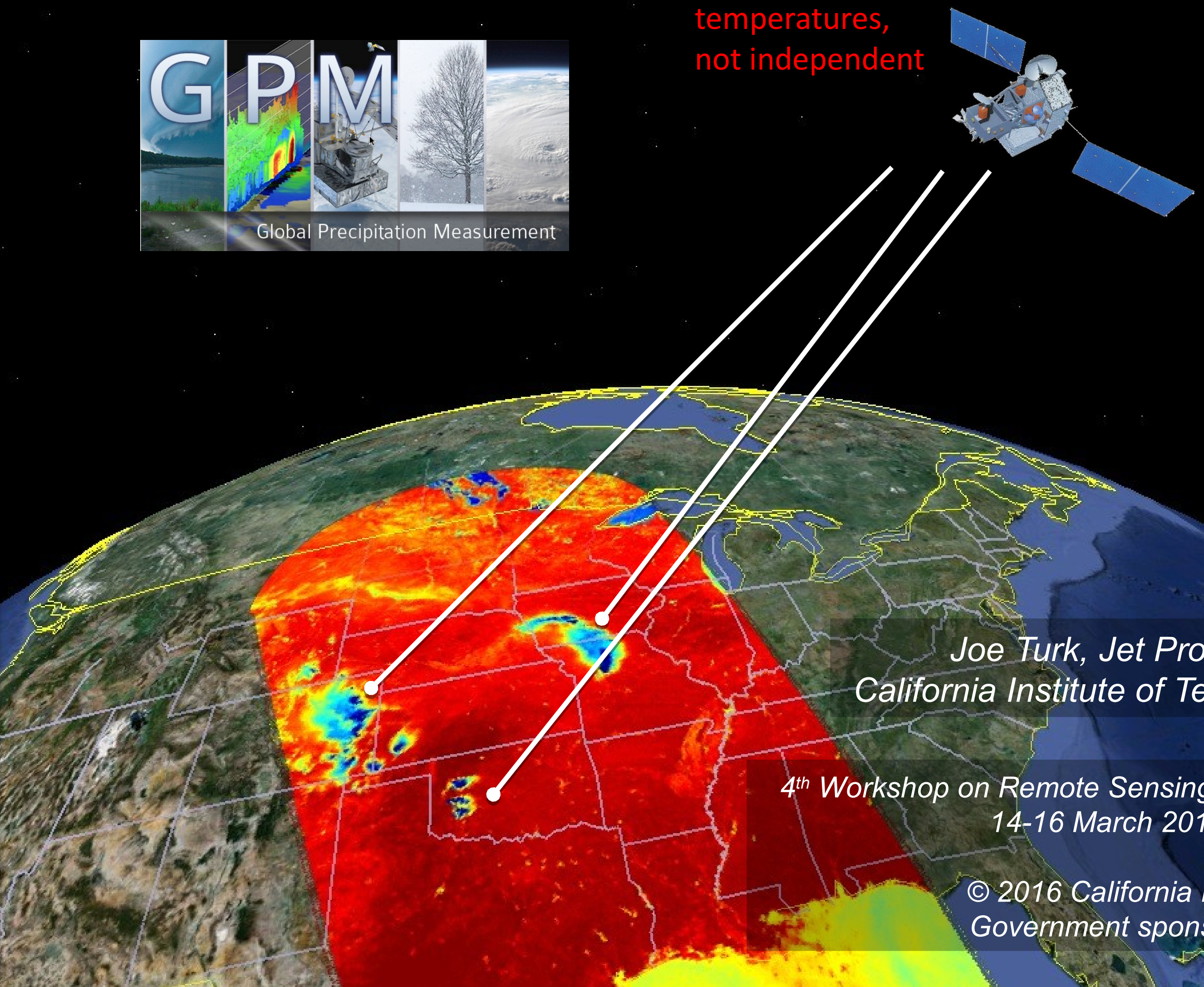
Estimating Non-Raining Surface Parameters to Assist GPM Constellation Radiometer Precipitation Products



Joe Turk, Jet Propulsion Laboratory,
California Institute of Technology, Pasadena, CA

4th Workshop on Remote Sensing and Modeling of Surface Properties
14-16 March 2016, Grenoble, France

Government sponsorship acknowledged

GPM Land Surface Working Group (LSWG)

- Meetings/Presentations
- Data
- Documents
- Publications and References

Current event

*** Monthly Telecon: Feb. 17, 2016, 10:00 AM**

- Documents folder

About LSWG

LSWG is a community group of scientists working on land surface-related topics to support GPM. Current co-chairs are Joe Turk (JPL) and Christa Peters-Lidard (GSFC).

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5825 University Research Ct., Ste. 4001
College Park, MD 20740

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With contributions from:

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and the GPM Land Surface Working Group

http://lswg.umd.edu

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Future CGMS Land Surface Working Group
(Steve English's presentation earlier today)

Land surface modeling and observations are a cross-cutting theme extending across current five CGMS WG's, eg

- IPWG: longstanding action items on cold season, complex terrain (esp problematic for snow/drizzle)- Oct 2016 snowfall workshop in Bologna
- IWWG: surface winds closer to coasts, proposed wind+currents missions
- IROWG: increased exploitation of land/ocean surface reflections

Action items from WG's useful for strengthening science objectives for future space missions, e.g NASA's ongoing (2017) Decadal Survey

Topics are often specific, but common themes and challenges ("weather" lies between the surface and each observing platform), WG's use each others data and products

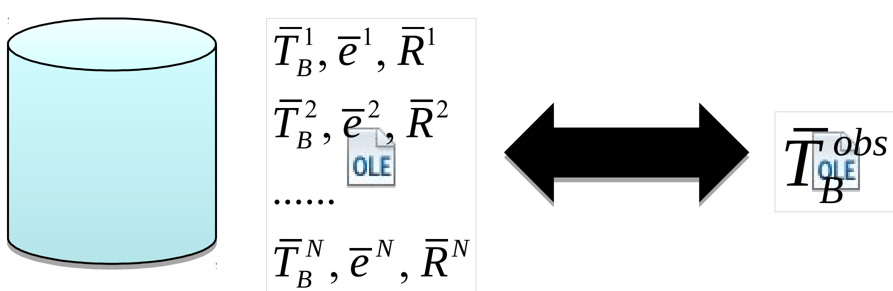
Why is this work needed?

- The information content within space-based precipitation radar/radiometer observations is insufficient to describe the environmental and surface state controlling the precipitation process physics.

- Retrieval process brings in a-priori simulations and ancillary data, in order to apply common physics across all platforms/sensors. Places a heavy burden on the “realism” of the Z and TB simulations.

- For simulations the MW surface emissivity vector needs to be specified for each sensor type, alongside associated thermodynamic state.

- And for retrievals, some way of “connecting” to the properties used for creating each database profile

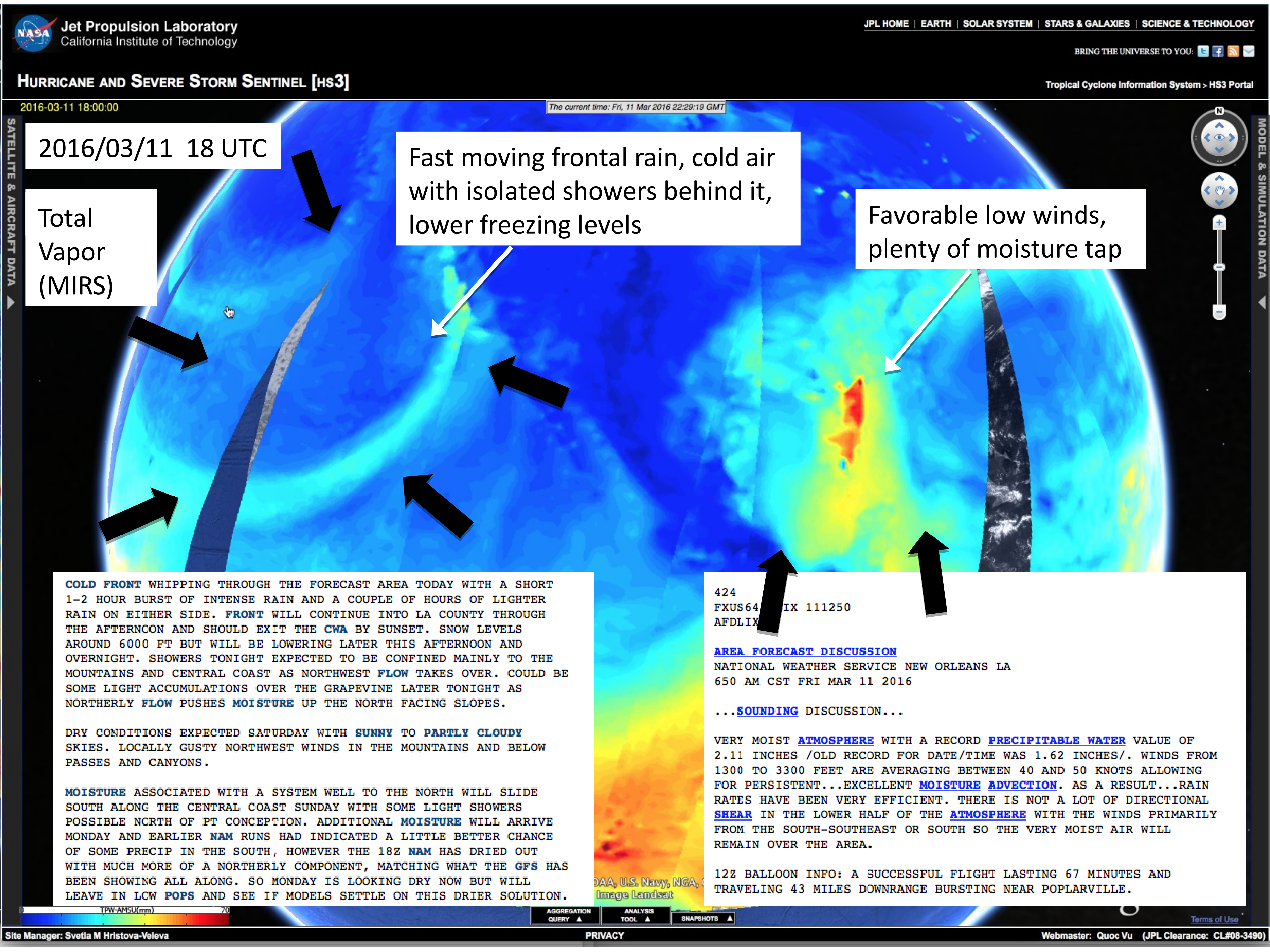


A-priori

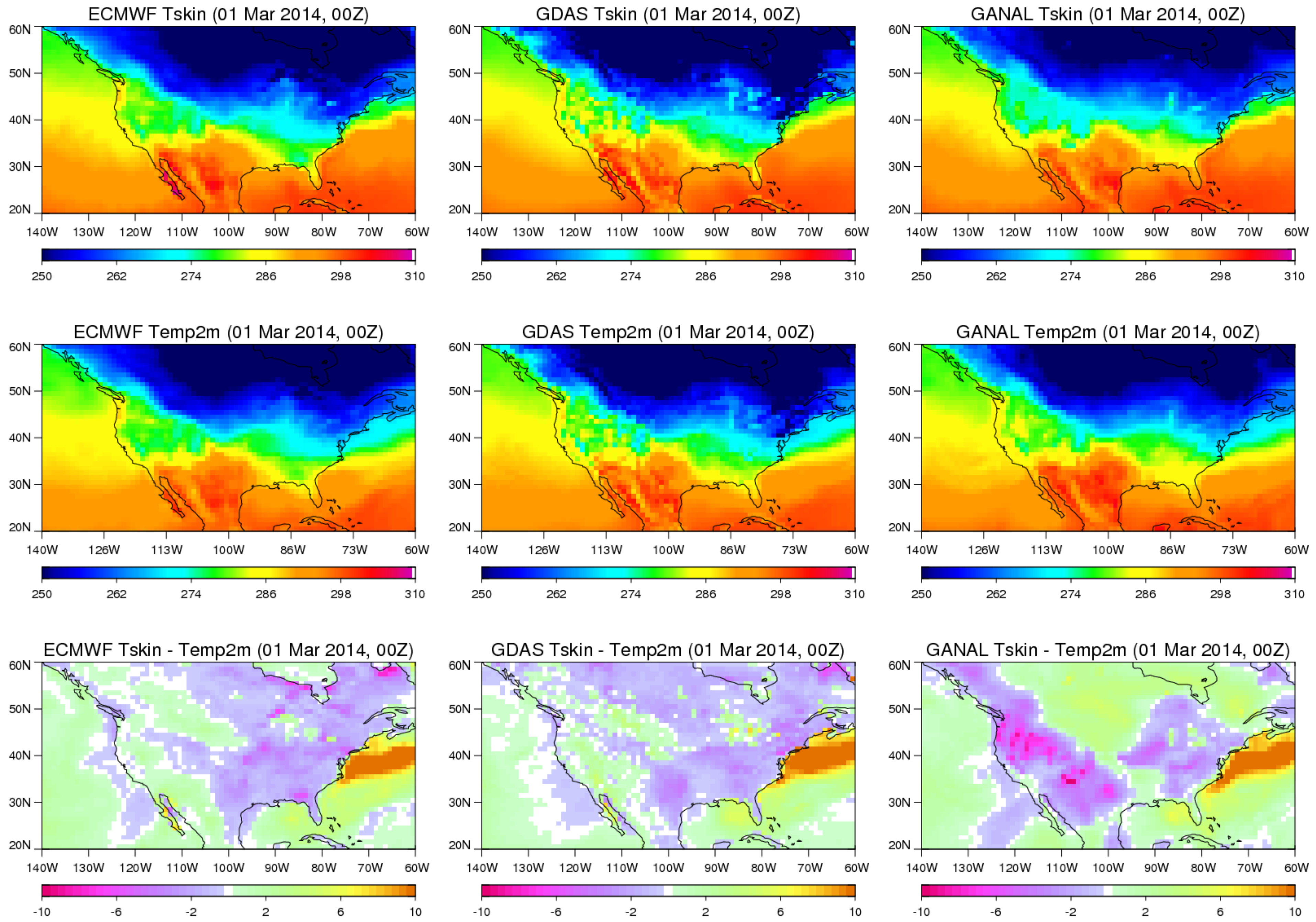
Observations

“connect” surface and environmental conditions to corresponding conditions within the a-priori collection

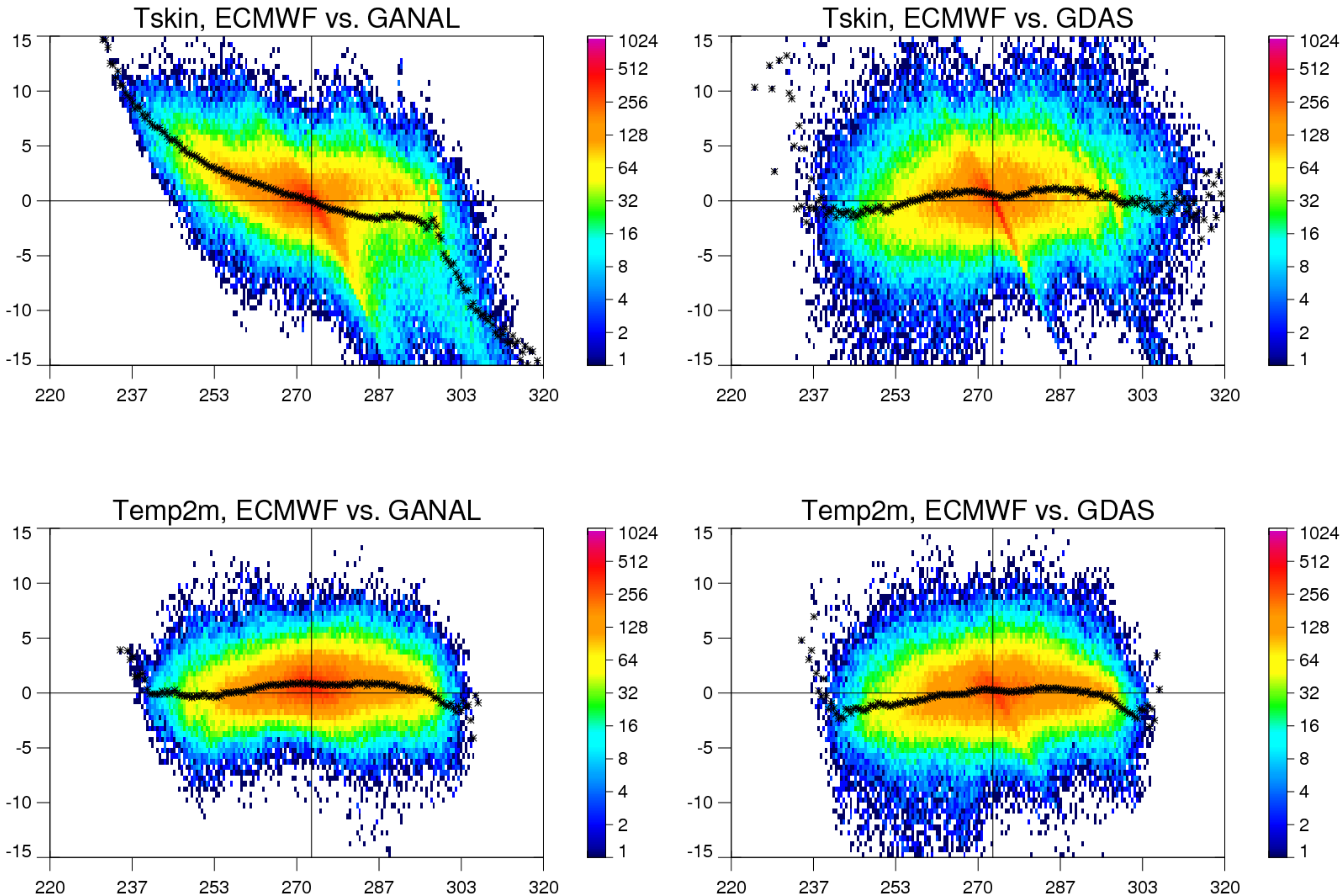
Current GPM-GPROF does this thru a “classification index”


