

How well do passive microwave algorithms estimate vertical profiles of precipitation?

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Overview of Presentation

- Even though some radiometer-based techniques provide an estimate of the condensed water vertical structure, nearly all validation studies to date examine only the “surface” precipitation rate.
- As concluded by a previous study¹ (Utsumi et al., 2019, JHM), the use of the vertical precipitation profile information can improve sub-hourly surface precipitation estimates.
- As highlighted in the recent NASA decadal survey, with emphasis on cloud-precipitation “processes”, an improved depiction of the vertical structure is meaningful.
- Here, the **joint verification** of the vertical structure of the condensed water content and surface precipitation rate is examined for two radiometer algorithms, the GPROF V05 and the emissivity principal components (EPC) technique developed by the authors.

¹ Utsumi, N., H. Kim, F. J. Turk, and Ziad. S. Haddad, 2019: Improving Satellite-Based Subhourly Surface Rain Estimates Using Vertical Rain Profile Information. *J. Hydrometeor.*, **20**, 1015–1026

Design of this study

- ❑ 1-year (June 2014 – May 2015) for GPM-GMI

Profiles higher than 2km above reference level are investigated.

- ❑ PMW retrievals

- GPROF V05
- Emissivity Principal Component (EPC) algorithm (Turk et al. 2018)

A priori database is binned and searched by emissivity principal components (EPC)

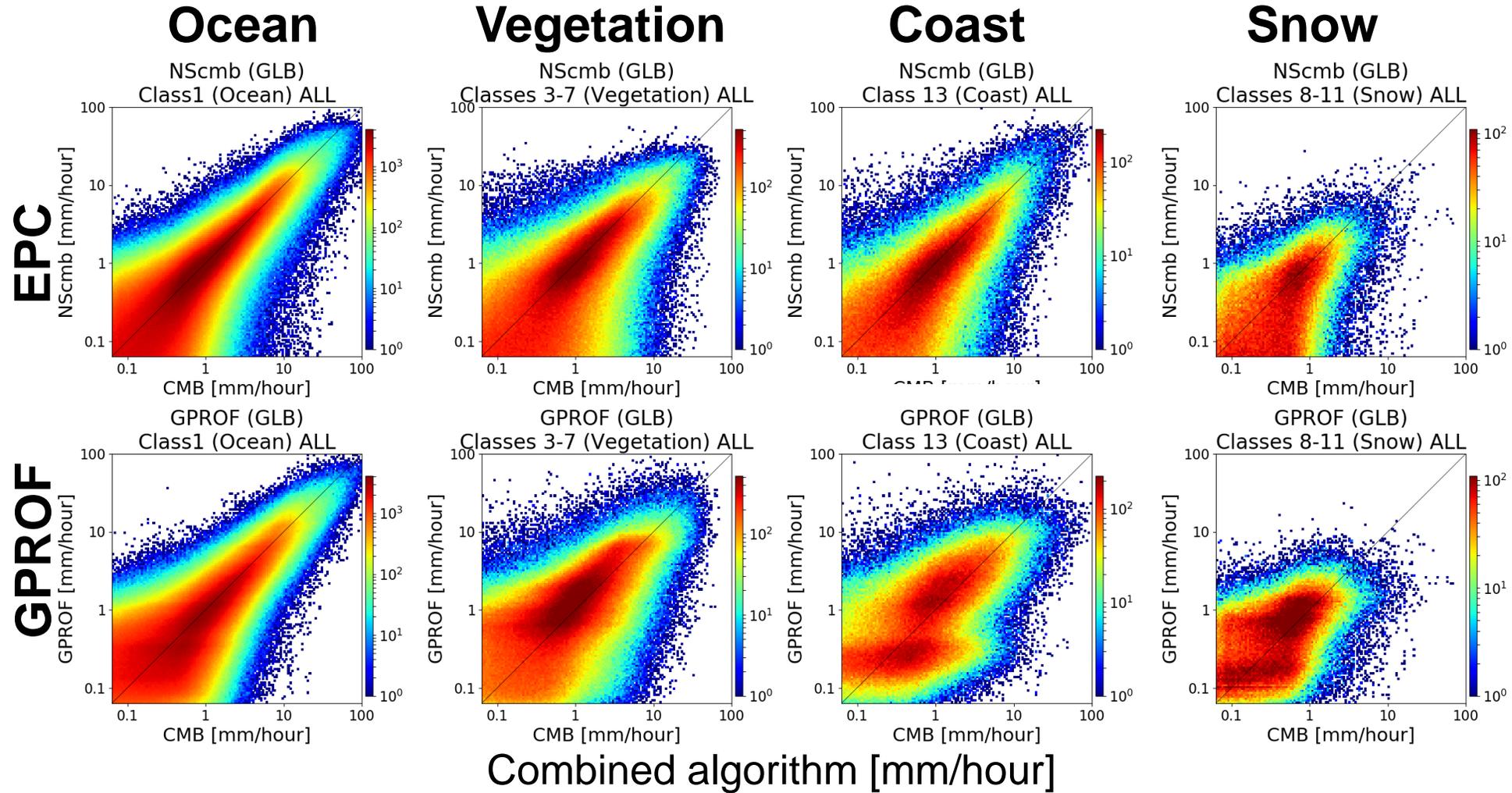
- ❑ Reference data

- Combined algorithm product (CMB) V06

- ❑ Other data

- Surface type: obtained from GPROF V05 product.

Overall performance (Relative to Combined algorithm) (June 2014 – May 2015)



Surface precipitation is well estimated by PMW algorithms.
What about the precipitation profiles from PMW algorithms?

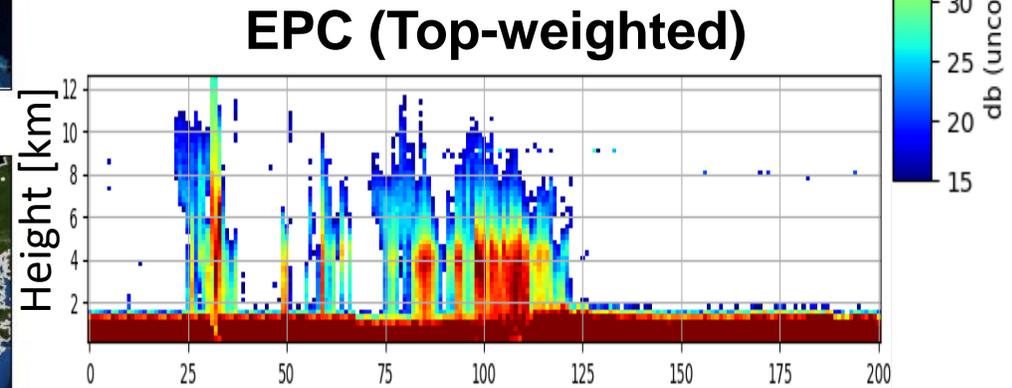
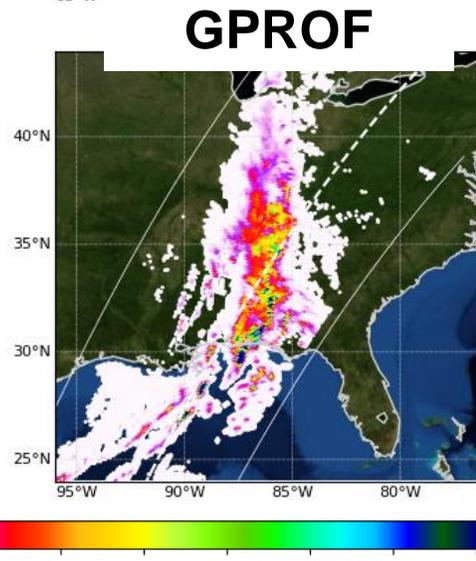
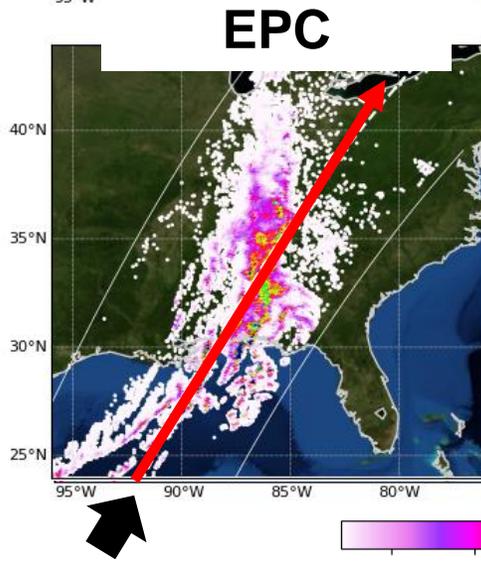
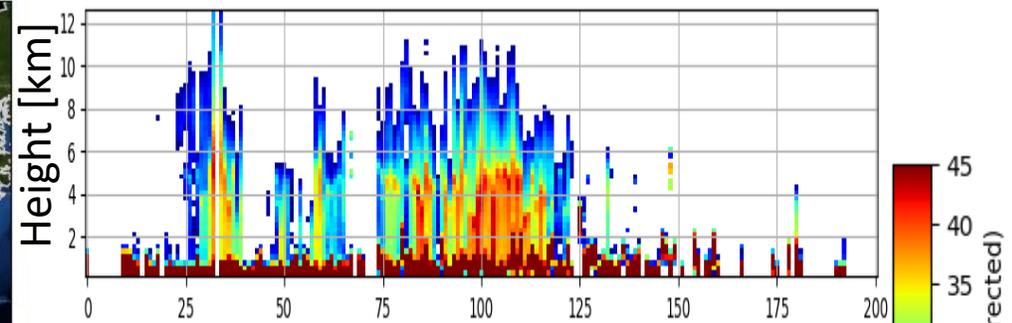
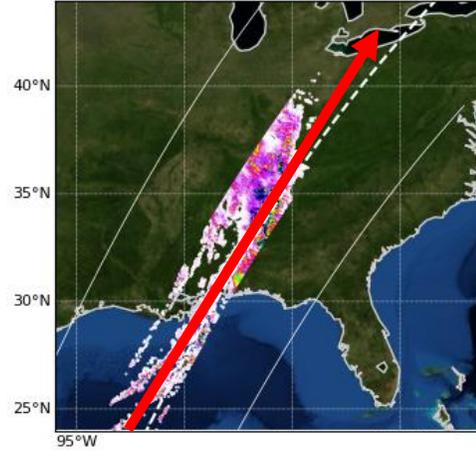
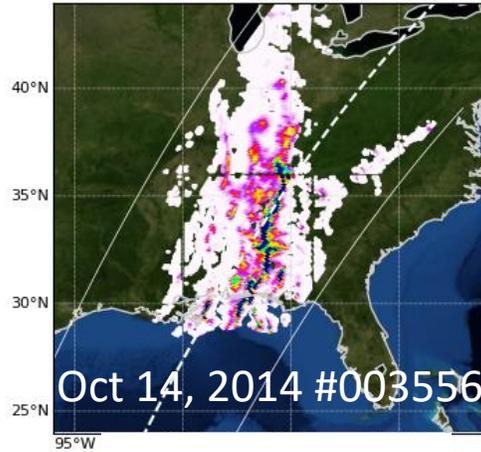
Frontal rain: Oct 14, 2014 #003556

Precipitation signal profile (dBZ)

MRMS

Combined

DPR-Ku (zFactorMeasured)



