GPM Observations of Microwave Land Surface Emissivity and Radar Backscatter

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Background/Motivation

• GPM precipitation algorithms require knowledge of surface emissivity and/or backscatter cross-section
  – DPR algorithms rely on Surface Reference Technique to estimate path-integrated attenuation (PIA)
  – Combined DPR+GMI algorithm uses PIA and performs radiative transfer simulations in optimization procedure
  – Generation of GPROF database for partner constellation members require transfer from GMI freq/angle to other imagers/sounders

• Existing atlases (TELSEM) used in at-launch algorithms, but missing:
  – Frequencies > 90 GHz
  – Relationship between emissivity and radar backscatter cross-section ($\sigma_0$)

• Unique capabilities of GPM instruments provide new opportunity for land surface studies
Outline

• Overview of GMI and DPR instruments and precipitation algorithms
• Description of GMI surface emissivity retrieval & challenges
• One-year preliminary database of GMI emissivity matched to DPR $\sigma_0$:
  – Gridded means
  – Impact of seasonal cycle, snow cover, recent rainfall
  – EOF analysis
• GPM Combined Algorithm Implementation
GMI Characteristics

• 13 channels from 10-183 GHz
• 1.2m reflector provides resolution ranging from 25km at 10 GHz to 6km at 89+ GHz
• Four-point calibration at 10-36 GHz (calibration standard for constellation 1C products)
• 52.8° EIA at 10-89 GHz and 49.1° EIA at 166-183 GHz (scan lines do not match)

GMI precipitation algorithm (GPROF) is a Bayesian procedure that weights a database of profiles based upon closeness to observed TBs. Explicit knowledge of surface emissivity not required, but databases are separated based upon surface type classification (14 classes), T2m, and TPW.

Mean Simulated - GMI Tb (using buoy wind and SST + MERRA water vapor)

<table>
<thead>
<tr>
<th>Emissivity Model</th>
<th>10 V</th>
<th>10 H</th>
<th>18 V</th>
<th>18 H</th>
<th>23 V</th>
<th>36 V</th>
<th>36 H</th>
<th>89 V</th>
<th>89 H</th>
<th>166 V</th>
<th>166 H</th>
<th>183 ± 3</th>
<th>183 ± 7</th>
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<tbody>
<tr>
<td>RSS</td>
<td>-1.1</td>
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<tr>
<td>FASTEM6</td>
<td>0.2</td>
<td>-0.6</td>
<td>0.1</td>
<td>0.8</td>
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<td>-</td>
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<td>-0.5</td>
<td>-0.5</td>
<td>-3.5</td>
<td>-1.0</td>
</tr>
</tbody>
</table>
DPR Characteristics

- Ku scans ±18° at 49 positions and 250m range resolution, oversampled at 125m
- Ka scans ±9° at 25 positions (matched to Ku) with an additional 24 interlaced positions in High-Sensitivity mode (500m range resolution oversampled to 250m)
- Ku receiver saturates at lower level than TRMM PR (22.5 dB)
- DPR algorithms use **Surface Reference Technique to infer PIA** (and its uncertainty) or differential PIA
- DPR+GMI algorithm uses **PIA and explicit surface emissivity estimates** (with uncertainty)
Emissivity Retrieval from GMI

Key assumptions:

• Skin temperature from ancillary data (MERRA/GANAL)

• All channels considered independent, except:
  – 23.8V (interpolated from 18.7V and 36.6V)
  – 183 ± 3 and 183 ± 7: Use same as 166V

• Adjust temperature/water vapor EOFs from analysis state

• No cloud liquid (IR Tb can be used to screen in post-processing)

• No post-1C RFI screening
Retrieval Issues:
Simulated – Observed Tb Residuals
Retrieval Issues:
Dependence on Skin Temperature Source
Database Overview

• Database is designed to meet combined algorithm needs:
  – Gridded means of emissivity at each frequency and $\sigma_0$ at each frequency and incidence angle
  – Covariance matrix between emissivity and $\sigma_0$ at all incidence angles to derive EOFs

• Challenge 1: Poor sampling of DPR at a given incidence angle

• Challenge 2: How to effectively use ancillary data to condition the mean and covariance matrix?
DPR sampling
Conditional Subsets – Impact of Seasonal Cycle on Emissivity

Maps showing Dec Column Water Vapor, Dec 10H emis, Dec 37H emis, and Dec 166H emis.
Conditional Subsets – Impact of Seasonal Cycle on DPR Backscatter
Conditional Subsets – Impact of Snow Cover on Emissivity
Conditional Subsets – Impact of Snow Cover on DPR Backscatter

![Graphs showing the impact of snow cover on DPR backscatter](image-url)
Impact of Recent Rainfall

Extreme flooding event in early October 2015

Change in GMI 10H emissivity

Change in $\sigma_0$ anomaly
GPM Combined Algorithm Implementation
(Proposed for V5)

• Generate ensemble of solutions (modify precipitation profile and surface properties)
  – Use gridded mean (by month) as base state emissivity, $\sigma_0$
  – Use class-based covariance-derived EOFs to guide perturbations to base state

• Ensemble filter uses sample covariance to determine sensitivity of measurements to precipitation/surface parameters and adjusts each ensemble member accordingly

• Final solution is mean of filtered ensemble
Vegetation Class Example

Global Precipitation Measurement

4th Workshop on Remote Sensing and Modeling of Surface Properties
Grenoble :: 14-16 March 2016
Snow Class Example

4th Workshop on Remote Sensing and Modeling of Surface Properties
Grenoble :: 14-16 March 2016
Algorithm mechanics – generate ensemble and covariances, then filter ensemble

Initial Ensemble
(Mean and Obs. Error)

+ Ensemble covariances

Mean Rain
Ku $\sigma_0$ error

Mean 18H Emis
18H error

Rain adjustment (mean and $\sigma$)

Rain-Ku
Rain-18H

Emis adjustment (mean and $\sigma$)

Emis-Ku
Emis-18H
Summary

• GMI is well-calibrated; emissivity can be retrieved up to 166 GHz under some conditions
• A 1-year database (Sept 2014-Aug 2015) of co-located DPR backscatter and GMI emissivity has been created
• Snow cover is the most dominant variable affecting backscatter and emissivity at a given location, but soil moisture/surface water and vegetation changes also have an effect
• Plan to produce all-sky emissivity estimates and use database-derived covariances in next version (5) of GPM products
• Research Topics:
  – How to use ancillary data (snow cover/depth/SWE, soil moisture, vegetation data, ...) to optimize EOF selection
  – Move towards physically-based instead of statistical emissivity/backscatter models
  – Understand impact of recent or ongoing precipitation (rain or snow) on surface properties