Enhancing GPM Passive and Combined Microwave Algorithms with Dynamic Surface Information for Drizzle Retrieval and Improved Precipitation Detection Over Land

Sarah Ringerud, Joe Munchak, Christa Peters-Lidard, Yalei You

Following the 2014 launch of the Global Precipitation Measurement Mission (GPM), an unprecedented combination of coincident active and passive microwave observations are available for state of the art precipitation retrieval. The GPM Combined Algorithm forms the backbone of this effort, optimizing geophysical variables for agreement with the full suite of multi-spectral information content. These combined retrievals are then utilized, along with a radiative transfer model, as a database applied for retrievals across a constellation of passive microwave radiometers of varying frequencies. By keeping such retrievals related through the transfer standard of the combined algorithm, level 3 products such as the Integrated Multi-satellitE Retrievals for GPM (IMERG) are able to provide consistent global products for users at the higher temporal resolution required for hydrological applications. In initial versions of the combined product, precipitation retrievals are carried out only in the presence of a signal from the active radar. As a result, light precipitation and drizzle below the threshold of DPR sensitivity are not included in any of the products down the chain from the constellation to IMERG. In this work, the effects of enhancing the retrievals with a surface emissivity and non-raining water vapor retrieval using the passive observations are explored. Over both ocean and land, the surface retrieval is used to identify areas with high probability of light precipitation and drizzle which is then quantified using techniques derived from the higher sensitivity CloudSat mission. Results indicate successful inclusion of drizzle in the retrievals that can then be included in the constellation databases, as well as improvement in passive microwave false positive precipitation signals over land in cases where surface scattering was misinterpreted as precipitation signal. The inclusion of the dynamic surface information also creates a more robust, radiometrically consistent retrieval scheme for process studies and hydrologic applications.

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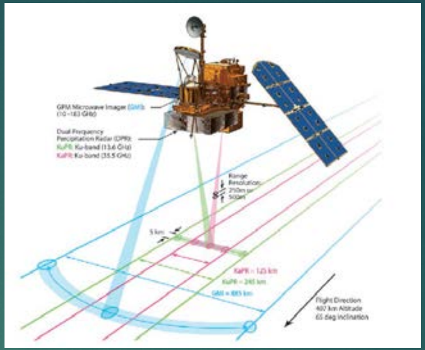
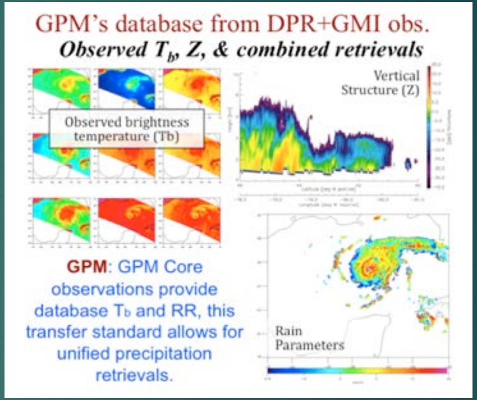
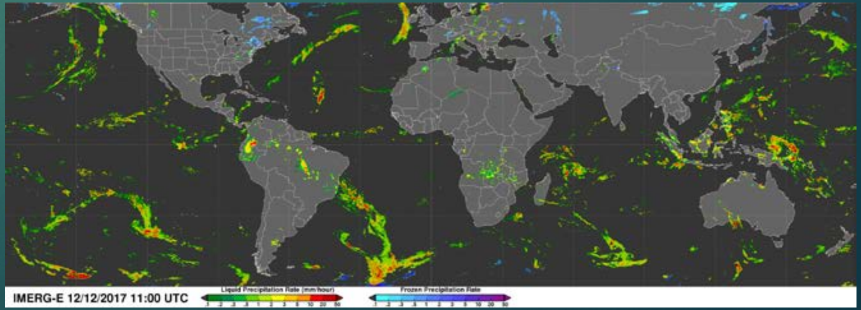
Introduction



- GPM Algorithm Flow
  - Combined retrieval
    - Active + Passive optimal solution for GPM core in areas with active signal
    - Transfer Standard
  - Passive Constellation Retrievals
    - Database constructed from CMB retrievals + non-raining (model, OE)
    - Constrained Bayesian
  - IMERG
    - Integrated product every 30 min
    - Constellation+IR+gauges
    - Products intercalibrated to Combined retrievals





