Aquarius/SAC-D and Soil Moisture

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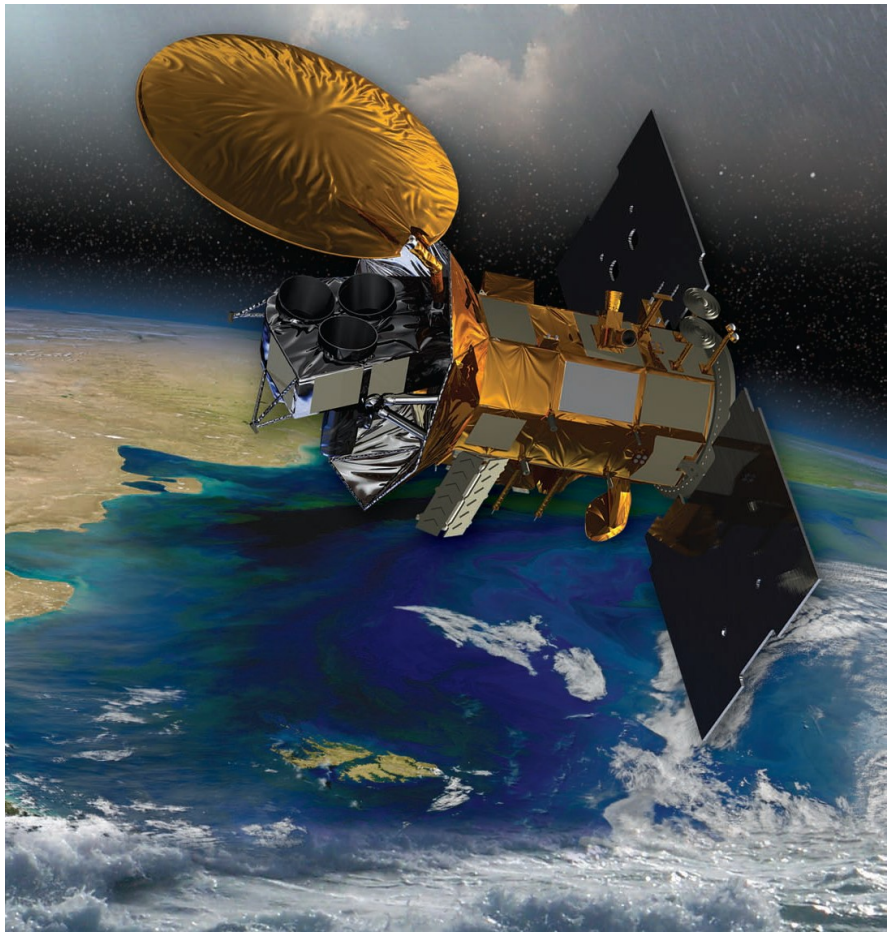
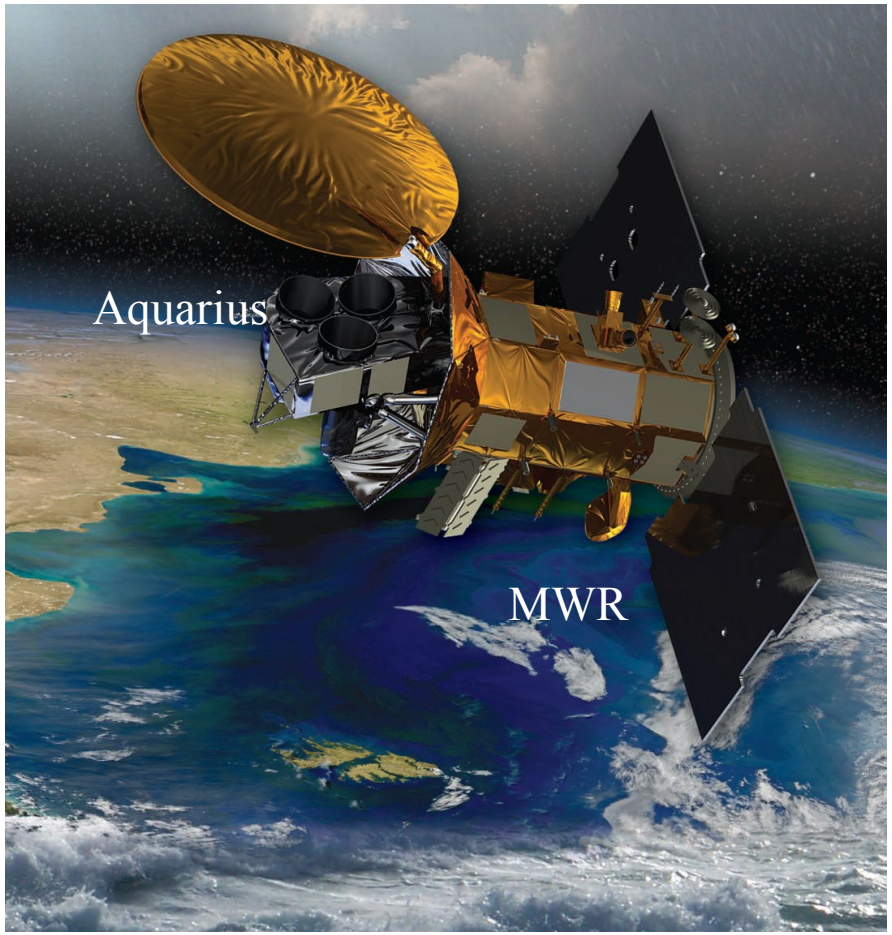


