

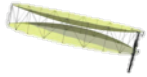


Soil Moisture
Active Passive
Mission
SMAP
Cal/Val Plan
Workshop 2012

L1 Radiometer T_B

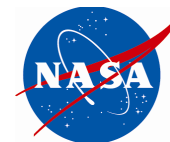
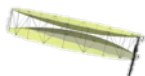
Ed Kim, Radiometer T_B Cal/Val Lead
J. Piepmeier, P. Mohammed, J. Peng,
D. Hudson, M. Brandt

NASA Goddard Space Flight Center

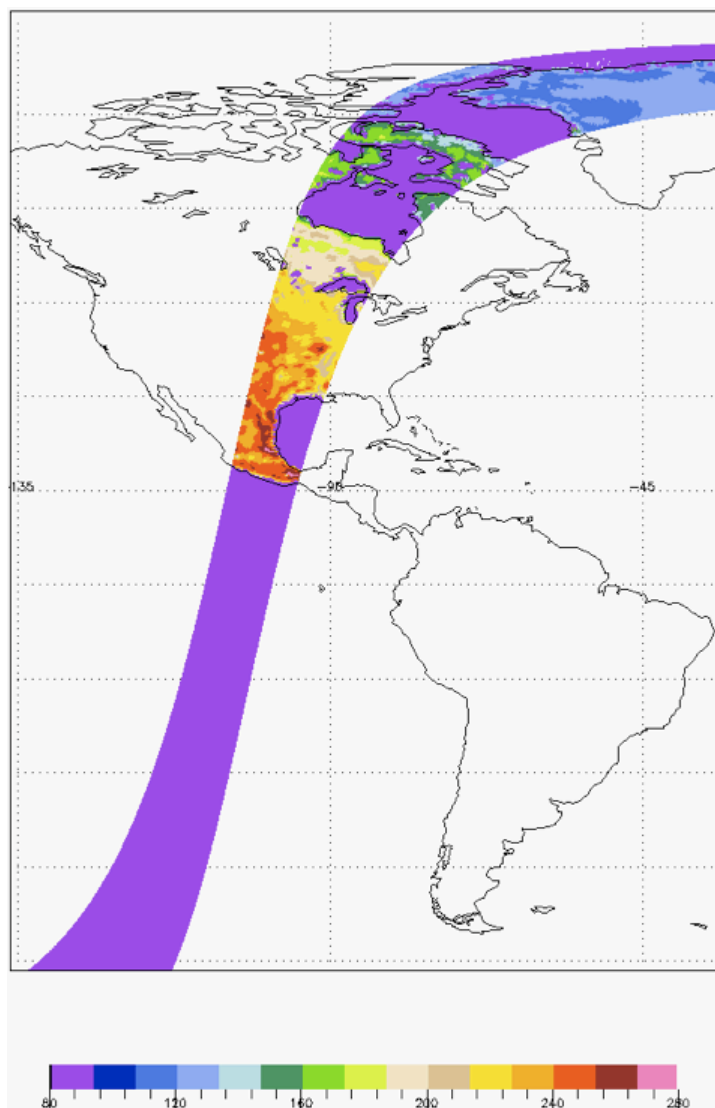


Outline

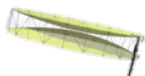
- Radiometer L1_TB product description
- L1_TB required corrections
- L1_TB error budget & margins
- Processing flow
- Ancillary data
- Internal T_A cal
- External cal
- Simulations
- Pre-launch Cal/Val activities
- Post-launch Cal/Val activities



