Integrated Hydrologic/Radiometric Validation to Improve Physical Precipitation Retrievals for GPM

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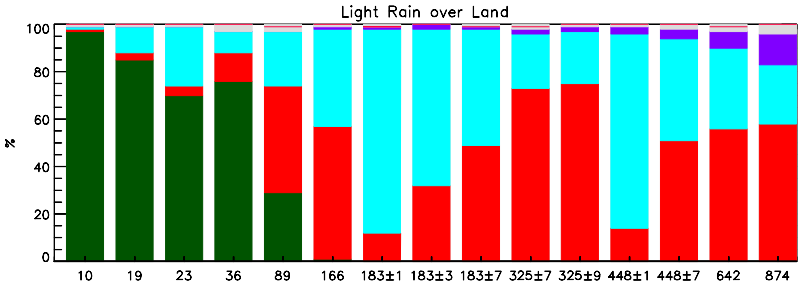
Motivation:
Contribution of Land Surface to Tb

Light Rain



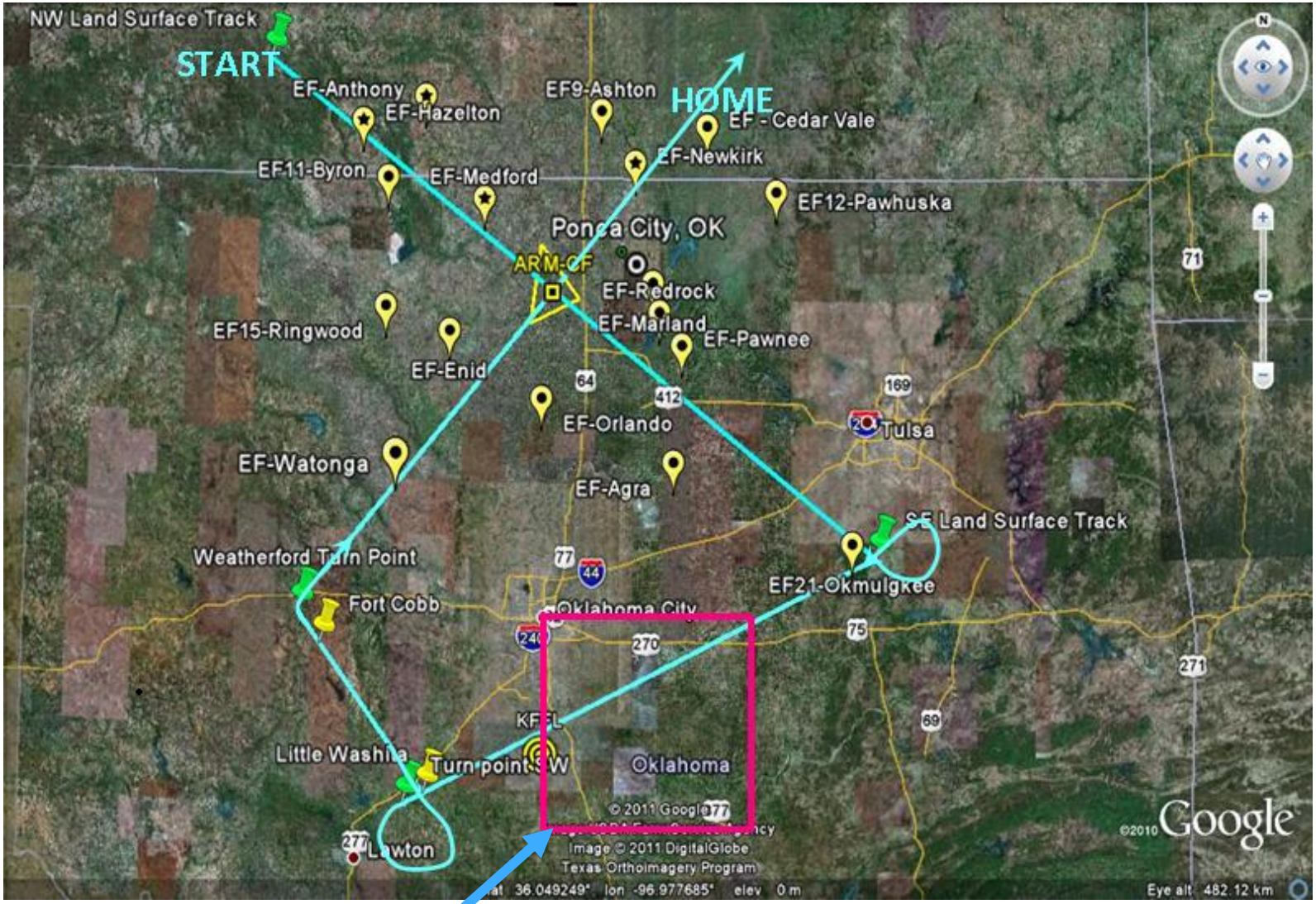
GPROF 2014 Retrieval Roadmap

- S0 – Surface-blind channels
- S1 – A-priori emissivity classes
- S2 – Physical emissivity models

Surface
Hydrometeors
Relative humidity
Cloud water + cloud ice + cosmic background (~1%)
Atmospheric oxygen and nitrogen

Courtesy: G. Skofronick Jackson and B. Johnson, JGR, 2010

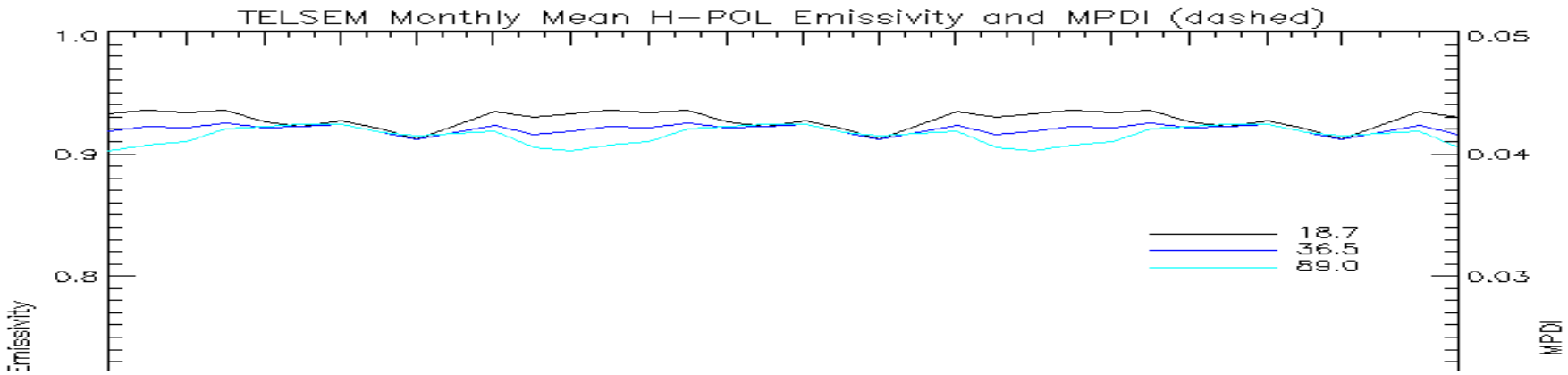
Integrated Validation Location: SGP/MC3E Site

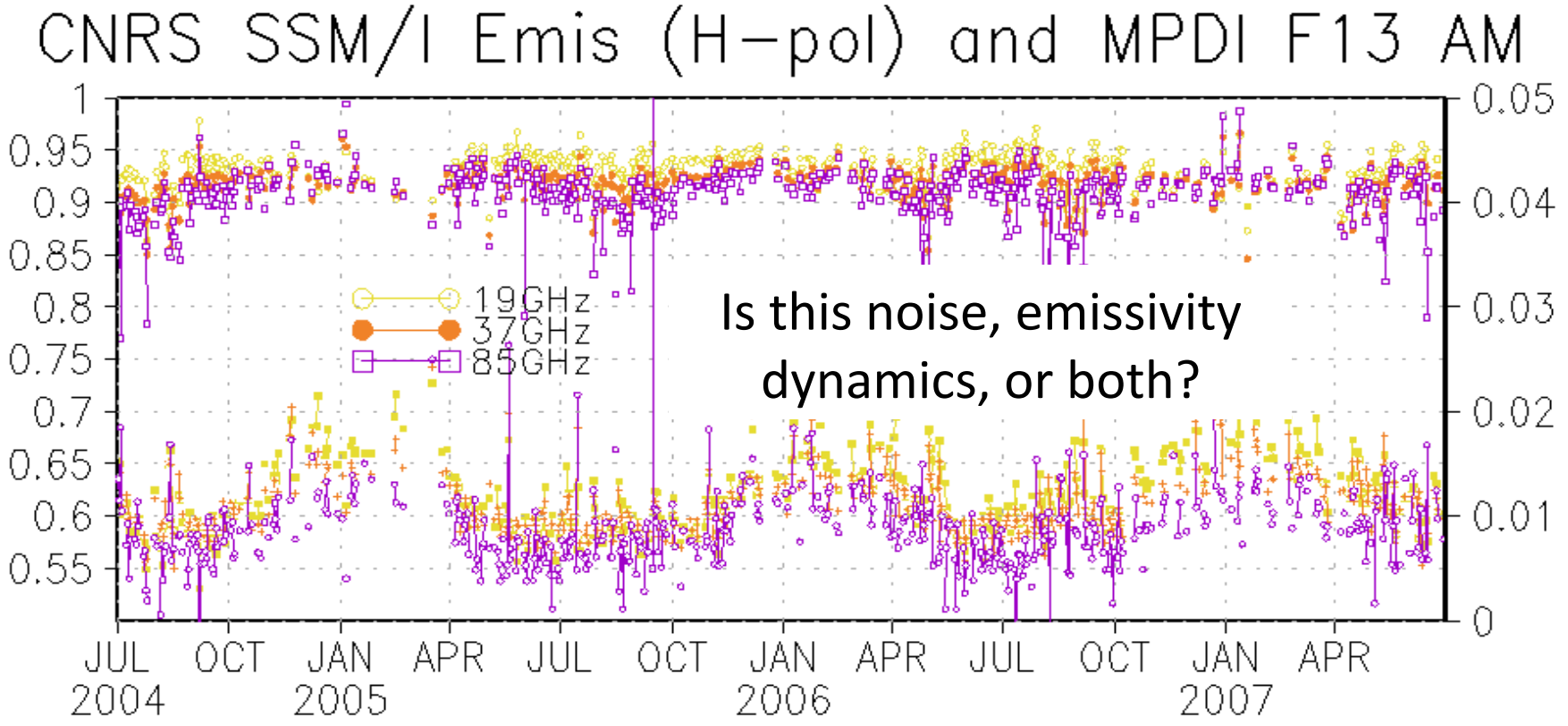


TELSEM/LIS/RTM Modeling Domain (1x1-deg, May 8, 2011 Dedicated LSM Flight)

(Image Courtesy W. Petersen)

S1 Approach: TELSEM (from SSM/I)

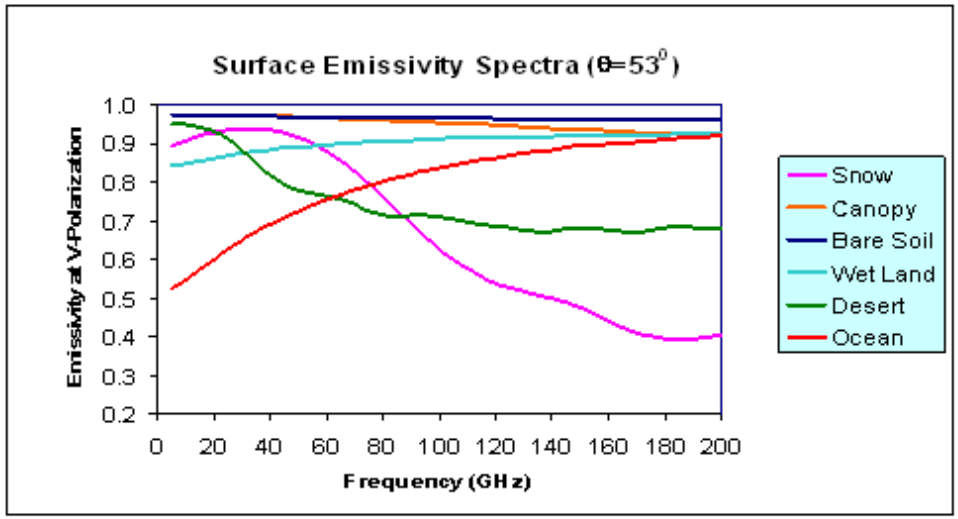


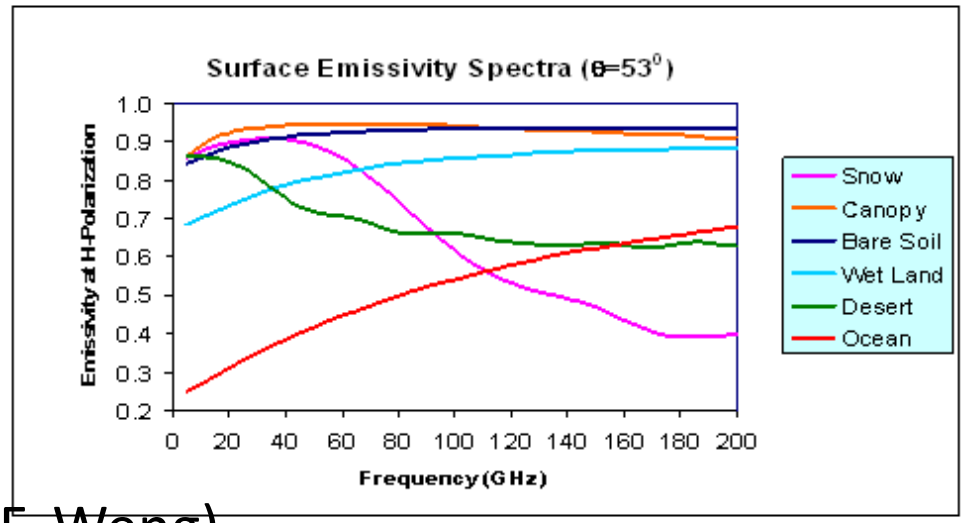


S2 Approach: Emissivity Spectra and Models in CRTM2

- **Open water** – two-scale roughness theory
- **Sea ice** – Coherent reflection
- **Canopy** – Four layer clustering scattering
- **Bare soil** – Coherent reflection and surface roughness
- **Snow/desert** – Dense media theory

