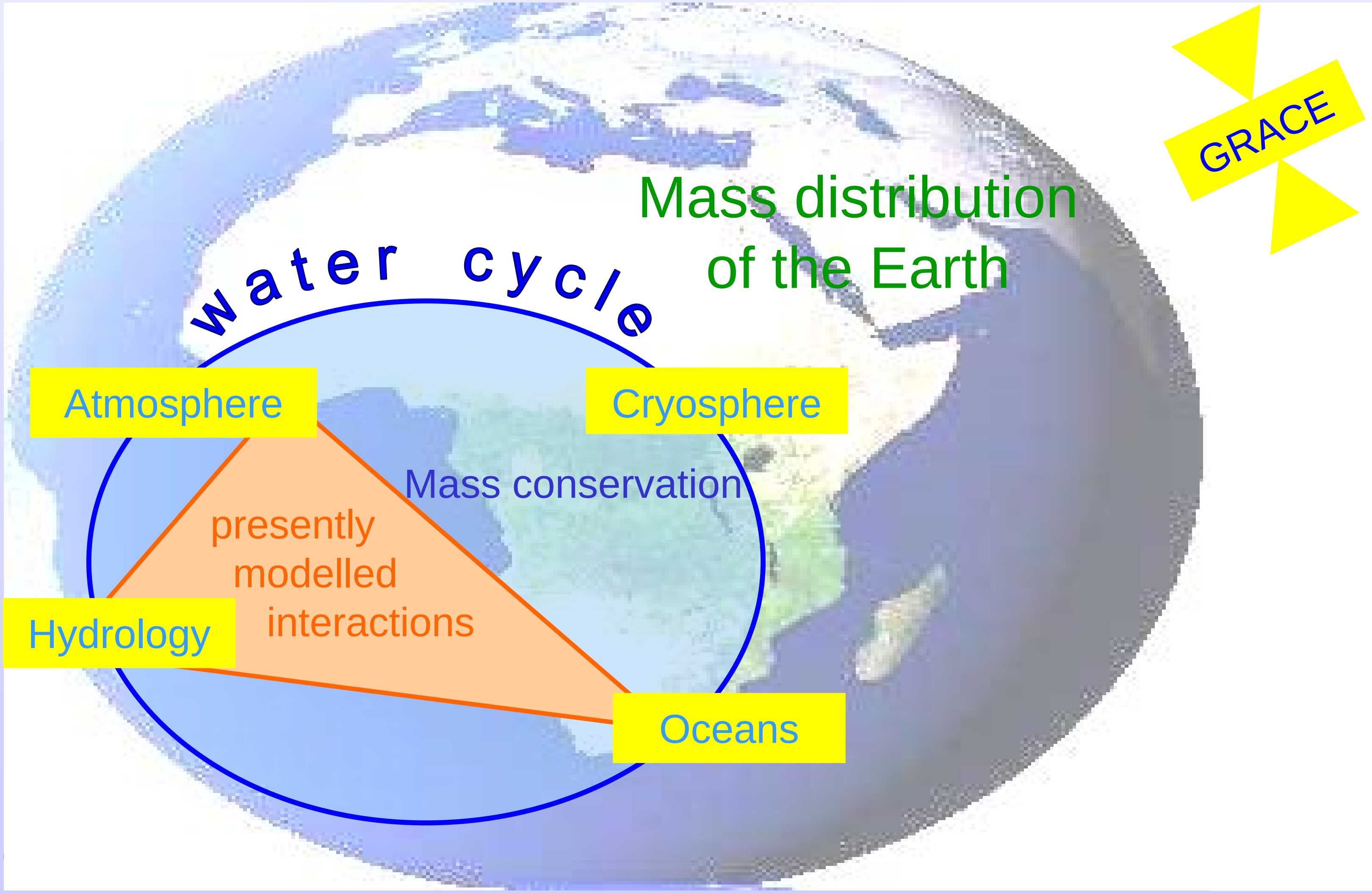
Datum realization

Inter-technique combination of all "observations"

