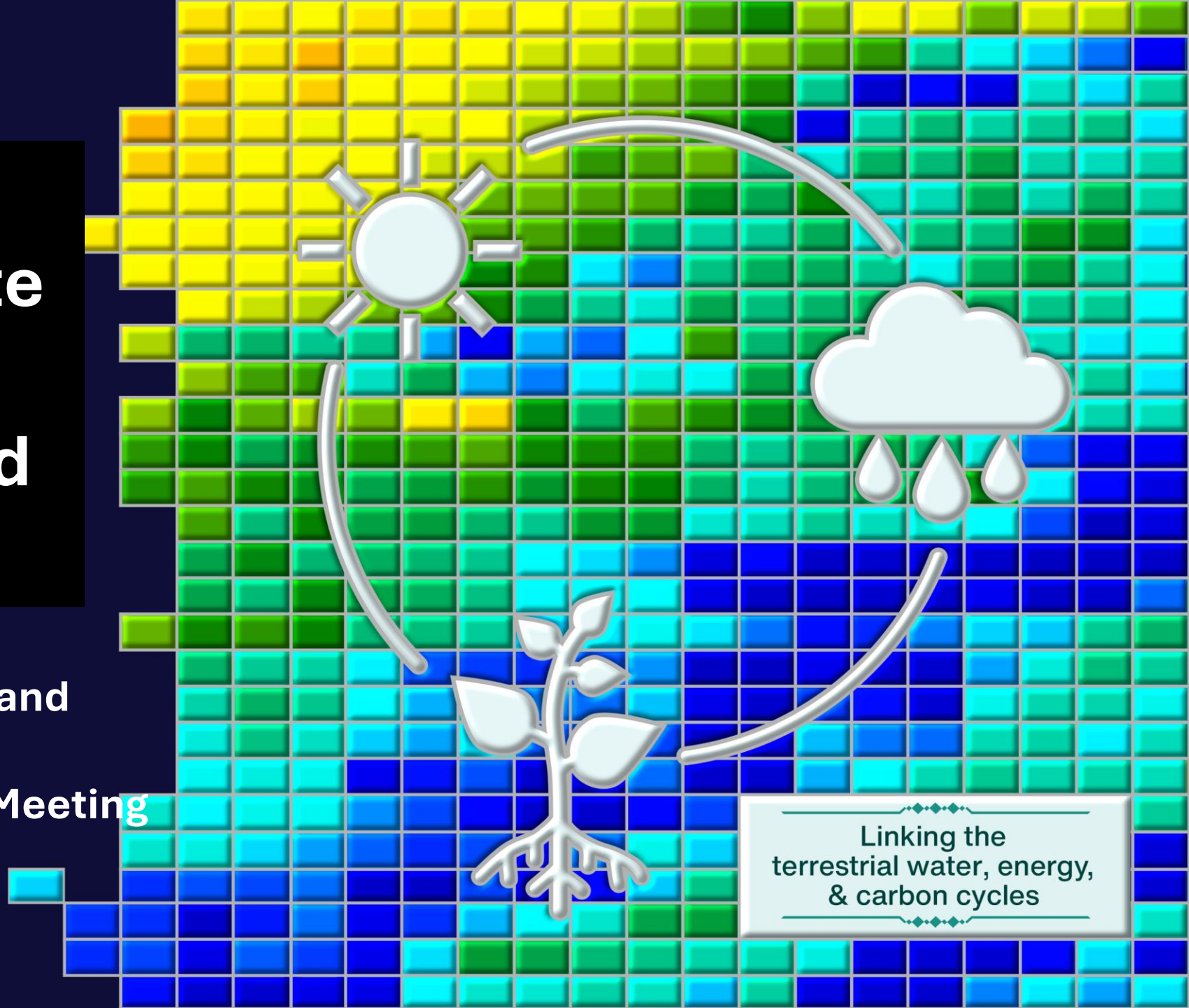
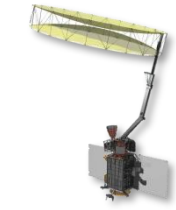




NASA Soil Moisture Remote Sensing Capabilities and Future Plans

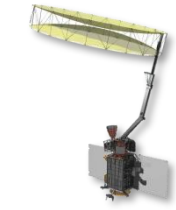
Simon Yueh (JPL),
Rajat Bindlish (GSFC), and
Xiaolan Xu (JPL)
Hydrosphere Investigator Meeting
September 2026





Outline

- Soil Moisture Technology Options
- Synopsis of soil moisture missions
- Future Outlook

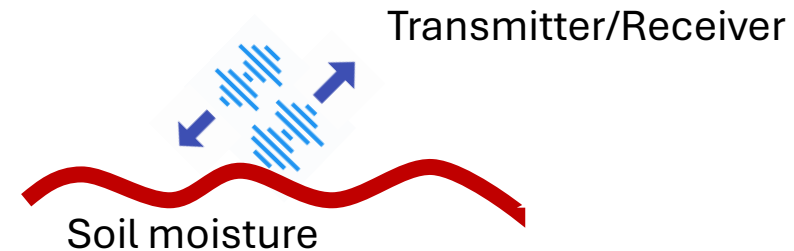


Three Main Microwave Satellite Technologies

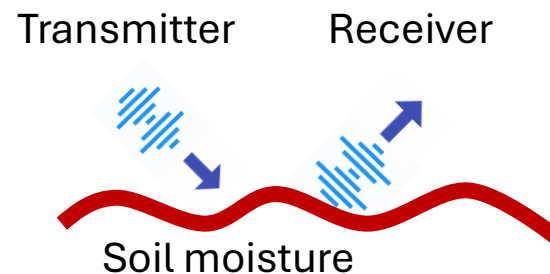
- Radiometer (Brightness temperature): 30-70 km

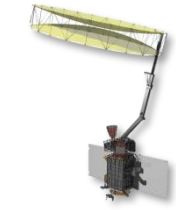


- Radar (Normalized Radar Cross-section): 100 m – 20 km
 - Synthetic Aperture Radar
 - Scatterometer



- Bistatic Radar (Signals of Opportunity): 1-30 km





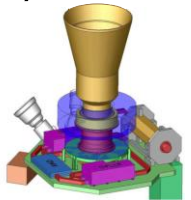
NASA Soil Moisture Active Passive Mission

L-band unfocused SAR and radiometer system, offset-fed 6 m light-weight deployable mesh reflector. Shared feed for

➤ 1.2 GHz Radar 1-3 km (30% nadir gap)
HH, VV and HV

➤ Ceased operation on July 7, 2015

➤ 1.4 GHz Radiometer at 40 km (-3 dB)
H, V, 3rd and 4th Stokes

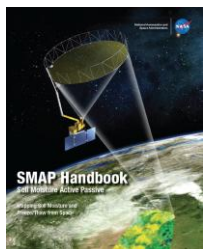


Conical scan, fixed incidence angle at 40°

Contiguous 1000 km swath 2-3 days revisit

Sun-synchronous 6am/6pm orbit (680 km)

