Toward the assimilation of W-band radar data in a kilometer-scale NWP model

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Image: NASA/ESA

Context

Heavy precipitation events in the Mediterranean

- **HyMeX** program (2010-2020) aims at improving the prediction of such events
- The HyMeX first Special Observing Period (SOP1, Fall 2012)
  $\Rightarrow$ **18 flights of the Doppler W-band radar RASTA**

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Doppler W-band radar

- Sensitive to cloud microphysics
- Sensitive to dynamics

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2. Data Assimilation

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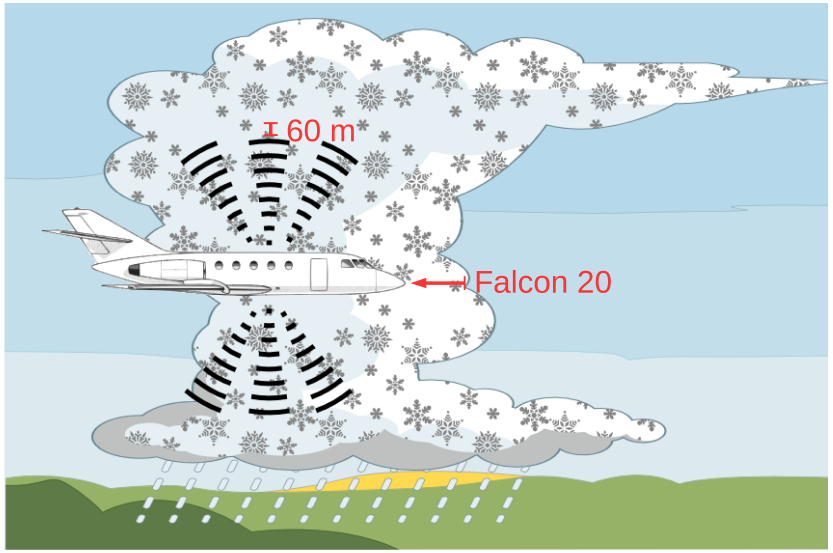
1. Forward operator for km-scale NWP models
2. Assimilation of Doppler W-band radar data in a km-scale NWP model

Radar data and the AROME NWP model

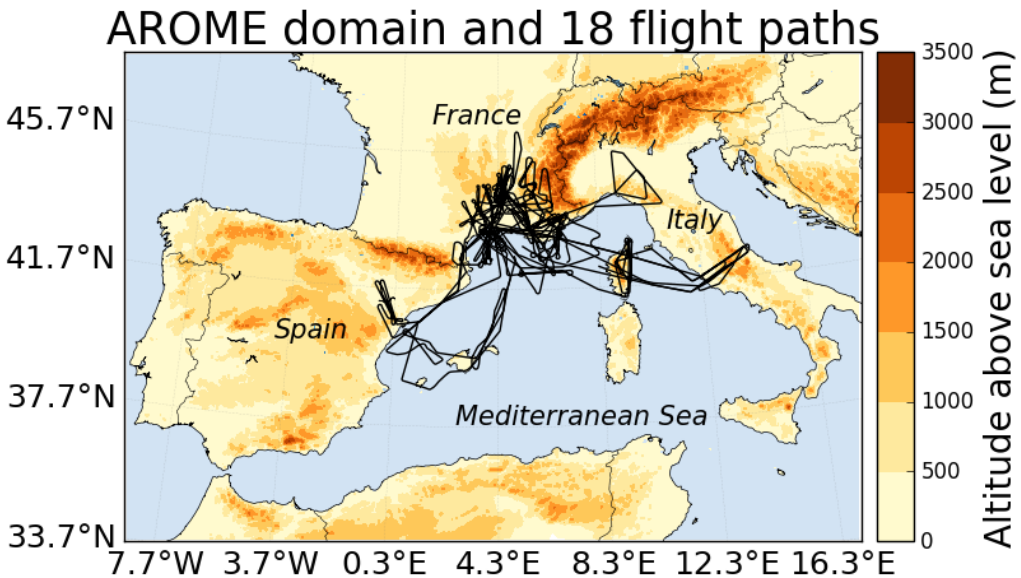
The airborne radar RASTA

- W-band - 95 GHz
- Doppler + Multi-beam antenna system
  $\Rightarrow$ retrieval of the 3D cloud wind field
- High vertical (60m) and time resolution (1.5s)



The AROME NWP model

- horizontal resolution 2.5 km
- One-moment bulk microphysical scheme (ICE3)
- 3-h 3D-var assimilation system