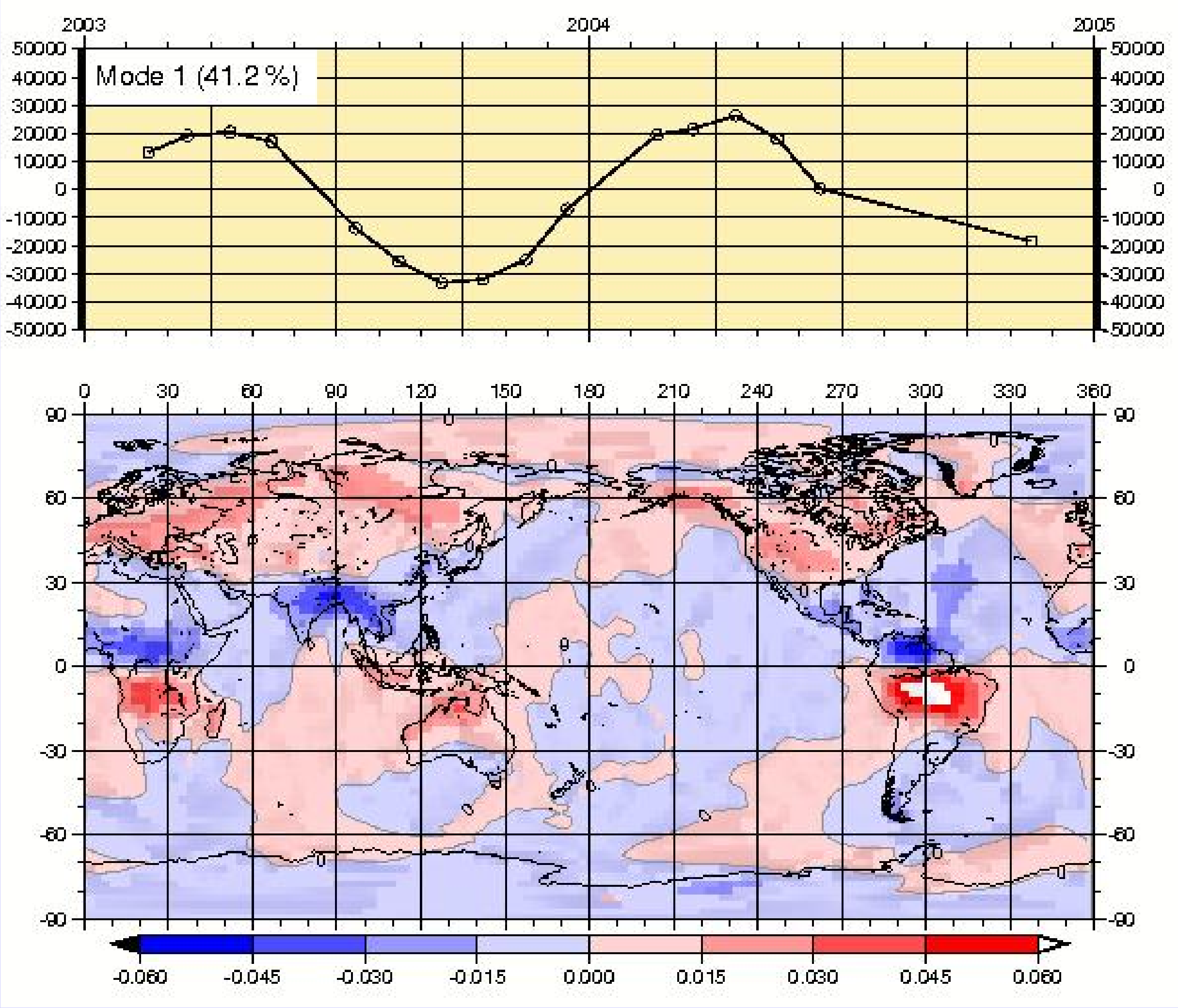
$$b + v = f(TRF(x, v, \ldots), ERP, low\ degree\ C_{nm}\ u.\ S_{nm})$$

