Use of Smallsat-Sized Conical- and Cross-Track Scanning Passive Microwave Sensors to Complement the Precipitation Constellation and Facilitate Oceanic Convection Investigations

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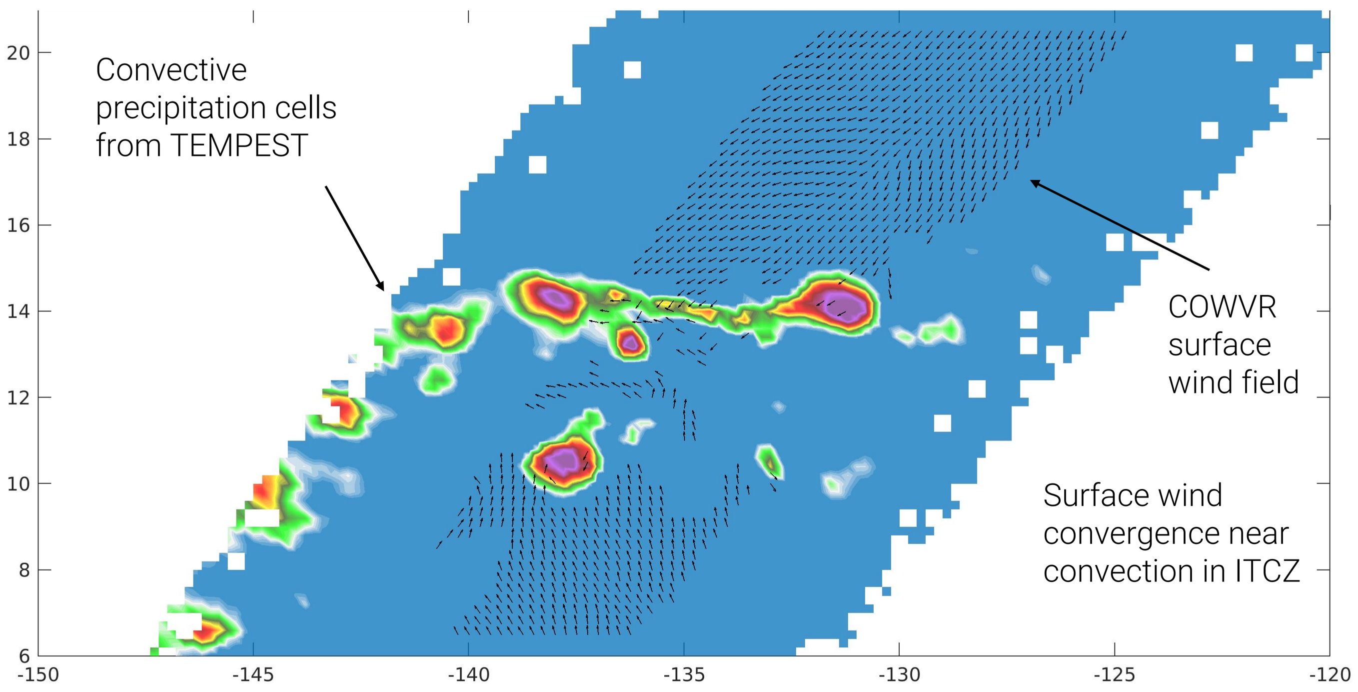
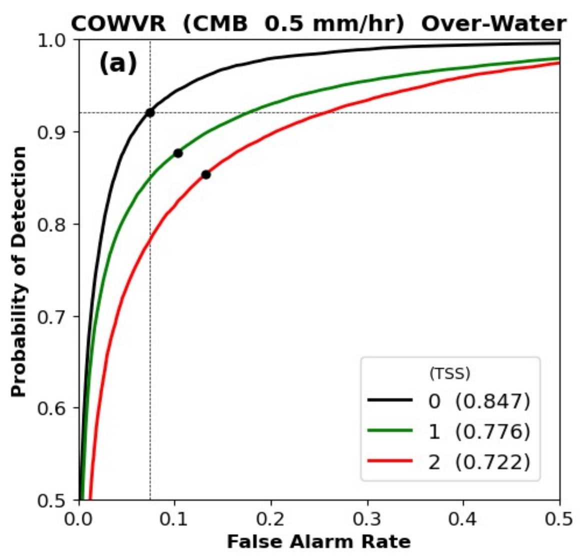
The Compact Ocean Wind Vector Radiometer (COWVR, 18-34 GHz) and Temporal Experiment for Storms and Tropical Systems (TEMPEST, 89-183 GHz) were developed to demonstrate low-cost microwave (MW) sensor technologies for weather and oceanic applications, while maintaining similar performances as more expensive instruments. As part of the US Department of Defense sponsored Space Force Space Test Program (STP-H8) mission, COWVR and TEMPEST were launched on 21 December 2021 and installed on the International Space Station (ISS) Japanese Experiment Module (JEM). Both COWVR and TEMPEST are currently (July 2023) operating nominally on-orbit. While not the primary objective, the orbit, swath, and moderate (3-year) station time for COWVR + TEMPEST make these joint observations desirable for precipitation science. While TRMM and GPM provide joint passive MW and precipitation profiling radar observations, COWVR+TEMPEST analysis suggests precipitation science investigations can benefit from joint passive MW sounding and passive MW polarimeter observations.