Cross section

***Top-weighted:**
Profile database entry that has the top-weight in Bayesian weighting

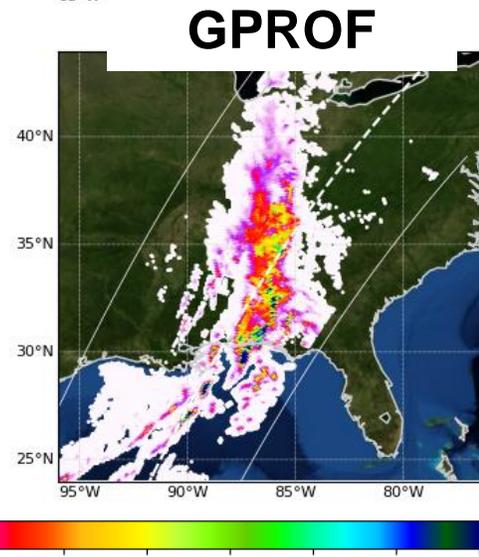
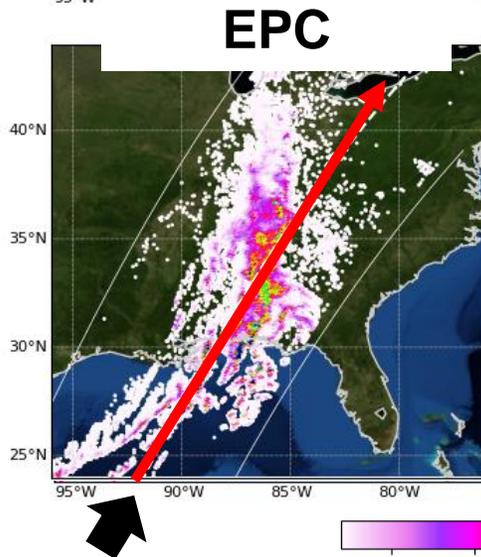
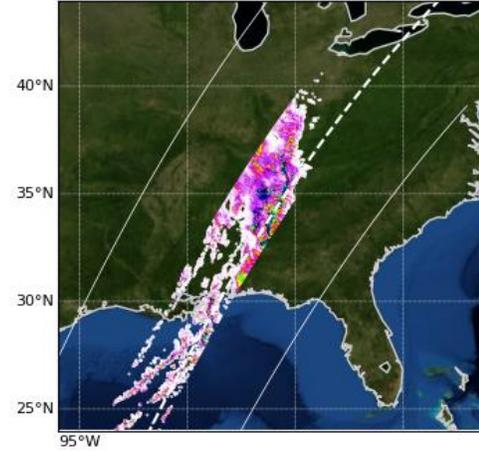
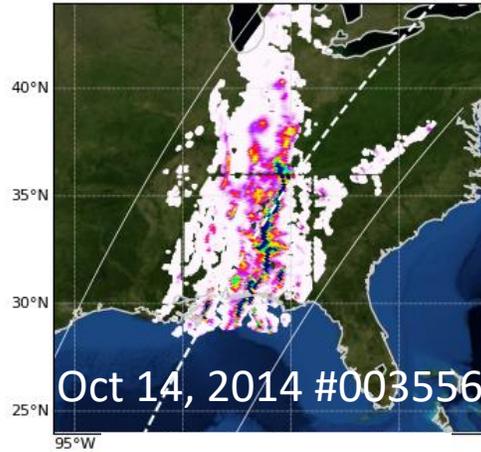
Precipitation profile signals are well captured by PMW algorithm

Frontal rain: Oct 14, 2014 #003556

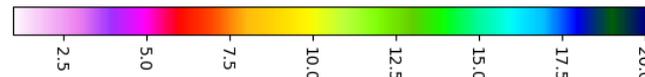
Condensed water content profile
(g/m³)

MRMS

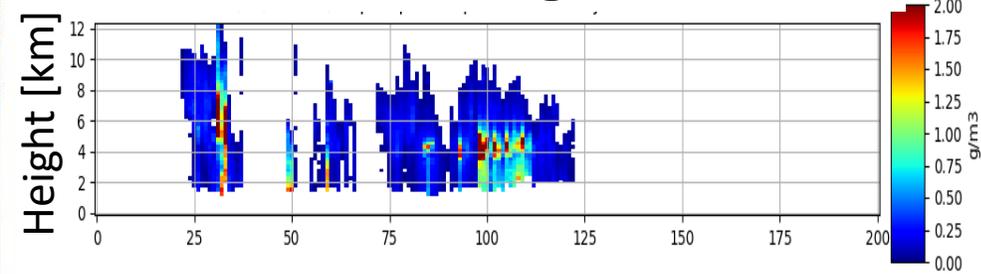
Combined



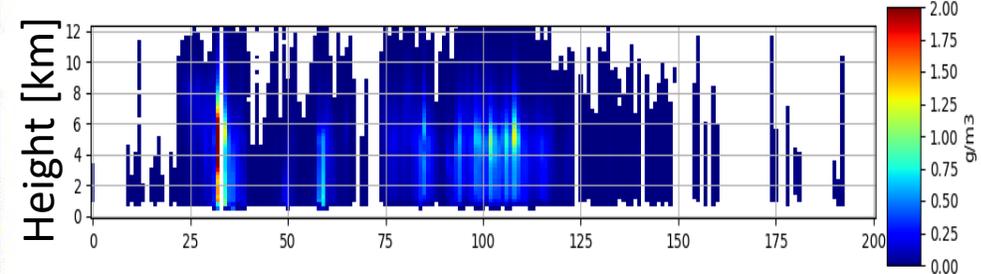
Cross section



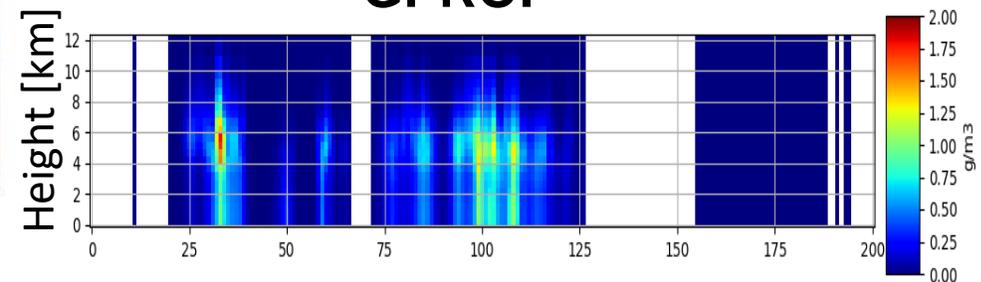
Combined algorithm



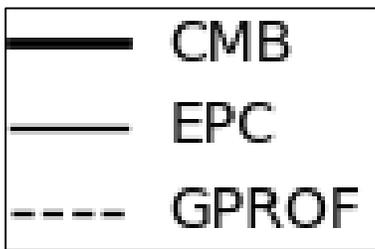
EPC



GPROF



Precipitation water content profiles are also estimated by PMW (with bias).



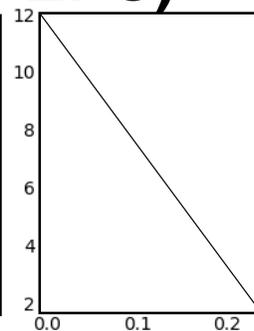
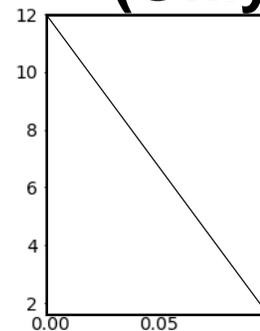
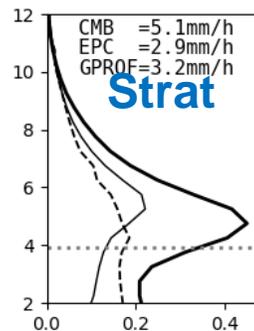
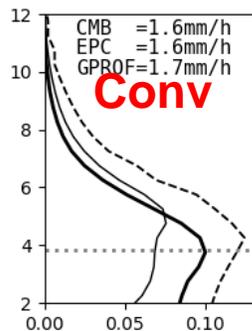
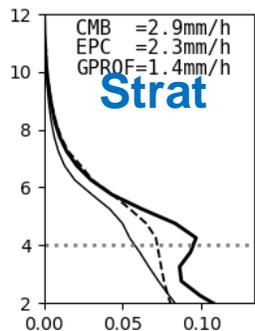
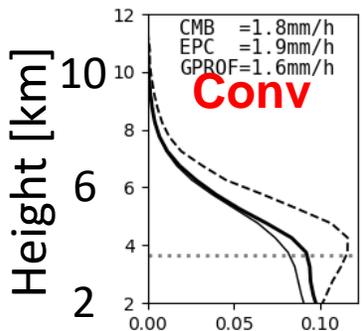
Condensed water content profiles

Ocean

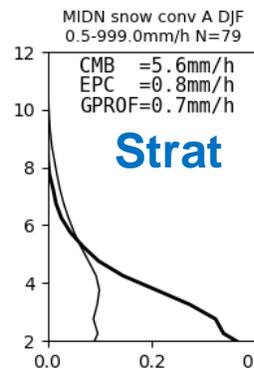
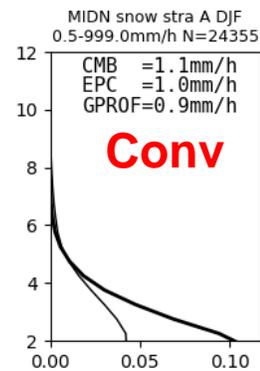
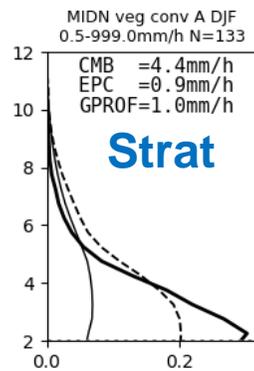
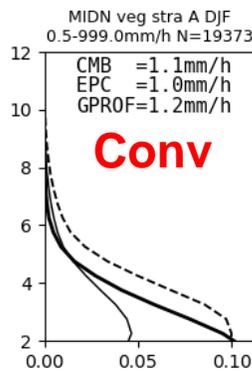
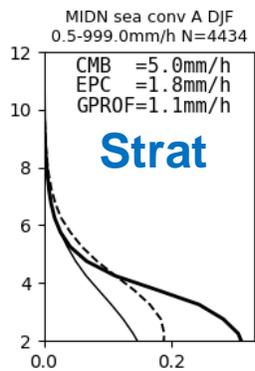
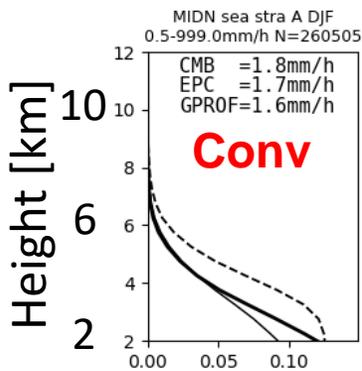
Vegetation

Snow surface
(Only EPC)

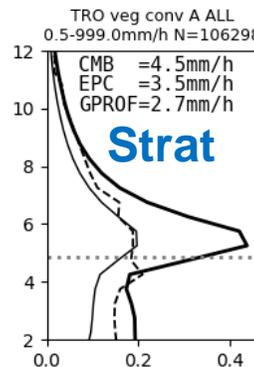
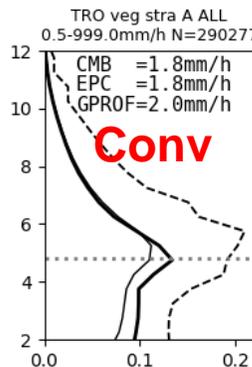
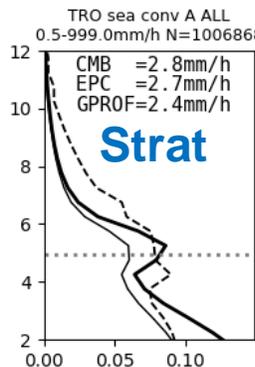
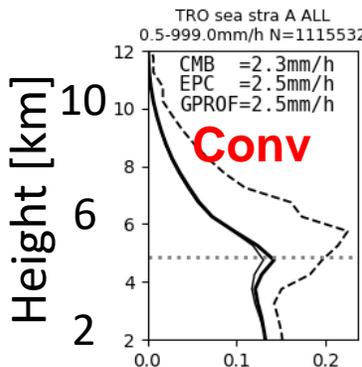
35N – 50N
(JJA)



