GNSS RO Quality Control in NWP

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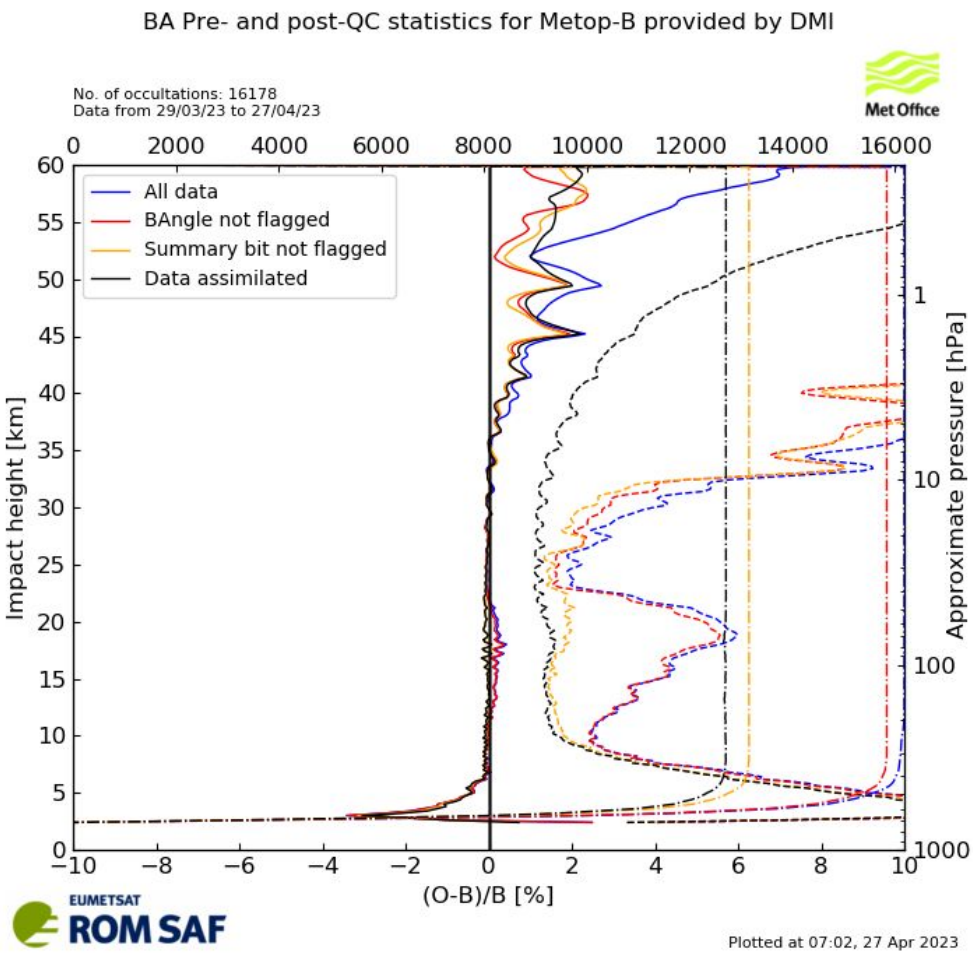
Why Quality Control in Data Assimilation?

- A crucial activity is understanding the errors in the available observations.
  - A typical way to construct an analysis is to weight the observations and background forecast according to their respective errors (e.g., Rawlins et al. 2007).
  - This assumes that the errors in the observations follow a gaussian distribution with negligible biases (Lorenc 1986).
- Some observations are affected by much larger errors and need to be removed in order to produce a good analysis,

  -- process of quality control (QC).

ROM SAF near-real time (NRT) monitoring before and after QC



Objectives and outline

1. Catalogue QC methods of bending angle RO assimilation used for DA by NWP centres within EUMETSAT member states and in other major NWP centers.

2. Implement the QC methods in Joint Effort for Data assimilation Integration (JEDI)

3. Compare and provide an assessment of the considered methods

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1. **Catalogue QC methods of bending angle RO assimilation used for DA by NWP centres within EUMETSAT member states and in other major NWP centers.**
    - Common themes:
        - Preliminary/Sanity checks
        - Background check
        - **Super Refraction QC**
    - Unique themes
        - VarQC
        - Other (1DVar etc…)

2. Implement the QC methods in Joint Effort for Data assimilation Integration (JEDI)
    - Ben Ruston, poster 2, 1-B

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Super Refraction QC

Center	Name	Description	Equation	Default threshold	JEDI Parameter
MF	**MF**	check for sharp refractivity gradients and its second derivative in **observations**		any threshold is violated	•gradient thresholds •second Derivative •max check height
NRL	**NRL**	check difference between the maximum and minimum of simulated bending angles in a 1 km layer	$\max(\alpha_{model}) - \min(\alpha_{model})$	> 0.005 rad	•threshold •variable to check •max check height •bin size
NCEP	**NBAM**	2-step methods based on the modelled refractivity gradient		a. reject obs whose impact parameter ≤ IHmodel(k+5) b. reject obs below the profile maximum	•steps to check •max check height •step 1 threshold •step 2 threshold •sharp gradient offset
ECMWF /MO	**Impp**	check vertical difference of modelled impact parameter between a given layer and the one below	dx	> 10 m	•threshold
MO	**MO**	Check the vertical gradient of the modelled refractivity is above some thresholds		$< -0.08\ \mathrm{N\ m^{-1}}$	•gradient threshold •sharp gradient

