GENERATION OF REFRACTIVITY CLIMATOLOGIES WITHOUT STATISTICAL OPTIMIZATION

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Outline

- *Bending angle* to *refractivity* processing
- Monthly mean bending angles in latitude bands
- Upper-level handling of the mean bending angles
- Non-linearities in the *BA* to *REF* processing
- Conclusions

BA to *REF* processing

– single profiles –

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 => $\langle N(H) \rangle$

Statistical optimization is foremost required for single-profile processing.

In the *ROtrends* study, statistical optimization was identified as a source of structural uncertainty [Steiner et al., 2012].

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BA to *REF* processing

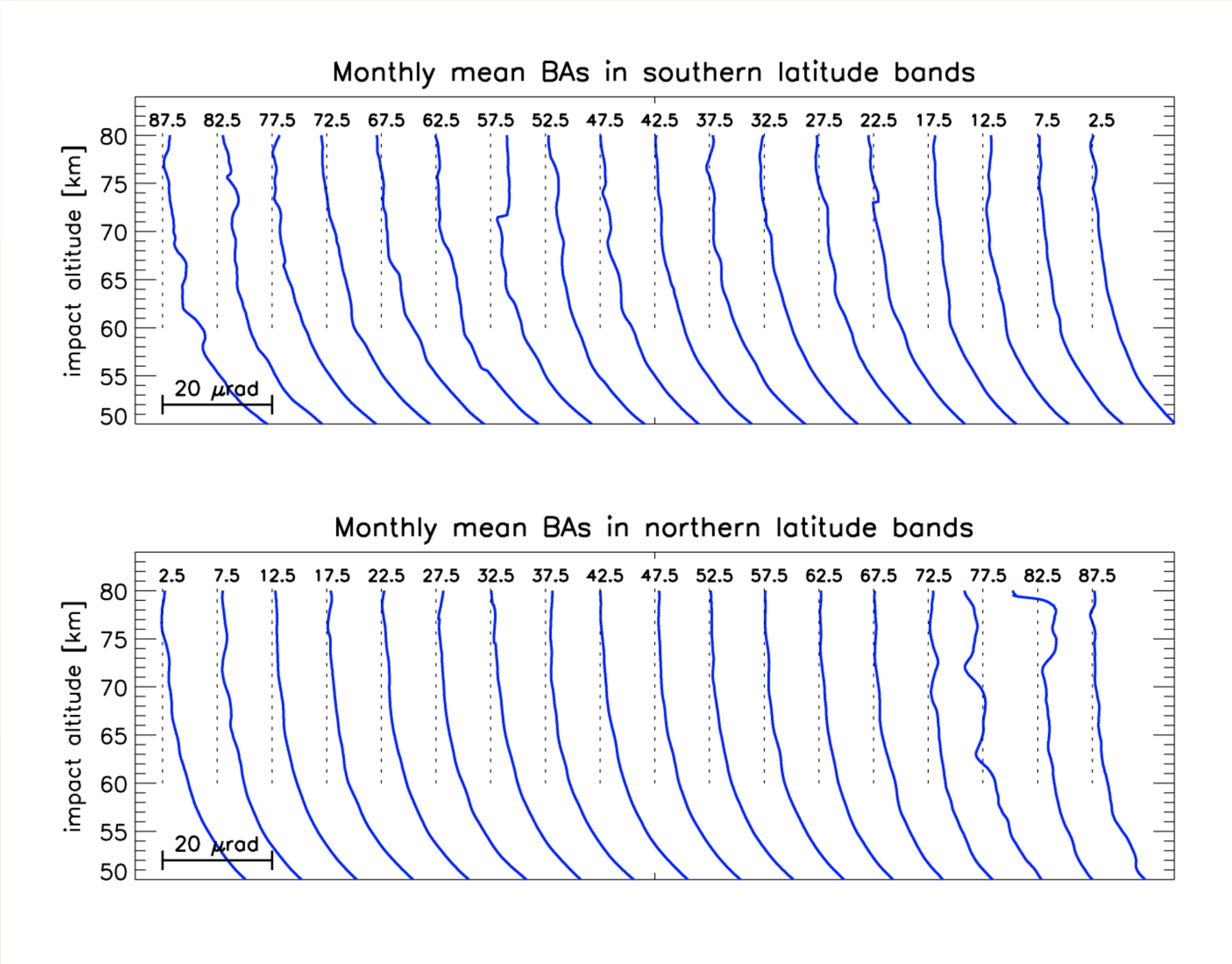
– zonal monthly means –

1) Zonal monthly mean 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 => $\langle N(H) \rangle$

By processing a mean field instead of single profiles, we can use *observed* data up to higher altitudes, and thus reduce biases due to upper-level handling of the bending angles.

Monthly mean bending angles

– means, COSMIC, Jan 2011 –



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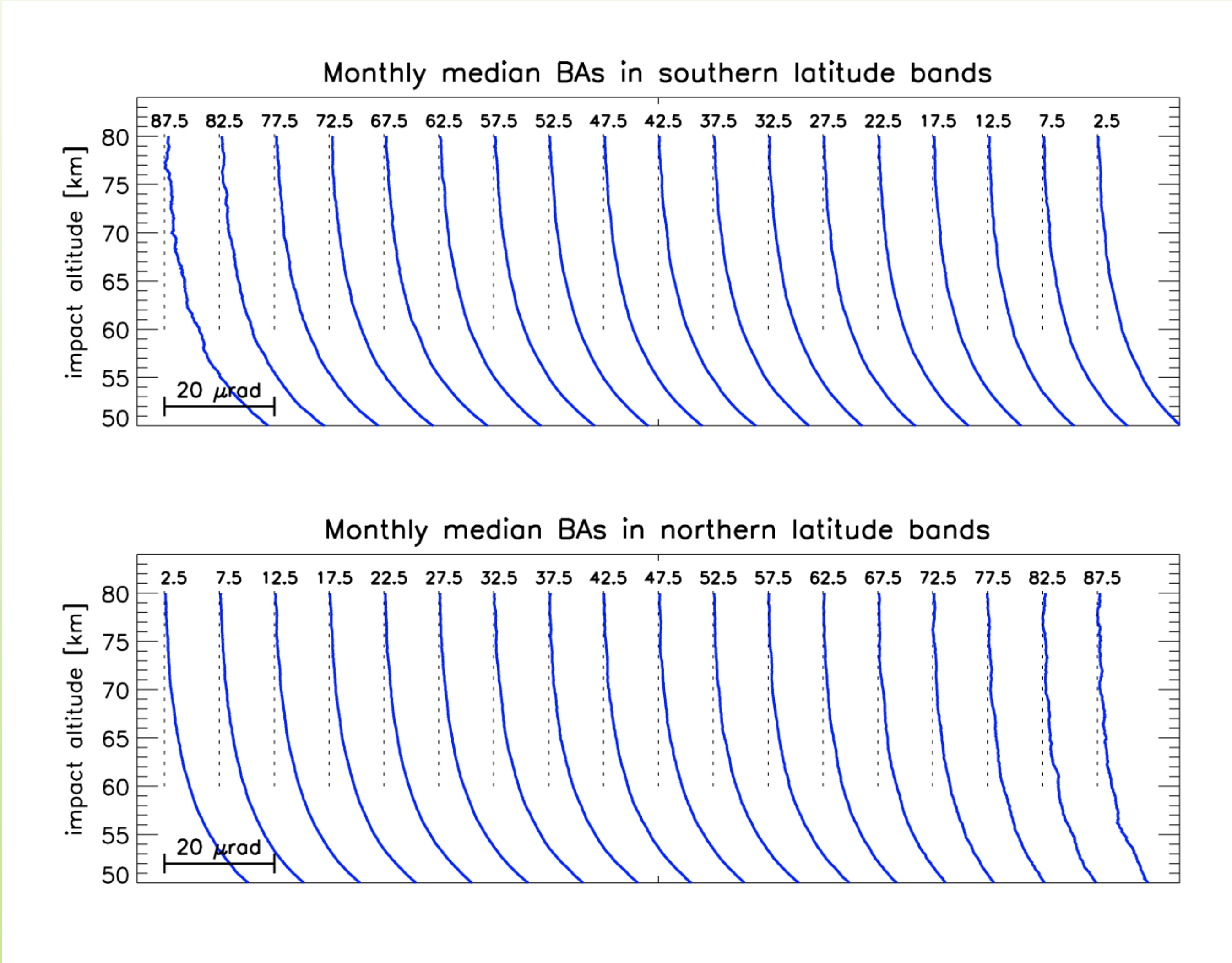
Monthly mean bending angles
– medians, COSMIC, Jan 2011 –



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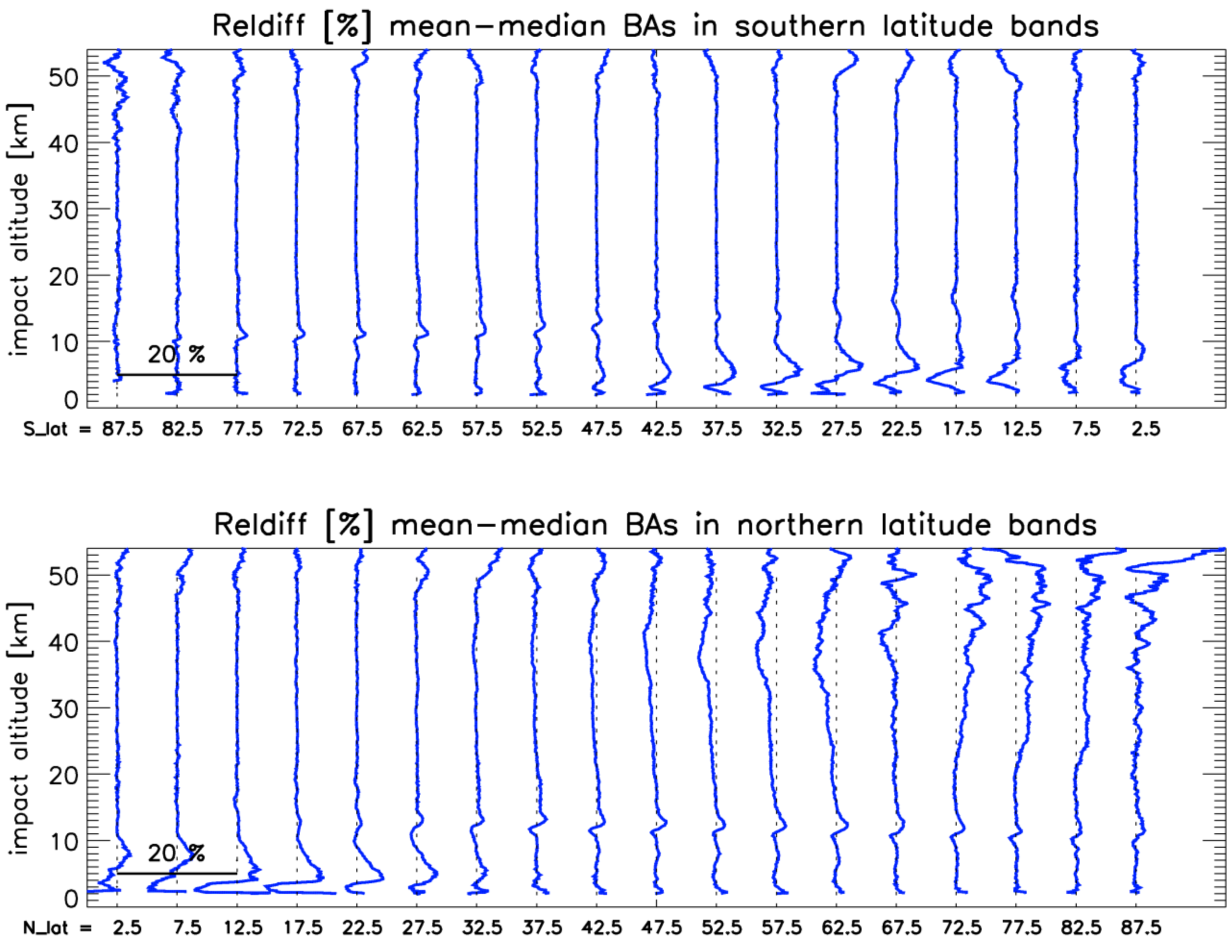
Monthly mean bending angles

