The RC-index of magnetospheric ring-current activity and revised observatory monthly mean values

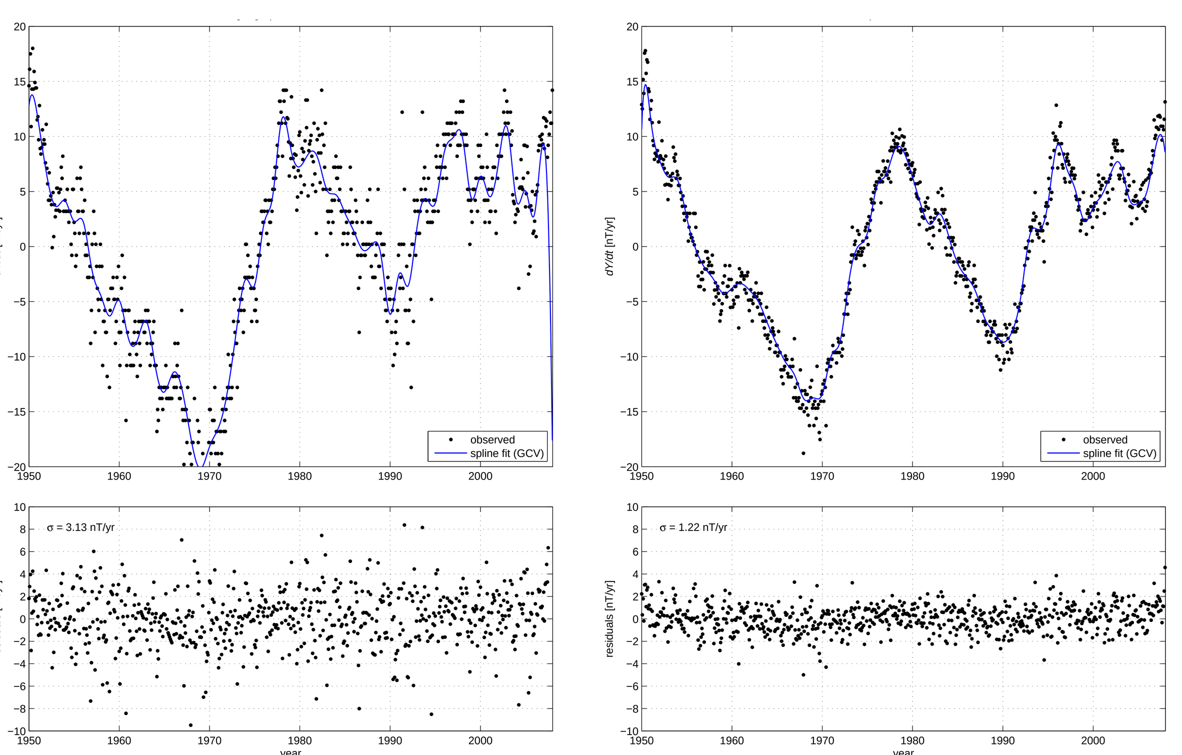
Nils Olsen[1,2], Christopher C. Finlay[2] and Kathryn A. Whaler[1]

[1]School of GeoSciences, University of Edinburgh; [2]DTU Space, Technical University of Denmark

Introduction

The strength of the magnetospheric ring-current is traditionally monitored by the *Dst*-index, which is based on hourly mean values from four low-latitude observatories after ad-hoc removal of the internal field contributions and of regular daily geomagnetic variations. Long-period variations of the ring-current cannot be monitored by *Dst*, and thus *Dst* is not an appropriate index to correct magnetic field observations for magnetospheric contributions in modelling of the internal (core and crustal) field. Monthly means of the magnetic field measurements taken by ground observatories are a useful data source for studying temporal changes of the core magnetic field. However, the usual way of calculating monthly means as the arithmetic mean of all days (geomagnetic quiet as well as disturbed) and all local times (day and night) may result in contributions from external (magnetospheric and ionospheric) origin in the monthly means. Such contamination makes monthly means less favourable for core field studies. We calculated revised monthly means from observatory hourly means using robust means and after removal of external field predictions.

