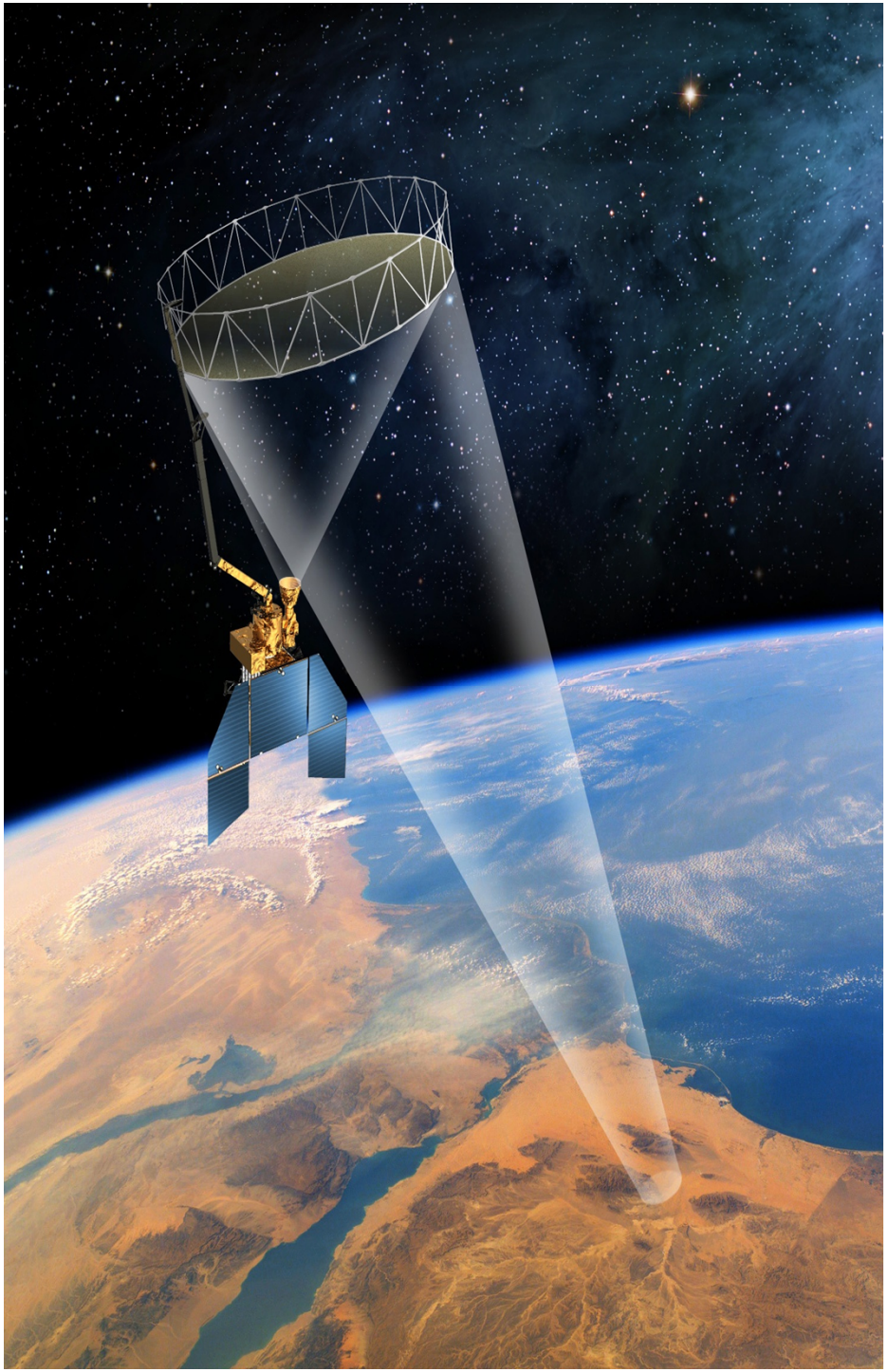

SMAP Data Products

BHW5

5th Interagency Surface Dynamics Working Group Meeting
Tucson, Arizona
March 3, 2011

Barry Weiss

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

Slide 1

BHW5 Is it soil dynamics or surface dynamics?

JPL, 2/18/2011

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Presentation Outline

- Overview of proposed SMAP Data Products
- Data product content
- Data Product format and design
- SMAP project plans to generate and provide data products

BHW4

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Proposed SMAP Data Products

Data Product Short Name	Description	Data Resolution	Grid Spacing	Granule Extent
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	5x30 km (10 slices)	Half Orbit
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1-3 km	1 km	Half Orbit
L1B_TB	Radiometer T_B in Time Order	36x47 km	36x47 km	Half Orbit
L1C_TB	Radiometer T_B	--	36 km	Half Orbit
L2_SM_A	Radar Soil Moisture	--	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	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

Slide 3

BHW4 Should we list Level 1A, should we avoid Level 4?
JPL, 2/18/2011

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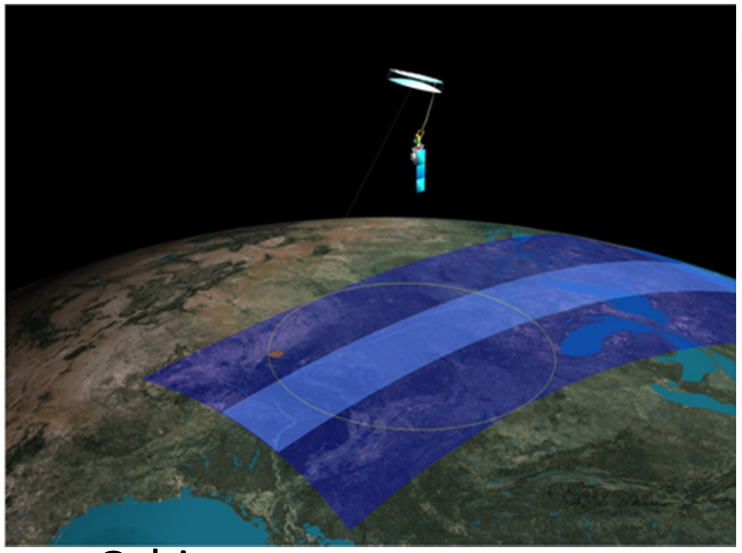
Proposed SMAP Measurement Approach

- Instruments:
  - Radar: L-band (1.26 GHz)
    - High resolution, moderate accuracy soil moisture
    - Freeze/thaw state detection
    - SAR mode: 3 km resolution
    - Real-aperture mode: 30 x 6 km resolution
  - Radiometer: L-band (1.4 GHz)
    - Moderate resolution, high accuracy soil moisture
    - 40 km resolution
  - Shared Antenna
    - 6-m diameter deployable mesh antenna
    - Conical scan at 14.6 rpm
    - Constant incidence angle: 40 degrees
      - 1000 km-wide swath



- Orbit:
  - Sun-synchronous orbit
  - 6 am local time descending
  - 6 pm local time ascending
  - 685 km altitude
  - Global coverage once every three days
- Mission Operations:
  - 3-year baseline mission

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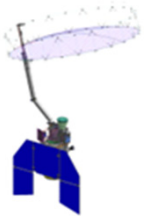
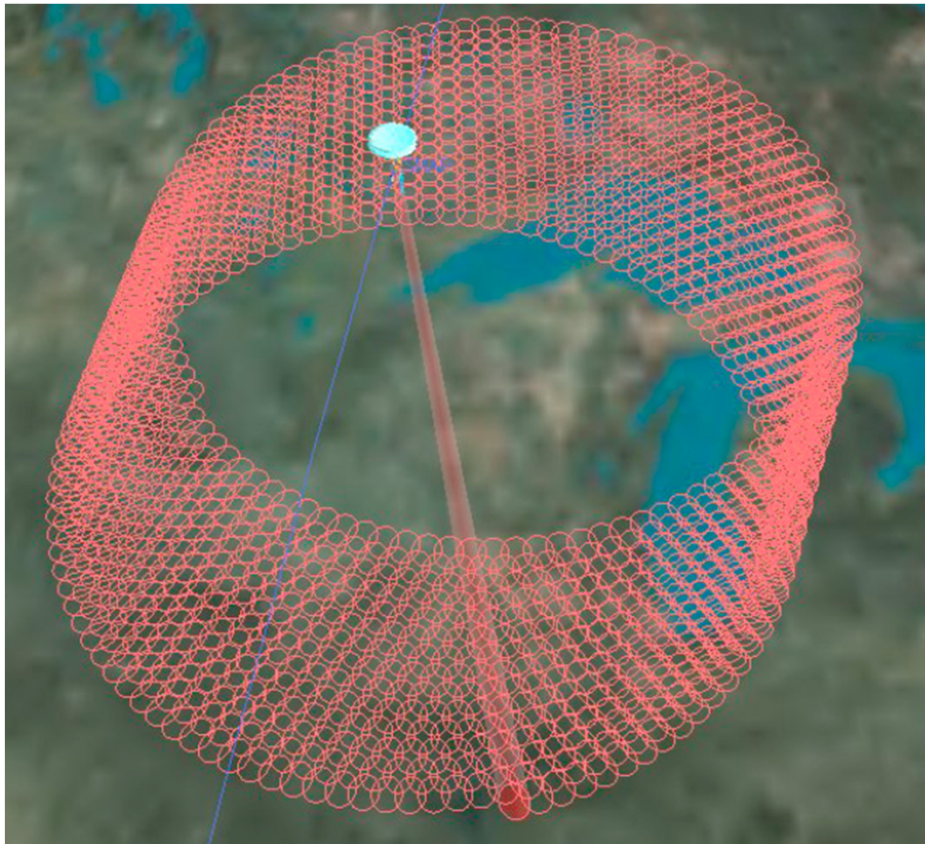
Data Acquisition Plan



- Radiometer data:
  - Continuous collection over the entire orbit and entire 360 degree antenna scan
  - Capable of periodic “cold sky” looks
- High-resolution Synthetic Aperture Radar (SAR) data:
  - Collection over the entire 360 degree antenna scan over land and coastal water during the AM orbit
  - Collection over the forward portion of the antenna scan over land and coastal water North of 45 degrees North latitude during the PM orbit.
- Low-resolution, real aperture radar data
  - Continuous collection over entire orbit and entire antenna scan



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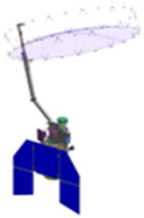
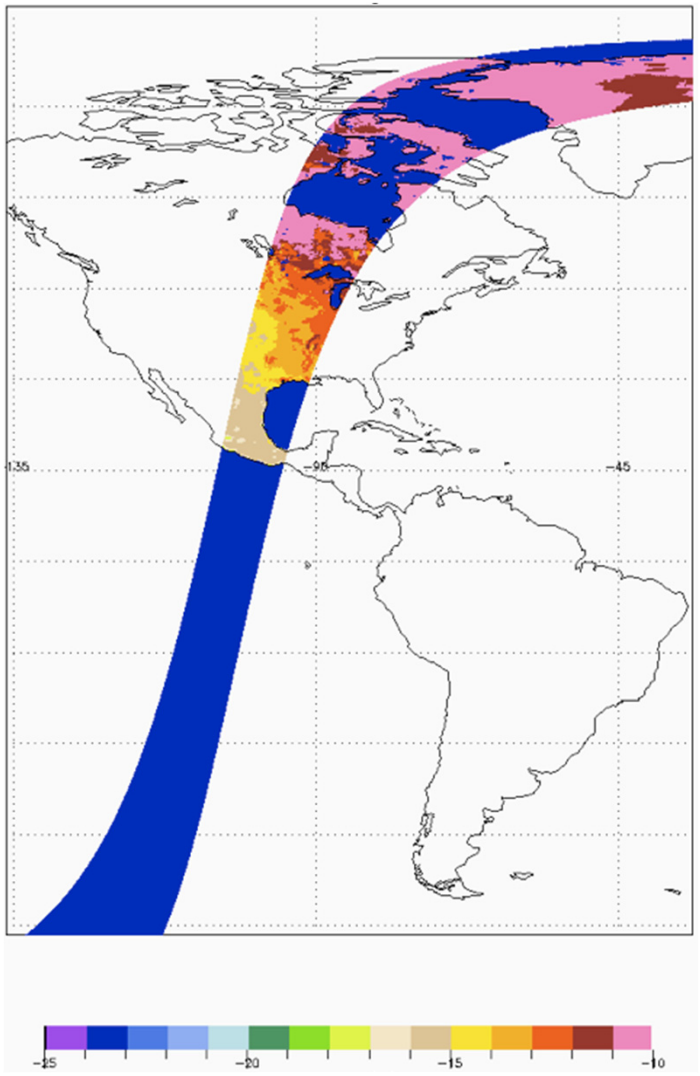
Level 1B Radar Product





Sigma0 VV (dB)

- Level 1B radar coverage continuous over all surface types.
- To contain Earth-located, calibrated radar backscatter measurements for co-pol and cross-pol data in time-order.
- Estimated Kp errors assigned to each measurement.
- Forward looking and aft looking measurements stored separately.
- To include spacecraft orbit and attitude information and instrument pointing geometry.
- To provide calibrated backscatter measurements for approximately ten range-resolved "slices" of the full radar FOV footprint. (~30 km by 5 km.)

