GRAS SAF Open Loop Workshop
Helsingør, Denmark
June 6-8, 2005

DMI Technical Report 05-11
ISSN: 1399-1388
Kent B. Lauritsen and Frans Rubek, editors

Radio Holographic Filtering and Error Estimation of Radio Occultation Data

Michael E. Gorbunov (1), K. B. Lauritsen (2), A. Rhodin (3),
M. Tomassini (3), and L. Kornblueh (4)
(1) Institute for Atmospheric Physics, Moscow, Russia, gorbunov@dkrz.de
(2) Danish Meteorological Institute, Copenhagen, Denmark
(3) German Weather Service, Offenbach, Germany
(4) Max-Planck Institute for Meteorology, Hamburg, Germnay

Processing of radio occultation data requires filtering for the noise reduction. We discuss the radio holographic filtering algorithms. The algorithm is based on the synthesis of canonical transform (CT2) method and radio holographic synthesized aperture (RHSA) method. The field in the CT2-transformed space is multiplied with a reference signal to subtract the regular phase variation and to compress the spectrum. Then it is convolved with a gaussian filter window and divided by the reference signal to restore the phase variation. This algorithm is very simple to implement and it is numerically efficient. The error estimation of the retrieved bending angle profiles is performed by the computation of the width of the running spectra of the wave field in the transformed space multiplied with the reference signal. We demostrate the application of these filtering and error estimation techniques for processing CHAMP data. We describe the method of the discrimination of corrupted samples in the L2 channel, which is most succeptible to signal track errors. We present the results of the statistical comparison of the CHAMP data with the analyses of the German Weather Service (DWD). The statistical analysis shows a good agreement between the CHAMP and DWD error estimates and the observed CHAMP—DWD differences.

Radio holographic filtering and error estimation of radio occultation data

M. E. Gorbunov
(Institute for Atmospheric Physics, Moscow)

K. B. Lauritsen
(Danish Meteorological Institute, Copenhagen)

A. Rhodin, M. Tomassini
(German Weather Service, Offenbach, Germany)

L. Kornblueh
(Max-Planck Institute for Meteorology, Hamburg, Germany)

Overview

- Radio Holographic Filtering
- Radio Holographic Error Estimation
- Quality Control of CHAMP Data
- Examples
- Statistical Analysis of CHAMP data

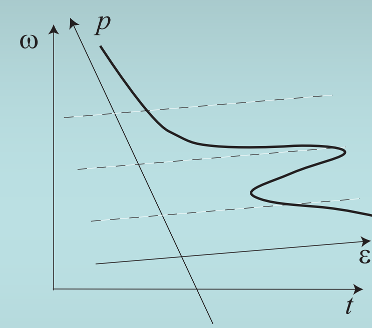
Radio Holographic Filtering

CT processing

$$u(t) = A(t)\exp\left(ik\Psi(t)\right), \quad \omega = \frac{d\Psi(t)}{dt}$$

$$w(p) = \sqrt{\frac{-ik}{2\pi}}\int a_2(p,t)\exp(ikS_2(p,t))u(t)\,dt;$$

$$w(p) = A'(p)\exp\left(ik\Psi'(p)\right), \quad \varepsilon = \frac{d\Psi'(p)}{dp}$$

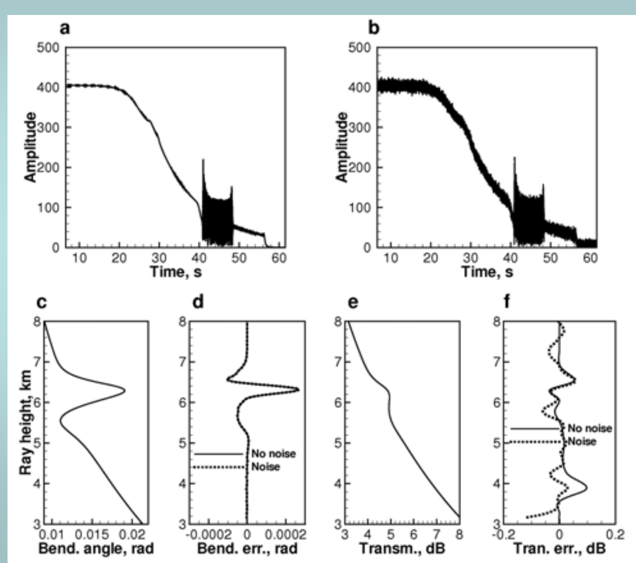


Radio holographic filtering

$$w_m(p) = \exp\left(ik\Psi'_m(p)\right)$$ Reference signal in p-domain

$$\overline{w}(p) = w_m(p)\left(W(p) * \frac{w(p)}{w_m(p)}\right), \qquad W(p) = \frac{1}{\sqrt{2\pi}\sigma_p}\exp\left(-\frac{p^2}{2\sigma_p^2}\right)$$