Jet Propulsion Laboratory
California Institute of Technology
JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | SCIENCE & TECHNOLOGY
BRING THE UNIVERSE TO YOU:
HURRICANE AND SEVERE STORM SENTINEL [HS3]
Tropical Cyclone Information System > HS3 Portal
2016-03-11 18:00:00
The current time: Fri, 11 Mar 2016 22:29:19 GMT
SATELLITE & AIRCRAFT DATA
MODEL & SIMULATION DATA
2016/03/11 18 UTC
Total Vapor (MIRS)
Fast moving frontal rain, cold air with isolated showers behind it, lower freezing levels
Favorable low winds, plenty of moisture tap
COLD FRONT WHIPPING THROUGH THE FORECAST AREA TODAY WITH A SHORT
1-2 HOUR BURST OF INTENSE RAIN AND A COUPLE OF HOURS OF LIGHTER
RAIN ON EITHER SIDE. FRONT WILL CONTINUE INTO LA COUNTY THROUGH
THE AFTERNOON AND SHOULD EXIT THE CWA BY SUNSET. SNOW LEVELS
AROUND 6000 FT BUT WILL BE LOWERING LATER THIS AFTERNOON AND
OVERNIGHT. SHOWERS TONIGHT EXPECTED TO BE CONFINED MAINLY TO THE
MOUNTAINS AND CENTRAL COAST AS NORTHWEST FLOW TAKES OVER. COULD BE
SOME LIGHT ACCUMULATIONS OVER THE GRAPEVINE LATER TONIGHT AS
NORTHERLY FLOW PUSHES MOISTURE UP THE NORTH FACING SLOPES.
DRY CONDITIONS EXPECTED SATURDAY WITH SUNNY TO PARTLY CLOUDY
SKIES. LOCALLY GUSTY NORTHWEST WINDS IN THE MOUNTAINS AND BELOW
PASSES AND CANYONS.
MOISTURE ASSOCIATED WITH A SYSTEM WELL TO THE NORTH WILL SLIDE
SOUTH ALONG THE CENTRAL COAST SUNDAY WITH SOME LIGHT SHOWERS
POSSIBLE NORTH OF PT CONCEPTION. ADDITIONAL MOISTURE WILL ARRIVE
MONDAY AND EARLIER NAM RUNS HAD INDICATED A LITTLE BETTER CHANCE
OF SOME PRECIP IN THE SOUTH, HOWEVER THE 18Z NAM HAS DRIED OUT
WITH MUCH MORE OF A NORTHERLY COMPONENT, MATCHING WHAT THE GFS HAS
BEEN SHOWING ALL ALONG. SO MONDAY IS LOOKING DRY NOW BUT WILL
LEAVE IN LOW POPS AND SEE IF MODELS SETTLE ON THIS DRIER SOLUTION.
424
FXUS64 IX 111250
AFDLIX
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE NEW ORLEANS LA
650 AM CST FRI MAR 11 2016
...SOUNDING DISCUSSION...
VERY MOIST ATMOSPHERE WITH A RECORD PRECIPITABLE WATER VALUE OF
2.11 INCHES /OLD RECORD FOR DATE/TIME WAS 1.62 INCHES/. WINDS FROM
1300 TO 3300 FEET ARE AVERAGING BETWEEN 40 AND 50 KNOTS ALLOWING
FOR PERSISTENT...EXCELLENT MOISTURE ADVECTION. AS A RESULT...RAIN
RATES HAVE BEEN VERY EFFICIENT. THERE IS NOT A LOT OF DIRECTIONAL
SHEAR IN THE LOWER HALF OF THE ATMOSPHERE WITH THE WINDS PRIMARILY
FROM THE SOUTH-SOUTHEAST OR SOUTH SO THE VERY MOIST AIR WILL
REMAIN OVER THE AREA.
12Z BALLOON INFO: A SUCCESSFUL FLIGHT LASTING 67 MINUTES AND
TRAVELING 43 MILES DOWNRANGE BURSTING NEAR POPLARVILLE.
Site Manager: Svetla M Hristova-Veleva
PRIVACY
Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

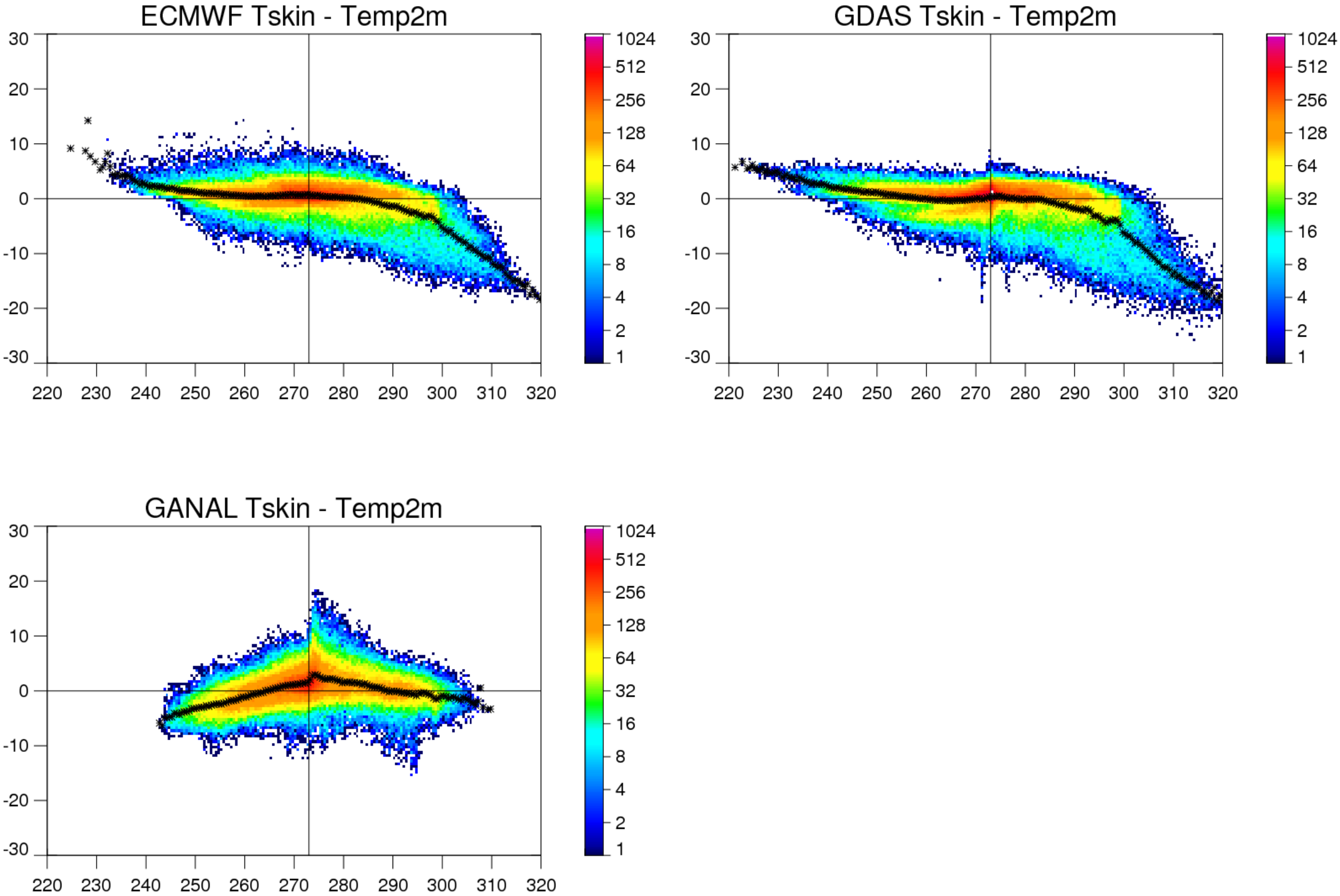
(Figure courtesy of Dr. Wes Berg, Colorado State Univ.)



(Figure courtesy of Dr. Wes Berg, Colorado State Univ.)



(Figure courtesy of Dr. Wes Berg, Colorado State Univ.)



Using GMI/DPR Observations for Constraining Constellation Precipitation Estimates

Most of the time it is not raining, and the surface can be studied from these observations, in light of previous conditions

Can we extract some “range” of surface and environmental conditions directly from the observations, to *lessen* dependencies upon model sources?

Use DPR Ku/Ka-band capability to discriminate “no-cloud” GMI scenes, relative to the sensitivity at Ka-band (fully accepting that DPR is *not* a cloud radar)

Historical Context: Grody's 1991 Scattering Index (SI)

Uses the 22V SSMI observations to estimate the non-scattering contribution to the 85V observations

$$SI = F - TB_{85V}$$

$$F = a_0 + a_1 TB_{19V} + a_2 TB_{22V} + a_3 TB_{22V}^2$$

$$SI > 10 \quad \rightarrow scattering\,materials$$

Various multispectral tests for discriminating snow, ice, desert, precipitation

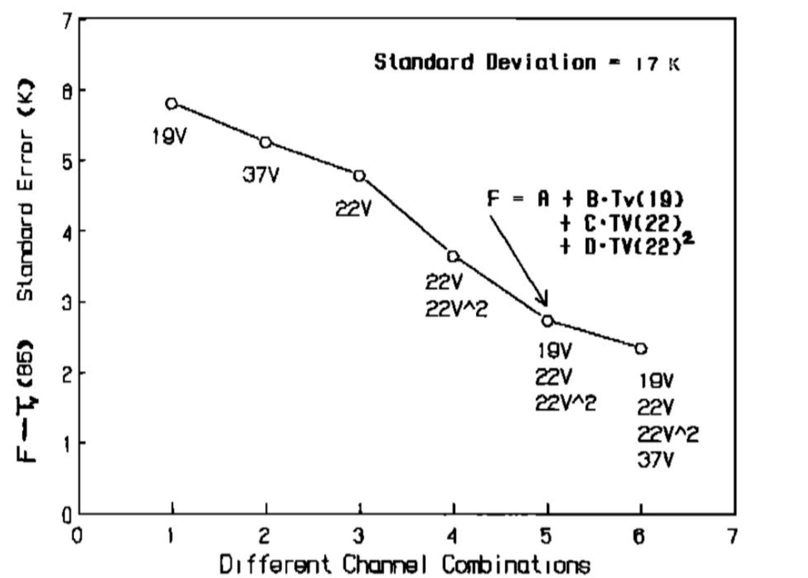
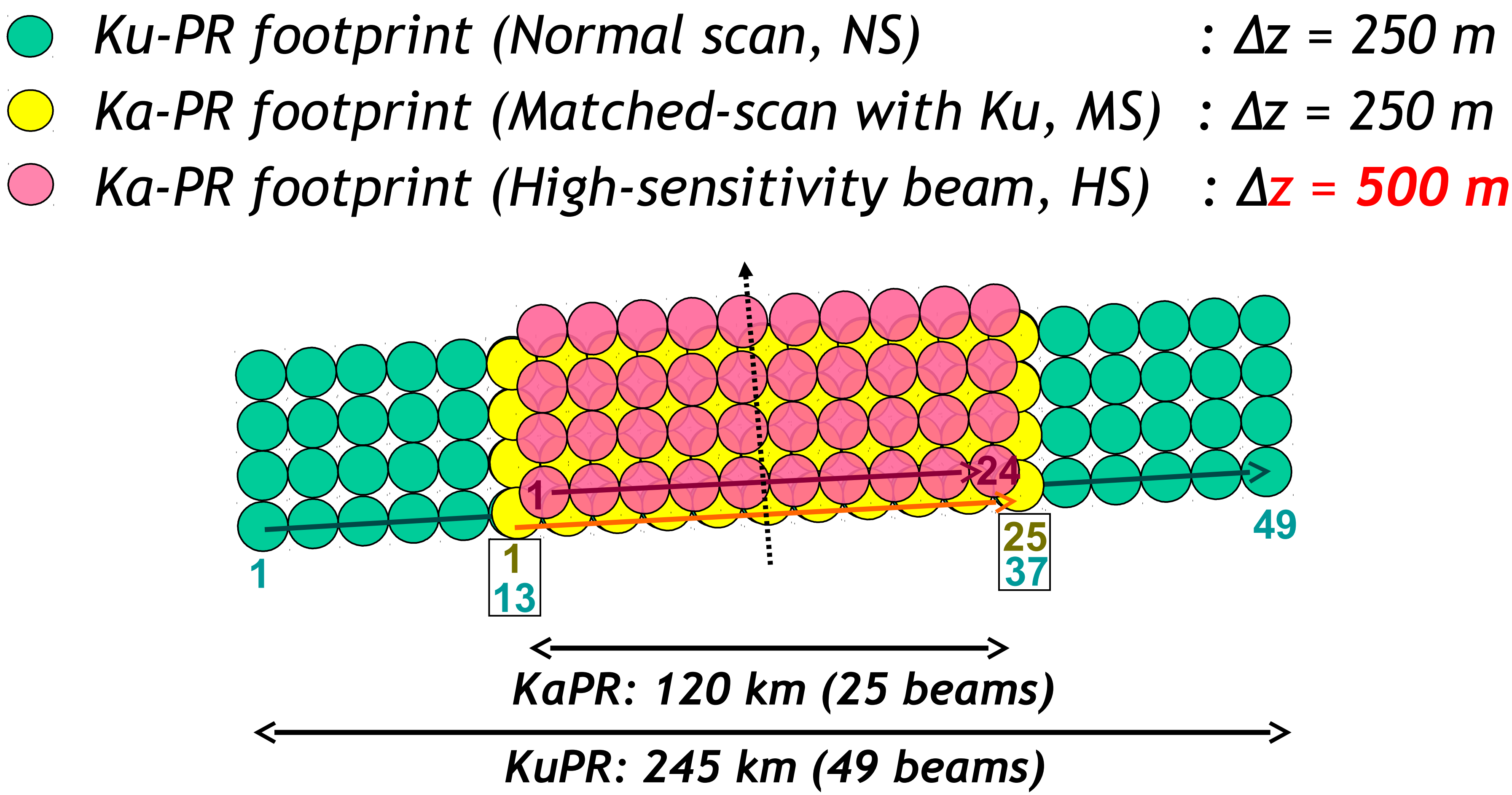


Fig. 3. Standard error of the estimated 85-GHz vertically polarized measurement, F, as derived using different combinations of the lower-frequency SSMI channels. The plot shows the errors relative to the actual measurements, $F - T_v(85)$, for different channel combinations. Results are based on a global data set of nonscattering materials over land and ocean.