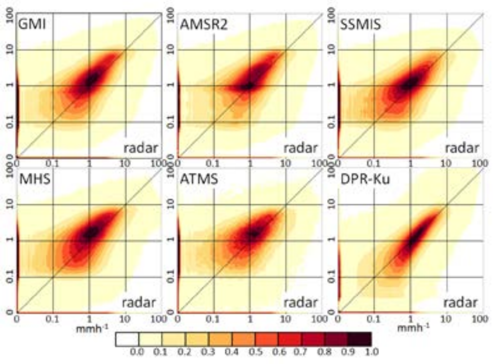
Bayesian (GPROF-type) vs. 1DVAR (MiRS-type)

- NASA Goddard Profiling Algorithm (GPROF)
  - Probability of R given Tb
  - Database constructed from Combined Retrievals
  - Model TPW, 2m T, surface type (Ocean + Ice + Coast + Land (10))
  - Retrieves precipitation – requires ancillary geophysical parameters
  - Limited to what combined algorithm retrieves (must have active radar signal)
  - Nature of Bayesian – lots of light precipitation – do 2 passes

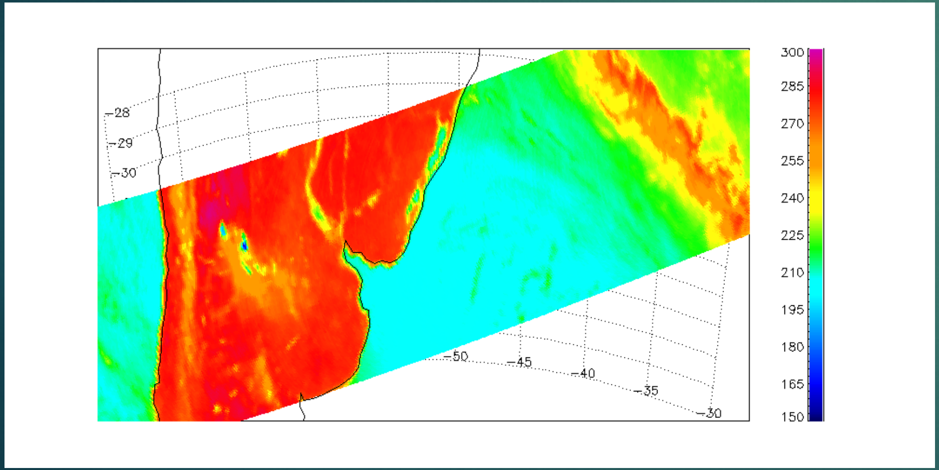
- NOAA Microwave Integrated Retrieval System (MiRS)
  - 1DVAR – physically-based iterative inversion that finds best-fit solution given all Tb
  - Two loops: first assumes no hydrometeors (absorption only)
    - If no convergence, 2^{nd} loop with multiple scattering
  - Retrieves full suite of geophysical parameters (surface: T and ε and atmosphere: T, WV, cloud, hydrometeors)
  - Can be underconstrained

Complications Over Land Surfaces

- High land surface emissivity makes hydrometeor absorption signal difficult to distinguish – basically limited to scattering/precipitation rate relationships



KIDD ET AL. 2017: Normalised density scatterplots of the V05 GPROF and DPR-Ku precipitation products versus surface radar data over the United States region; all products are compared at a nominal resolution of 15x15km (note that zero values are plotted along the x and y axes)

