Assessment of the structural uncertainty of MetOp-A/GRAS products

Stig Syndergaard
Danish Meteorological Institute, Copenhagen, Denmark

2nd IROWG Workshop
Estes Park, Colorado, 28 March – 3 April, 2012

Background

- DMI study funded by EUMETSAT (outside of the ROM SAF)
- Builds on EUMETSAT funded UCAR study a couple of years ago:
  - Assessment of the structural uncertainty of GRAS product retrievals in view of climate applications (Rocken et. al, 2010)
- DMI study to look at the differences between MetOp/GRAS products processed by DMI and the corresponding products processed by CDAAC:
  - bending angle
  - refractivity
  - dry temperature
- Starting from excess phases and amplitudes provided by UCAR study
- Side benefit: opportunity for us to learn and discover any possible deficiencies in our processing (and possible deficiencies in the CDAAC processing)

<u>Work in progress – study ongoing</u>

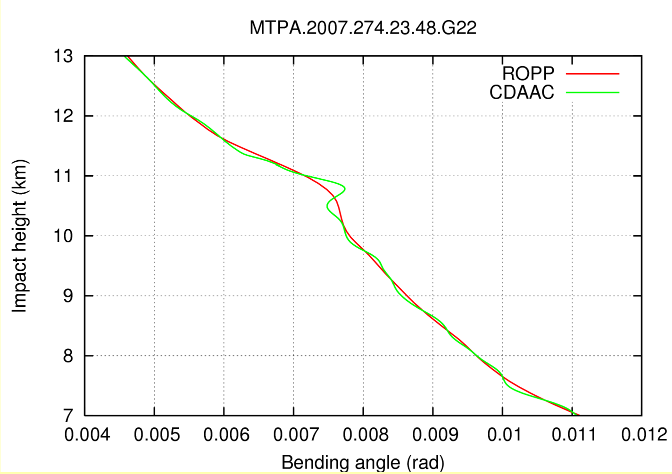
Data

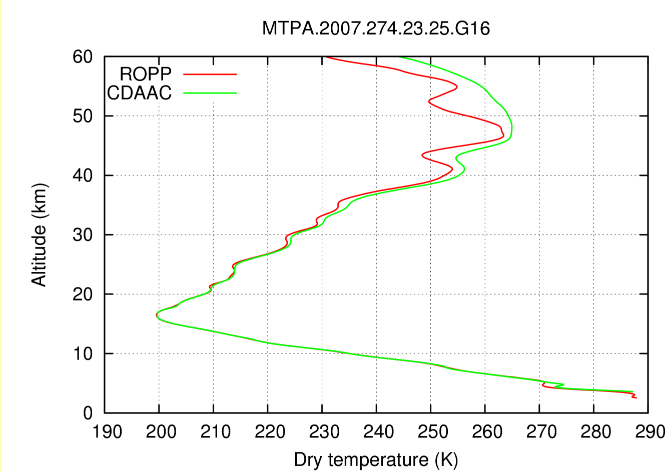
- One month of MetOp/GRAS from UCAR study (October 2007, days 2007.273-304)
- Closed loop excess phase and amplitude at 50 Hz
- MetOp-A and GPS orbits at 50 Hz
- Both single-differencing (SD) and zero-differencing (ZD)
- Gaps in closed loop data filled in CDAAC processing
- Data processed at DMI using ROPP (not yet used operationally)
- All data not yet analyzed; will show only preliminary results for 2007.274

ROPP processing – main features

- L2 amplitude correction and excess phase filtering (Gorbunov et al., 2006)
- GO above 25 km; CT2 below 25 km (Gorbunov and Lauritsen, 2004)
- Global search of 'best fit' modified MSIS profile at high altitudes (Lauritsen et al., 2011) – more on that later
- Dynamical error estimation and Optimal Linear Combination (OLC) of L1 and L2 bending angles / Statistical Optimization (SO) (Gorbunov, 2002)
- Filtering with a window of about 2 km
- QC based on L2 and SO badness scores:
  - L2 badness: Based on impact parameters and their RMS deviation obtained from a radio holographic analysis; maximum value between 15 and 50 km – in this study threshold set to 85; may be revised
  - SO badness: Maximum value of relative error of OLC solution (from error covariance of solution) – in this study threshold set to 100; may be revised