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

Improvement of geophysical models



Principal Component Analysis PCA



Principal components:
Represent the temporal evolution of the intensity

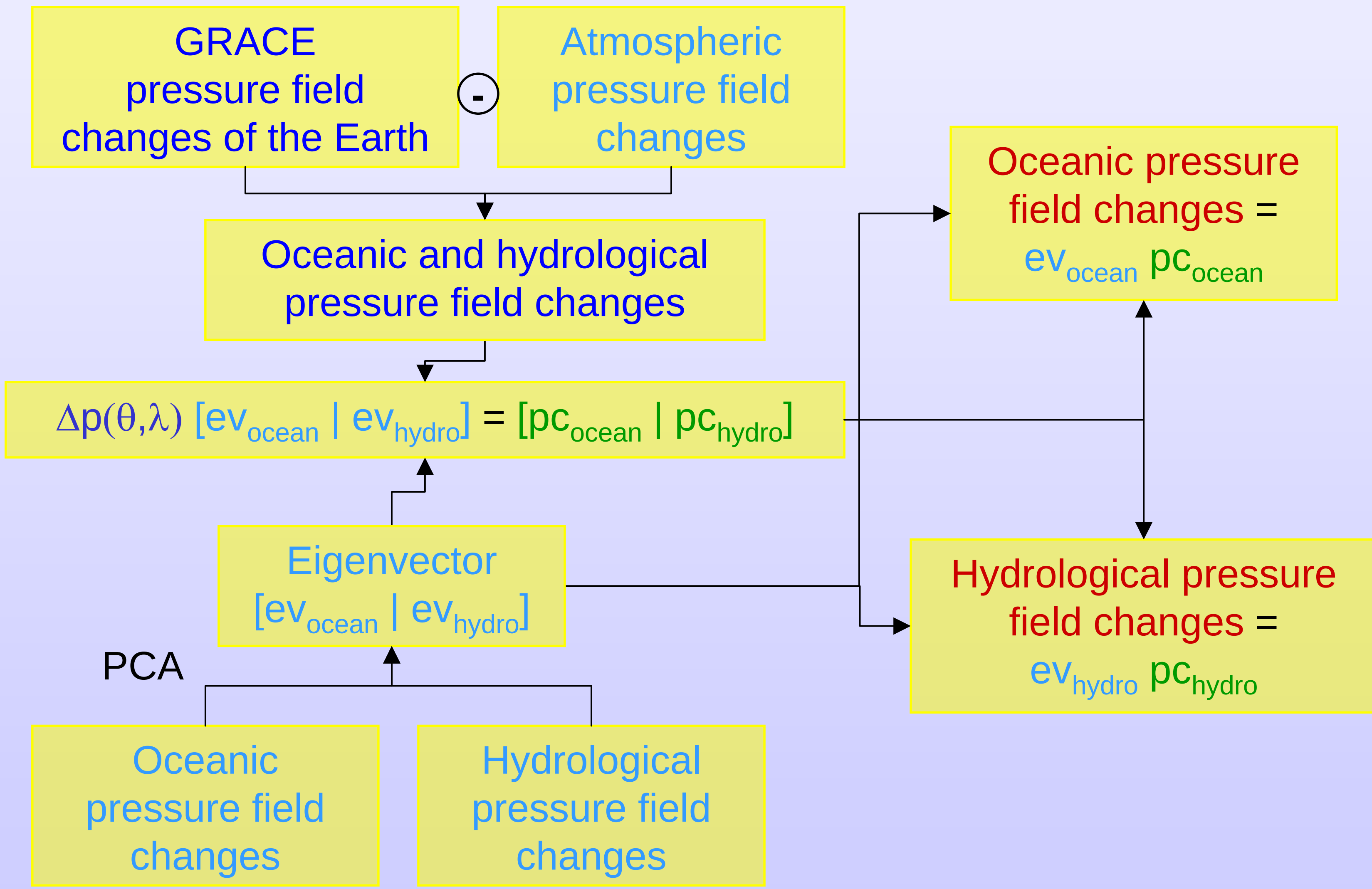
•

Eigenvector:
Represents dominant spatial patterns of variability

=

Signal:
Represents spatial and temporal patterns

Adapting of geophy. models to GRACE-obs.



