Aquarius Soil Moisture Retrieval

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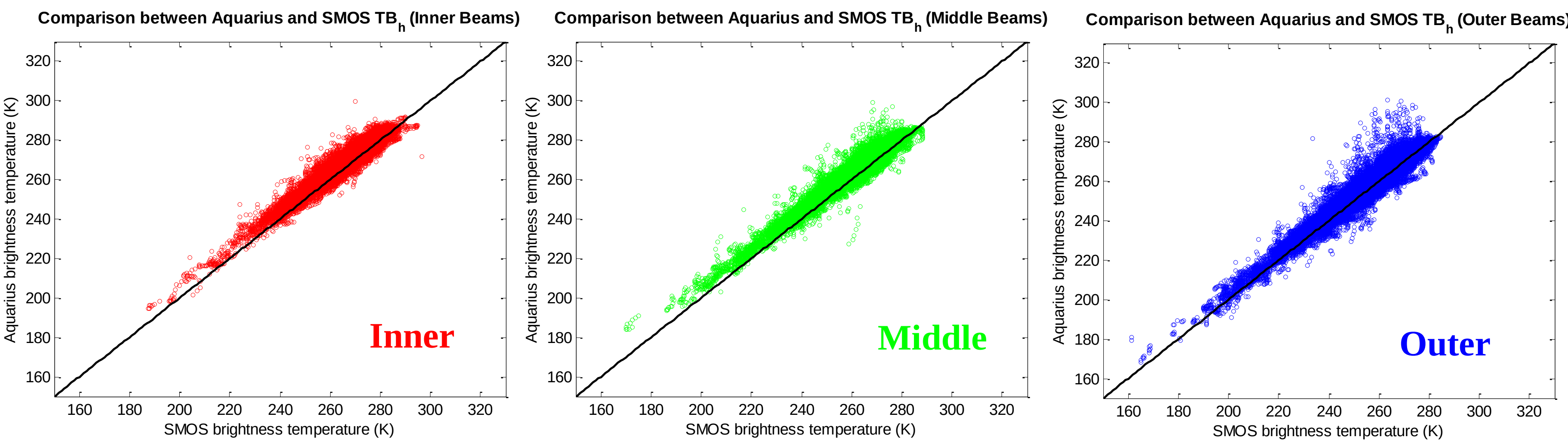
Overview

- Aquarius L-band brightness temperature over land
- Soil moisture retrievals
- Vegetation parameterization using Aquarius backscatter data
- Land surface temperature and the MWR

Inter-comparison Between Aquarius and SMOS TB Observations: Methodology

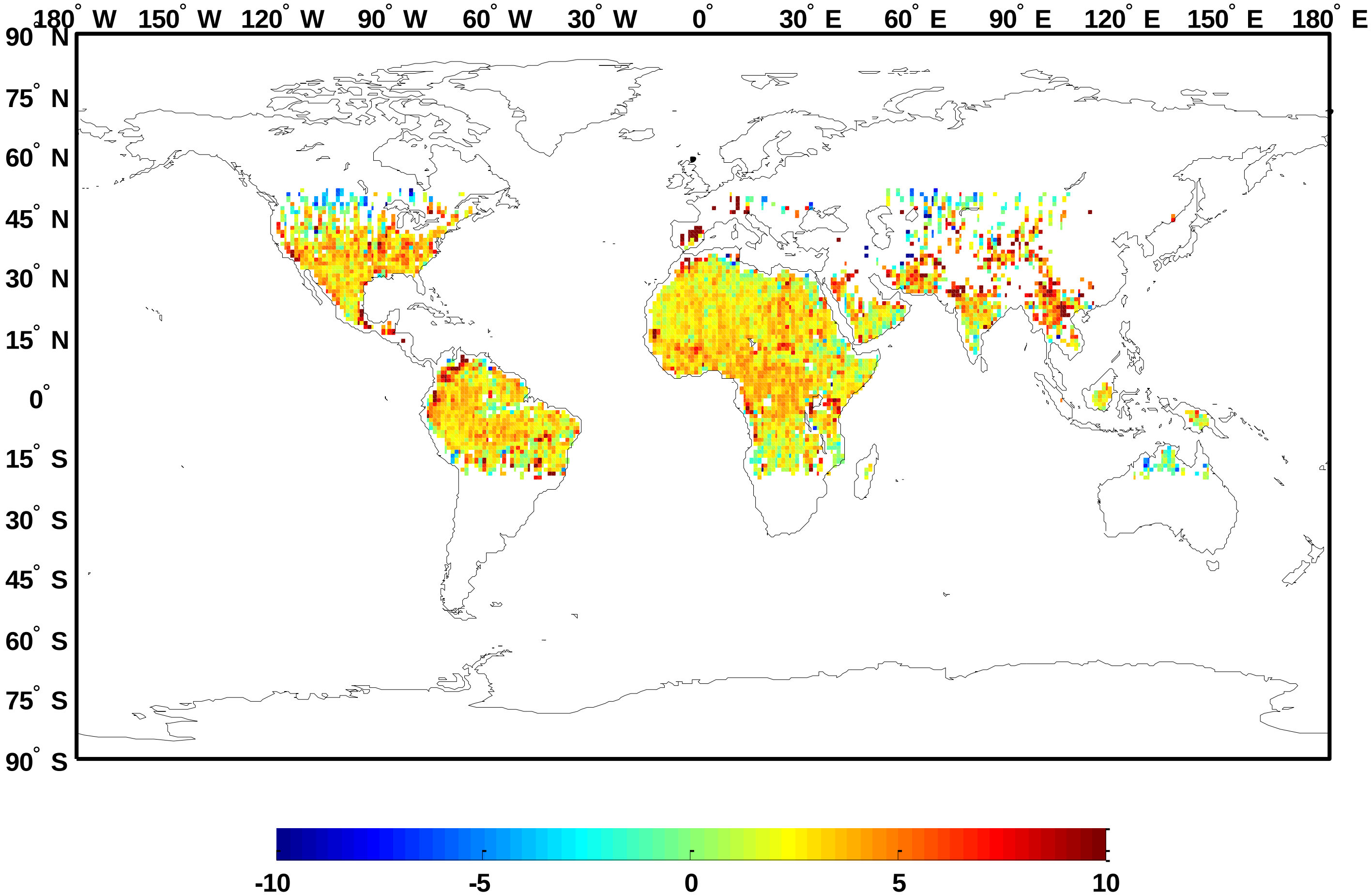
- Recognize that during C/V that there will be some possible calibration issues but before we started to look at SM retrievals we needed to know if the data were reasonable
- Approach: Use SMOS as a tool in assessing the calibration of the Aquarius radiometer over land (under the assumption that SMOS is a well calibrated L-band radiometer)
- Aquarius data Version 1.2.2
- Period of record : August 25, 2011 – February 29, 2012
- Land (and ocean)
- Concurrent SMOS and Aquarius observations within 30 min (results in data only between latitudes [40, -40])
- Same incidence angle (after re-processing SMOS data)
- Only alias free portions of SMOS observations
- Processing notes:
  - Multiple SMOS DGG locations within a single Aquarius footprint
  - Min number of SMOS observations per Aquarius footprint required– 20 (to minimize partial Aquarius footprint coverage)
  - Std. Dev. of SMOS data averaged < 5 K (land) and 1K (ocean) (to minimize footprint variability; also results in screening RFI)
  - Differences in azimuth angle and orientation of the footprints ignored

Comparison Between Aquarius and SMOS over Land (h-pol)



- Scatter increases with angle
- ~RMSE 4K
- ~Bias 3K (Aquarius>SMOS)

Difference between Aquarius TB and SMOS TB (K)



- Vegetated regions > non-vegetated regions
- Asia...RFI?