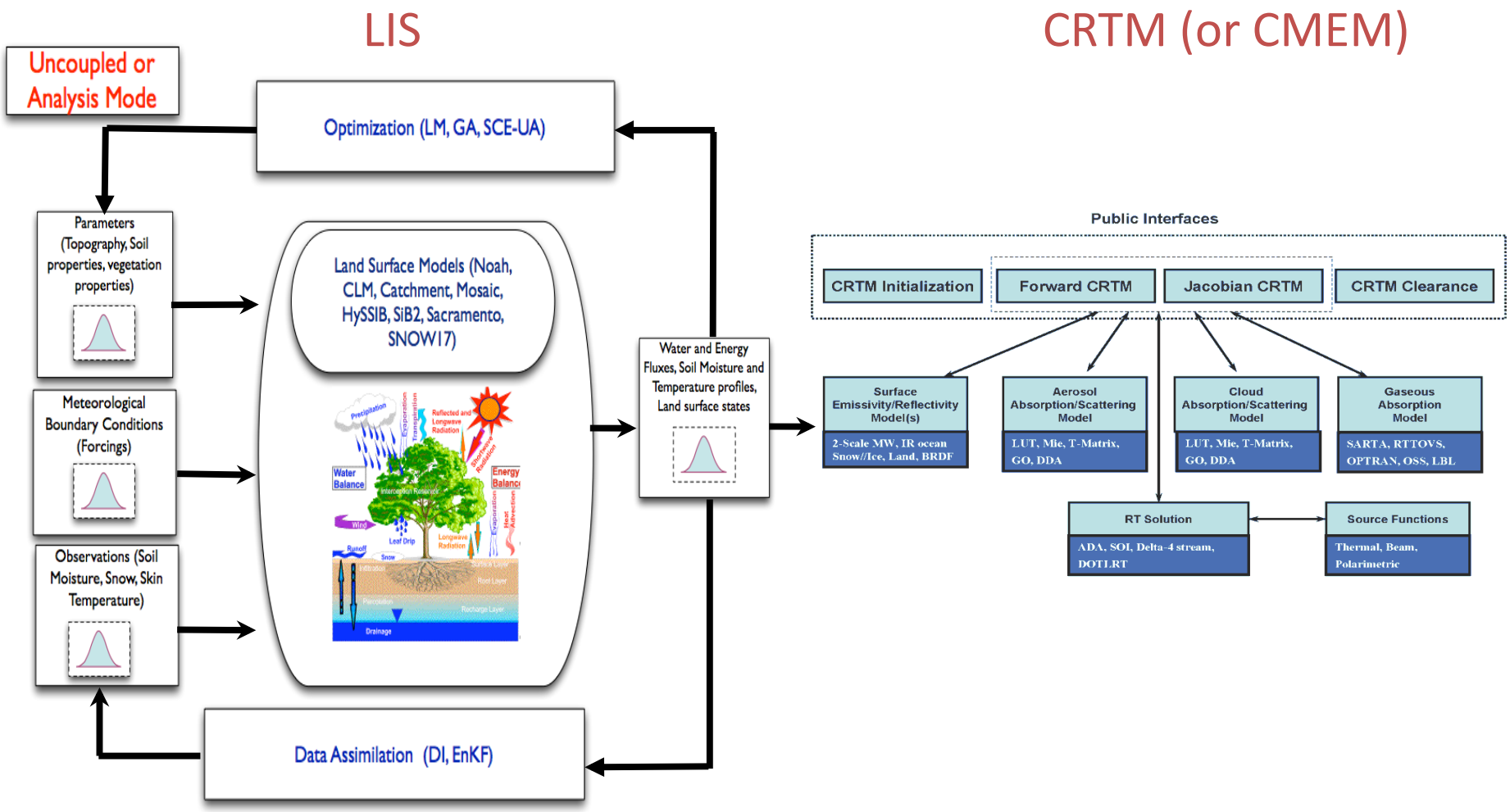
Weng et al (2001, JGR)





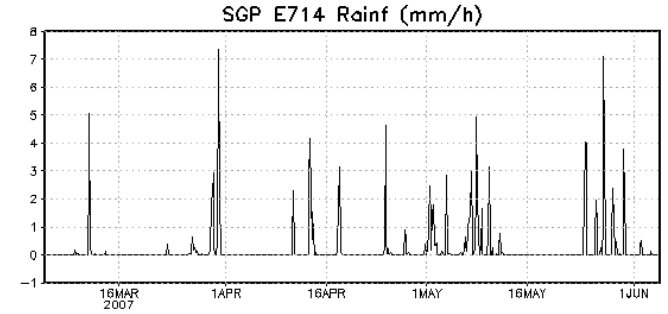
(Slide courtesy F. Weng)

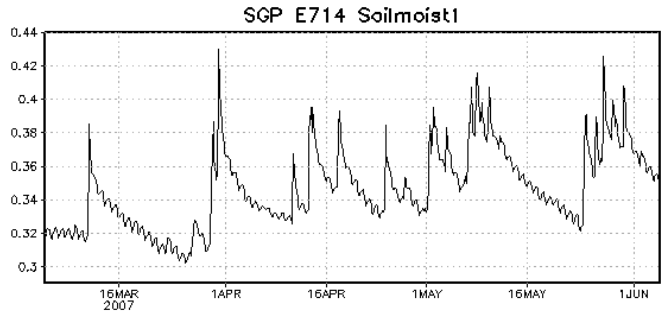
S2 Approach: LIS-RTM Forward Modeling

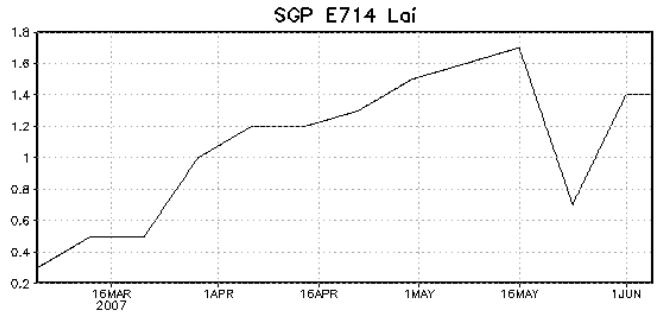


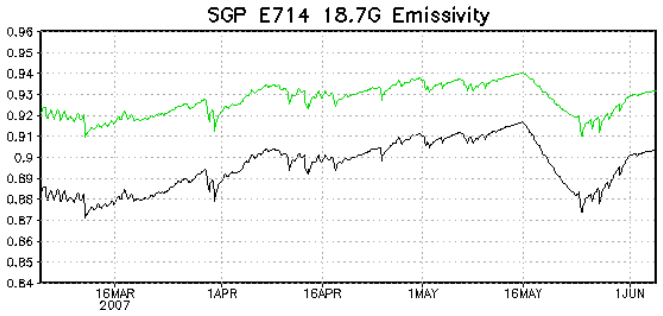
S2 Results: LIS-CRTM2 Input and Emissivity Output for Seasonal Dynamics:

SGP
1 Mar-5 Jun 2007



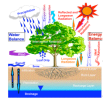






V-pol
H-pol

NLDAS2 Rainfall



Noah LSM Soil moisture

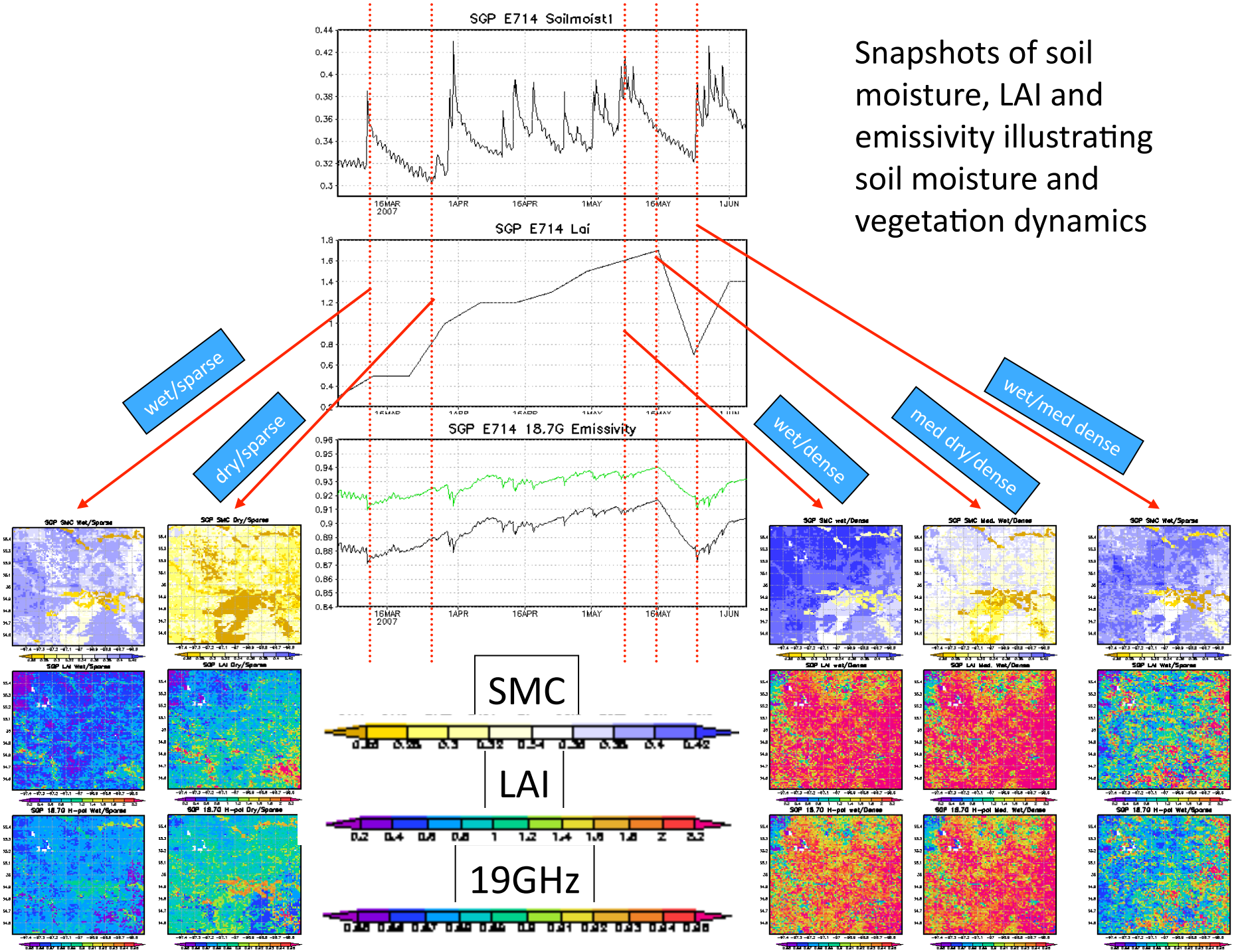
+

MODIS Vegetation

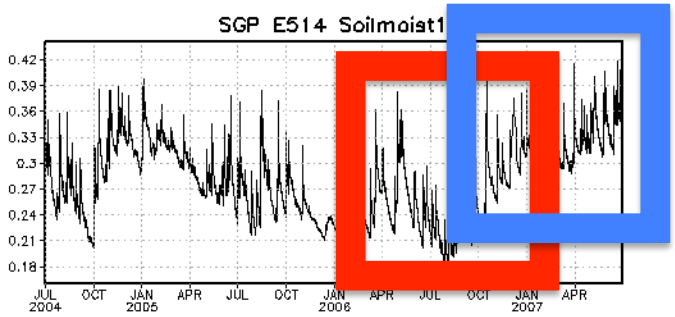
=

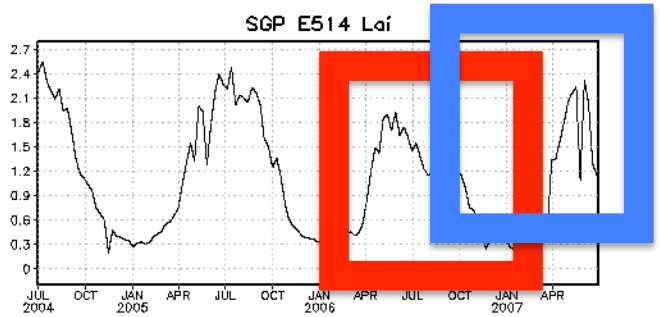
CRTM2 Emissivity

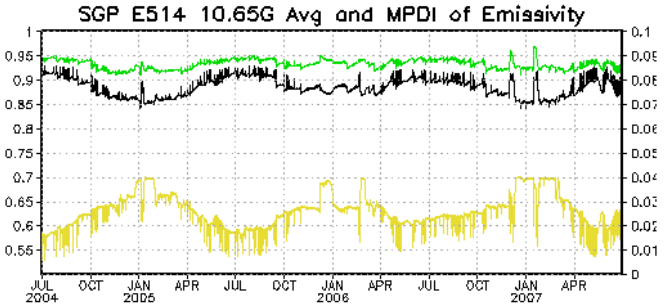
Snapshots of soil moisture, LAI and emissivity illustrating soil moisture and vegetation dynamics

