CASIA project: CAIRT and Sinergy with IASI-NG

CAIRT tangent points analysis – Luca Sgheri and Francesco Pio De Cosmo (IAC-CNR)

CAIRT tangent points analysis: Definition of Line of Sight (LoS)

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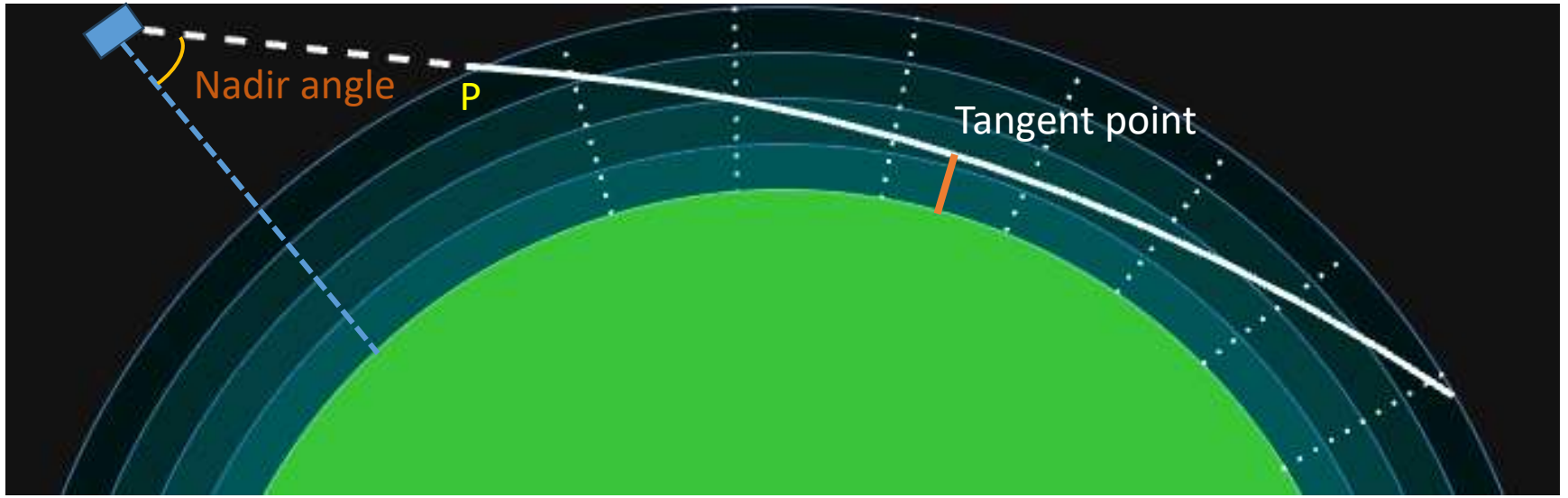
LoS: solutions of:

$$\frac{d}{ds}\left(n(\mathbf{L}(s))\frac{d}{ds}\mathbf{L}(s)\right) = \nabla n(\mathbf{L}(s))$$

s – arc parameter
$\mathbf{L}(s)$ – LoS as a function of s
n – refractive index of atmosphere



On the orbit plane: (x, y)

$$\begin{cases} y_1(s) = x(s) \\ y_2(s) = y(s) \\ y_3(s) = n\big(x(s), y(s)\big)x'(s) \\ y_4(s) = n\big(x(s), y(s)\big)y'(s) \end{cases} \Rightarrow \begin{cases} y_1'(s) = y_3(s)/n\big(y_1(s), y_2(s)\big) \\ y_2'(s) = y_4(s)/n\big(y_1(s), y_2(s)\big) \\ y_3'(s) = n_x\big(y_1(s), y_2(s)\big) \\ y_4'(s) = n_y\big(y_1(s), y_2(s)\big) \end{cases}$$

Outside the atmosphere:
LoS is a straight line

Initial conditions:
Coordinates and incident angle at point **P**,
Where the LoS enters the atmosphere.

[1] Born, M. and Wolf, E.: Principles of Optics, 4th Edn., Pergamon Press, 1970.