Comments

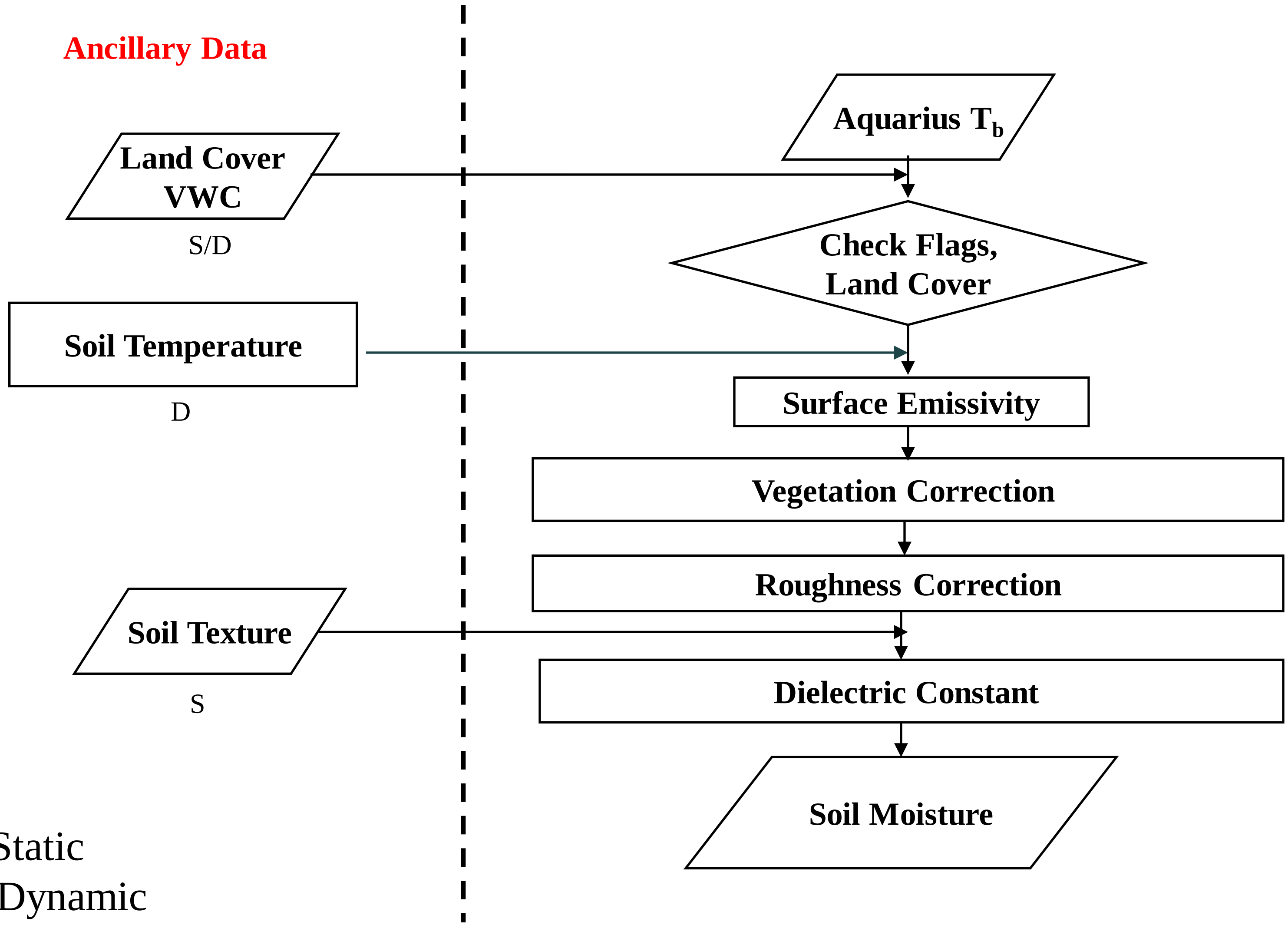
- Intercomparison results: Not too bad.....expecting improvements
- Scatter due to:
  - RFI (possible RFI in SMOS/Aquarius)
  - Heterogeneous footprint
  - Different azimuth angles
  - Noise in SMOS data
- Other analyses include vicarious calibration sites (ocean, Amazon, Dome-C)
- Note: 3K bias with Aquarius ~ 0.01-0.02 m^3/m^3 underestimation of soil moisture

Aquarius Soil Moisture Retrieval

Passive Soil Moisture Algorithm

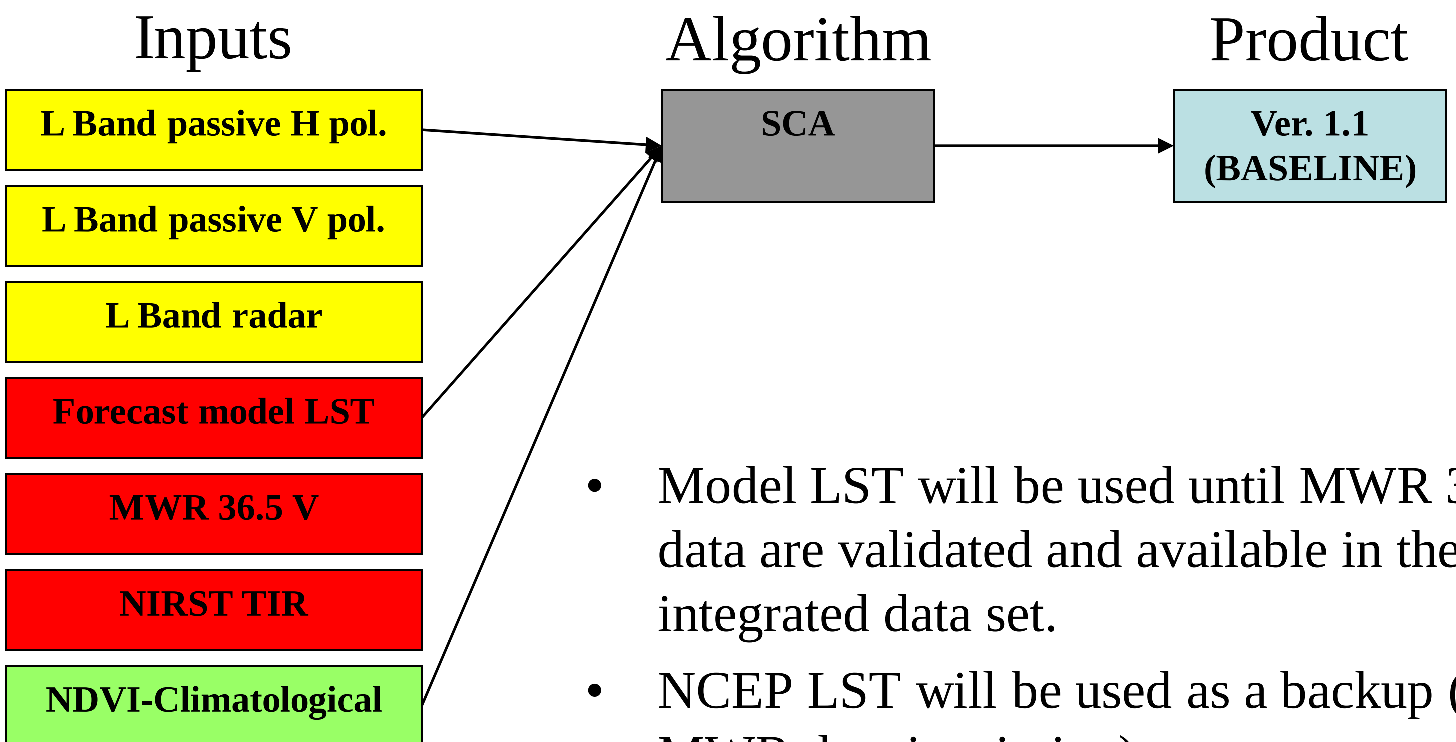
- The baseline soil moisture algorithm uses the radiative transfer equation ($\tau-\omega$ model) and H pol observations along with ancillary data to estimate soil moisture.
- Same as the baseline SMAP L2 Soil Moisture algorithm, referred to as the Single Channel Algorithm (SCA).
- A difference between the Aquarius and SMAP implementation is the need to incorporate incidence angle effects.
  - Already included in the radiative transfer equation but have not been rigorously evaluated on a global basis.