ROPP and CDAAC differences - examples

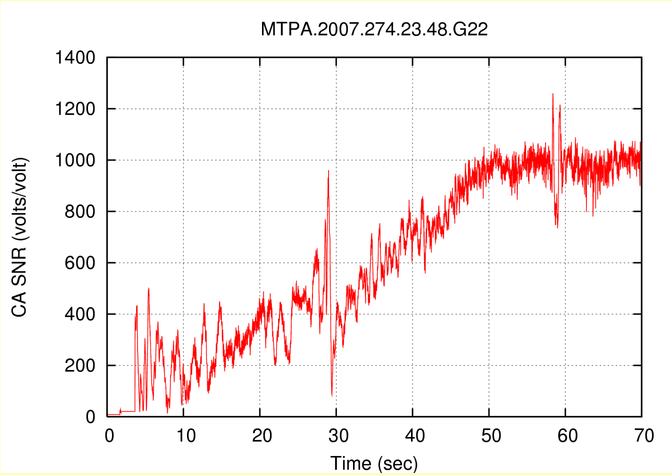


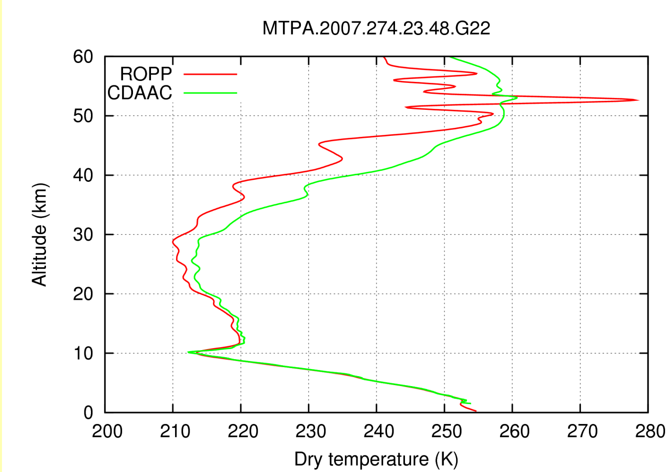


- ROPP (with 2 km smoothing) has generally lower resolution than CDAAC
- ROPP has generally more noise/wiggles at high altitudes (statistical optimization)

Work in progress to tune filter settings and SO approach in ROPP for operational processing within the ROM SAF