External contributions in monthly means: dY/dt at Niemegk/Germany

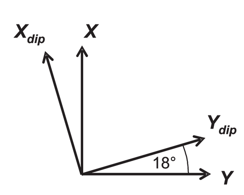


Black symbols: observations (annual differences of monthly means)

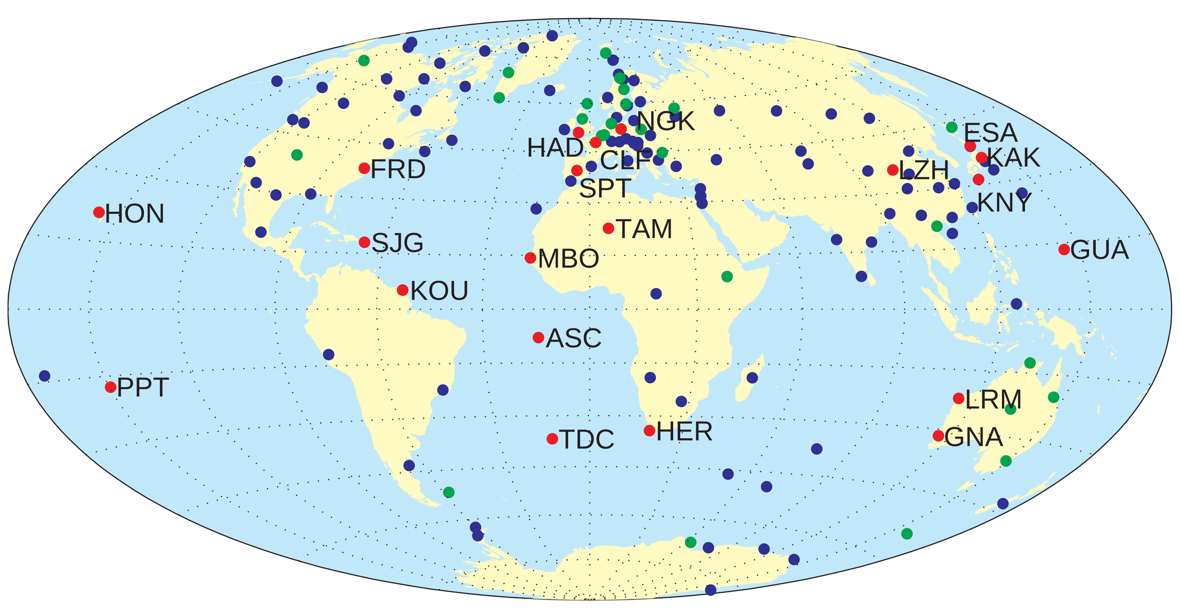
Blue curve: cubic B-spline fit (1-year knot separation) obtained by generalized cross-validation (GCV).

Decrease of standard deviation σ (wrt GCV spline fit) from 3.13 nT/yr to 1.22 nT/yr

Contribution from the magnetospheric ring-current is reduced when rotating the horizontal components X, Y from the geographic to the dipole frame (a rotation by 18° in the case of NGK)



Location of the 146 magnetic observatories



Emphasized (green or red symbols) are the 43 observatories that provided Quasi-Definitive data in 2013, out of which 21 observatories (red dots with three letter code given) were used for calculating the *RC* index.

