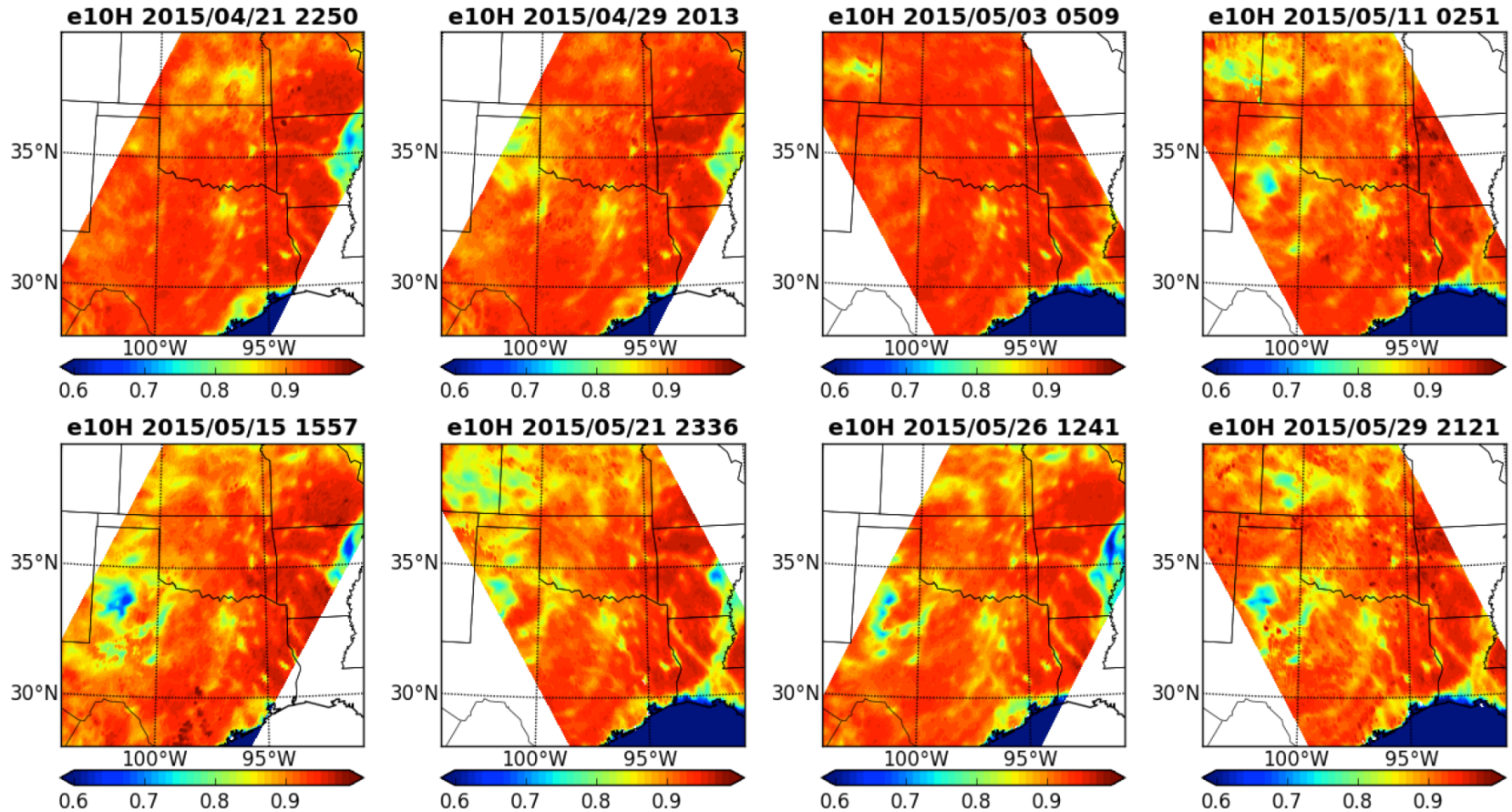
An Examination of GPM and TRMM Surface Properties Under a Variety of Precipitating Conditions

Texas/Oklahoma May 2015 rains



F. Joseph (Joe) Turk, Jet Propulsion Laboratory,
California Institute of Technology, Pasadena, CA

GPM/PMM Land Surface Working Group, 13 July 2015, Baltimore, MD

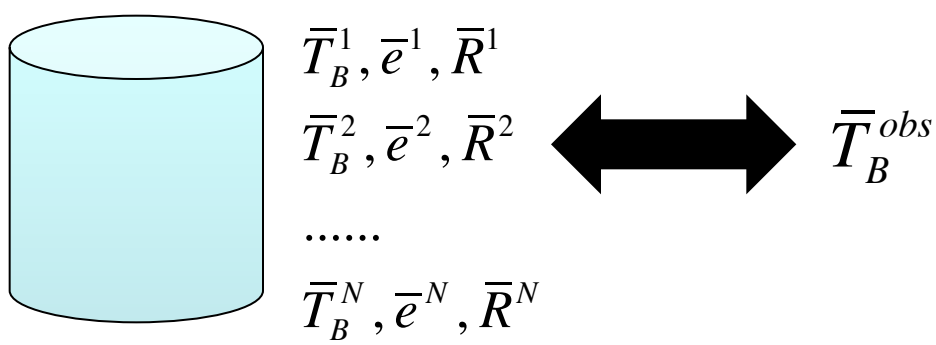
Why is this work needed?

- A-priori databases for current constellation radiometer-based precipitation are empirically generated from (mostly) ground-based radar precipitation data.

- Future databases are envisioned to be physically generated, in order to apply common physics across all platforms/sensors

- Therefore the emissivity vector needs to be specified for each sensor type

- And some way of "connecting" to the land properties used for creating each database profile, when carrying out the retrieval



A-priori database ***Observations***

"connect" land surface emissivity conditions at the time of the retrieval, to corresponding land surface emissivity conditions within the database

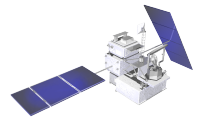
Current GPROF does this thru a "classification index"

Outline

- Summary of 2015 updated TMI physical emissivity modeling and 1998-2014 daily gridded dataset
- Adaptation of observationally-based emissivity specification from Turk et. al. 2014 approach, using current 14 months of GMI/DPR
- Variability in the (non-raining) joint Ku-band radar backscatter cross section and emissivity, as a function of previous rainfall accumulations (“wet surface” effect)

Contributions from P. Kirstetter, L. Li, Z. Haddad, J. Munchak, S. Durden, S. Ringerud, Y. Tian, and the PMM Land Surface Working Group

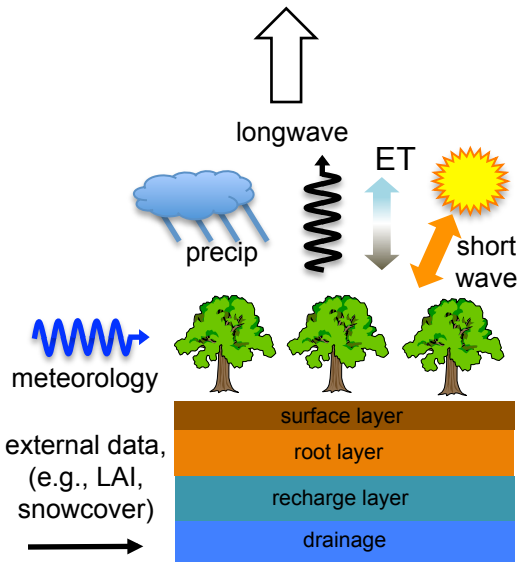
Difference & Similarity Between LSM & Simple Physical



Land Surface Model

Diverse dynamic land model carrying many surface, subsurface and near-surface parameters that are fed to forward simulations

Forward simulator for any sensor supported in CRTM, CMEM



oversimplified and non-complete

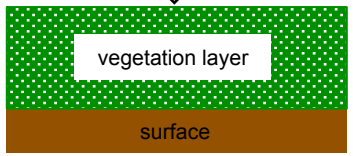
Simple Physical

Retrieves a three physical parameters that control surface emissivity (vegetation water content, soil moisture, surface temperature)

Works off of MW satellite observations

By design the retrieval agrees with TB observations, in a TB minimization sense

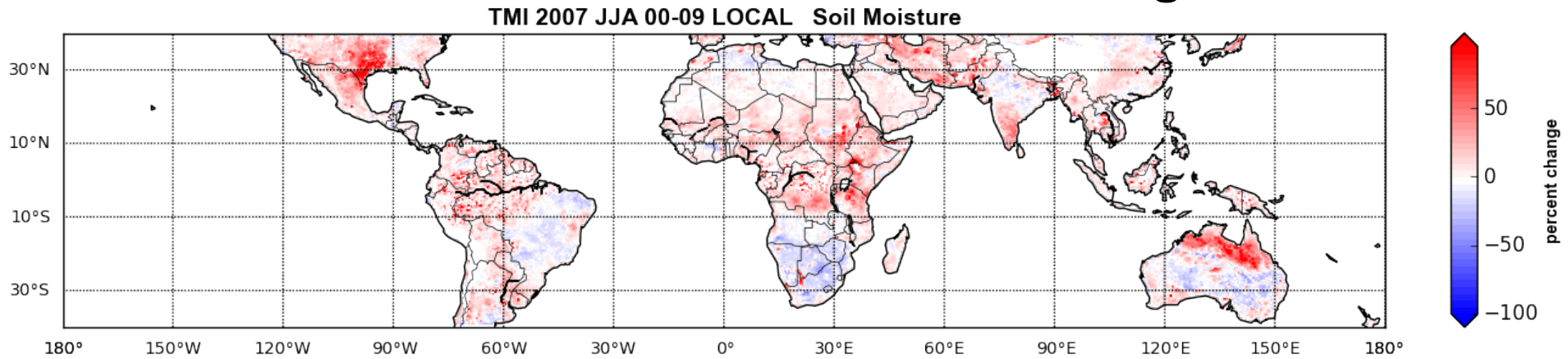
Adjust physical parameters to bring simulated and observed TB (10H/V, 19H/V, 37H/V GHz) into simultaneous accord

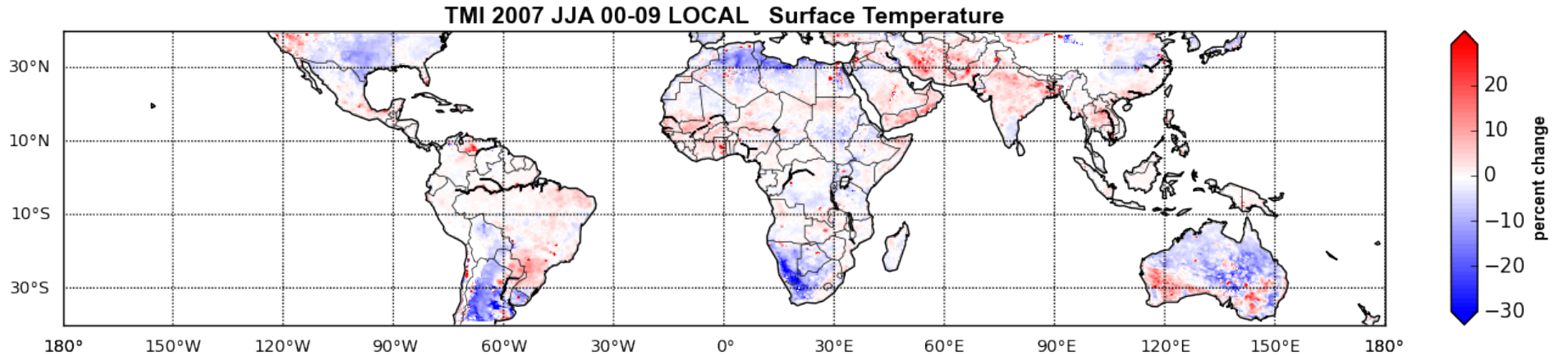


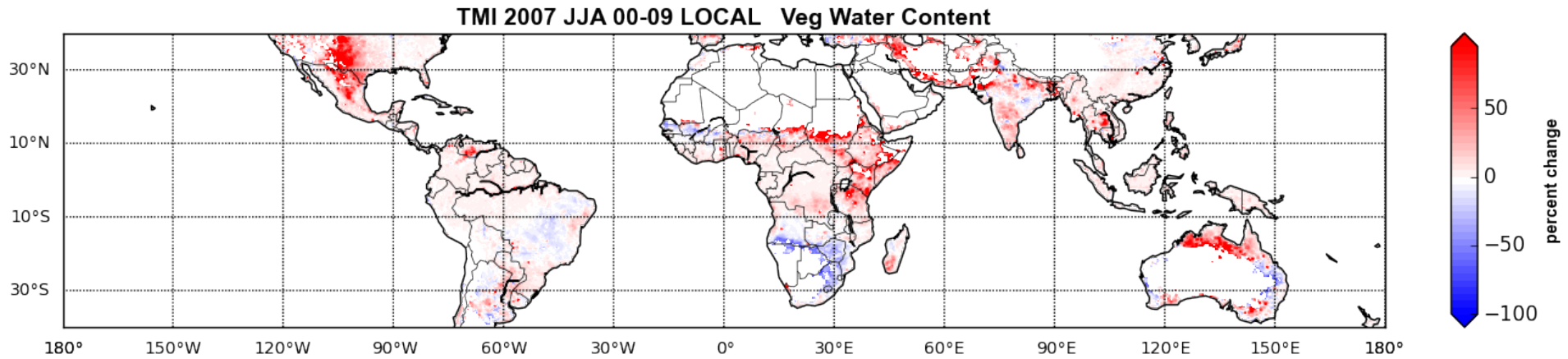
two-layer, zero-order model

$$\text{vegetation} = f(\tau, \omega)$$

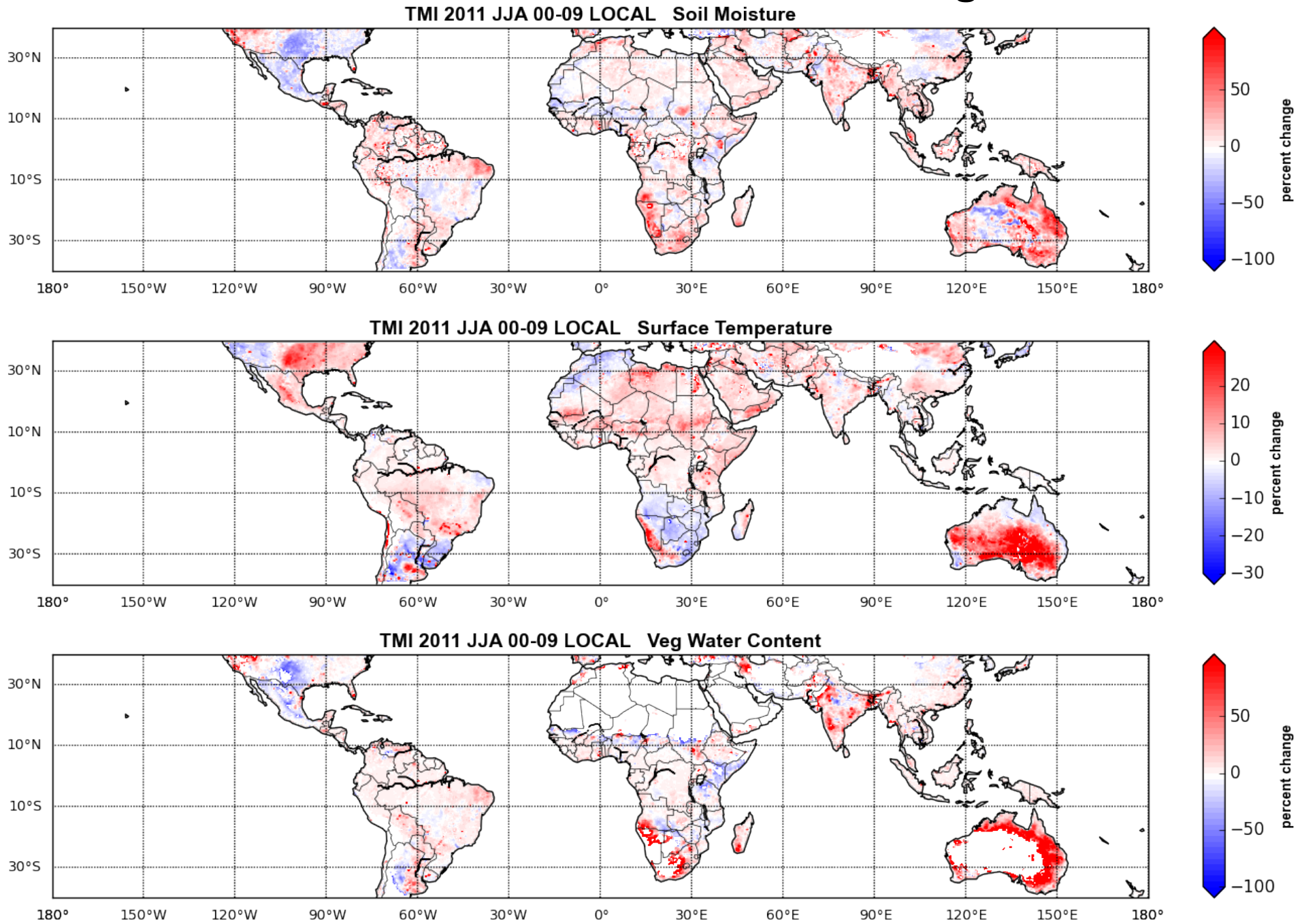
2007 relative to 2002-2012 average







2011 relative to 2002-2012 average



Current Status

New processing and testing of TMI physical retrievals is complete from 2002-2012, other TRMM years currently being processed (WindSat at 6AM only already complete from 2003-2012)

Data packaged in daily netCDF files on 25-km EASE grid (586x1383) used for AMSR-E land products: latitude, longitude, epoch time, local time (0-24 h), soil moisture, vegetation water content (VWC), surface temperature, emissivity*6

Add in NDVI and EVI interpolated from 16-day MODIS, to compare VWC and NDVI (any interest?)