– reldiff mean-median, COSMIC, Jan 2011 –



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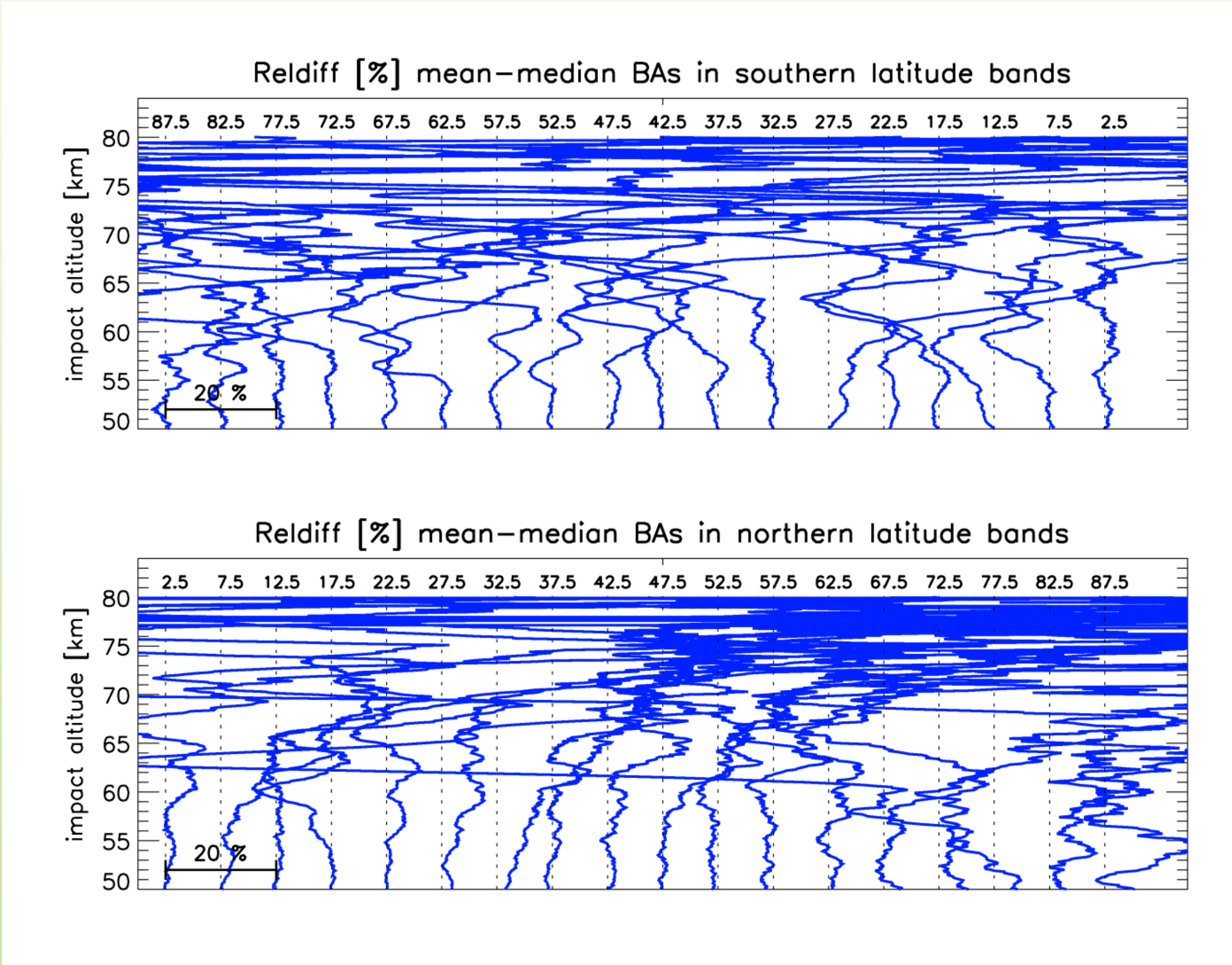

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BA to *REF* processing
– zonal monthly means –

<u>Steps 1 & 2: upper-level handling of mean bending angles</u>

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 60 kilometers
- medians between 60 and 80 kilometers
- exponential fall-off above 80 kilometers

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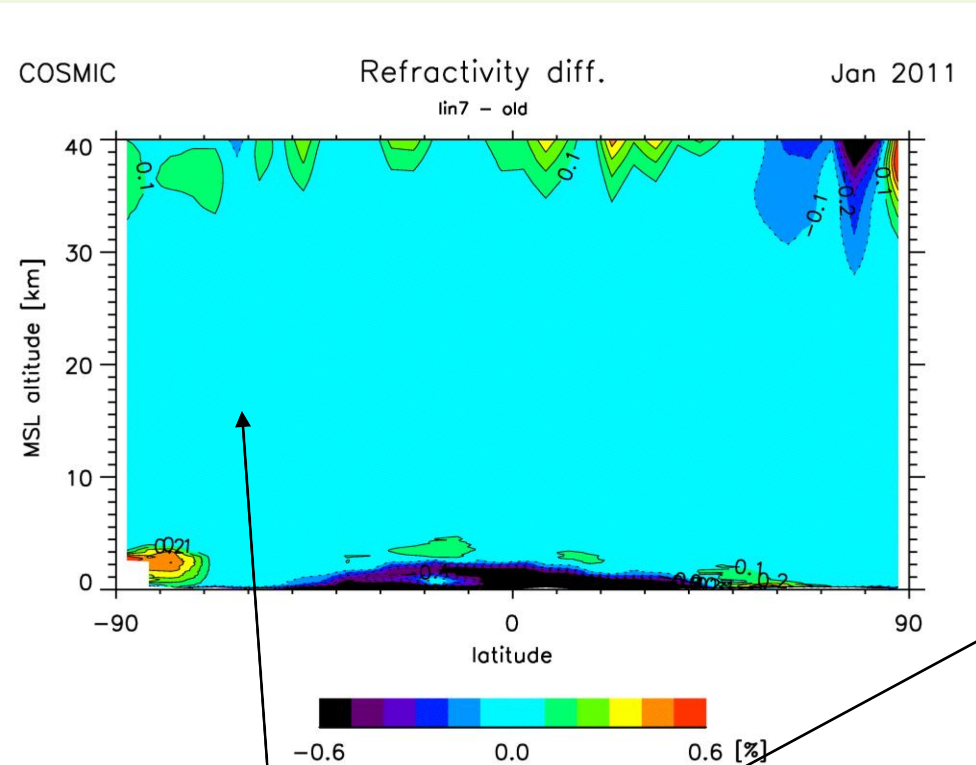
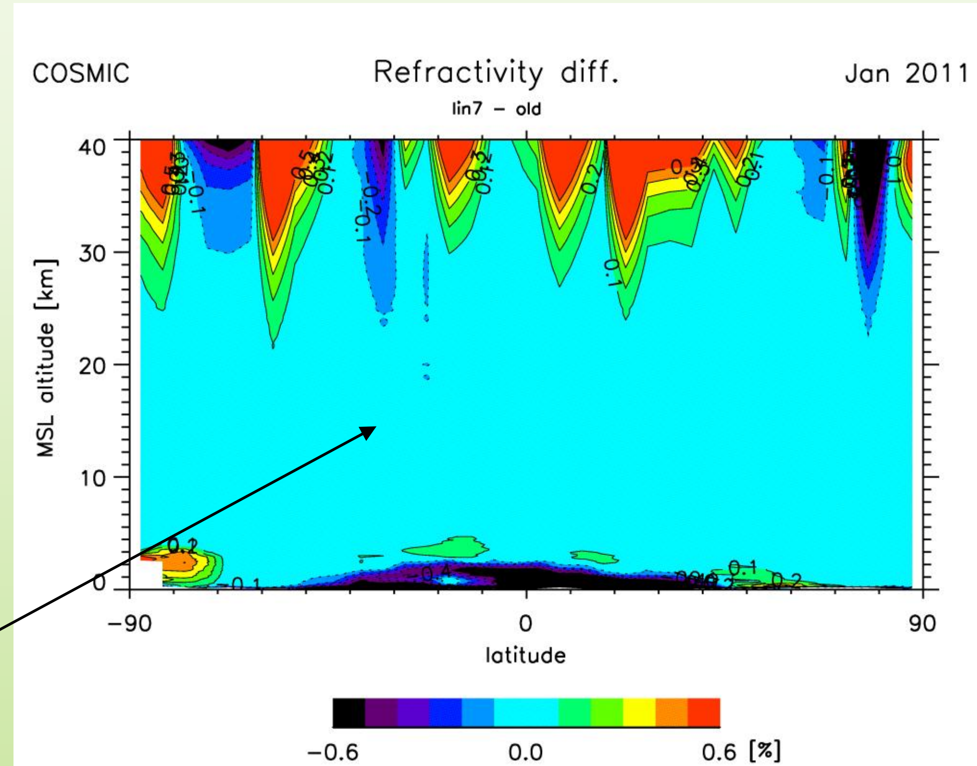
Impact of median vs. mean

– agreement with single-profile processing –

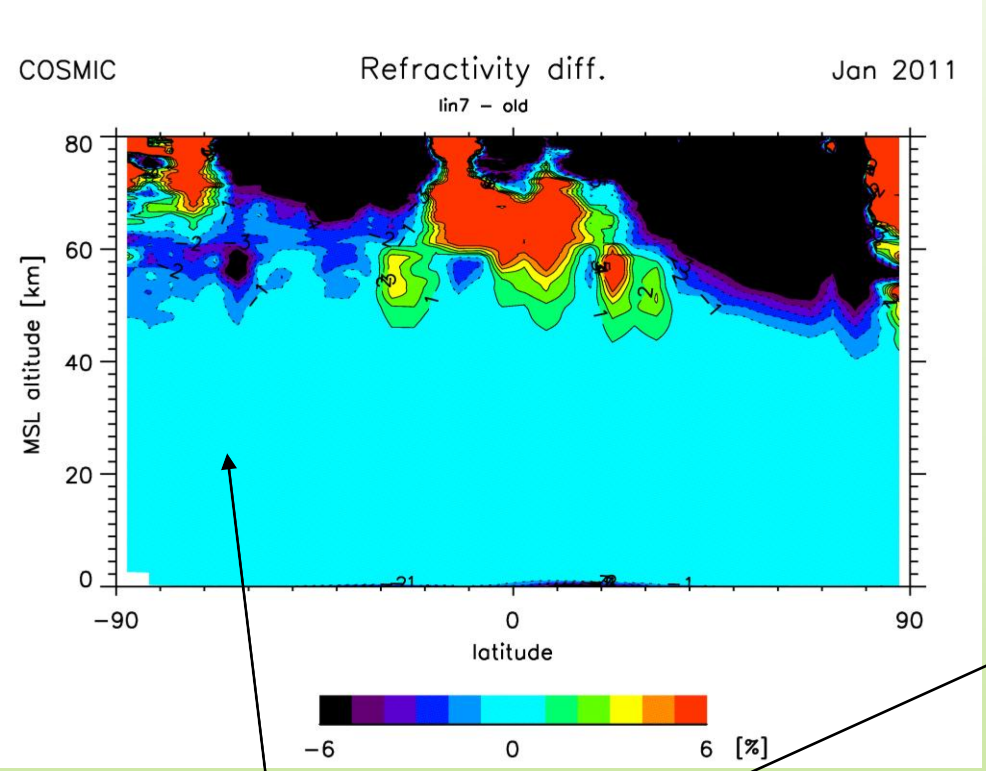


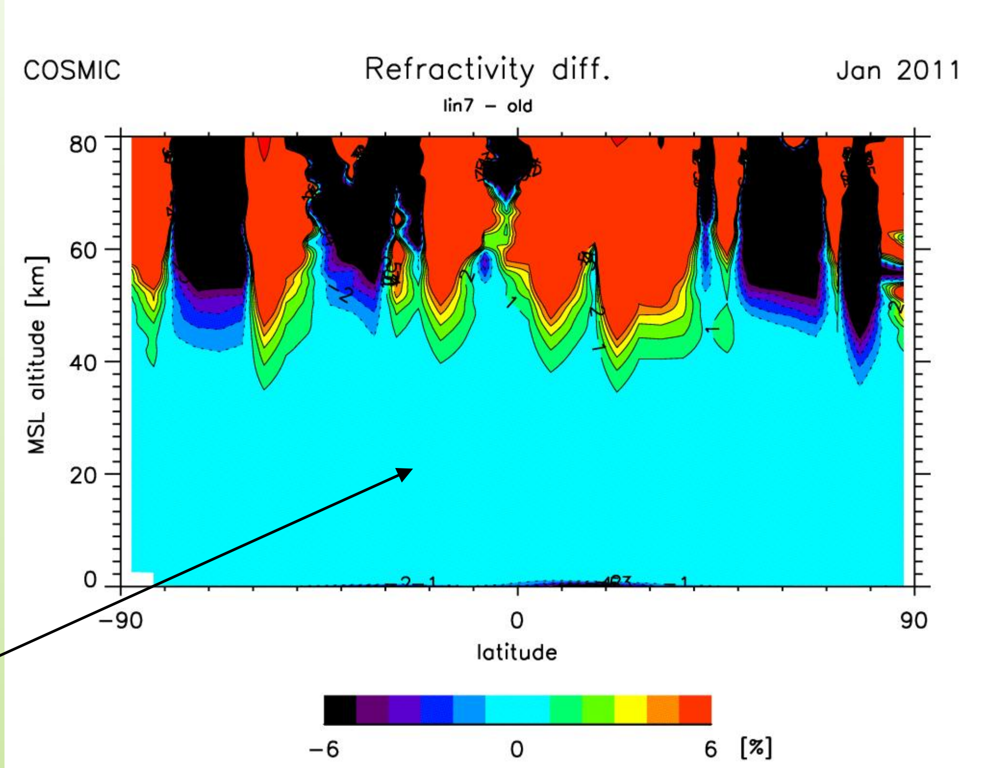


The use of *median* instead of *mean* in the 60-80 km height range gives better agreement with climatologies from single-profile processing.