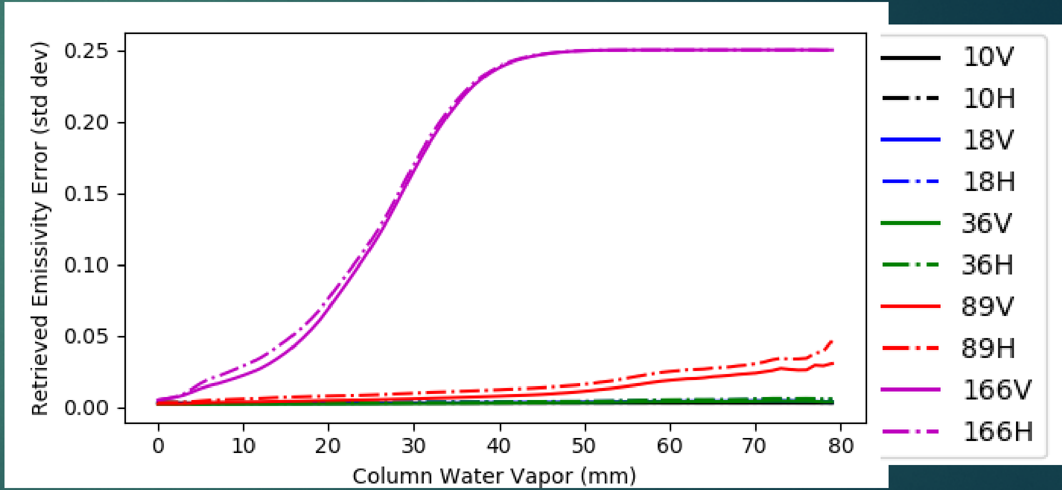


Calculations from 1 year of retrievals over non-snow land surfaces (Ku rain rate over GMI footprint area):
0-1 mm/hr: 73% of raining footprints
: mean ku: .30, mean GPROF: .49 (+63%)
1-5 mm/hr: 23% of raining footprints
: mean ku: 2.1, mean GPROF: 2.3 (+8%)
5-10 mm/hr: 3% of raining footprints
: mean ku: .6.72, mean GPROF: 5.39 (-20%)
10+ mm/hr: 1% of raining footprints
: mean ku: 19.67, mean GPROF: 7.62 (-61%)

Munchak et al. 2019 Land Surface Emissivity Retrieval

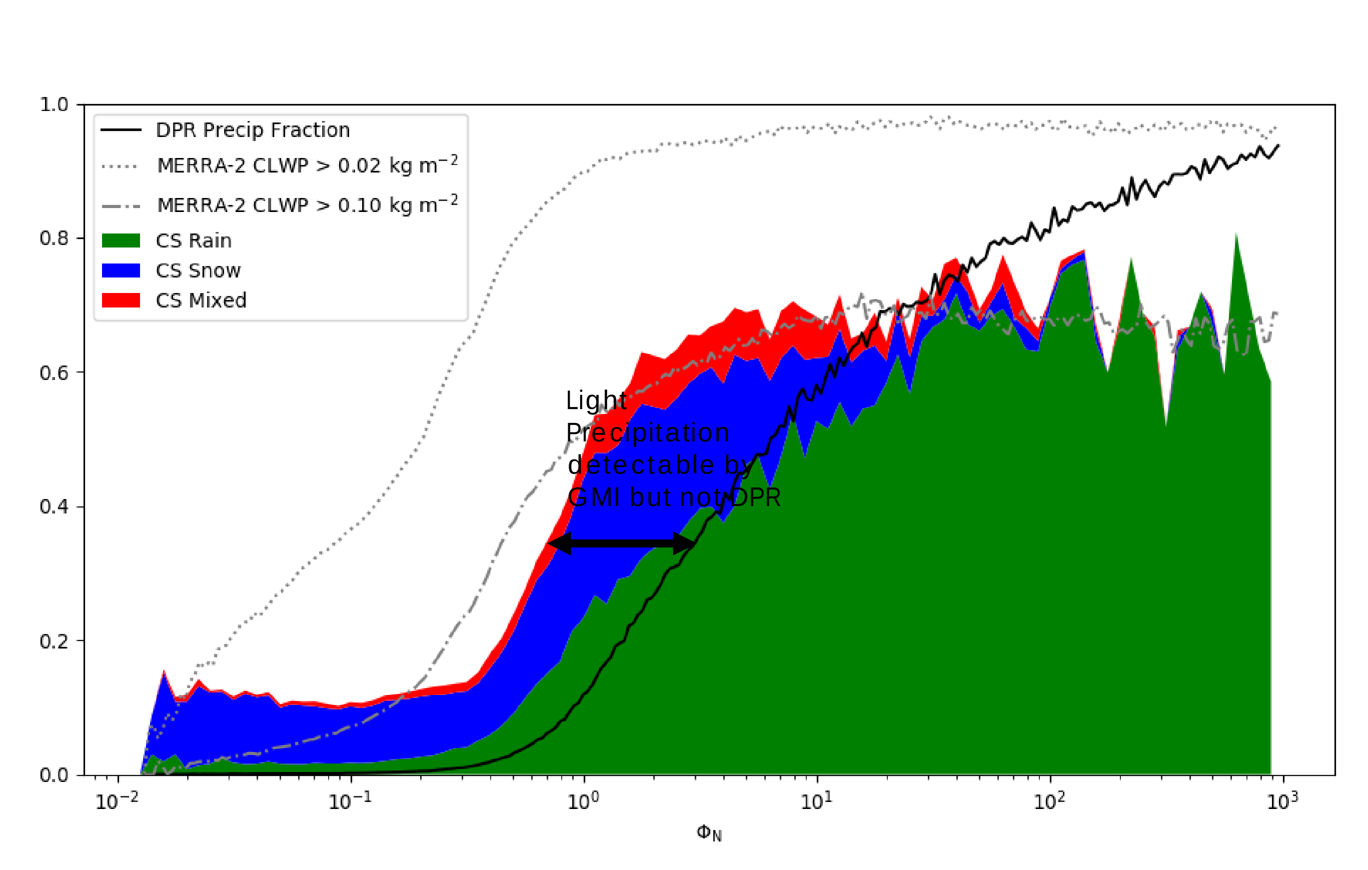
- Optimal Estimation Retrieval for GPM GMI (could extend)
  - Paper currently in revision
  - Anticipated to be part of Combined retrieval product in Version 7
  - MERRA-2 first guess, error covariance constructed from radiosonde
  - Retrieve emissivity vector, water vapor
  - Output includes measure of convergence (Normalized Error)