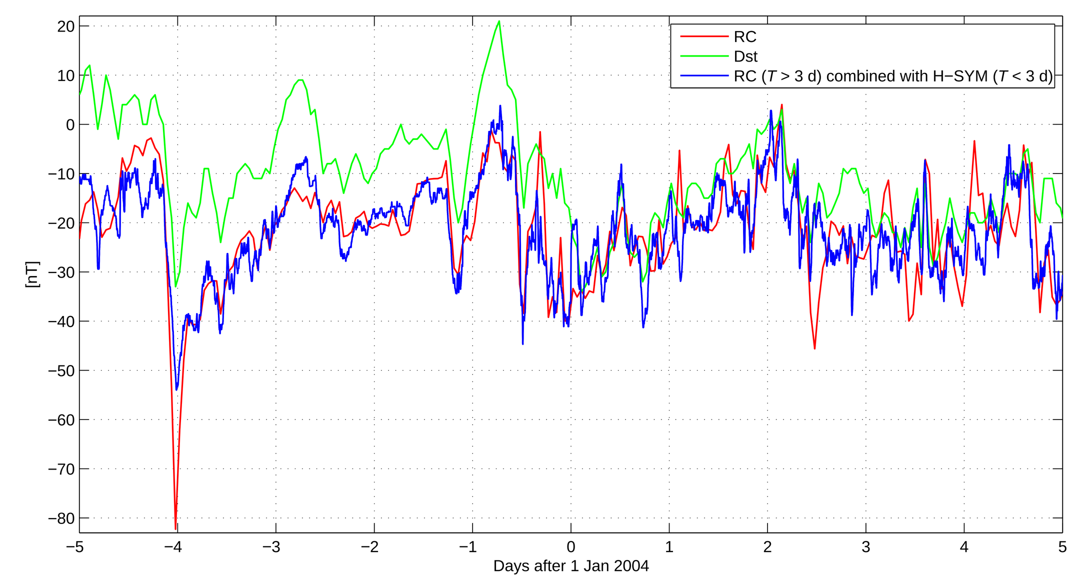
RC-index of magnetospheric ring-current strength

RC is determined in the following way:

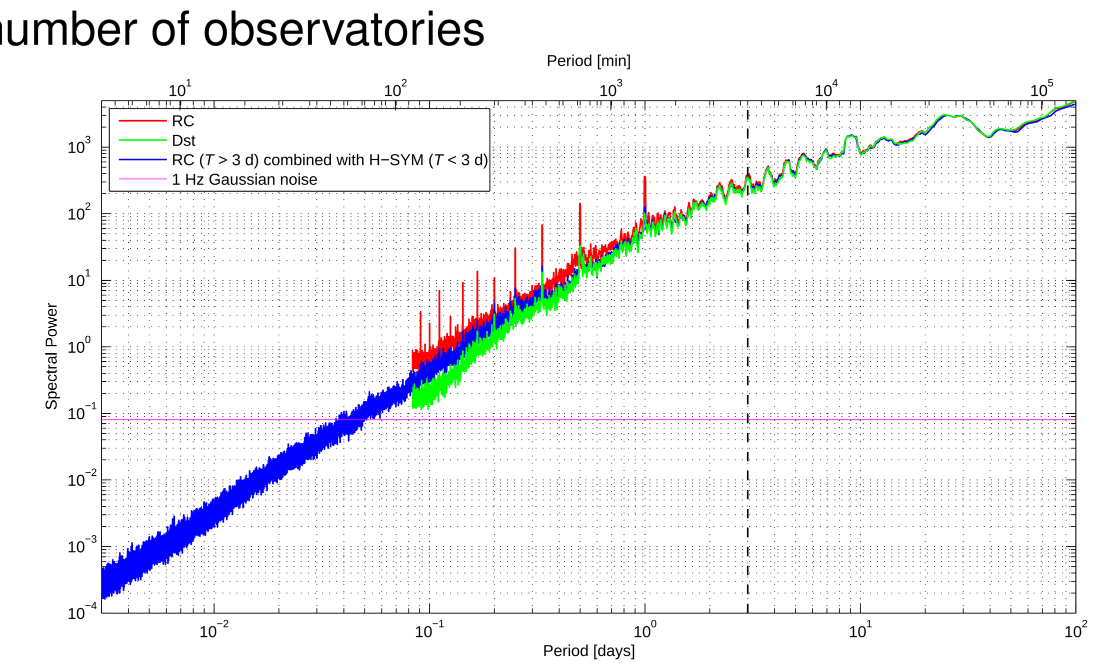
- Hourly Mean Values (HMV) of horizontal components from 21 observatories in dipole frame
- subtraction of CHAOS-4 core field
- subtraction of mean value during quiet conditions
- spherical harmonic analysis ($n = 1, m = 0, 1$) of data in night sector (between 18 and 06 LT) yields sum of external and induced potential coefficients v_1^m
- $RC = -v_1^0 = \epsilon + \iota$ is decomposed into external, ϵ, and induced, ι, parts using 1D mantle conductivity model
- high-frequency version of *RC* by merging *RC* from HMV (for periods $T > 3$ days) with H-SYM ($T < 3$ d)