Grody, N.C. (1991), Classification of snow cover and precipitation using the Special Sensor Microwave Imager. J. Geophys. Res., *96*, 7423-7435.

Concept of the DPR antenna scan

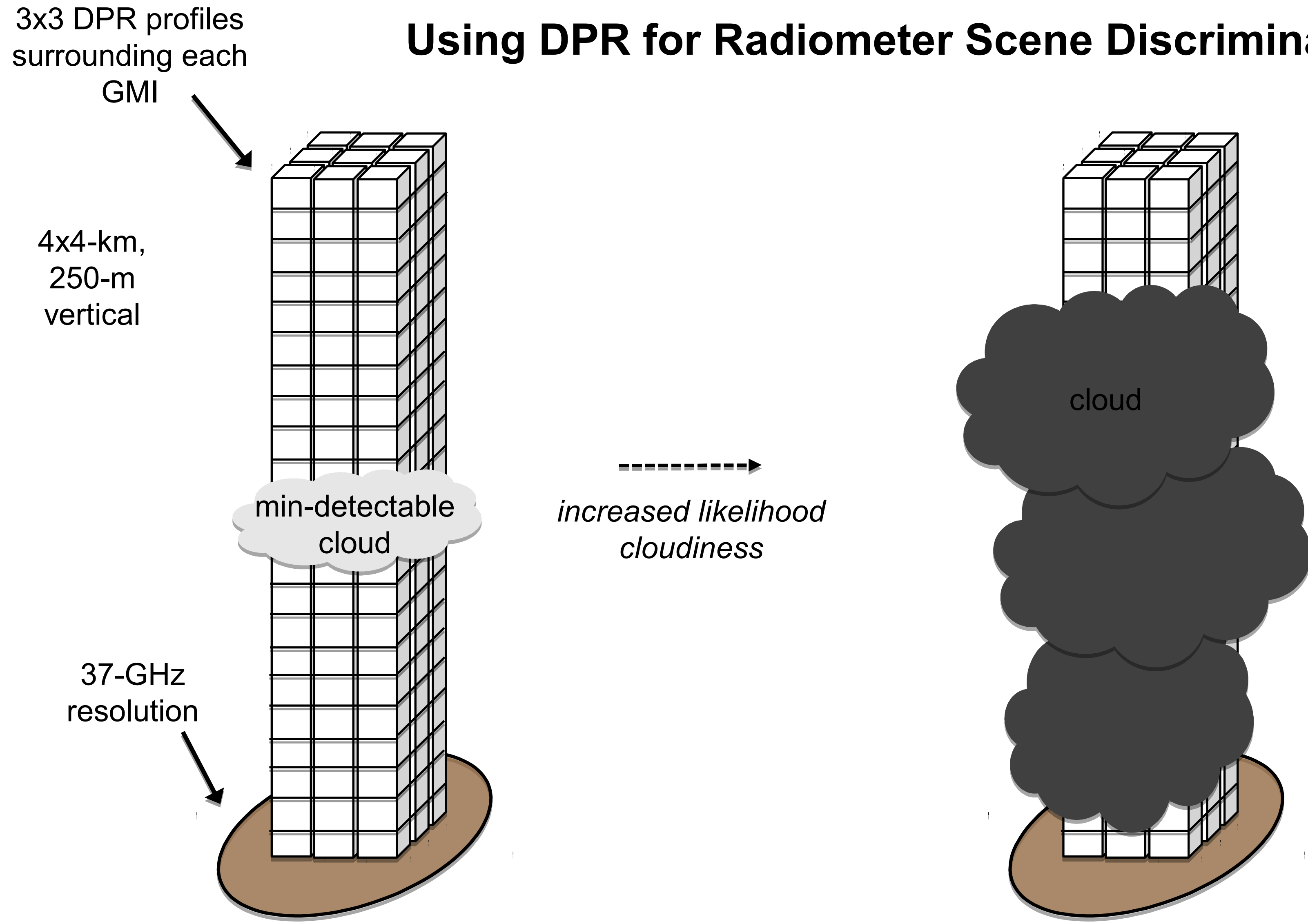
Courtesy T. Iguchi, NICT



In the interlacing scan area (pink), the KaPR can measure snow and light rain in a high-sensitivity mode with a double pulse width.

The synchronized matched beam (yellow) is necessary for the dual-frequency algorithm.

Using DPR for Radiometer Scene Discrimination

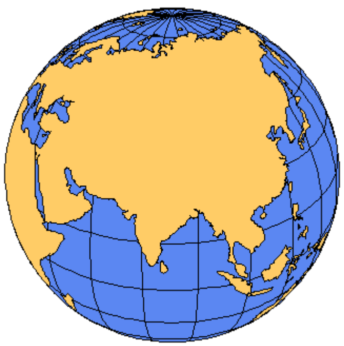


Z(Ku) < 15 dB and
Z(Ka) < 15 dB and
Z(Ka-HS) < 15 dB
(all bins) ➔ "no cloud"

N bins where Z(Ku) > 20 dB as a proxy for increased level of cloudiness and precipitation
N > 20 ➔ "low probability"
N > 50 ➔ "medium probability"
N > 100 ➔ "high probability"

Analysis Matched GMI/DPR Data

Extensive, diverse collection from 1+ year of GMI "no-cloud" emissivity vectors everywhere within ±65 degree latitude, without regard to the surface type



$$\begin{bmatrix} TB_{10V} \\ TB_{10H} \\ \cdots \\ TB_{89H} \\ TB_{166V} \\ TB_{166H} \end{bmatrix} + \begin{bmatrix} e_{10V} \\ e_{10H} \\ \cdots \\ e_{89H} \\ T_{sfc} \\ TWV \end{bmatrix}$$

Tsfc and total vapor added

Principal component analysis :

$$\vec{u} = \left[E\right]^T \vec{e}$$

$$\left[\Lambda\right] = \left[E\right]^{-1}\left[S_x\right]\left[E\right]$$

$$\vec{e} \equiv \left[E\right]\vec{u}$$

$$\vec{e} \cong \left[E\right]\hat{u}$$

If there was some way to estimate each principal component from the observations, then the emissivity vector e could be *approximately* reconstructed from the TB observations

Assume nonlinear TB combinations and polarization ratios "carry" the information on the surface properties

$$u_i = a_0 + \sum_{j=1}^{N} a_j TB_j + \sum_{j=1}^{N}\sum_{k=j}^{N} b_{jk} TB_j TB_k + \sum_{j=1}^{3} c_j PR_j \qquad i = 1,9$$

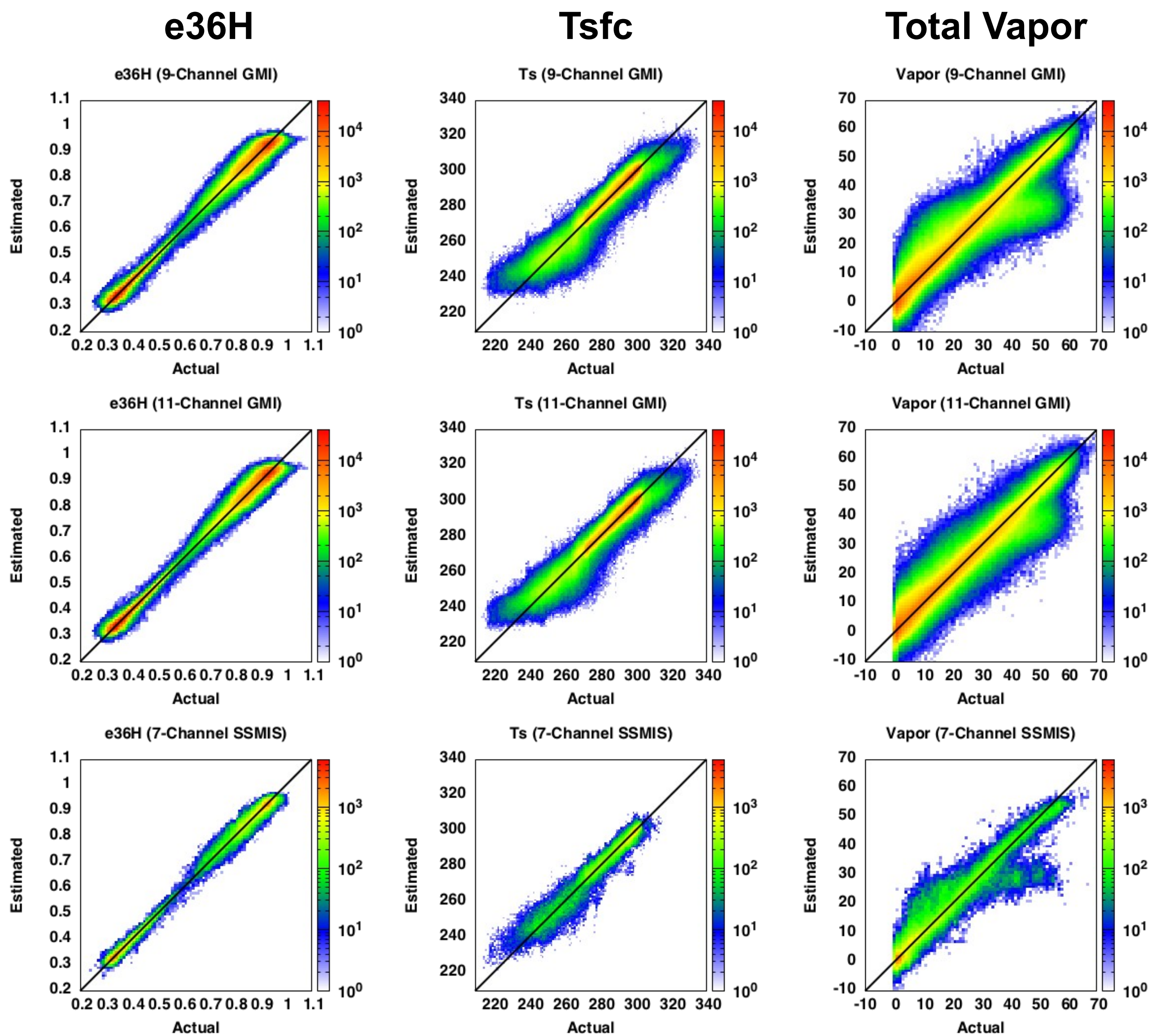
$$PR_j = (TB_j^V - TB_j^H)/(TB_j^V + TB_j^H) \qquad j = 1,3$$

TB-Reconstructed Emissivity State Vector

N=9 (10-89 GHz)
High water vapor over land underestimated

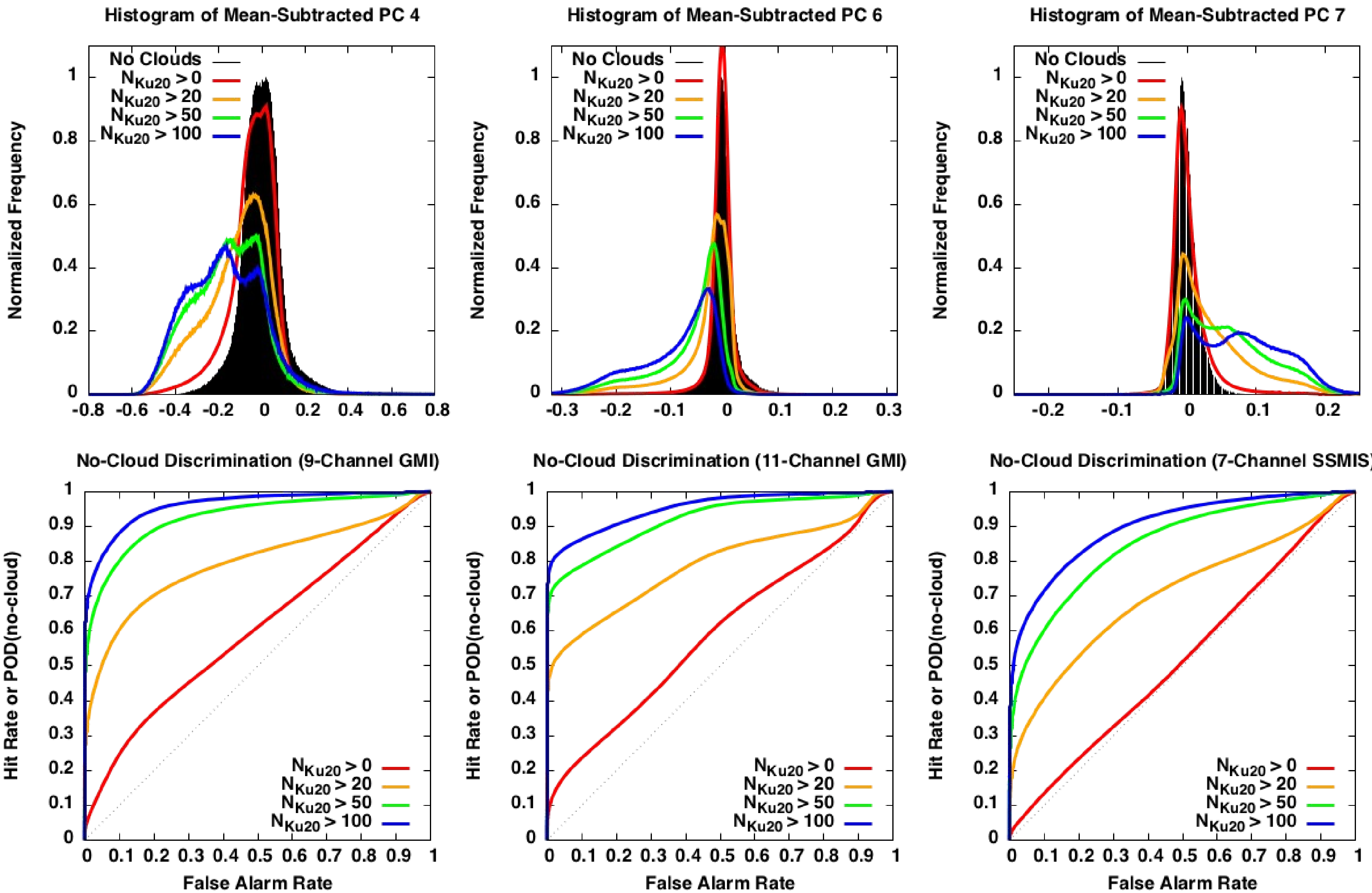
N=11 (10-166 GHz)
Improvement in over-land total vapor with inclusion of 166 GHz channels

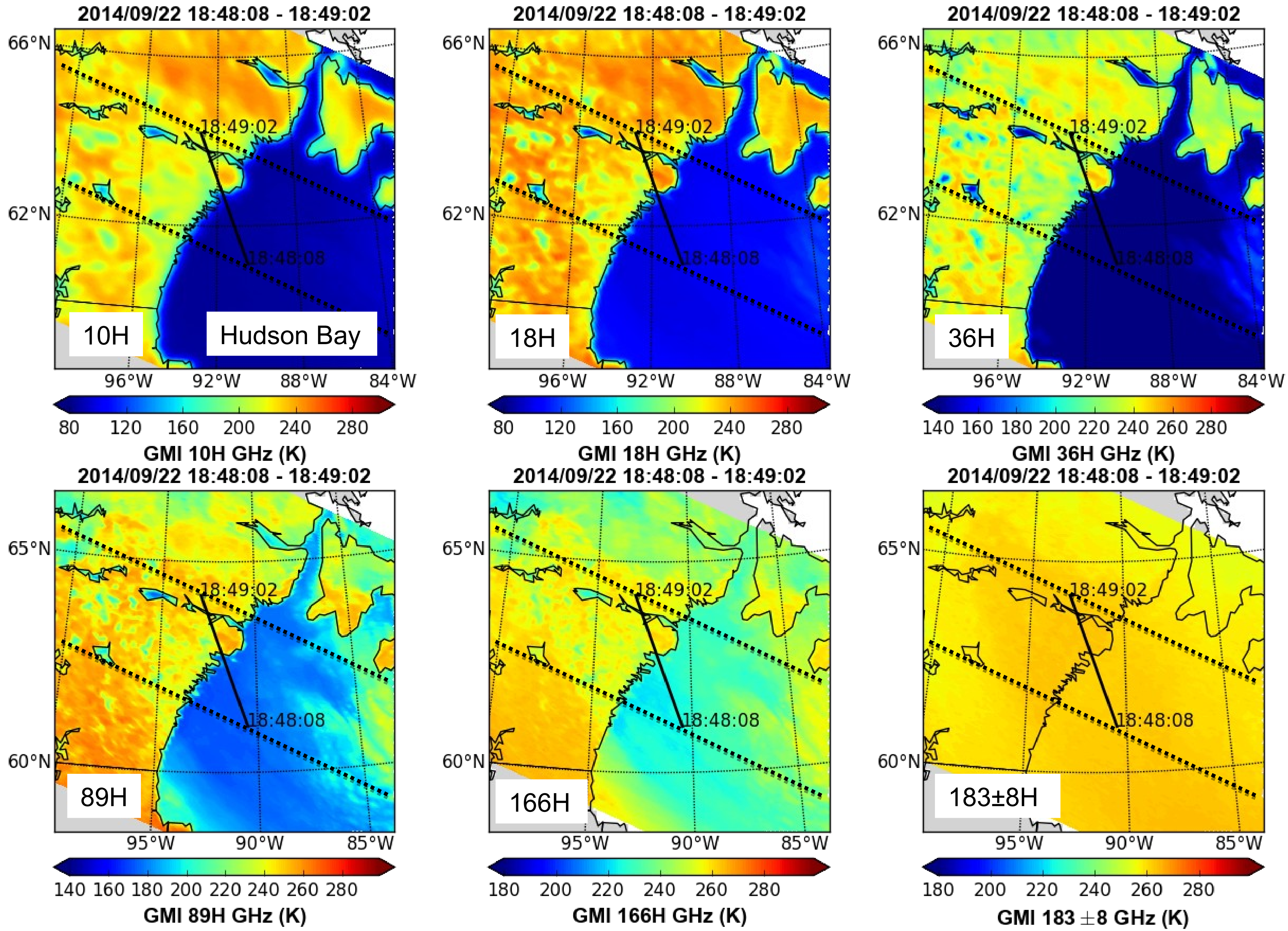
N=7 (19-85 GHz SSMIS)
SSMIS (no 10 GHz) dataset from 1-year of F17-GPM 15-min coincidences