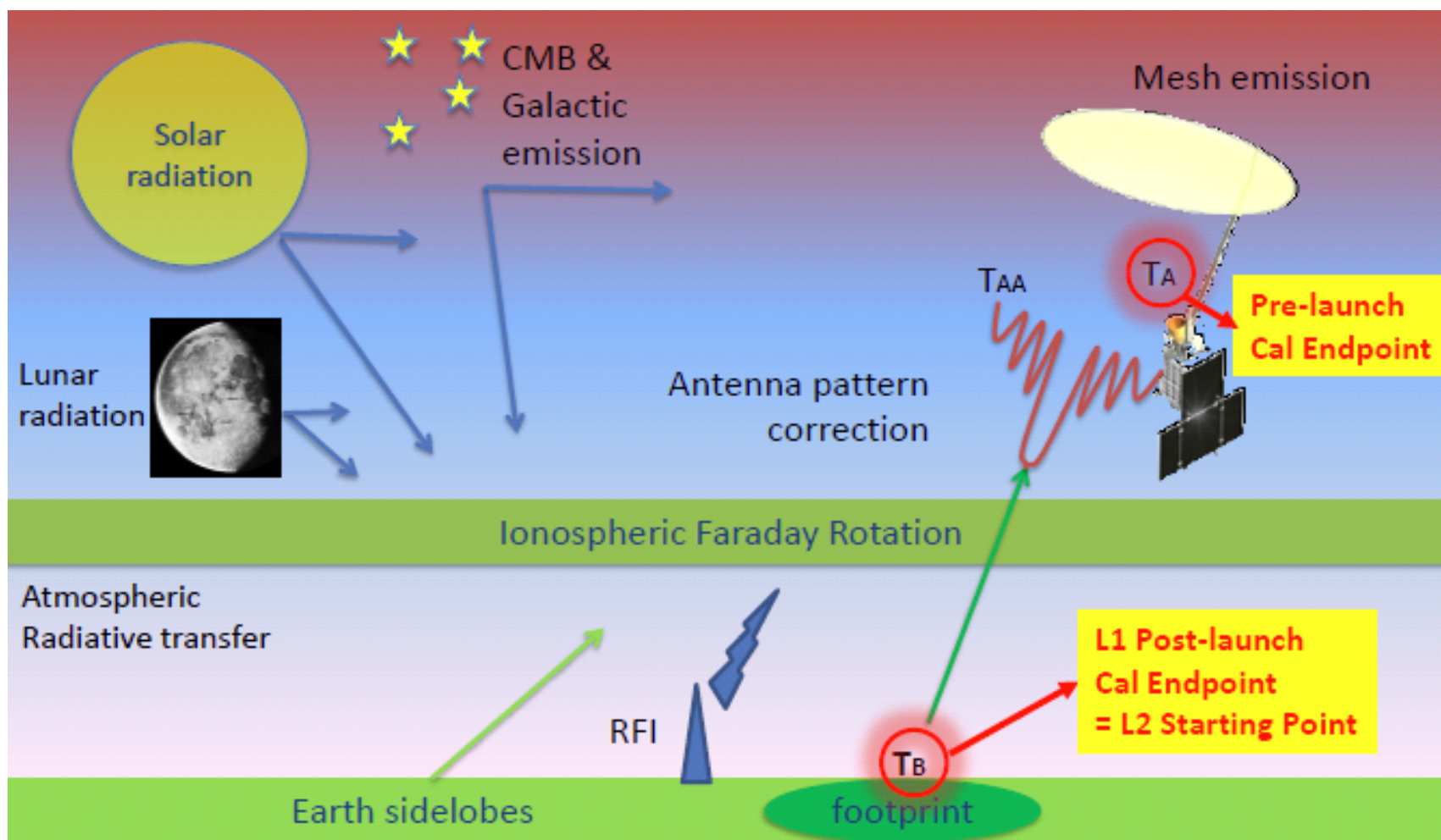
Radiometer L1_TB Product Description

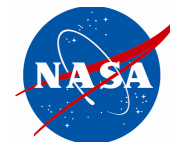
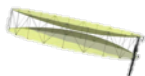


- Time ordered data in half orbit granules
- Geolocated & calibrated data for each EFOV
 - EFOV footprint is 39 km x 47 km ellipse
 - Apparent aperture (antenna) temperatures
 - Brightness temperature (T_B) at Top-of-ionosphere (TOI)
 - Brightness temperature (T_B) at the surface
- All four modified Stokes parameters (V, H, 3 & 4)
- Full-band data has continuous spatial coverage over land, ocean, & ice
- Sub-band data (high rate, for RFI detection and removal) over land areas & ocean & Antarctic cal target regions & during cold space views
- Internal calibration coefficients & other parameters to document L1B calibration used
- Various quality flags



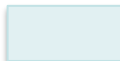
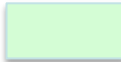
L1_TB Required Corrections

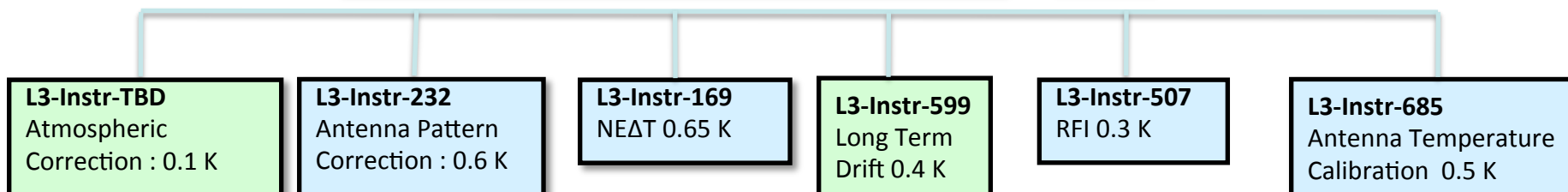




Radiometer L1_TB Error Budget/Margins

L2-SR-45 : The L1B_TB brightness temperatures shall have mean uncertainty from all sources (excluding rain) of 1.3 K or less (1-sigma)

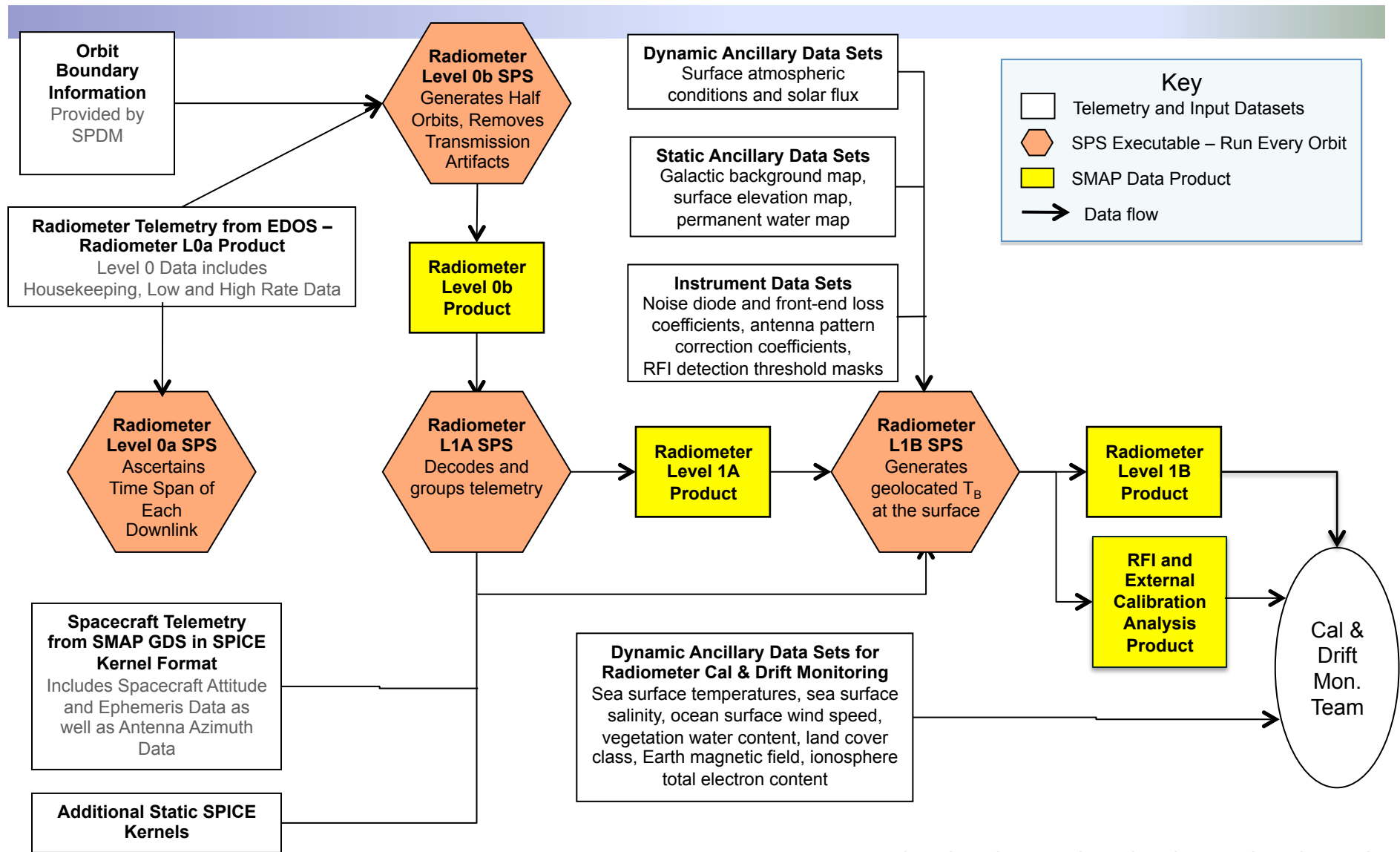
 Driven by instrument design or pre-launch calibration
 Driven by post-launch calibration