Information Content



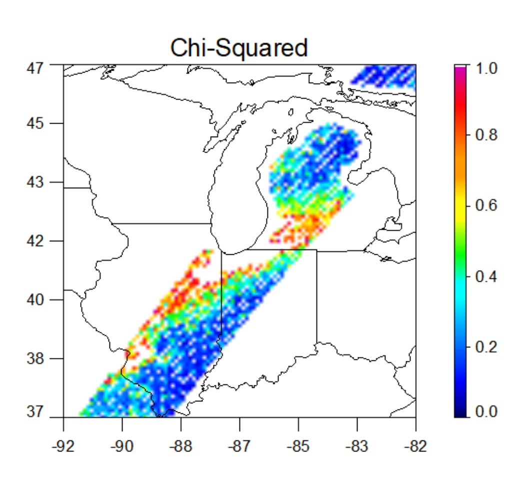
Mean posterior emissivity error (square root of diagonal elements of Sx) Munchak et al. 2019 (In revision)

Precipitation Screening by Normalized Cost Function



Munchak et al. 2019 (In Revision)

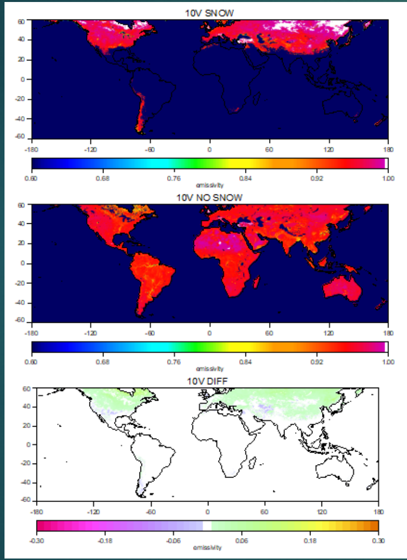
“Hybrid” Retrieval with Dynamic Surface Constraints

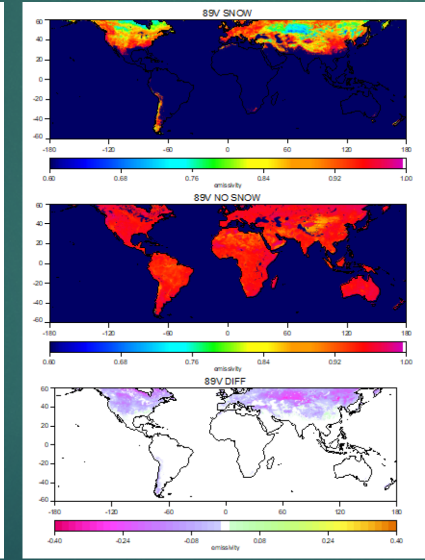


- First Pass: OE output from Munchak et al. scheme
  - Use retrieved emissivity to determine snow cover
  - Precip-free areas use retrieved values
- Bayesian Retrieval where Indicated by Normalized Error Parameter
  - Test several cutoff values
  - Use GPROF database, organized/constrained with **retrieved** parameters
  - Use recent precipitation-free retrieved emissivity climatology at 19 GHz as retrieval constraint (+search below)
  - Use retrieved TPW where error parameter shows convergence, interpolate and constrain retrieval in areas (+search above)