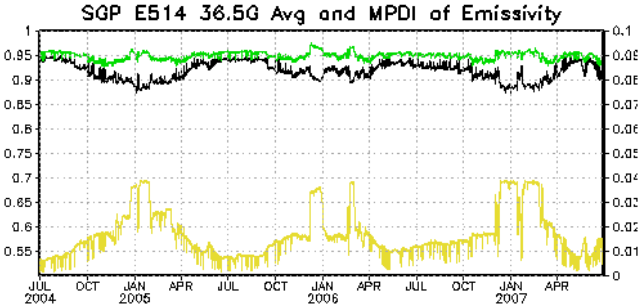


S2 Results: LIS-CRTM2 Input and Emissivity Output for Interannual Dynamics: SGP; 1 Jul 2004-1 Jul 2007





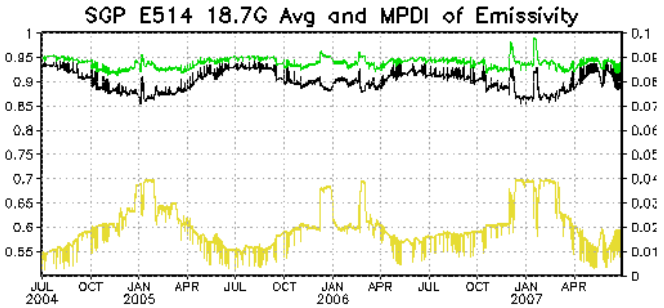


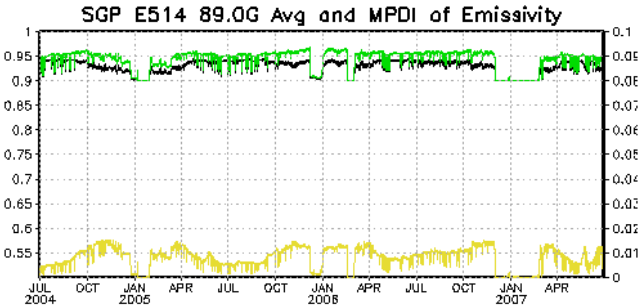


V-pol

H-pol

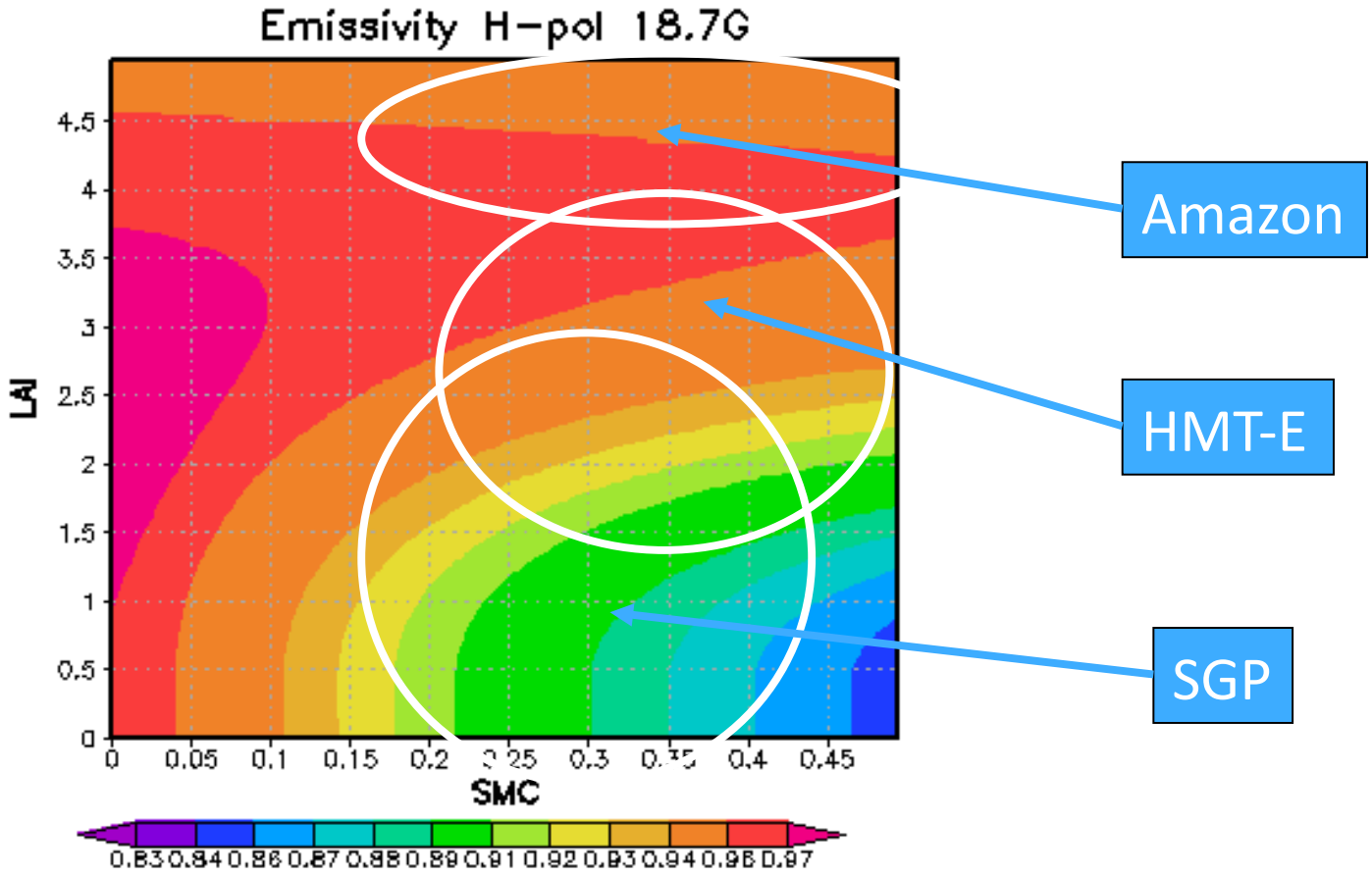
MPDI





S2 Database and Clustering: Soil moisture/LAI "regime diagram".

- Different locations/climate regimes correspond to different areas in the diagram.
- Self-similar land classes can be defined as those areas with same regime diagrams

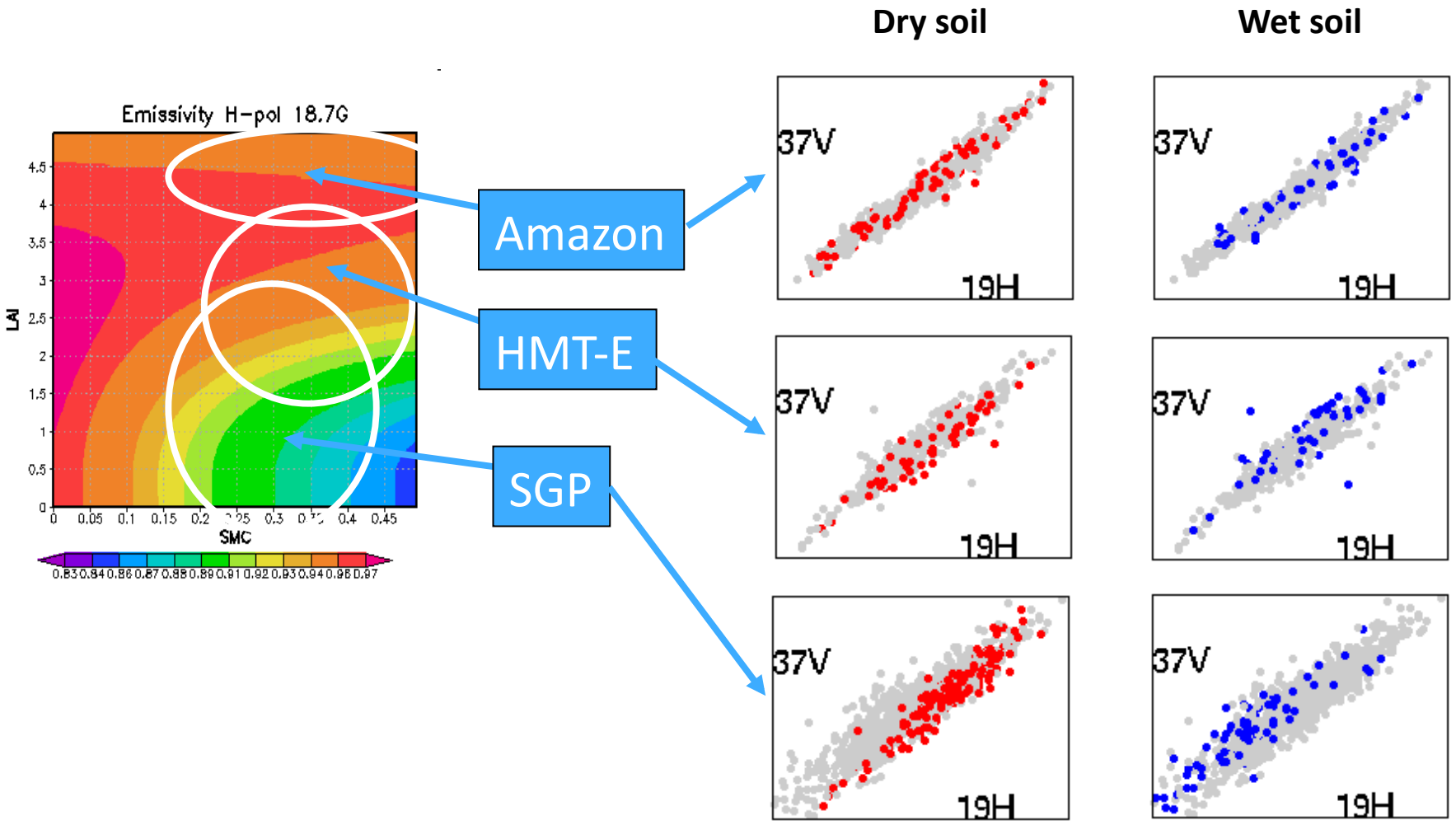


Regime diagram from off-line CRTM2

SMC: soil moisture content LAI: leaf area index

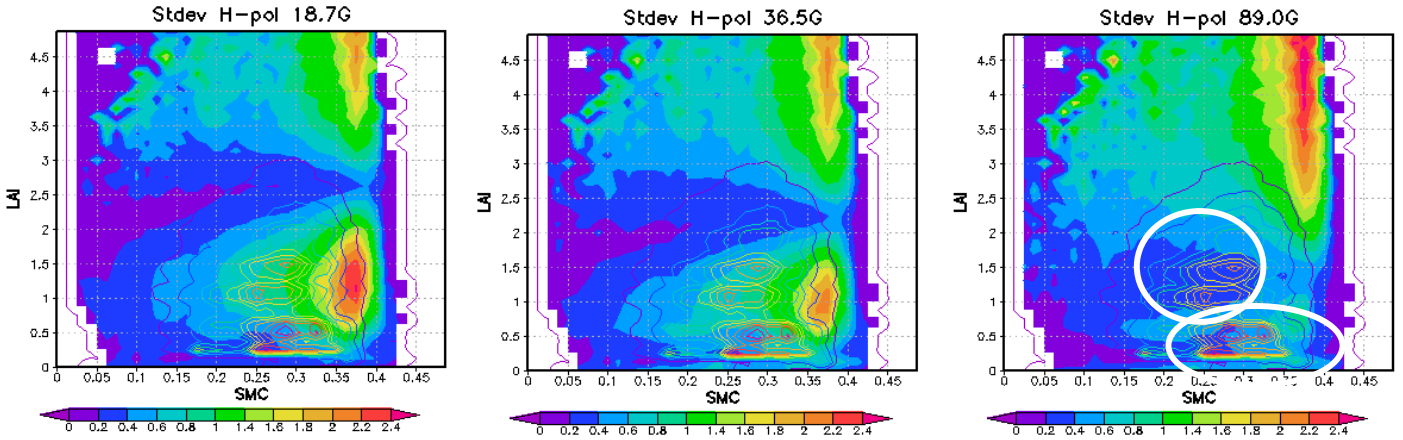
S2 Database and Clustering : Channel covariance also depends on the location of data in the SMC-LAI regime