Full dataset available by request, or may host online (≈ 200 GB)

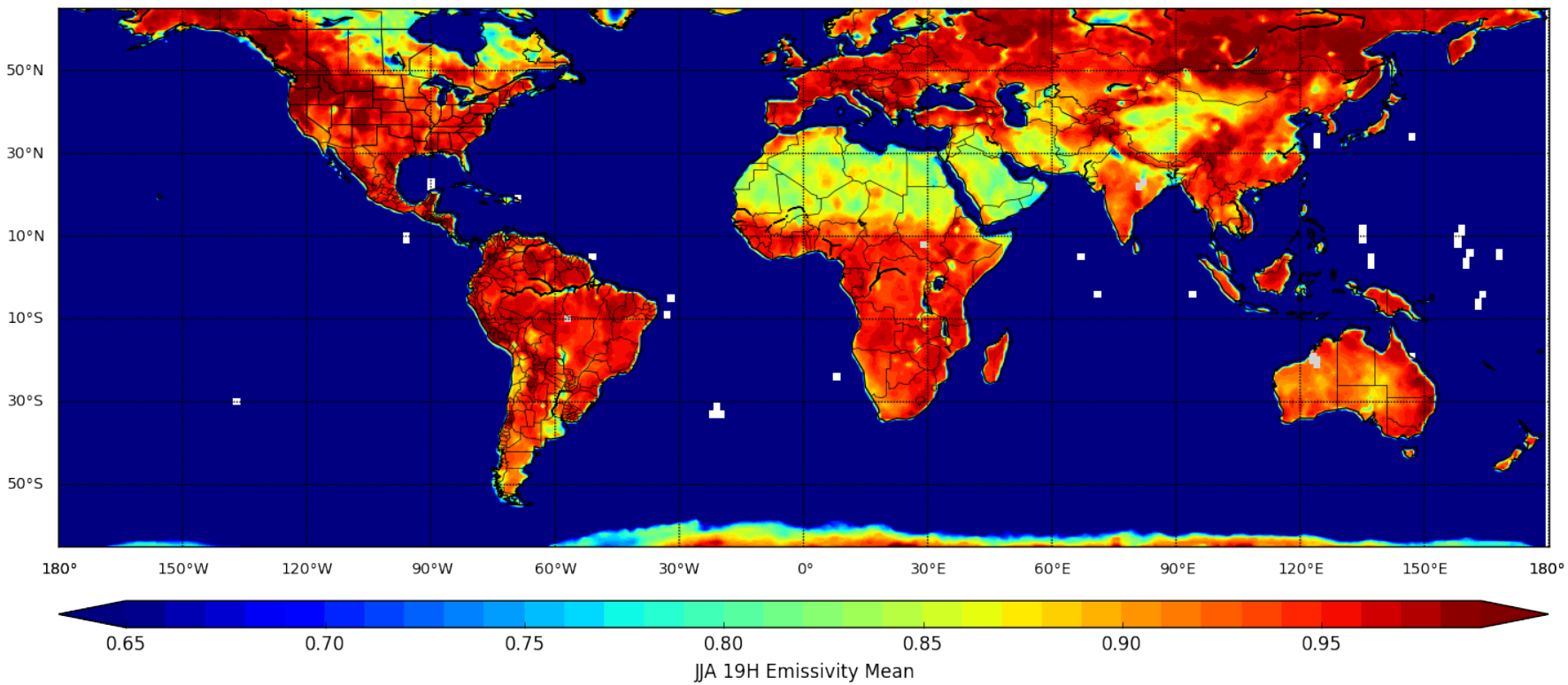
jturk@jpl.nasa.gov

Turk, F.J., L. Li, and Z.S. Haddad, 2014: A Physically Based Soil Moisture and Microwave Emissivity Data Set for Global Precipitation Measurement (GPM) Applications. *IEEE Trans. Geosci. & Rem. Sens.,* **52**, no. 12.

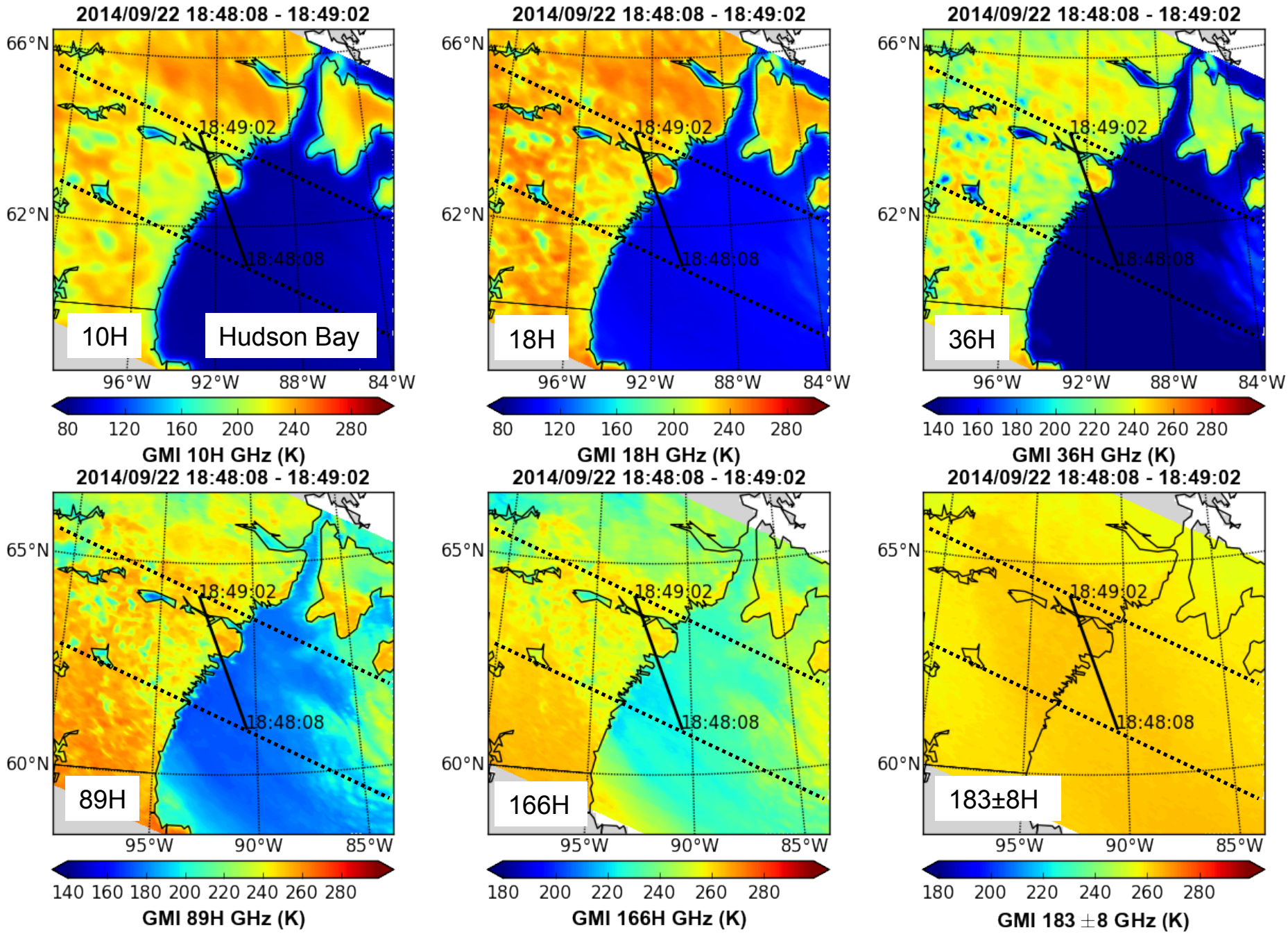
Analysis from Current Year of Matched GMI/DPR Data

Much of the time it is not raining, and the emissivity can be studied from the non-rain observations.

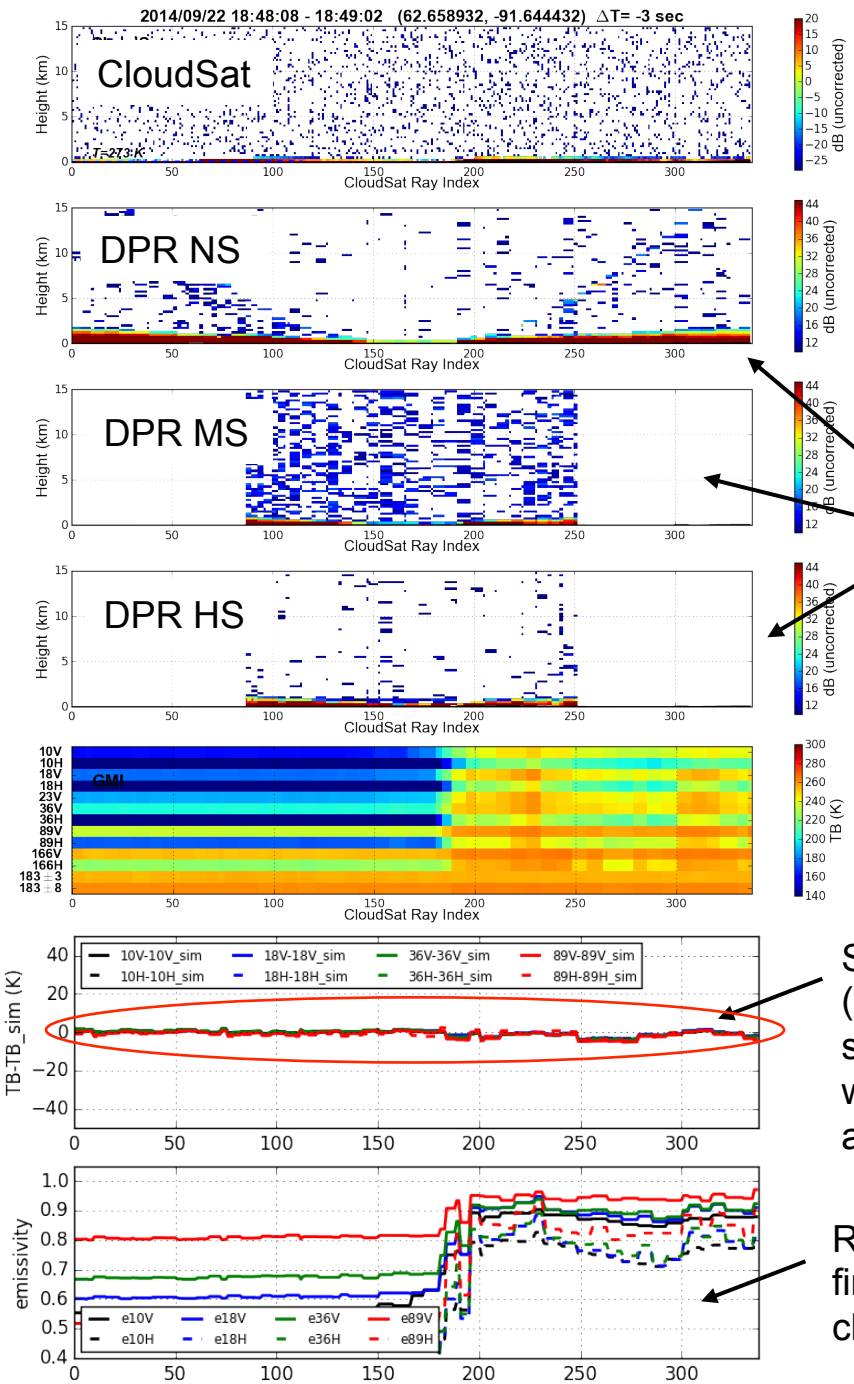
Use DPR NS & HS scans to globally collect “no-cloud” scenes (realizing that this is not the same as “clear”) everywhere regardless of underlying surface



19H Average Emissivity from GMI June-July-August 2014


2014/09/22 18:48:08 - 18:49:02
66°N
62°N
18:49:02
18:48:08
10H
Hudson Bay
96°W
92°W
88°W
84°W
80 120 160 200 240 280
GMI 10H GHz (K)
2014/09/22 18:48:08 - 18:49:02
66°N
62°N
18:49:02
18:48:08
18H
96°W
92°W
88°W
84°W
80 120 160 200 240 280
GMI 18H GHz (K)
2014/09/22 18:48:08 - 18:49:02
66°N
62°N
18:49:02
18:48:08
36H
96°W
92°W
88°W
84°W
140 160 180 200 220 240 260 280
GMI 36H GHz (K)
2014/09/22 18:48:08 - 18:49:02
65°N
60°N
18:49:02
18:48:08
89H
95°W
90°W
85°W
140 160 180 200 220 240 260 280
GMI 89H GHz (K)
2014/09/22 18:48:08 - 18:49:02
65°N
60°N
18:49:02
18:48:08
166H
95°W
90°W
85°W
180 200 220 240 260 280
GMI 166H GHz (K)
2014/09/22 18:48:08 - 18:49:02
65°N
60°N
18:49:02
18:48:08
183±8H
95°W
90°W
85°W
180 200 220 240 260 280
GMI 183 ±8 GHz (K)