SCA Soil Moisture Retrieval (Ver. 1)



S-Static
D-Dynamic

Aquarius/SAC-D Soil Moisture Retrieval Ver. 1



- Model LST will be used until MWR 36.5 V data are validated and available in the integrated data set.
- NCEP LST will be used as a backup (in case MWR data is missing)

Aquarius Soil Moisture Algorithm and Incidence Angle

- Passive algorithm:
  - τ-ω model

$$TB = T_{soil}(1 - R_{soil}) \exp^{-\tau\cos\theta} + T_{veg}(1 - \omega)(1 - \exp^{-\tau\cos\theta})(1 + R_{soil}\exp^{-\tau\cos\theta})$$

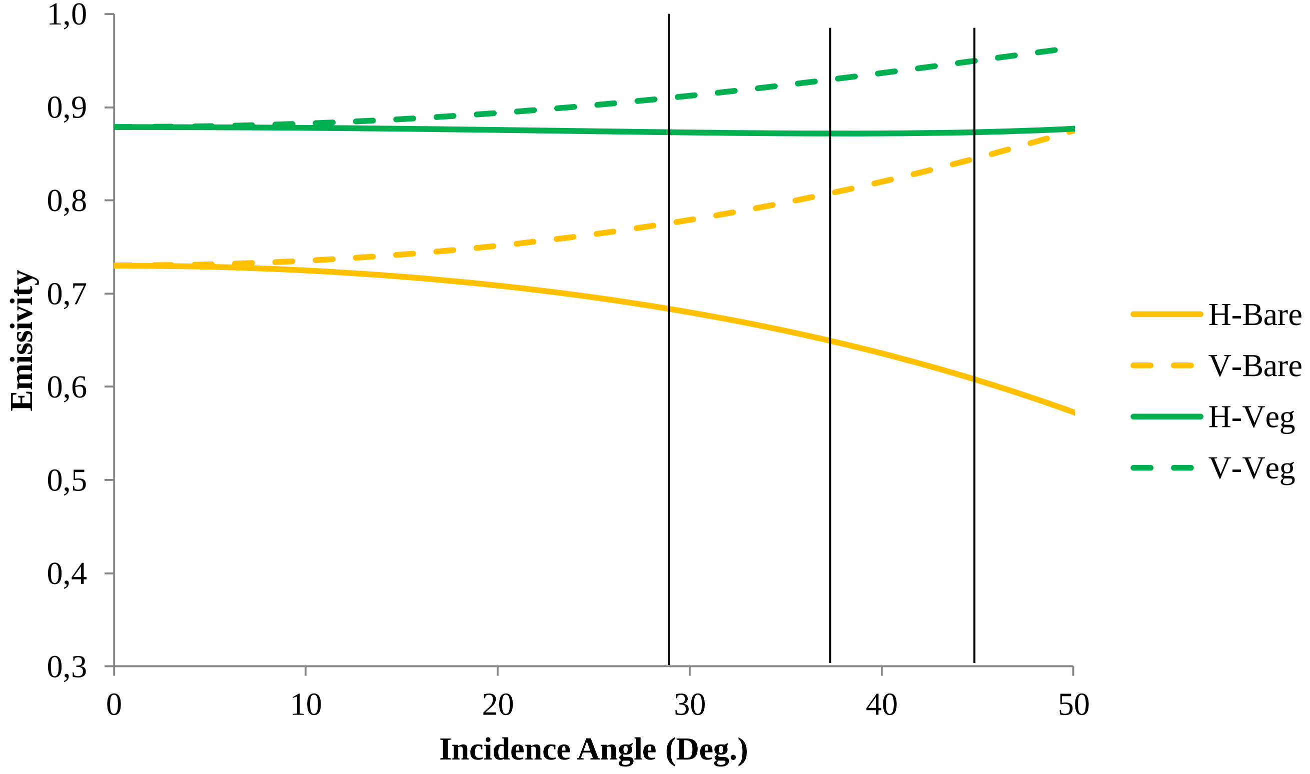
  - Fresnel equation (Horizontal Polarization)

$$R_{Soil}(\theta) = \left| \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right|^2$$

- Earlier soil moisture efforts have focused on retrievals using constant incidence angle (conical scanners)
- Do we need to develop an incidence angle correction?
  - Note: Incidence angle is already incorporated into both the τ-ω and Fresnel equations
- Critical issue in using all three Aquarius beams