Aquarius/SAC-D and Soil Moisture

+ L-band dual polarization
+ Combined active and passive
- Coarse spatial resolution (~100 km)
- Reduced temporal frequency (7 days)
+ Exact repeat: 6 AM/PM
- Limited swath (3 fixed beams) (350 km)
+ SAC-D instruments
+ Launch June 2011 (no sooner)

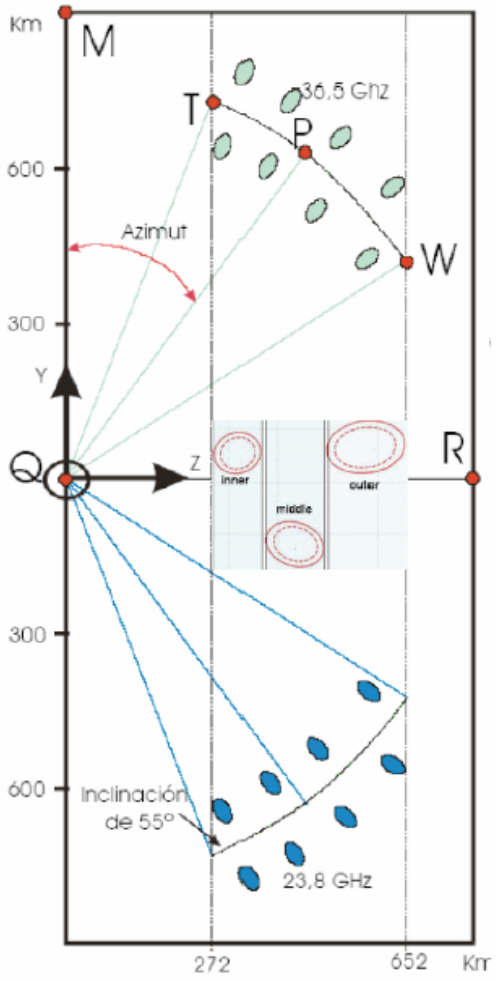


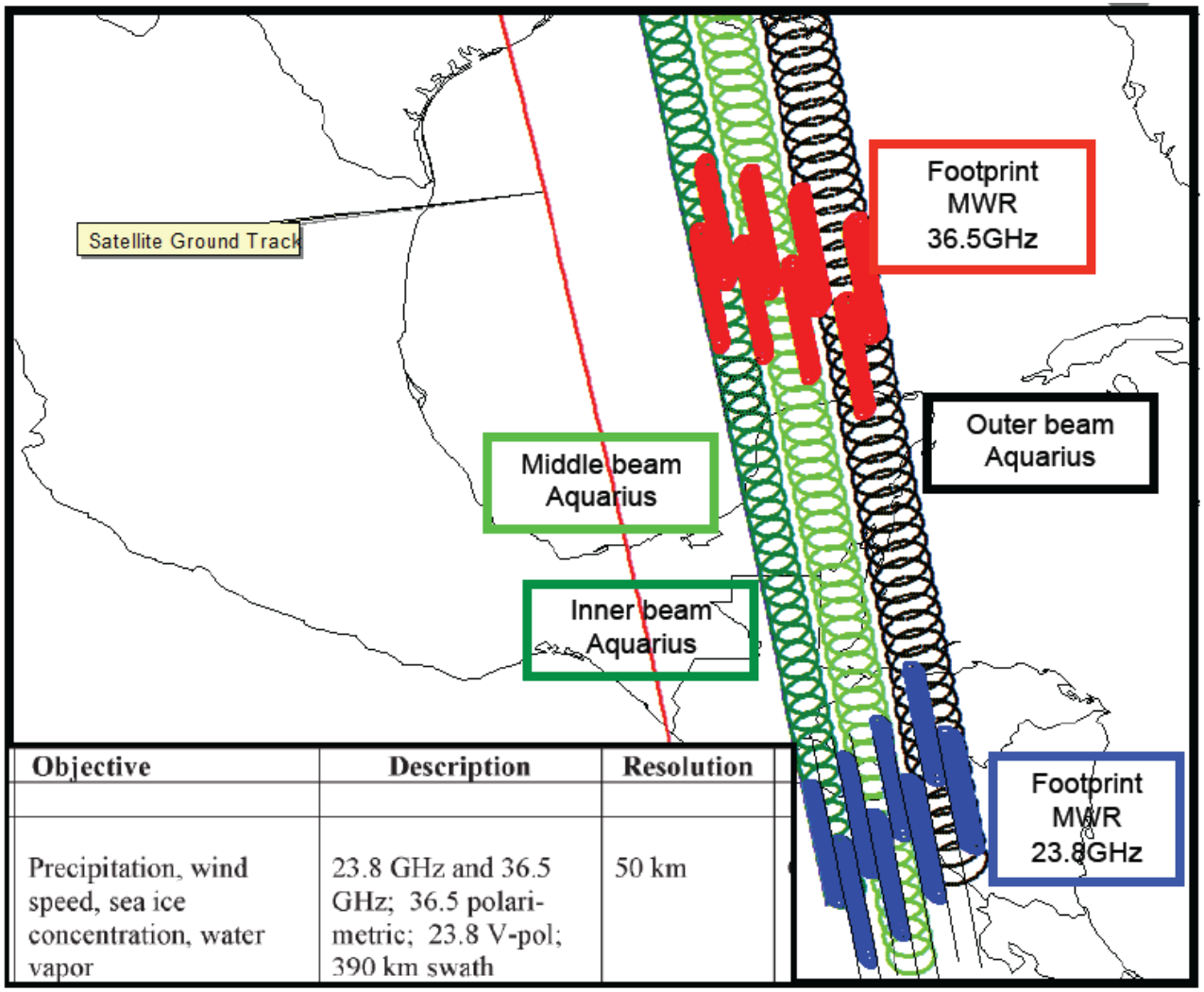
Aquarius/SAC-D Instruments

Aquarius/SAC-D Science Instruments				
Instrument	**Objective**	**Description**	**Resolution**	**Source**
Aquarius:	Sea Surface Salinity (SSS)	Integrated 1.413 GHz polarimetric radiometer, 1.26 GHz radar, 390 km swath	3 beams 76x94 km, 84x120 km, 96x156 km	NASA
MWR: Microwave Radiometer	Precipitation, wind speed, sea ice concentration, water vapor	23.8 GHz and 37 GHz; Dual polarized; 390 km swath	40 km	CONAE
NIRST: New IR Sensor Technology	Hot spots (fires); Sea Surface Temperature	Bands: 3.8, 10.7 and 11.7 μm Swath: 180 km;	350 meters	CONAE
HSC: High Sensitivity Camera	Urban lights; fires, Aurora	Bands: 450-900 nm; Swath: 700 km;	200-300 m	CONAE
DCS: Data Collection System	Environmental data collection	Band: 401.55 MHz uplink	2 contacts per day w 200 platforms	CONAE
ROSA: Radio Occultation Sounder for Atmosphere	Atmosphere temperature and humidity profiles	GPS occultation	Hor: 300 km Vert: 300 km	ASI (Italy)
CARMEN 1: (ICARE and SODAD)	ICARE: Effect of cosmic radiation on electronics; SODAD: Distribution micro-particles and space debris	ICARE: Three depleted Si and Si/Li detectors SODAD: Four SMOS sensors	I: 256 channels S: 0.5 μ at 20 km/s sensitivity	CNES (France)