22 September 2014
Hudson Bay Land-Water

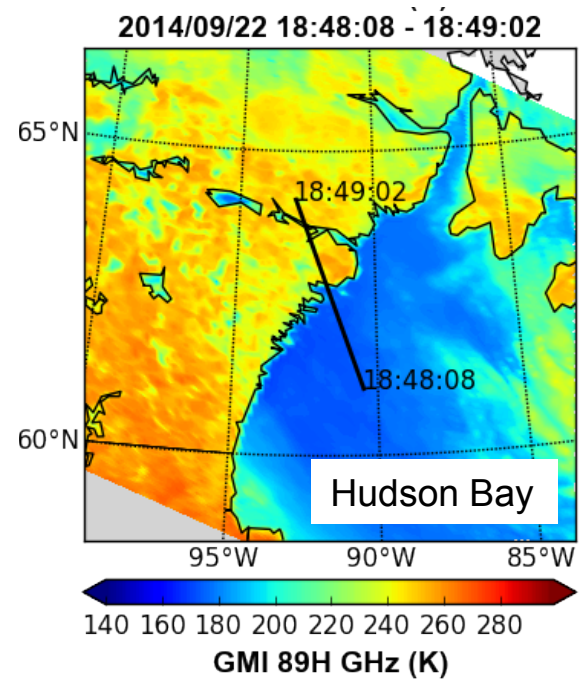


No clouds evident in all three DPR scans

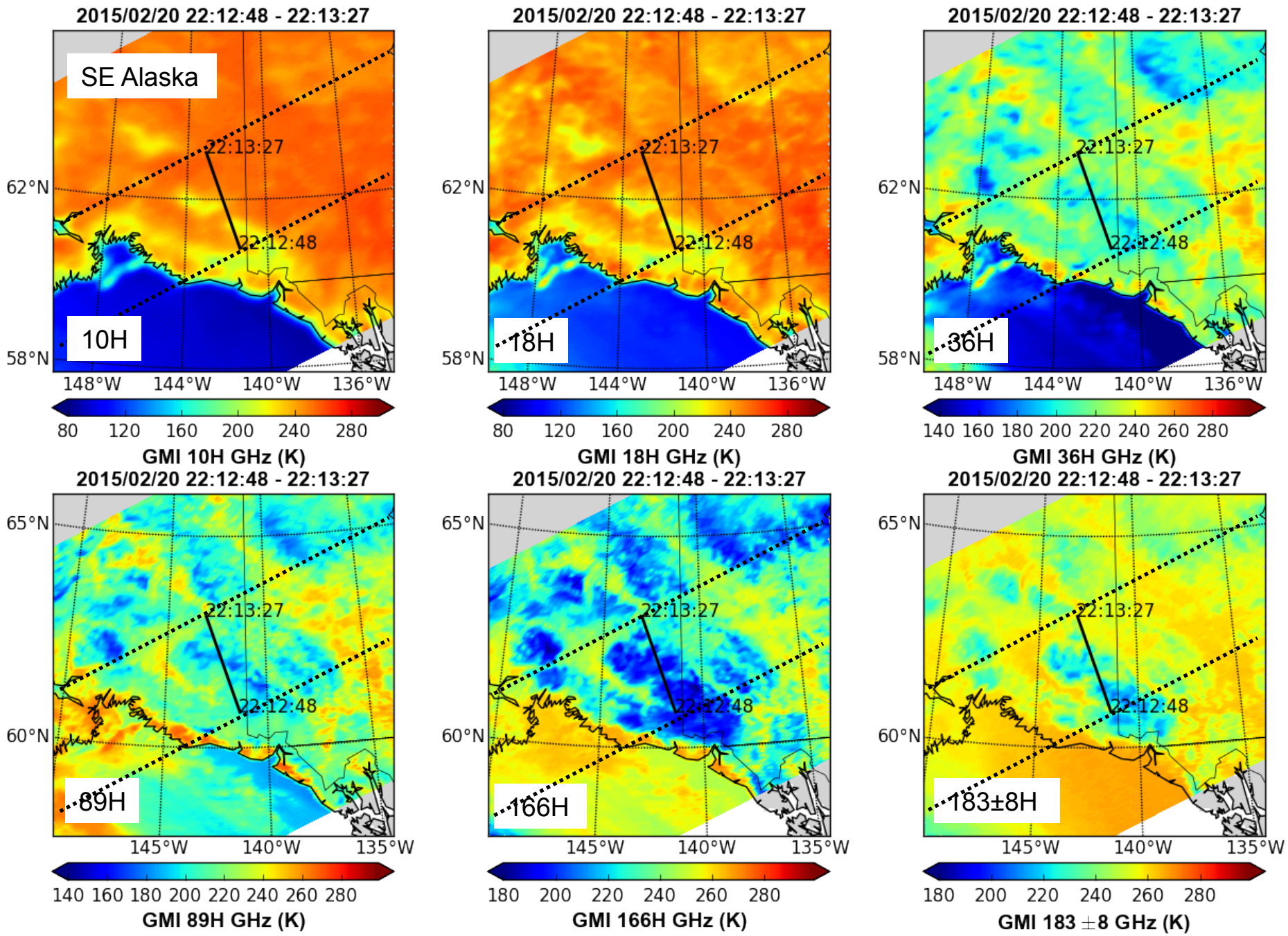
Trace of all 13 GMI channels

Simulated TB difference (using ECMWF) Near seamless land-coast-water transition across all 9 GMI (S1) channels

Resultant emissivity at first 9 GMI (S1) channels



With this method, the emissivity vector is estimated directly from the TBs (nothing else needed), along with a probabilistic confidence measure


2015/02/20 22:12:48 - 22:13:27
SE Alaska
10H
22:13:27
22:12:48
62°N
58°N
148°W 144°W 140°W 136°W
80 120 160 200 240 280
GMI 10H GHz (K)
2015/02/20 22:12:48 - 22:13:27
18H
22:13:27
22:12:48
62°N
58°N
148°W 144°W 140°W 136°W
80 120 160 200 240 280
GMI 18H GHz (K)
2015/02/20 22:12:48 - 22:13:27
36H
22:13:27
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62°N
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140 160 180 200 220 240 260 280
GMI 36H GHz (K)
2015/02/20 22:12:48 - 22:13:27
89H
22:13:27
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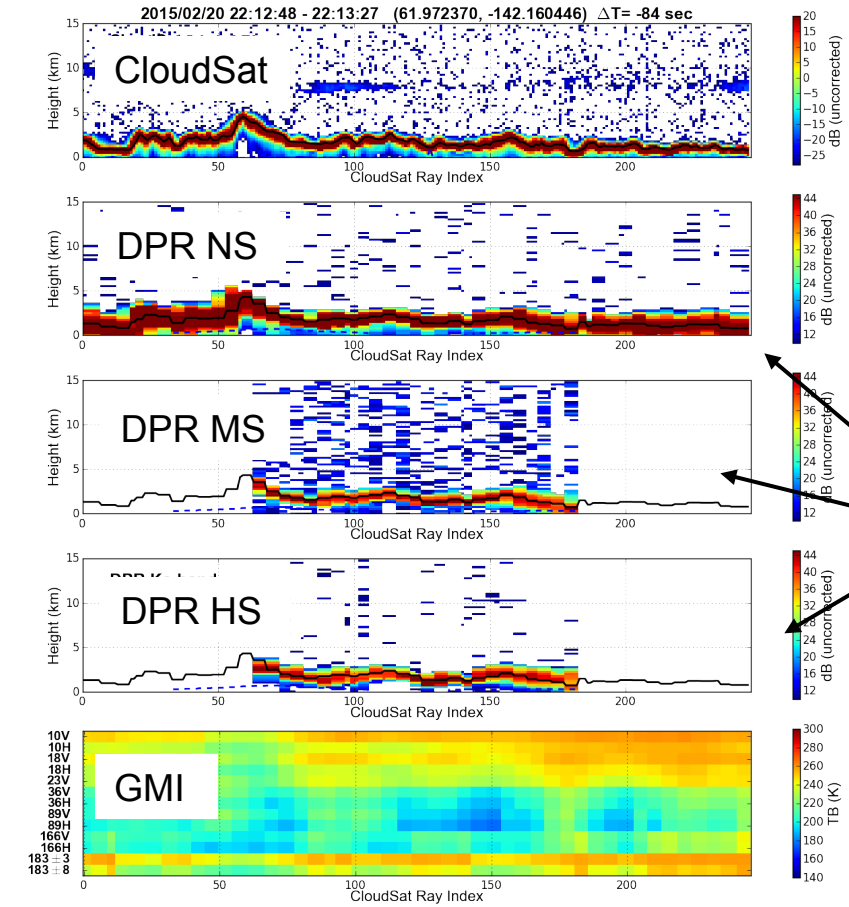
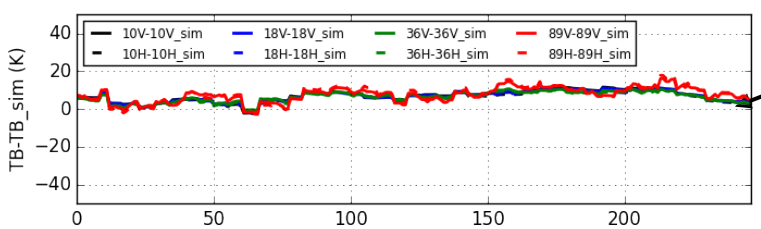
65°N
60°N
145°W 140°W 135°W
140 160 180 200 220 240 260 280
GMI 89H GHz (K)
2015/02/20 22:12:48 - 22:13:27
166H
22:13:27
22:12:48
65°N
60°N
145°W 140°W 135°W
180 200 220 240 260 280
GMI 166H GHz (K)
2015/02/20 22:12:48 - 22:13:27
183±8H
22:13:27
22:12:48
65°N
60°N
145°W 140°W 135°W
180 200 220 240 260 280
GMI 183 ±8 GHz (K)

20 February 2015
Alaska winter mountainous terrain

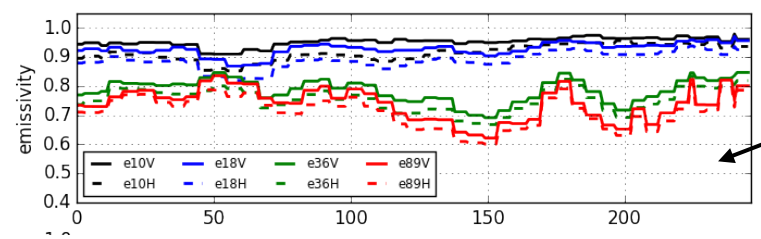


No clouds evident in all three DPR scans

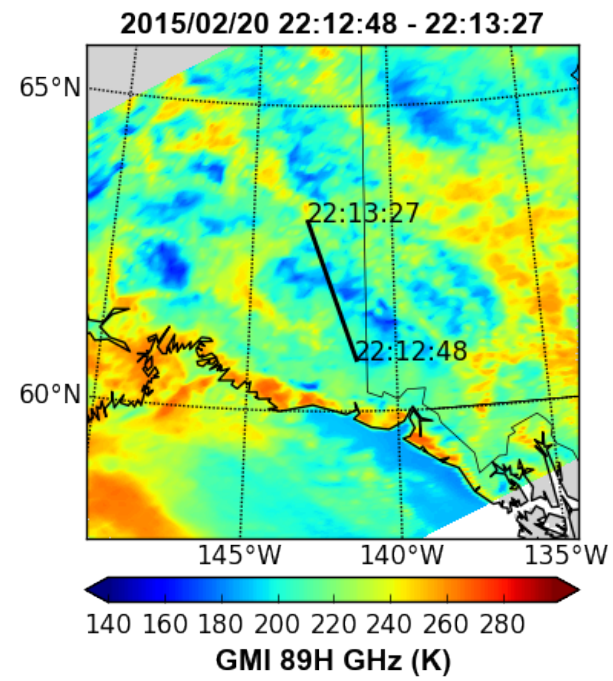
Trace of all 13 GMI channels



Simulated TB difference (using ECMWF) within 10K across all 9 GMI (S1) channels

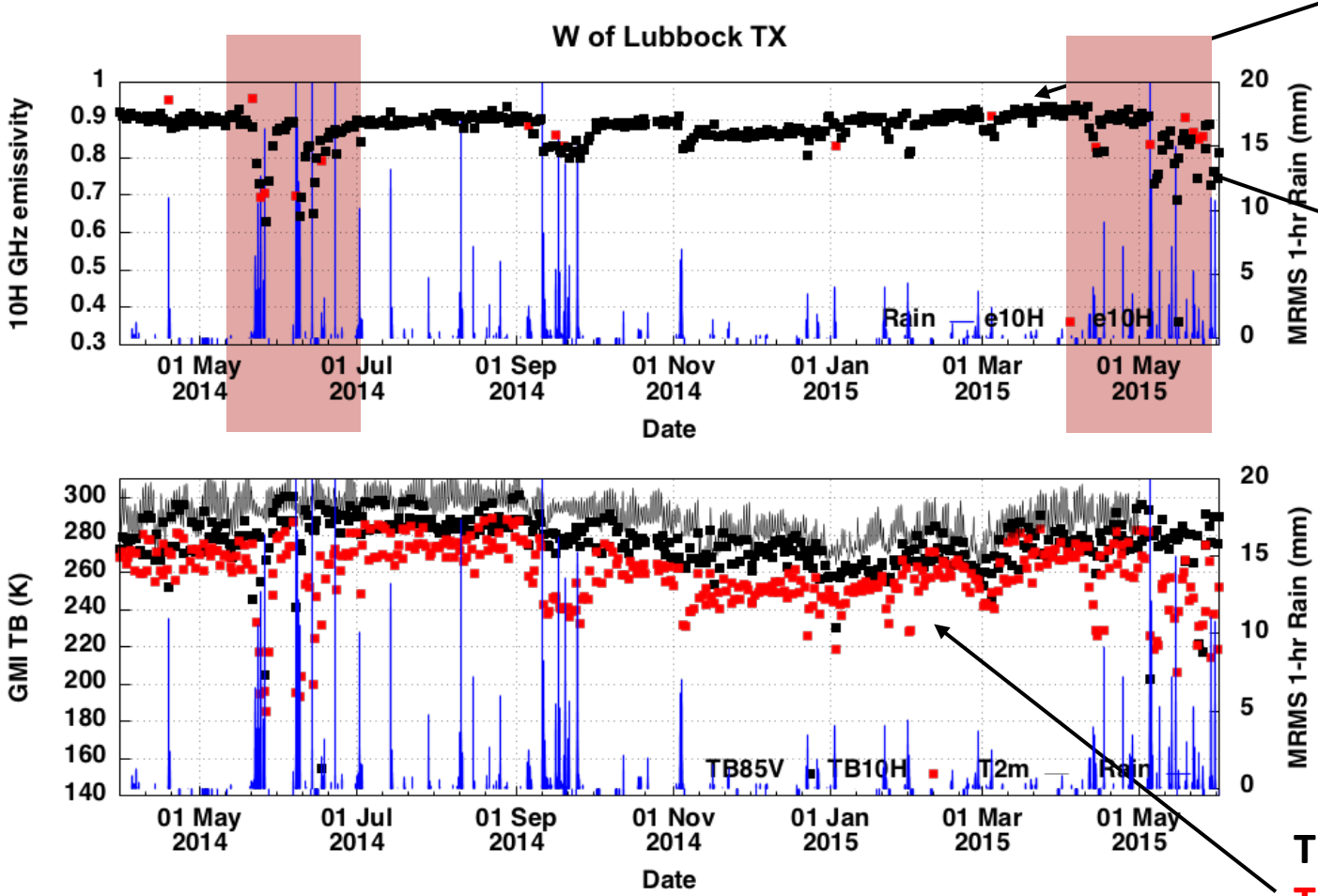


Resultant emissivity at first 9 GMI (S1) channels



Extension to 166 GHz being examined for very dry cold scenes

Rain/Emissivity 10H Timeseries near a point: West of Lubbock, TX



emis 10H from Turk et. al. (2014) technique

(red symbols indicate reduced confidence)

MRMS 1-hr accumulations (blue impulses)

TB 85V (black)

TB 10H (red)

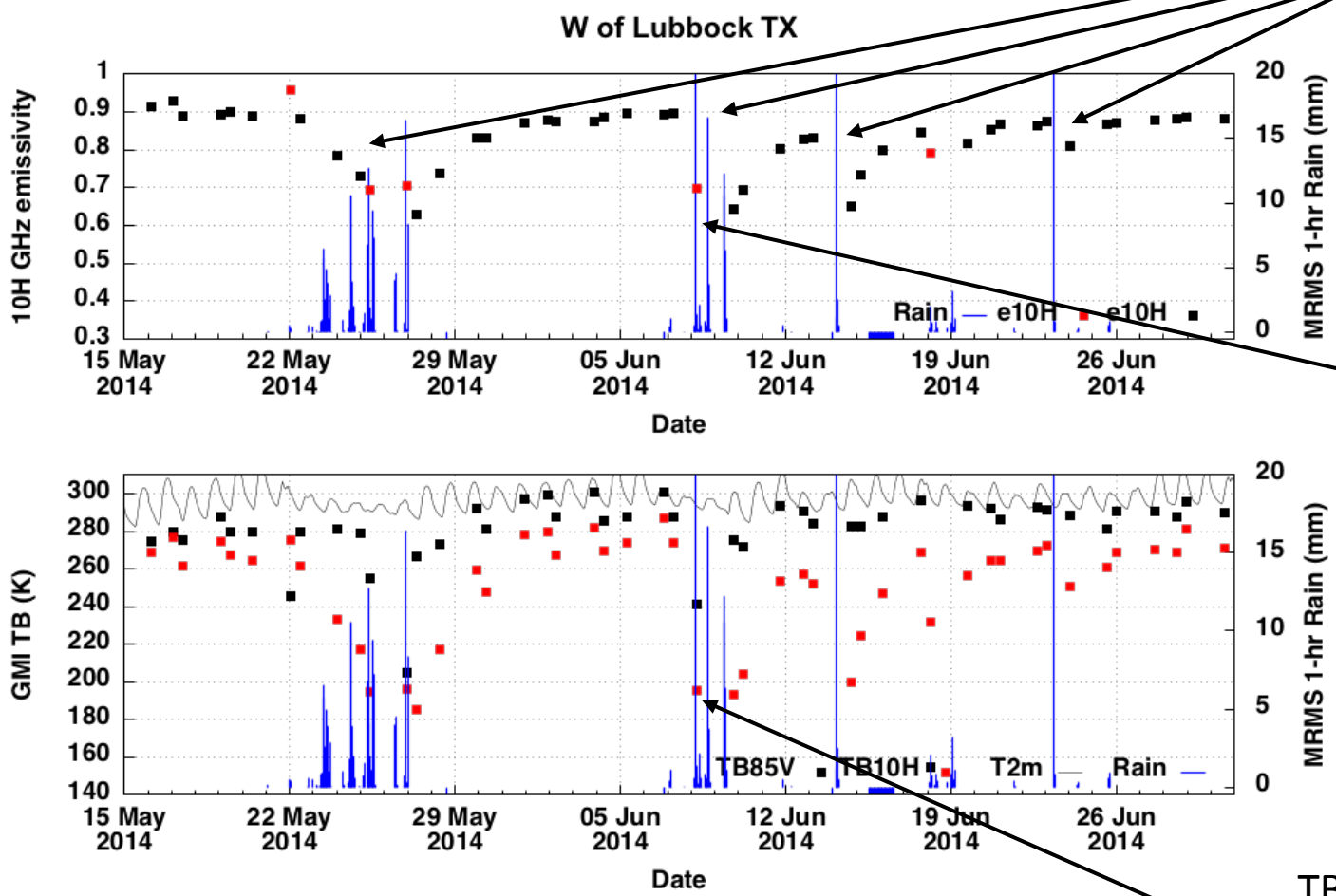
T2m (thin black line)