Data assimilation, Model and Experiment

- Experimental period: November 2022

- MO 6h forecast: ~ 10 km resolution/70 vertical layers

- RO observations:
  - Spire/Metop: ROM SAF processing
  - Other missions: NCEP GDAS

- Operator: MO bending angle 1d operator

- Same preliminary checks

- Super Refraction **Implementation in JEDI**
  - **MF** – Météo France
  - **NRL** – NRL
  - **NBAM** – NCEP
  - **Impp** – ECMWF/MO
  - **MO** – MO

```
- filter: GNSSRO Impact Height Check
  filter variables:
  - name: bendingAngle
  gradient threshold: -0.08
  sharp gradient offset: 600
  surface offset: 500
  action:
    name: set
    flag: srCheckMO
- filter: GNSSRO Impact Height Check
  filter variables:
  - name: bendingAngle
  gradient threshold: -0.08
  sharp gradient offset: 600
  surface offset: -1500
  action:
    name: set
    flag: srCheckMONOsfcoffset
- filter: GNSSRO Impact Height Check
  filter variables:
  - name: bendingAngle
  gradient threshold: -0.08
  sharp gradient offset: 0
  surface offset: -1500
  action:
    name: set
    flag: srCheckNOoffset
- filter: Obs Refractivity Gradient Check
  filter variables:
  - name: bendingAngle
  gradient min: -0.05
  gradient max: -1.0e-6
  second derivative: 0.0001
  max check height: 18000
  action:
    name: set
    flag: srCheckMF
- filter: Obs Refractivity Gradient Check
  filter variables:
  - name: bendingAngle
  gradient min: -0.05
  gradient max: 1.0e+10
  second derivative: 1.0e+6
  action:
    name: set
    flag: srCheckMF2
```

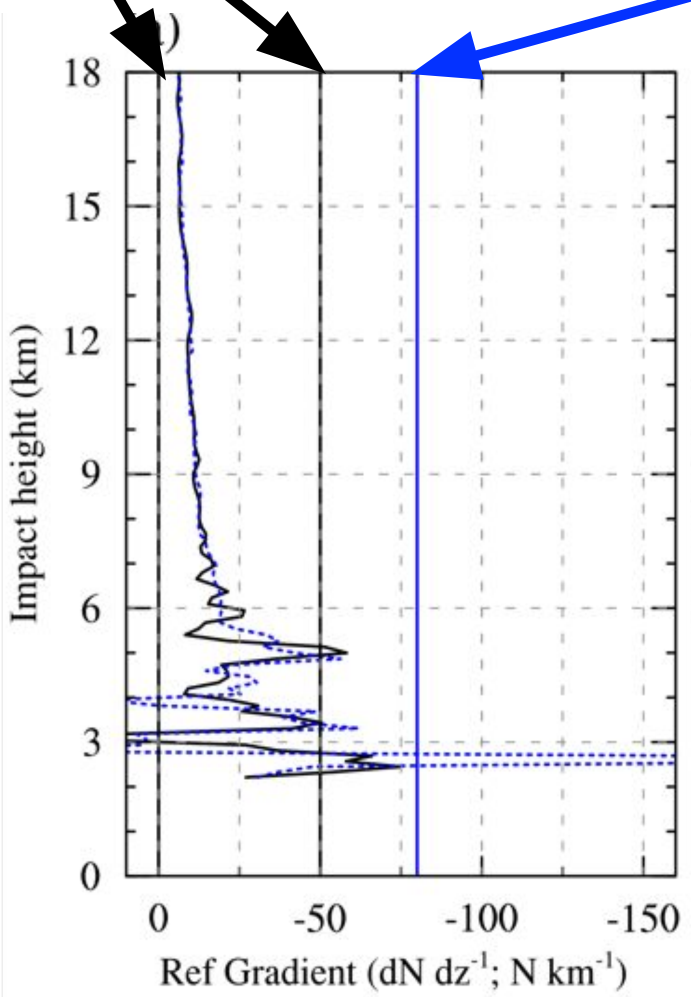
Sensitivity to Refractivity Gradient used by NWP centres