To date, over 2000 studies in peer-reviewed journals have been published





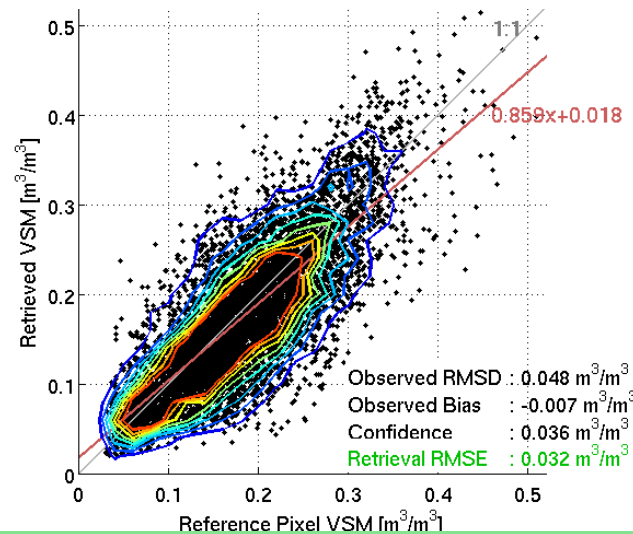
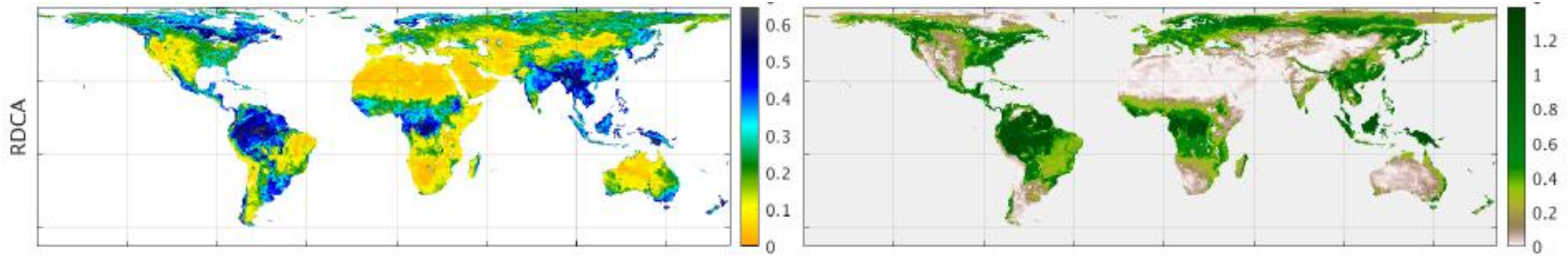
SMAP Dual Channel Algorithm for Soil Moisture and Vegetation Optical Depth

- SMAP dual-channel algorithm can retrieve soil moisture and vegetation optical depth from dual-polarized brightness temperatures

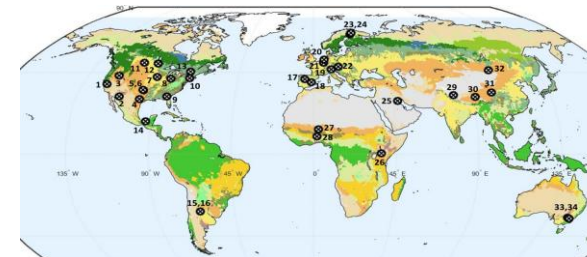
Soil Moisture

07/2016

Vegetation Optical Depth

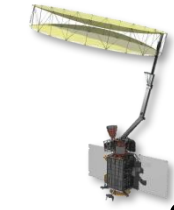


AM	ubRMSE	Bias	R
DCA	0.037	-0.007	0.82



25 SMAP
cal/val
sites

SMAP 36-km soil moisture products validated with more than 5 years of data from Core Cal/Val sites



SMAP National Interest Fact Sheet

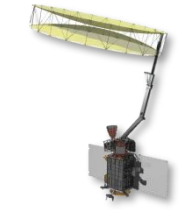
SMAP data are used for weather forecasts, crop yield predictions, wildfire risk, land slide risk, floods and drought monitoring.

- SMAP products are used for weather forecasts, crop yield predictions, wildfire risk, land slide risk, floods, and monitoring
- More than 20 government and private users, such as
 - GEE, London Stock Exchange, Bayer Crop Service, Louis Dreyfus, Cultivo

Known operational government users	
USDA National Agricultural Statistics Services (NASS)	USDA-NASS uses SMAP surface and root-zone soil moisture data in their Crop Condition and Soil Moisture Analytics Tool (Crop-CASMA) to provide guidance on the field conditions.
USDA Foreign Agricultural Services (FAS)	USDA-FAS uses SMAP surface and root-zone soil moisture data to generate global, monthly forecasts for agricultural commodities.
Global Hydro-Intelligence office at the Pentagon	US Air Force uses the near real-time SMAP brightness temperature and soil moisture data to initialize numerical weather forecasts for the intelligence office.
NOAA National Integrated Drought Information System (NIDIS)	NIDIS uses SMAP surface and root-zone soil moisture anomalies as an input to produce drought severity maps.
New South Wales Department of Primary Industries and Regional Development*	NSW regional government uses SMAP data to produce seasonal assessments of environmental conditions that support state industries and regional development.
Servicio Meteorológico Nacional Argentina*	Argentina Meteo uses SMAP surface soil moisture data to provide maps for agricultural and water resource monitoring.
The National Surface and River Prediction System (NSRPS)	NSRPS assimilates SMAP brightness temperature data into the Canadian Land Data Assimilation System (CaLDAS).
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)	EUMETSAT reformats and redistributes the SMAP data to operational users in Europe.
European Centre for Medium-Range Weather Forecasts (ECMWF)	ECMWF uses SMAP data in the Integrated Forecasting System (IFS) for operational monitoring of weather forecasts.
Thailand Hydro-Informatics Institute (HII)	HII uses SMAP-Sentinel-1 surface soil moisture to support hydrological and water resource monitoring for drought and flood risk.
National Hurricane Center (NHC)	NHC forecasters use the SMAP wind product pulled by NOAA into the cloud AWIPS system to determine the intensity of tropical cyclones.