Impact of median vs. mean

– agreement with single-profile processing –





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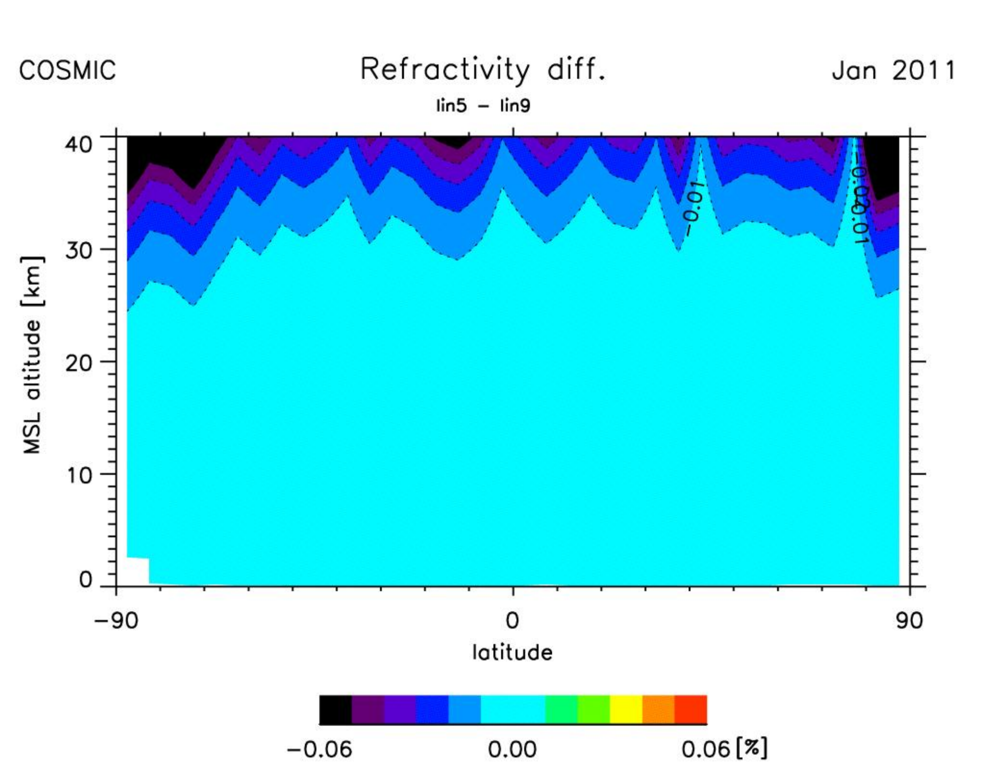
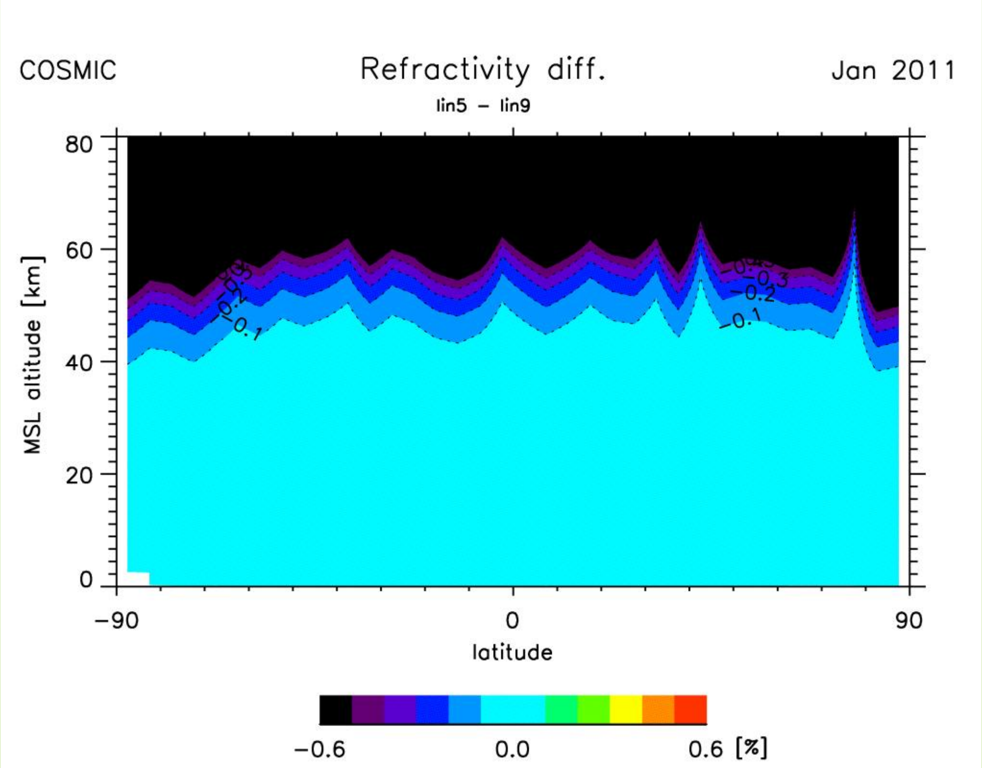
Impact of exponential extrapolation
– differences between 5 and 9 km scale height –





The impact of the extrapolation above 80 km is less than 0.01% at 25 km, and less than 0.1% at 40 km.

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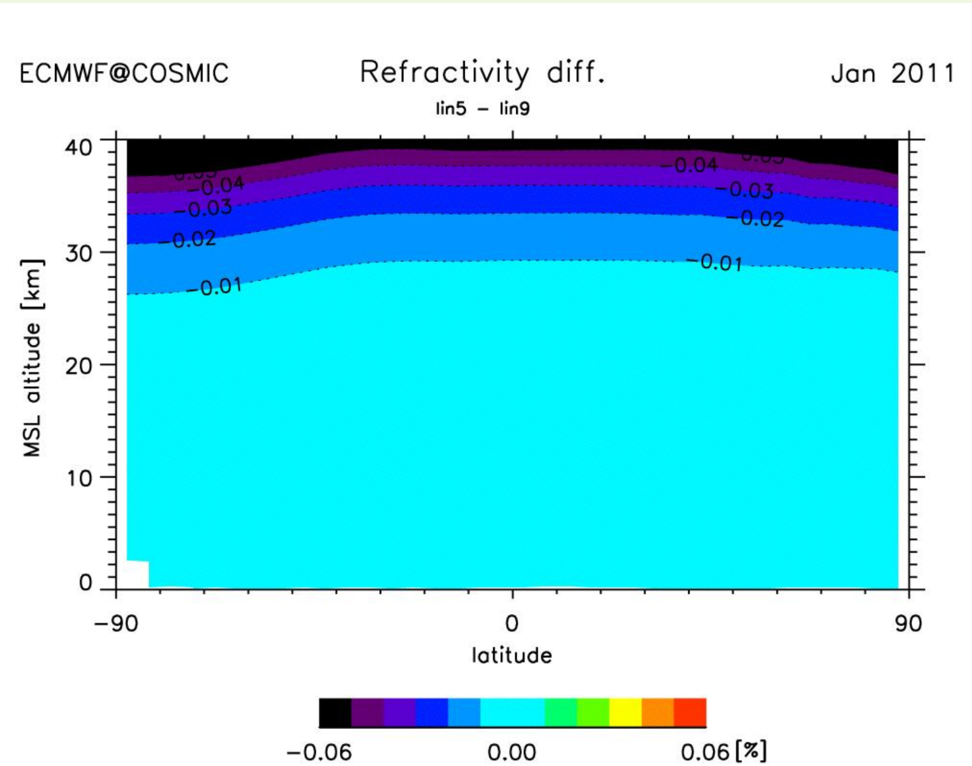

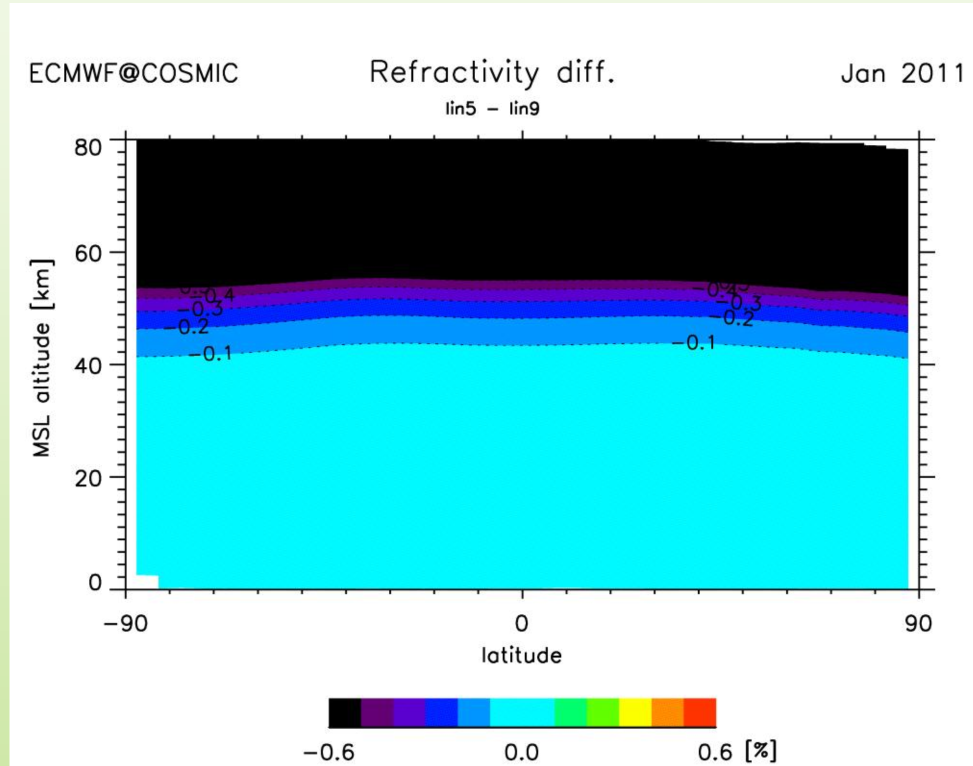

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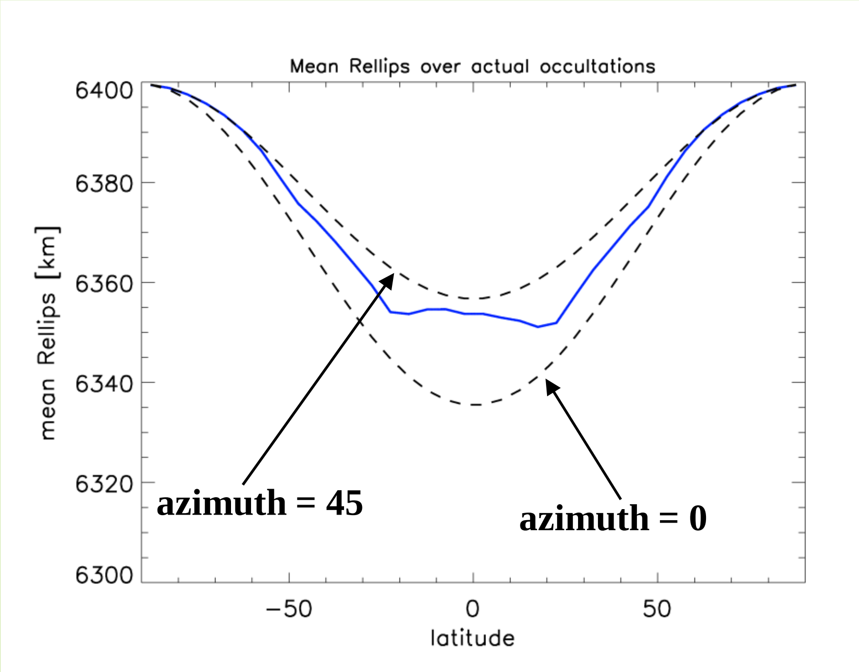
BA to *REF* processing
– zonal monthly means –

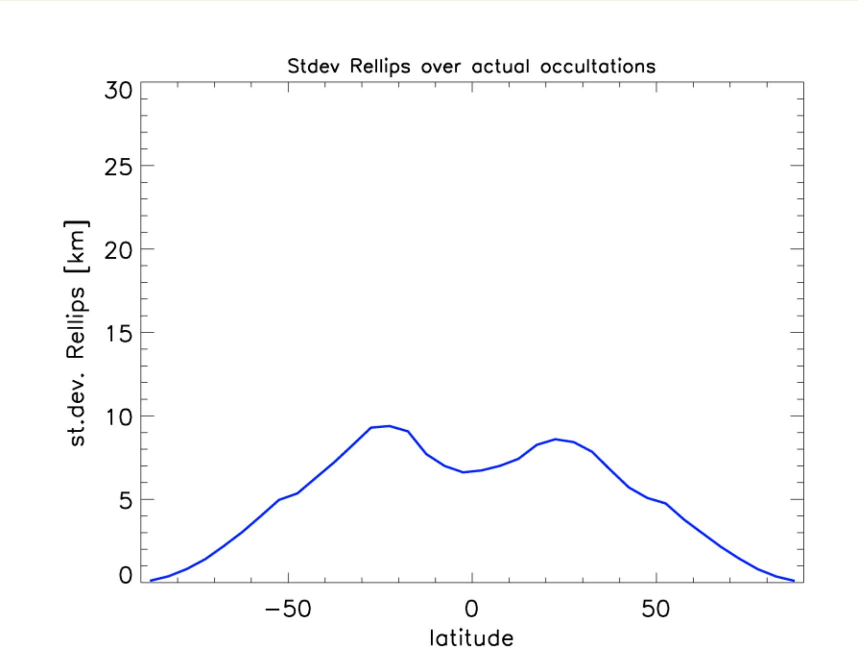
Step 3: change of height scale (radius of curvature for grid boxes)

The mean field $\langle \alpha(H_a) \rangle$ should be converted to $\langle \alpha(a) \rangle$ before Abel.

Assign a single radius of curvature, R, to each grid box.

Each profile within a grid box has its own radius of curvature $R + \Delta_i$.





BA to *REF* processing
– zonal monthly means –

Assume $R = \overline{R} = \langle R_{c,i} + u_i \rangle$

If all profiles in the grid box had the same radius of curvature, the BAs at *impact altitude* H_a would be identical to the BAs at *impact parameter* $a = H_a + R$.