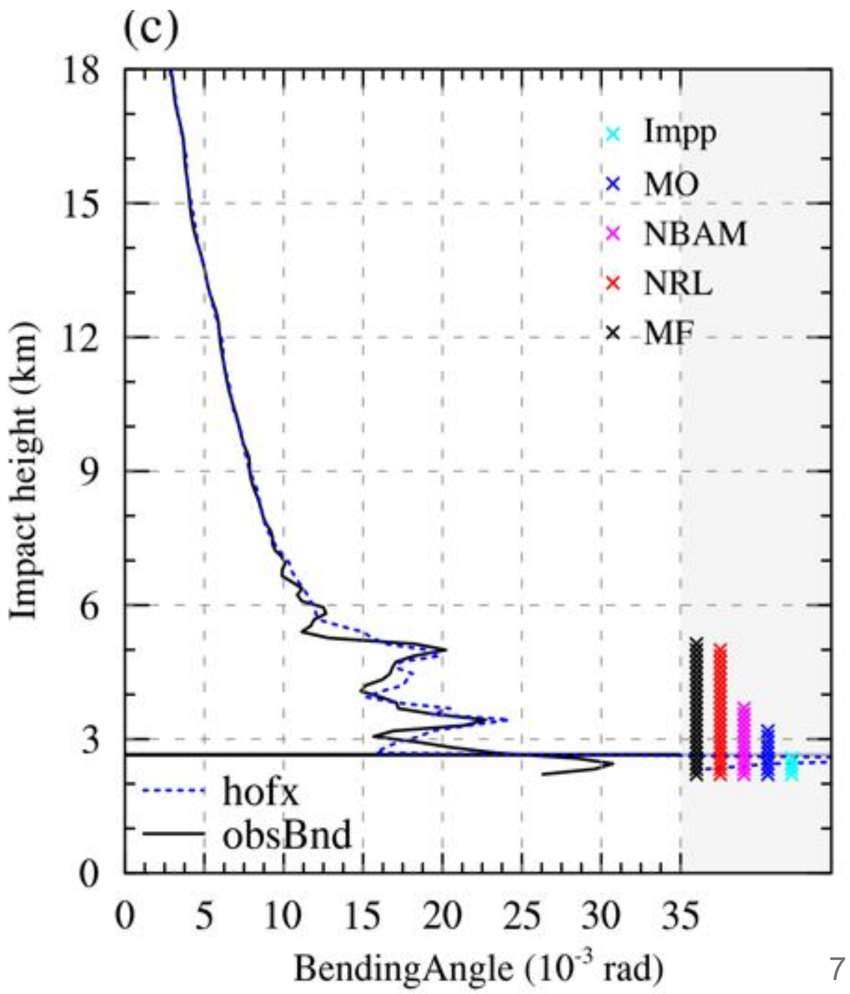
MF: $-10^{-6}\ \mathrm{Nm}^{-1} > \frac{\mathrm{d}N}{\mathrm{d}z} > -0.05\ \mathrm{Nm}^{-1}$