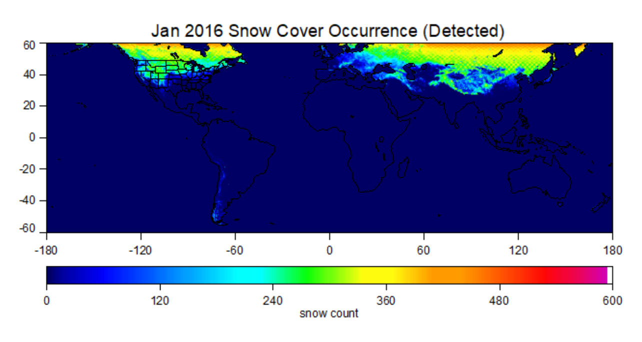
Emissivity-based Snow Cover

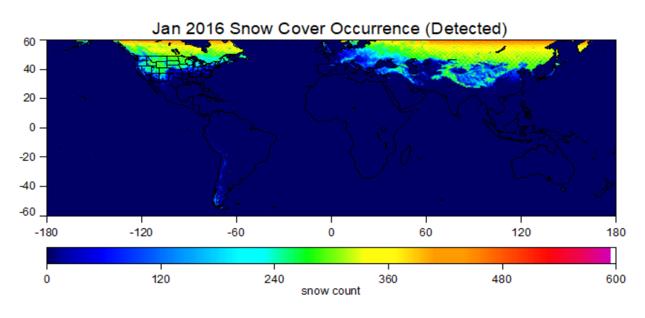
- Physical basis: emission signal at low frequency + scattering signal in high frequency
  - Compare to snow-free emissivity for that location



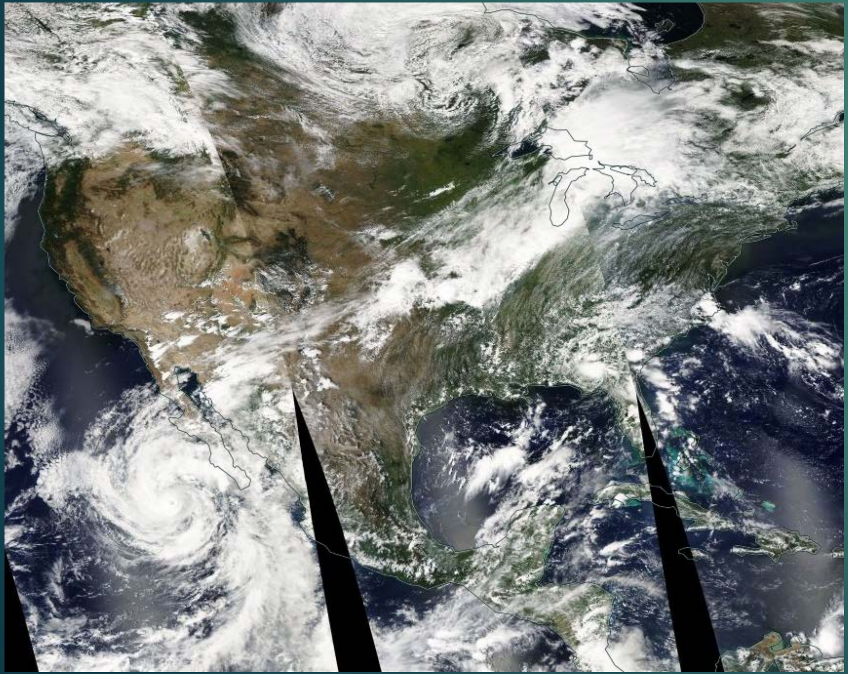


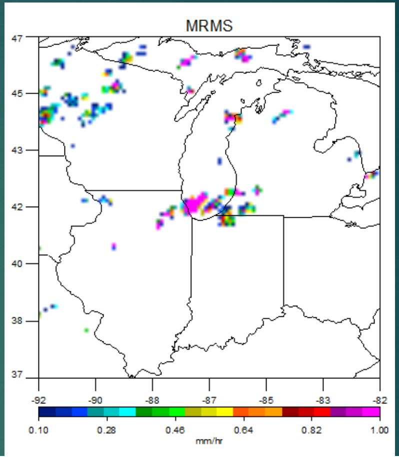
Autosnow: NOAA Blended optical-microwave retrieval algorithm – daily (used by GPROF)

