The UMT AMSR-E Land Parameter Database Version 1.1 *and* Planned Updates

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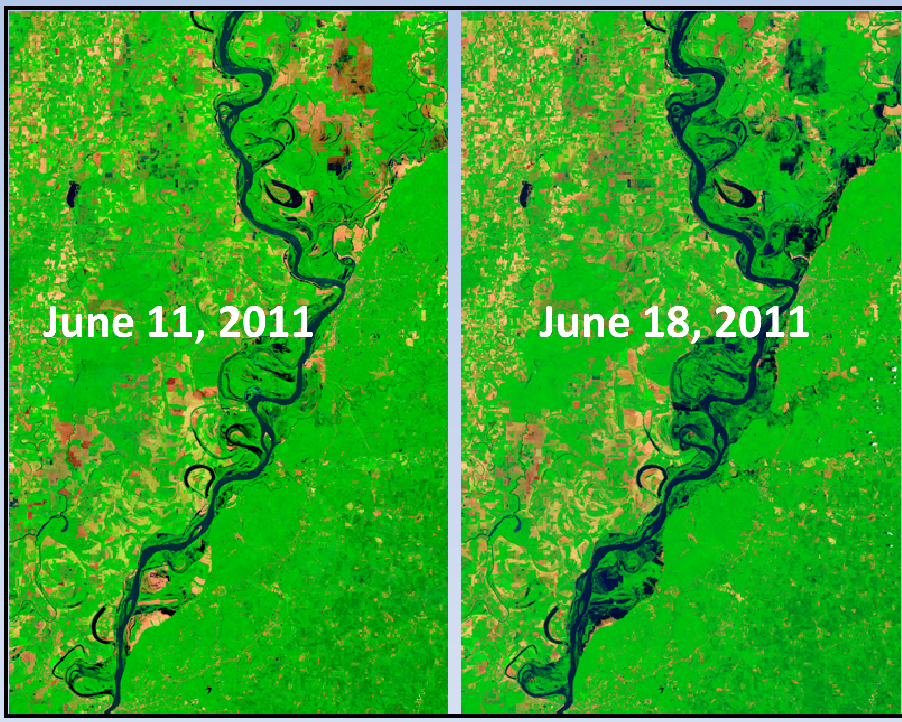
Motivation

- Land surface and ecosystem studies critically need independent datasets to complement reanalysis and optical-IR datasets.
- Few microwave land temperature and moisture datasets explicitly consider seasonally varying fractional open water (wetlands, watercourses, irrigation, flooding).
- Scientifically interesting land surface and ecological problems occur in regions with much open water (e.g. the Arctic).
- It matters greatly to ecosystems (and to people) if they are flooded or merely wet.

Examples

Recent Flooding:

Mississippi River near Vicksburg



NASA Earth Observatory image created by Jesse Allen and Robert Simmon, using Landsat data provided by the USGS.

Ecosystem-Climate Interactions:

26 OCTOBER 2007 VOL 318 SCIENCE

Amazon Forests Green-Up During 2005 Drought

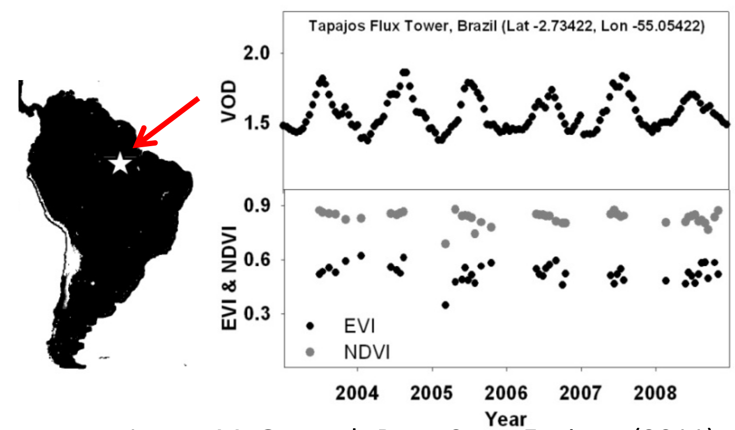
Scott R. Saleska,[1*†] Kamel Didan,[2*] Alfredo R. Huete,[2] Humberto R. da Rocha[3]

GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L05401, doi:10.1029/2009GL042154, 2010

Amazon forests did not green-up during the 2005 drought

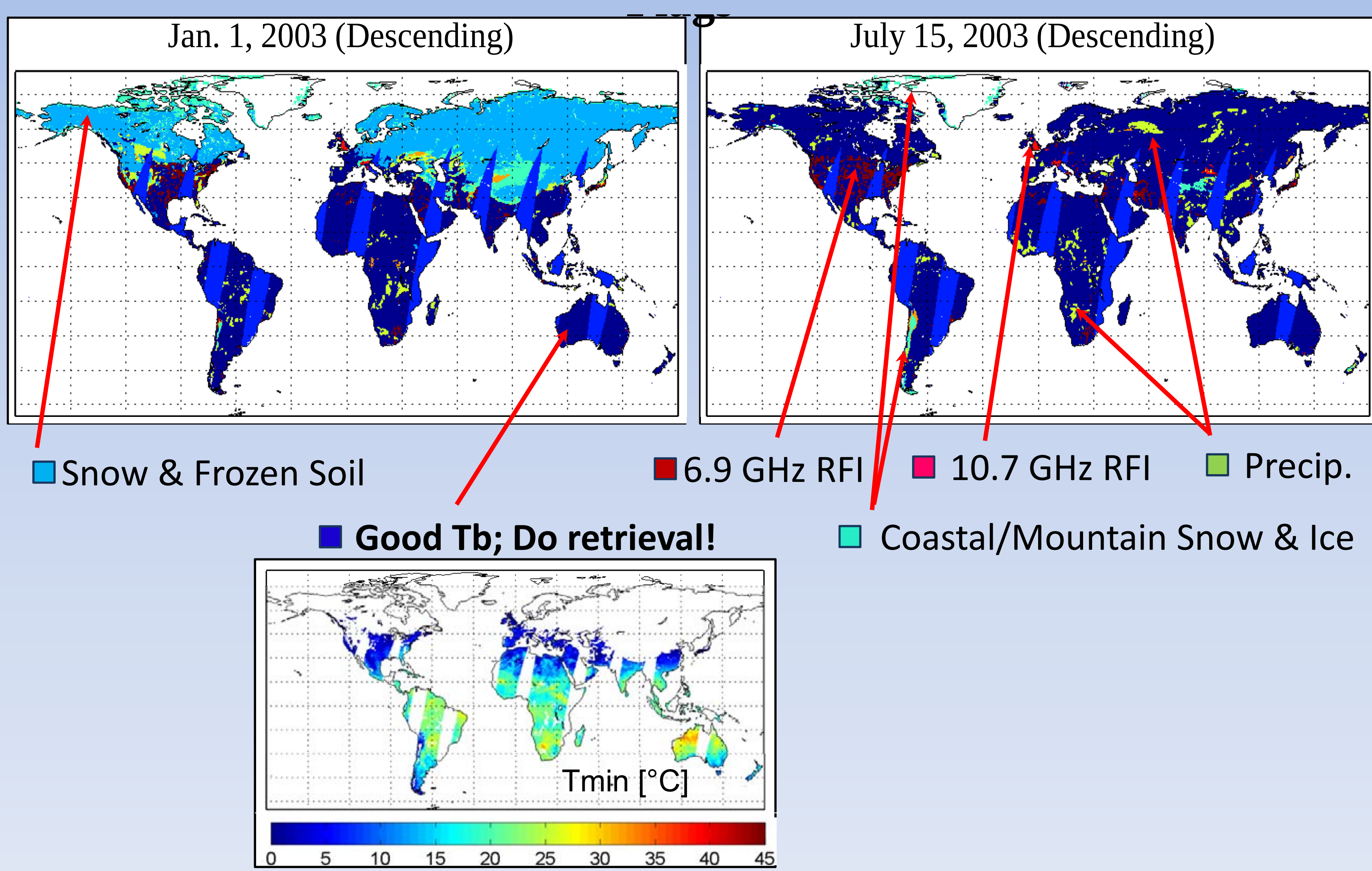
Arindam Samanta,[1] Sangram Ganguly,[2] Hirofumi Hashimoto,[3] Sadashiva Devadiga,[4] Eric Vermote,[5] Yuri Knyazikhin,[1] Ramakrishna R. Nemani,[6] and Ranga B. Myneni[1]

Received 11 December 2009; accepted 26 January 2010; published 5 March 2010.



Jones, M. O. et. al. *Rem. Sens. Environ.* (2011)

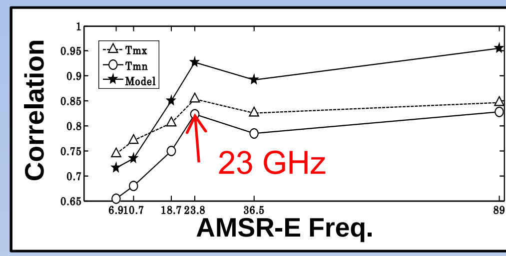
Tb Input Pre-Screening

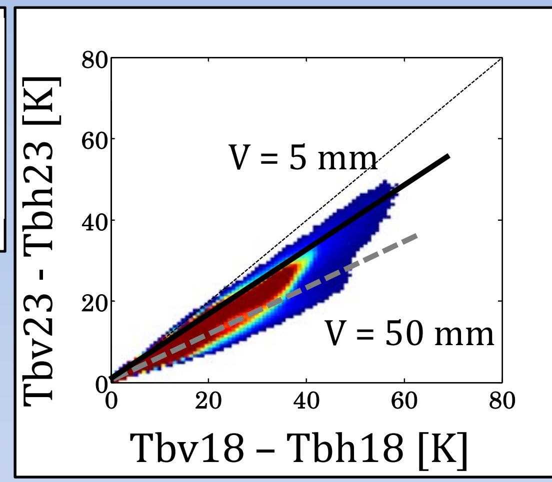


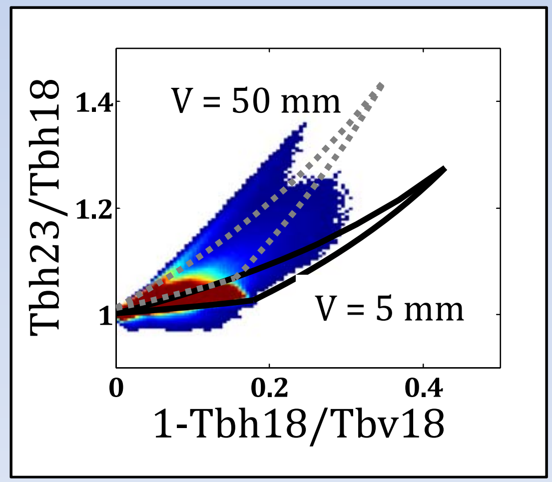
Temperature/Emissivity/Water Vapor Algorithm

Frequencies used:
- 18.7, 23.8 GHz (V, H pol.)