ROPP and CDAAC differences - examples

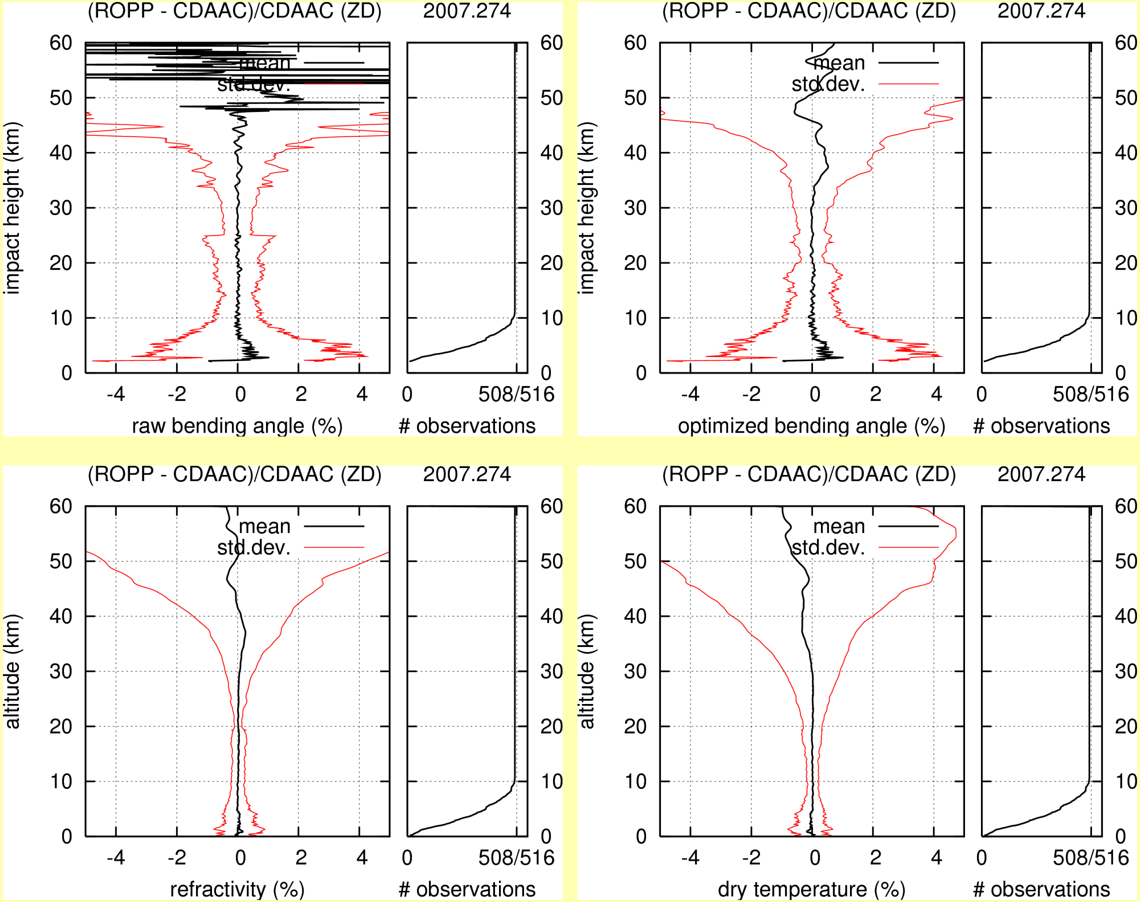




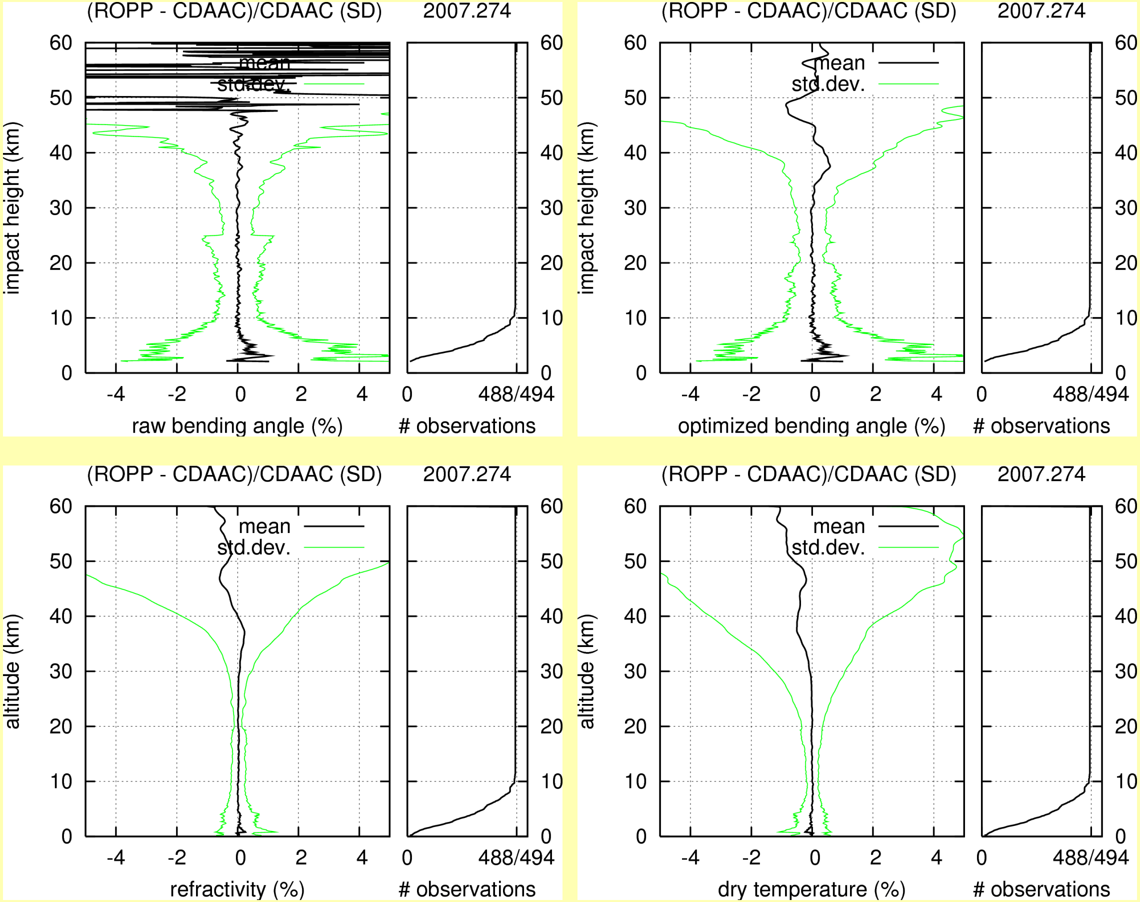
- Sporadic E-layers (Es) affect some occultations (Zeng and Sokolovskiy, 2011)
- Scintillations from Es are not well handled by the current ROPP processing

Work in progress to tune filter settings and SO approach in ROPP for operational processing within the ROM SAF