Numerical Simulation



Radio Holographic Error Estimation

$$w(p,\xi)=\int_{p-\frac{\Delta p}{2}}^{p+\frac{\Delta p}{2}} \frac{w(p')\cos\frac{\pi(p'-p)}{\Delta p}\exp(-ik\xi p')}{\exp\left(ik\Psi'_m(p')\right)}dp'$$

Running spectra in p-domain

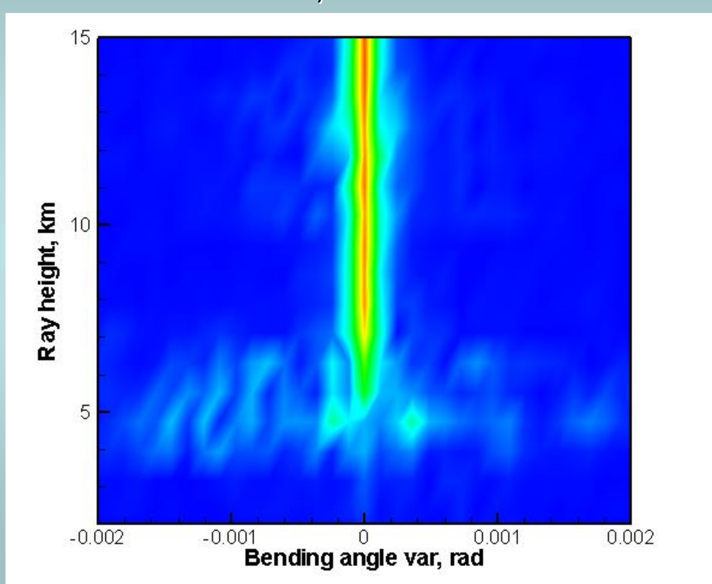
ξ – momentum conjugated to impact parameter = bending angle variation

$$\delta\varepsilon_T(p)=\left(\frac{\int\left|w(p,\xi)\right|^2\xi^2 d\xi}{\int\left|w(p,\xi)\right|^2 d\xi}\right)^{1/2}$$

Bending angle error = bending angle spectral width in p-domain

Occultation 0004, 2004.01.18

UTC 00:24, 50.4N 116.1W



Quality Control of CHAMP Data

$$v_{1,2}(t,\eta) = \int_{t-\frac{T}{2}}^{t+\frac{T}{2}} \frac{u_{1,2}(\tau)\cos\frac{\pi(\tau - t)}{T}\exp(-ik\eta\tau)}{\exp\left[ik\left(\Psi_m(\tau) - \dot{\Psi}_m(t)\tau\right)\right]} d\tau$$

Running spectra in t-domain

$$\bar{p}_{1,2}(t) = \frac{\int \left|v_{1,2}(t,\eta)\right|^2 p(t,\eta)\, d\eta}{\int \left|v_{1,2}(t,\eta)\right|^2 d\eta}$$

Mean impact parameters

$$\delta p_{1,2}(t) = \left(\frac{\int \left|v_{1,2}(t,\eta)\right|^2 \left(p(t,\eta) - \bar{p}_{1,2}(t)\right)^2 d\eta}{\int \left|v_{1,2}(t,\eta)\right|^2 d\eta} \right)^{1/2}$$

Impact parameter spectral width

$$W(t) = 1 - \exp\left[-\frac{\left(\bar{p}_2(t) - \bar{p}_1(t)\right)^2 + \delta p_2^2(t)}{\Delta p^2} \right],$$

$$D_i\Psi_2^{cor} = D_i\Psi_2\left(1 - W(t_i)\right) + \left(D_i\Psi_1 + D_i\Delta\Psi_{ION}\right)W(t_i)$$

