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Adaptation of GPS-RO observation operator to the presence of atmospheric horizontal gradients

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Karen Boniface, Josep M. Aparicio

Data Assimilation and Satellite Meteorology

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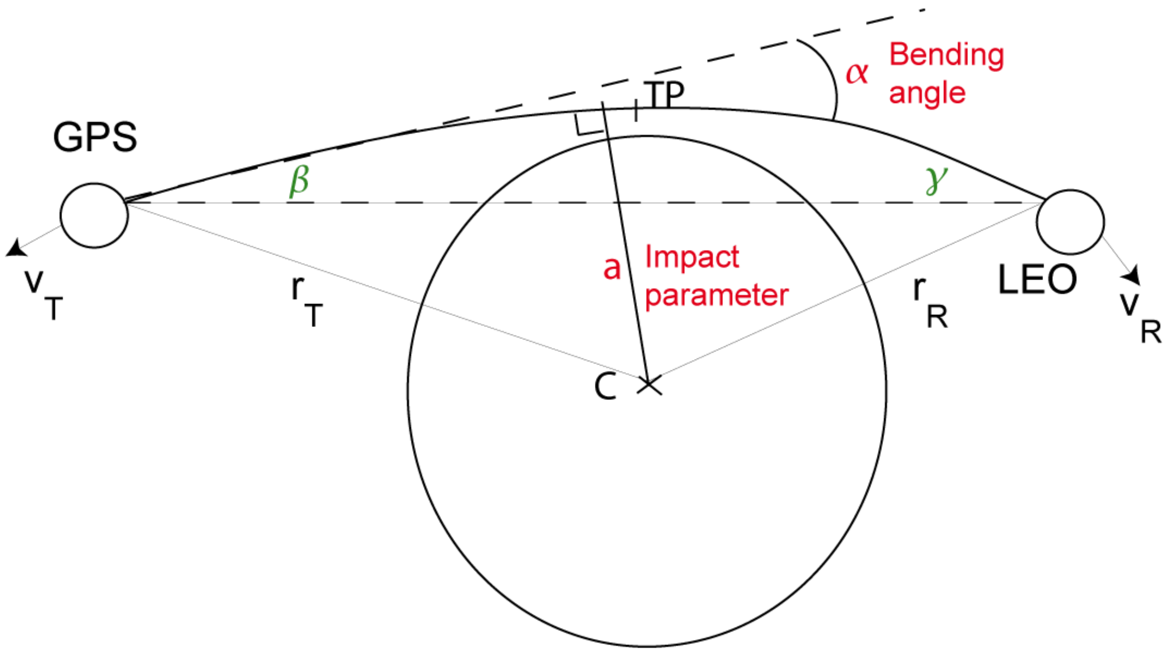
Overview

- GPS-RO geometry and classical retrievals
- Source of errors in retrieved refractivity profiles
- *State of the art*: Horizontal refractivity gradients
- Our approach
- How corrections on α and a are computed ?
- Horizontal refractivity gradients distribution
- Perspectives and conclusion

GPS-RO geometry: classical retrievals



We will not assume that the atmosphere is locally spherically symmetric:

→ <u>impact parameter is not constant along the ray</u>

Source of errors in retrieved refractivity profiles

- Neglecting horizontal structure along the ray path.
- Geometrical / wave optics may insufficiently account for effects of diffraction in the lower troposphere.
- Obliquity of RO profiles :
  - Representativeness errors considering that the retrieved profiles are vertical scans (Foelsche et al., 2011): azimuth angle has to be considered.
  - NWP experiments confirmed that GPS RO soundings are more accurate if obliquity is considered (Cucurull 2011).

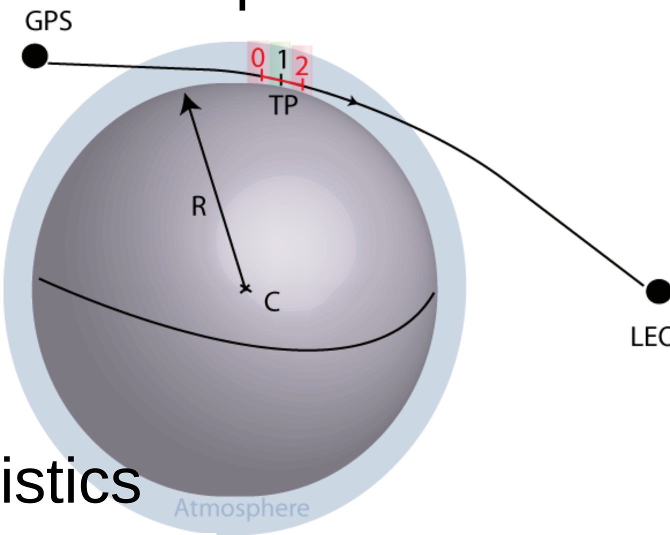
- Obliquity, representativity & horiz gradient are related.