← 14 months →

1 Apr 2014 – 1 Jun 2015

Soil type and scrub-like vegetation exhibit rapid rain response and dry-down

6-Week Zoom-in West of Lubbock, TX



Response to rain events captured by next GMI observation

red symbols occur when there is rain at the GPM overpass time

Note that many GPM overpasses occur "in between" rain events

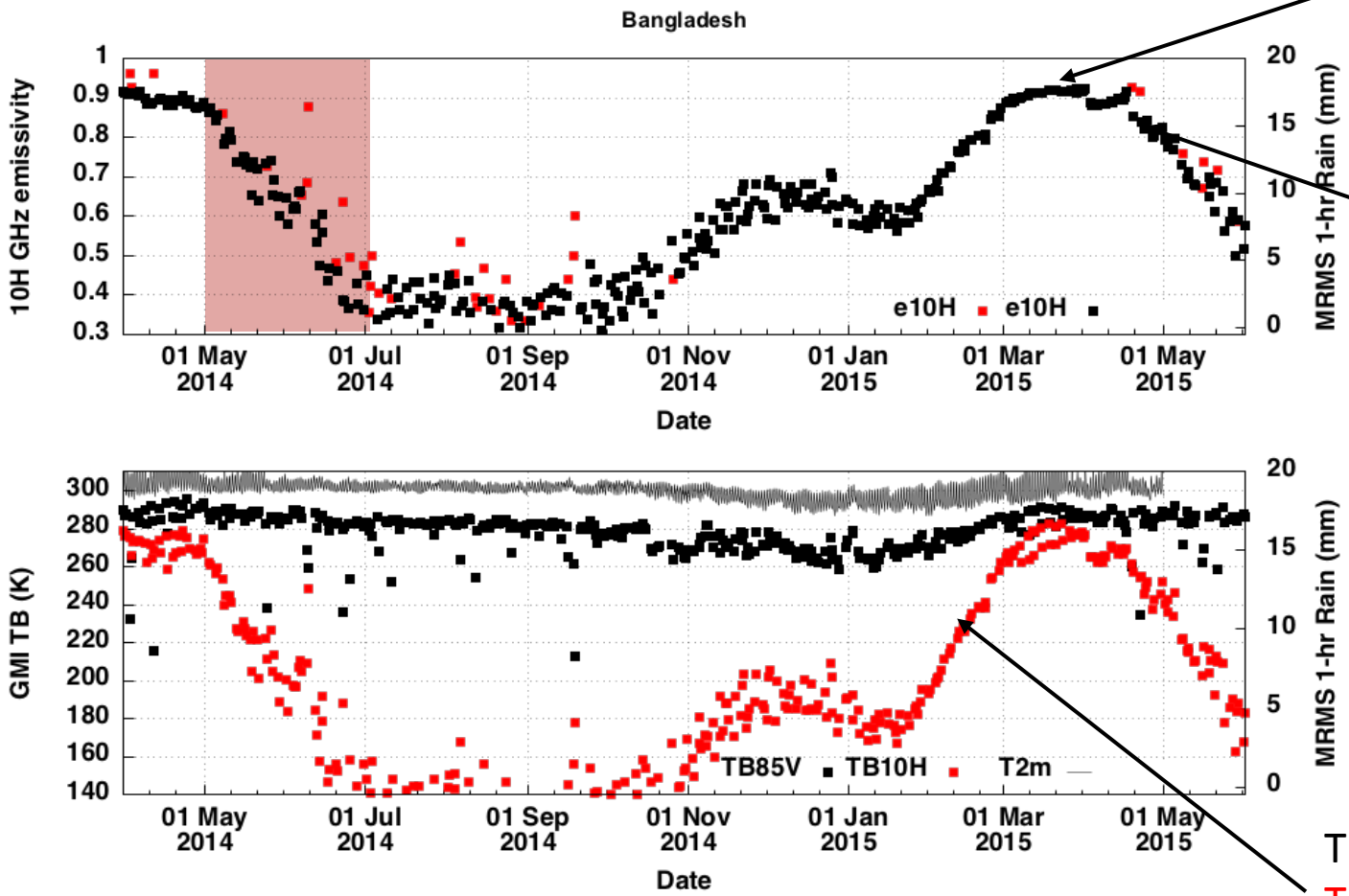
TB 85V > TB 10H during conv. rain over land (usually the other way around)

← 6 weeks →

15 May – 1 Jul 2015

Soil type and scrub-like vegetation exhibit rapid rain response and dry-down

Bangladesh Braided Rivers (Ganges Floodplain NE of Dhaka)



emis 10H from Turk et. al. (2014) technique, adapted to GMI using DPR

(red symbols indicate reduced confidence)

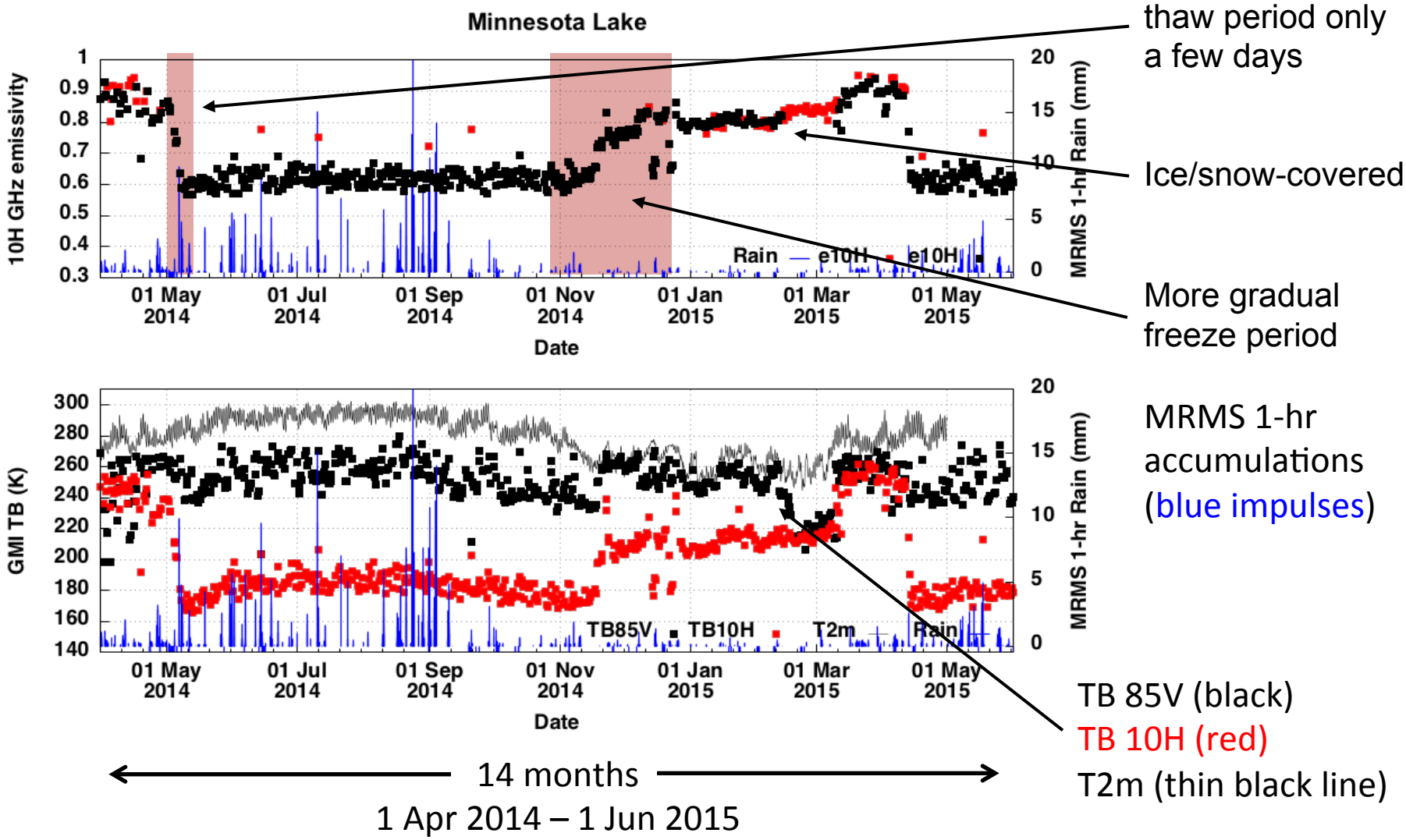
MRMS 1-hr accumulations (blue impulses)

TB 85V (black)
TB 10H (red)
T2m (thin black line)

← 14 months →
1 Apr 2014 – 1 Jun 2015

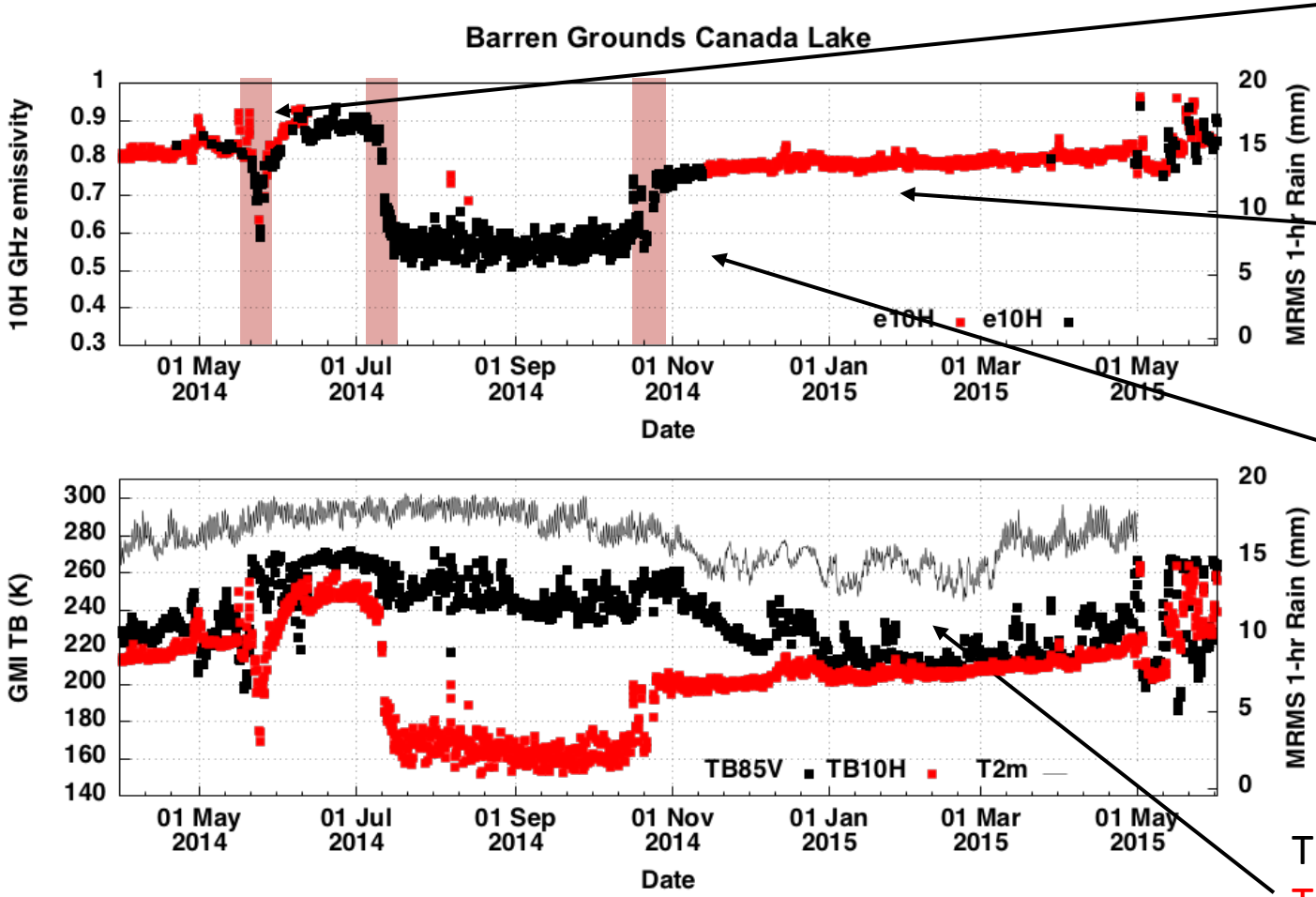
Can also experience rapid emissivity change across inundated areas

Minnesota Inland Lake (10H)



Rapid emissivity change from freeze-thaw cycles

Northern Canada Barren Grounds Lake (10H)



Exposed open water "leads", or rain-on-snow?

Slow change in snow cover as it ages

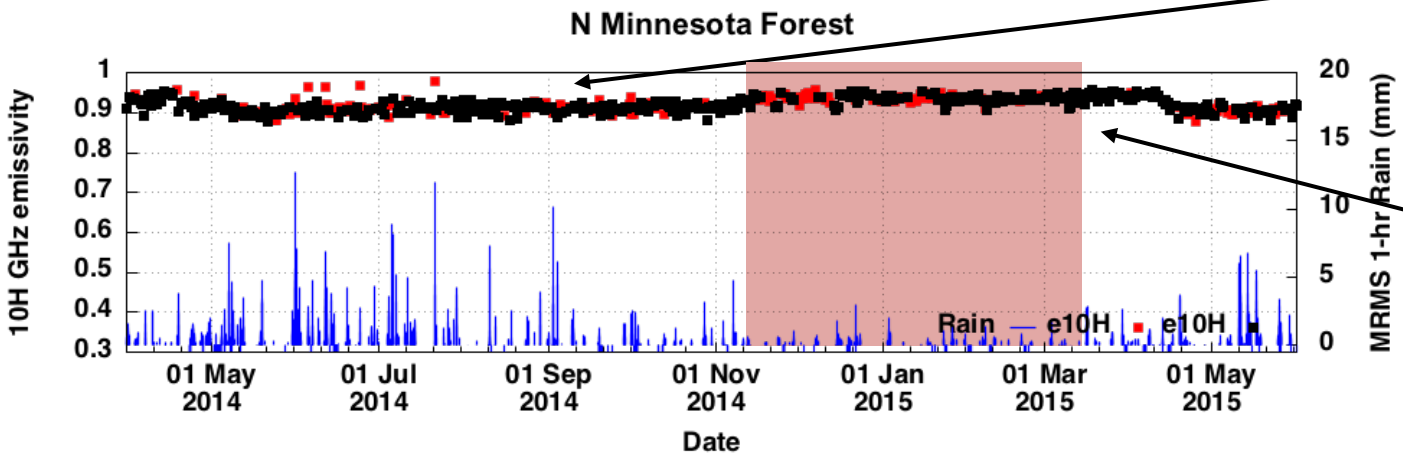
Much shorter freeze period

TB 85V (black)
TB 10H (red)
T2m (thin black line)

14 months
1 Apr 2014 – 1 Jun 2015

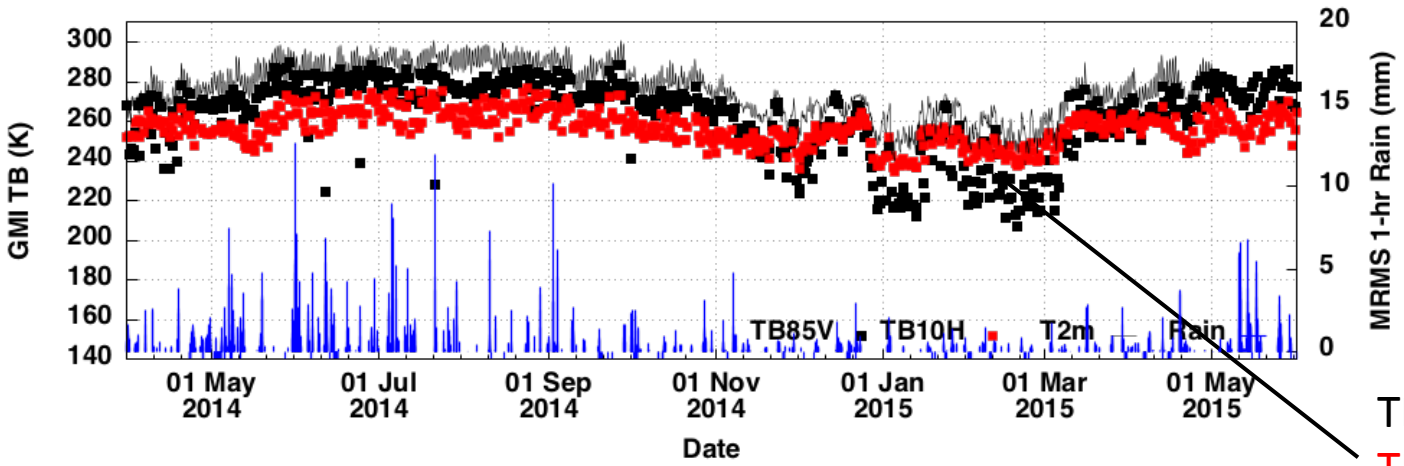
More rapid emissivity change from freeze-thaw cycle and snow morphology