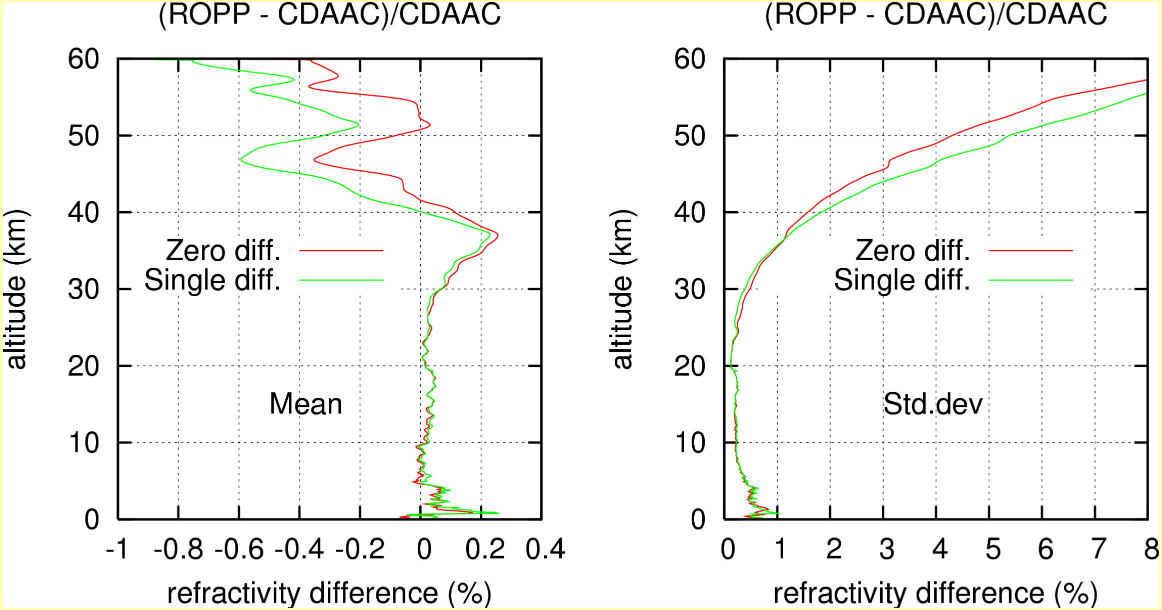
Global statistics – zero-differencing (ZD)



Global statistics – single-differencing (SD)

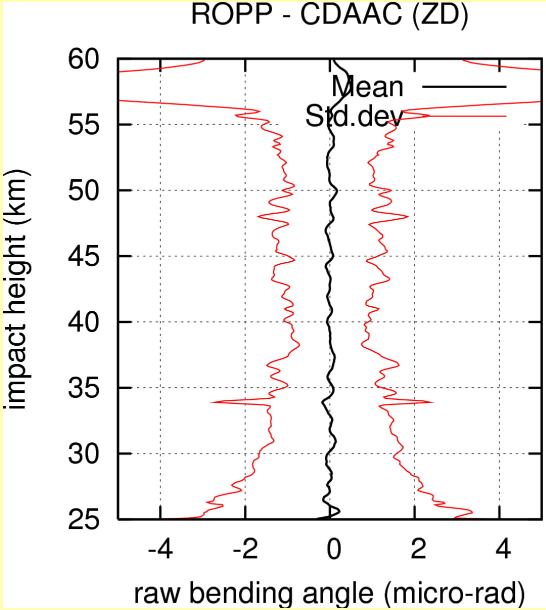


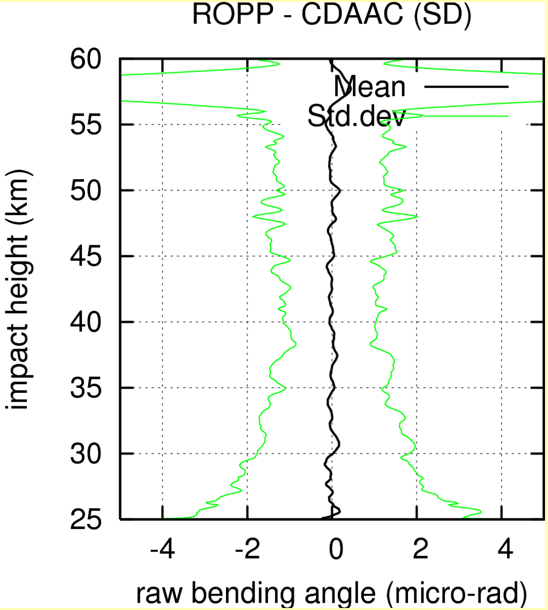
Zero- versus single-differencing



- Zero-differencing: Smaller differences at high altitudes
- Overall differences in-line with previous studies using CHAMP and COSMIC data (e.g., Ho et al., 2009; Gorbunov et al., 2011; Steiner et al., 2012; Ho et al., 2012)