High/low LAI -> low/high SMC sensitivity

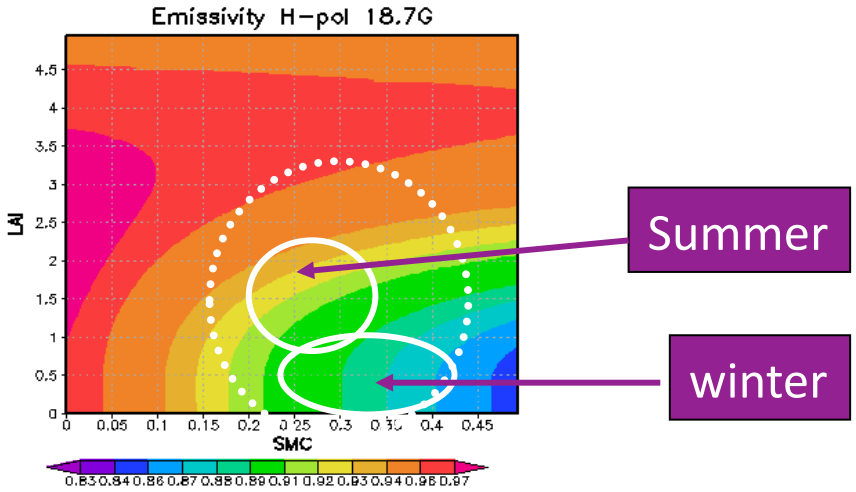


S2 Dynamic Modeling: SMC-LAI vs. Emissivity Variance

Standard deviation of on-line LIS/CRTM2 runs over SGP, 2004-2007, 1x1-km. Contour lines show the number of data points.

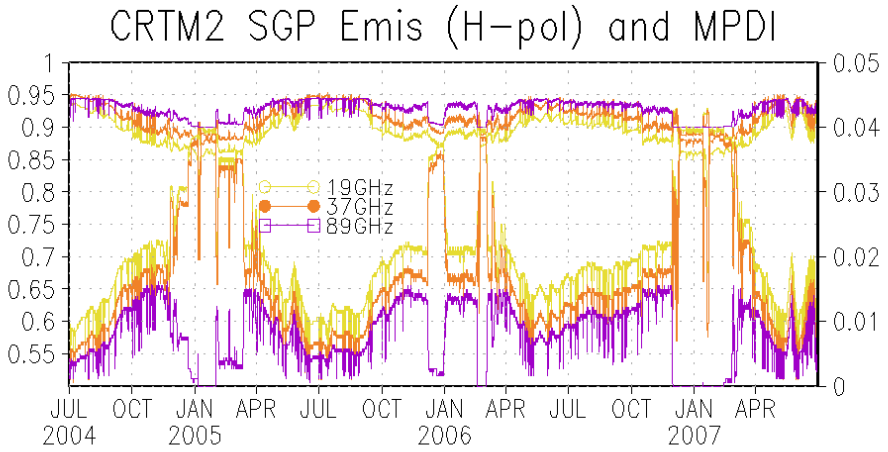


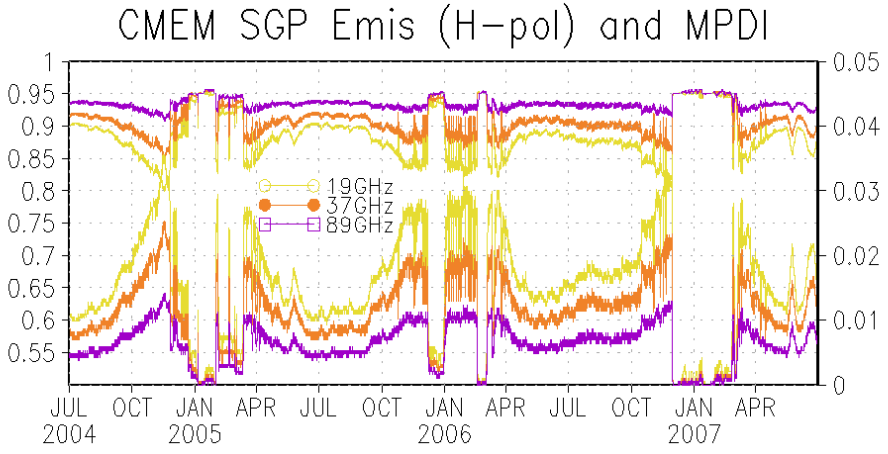
At SGP, seasonal clustering is also visible in the regime diagram



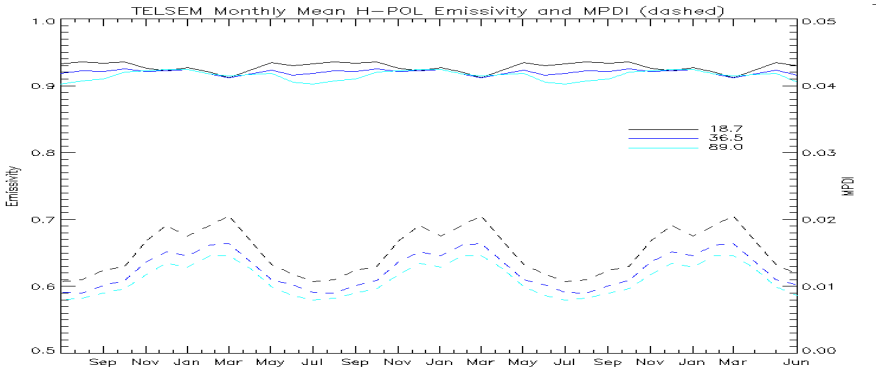
S2 vs. S1: LIS-CRTM2 and LIS-CMEM vs. TELSEM and CNRS:SGP; 1 Jul 2004-1 Jul 2007

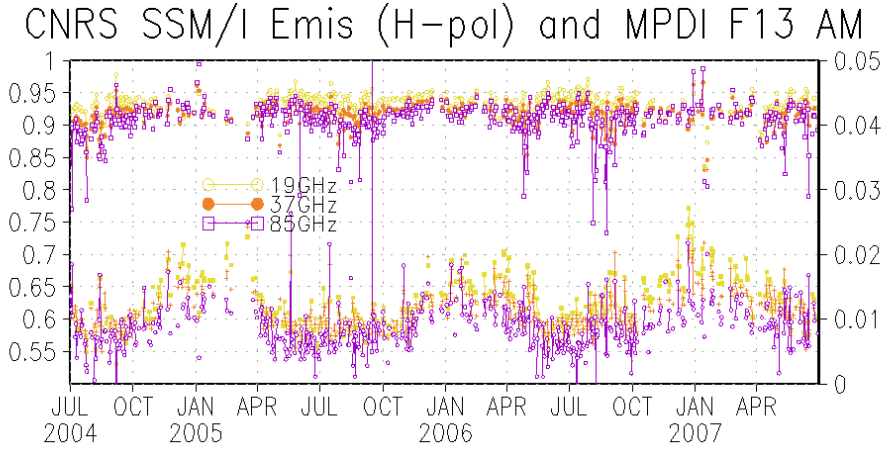
S2:LIS-RTM-modeled





S1: Satellite data





Summary

- The integrated LIS/RTM framework can be calibrated to “best clear air climatologies” to generate dynamic radiometric signatures.

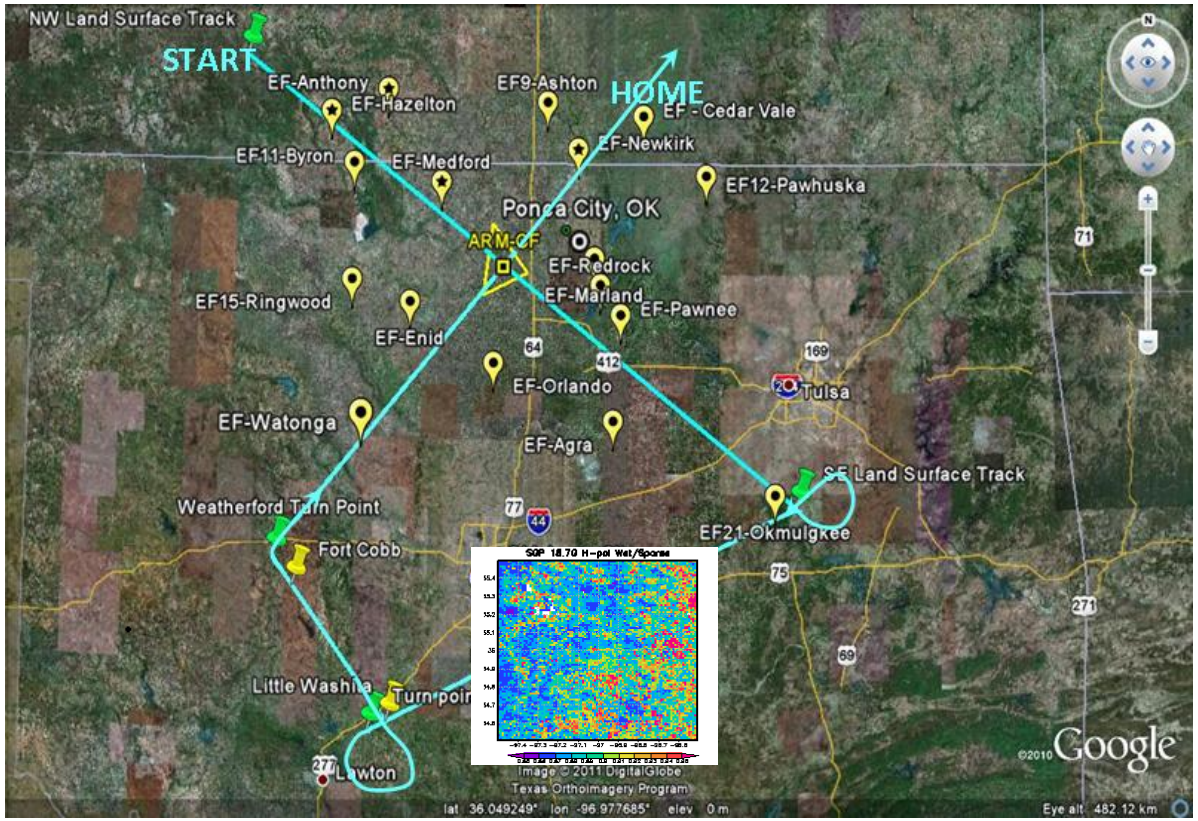
- Our modeling studies suggest that SMC-LAI combined can serve as a good predictor for the dynamics of land surface emissivity.

- The SMC-LAI regime diagram gives us a unified paradigm to understand the nonlinear interplay of soil and vegetation, and gives insight into the variance and co-variance of emissivity.

- More reference data are needed to verify, validate and calibrate model results. Discrepancies among S2 and S1 approach and reference datasets need to be resolved.

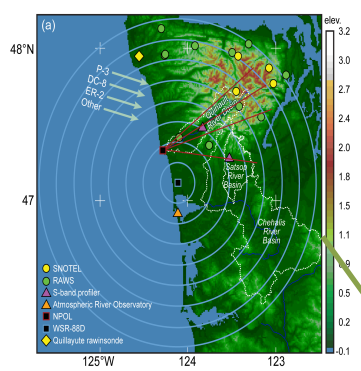
LSWG Meeting: 6;30-7:30 Tonight
Red Rover
Agenda: Strategy to support/unify S1/S2

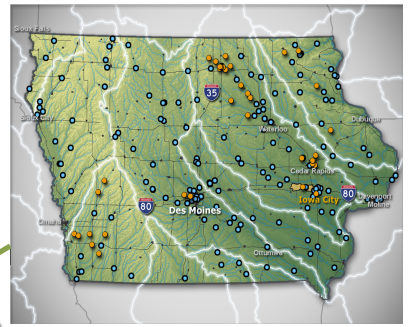
- Integrated Hydrologic/Radiometric validation is needed to support S2 approach. MC3E first "clear air" collection with soil moisture flights.