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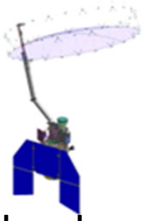
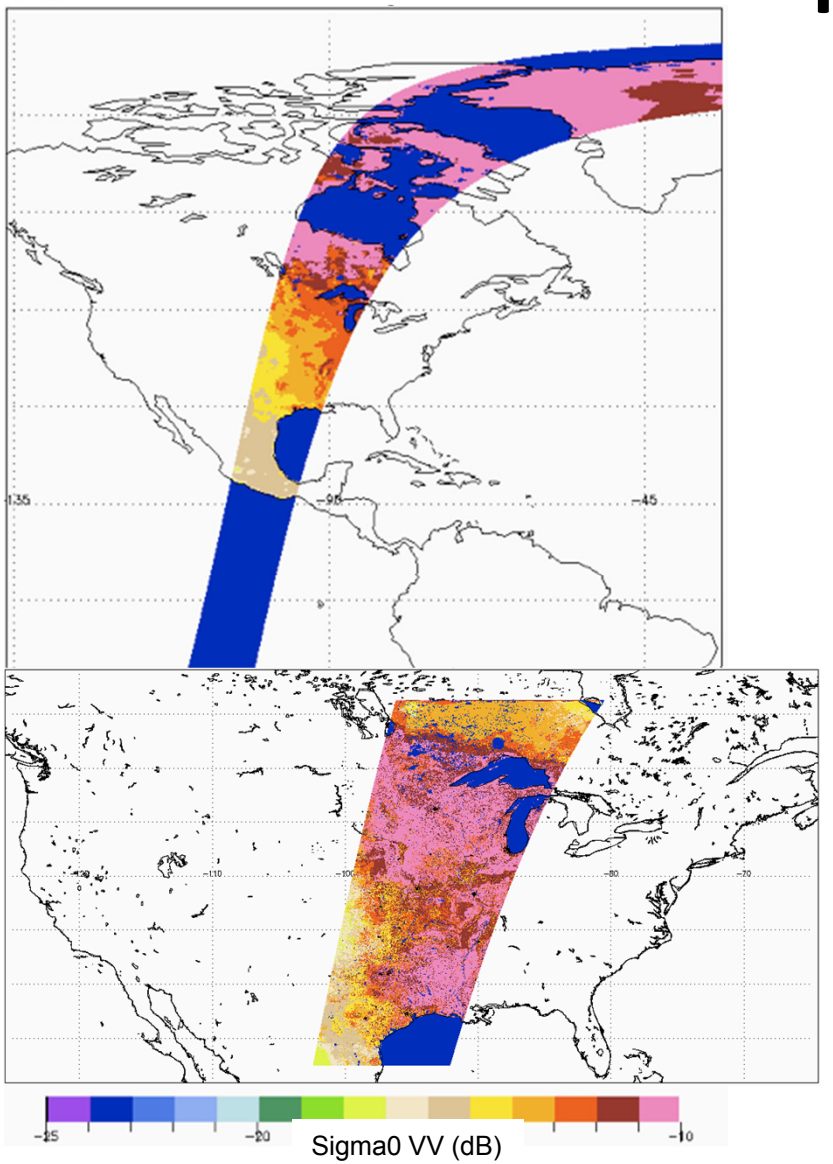
Level 1C High Resolution Radar Product





- L1C Hi-Res radar coverage restricted to land and coastal water.
- To include spacecraft orbit and attitude information and instrument pointing geometry.
- SAR to provide high-resolution single-look measurements. Resolution would vary from ~400 m at the swath edge to about 1.2 km at 150 km from the nadir sub-track. Nadir looks are thin slices as wide as the beam footprint.
- Calibrated forward looking and aft looking measurements stored separately.
- H-pol, v-pol and cross-pol backscatter measurements multi-looked separately.
- Data posted in a 1 km grid cells in an along track /cross track swath grid.
- Product would provide reference to global and polar 1 km EASE grid coordinates.

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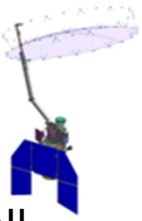
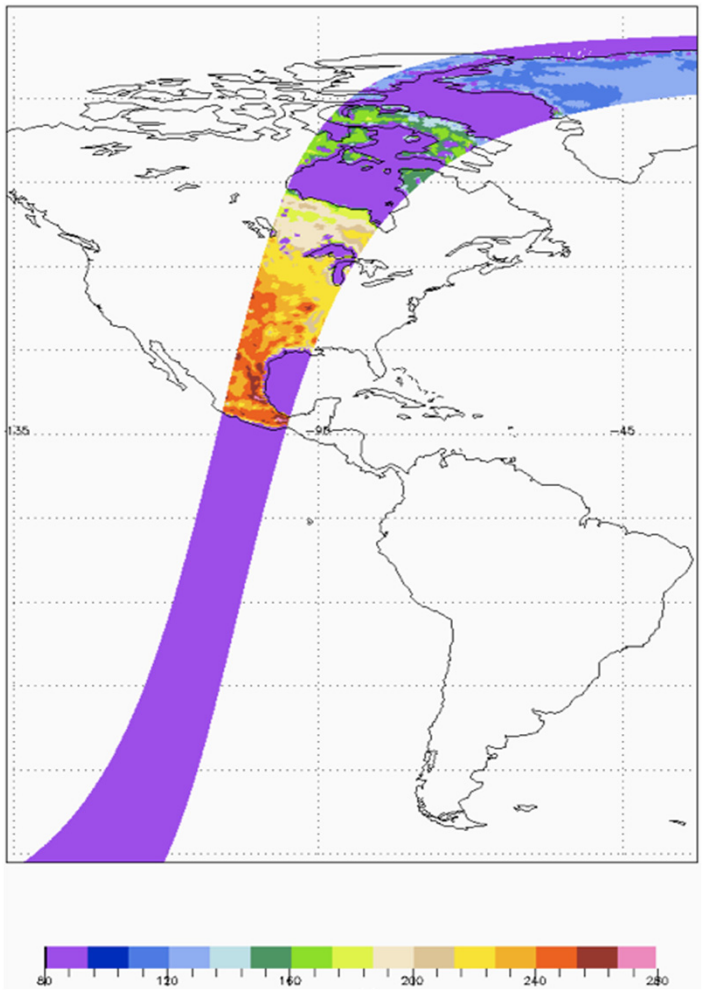
Level 1B Radiometer Product





L1B Time-ordered H-pol TB (K)

- L1B radiometer coverage continuous over all surface types.
- To include spacecraft orbit and attitude information and instrument pointing geometry.
- To contain time ordered Earth-located, calibrated brightness temperatures for each FOV footprint.
- Forward looking and aft looking measurements stored separately.
- Each footprint includes H-pol, V-pol and unpolarized Tb measurements.
- Footprint resolution to be approximately 40 km.
- Unpolarized Tb used to infer Faraday rotation corrections for the H –pol and V-pol Tb measurements.
- Product would provide reference to cylindrical and polar 36 km EASE grid coordinates for each footprint.

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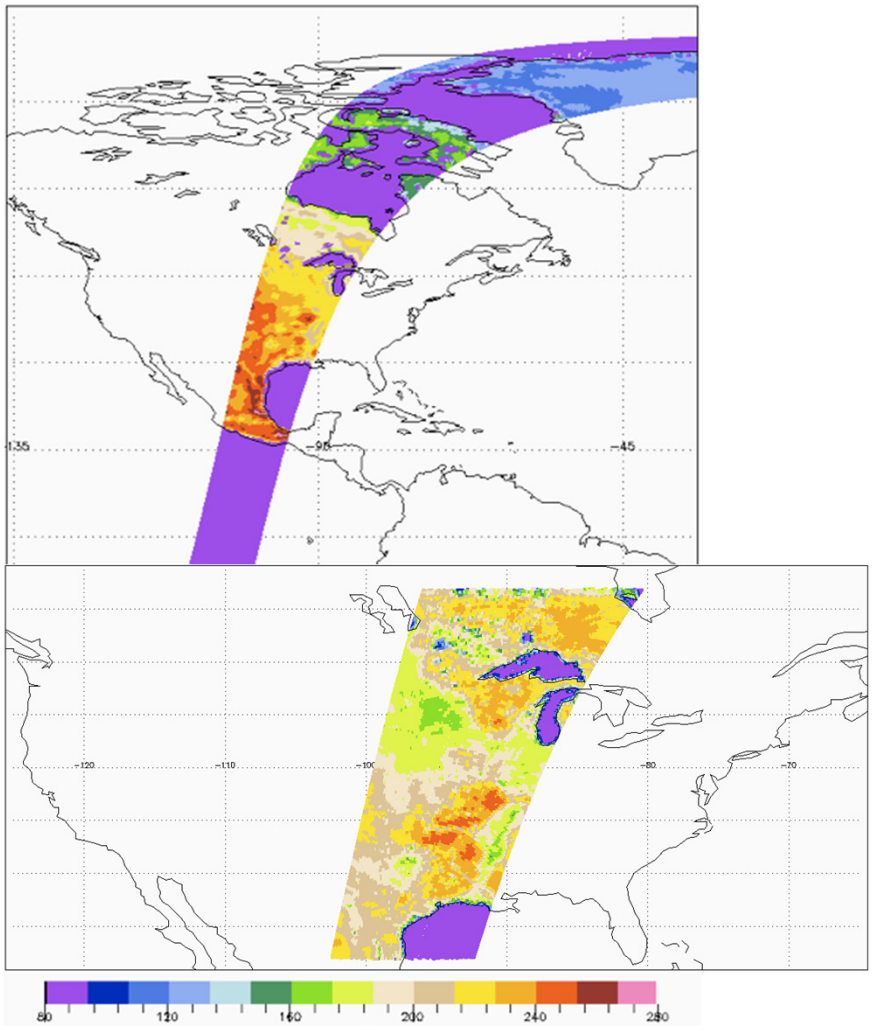
Level 1C Radiometer Product



L1C Earth-fixed H-pol TB (K)

- Level 1B Radiometer data gridded on a 36 km cylindrical Earth-fixed grid.
- Forward looking and aft looking observations stored separately.
- Input to Level 2 Radiometer 40 km soil moisture and Level 2 active/passive soil moisture processing.

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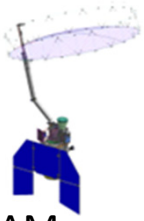
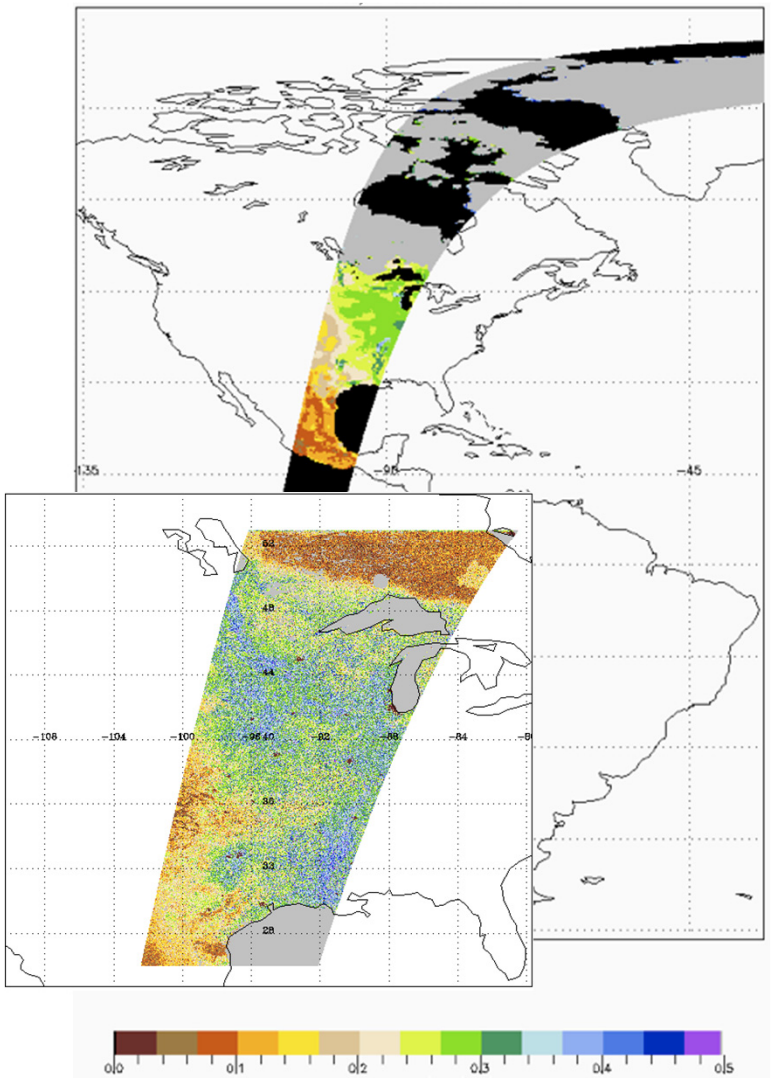
Level 2 High Resolution Radar 3 km Soil Moisture Product





Volumetric Soil Moisture (cm^3/cm^3)

- PM Product to cover entire Earth land mass, AM product restricted to land north of 45 North Longitude
- AM data acquired specifically for freeze-thaw retrievals.
- To employ 1 km High Resolution radar L1C data averaged over 3 km cylindrical EASE grid cells to reduce Kp noise.
- Soil moisture retrievals to use snapshot and/or time-series algorithms.
- Depending on the terrain classification, multiple optional models/algorithms may be employed for retrieval.
- Would provide scene heterogeneity information for the the Level 3 AP algorithm processing.
- Would provide freeze-thaw state and transient water body information that the other Level 2 soil moisture processes require.
- To include quality masks for urban areas, mountainous terrain, dense vegetation, snow and ice.