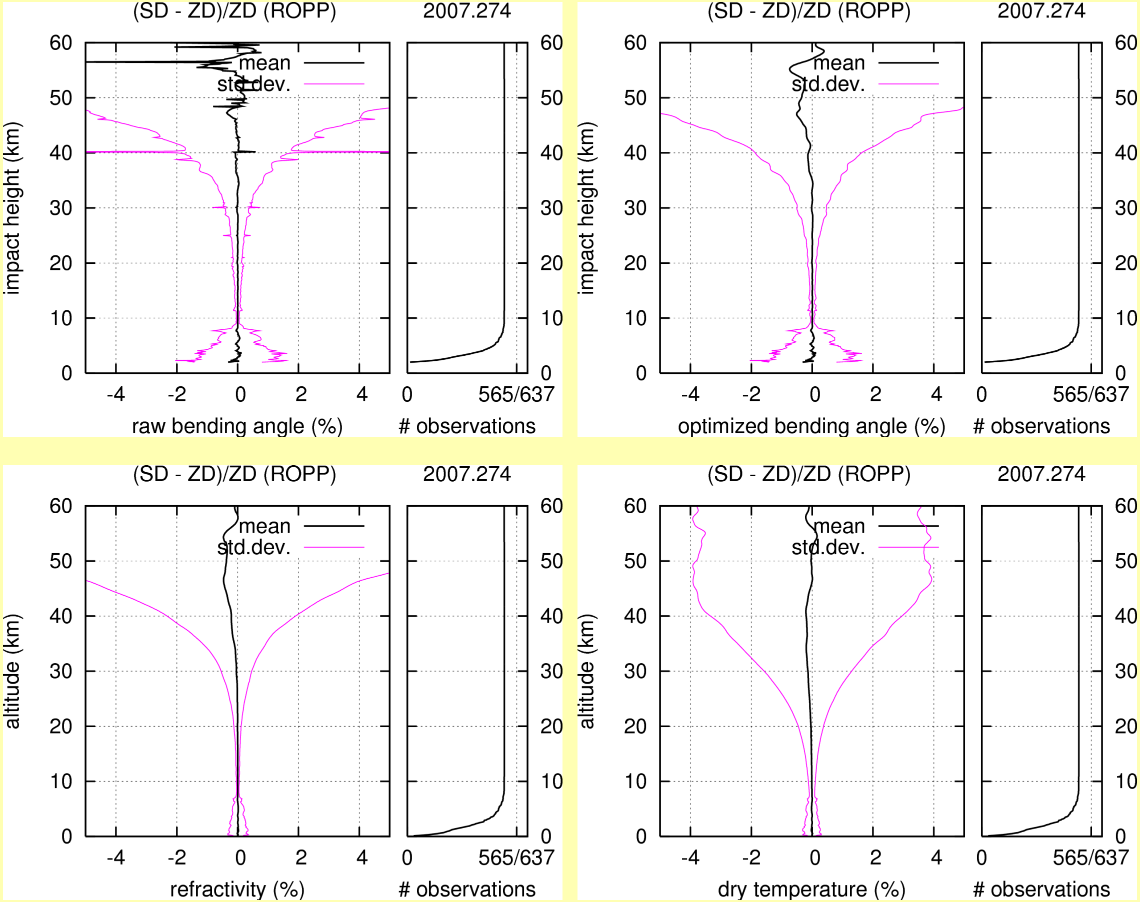
Zero- versus single-differencing



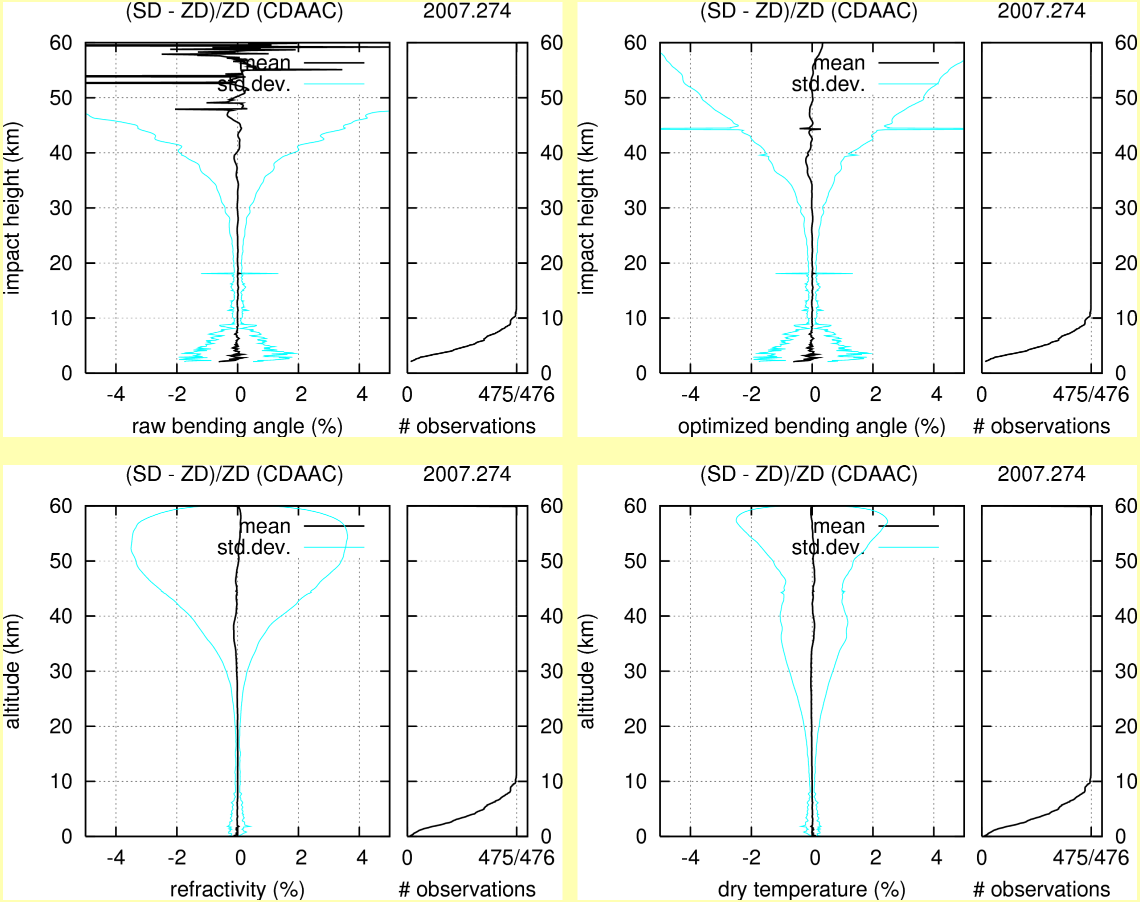


- Zero-differencing: Smaller differences at high altitudes
- Outliers in bending angle yet to be tracked down

