Long and Short Term Stability of SMOS Measurement with NIR Front-end Models
SMOS & Aquarius Workshop, Brest, France, April 15-17 2013

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Motivation – temporal biases in SMOS measurements

Noisi Injection Radiometer (NIR) units in SMOS

Stability of SMOS measurements at Pacific with 4 different front-end models.

Can the current stability be improved?
Motivation

- **Seasonal** (long term) variations? Different bias signature over summer and winter periods.

- **Latitudinal** (short term) variations? Strong SSS-error gradient at the >30°N.
**Motivation**

- **Orbital** (short term) variations? Different bias signature for ascending and descending measurements.

- This hovmoller-plot presents Desc-Asc bias in AF-FOV obtained from thousands of half-orbits over different seas.

*Credits: J. Tenerelli*
SMOS reference radiometers - the NIR units

Several purposes on SMOS:

1) to measure the zero baseline visibility (antenna temperature)
2) to measure the calibration diode power level
3) to establish baselines with other receivers
4) to calibrate NIR/LICEF antenna losses
5) to detect RFI
NIR Field-of-View

- HPBW of NIR antennas are ± 28-32°. Footprint on ground spans over approximately 1000 km circle.
- Antenna temperature measured by the units is used to determine the overall brightness temperature level of the synthesized image.

Pure sea view
\[ T_{A,\text{min}} \approx 80 \text{ K} \]

Pure land view
\[ T_{A,\text{max}} \approx 220 \text{ K} \]
Stability test area
Pacific Ocean

• One of the stability test areas is an area at Pacific Ocean.

• A forward model has been established to simulate both
  1) The brightness temperature of the area
  2) NIR antenna temperatures when measuring the target area

• Stability of SMOS images and NIR measurements are assessed.

• (Bi-weekly measurements of sky.)
Stability test area
Pacific Ocean

- Bias measured from the test area averaging pixels within the AF-FOV area.
- Ascending and descending passes separately.
- Current performance state decreasing trend along the mission (0.2-0.3 K/year) and ~1.2 K peak-to-peak errors over this trend.
- How can we do better?
• Soon after the commissioning, drifts was observed in sky measurements. This drift in antenna temperature was resulted when either NIRs of pure LICEFs were used in measurements.

→ The phenomenon causing the drift is common to LICEFs and NIRs → Antenna ?
NIR front-end attenuation L1

- On-ground, L1 was determined by the antenna manufacturer to be 0.05 dB. L1+L2 attenuation level of ~0.2 dB was anticipated by on-ground characterization of NIR units.
The first attempt to correct biases was developed based on strong correlations between the observed drift and the physical temperature of the antenna patches ($T_{p7}$). This dynamic model ("1-slope model") related L1 to patch temperatures.

The method defines L1 attenuation for each epoch. It consists of a part coping with long-term and short-term biases.

The 1-slope model was implemented for the first mission reprocessing (504), since it was noticed to decrease the discrepancy between ascending and descending passes.

\[ L_1(t) = dL_{1,0} + \alpha \left( \overline{T}_{p7} - \overline{T}_{p7,\text{ref}} \right) + \beta \left( T_{p7} - \overline{T}_{p7,\text{ref}} \right) \]

- Long-term
- Short-term
A) 1-slope antenna model

- L1 values from an exemplary half-orbit in January 2011.
- L1 values follow the $T_{\text{p7}}$ temperature profiles.
Performance of the front-end models

A) 1-slope antenna model

- Nominal NIR processing (v350, with ground characterization)
- Strong asc-desc bias

**Brightness temperature bias**

\( \Delta T = 0.631\text{K} \)
- Slope = -0.191K/yr
- Mean = -0.125K

**Antenna temperature bias**

\( \Delta T = 0.568\text{K} \)
- Slope = 0.097K/yr
- Mean = -0.182K

Images: UPC
Performance of the front-end models
A) 1-slope antenna model

- Previous mission reprocessing data (v504, the 1-slope model)
- Antenna temperature bias stabilises. Brightness temperature bias not. Asc-Desc bias of 2010 decreases, which was one of the reasons to select the model for reprocessing.