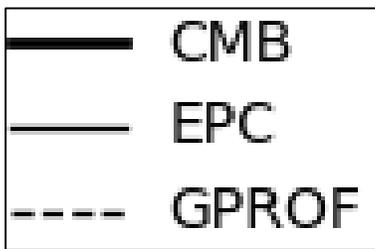
35N – 50N
(DJF)



15S – 15N
(ALL)



Condensed water content (g/m³)



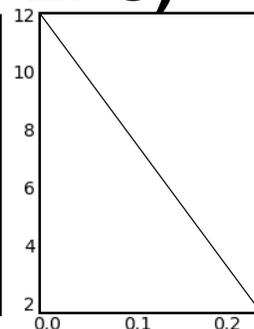
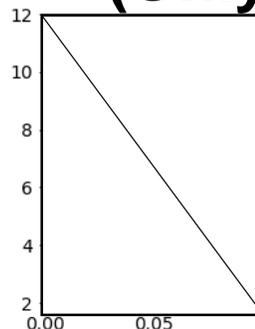
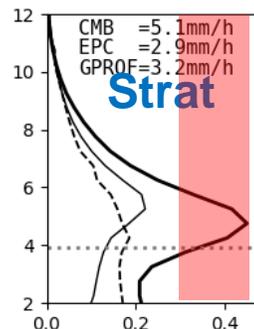
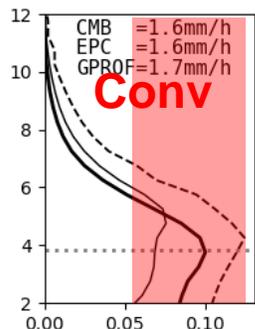
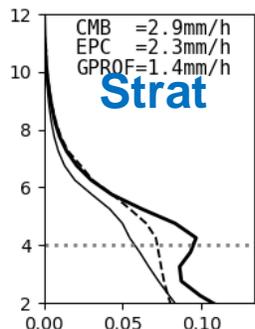
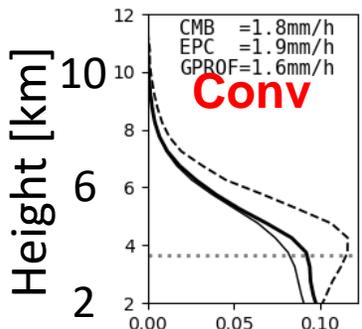
Condensed water content profiles

Ocean

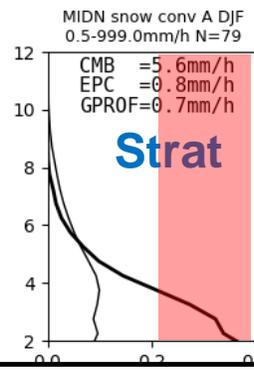
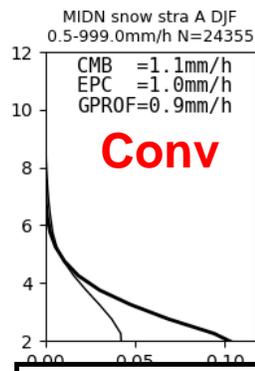
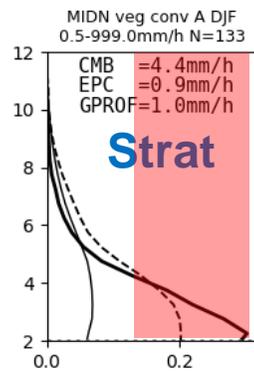
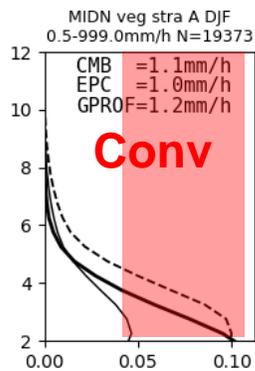
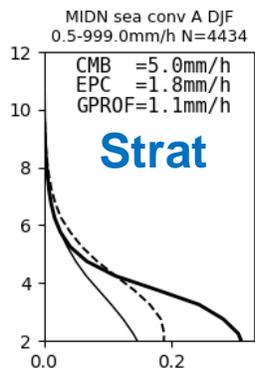
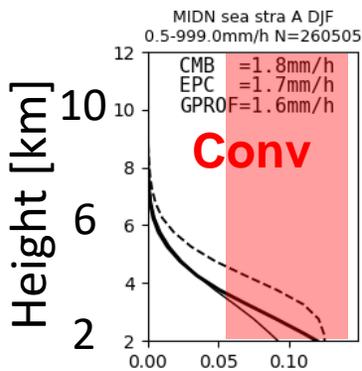
Vegetation

Snow surface (Only EPC)

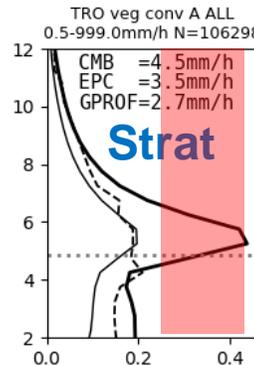
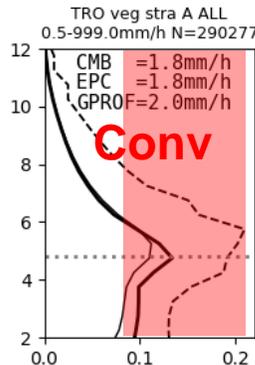
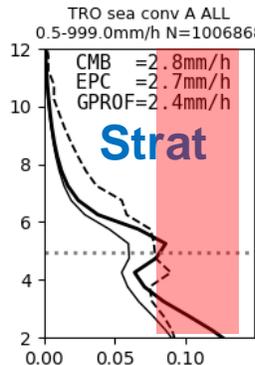
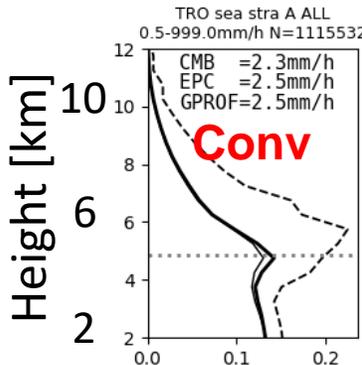
35N – 50N
(JJA)



35N – 50N
(DJF)

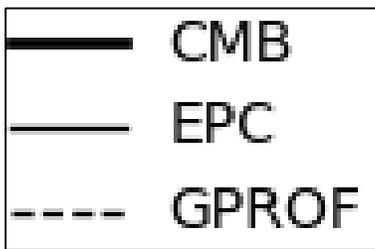


15S – 15N
(ALL)



Significant underestimation & overestimation (up to ~60%) of amplitude are found (vegetation & snow)

Condensed water content (g/m³)



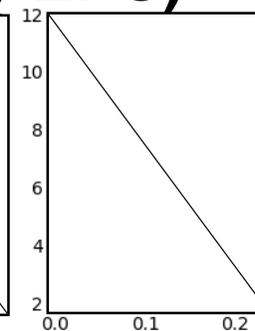
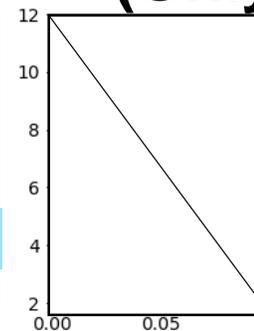
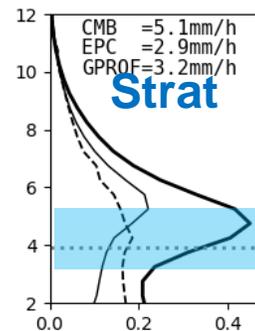
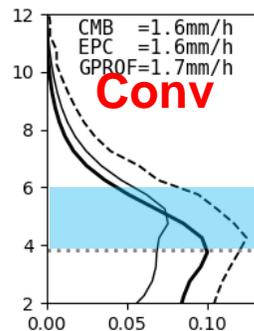
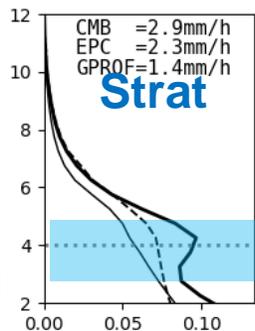
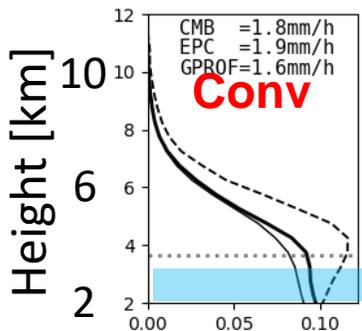
Condensed water content profiles

Ocean

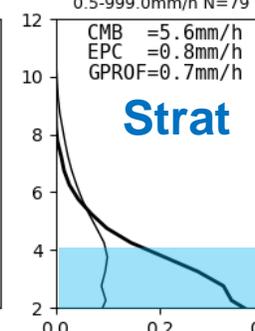
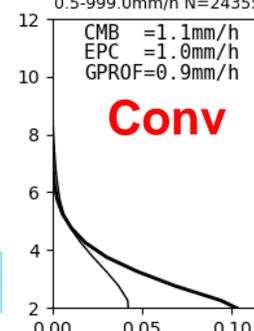
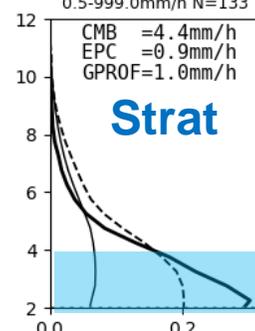
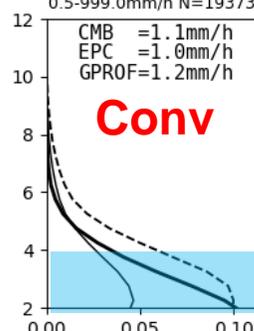
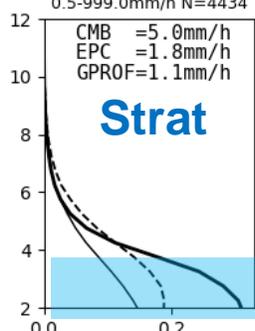
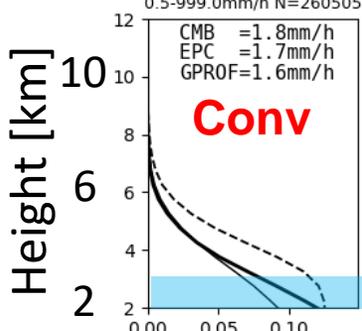
Vegetation

Snow surface (Only EPC)