MO : $\frac{\mathrm{d}N}{\mathrm{d}z} < -0.08\ \mathrm{N\ m}^{-1}$

Black
-OBS

Blue
-modelled





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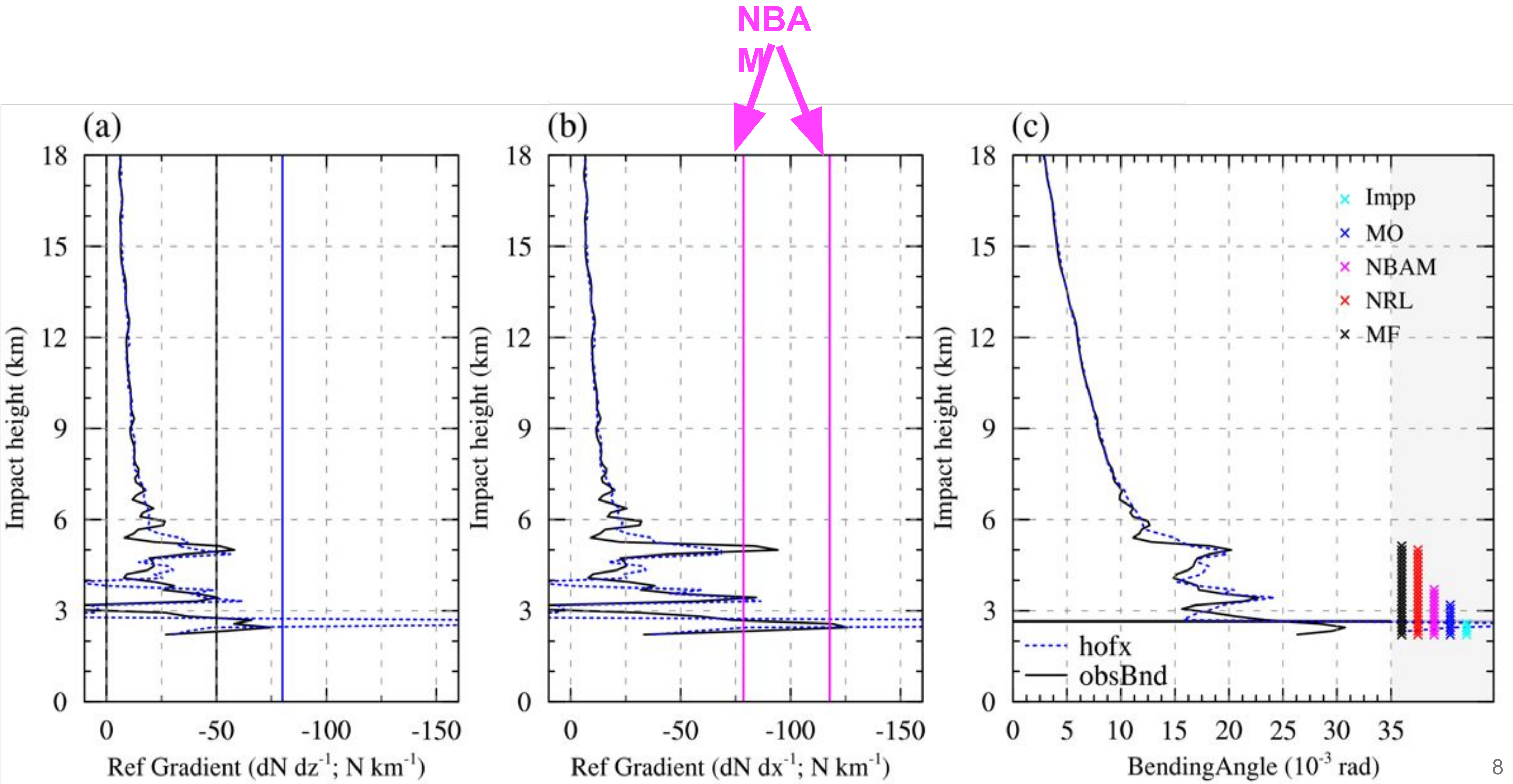
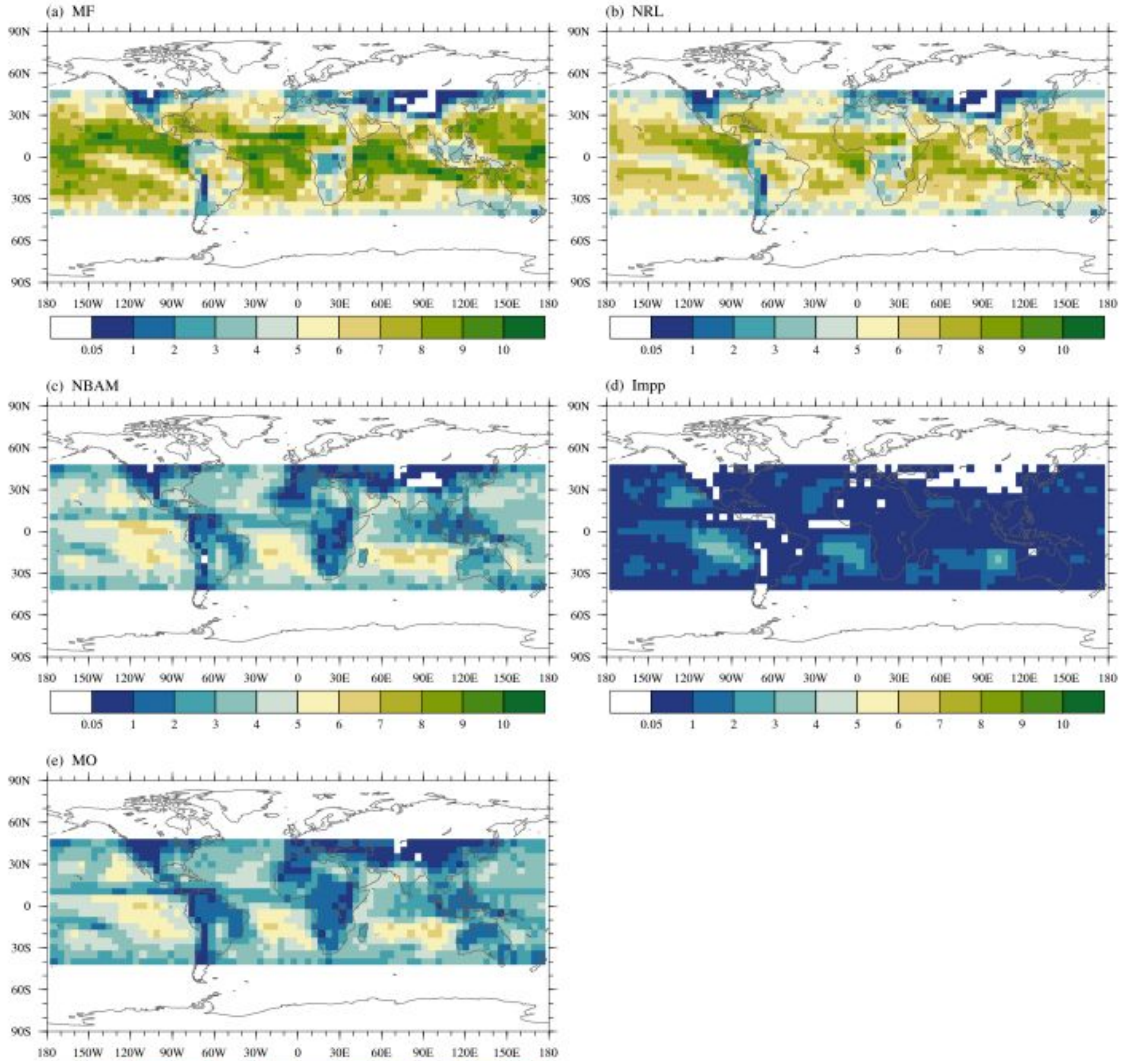
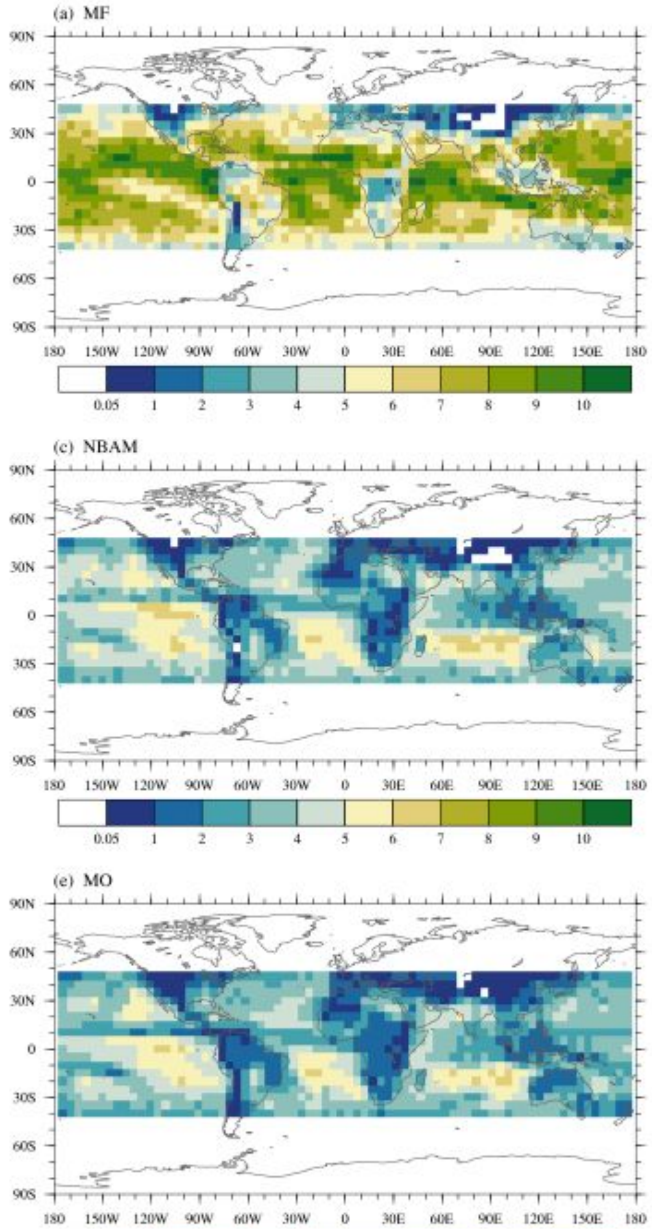