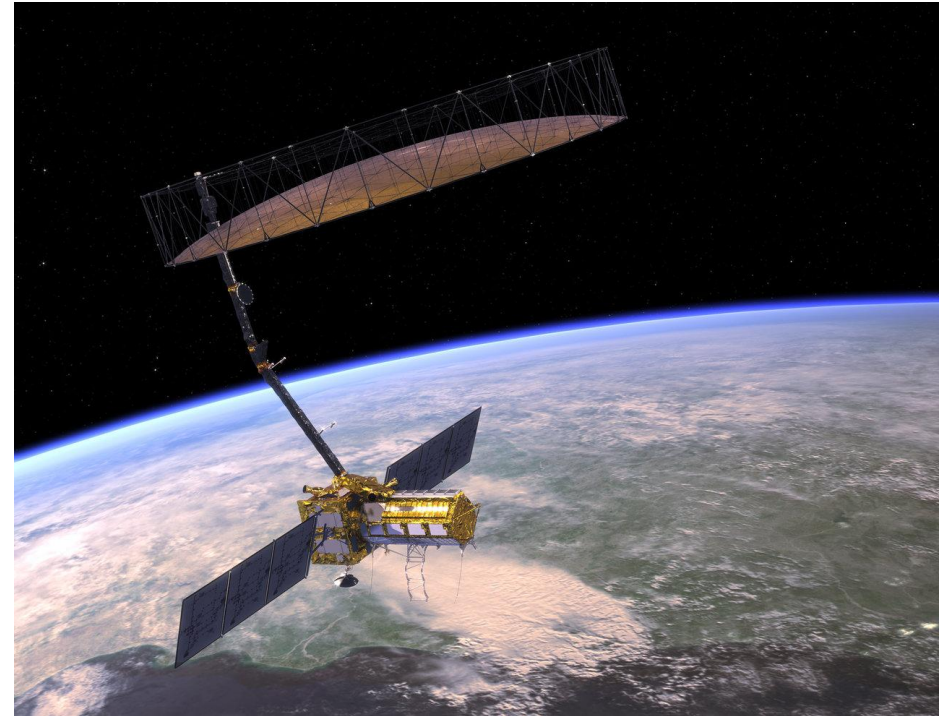
Known operational users in the private sector	
Google Earth Engine (GEE)	GEE pulls and reformats SMAP soil moisture products for distribution to its users.
London Stock Exchange Group (LSE)*	LSE uses SMAP surface soil moisture data within their Agriculture and Weather Research group.
Bayer Crop Science (BCS) Digital Farming Solutions*	BCS uses SMAP soil moisture data to test derivative offerings, a financing entity structured as a trust for farmers.
Louis Dreyfus Company India (LDC-I)*	LDC-I uses SMAP surface soil moisture data for operationally monitoring critical weather conditions to advise farmers and producers.
Cultivo*	Cultivo uses SMAP soil moisture data along with other environmental remote sensing data to develop seasonal and long-term adaption solutions for investors.
Planet Labs (PL)*	PL uses SMAP brightness temperature product as an input for their Soil Water Content products.
Amentum Space Exploration Division* (ASED)	ASED uses SMAP surface soil moisture data in their launch and mission operations solutions.
Surrey Satellite Technology-Ltd. (SSTL)*	SSTL uses SMAP soil moisture data to support the design and development of European Space Agency HydroGNSS mission.
Spire Global*	Spire uses SMAP brightness temperature and soil moisture data to identify, track, and predict weather systems for their operations.

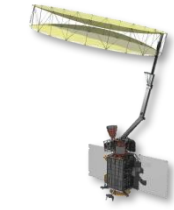
*Based on NSIDC response to users' inquiries



NASA-ISRO Synthetic Aperture Radar

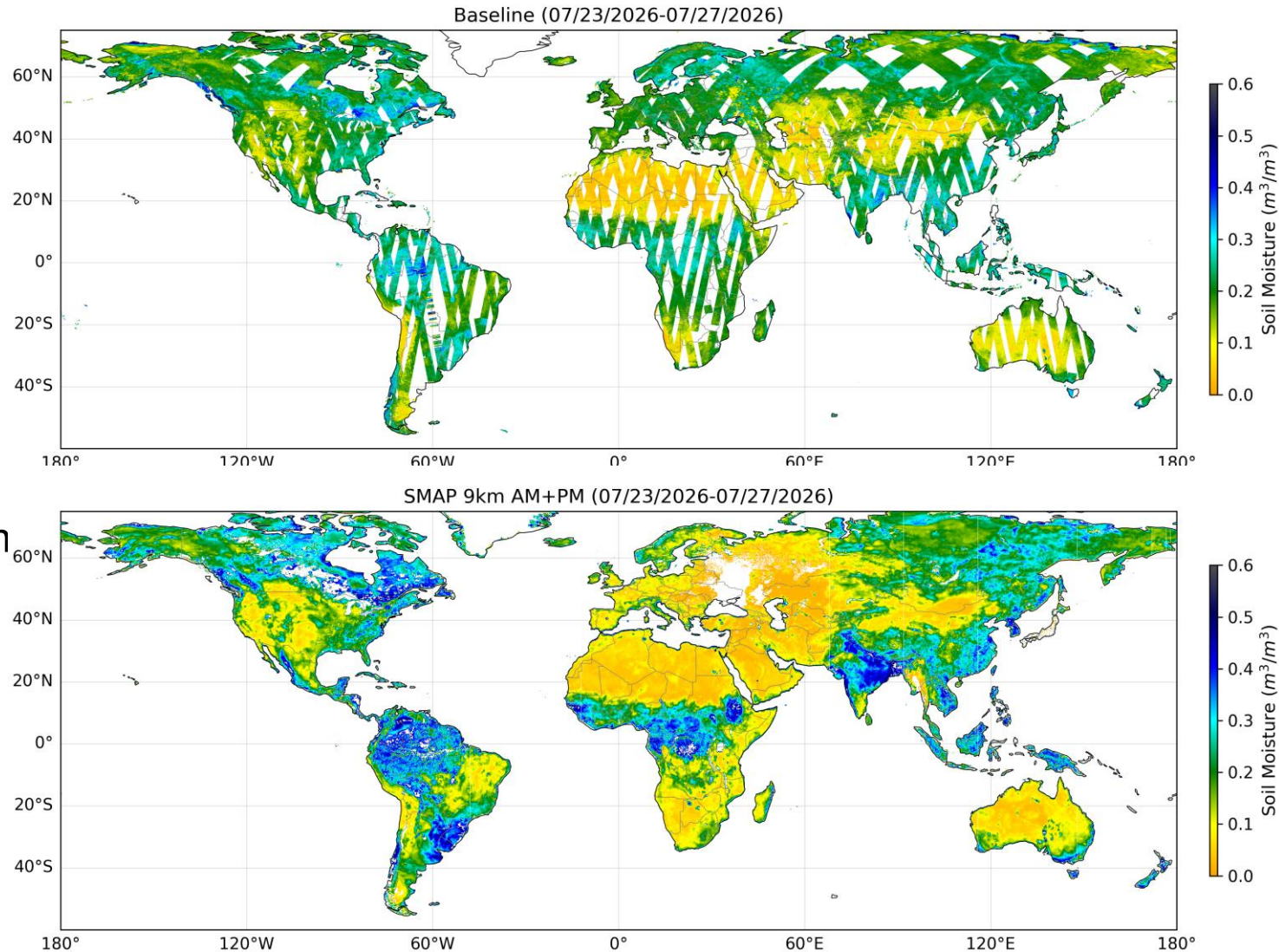
- NASA Decadal Survey
- **L-band (1.2-GHz) radar (JPL)**
- **S-band (3 GHz) radar (ISRO)**
- Shared sub-illuminated antenna (12-m diameter)
- Dual and quad polarization
- 240-km swath width
- 3 to 100 m spatial resolution
- Launched on July 30, 2025