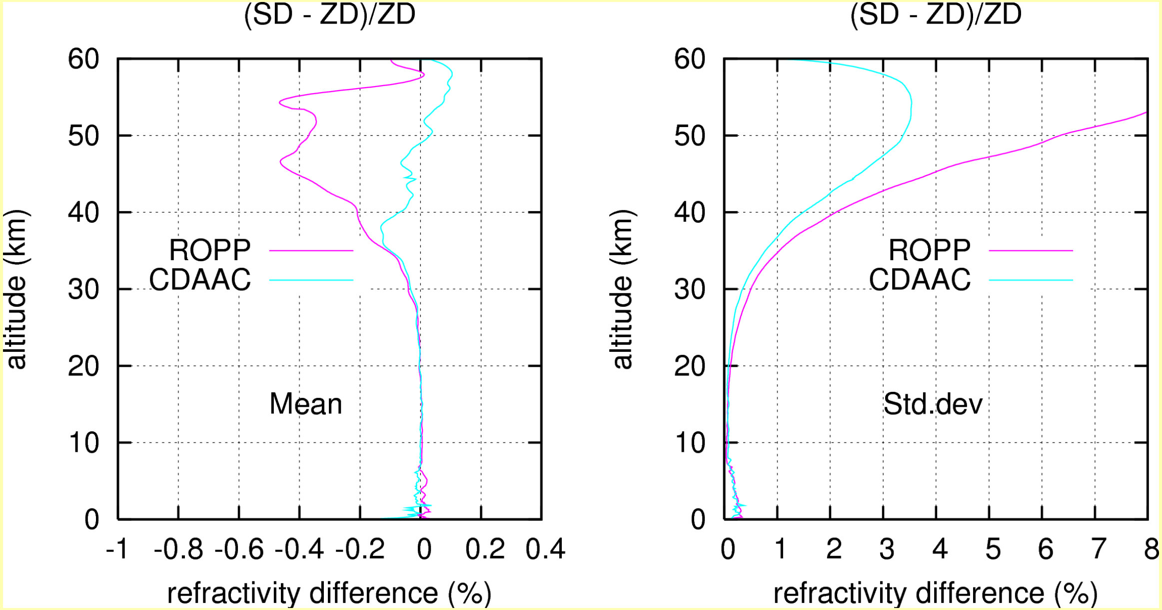
Global statistics – ROPP against ROPP



Global statistics – CDAAC against CDAAC



ROPP versus CDAAC

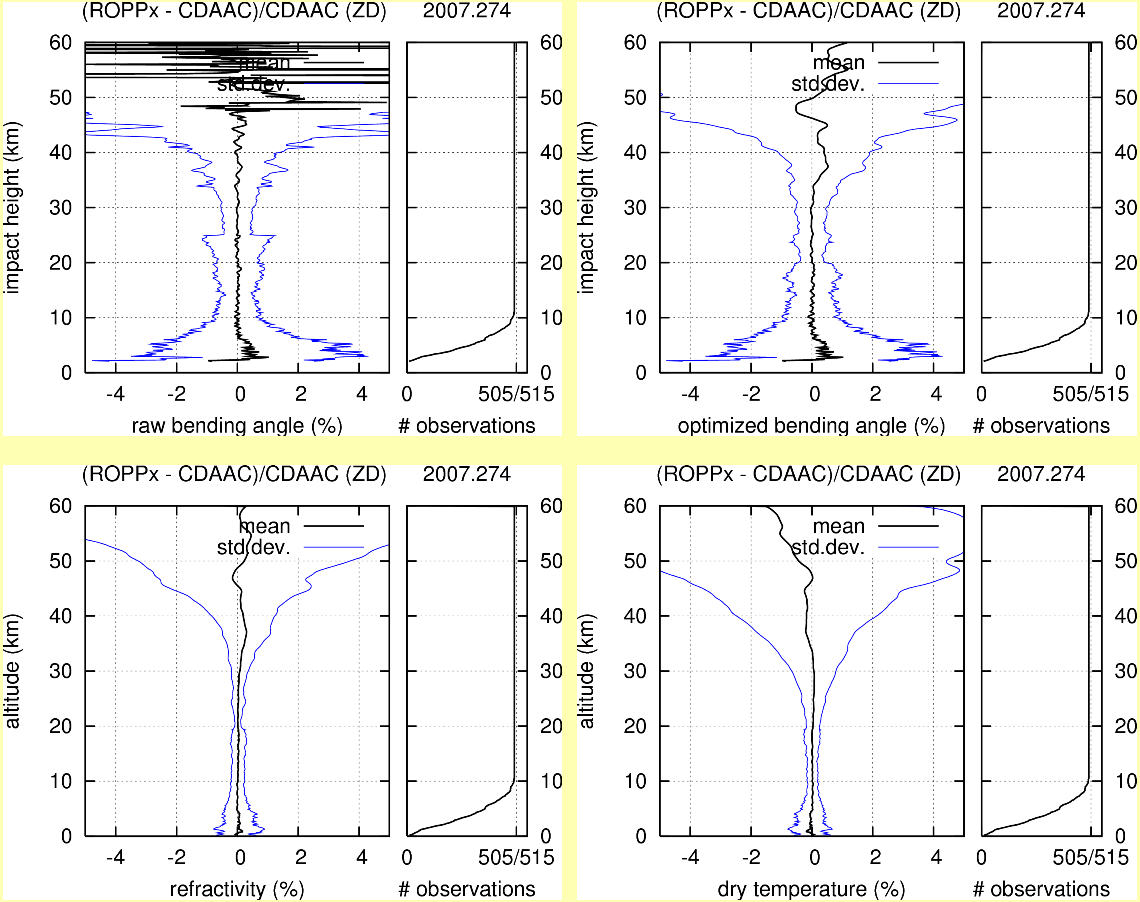


- CDAAC better consistency between SD and ZD at high altitudes
- ROPP SO allows different climatological background for SD and ZD
- Difference between ROPP and CDAAC (SD against ZD) below 8 km – not understood