Incidence Angles
29°, 38°, 46°

Aquarius/SAC-D Microwave Footprints





Objective	Description	Resolution
Precipitation, wind speed, sea ice concentration, water vapor	23.8 GHz and 36.5 GHz; 36.5 polari-metric; 23.8 V-pol; 390 km swath	50 km

Soil Moisture Retrieval Using Aquarius

- Approaches used with AMSR-E and SMAP L2/L3 Radiometer algorithms can be applied to Aquarius.
- The coarse spatial and temporal resolution may prove to be a limitations on the accuracy and utility of soil moisture from Aquarius.
- Opportunity to explore the use of coincident active and passive L-band observations. Cannot address the SMAP 10 km product issues.
- Availability of the MWR for LST.
- Need to address incidence angle differences of the Aquarius beams (and MWR).

Passive and Active Soil Moisture Algorithms

- Active microwave
  - No robust retrieval technique has been developed and validated for use with high resolution SAR data
    - Two decades of C-band (ERS, Radarsat, ...) and one decade of L-band (JERS, PALSAR)
    - Statistical and semi-empirical methods for specific sites/conditions, i.e. the Dubois model.
    - SMAP and SAOCOM are focusing on this problem.
  - Operational products have been developed using coarse resolution (50 km) C-band scatterometers
    - Temporal change technique.
    - Extended period of observations required to develop frequency specific calibration of each footprint!
    - Considered an index as opposed to actual soil moisture.

