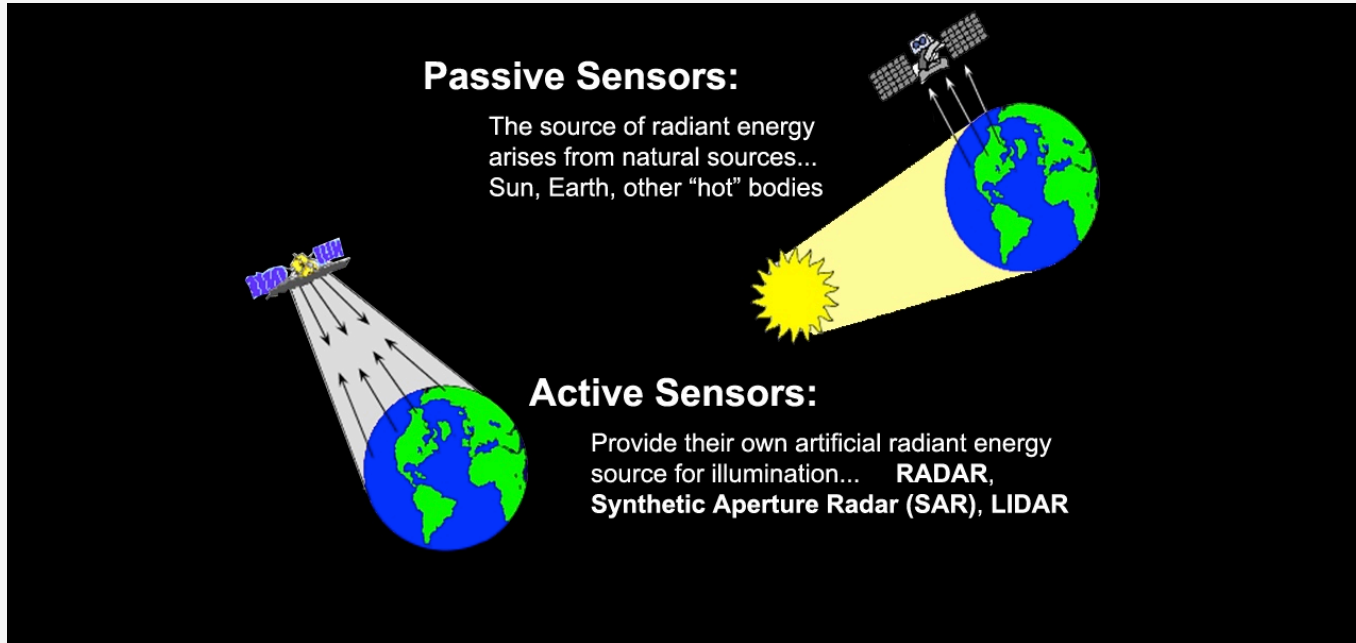Description of the Instruments and Algorithm Approach

Passive and Active Remote Sensing

SMAP uses active and passive sensors to measure soil moisture

Passive Sensors:
The source of radiant energy arises from natural sources... Sun, Earth, other "hot" bodies

Active Sensors:
Provide their own artificial radiant energy source for illumination... **RADAR, Synthetic Aperture Radar (SAR), LIDAR**

Microwave Remote Sensing

- With Visible and Infrared sensors the soil is masked by clouds and vegetation. Optical sensors operate by measuring scattered sunlight and are "daytime only".