CAIRT tangent points analysis: LoS and radiative transfer

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On each sector of elliptic annulus (clover) crossed by the LoS:

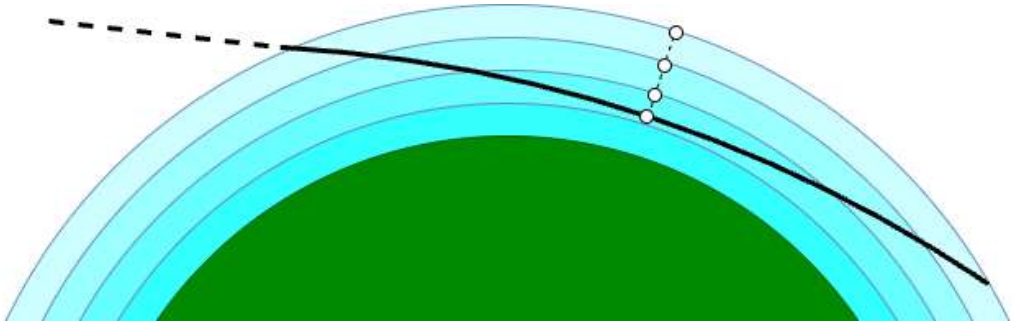
$$C(x) = \int_{s_0}^{s_1} x(\mathbf{L}(s)) \frac{p(\mathbf{L}(s))}{T(\mathbf{L}(s))} ds$$

Column of gas x on each clover. p – pressure, T – temperature.

If the atmosphere could be considered horizontally homogeneous (i.e. no horizontal gradients):

Line integrals could be transformed into vertical integrals,
using Snell's law and an integral transformation,

i.e.: no need of ray tracing.



CAIRT tangent points analysis: AX-DX differences

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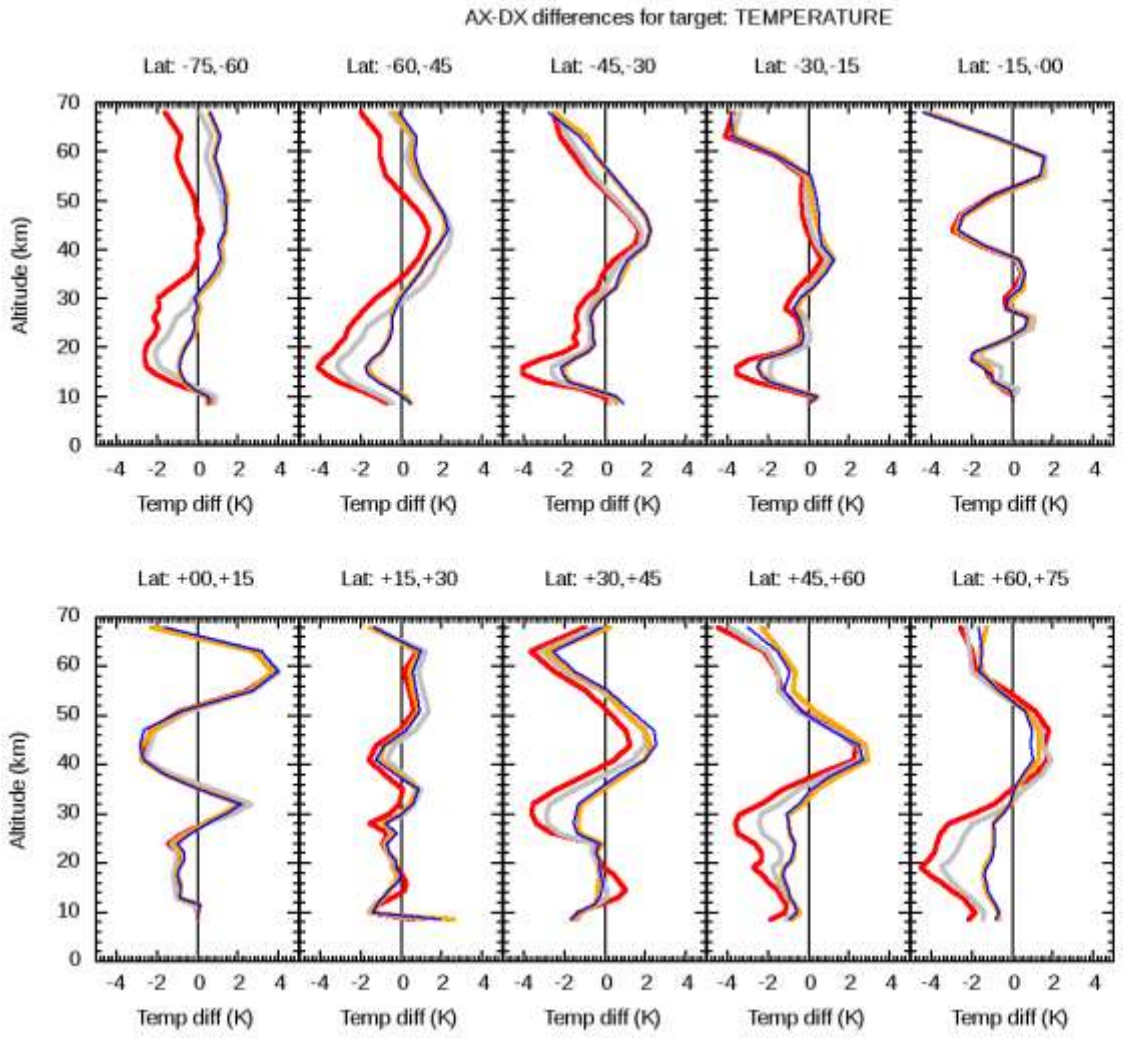
AX-DX differences: Differences on averages on the same latitudinal band in the ascending part of the orbit versus the descending part of the orbit.