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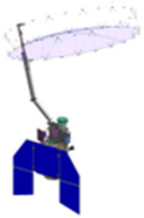
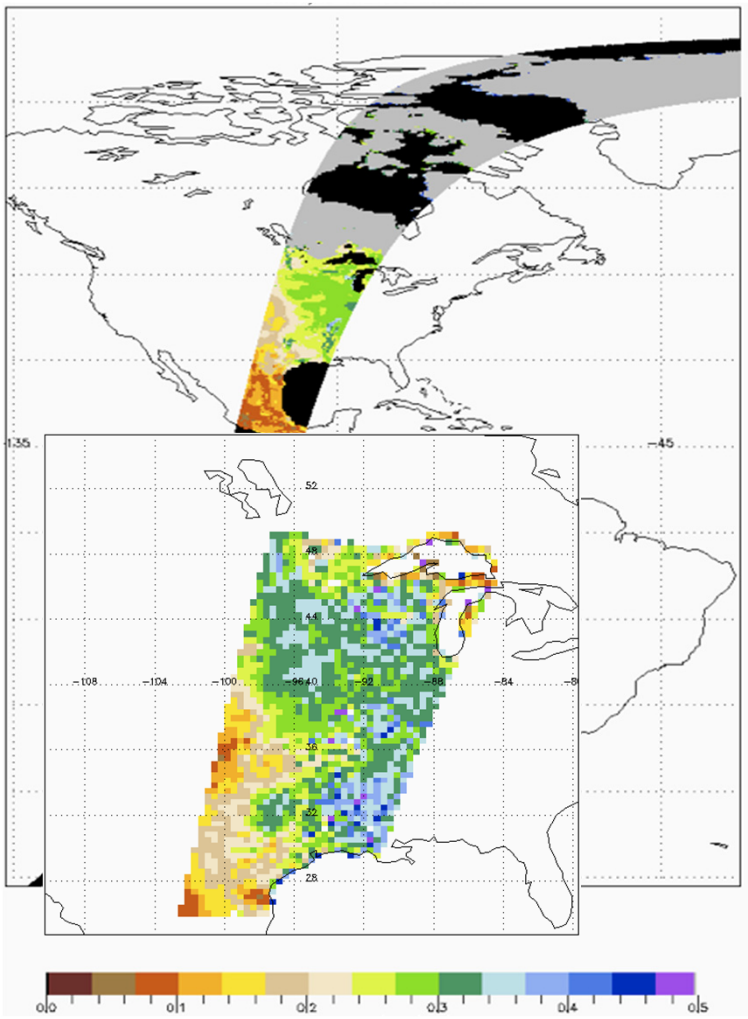
Level 2 Radiometer 36 km Soil Moisture Product





Volumetric Soil Moisture (cm^3/cm^3)

Designed to:

- Provide retrieved soil moisture over land with 4% accuracy for low-to-moderately vegetated areas.
  - Low to moderate vegetation definition is vegetation_water_content <= 5 kg/m2.
- Post on 36 km cylindrical EASE grid cells.
- Depend upon transient water body and freeze-thaw state retrievals based on High Resolution radar.
- Estimate soil moisture based on AM observations.
- Include quality masks for urban areas, mountainous terrain, dense vegetation, precipitation, snow and ice.

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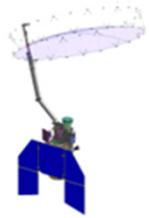
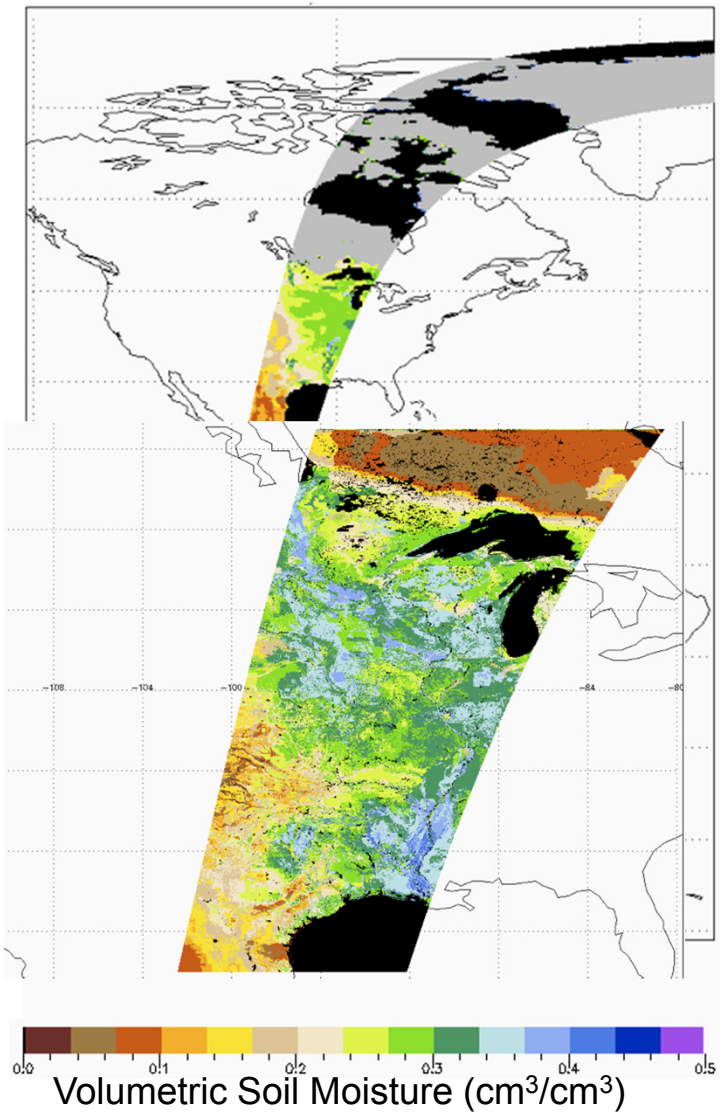
Level 2 Active/Passive 9 km Soil Moisture Product





Designed to:

- Merge radar and radiometer channels using a time series algorithm and spatial heterogeneity of L1C radar product.
- Provide retrieved soil moisture over land with 4% accuracy for low-to-moderately vegetated areas.
  - Low to moderate vegetation definition is vegetation_water_content <= 5 kg/m2.
- Post on a 9 km cylindrical EASE grid cells.
- Employ transient water body and freeze-thaw state retrievals from High Resolution Radar processing.
- Include quality masks for urban areas, mountainous terrain, dense vegetation, precipitation, snow and ice.
- Input to Level 4 soil moisture processing.

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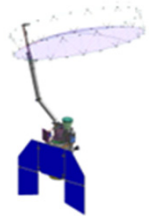
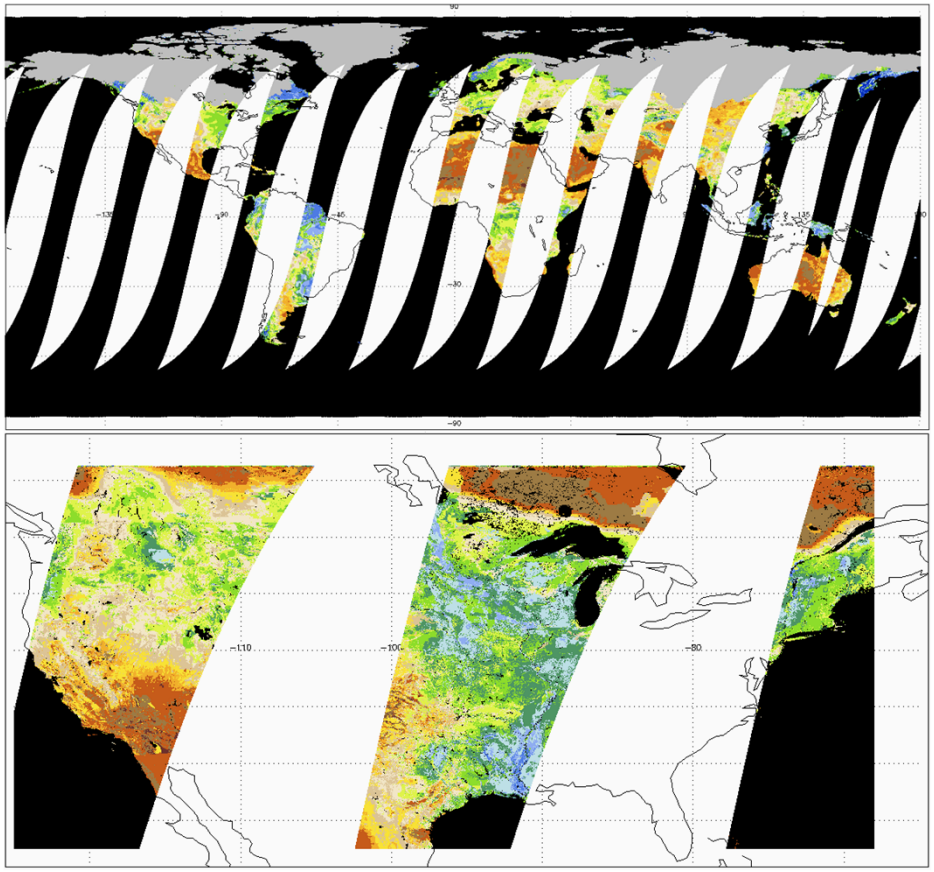
Level 3 High Resolution Radar 3 km Soil Moisture Product





Volumetric Soil Moisture (cm^3/cm^3)

- Composite of all Radar Level 2 half orbit products acquired during the same UTC day.
- Multiple measurements may overlap at high latitudes. Algorithm to select measurements acquired closest to 6 AM solar time.
- Posted on cylindrical 3 km EASE grid cells.
- Soil moisture retrievals use snapshot and/or time-series algorithms.
- Depending on the terrain classification, multiple optional models/algorithms may be employed for retrieval.
- Based exclusively on AM data.