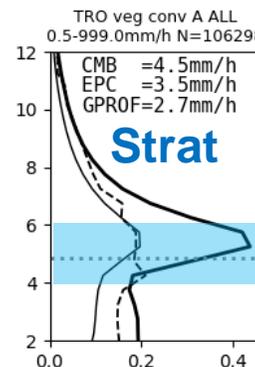
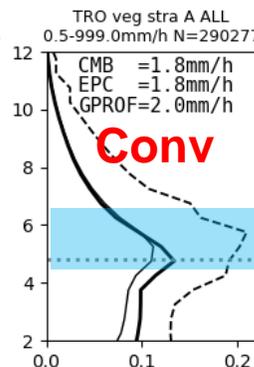
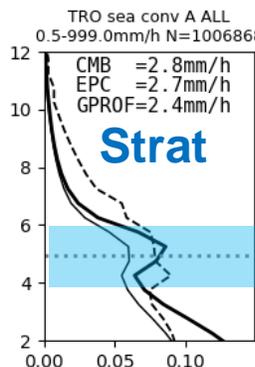
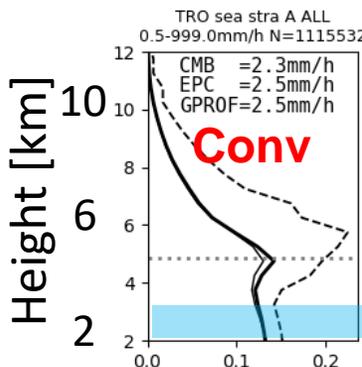
35N – 50N
(JJA)



35N – 50N
(DJF)

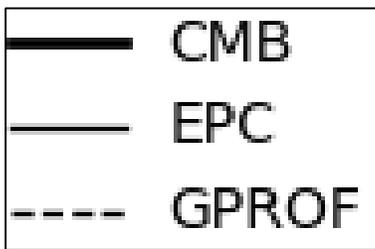


15S – 15N
(ALL)



Vertical shapes are generally captured (w/ ~1km error of peak water content height)

Condensed water content (g/m³)



Condensed water content profiles

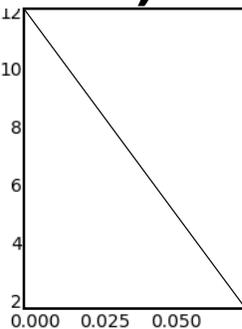
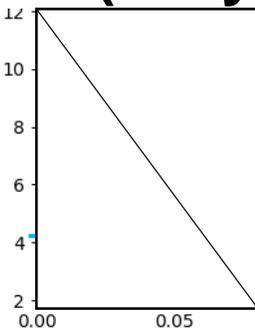
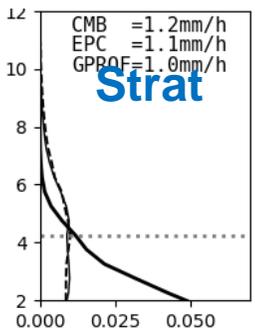
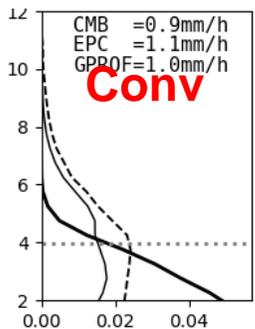
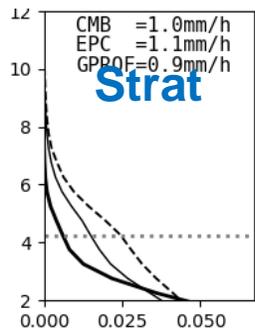
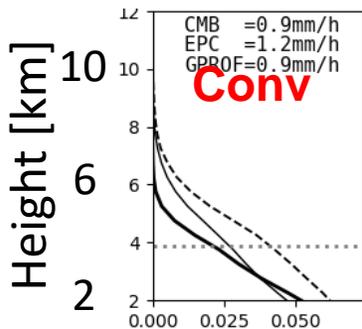
(Shallow* precip.) * Storm top (Ku) < Freezing level

Ocean

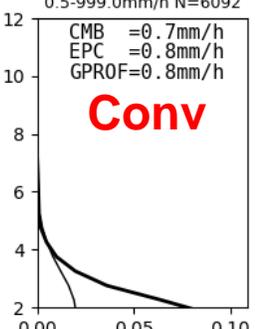
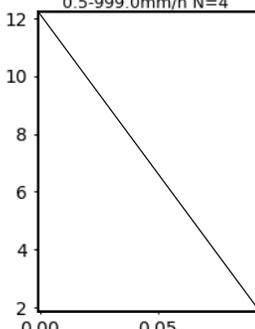
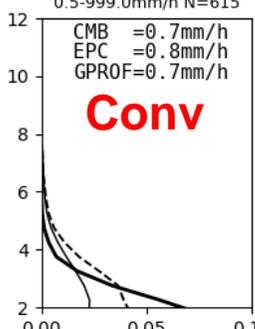
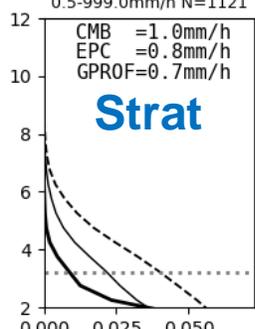
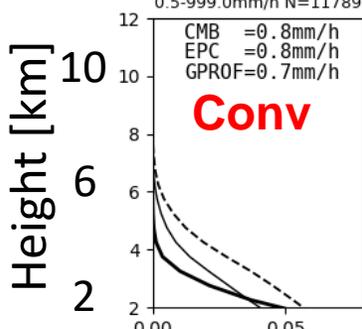
Vegetation

Snow surface
(Only EPC)

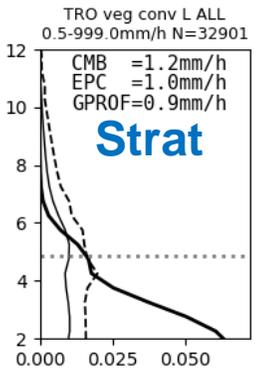
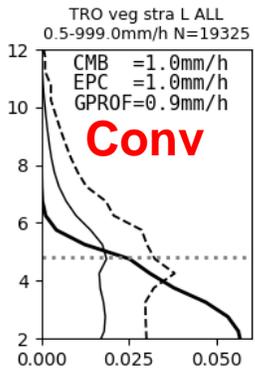
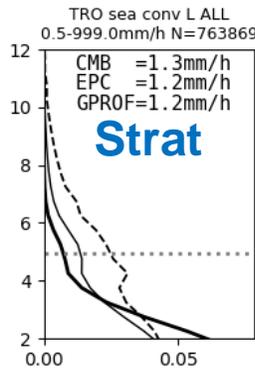
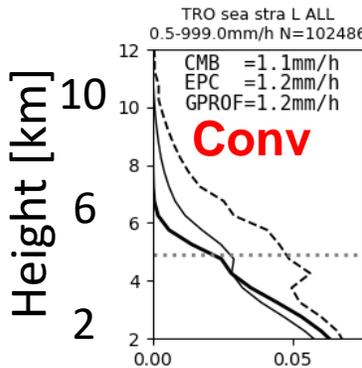
35N – 50N
(JJA)



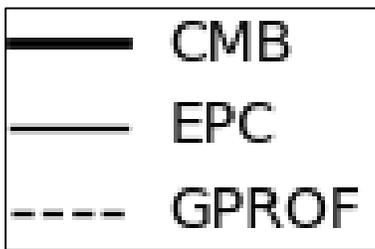
35N – 50N
(DJF)



15S – 15N
(ALL)



Condensed water content (g/m³)



Condensed water content profiles

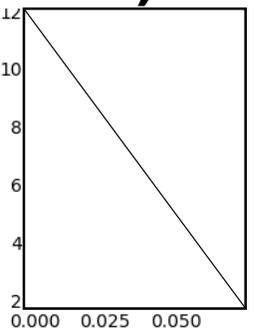
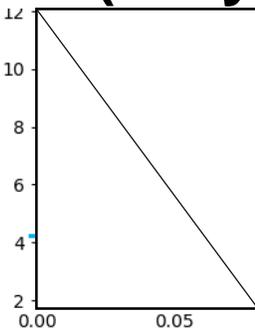
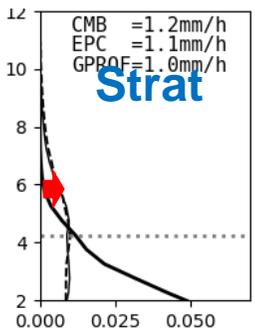
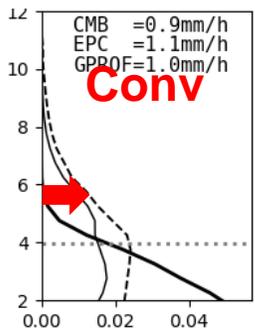
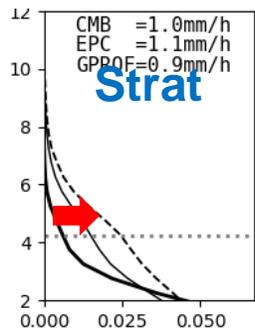
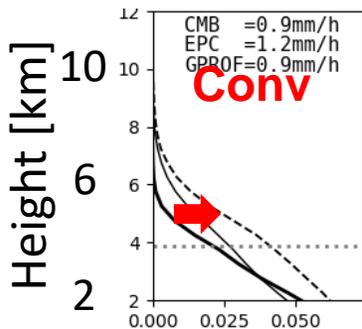
(Shallow* precip.) * Storm top (Ku) < Freezing level

Ocean

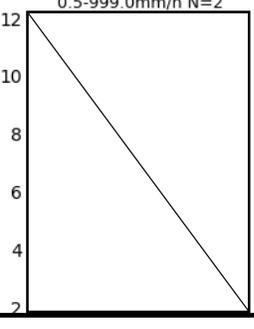
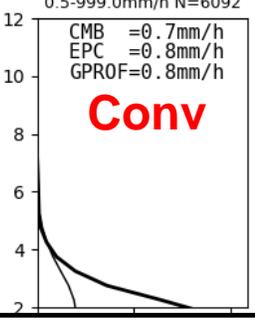
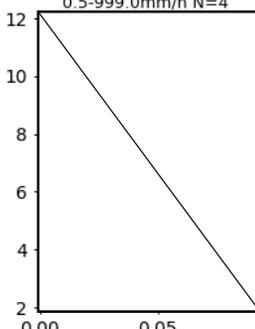
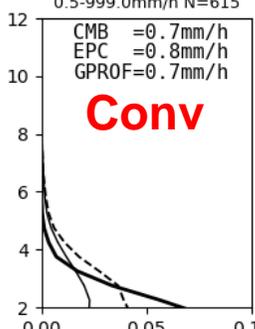
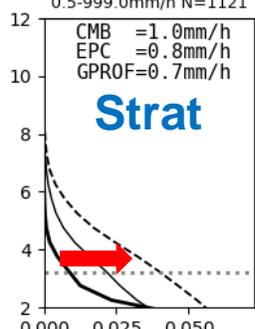
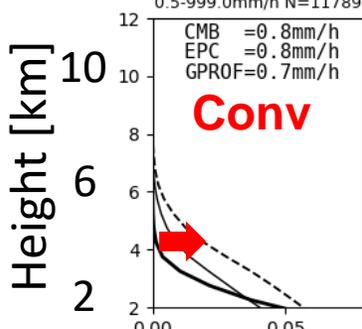
Vegetation

Snow surface
(Only EPC)

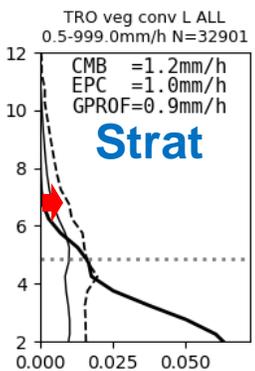
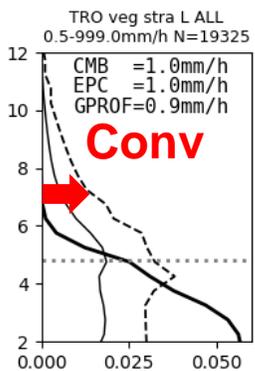
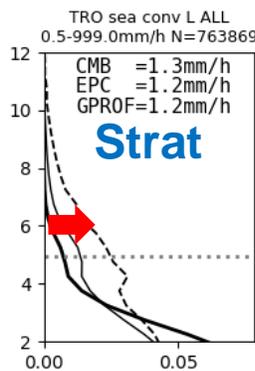
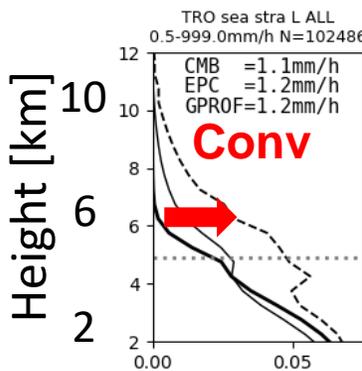
35N – 50N
(JJA)