Discrimination Performance
N(Ku) > 20 dB in column
N>0 N>20 N>50 N>100

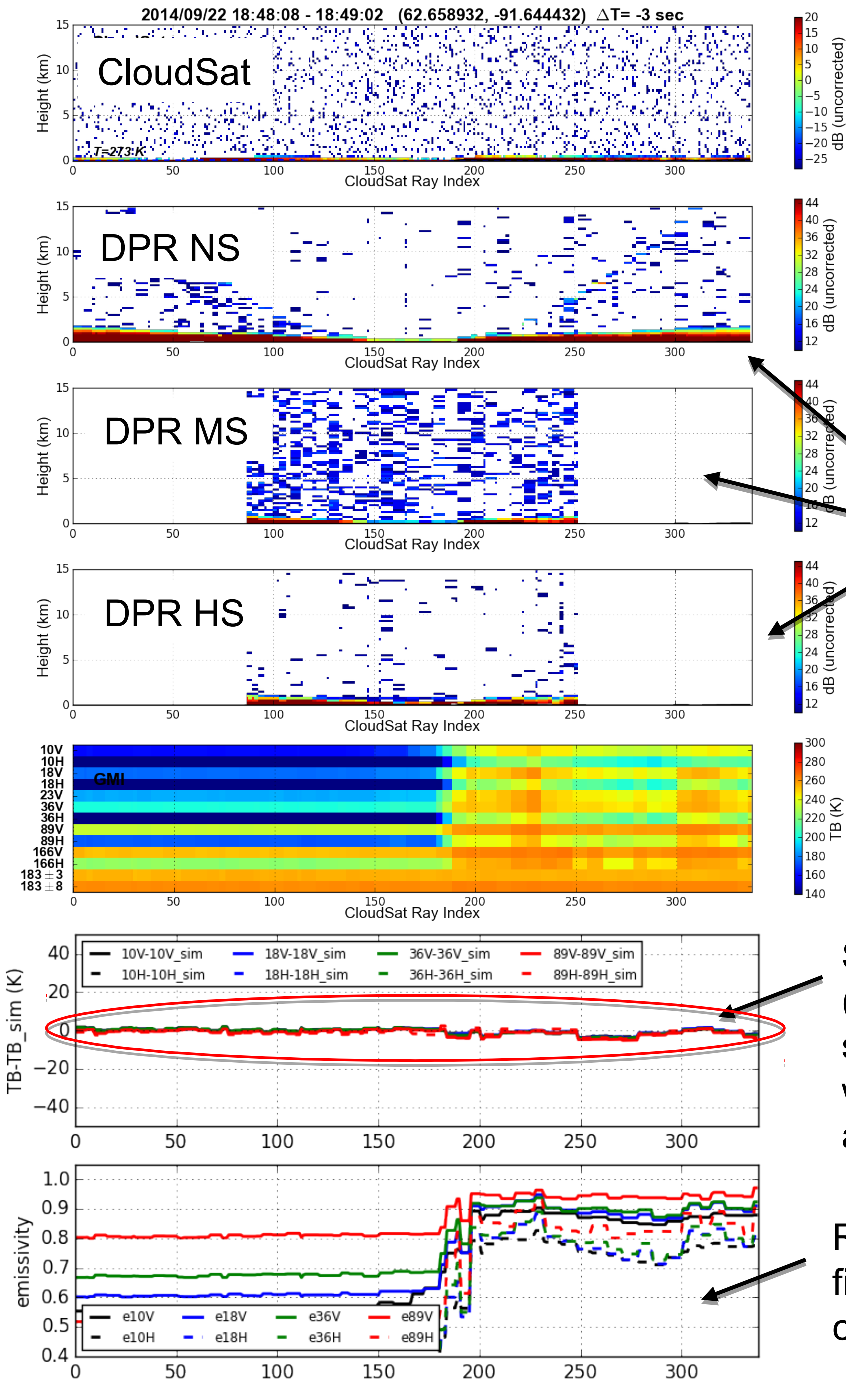
3 PC-based discriminant, using 9-channels in the regression, is a good compromise, also since S2 (166, 183 GHz) channels not always available





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
18H
80 120 160 200 240 280
GMI 18H GHz (K)
2014/09/22 18:48:08 - 18:49:02
36H
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
95°W
90°W
85°W
89H
140 160 180 200 220 240 260 280
GMI 89H GHz (K)
2014/09/22 18:48:08 - 18:49:02
166H
180 200 220 240 260 280
GMI 166H GHz (K)
2014/09/22 18:48:08 - 18:49:02
183±8H
180 200 220 240 260 280
GMI 183 ±8 GHz (K)

GPM+CloudSat Coincidence
22 September 2014
Hudson Bay Land-Water

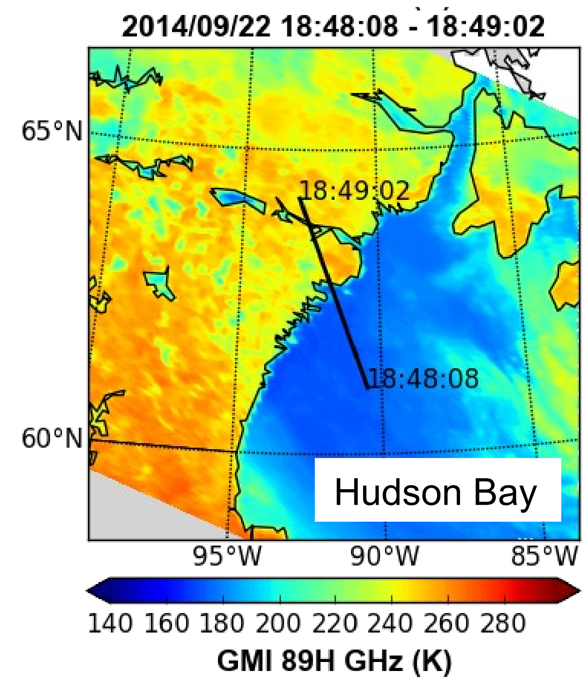


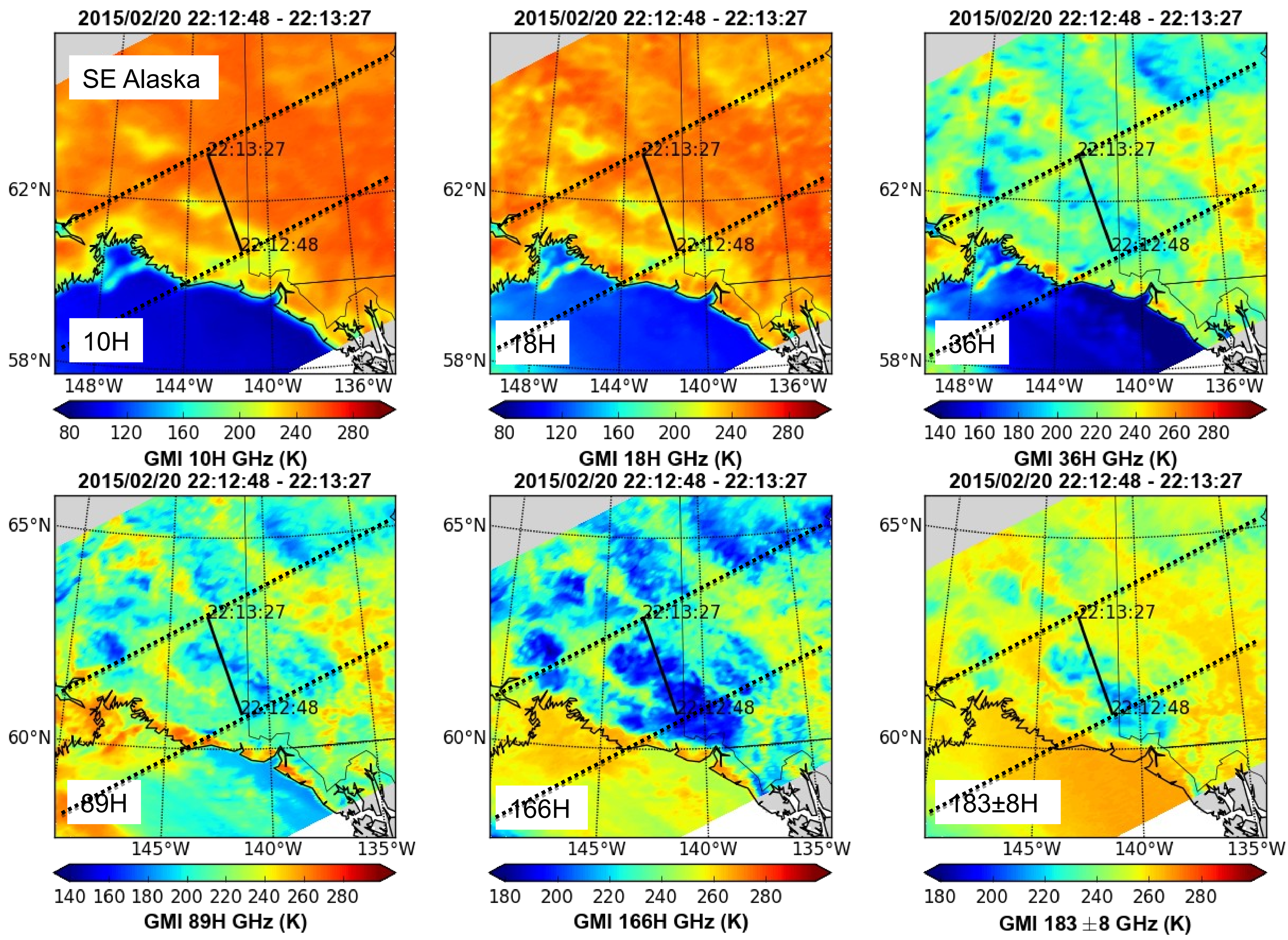
No clouds evident in all three DPR scans

Trace of all 13 GMI channels

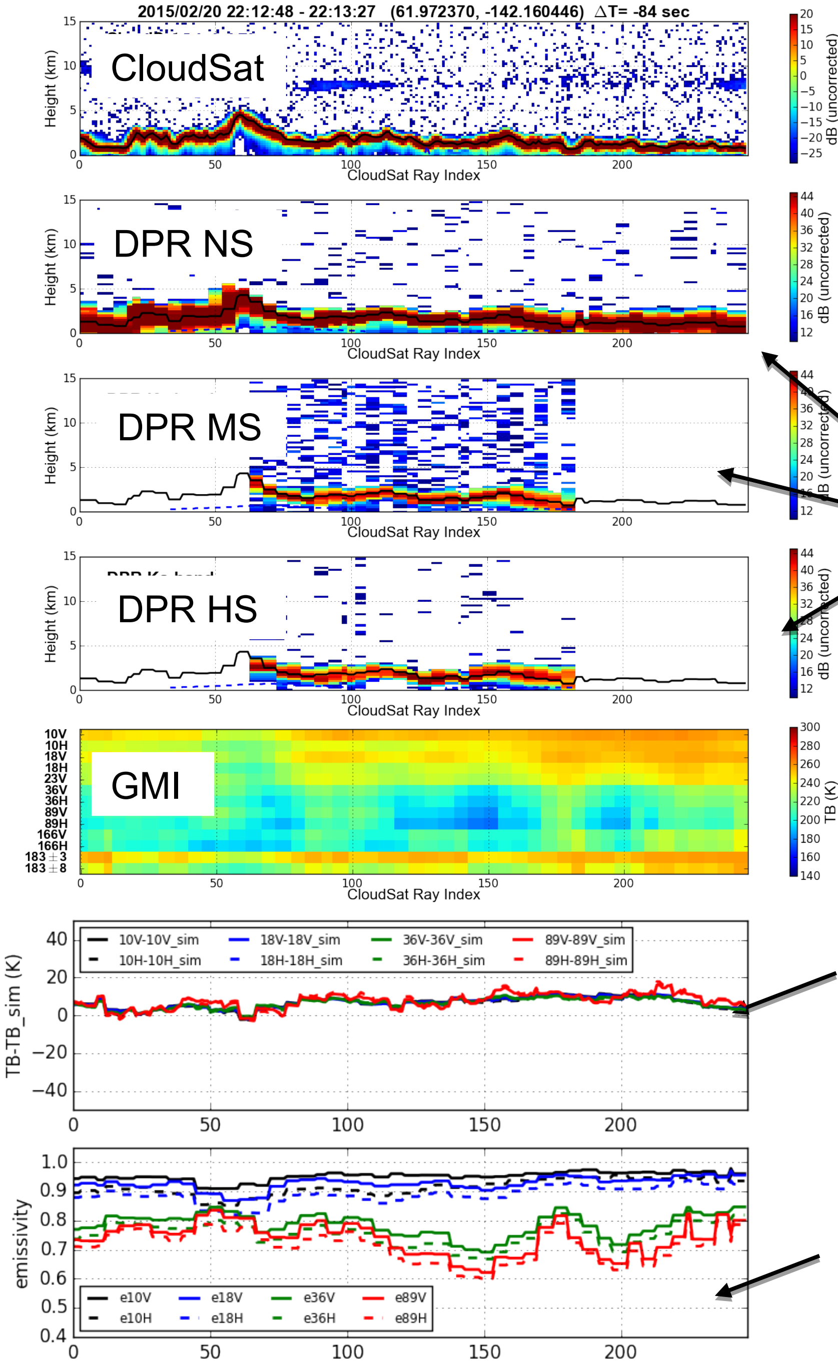
Simulated TB difference (using ECMWF) Near seamless land-coast-water transition across all 9 GMI (S1) channels