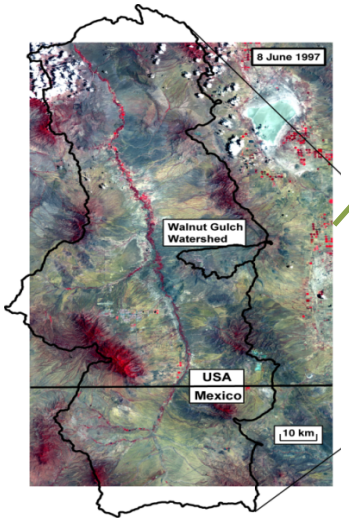


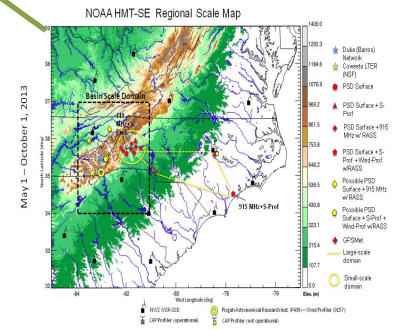
Hydrology WG Meeting: 6-7 Tonight Hopscotch

Agenda: Integrated Hydro-GV Testbeds







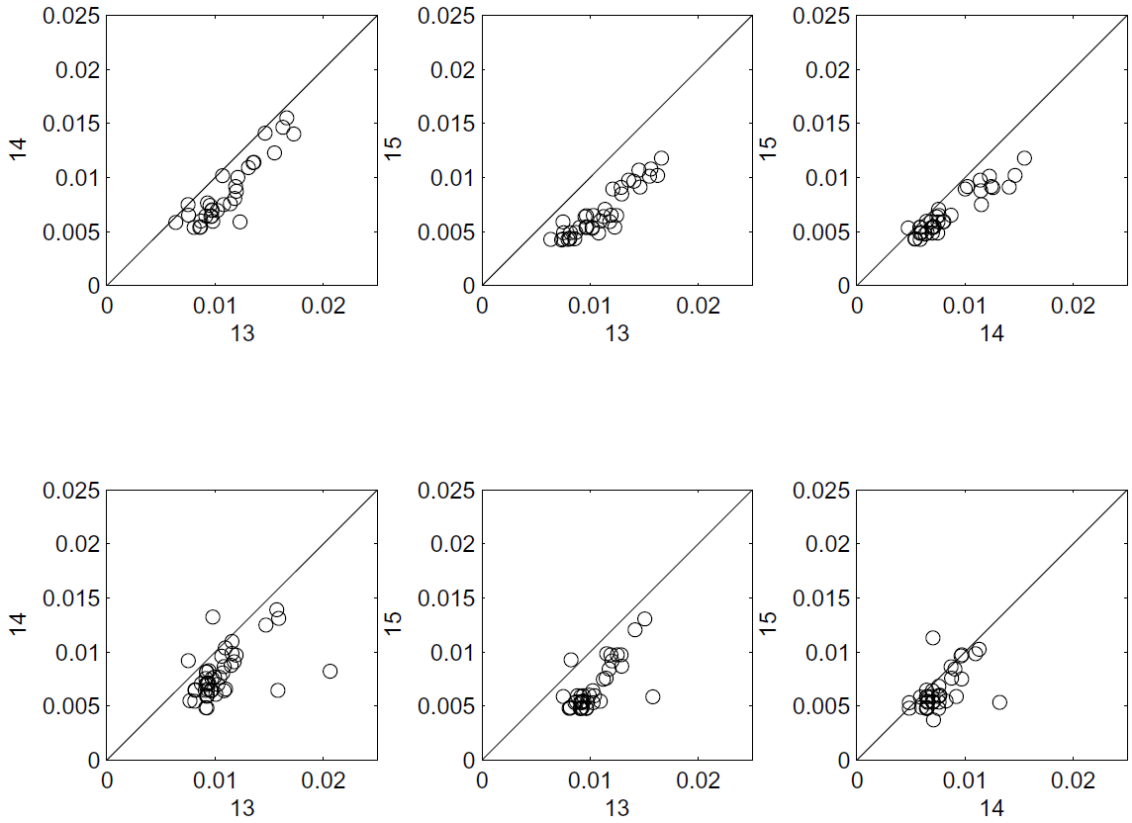


Backup slides

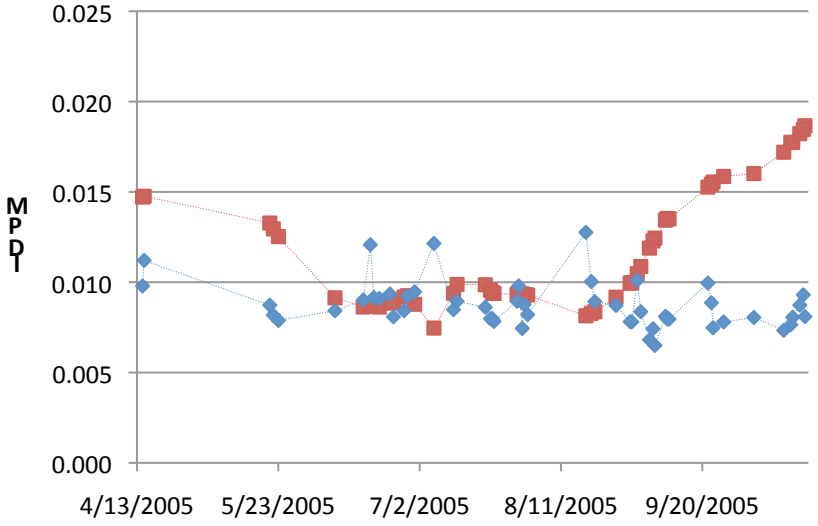
Validation, calibration and error analysis:

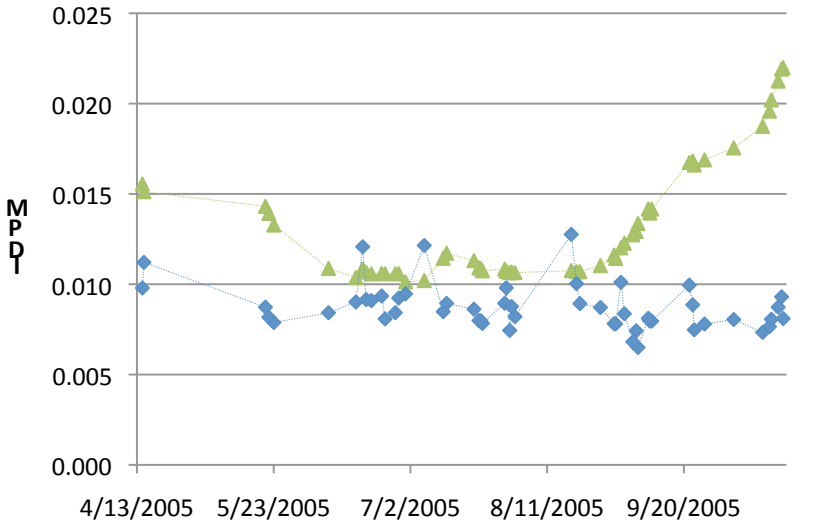
-- considerable uncertainties and the small number of data points in reference data hinder model validation and calibration.

Inter-comparison of SSM/I 37G emissivity MPDI over SGP, after additional cloud screening



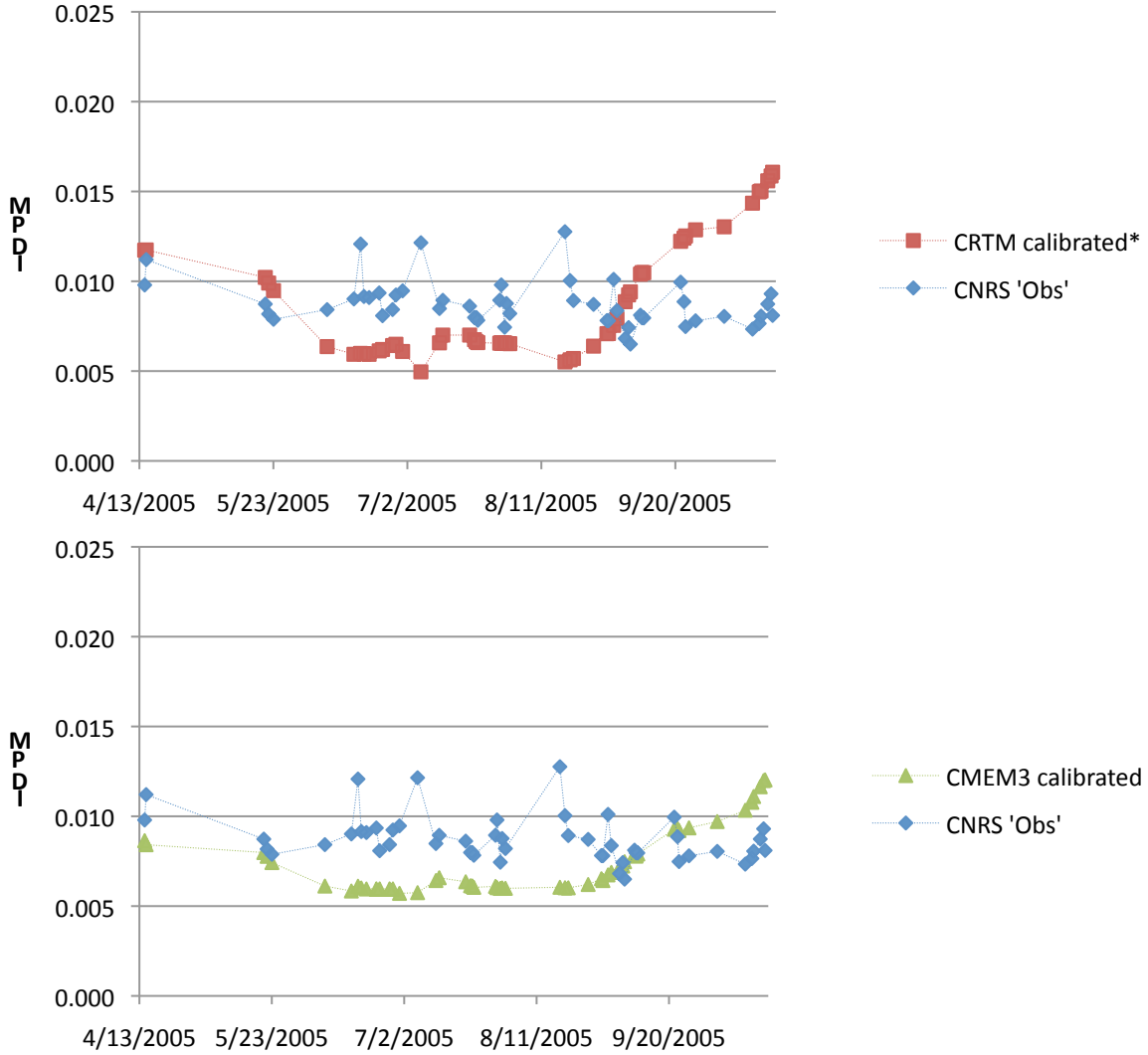
Un-calibrated forward models





- 19 GHz MPDI shown
- MPDI shown as sensitive to land surface and avoids T_s problems
- CRTM and CMEM behavior is very similar. Not surprising as they largely draw from same reported relationships
- CNRS retrievals were conservatively cloud-screened #obs-weighted avg. of at least 2 of {F13,F14, F15}, with min. total 15 obs
- Both match well the high-LAI summer
- Both significantly overestimate in Spring and Fall; but poor inputs (e.g,. Noah soil moisture, MODIS LAI) cannot be ruled out.
- The CNRS retrievals seem immune to the decrease in LAI and soil moisture drydown in September/October.
- Eventually a few higher MDPI retrievals do appear in late Fall/Winter but conservative cloud and snow masks avoid this period.

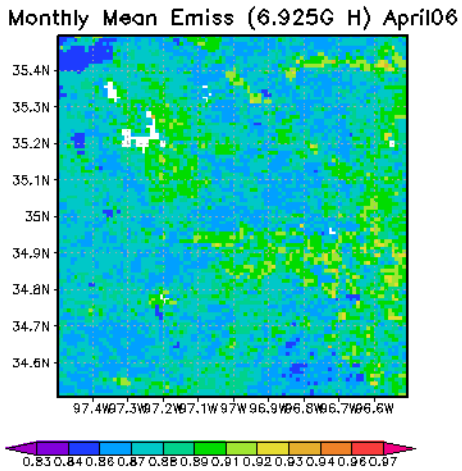
Calibrated forward models

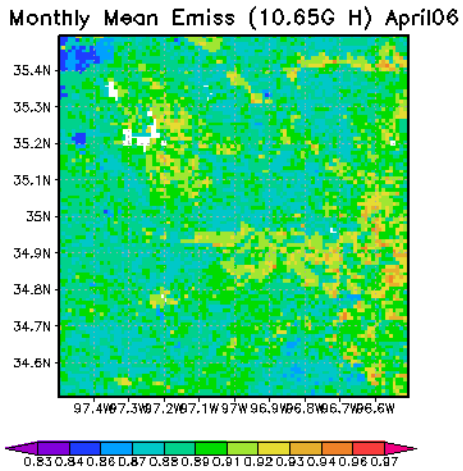


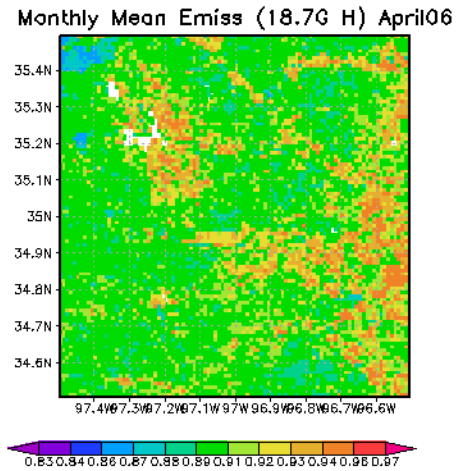
- Both were calibrated to the CNRS obs with a genetic algorithm (GA) to minimize RMSE
- The parameters calibrated varied as CRTM and CMEM make different decisions on inputs and mappings to equation variables. Surface roughness, ratio of vegetative water content to LAI, and leaf diameter were common to both.
- For both CRTM and CMEM, the calibration process increased the surface roughness to decrease the Spring/Fall MPDI. (Vegetative parameter values were modified but these were modest by comparison to roughness.)
- But this is achieved by sacrificing the good summer match
- Understanding the divergence in the models and retrievals, and relation to LAI/soil moisture is critical to improving the modeling
- Separate calibration of these periods may partially resolve the problem. This would allow, for example, different roughness values in different seasons.