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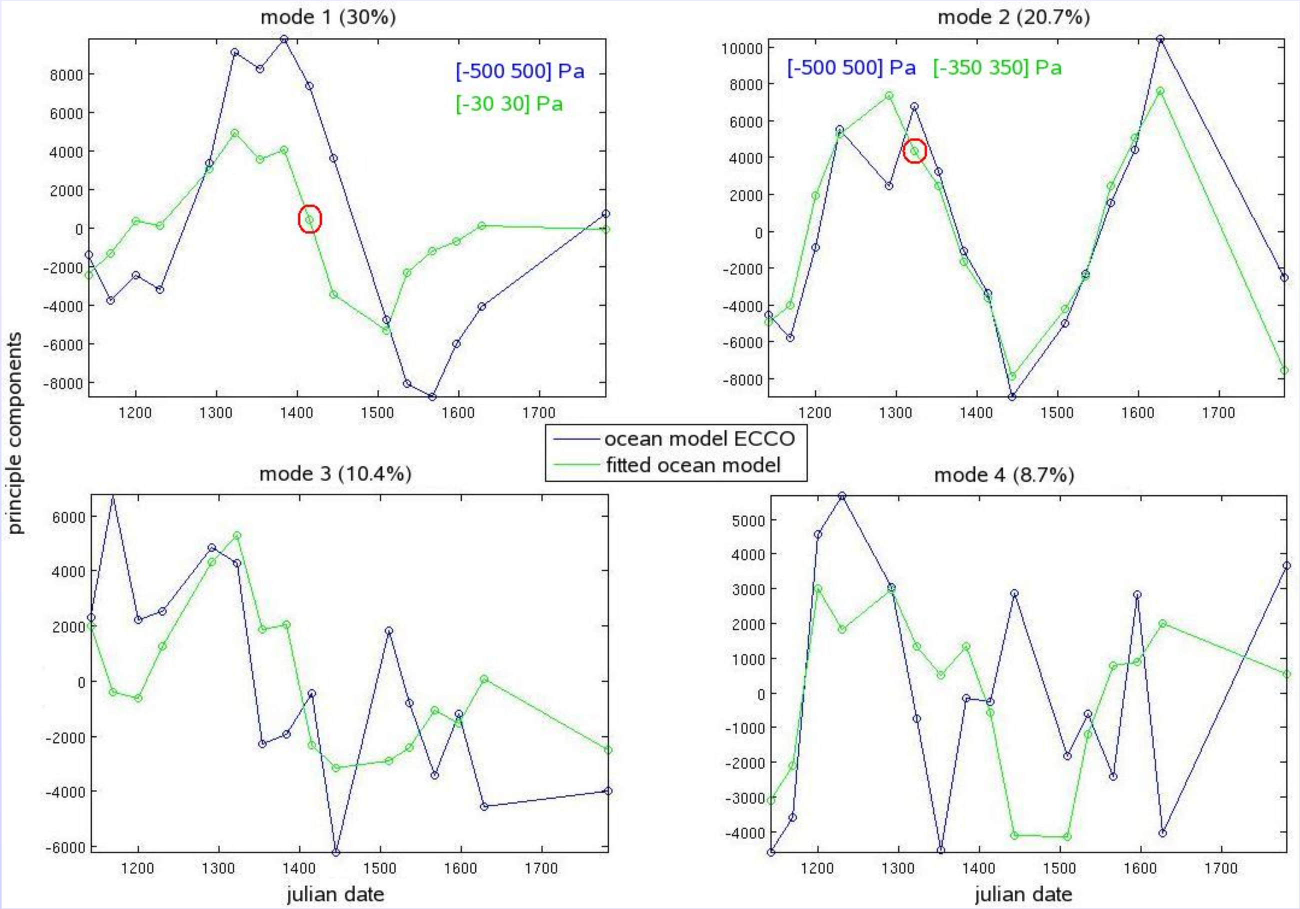
