Level 3-4 Algorithm Cal/Val Requirements

- L3_SM_40km Cal/Val requirements (P. O’Neill)
- L3_SM_HiRes Cal/Val requirements (J.C. Shi)
- L3_SM_A/P Cal/Val requirements (N. Das)
- L3_F/T & L4_C Cal/Val requirements (J. Kimball)
Radiometer SM L3 Data Flow

Static Ancillary Data
Dynamic Ancillary Data
L3_SM_HiRes
L3_F/T_HiRes

LIC_TB
Earth-Gridded
Brightness
Temperatures

L3_SM_40km
Retrieval Algorithm

L3_SM_40km
Earth-Gridded
Soil Moisture
## L3_SM_40km Inputs / Outputs

### DATA INPUT:
- Grid cell location on fixed Earth grid (lat, lon)
- Time tag (date and time of day)
- Calibrated L1C_TB
- Static ancillary data: [permanent masks (land / water, urban, etc.), soil type, DEM info, % land cover types]
- Dynamic ancillary data:  
  - Soil temperature
  - Vegetation water content
  - Vegetation parameters \((b, \tau, \omega)\)
  - % open water in pixel [from L3_SM_HiRes]
  - Temperature of open water from Ts at 6 am
  - Frozen ground flag [from L3_F/T_HiRes]
  - Precipitation flag (if set) [from ???]
  - Snow/ice flag (if set) [from ???]
  - RFI flag [from L1_TB]
  - Quality flag [from L1_TB]

### DATA OUTPUT:
- Grid cell location on fixed Earth grid (lat, lon)
- Time tag (date and time of day)
- Calibrated L1C_TB
- Retrieved soil moisture for 6 am overpass
- Dynamic ancillary data:  
  - Soil temperature
  - Vegetation water content
  - Vegetation parameters \((b, \tau, \omega)\)
  - % open water in pixel [from L3_SM_HiRes]
  - Temperature of open water [from L3_SM_HiRes]
  - Frozen ground flag
  - Precipitation flag (if set)
  - Snow/ice flag (if set)
  - RFI flag
  - Quality flag
### L3_SM Single-Channel Error Budget Table

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Est. TB Error (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Gases &amp; Clouds</td>
<td>0.15</td>
</tr>
<tr>
<td>Soil Temperature (2°C error)</td>
<td>1.7</td>
</tr>
<tr>
<td>Vegetation Water Content (10%)</td>
<td>1.6</td>
</tr>
<tr>
<td>Model Parameterization (h, ω, b, all at 5% error, classification, etc.)</td>
<td>1.4</td>
</tr>
<tr>
<td>Surface Heterogeneity</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Total RSS of Geophysical Errors</strong></td>
<td><strong>2.87</strong></td>
</tr>
<tr>
<td>Radiometer Precision &amp; Calibration Stability</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Total RSS Error</strong></td>
<td><strong>3.15</strong></td>
</tr>
</tbody>
</table>

[ Error budget to be confirmed ]

[ radiometer absolute calibration error not yet included ]
**L3_SM_40km Algorithm Priorities**

**Pre-Launch** – leads to selection of baseline algorithm & expected SM retrieval accuracy performance

- **refine model parameterizations** – **VEGETATION** is a priority
  -- need good b (or τ) and ω for main vegetation types
  -- polarization & seasonal dependence?
  -- determination of VWC
  -- scaling for effective VWC

- **how good is radar information on % open water in pixel?**

- **develop & compare algorithm error budgets**
  -- need to know error in ancillary data sets

- **evaluate algorithm performance using:**
  -- algorithm testbed simulations
  -- analysis of ground & A/C measurements
  -- SMOS / Aquarius data

Twin Otter w/PALS and ComRAD microwave truck system, SMAPVEX08, October 13, 2008
**Post-Launch** – are accuracy requirements met?