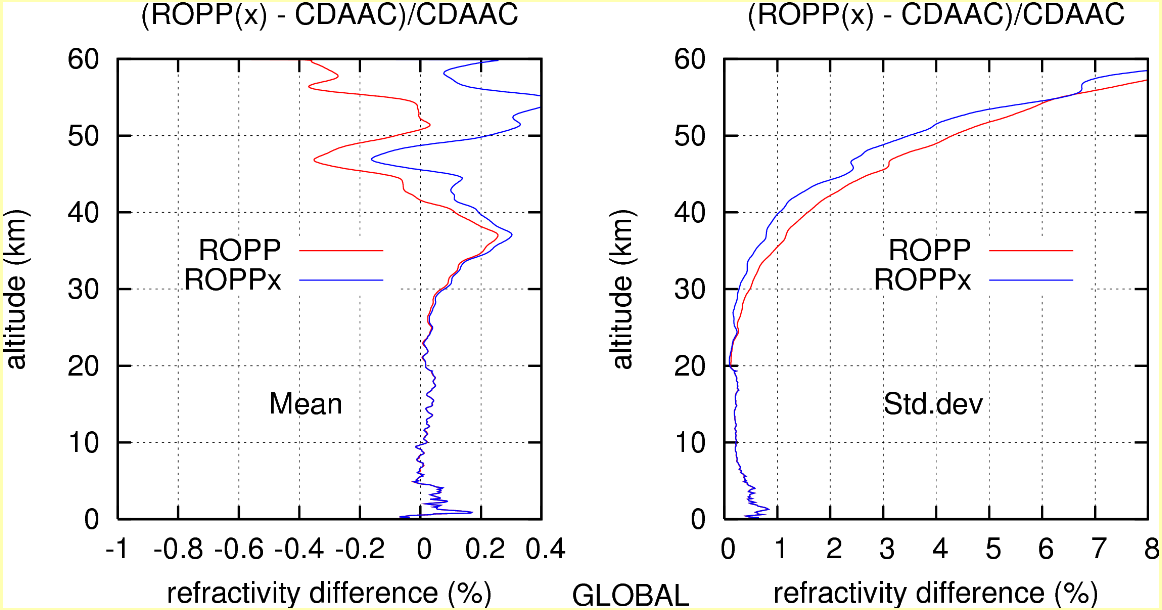
Climatology in statistical optimization

- CDAAC: Approach by Lohmann (2005)
  - NCAR climatology
  - Modified by two-parameter fit to data at high altitudes
- ROPP: Approach by Lauritsen et al. (2011)
  - MSIS climatology
  - Modified by two-parameter (a and b) least squares fit to data at high altitudes
  - Minimizing $|| \ln(\alpha_{\rm obs}) - (\ln(a) + b \ln(\alpha_{\rm gmsis}))||$
  - Global search (lat,lon,month) through modified MSIS profiles ($a\alpha^b_{\rm gmsis}$)
  - a and b determined as pair with minimum L2-norm: $|| \ln(a), (b-1)||$
- ROPPx (under development within the ROM SAF): Somewhat similar to aproach by Gobiet and Kirchengast (2004)
  - MSIS climatology
  - Best fit global search (lat,lon,month) through MSIS profiles at high altitudes
  - Chosen profile modified by two-parameter (a and b) least squares fit at high altitudes (currently 40 to 60 km)
  - a and b determined by least squares fit: minimizing $||\alpha_{\rm obs} - a\alpha^b_{\rm gmsis}||$

Global statistics – zero-differencing (ZD)

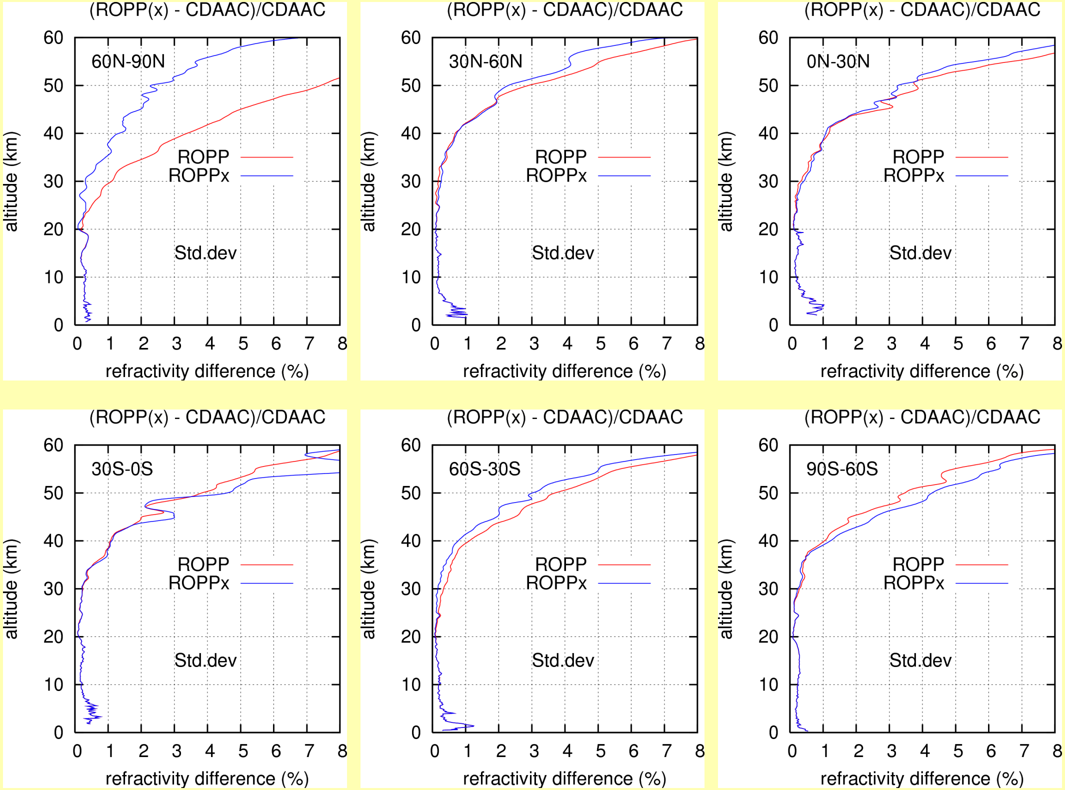


ROPP versus ROPPx - globally



- ROPPx: Smaller difference to CDAAC at high altitudes
- ROPPx allow better fit between 40 and 60 km (but does not go well with the current background error estimation in ROPP which is based on the range between 12 and 35 km – needs to be addressed; problem not shown here)
- Current ROPP approach seems to find poorer background fits at Northern high latitudes:

ROPP versus ROPPx - by latitude band



- ROPPx 'improvement' mostly at Northern high latitudes

Summary and last words

- Compared ROPP processing with CDAAC processing for assessment of structural uncertainty in MetOp/GRAS data
- Starting from common excess phase and amplitude processed at CDAAC
- Structural uncertainty in bending angle, refractivity, and dry temperature is smaller for ZD than for SD
- Coarser resolution in ROPP (in current setup) than in CDAAC profiles
- More noise/wiggles in ROPP at higher altitude; does not handle Sporadic-E well
- Preliminary statistical comparisons show differences in-line with previous studies
- Work in progress within the ROM SAF to modify the statistical optimization approach in ROPP

I'd say: use of a particular climatology (MSIS, NCAR or whatever) is probably much less important than what you do with it (global search; fitting and/or scaling; strategy for chosing the 'best fit'; background error estimation, etc. . .)