- Microwaves can penetrate through clouds and vegetation, operate day and night, and are highly sensitive to the water in the soil due to the change in the soil microwave dielectric properties.
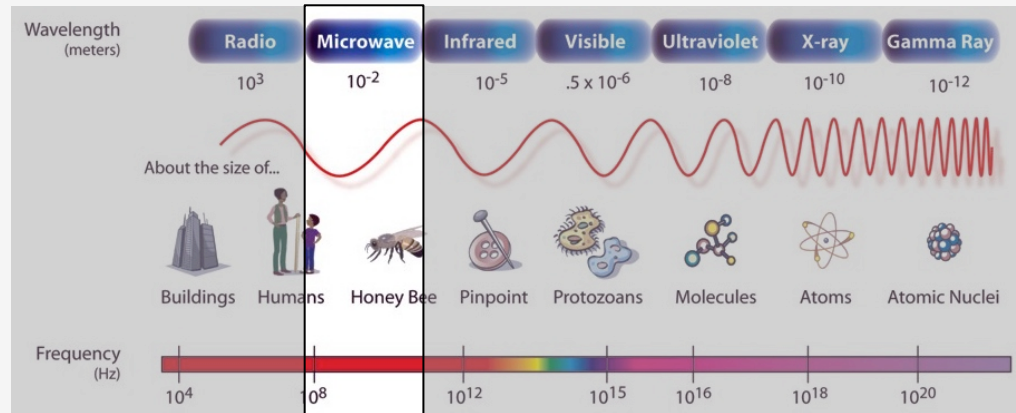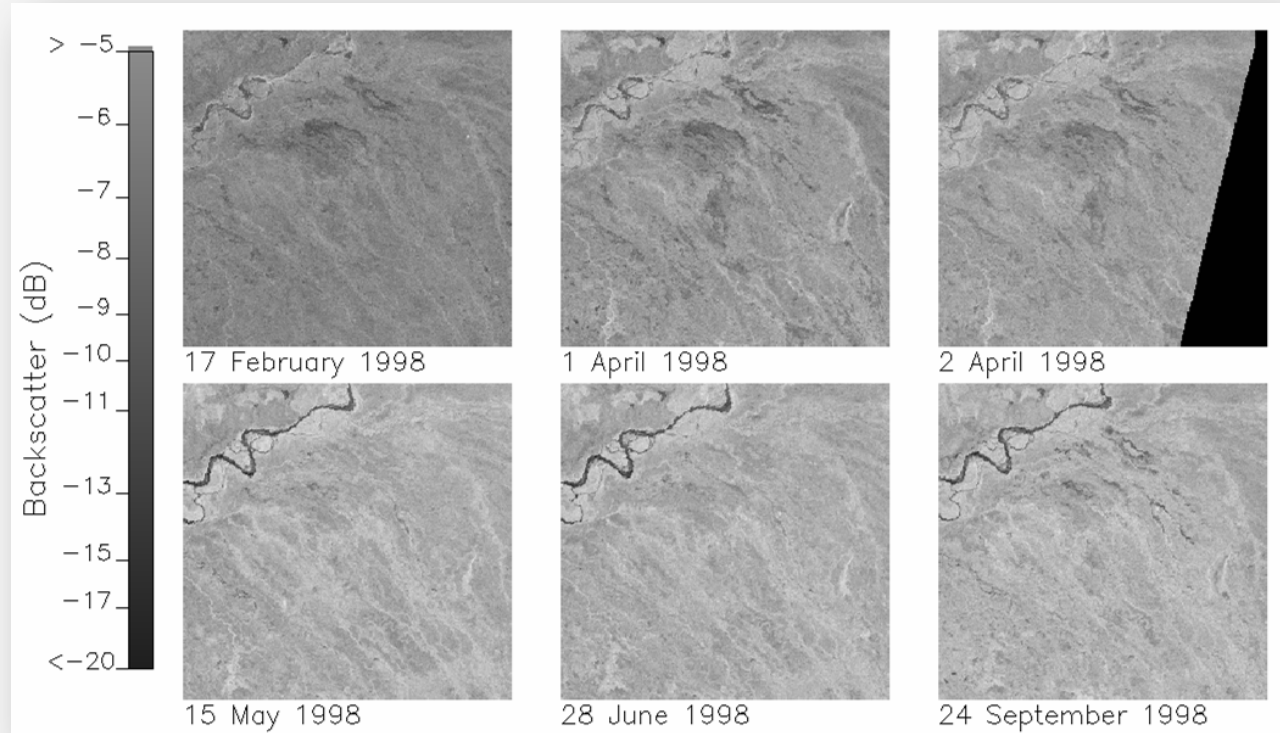
Advantages of L-Band

Vegetation attenuation increases as frequency increases
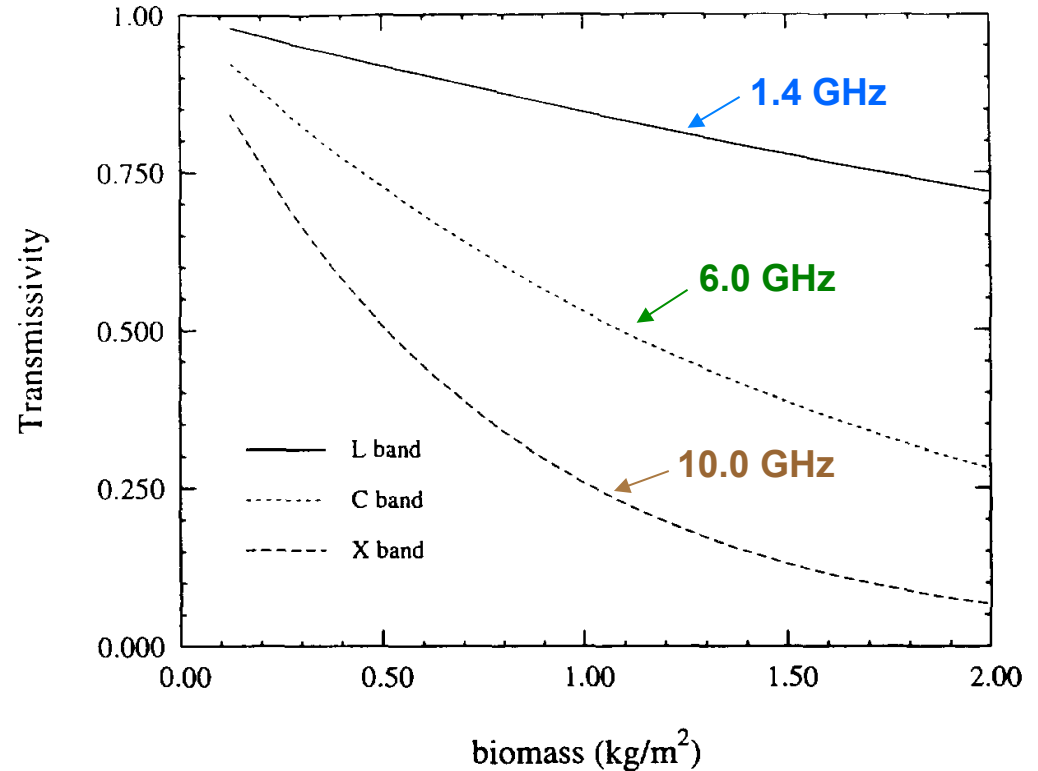
Land Surface Dielectric: Surface Freeze/Thaw State

As the land surface transitions from frozen to thawed, there is a large change in dielectric producing a notable increase in radar backscatter, on the order of 3 dB.