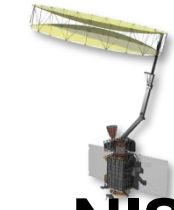




NISAR Soil Moisture Product

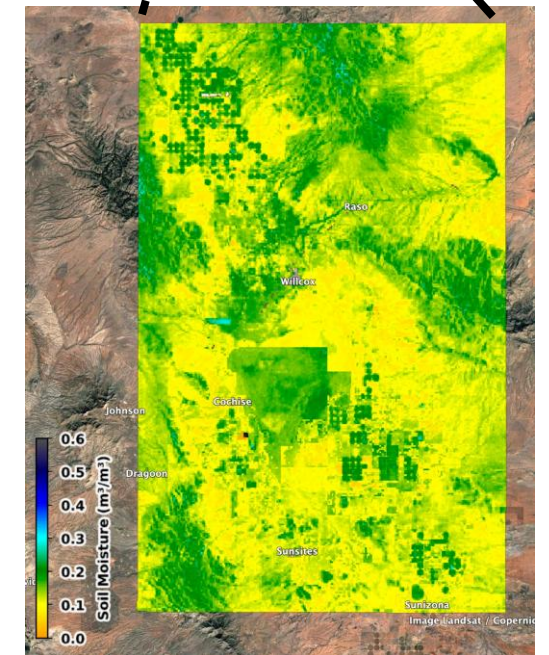
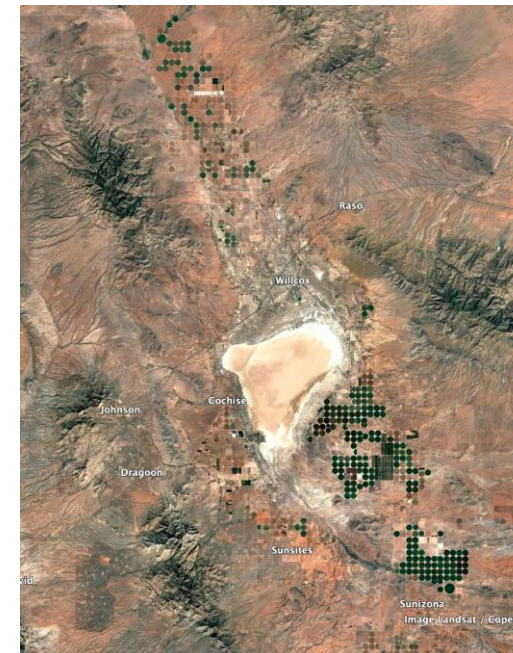
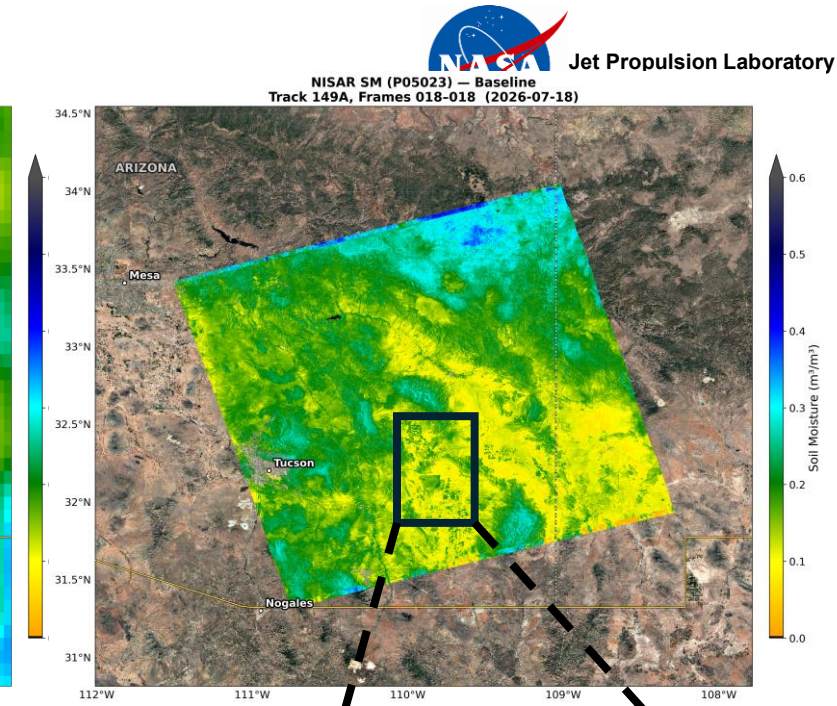
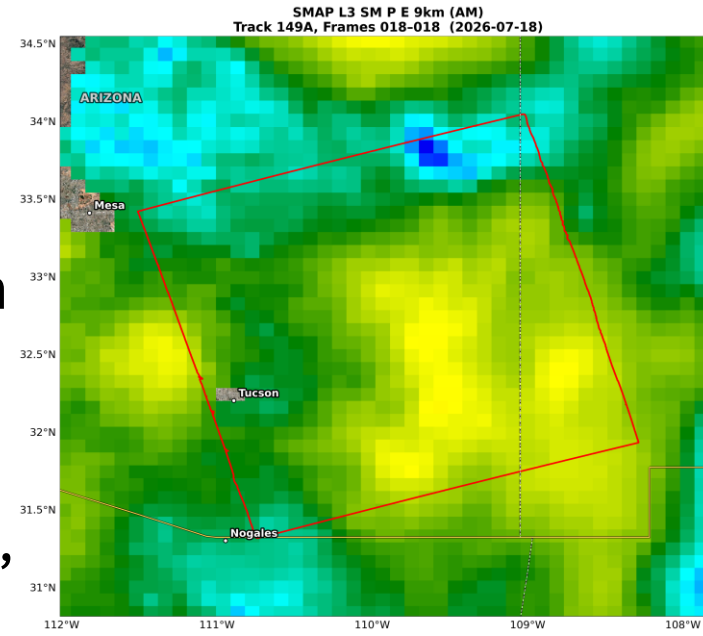
- Uses only L-band radar observations
- Repeat interval of 12 days (6 days when using both ascending/descending modes)
- Spatial resolution: 200 m
- Accuracy goal: $0.06 \text{ m}^3/\text{m}^3$ (over areas with VWC below $5 \text{ kg}/\text{m}^2$)
 - Areas with active precipitation, snow, frozen ground, urban, dense vegetation are flagged
- NISAR Soil Moisture product – ensemble of multiple algorithm approaches
 - Physical model algorithm
 - Time-series ratio algorithm
 - Multiscale fusion algorithm