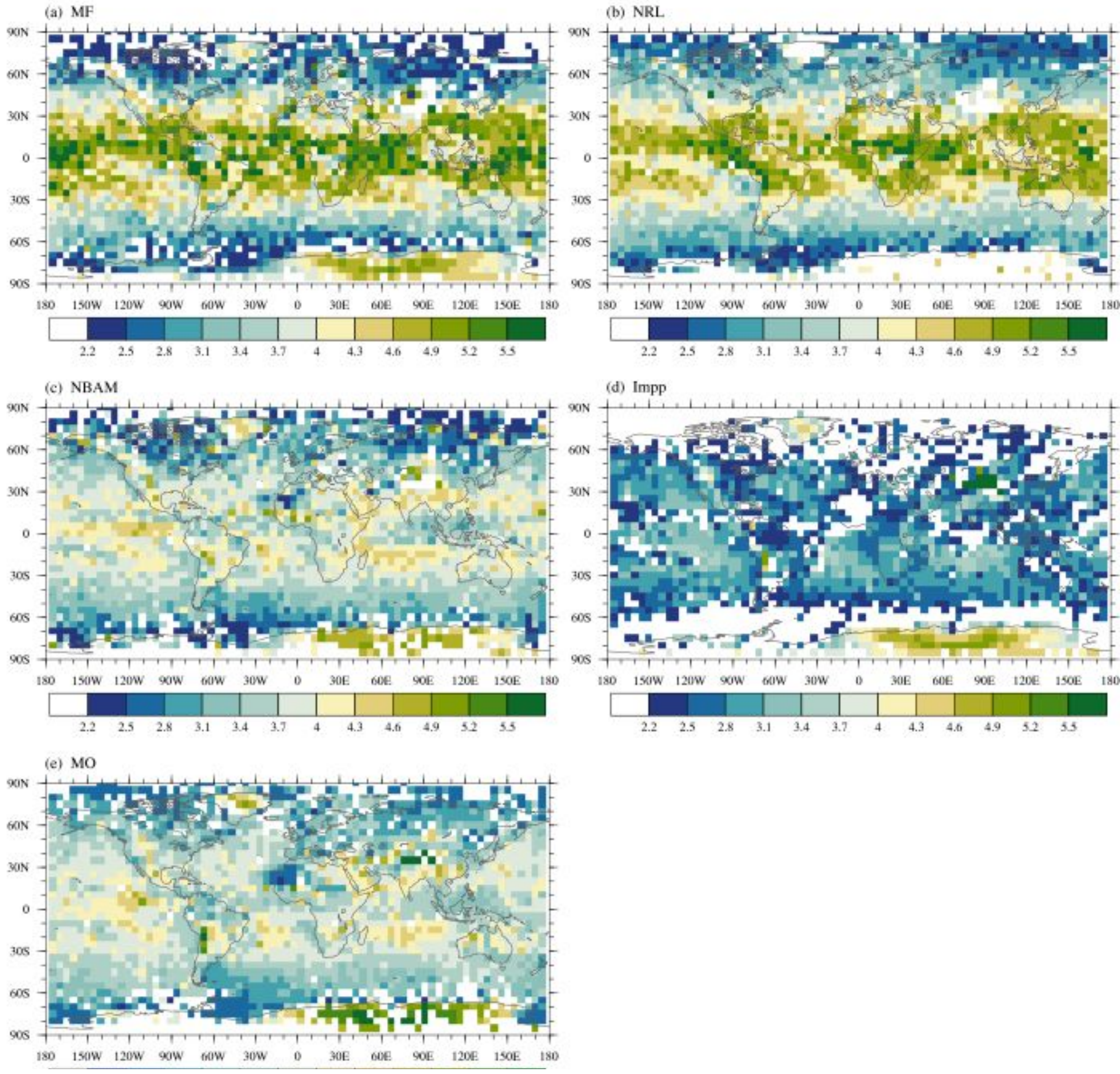
Comparison – COSMIC2 observation rejection



- **Impp(ECMWF)** rejects the least observations due to its <u>strict failure</u> threshold– impact parameter monotonicity (dx<10).
- **MF and NRL** reject the most observations due to its <u>strict passing</u> threshold, picking up noise of profiles.
- **MO and NBAM** produces the rejection pattern in consistence with the off west coast stratocumulus.