Northern Minnesota Forest (10H)



Fairly steady

Slight increase while snow covered



TB 85V (black)

TB 10H (red)

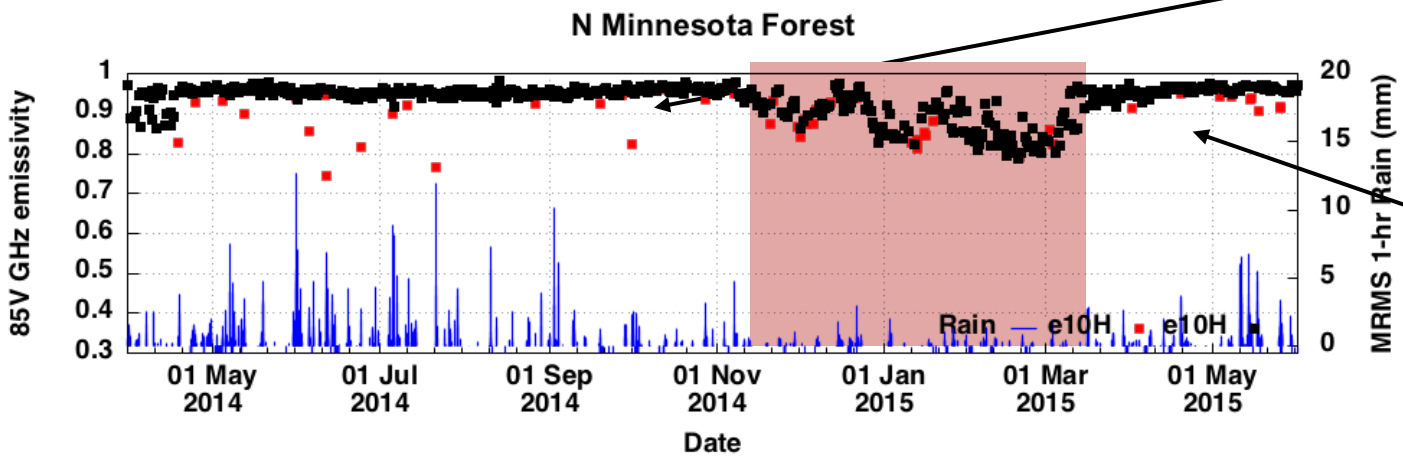
T2m (thin black line)

← 14 months →

1 Apr 2014 – 1 Jun 2015

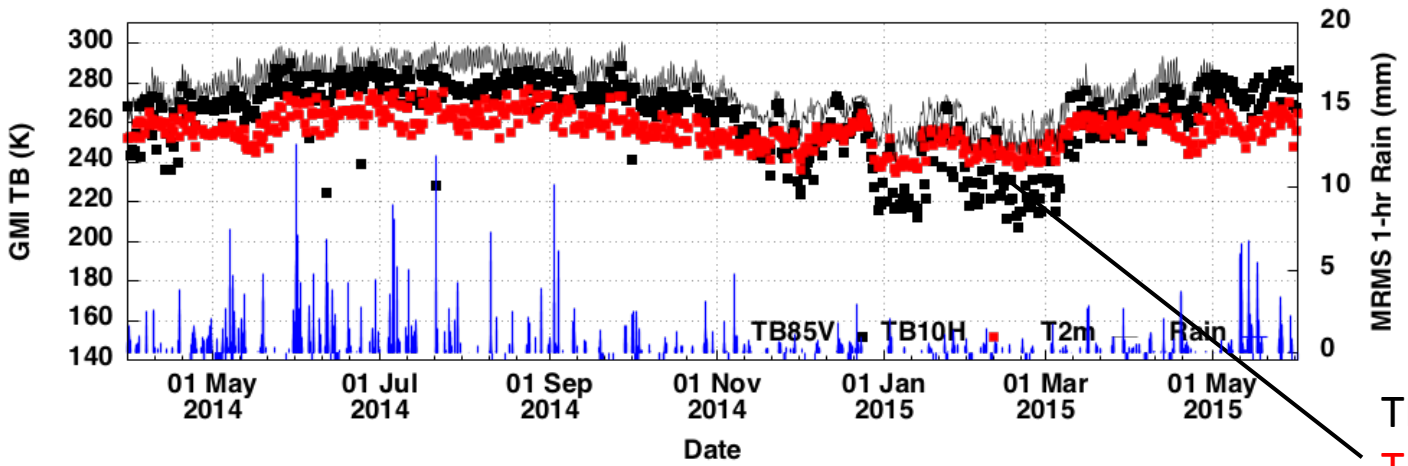
Fairly steady with slight increase with snowcover and variability with morphology

Northern Minnesota Forest (85V)



Fairly steady

85V decreases more due to scattering (and is more variable) during snow covered period



MRMS 1-hr accumulations (blue impulses)

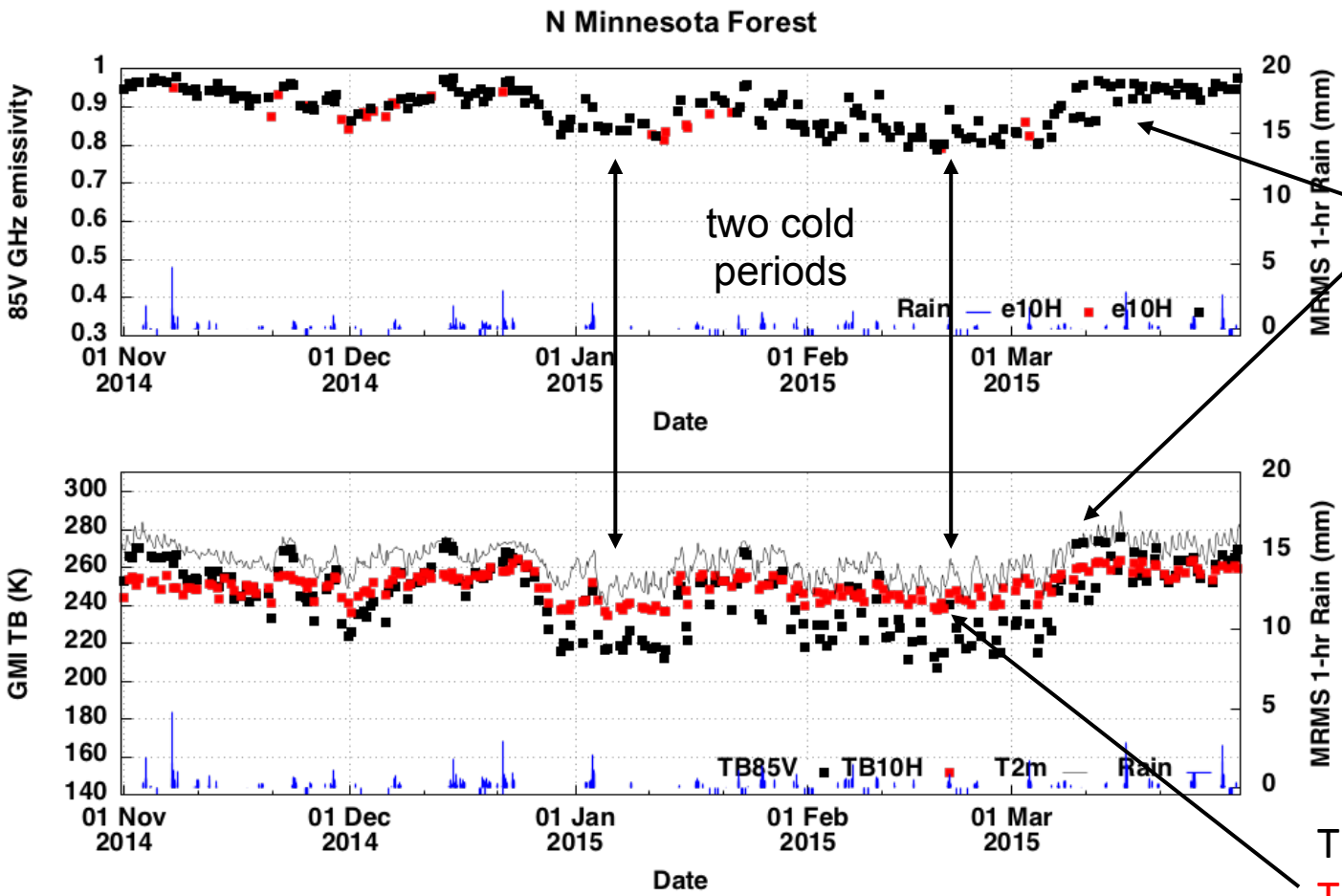
TB 85V (black)
TB 10H (red)
T2m (thin black line)

← 14 months →

1 Apr 2014 – 1 Jun 2015

Fairly steady with slight increase with snowcover and variability with morphology

Winter 5-month Zoom-in Northern Minnesota Forest (85V)



85V emis changes with snow morphology

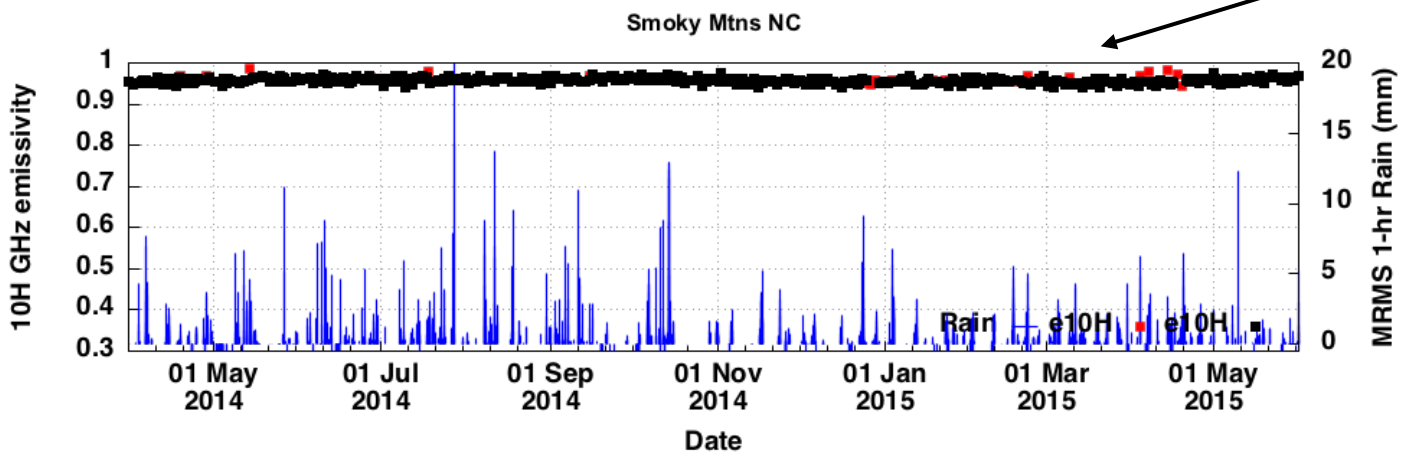
tracks 2m air temperature and 85 GHz snow scattering induced depressions

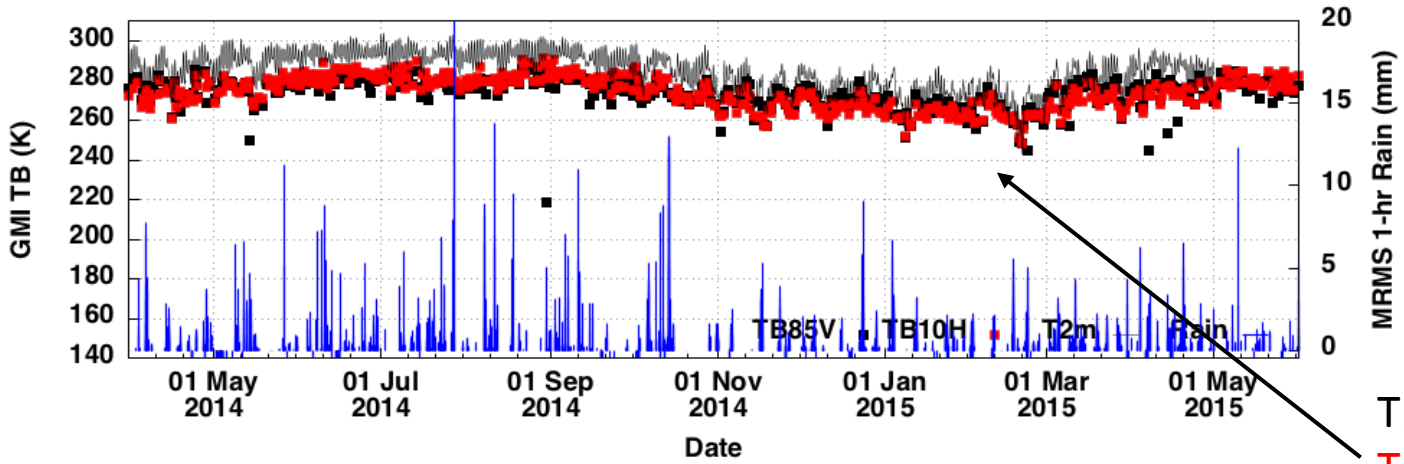
TB 85V (black)
TB 10H (red)
T2m (thin black line)

14 months
1 Apr 2014 – 1 Jun 2015

snowcover and variability with morphology (crystal and grain sizes, spacing, etc)

Appalachian Forest (10H)





Rock steady

No rain effect noticeable

85V is also steady near 0.95

MRMS 1-hr accumulations (blue impulses)

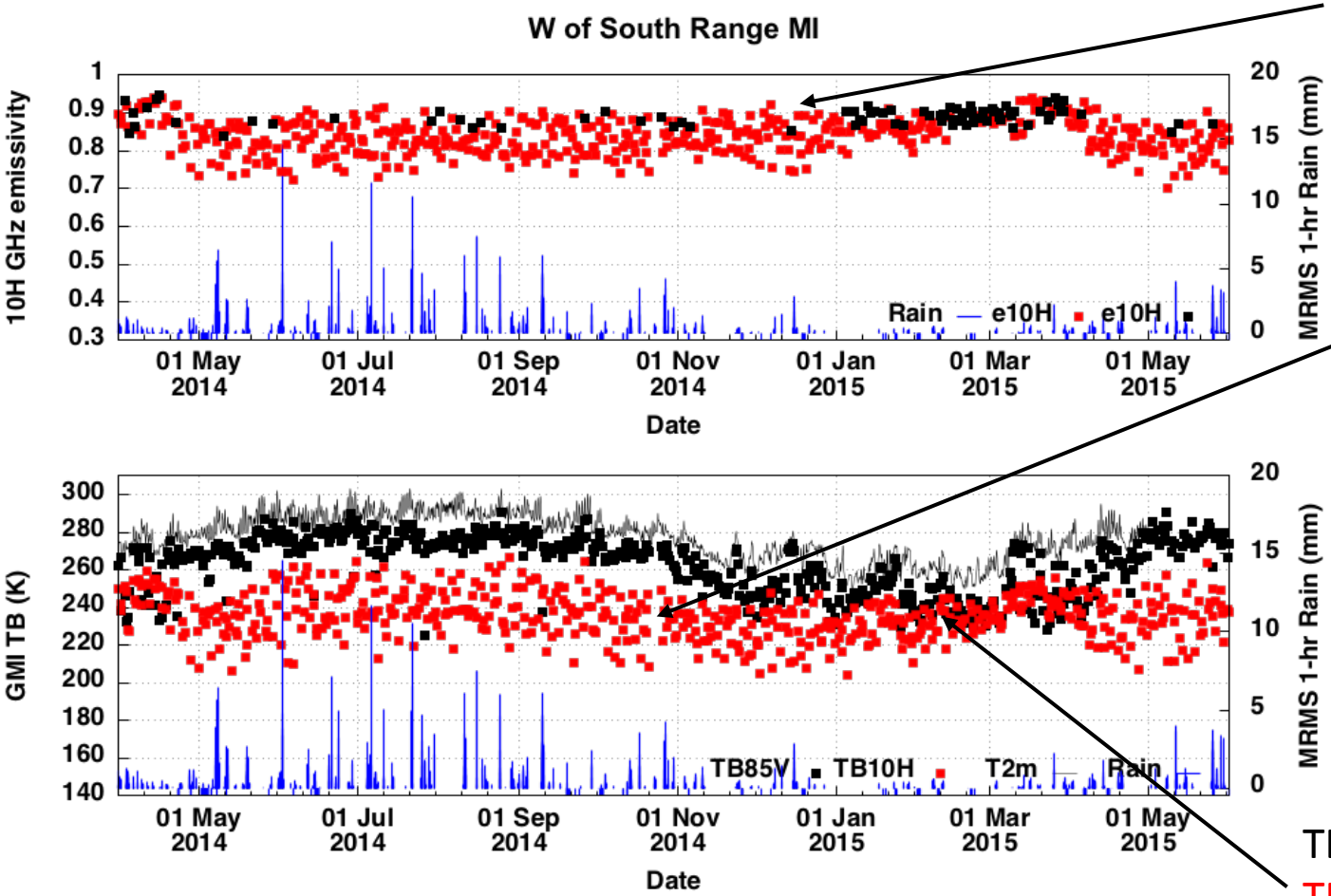
TB 85V (black)
TB 10H (red)
T2m (thin black line)