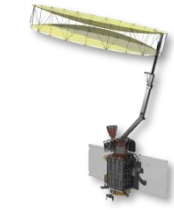




NISAR Soil Moisture Product

- NISAR soil moisture retrievals provide high spatial information
 - Need to validate soil moisture retrievals
- Joint cal/val effort for high resolution soil moisture (NISAR, SMAP-NISAR)
- Applications of high-resolution soil moisture
 - Agriculture
 - Irrigation and water demand
 - Hydrosphere-Biosphere interaction
 - Landslide
 - Wildfire
 - Land surface hydrology
 - Floods modeling and so on





SMAP-NISAR Active Passive Disaggregation

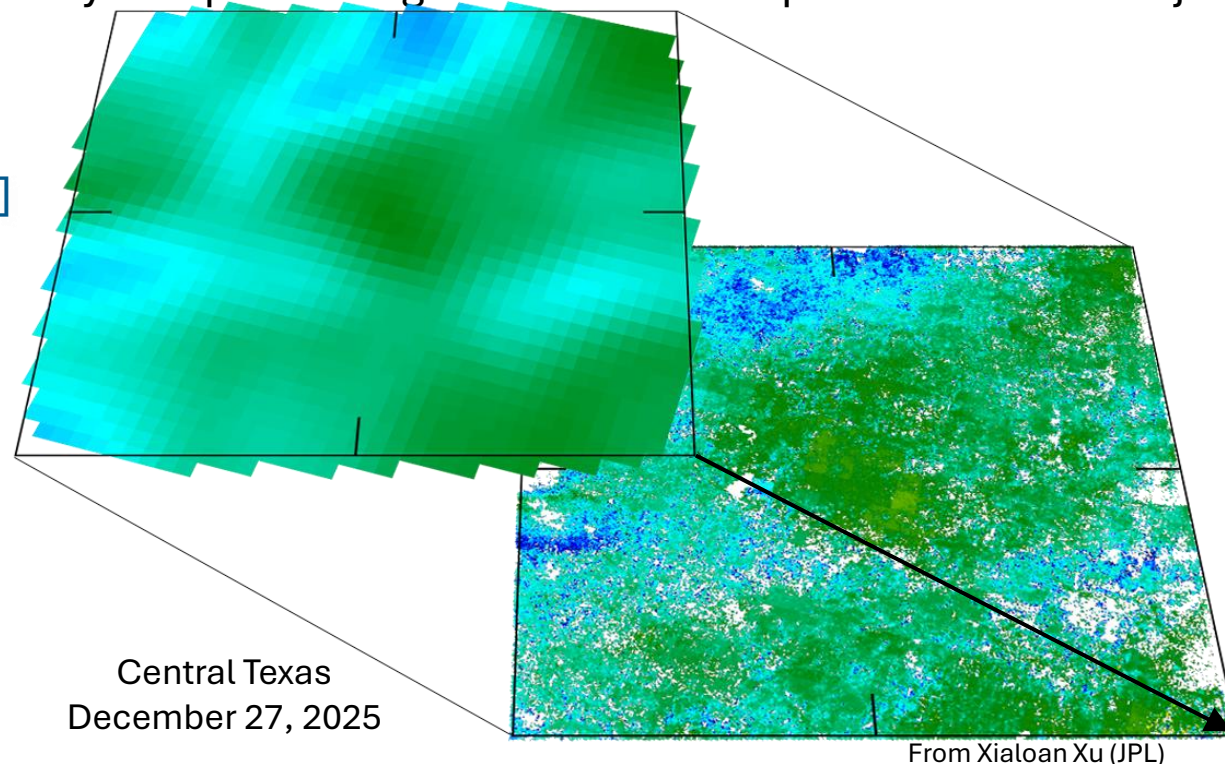
- **Goal:** High-resolution 100 [m] soil moisture product opportunity:
 - Value proposition: Demonstrate the complementary strength of L-band radiometer (accuracy) and L-band radar (high resolution)
 - Self-consistent with the radiometer-only product if aggregated to the radiometer resolution
 - The SMAP-NISAR product not only recaptures original SMAP active-passive mission objective but outperforms it in resolution.

Science Transition from:

SMAP radiometer-only 40 [km]

SMAP radiometer-only use-cases:

- Land-atmosphere feedbacks
- Drought monitoring
- Global ecology



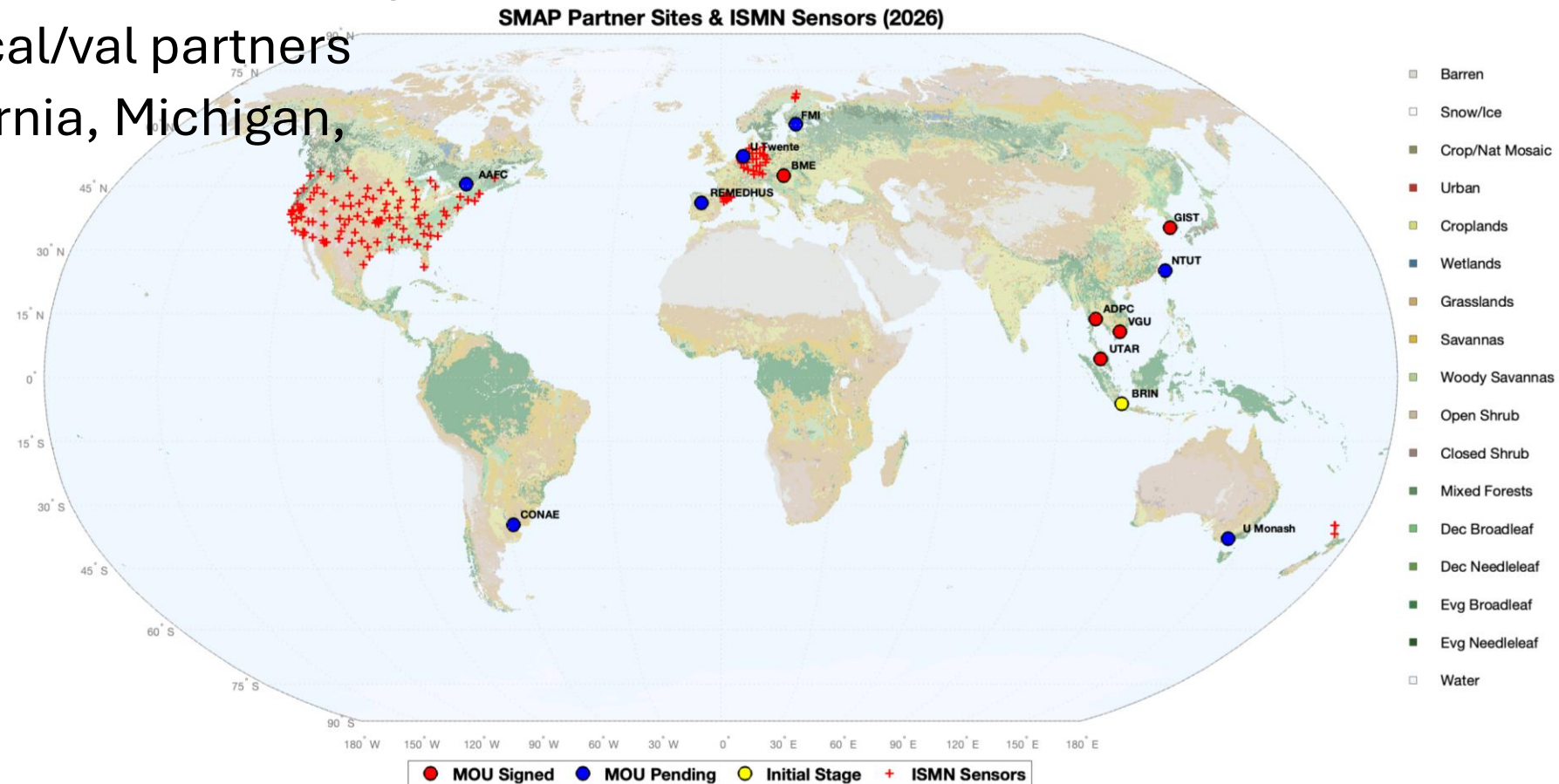
Science Transition to: **SMAP-NISAR 100 [m]**