State of the art : horizontal refractivity gradients

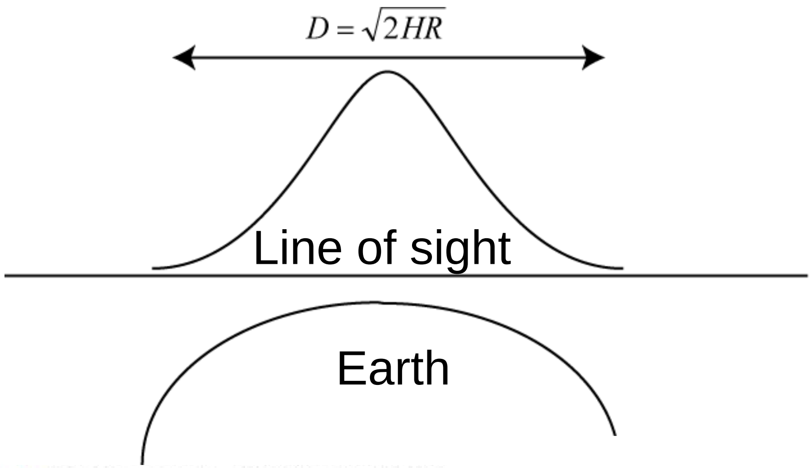
- Kursinski et al., (1997) : characterize refractivity errors associated with realistic horizontal refractivity variations using the NMC regional forecast ETA model
- Ahmad and Tyler (1999) highlight that large-scale departure in spherical symmetry can be modeled as an error in the location of the center of curvature of the atmosphere
- Healy (2001) demonstrated that horizontal refractivity gradients primarily cause errors in the derived impact parameter
- Poli and Joiner (2004) : tangent point drift effects are accounted considering a slant profile that follows the tangent point trajectory.

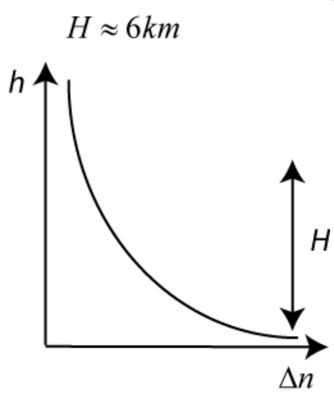
Our approach

- How atmospheric gradients have been computed ?
  - Along the ray (1D operator)
  - Location of RO profiles (1) deduced from atmprf files: *observable*
  - Atmospheric profiles location (0-2)



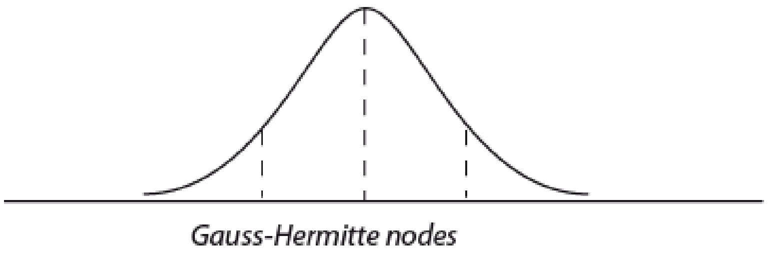
- Gradients and refractivity characteristics

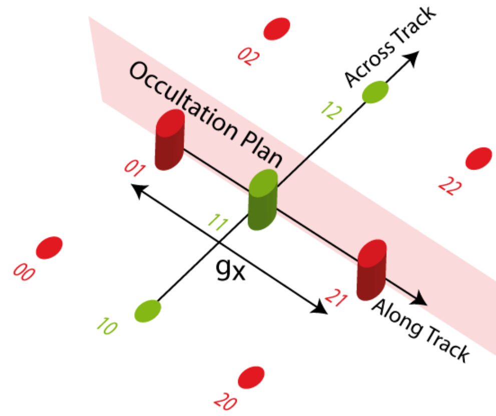




Our approach

- Characteristic size of the Gaussian region (250km)





- 3rd order Gauss-Hermitte quadrature
  - Cheapest simplification of a quasi-gaussian to 3 points
- Occultation plan coordinates extracted from atmPrf files
- Along track gradients are then computed with the background refractivity field from Environment Canada model

Our approach

- Why gradients have been computed in this way ?
  - Computing cost efficiency needed for further implementation.
  - 1D operator solution privileged instead of full 2D
  - Gauss-Hermitte quadrature is an easy approximation and is possible using the following assumptions:
    - Refractivity and gradients follow a quasi Gaussian distribution along line of sight

How corrections on α and a are computed ?