PRECIPITATION USING A COMBINATION OF COWVR+TEMPEST CHANNELS

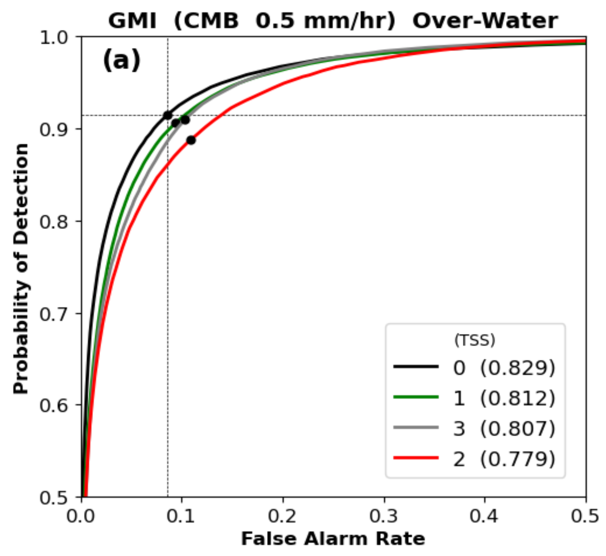
Precipitation Discrimination at the 0.5 mm/hr Level (Over-Water)

COWVR+TEMPEST



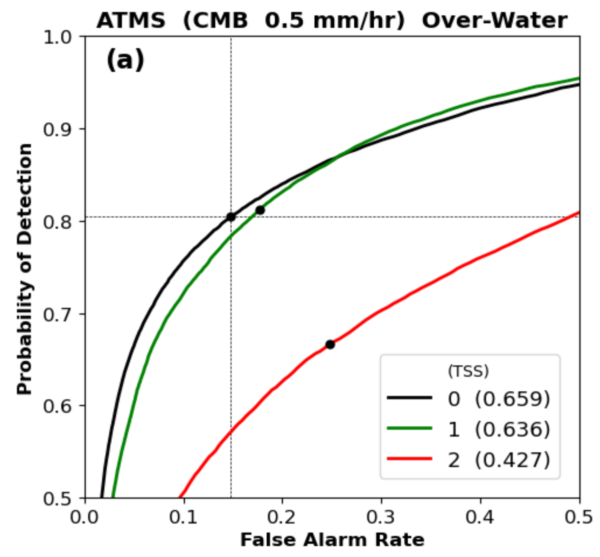
18-183 GHz (LF+HF)
18-89 GHz
89-183 GHz (HF-only)

GPM GMI



10-183 GHz (LF+HF)
10-89 GHz
89-183 GHz (HF-only)
18-183 GHz (No 10 GHz)