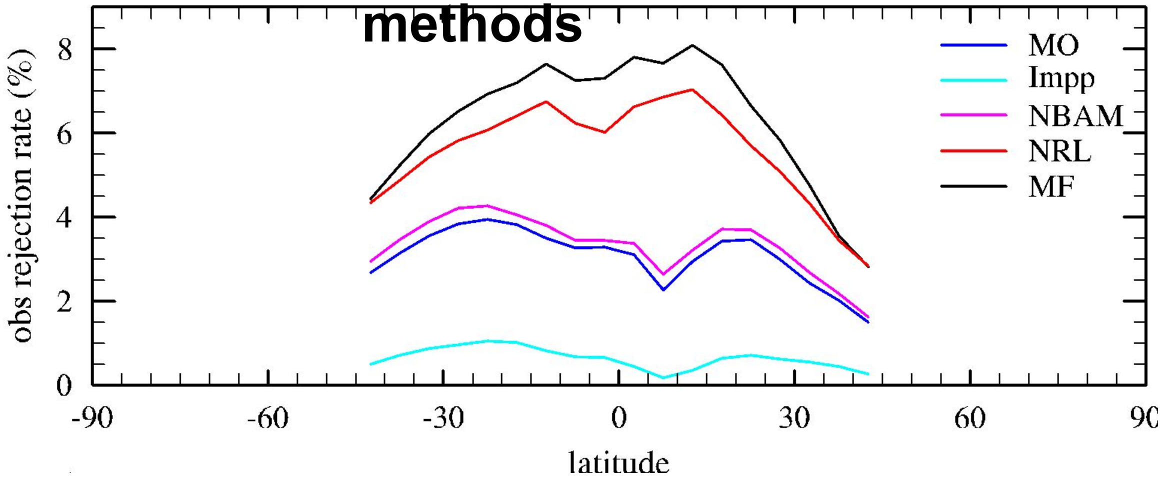
Comparison – COSMIC2 observation rejection