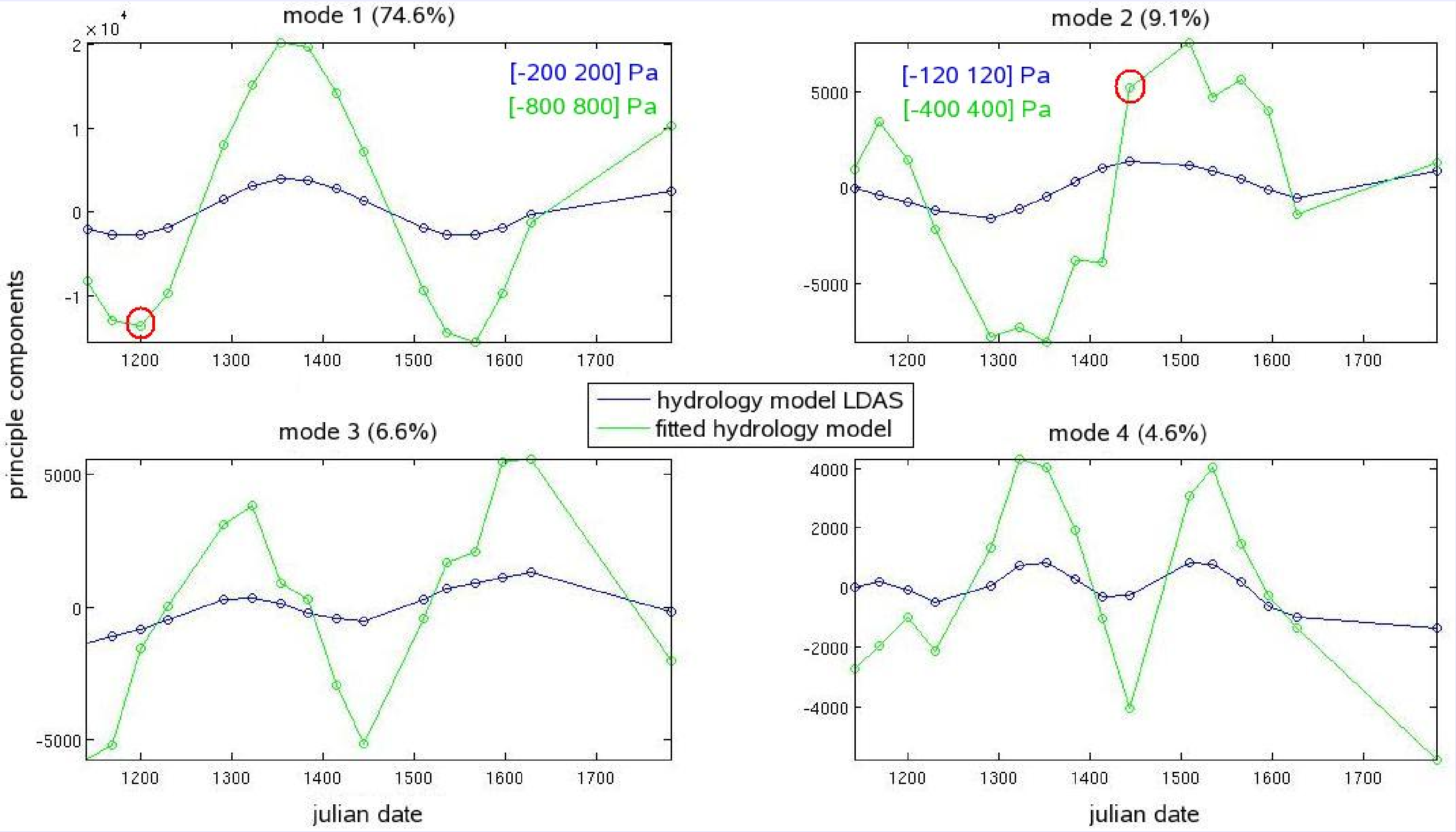
Comparison of principal components



