National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP

L1 Radar Cal/Val Status

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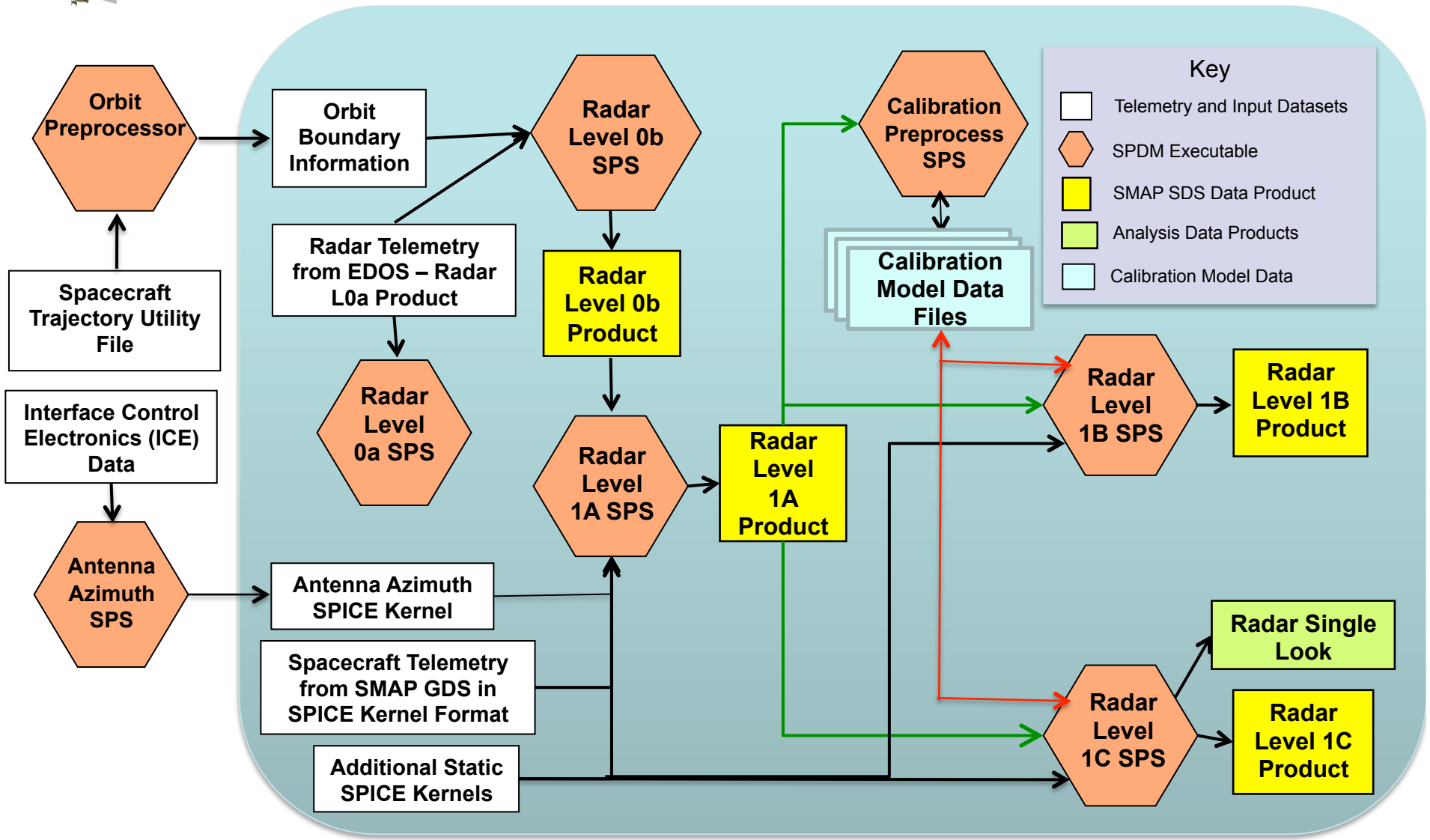
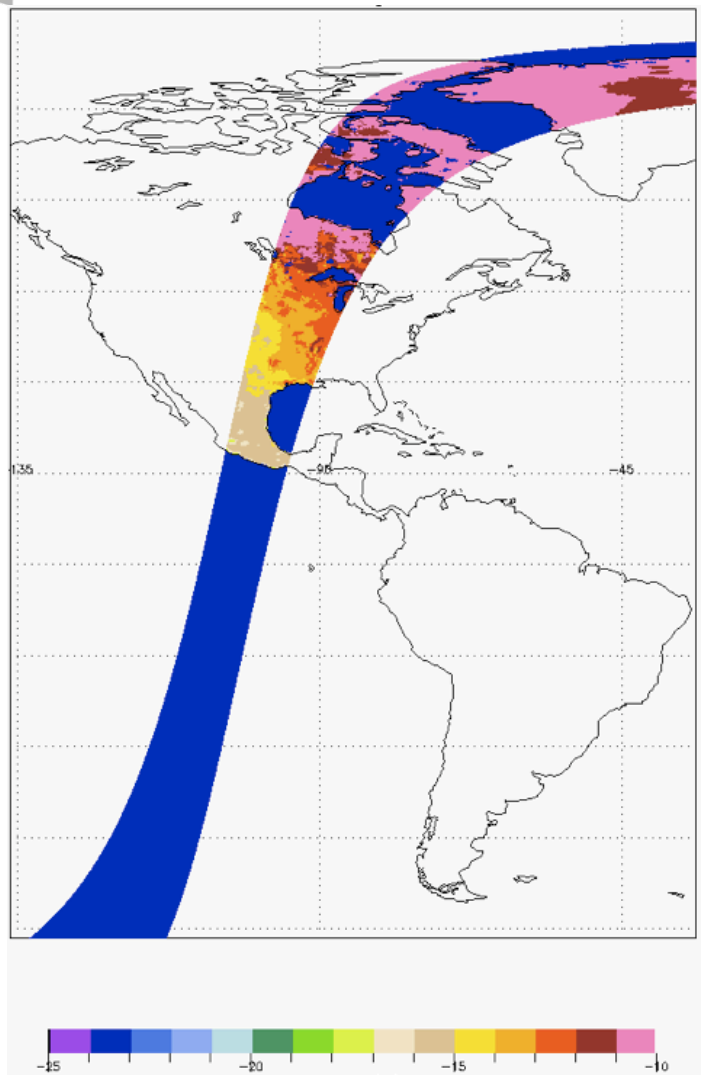
Level 0/1 Architecture