# Relation Between Brightness Temperature and Soil Moisture

[Jackson and O'Neill, *IEEE TGARS, GE-25*, 1987.]
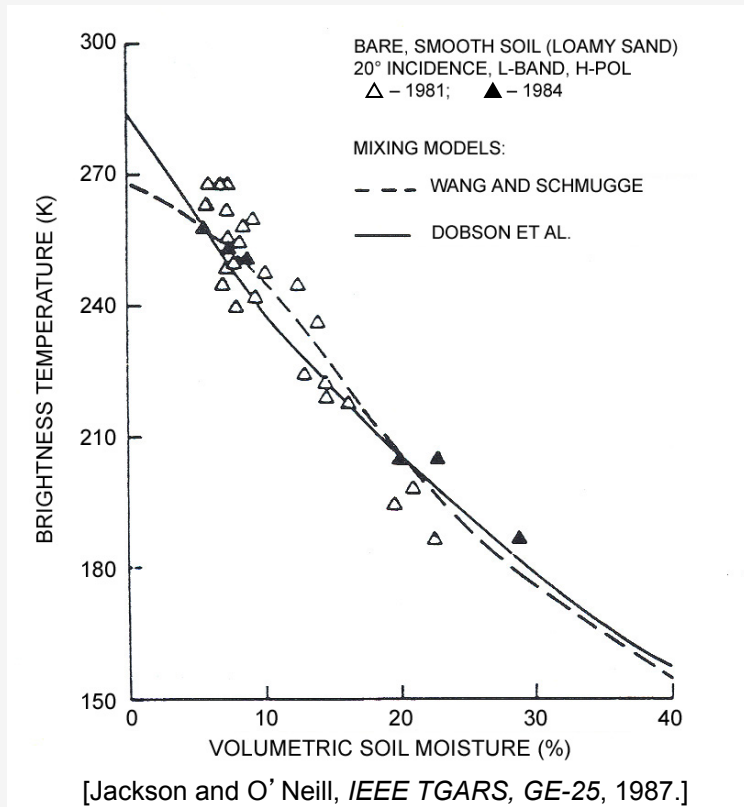
Measurement Approach

- p = H, V (radiometer) y pq = VV, HH, HV (radar)
- Contributions from the: soil, vegetation, and soil-vegetation interaction
- Soil moisture is the dominant contributor to the signal
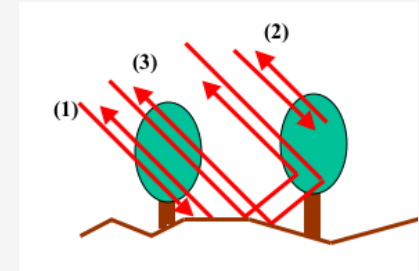- Soil moisture measurements are corrected for the effects of vegetation, surface roughness and temperature

Emission

$$T_{Bp}^{t} = T_{Bp}^{s} L_p + T_{Bp}^{v} + T_{Bp}^{sv}$$
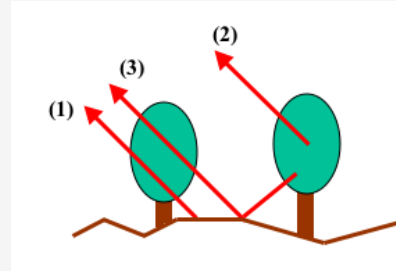
Backscatter

$$\sigma_{pq}^{t} = \sigma_{pq}^{s} L_{pq}^{2} + \sigma_{pq}^{v} + \sigma_{pq}^{sv}$$

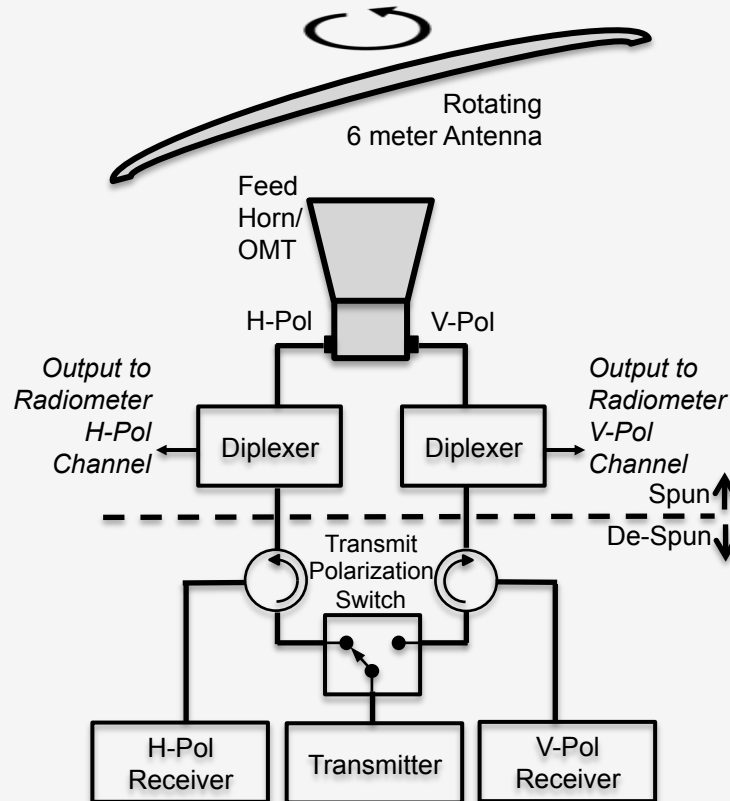# Ancillary Data Sources

Ancillary data are used to estimate the key unknown parameters: surface temperature (≈ surface air temp. at 6 am), vegetation opacity, surface roughness and soil texture