Resultant emissivity at first 9 GMI (S1) channels




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

GPM+CloudSat coincidence
20 February 2015
Alaska winter mountainous terrain

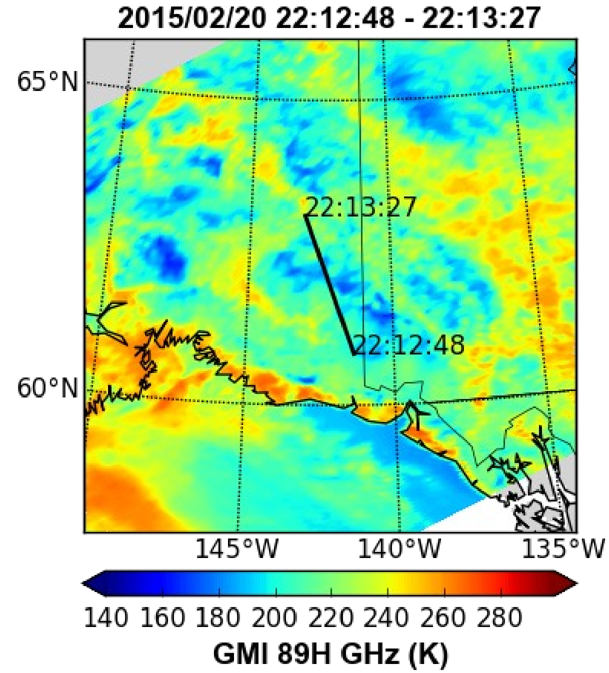


No clouds evident in all three DPR scans

Trace of all 13 GMI channels

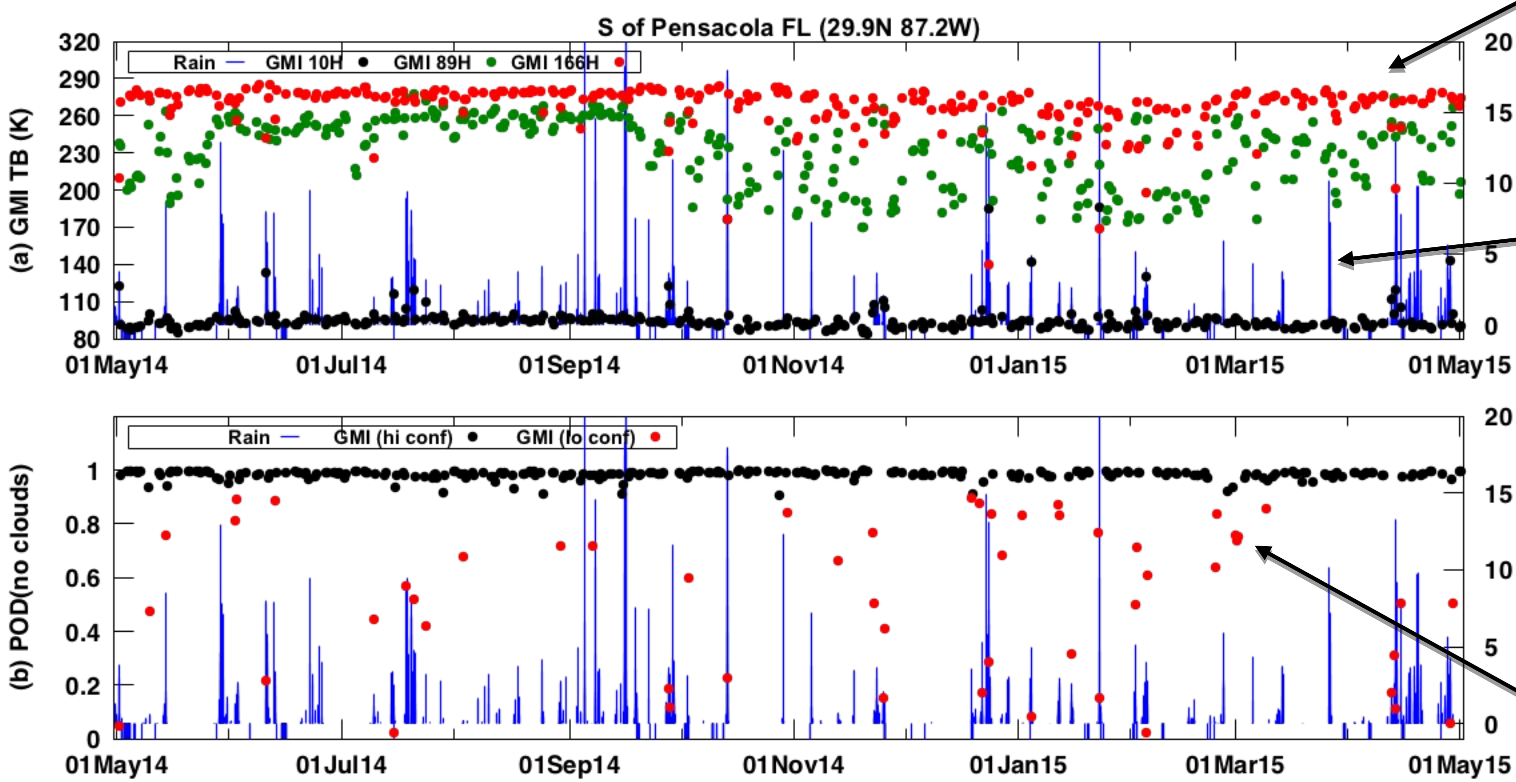
Simulated TB difference (using ECMWF) within 10K across all 9 GMI (S1) channels

Resultant emissivity at first 9 GMI (S1) channels



Extension to 166 GHz being examined for very dry cold scenes

Rain/Emissivity State Timeseries near a point: S of Pensacola, FL, US



Observations
TB 10H
TB 89H
TB 166H

MRMS
1-hr rain

Discrimination
POD("no-cloud")
90% High
Confidence

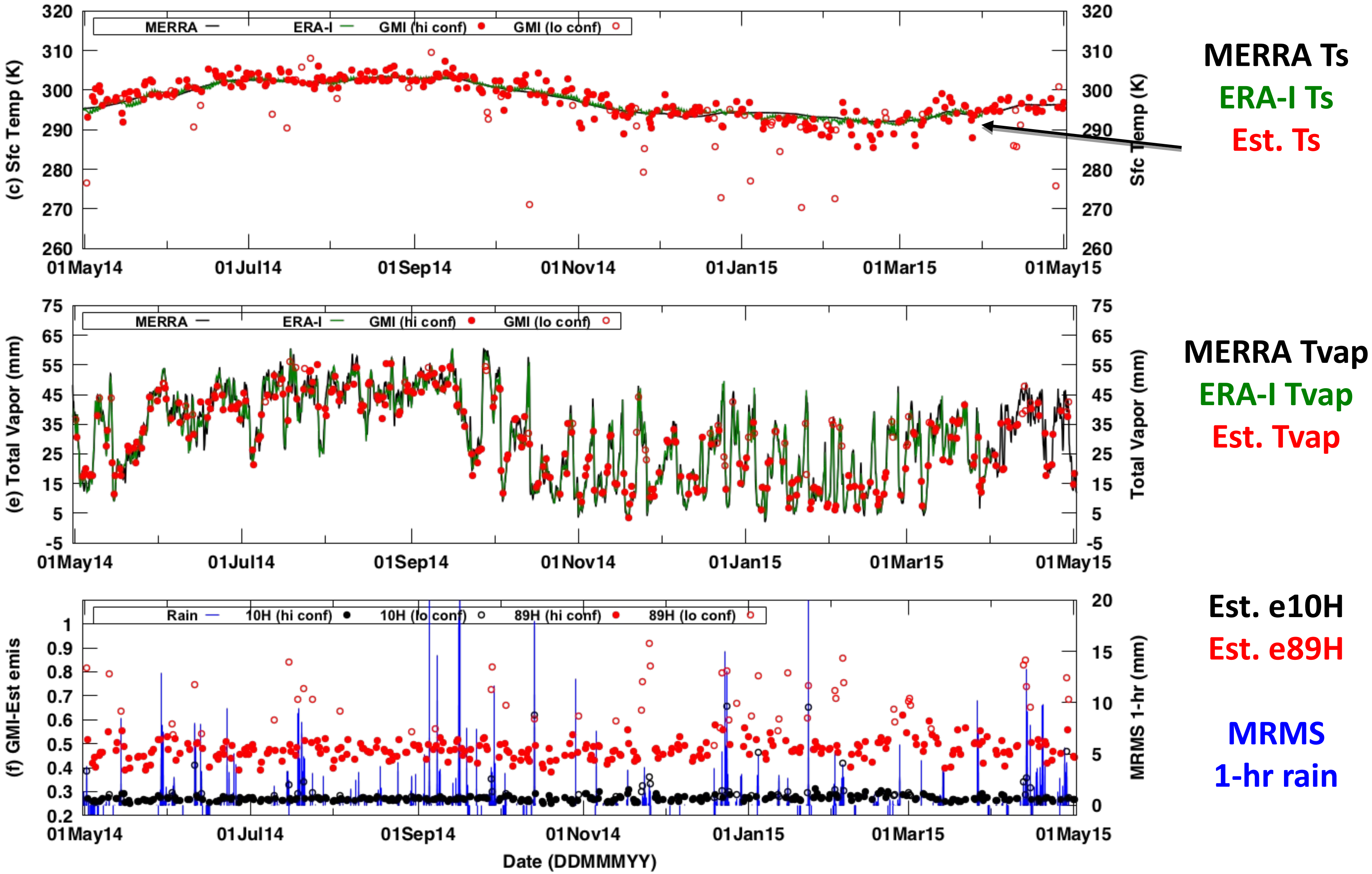
< 90%=Reduced
Confidence

12 months
1 May 2014 – 1 May 2015

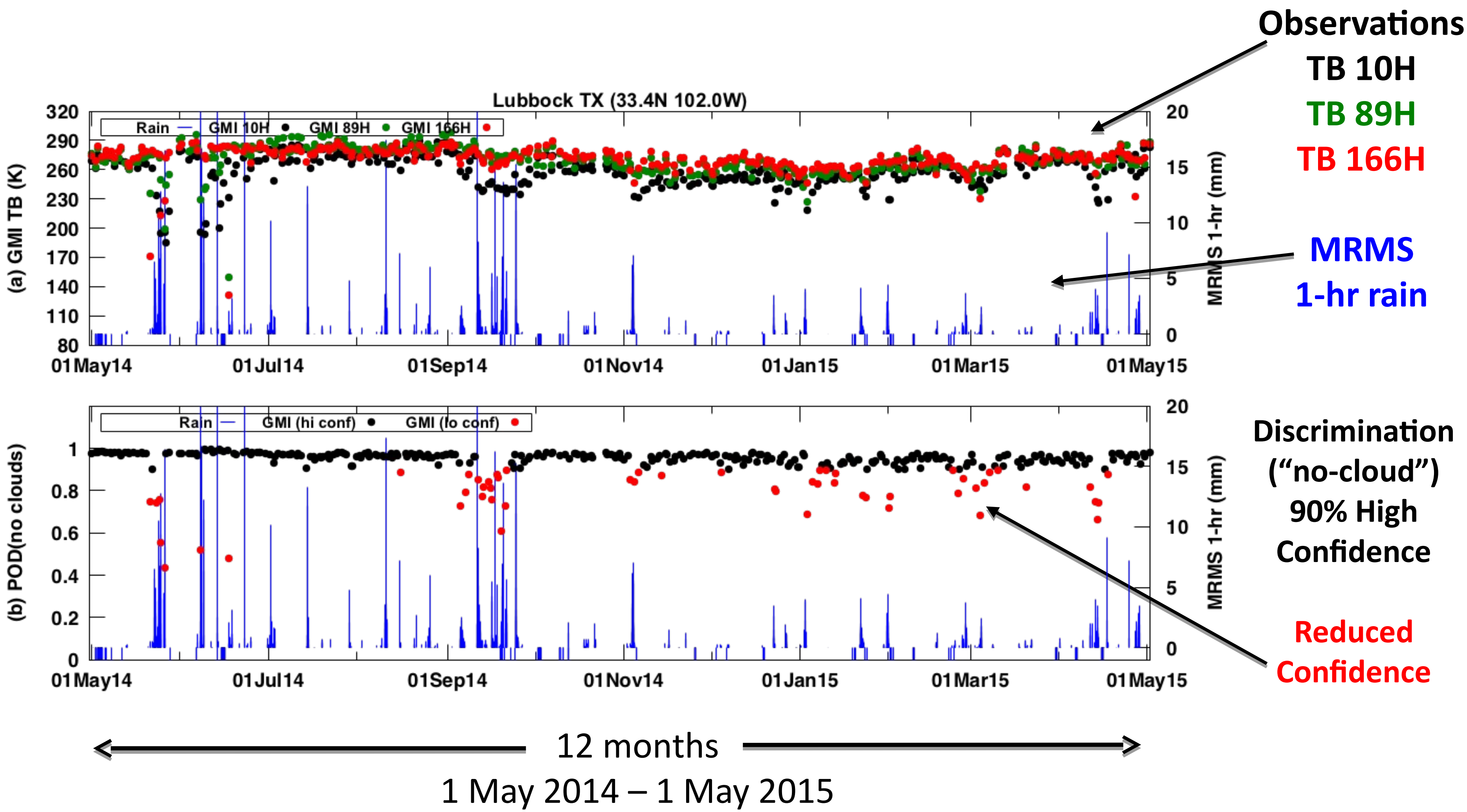
Mid-Latitude, Over-Water, No Coastal/Mixed Pixel Conditions

Rain/Emissivity State Timeseries near a point: S of Pensacola, FL, US

Closed Circles= High Confidence, Open Circles= Reduced Confidence



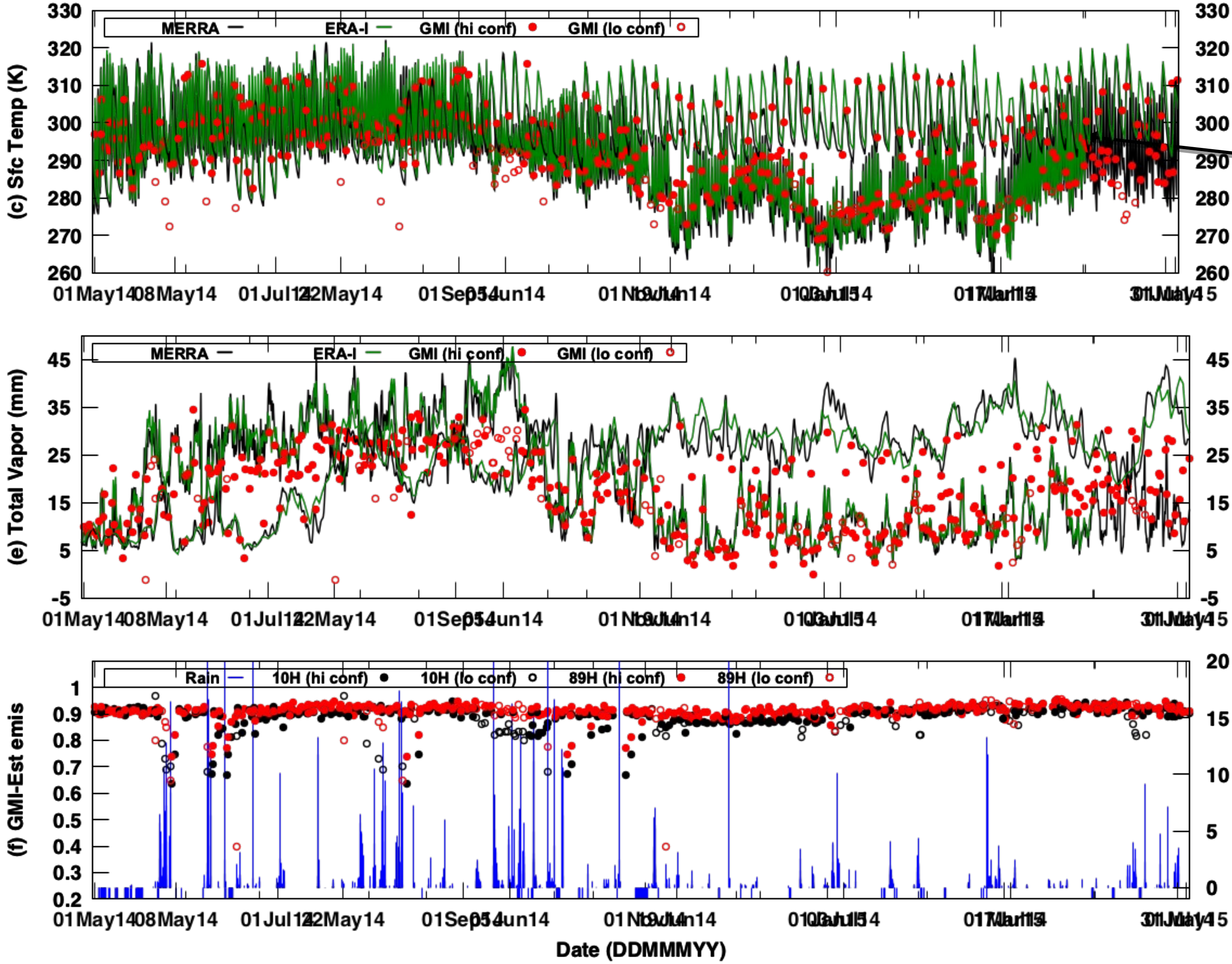
Rain/Emissivity State Timeseries near a point: West of Lubbock, TX, US