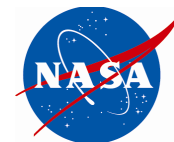
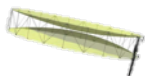
- “Non-calibration” error terms:
 - NEΔT is random term essentially unaffected by calibration.
- Calibration error terms:
 - Antenna temperature (T_A) calibration
 - Antenna pattern correction. Includes effects of side-lobes and mesh emissivity.
 - Atmospheric correction
 - Long-term drift
- RFI term is due to residual error after removal of RFI contamination. Not strictly “calibration” but mitigation algorithm parameters will be tuned in SDS.

Error Term	Allocation	PDR CBE	CDR CBE
Antenna Pattern Correction	0.60 K	0.35 K	0.40 K
NEΔT	0.65 K	0.51 K	0.54 K
Antenna Temperature Calibration	0.50 K	0.4 K	0.44K
RFI	0.30 K	0.17 K	0.19 K
Long Term Drift	0.40 K	0.4 K	0.20 K
Atmospheric Correction	0.10 K	0.1 K	0.04 K
RSS Total		0.86 K	0.85 K
Requirement	1.3 K	1.3 K	1.3 K
“Linear” Margin		0.9 K	0.44 K
“RSS” Margin		0.44 K	0.92 K

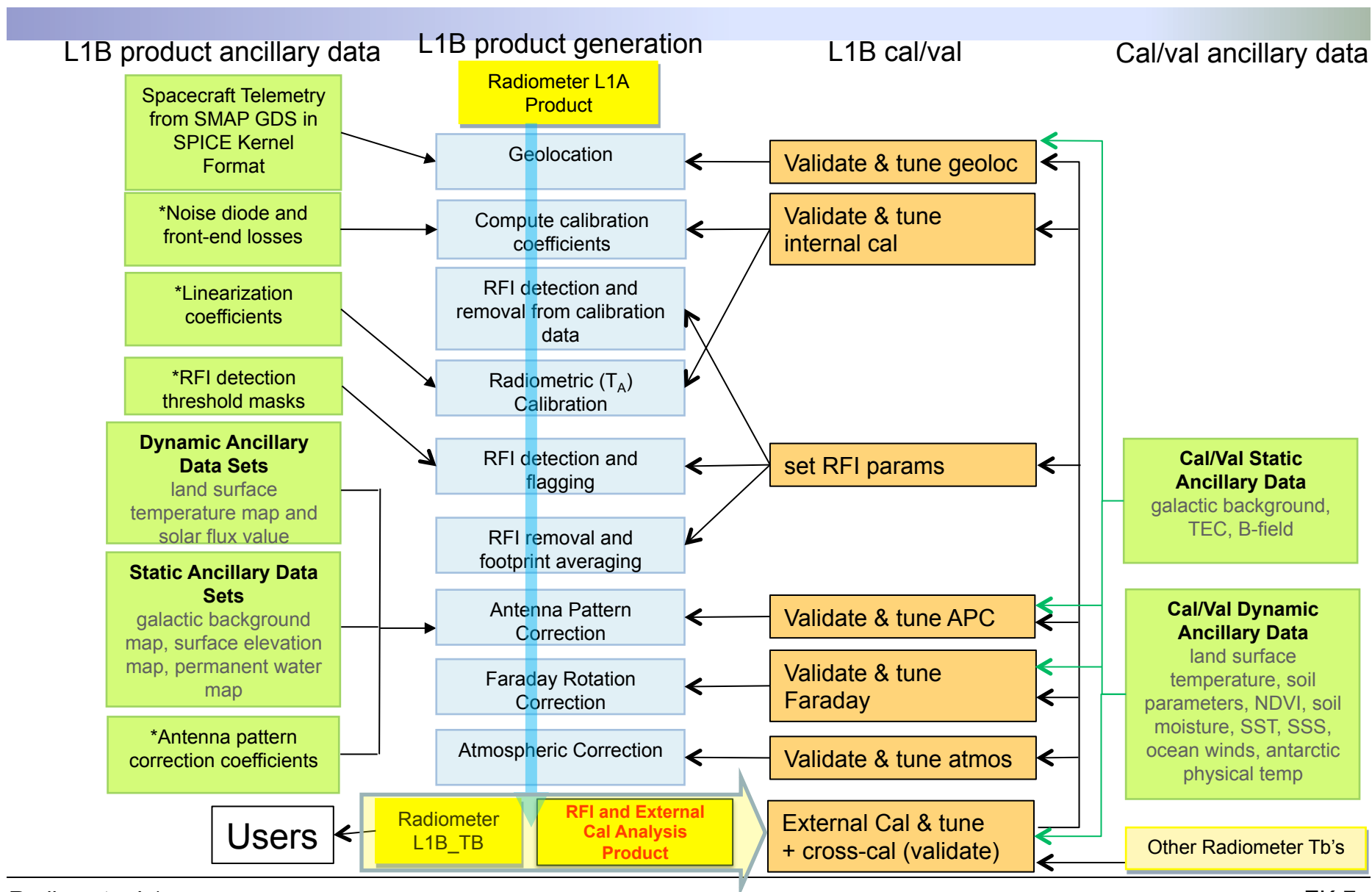
Radiometer Level 1 Data Processing Architecture

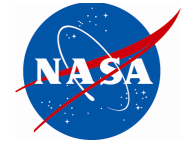
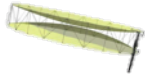