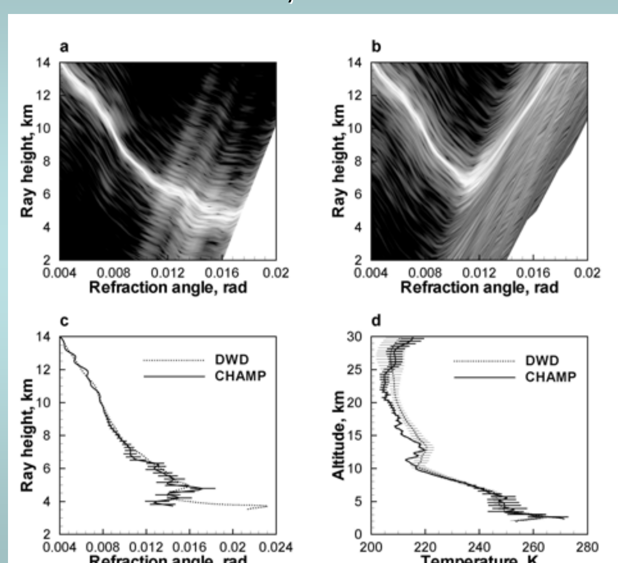
$$\Psi_2^{cor}(t_i) = \sum_{j=1}^{i-1} D_j\Psi_2^{cor},$$

$$A_2^{cor}(t_i) = A_2(t_i)\left(1 - W(t_i)\right).$$

Weighting function $W(t)$ discriminates L2 data in multipath areas and after signal track loss,
Δp = 0.2 km
$\Delta\Psi_{ION}$ - estimate of ionospheric phase path difference