But the spread in *impact parameters* $H_a + \overline{R} + \Delta_i$, in combination with a non-linear $\alpha(a)$ relation, leads to a bias in the mean BA at a fixed $H_a + R$.

$$\langle \alpha_i(H_a) \rangle \quad \not\Leftrightarrow \quad \langle \alpha_i(H_a + \overline{R}) \rangle$$

$$\langle \alpha_i(H_a) \rangle \quad \Leftrightarrow \quad \langle \alpha_i(H_a + \overline{R} + \Delta_i) \rangle = \langle \alpha_i(H_a + \overline{R}) \rangle + \delta$$

$$\delta \approx \frac{1}{2} \frac{d^2\alpha}{da^2} \langle \Delta_i^2 \rangle$$

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BA to *REF* processing
– zonal monthly means –

This bias can be partly offset by assuming that $R = \bar{R} + \Delta R$, where ΔR is chosen such that

$$\frac{d\alpha}{da}\Delta R + \delta = 0$$

Step 4: inverse Abel transform

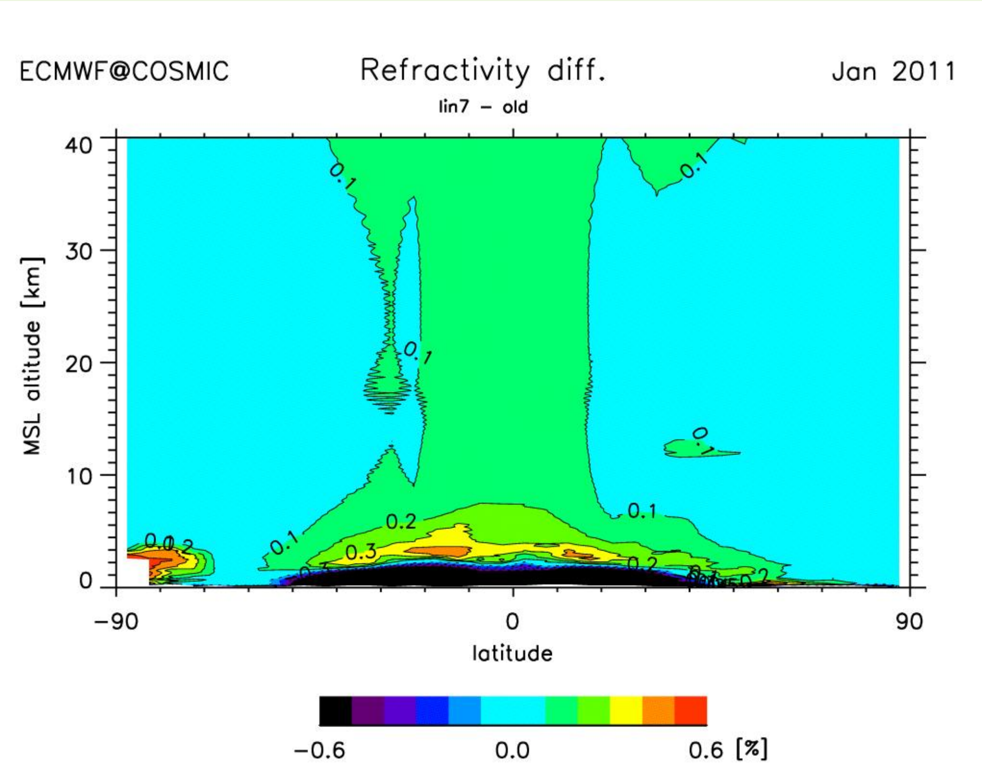
$$\langle N(x)\rangle = 10^6 \exp\left(\frac{1}{\pi}\int_x^\infty \frac{\langle \alpha(a)\rangle}{(a^2 - x^2)^{1/2}}\,da\right) - 10^6$$

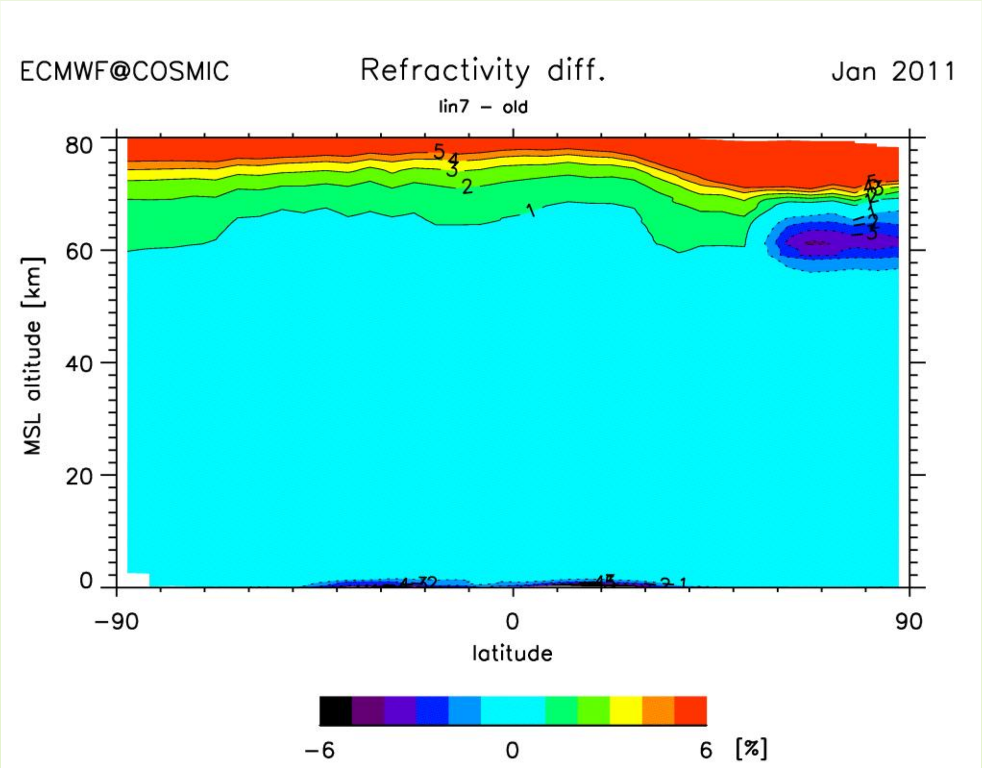
Step 5: change of height scale

$$\langle N(a)\rangle \;\mapsto\; \langle N(H)\rangle = \left\langle N\left(a \big/ (1 + 10^{-6} N(a)) - R\right)\right\rangle$$

Mean-field versus single-profile processing
– relative differences (collocated ECMWF) –

***H* < 60 km: mean; *H* = 60-80 km: median; *H* > 80 km: exponential with 7.5 km scale height**
R: radius of curvature for *az* = 0





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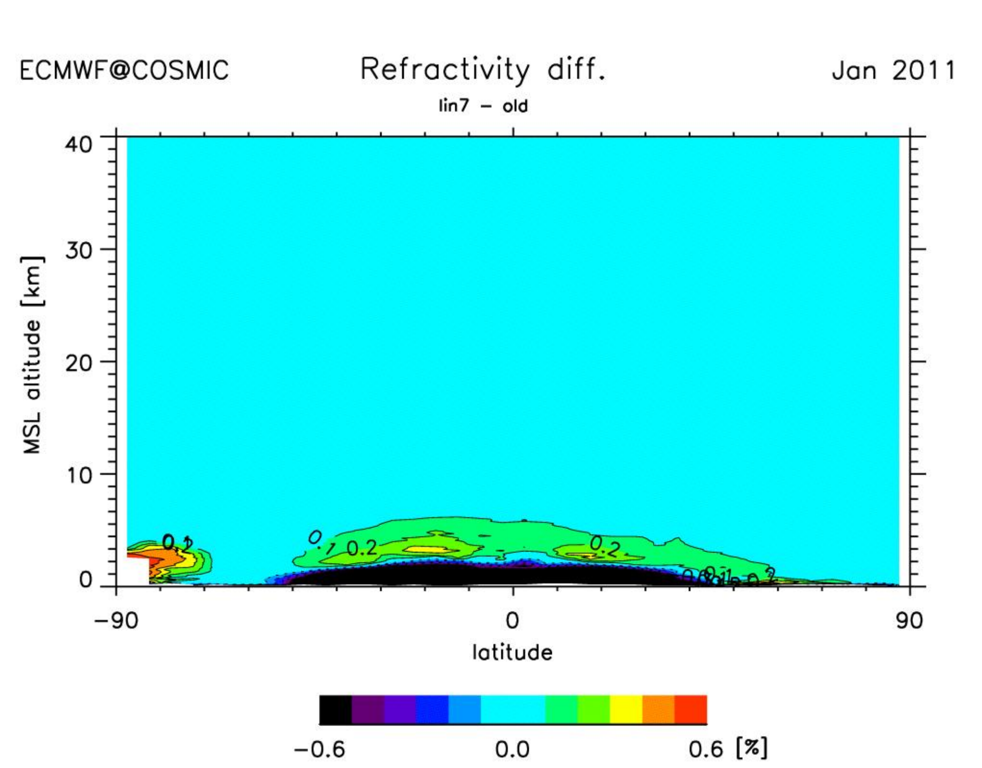

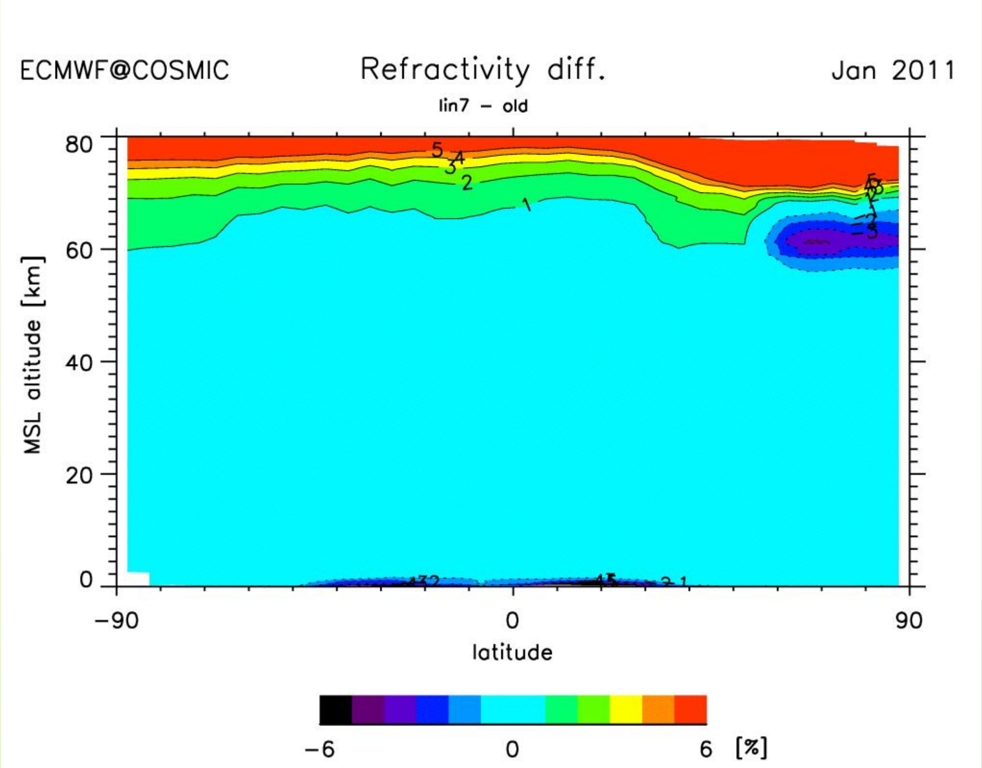

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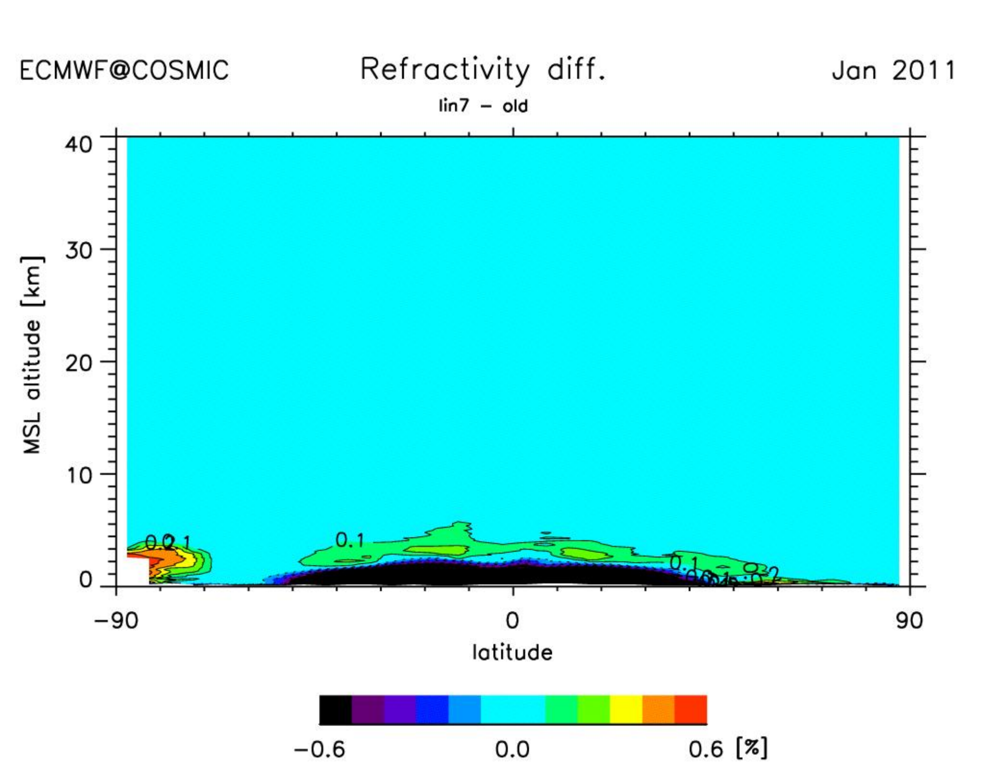