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

Rain/Emissivity State Timeseries near a point: West of Lubbock, TX, US

Closed Circles= High Confidence, Open Circles= Reduced Confidence



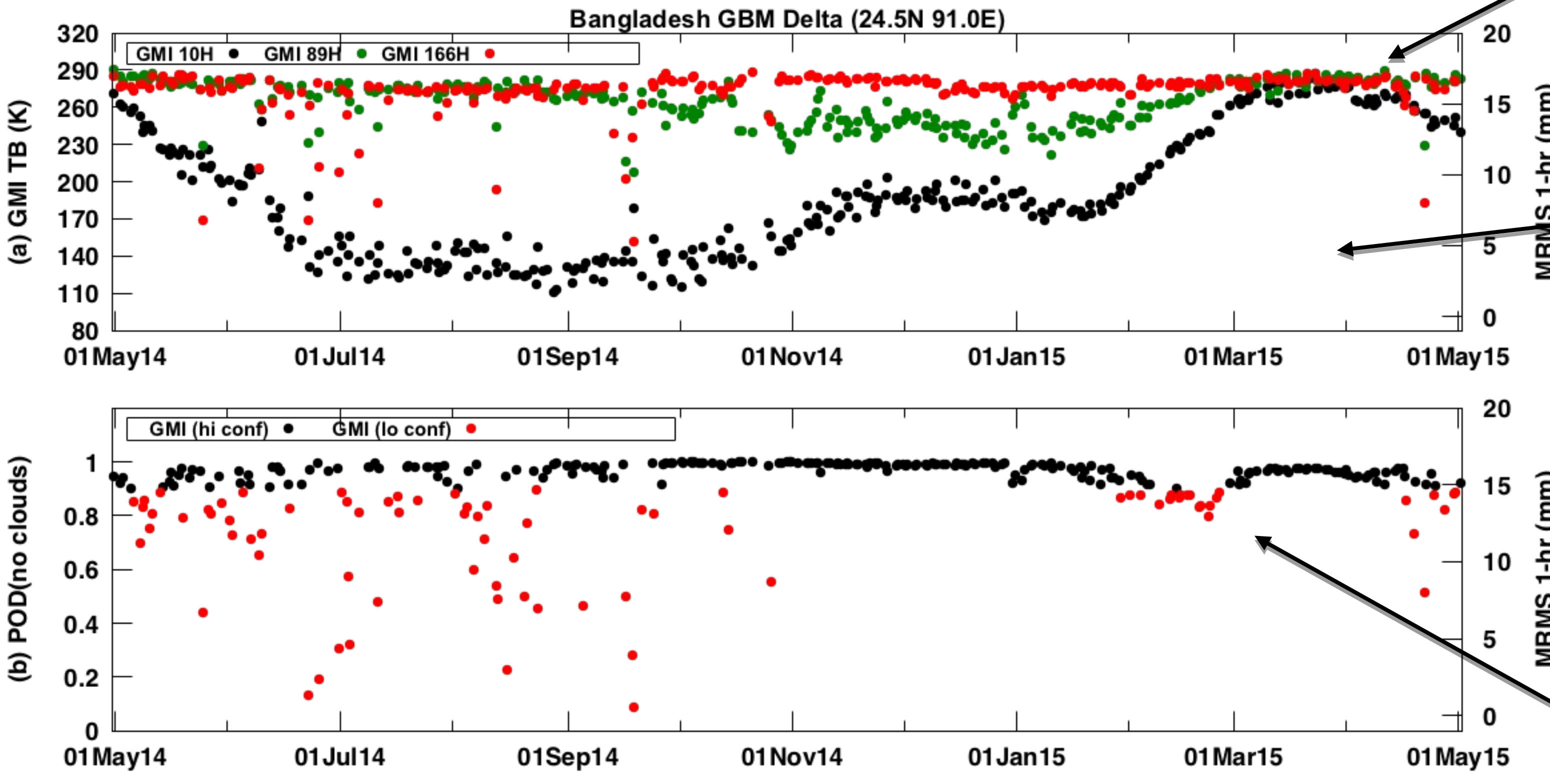
MERRA Ts
ERA-I Ts
Est. Ts

MERRA Tvap
ERA-I Tvap
Est. Tvap

Est. e10H
Est. e89H

MRMS
1-hr rain

Meghna River, Bangladesh, Seasonal Wetland ("Haor")



Observations
TB 10H
TB 89H
TB 166H

MRMS
1-hr rain

Discrimination
("no-cloud")
90% High
Confidence

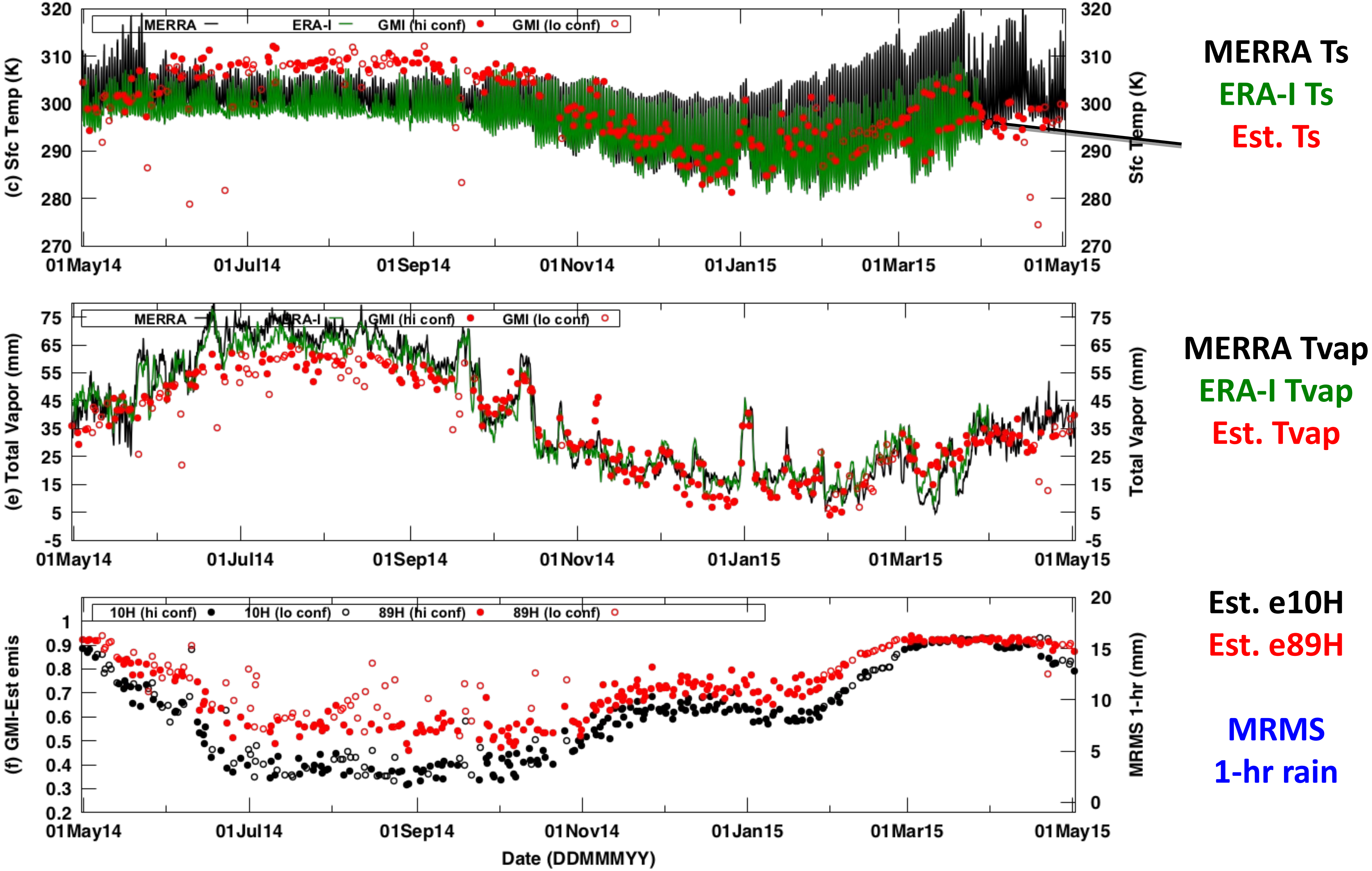
Reduced
Confidence

12 months
1 May 2014 – 1 May 2015

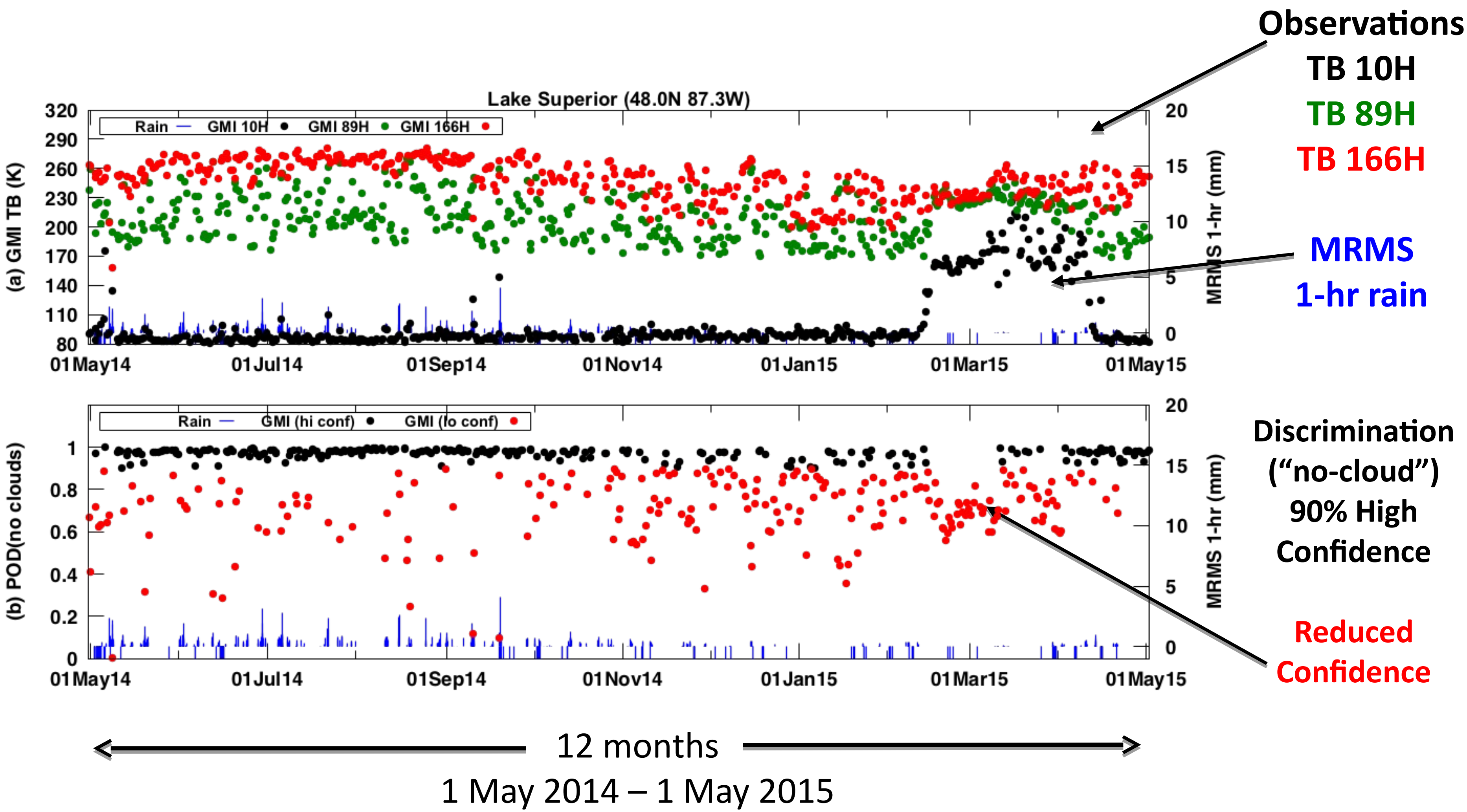
Can also experience rapid emissivity change across inundated areas

Meghna River, Bangladesh, Seasonal Wetland ("Haor")