← 14 months →

1 Apr 2014 – 1 Jun 2015

Dense leafy tree cover, steady all-year round

Upper Michigan Forest (10H)



Considerable emis. variability at 10H, less so in winter months

Wide variability in TB 10H from overpass to overpass (not a time-of-day effect)

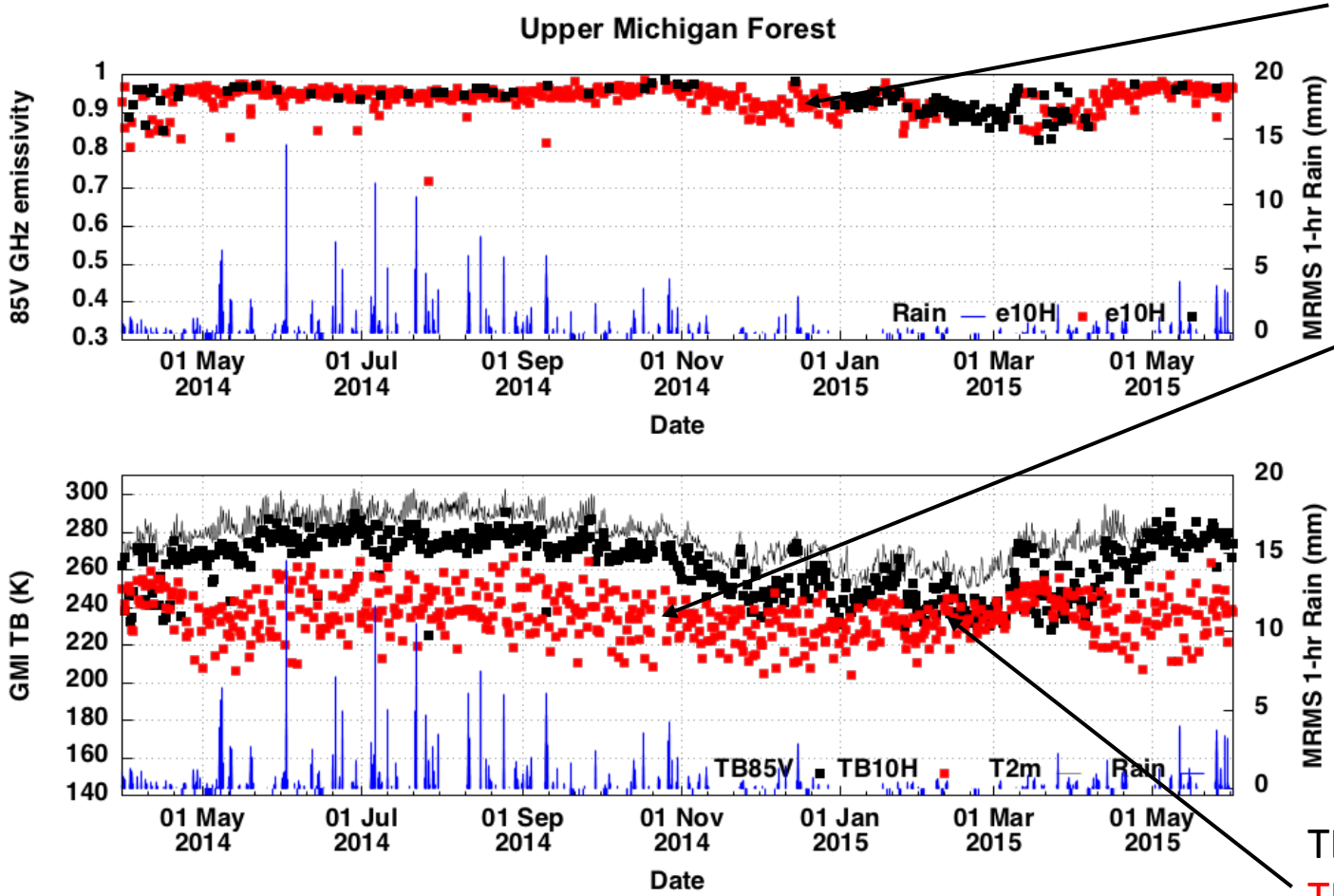
MRMS 1-hr accumulations (blue impulses)

TB 85V (black)
TB 10H (red)
T2m (thin black line)

14 months
1 Apr 2014 – 1 Jun 2015

Different forest type- More open exposed soil between trees ("mixed pixel" effect)

Upper Michigan Forest (85V)



Much less emis. variability at 85V

(more like the Minnesota forest case)

Wide variability in TB 10H from overpass to overpass (not a time-of-day effect)

TB 85V (black)

TB 10H (red)

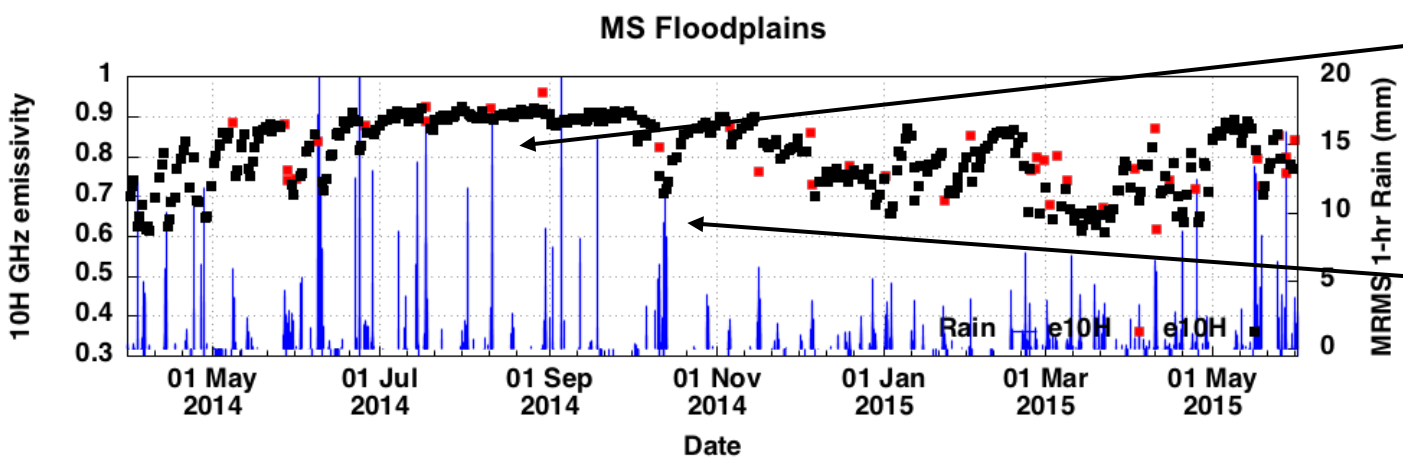
T2m (thin black line)

14 months

1 Apr 2014 – 1 Jun 2015

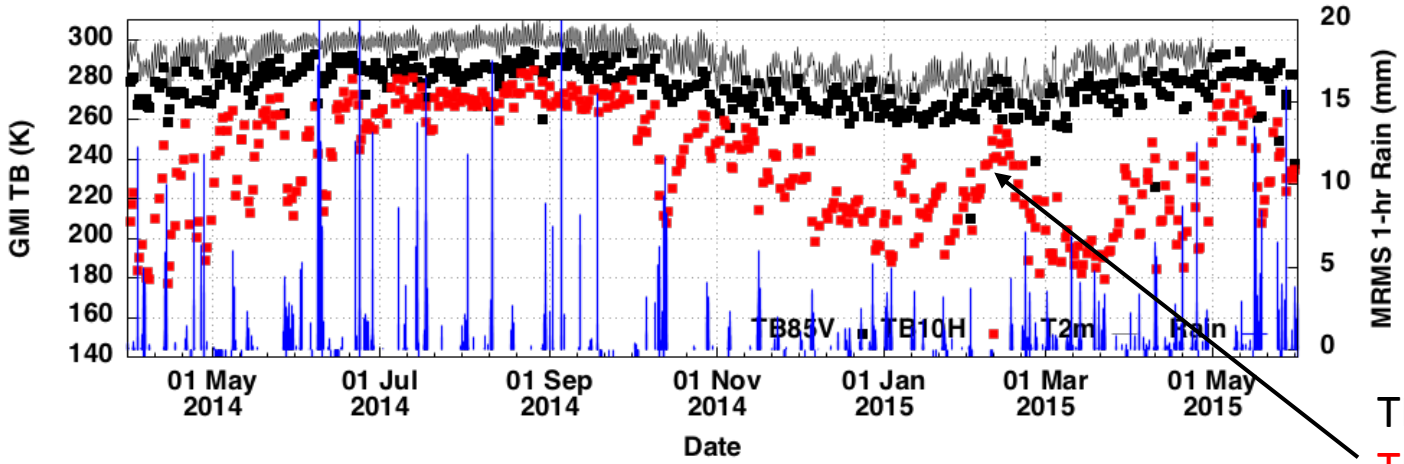
Different forest type- More open exposed soil between trees ("mixed pixel" effect)

Mississippi River Alluvial Plains



Little response to rain events in summer months

Response to rain events later in the year



MRMS 1-hr accumulations (blue impulses)

TB 85V (black)
TB 10H (red)
T2m (thin black line)

← 14 months →

1 Apr 2014 – 1 Jun 2015

Rapid emissivity change from vegetation and agricultural practices

Role of the Surface: Radar

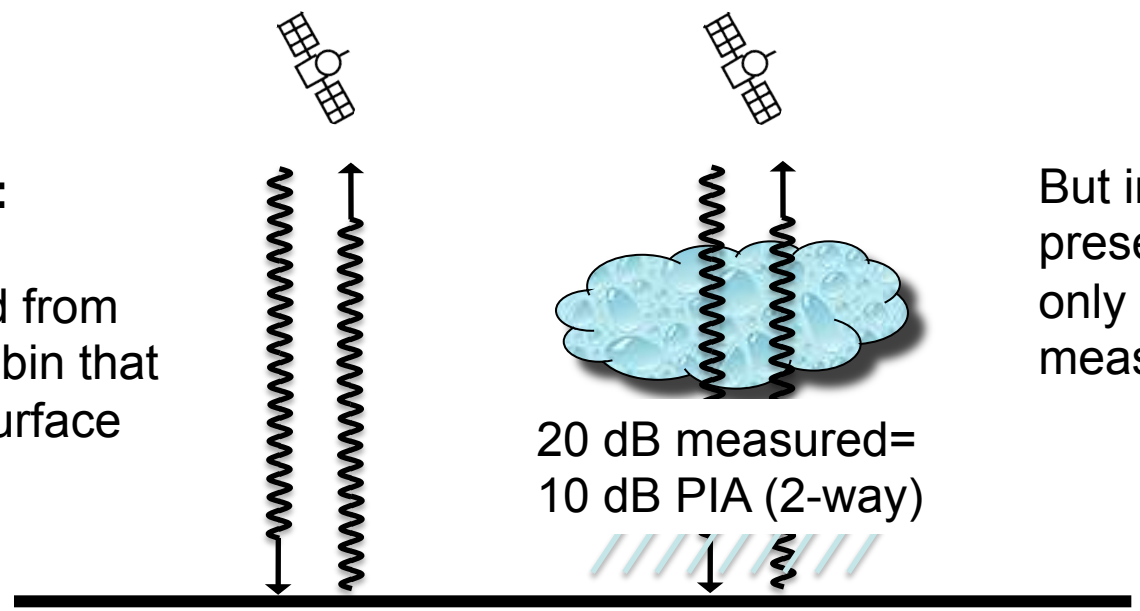
The GPM radar operates at frequencies where the radar propagation is attenuated by rain, and to a lesser extent, clouds.

Knowledge of the Path Integrated Attenuation (PIA) is used as a constraint to partition the radar attenuation, and derive rainrate

Clear Scene

Rainy Scene

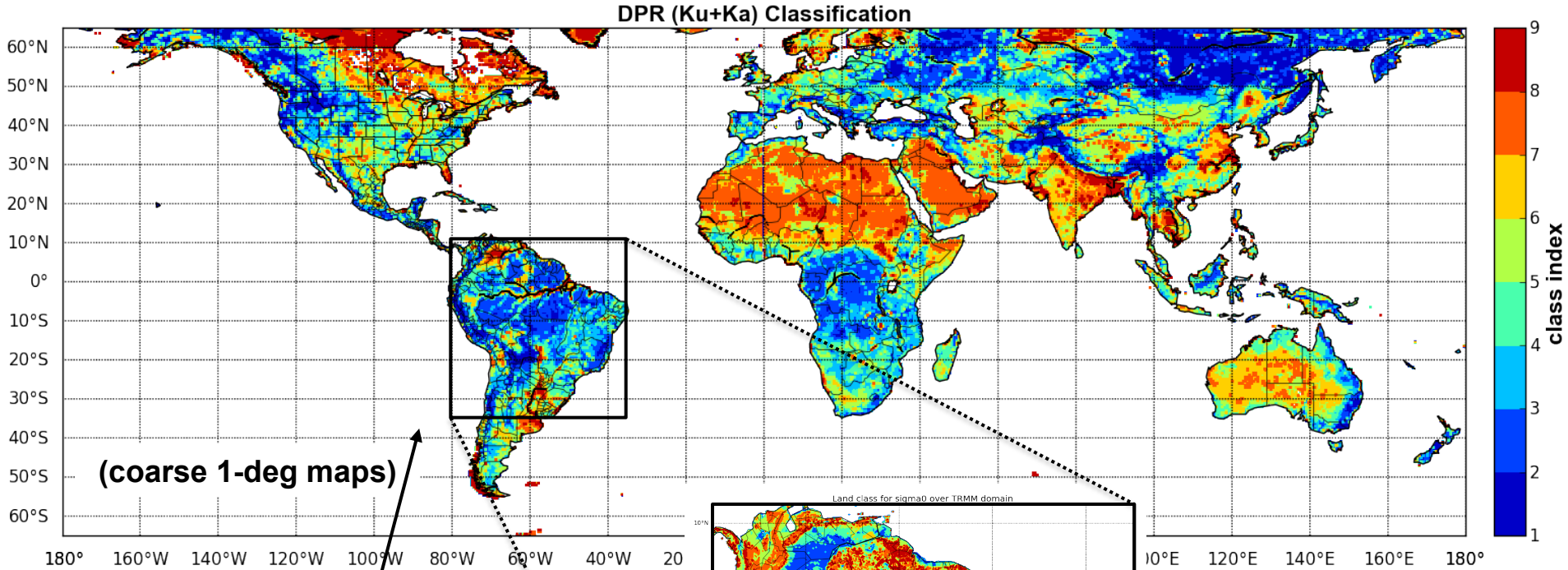
Example:
30 dB is measured from the radar bin that hits the surface



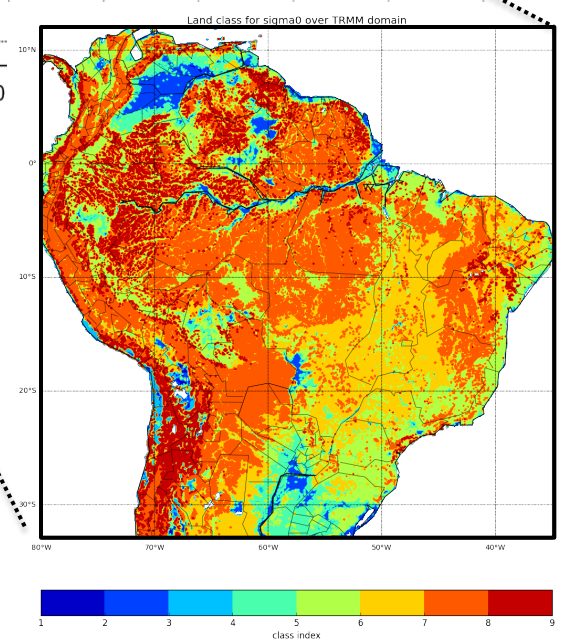
But in the presence of rain, only 20 dB is measured

Strongly reflecting ocean surface (easier)
Highly variable land surface (difficult)

Early Results from Durden Classification Applied to DPR



(coarse 1-deg maps)



DPR Classification
Class 3 appears like dense vegetation, class 8-9 more like bare soil

Previous PR Classification
Class 6-7 separation generally coincides with the change from grass savanna to grass prairie

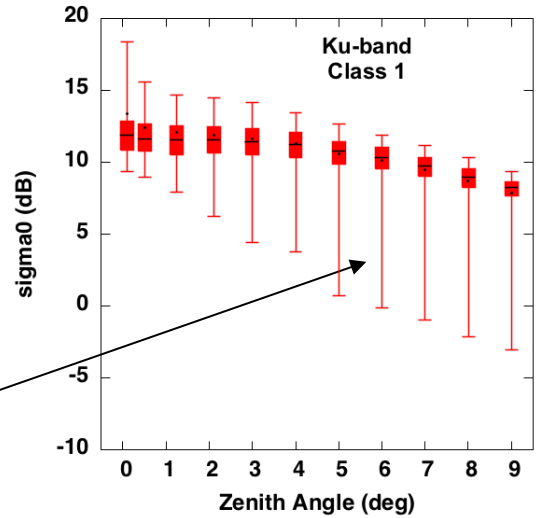
Owing to the unsupervised classification used, note that while PR and DPR patterns appear similar, the class index numbers do not correspond.