- Computation of a new center of curvature including existence of horizontal refractivity gradients

atmPrf → aimp, α → Equivalent Doppler shift (*d*) at sample i → Iterative Newton Method

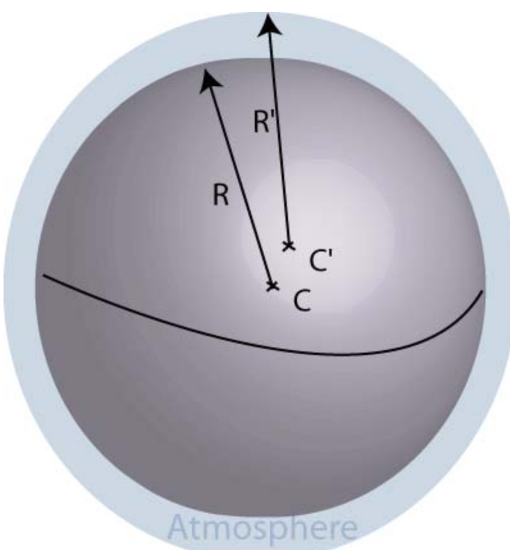
$$\alpha_{corr}(d) = \alpha_{g_x=0}(d) + \left.\frac{d\alpha}{dg_x}\right|_{g_x=0} g_x$$