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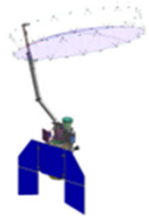
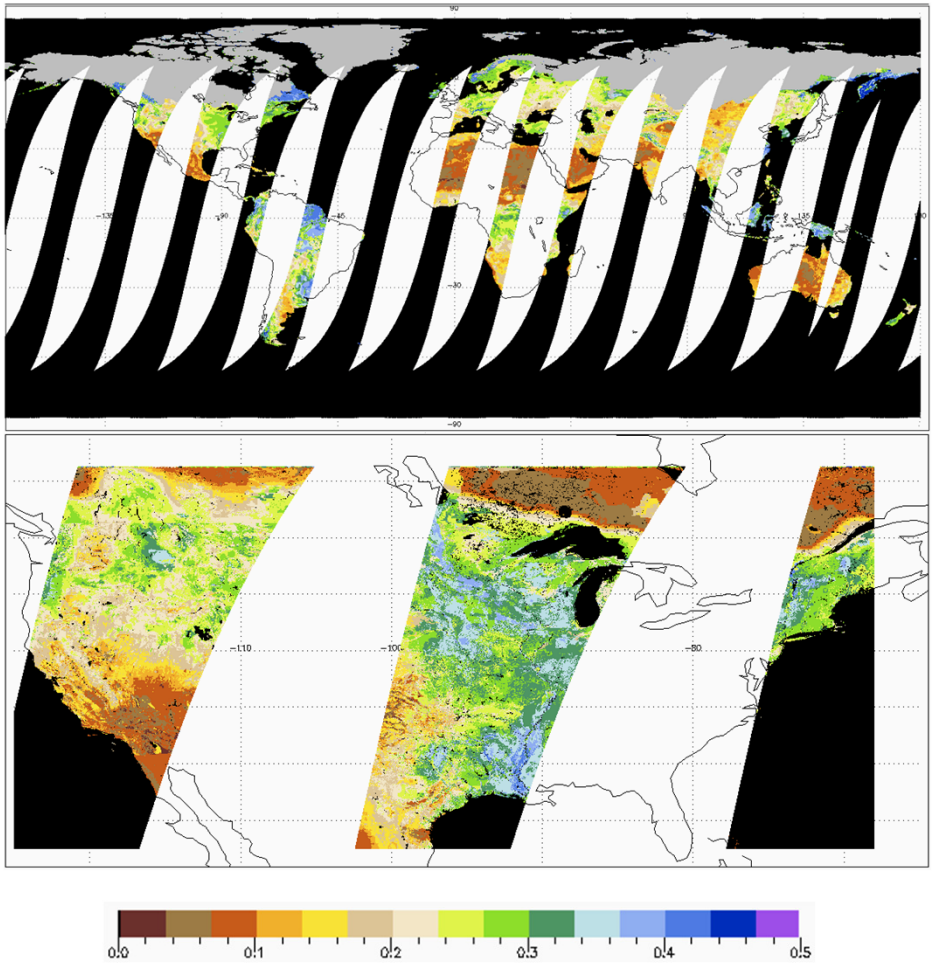
Level 3 Radiometer 36 km Soil Moisture Product





Volumetric Soil Moisture (cm^3/cm^3)

- Composite of all Radiometer Level 2 half orbit products acquired during the same UTC day.
- Multiple measurements may overlap at high latitudes. Algorithm to select measurements acquired closest to 6 AM solar time.
- Posted on 36 km cylindrical EASE grid cells.
- Would provide retrieved soil moisture over land with 4% accuracy for low-to-moderately vegetated areas.
  - Low to moderate vegetation definition is vegetation_water_content <= 5 kg/m2.
- Based exclusively on AM data.

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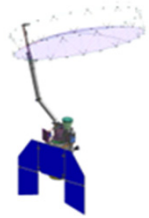
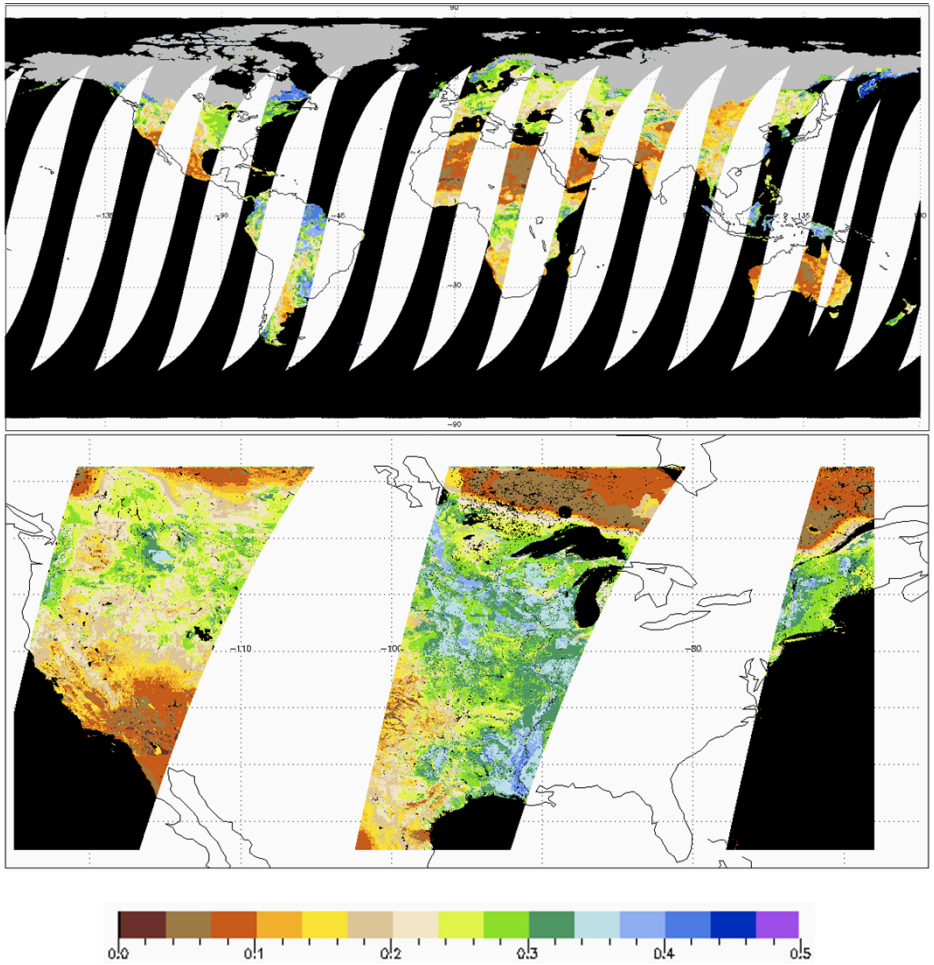
Level 3 Active/Passive 9 km Soil Moisture Product





Volumetric Soil Moisture (cm^3/cm^3)

- Composite of all Active/Passive Level 2 half orbit products acquired during the same UTC day.
- Multiple measurements may overlap at high latitudes. Algorithm to select measurements acquired closest to 6 AM solar time.
- Posted on 9km cylindrical EASE grid cells.
- Would provide retrieved soil moisture over land with 4% accuracy for low-to-moderately vegetated areas.
  - Low to moderate vegetation definition is vegetation_water_content <= 5 kg/m2.
- Based exclusively on AM data.
- Input to Level 4 soil moisture processing.

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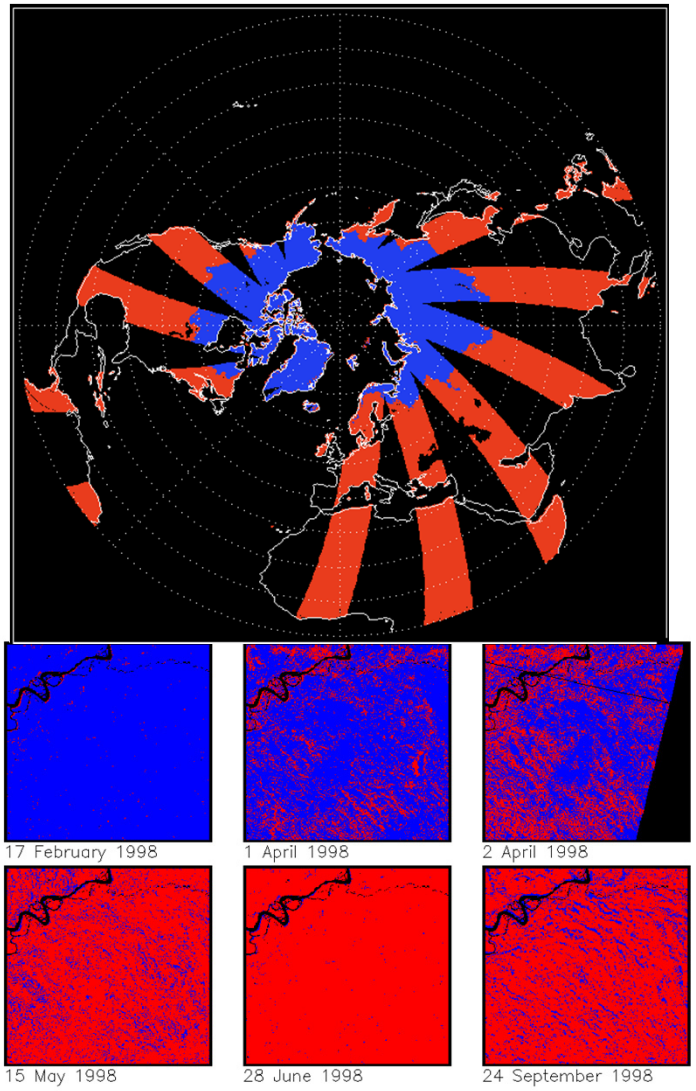
Level 3 Freeze/Thaw Product



Daily Freeze/Thaw State

- Would quantify daily freeze/thaw state as a binary condition for land surface.
- Would employ the 1 km Level 1C High Resolution Radar data and a time-series change detection algorithm to infer freeze/thaw state.
- Would provide 80% freeze/thaw state accuracy
- Would represent 2 day average temporal intervals for regions North of 45° N.
- Each product would represent a single calendar day UTC.
- Posted to a 3 km polar EASE grid with 1 to 3 km spatial resolution.

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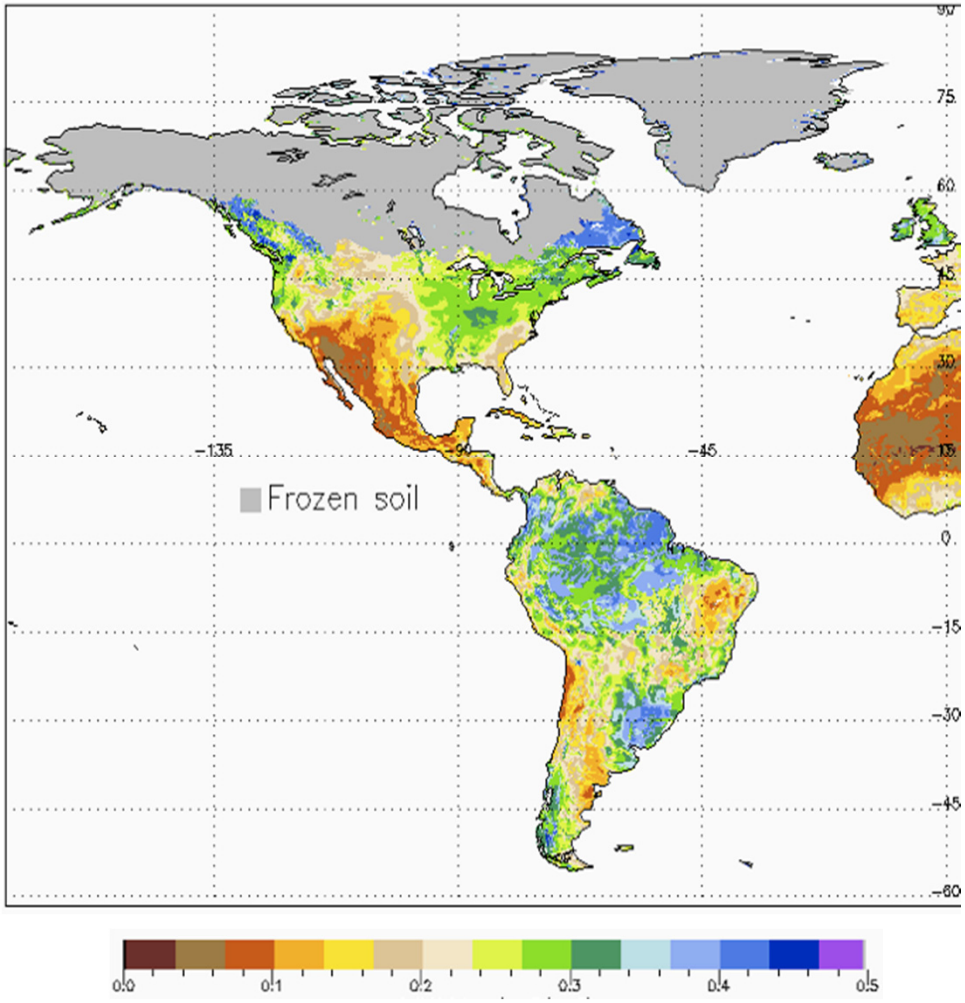
Level 4 Surface and Root-Zone Soil Moisture Product



Volumetric Soil Moisture (%)

- Assimilate SMAP data into a state-of-the-art land surface model to derive global estimates of root-zone moisture.
- Would use L1C Radiometer, Level 3 High Resolution Radar Soil Moisture, and Level 3 Freeze/Thaw.
- Global output would represent 3 hour intervals at 9 km resolution with 7-day latency.