Comparison of *RC* with *Dst*

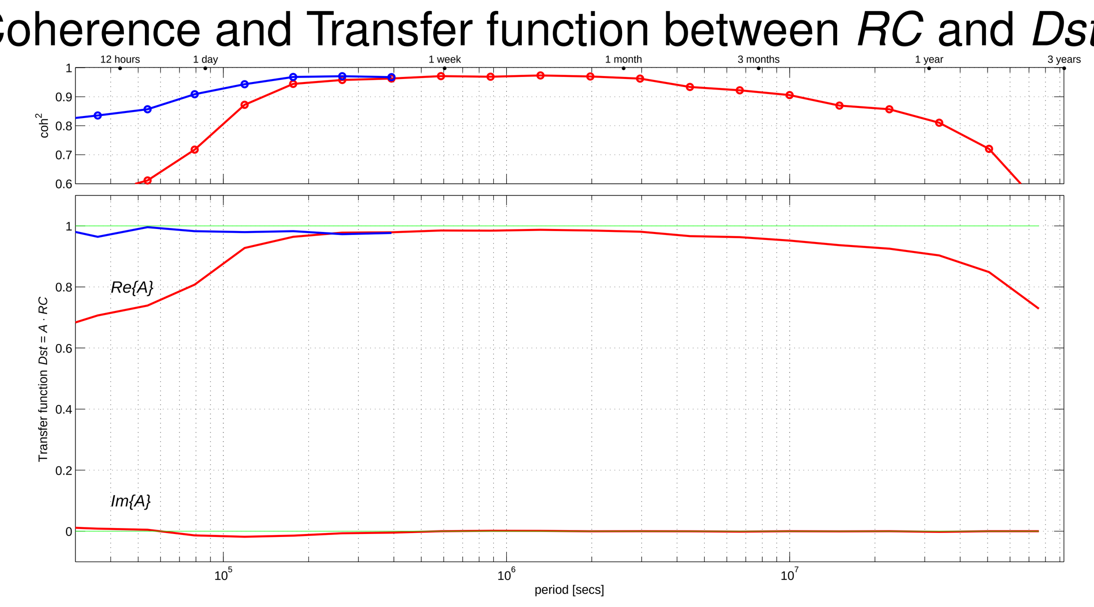
Jump in *Dst* baseline on 1 Jan 2004:



Spectral lines in *RC* at daily harmonics indicate persistent UT variation, probably due to varying number of observatories