1. Forward operator for km-scale NWP models
2. Assimilation of Doppler W-band radar data in a km-scale NWP model

The forward operator

Input

From AROME

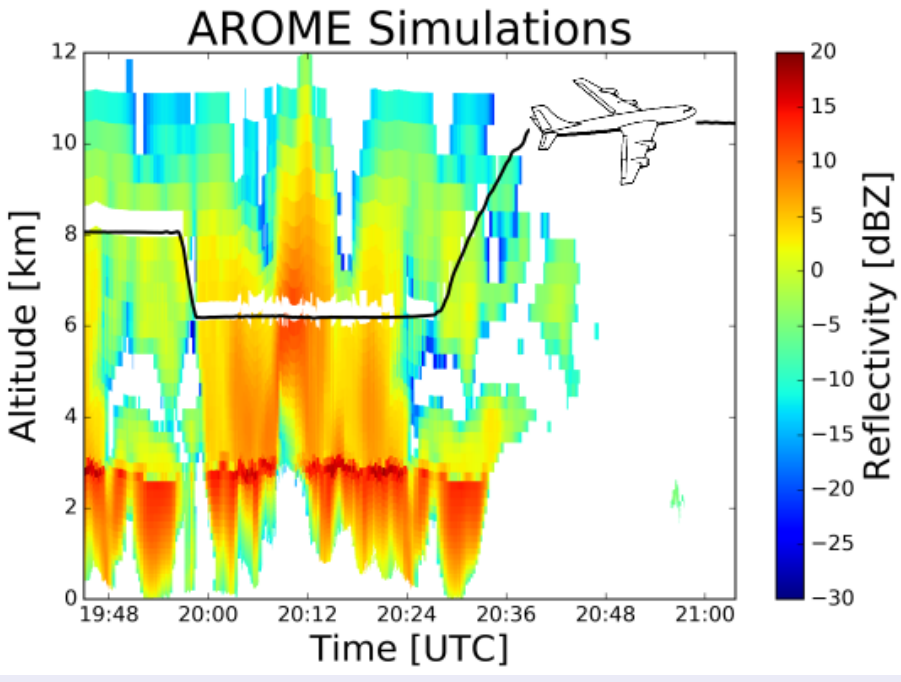
- Hydrometeor contents (snow, pristine ice, graupel, rain, cloud liquid water)
- PSDs and mass-diameter relationships (ICE3)
- Temperature, Pressure, Humidity

Effective shape of hydrometeors

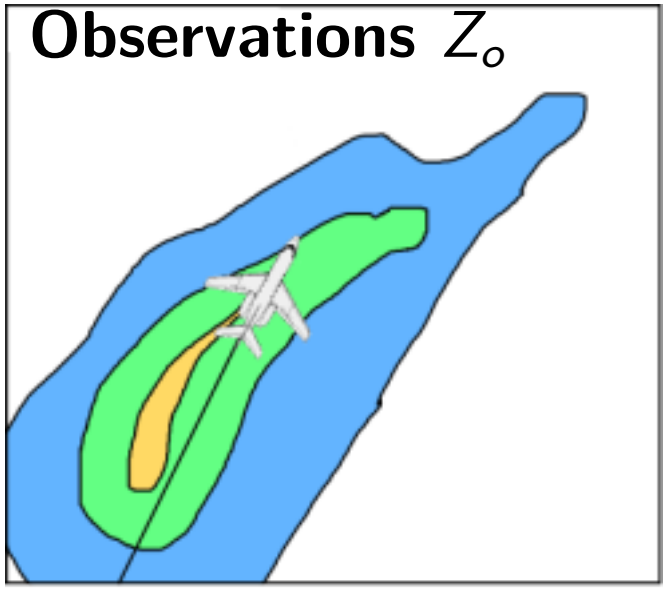
- Oblate spheroid or spherical
- T-matrix method (Mishchenko and Travis, 1994)

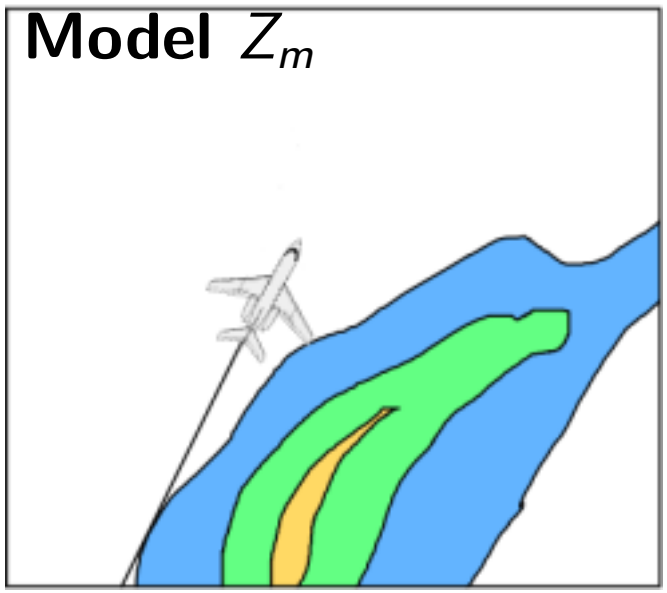
Output

- Attenuated reflectivity
- Radar sensitivity



Validation: the Most Resembling Column (MRC) method





Motivation

- "Double penalty problem" for km-scale models (cloud misplacement between model and observations)

- Grid to grid comparison unsuitable

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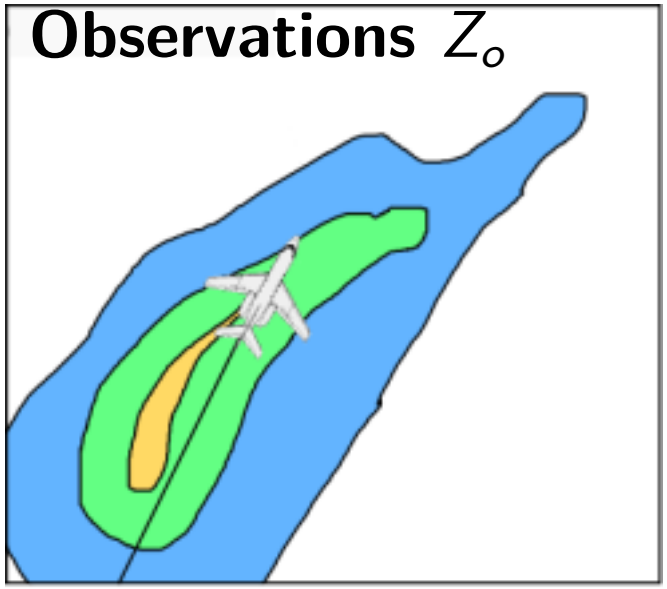

