Exploring the Ice Scattering Signal of the GMI 166 GHz Channel

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MICROWAVE RADIOMETRY: ICE SCATTERING

Passive microwave imager channels in the 37 to 89 GHz range have long been used to detect precipitation-sized ice particle scattering signatures in clouds. Dual polarization plays an important role in distinguishing between scattering signatures and other background variability, as demonstrated by Spencer et al. (1989), Petty (1994), and others.

GPM MICROWAVE IMAGER (GMI)

The GMI is the first satellite radiometer to possess dual-polarized channels at 166 GHz. These high-frequency channels are more susceptible to emission and attenuation by cloud liquid water and water vapor lower-frequency channels, but are also more sensitive to ice scattering. This research studies the ice scattering information contained in the 166 GHz channels compared to the historically used 85/89 GHz channels on previous sensors. A 166 GHz scattering index is developed to examine the characteristics of the 166 GHz scattering signature in cold-season precipitating cloud systems over the North Atlantic Ocean and the Great Lakes regions. Pre-GPM A-Train radar/radiometer convective snow analyses are also shown to provide valuable context for GPM precipitation retrievals. High-frequency scattering signatures for different snowfall modes are also presented.

SHALLOW CONVECTIVE SNOW DETECTION (PRE-GPM)

Case Study: A-Train Observations (*Fig. 1*)

- Cold-air outbreak interacting with open ocean
- Intense snowfall production possible
- Can contain significant cloud liquid water
- 89 GHz scattering not very significant
- Radiometer precipitation retrievals struggle
- Further studies needed to improve retrievals for this unique cold-season precipitation type