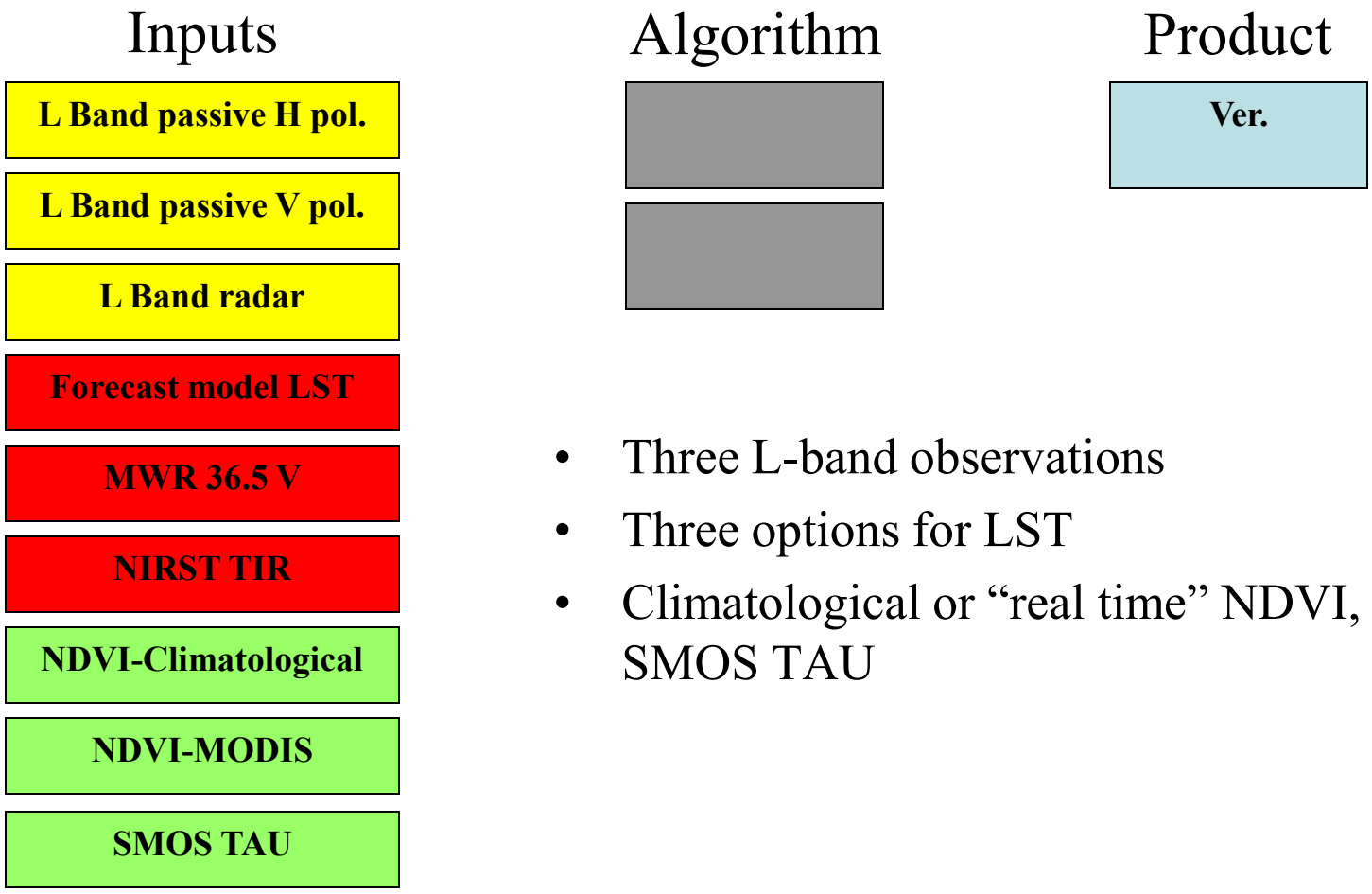
Passive and Active Soil Moisture Algorithms

- Passive and active microwave synergy
  - There have been a few very limited studies.
  - SMAP has this capability but the primary focus at the moment is on resolution enhancement.
    - Utilizing the radar data directly in the retrieval algorithm is under consideration.
  - Mixing and matching passive and active data from existing satellites as a means of simulating Aquarius may not be useful. *(or worth the effort at this point).*
    - AMSR-E/SMOS and ASCAT/QUIKSCAT: vegetation and roughness effects are very important and vary with frequencies and polarizations. Need concurrent observations.
    - SMOS and ALOS: issues with disparate scales need to be resolved. Need concurrent observations.