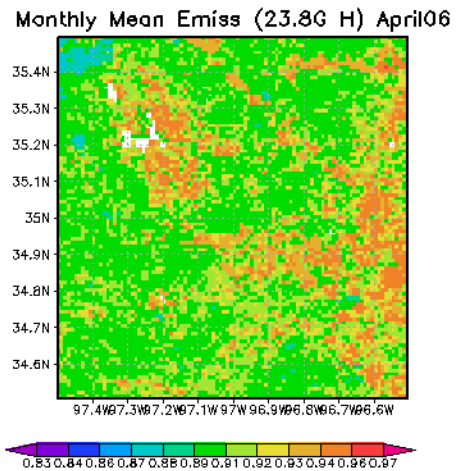
Example: Monthly mean emissivity produced by LIS/CRTM2 at SGP

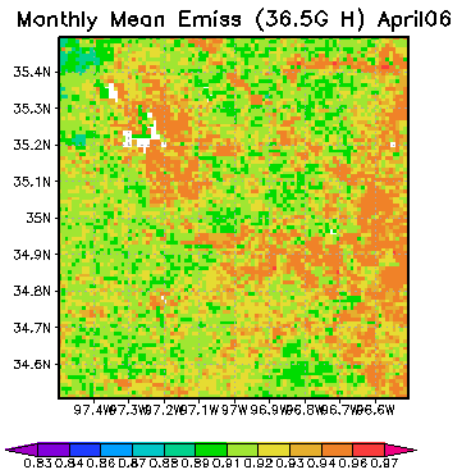
(AMSR-E frequencies, 1x1-km resolution)

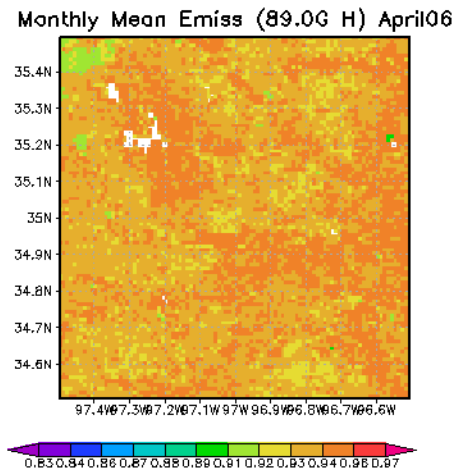






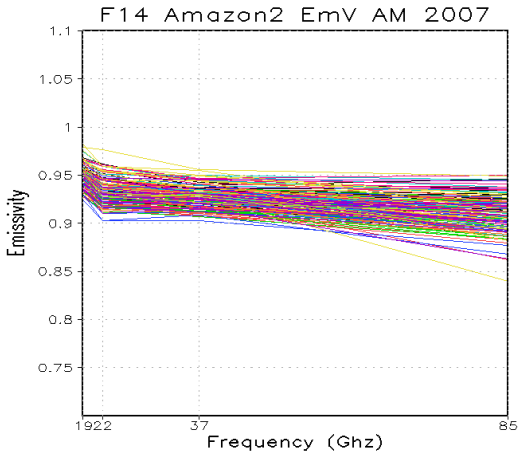


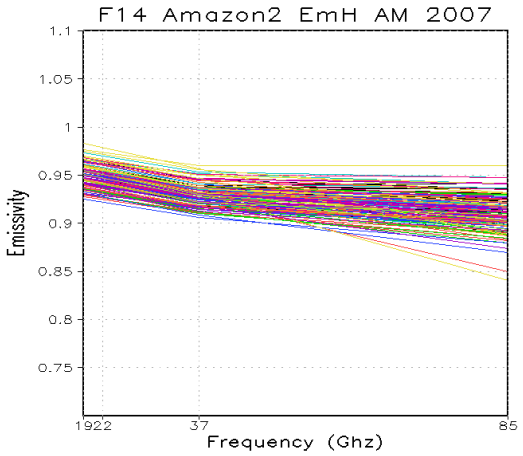




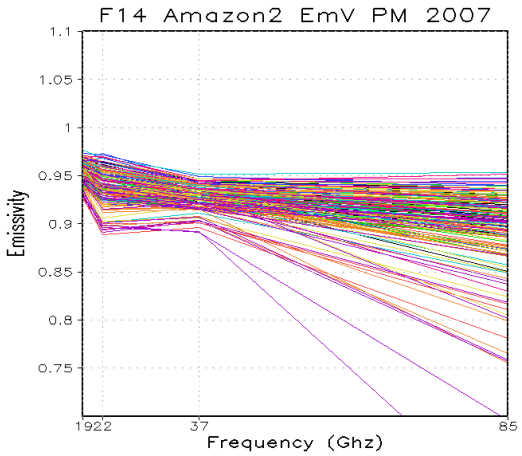
5. Validation, calibration and error analysis

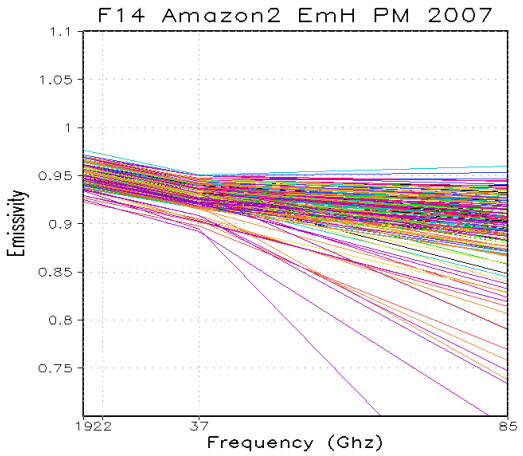
Diagnosing uncertainties in retrievals: atmospheric contamination is the leading cause





Morning pass over Amazon



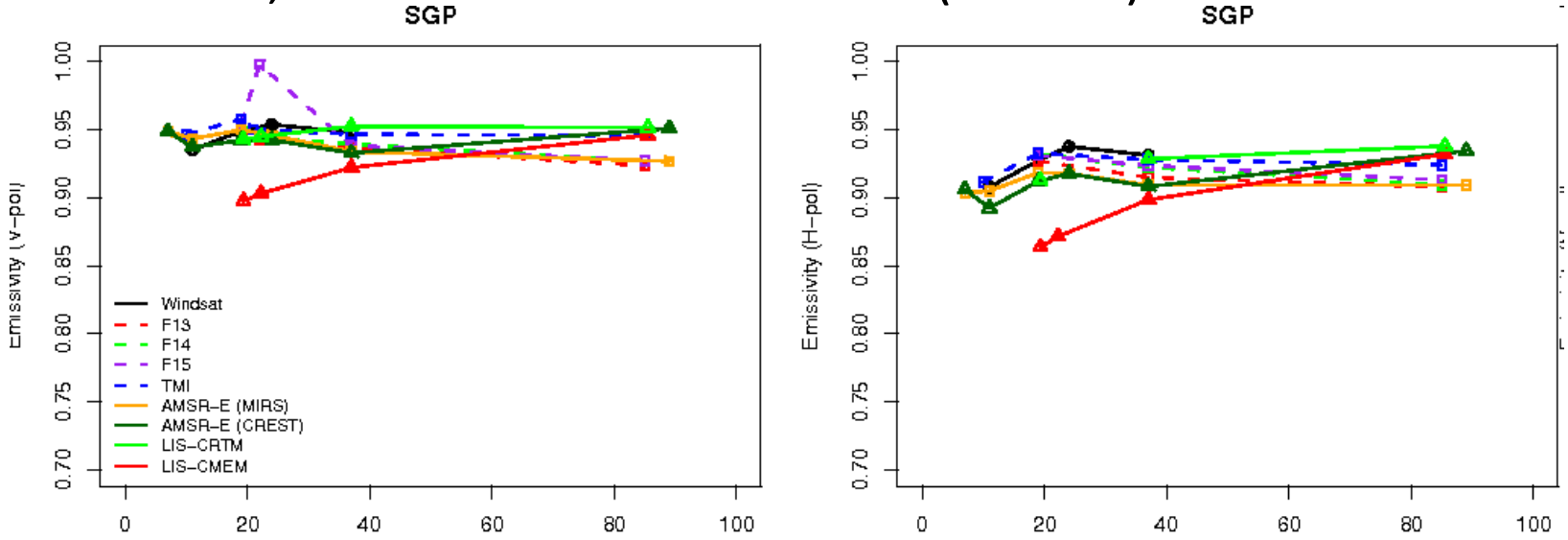


Afternoon pass over Amazon – it encounters the diurnal rain/cloud cycle

Validation, calibration and error analysis:

-- considerable uncertainties in reference data hinder model validation and calibration.

-- need more, consistent reference data (MC3E?)



MC3E AMPR TB

(Courtesy W. Petersen)

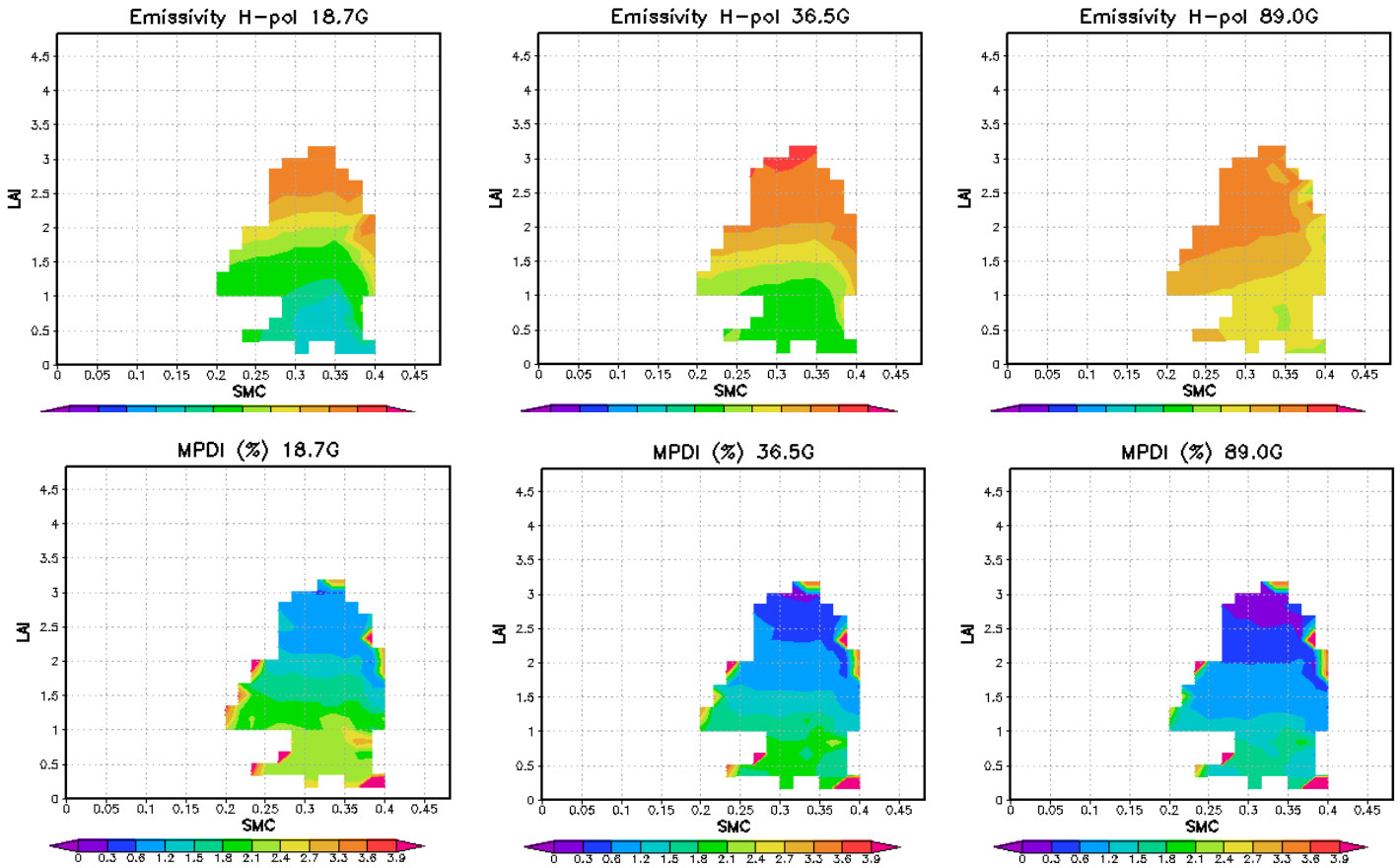
Real-time, online runs can largely reproduce the same regime diagram for either emissivity or MPDI