Parameter	Description/Sources
Surface air meteorology	- Data assimilation (GEOS/DAO) - Forecast models (NCEP and ECMWF)
Vegetation opacity	- Vis/IR satellite-derived NDVI, LAI, landcover (MODIS, IGBP-DIS) - Historical phenology (AVHRR)
Surface topography	- Digital elevation models (USGS and SRTM)
Soil texture	- Soils databases (Global, NGDC; US, STATSGO)
Land/water boundaries	- Coastal boundaries and inland water bodies (NGDC)

Radar and Radiometer Operation

SMAP Products

| Data Product Short Name	Description	Grid Resolution	Granule Extent
L1A_Radar	Parsed Radar Instrument Telemetry		Half Orbit
L1A_Radiometer	Parsed Radiometer Instrument Telemetry		Half Orbit
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	Half Orbit
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1 km	Half Orbit
L1B_TB	Radiometer T_B in Time Order	39x47 km	Half Orbit
L1C_TB	Radiometer T_B	36 km	Half Orbit
L2_SM_A	Radar Soil Moisture (includes Freeze-Thaw)	3 km	Half Orbit
L2_SM_P	Radiometer Soil Moisture	36 km	Half Orbit
L2_SM_AP	Active-Passive Soil Moisture	9 km	Half Orbit
L3_FT_A	Daily Global Composite Freeze/Thaw State	3 km	North of 45° N
L3_SM_A	Daily Global Composite Radar Soil Moisture	3 km	Global
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	36 km	Global
L3_SM_AP	Daily Global Composite Active-Passive Soil Moisture	9 km	Global
L4_SM	Surface & Root Zone Soil Moisture	9 km	Global
L4_C	Carbon Net Ecosystem Exchange	9 km	North of 45° N

Data Product Design

- **All products are in HDF5 format**
  - Each SMAP HDF5 file contains the primary data parameters (e.g., soil moisture, freeze/thaw, sensor data) and all data used in the production of those primary parameters. These files also include metadata, geolocation information, quality flags, etc.

- **Projection: EASE-Grid 2.0**
  - Equal-area projection
  - Level 2, 3, 4, and radiometer L1C are in this projection

- **Values**
  - Radiometer data (brightness temperature) is in Kelvin
  - Radar data is in sigma naught
  - Soil moisture is a volumetric measurement expressed as cm^3/cm^3
  - Freeze/thaw is a binary measurement, either frozen or thawed
  - Net ecosystem exchange is in grams of carbon/square meter per day