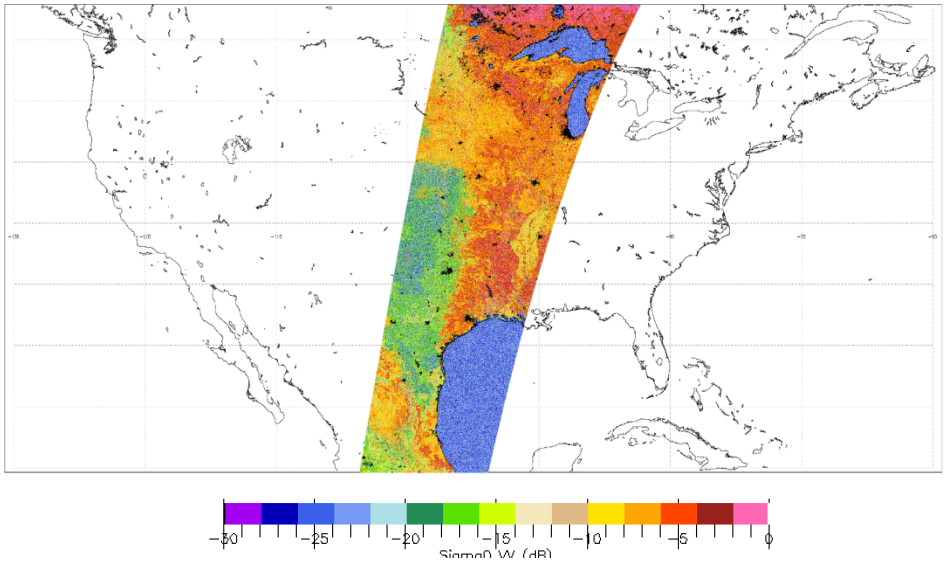
Radar Level 1B Product



Sigma0 VV (dB)

- Each granule contains time ordered data that covers one spacecraft half orbit.
- Coverage is continuous over all surface types.
- Contains Earth-located, calibrated radar backscatter measurements for co-pol and cross-pol data.
- Estimated Kp errors assigned to each measurement.
- Includes spacecraft orbit and attitude information and instrument pointing geometry.
- Includes short term and external calibration data used to generate product output.
- Provides calibrated backscatter measurements for approximately ten range-resolved "slices" of the full radar FOV footprint. (~30 km by 5 km.)