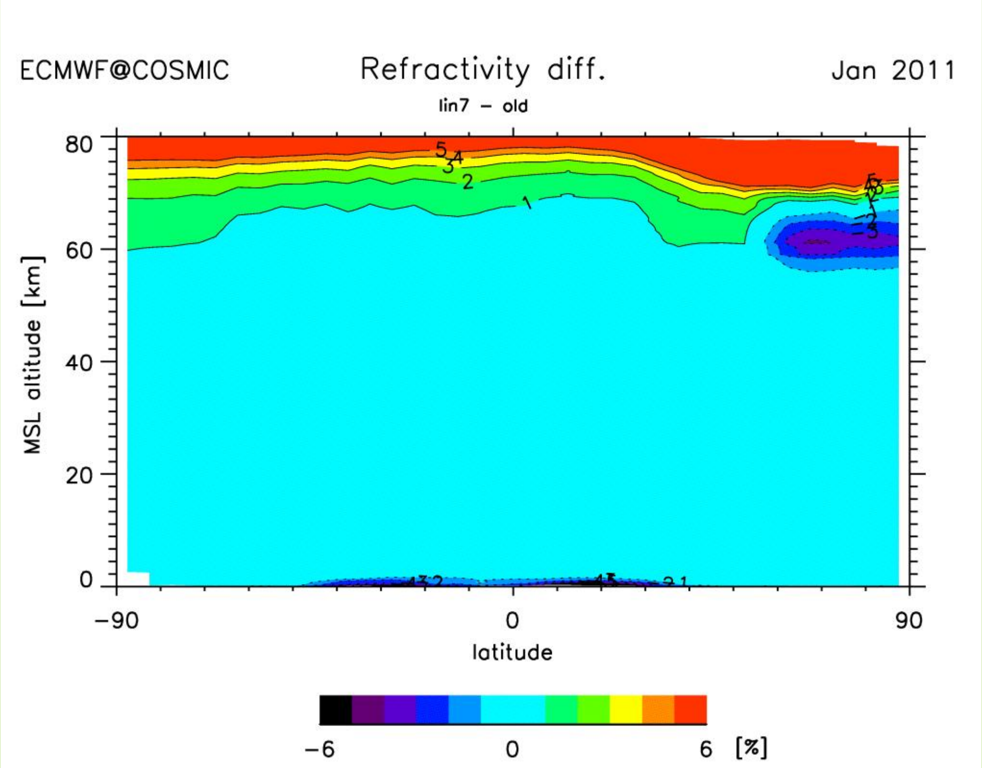

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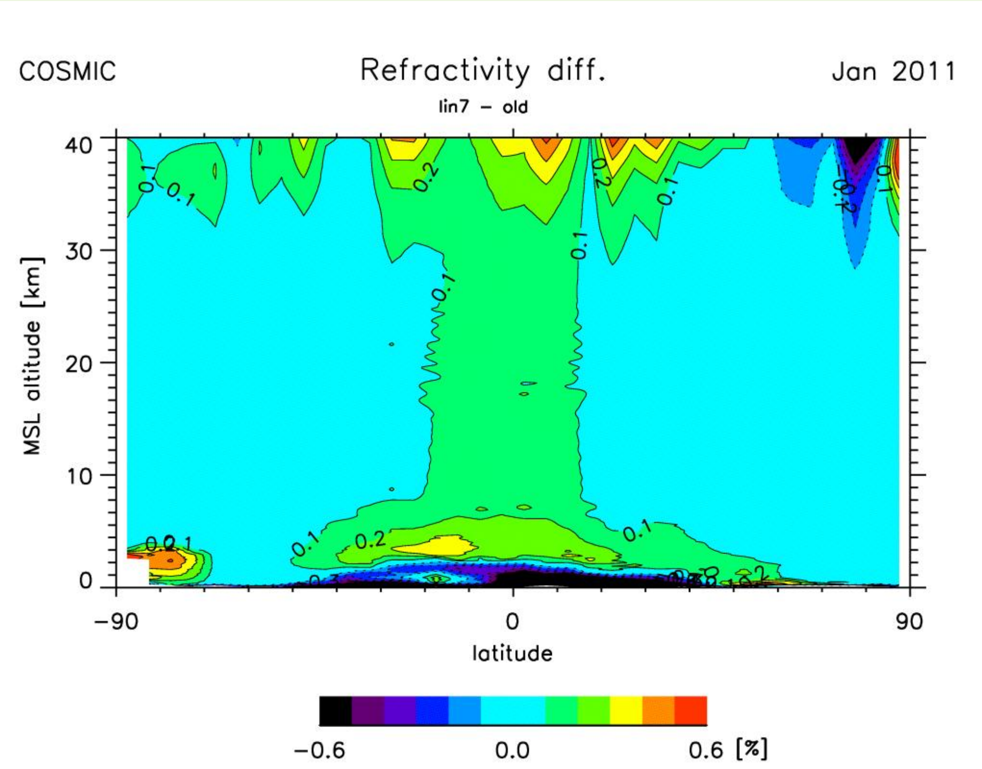

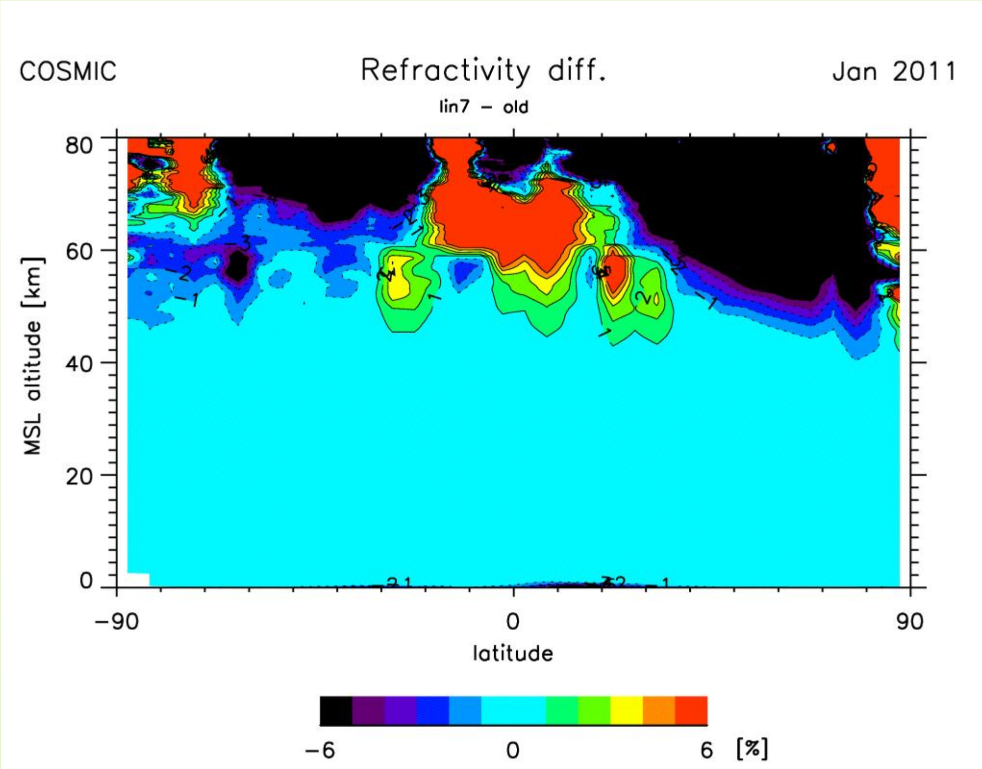

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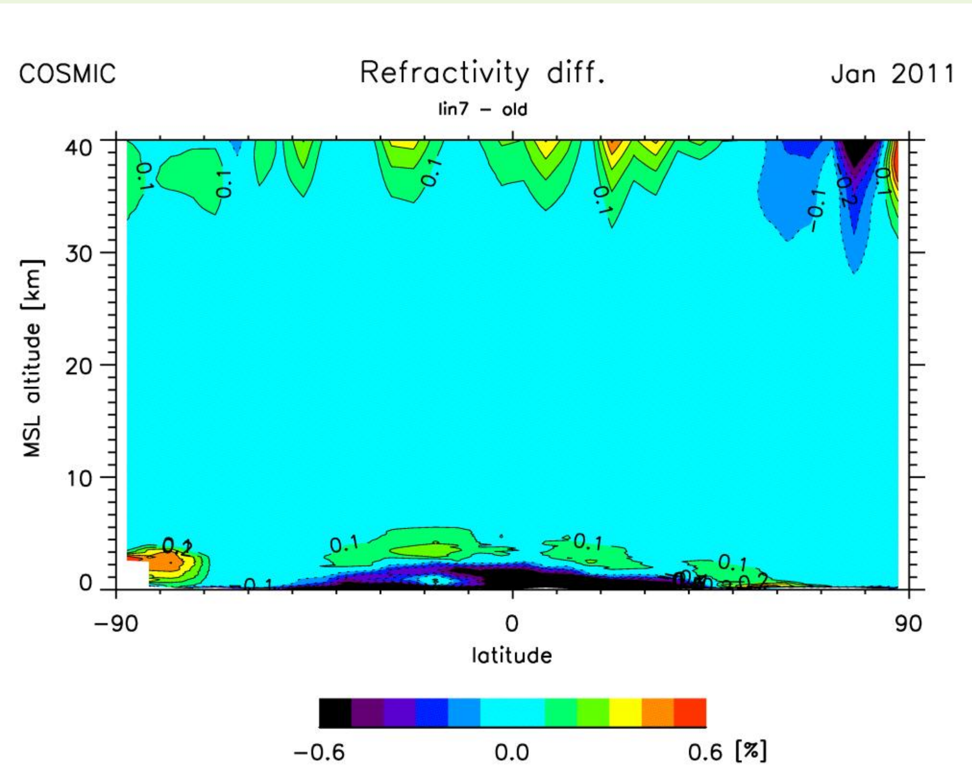

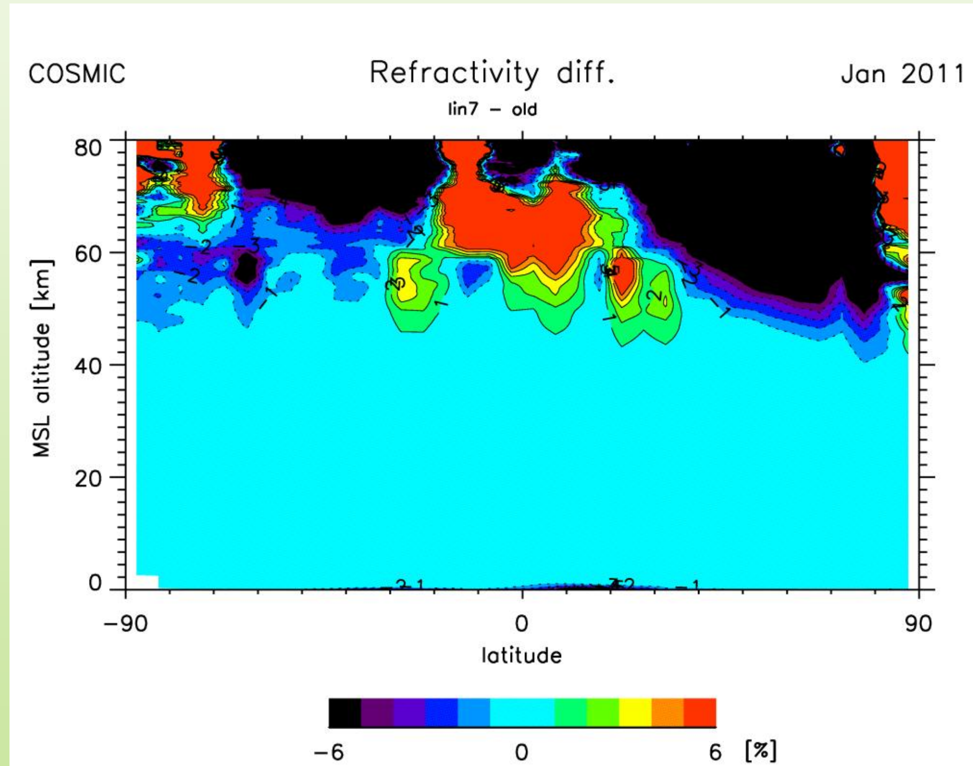

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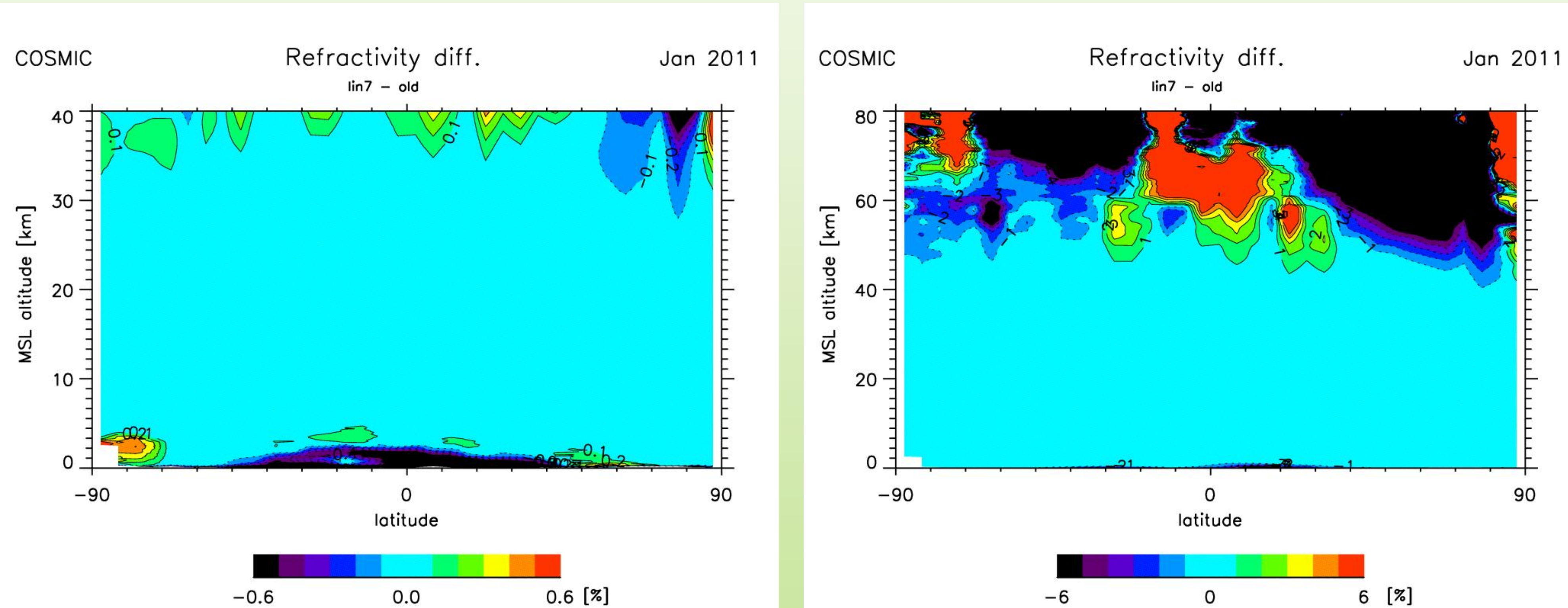