Radiometer Data – Level 1C
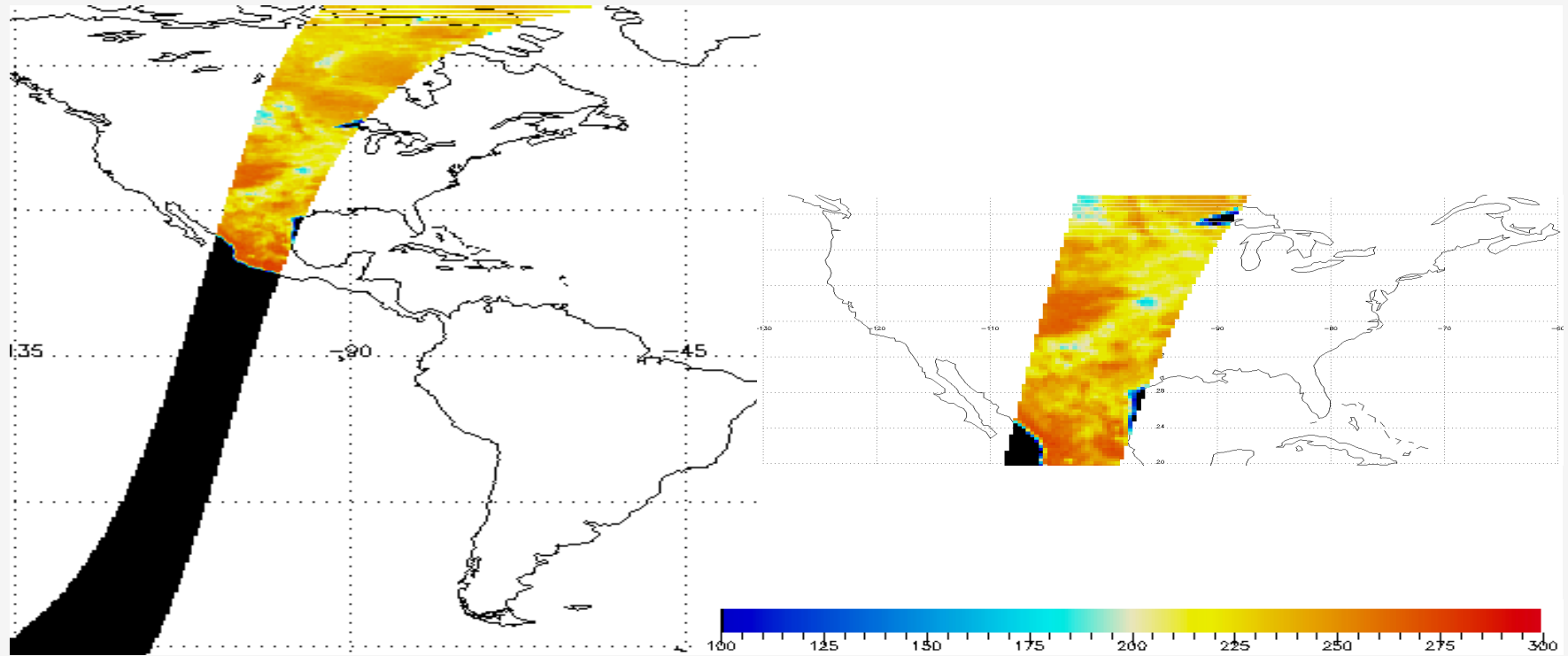
Soil Moisture Derived from the Radiometer- Level 3
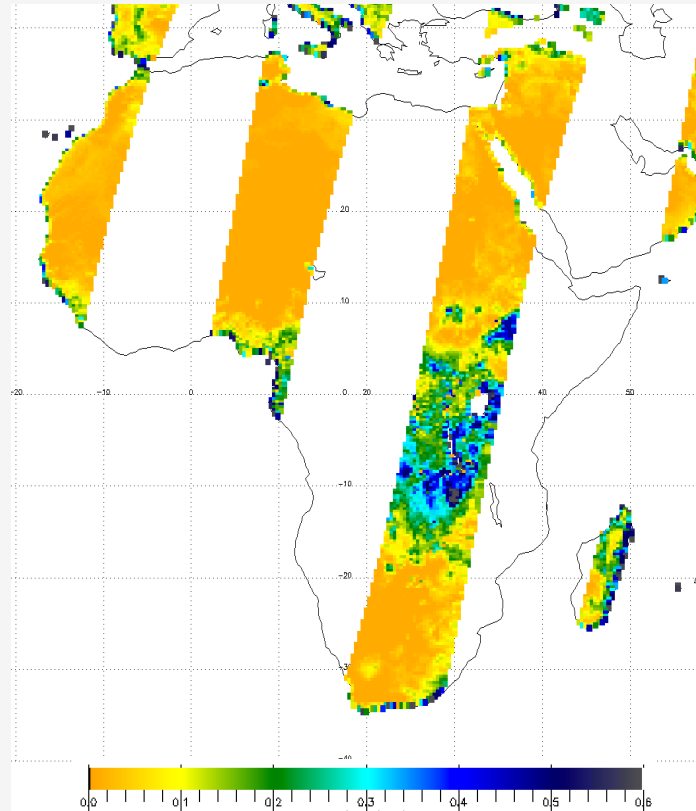
Surface and Root Zone Soil Moisture- Level 4

Root zone soil moisture [m³ m⁻³]   26 Apr 2015 at 00:00 UTC

0.00   0.08   0.16   0.24   0.32   0.40   0.48   0.56   0.64
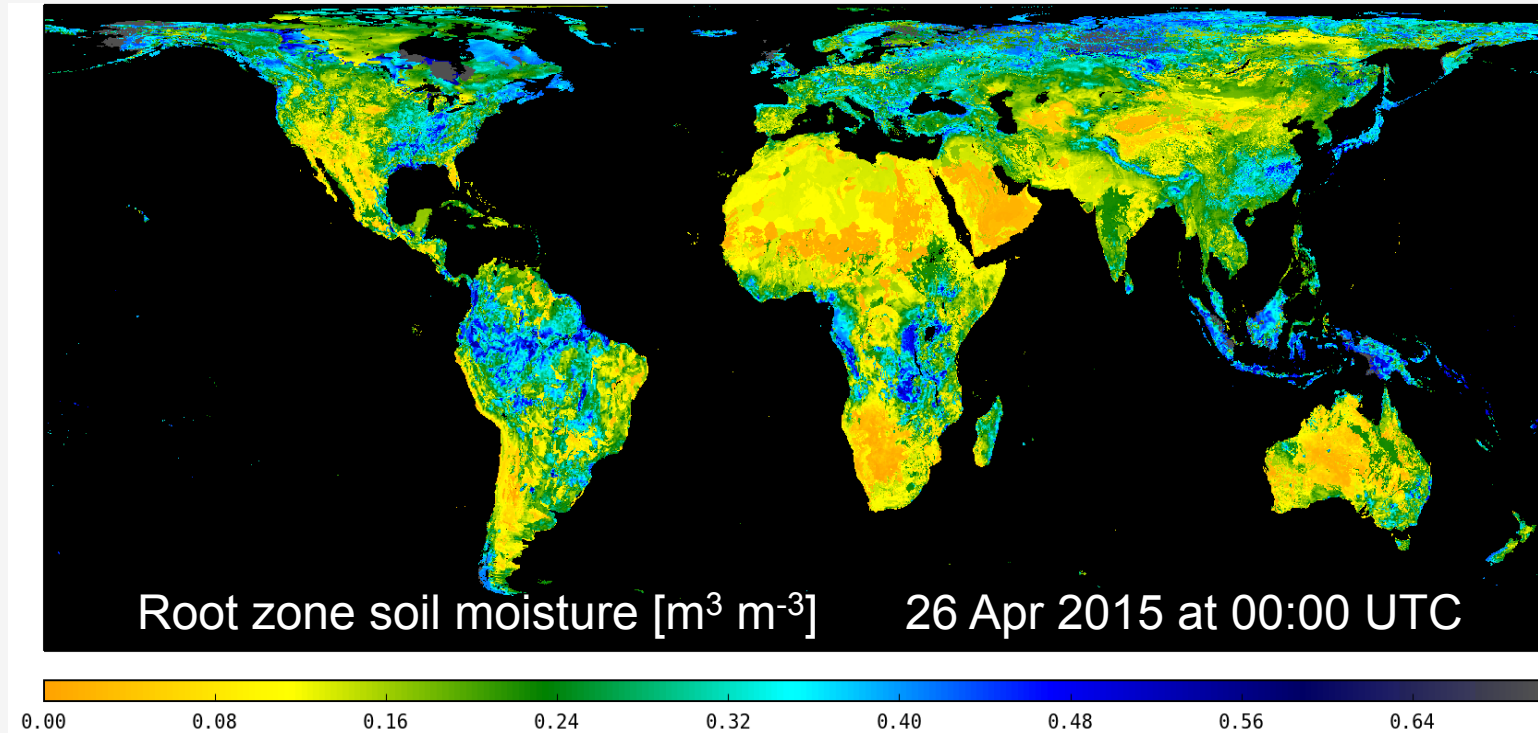
Net Ecosystem Carbon Exchange- Level 4