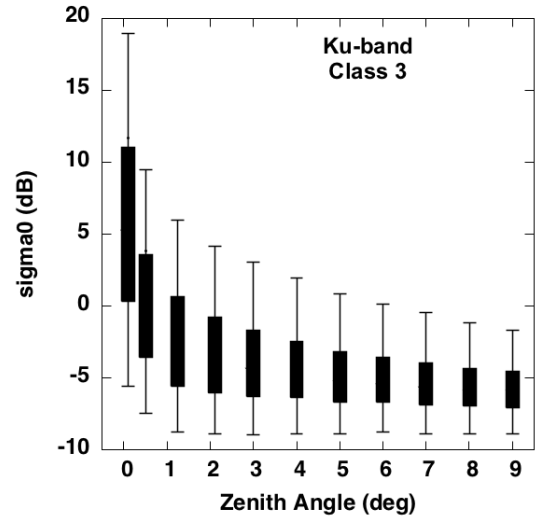
Role of the Surface: Radar

The backscatter from the surface is large and highly variable across different types of surfaces, and the radar scan angle.

Ocean

Variability from light winds

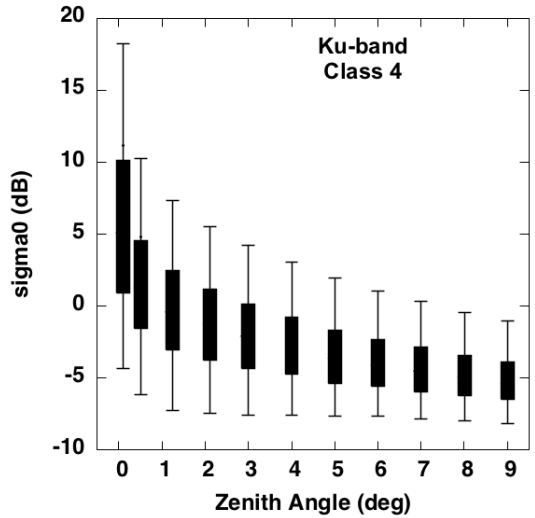


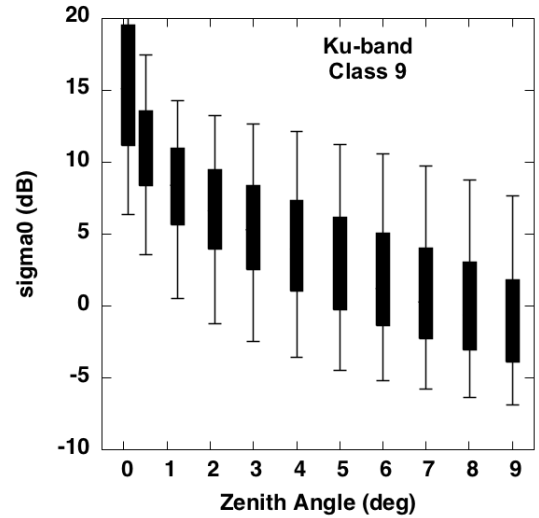


Heavy Vegetation

Scattering off the top of the tree canopy

Lighter Vegetation



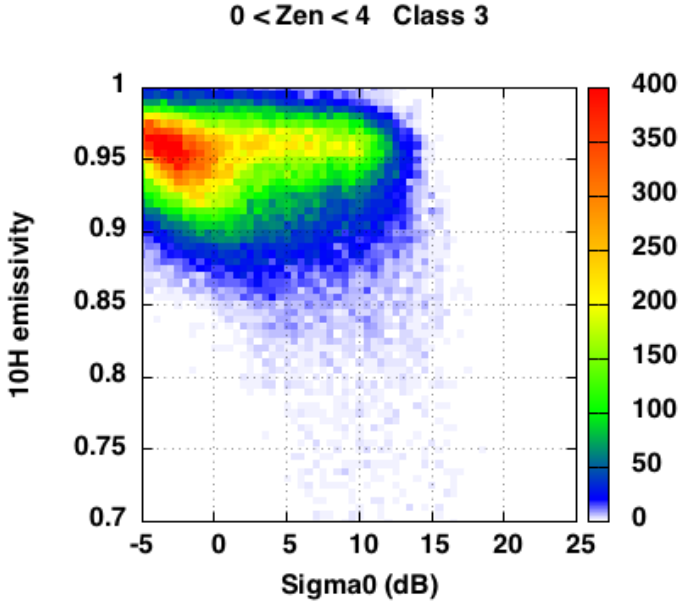


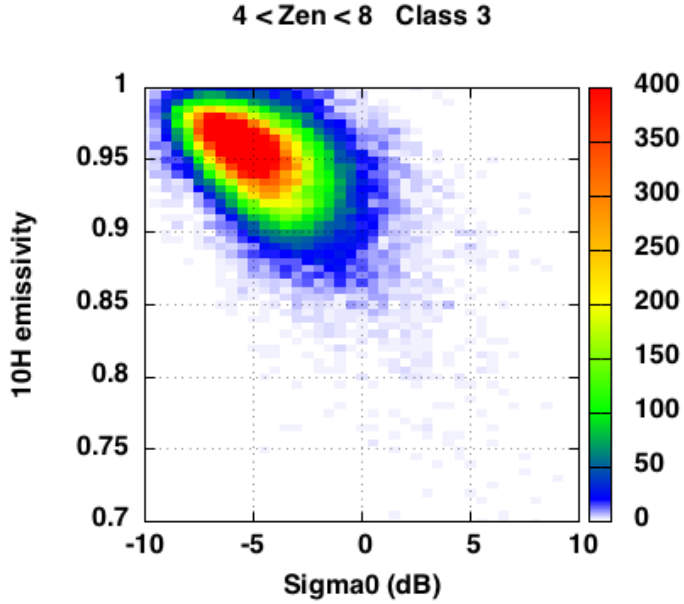
Bare Soil

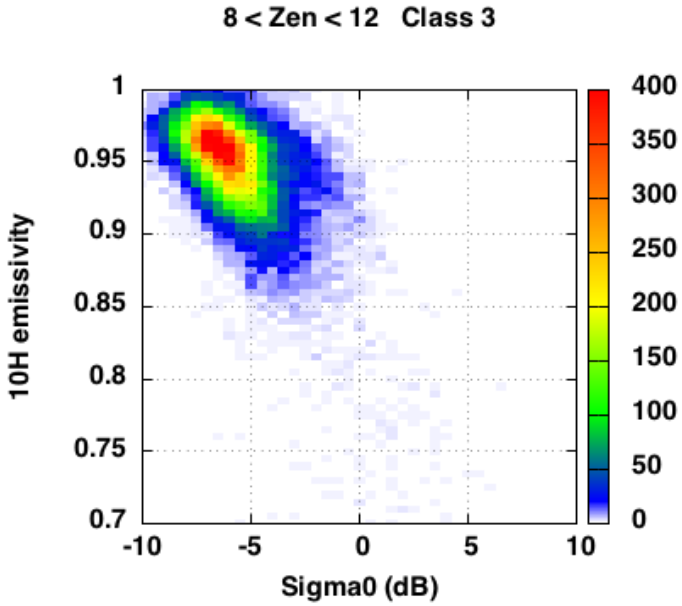
more "mirror-like"

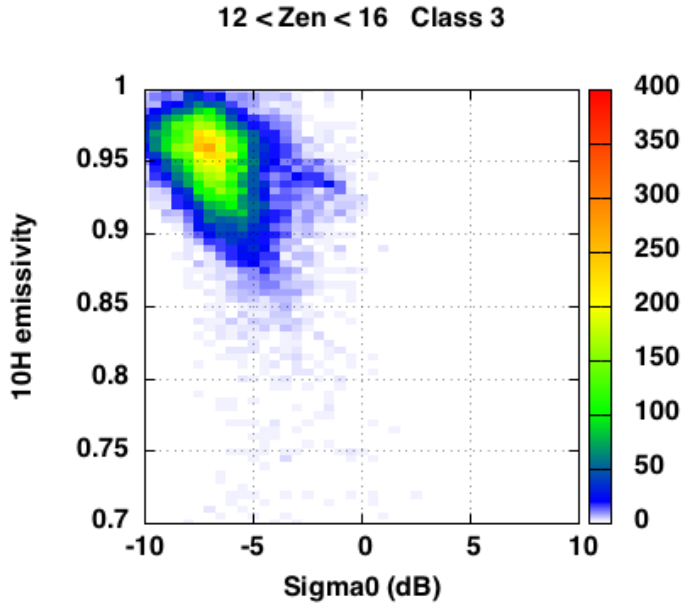
(from DPR Ku-band)

From DPR-NS: Joint PDFs Class 3 No-Rain Prev 24-hrs

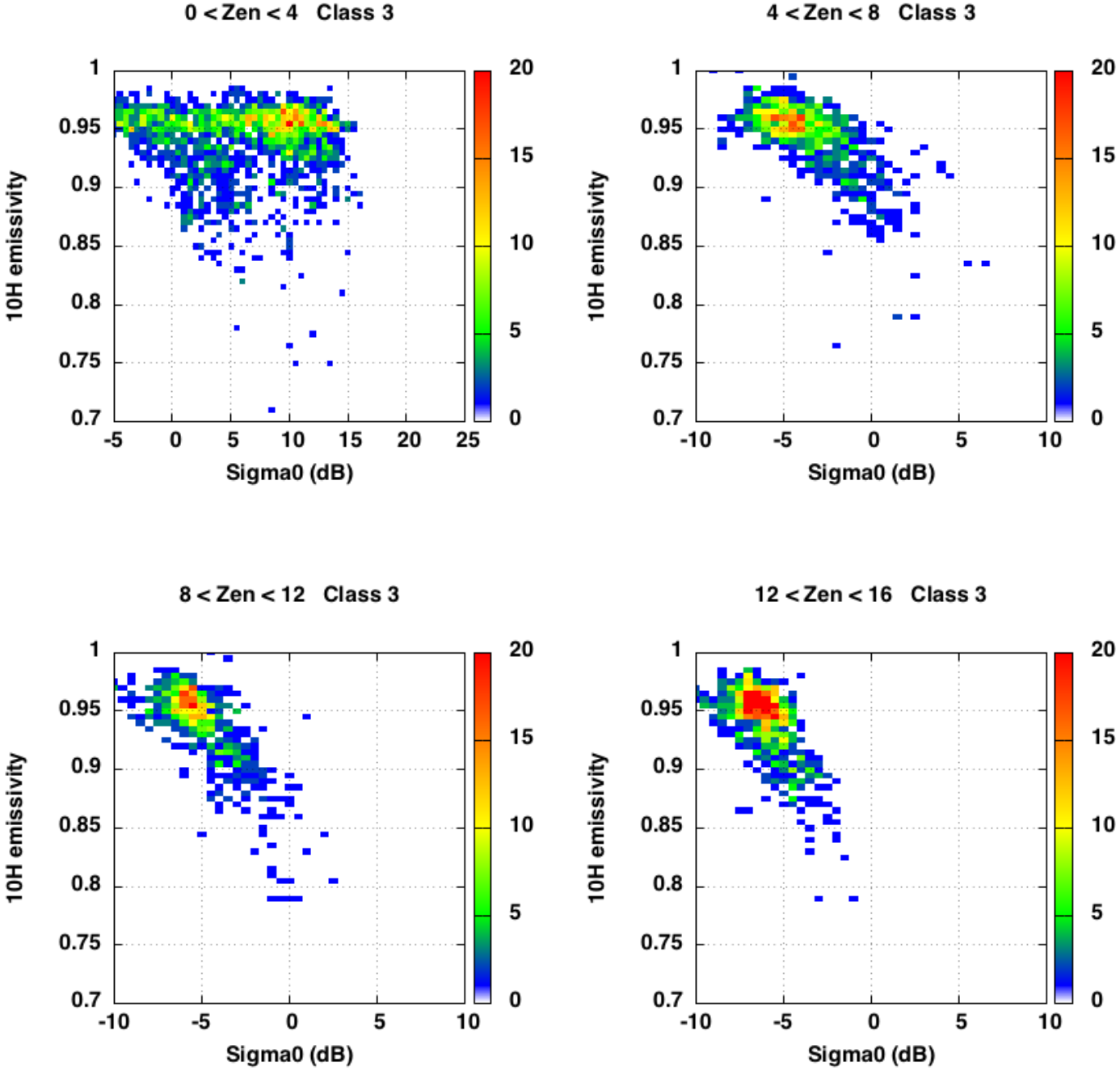




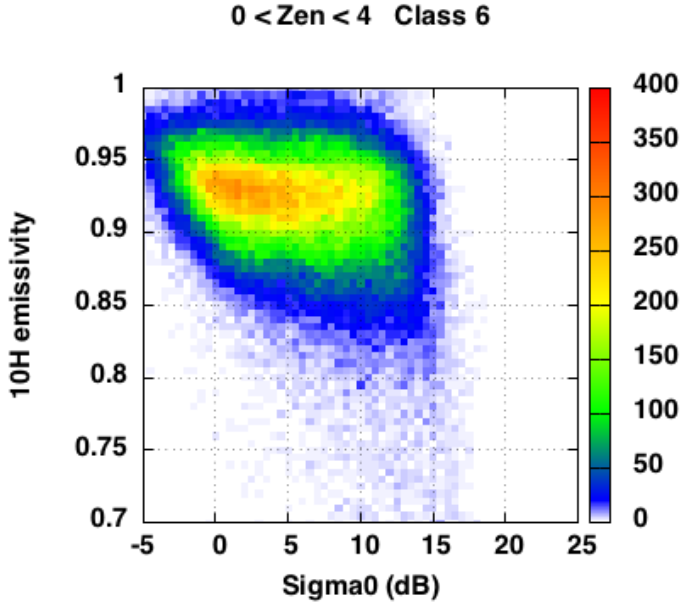


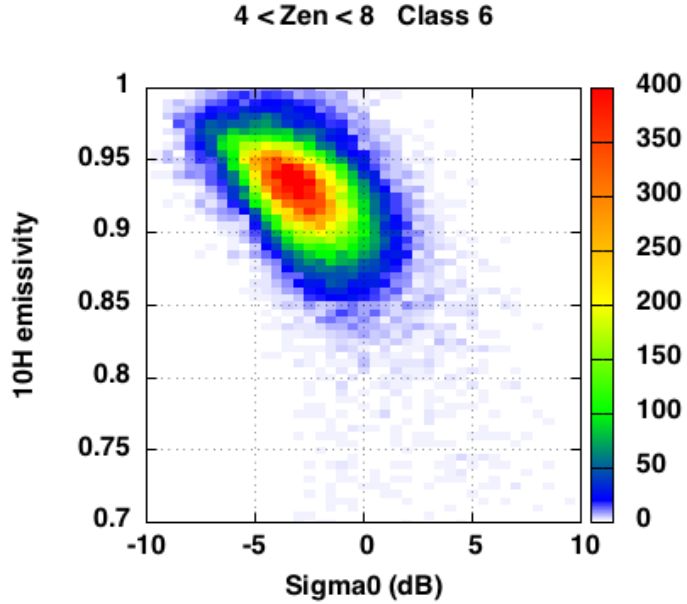


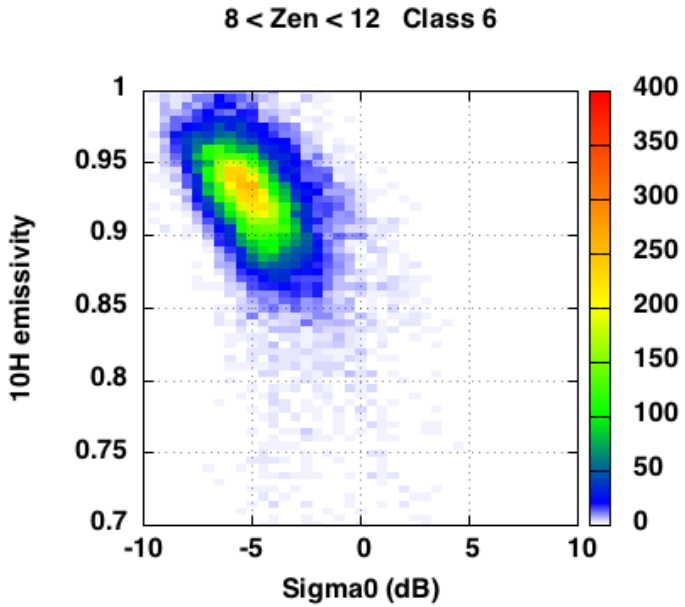
From DPR-NS: Joint PDFs Class 3 > 25-mm Prev 24-hrs