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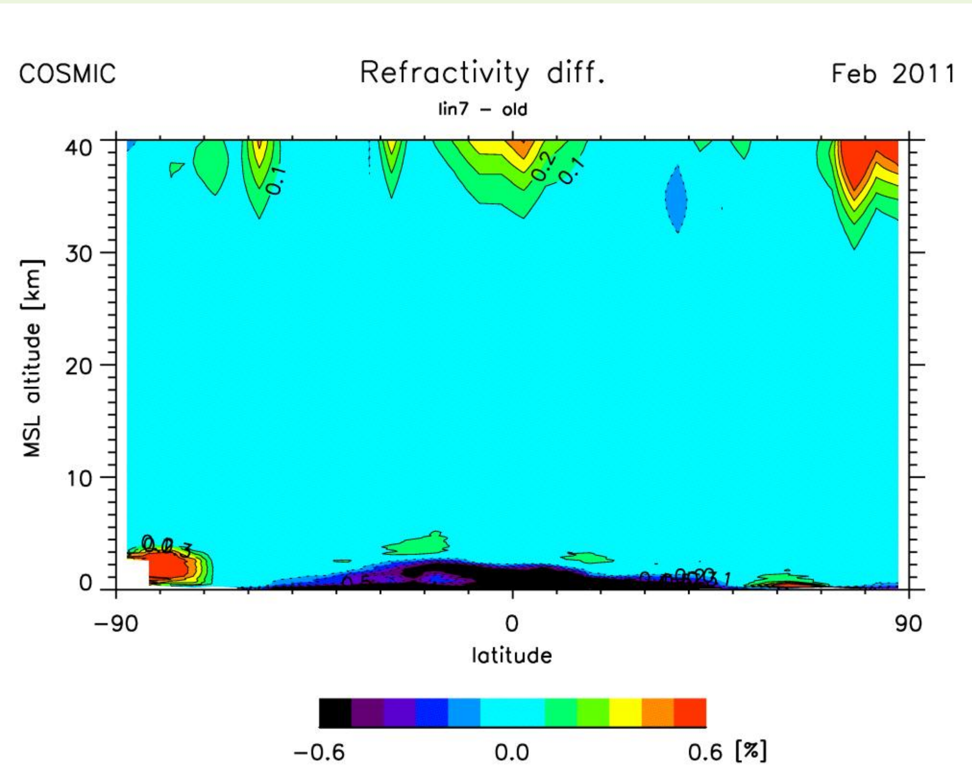

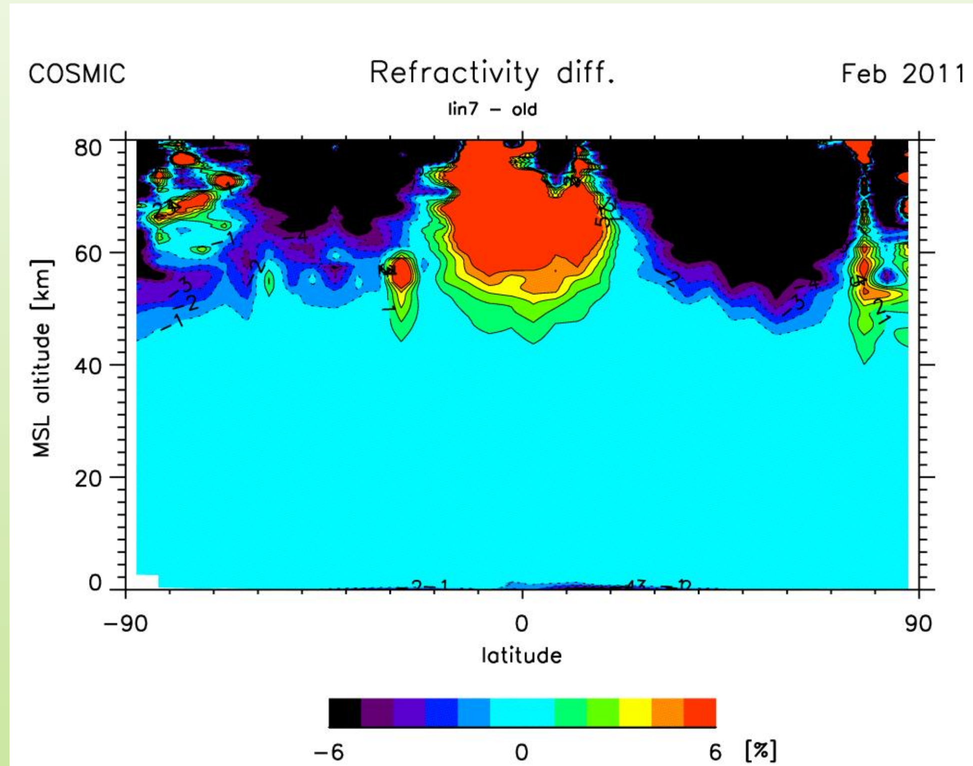

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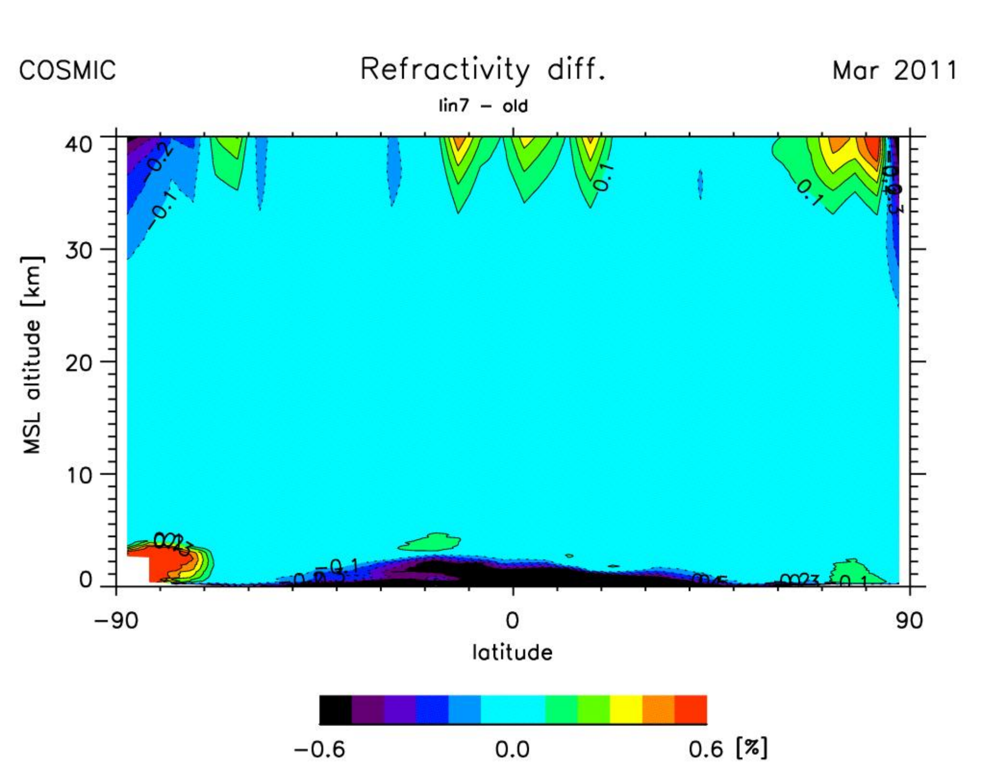

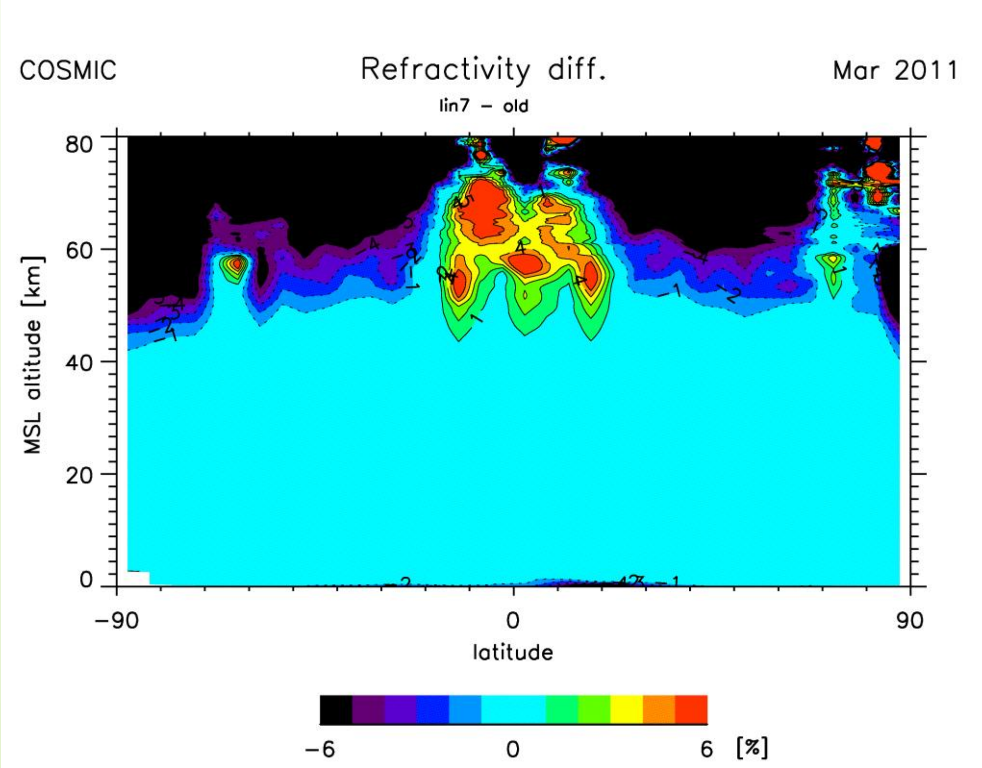

Conclusions

- mean-field processing is an option when there are many enough profiles in each grid box – we can do without stat. opt.
- above 60 km the means become noisy – medians can still be used
- above 80 km exponential extrapolation is sufficient
- less than 0.1% difference from single-profile processing above lower troposphere, up to 1.0% difference in the lowest few kilometers
- profile-to-profile variability in radius of curvature within grid boxes needs to be handled – corrections can be devised

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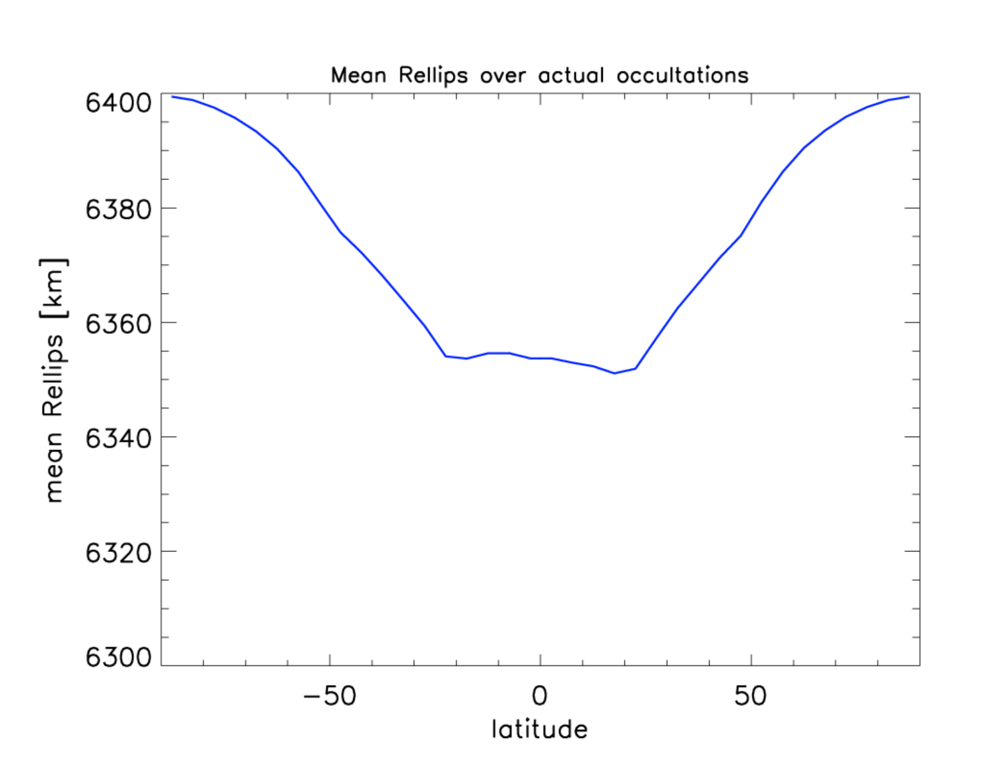
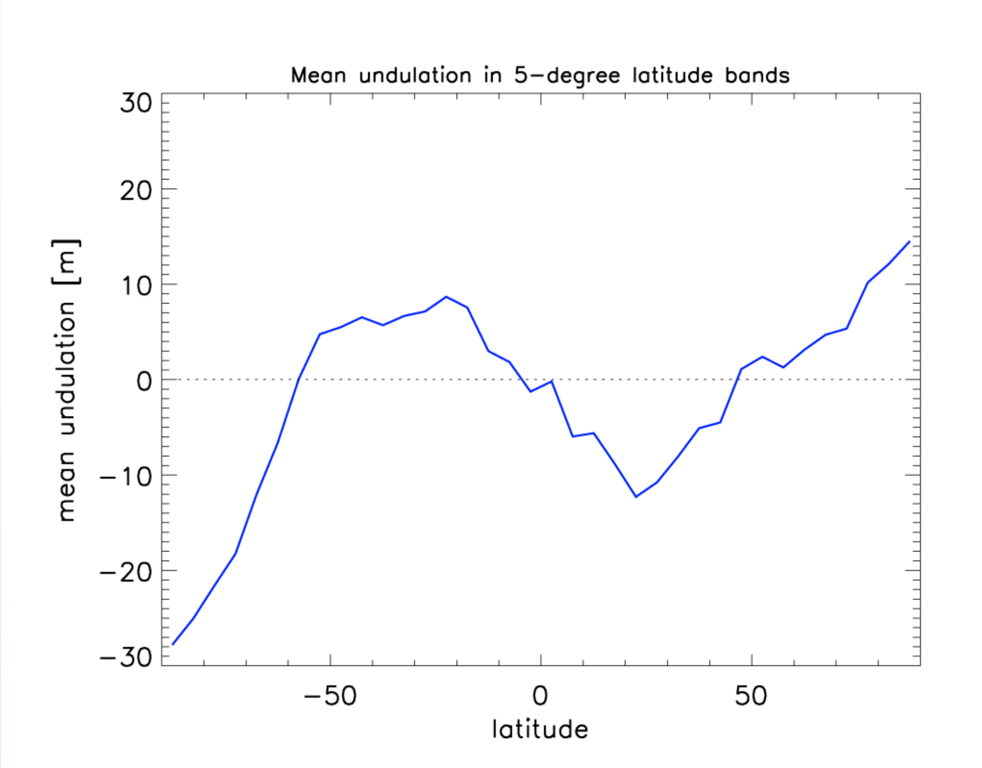
STOP