Coherence and Transfer function between *RC* and *Dst*

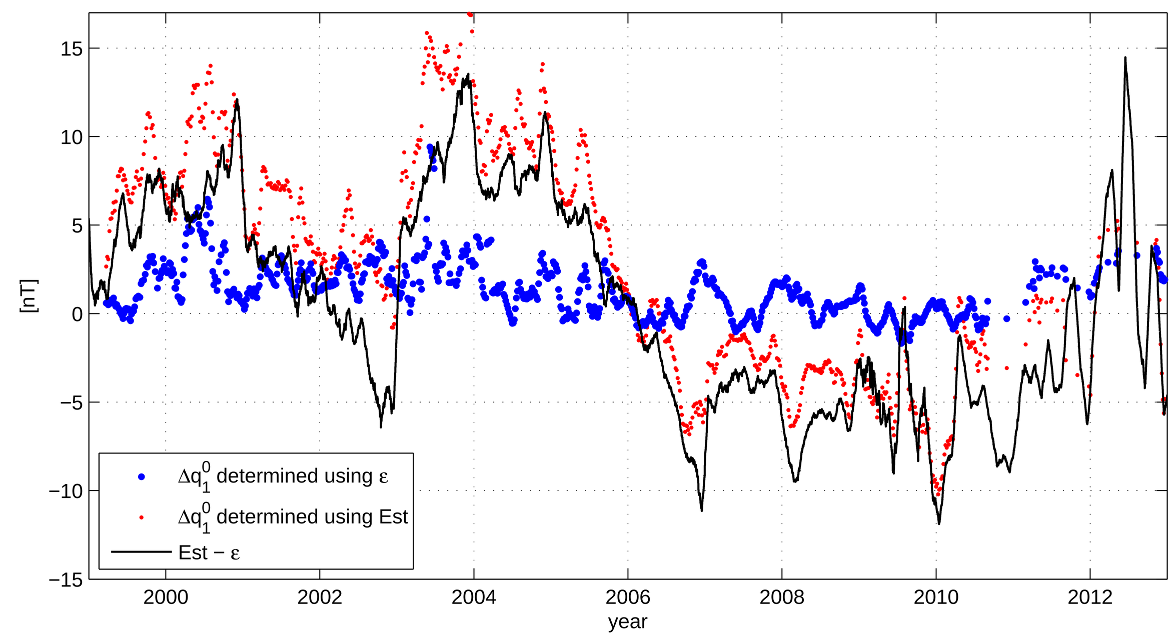


Baseline of *RC* and *Dst* determined with satellites

As part of the CHAOS-4 model the large-scale magnetospheric field is estimated. The degree-1 coefficients in *SM* coordinates depend explicitly on time and are further expanded as

$$q_1^0(t) = \hat{q}_1^0 \left[\epsilon(t) + \iota(t)\left(\frac{a}{r}\right)^3\right] + \Delta q_1^0(t)$$

with "baseline corrections" Δq_1^0 estimated in bins of 5 days length.

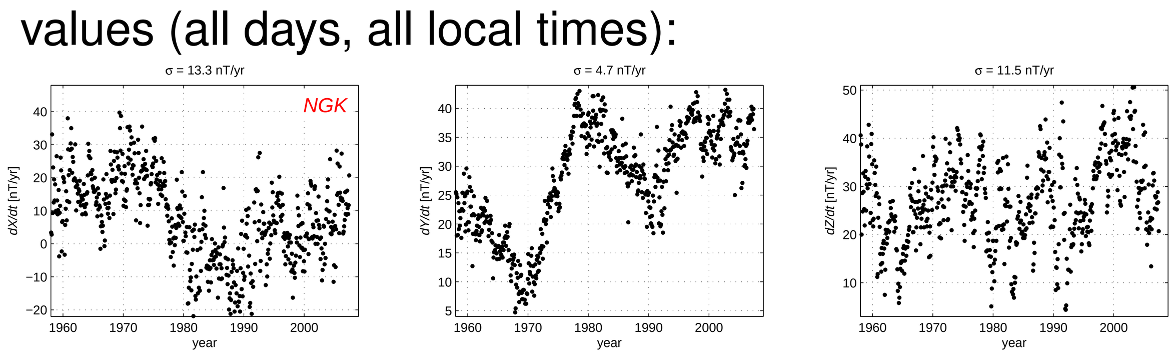


The blue dots show Δq_1^0 against time. Values from a similar model run parametrized by *Dst* instead of *RC* are shown in red. The difference $\epsilon(t) - Est(t)$ between the external parts of *RC* and of *Dst* is shown by the black curve. All values are 30-day running means.