*produced over selected regions and on demand



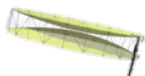
Radiometer L1B Cal/Val Processing Flow



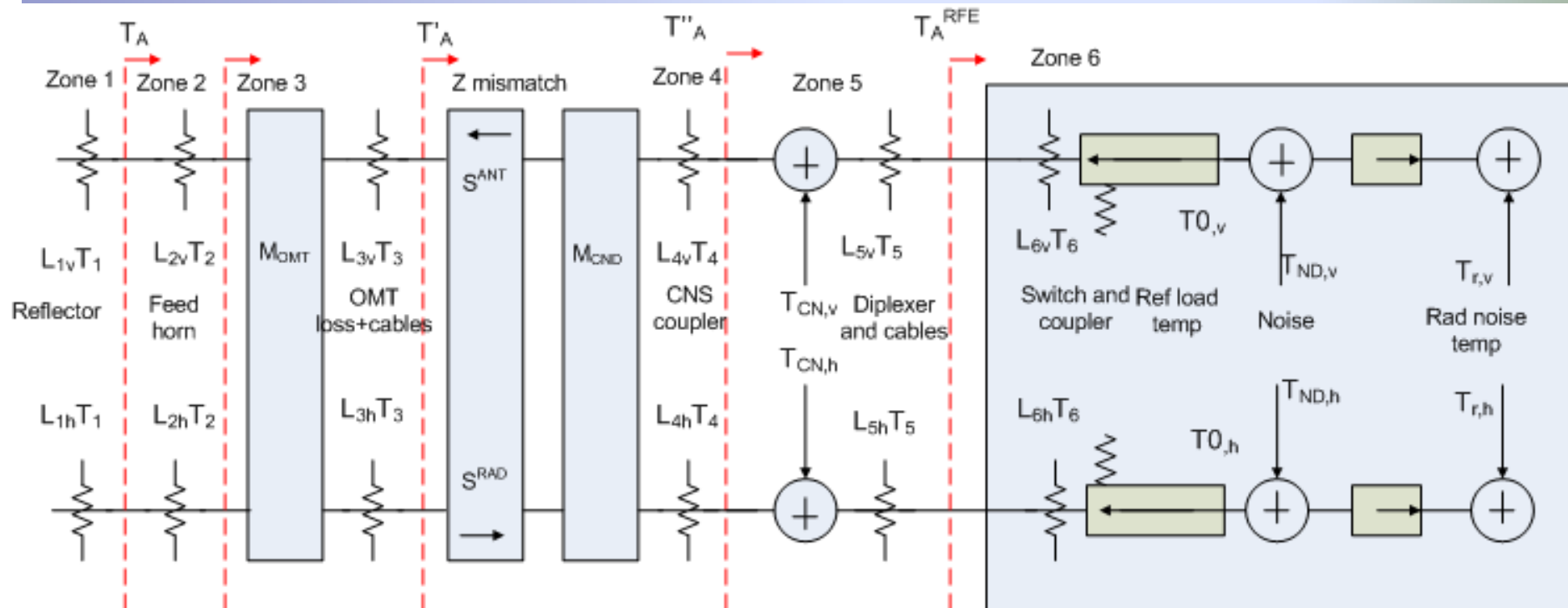


Ancillary Data For Cal/Val

Category/Usage	Ancillary Data Set	Data Source	Frequency of Delivery
Ocean Surface External T_B Calibration	Sea Surface Temperature	NCEP	Daily for Cal/Val, weekly thereafter
	Sea Surface Salinity	WOD09 (HYCOM)	Daily for Cal/Val, weekly thereafter
	Ocean Surface Winds	NCEP	Daily for Cal/Val, weekly thereafter
Antarctica External T_B Calibration	Antarctic Ice Temperature	NCEP	Daily for Cal/Val, weekly thereafter
Cold Space External T_B Calibration	Galactic Maps of L-band T_B	Le Vine & Abraham (Aquarius)	Static
Third Stokes T_B Calibration Faraday Rotation Validation	Earth Magnetic Field	IGRF	Delivered once very five years
	Ionosphere Total Electron Content	IRI	Delivered once every several years
Land Surface Brightness Temperature Validation	Land Surface Temperature	GEOS 5.7.2	Daily for Cal/Val, weekly thereafter
	Normalized Difference Vegetation Index	MODIS NDVI	Daily for Cal/Val, weekly thereafter
	Soil Moisture (5 cm)	GEOS 5.7.2	Daily for Cal/Val, weekly thereafter
	Sand and Clay Fraction	HWSD	Static
	Open Water Fraction	MODIS MOD44W	Static
	h Roughness Parameter	GSFC	Static
	Land Cover Classification	MODIS IGBP	Possible update, but apply to all mission data



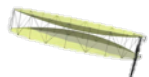
Internal (T_A) Calibration



Model accounts for losses, temps, mismatches

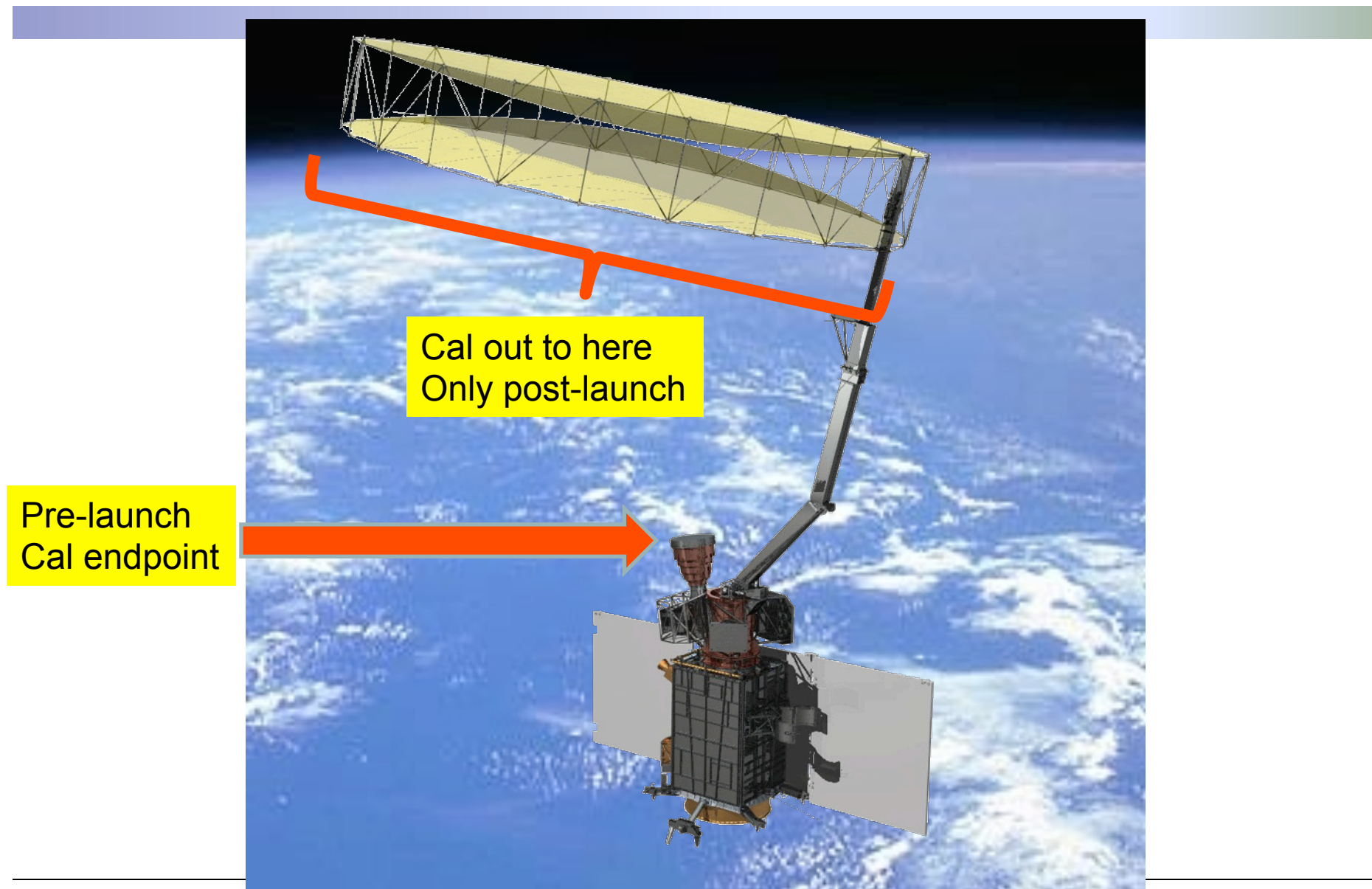
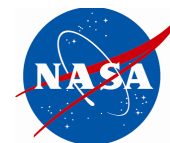
- $L_{\#,v,h}$ losses for zone # and polarization v or h
- $T_{\#}$ Physical temperature for zone #
- T_X Radiometric antenna temp Stokes vector
- M Mueller matrix
- S Two port S-Parameter matrix