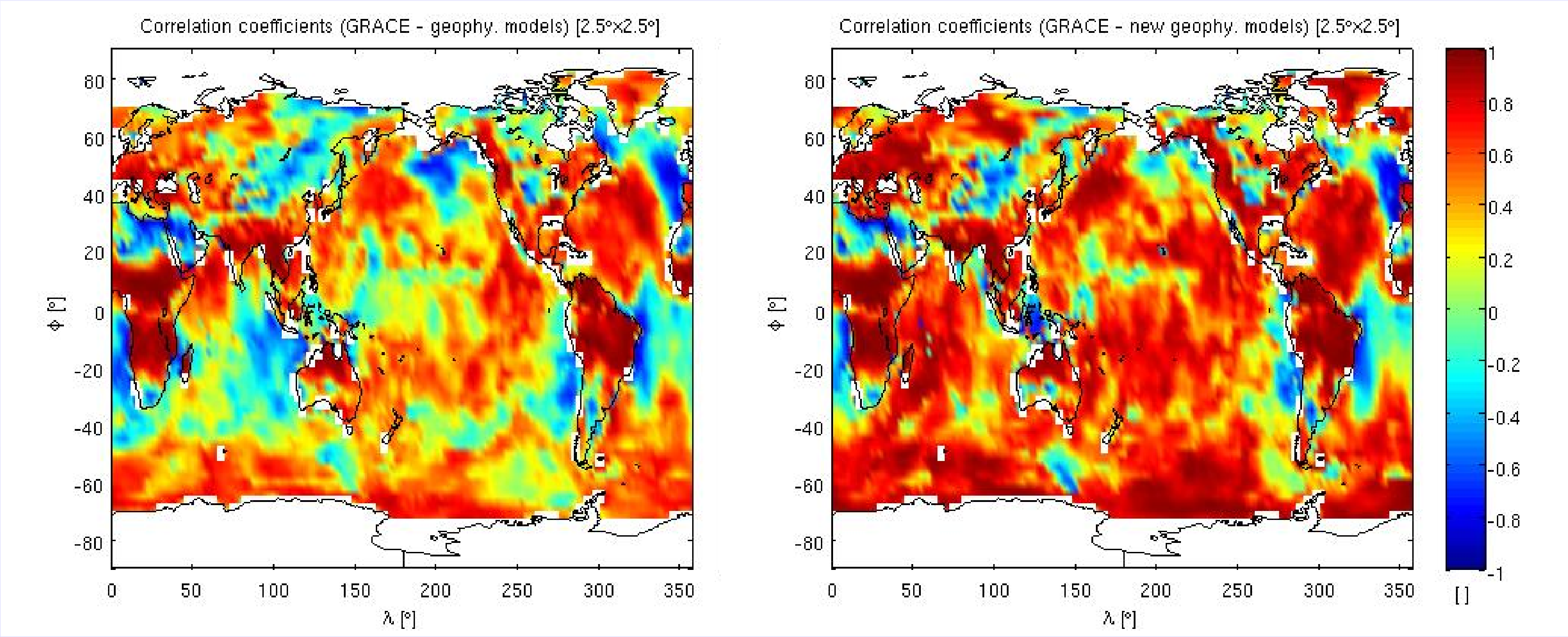
Pressure field changes of the ocean model ECCO are smaller than of the adapted ocean model!