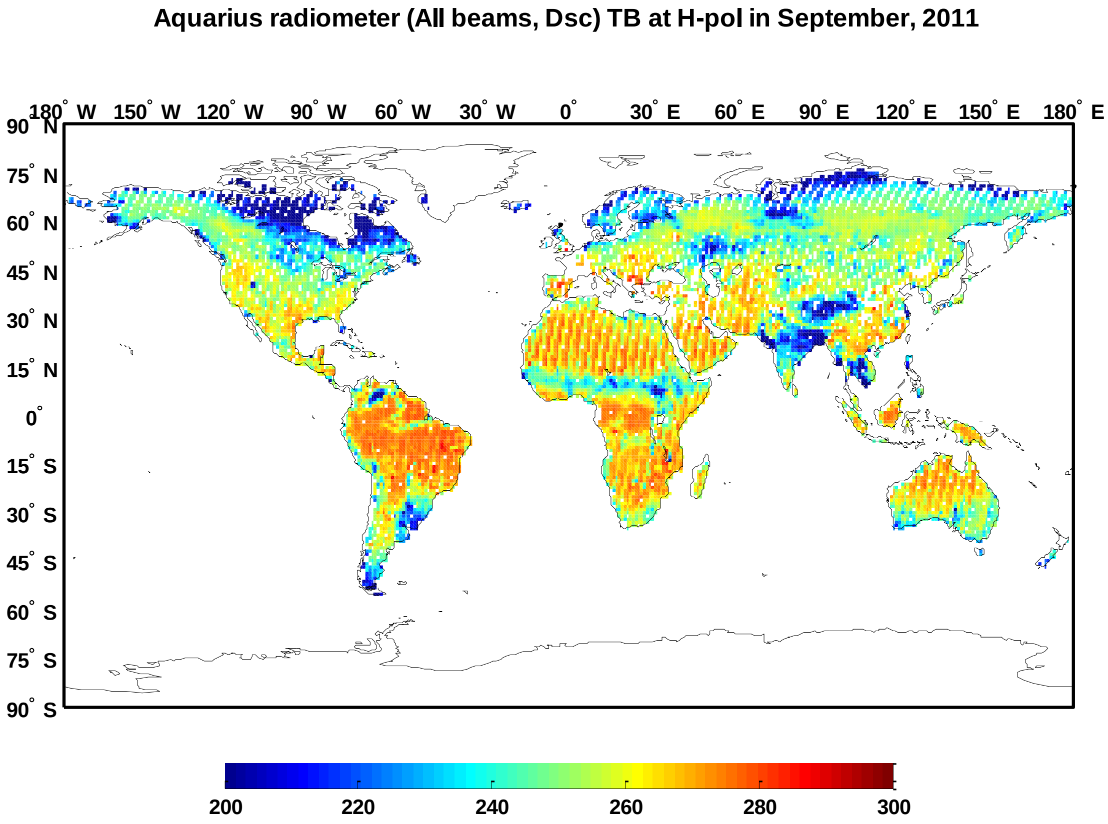
Incidence Angle and Vegetation

- As vegetation optical depth increases – effect of incidence angle decreases



Aquarius TB-H and Incidence Angle

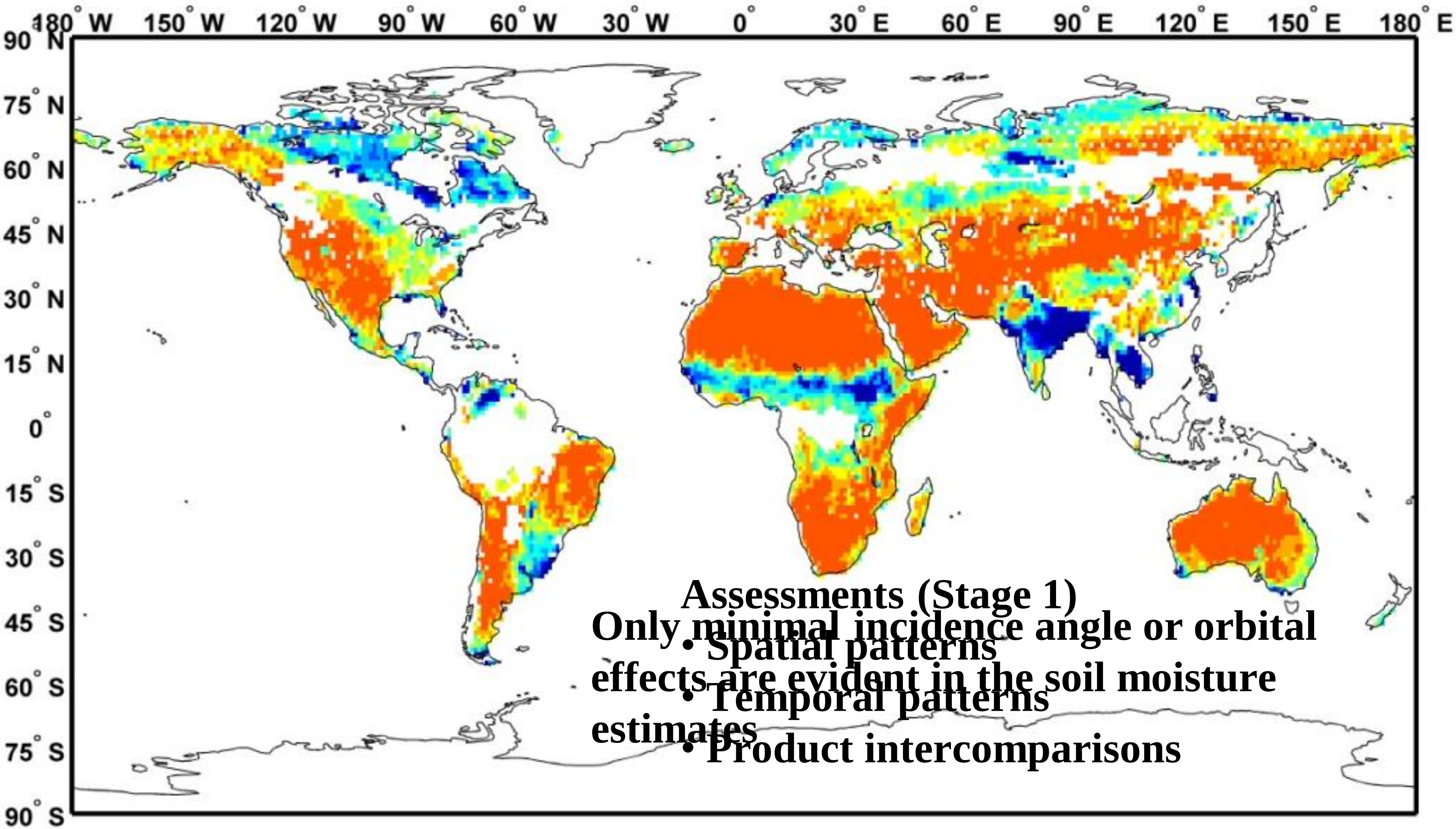
- This image shows all descending TB-H data collected during Sept. 2011.
- Incidence angle effects are stronger over arid regions and areas with low vegetation optical depth
- Spatial patterns are consistent with incidence angle and vegetation.



Obvious incidence angle or orbital effects

Aquarius SCA Soil Moisture

Sept. 2011 Composite (Asc. and Dsc.)



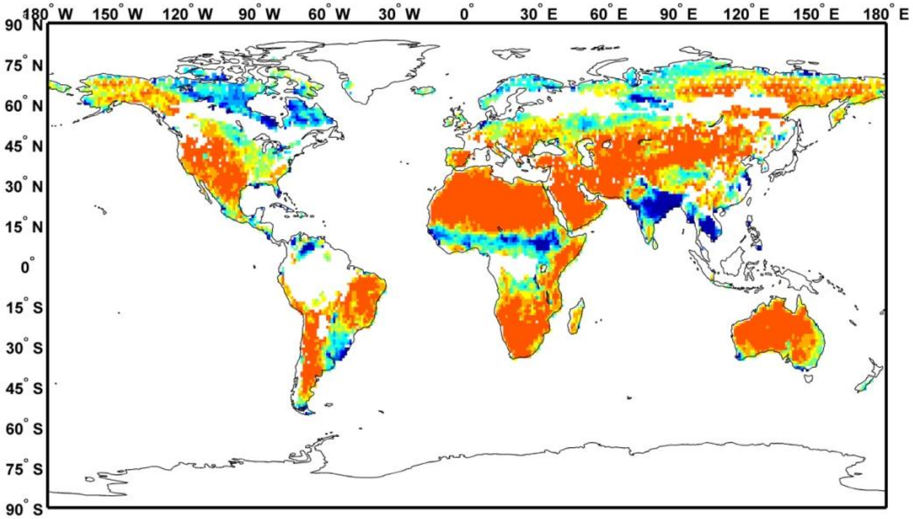
Assessments (Stage 1)