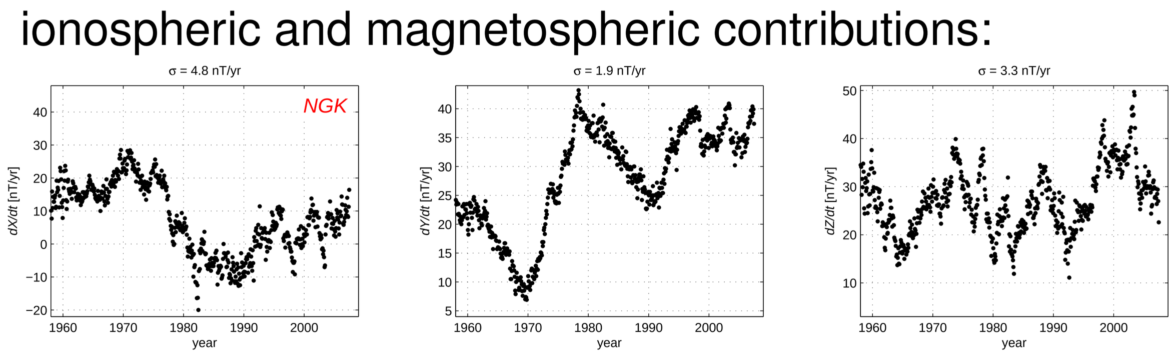
Calculation of monthly means for Niemegk (NGK)

Analysis of 50 years (1958-2007) of HMV

Ordinary Monthly Means (OMM) calculated in the traditional way as arithmetic mean from hourly mean values (all days, all local times):