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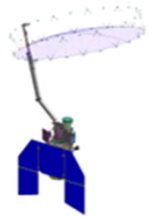
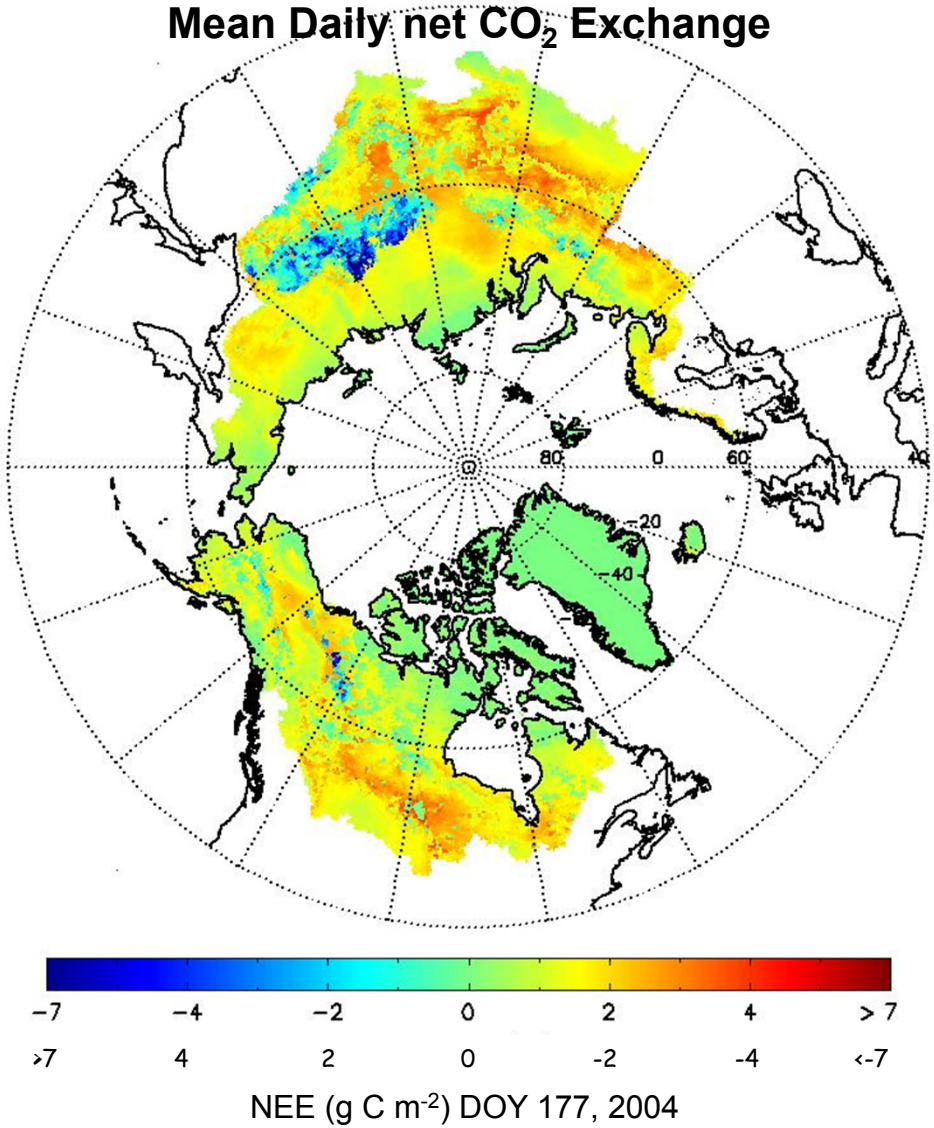
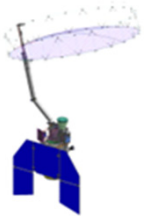
Level 4 Carbon Product





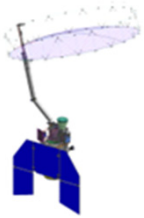
- Would quantify the net carbon flux in boreal landscapes
- Would reduce uncertainty regarding missing carbon sink on land.
- Applies a soil decomposition algorithm driven by SMAP L4_SM and Gross Primary Production (GPP) inputs to compute net land-atmosphere CO_2 exchange (NEE).
- Would produce daily global maps of NEE at 9 km resolution with a 14-day latency.
- Accuracy commensurate with tower based CO_2 observations. (RMSE ≤ 30 g C m^{-2} yr^{-1}).

Data Product Design Drivers



- Data design must balance requirements of the mission Science Team with the needs of the User Community
- All Data Products must:
  - Conform with mission requirements
  - Provide users with the information they need
  - Have a consistent format and architecture
  - Contain adequate self descriptive information
  - Be easy to use

Product Generation Practice



- Within the project - Algorithm Development Team and Science Data System Team collaborate to generate design
  - Develop a complete product design that would include essential data as well as valuable ancillary data
  - Coordinate product content to ensure that data required in subsequent processes are documented and available
  - Coordinate naming conventions so that elements that represent same measures have the same or very similar names
  - Ensure that the products provide the data that the science community needs
- Within the larger community – SMAP Science Data System (SDS) team is actively involved with NASA Earth Science Data Systems Software Process Group (SPG)
  - Ensure that standards are endorsed by the SPG
  - Ensure that products contain essential metadata so that requisite data could be located on multiple systems including the Data Centers and ECHO
  - Track upcoming technologies, incorporate features that would enable adoption of those technologies as they become more widespread

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Product Format
Hierarchical Data Format (HDF5)

- HDF5 combines a robust data model with a file format and a user library
  - Major object components:
    - Datasets – major product content
    - Dataspace – description of product content shapes
    - Datatypes – flexible means to type data
    - Groups – flexible means to group data
    - Attributes – descriptive elements
  - Supports a large variety of platforms and common software languages
    - IDL and Matlab both have well defined and easy to use HDF5 interfaces
  - Has considerable heritage – introduced in 1999-2000
  - Provides a highly flexible architecture to read, extract and write data
  - Operates efficiently with very large data sets
  - Large numbers of new technology data service providers function well with HDF5
- Support available through the HDF Group.
  - Website at http://www.hdfgroup.org/

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SMAP Data Product Design
A Consistent and Simple Standard

- **Data product types or collections**
  - Set of files with conformant output generated using the same Science Processing Software (SPS)
  - All data product types should employ a single standard format
- **Data granule or file**
  - An instance of a data product type
- **Product data**
  - Includes both algorithmic output as well as valuable ancillary data
  - Separated into distinct groups of arrays
    - Arrays within each group are conceptually related
    - Within each group, arrays have the same or very similar dimension shapes
    - Within each group, array elements with the same dimension indices apply to the same measurement or retrieval instance
- **Metadata**
  - Product metadata – applies to the entire content of a data granule
  - Local metadata – applies to a particular element in the product

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Data Correlation in SMAP Product Design

Three data groups appear in the prototype Radar Level 1B Product design:

Attitude and Ephemeris Group

Each of the arrays in this group contains one representative element for each antenna rotation. The following array elements are examples of spacecraft positions and attitudes with a representative time at ***antenna_scan_time_utc[1000]***:

- ***sc_nadir_lon[1000]***
- ***y_pos[1000]***

Sigma0 Data Group

Each of the arrays in this group contains one representative element for each low resolution sigma0. The following array elements are examples of measurements for the low resolution sigma0 with a representative time at ***sigma0_time_utc[20000]*** :

- ***antenna_boresight_azimuth[20000]***
- ***sigma0_hh[20000]***

Sigma0 Slice Data Group

Each of the arrays in this group contains one representative element for a slice in each low resolution sigma0. The following array elements are examples of measurements for the 7th slice of the low resolution sigma0 with a representative time at ***sigma0_time_utc[20000]***:

- ***Slice_slant_range[20000][6]***
- ***slice_sigma0_vv[20000][6]***

Metadata Categories and Coverage

- **Product metadata – applies to the entire content of a data granule**
  - Mission specific information
  - Spatial and time boundary information
  - Data version information – algorithm, Science Processing Software (SPS), Science Data System (SDS) release, HDF5 version
  - Granule pedigree or lineage
    - Lists of the input that were used to generate a data granule
  - Technical parameters that apply to the entire data granule
    - Orbit mechanical data
    - Instrument specific information
    - Small tables of calibration and/or algorithmic coefficients
    - Algorithmic parameters and options
  - Data quality and completeness
  - References to related documentation
- **Local metadata – applies to particular arrays in the product.**
  - Maxima, minima, units, dimension definitions, identification of statistical methods

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Quality Information

- Product metadata – covers the content of the entire product
  - Overall quality information for entire product content
    - Completeness – fraction of expected data that appears in the product
    - Range Check – fraction of data pixels that fall within an acceptable range
    - Quality Check – fraction of data pixels that are deemed acceptable quality
- Associated with each pixel – enables users to assess quality of each individual element
  - Quantitative error bar whenever possible
  - Bit flags for qualitative information
    - Individual bits flag individual conditions
    - In general, ‘0’ indicates desirable conditions, ‘1’ represents questionable or undesirable conditions
    - When the overall bit flag value is zero, the data are clean

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Ancillary Data in SMAP Products

- SMAP processing algorithms plan to use a considerable amount of ancillary data. Some examples are:
  - Meteorological data from ECMWF
  - Surface information from MODIS
  - Digital Elevation Map based on multiple sources
- The proposed SMAP strategy for inclusion of ancillary data is:
  - Dynamic ancillary data needed for algorithmic use would appear in SMAP products
  - Static ancillary data needed for algorithmic use may appear in distributable tables rather than in the data products
    - The project to provide these tables to Early Adopters before launch
    - Data Center to provide tables after launch

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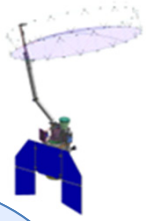
Proposed SMAP Data Product Structure



Product Metadata – Stored in attributes in the HDF5 Metadata Group.

HDF5 Data Group 1 – One of multiple HDF5 groups.
All data sets in this group have corresponding array indices.

HDF5 Data Set 1 – Array of Product Data

Local Metadata – Max, min, units, dimension sizes, statistical methods, etc. – CF compliant

.....

HDF5 Data Set J – Array of Product Data

Local Metadata – Max, min, units, dimension sizes, statistical methods, etc. – CF compliant

.....
.....

HDF5 Data Group N – All data sets in this group have corresponding array indices.

HDF5 Data Set M – Array of Product Data

Local Metadata – Max, min, units, dimension sizes, statistical methods, etc. – CF compliant

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SMAP Product Development Plan

- Data Product Availability and Volumes
- Generation of Model SMAP Products
- Current Data Product Simulation

BHW6

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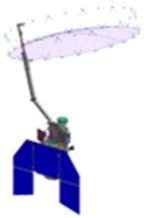
Proposed SMAP Data Product Availability



Data Product Short Name	Description	Initial Availability After Launch	Latency after Acquisition
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	6 months	12 hours
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	6 months	12 hours
L1B_TB	Radiometer T_B in Time Order	6 months	12 hours
L1C_TB	Radiometer T_B on Earth Grid	6 months	12 hours
L2_SM_A	Radar Soil Moisture on Earth grid	6 months	24 hours
L2_SM_P	Radiometer Soil Moisture on Earth Grid	6 months	24 hours
L2_SM_AP	Active-Passive Soil Moisture on Earth Grid	6 months	24 hours
L3_FT_A	Daily Freeze/Thaw State on Earth Grid	9 months	49 hours
L3_SM_A	Daily Radar Soil Moisture on Earth grid	9 months	49 hours
L3_SM_P	Daily Radiometer Soil Moisture on Earth Grid	9 months	49 hours
L3_SM_AP	Daily Active-Passive Soil Moisture on Earth Grid	9 months	49 hours
L4_SM	Surface & Root Zone Soil Moisture on Earth Grid	9 months	7 days
L4_C	Carbon Net Ecosystem Exchange on Earth Grid	9 months	14 days

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BHW6 Should we list Level 1A, should we avoid Level 4?
JPL, 2/18/2011

BHW7

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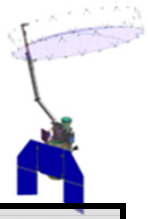
Anticipated SMAP Data Product Volumes



