Can Current Hyperspectral Infrared Sounders Capture the Small Scale Atmospheric Water Vapor Spatial Variations?

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1. Motivation

- Most InfRared(IR) sounder data used by NWP are over the ocean and in clear skies, especially for water vapor absorption channels. Limited water vapor absorption IR radiances over land are assimilated into NWP.

- The question is **Can Current Hyperspectral Infrared Sounders Capture the Small Scale Atmospheric Water Vapor Spatial Variations?**

Detailed Questions?

1.How large is the sub-footprint moisture spatial variation for a given hyperspectral IR sounder resolution? Does the hyperspectral IR sounder sub-footprint moisture variation have seasonal, regional and diurnal characteristics?

2.What are the implications of sub-footprint moisture variations on the applications of the current hyperspectral IR sounder water vapor channel radiances for nowcasting and data assimilation in NWP models?

3.What is the required resolution for future hyperspectral IR sounders to depict small-scale water vapor variation for various applications?

2. Data

- AHI Water Vapor radiance measurements along with cloud mask products from one year (2016) have been used (The spectral resolution function is shown in Figure 1).
- Hyperspectral IR sounders Water Vapor radiance measurements with different spatial resolutions (Listed in Table 1) are simulated from three AHI/H8 water vapor absorption bands radiance with 2 km resolution (Nadir).
- To avoid the influence of large zenith angel, limited AHI measurements with selected region are used (See Figure 2).

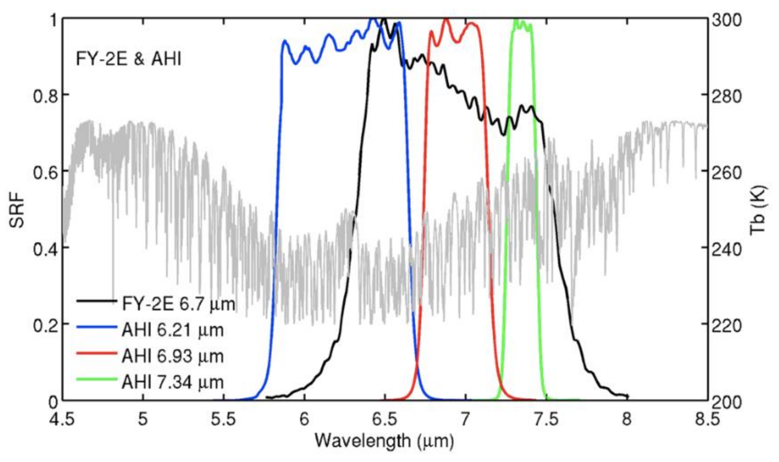


Figure 1. SRFs (spectral resolution function) of water vapor absorption bands for /AHI/ Himawari-8

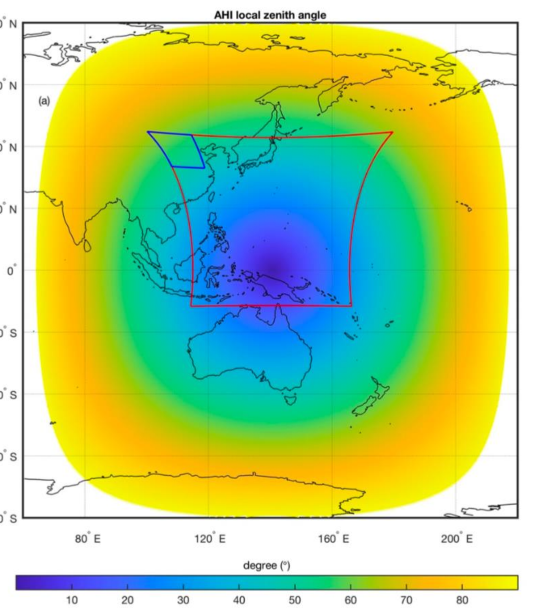


Figure 2. The selected study region (the red frame) overlaying a LZA (Local zenith angle) image, along with a smaller north China region (the blue frame) to represent specific coverage over land