BA to *REF* processing
– radius of curvature variability –

Mean radius of curvature



Mean undulation



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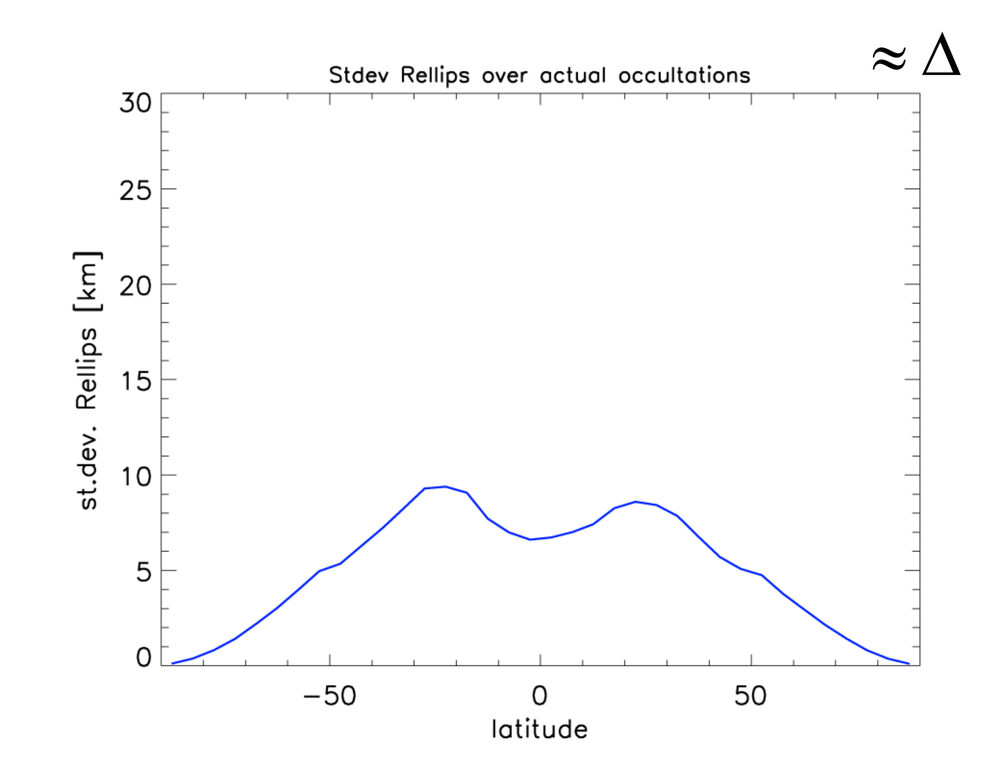
BA to *REF* processing

– radius of curvature variability –

St.dev radius of curvature



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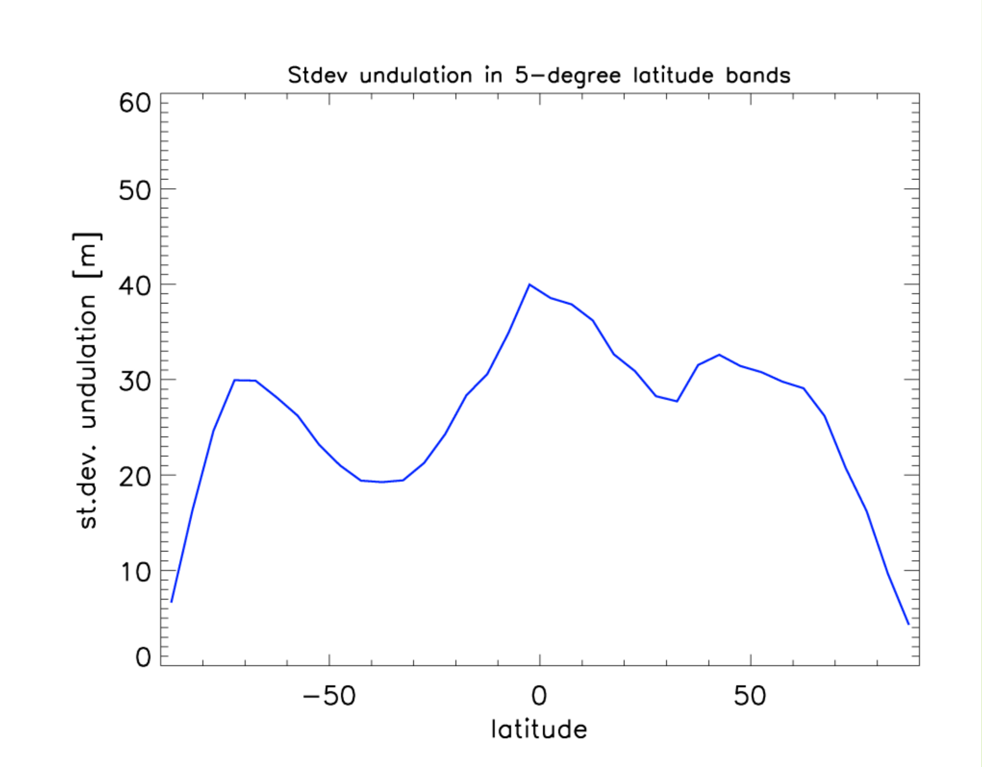
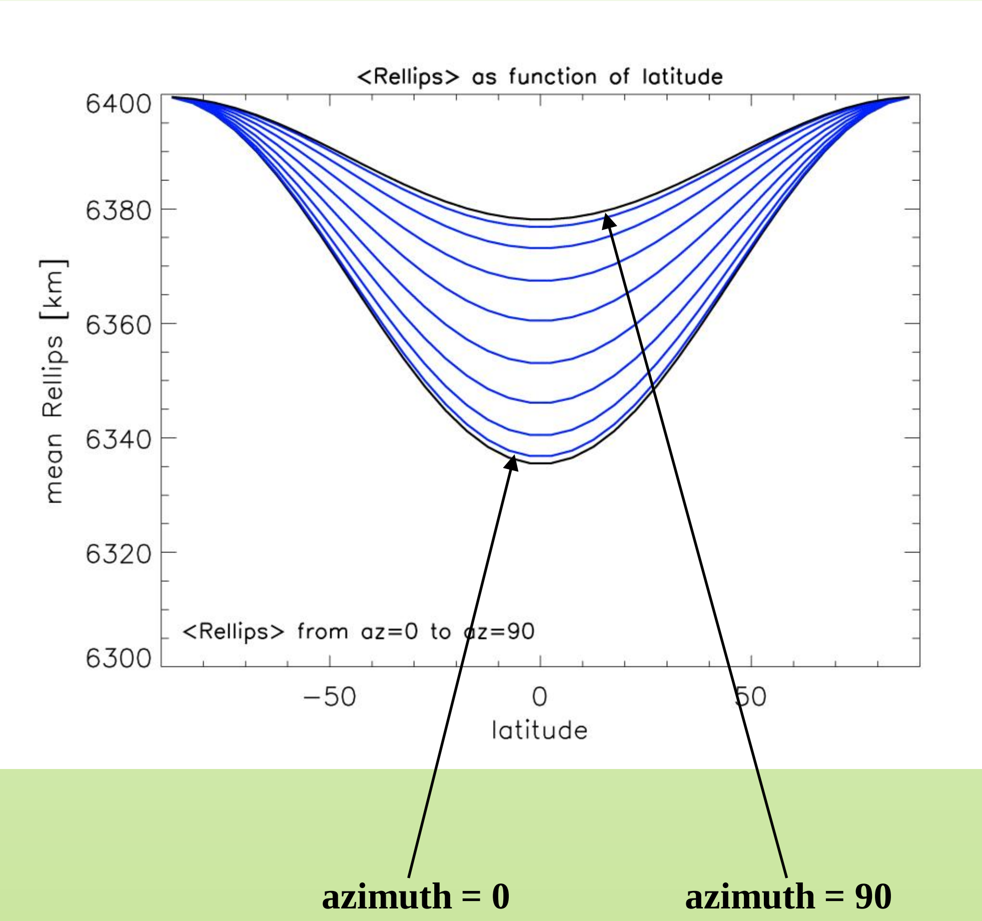
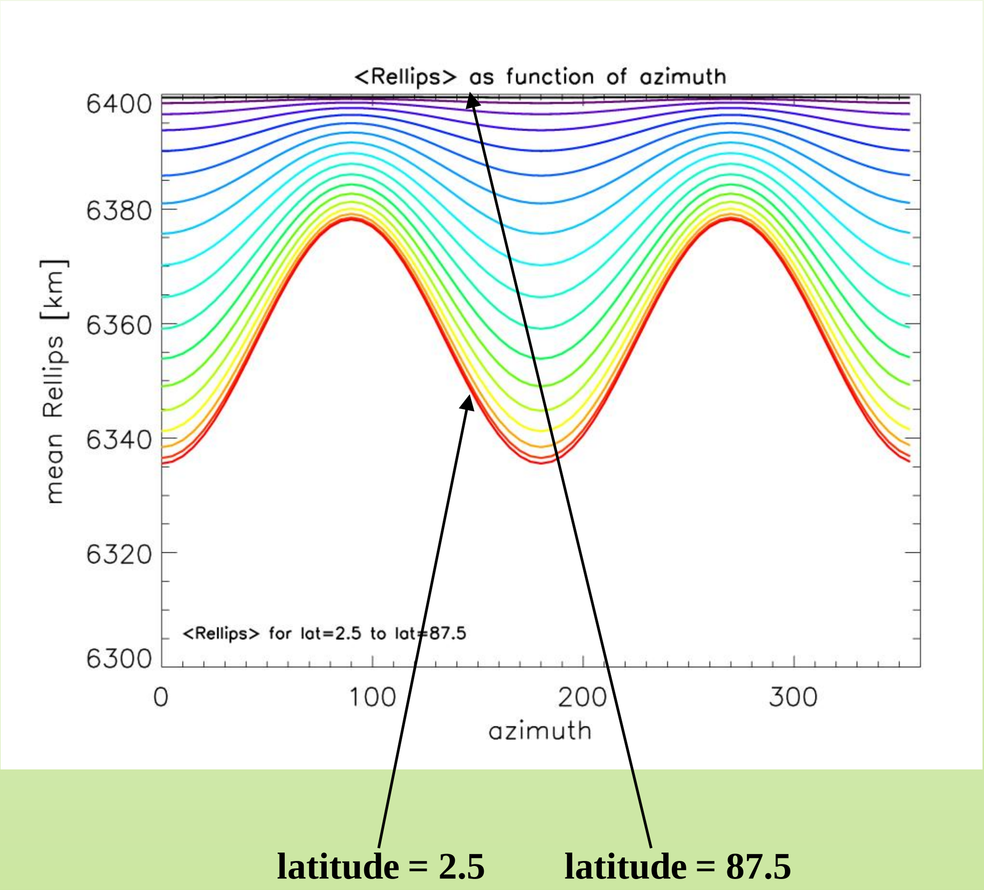