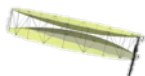
- Only a few of the parameters are key, but all are included for completeness
- All parameters characterized pre-launch
- Most parameters won't differ much from pre-launch values
- Post-launch adjustments will be few & small



SMAP Cal/Val Workshop 2012

Calibrating the SMAP Radiometer





External Calibration

- **Purpose**

- Enables end-to-end cal since an on-board beamfilling target is not feasible

- **Target Criteria**

- beamfilling, homogeneous, stable, and have known T_B
- Use 3 views of external targets w/different T_B 's to characterize gain, offset, NL, drift

- **Candidate targets**

- **Antarctica** (~200K)

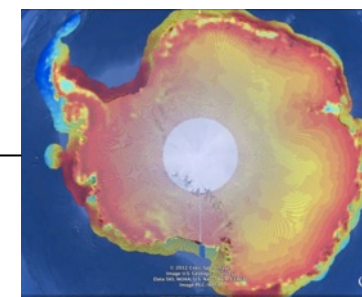
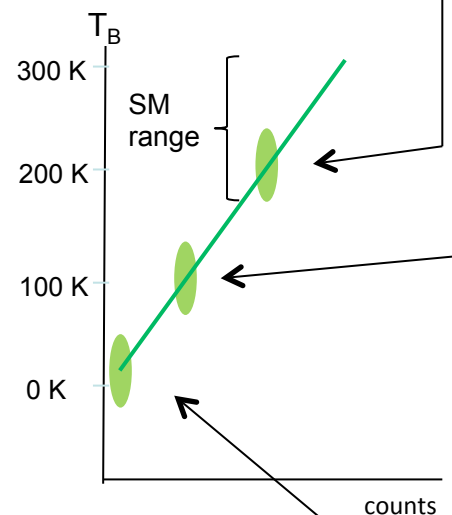
- SMOS work shows promise
- Near pole → Visible multiple times/day
- No maneuver or special mode required
- RFI unlikely

- **Ocean** (~100K)

- leverage Aquarius work on same
- No maneuver or special mode required
- Absolute T_B cal depends on ocean model accuracy
- RFI still possible

- **Cold Space** (~10K)

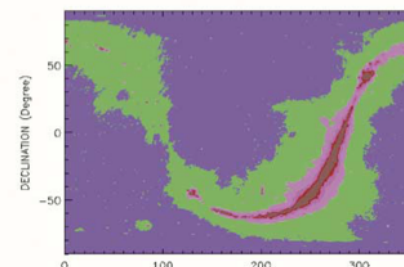
- Requires s/c maneuver; limits how often (monthly)
- Avoid looking toward celestial source regions
- RFI unlikely



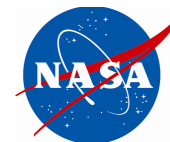
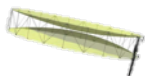
Antarctica



Ocean



Cold Space



Cross calibration

Satellite

- SMAP will leverage T_B 's from other missions—e.g., SMOS, Aquarius to cross calibrate T_B 's
- *Simultaneous overpasses*
- *Views of same external targets*
- There are active funded projects now working on L-band cross-cal: SMOS & Aquarius
- There is a long history of cross-cal for microwave sounders (data since 1970s; >10 satellites; Climate Data Records, papers in Science, etc.)

Airborne

- T_B 's from available airborne campaigns as another source of cross-calibration data. SMAP can leverage non-SMAP airborne campaigns.
- Not required, but may be useful

Ground-based

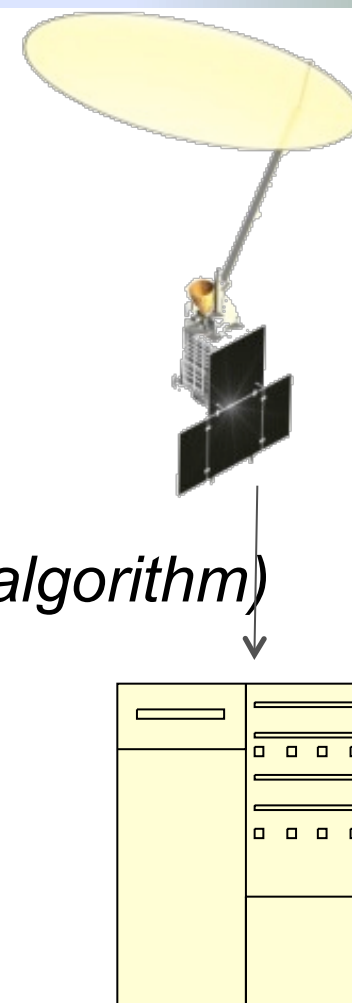
- Comparison vs. ground T_B observations useful only if the point-to-pixel scaling is well characterized (rare)