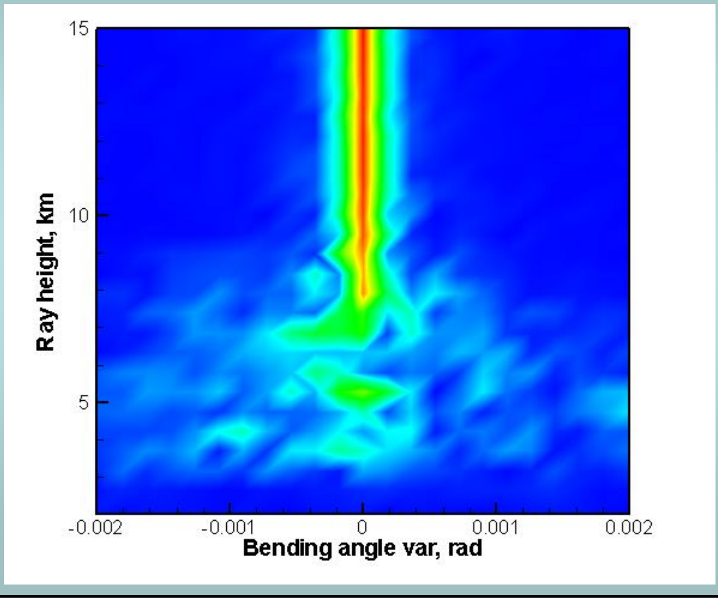
Occultation 0004, 2004.01.18

UTC 00:24, 50.4N 116.1W



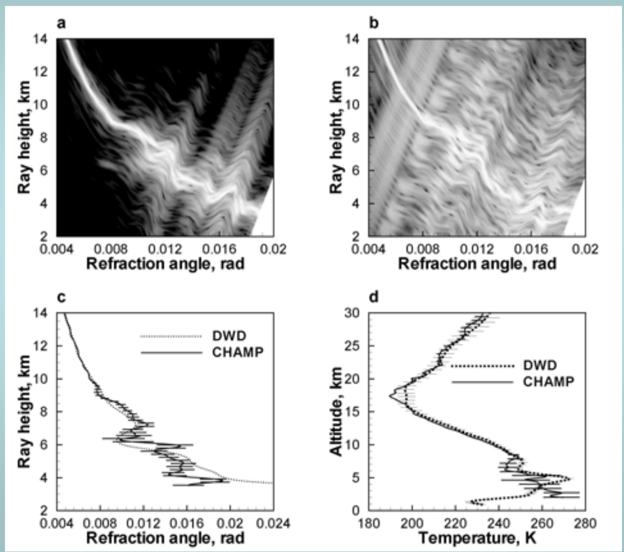
Occultation 0041, 2004.01.18

UTC 04:09, 26.0S 19.4E



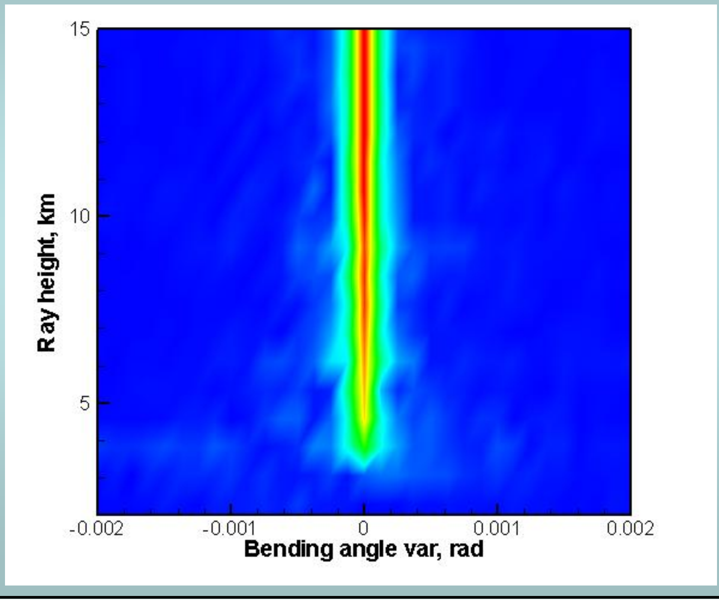
Occultation 0041, 2004.01.18

UTC 04:09, 26.0S 19.4E



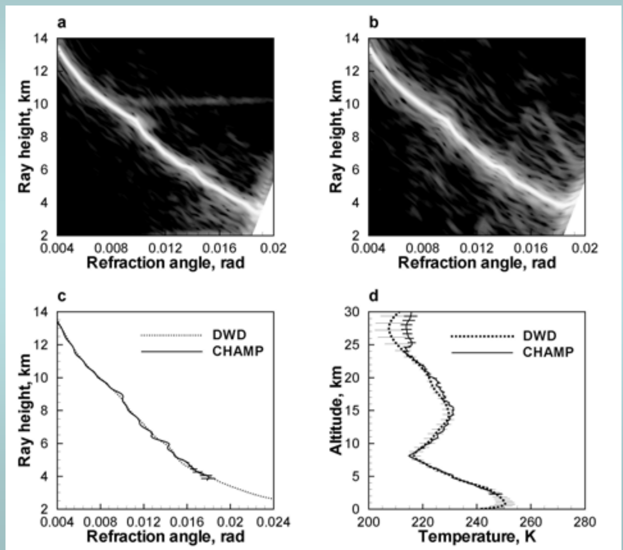
Occultation 0097, 2004.01.18

UTC 09:50, 78.8N 125.6W

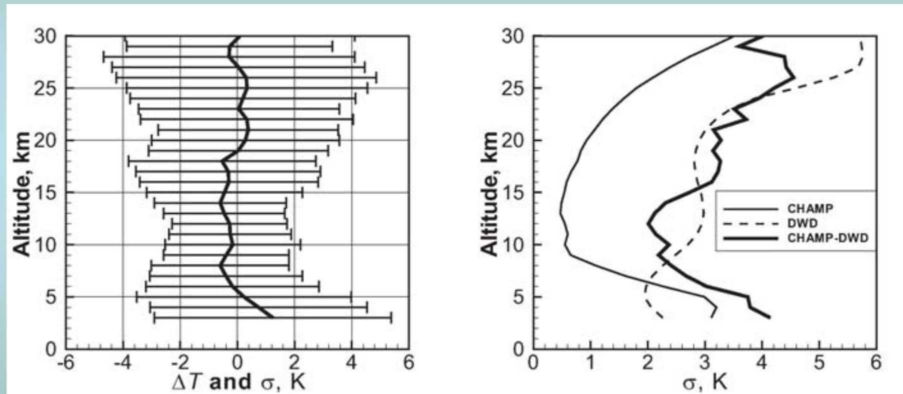


Occultation 0097, 2004.01.18

UTC 09:50, 78.8N 125.6W



Statistical Analysis
2004.01.18



Conclusion

- Radio holographic filtering is simple and numerically effective
- Error estimation and quality control allow creating robust algorithms for operation data processing
- Error estimation of CHAMP and DWD data are consistent with the observed CHAMP-DWD differences