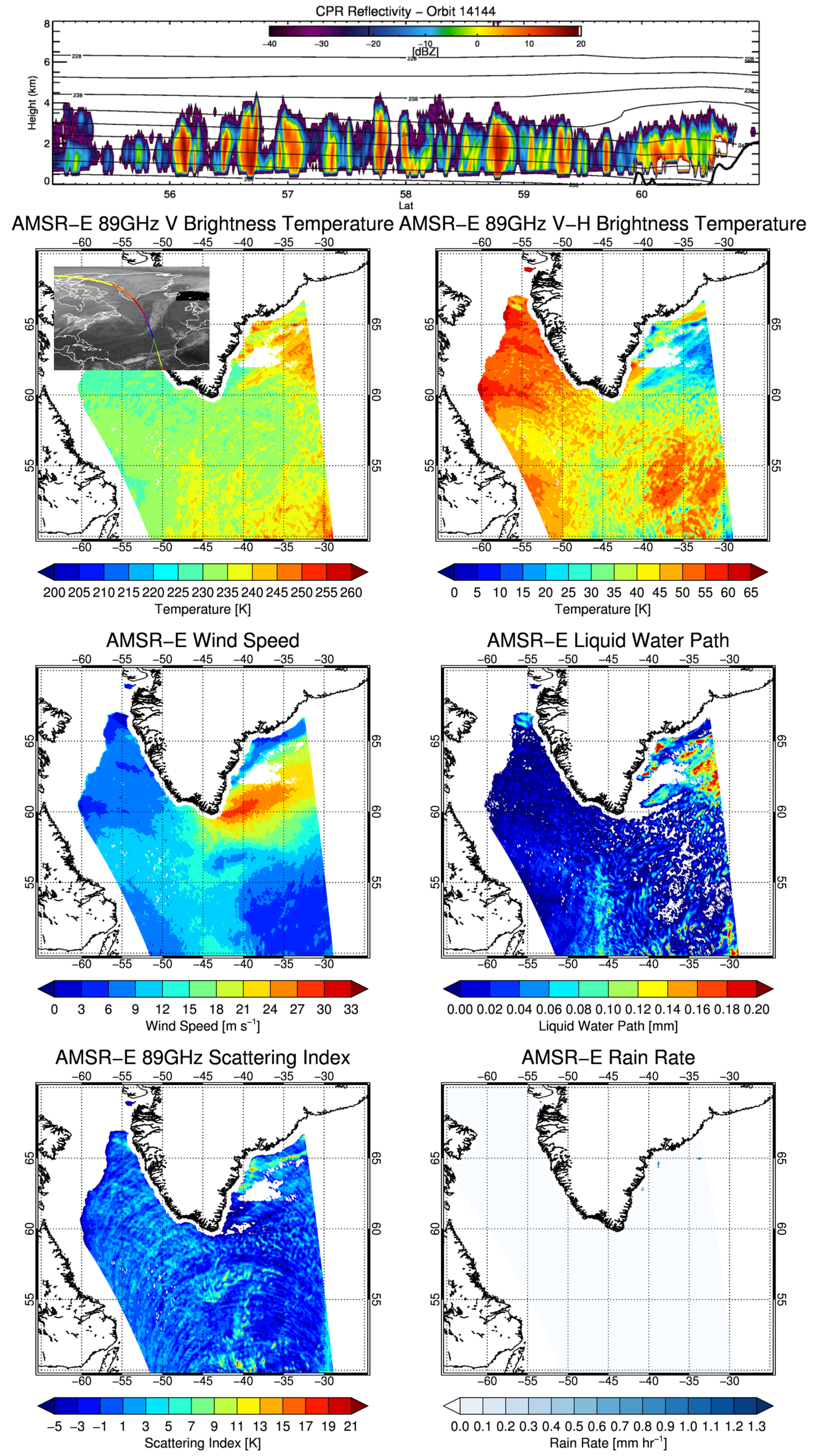

Fig. 1: CloudSat reflectivity profile (top), AMSR-E L2A T_B89 (2nd row), L2B wind speed and liquid water path (3rd row), 89 GHz scattering index (bottom left; from Petty 1994), and surface rain rate (bottom right; GPROF) for a convective snow event near Greenland (1458Z 24 Dec 2008).

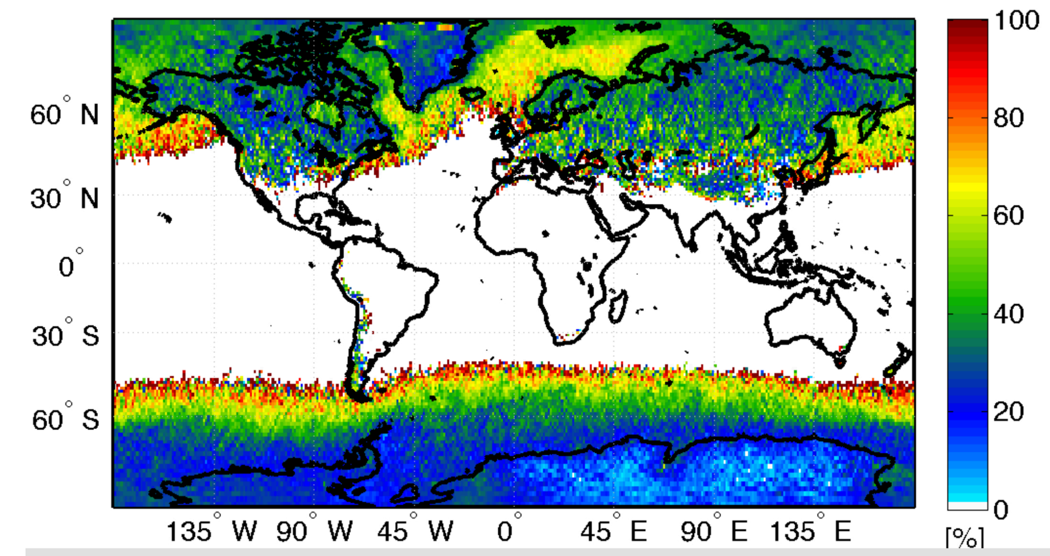

Fig. 2: Shallow cumuliform snow fraction using 2006-2010 CloudSat dataset (see Kulie et al. 2016 for further details)

A-Train: Global Convective Snow

- Ubiquitous global snowfall mode (*Fig. 2*)
- Informs where it occurs, frequency of occurrence, and estimated fraction of annual snowfall accumulation. *Excellent independent GPM evaluative dataset.*
- Typically associated with distinct radiometric signatures. Scattering signature not correlated to snowfall rate - especially higher snowfall rates – unlike deeper synoptic snowfall events (*Fig. 3*).

GPM Questions

- What is the GPM radar + radiometer algorithm performance in regions prone to shallow convective snow as indicated by A-Train observations?
- Additional scattering information from 166 GHz obs for convective snow?
- Will a 166 GHz scattering index be useful to isolate scattering signature (see next section)?