Aquarius Soil Moisture Algorithms

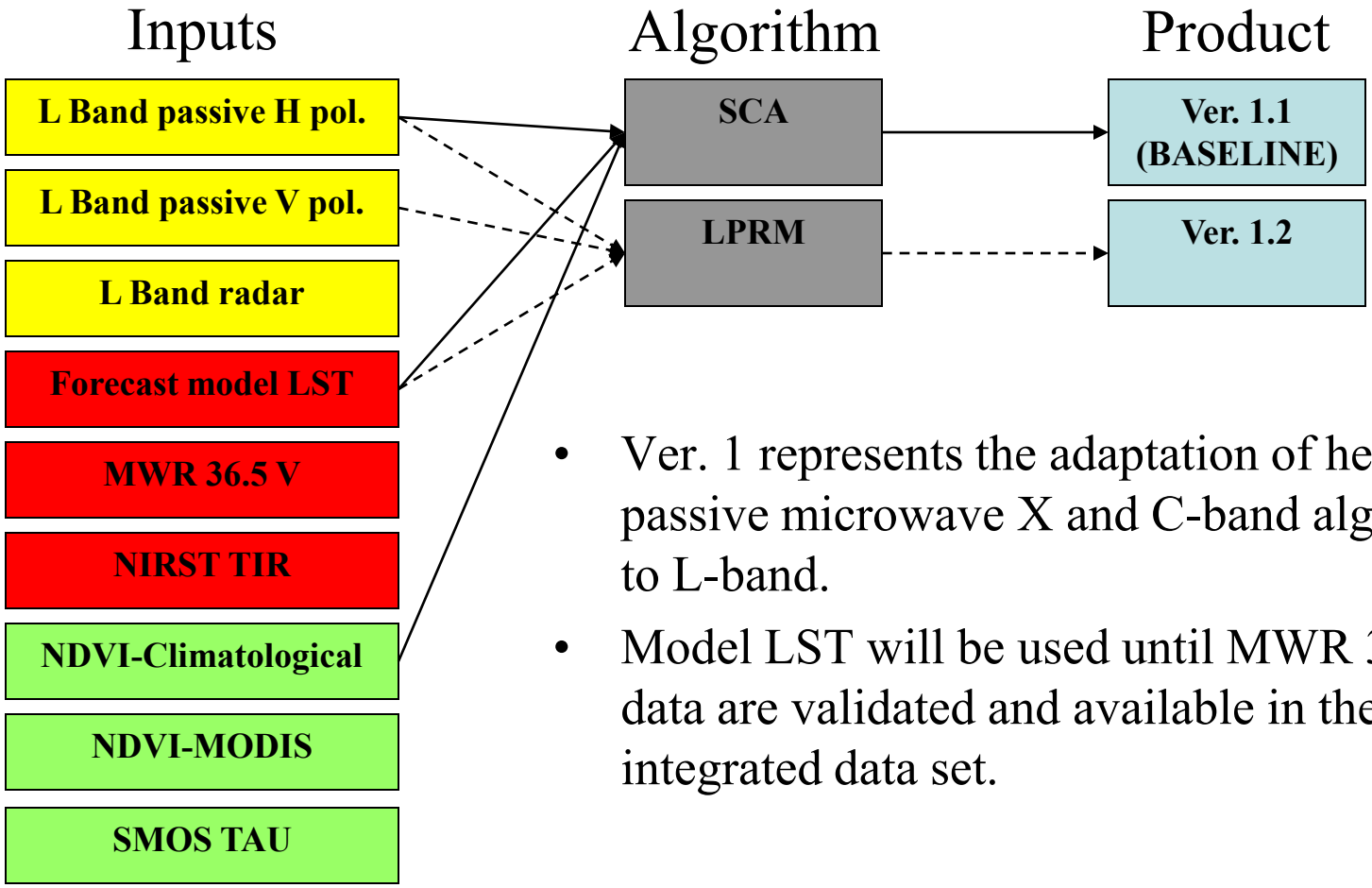
- Our approach will be to build from proven techniques and add in the capabilities of Aquarius/SAC-D
- Initial selection for this study:
  - Single Channel Algorithm (SCA)
  - Land Product Retrieval Algorithm (LPRM)

Aquarius/SAC-D Soil Moisture Retrieval



- Three L-band observations
- Three options for LST
- Climatological or “real time” NDVI, maybe SMOS TAU

Aquarius/SAC-D Soil Moisture Retrieval Ver. 1



- Ver. 1 represents the adaptation of heritage passive microwave X and C-band algorithms to L-band.
- Model LST will be used until MWR 36.5 V data are validated and available in the integrated data set.

Potential of Aquarius/SAC-D Measurements in Soil Moisture Retrieval

Aquarius Radiometer

$$T_{B_{p,f,\Theta}} = \varepsilon_{p,f,\Theta} T + (1 - \varepsilon_{p,f,\Theta}) T_{sky}$$

Brightness temperature (T_B) is a function of emissivity (e) and physical temperature (T).