Parameters retrieved:
- Surface Air temperature (*Tmin,Tmax*)
- Total Column Atmospheric Water vapor (*V*)
- Open Water Fraction (*fw*)
- Vegetation Optical Depth (*VOD(18,23)*)







<u>Steps:</u>

1. Iterate using Tb ratios to estimate V,fw, VOD:

$$MAWVI = \frac{Tb_{v23} - Tb_{h23} + \beta_1}{Tb_{v18} - Tb_{h18} + \beta_2} \approx B\left(\frac{ta23}{ta18}\right)^2$$

$$B = \frac{\varepsilon_{v23} - \varepsilon_{h23}}{\varepsilon_{v18} - \varepsilon_{h18}} = f(fw, VOD) \qquad Tm = Ts * dm$$

2. Then invert Tb model:

$$Ts = f(Tb, V, fw, VOD)$$

Jones, L.A., et al. 2010. *IEEE JSTARS* 3(1), 111-123.

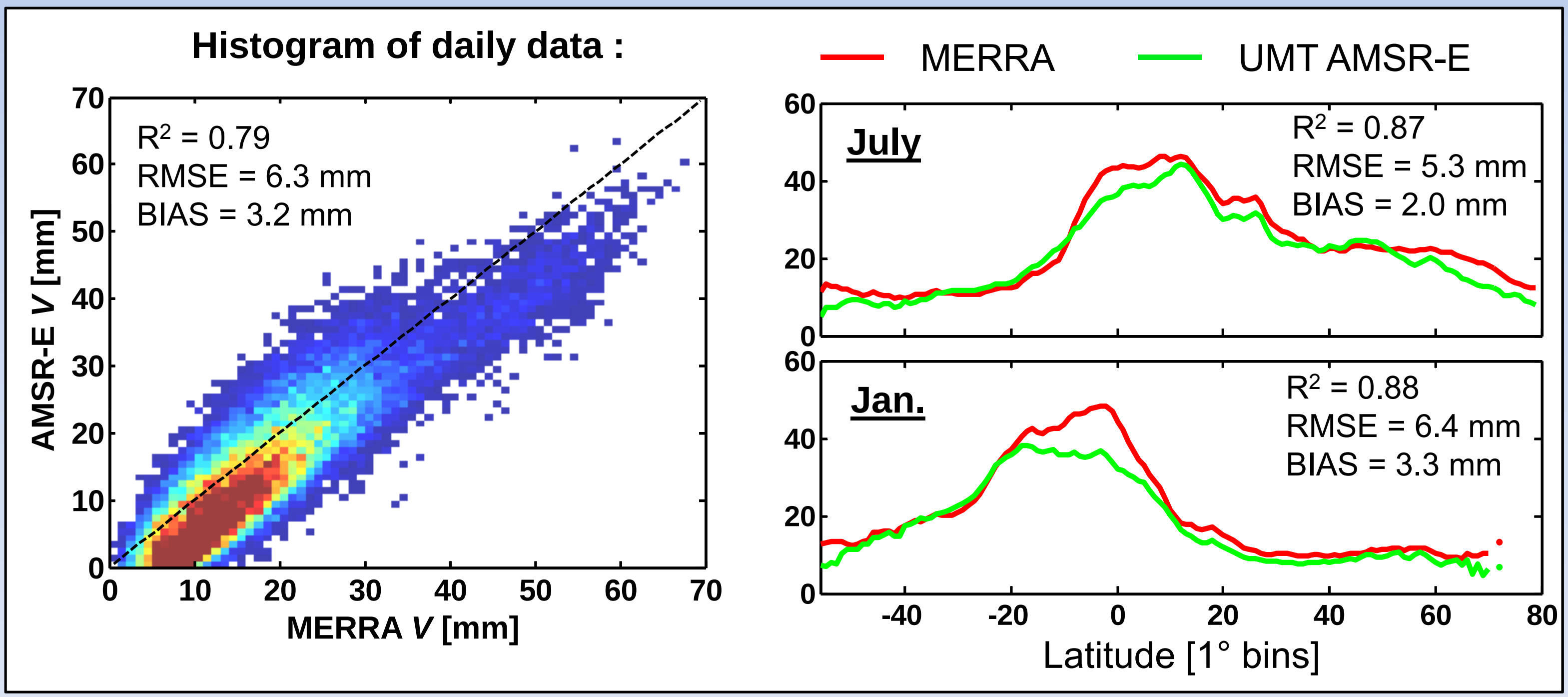
Verification of Water Vapor Accuracy

$$MAWVI = \frac{Tb_{v23} - Tb_{h23} + \beta_1}{Tb_{v18} - Tb_{h18} + \beta_2}$$

Small for dense vegetation (heavily forested regions)

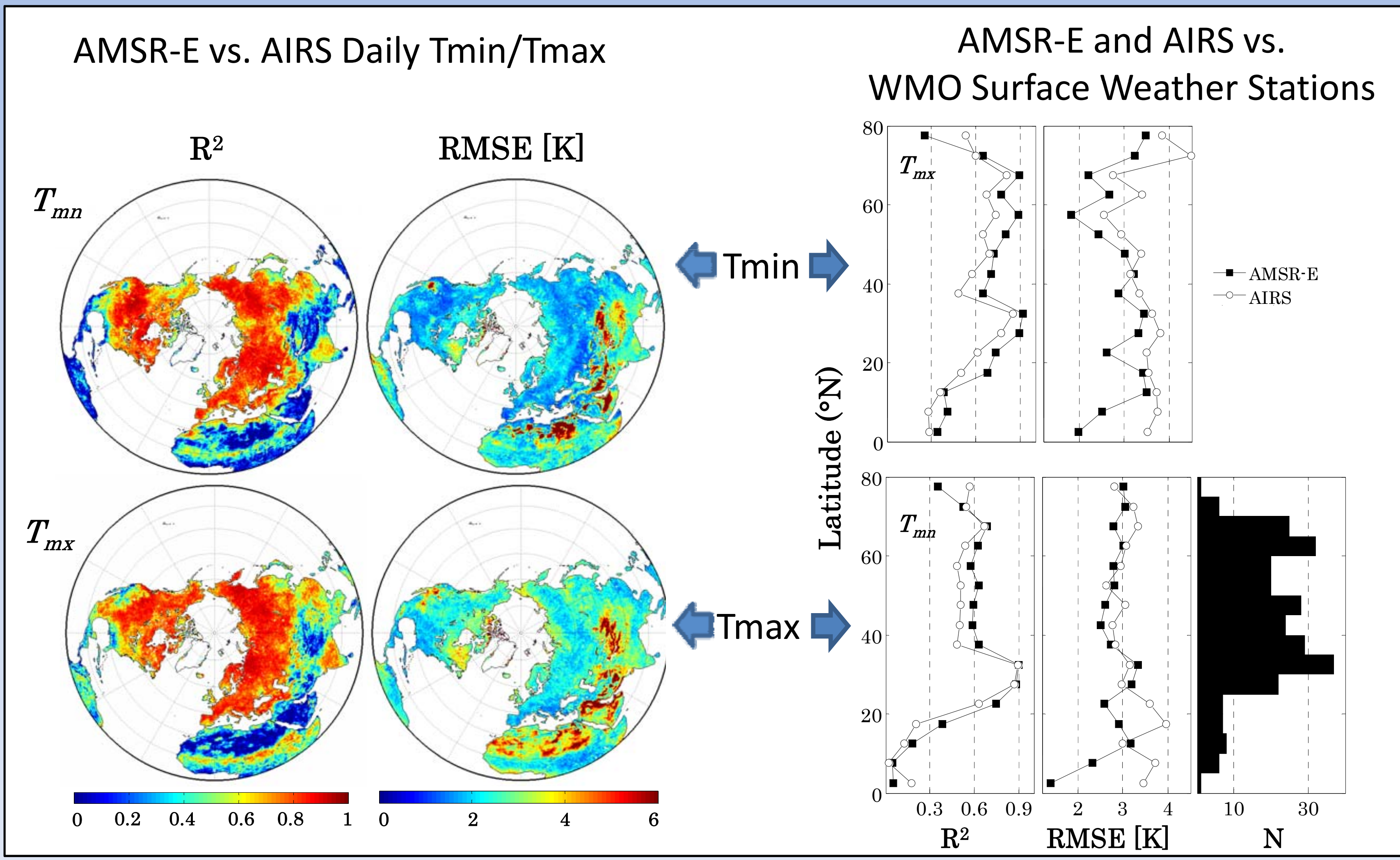
Some results for AMSU and SSMI/S TPW for comparison[1]:

	RAOB	ECMWF
R^2	0.85	0.96
RMSE	5.0	3.2
BIAS	2.0	0.5



[1]Boukabara, S.A., et. al., *TGRS* 2010

Verification of Temperature Accuracy



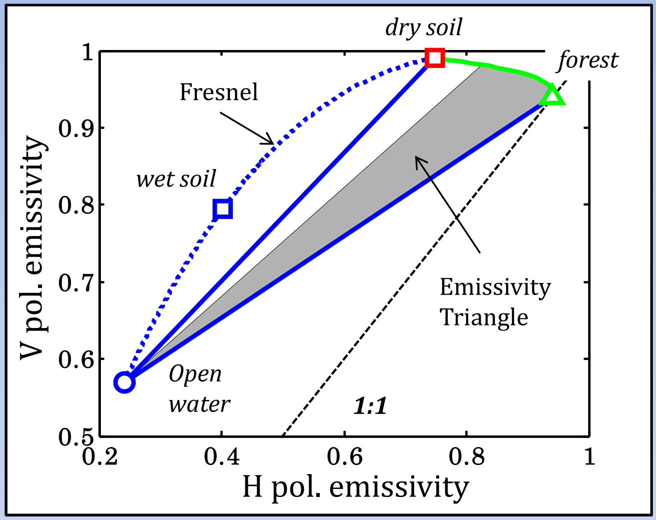
Soil Moisture Algorithm

Input Data:

- 6.9 or 10.7 GHz (V, H pol.)
- Temperature, Open Water fraction

Parameters retrieved:

- Soil Moisture (*SM*)
- Vegetation Optical Depth (*VOD(10,6)*)



Steps:

1. Estimate surface emissivities (v,h) using temperature input and calculate their slope (*a*) relative to open water emissivity :

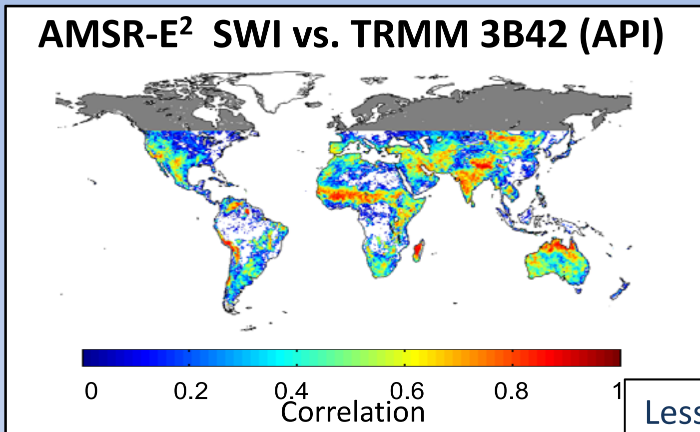
$$a = \frac{\varepsilon s_v - \varepsilon w_v}{\varepsilon s_h - \varepsilon w_h}$$

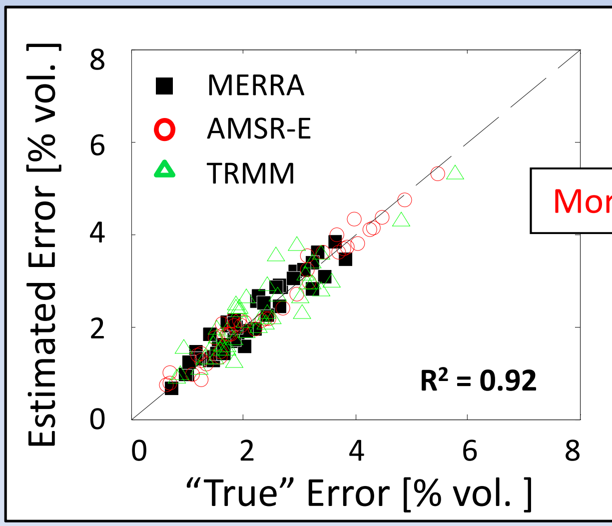
2. Smooth slope and fw (30-day moving median) and use to invert *τ-ω* equation for VOD (soil emissivity held at constant baseline value).

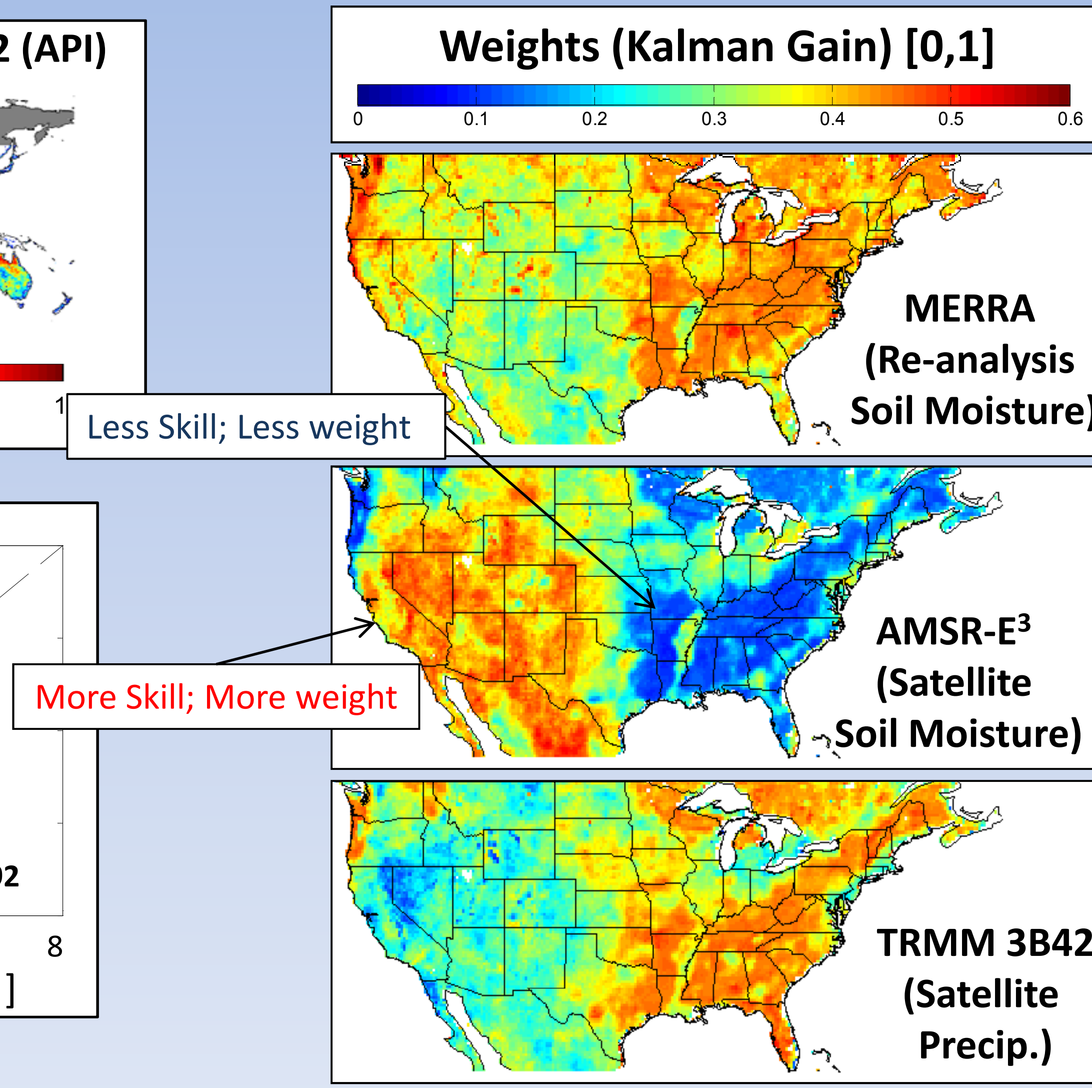
3. Use VOD, fw, and temperature to invert daily *τ-ω* equation for daily soil moisture change above the baseline.

Jones, L.A., et al. 2009. *Proc. IGARSS '09*.

Soil Moisture Information for Daily Anomalies[1]