RED: no gradients
GREY: gradients from climatology (IG2)
BLUE: gradients from previous reprocessing
GOLD: gradients from ECMWF reanalysis

Differences in the equatorial bands are due to the day/night difference (solar tides).

Differences in the other latitudinal bands are due to the lack of horizontal gradients are greatly reduced if a gradient consistent with the single retrieval is introduced.



[1] M. Kiefer et al. : Impact of temperature field inhomogeneities on the retrieval of atmospheric species from MIPAS IR limb emission spectra, Atmos. Meas. Tech., 3, 1487–1507, 2010

CAIRT tangent points analysis: Effect on tangent point location

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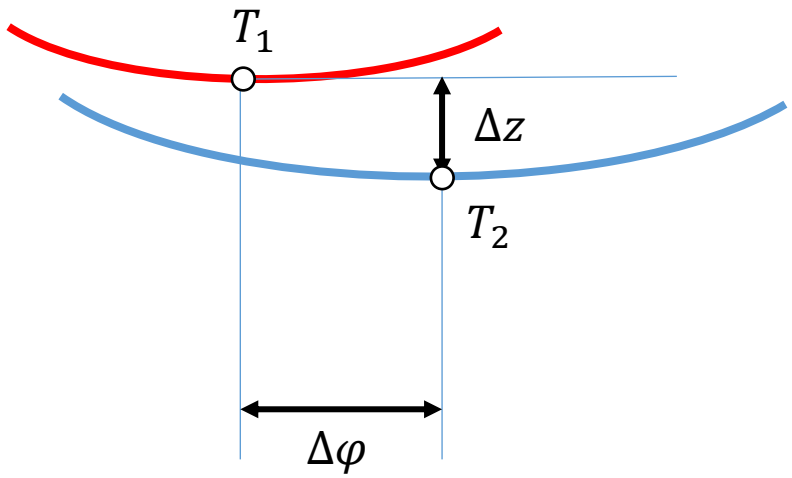
Differences in tangent points position:

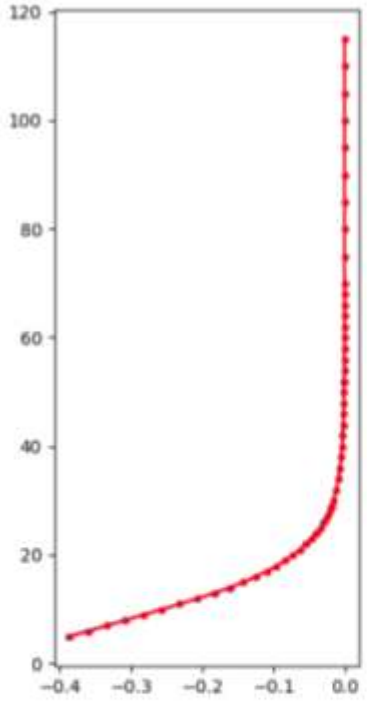
LoS calculated with US76 or IG2 atmosphere

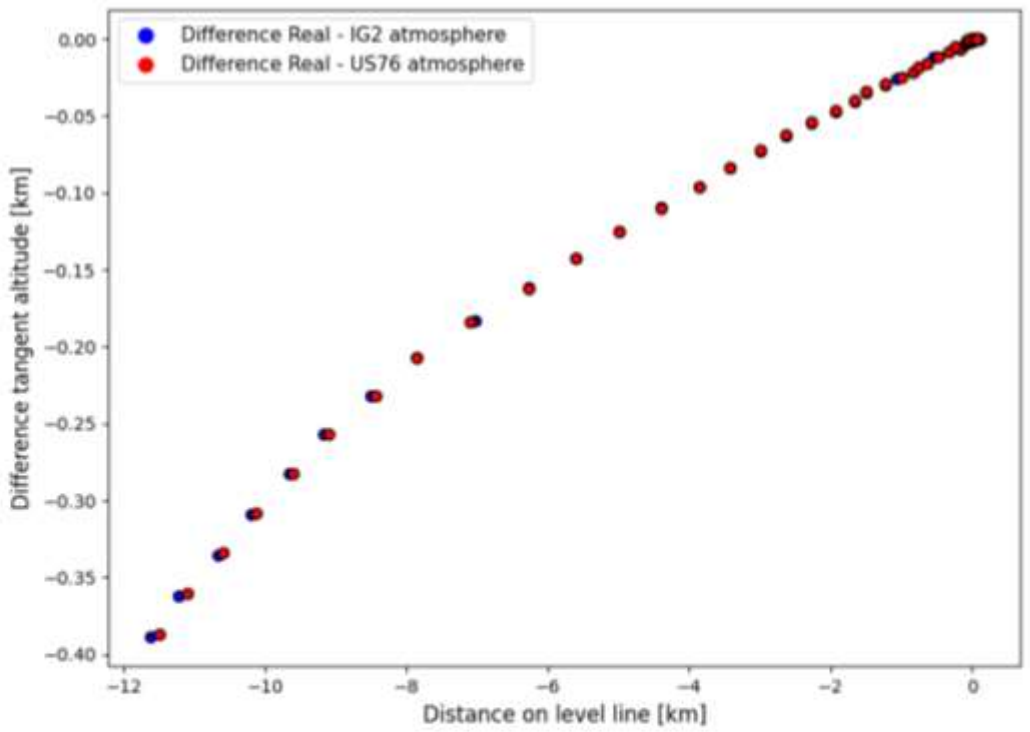
vs.

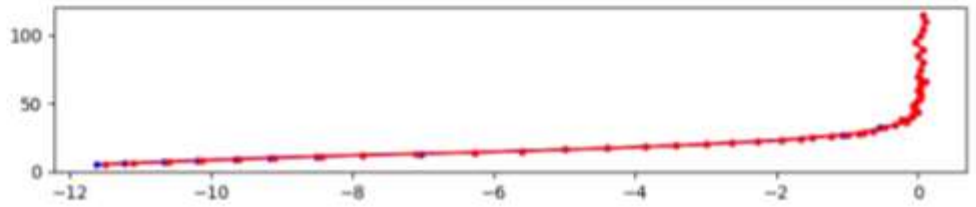
LoS calculated with full ERA5 atmosphere