Comparision of principal components



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

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

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

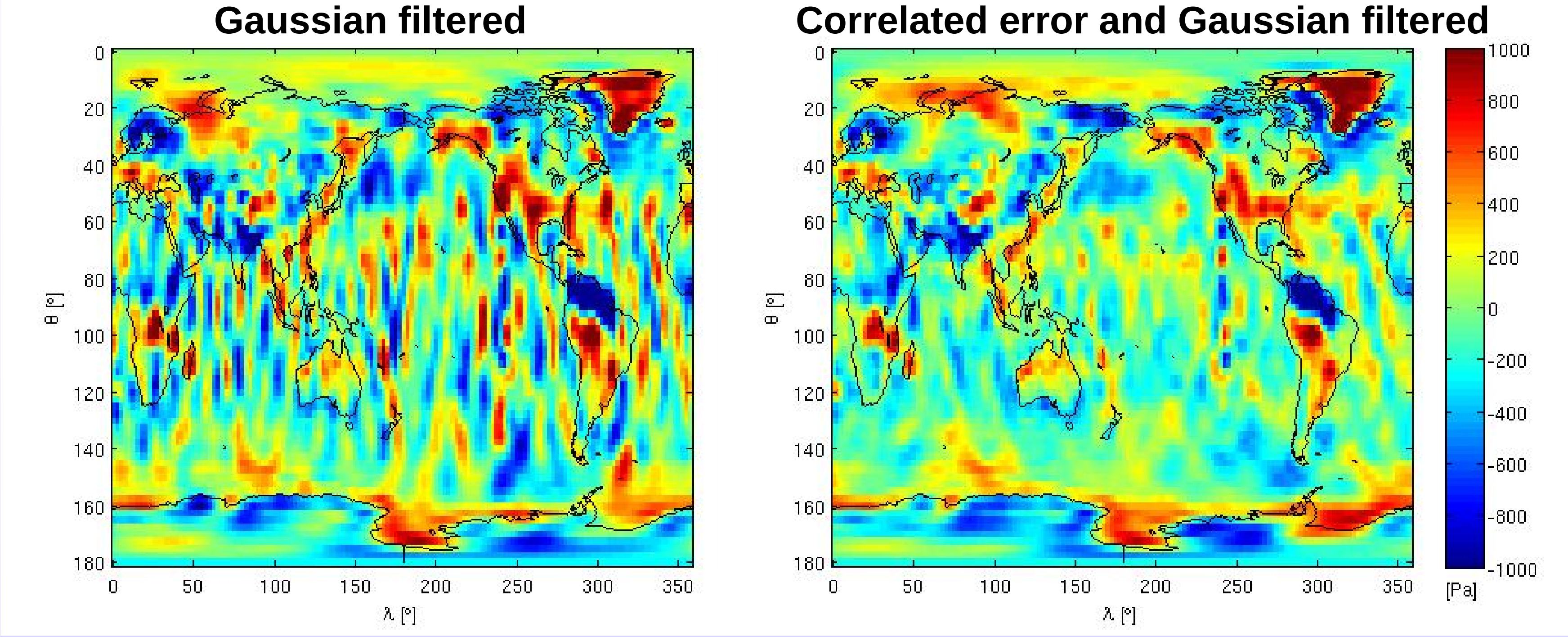
Correlated error filter form DON CHAMBERS