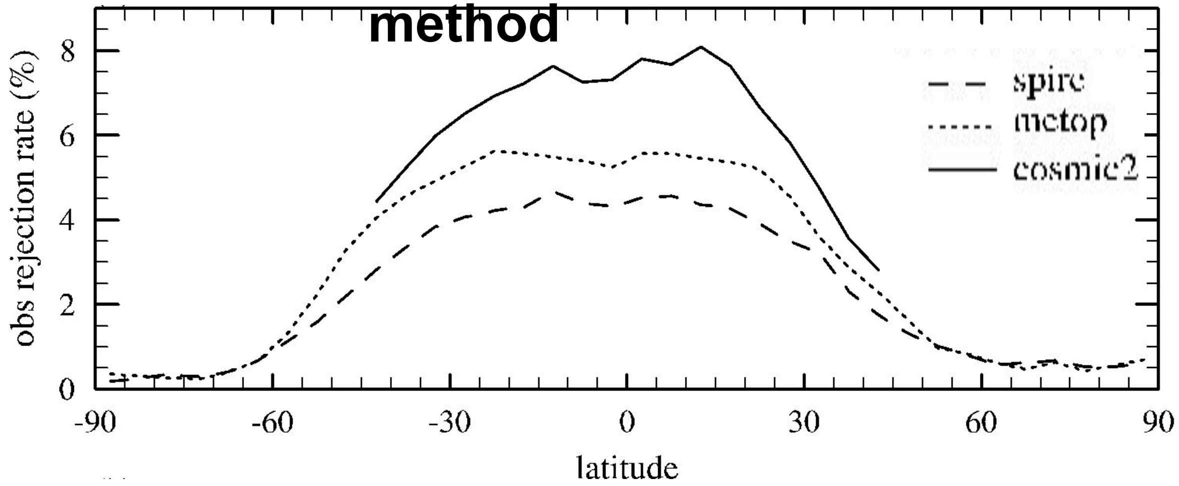


Comparison – zonal mean rejection rate

COSMIC2, all methods



3 missions, MF method

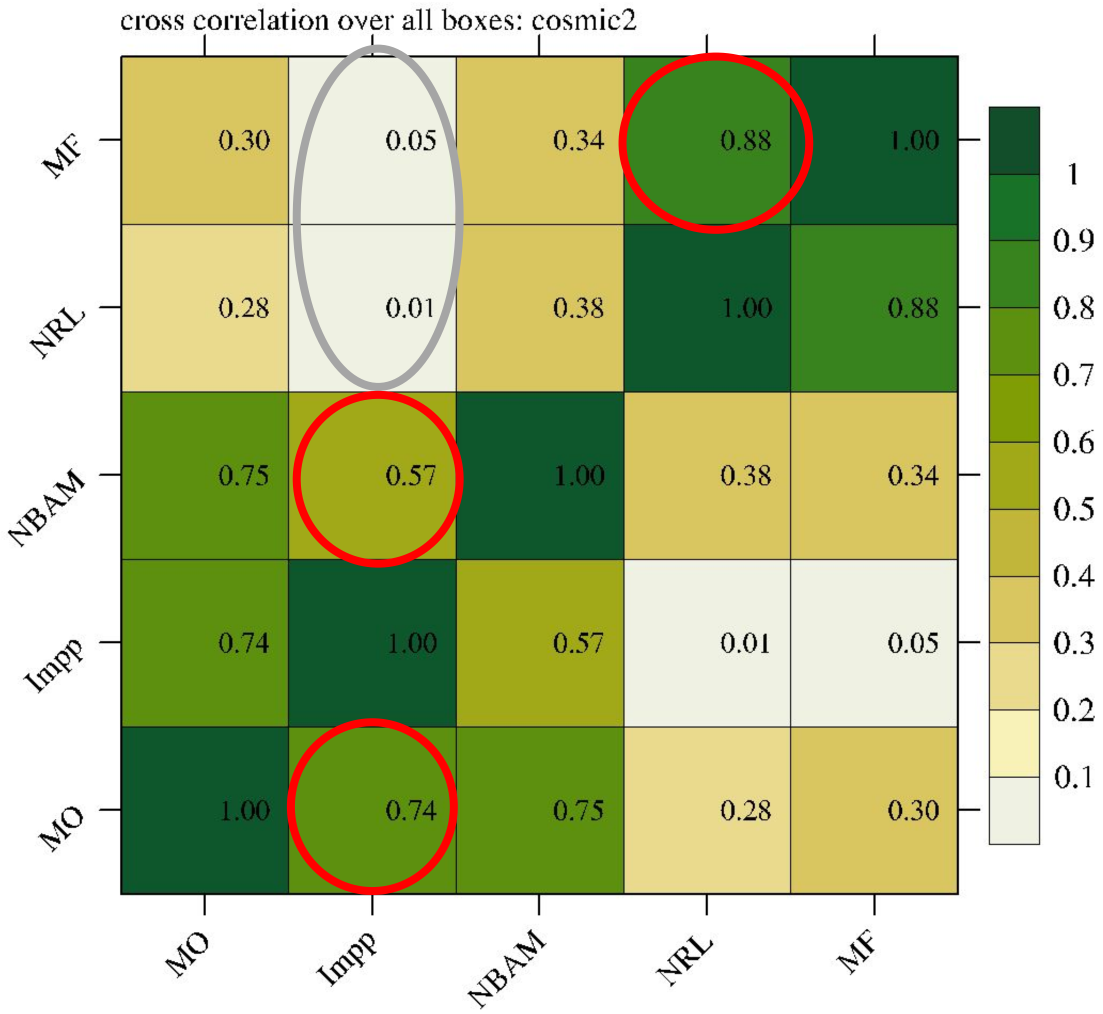


- **MF** and **NRL** rank the top two, and **Impp** the lowest one, in terms of rejecting observations

- **MF** shows the biggest range of rejection rate for the three missions, with the largest rate for COSMIC-2 and smallest for Spire.

- Due to different processing? MF detects SR/noise in the **observation space** by checking the refractivity gradient.

Correlation of methods

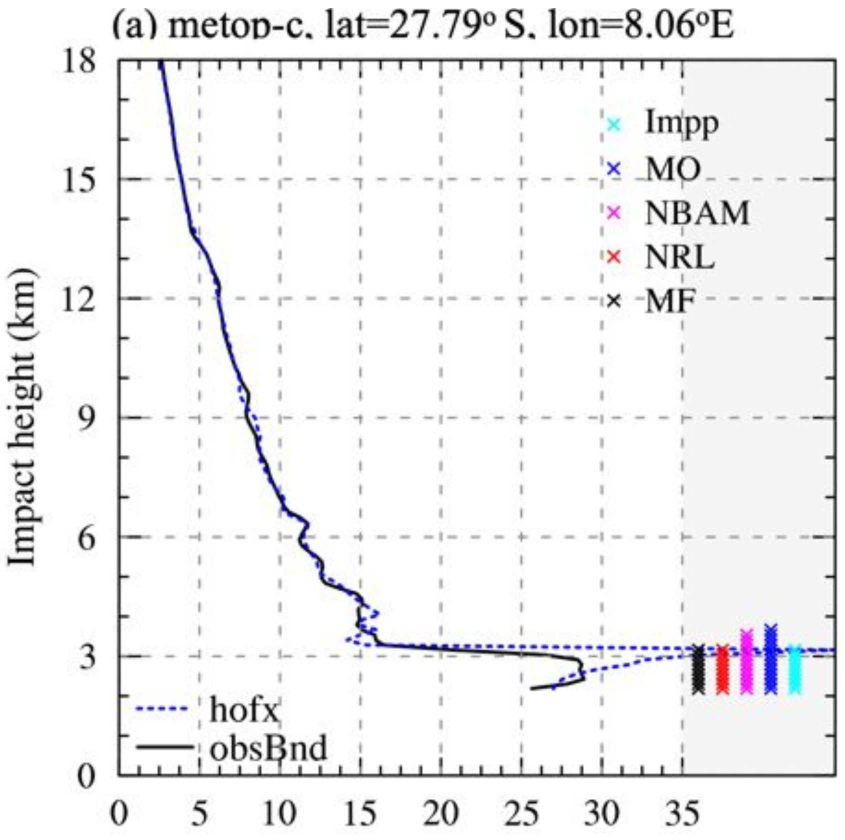


- **Impp** checks the monotonicity of modelled impact parameters.
- **NRL** checks the bending angle simulations
- **MF** checks the refractivity observation gradient.