ENLF Tower Site
(CA-OJP, 53.92°N, 104.7°W)

L4_C NEE (DOY 196, g C m⁻² d⁻¹)
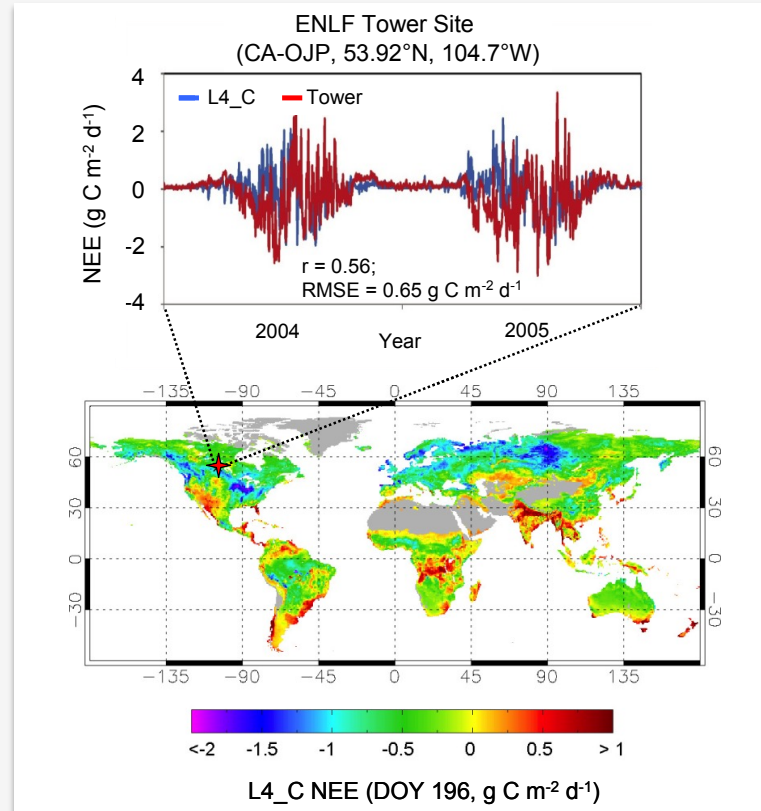
SMAP Enhanced Active-Passive Product Using Sentinel

SMAP-only Passive Product
Retrieved Soil Moisture 36 km

SMAP-Sentinel Active-Passive Product
Retrieved Soil Moisture 3 km

SMAP-Sentinel Active-Passive Product
Retrieved Soil Moisture 1 km

m³/m³

0.0 0.1 0.2 0.3 0.4 0.5 0.6

Soil Moisture at Different Resolutions Retrieved for May 17th, 2015 Over Manitoba region Canada

