SIMPLIFIED GENERATION OF REFRACTIVITY CLIMATOLOGIES

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Background & objectives

- Processing to refractivity is done using an *optimized* bending angle profile. This is to suppress upper-level BA noise that may impact the retrieved refractivity lower down.

- *Statistical optimization* can be a complex process involving smoothing and merging with a background.

- The *ROtrends project* showed that it may be a source of structural uncertainty [Steiner et al., 2012].

- **Objective**: retrieve monthly refractivity climatologies directly from monthly bending angle climatologies. Use observed data as high up as possible, and then use a simple *a priori* from an altitude where it does not impact below 40 km. Evaluate the differences between this new method and the standard method.

- Recent studies [Ao et al., 2012, Gleisner and Healy, 2012] demonstrate the feasibility of this approach.
Single-profile processing

1) Raw LC BA profiles => $\alpha_{LC}(a)$
2) Statistical optimization => $\alpha_{SO}(a)$
3) Inverse Abel transform => $N(a)$
4) Change of height scale => $N(H)$
5) Interpolation to common grid => $N(H)$
6) Averaging in grid boxes => $\langle N(H) \rangle$
Average-profile processing

1) Zonal monthly average grid => $\langle \alpha_{LC} (H_a) \rangle$
2) Upper level handling => $\langle \alpha_{LC} (H_a) \rangle$
3) Change of height scale => $\langle \alpha_{LC} (a) \rangle$
4) Inverse Abel transform => $\langle N(a) \rangle$
5) Change of height scale => $\langle N(H) \rangle$
6) Interpolation to common grid => $\langle N(H) \rangle$
Monthly average bending angles
– means, COSMIC, Jan 2011 –
Monthly average bending angles
– medians, COSMIC, Jan 2011 –

Monthly median BAs in southern latitude bands

Monthly median BAs in northern latitude bands

Impact altitude [km]

20 µrad
Monthly average bending angles
– reldiff mean-median, COSMIC, Jan 2011 –
Monthly average bending angles
– reldiff mean-median, COSMIC, Jan 2011 –
Average-profile processing

Upper-level handling of average bending angles
The zonal mean bending angles become increasingly noisy with altitude. Above 60 kilometers the median, rather than the mean, may provide a better description of the neutral-atmosphere bending angle.

We use:
• means up to 50 kilometers
• merge means and medians between 50 and 60 kilometers
• medians between 60 and 80 kilometers
• exponential fall-off above 80 kilometers
Average-profile processing

Change of height scale

The mean field $\langle \alpha(H_a) \rangle$ should be converted to $\langle \alpha(a) \rangle$ before Abel. We must assign a single radius of curvature, $R$, to each grid box, even though each profile within a grid box has its own radius of curvature $R + \Delta_i$.
Average-profile processing

We use the mean radius of curvature, $R = \bar{R} = \langle R_{c,i} + u_i \rangle$, for each latitude band, such that conversion from *impact altitude* to *impact parameter* become:

$$\langle \alpha(H_a) \rangle \propto \langle \alpha(a) \rangle = \langle \alpha(H_a + R) \rangle$$

**Inverse Abel transform**

$$\langle N(x) \rangle \approx 10^6 \left( \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{\langle \alpha(a) \rangle}{(a^2 - x^2)^{1/2}} \, da \right)$$

**Change of height scale**

$$\langle N(a) \rangle \propto \langle N(H) \rangle = \left\langle N(a/(1+10^{-6} N(a)) - R) \right\rangle$$
Differences from single-profile processed data
– Jan 2011 –
Differences from ECMWF
– Jan 2011 –

Average-profile processed

COSMIC Refractivity diff. Jan 2011

Single-profile processed

COSMIC Refractivity diff. Jan 2011

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Average-profile processing and small data numbers

During the COSMIC time period there are around 1000-2500 occultations per day. Does average-profile processing work during time periods with significantly smaller data numbers?

We randomly removed 85% of the data and repeated the study, to simulate data sparse periods.
Differences from single-profile processed data

– Jan 2011 –

Full data set

85% reduced data set
Differences from ECMWF
– Jan 2011 –

Average-profile processed, full data set

Average-profile processed, reduced data set
Preliminary conclusions

- average-field processing appears to be a useful method to produce monthly climatologies – perhaps no need for statistical optimization in this case,
- average-field processing appears to be useful also during time periods with small data numbers, such as the pre-COSMIC period,
- above 55-60 km the means become biased – in the 60-80 km height range we need to reduce the impact of outliers, e.g., through the use of median or robust mean,
- above 80 km exponential extrapolation is sufficient – no significant impact below 40 km,
- less than 0.1% difference from single-profile processing above lower troposphere and below 35-40 km,
STOP
Differences from single-profile processed data
– Jan 2011 –
Differences from single-profile processed data
– Feb 2011 –
Differences from single-profile processed data
– Mar 2011 –
Differences from ECMWF
– Jan 2011 –

Average-profile processed

Single-profile processed

COSMIC Workshop 31 Oct 2012
Differences from ECMWF

– Feb 2011 –

Average-profile processed

Single-profile processed
Differences from ECMWF
– Mar 2011 –

Average-profile processed

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**Full data set**

**85% reduced data set**

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**COSMIC**

Ref refractivity diff. Jan 2011

- COSMIC
- Ref refractivity diff.
- Jan 2011

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**COSMIC**

Ref refractivity diff. Jan 2011

- COSMIC
- Ref refractivity diff.
- Jan 2011

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COSMIC Workshop 31 Oct 2012
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Average-profile processed, reduced data set
Differences from ECMWF
– Feb 2011 –

Average-profile processed, full data set

Average-profile processed, reduced data set
Differences from ECMWF
– Mar 2011 –

Average-profile processed, full data set

Average-profile processed, reduced data set