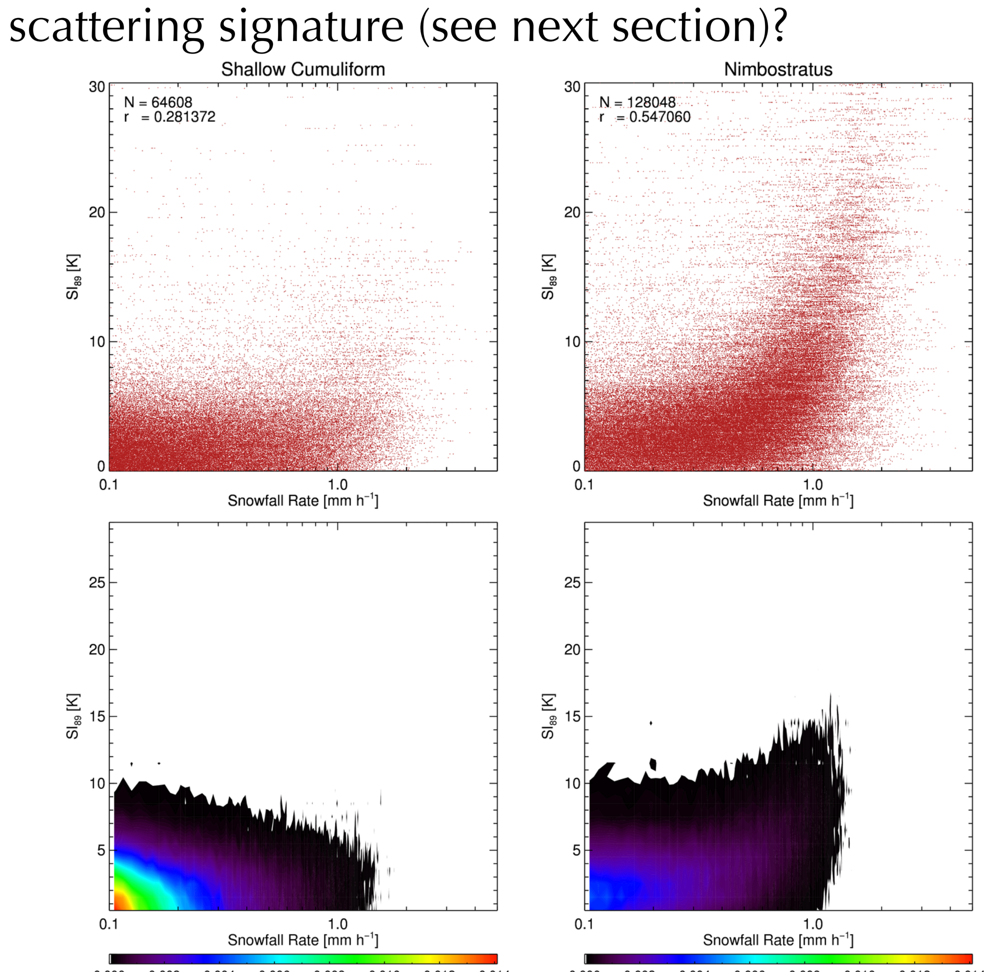

Fig. 3: 2006-2010 CloudSat snowfall rate vs. AMSR-E 89 GHz scattering index values for over-ocean convective and synoptic snowfall events in the North Atlantic region near Greenland.