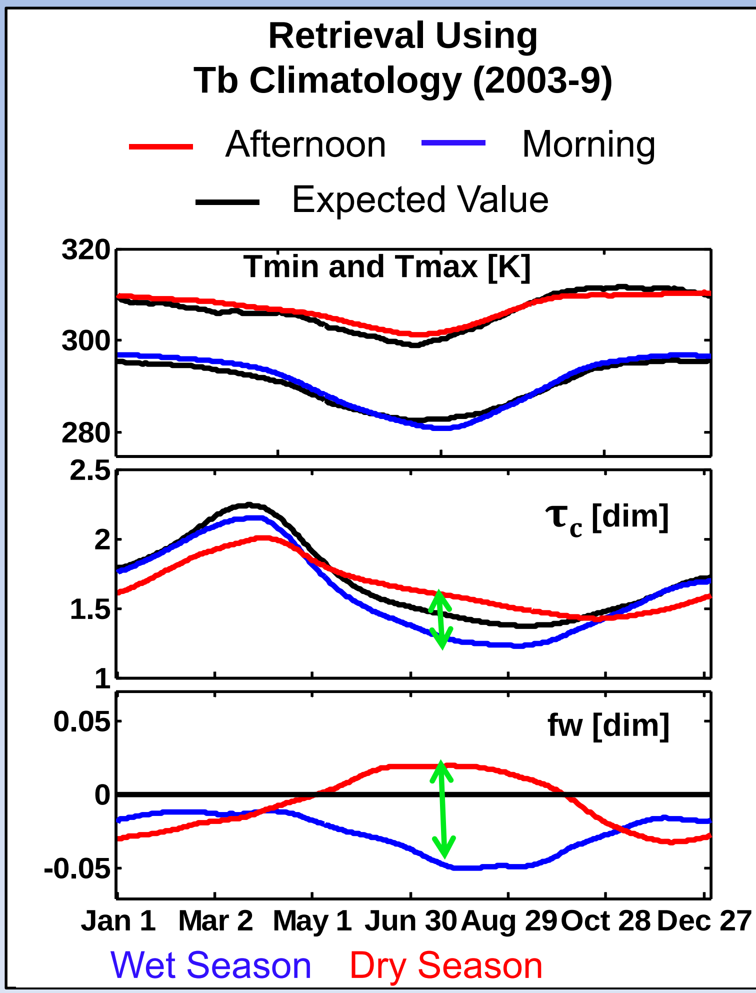




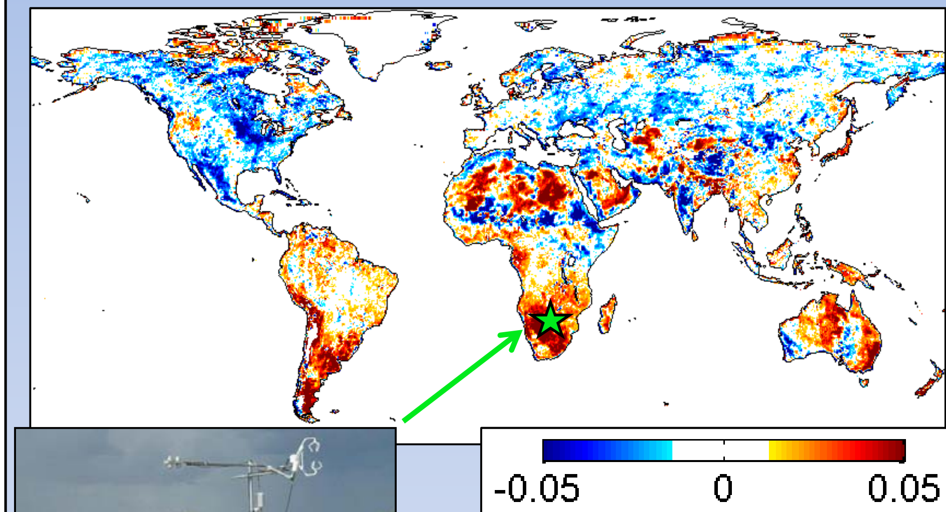
[1]Jones, L. A. et al. (in prep.); [2]UMT C/X-band soil moisture; [3]Vienna University X-band soil moisture

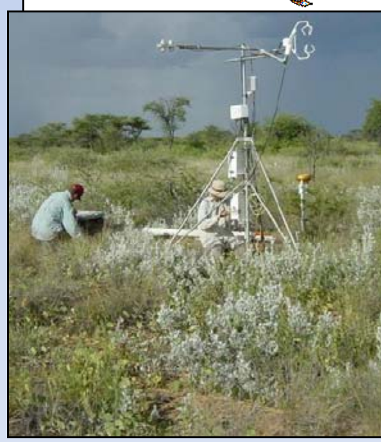

Now for the **DARK SLIDE**!

Odd Patterns: Seek out and destroy…



fw (afternoon) – fw (morning) for July 19



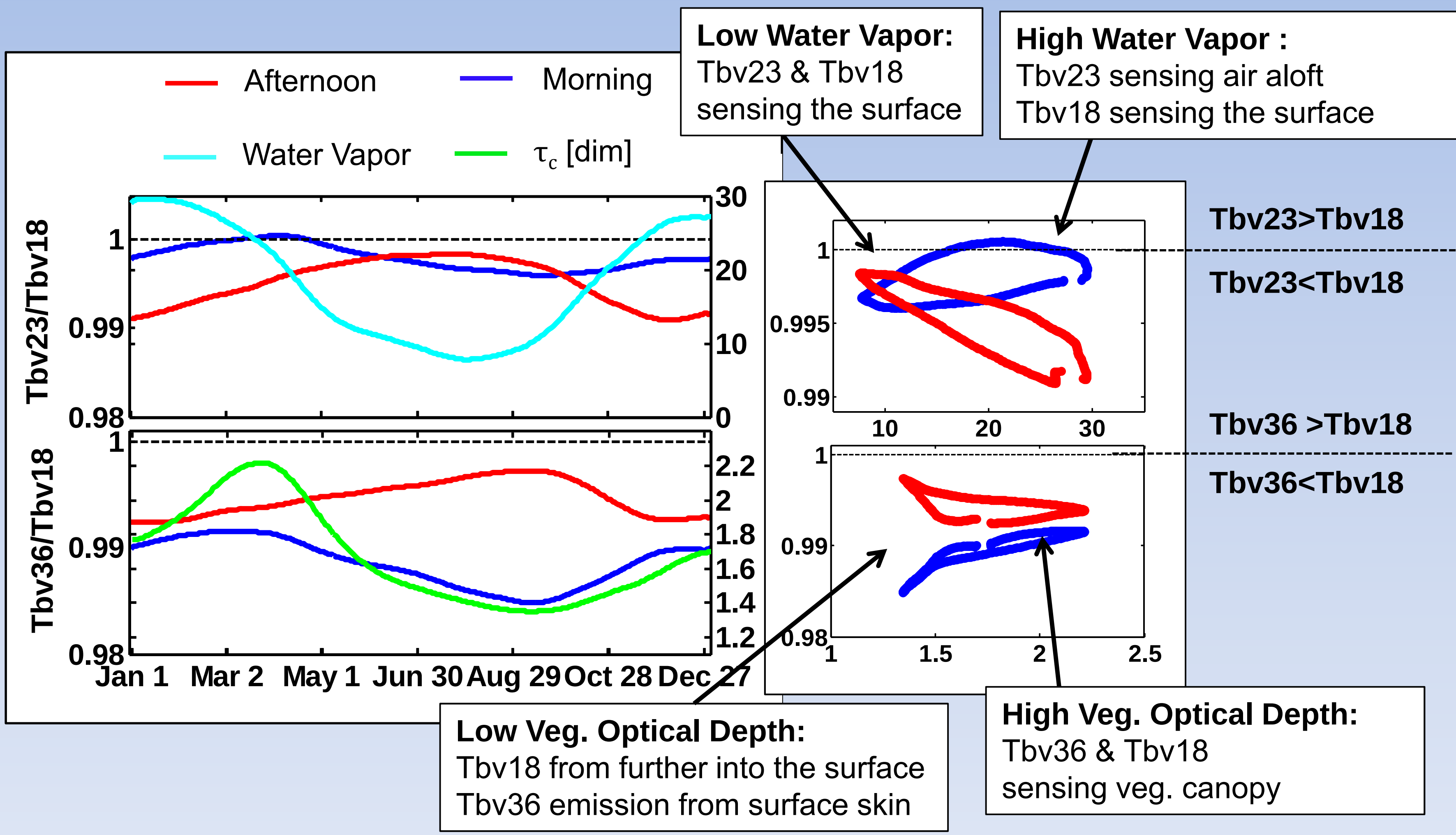


Ghanzi Flux Tower, Botswana[1]

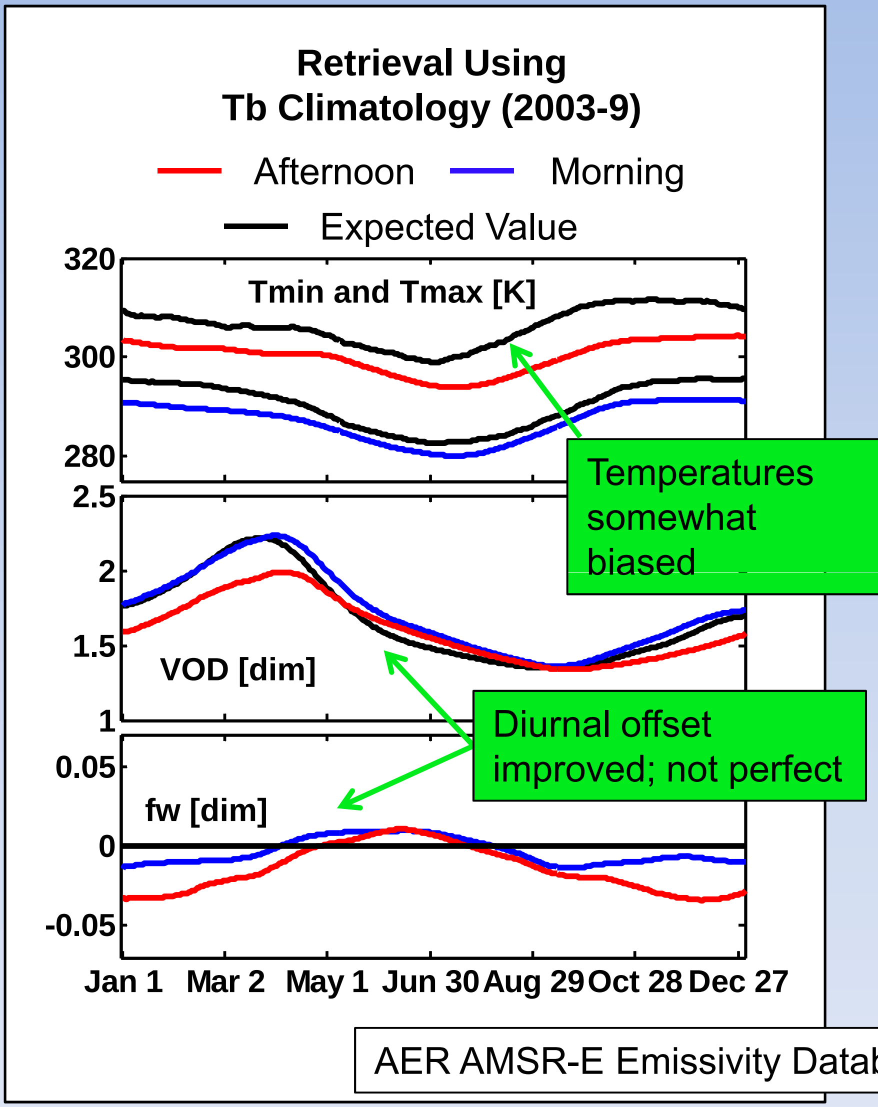
(Photo taken during Wet Season)