- comparison against long-term measurement networks which include surface soil moisture
- field measurements from intensive SMAP C/V field campaigns
- modeling / data assimilation & other satellites (GCOM-W?)
# RADAR CAL/VAL DATA REQUIREMENTS

<table>
<thead>
<tr>
<th>What is to be Tested</th>
<th>Optimum Platform/Scene</th>
<th>Spatial/Temporal Reqmnt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of Validity of Dubois model</td>
<td>Aircraft (UAVSAR/PALSAR) over areas with varying amounts and types of vegetation</td>
<td>50 km x 50 km Preferably few acquisitions with different moisture conditions</td>
</tr>
<tr>
<td>Effects of viewing geometry</td>
<td>Crossing flight lines over areas with topography and/or crops with row structure</td>
<td>Same</td>
</tr>
<tr>
<td>Scaling effects</td>
<td>Aircraft over heterogeneous areas</td>
<td>Same</td>
</tr>
<tr>
<td>Time Series Algorithm</td>
<td>Initially truck mounted scatterometer, later aircraft Data over different vegetation classes</td>
<td>Long time series preferably on daily basis</td>
</tr>
</tbody>
</table>
CAL/VAL for L3_SM_A/P product

Dara Entekhabi (MIT) and Narendra Das (JPL/CalTech)

SMAP Algorithms and Calibration/Validation Workshop
June 9-11, 2009
Oxnard, CA
Focus Should be on Algorithm Development Efforts

- Requires longer Time-Series Airborne Radiometer and Radar Data
  - To test the time series algorithms approach rigorously
  - To cover full dynamic range of soil moisture evolution
  - To investigate affects of changing VWC on time series parameters
  - Airborne L-band radiometer and radar at different azimuth viewing angle to investigate influence of azimuthal affects on time series algorithms

- Ground truth required at compatible spatial scales

- Accommodate varied landuse/landcover to enhance applicability

- Develop spatial scaling methods to scale in situ data to evaluate the global soil moisture products
Post-launch Cal/Val Activities for L3_SM_A/P product

Focus on calibration and fine tuning of algorithm used for L3_SM_A/P product, and to estimate bias and errors in the product

• Highest priority: Soil moisture ground truth sites with scaling established (temporally stable) to 10 km land cover and soil moisture conditions as required for the product

• Use ancillary information (e.g., Precipitation and VWC) for validation

• Use independent hydrological models for validation

• Other compatible satellite data for validation
SMAP L3_F/T & L4_C Cal/Val Requirements & Approach
Cal/Val activities address algorithm accuracy requirements

**L3 F/T:**
Obtain measurements of binary F/T transitions in boreal (≥45N) zones with ≥80% spatial classification accuracy (baseline); capture F/T constraints on boreal C fluxes consistent with tower flux measurements.

**L4 Carbon:**
Obtain estimates of land-atmosphere CO₂ exchange (NEE) at accuracy level commensurate with tower based CO₂ Obs. (RMSE ≤ 30 g C m⁻² yr⁻¹).
Planned L3_F/T Cal/Val activities

**Pre-launch:**
- Algorithm definition, testing, refinement using SMAP SDS test-bed simulations & available satellite L-band radar (PALSAR, SAOCOM) data;
- Focused campaigns using available airborne (UAVSAR) and satellite L-band radar data spanning F/T transitions over regional gradients (climate, land cover, terrain);
- Initialization of algorithm parameters (e.g. F/T reference states) over L3_F/T domain;

**Post-launch:**
- L3_F/T comparisons over northern biophysical monitoring sites (e.g. FLUXNET, WMO, ALECTRA);
- Intensive validation Field campaigns (airborne & tower based L-band Obs. with in situ measurements).
Planned L4_C Cal/Val activities

**Pre-launch:**
- Assess accuracy of L4_C inputs (L4_SM; GPP) over northern (≥ 45°N) domain;
- Algorithm development, testing, refinement using available inputs (e.g. MODIS GPP, SMOS, GMAO SM & T);
- Initialization/calibration/optimization of L4_C algorithm parameters (e.g. BPLUT, SOC pools);

**Post-launch:**
- Verify L4_C accuracy using CO₂ data from northern monitoring sites (e.g. FLUXNET);
- Re-initialization of algorithm parameters using SMAP and L4_SM inputs;
- Carbon model assimilation of L4_C products (e.g. NASA-TOPS, NOAA-CarbonTracker);
Pre-launch: Verify L3_F/T accuracy requirements

- Define domain & conditions where SMAP can meet L3_F/T requirements.

- Classification error increases rapidly as spatial resolution approaches scale of landscape F/T spatial heterogeneity.