Orbital coordinate (in MIPAS convention): 270°









CAIRT tangent points analysis: Examples of Lines of Sight

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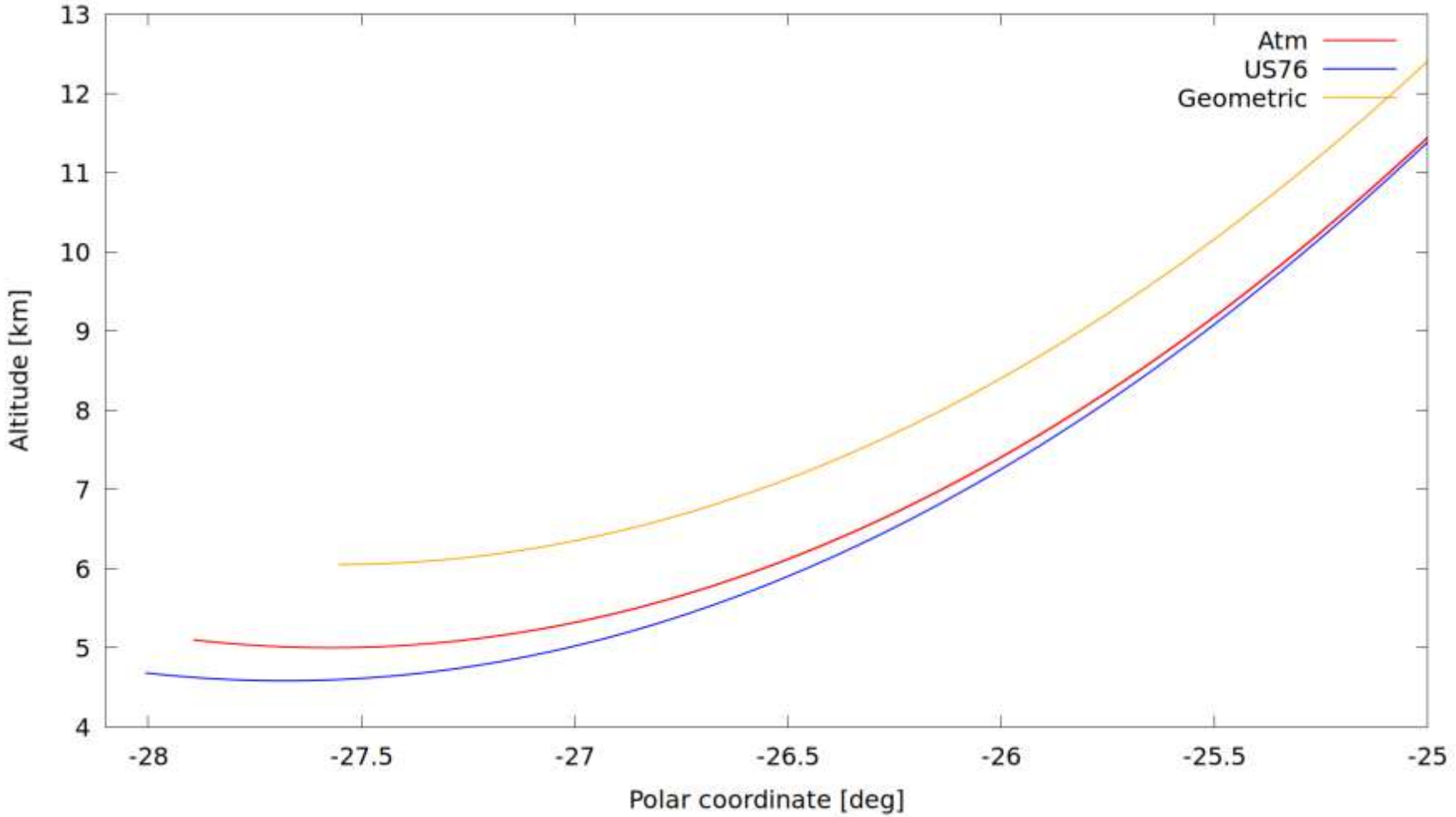
LoS for tangent height 5km:
Gold: Geometric (no atm)
Blue: US76 atmosphere
Red: Real atmosphere