Radar Level 1C Product



Sigma0 VV (dB)

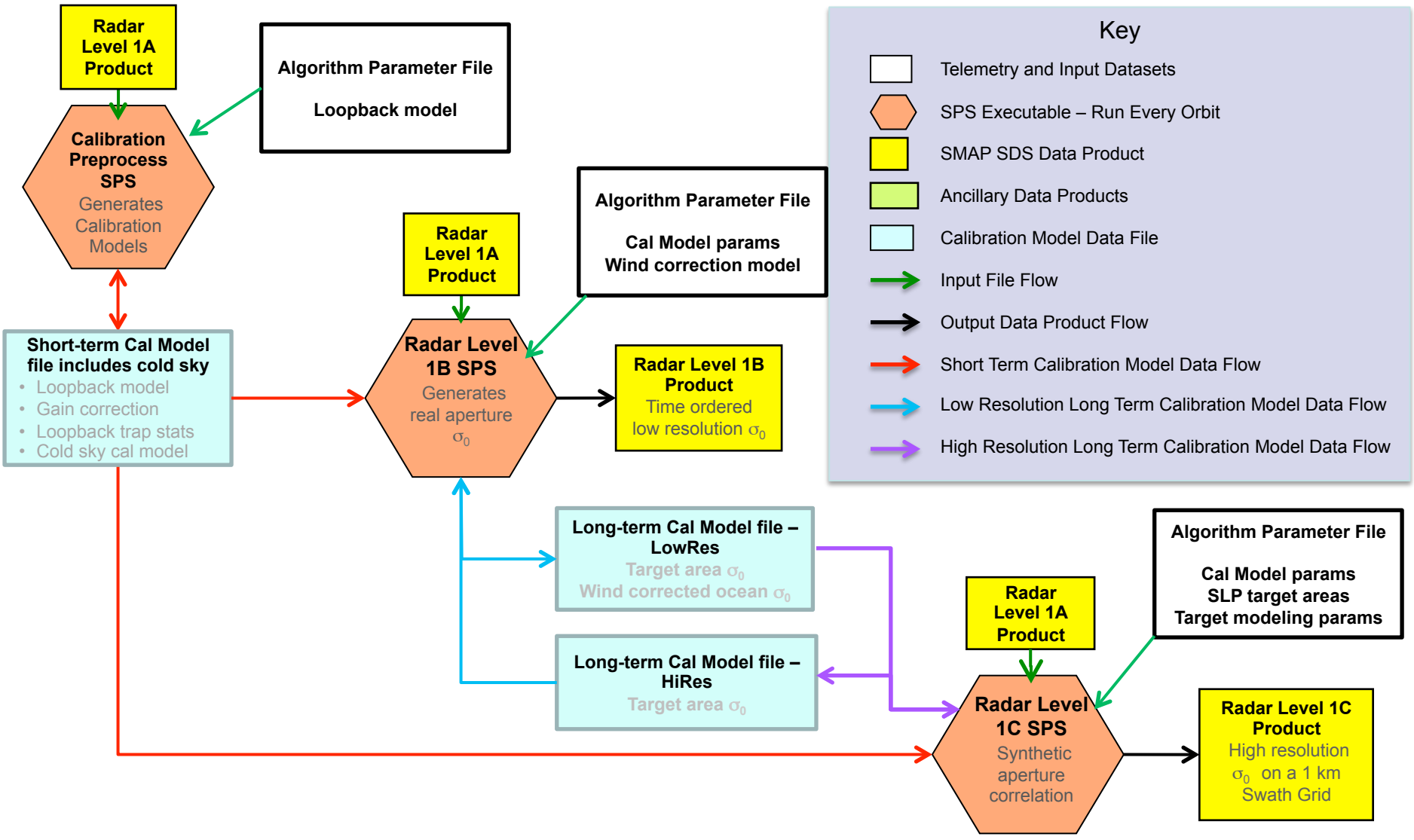
- Each granule contains geographically ordered data in 1 km grid cells in an along track/cross track swath grid.
- Coverage is restricted to land and coastal water over one spacecraft half orbit.
- SAR provides high-resolution single-look measurements. Resolution varies from ~400 m at the swath edge to about 1.2 km at 150 km from the nadir sub-track. Nadir looks are thin slices as wide as the beam footprint.

- Contains Earth located and calibrated h-pol, v-pol and cross-pol backscatter measurements, each separately multilooked
- Radar measurements achieve 1 km resolution over 70% of the swath. Resolution degrades in the nadir region.
- Forward looking and aft looking measurements stored separately.
- Includes spacecraft orbit and attitude information and instrument pointing geometry.
- Includes short term and external calibration data used to generate product output.
- Provides reference to global and polar 1 km EASE grid coordinates.