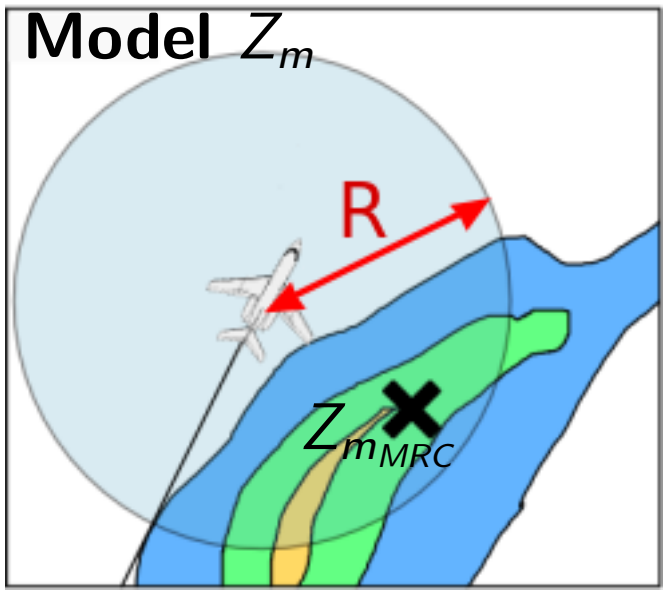

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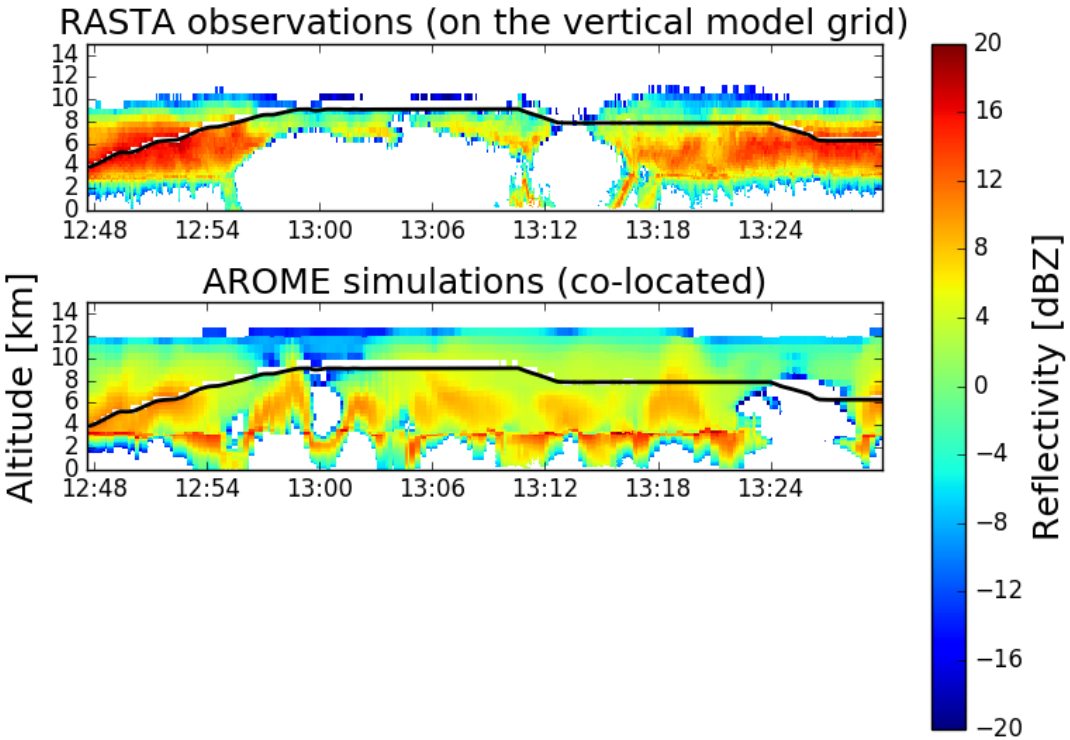
The MRC method

- We pick the Most Resembling simulated Column $Z_{m_{MRC}}$ around the radar
- $Z_{m_{MRC}} = \text{argmin } STD(Z_o - Z_m)$
- $R = 160$ km