ATMS



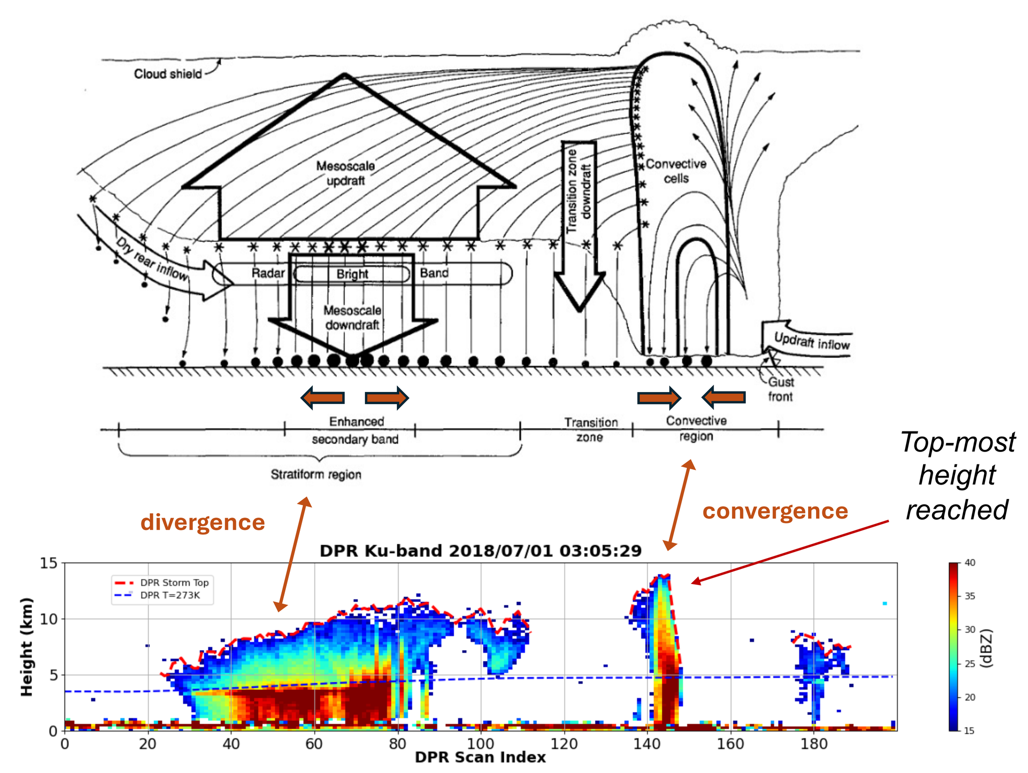
23-183 GHz (LF+HF)
23-183 GHz (no 50 GHz)
89-183 GHz (HF-only)

Many future passive MW sensors will be high frequency (HF) across-track sounders with lowest operating frequencies near 90 GHz. Physically, the use of HF-only sensors for precipitation skews the precipitation estimates towards indirect, ice-based (scattering) retrievals. Over certain Earth surfaces, a portion of light precipitation (2 mm hr^{-1} or less) may remain undetected, which has ramifications for global satellite-based precipitation products.

COWVR complements the HF-only TB observations with the preferred lower-frequency (< 37 GHz), constant-incidence, polarized TB observations. Assessment shows that over-ocean, COWVR+TEMPEST can discriminate precipitation at the 0.5 mm/hr level or higher, with similar performance as the GPM Microwave Imager (GMI).

OCEAN SURFACE WINDS AND CONVERGENCE NEAR PRECIPITATION

Conceptual figure shown is taken from Figure 18 in Biggerstaff and Houze, 1991:



Convection and stratiform precipitation features are revealed in GPM DPR radar profiles in the tropics, where convection and downbursts drive vertical exchanges of momentum, heat, and moisture. Is there a corresponding signal in the COWVR surface wind derivative field?

COWVR's lowest frequency (18 GHz) is not optimal for wind vector estimates near precipitation, so this analysis largely reflects valid wind derivative fields in the environment surrounding precipitation (large scale). Datasets used:

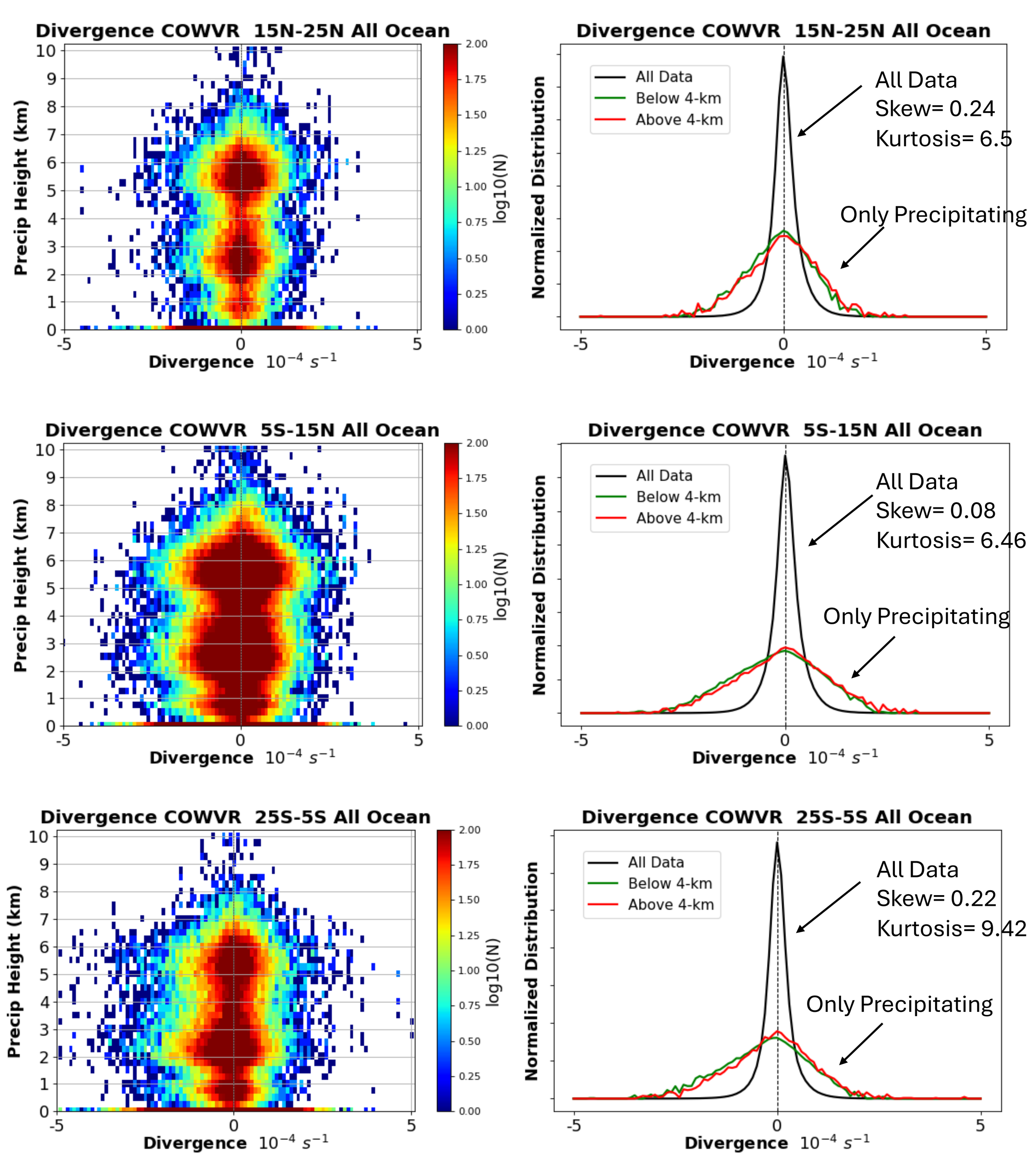
- Valid COWVR EDR wind vector (u, v) data between 25S-25N latitude, derived divergence $\delta \approx \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$ (units of s^{-1}). ~1000 orbits during JJA months 2022/2023.
- Estimates of vertical precipitation structure from same COWVR+TEMPEST data using the emissivity principal components (EPC) profiling algorithm (Utsumi et al, 2020), and corresponding top-most height of precipitation water content.

1-D and 2-D histograms of precipitation height vs. divergence

Not surprisingly, the distribution of the ocean wind divergence is broadened near precipitation, with the strongest signal within the ITCZ (5S-15N) latitudes

How does this change as convection develops in the vertical?

Do the identified features differ across ocean basins?