Ancillary Data Sets

Ancillary Data Set	Data Source	Frequency of Delivery
Spacecraft Ephemeris	SMAP Navigation	Once per day, includes predicted and reconstructed data
Spacecraft Attitude	NAIF	Once every two hours
Antenna Azimuth	SMAP S-Band Downlink	Once per downlink
SMAP Spacecraft Clock	NAIF	Based on changes in time correlation
Additional SPICE Kernels	NAIF	Some kernels will be updated. They always apply to all of the mission data
Digital Elevation Map	USGS GMTED2010 - NAIF	Constant for the entire mission
Antenna Pattern	Instrument team	Constant
Calibration Model Data	Internal Data Set	Subsystem regularly updates and reuses these data
Ocean Surface Winds	NCEP	Every six hours, Includes forecast and analysis data
Earth Magnetic Field	IGRF	Delivers once every five years.
Ionospheric Total Electron Content	GPS Service for Geodynamics (IGS)	Available daily. Covers 2 hour time periods.

L1 Radar Cal/Val Data Processing Flow



Pre-launch Simulations for Software Testing

Test Radar Telemetry from Inst. Sys. Engr

Add EDOS formatting

Radar Level 0a,b SPS's
Generates Half Orbits, Removes EDOS and RF

Radar Level 0b Product

Radar Level 1A SPS
Decodes and groups telemetry

Radar Level 1A Product

Calibration Preprocess SPS
Generates Calibration Models

Spice Kernels
Nominal Orbit ephemeris from Nav
S/C attitude from att simulator
Antenna rotation position from antenna simulator
Fixed Kernel files including DEM

Point Target Sim
Low-Res Inst. Sim
Cal Model Sim

Radar Level 1A Product

Radar Level 1B SPS
Generates real aperture σ_0

Cassini Spice Kernels

Cassini L1A Data File

Data Reformatter

Radar Level 1A Product

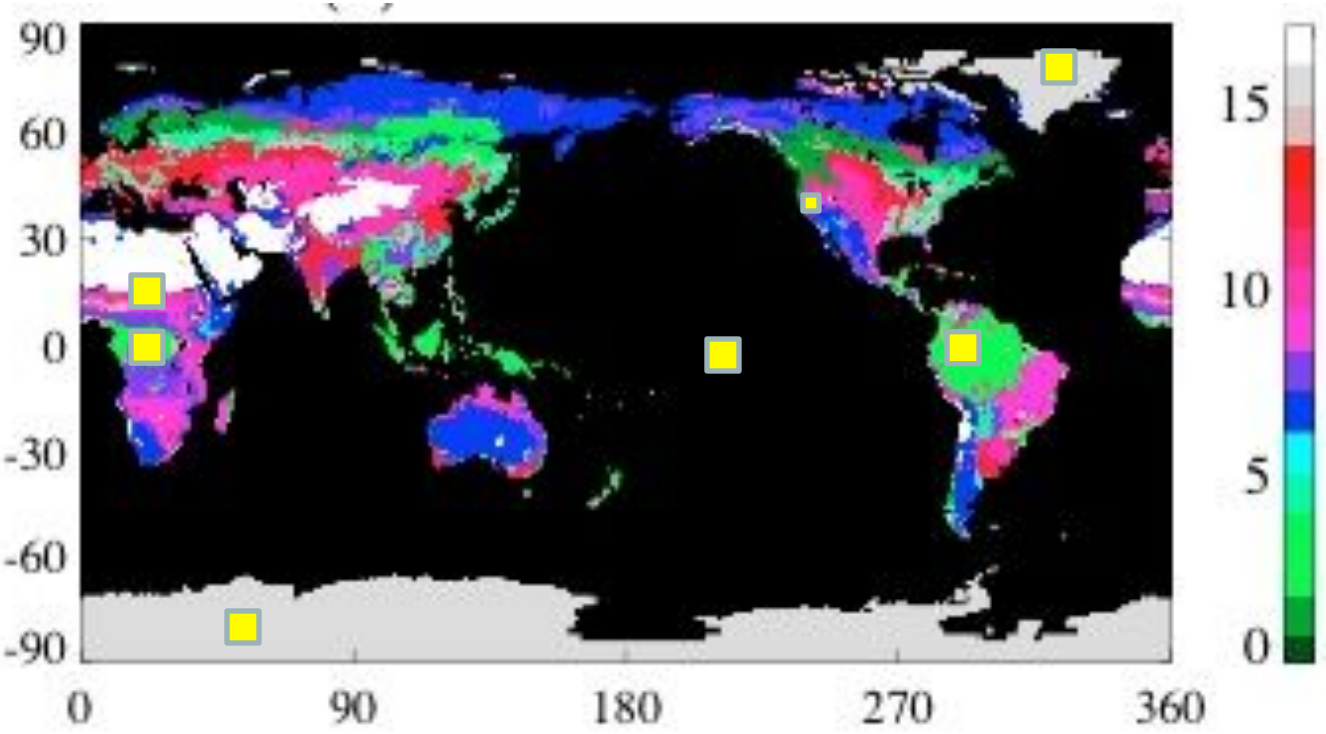
Radar Level 1C SPS
Synthetic aperture correlation