Closed Circles= High Confidence, Open Circles= Reduced Confidence



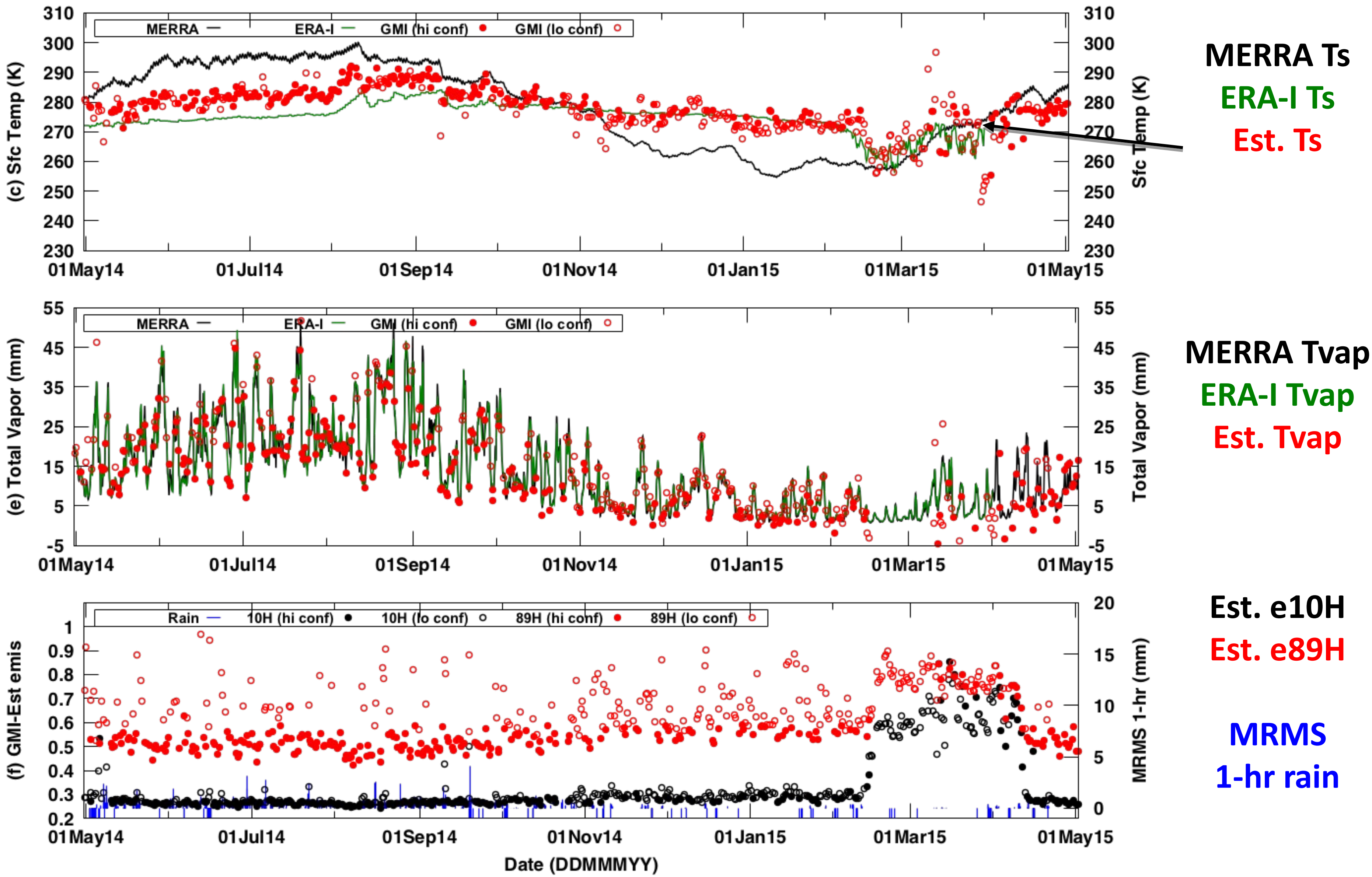
Middle of Lake Superior, US/Canada



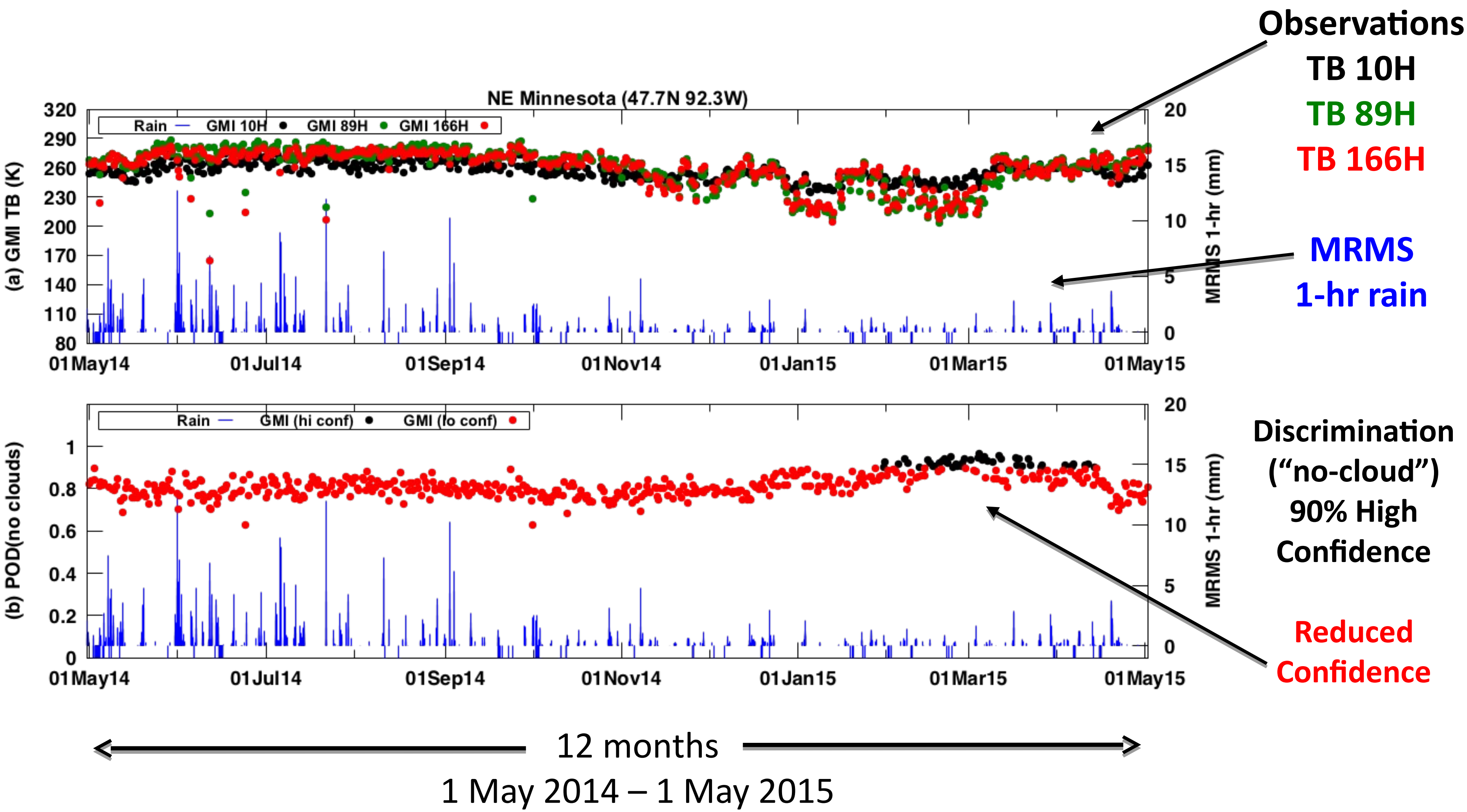
Inland Water Throughout Freeze-Thaw Conditions

Middle of Lake Superior, US/Canada

Closed Circles= High Confidence, Open Circles= Reduced Confidence



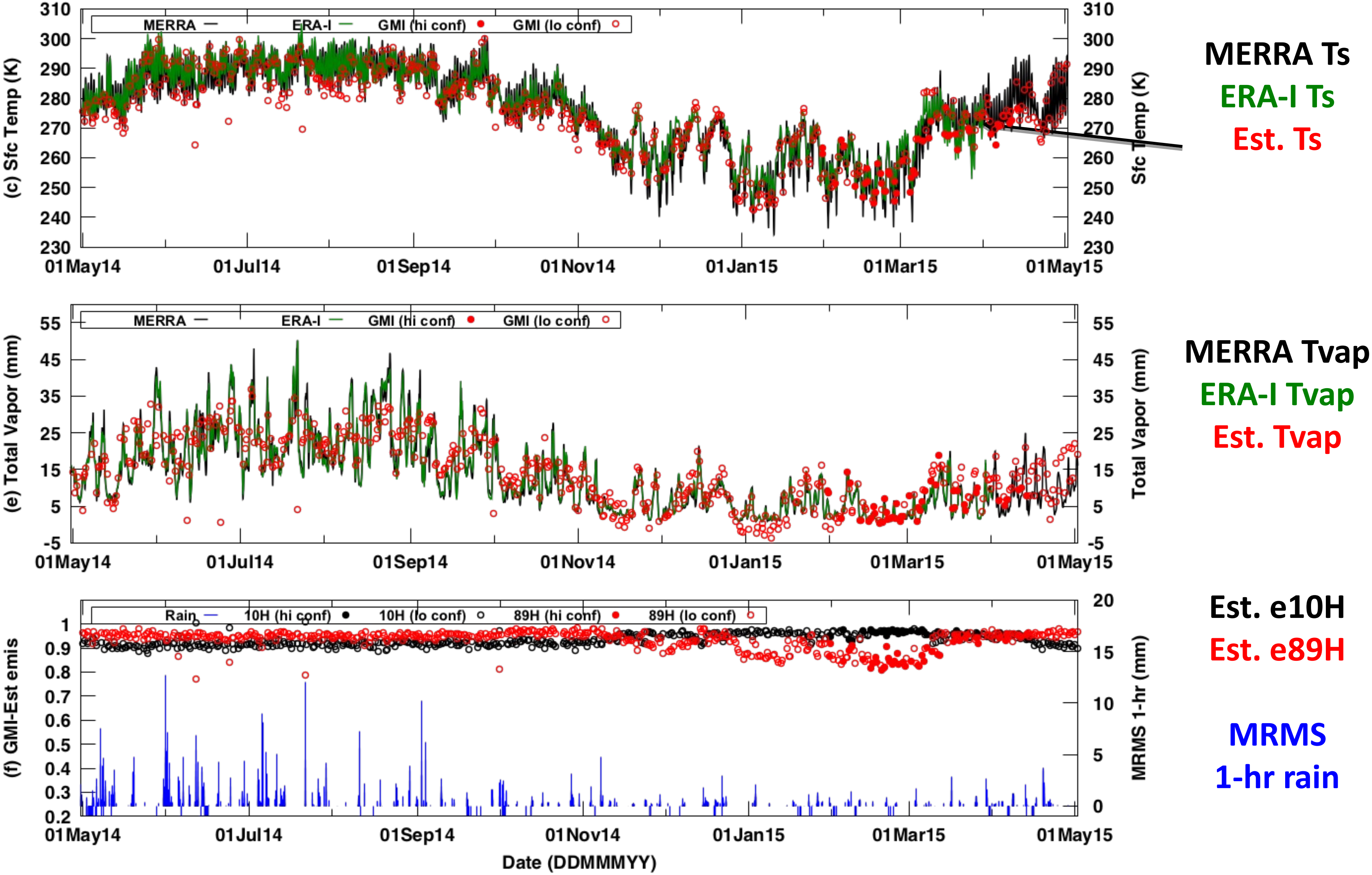
Northern Minnesota Forest, US



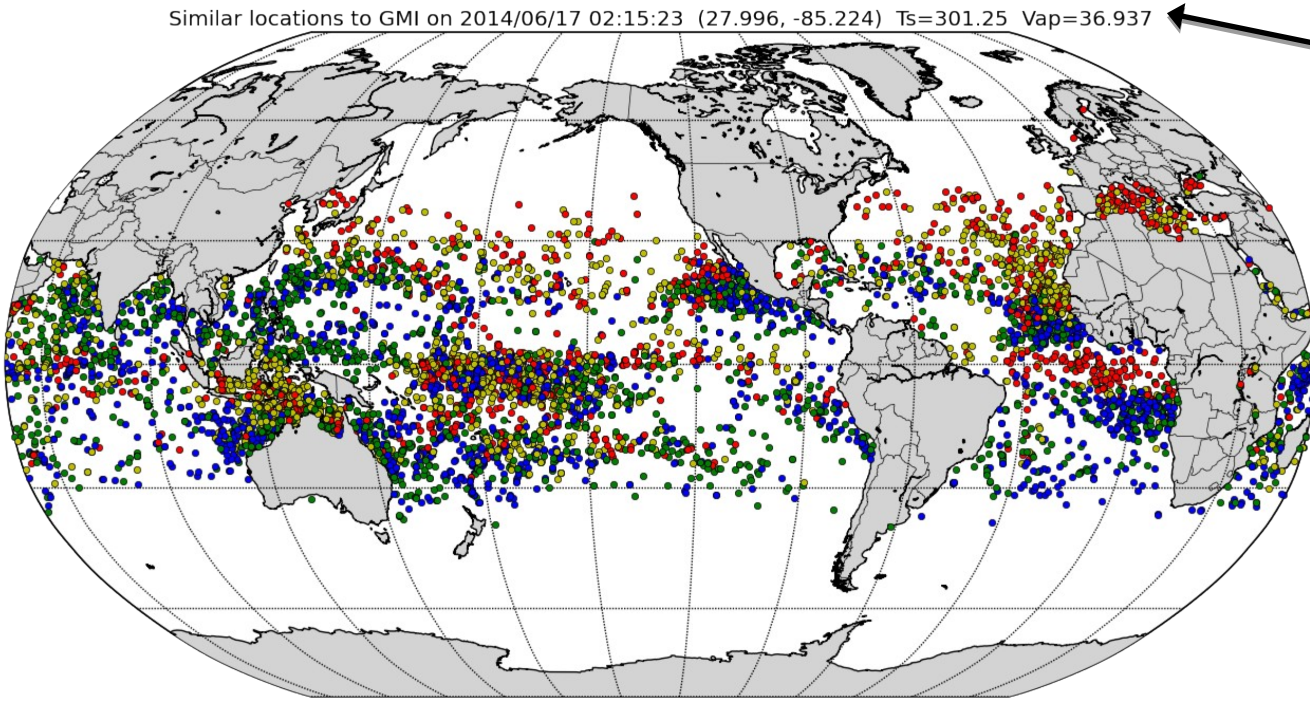
Cold surface, snowcover in cold season

Northern Minnesota Forest, US

Closed Circles= High Confidence, Open Circles= Reduced Confidence



Applicability to Database Search: Example from Over-Ocean Warm SST



Gulf of Mexico
17 June 2014

DJF **MAM**
JJA **SON**

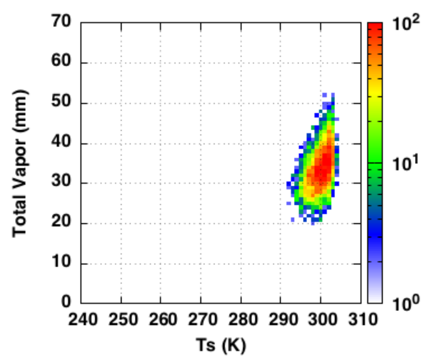
Search for "nearby" entries in leading EOF-space:

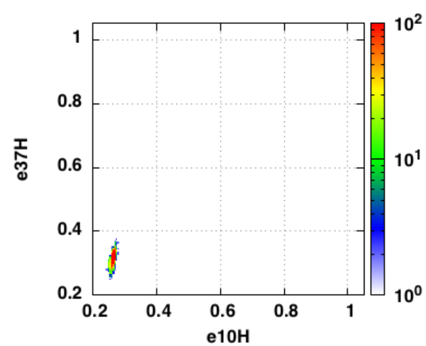
$$r = \sqrt{\frac{1}{N}\sum[(u^{obs} - u_i^{sim})/\sigma_i]^2} \quad N = 3$$

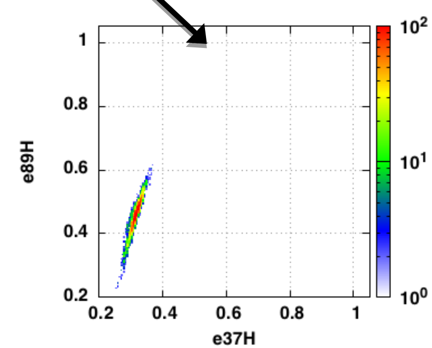
Throughout the process, the only time that latitude/longitude was ever consulted, was to plot the points on the map

Associated co-variability in emissivity

Associated co-variability in Tsfc and WV state variables

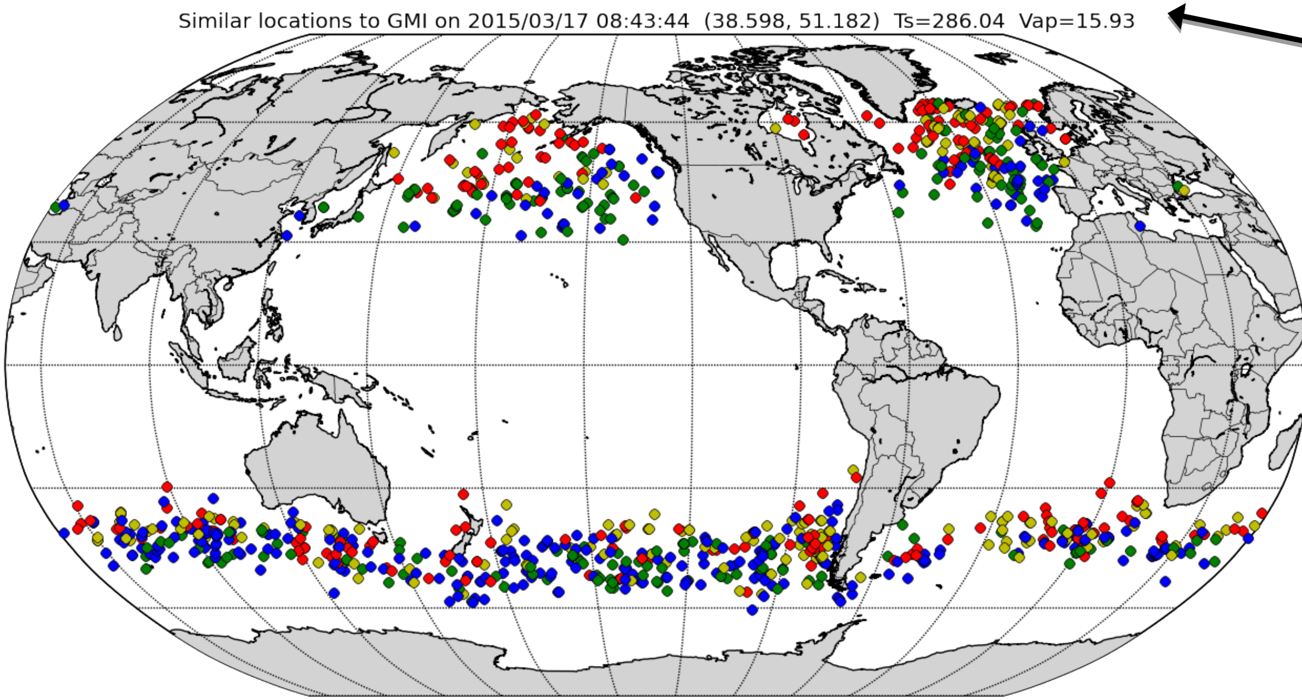






suggests possible alternate ways to index databases (transformation of variables)