35N – 50N
(DJF)



15S – 15N
(ALL)



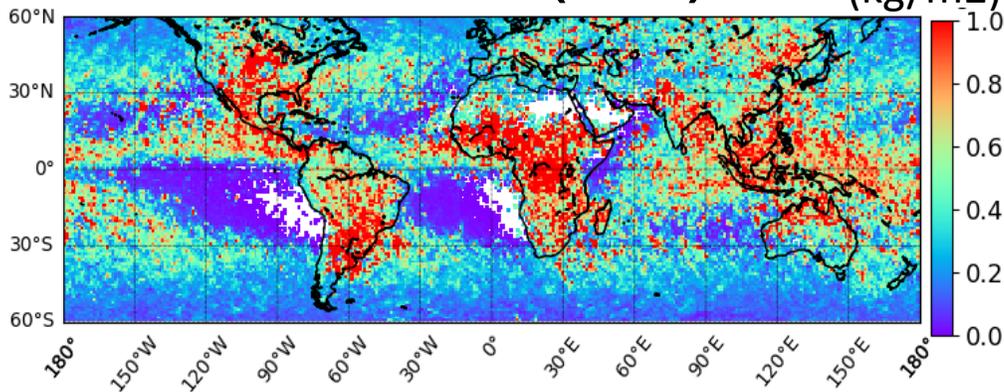
Precipitation height is systematically overestimated for warm precipitation

Condensed water content (g/m³)

Total condensed water content (kg/m²) (>2km)

Combined (CMB)

(kg/m²) (JJA+DJF, surface >0.5mm/h)



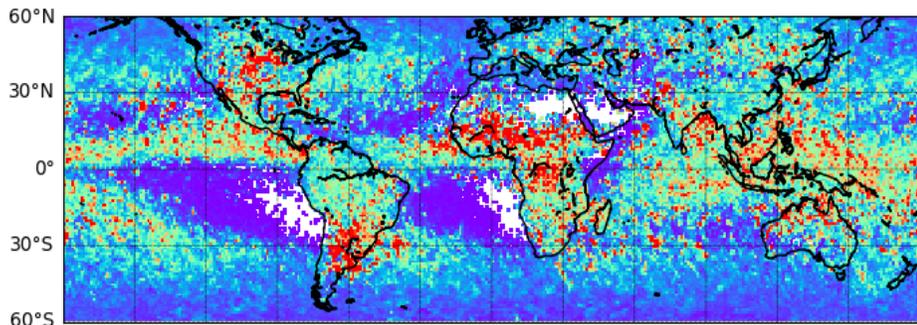
EPC

Underestimation (land)

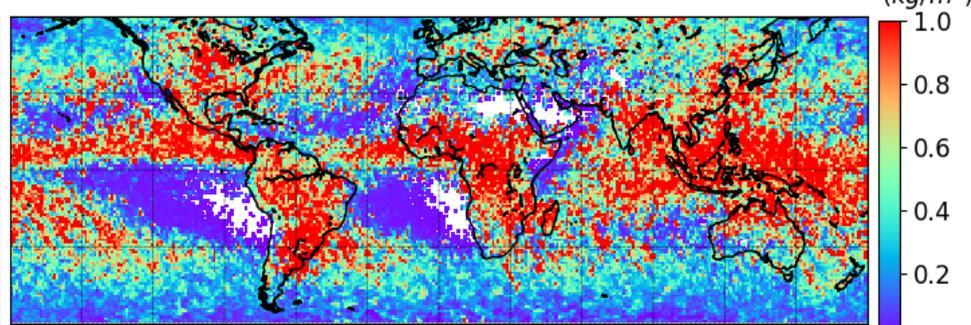
GPROF

Overestimation (ocean)

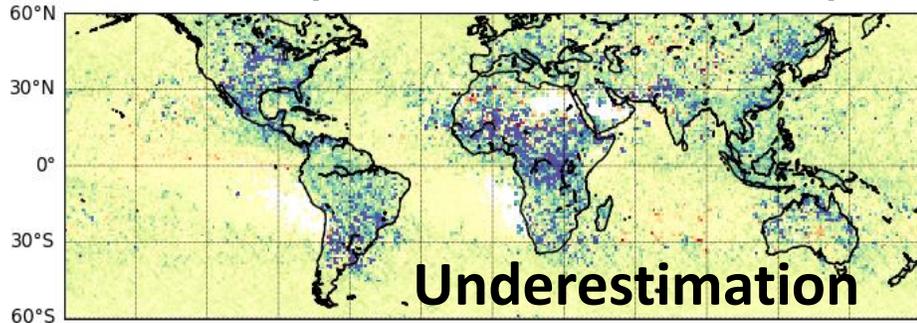
EPC



GPROF

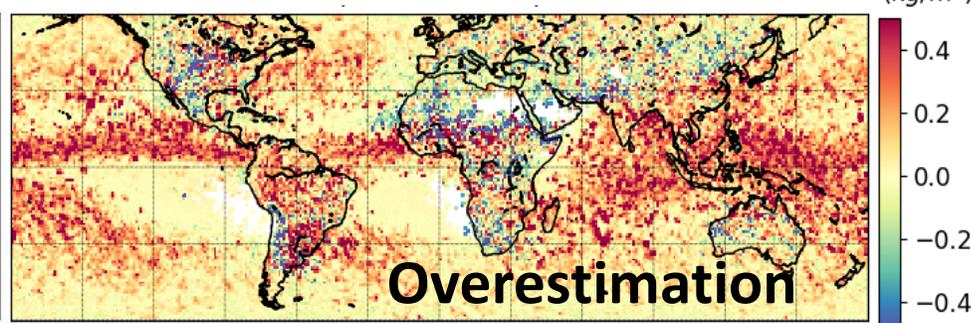


EPC (bias relative to CMB)



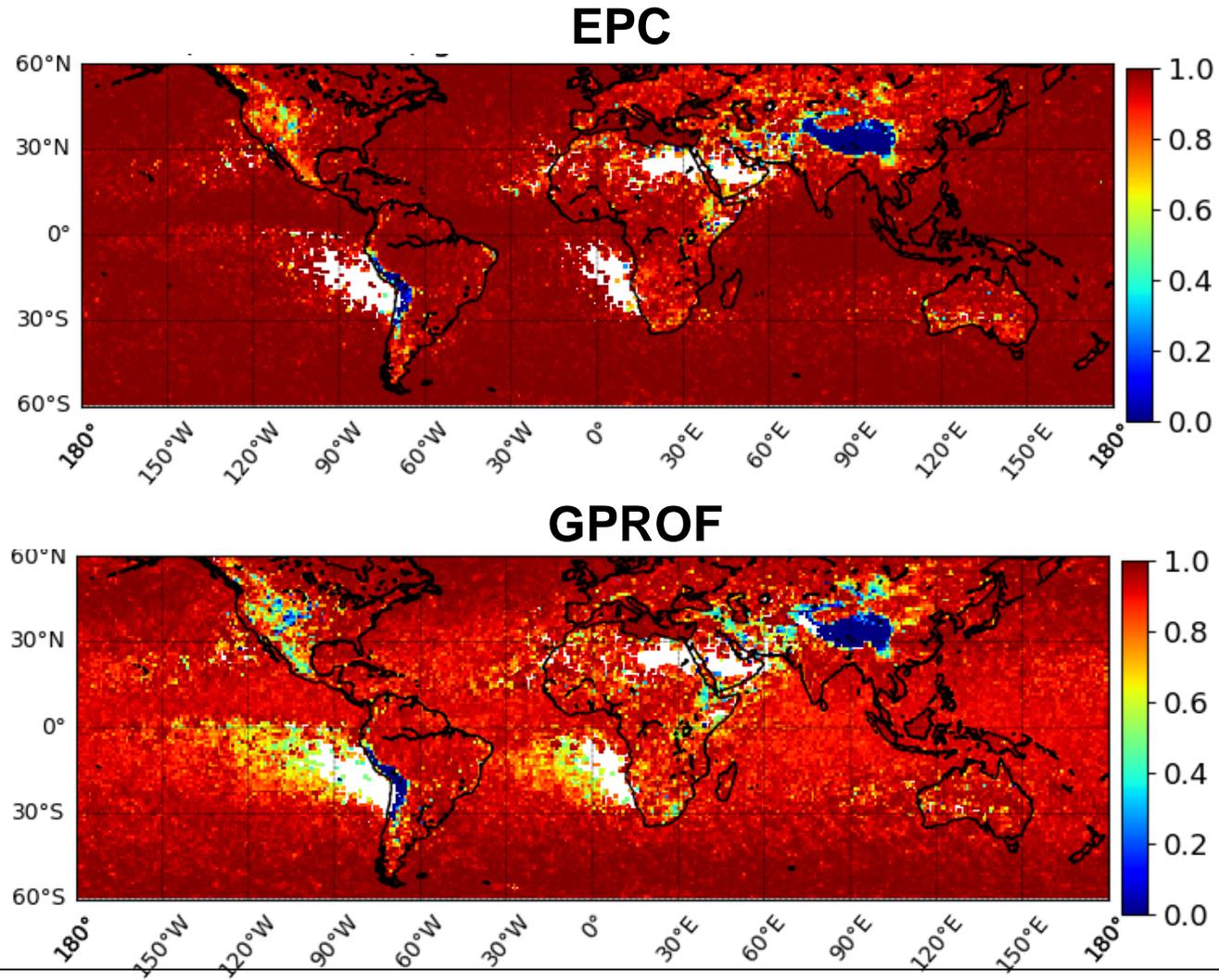
**Underestimation
(Over land)**

GPROF (bias relative to CMB)



**Overestimation
(Over ocean)**

Profile shape **correlation coefficient** (relative to combined algorithm)