- **Spatial patterns**
- **Temporal patterns**
- **Product intercomparisons**

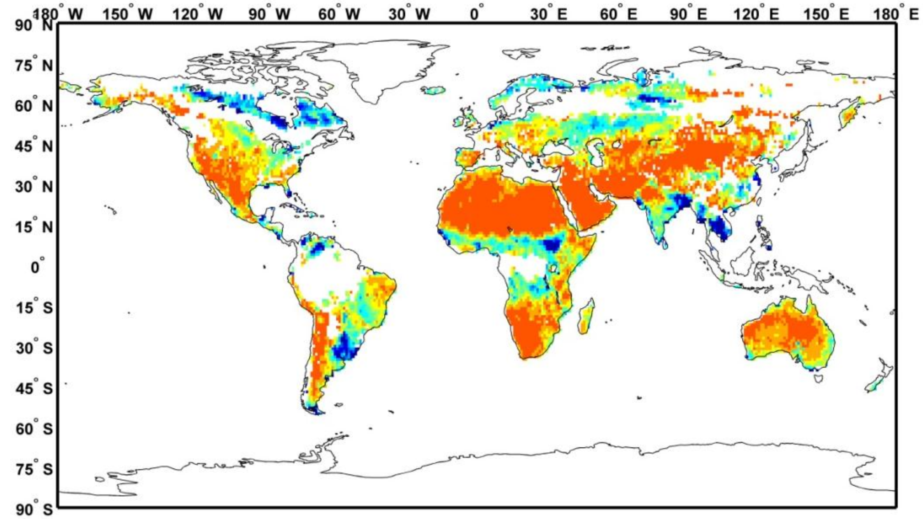
Only minimal incidence angle or orbital effects are evident in the soil moisture estimates