Observations are made at a specific polarization (p), frequency (f), and angle (Θ)

$$e_{p,f,\Theta} = \frac{T_{B_{p,f,\Theta}}}{T}$$

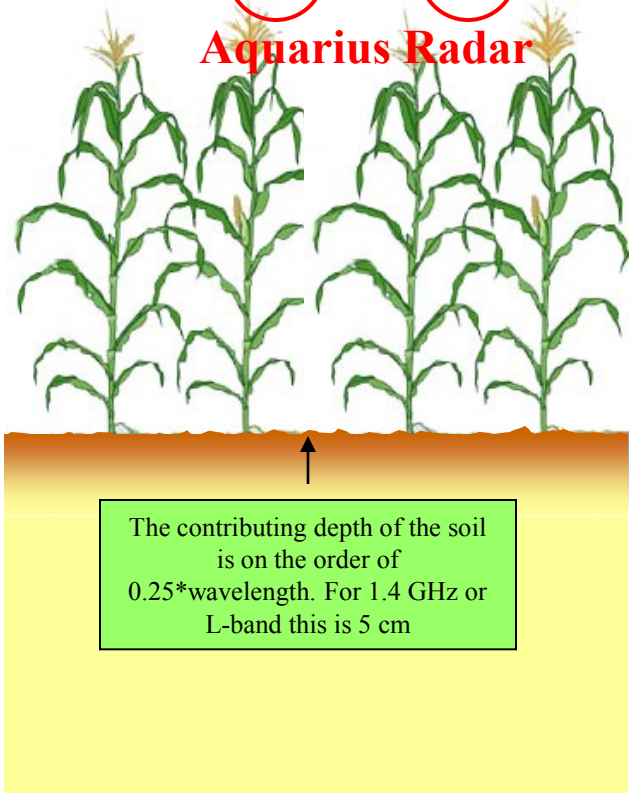
The second term is small resulting in a simple relationship for e

SAC-D 36.5 GHz or NIRST

$$e_{p,f,\Theta} = [1 - \omega_{p,f,v}][1 - \gamma_{p,f,v,\Theta}][1 + [1 - e^{surf}_{p,f,\Theta}]\gamma_{p,f,v,\Theta}] + e^{surf}_{p,f,\Theta}\gamma_{p,f,v,\Theta}$$

The observed e is the result of contributions from the soil surface (e^{surf}) modified by the scattering (ω) and attenuation (γ) of the vegetation (v)

Aquarius Radar



The contributing depth of the soil is on the order of 0.25*wavelength. For 1.4 GHz or L-band this is 5 cm

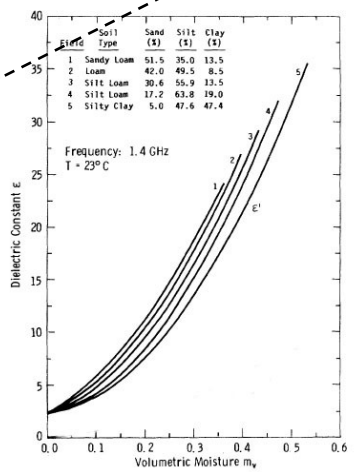
Aquarius Radar

$$e^{soil}_{p,f,\Theta} = -(1 - e^{surf}_{p,f,\Theta}) \exp[-h_{p,f,g} \cos^2\Theta]$$

e^{surf} is the soil emission (e^{soil}) modified by the surface roughness (h)

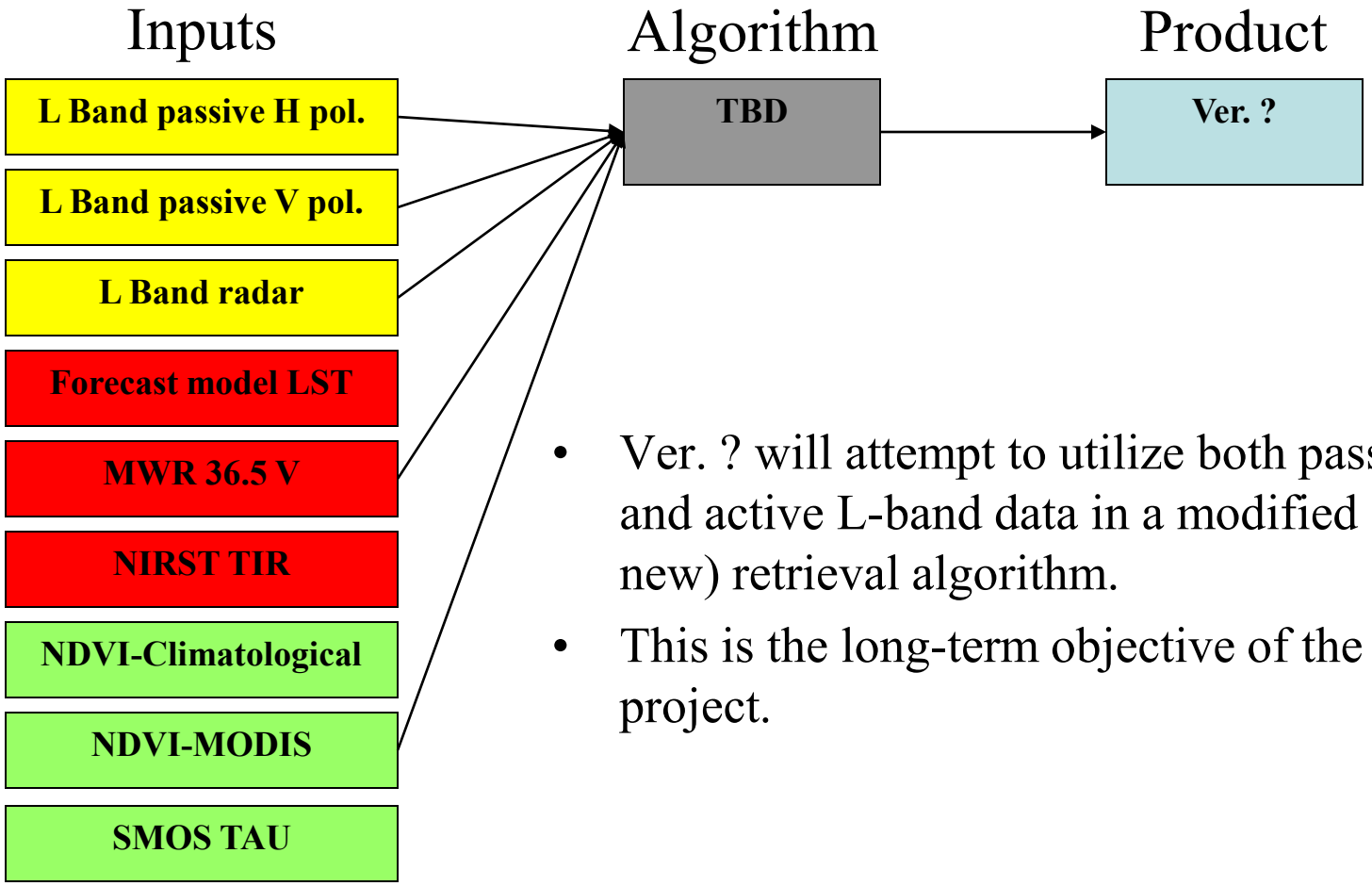
$$e^{soil}_{H,f,\Theta} = -\frac{\cos\Theta - \sqrt{\varepsilon - \sin^2\Theta}}{\cos\Theta + \sqrt{\varepsilon - \sin^2\Theta}}$$