Newly captured applications with SMAP-NISAR:

- Field-scale agriculture
- Floodplain runoff
- Landslide hazard
- Wildfires risk⁰

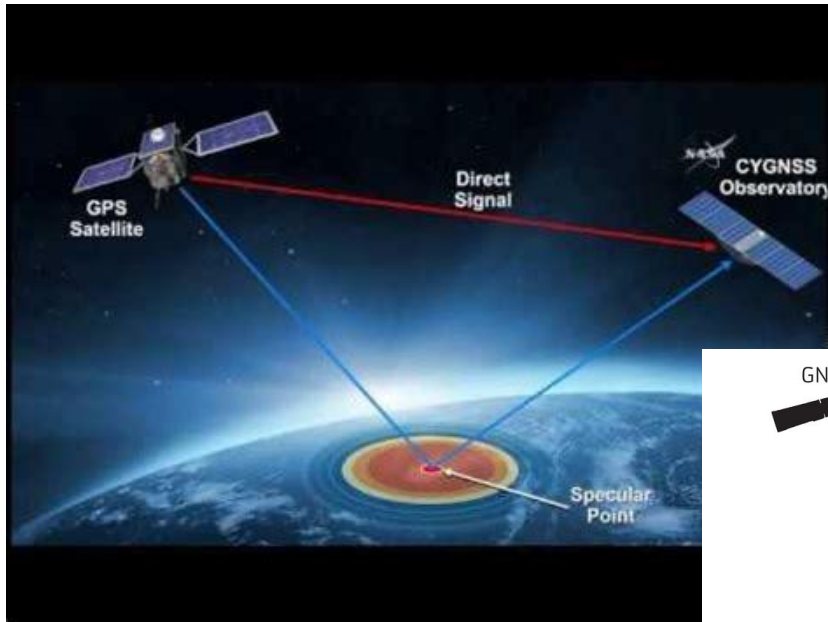
Joint Cal/Val by SMAP and NISAR Projects

- Joint cal/val effort for high resolution soil moisture (NISAR, SMAP-NISAR)
 - International SMAP cal/val partners
 - NISAR sites in California, Michigan, and Florida
 - ISMN

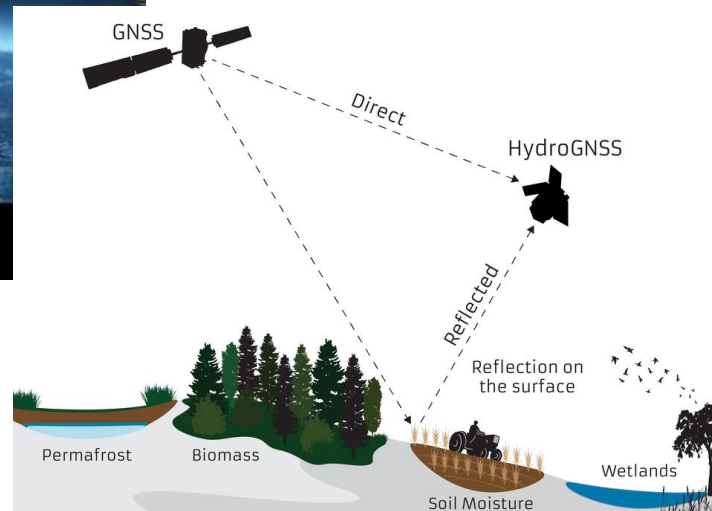


NASA CYGNSS Reflectometry

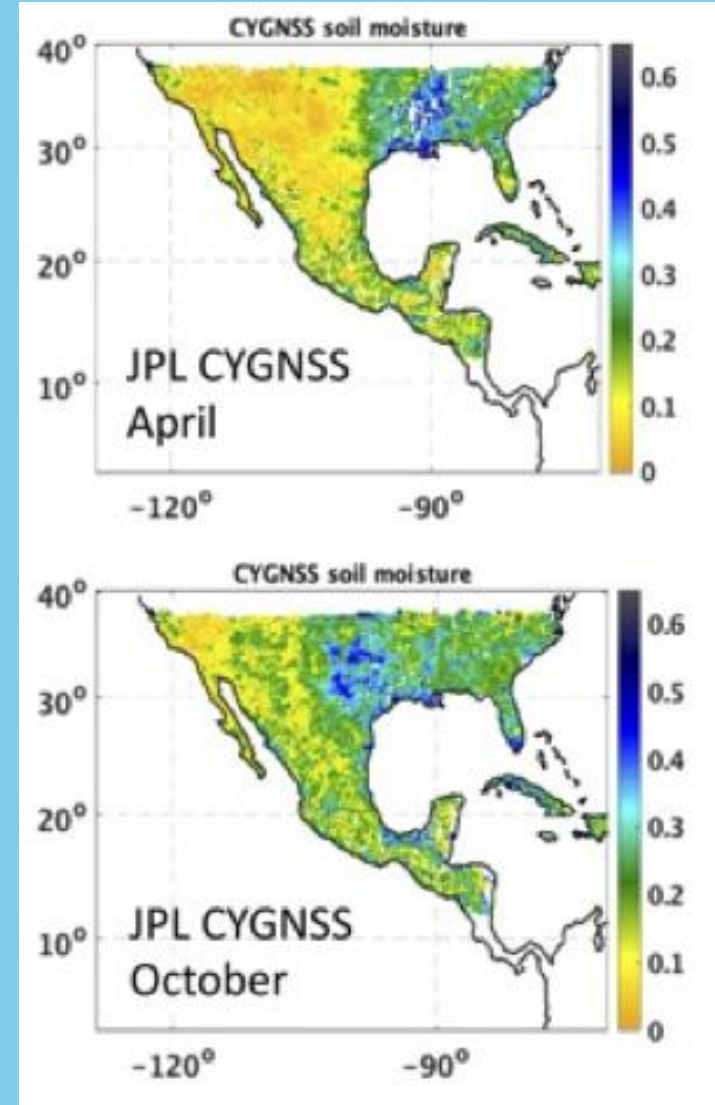
- Launched in Dec 2016 for ocean winds
- 8 smallsats with line tracks for land and ocean observation
- Revisit every few hours for 25 km grids.
- ~25 km resolution