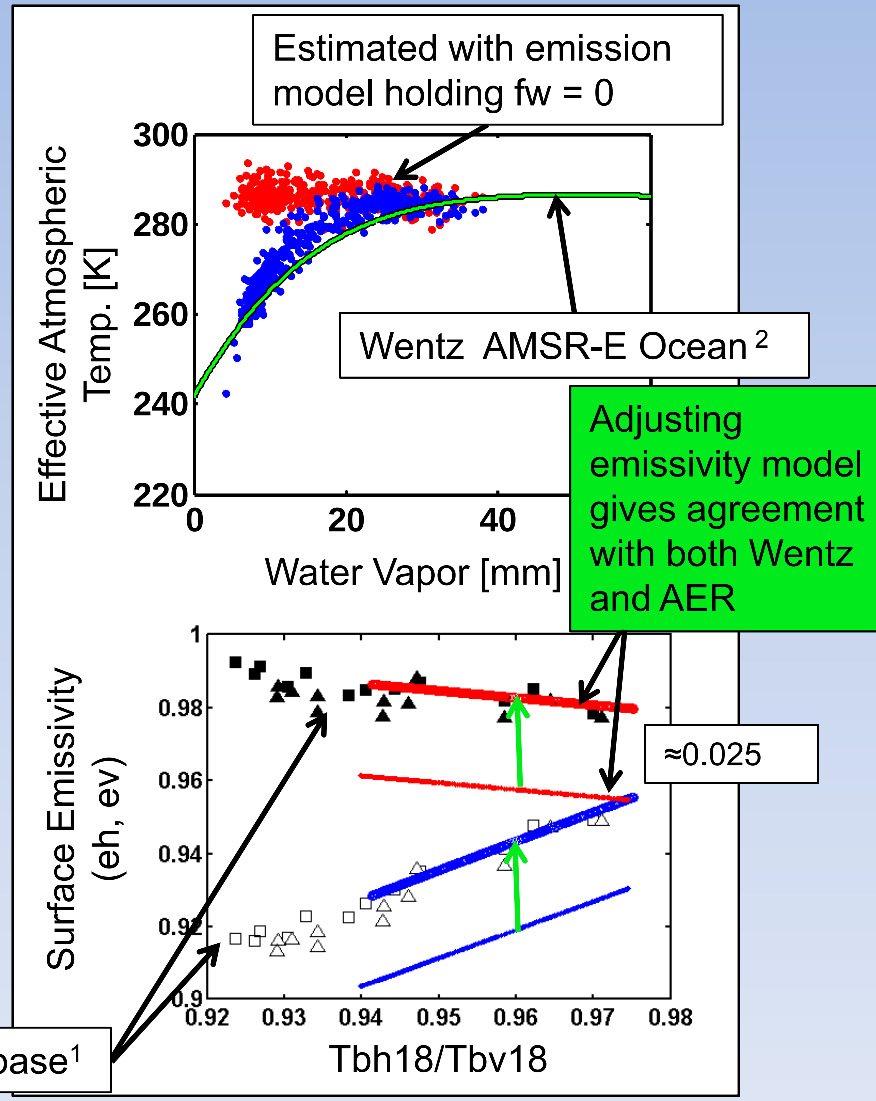
[1]PI: C. A. Williams (Clark University)

Vertical Temperature Gradient



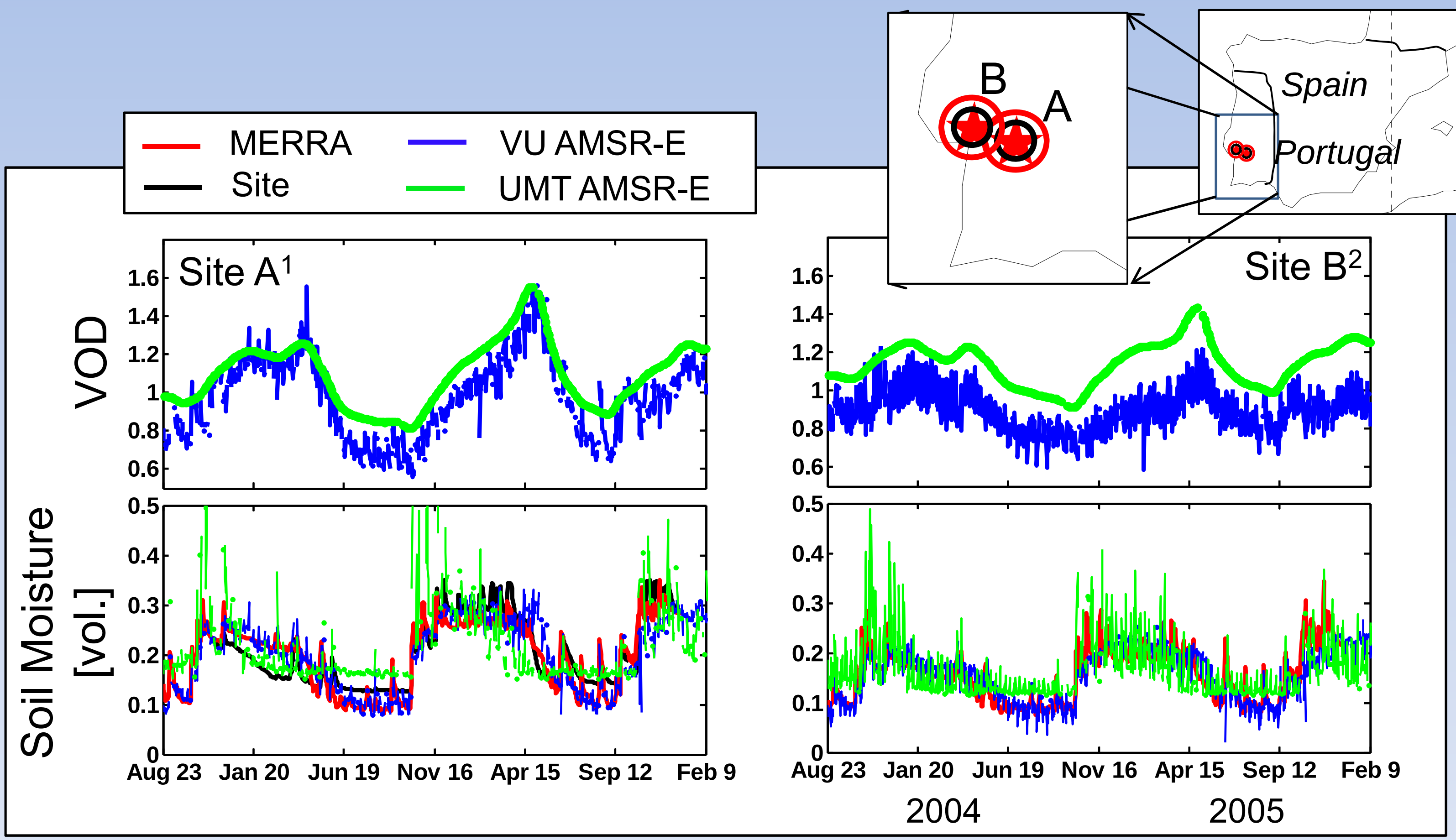
Effective atmospheric Temperatures





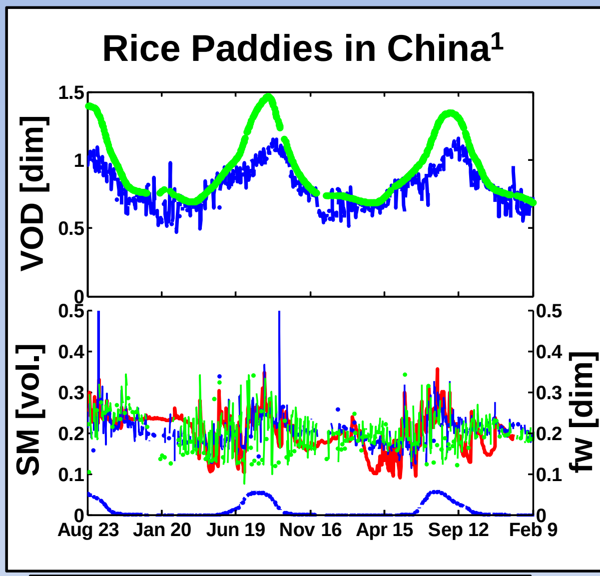
[1]Moncet, J. and P. Liang; [2]available at: ssmi.com

UMT (Grid) and VU Soil Moisture with Coastal Contamination

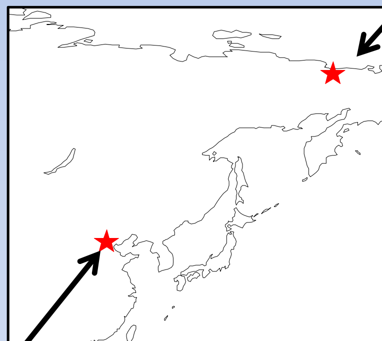


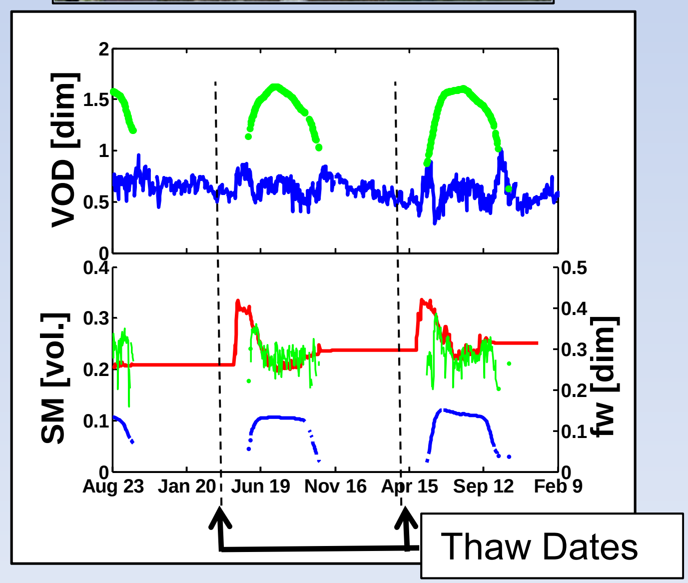
[1]PI: Joao Pereira; [2]PI: Casimiro Pio

Adventures in Asia with Vegetation and Open Water



VU AMSR-E
UMT AMSR-E
MERRA





[1]PI: Shiping Chen; [2]PI: Lutz Merbold

Tying Down the Ends with Multiple Comparisons

Ground-based:

- Eddy Covariance Flux Tower Network (Air temperature, Soil Moisture)
- WMO Surface Weather Stations (Air temperature)
- IRGA Radiosonde Database (Water Vapor, Air temperatures)

Satellite-based:

- TRMM 3B42 (Soil Moisture)
- MODIS EVI/NDVI (VOD)
- SRTM/MOD44W (fw)
- AMSR-E Emissivity Database from AER (Moncet, Liang)
- AMSR-E VU land Parameter Database
- AIRS (Temperature and Water Vapor)

Re-analysis:

- MERRA

adventurousbusiness.co.uk

Summary of Planned Updates

Completed and Ongoing:

- ❑ Verified and identified major areas for improvement in original algorithm.
- ❑ Re-formulated RTM and numerics for the future updates.