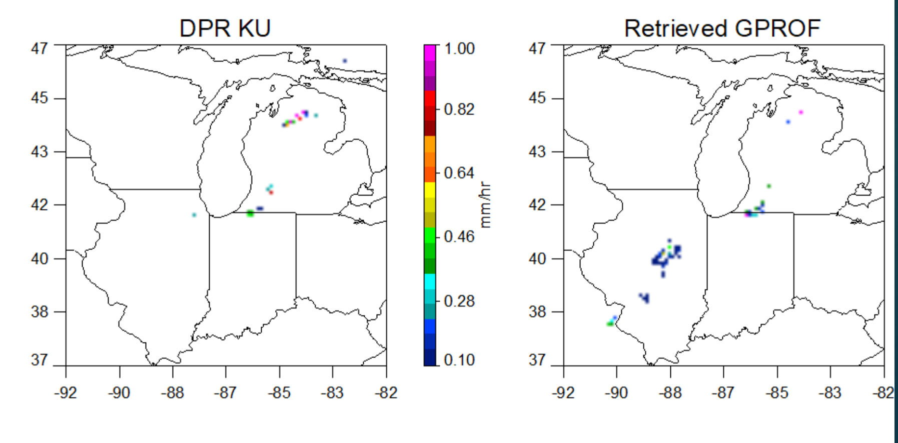




Retrieval Example: September 8, 2015

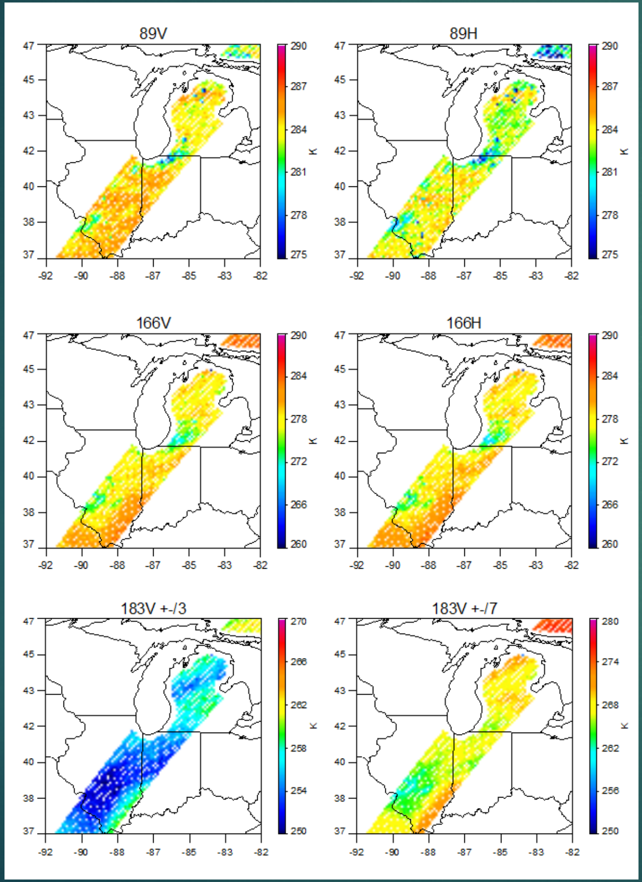


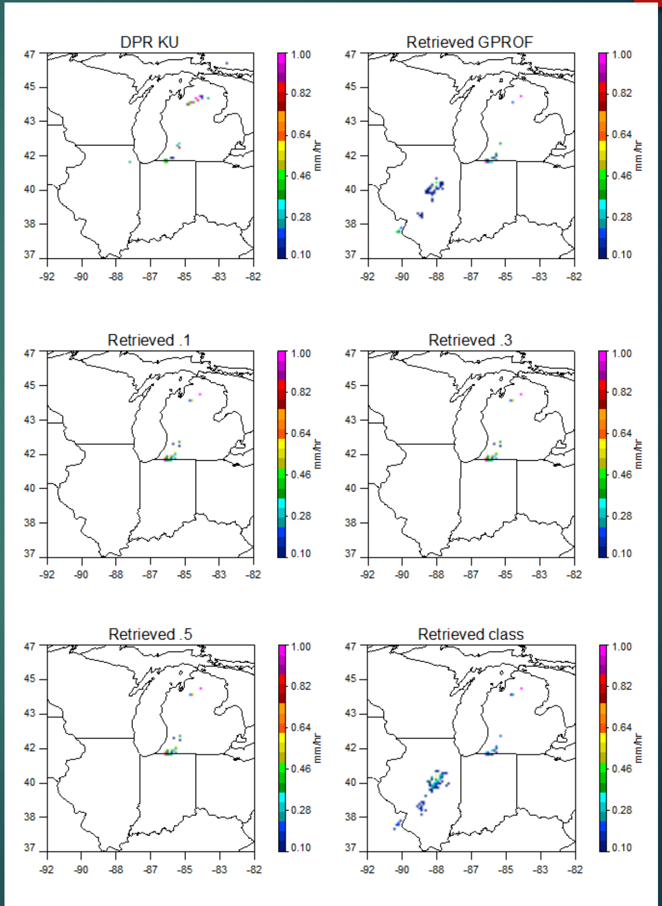




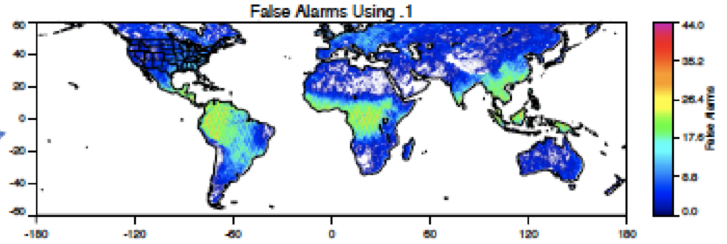
Retrieval Example: September 8, 2015

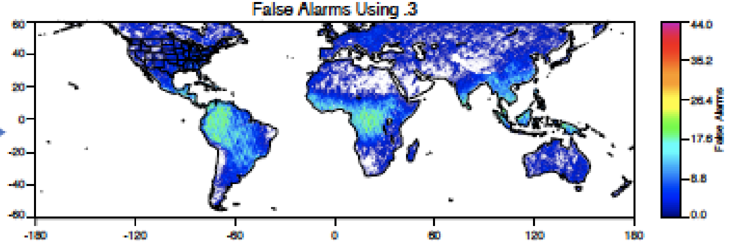
There is clearly scattering associated with the cloud cover – this is weighted heavily in the Bayesian retrieval and GPROF/Class retrievals put