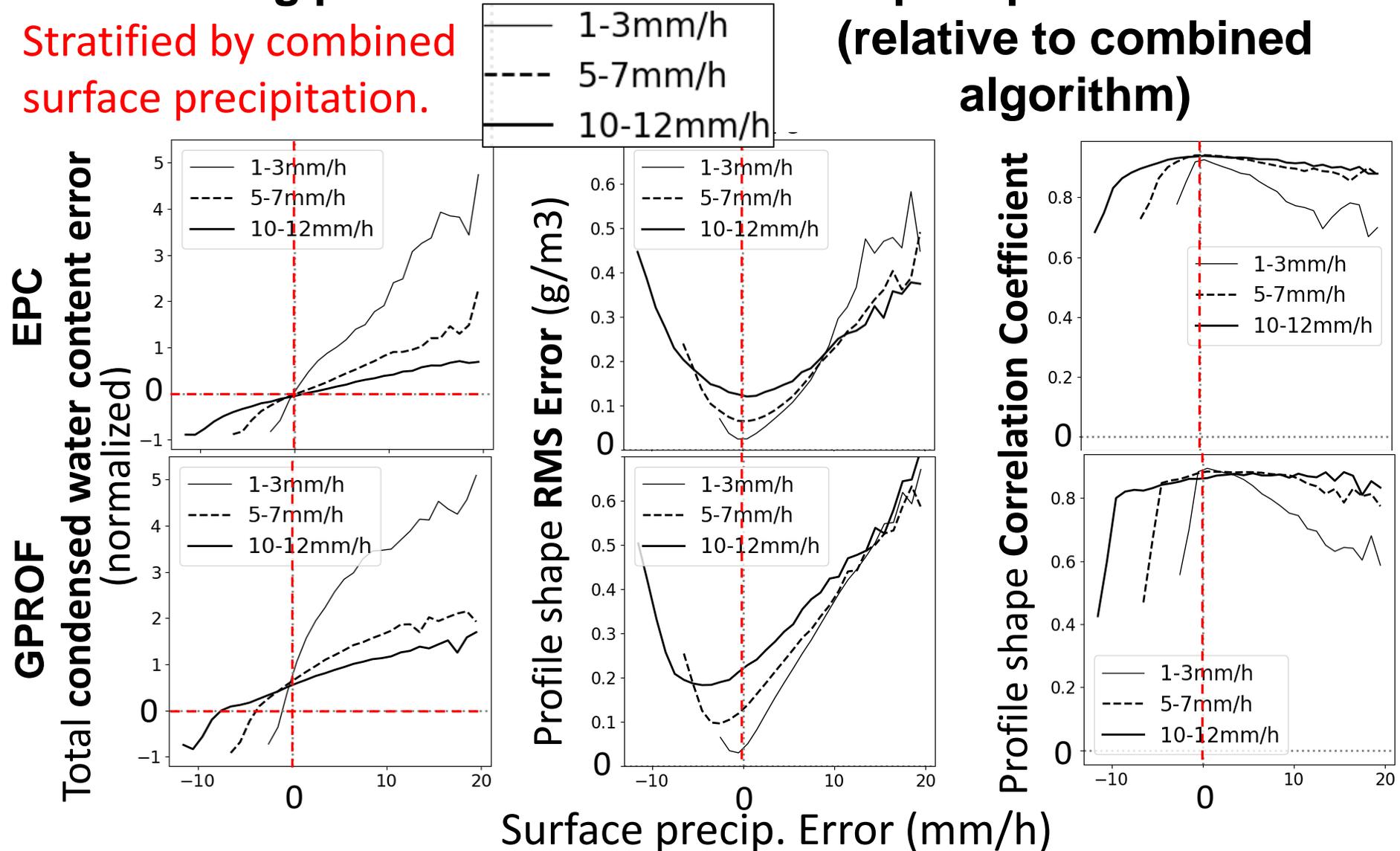


Although there are bias for profile amplitude, the shapes of the profiles are well captured by PMW algorithms.

Profiling performance and surface precipitation error

Stratified by combined surface precipitation.

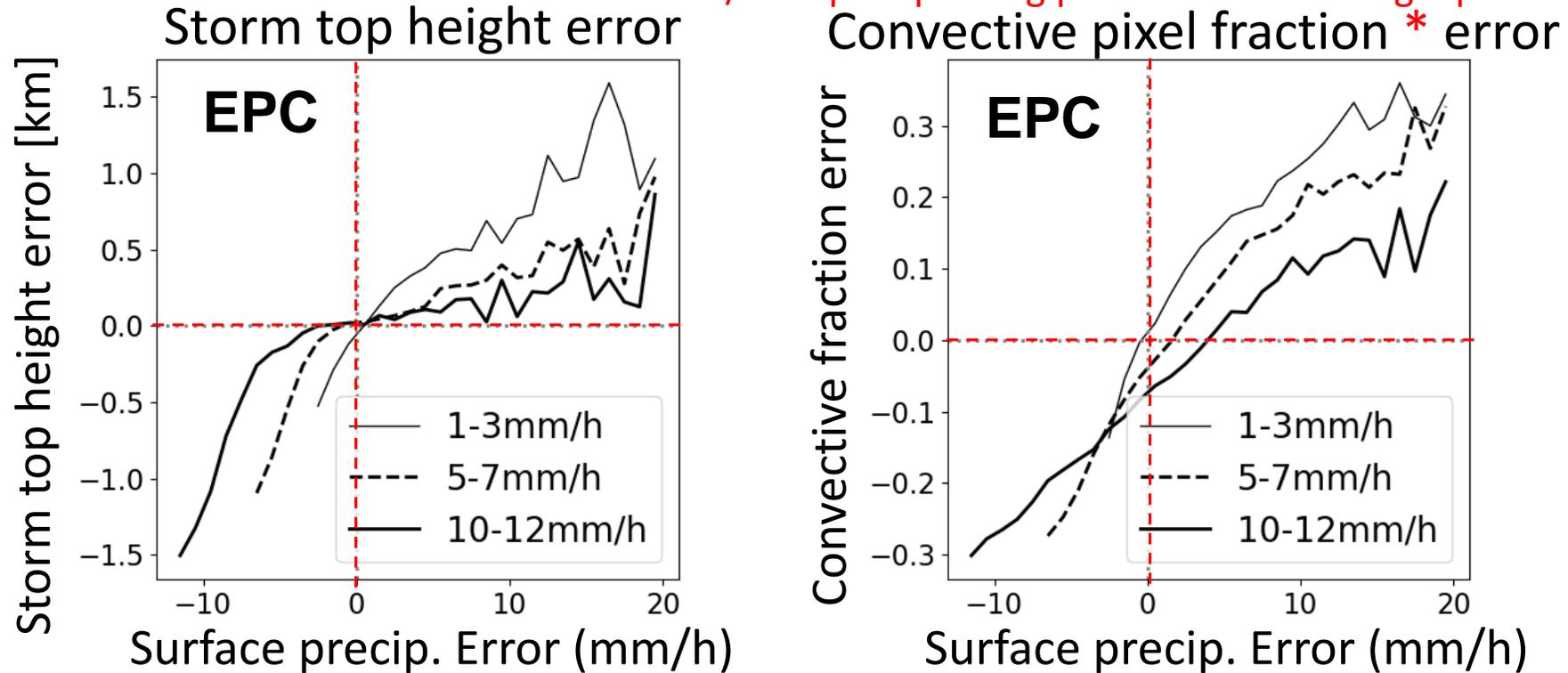
(relative to combined algorithm)



The error in the estimation of the surface precipitation rate and its corresponding profile are strongly related

Profiling performance and surface precipitation error

* # of conv / # of precipitating pixels in surrounding 9 pixels



- Errors in storm top height & convective fraction are strongly correlated with errors in surface precipitation.
- This suggests that if these or related parameters could be successfully constrained in the algorithm, it would reduce the error in the surface precipitation estimates. (consistent with previous studies; e.g., Petković et al., 2018)

Summary

Background questions

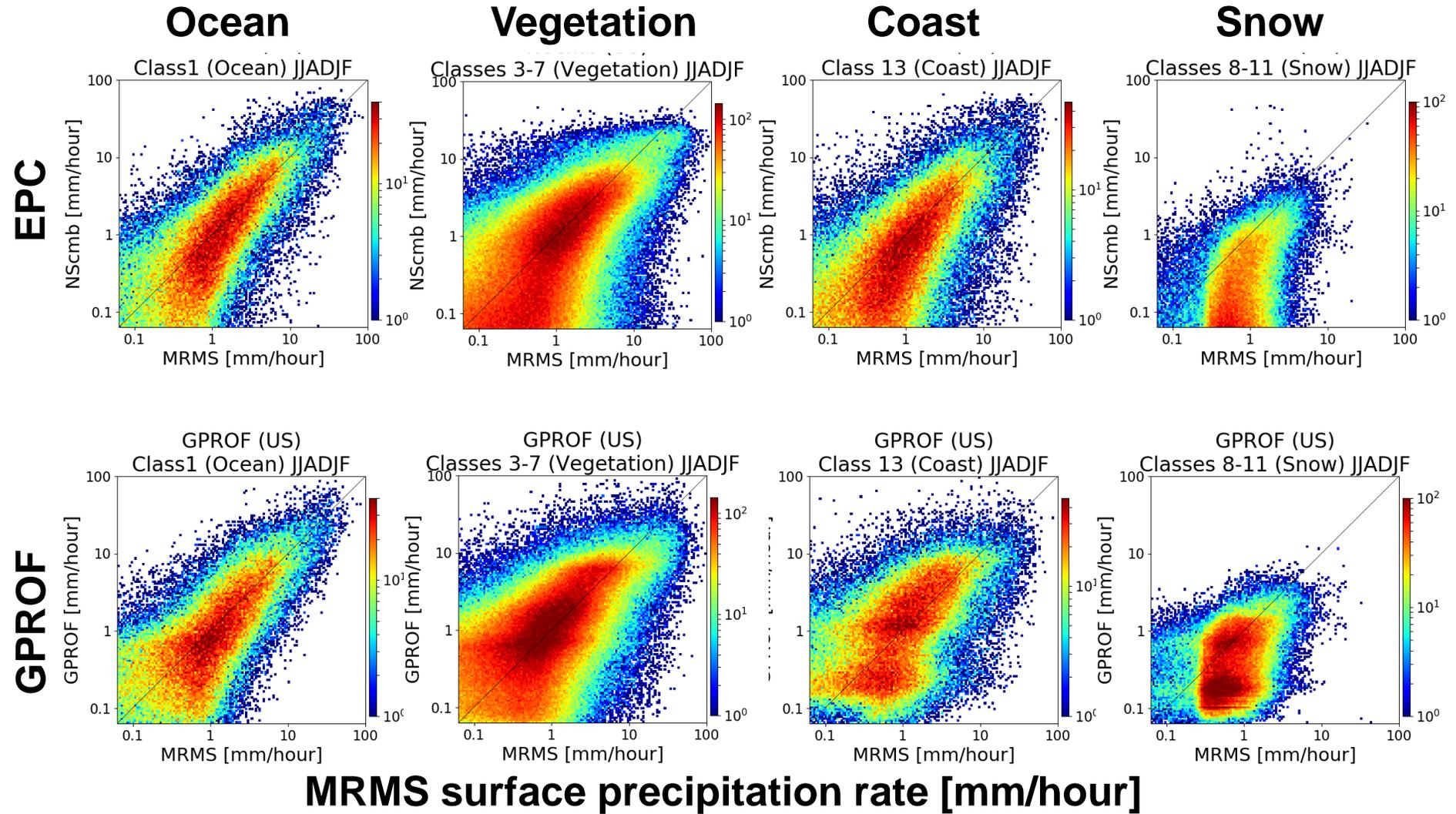
- How well do PMW algorithms represent vertical structures of precipitation?
 - Is there a connection between the performances for surface precipitation estimates and vertical structure estimates?
-
- PMW algorithms can represent average shapes of precipitation profiles.
 - But there are some biases for the condensed water content by current implementation of the algorithms.
 - There are significant bias for the amplitude (up to ~60%, underestimation & overestimation) over vegetation & snow surfaces.
 - Precipitation height for shallow precipitation is systematically overestimated by PMW algorithms
 - Error in surface precipitation rate is strongly related to:
 - the error in its profile
 - the error in storm top height and convective pixel fraction.