Data Product Short Name	Description	Daily Volume (GBytes)	Yearly Volume (TBytes)
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	9.002	3.288
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	45.281	16.539
L1B_TB	Radiometer T_B in Time Order	1.607	0.587
L1C_TB	Radiometer T_B on Earth Grid	0.270	0.099
L2_SM_A	Radar Soil Moisture on Earth grid	2.132	0.779
L2_SM_P	Radiometer Soil Moisture on Earth Grid	0.014	0.005
L2_SM_AP	Active-Passive Soil Moisture on Earth Grid	1.004	0.367
L3_FT_A	Daily Freeze/Thaw State on Earth Grid	2.331	0.569
L3_SM_A	Daily Radar Soil Moisture on Earth grid	9.958	3.637
L3_SM_P	Daily Radiometer Soil Moisture on Earth Grid	0.037	0.014
L3_SM_AP	Daily Active-Passive Soil Moisture on Earth Grid	0.578	0.552
L4_SM	Surface & Root Zone Soil Moisture on Earth Grid	0.604	0.220
L4_C	Carbon Net Ecosystem Exchange on Earth Grid	17.331	6.331

Slide 30

BHW7 Should we list Level 1A, should we avoid Level 4?
JPL, 2/18/2011

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SMAP Product Simulations

- The team is currently generating simulated data products
  - Contents are not complete, but are adequate to test algorithms
- The project processes these simulated data sets into HDF5 format that conforms with SMAP product design
  - Project places these model products on a data server, along with plots and descriptive information
  - Use of HDF5 products enables users to:
    - Generate software now that would function after launch
    - Provide feedback about product format and design
  - The following data sets are currently on the server:
    - One year of SMAP L2_SM_P data – all of calendar year 2003
    - Two months of SMAP L2_SM_A data – March 14, 2003 to May 17, 2003
    - Two months of SMAP L2_SM_AP data – March 14, 2003 to May 17, 2003
    - Seven SMAP_L3_FT_A files – seven representative dates in spring 2003
- Project would make the above products available to early adopters

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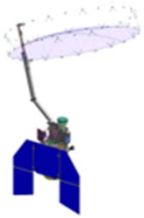
SMAP Data Simulation Plans



- GloSim1 data are available now
  - Combines 0.01 degree North American dataset with a 0.25 GLDAS dataset.
  - Radiometer soil moisture data available for year
  - Radar soil moisture data available for 10 weeks
- GloSim2 Plans
  - These data would enable end-to-end tests into Level 4 modeling, and thus provide more realistic scientific results
  - Team goal is to generate these data by the end of the September
  - Would generate Radar Level 1C and Radiometer Level 1B Products based on these simulations as well
  - Preparation is dependent on the receipt of land surface model

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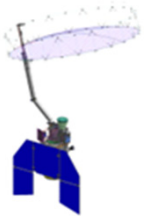
To Gain Access to Simulated Data Products



- Access to simulated data products would be limited to members of the SMAP Science Definition Team and Early Adopters
  - Currently available on the web server
  - After a Data Center is selected, and the project reaches an agreement with that Data Center, they would provide model data products
  - Susan Moran distributed a template Memorandum of Agreement for Early Adopters
  - Once that agreement is complete, the SMAP SDS encourages Early Adopters to submit an E2190 form.
    - Required to get a JPL username and password.
    - Given the JPL username and password, the SDS would provide new users with instructions to access data on the web server
    - Contacts for E2190 include:
      - Robert.D.Toaz@jpl.nasa.gov, Jennifer.W.Cruz@jpl.nasa.gov, Barry.H.Weiss@jpl.nasa.gov

Backup

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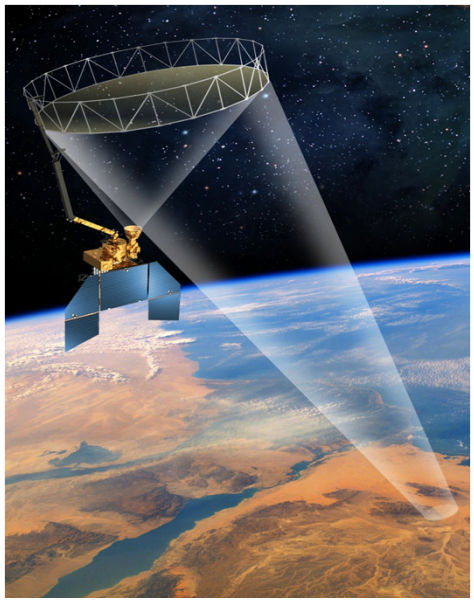
Mission Overview



The proposed SMAP mission was in the first tier recommended by 2007 NRC Earth Science Decadal Survey

Primary Science Objectives :

Global, high-resolution mapping of soil moisture and its freeze/thaw state to:

- Link terrestrial water, energy and carbon cycle processes
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Extend weather and climate forecast skill
- Develop improved flood and drought prediction capability

Observatory Features:

- 3-axis stabilized spacecraft with zero momentum biased attitude control
- Single string avionics and power control/distribution electronics
- Selected redundancy in ACS sensors, actuators, and telecom radios
- Deployable fixed solar array
- Command Telemetry & Doppler via S-band to NEN & SN
- Science data return at 130 Mbps via an X-band link to the NEN
- Hydrazine blow-down propulsion

Proposed Mission Implementation:

Partners	• JPL (project & payload mgmt, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Risk	• 7120.5D Category 2; 8705.4 Payload Risk Class "C"
Launch	• Nov. 2014, Launch Vehicle is TBD
Orbit	• Polar sun synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band SAR (JPL) • L-band radiometer (GSFC) • Shared 6m rotating (15 rpm) antenna (JPL)

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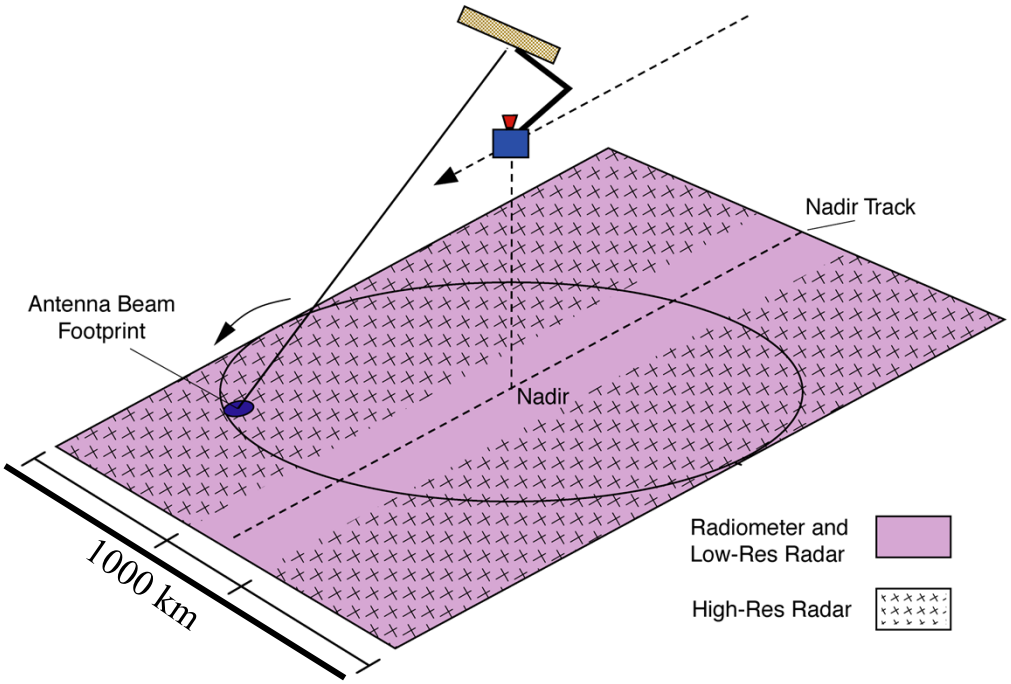
Instrument Key Features

- To meet requirement for 3-day revisit time at AM local time…
  - ⇒ *1000 km swath at 670 - 685 km dawn/dusk sun-synchronous orbit.*
- For wide measurement swath of combined L-Band active and passive measurements…
  - ⇒ *Conically scanning reflector antenna.*



- To achieve L-Band passive resolution of 40 km and and active resolution of 3 km …
  - ⇒ *6 meter aperture antenna*
  - ⇒ *14.6 rpm rotation rate*
  - ⇒ *Real-aperture radiometer*
  - ⇒ *Synthetic-aperture radar processing*
- Incidence angle
  - ⇒ *Near-constant 40 deg incidence angle*

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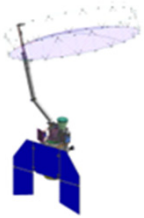
Science Objectives



The proposed SMAP mission plans to acquire global soil moisture and freeze thaw data to enhance the capability of science applications developers to:

1. Understand the processes that link the terrestrial water, energy and carbon cycles
2. Estimate global water and energy fluxes at the land surface
3. Quantify net carbon flux in boreal landscapes
4. Enhance weather and climate forecast skill
5. Develop improved flood prediction and drought monitoring capability

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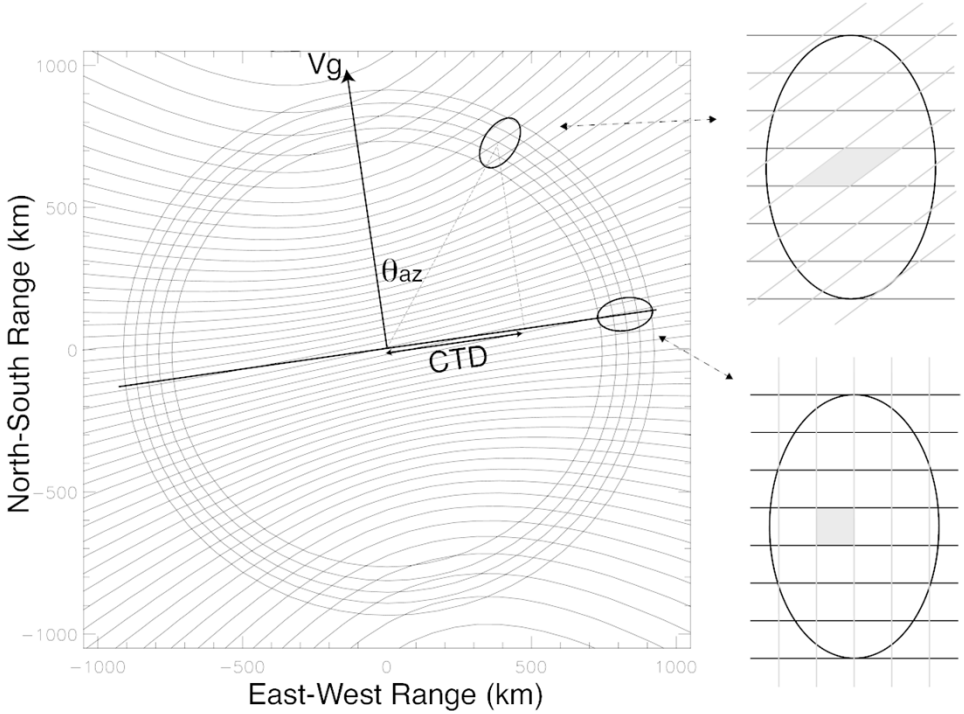
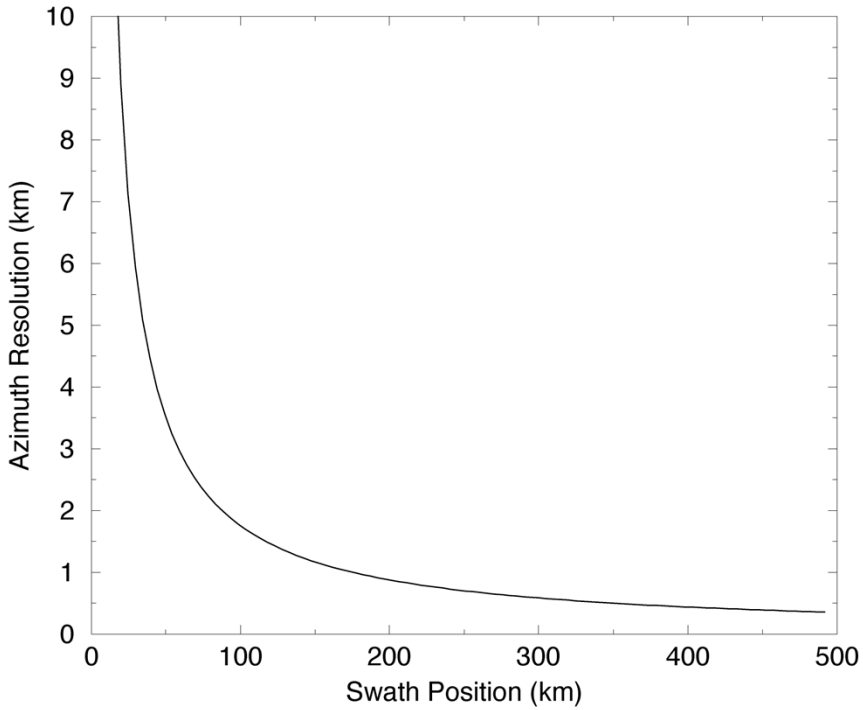
Radar Resolution Approach





- Unfocused SAR processing.
- Azimuth resolution, and number of azimuth looks, driven by unique scanning geometry.
- High-resolution SAR data that can meet the proposed science requirements for resolution and accuracy appears over outer 70% of the measurement swath.