Planned:

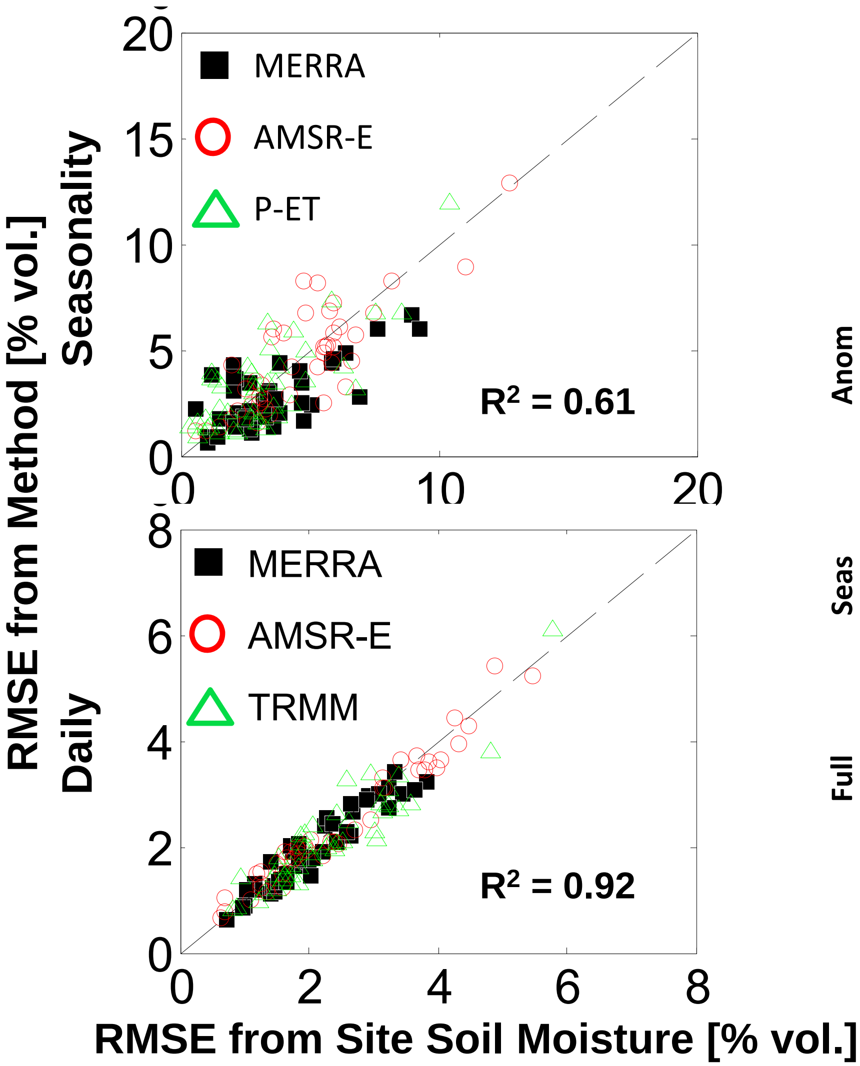
- ❑ Re-parameterize temperature/emissivity/water vapor algorithm using IRGA radiosonde network and external temperature/emissivity information.
- ❑ Update soil moisture algorithm for simultaneous VOD and SM estimation, using temperature and water fraction data as input.
- ❑ Run algorithm with L2A swath (rather than gridded) Tb data as input.

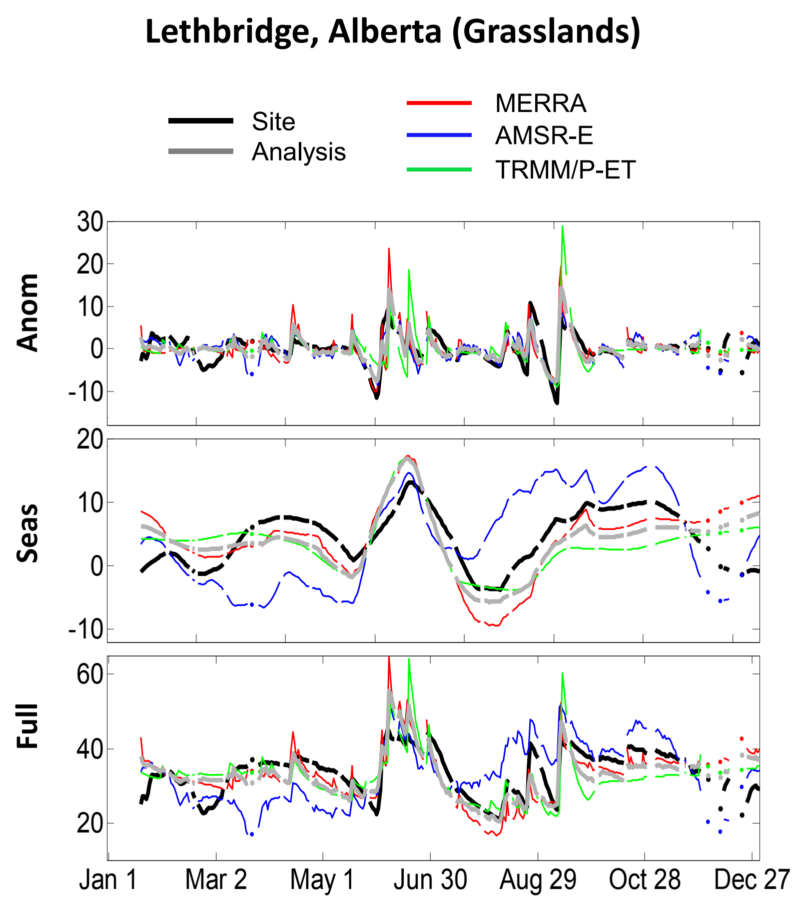
Current version of the data and documentation available at:
http://nsidc.org/data/nsidc-0451.html

Comments and requests email me: lucas@ntsg.umt.edu

EXTRA SLIDES

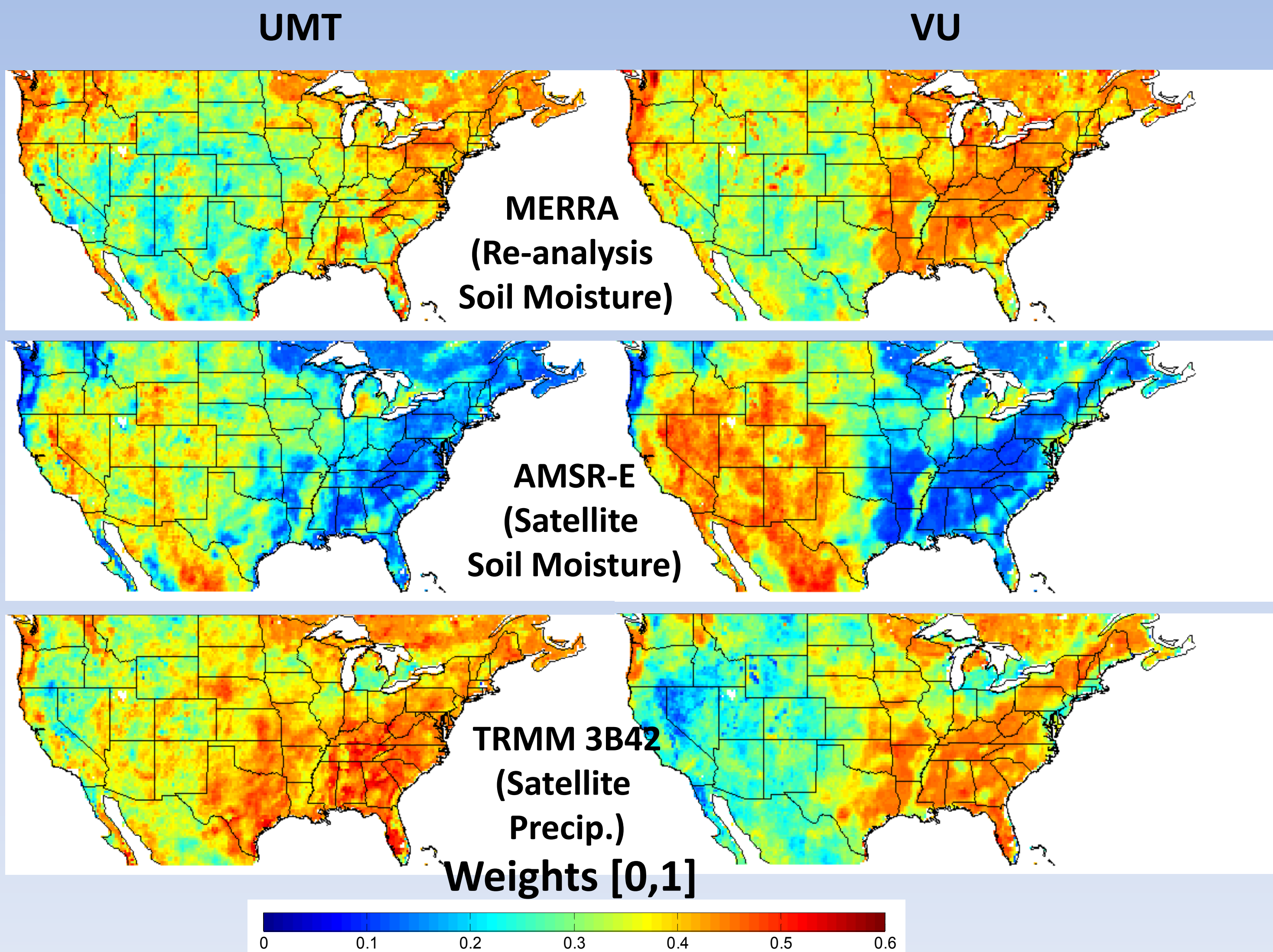
Estimating Uncertainty with Data Assimilation