Suggestions and future work

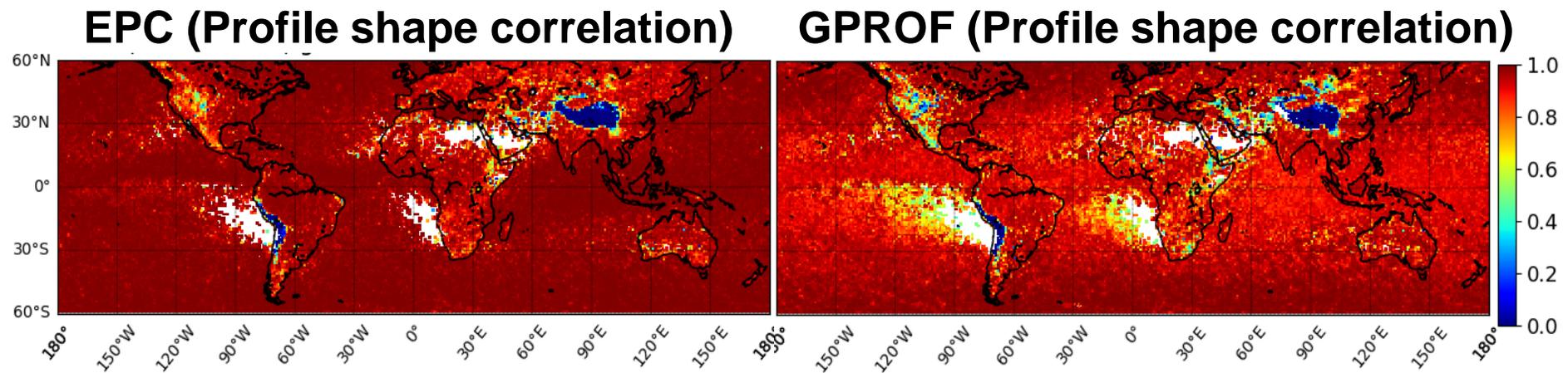
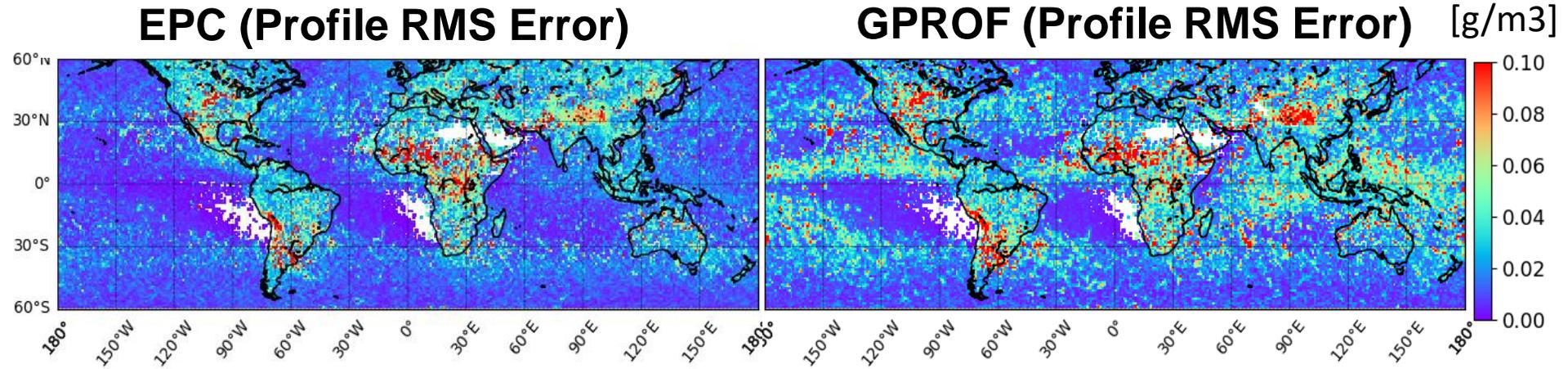
- The strong correlations between surface precipitation error and storm top height & convective fraction errors suggest a proper constraint on these parameters in the algorithms would improve surface precipitation estimates.
- This study assumes the combined algorithm as a reference. Future work will include dense ground-based radar coverage (e.g., MRMS over SE. United States).
- Further investigation for cold season and snow profile using collection of FMI C-band radar data.
- This study was only for GPM-GMI. Similar validation of other constellation radiometers products is in progress.

Backup slides

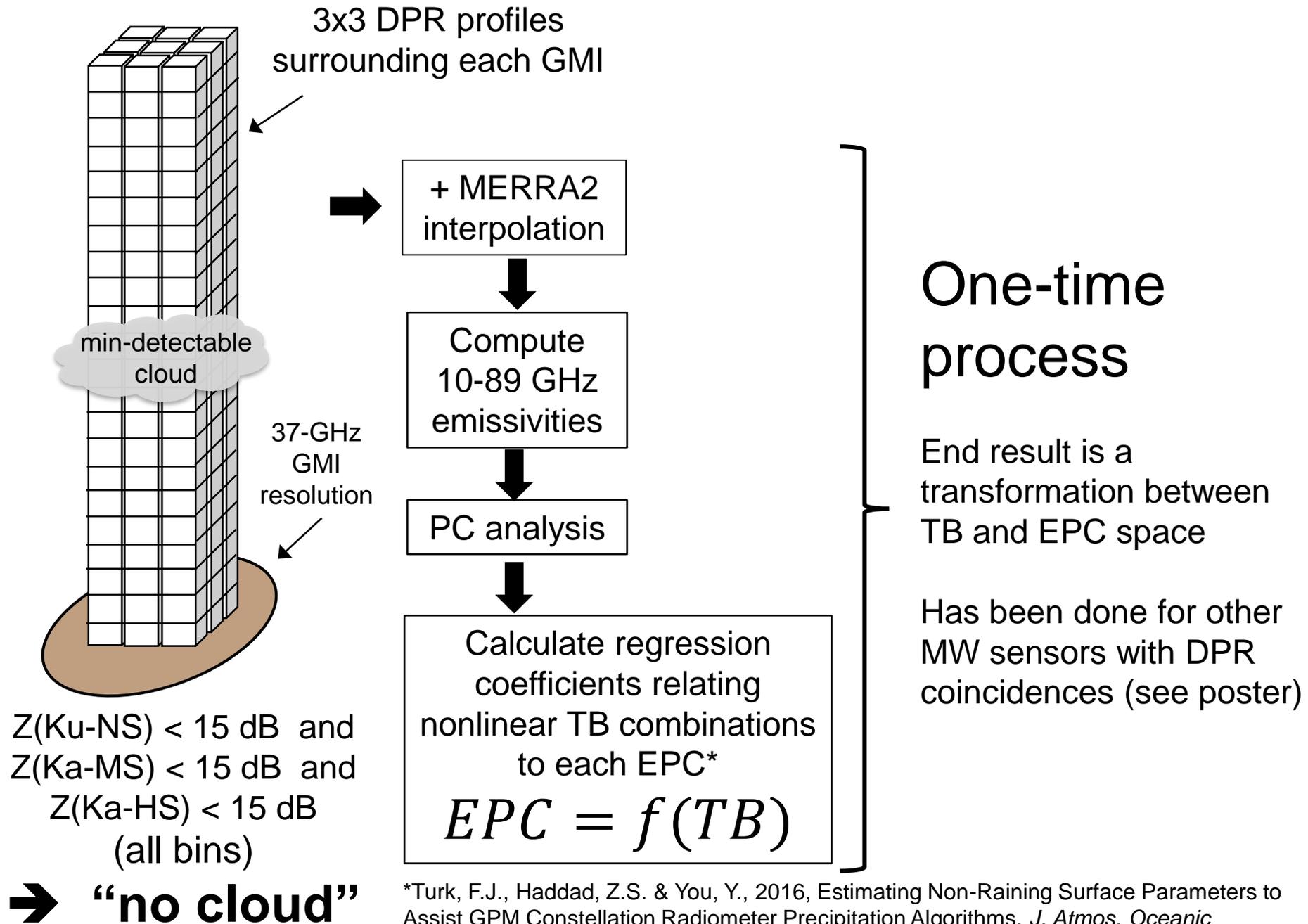
Overall Performance (Relative to MRMS) (JJA+DJF 2017)



Profiling performances (relative to combined algorithm)



* Performances are estimated for average profile at each pixel

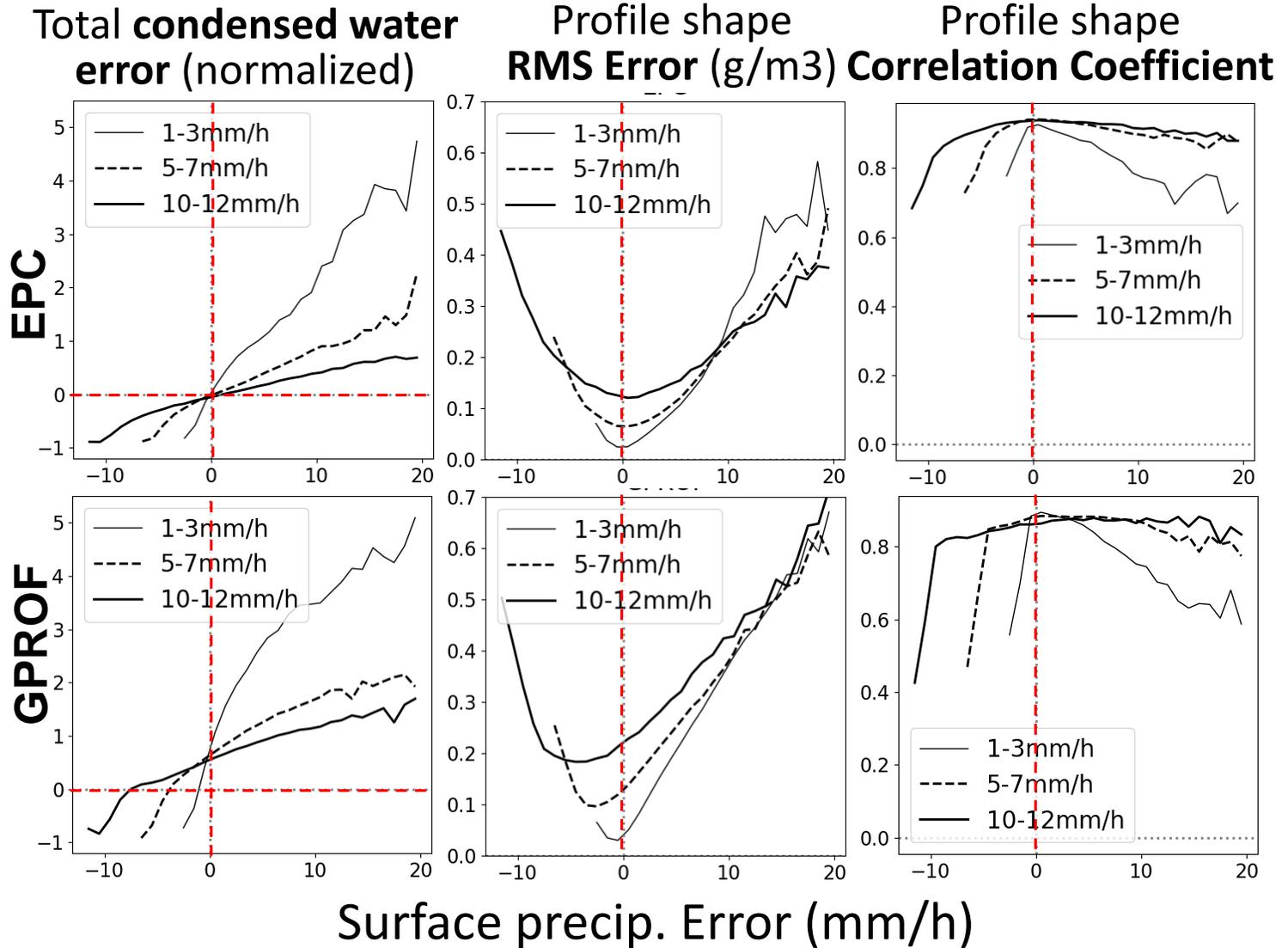
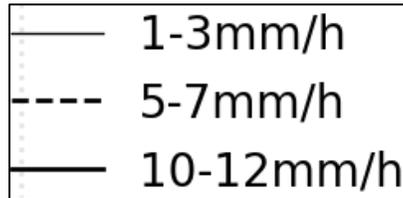


Z(Ku-NS) < 15 dB and
 Z(Ka-MS) < 15 dB and
 Z(Ka-HS) < 15 dB
 (all bins)

*Turk, F.J., Haddad, Z.S. & You, Y., 2016, Estimating Non-Raining Surface Parameters to Assist GPM Constellation Radiometer Precipitation Algorithms, *J. Atmos. Oceanic Technol.*, 33(2016), pp. 1333-1353.