- F/T spatial heterogeneity varies by region and on a seasonal basis; heterogeneity is maximized during spring/fall transitions, in complex land cover and terrain, and along lower elevations and latitudinal boundaries.

- Classification accuracy drops off rapidly with decreasing spatial resolution during F/T transitions when landscape heterogeneity is maximized.
Pre-launch: Establish L-band reference states for L3_F/T Algorithms

• Utilize SMAP SDS algorithm test-bed with available satellite L-band radar data (PALSAR, SAOCOM) to assess expected dynamic range of L-band backscatter variability over northern domain;

• Define L3_F/T frozen & non-frozen reference conditions

L3_F/T seasonal threshold Algorithm:

\[ \Delta(t) = \sigma(t) - \left\{ \sigma_{fr} + \left( \sigma_{th} - \sigma_{fr} \right) T \right\} \]

- \( \Delta(t) > 0 \) Thawed
- \( \Delta(t) \leq 0 \) Frozen

SeaWinds (2004) Ku-band frozen (mean dB, Jan) and non-frozen (mean dB, July) reference states
JERS-1 L-band Freeze-Thaw classification assessment using in situ temperature data

Validation with *in situ* Biophysical Measurements

L-band backscatter increases with thaw
Post-launch: L3_F/T validation using FLUXNET

Verify F/T accuracy and Carbon linkages

Pre-Launch: Calibration of L4_C parameters using FLUXNET

- Baseline L4_C algorithm parameterized for general biomes and assumptions of dynamic equilibrium between GPP and R under average climate conditions, but succession and disturbance can push ecosystem from steady-state;

- Parameterization error contributes ~30% of total L4_C uncertainty;

- CO₂ measurements from global observation networks (FLUXNET) can be used for model calibration and to account for non steady-state conditions;

NOAA CarbonTracker:

- Carbon data assimilation system for tracking global CO₂ exchange and net C source/sink activity;
- Atmospheric perspective based on atmospheric transport model (TM3) constrained by satellite remote sensing and sparse surface observations;
- Accounts for fossil-fuel and fire related CO₂ emissions;
- Currently uses 1-degree CASA land model to define land-atmosphere C exchange (NEE);
- Provides means to quantify boreal Carbon source/sink activity (SMAP Decadal Survey objective);

Post-launch: L4_C model assimilation to quantify boreal C source-sink activity

Annual C balance

<table>
<thead>
<tr>
<th>Year</th>
<th>First Guess</th>
<th>Estimate</th>
<th>Fire Emission</th>
<th>Fossil Emission</th>
<th>Total Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>-0.30 ± 1.67</td>
<td>1.37 ± 1.35</td>
<td>0.15</td>
<td>0.11</td>
<td>-1.11 ± 1.35</td>
</tr>
<tr>
<td>2001</td>
<td>-0.25 ± 1.67</td>
<td>-1.18 ± 1.33</td>
<td>0.11</td>
<td>0.11</td>
<td>-0.96 ± 1.33</td>
</tr>
<tr>
<td>2002</td>
<td>-0.24 ± 1.80</td>
<td>-1.25 ± 1.38</td>
<td>0.25</td>
<td>0.11</td>
<td>-0.89 ± 1.38</td>
</tr>
<tr>
<td>2003</td>
<td>0.02 ± 1.61</td>
<td>0.86 ± 1.25</td>
<td>0.38</td>
<td>0.11</td>
<td>-0.37 ± 1.25</td>
</tr>
<tr>
<td>2004</td>
<td>0.01 ± 1.60</td>
<td>1.07 ± 1.32</td>
<td>0.15</td>
<td>0.12</td>
<td>-0.80 ± 1.32</td>
</tr>
<tr>
<td>2005</td>
<td>-0.03 ± 1.57</td>
<td>-1.12 ± 1.25</td>
<td>0.11</td>
<td>0.12</td>
<td>-0.89 ± 1.25</td>
</tr>
<tr>
<td>2006</td>
<td>0.16 ± 1.72</td>
<td>-0.98 ± 1.21</td>
<td>0.14</td>
<td>0.12</td>
<td>-0.71 ± 1.21</td>
</tr>
</tbody>
</table>

http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/index.html