Monthly Aquarius Soil Moisture

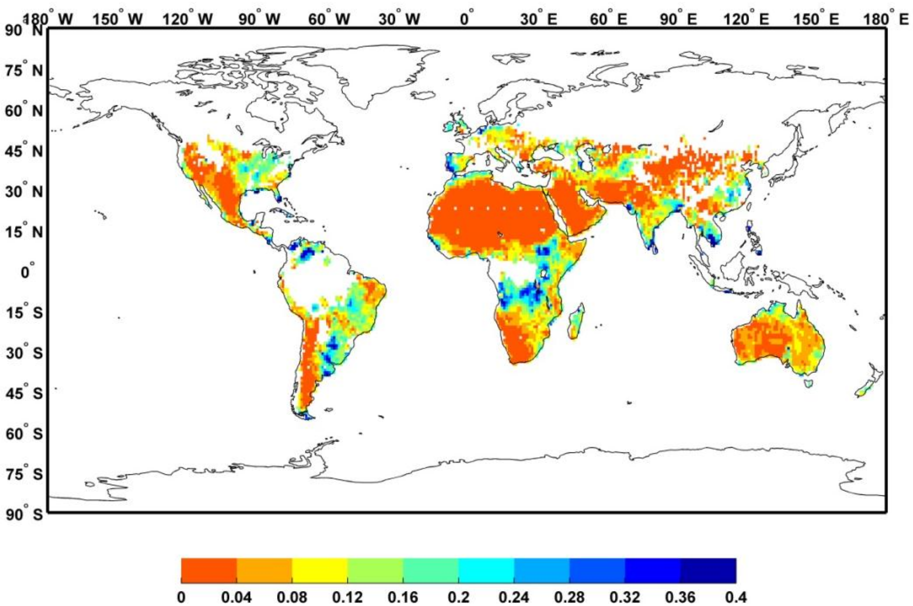
September 2011



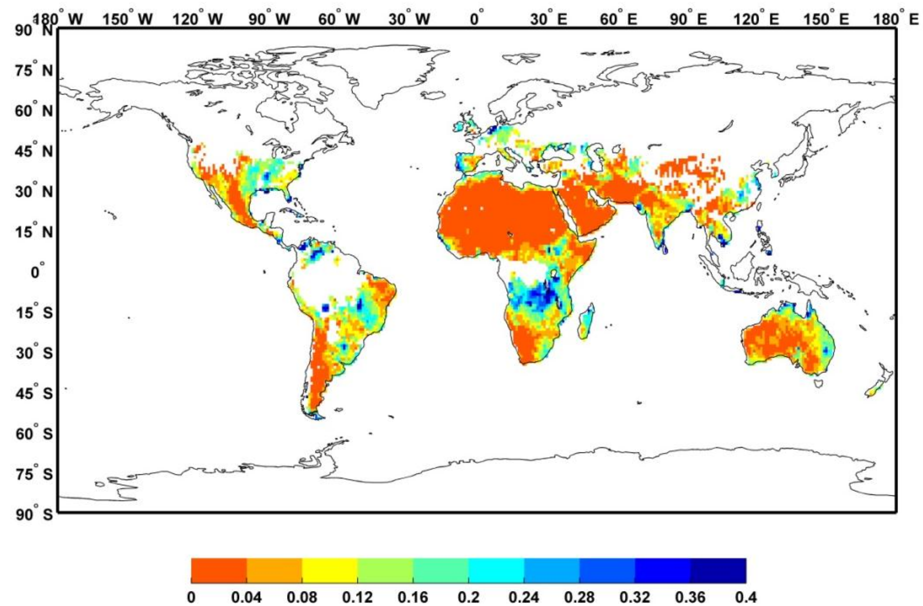
October 2011



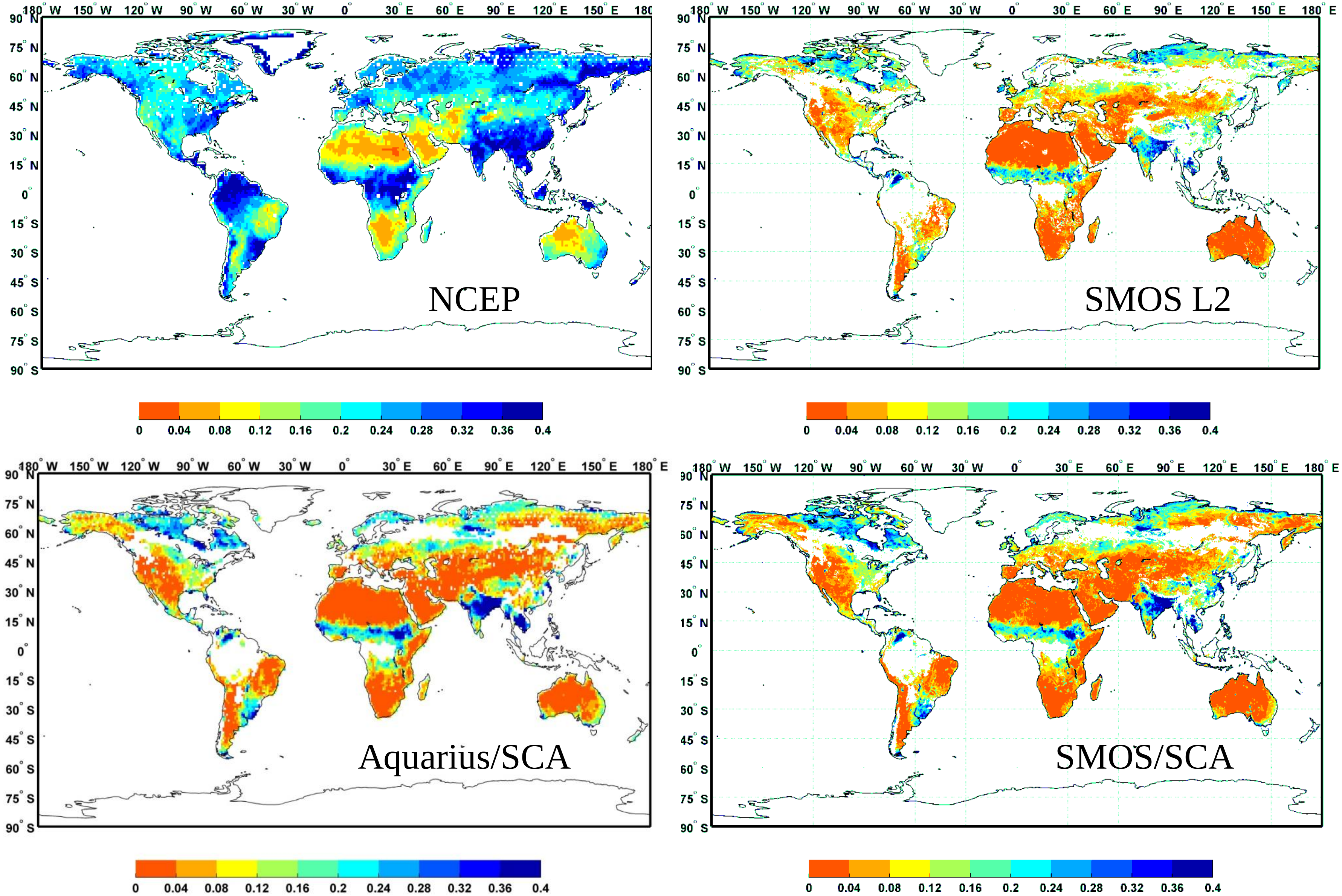
November 2011



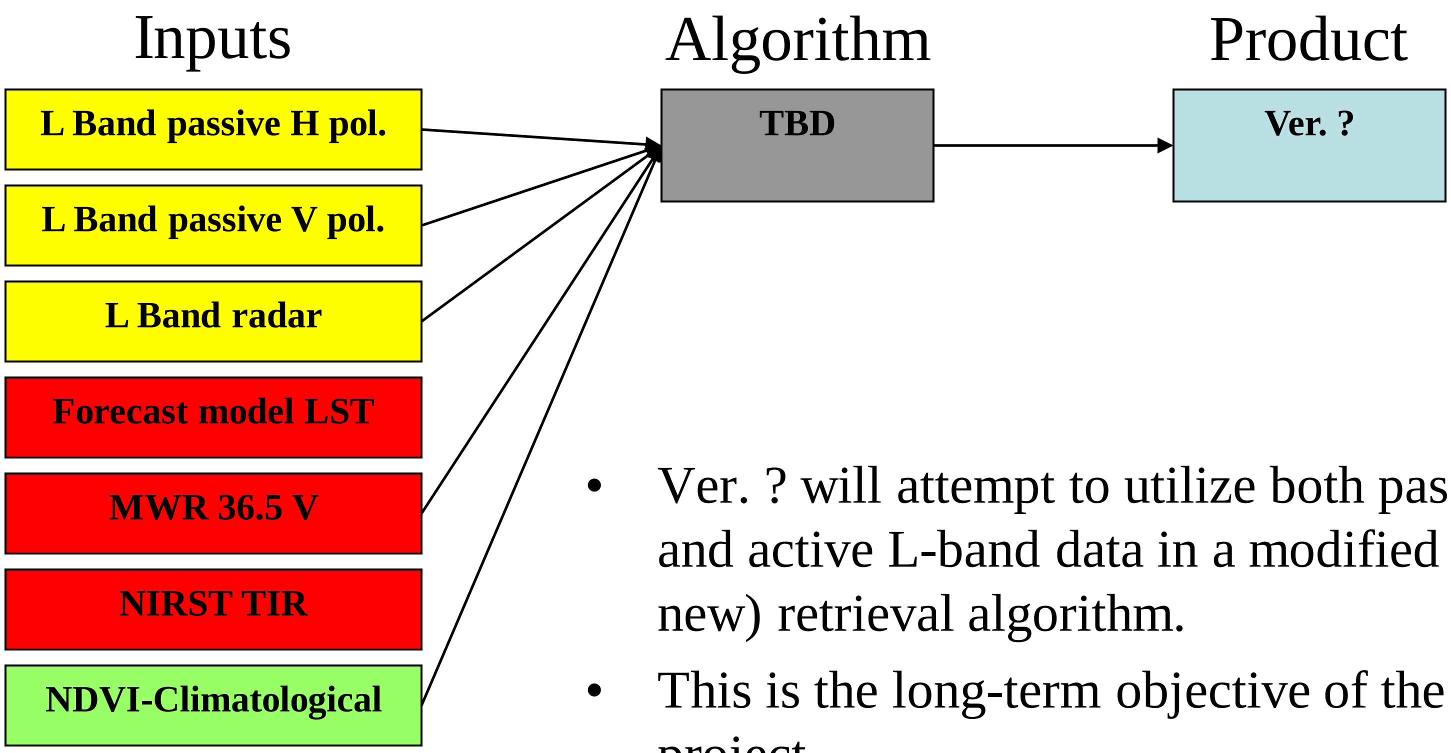
December 2011



Four Global Soil Moisture Products (Sept. 2011)



Aquarius/SAC-D Soil Moisture Retrieval Ver. ?



- Ver. ? will attempt to utilize both passive and active L-band data in a modified (or new) retrieval algorithm.
- This is the long-term objective of the project.
- New vegetation and LST products from Aquarius/SAC-D will be required.

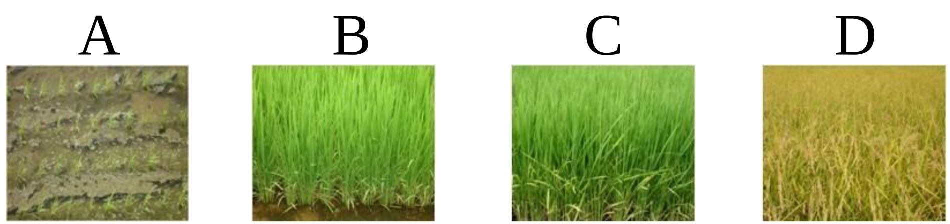
Vegetation Information from Radar Data

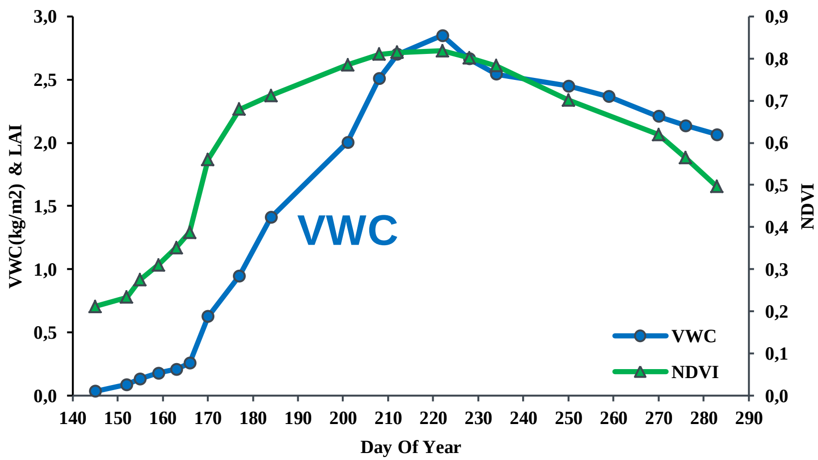
- It is well known that radar responds to variations in electrical and structural properties of vegetation.
- Polarimetric measurements and indices such as the Radar Vegetation Index (RVI) may provide information that can be used in soil moisture algorithms.