The e^{soil} is a function of the soil dielectric properties (ε_r)



A dielectric mixing model relates ε_r to soil moisture based on sand and clay fractions

Aquarius/SAC-D Soil Moisture Retrieval Ver. ?

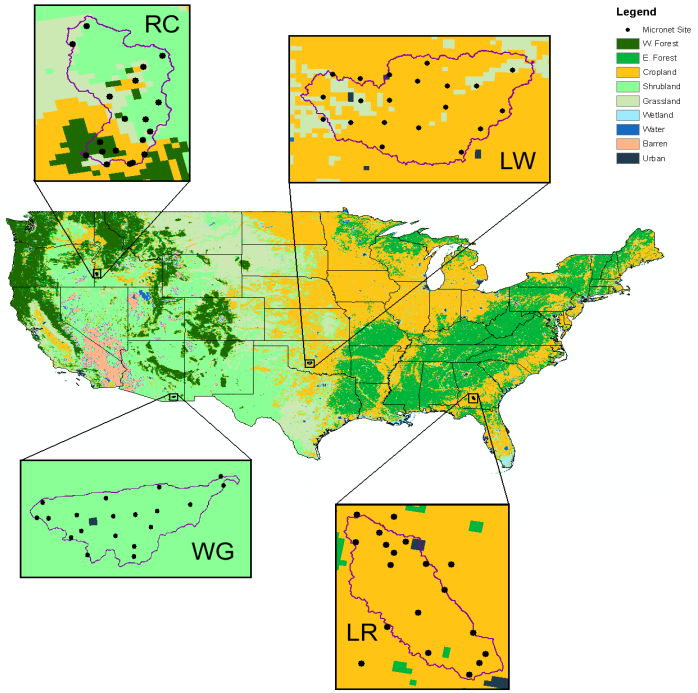


- Ver. ? will attempt to utilize both passive and active L-band data in a modified (or new) retrieval algorithm.
- This is the long-term objective of the project.

Aquarius Soil Moisture Validation

- Exploit existing resources (satellite/model/in situ)
  - GCOM-W, SMOS, SMAP
  - Argentina collaboration

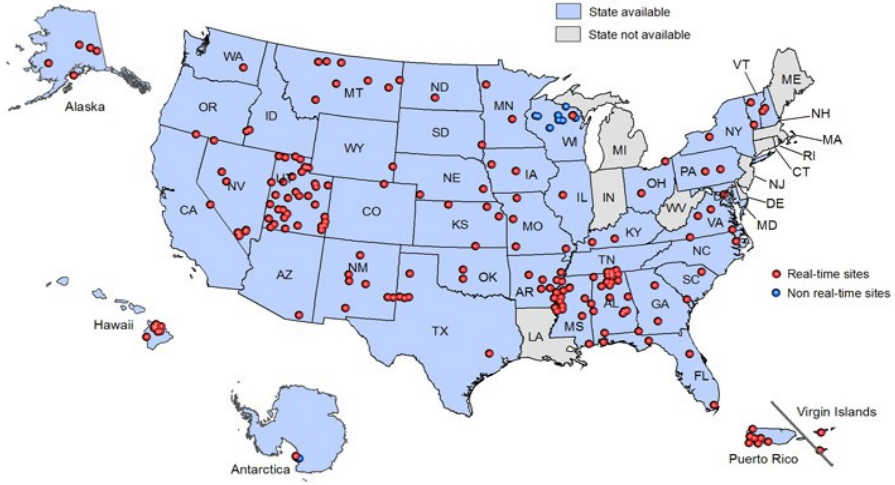
Sparse and Dense In Situ Soil Moisture Networks (Examples)