Applicability to Database Search: Example from Midlatitude Inland Water



Center of the Caspian Sea 17 March 2015

DJF MAM JJA SON

Search for "nearby" entries in leading EOF-space:

$$r = \sqrt{\frac{1}{N}\sum[(u^{obs} - u_i^{sim})/\sigma_i]^2} \quad N=3$$

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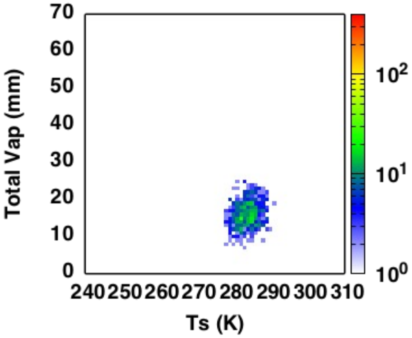
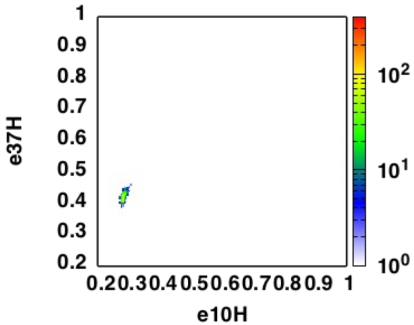
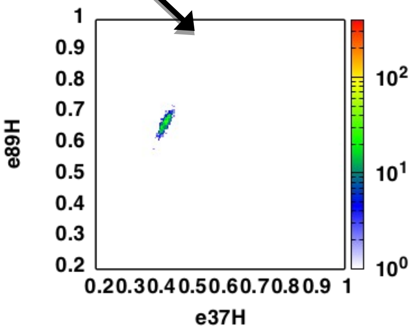
Associated co-variability in Tsfc and WV state variables

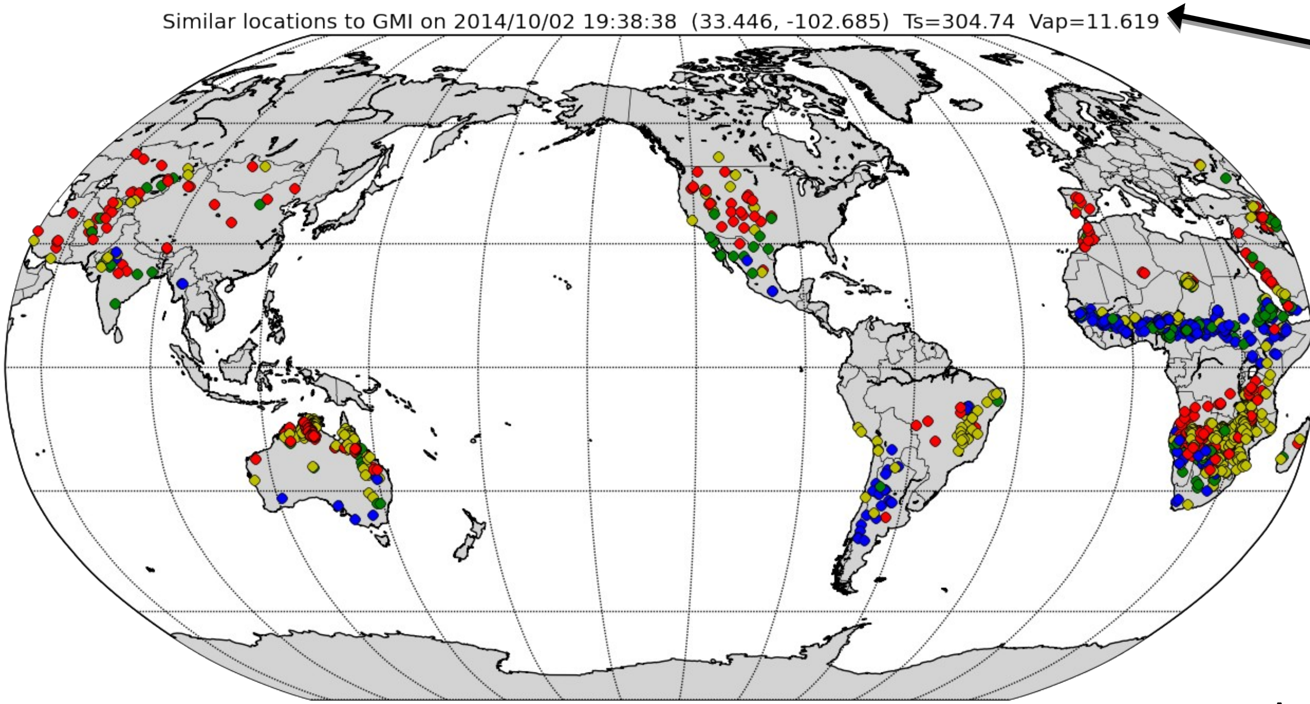






suggests possible alternate ways to index databases (transformation of variables)

Applicability to Database Search: Example from Bare Soil-Like, Daytime



West Texas
2 October
2014

DJF **MAM**
JJA **SON**

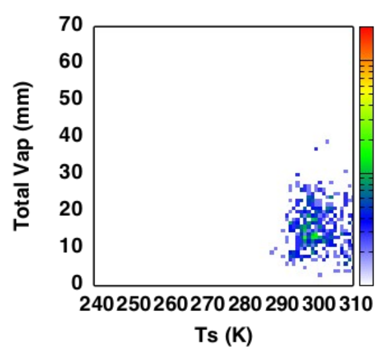
Search for "nearby" entries in leading EOF-space:

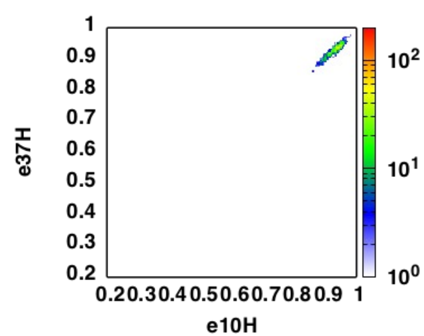
$$r = \sqrt{\frac{1}{N}\sum[(u^{obs} - u_i^{sim})/\sigma_i]^2} \quad N = 3$$

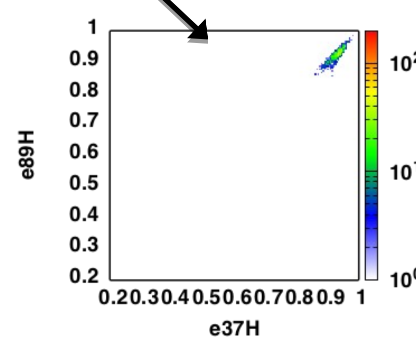
Associated co-variability in emissivity

Throughout the process, the only time that latitude/longitude was ever consulted, was to plot the points on the map

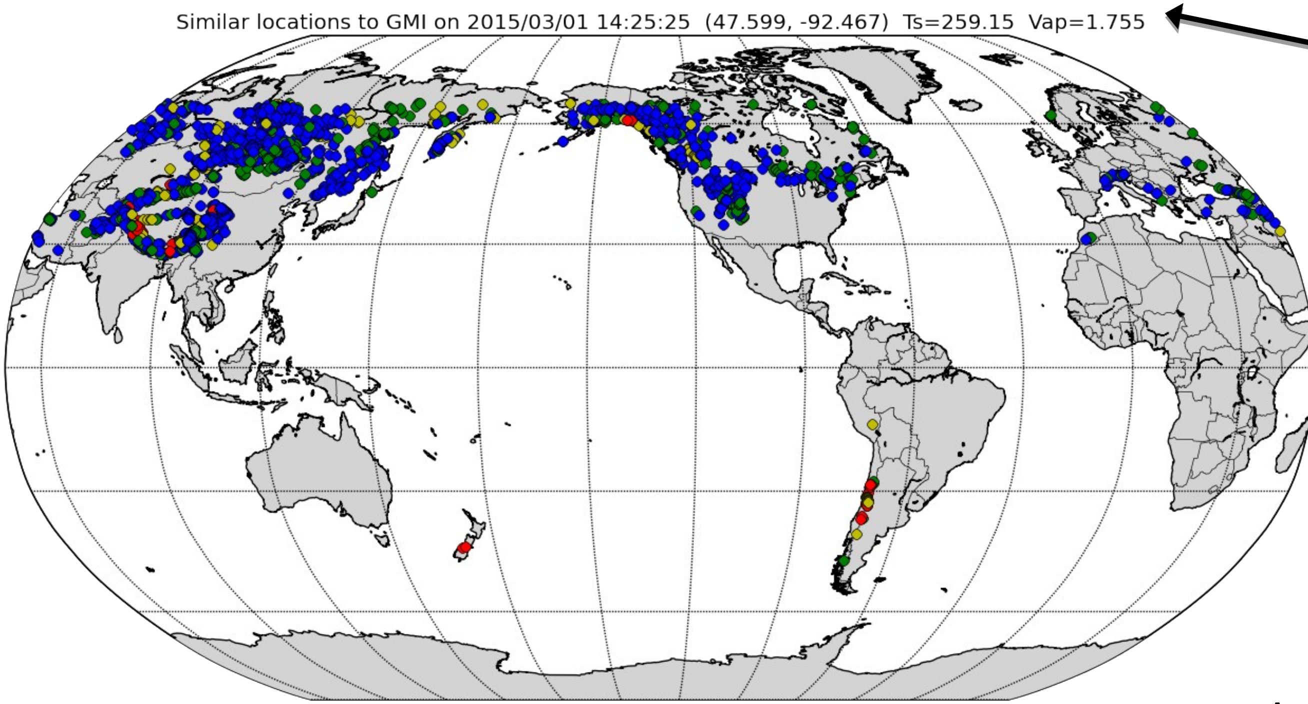
Associated co-variability in Tsfc and WV state variables







Applicability to Database Search: Snow Covered, Cold, Dry



NE Minnesota, snow-covered 1 March 2015

DJF MAM
JJA SON

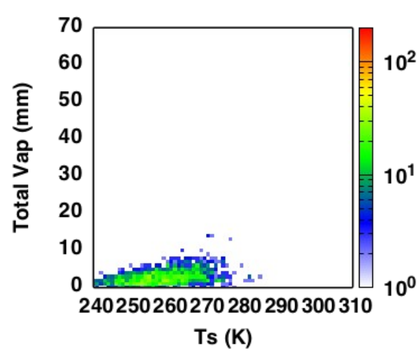
Search for "nearby" entries in leading EOF-space:

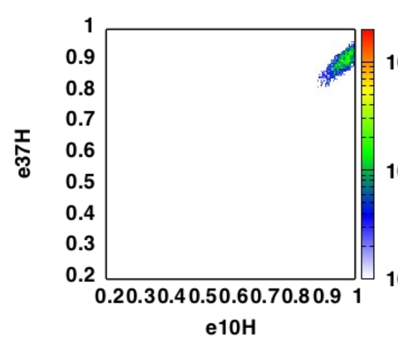
$$r = \sqrt{\frac{1}{N}\sum[(u^{obs} - u_i^{sim})/\sigma_i]^2} \quad N=3$$

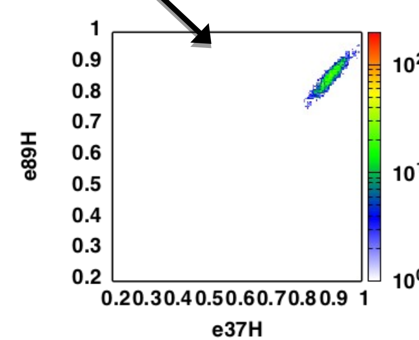
Associated co-variability in emissivity

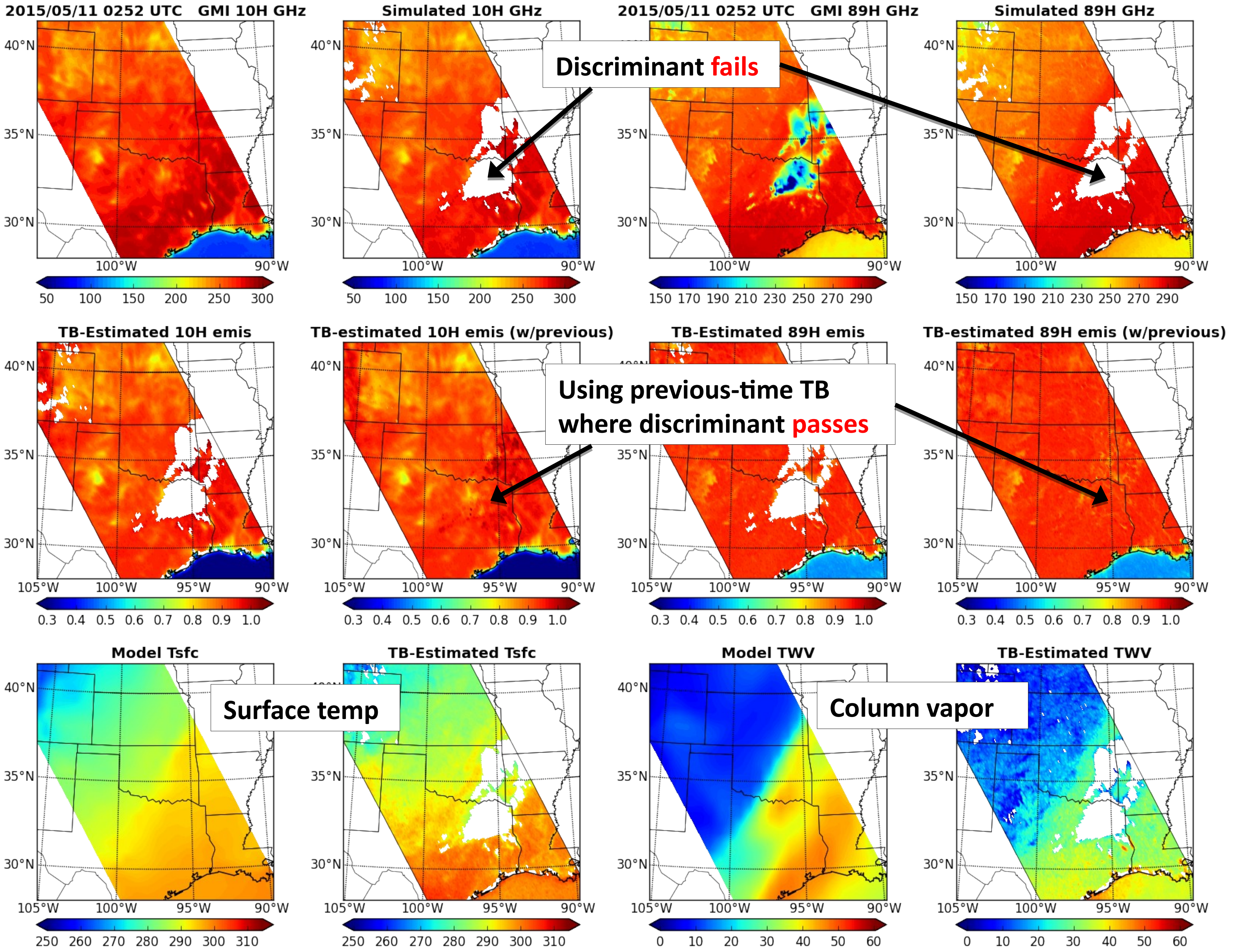
Throughout the process, the only time that latitude/longitude was ever consulted, was to plot the points on the map

Associated co-variability in Tsfc and WV state variables








2015/05/11 0252 UTC GMI 10H GHz
Simulated 10H GHz
2015/05/11 0252 UTC GMI 89H GHz
Simulated 89H GHz
Discriminant fails
TB-Estimated 10H emis
TB-estimated 10H emis (w/previous)
TB-Estimated 89H emis
TB-estimated 89H emis (w/previous)
Using previous-time TB where discriminant passes
Model Tsfc
TB-Estimated Tsfc
Model TWV
TB-Estimated TWV
Surface temp
Column vapor
40°N
35°N
30°N
105°W
100°W
95°W
90°W
50 100 150 200 250 300
150 170 190 210 230 250 270 290
0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
250 260 270 280 290 300 310
0 10 20 30 40 50 60

Current Efforts

Further evaluate emissivity vector formulation for stratifying/searching existing GPM a-priori databases (transformation of variables to different search index space)

Further evaluate utility of 166 GHz channels for cold-season (< 10 mm vapor) precipitation using GPM-CloudSat (W-band) coincidence dataset, , to better guide GPM snowfall and light rain TB simulations

Offline version of GPROF-GPM to test and evaluate use of observationally-based emissivity vector in forward TB radiometer simulations

3-freq (Ku/Ka/W-band) Advanced Precipitation Radar (APR-3) data and MW radiometer during OLYMPEx (Nov-Dec 2015)