precipitation in this area. By joining this system to the OE retrieval, we add information and can get rid of many false alarms. Using retrieved TPW in this case also plays a role.

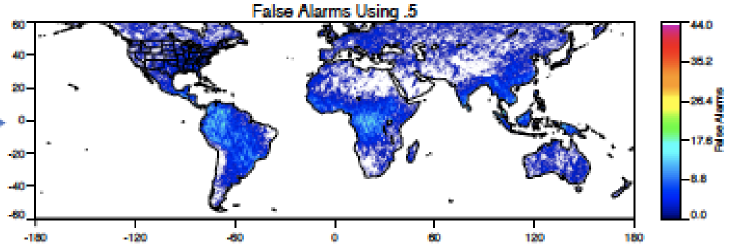


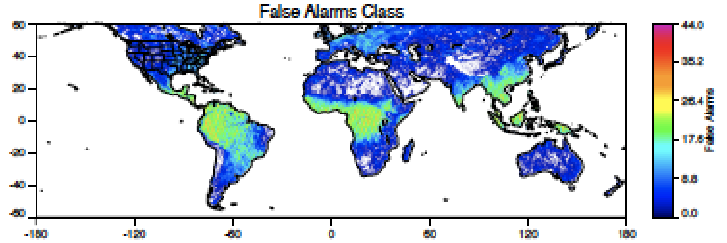


	Correlation	Bias	RMSE	FAR	POD
Chi-sq > .1	0.47	0.044	1.04	0.29	0.91
Chi-sq > .3	0.47	0.038	1.04	0.15	0.84
Chi-sq > .5	0.47	0.035	1.04	0.08	0.75
Class	0.47	0.045	1.07	0.29	0.9