**Brightness temperature bias**

\[ \Delta T = 0.631K \]
\[ \text{Slope} = -0.202K/yr \]
\[ \text{Mean} = -0.180K \]

**Antenna temperature bias**

\[ \Delta T = 0.643K \]
\[ \text{Slope} = -0.142K/yr \]
\[ \text{Mean} = 0.026K \]

Images: UPC
B) External L1 calibration

- A method to determine L1 from measurements of sky was introduced by UPC. The method suggested slowly varying L1. In short-term the L1 is constant.
- Based on measurements of sky and internal load.
- L1 values from the method were clearly larger than those determined on-ground those of the 1-slope model.
- Significant differences between units.
Performance of the front-end models
B) External L1 calibration

- Previous mission reprocessing data (v504, the 1-slope model) here for comparison...

Brightness temperature bias

Antenna temperature bias

Images: UPC
Performance of the front-end models

B) External L1 calibration

- And here with the external L1 calibration… (not yet implemented in L1OP).
- Differences to the 1-slope processed data are small. However, gives more consistent calibration parameters (L1, gain, …)

Brightness temperature bias

Antenna temperature bias

Images: UPC
C) Linear thermal model for the NIR front-end gain and offset (i.e. a/b-correction)

- A correction defined for the units prior to launch, but not defined yet due to demand of large amount of data.
- The method relates the drifts in sky calibration linearly to gain and offset terms the NIR channels, i.e. not assigning them to L1.

\[
T_A = (-T_{NA}') \eta + T_U' = A \eta + B
\]

\[
T_{NA}' = L_1 L_2 T_{NA}
\]

\[
T_U' = L_1 L_2 L_{NC} L_A T_U - (T_{p7}(L_1 - 1) + L_1 T_{p6}(L_2 - 1) + L_1 L_2 T_{p3}(L_{NC} - 1) + L_1 L_2 L_{NC} T_{Cab}(L_A - 1))
\]

\[
T_A = A_{(Tp7)} \eta + B_{(Tp7)}
\]

\[
T_A = (A + a \Delta T_{p7}) \eta + (B_{(Tp7)} + b \Delta T_{p7})
\]
Performance of the front-end models C) a/b correction

• Previous mission reprocessing data (v504, the 1-slope model) here for comparison…
Performance of the front-end models
C) a/b correction

- a/b correction much decreases the seasonal error in brightness temperature level.
- Negative trend 0.2 K/year remains, seasonal peak-to-peak error 0.6 K on top of that.
D) ”All-licef” mode

- NIR’s are switched off from the noise injection mode and used as LICEFs. The antenna temperature is determined averaging measurements of all LICEFs.
- Negative trend < 0.1 K/year, seasonal peak-to-peak error 0.7 K on top of that.

![Brightness temperature bias](chart1)

![Antenna temperature bias](chart2)

**Brightness temperature bias**
TB-level I/2 biases, ALL LICEF [K]

**Antenna temperature bias**
I/2 biases, TA level, ALL LICEF [K]

All-licef credits: UPC
Performance of the front-end models
C) a/b correction

- a/b correction much decreases the seasonal error in brightness temperature level.
FURTHER IMPROVEMENTS WITH NIRS?

Error in sky measurements

- We use two-week old calibration for each measurement.
- Antenna temperature during sky measurement can be modeled with antenna patterns and L-band sky map.
FURTHER IMPROVEMENTS WITH NIRS?

Error in sky measurements

- Accuracy of NIR CA is significantly better than that of the BC unit.
- Seasonal behaviour with BC?

![Graphs showing error in sky measurements with X-pol and Y-pol](image-url)
FURTHER IMPROVEMENTS WITH NIRS?

TA error at Pacific (now channel-wise)

- Clearly, BC has a negative trend whereas CA gives more stable response.
Summary and conclusions

- Temporal stability of SMOS measurements is dominated by changes in the antenna layer of the NIR and LICEF units.
- To cope with these effects, several front-end models have been assessed in three years.
- With the currently implemented model, stability of ~0.2-0.3 K/year with 1.0-1.2 K peak-to-peak annual variations on top of this at the Pacific test site are measured.
- **We can still do better**: In the lack of better thermal model for NIR BC, using only NIR CA will do the job.
  - The negative trend is much subjected to NIR BC.
  - Also the seasonal error structure of BC is stronger.
- The **Sun L-band signal** (direct or reflected) has an influence not yet completely understood.
SMOS-Mission Oceanographic Data Exploitation

SMOS-MODE

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SMOS-MODE supports the network of SMOS ocean-related R&D

Next plenary meeting foreseen in October 2013

Additional institutions and countries are welcome!
Thank you, any questions?

ADVANCE NOTICE

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Espoo (Helsinki), Finland
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