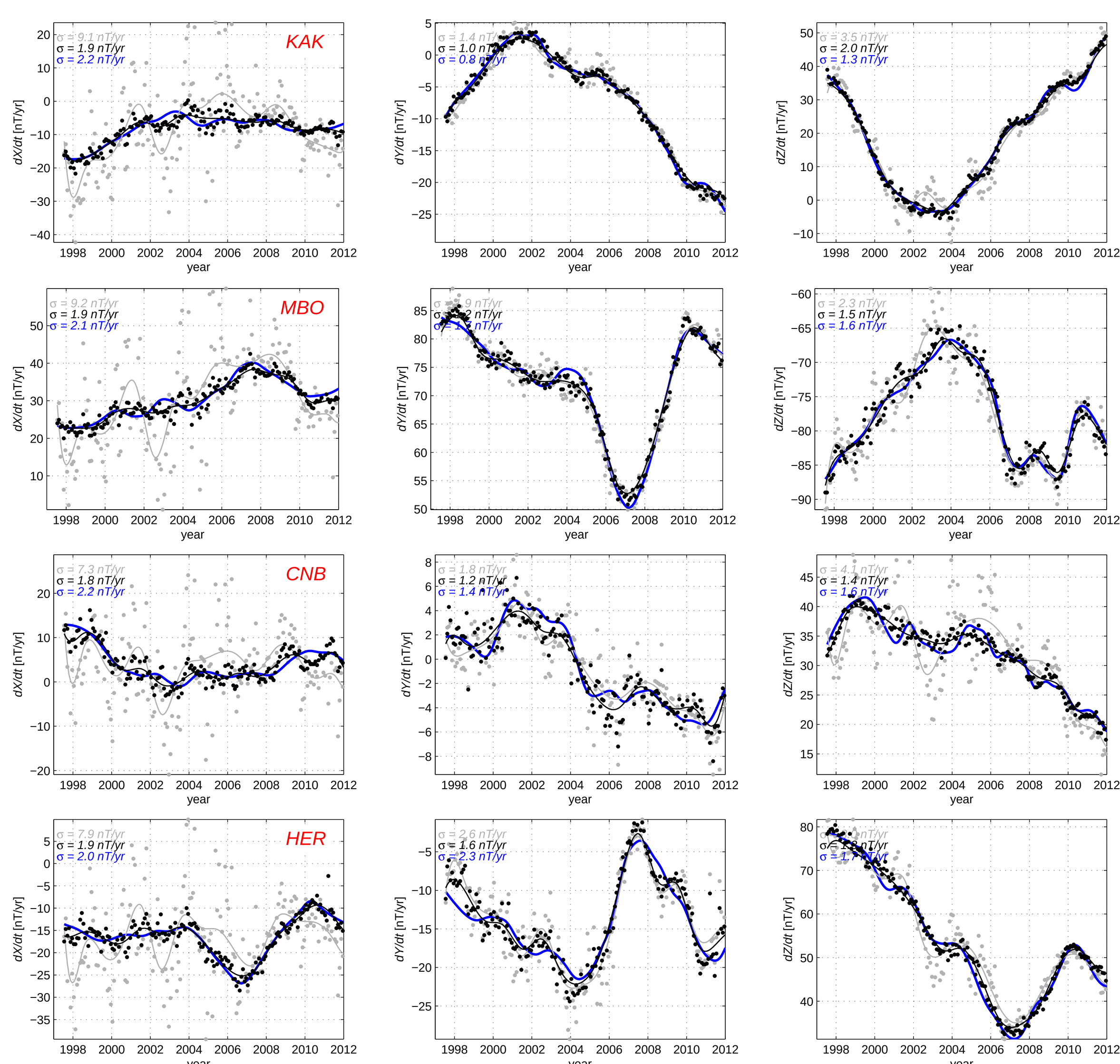


Revised Monthly Means (RMM) calculated as the robust (Huber) average of data after removal of ionospheric and magnetospheric contributions:



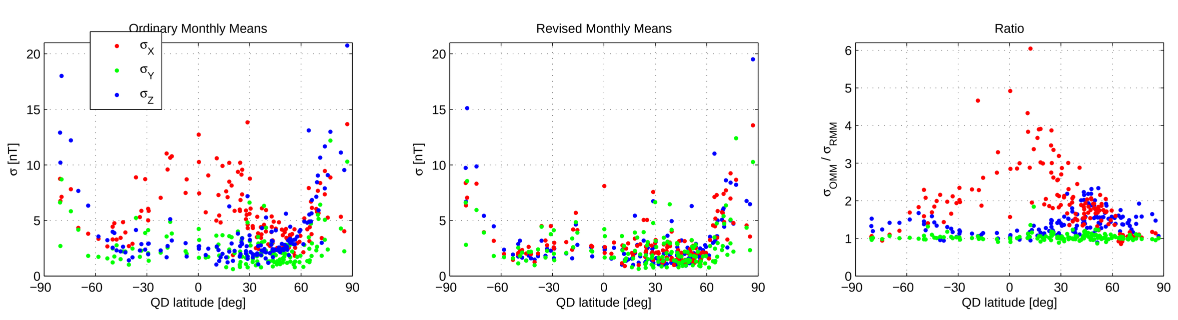
Standard deviation σ (wrt a GCV spline fit) is reduced by a factor of 3

Some other observatories



Black dots: Revised monthly means (RMM)
Black curve: GCV spline fit to RMMs
Blue curve: CHAOS-4 model values
Grey dots: Ordinary monthly means (OMM)
Grey curve: GCV spline fit to OMMs
standard deviations σ of GCV fit wrt OMMs, resp. RMMs, and of σ CHAOS-4 wrt RMMs