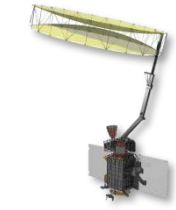


ESA HydroGNSS, 2025



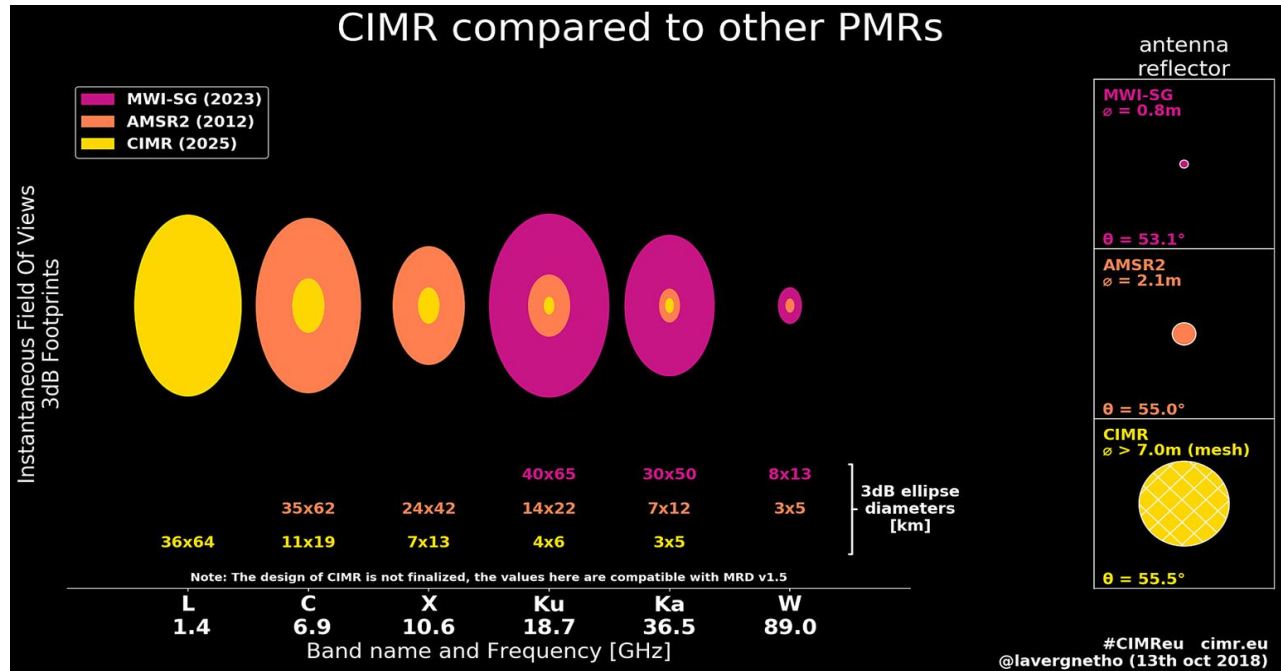
JPL CYGNSS soil moisture

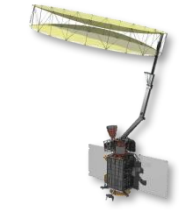




Copernicus Imaging Microwave Radiometer

- European Union Copernicus Program
- L-/C-/X/Ku band
- 56 km resolution at L-band
- 7 m antenna
- Polarimetric
- RFI mitigation
- Full angular scan
- 1800-km swath width
- To be launched in 2029+





European Union Copernicus ROSE-L

- European Union Copernicus
- L-band (1.2-GHz) radar
- 11 m x 3.6 m antenna
- Multipolarization
- 240-km swath width
- To be launched in 2029+



JAXA PALSAR

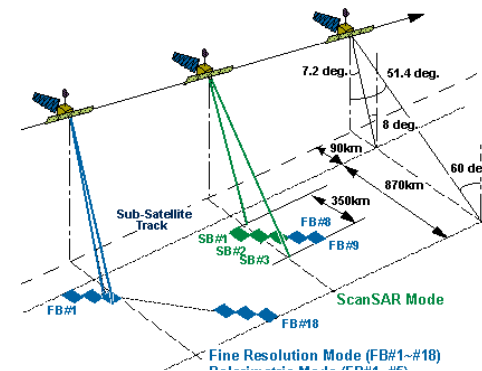
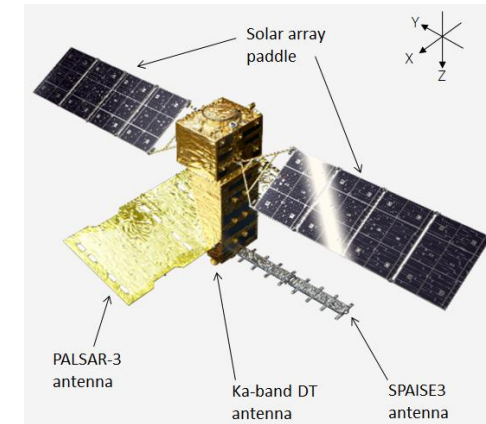
JERS-1: 1992

ALOS: PALSAR 2006-2011

ALOS-2: PALSAR-2 2014-

ALOS-4: PALSAR-3 2024-

- Phased Array type L-band Synthetic Aperture Radar (PALSAR)
- L-band frequency (1.2 GHz)
- Spotlight
- Stripmap
- ScanSAR
- Multi-polarization
- Spatial resolution: 3 to 25 m



SAR mode	Spotlight (sliding)	Stripmap				ScanSAR	
Center frequency [MHz]	1257.5	1257.5	1236.5 or 1257.5 or 1278.5				
Bandwidth [MHz]	84	84	42	28	28	25	
Resolution [m]	3 x 1 (Rg x Az)	3	6	10	10	(1 look)	
Swath width [km]	35	200	100	200	100	200	700 (4 scan)
Polarization*	1, 2	1, 2	1, 2, 4	1, 2	1, 2, 4	1, 2	1, 2
Available Incidence angle range	8-70	30-56	8-70	30-56	8-70	29-56	8-70
NESZ	< -20 dB	< -20 dB	< -24 dB	< -24 dB	< -28 dB	< -28 dB	< -20 dB
Rg S/A	> 15 dB	> 15 dB	> 15 dB	> 20 dB	> 20 dB	> 15 dB	> 15 dB
Az S/A	> 15 dB	> 15 dB	> 15 dB	> 15 dB	> 20 dB	> 15 dB	> 15 dB
Cross Polarimetric Discrimination			> 30 dB				
Split-band option (ionospheric correction mode)		N/A		28x10 MHz	N/A	N/A	

*1: Polarization basis: horizontal (H) and vertical (V). 1 = HH or VV or HV or VH. 2 = HH & VV. 4 = HH & VV & HV & VH.