89 AND 166 GHZ SCATTERING INDEX - GPM

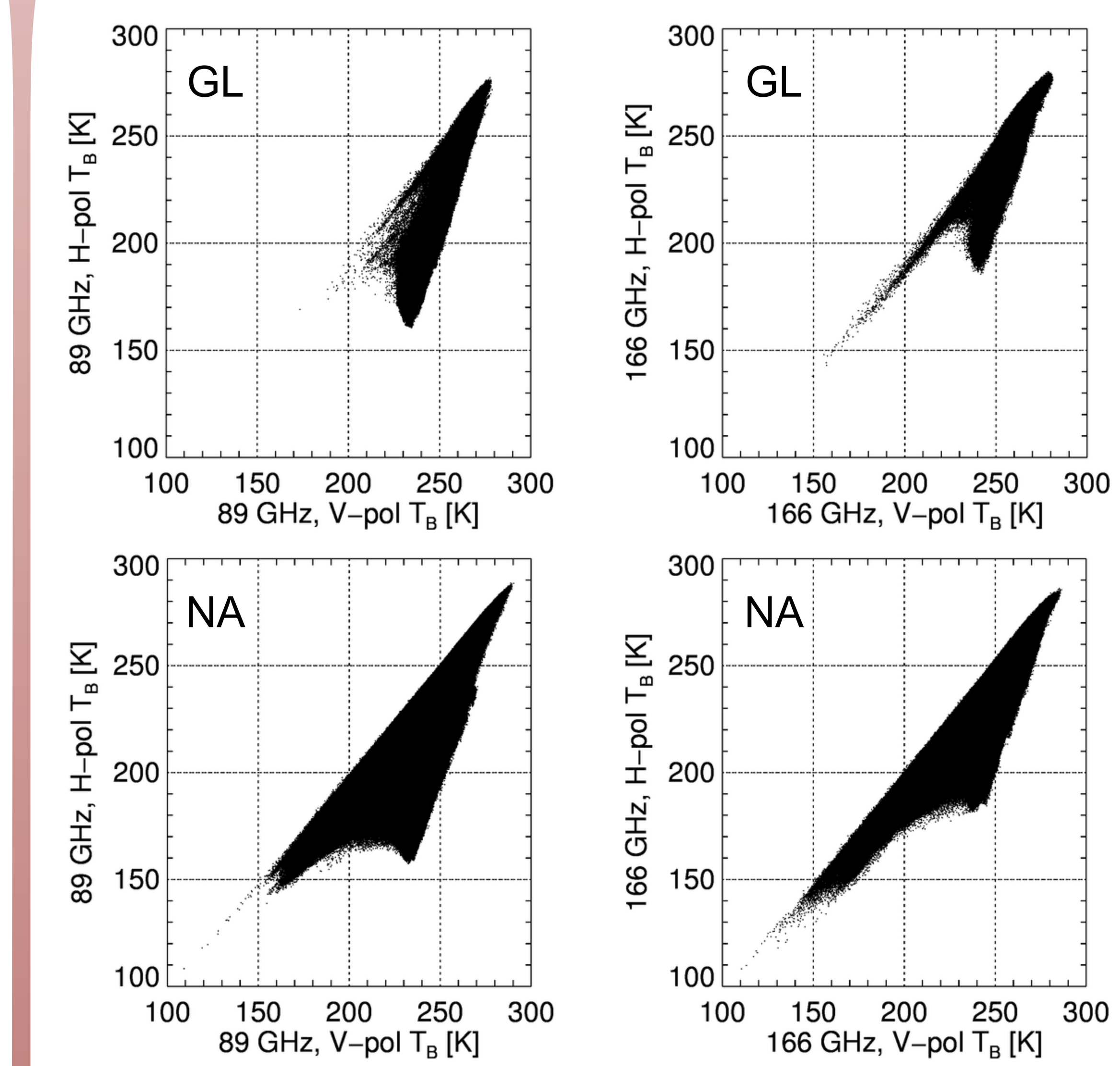

Fig. 4: GPM 89 and 166 GHz T_B, horizontal vs. vertical polarization, for the cool-season months of 2014-2015. Open water points only over the Great Lakes (*GL*) and North Atlantic (NA) regions.

Scattering Index (SI) Derivation

- The SI is closely related to the Polarization Corrected Temperature (PCT) of Spencer et al. (1989)
- Adapted to account for background T_B variations from wind speed and water vapor by Petty (1994)
- For a given pair of dual-polarization channels,

$$SI = P \cdot T_{V,0} + (1-P)\cdot T_C - T_V$$

$$P = \frac{T_V - T_H}{T_{V,0} - T_{H,0}}, T_C = 273K$$

- SI is near zero for scenes in which T_Bs vary linearly between the open-ocean dual-pol value ($T_{V,0}$, $T_{H,0}$) and a saturated value (T_C)
- SI > 0 indicates more T_B reduction than expected for a given polarization difference and belies significant scattering from ice

166 GHz Scattering Index Utility

- Comparisons of V vs. H channels at 89, 166 GHz for cold season precipitation over water reveal a stronger and more distinct ice scattering signature at the higher frequency (*Fig. 4, Fig. 5*)
- 166 GHz scattering information should improve high-latitude, cold-season precipitation retrievals

GPM Future Work

- Co-locate SI_{166} with GPM DPR surface precip rates
- Do convective snow events display 166 GHz scattering signature, or similar to 89 GHz?
- Systematic scattering signatures for different types of snowfall events?
- Is SI_{166} is more/less strongly correlated with near-surface precipitation, or is it primarily controlled by non-precipitating ice at higher altitudes?