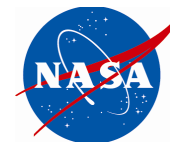
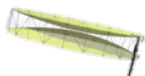
Technically, “cross-calibration” here = “validation” under the CEOS definition of using “independent means”



RFI Detection-Mitigation Concept for SMAP

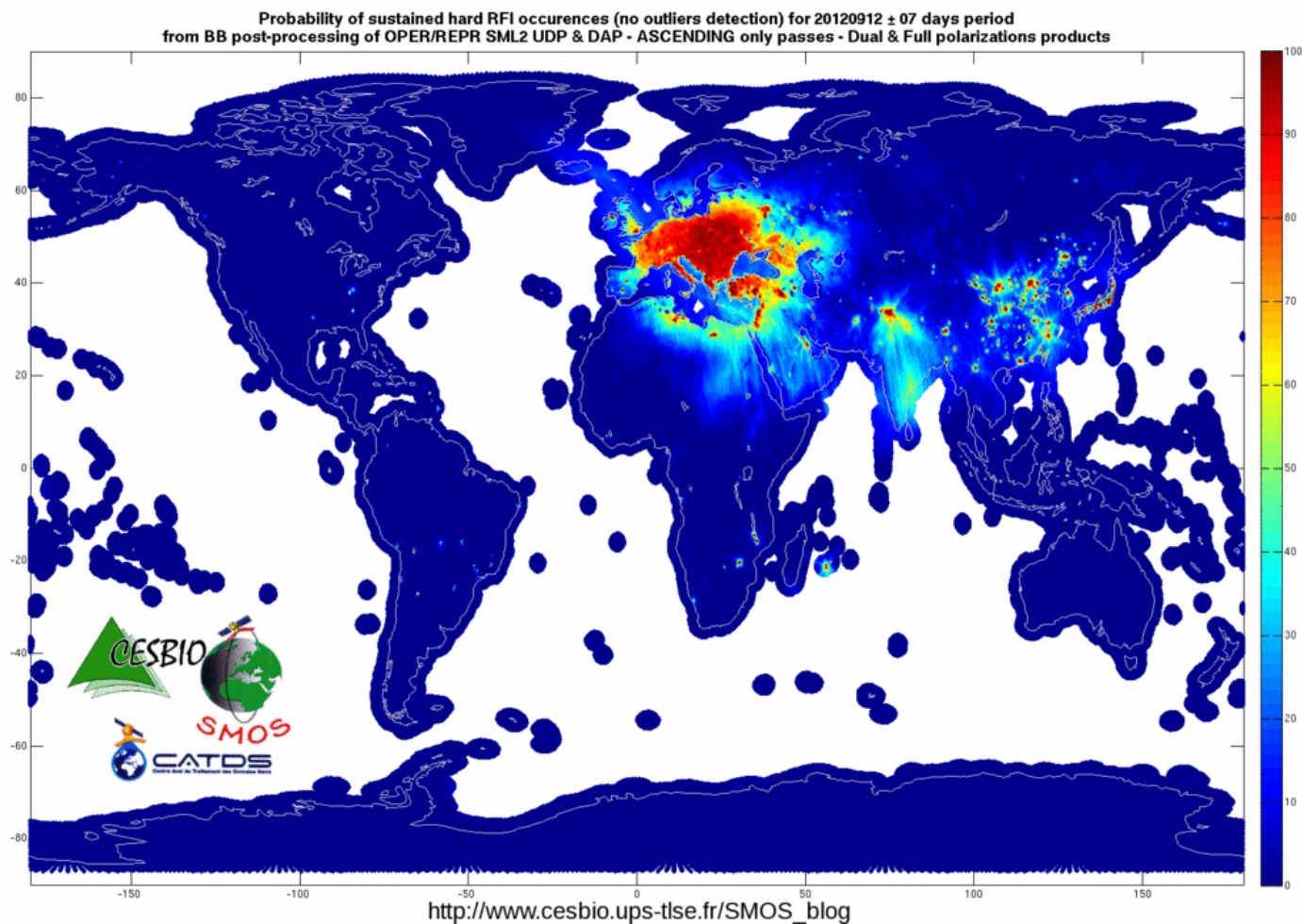
- Observation (on board)
 - *Fast time domain (T.D.) sampling*
 - *Frequency domain (F.D.) measurement over sub-bands*
 - *Kurtosis (test for signal Normality) in each sub-band*
 - *Polarization characteristics*
 - *Hardware based digital backend*
- Detection and Mitigation (on ground)
 - *Ground science processing based (L1A/B algorithm)*
 - *Use time and/or frequency diversity from SMAP data*
 - *Apply detection algorithm on telemetered data in SDS*
 - Time domain peak detection
 - Cross-frequency peak & kurtosis detection
 - Polarization anomaly detection
 - *Remove “bad” samples and integrate to footprint*

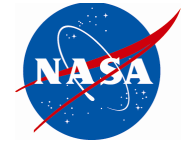
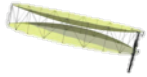




RFI environment seen by SMOS

SMAP will see something similar but different



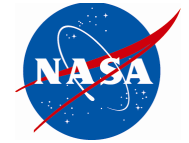
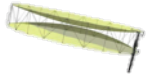


Pre-launch cal/val data is primarily associated with internal cal--measuring hardware that can only be done on the ground

- *Practice on ETU hardware (in progress)*
- *Get nominal launch values from flight unit h/w measurements*
- *Examples: internal losses, noise diode output, nonlinearity coefficients*

But even for parameters that can only be measured on-orbit, we must equip the L1 algorithms with nominal values at launch in order to enable L1 data processing to proceed before cal/val is complete.