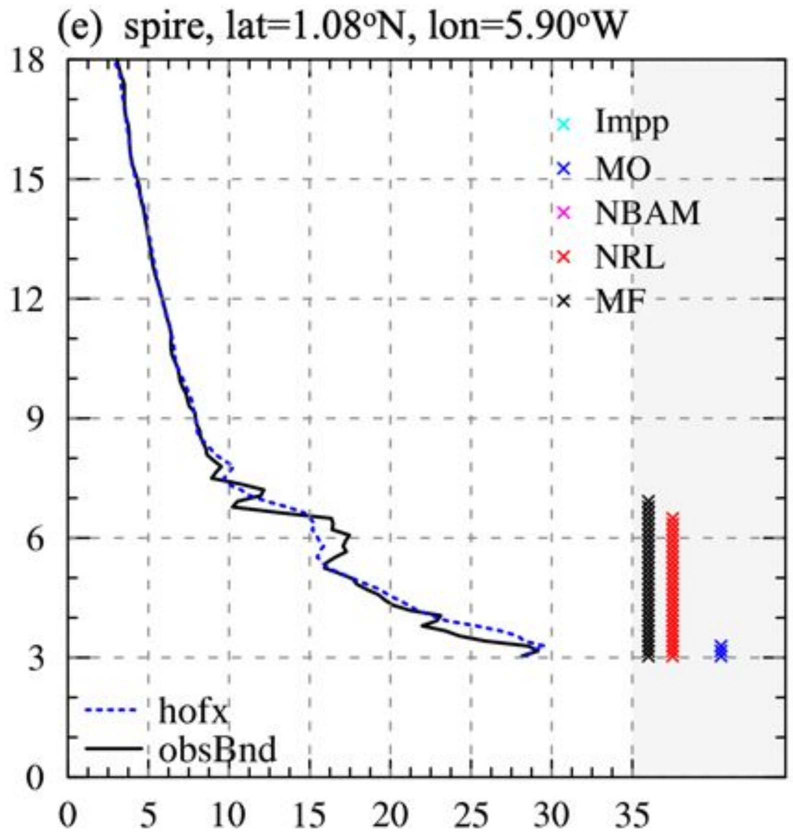
- **Impp** has the smallest correlation with **NRL and MF**;
- **Impp** correlates the best with **MO and then NBAM**.
- Correlation between **NRL and MF** are very high. This is because the two methods share the common strict thresholds of acceptance which checks noisy layers.

Sample Profiles

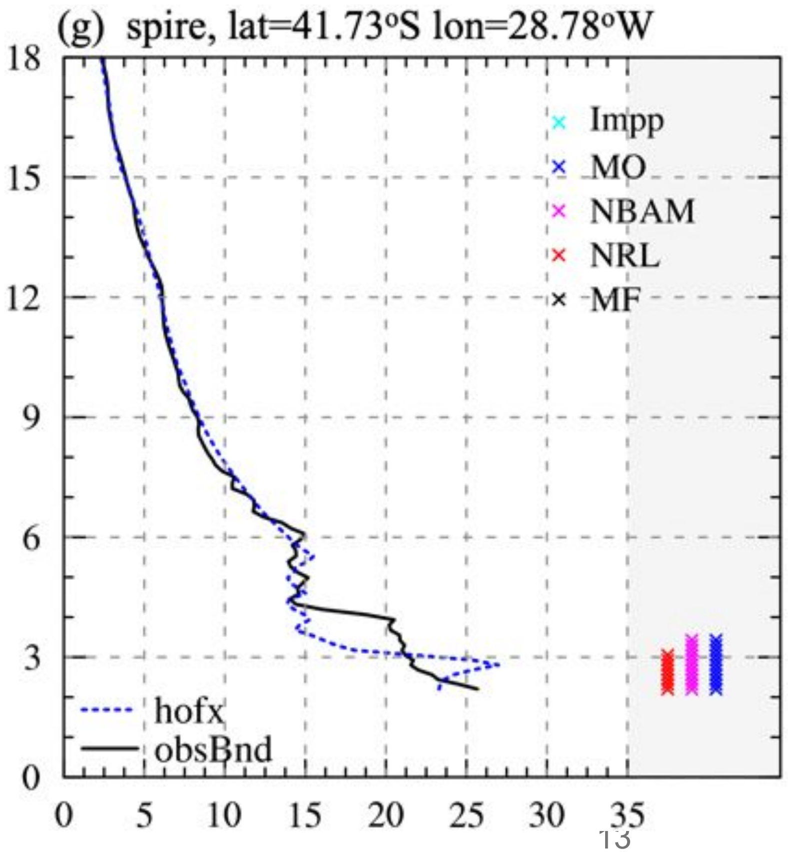
All methods produce similar SR



MF and NRL identifies noisy layers



Disagreement between model and Obs



Summary

- Large differences exist among NWP centers in the super refraction QC.
- Missions have their own characteristics.