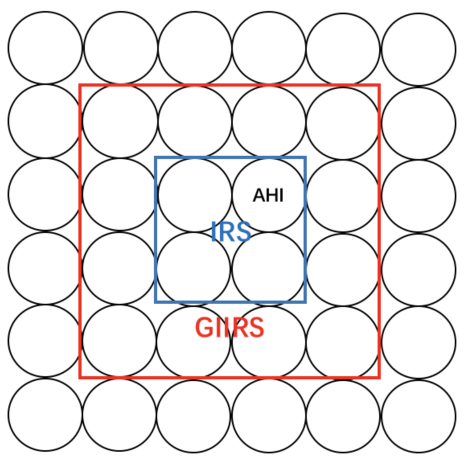
Table 1. Spatial resolution of Hyperspectral IR sounders used in the study

Hyper-sounder	FY4A-GIIRS	AIRS/CrIS/HIRAS	FY4B-GIIRS/ IASI	Future-GIIRS	MTG-IRS
Spatial- resolution	16 km	14 km	12 km	8 km	4 km

3. Methodologies

Hyperspectral IR sounders Water Vapor radiance measurements with different spatial resolutions are simulated from three AHI/H8 water vapor absorption bands radiance with 2 km resolution (Nadir). Like averaged radiance of 16/4 AHI pixel could represent the radiance from GIIRS/IRS.

Conceptual graph



BT variations (BTV) is used to describe Sub-footprint atmospheric moisture spatial variations for the given IR sounder footprint

$BTV = BT_{max} - BT_{min}$

BT difference between the warmest and coldest pixels within the sounder' footprint

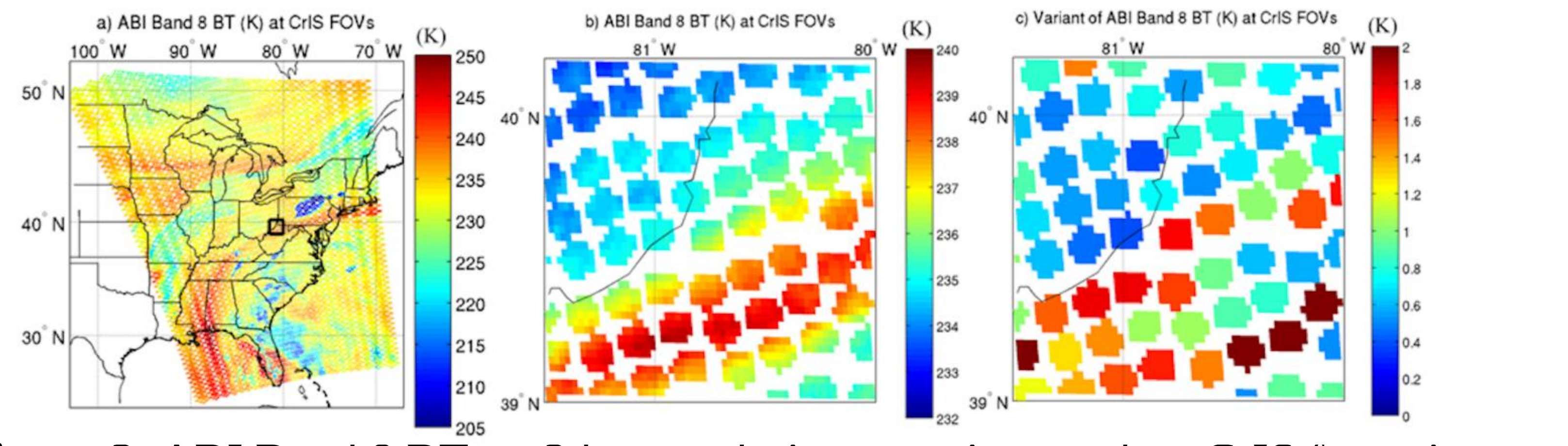


Figure 3. ABI Band 8 BTs at 2 km resolution superimposed on CrIS footprints for a CrIS granule and the zoom-in of ABI band 8 BTs from a small clear sky area depicted in the black box in the left panel, along with the CrIS sub-footprint BTVs at 18:22 UTC on May 15, 2018.