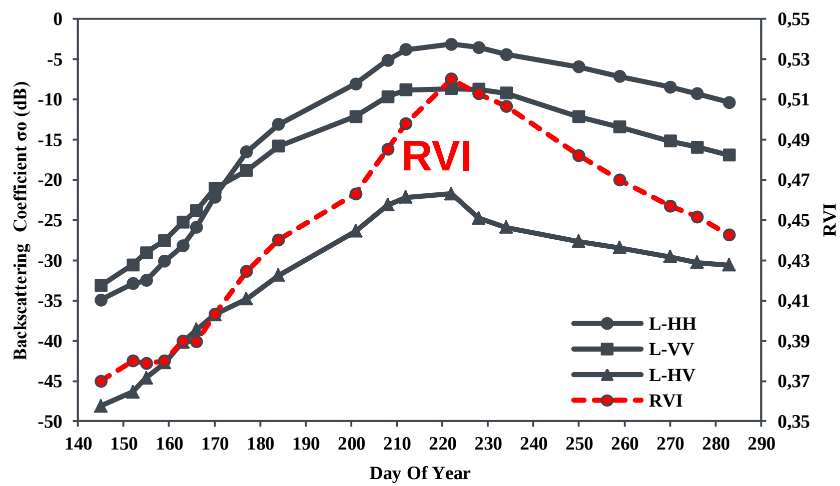
$$RVI = \frac{8\sigma_{HV}}{\sigma_{HH} + \sigma_{VV} + 2\sigma_{HV}}$$

- RVI generally ranges between 0 and 1; near zero for a smooth bare surface and increases as the vegetation grows
- RVI is a measure of the randomness of the scattering
- Some examples of polarimetric measurements and vegetation parameters over a crop growing season (including RVI).

Seasonal Patterns of L-band Backscatter, and Vegetation Parameters for Flooded Rice (Kim et al. 2012)

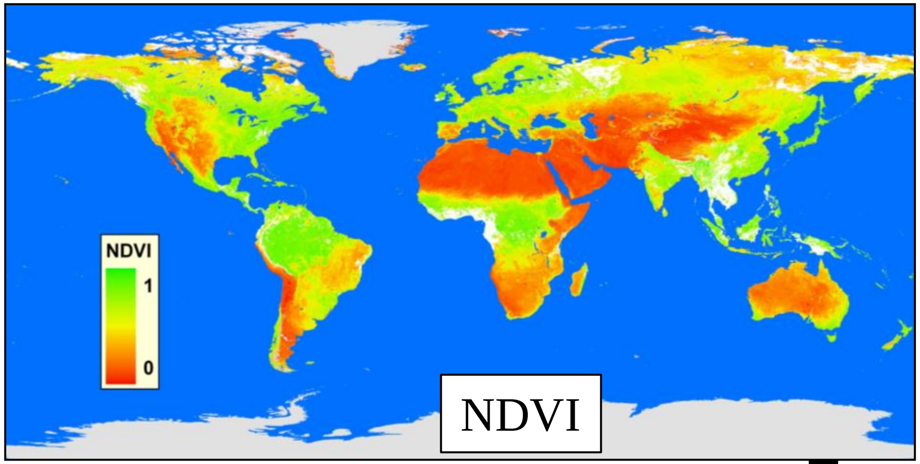


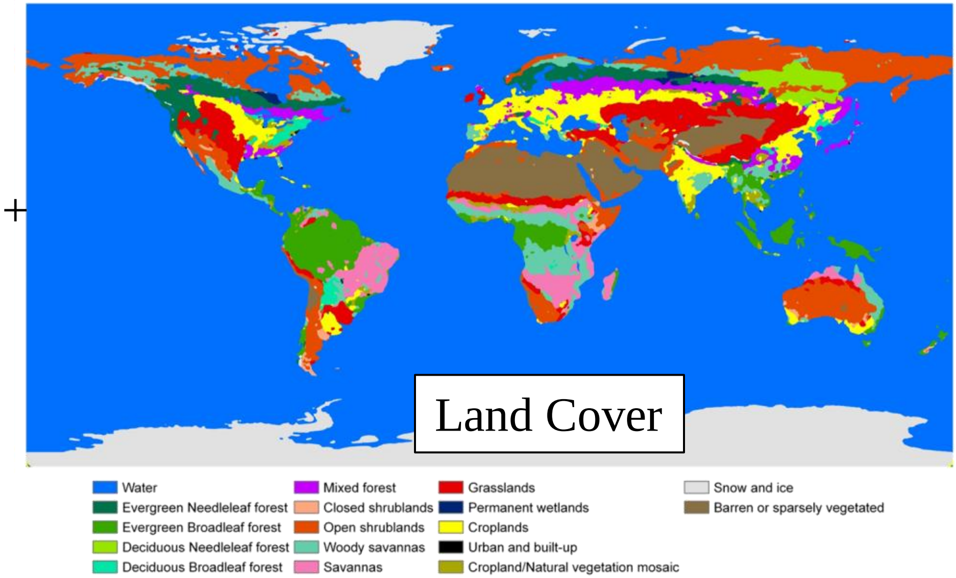


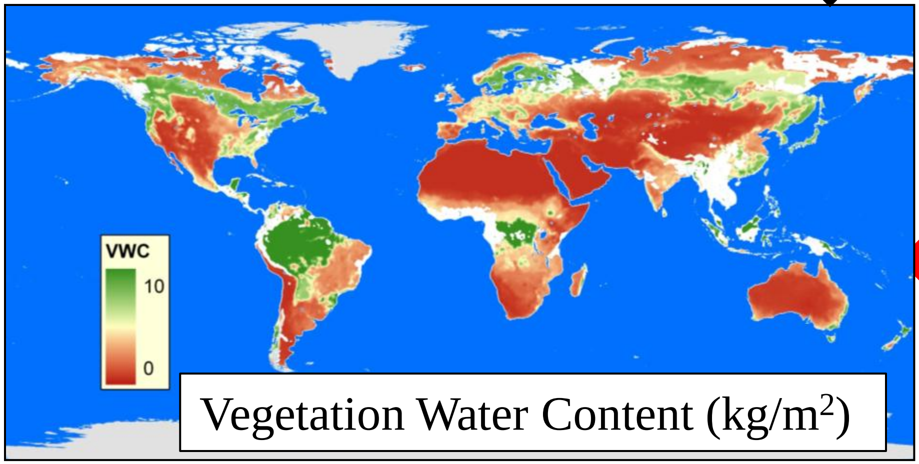


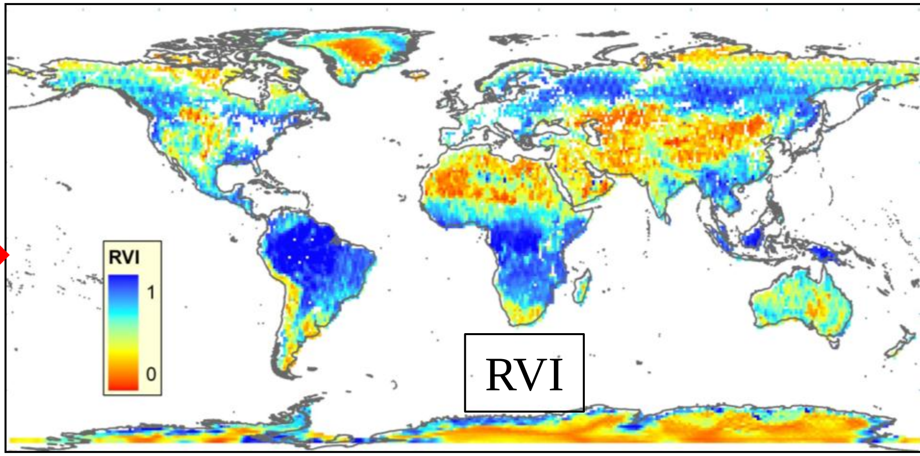
- The baseline algorithm uses NDVI to estimate VWC.
- RVI is very similar to VWC....for this case.