Application of the MRC method

09/29/2012 flight



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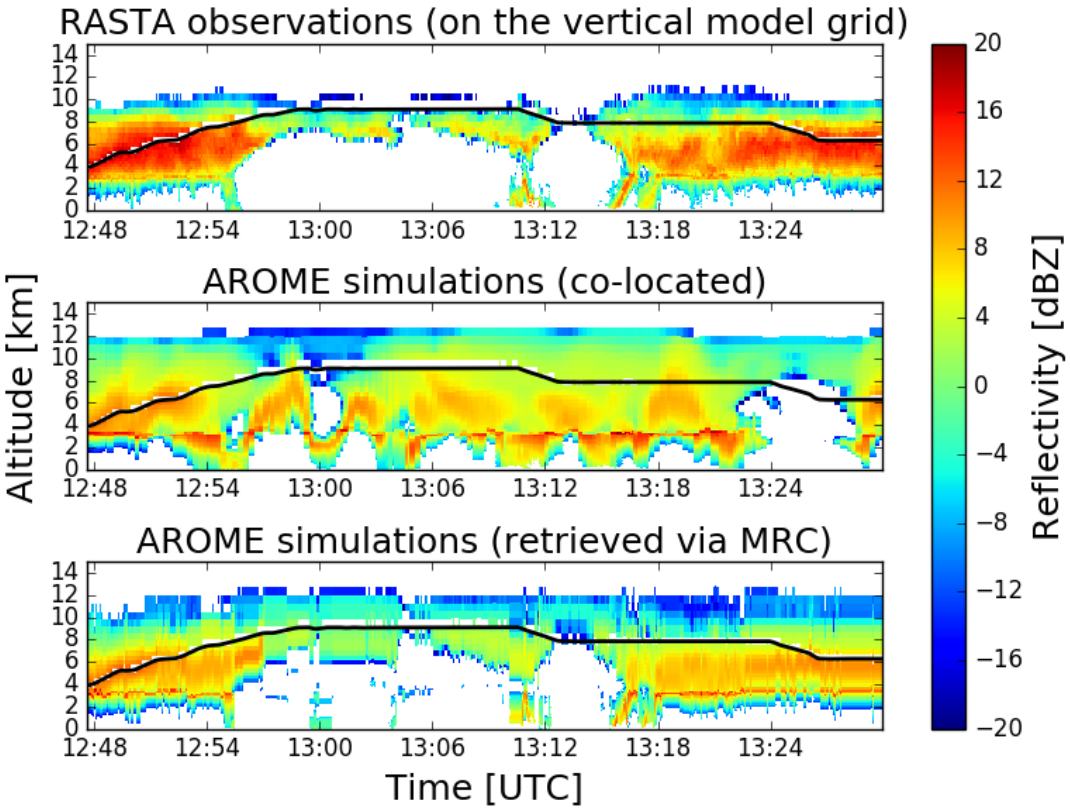

- Spatial mismatches are overcome

- Forward operator can be validated

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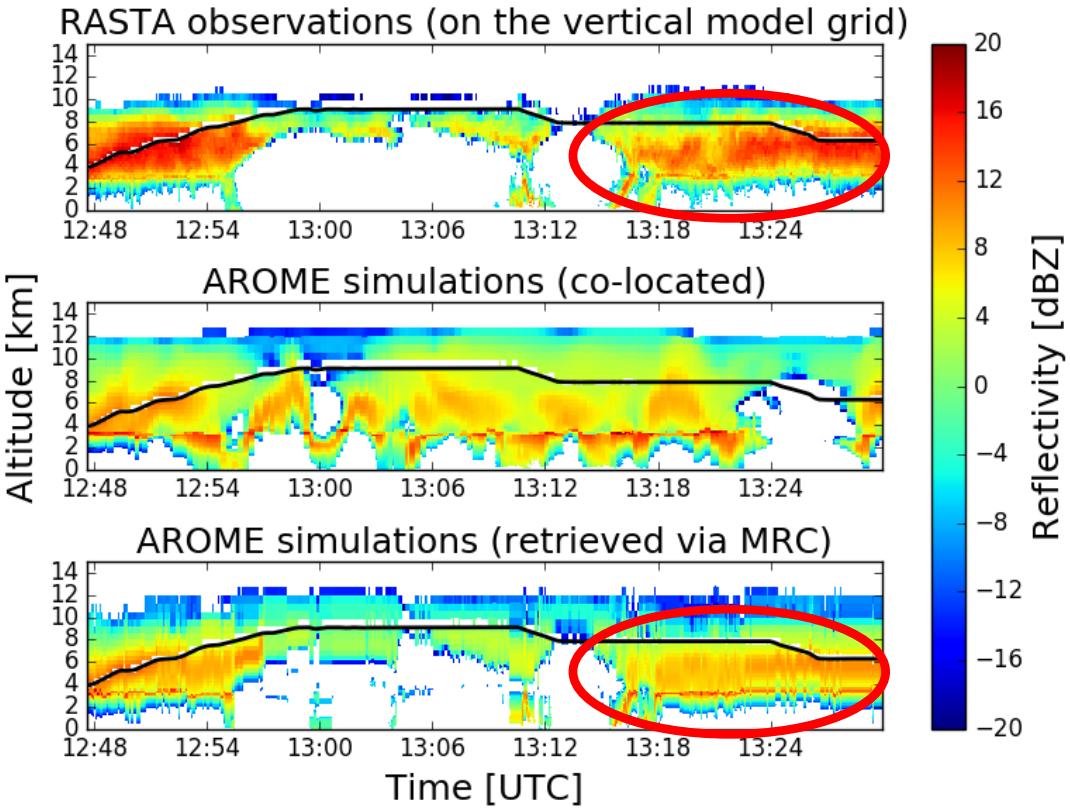

- Spatial mismatches are overcome

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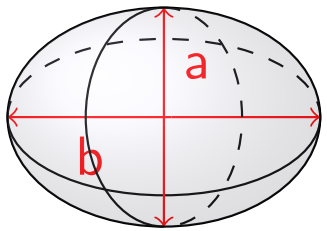
- Underestimation of the reflectivity in ice levels (Spherical approximation valid?)