DENSE: ARS Soil Moisture Validation Watersheds

AZ-WG OK-LW GA-LR ID-RC

Land Cover Conditions in the Watersheds



SPARSE:. The USDA SCAN

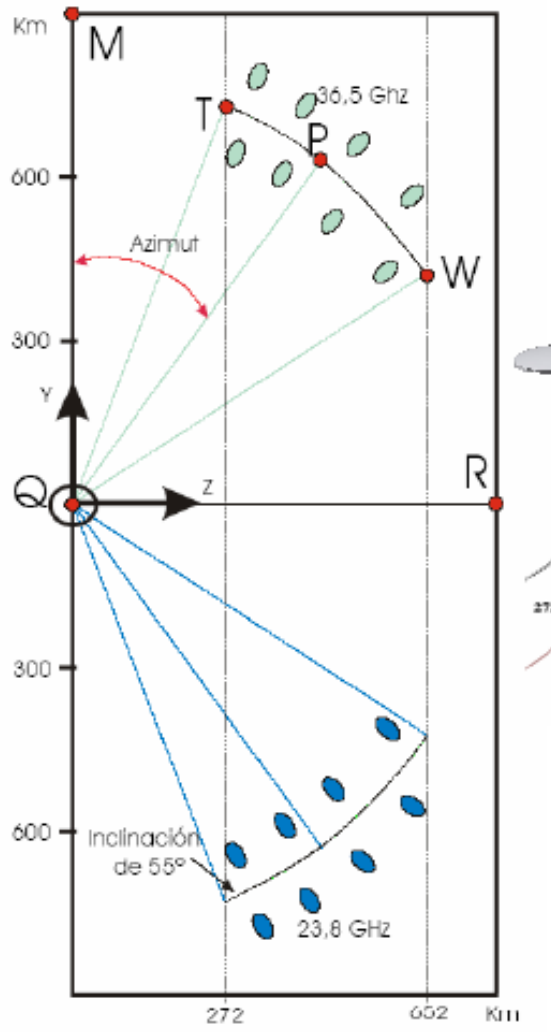
Summary

- Aquarius/SAC-D provides opportunities to explore new approaches to soil moisture retrieval.
  - First space borne data that can be used to assess the synergy of L-band passive and active observations for improving remote sensing of soils and vegetation.
- Our approach will build from heritage satellite-based low frequency passive microwave algorithms
  - Two soil moisture algorithms that are currently being used with AMSR-E observations.
- These utilize a unique element of Aquarius/SAC-D, 1.4 and 36.5 GHz radiometers.
  - Information from the MWR 36.5 V GHz is used to derive land surface temperature (LST), which is then employed in computing emissivity.
  - The retrieved LST is another potential Aquarius/SAC-D product.
- These results will serve as a baseline for research on a combined passive-active soil moisture algorithm.
  - Improvements in corrections for roughness, vegetation, and transient water effects.

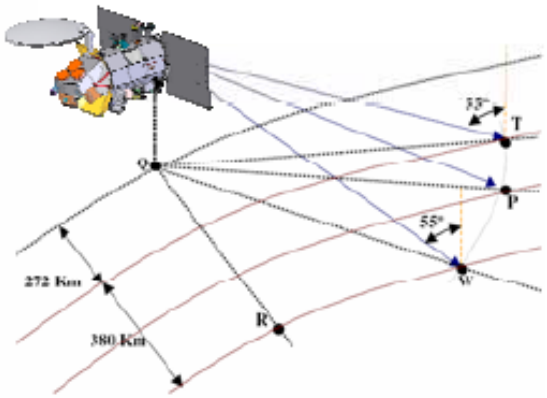
Collaboration

- In situ network data
- Alternative algorithms
- Calibration of the Aquarius radiometer and scatterometer using PLMR and PLIS
  - Funding
  - Timing
- Validation of the Aquarius soil moisture (and LST) products with a field campaign
  - Funding
  - Timing

MWR Acquisition Geometry



Incidence Angle Diagram.



Beam	Incidence Angle [º]	Azimut [º]
1	52	24,56
2	58	23,16
3	52	32,33
4	58	29,56
5	52	41,44
6	58	37,12
7	52	52,97
8	58	46,13

Reference coordinate system.

MWR Products

MWR beam overlapping along track