Tangent height vertical error:
GEO-Real: 1km
US76-Real: 400m



CAIRT tangent points analysis: Comparison with MIPAS values

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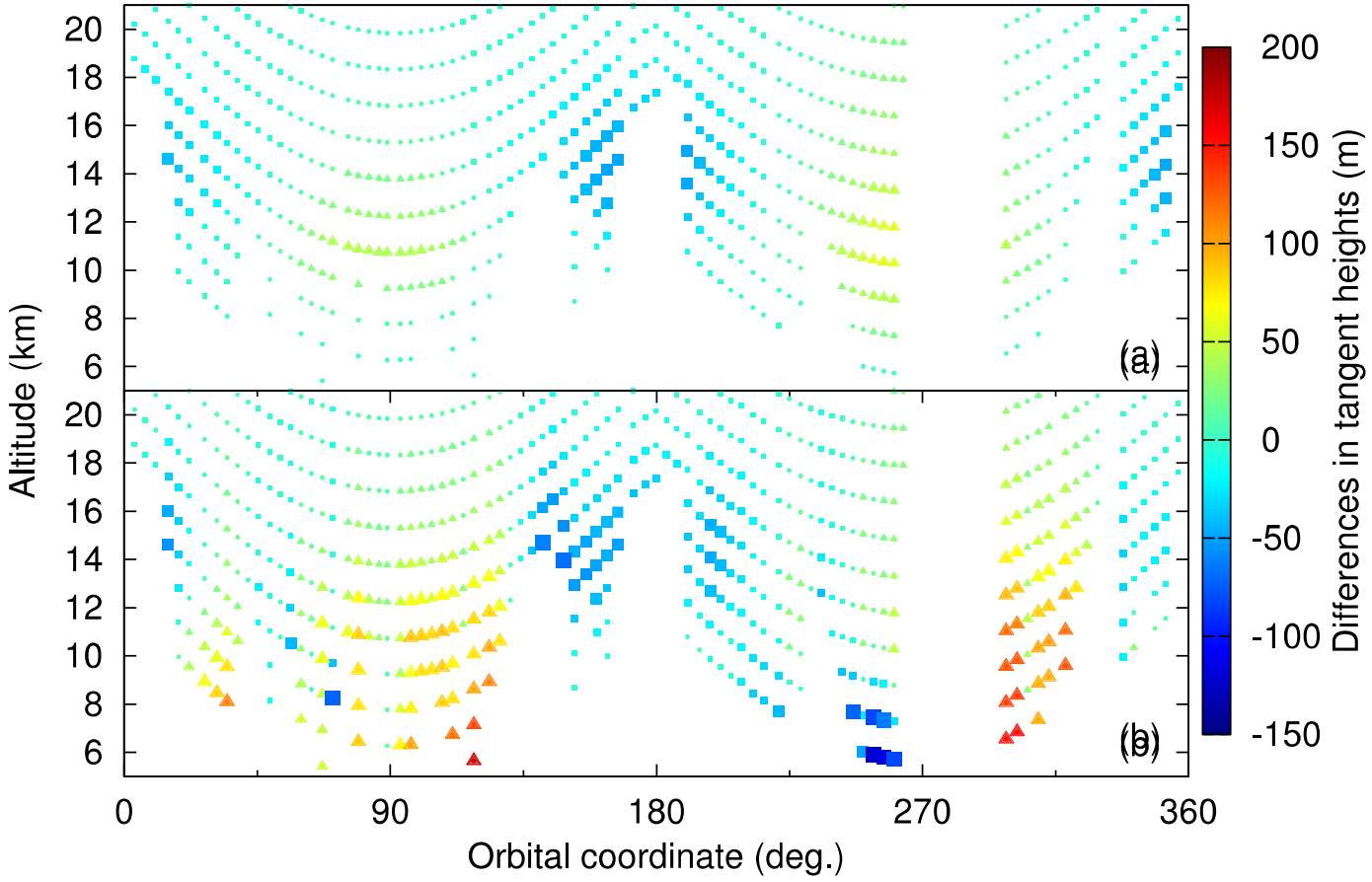
Calculations for MIPAS instrument:
Upper plot: IG2 vs. US76
Lower plot: Retrieved atmosphere vs. US76

Results consistent with MIPAS, differences:
- Orbital coordinates of tangents point kept fixed.
- Tangent pressures retrieved.
- Lowest scan higher than lower LoS of CAIRT acquisition.