Effective shape of ice hydrometeors j

Effective axis ratio $r_j = \frac{a}{b}$, with $j \in (snow, graupel, ice)$

- $r_j = 1 \Leftrightarrow$ spherical particle
- Three effective axis ratios to estimate: $r_{graupel}$, r_{snow}, r_{ice}



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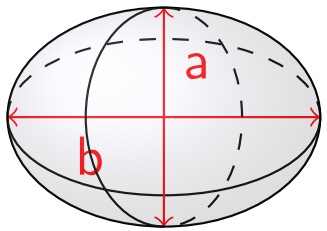

Determination of the optimum $(r_{graupel}, r_{snow}, r_{ice})$

- Retrieved globally over the 2-month period
- $(r_{graupel}, r_{snow}, r_{ice}) = \text{argmin } \overline{STD(Z_o - Z_{m_{MRC}})}$

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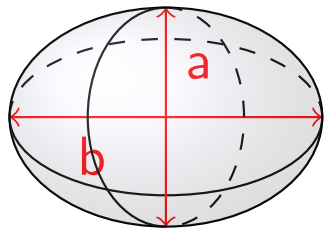

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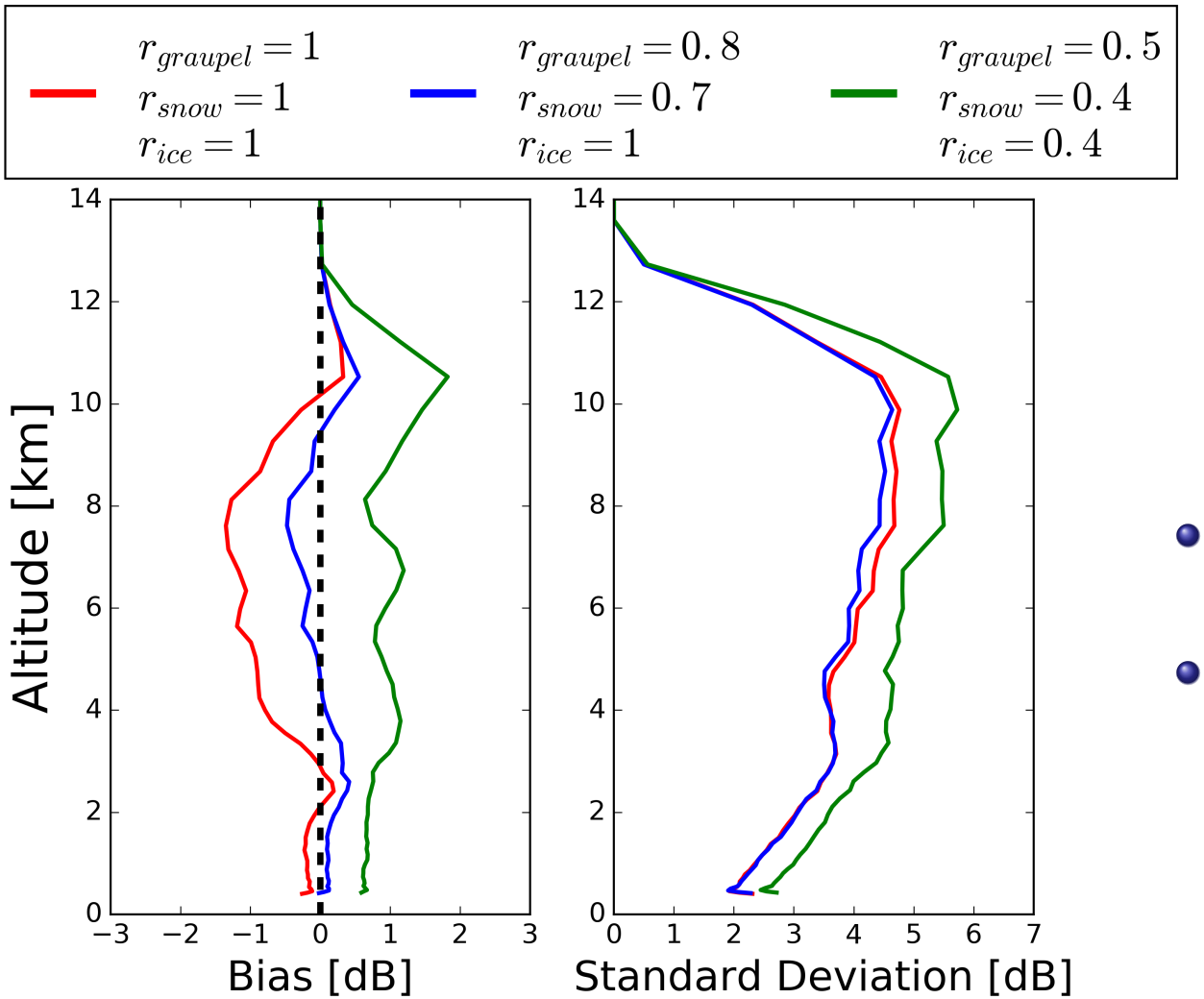
Results

- $r_{graupel} \approx 0.8$, $r_{snow} \approx 0.7$ (Consistent with other studies: Putnam et al. (2017), Garrett et al. 2015...)
- $r_{ice} = 1$ (spherical). ICE3 produces too much pristine ice?

Evaluation of spheroidal simulations (2-month period)



- Bias, standard deviation reduced at all altitude levels
- Better agreement with RASTA observations

- Borderies et al. Simulation of W-band radar reflectivity for model validation and data assimilation, in revision for qjrms.