Internal Calibration

- **Loopback Calibration**
  - CalPreProc computes a running average and temperature based model fits as needed for each data take producing a short term gain correction, and collects data and statistics in cal model data file
  - L1B and L1C processors read and apply short term gain correction
- **Loopback Trap**
  - Collected by CalPreproc in cal model data file along with summary statistics for analysis by external tools
- **Noise Subtraction**
  - L1B and L1C processors average noise channel measurements for each polarization and subtract from echo measurements to estimate signal-only measurements
- **Matched load measurements**
  - Collected by CalPreProc in cal model data file for use by external tools
  - Used by CalPreProc during cold-space measurements to compute system noise temperature and Rcvr gain
- **Transmit Power Monitor**
  - Collected by CalPreproc in cal model data file along with summary statistics for analysis by external tools

External Calibration Targets

- Rain forest areas (Amazon, Congo) have good temporal stability, azimuthal isotropy, and large homogeneous areas.
- Oceans vary with wind speed and direction which can be modeled and removed leaving a stable residual
- Some desert areas also have good stability albeit at lower backscatter levels
- Parts of the ice sheets also have good stability
- Corner reflectors are a backup option



External targets

External Calibration/Validation

- **Relative Bias Removal**
  - Antenna pattern correction using homogeneous target area (Amazon)
  - Balancing out residual systematic variations observed as functions of scan angle and orbit latitude.
    - Applies to 3 channels: HH, co-pol ratio (HH/VV), and cross-pol ratio (HH/XY)
    - Based on azimuthally symmetric reference target results: amazon, model corrected oceans, ice sheets
- **Long Term Detrending**
  - Target Selection
    - Land – SLP target list will include candidate target areas based on PALSAR/Aquarius data which will be analyzed for stability during L1 Cal/Val
    - Oceans – Selection mask refined during L1 Cal/Val using L1B data
  - Model Refinement
    - Land – Seasonal variation model applied if needed to reduce target variability
    - Ocean – SMAP specific wind correction model fitted to ocean data to minimize residual variation
  - De-trending Procedure
    - L1B,C SPS's maintain running averages of selected stable model corrected target areas
    - L1B,C SPS's read running averages, compute and use bias correction from latest running average window.

External Calibration/Validation cont.

- **Absolute Calibration Goal**
  - Plan to set SMAP sigma0s to level provided by:
    - ALOS/PALSAR (1,2)
      - High-res system calibrated with man-made references
      - Assume that stable Amazon target areas have not changed between end of PALSAR data and start of SMAP mission.
    - Aquarius
      - Data readily available
      - Likely to overlap operations with SMAP
      - Wind corrected ocean data provide extensive averaging to cross-calibrate with SMAP
      - Provides a bridge to earlier PALSAR data
    - Corner reflectors can be used as backup
- **L1B and L1C cross-calibration**
  - Validates processing algorithms against each other
- **Algorithm performance, focusing, resolution, geo-location**
  - Examination of full resolution single look images
  - Coastlines, sharply defined features, corner reflectors for focusing and geo-location validation
  - Coastal waters, low backscatter desert areas for ambiguity issues
  - Swath oriented artifacts (eg., banding) reveal attitude knowledge issues

L1 Radar Cal/Val Data Sources

Internal Data Set	Data Source	Frequency of Delivery
L1A,B,C data files	SDS L1 radar operational processing	Once per half orbit
SLP (single look product) files	SDS L1 radar operational processing	On command for selected target areas
Calibration Model Files (3 types)	SDS L1 radar operational processing	Updated after each data take
SPICE Files	SMAP Mission Operations	Varies. Attitude ckernel every 2 hours, S/C ephemeris once per day, antenna azimuth once per downlink
Algorithm Parameter Files	SDS L1 radar operational processing	Always available to cal/val team