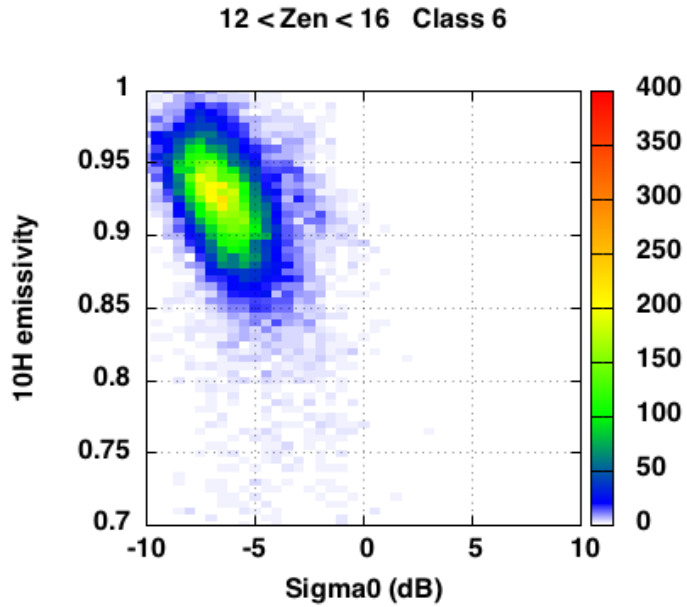


From DPR-NS: Joint PDFs Class 6 No-Rain Prev 24-hrs

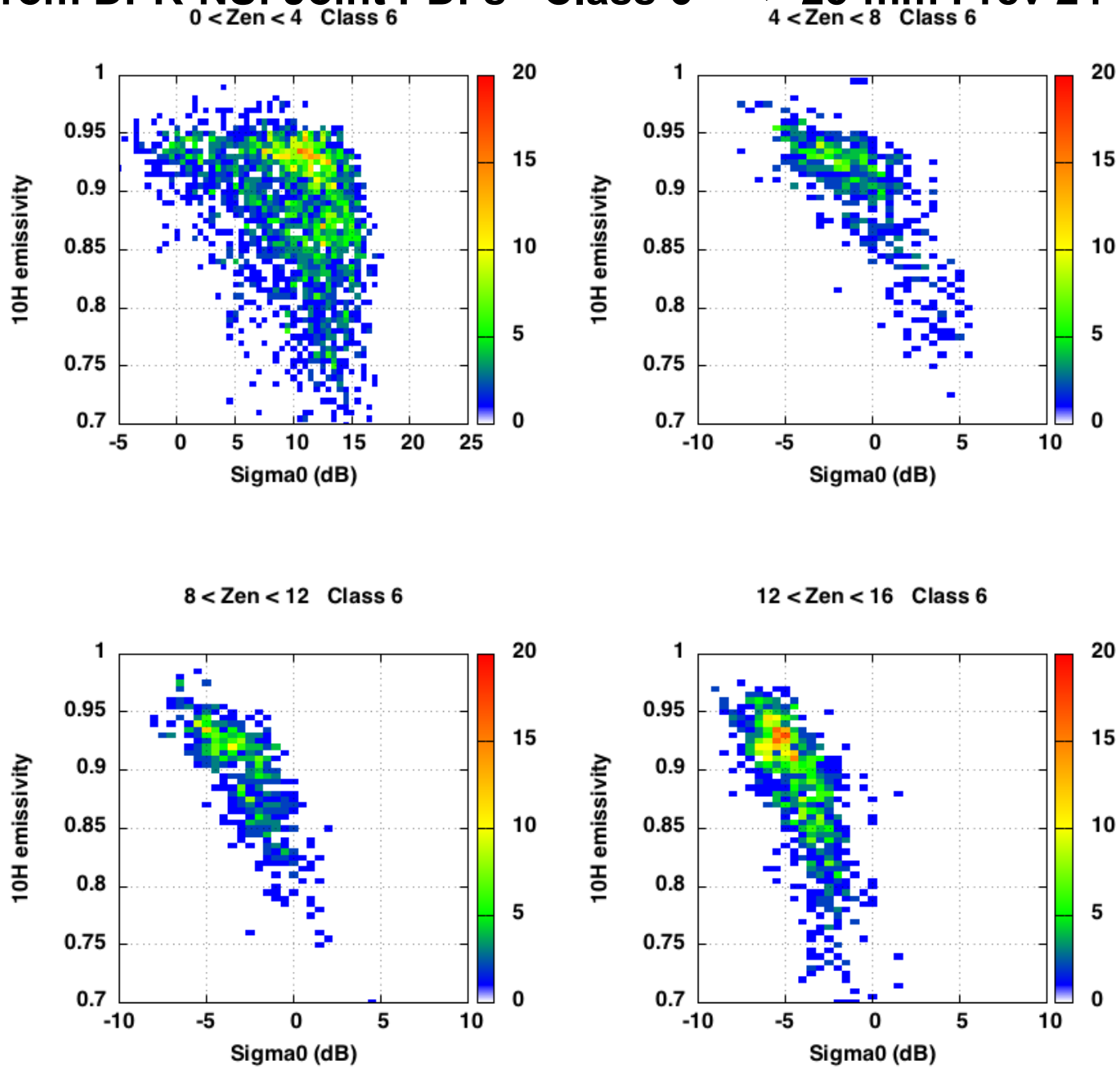








From DPR-NS: Joint PDFs Class 6 > 25-mm Prev 24-hrs



Comments and Proposed Future

The spatial/temporal complexity of most land surfaces, coasts, mixed pixels, is poorly represented by finite, static classifications. Use the observations “on-the-fly” to represent the surface.

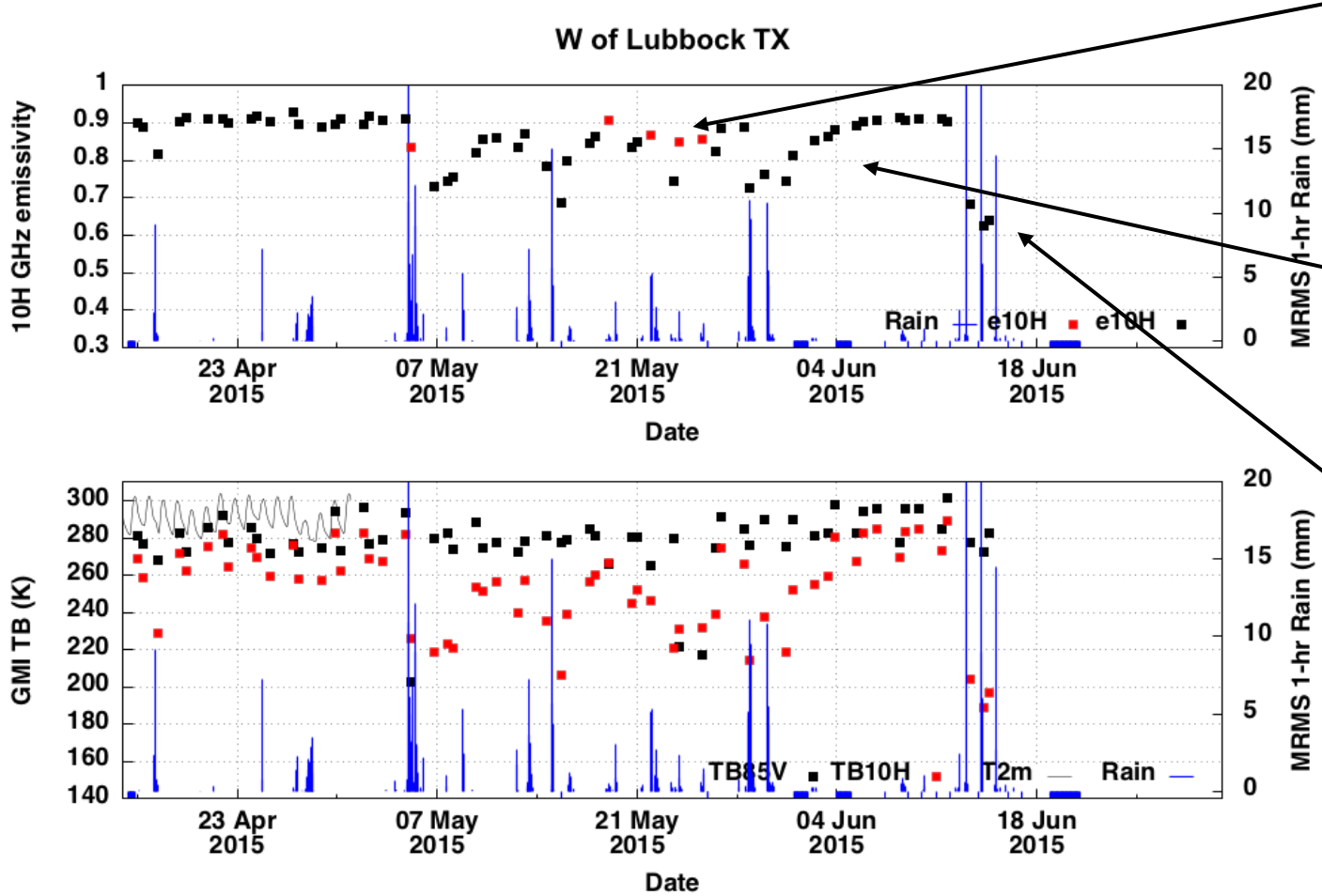
Establish temporal database (like DPR radar retrieval, B. Meneghini Tues presentation) for low-confidence scenes – much “shorter” with the constant incidence angle (test version already done)

Evaluation of GPROF retrievals separated by land surface conditions (didn’t discuss here)

Work with an offline version of GPROF-GPM to test and evaluate use of observationally-based emissivity in forward TB radiometer simulations (D. Randel Monday AM presentation).

Examine further extension to 166 GHz for very dry (< 10 mm column vapor) cold season scenes, to help others involved with GPM snowfall and light rain TB simulations.

8-week Zoom-in West of Lubbock, TX



In this period, the land does not have much time to "dry down"

dry down period

Note that many GPM overpasses occur "in between" rain events

8 weeks

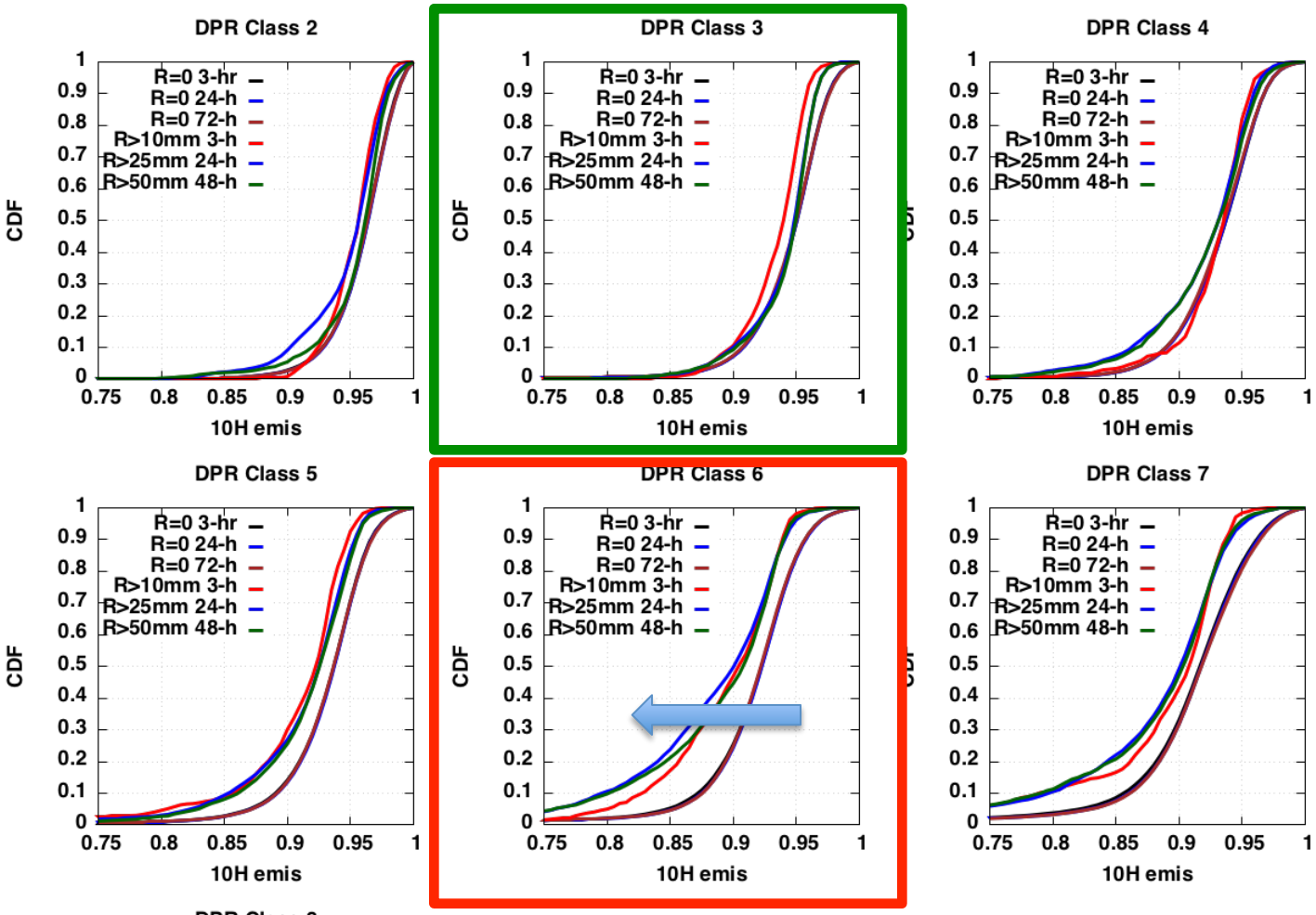
15 Apr 15 – 15 Jun 2015

TB 85V (black)

TB 10H (red)

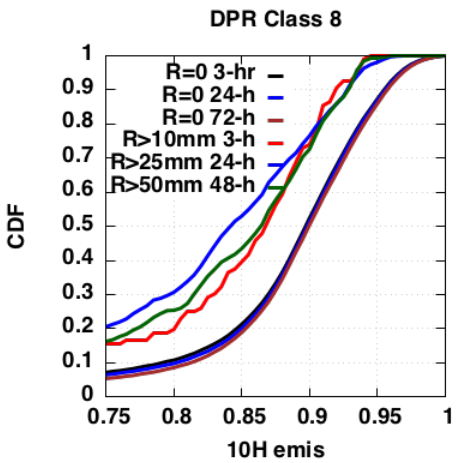
T2m (thin black line)

Soil type and scrub-like vegetation exhibit rapid rain response and dry-down



April 2014-June 2015 GMI 10H

Rain totals from MRMS back 72-h, in 1-hr increments



Emissivity CDF's "shift to the left" when there is a "wet surface" effect

R > 10 mm in previous 3-h (red)
R > 25 mm in previous 24-h (blue)
R > 50 mm in previous 48-h (green)