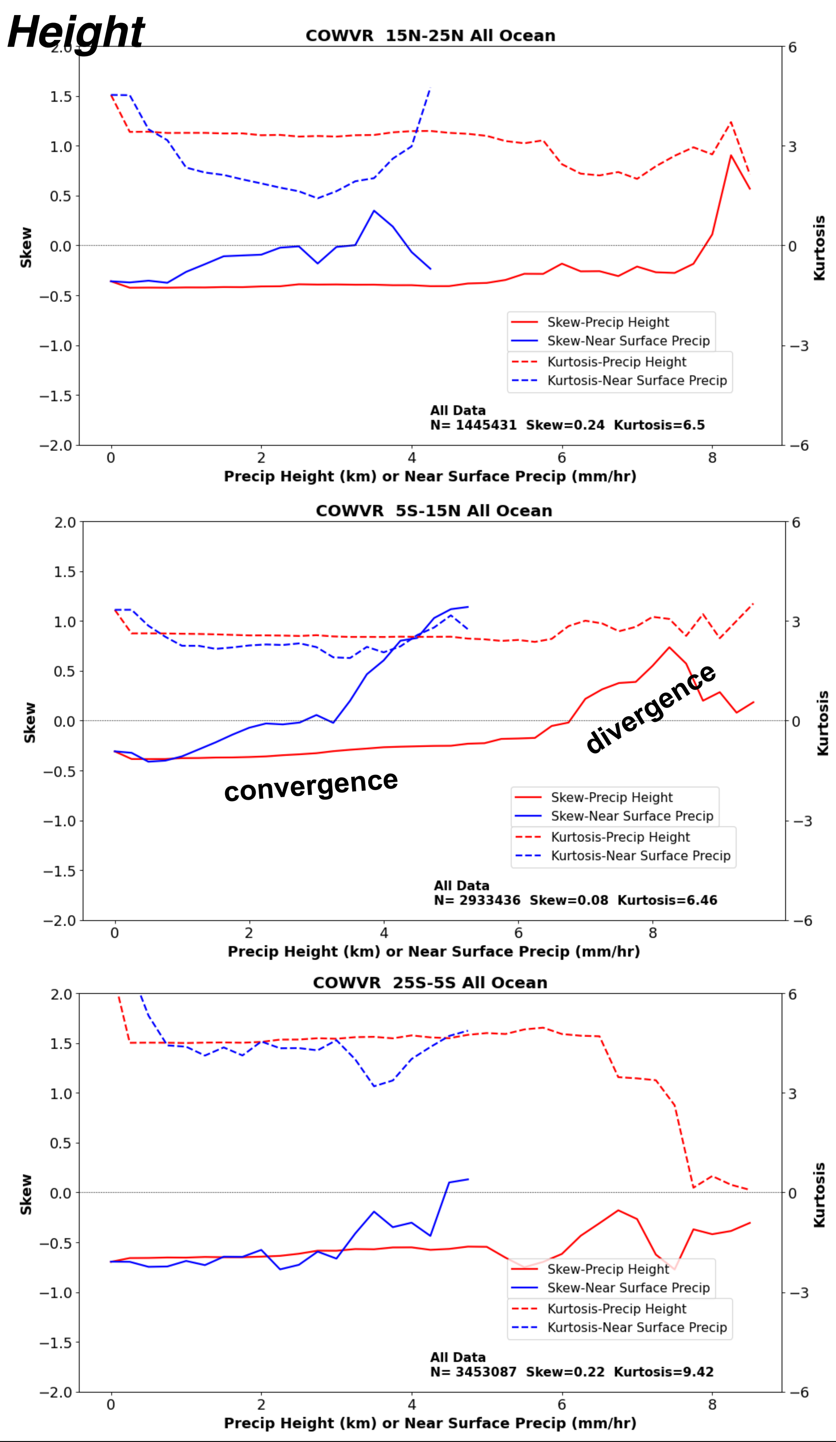


Skew vs. Precipitation Height

In the ITCZ, the skew of distribution (solid red line) is negative (surface convergence) for precipitation whose top-most level is below ~6-km height, and skews to positive (divergent air at the surface) for precipitation above this level

This implies predominant upward air movement during shallow convection, and predominant downdraft (near surface divergence) for deeper convection

This signal is less apparent outside of the ITCZ



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Utsumi, N., Turk, F.J., Haddad, Z.S., Kirstetter, P.-E., Kim, H., 2020. Evaluation of Precipitation Vertical Profiles Estimated by GPM-Era Satellite-Based Passive Microwave Retrievals. *J. Hydrometeorology* 22, 95–112.