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Retrieving Boundary Layer Humidity Using GNSS Radio Occultation and Passive Nadir Microwave Data

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Outline

- Super Refraction Layer (SRL)
- SRL: simple mathematical model
- Water vapor retrieval algorithm
- Radiosonde based simulation
- Summary
- Next steps
- Acknowledgment

SRL and its effects

https://petapixel.com/2021/03/06/floating-ship-3photographed-in-the-sky-off-the-u-k-coast/

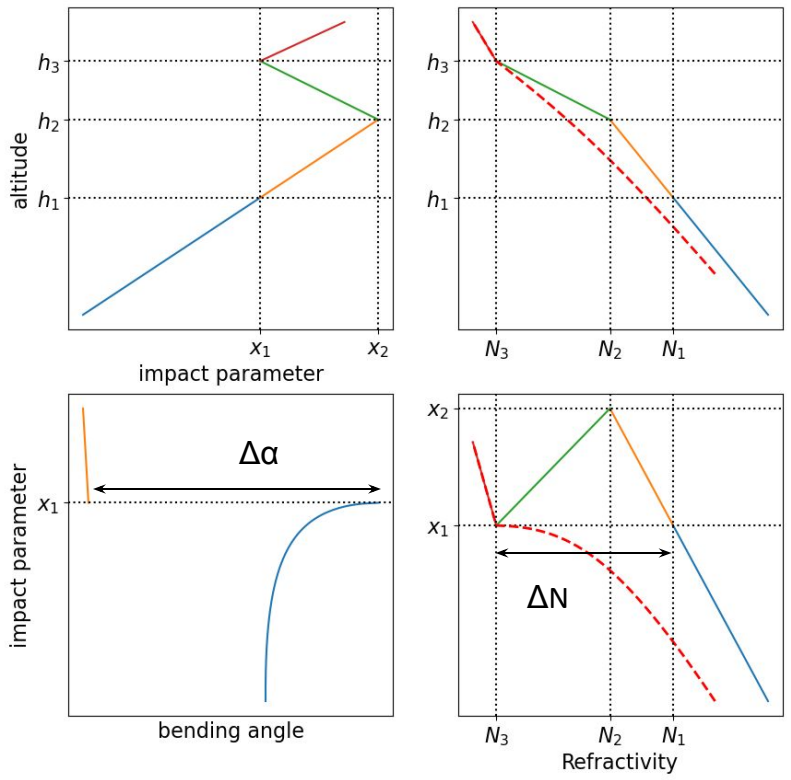
- SRL – super refraction layer – atmospheric layer where the refraction index gradient is so large

$$\frac{dn}{dx} > \frac{1}{R_{cur}}$$

  that it traps crossing rays.

- Responsible for "Fata Morgana" (mirage)
- It is known in radar to produce ghost targets
- In RO data processing it results in the negative refractivity bias

SRL: simple math model



We can learn a lot from a simple **three linear segment** model for refractivity as it can be fully traced analytically

1. Since the observation is made in impact parameter space the SRL generates a discontinuity at x1 for both bending angle and refractivity
2. The effect of SRL on the bending angle and thus on the refractivity retrieval can be evaluated and mitigated
3. For this model The SRL effect is controlled by a single parameter (see Xie et al, 2006)