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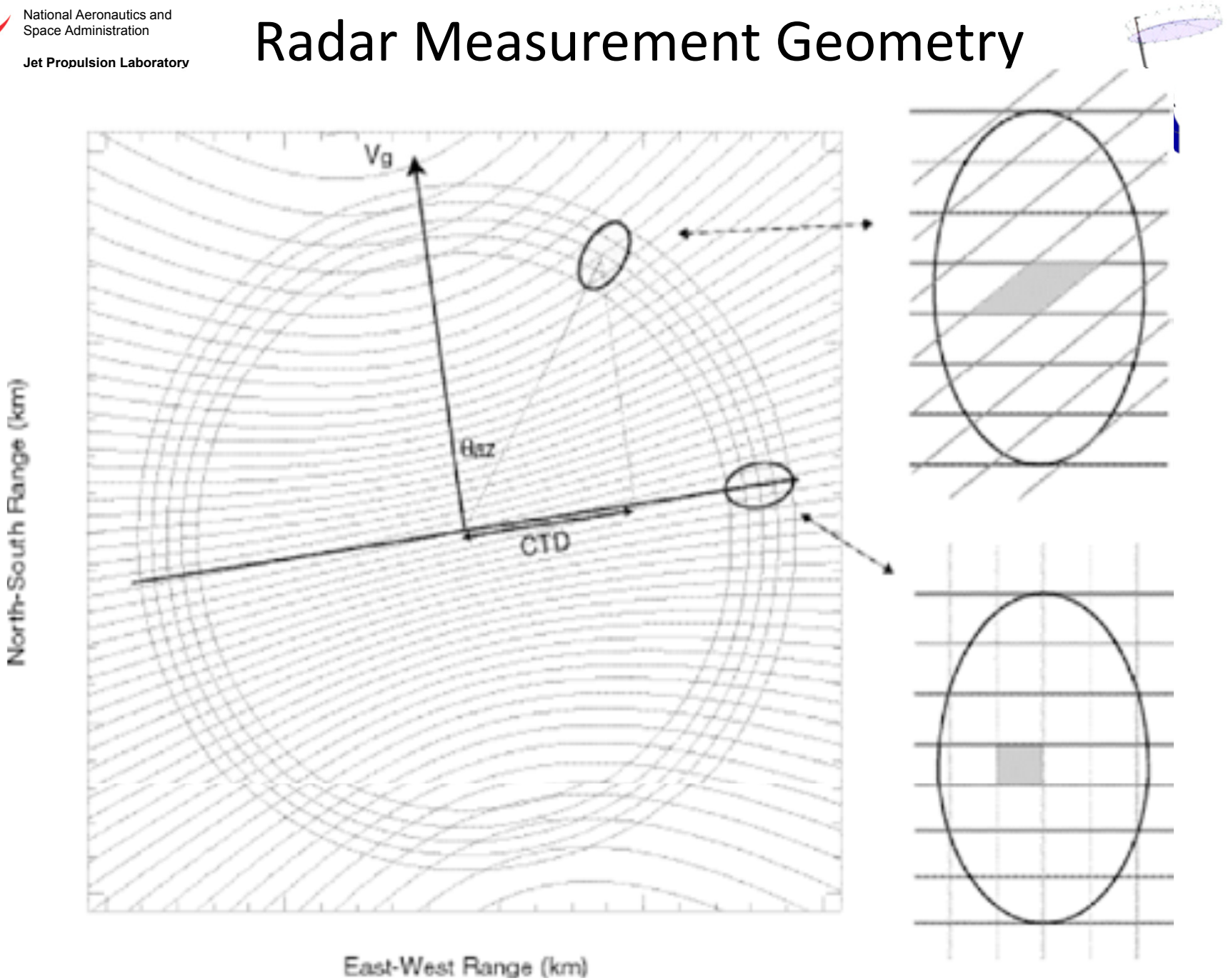
Radar Measurement Geometry



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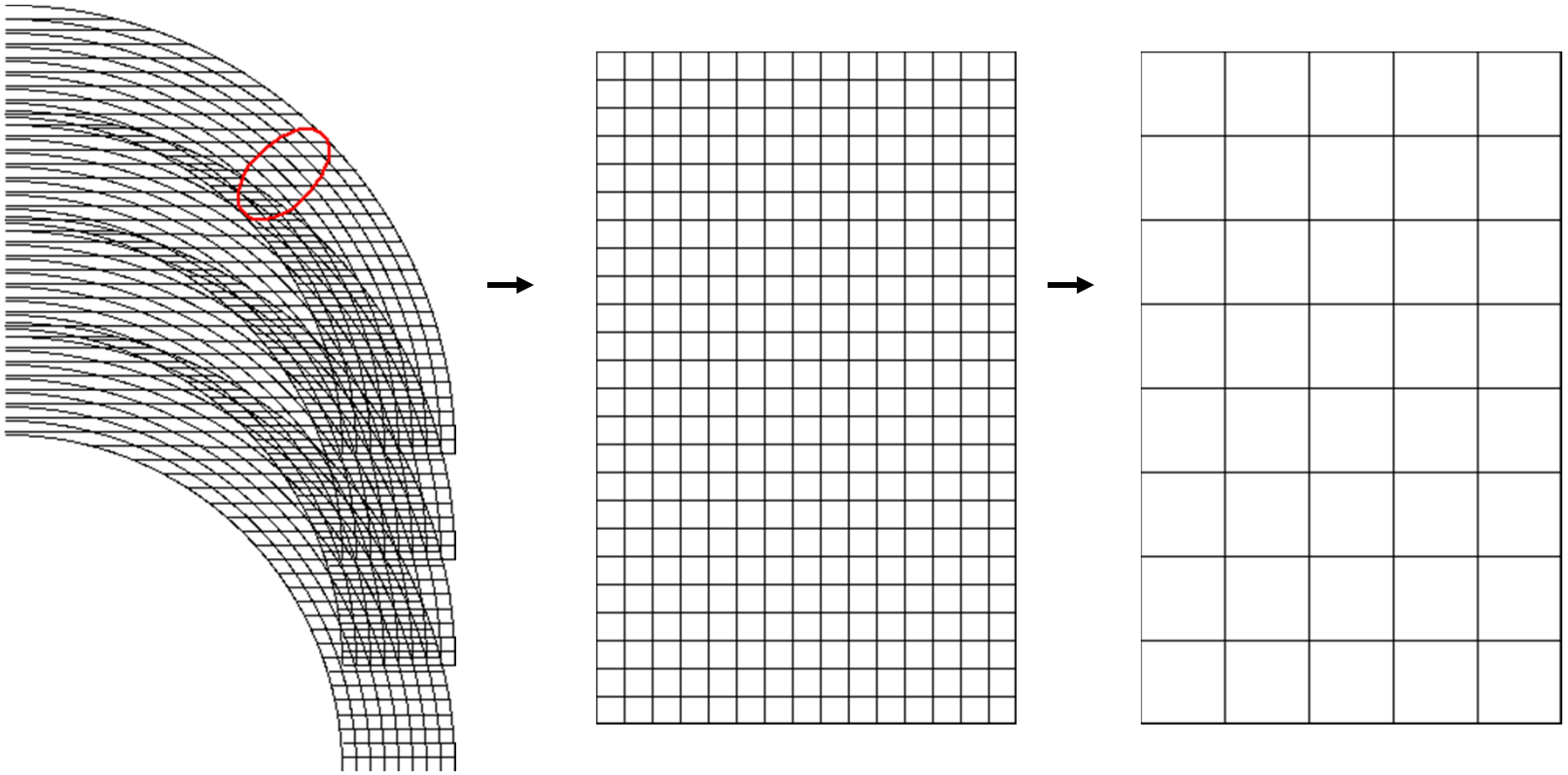
Radar Data Products



Single-Look, Time-Ordered Data

- Native resolution: 250 m in range, 400+ m resolution in azimuth.
- Each resolution element constitutes one independent "look" at surface.

1 km Gridded, Re-Sampled Data

- Data resampled and posted on 1 km grid, resolution may still be > 1 km near nadir.
- Each resolution cell now has multiple "looks" at surface, decreased measurement variance.

3 km Averaged Data

- 1 km posted product can be averaged up to 3 km, 10 km, etc. by investigators.
- Improved number of looks (and hence precision) at expense of spatial resolution.

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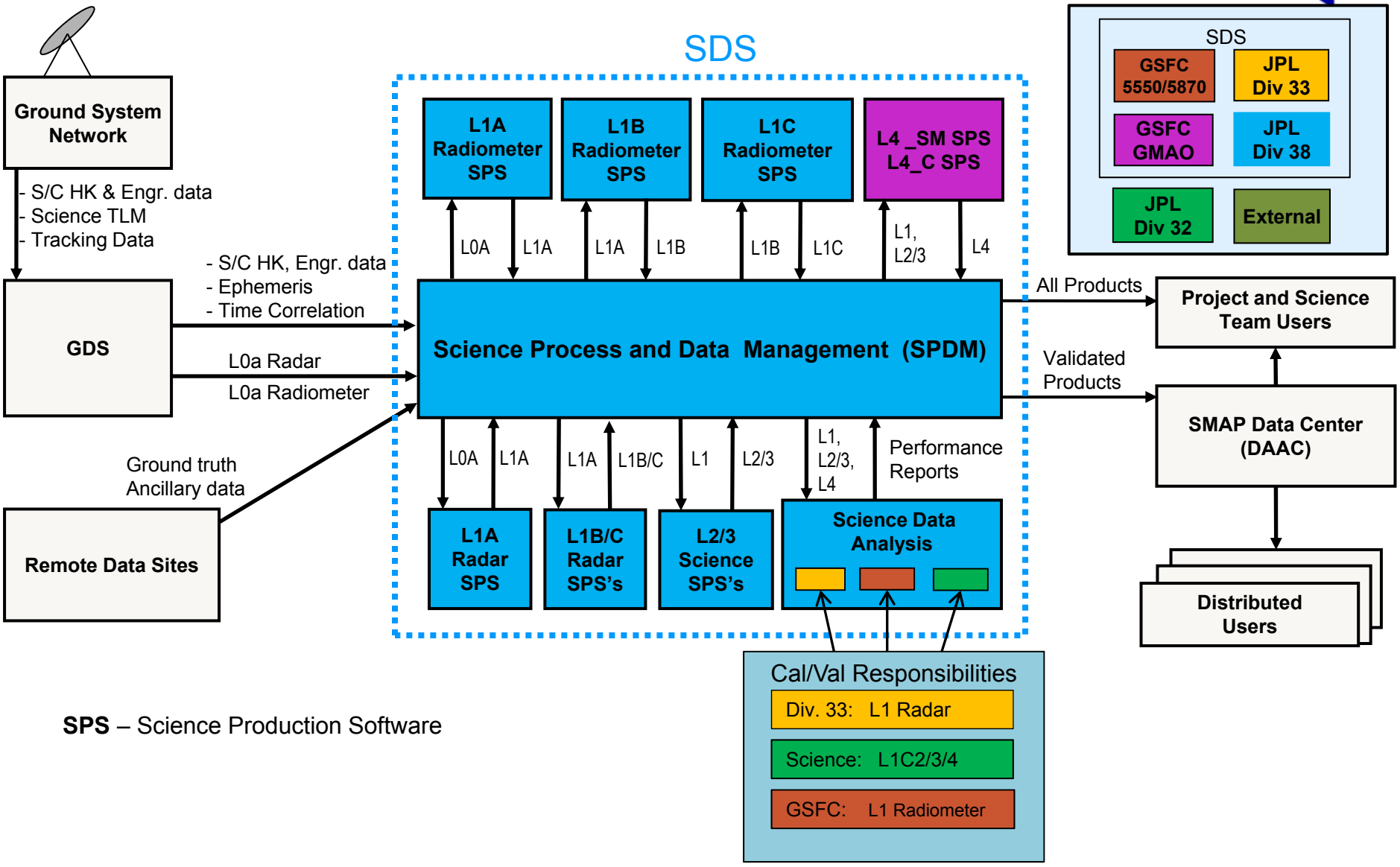
Proposed Science Data System (SDS) Operations Architecture