[1] M. Ridolfi and L. Sgheri: Characterization of model errors in the calculation of tangent heights for atmospheric infrared limb measurements, Atmos. Meas. Tech., 7, 4117–4122, 2014

CAIRT tangent points analysis: Optimizations of ray-tracing

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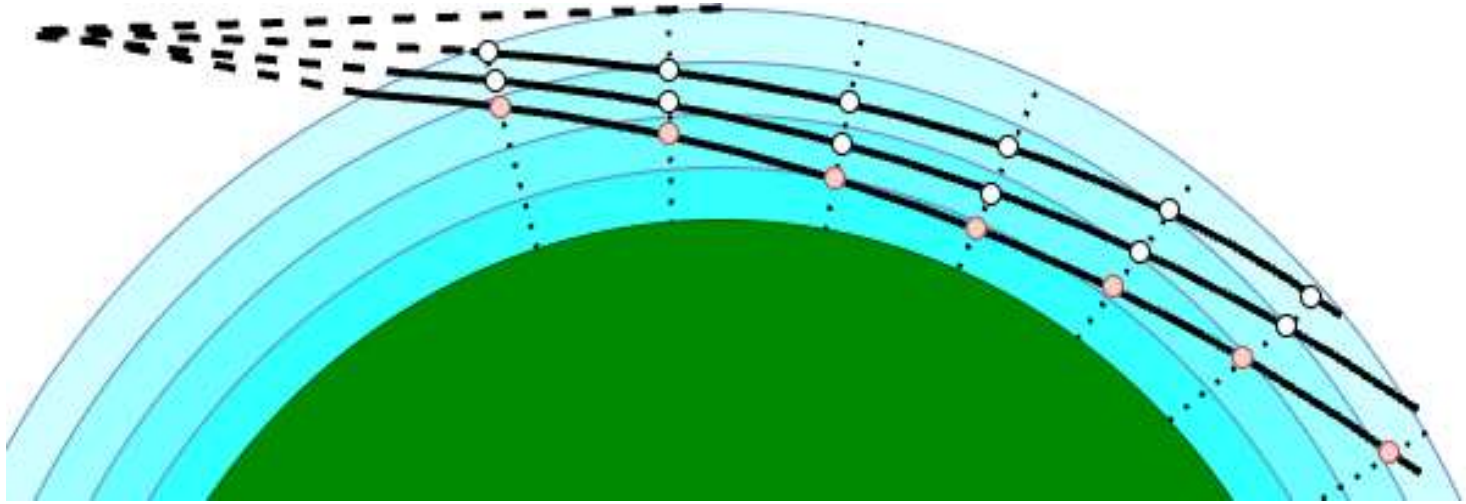
Possible optimizations for ray tracing:

- Tangent points with altitude larger than 80 km are not useful for CAIRT/IASI-NG synergy. Non LTE effects should be taken into consideration.
- Upper LoS are anyway very close to straight lines.



Focus on intersection points with φ-grid lines:

- Calculate only a subset of the LoS and then derive the missing $\Delta z_{i,j}$ by using a LUT or a neural network approach.

- In between the intersection point we can use the linear approximation (errors do not build up), or a curve with a preset curvature depending on altitude.

Conclusions:

- Ray tracing needs to be implemented. Use of standard or climatological atmospheres implies a difference in the tangent point heights of up to 400m, and a horizontal displacement of up to 12km.

- For the CAIRT/IASI-NG synergy it is foreseen that not all the CAIRT LoS will be used.

- Some form of optimization to reduce the time needed for the ray-tracing algorithm must be put in place.

THANK YOU FOR YOUR ATTENTION