1 Forward operator for km-scale NWP models

2 Assimilation of Doppler W-band radar data in a km-scale NWP model

Assimilation of reflectivity Z and horizontal wind (u, v)

Step 1 to assimilate Z *(Caumont et al. 2010, Wattrelot et al. 2014)*:

- 1D Bayesian retrieval: $Z \Rightarrow$ Pseudo-Observations Relative Humidity, RH_{PO}
- Use of the RASTA forward operator

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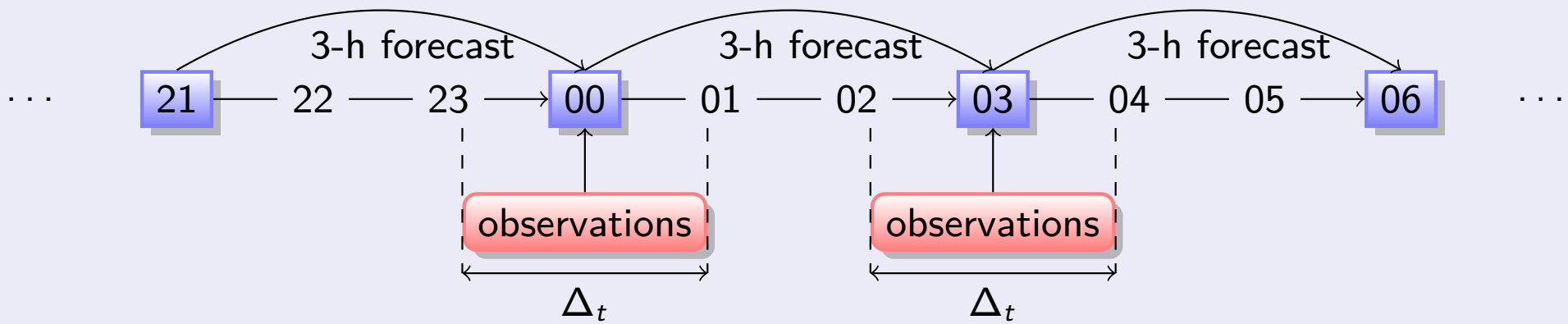
Step 2: RH_{PO} and/or (u,v) are assimilated every 3 hours in the 3D-Var



Impact on the predictions over a 2-month period

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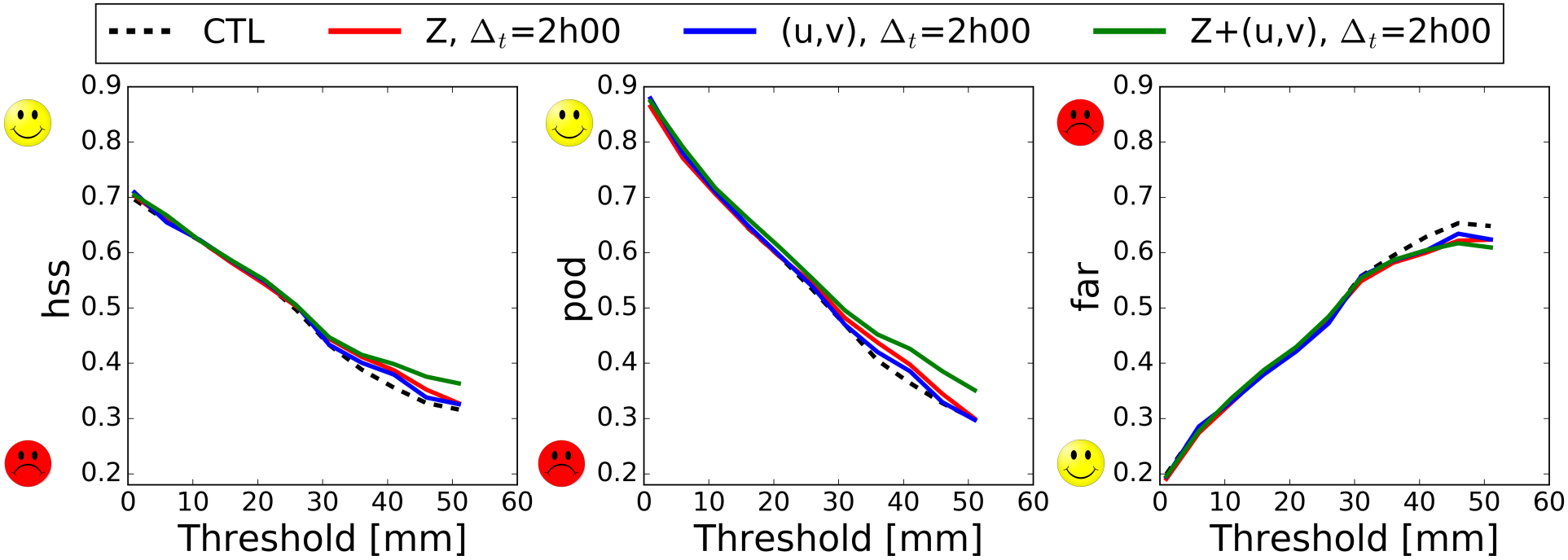
9-h accumulated rainfall forecasts against rain gauges