Source: Narendra Das
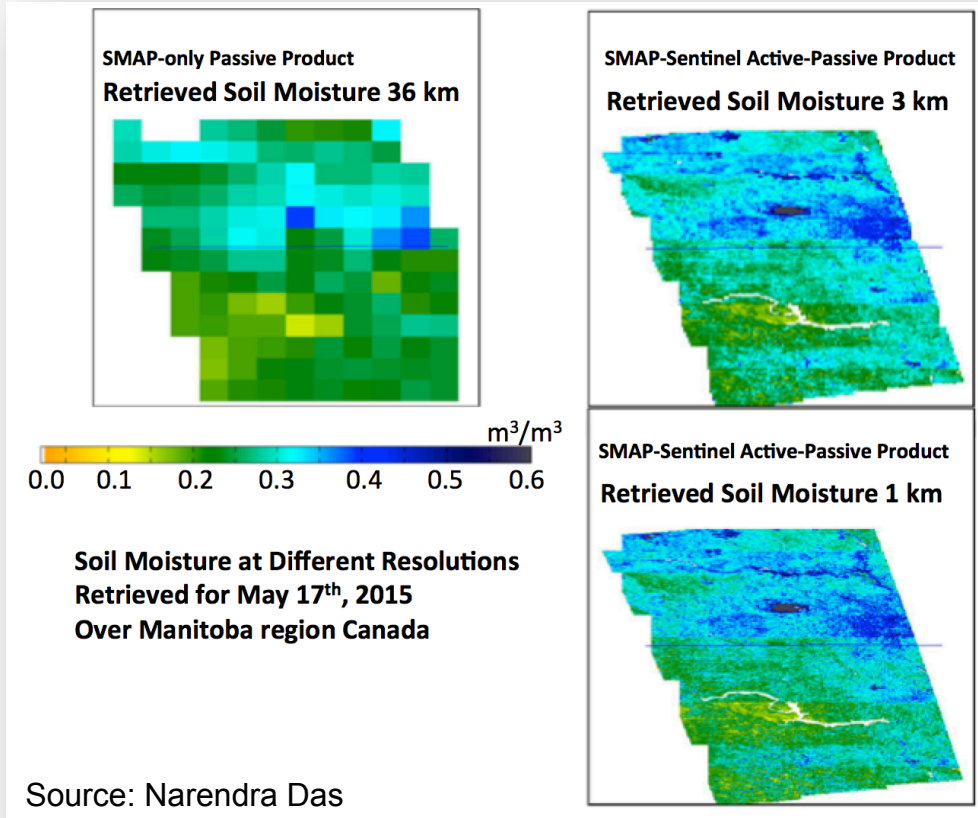
Soil Moisture Retrieval Map
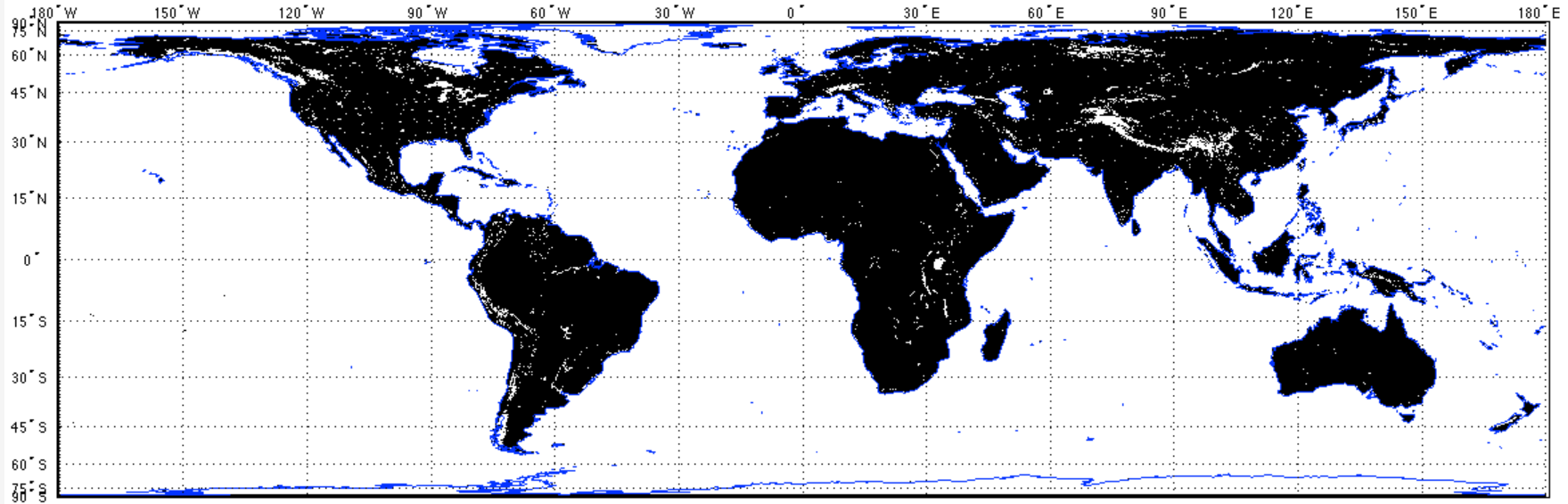
Retrievable Mask (Black Colored Pixels) Prepared with Following Specifications:

    a) Urban Fraction < 1

    b) Water Fraction < 0.5

    c) DEM Slope Standard Deviation < 5 deg

Soil Moisture Expected Accuracy
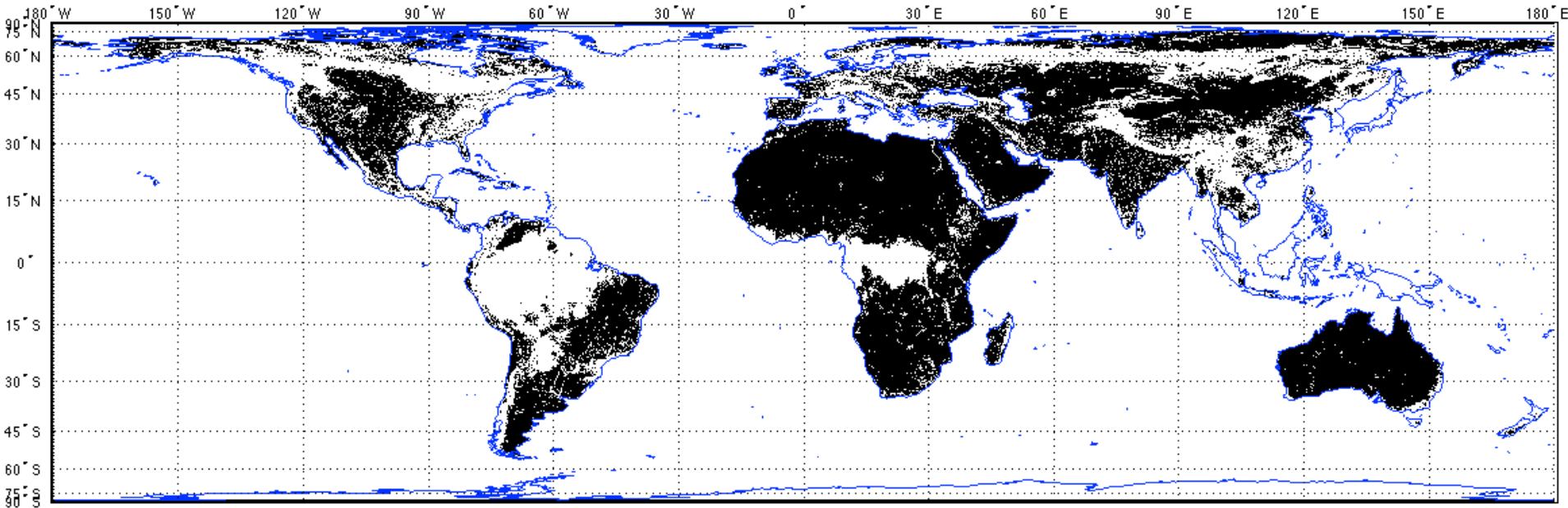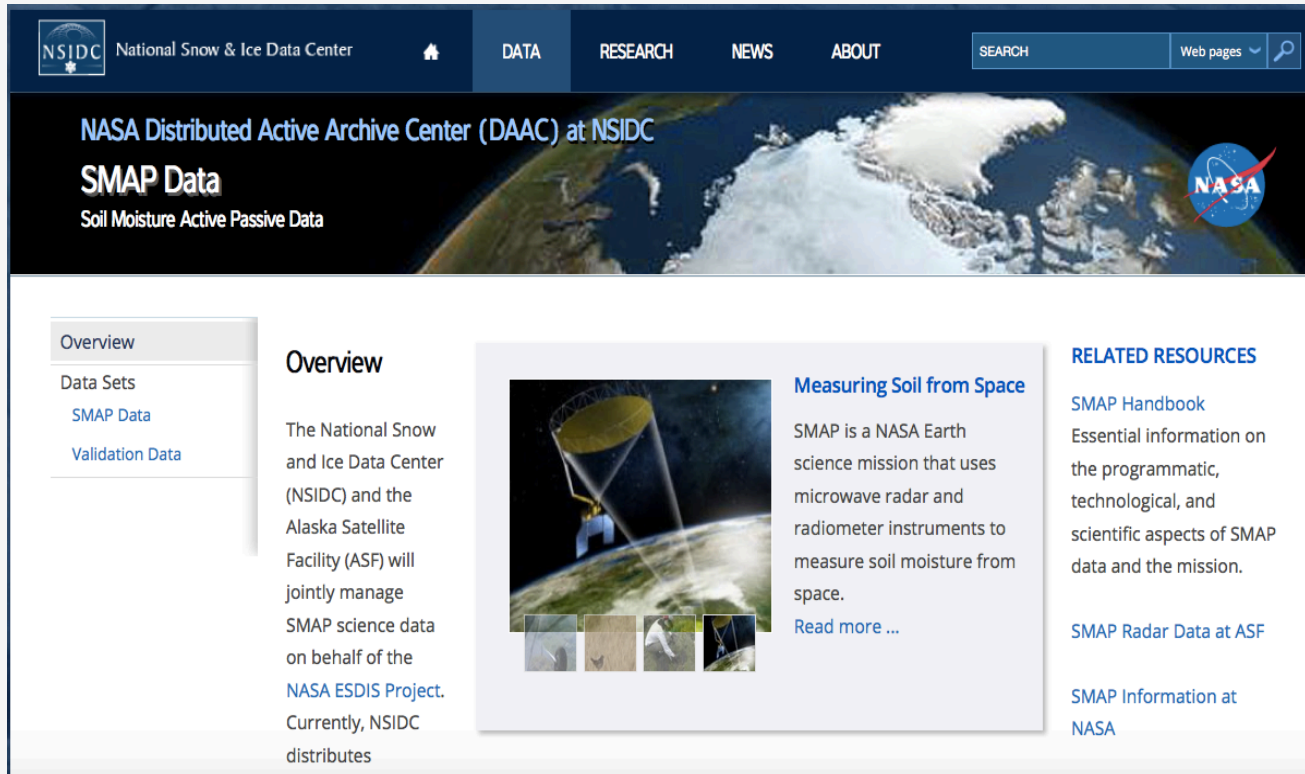
Retrieval expected quality mask (black colored pixels indicate good quality) with following specifications:
  a) Vegetation water content ≤ 5 kg/m^2; b) Urban fraction ≤ 0.25
  c) Water fraction ≤ 0.1; d) DEM slope standard deviation ≤ 3 deg

Access to SMAP Data: NSIDC

http://nsidc.org/data/smap/

Access to SMAP Data: ASF

https://www.asf.alaska.edu/smap