Ellipsoid radius of curvature
– longitudinal averages –





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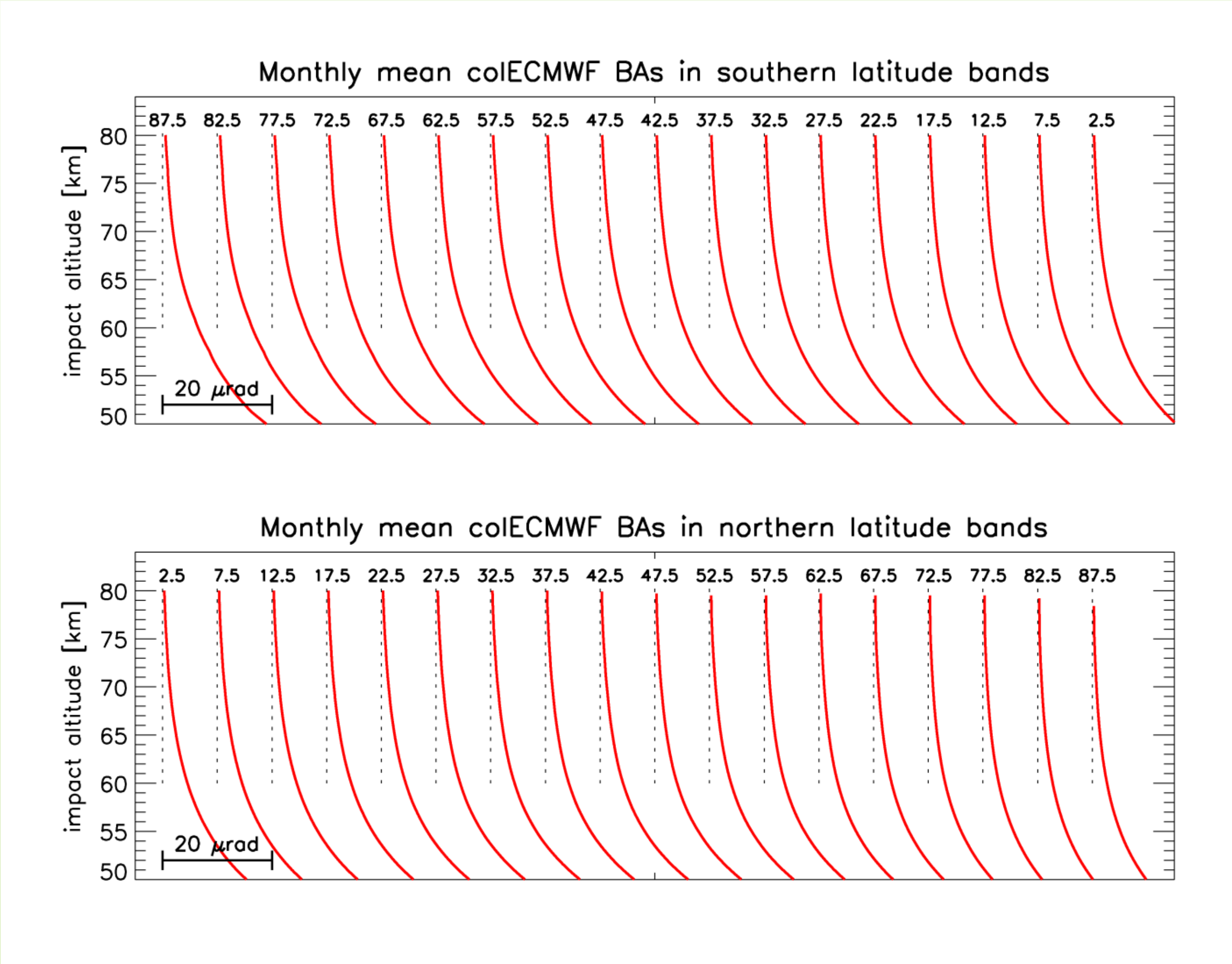
Monthly mean bending angles

– means, ECMWF (colloc.), Jan 2011 –



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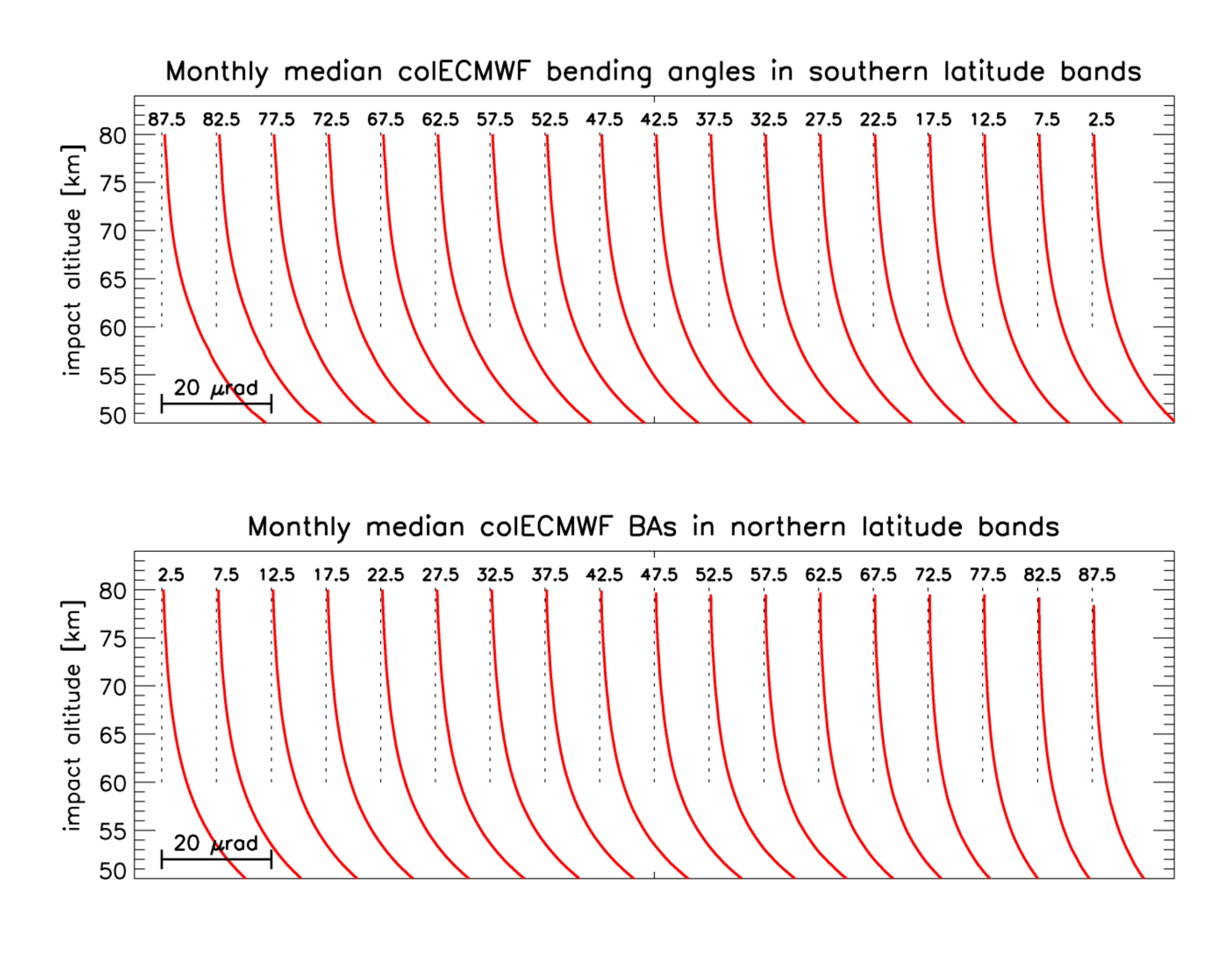

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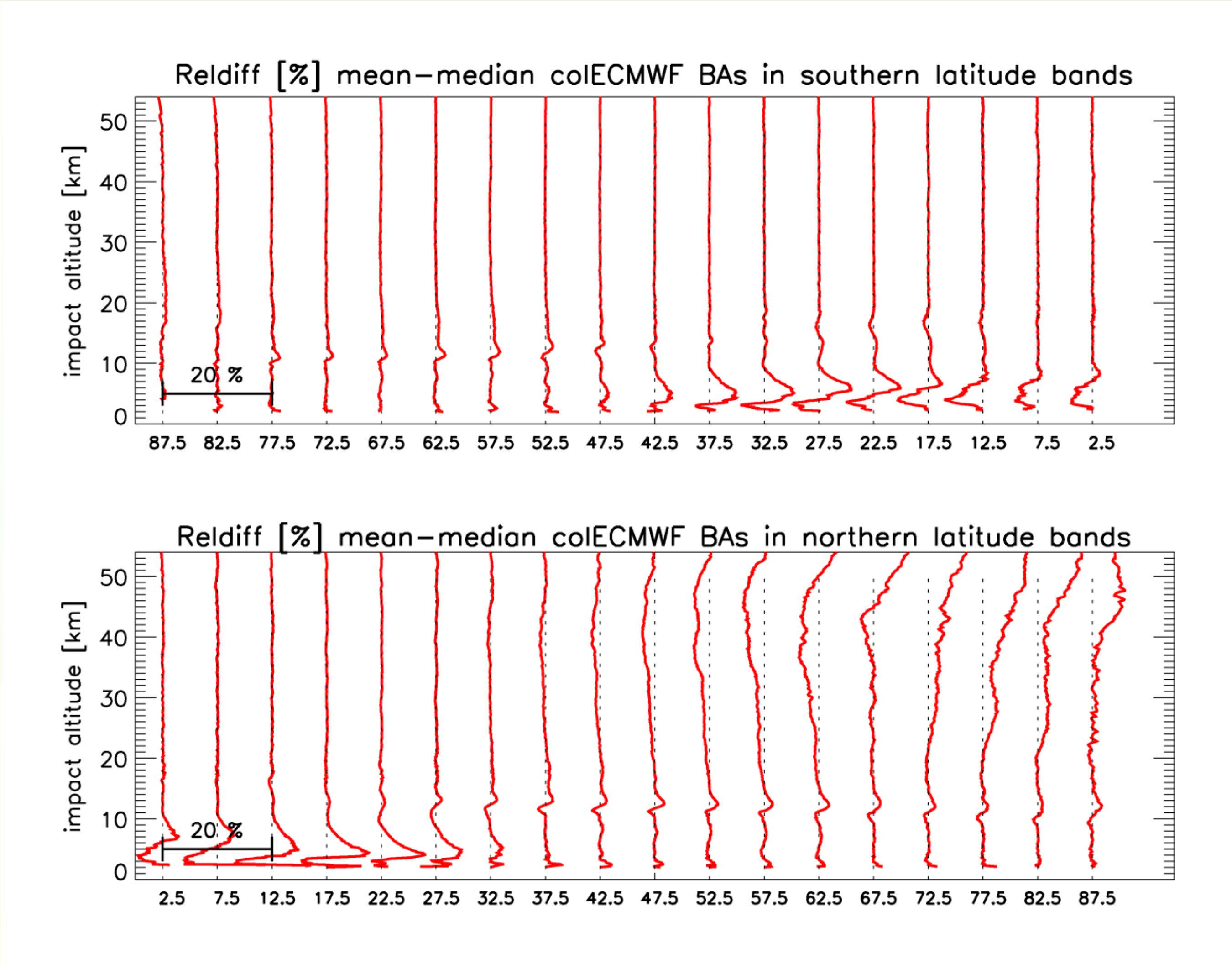

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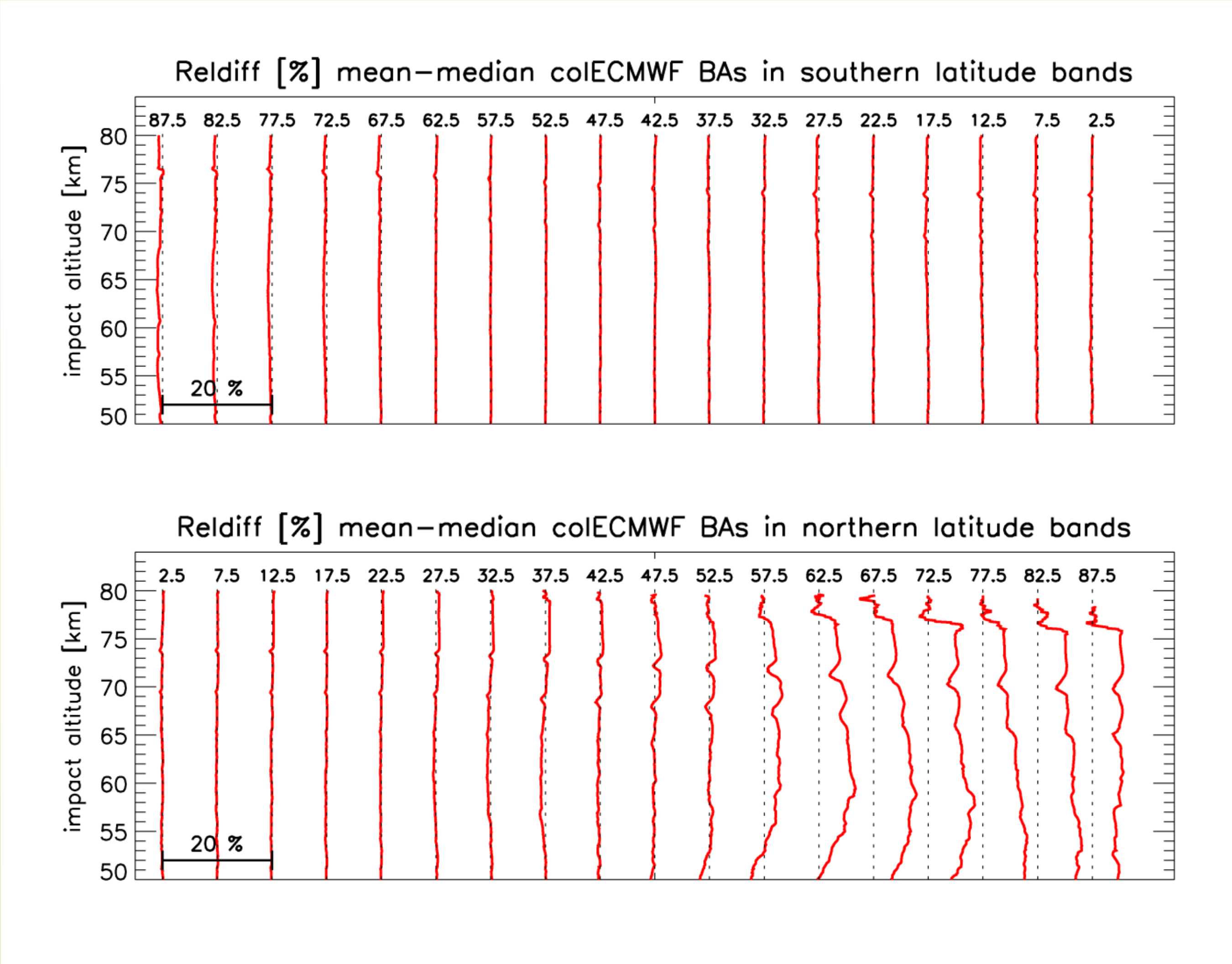

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