$$a_{corr}(d) = a_{g_x=0}(d) + \left.\frac{da}{dg_x}\right|_{g_x=0} g_x$$

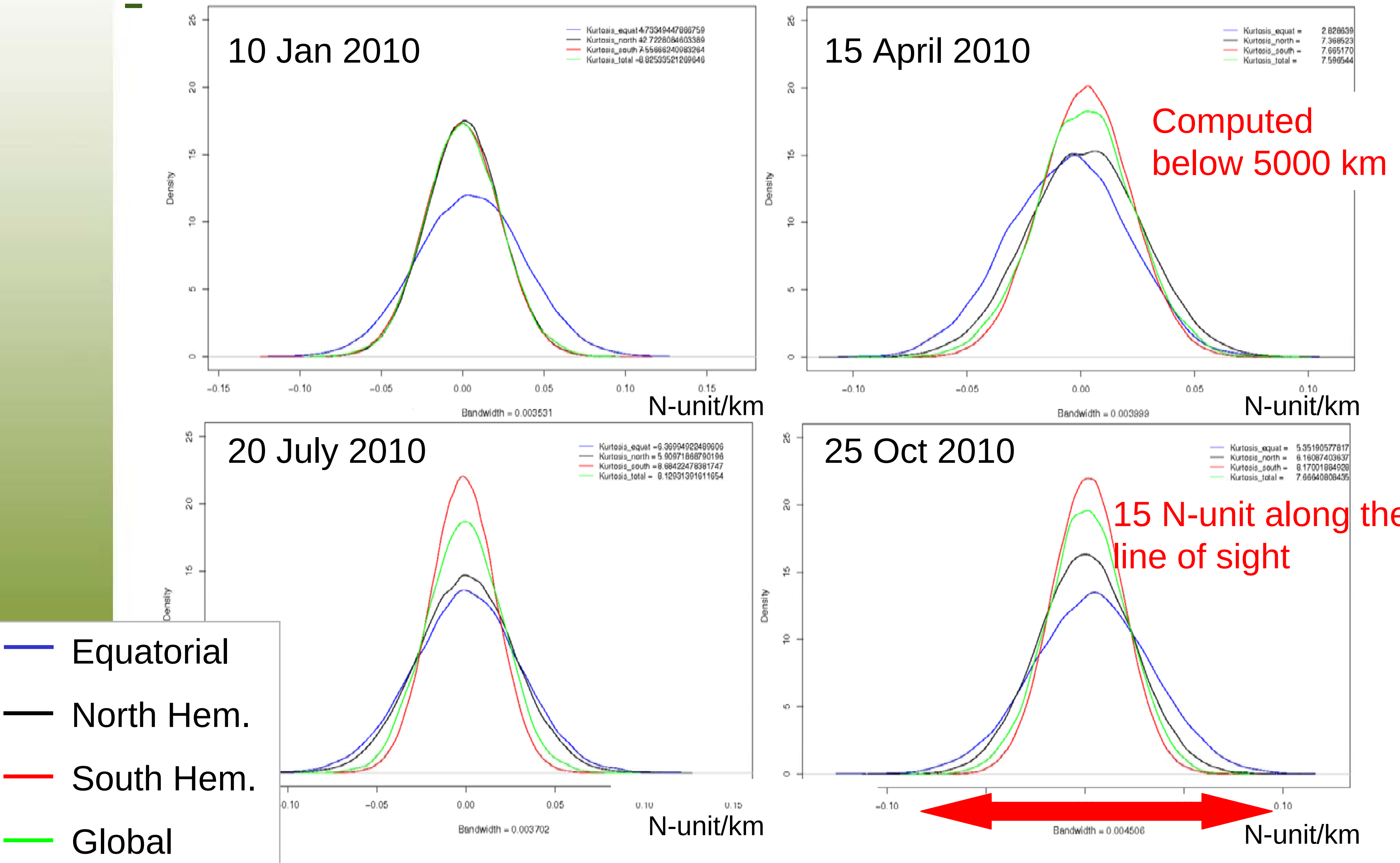
From data providers

Geometry of problem

Extracted from our background field

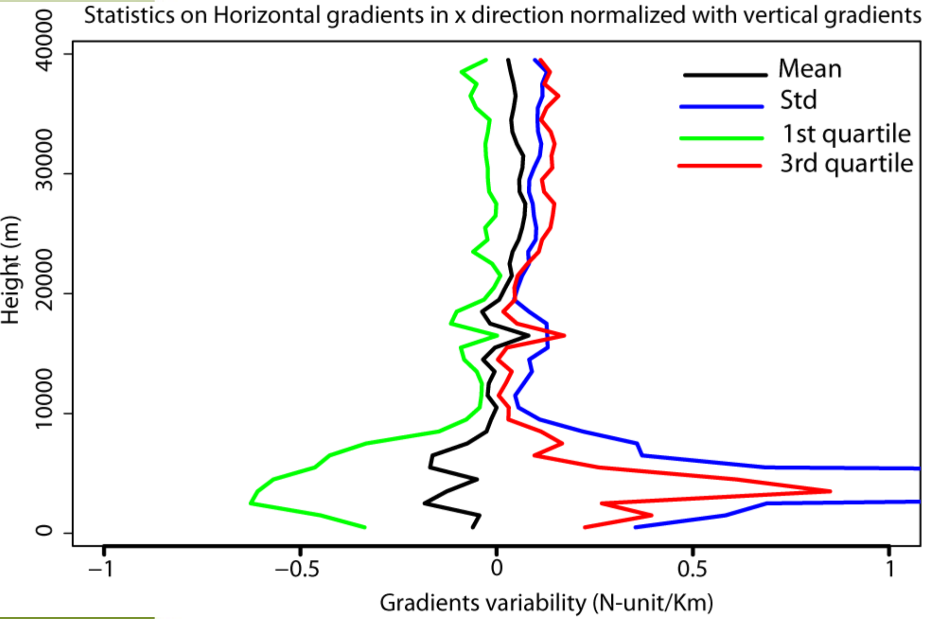


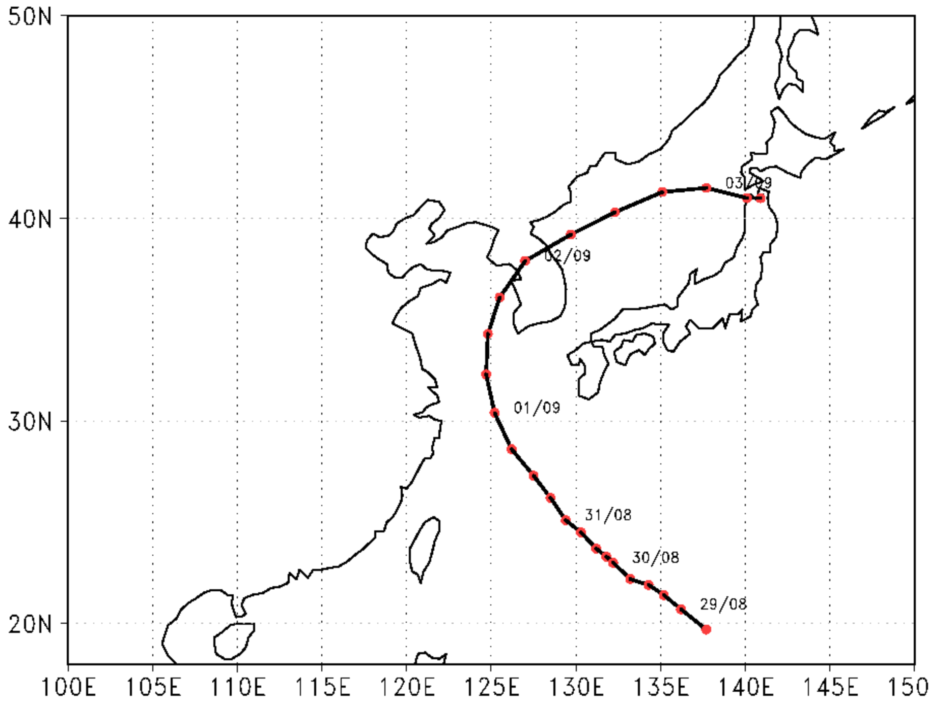
Horizontal refractivity gradients distribution



Horizontal refractivity gradients distribution

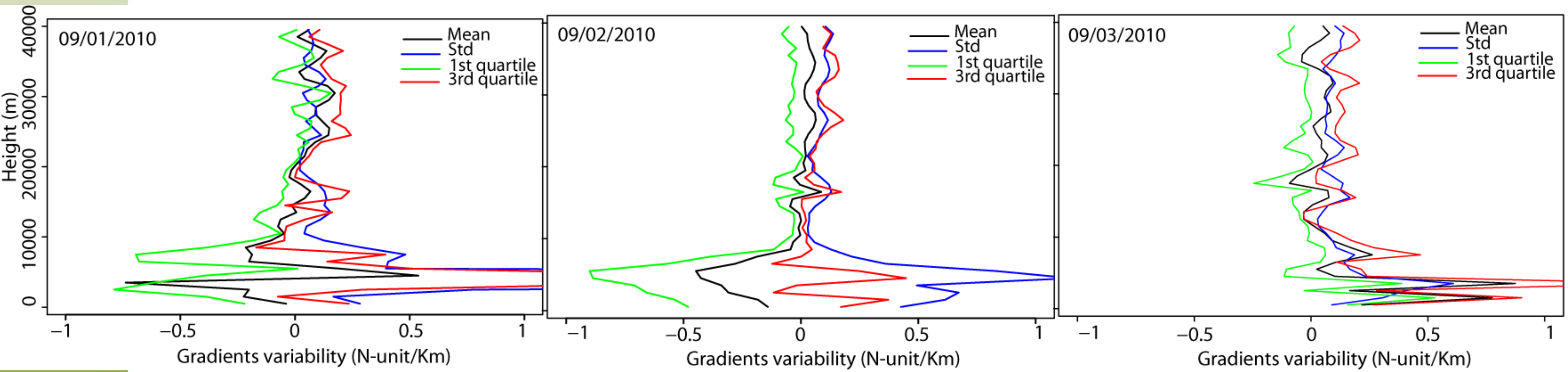
- Study case : Kompasu Typhoon (2010)
- Gradients distribution between 1st to 3rd Sept
- We select profiles for P < 960 hPa and no relief





Horizontal refractivity gradients distribution

- Statistics on horizontal gradients in x direction normalized with respect to vertical gradients



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Conclusion and Perspectives

- Presence of horizontal refractivity gradients is significant :
  - at different time of the year
  - in case of strong pressure gradients
  - Globally distributed
- 1-D operator solution is proposed: linear correction to account for refractivity gradients along the sight line.

$$\alpha_{corr}(d) = \alpha_{g_x=0}(d) + \left.\frac{d\alpha}{dg_x}\right|_{g_x=0} g_x \;;\; a_{corr}(d) = a_{g_x=0}(d) + \left.\frac{da}{dg_x}\right|_{g_x=0} g_x$$

- Evaluate data assimilation impacts using the Environment Canada system

Thank you for your attention