Ancillary Data Set	Data Source	Frequency of Delivery
Ionospheric Total Electron Content	International Reference Ionosphere (IRI)	Delivers once every several years.
Land Classification Map	MODIS-IGBP	Static
Faraday Rotation Angle	SMAP Radiometer Level 1B Product	Daily
L-Band Radar Data from other missions	Aquarius	Daily delivery for sanity check during cal/val. Less frequent deliveries for ongoing calibration after cal/val ends.
PALSAR Quad-Pol Data	Alaska Satellite Facility	Selected scenes of PALSAR data based on availabilty

L1 Radar Cal/Val Tools

- QA report from CalPreProc, L1B, L1C processors
  - Operational quick check to identify potential issues with the data or processing algorithms
- Instrument Performance Tools
  - Verify performance of internal calibration data and models
- Algorithm Performance Tools
  - Verify impulse response, geolocation, attitude, antenna pattern using external target data
- Bias removal, de-trending, cross-calibration support tools
  - Use external target data to remove overall calibration issues and set absolute calibration

RFI Detection and Removal

- **L1B SPS flags RFI contaminated measurements but performs no correction**
  - Noise channel measurements (1/PRI) and a threshold in the algorithm parameter file determine which measurements to flag as contaminated
- **L1C SPS applies the Slow Time Threshold (STT) algorithm to flag and correct RFI contaminated measurements**
  - STT: Moving window average of range lines followed by median filter of slow time samples
  - Slow time samples equal to or greater than the median by threshold amount are flagged and replaced by samples from adjacent unflagged range lines with added noise to reduce bias.
  - Kp estimates for output image points adjusted for sample removal due to RFI contamination
  - Adjustable parameters include length of range line window, median filter width, level of median threshold, and number of range points. Based on RFI study group results and analysis of RFI survey data collected in Cal/Val phase.
- **Expected Performance of STT**
  - RFI Study group used simulations and PALSAR data to study performance of STT algorithm and concluded that it would meet SMAP requirements for current RFI conditions.
- **Bit flags that cover RFI detection and correction will accompany all radar measurements**
  - One bit will indicate whether RFI was detected
  - If RFI was detected, a second flag will indicate whether the pixel was corrected

Faraday Rotation Correction

- Use GPS-based TEC measurements to estimate Faraday Rotation Angle
  - Files may have up to 24 hour latency
- Faraday Rotation correction appears in both the Radar L1B and Radar L1C Products
  - Records whether the Faraday Rotation correction exceeds a threshold value for the pixel/slice in an associated bit flag.
  - If correction exceeds threshold, applies correction to corresponding pixel/slice. Stores the correction in separate field.
- Backup approach
  - If GPS-based TEC measurements are not available from IGS, use the model based TEC estimation by IRI.
  - Use Faraday Rotation Angle estimated from Radiometer 3rd stokes for the cross-validation with the Baseline algorithm.
    - During Bulk Reprocessing, the radar process may import the Faraday Rotation Angle calculated in the Radiometer Level 1B algorithm.

L1 Radar Objectives and Motivation for Phase 1 Rehearsal

- Ensure adequate preparation for the post-launch cal/val period
- Identify missing tools and help to prioritize final development
- Produce simulated data sets that span a range of problems for use by processors and cal/val tools
- Develop understanding of data characteristics for various problems/anomalies that might occur post-launch
  - Attitude Biases, Position Biases
  - Antenna pattern biases
  - Drifts in instrument performance
  - Subtle implementation errors/approximations that cause geolocation errors or other defects in output products
  - Impact of RFI and FR
- Correct software problems revealed by Rehearsal simulations
- Develop and test preliminary set of cal/val tools and related QA outputs
- Train L1 radar team to identify/detect problems in the incoming data
  - Blind test using simulated data

Status and Progress

- All major elements are designed
  - L1B designed in outline form
- All data products are designed
- Substantial portions of major software have been implemented
  - L0a,b starting implementation
  - L1A close to complete
  - Simulation and L1C algorithms largely complete at release 3 (Jan 2013).
  - Cal/Val tools implemented in release 4 (Aug 2013) and 5 (April 2014)
  - L1B algorithm implemented after release 5
- Reviews
  - ATBD review Jan 2012
  - Cal/Val review Oct 2, 2012
  - SDS CDR Oct 10-11 2012