4. Results and Findings

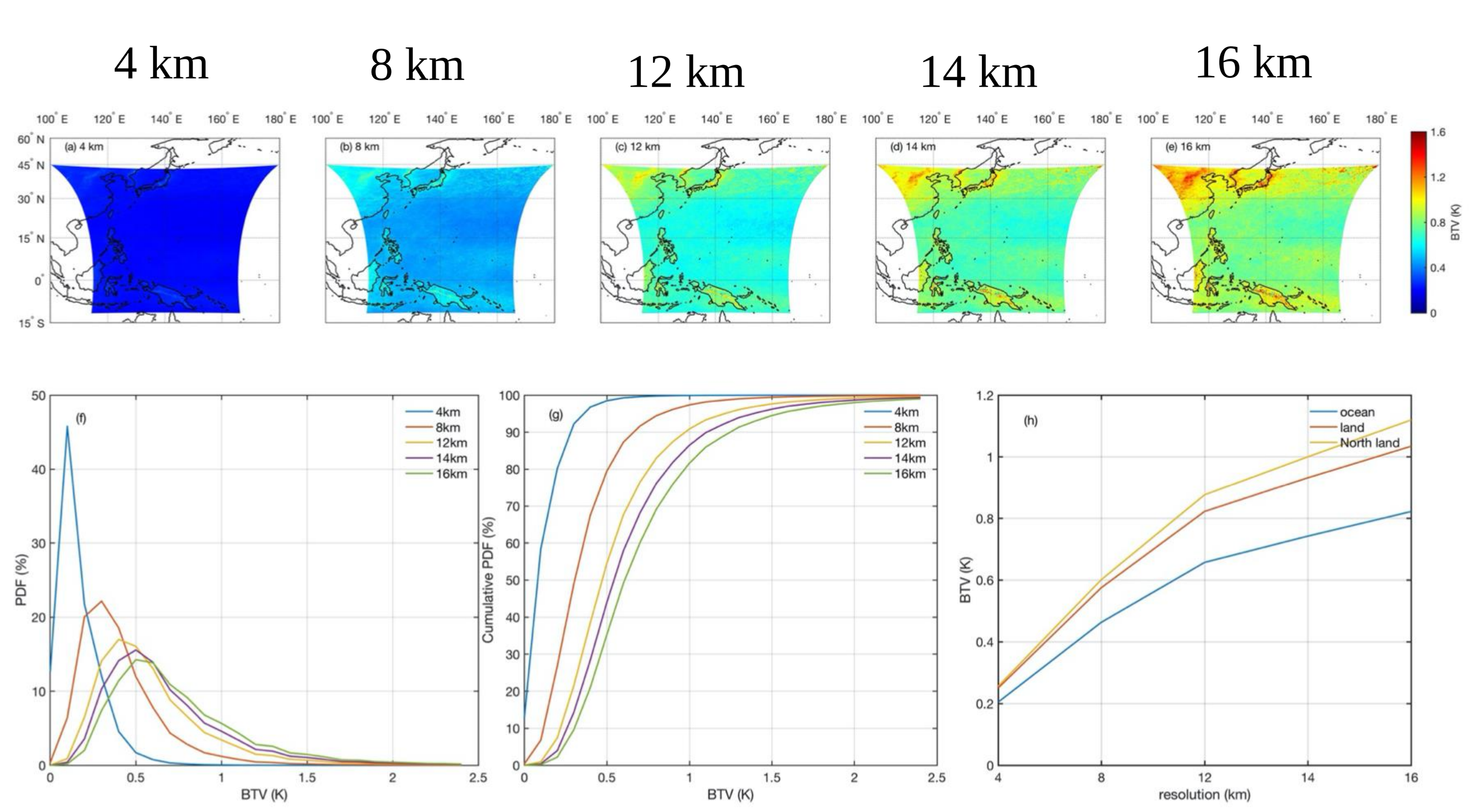


Figure 4. Annual averaged sub-footprint BTV images for spatial resolutions between 4 and 16 km (top row) for AHI Band 8 (6.28 µm band) along with the probability distribution and the cumulative probability distribution of sub-footprint BTV (lower left/middle panel), and the annual averaged BTVs for three regions including ocean, land and the northern land region

Conclusions:

(1) BTV over land > over ocean
(2) BTV > IASI observation error (0.2~0.3K)
(3) upper tropospheric moisture (Band 8) has a slightly larger sub-footprint BTV Slight seasonal differences. No noticeable diurnal differences (Not shown)
(4) The sub-footprint BTVs should be considered in data assimilation, e.g. quality control or estimates of scene-dependent observation error covariance matrix

Reference:

Di, D., Li, J., Li, Z., Li, J., Schmit, T. J.,& Menzel, W. P. (2021). Can current hyperspectral infrared sounders capture the small scale atmospheric water vapor spatial variations? *Geophysical Research Letters*