- *Parameter values derived from combination of simulations & some measurements (example: reflector temperature/emissivity)*



Simulations to be Performed before launch

Purpose: confirm operation of correction algorithms & tools; optimization

test geolocation cal/val
scheme

Reflector thermal behavior
(needed for T_A cal)

Faraday correction

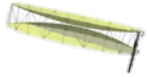
sims to check external cal-
related elements

- *External target views (orbit, swath, scan)*
- *Cold space view back lobe contribution, land contamination*

RFI

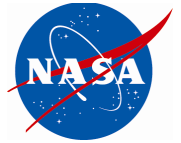
Antenna pattern related
parameters (test sidelobe
correction scheme using
L1B forward sim)

Atmospheric correction

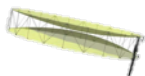


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SMAP T_B Forward Simulator-1



- Simulator purpose: algorithm development, Cal/Val, & optimization
- Forward T_B simulator strategy: SMAP-ify the Aquarius simulator since it already contained most of what we need
- Major differences in SMAP vs. Aquarius simulation
 - *Conical scanning vs. fixed beam*
 - *Different antenna pattern*
 - *Land focus vs. ocean*
- Currently in use at Goddard for radiometer L1_TB work
 - *Supporting L1_TB algorithm development*
 - *Using SMAP antenna pattern*

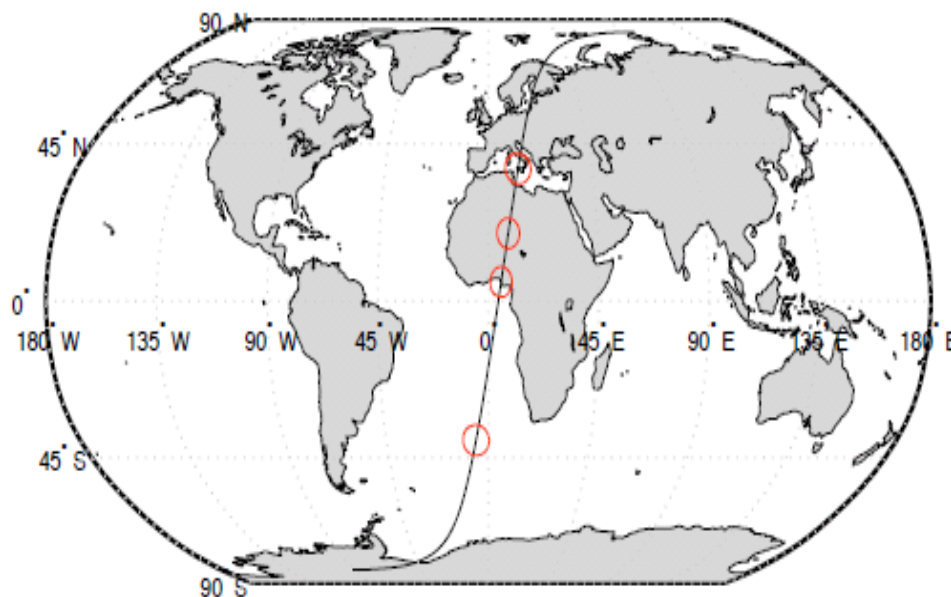


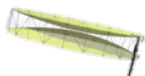
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SMAP T_B Forward Simulator-2



- Example case
 - *Simulated 4 cases along 1 descending orbit*
 - *Examined results for L1 error budget implications*
- Sources & effects included
 - *Solar direct, reflected*
 - *Lunar direct, reflected*
 - *Galactic direct, reflected*
 - *Land, atmosphere, ocean*
 - *Faraday rotation*
 - *Antenna sidelobes*
- 4 cases
 - *All ocean 360 scan*
 - *All land 360 scan*
 - *Half ocean/half land*
 - *Mixed land/ocean scene*



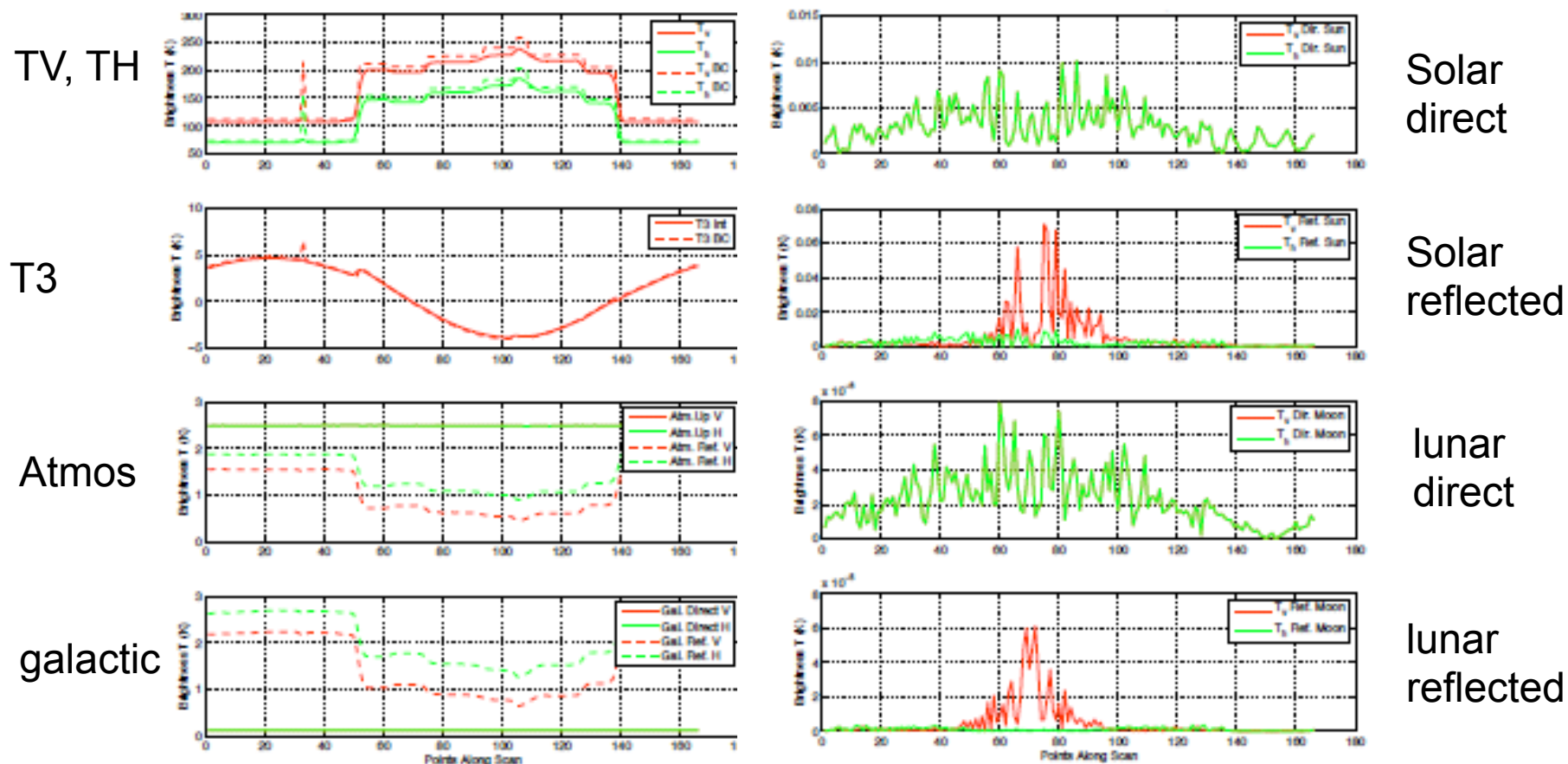


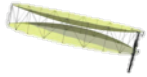
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SMAP T_B Forward Simulator-3