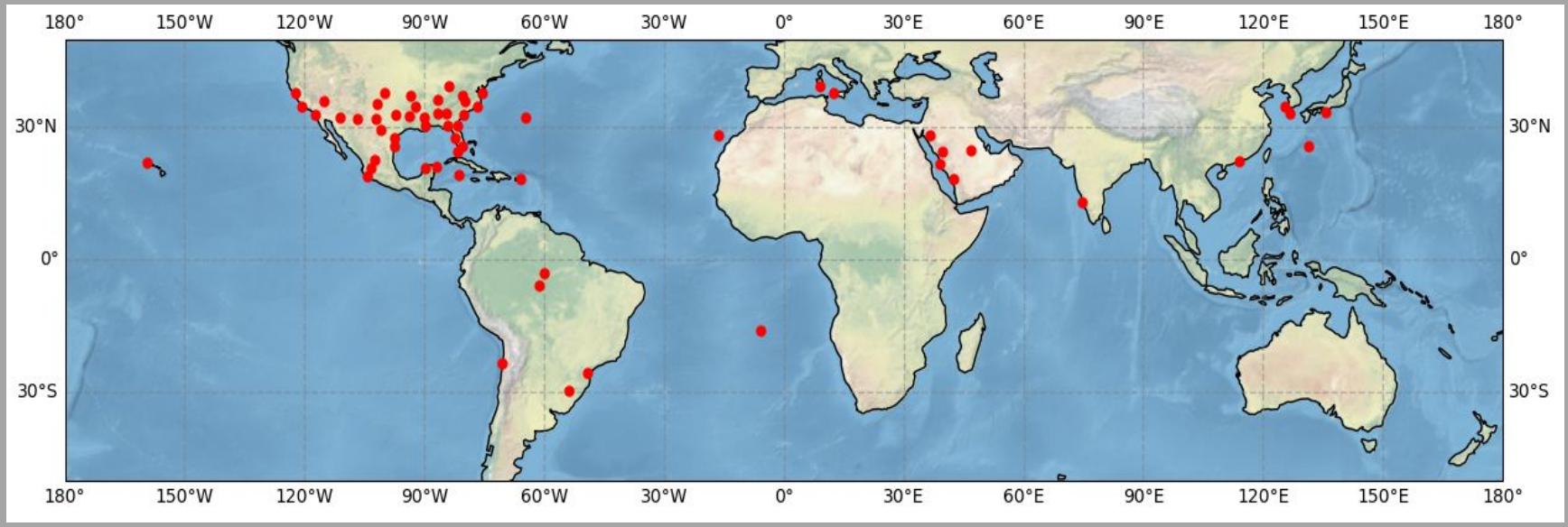
Water vapor retrieval

- The RO allows to retrieve a single parameter: refractivity, N;
- Water vapor retrieval requires to have estimate of the temperature profile, T;
- We use NWP to get the first guess of temperature profile;
- The water vapor mixing ratio, q, and pressure, p, are computed iteratively employing

$$N = \frac{p}{T}\left(k_1 + \frac{k_2}{T}\frac{q}{\varepsilon + q}\right)$$

- as well as hydrostatic equation;
- The MW radiance is used to adjust a part of the temperature profile below SRL;

Radiosonde based simulation



- A set of radiosonde profiles (238) from 61 locations between 40N and 40S were selected (both: day and night);
- Cases with multiple SRL have been identified and rejected;

Radiosonde data processing

Step 1 Identify SRL top, compute bending angle as a function of impact parameter;

Step 2 Ingest NWP data to produce the first guess;

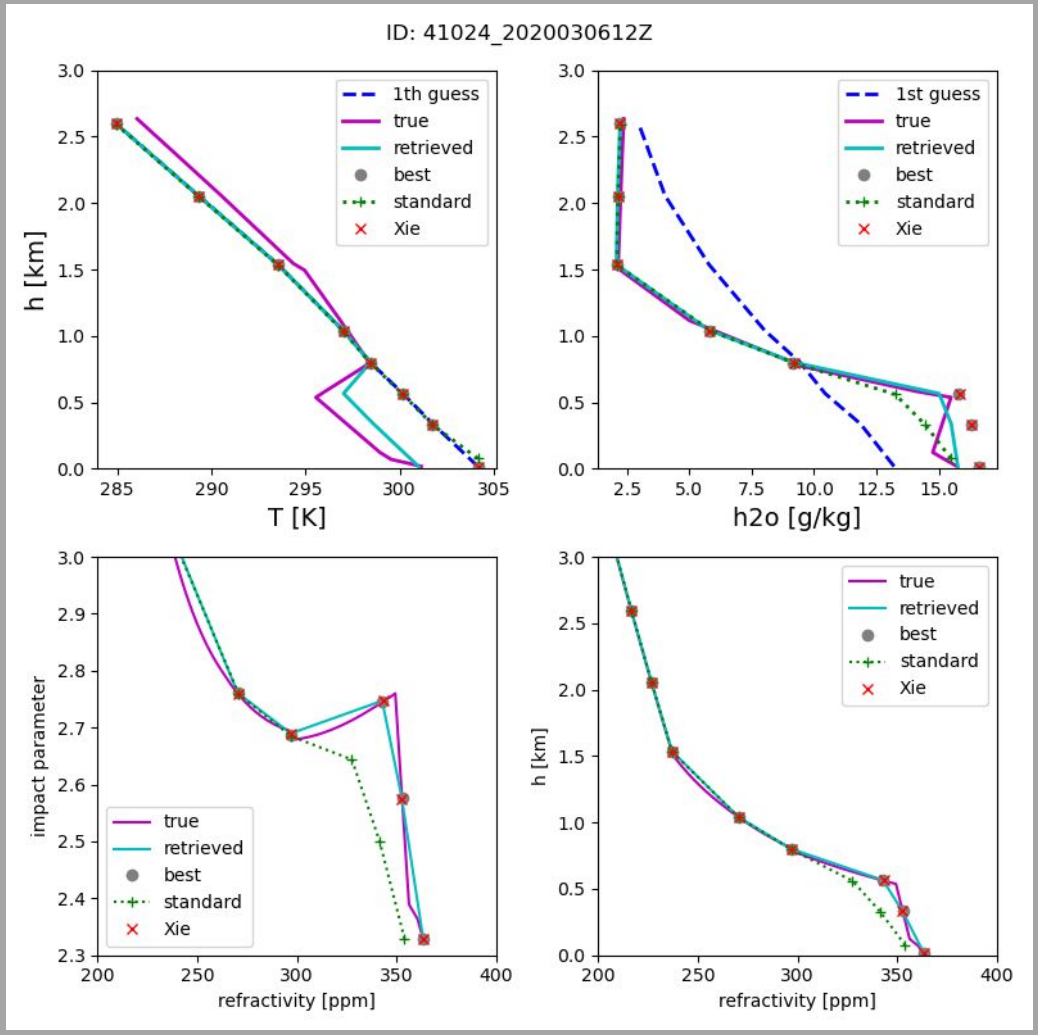
Step 3 Invert bending angle profile to compute effective refractivity;