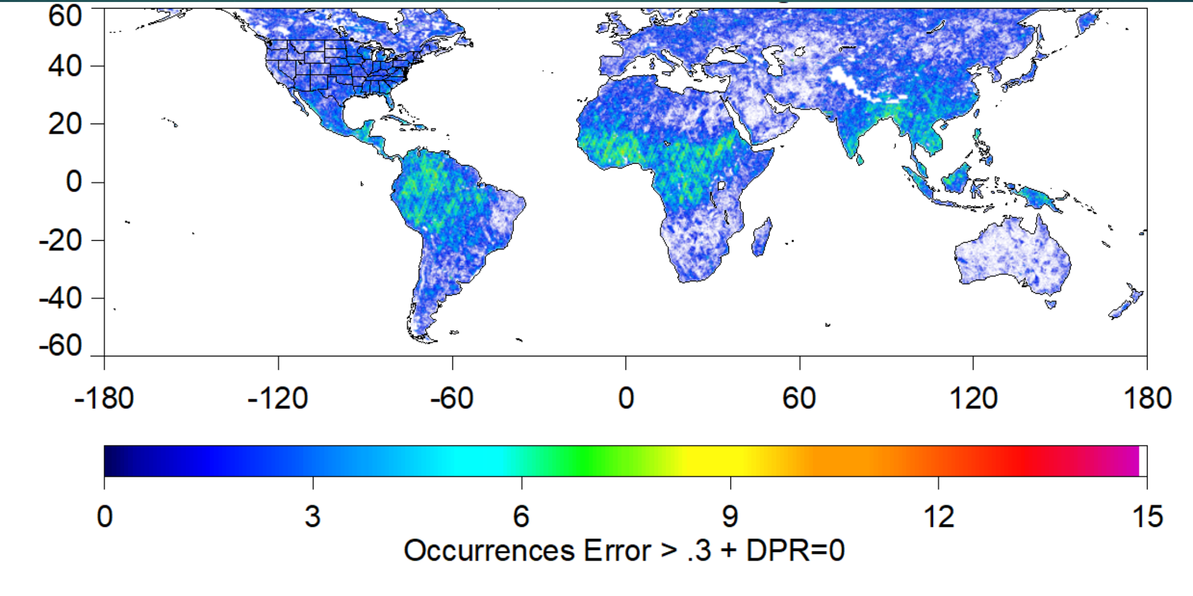


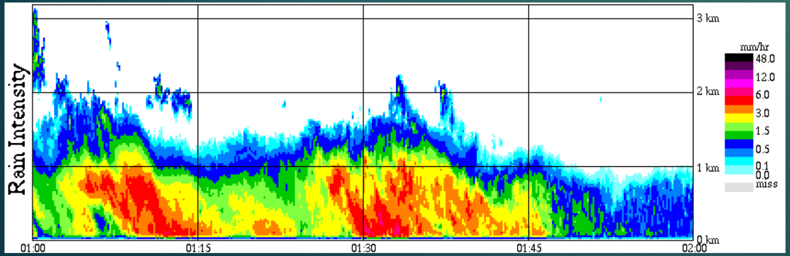


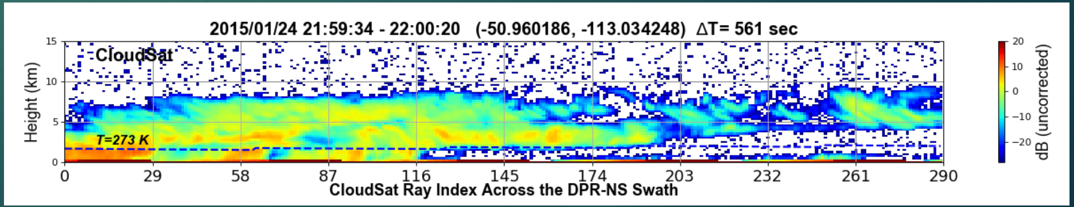


1 Yr Snow-free surfaces

Drizzle Retrieval: Work in Progress







Conclusions

- Munchak emissivity retrieval anticipated to be part of combined algorithm output in V7
- Using dynamic observationally-based constraints and OE-based first pass enhances the retrieval
  - Use of retrieved TPW and emissivity as constraints makes retrieval more physically consistent and helps with issues at high gradient areas such as frontal boundaries
  - Significant decrease in false alarms WRT DPR
  - Small decrease in POD - find "sweet spot" to optimize this
- Drizzle retrieval potential – add to Combined Retrieval product to filter through to constellation and IMERG
  - In the current formulation, Combined retrieval is the "right answer" – need to make any advances HERE
  - Get the "where" using the OE retrieval output, just need the "what" – looking at CloudSat and MRR – need to investigate relationships to environmental constraints for implementation of a parameterization for quantifying vertical profiles