Gaussian filter (r = 500km) form JOHN WAHR

Pressure field changes of the Earth

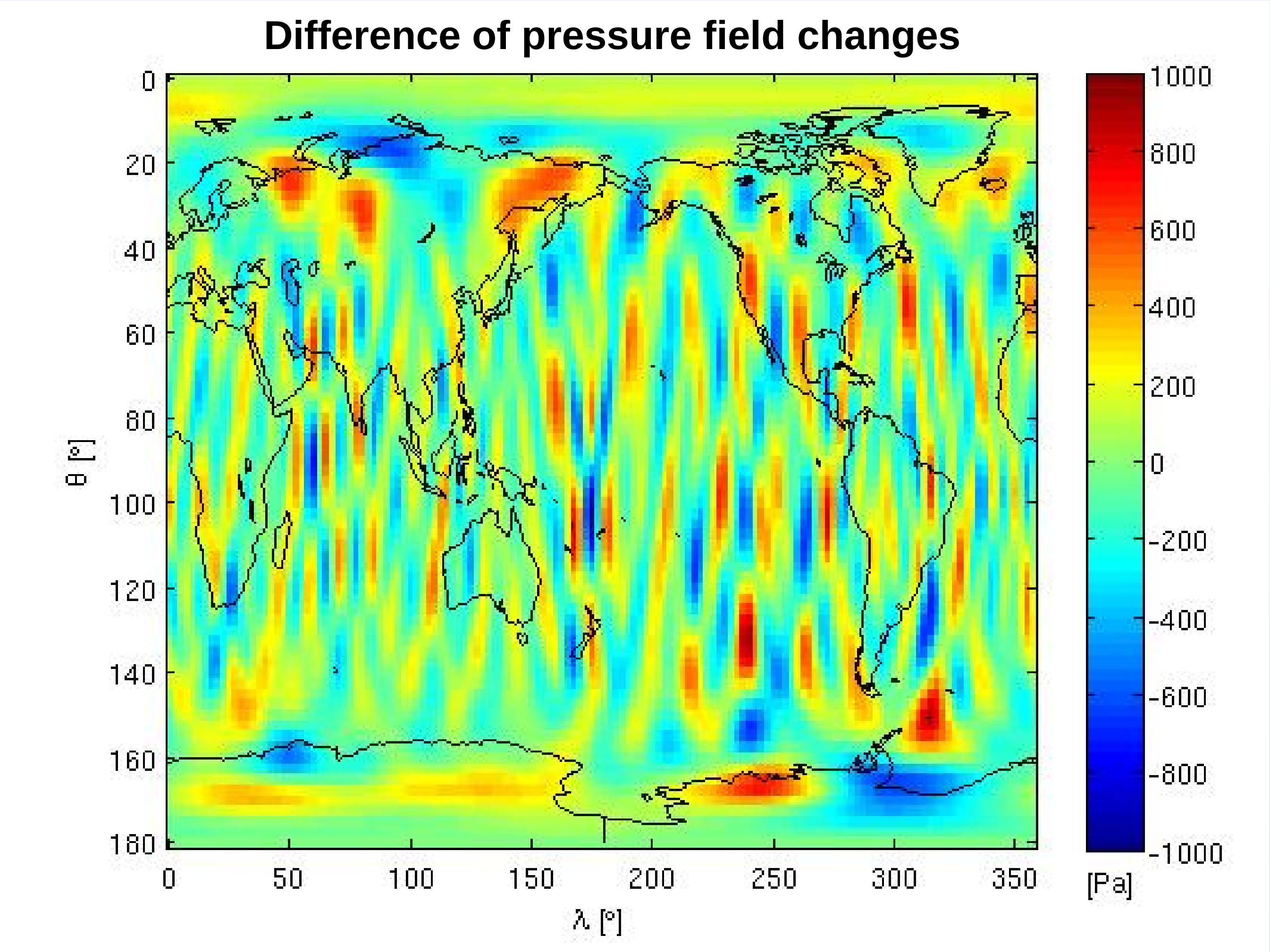
$$\Delta p(\theta,\lambda) = \frac{a_E g \rho_E}{3} \sum_{n=0}^{60} \sum_{m=0}^{n} \frac{2n+1}{1+k_n} \overline{P}_{nm}(\cos\theta)\left[\Delta C_{nm}\cos(m\lambda) + \Delta S_{nm}\sin(m\lambda)\right]$$

Pressure field changes



N-S-stripes disappear!

Difference of pressure field changes



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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

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

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

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

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

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