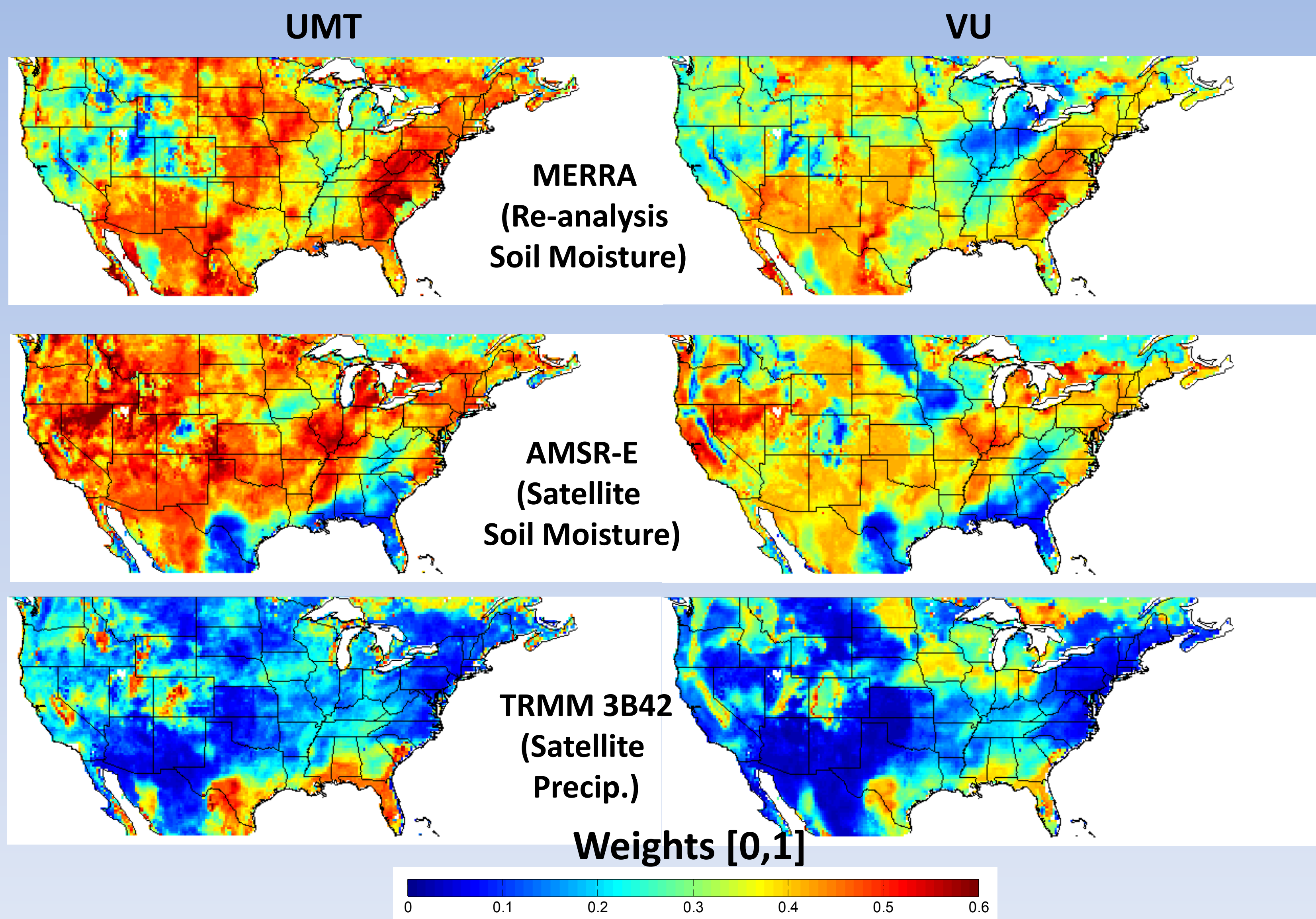


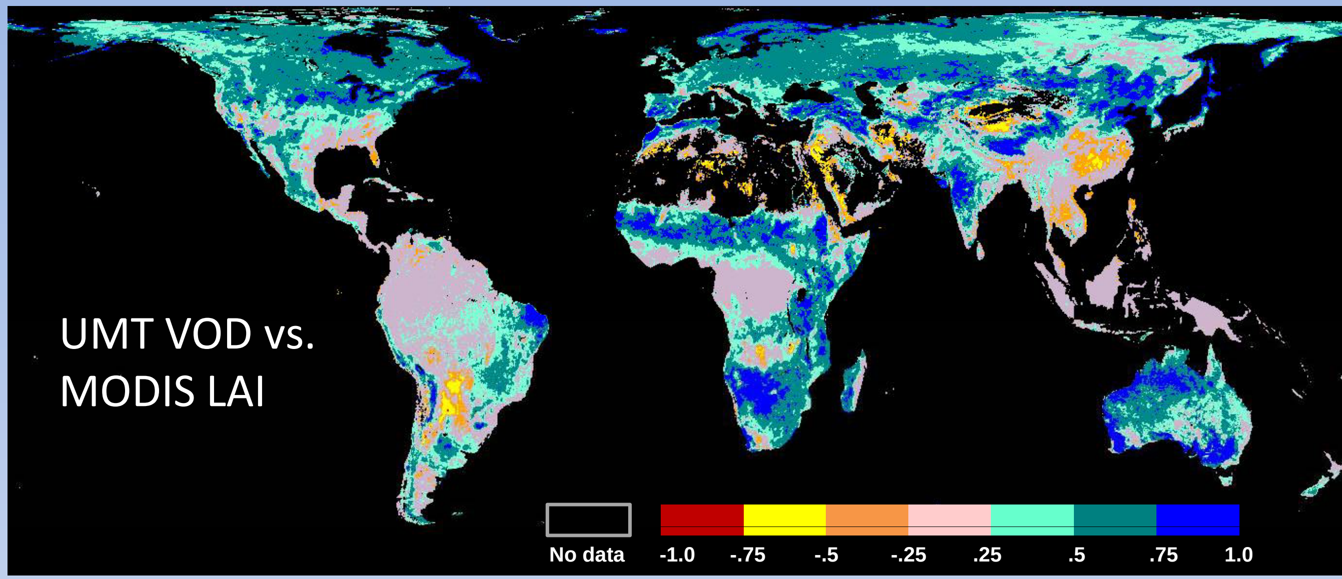
Jones, L. A. et. al. *J. Hydrometeorology* (in prep.)