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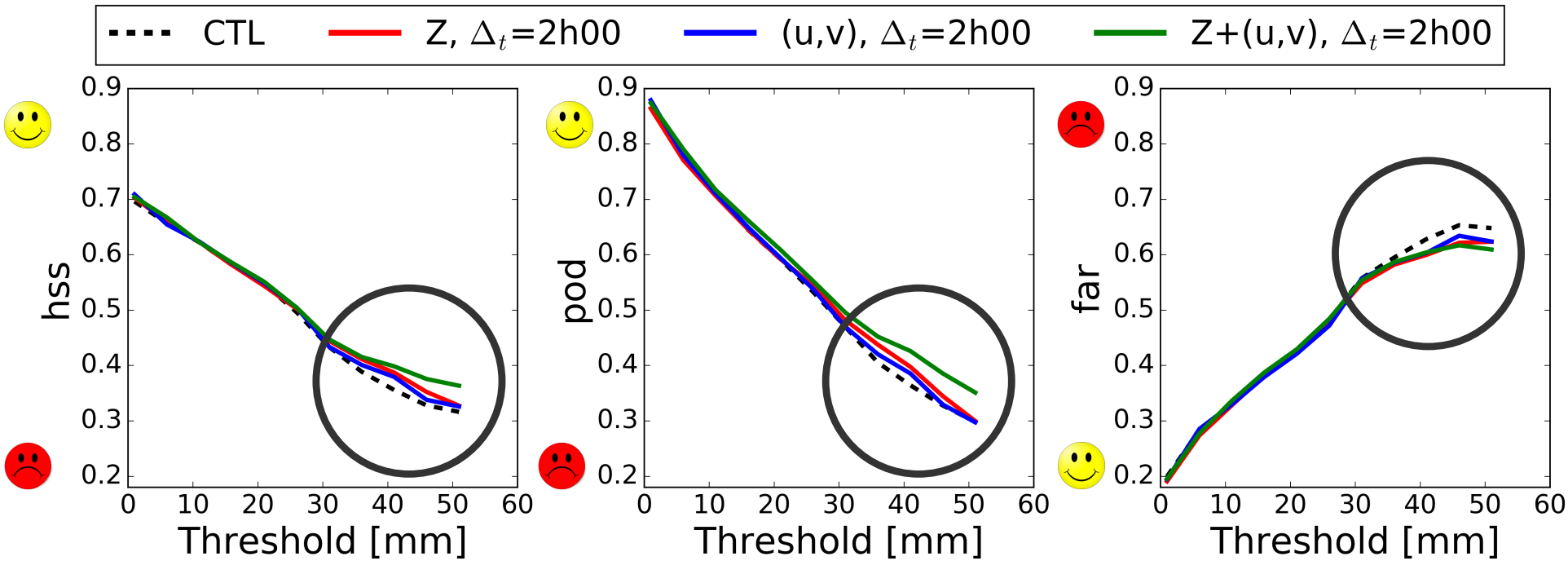

- Positive impact above 30 mm, neutral below (same result on 6-h forecast and 12-h forecast)
- Better impact if Z and (u, v) are assimilated jointly with $\Delta_t = 2h$

Conclusions and future work

Forward operator (Borderies et al., in revision for QJRMS)

- Vertically-pointing W-band radar (ground-based or airborne)

The Most Resembling Column (MRC) validation method

- Focus on errors in forward operator and in microphysics

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Future work

- In-depth analysis of the assimilation of RASTA reflectivity and velocity

Thank you for your attention

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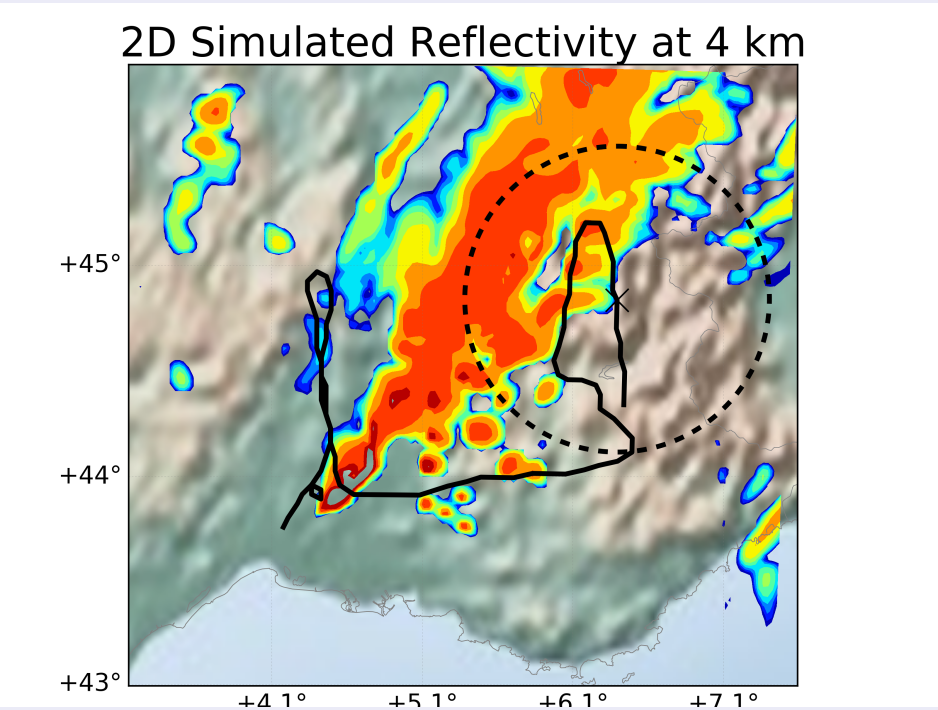
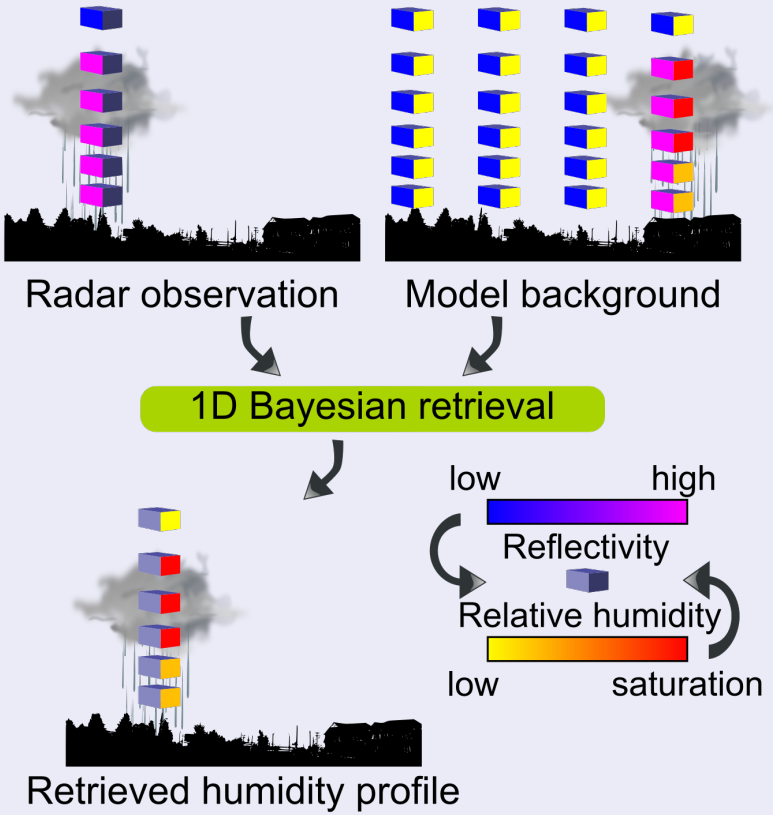
Image: NASA/ESA