- Example output (half land/half ocean case)





(Expected) Post-Launch Dataset and Cal Model Updates

On-orbit internal cal-related data (temperatures, ND parameters) will be used to update pre-launch internal cal parameters for actual on-orbit conditions

External cal-related data will be fed into external cal algorithm & used to update pre-launch values in the L1B cal model

--Daily using views of Antarctica & ocean targets; compute gain & offset, do trending

--Monthly using views of Antarctic, ocean, & cold space (update drift correction)

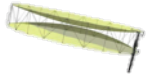
Tuning of RFI thresholds that can only be done with on-orbit data; update as RFI environment changes over time

Possible modification of RFI removal algorithm

--Will launch with latest results from pre-launch testing with synthetic RFI data, but SMAP is first time method is applied to satellite data

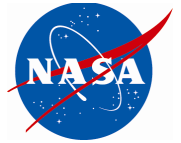
Geolocation tuning that can only be done with on-orbit data

Evaluation of APC, Faraday, & atmospheric corrections & possible adjustments

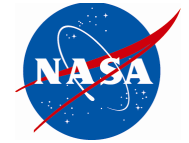
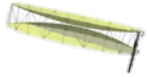


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Post-launch cal activities



1. *Geolocation*
2. *T_A calibration*
3. *RFI detection/mitigation parameter tuning*
4. *Antenna pattern correction*
5. *Drift monitoring & correction*
6. *Faraday rotation correction*
7. *Atmospheric correction*
8. *External target (end-to-end) calibration*
9. *Cross-calibration*
10. *Consistency with L2 Cal/Val*



Utility Tool Kits for Cal/Val (and performance trending)

NEDT

T_A calibration
parameters (internal
cal parameters)

RFI-related
parameters

Faraday rotation
correction

Atmospheric
correction

Geolocation
accuracy

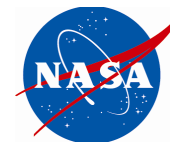
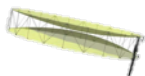
External cal
parameters

Drift

Cross calibration

Flag statistics

Automatic generation
of performance
reports (similar to
Aquarius tools)



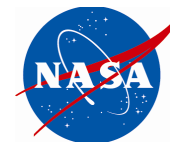
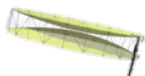
Assessment of Compliance to Cal/Val Requirements

Quantitative
evaluation of on-
orbit performance
vs. requirements

- *Wrt individual requirements on NEDT, drift, RFI, T_A , geolocation (L3-Instr-xxx, etc.)*
- *Wrt rolled-up requirements like L2-SR-45 (1.3K)*

Assess the
performance of
the external cal
approach itself, in
order to optimize
external cal

- *Assess where/when/how often the Antarctic & ocean obs are most useful. How to optimize wrt any limiting factors?*
- *Optimize the cold space view activity (location, duration, frequency). Is monthly sufficient wrt drift requirement?*



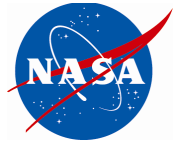
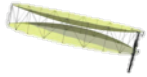
Status of Pre-Launch Work and Post-Launch Plan

Pre-launch

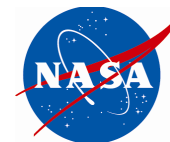
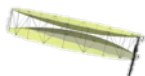
- *Internal cal-related:*
 - ETU h/w measurements in progress; risk reduction for FU h/w measurements
- *External cal-related:*
 - Simulations for Faraday & atmos corrections already used for algorithm development
 - Forward T_B sim mostly ready for checking Earth-viewing sidelobe correction
 - Forward T_B sim for solar, lunar, galactic, and CMB contributions ready

Post-launch

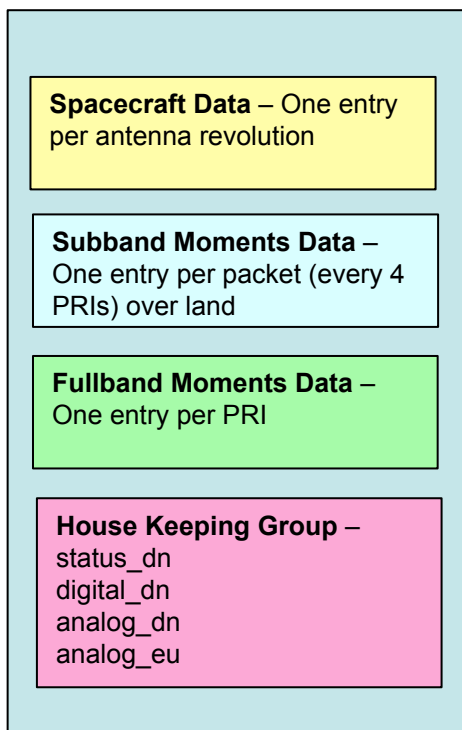
- *Basic external cal plan formulated & resource needs in-work with MS & SDS.*
- *Refinement of candidate target characteristics underway using SMOS & Aquarius data.*
- *Other refinement of external cal plan continuing*
- *Refinement of internal cal plan details awaiting ETU testing results*



Backup



Radiometer Level 1A Product Description



- **Spacecraft data**
 - Includes antenna scan times, S/C lat, lon, alt, vel, position, roll, pitch, yaw and rotation rate
- **Subband Moments Data**
 - Data obtained for 16 subbands
 - V and H polarization
 - Moments 1-4
 - 5 radiometric states: antenna, antenna + external noise diode, antenna + internal noise diode, reference, reference + internal noise diode
 - Occurs once every 4 PRIs
- **Fullband Moments Data**
 - V and H polarization
 - Moments 1-4
 - 5 radiometric states: antenna, antenna + external noise diode, antenna + internal noise diode, reference, reference + internal noise diode
 - Occurs every PRI
- **House Keeping Group**
 - Contains status and digital information from engineering telemetry
 - Analog digital numbers for temperatures and voltages
 - Analog engineering units for temperatures and voltages
 - Engineering telemetry obtained once per scan