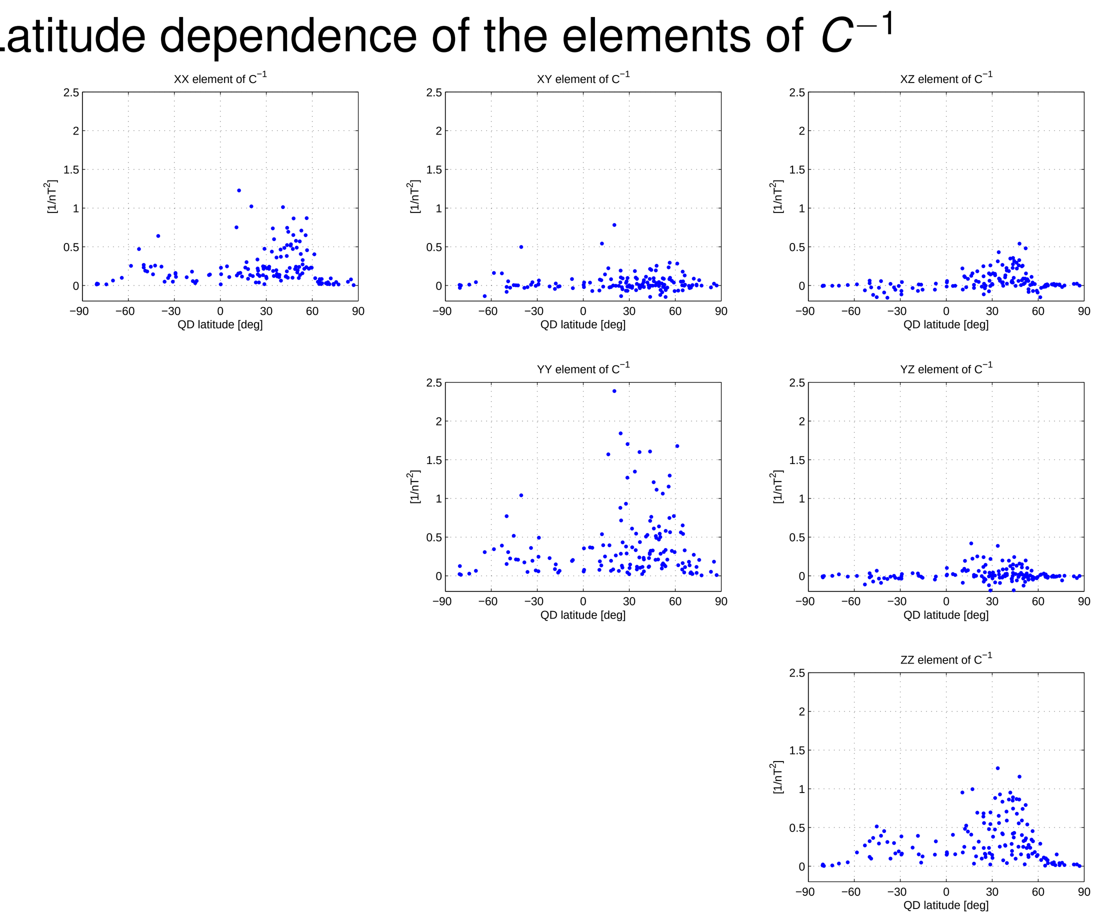
Latitude dependence of standard deviation σ



Largest improvement in X and Z, no difference in Y

Data Covariance Matrix

Latitude dependence of the elements of C^{-1}



For Niemegk the covariance matrix is

$$C = \begin{pmatrix} 1.7154 & -0.2838 & -0.7635 \\ -0.2838 & 0.9641 & 0.0004 \\ -0.7635 & 0.0004 & 1.2220 \end{pmatrix} \mathrm{nT}^2; \quad C^{-1} = \begin{pmatrix} 0.8658 & 0.2546 & 0.5409 \\ 0.2546 & 1.1121 & 0.1587 \\ 0.5409 & 0.1587 & 1.1562 \end{pmatrix} \mathrm{nT}^{-2}$$

School of GeoSciences, The University of Edinburgh, Grant Institute, Edinburgh EH9 3JW nio@space.dtu.dk www.spacecenter.dk/~nio