1D Bayesian retrieval of Relative Humidity *RH*

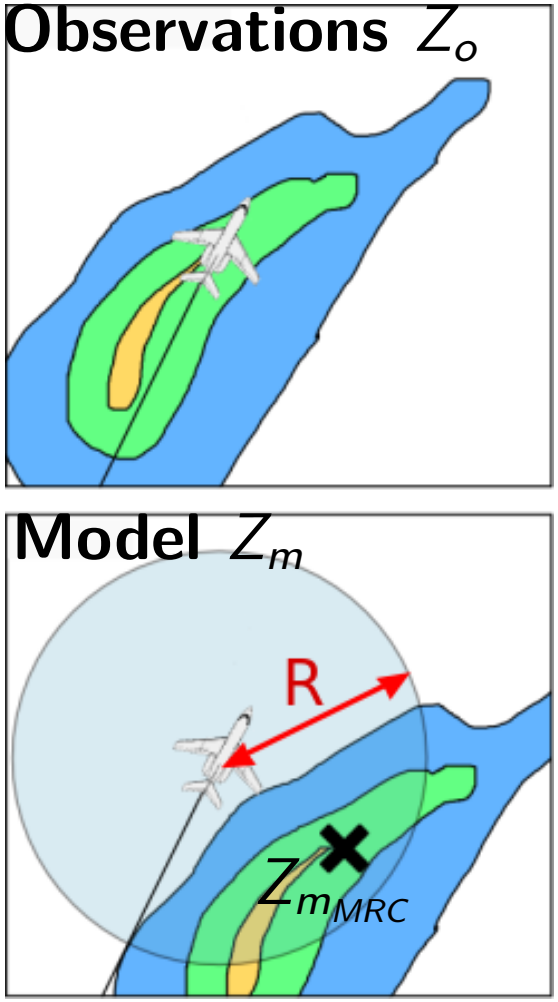
Best estimate of *RH* given the observed vertical profile Z_o

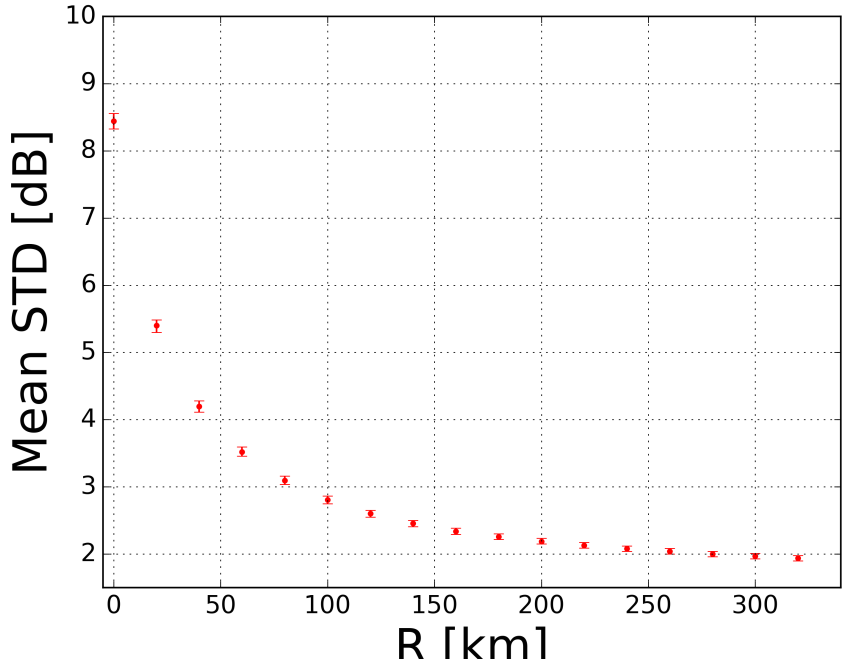
- Use of the RASTA forward operator
- Caumont et al. 2010, Wattrelot et al. 2014





MRC method: size of the neighborhood simulation domain R?





R = 160 km

- $\overline{STD(Z_o - Z_{m_{MRC}})}$, with $R \leq 160$km