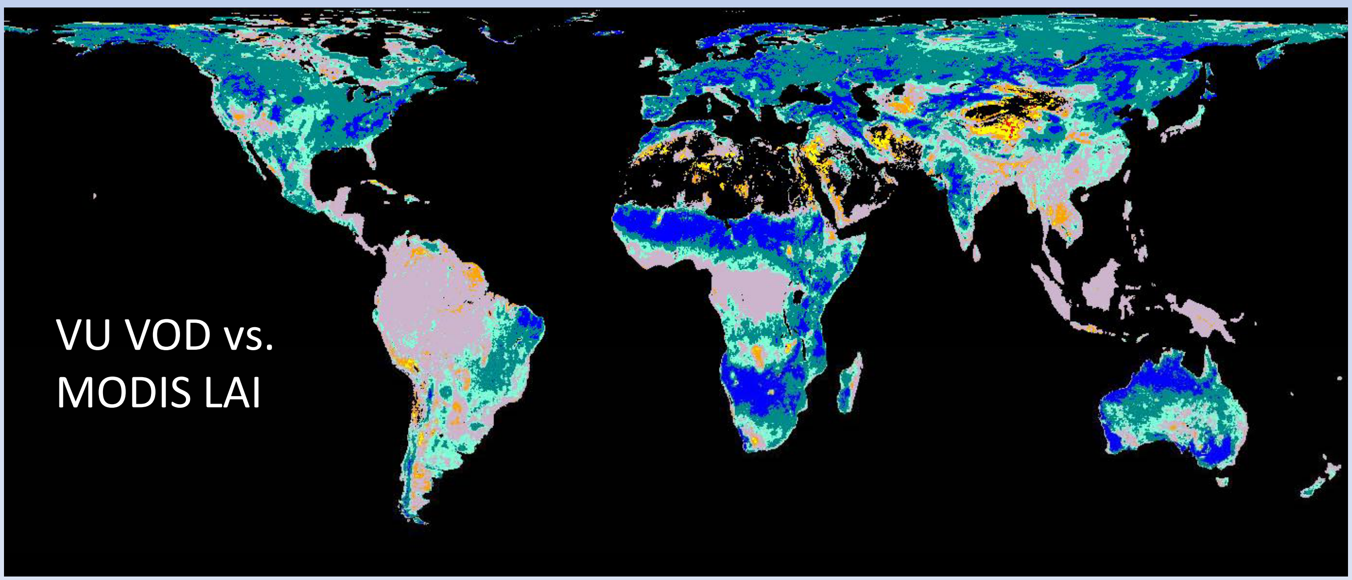
Daily Anomaly Comparison



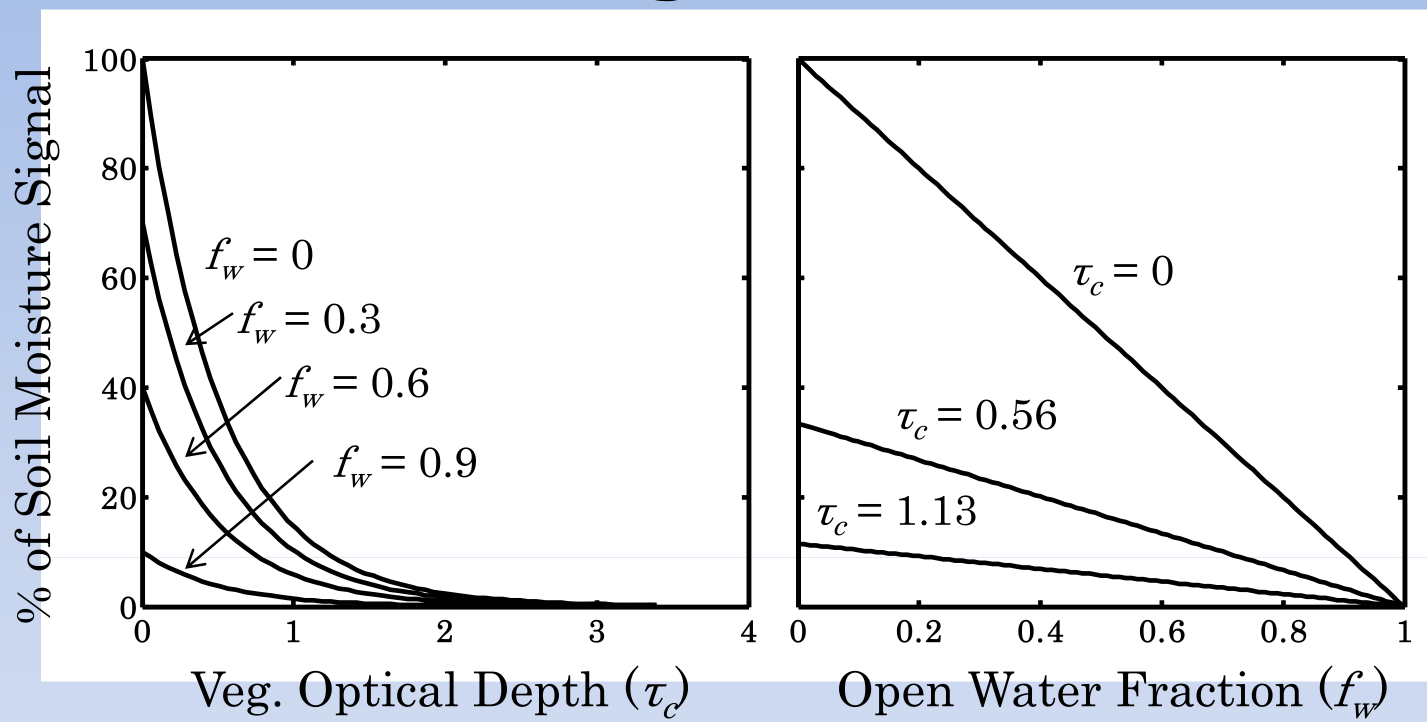
Seasonal Anomaly Comparison




UMT VOD vs.
MODIS LAI
No data
-1.0
-.75
-.5
-.25
.25
.5
.75
1.0


VU VOD vs.
MODIS LAI

Basis for separating land And water grid cell fractions



The soil moisture sensitivity range (10.7 GHz *Tbh* (0.05)-*Tbh*(*field capacity*)) declines exponentially with increasing vegetation and only linearly with increasing open water.

Basic RTE for Atmosphere and Surface

Brightness Temperature observed by AMSR-E:

$$Tb_{(f,p)} = ta_{(f)}Ts * \varepsilon_{(f,p)} + ta_{(f)}(1 - \epsilon_{(f,p)})(Tbd_{(f)} + ta_{(f)}Tc) + Tbu_{(f)}$$

Surface Emissivity:

$$\varepsilon_{(f,p)} = fw * \varepsilon w_{(f,p)} + (1 - fw)[(\varepsilon s_{(f,p)} - 1 + \omega_{(f,p)})tc_{(f)} + 1 - \omega_{(f)}]$$

Functional form for atmospheric contributions:

$$Tbd_f = (1 - ta_{(f)})Tm \qquad Tbu_f = (1 - ta_{(f)})Tm * du$$

$$Tm = \mathbf{F}(V)$$ or $$Tm = Ts * dm$$

Linear form if atmospheric contribution is specified:

$$Tb_{(f,p)} = (ta_{(f)}Ts - Qd_{(f)}Tm)\varepsilon_{f,p} + (Qd_{(f)} + Qu_{(f)})Tm$$

$$Qd_{(f)} = ta_{(f)}(1 - ta_f)(Tm + ta_{(f)}Tc)$$

$$Qu_{(f)} = (1 - ta_f)Tm * du$$

Expressions for MAWVI and Atmospheric Opacity

$$MAWVI = \frac{Tb_{v23} - Tb_{h23} + \beta_1}{Tb_{v18} - Tb_{h18} + \beta_2}$$

$$ta_{(f)} = \exp[-\frac{a(f,O) + a(f,V)}{cos(\theta)}]$$

$$V = \frac{\frac{1}{2}\log[\frac{MAWVI}{B}]cos(\theta) + ao_{23} - ao18}{av_{18} - av_{23}}$$

$$B = \frac{\varepsilon_{v23} - \varepsilon_{h23}}{\varepsilon_{v18} - \varepsilon_{h18}}$$

Algorithm Configurations

Original: Use Tm = Ts*dm. Neglect reflections for atmosphere/surface and veg/soil. Use Tbh/Tbv, Tbh23/Tbv18, and MAWVI. Iterate to find V, invert surface expression for tc/fw analytically in each step. Calculate Ts given V/tc/fw.

1. **Use Tm = Ts*dm:** Use Tbh/Tbv, Tbv23/Tbv18, Tbh23/Tbh18, and MAWVI. Solve for V using regression. Invert surface expression for tc/fw using specified V (linear). Calculate Ts given V/tc/fw.

2. **Use Tm = F(V):** Use Tbh,Tbv and MAWVI. Solve for V using regression. Invert surface expression for Ts/tc/fw using specified V (linear).

3. **Solve for dm (hold fw=0)**: Tbh/Tbv, Tbv23/Tbv18, Tbh23/Tbh18, and MAWVI. Solve for V using regression. Invert surface expression for tc/dm using specified V (linear). Calculate Ts given V/tc/dm.

NOTE: Impossible to solve for both fw and dm. All new configs. (1-3) can be used to estimate V (non-linearly) using MAWVI as long as Tm is properly specified.

Algorithm Numerics

From Rodgers (1976)

$\mathbf{x}$ parameters (Ts,VOD, V, fw)

$\mathbf{y}$ measurements (Tb, Tb ratios, or re-arranged RT constant terms)

$\mathbf{x_0}$ prior guess at parameters

$\mathbf{S_x}$ covariance of parameters about prior

$\mathbf{S_y}$ error Covariance of measurements

<u>Linear form (do once):</u>

$$\hat{\mathbf{y}} = \mathbf{A}\mathbf{x}$$

$$\mathbf{E} = \mathbf{y} - \mathbf{A}\mathbf{x_0}$$
$$\mathbf{K} = \mathbf{S_x}\mathbf{A}'(\mathbf{A}\mathbf{S_x}\mathbf{A}' + \mathbf{S_y})^{-1}$$

<u>Non-linear form (iterate):</u>

$$(\hat{\mathbf{y}}_\mathbf{i}, \mathbf{J_i}) = \mathbf{F}(\mathbf{x})$$

for $i = 1, ..., n$

$$\mathbf{E} = \mathbf{y} - \hat{\mathbf{y}}_\mathbf{i} - \mathbf{J_i}(\mathbf{x_0} - \mathbf{x_i})$$
$$\mathbf{K_i} = \mathbf{S_x}\mathbf{J_i'}(\mathbf{J_i}\mathbf{S_x}\mathbf{J_i'} + \mathbf{S_y})^{-1}$$
$$\mathbf{x_i} = \mathbf{x_0} + \mathbf{K_i}\mathbf{E_i}$$

Why use a linear surface RTE?

Linear Model

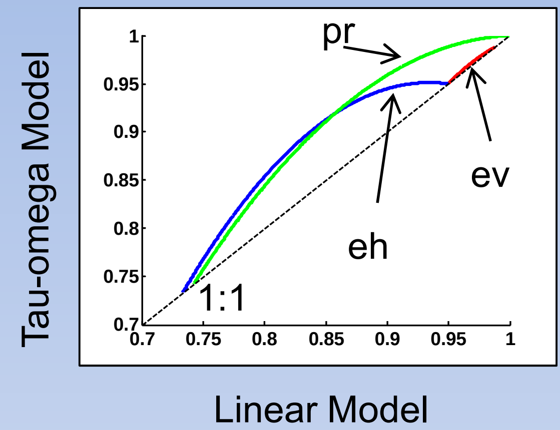
$$\varepsilon_{(f,p)} = \varepsilon s_{(f,p)} tc_{(f)} + (1 - tc_{(f)})(1 - \omega_{(f)})$$

Tau-omega (quadratic) Model

$$\varepsilon_{(f,p)} = \varepsilon s_{(f,p)} tc_{(f)} + (1 - tc_{(f)})(1 - \omega_{(f)})[1 + (1 - \varepsilon s_{(f,p)} tc_{(f)}]$$

- Linear easier to deal with analytically.
- Tau-omega can have local minimums in cost function space (frequency ratios are no longer simple monotonic functions of *tc*), posing problems for iterative algorithms.
- Linear might be a better fit for both surface roughness and vegetation.
- No obvious advantage to using tau-omega suggested by the emissivity data.

Why use a linear surface RTE? (cont.)



All LC Types (fw<0.05):

Linear Model   Tau-omega Model