Regime diagram from on-line LIS/CRTM2 runs over SGP, 0.25-deg

The ranges of SMC and LAI are reduced due to the coarse resolution.

emissivity

MPDI

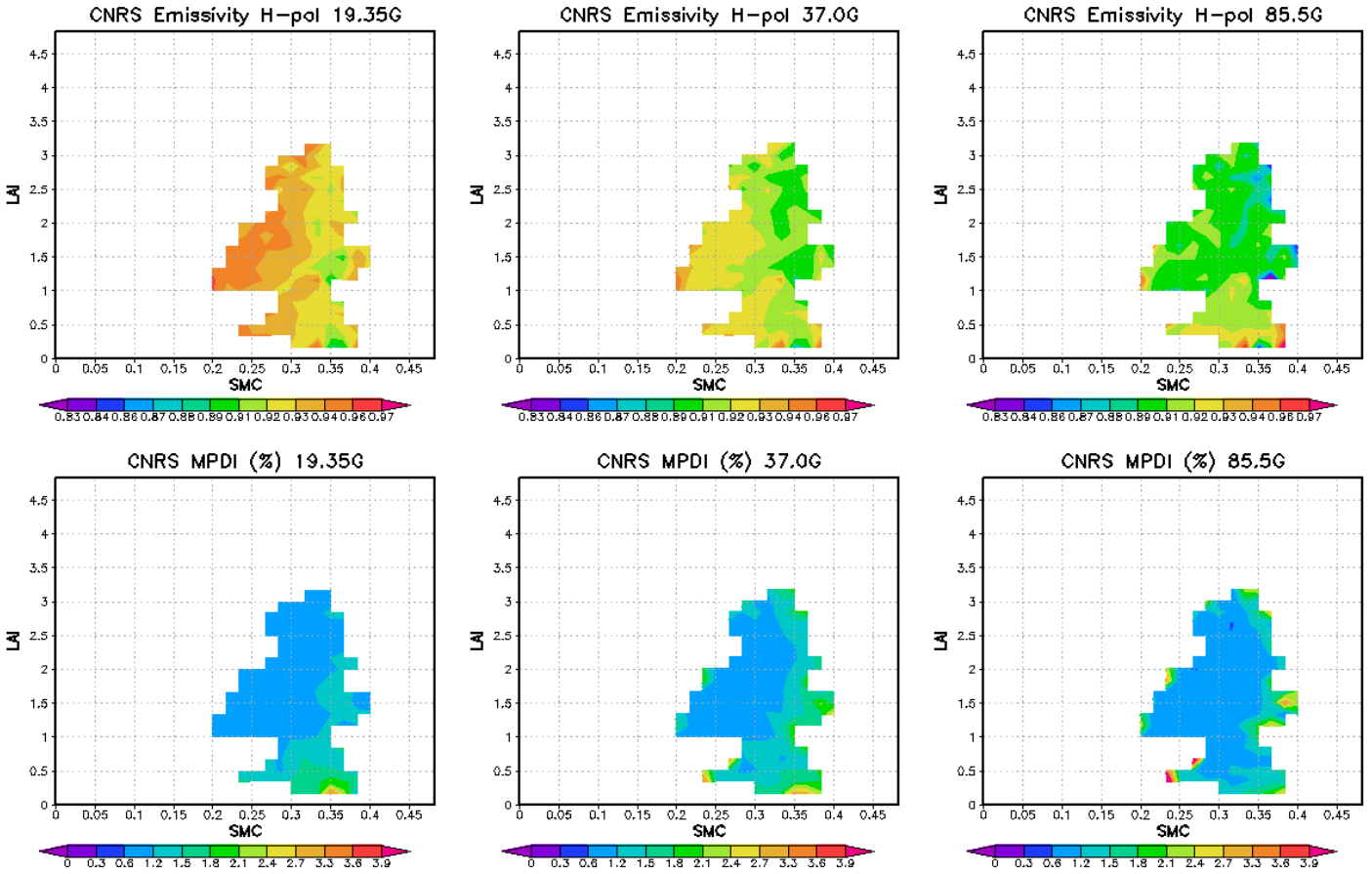


Retrieved emissivity values can be subject to the same SMC-LAI diagram.

CNRS-retrieved SSM/I emissivity and MPDI values in SMC-LAI diagram

emissivity

MPDI



-- Need more data points for robust results

-- Reasonable emissivity response to SMC, but no to LAI; MPDI reasonable to both

-- Some discrepancies

* lower emissivity at higher frequencies than lower ones

* emissivity response to LAI is different from model at 85 G

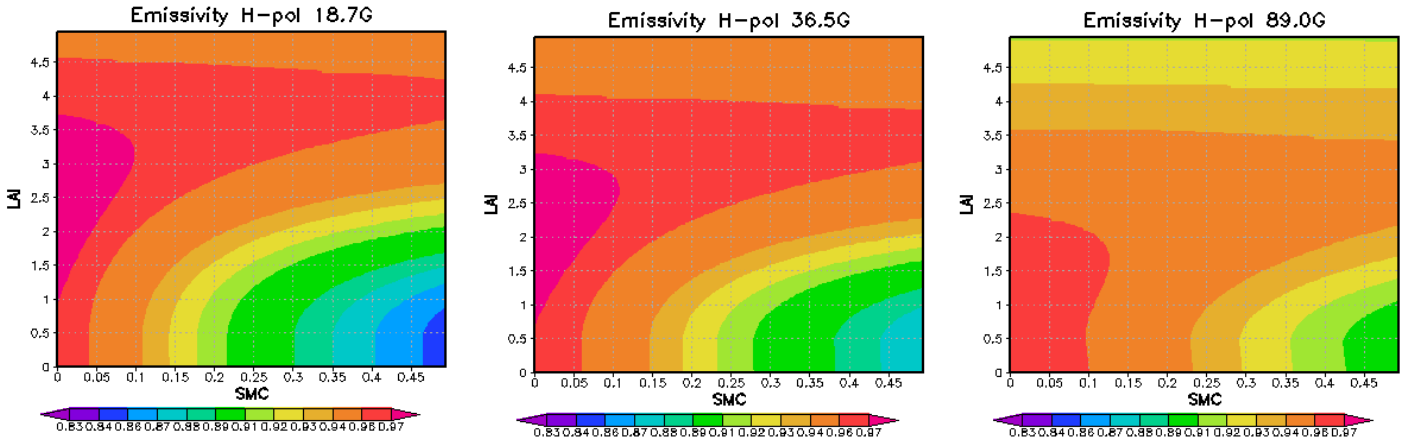
Land surface emissivity dynamics can be concisely summarized in a soil-moisture/vegetation "regime diagram"

Strong nonlinearity on both SMC and LAI defies single-variate regression or prediction.

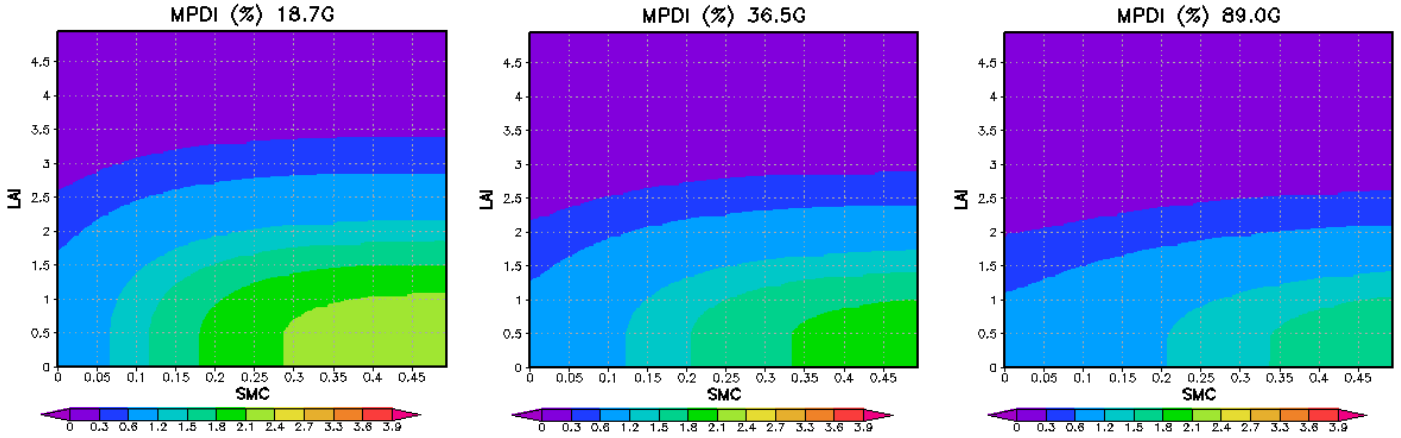
Regime diagram from off-line CRTM2, AMSR-E frequencies

SMC: soil moisture content LAI: leaf area index

emissivity



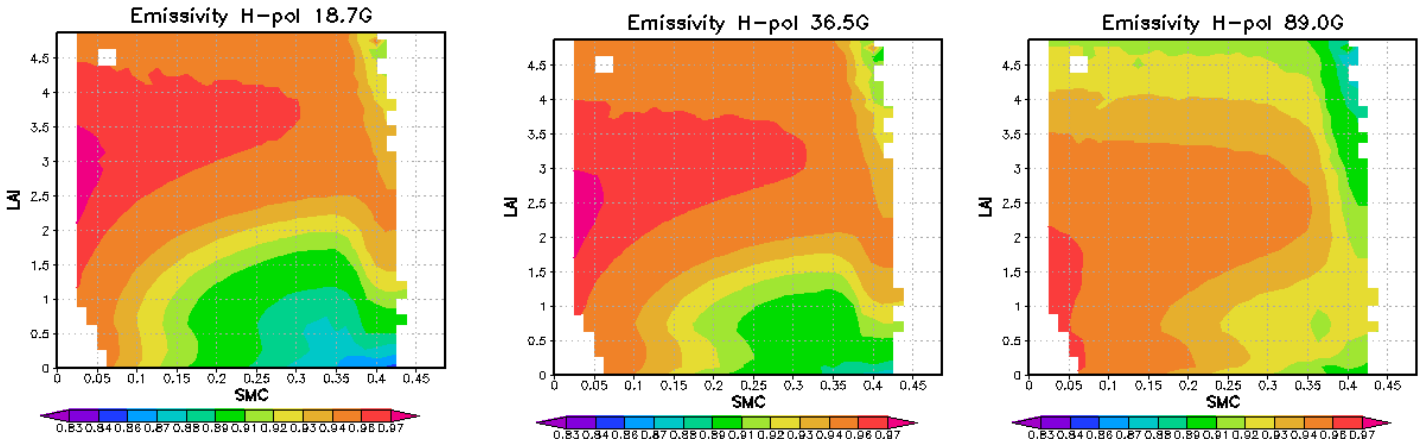
MPDI



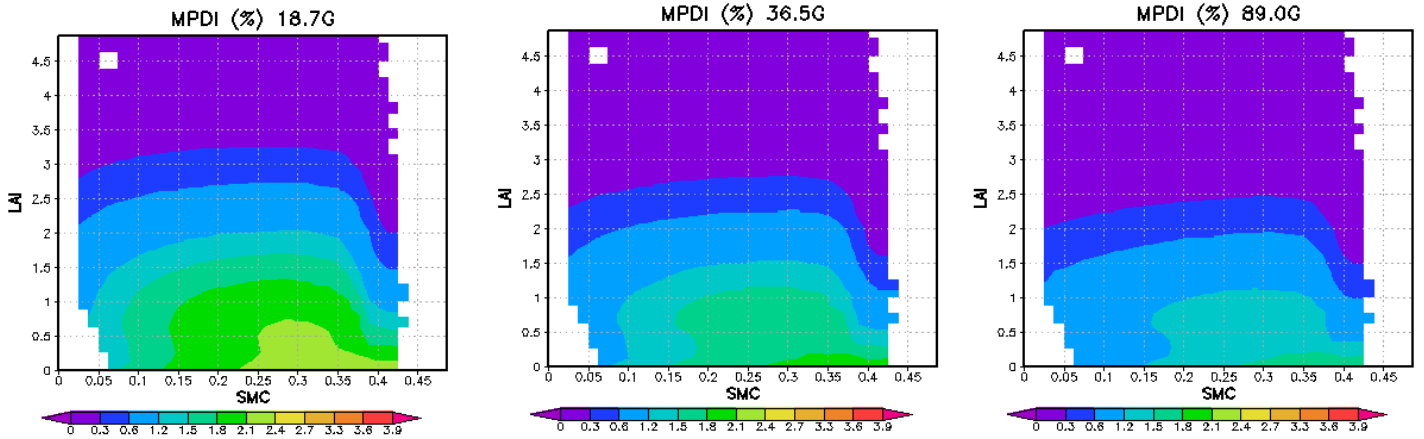
Real-time, online runs can largely reproduce the same regime diagram, despite of the variations of other variables and wide range of SMC-LAI values from high resolution runs.