*2: NESZ: Noise Equivalent Sigma Zero. This is the specified for entire swath width including 37 degrees incidence angle. Note that ALOS-2 specifications are for a point at 37 degrees incidence angle (=beam center), which is higher than ALOS-4 apparently.

*3: S/A: Signal to Ambiguity ratio. This is also the specified for entire swath width including 37 degrees incidence angle as same as NESZ.

Satellite Soil Moisture Data Characteristics

More than 10 missions and 8 Operational

	Mission Duration	SM Spatial Coverage ¹	Temporal Revisit	Orbit	Product Resolution
AMSR series (AMSR-E, AMSR2, AMSR3)	2002-present	Global land	2-3 days	(1:30 pm asc / 1:30 am desc)	25 km
WindSat (DoD)	2004-2012	Global land	2-3 days	Sun synch (6:00 am asc/ 6:00 desc)	25 km
ASCAT	2009-Present	Global land	2-3 days	Sun synch (9:30pm asc / 9:30am desc)	12.5 km/25 km
SMOS	2009-Present	Global land	2-3 days	Sun-synch (6am asc / 6pm desc)	25 km
Aquarius	2011-2015	Global land	8 days	Sun-synch (6pm asc / 6 am desc)	100 km
SMAP	2015-Present	Global land	2-3 days	Sun-synch (6am desc / 6pm asc)	1 km/3 km/ 9 km/36 km
CYGNSS, MUON, SPIRE	2017-Present	Mid-latitudes	Daily	Varying overpass time	~20 km
NISAR	2025-present	Global	6-12 days	6 am /6 pm	200 m
CIMR	2029 expected	Global	1-2 days	Sun-synch (6:00 AM/PM)	15 km/ 60 km
ROSE-L	2031 expected	Global	6-12 days	10:30 AM/PM	200 m
SMAP-Sentinel 1	2025-present	Global	6-12 days	6am/pm	100 m (UTM)
SMAP-NISAR	2026-present	Global	6-12 days	6am/p,	100 m (UTM)
HydroGNSS	2026-present	Global			~20 km

C, X-band Passive

C-band Active

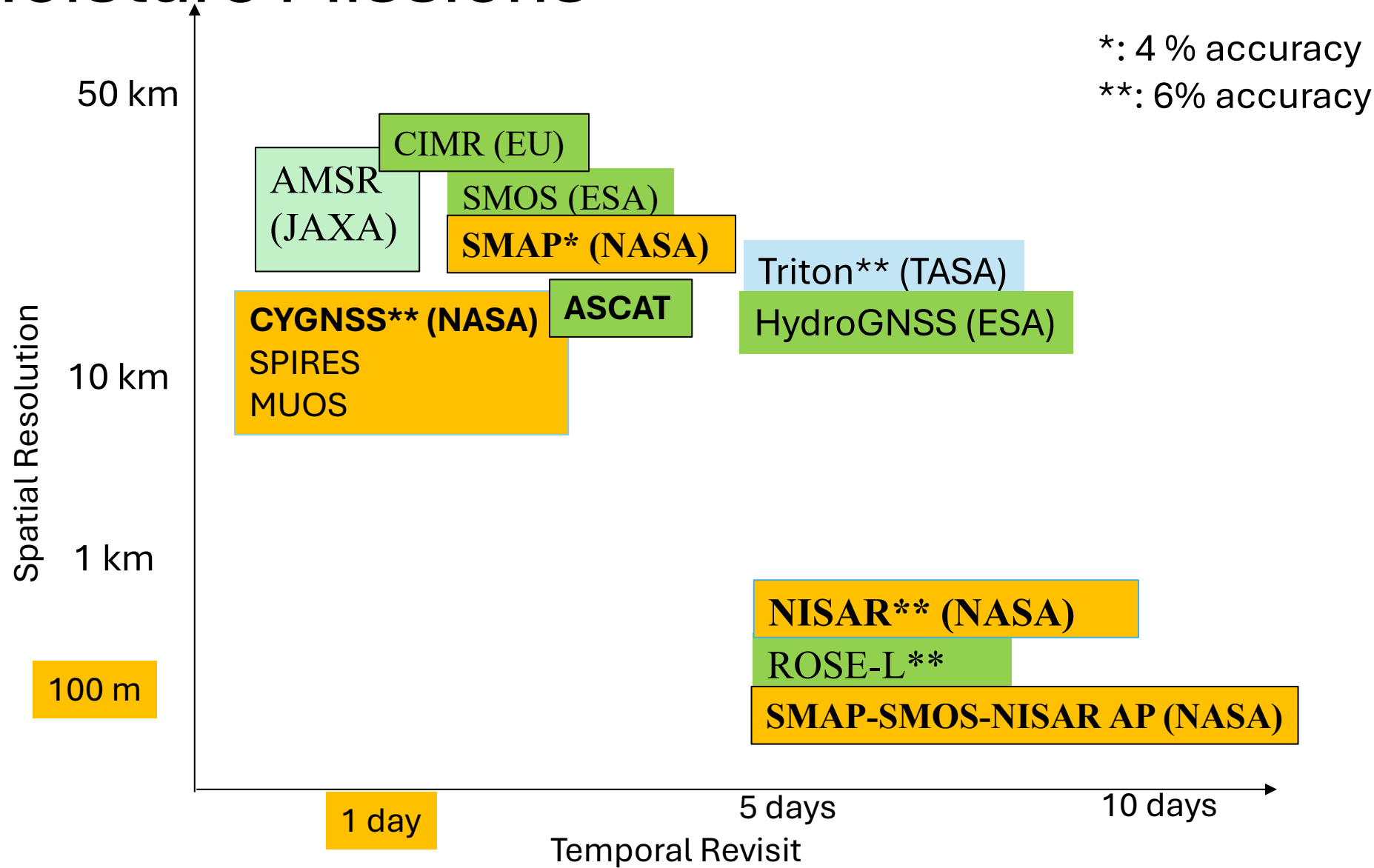
L-band Passive

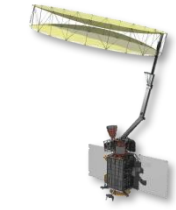
L-band Active

L-band Reflectivity



Spatial-Temporal Coverage of Soil Moisture Missions





Summary and Future Plans

- SMAP approved for the Senior Review Extension to operate from Fy27-FY29
 - Passive soil moisture products will continue for more than 14 years
 - SMAP-Sentinel will also continue
 - SMAP-SMOS-NISAR Data to be processed on the NASA-ESA MAAP (MIO)
 - To be distributed through NSIDC
 - Open source
- NISAR radar soil moisture has become available
- Joint cal/val program by SMAP and NISAR projects
- CYGNSS to decommission in 2027
- Two or more passive microwave soil moisture concepts submitted to Decadal Survey