Improving the Accuracy of Near-Surface 3-D Radar Refractivity Retrievals

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Introduction & Motivation

- The radar refractivity (N) retrieval provides insights on high-resolution near-surface moisture, which is important to understanding convective and boundary layer processes.
- For further quantitative application, such as data assimilation, or to implement radar refractivity networks, there remains some unsolved data quality problems.

Understanding the problem of refractivity retrieval

Noisy phase difference (Δϕ) and refractivity (N) bias caused by unknown target heights (Ht) & vertical variation of refractivity (dN/dh)

- Revisiting the Fabry et al. (1997) assumptions:
  1. Selected point targets are are all aligned with the radar antenna height (Htarget = Htareal) on a flat Earth.
  2. The vertical profile of refractivity index (dN/dh) is zero everywhere.

But, in reality:
- Propagation changes: The radar beam path (R) is affected by vertical gradient of refractivity (dN/dh).
- Targets are at different heights (and so is the terrain).
- Htarget ≠ Htareal; dN/dh biases ΔN

- Quantifying the problems:
- Rewrite the phase simulator (Park and Fabry, 2010):
  - the horizontal variation of N(φ,θ) & dN/dh
  - range (R) variation caused by dN/dh variation

\[ R = D + ΔN \left( H_p - H_{taper} - H_{rad} \right) \]

- Quantifying the Δϕ noisiness

- Quantifying the N bias

Let’s solve the problems!

Solution from returned powers

Estimate target height (Ht) and dN/dh

- Assumption: ‘Point’ target, radar antenna main beam pattern is described as a Gaussian.
- Center of Gaussian distribution = Estimated target elevation relative to radar.

Estimate target heights (Ht)

- Example of a fixed target from observation
  - Power (P) observed at successive elevation (θ).
  - Fit with radar antenna main beam pattern.
  - Find the representative elevation (θ) of the target.

Estimate dN/dh

- Radar beam path is affected by dN/dh.
- For a given target, the returned power changes temporally with dN/dh.

\[ \Delta P = \frac{P(θ)}{P(θ_{max})} \]

Solution from phases at dual-polarizations

Quality of phase: Rethink ‘point target’ assumption

- For a given ‘point’ target, the phase difference variations at horizontal and vertical polarization are assumed the same.
  \[ Δϕ_h = Δϕ_v = (ϕ_0 - ϕ_0) = (ϕ - ϕ_0) = 0 \]
- If not, it might be the ‘extended complex’ target. At the same time, the power also shows evidences of destructive interference.

30-second message

- The phase change in time of ground echoes is a noisy field, not predicted by the simple assumptions of Fabry et al. 1997.
- Dual-polarization data at multiple elevations provides information on the vertical gradient of refractivity (dN/dh) and the representative target heights (Ht), which are key factors that affect the quality of phase used for refractivity retrieval.
- By taking them into account, the noisiness of the phase difference are expectedly to be reduced and the bias of retrieved refractivity can be estimated. New data processing flow will be developed to provide a near surface 3-D refractivity map, which consists a 2-D horizontal refractivity map at given height and temporal dN/dh variation.

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