Step 4 Run in-house SRL effect correction algorithm (similar to Xie et al, 2006) to obtain refractivity;

Step 5 Use optimal estimation that includes MW TOA radiance and refractivity profile to adjust temperature profile below the SRL top;

Single profile from WMO 41024

6 March 2020 12Z



1st guess – NWP only

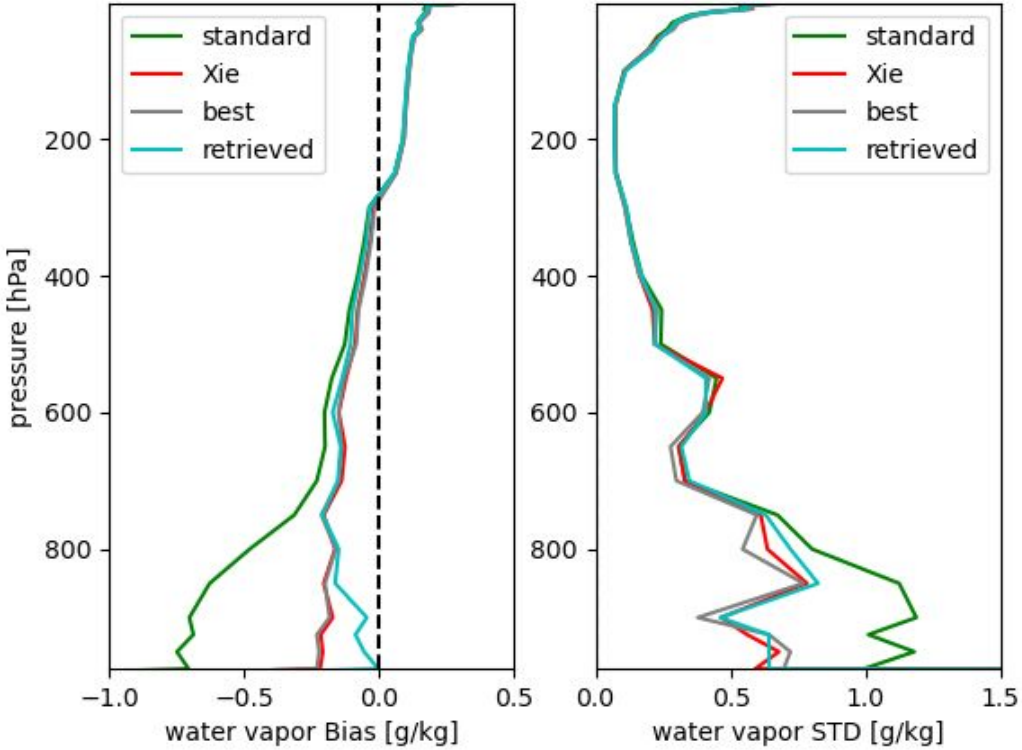
standard - no SRL correction

Xie - with SRL correction;

best - If refractivity profile is known;

retrieved - MW+SRL correction

Water vapor retrieval statistics:
Interpolated to a standard pressure grid



standard - no SRL correction

Xie - with SRL correction;

best - If refractivity profile is known;

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Summary

- We have developed an algorithm to mitigate the effect of SRL on the water vapor retrieval.
- The first results show a very good potential to retrieve water vapor using the NWP as the first guess.

- Known issues:
  1. the SRL parameterization has its weaknesses; for 5 of 238 cases the algorithm failed
  2. multiple SRL cannot be treated yet. we are exploring ideas based on the a simplified mathematical model of the SRL

Next steps

- Our goal is bring wave optics and start retrieval using phase and amplitude of the RO signal rather than bending angle
- Apply our algorithm to the real COSMIC2 data

- Collocation between MW and RO sensors will be discussed by Lucy Halperin in the her talk ”*Collocation Analysis of Radio Occultation Soundings and Passive Microwave Soundings for Profiling in the Marine Boundary Layer*”

Acknowledgment

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- Used data
  - ✔ NWP: https://www.ncei.noaa.gov
  - ✔ Radiosonde: http://weather.uwyo.edu
  - ✔ COSMIC-2: https://data.cosmic.ucar.edu