Surface precipitation error and profiling performance

Stratified by
DPRGMI
surface
precipitation.

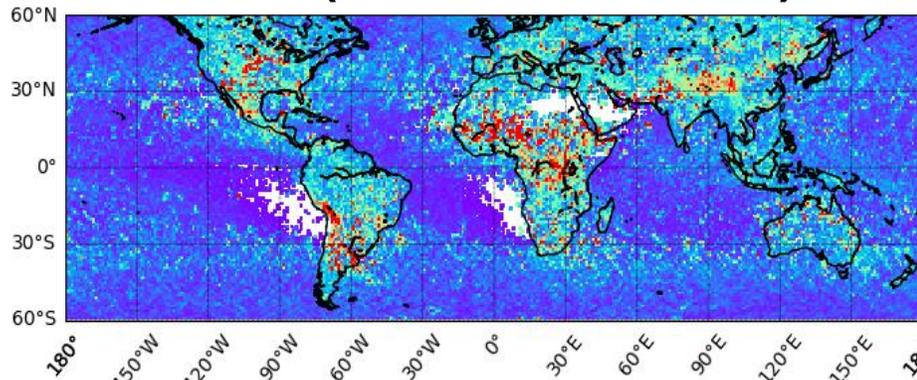


*For all surface
are mixed in
this analysis

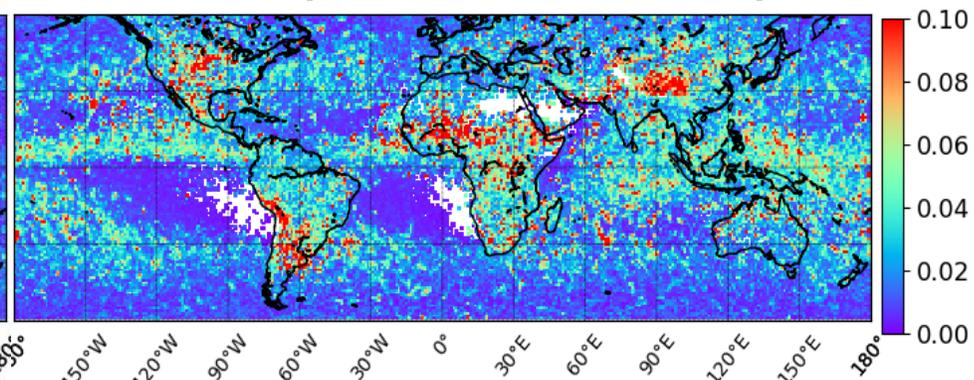
The error in the estimation of the surface precipitation rate and its corresponding profile are strongly related

Estimation performances (relative to combined algorithm)

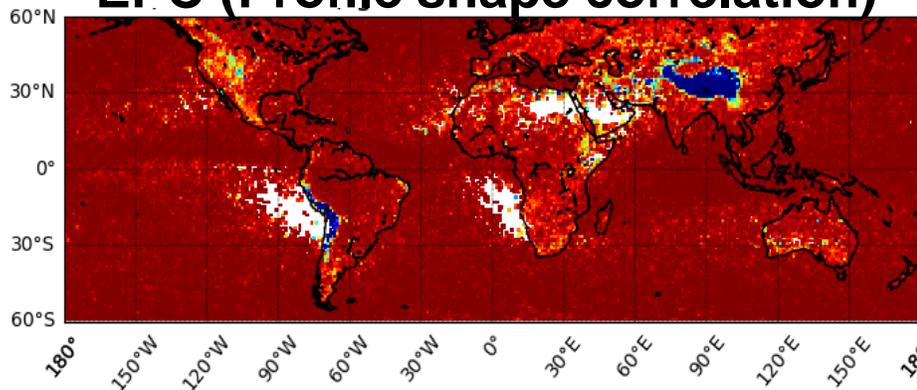
EPC (Profile RMS Error)



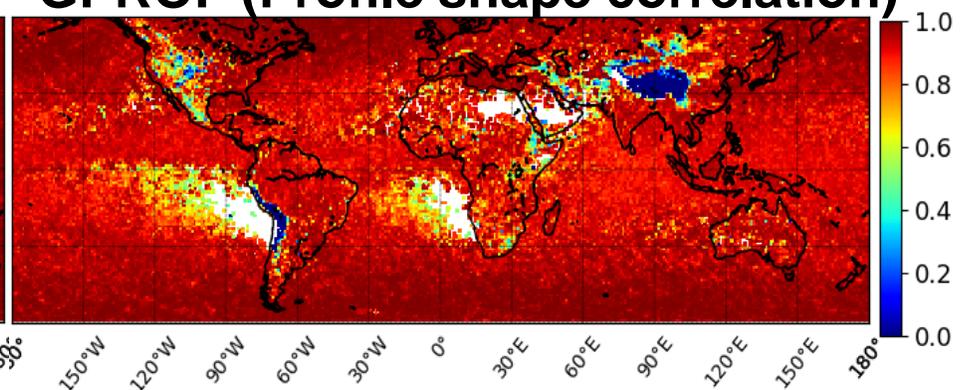
GPROF (Profile RMS Error)



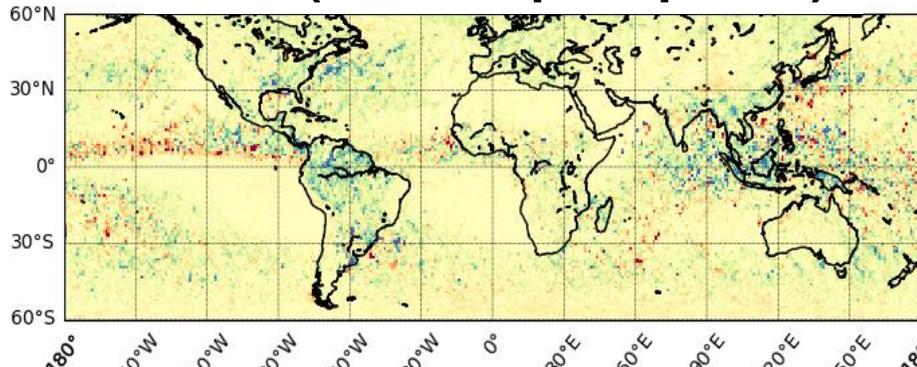
EPC (Profile shape correlation)



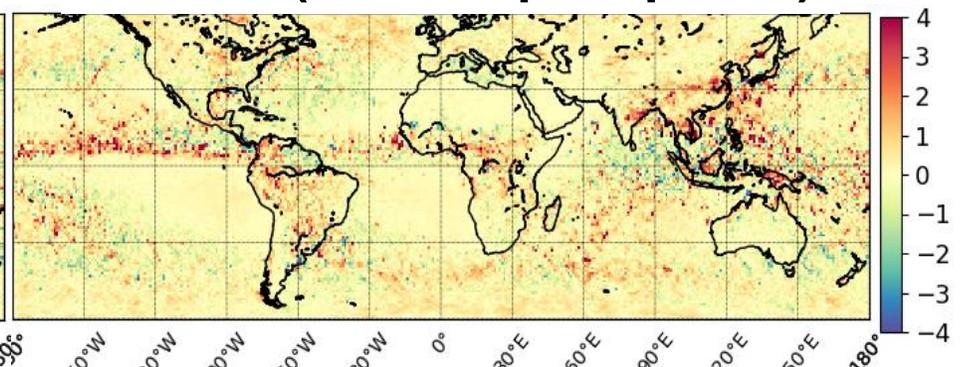
GPROF (Profile shape correlation)



EPC (Surface precip bias)



GPROF (Surface precip bias)



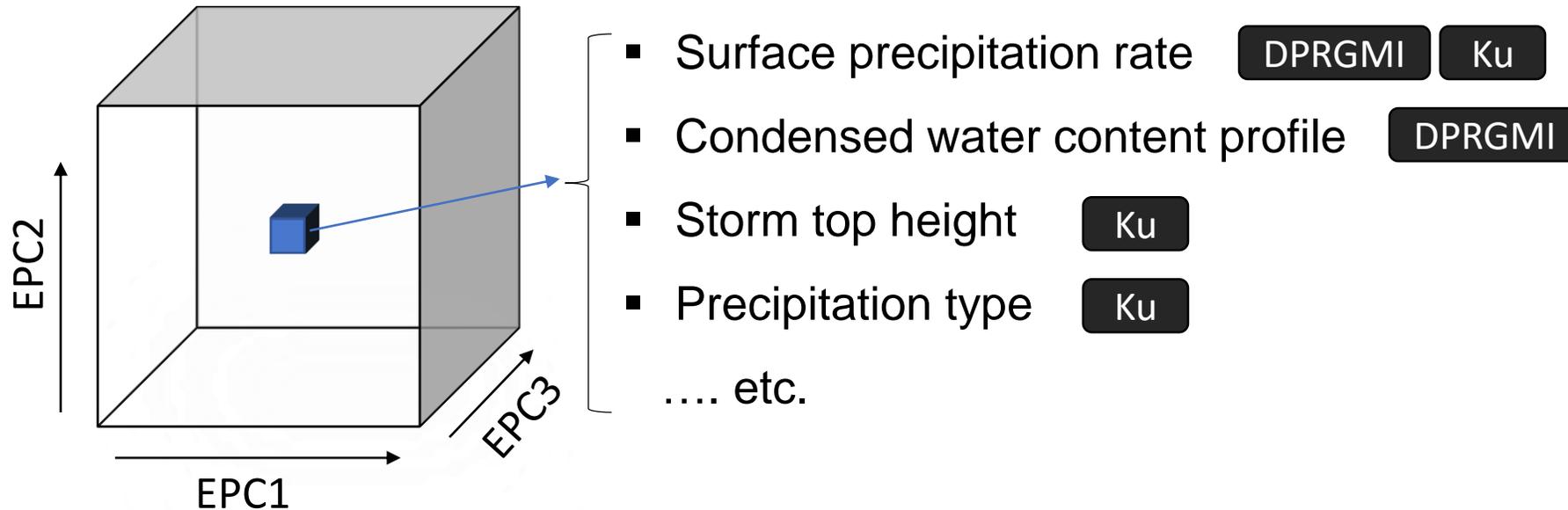
Background of the Emissivity Principal Components (EPC) Algorithm

- A main constraint on the interpretation of passive microwave TB is the “background” – the surface emissivity vector, or more generally, the joint surface and atmospheric moisture/temperature state.
- Previous work² have demonstrated a Bayesian-based precipitation retrieval framework that is based on the principal components of the joint emissivity vector and the associated environmental state (emissivity principal components, or EPC).
- The EPC is used to index and guide the *a-priori* database searches, to isolate candidates that are most congruent to the observations.

² Turk, F. J., Z. S. Haddad, P.-E. Kirstetter, Y. You, and S. Ringerud, 2018: An observationally based method for stratifying a priori passive microwave observations in a Bayesian-based precipitation retrieval framework. Quarterly Journal of the Royal Meteorological Society, 144, 145–164

a-Priori Database (DB) binned by EPC

A-Priori DB, indexed by EPC, was developed from DPR & each of the constellation of radiometer matching scenes.



- EPC is calculated from TB at each observation time.

$$EPC = f(TB) \leftarrow \text{Predefined regression function relating TB combinations to each EPC}$$

- Candidates that are most congruent to the observations are searched using EPC vector.

