Validation of Retrieved Water Vapor with an Airborne Millimeter-Wave Radiometer over Arctic Sea Ice

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Aim
- Improve the use of satellite data in the marginal ice zone and over first (FY) and multi-year (MY) ice

Current State
- Total water vapor (TWV) retrieval over open ocean with higher TWV values possible, using SSM/I
- Retrieval of TWV in polar regions more difficult because
  - TWV in polar atmospheres very low and
  - Surface emissivity is highly variable in polar regions.
- Recently developed algorithm for the Antarctic using SSM/I2 data to be validated (Miao et al., 2001)

SEPOR-POLEX (Surface Emissivities in Polar Regions–Polar Experiment)
- Airborne campaign using microwave radiometer MARSS on Met Office C-130 research aircraft
- MARSS (Microwave Airborne Radiometer Scanning System) has channels similar to those of AMSU B and SSM/I2 (Table 1)
- Five flights of up to 10 hours each (Fig. 1), consisting of a low level run over various ice types, a profile ascent and a high level return run along the same track, releasing dropsondes with Vaisala RS90 humidity sensors at 100 km intervals
- Mostly clear skies over ice and a northerly surface flow for all flights
- Fig. 2 (top) shows a typical time series of brightness temperatures for a high level run for the flight A827 marked red in Fig. 1

Table 1: Characteristics of MARSS onboard the C-130 during SEPOR-POLEX
<table>
<thead>
<tr>
<th>Frequency [GHz]</th>
<th>Beamwidth (FWHM) [°]</th>
<th>Calibration Accuracy [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>11.8</td>
<td>0.9</td>
</tr>
<tr>
<td>157</td>
<td>11.0</td>
<td>1.1</td>
</tr>
<tr>
<td>183 ± 1</td>
<td>6.2</td>
<td>1.0</td>
</tr>
<tr>
<td>183 ± 3</td>
<td>6.2</td>
<td>0.9</td>
</tr>
<tr>
<td>183 ± 7</td>
<td>6.2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Algorithm by Miao et al., 2001
- Uses the 183 GHz channels of the Special Sensor Microwave/Temperature 2 (SSM/T2) to obtain a high sensitivity to the water vapor variations in dry atmospheres
- Assumes equal emissivity and surface temperature for all 183 GHz channels
- Uses logarithm of ratio of brightness temperature differences, which is linear with absorption
- TWV is determined using the equation:
  \[ \text{TWV} = C_0 + C_1 \ln \frac{T_b}{T_i} \]
  \[ = C_0 + C_1 \ln \frac{Y_b}{Y_i} \]
  \[ = C_0 + C_1 \ln \frac{X_b}{X_i} \]
  \[ = C_0 + C_1 \ln \frac{T_i}{T_b} \]

- For TWV < 2 kg/m² three 183 GHz channels are used
- For 2 kg/m² < TWV < 6 kg/m² the 157 GHz and the two wider 183 GHz channels are used

Future Work
- Evaluate algorithm over land surfaces in regions with low TWV
- Account for difference in emissivity at 157 GHz and 183 GHz. This will follow an examination of emissivity from low-level runs of SEPOR-POLEX experiment
- Extend range of TWV algorithm by including 89 GHz channel, which has lower sensitivity to water vapor

Fig. 1: Flight tracks and ice concentration

Fig. 2: Timeseries of nadir brightness temperatures from 9 km altitude (top) and derived TWV (bottom) for A827 (Fig. 1)

Fig. 3: Brightness temperature differences and focal point for 157 GHz and the two wider 183 GHz frequencies

Fig. 4: TWV from dropsonde and radiometric data for all SEPOR-POLEX flights

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