Regime diagram from on-line LIS/CRTM2 runs over SGP, 1x1-km

emissivity



MPDI



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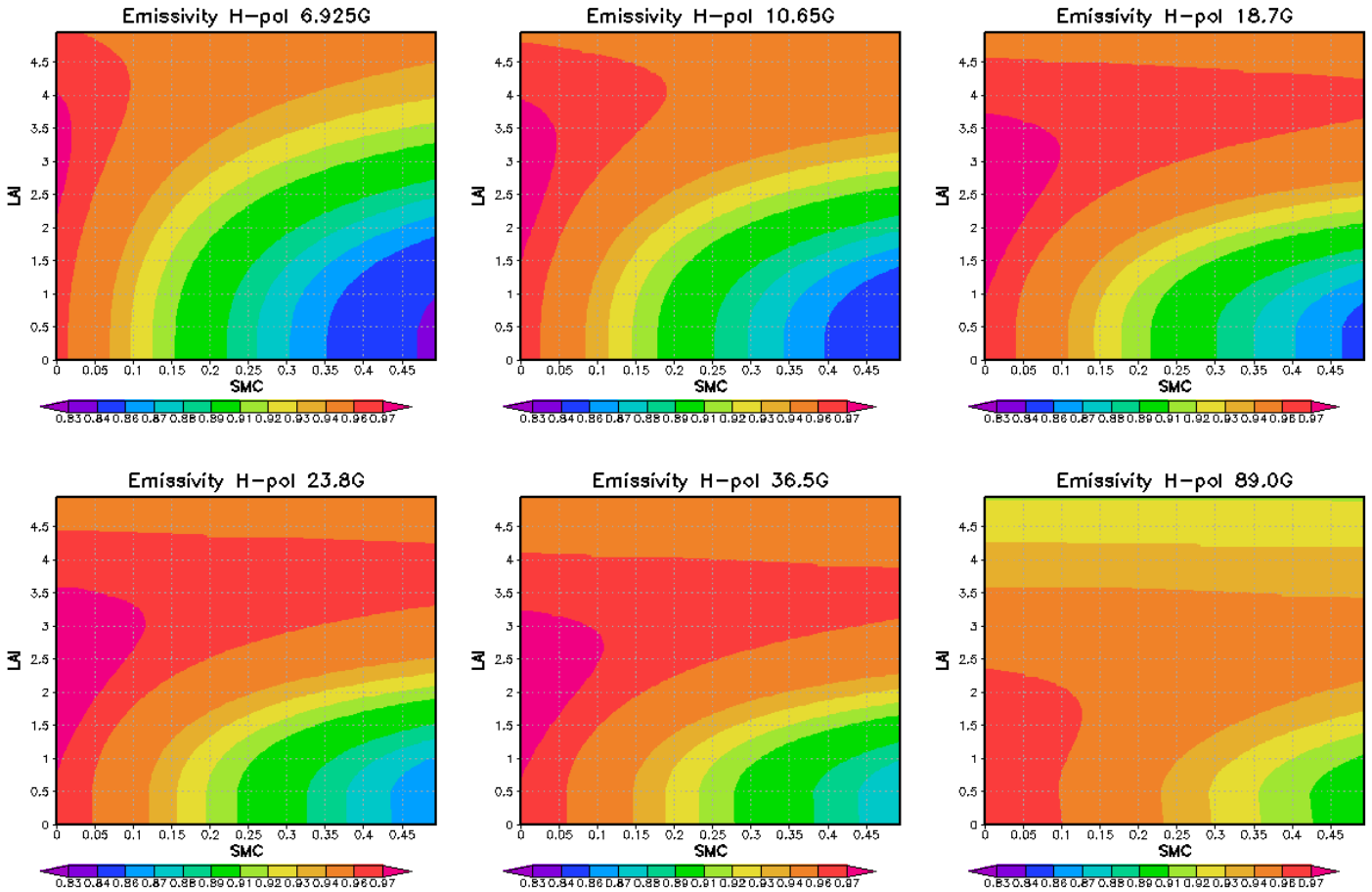
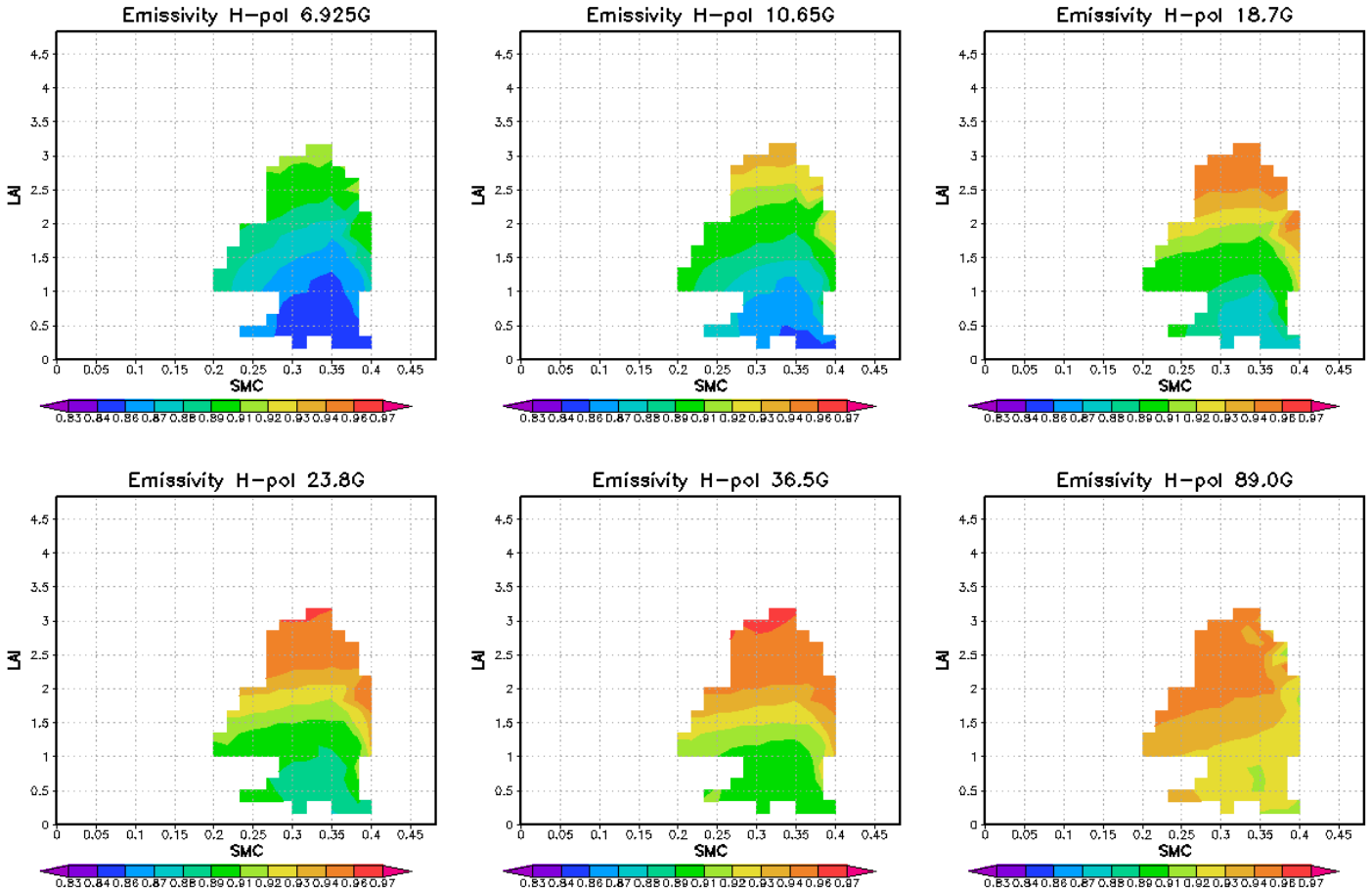


Real-time, online runs can largely reproduce the same regime diagram

Regime diagram from on-line LIS/CRTM2 runs over SGP, 0.25-deg

The ranges of SMC and LAI are reduced due to the coarse resolution.



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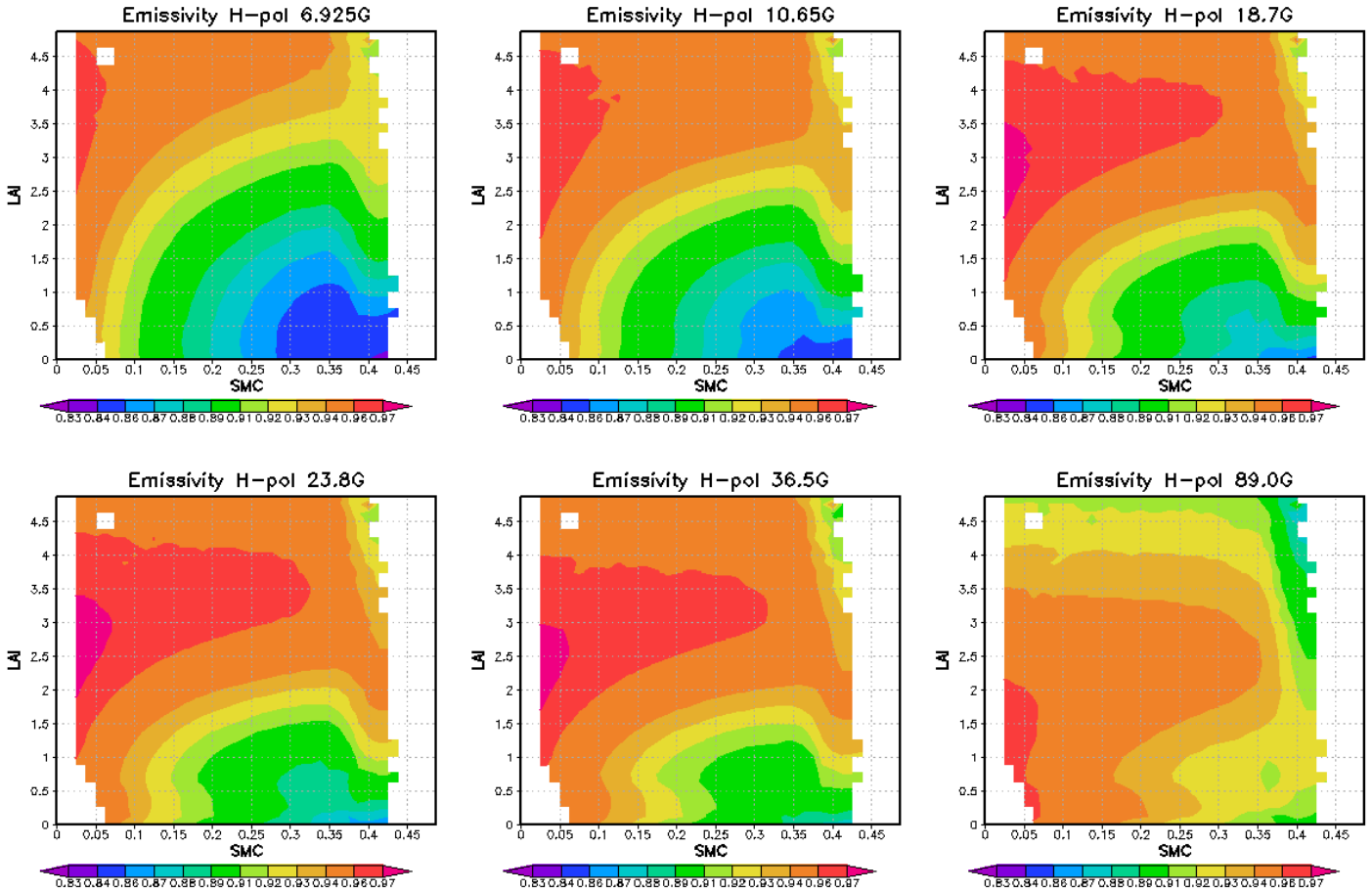
Regime diagram from on-line LIS/CRTM2 runs over SGP, 1x1-km



Modeling shows SMC-LAI combo is an excellent predictor of emissivity. Real-time, online runs show very small deviation from the average values determined by SMC-LAI (< 2.5%, mostly < 1%).

Standard deviation of on-line LIS/CRTM2 runs over SGP, 2004-2007, 1x1-km. Contour lines show the number of data points.