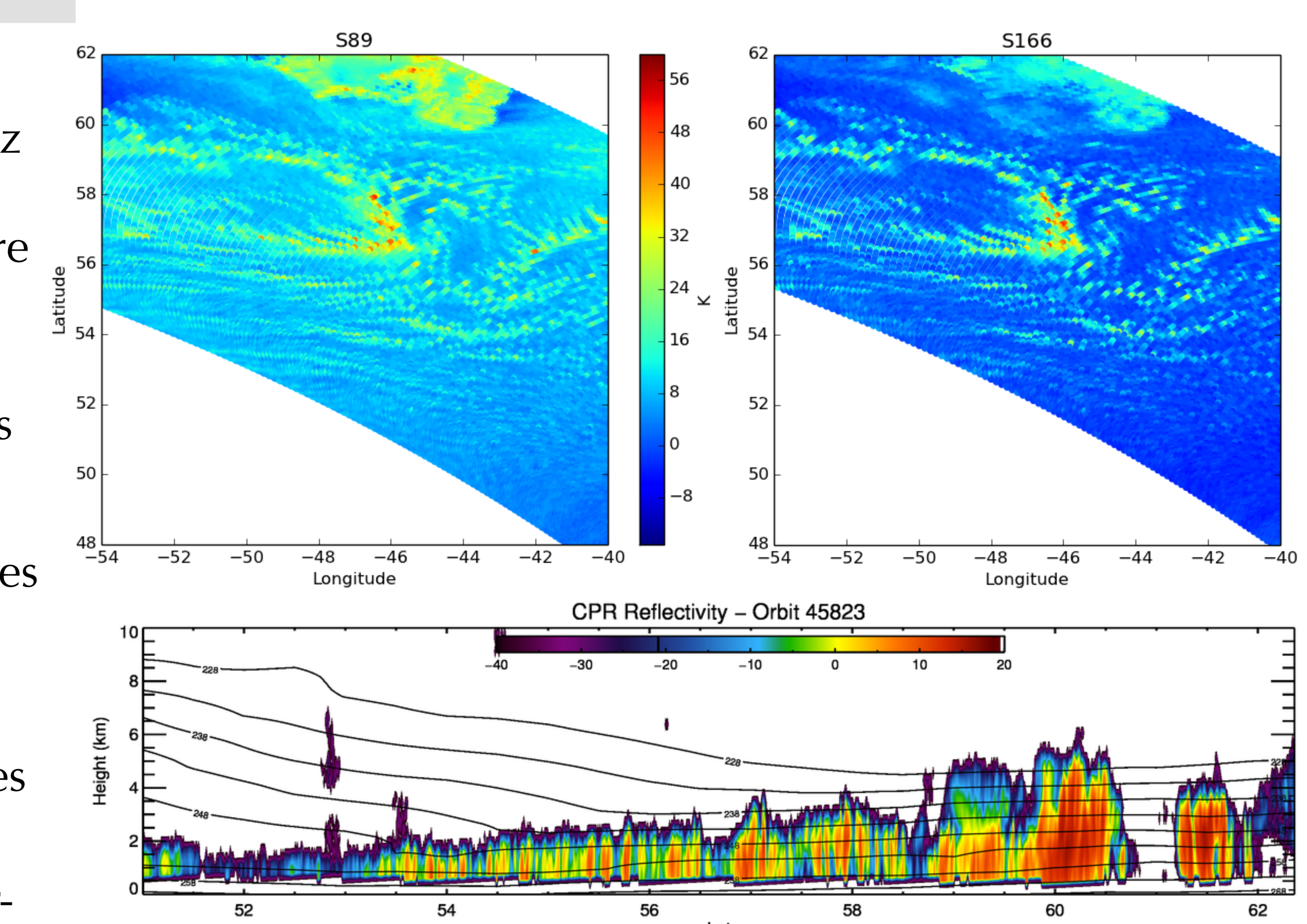

Fig. 5: GPM SI_{89} and SI_{166} from 8 Dec 2014 (top left and right, respectively). CloudSat overpass in the same region at 1531Z on 8 Dec 2014 (bottom).

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