SPS – Science Production Software

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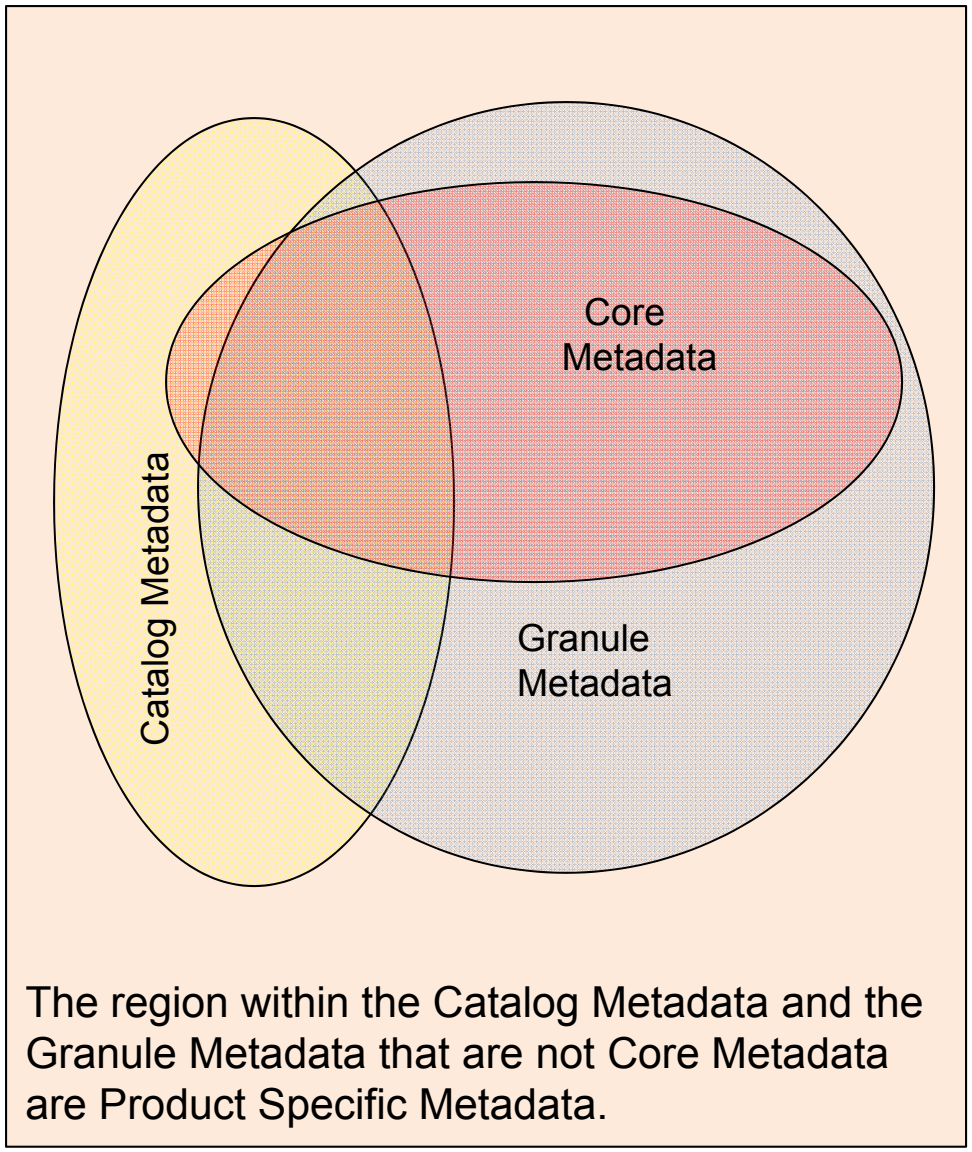
Global Metadata Classification



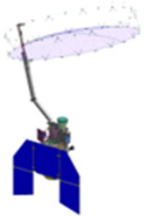
The region within the Catalog Metadata and the Granule Metadata that are not Core Metadata are Product Specific Metadata.

- **Catalog metadata versus File metadata**
  - Catalog metadata are stored in a database
    - For file reference, lookup and automated processing
    - Metadata elements required by the Data Center and ECHO
  - File metadata are listed in each product granule
    - Metadata elements may belong to both the catalog class and the file class
- **Core metadata versus Product Type Specific metadata**
  - Core metadata appear in all SMAP product types
  - Product Type Specific metadata appear in one or many product types
  - Core metadata and Product Type Specific metadata are mutually exclusive

Proposed Metadata Requirements

- The metadata shall provide users with adequate self descriptive information to enable an assessment of the content, the quality and the algorithmic conditions associated with any SMAP data product.
- The metadata shall enable users to locate specific and appropriate sets of data that they need for their investigation.
- The metadata shall enable users to correlate, interoperate and integrate SMAP data products with those generated by disparate sources, within and outside of NASA.

Global Metadata – ISO 19115



- "Geographic Information - Metadata" from the International Organization for Standardization
  - Provides a standardized means to describe Earth data
  - Provides a means to make products "self descriptive and independently understandable"
  - Incorporates all of the major categories required for a complete set of global metadata for each product granule
  - Incorporates all of the major categories required to generate a complete set of collection metadata.
  - Enables fulfillment of the requirement "to correlate, interoperate and integrate SMAP data products with those generated by disparate sources".
  - Uses XML representation to ease portability to the wider user community

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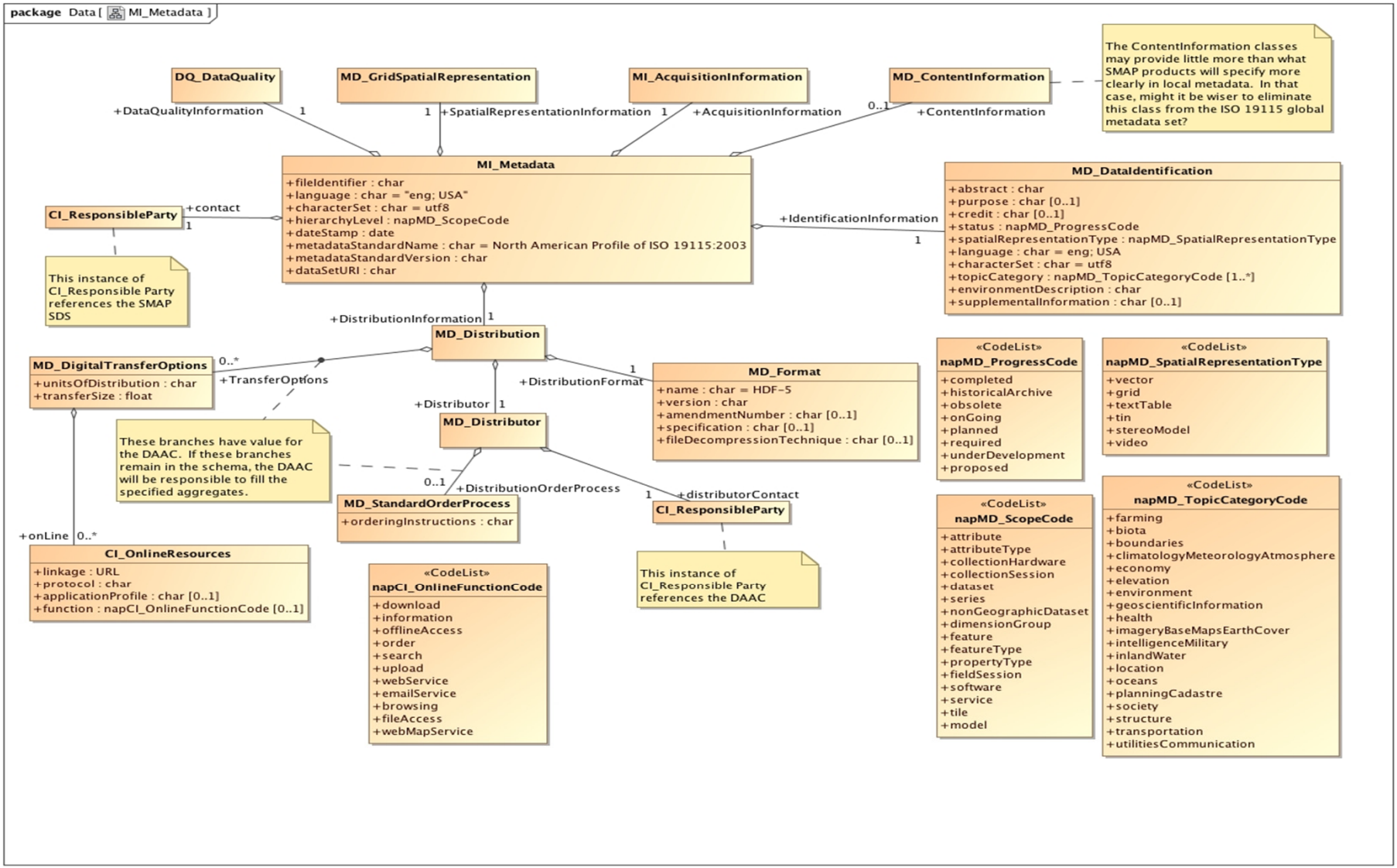
Proposed Top Level ISO Metadata Model



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CF Convention – Local Metadata

- The Climate and Forecast (CF) is a highly descriptive metadata convention with a widespread science user community
  - CF designed specifically designed to fit within attributes in netCDF files.
  - CF is based upon the Cooperative Ocean/Atmospheric Data Service (COARDS) standard
- The CF convention includes:
  - A standard to provide descriptive names for each variable in the product
  - Standards for the specification of data units for each variable in the product
    - UDUNITS provides a list of supported unit names
  - Standards for fill values for each variable in the product
  - Standards to express the range of data for each variable in the product
  - Standards to express bit flag definitions and define flag values
  - Standards to specify relationships between spatial and time coordinates for each variable in the product
    - Indicates which particular spatial or temporal coordinates correspond with which dimension axes and indices of a data variable.
  - Standards to specify statistical methods that were used to calculate each variable in the product
    - Clarifies temporal or spatial intervals that were used to provide statistical results.

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CF Global Metadata

- Five standard elements for description of the entire product
  - Title
  - Institution
  - Source
  - History
  - References
  - Each of the above five elements are character free-form stings, with no specification about content.

Metadata Use Recommendation

- The ISO 19115 provides ample metadata to cover the proposed SMAP requirements for granule and collection metadata
- The CF conventions provide detail required for local metadata that describe individual arrays in each product
- The small number of global elements that are required in the CF convention presents a minor issue:
  - Could SMAP ignore the small number of CF global elements, and remain “CF compliant”?
  - Is there some means to map the CF global elements into ISO?

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SMAP WIKI Access

The SMAP SDS Wiki is open to any member of the SMAP Project who is interested in retrieving information about Science Data System activities. All members of the Science Definition Team (SDT) and the Applications Early Adopters Group (AEG) can gain access to the Wiki. If associates of either the SDT or the AEG wish to gain access, they need to complete a short request form that specifies the following information:

- A statement of the purpose for accessing the SMAP SDS Wiki
- The specific information available on the Wiki that is needed to perform their job
- Any Wiki content that the user intends to modify or contribute

Regardless of Project category, all non-JPL personnel will need to submit the E2190 form in order to receive a JPL username and password, which is a prerequisite to gaining access to the Wiki.

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Data Product Access

- For those who already have a JPL user account, the following information is readily available
- Most recent data product descriptions are in spreadsheet form on the SMAP WIKI at:

  http://smap-sds-web.jpl.nasa.gov/confluence/display/SMAPDataProducts/SMAP+Data+Products
- Model data products in HDF5 format are available on the SMAP Data Server at the following URL:

  http://smap-sds-web.jpl.nasa.gov/samples
  - The data server also includes:
    - Descriptive information in README files
    - Plots of soil moisture for each soil moisture product
    - Plots of freeze-thaw condition for each freeze-thaw product
    - Model IDL code that reads and plots HDF5 products in directory software/IDL
  - The model products on the data server contain a subset of the full metadata and data elements described in the product spreadsheets

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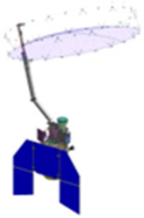
Model Soil Moisture and Freeze Thaw Data Products



- The model products are in HDF5 format
- The model products display the planned product design
  - "Metadata" Group contains product metadata
  - "Soil_Moisture_Retrieval_Data" Group contains the data arrays
  - Some products may have additional groups
- The model data products contain a subset of the data and metadata that will appear in the products the SMAP project will distribute after launch.
- At the very least, all of the Soil Moisture products contain the following:
  - Latitude
  - Longitude
  - Soil Moisture or Freeze/Thaw
- Additional data elements appear that may contain fill values
  - In most cases, null values are currently NaN
  - The project will generate a standard for null values, and use them in all data products
    - The project will document the specific null value in the product metadata as well as product documentation