Global Aquarius RVI (Sept. 11-17, 2011)









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$$RVI = \frac{8\sigma_{HV}}{\sigma_{HH} + \sigma_{VV} + 2\sigma_{HV}}$$

- Must proceed carefully
  - RVI has not been rigorously validated for a range of cover types
  - Since it utilizes multiple polarization backscatter and is highly dependent cross-pol, all channels must be well-calibrated
  - Aquarius provides coarse resolution observations. The validity of this methodology for different land covers and over heterogeneous domains needs to be examined.

Land Surface Temperature (LST)

- Required for all SM algorithms (T_B to emissivity)
- Options
  - Numerical Weather Forecast Model products
    - SMOS and SMAP approach
    - Several options and resolutions (NCEP, MERRA, ECMWF)
      - Currently NCEP product is integrated in the Aquarius L2 data
  - MWR 36.5 GHz V algorithm
    - All AMSR-E approaches use a variation of this
    - Heritage from SSM/I, TMI, AMSR-E, and WindSat
    - Potential mission product
    - Data integration issues?
    - Added capability to detect active precipitation, snow

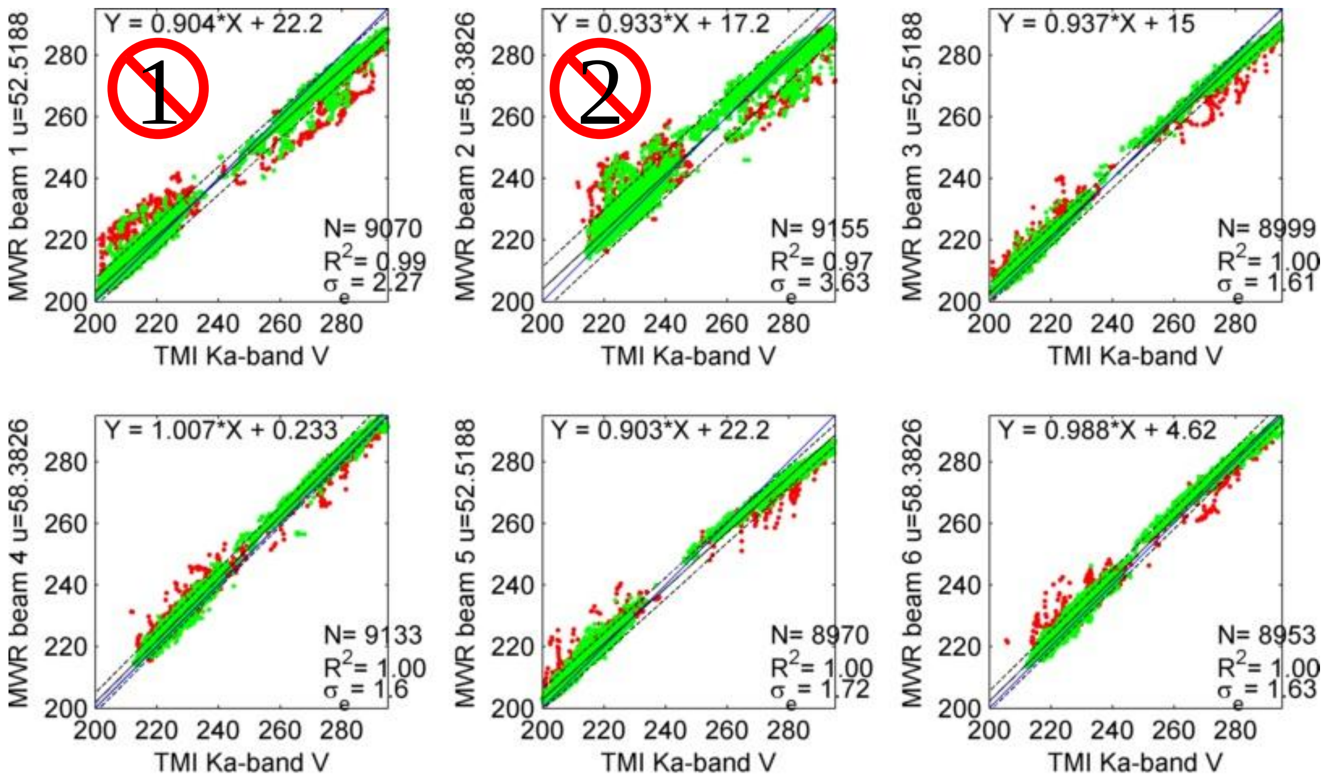
Microwave Radiometer (MWR) Evaluation over Land Using TRMM –TMI Data

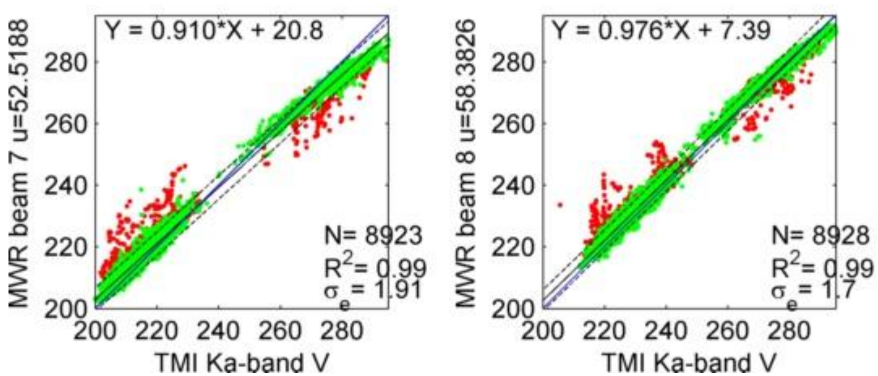
- Goal: Use MWR-based LST instead of NCEP forecast product
- Objective of initial evaluation: Assessment of the MWR Ka-band data over land as a preliminary step
- Focus of MWR initial calibration was over the ocean with (almost) coincident WindSat observations by Biswas, Jones, et al.: MWR_L1_V4.0
- Here we conducted an independent evaluation using TRMM-TMI data

Data Set Description

	SAC-D/Aquarius MWR	TRMM-TMI
Time-span	August 30, 2011 - Present	December 1997 - Present
Overlap available	November 1, 2011 to February 1, 2012	
Orbit	Polar Orbiting: 6AM/PM at Equator	Equatorial, varying overpass time
Ka-band Frequency	36.5 GHz	37.0 GHz
Earth incidence angle	4 X ~52.5, 4 X ~58.3	52.8
Spatial resolution	47 km	16x9 km
Scan	Non-scanning: 8 beams	Scanning 880 km swath

Plots of TB for Individual Beam Positions





- Red indicates near coast
- Computations only used the green points (>2^o from coast)
- Not concerned about slope or offset….just the scatter
- Based on these very preliminary results, beams 1 and beam 2 have very large scatter (SE>2 K)

Comments

- The comparison of MWR and concurrent TMI observations is more noisy than observed with previous studies of AMSR-E, SSM/I and WindSat
- This higher noise is partly due to the lower spatial resolution of the MWR, the effect of which is difficult to mitigate by downscaling TMI over land.
- Influence of the low ocean TB’s is detected as much as 100 km inland.

Summary

- Our initial approach to soil moisture retrieval uses the SCA with NCEP LST and MODIS NDVI climatology
  - Results are consistent with expected spatial patterns, SMOS, and model soil moisture.
  - Preliminary results are encouraging.
  - Effects of ongoing calibration activities are not expected to have a major impact on the soil moisture.
  - Next: Validation using in situ and alternative satellite SM products.
- The algorithm will be implemented in the Aquarius processor to provide a separate SM product. (Date: ??)
- Waiting on scatterometer and MWR calibrations to further investigate vegetation parameterization and LST.