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/T2 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/T2 (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

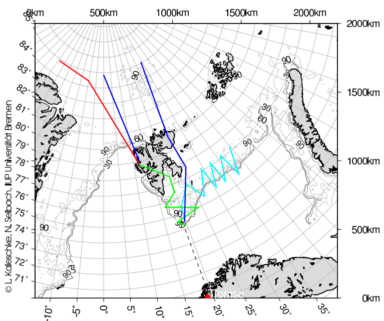

Fig. 1: *Flight tracks and ice concentration*

Table 1: *Characteristics of MARSS onboard the C-130 during SEPOR-POLEX (9 view angles in the range of +40° to −40° up- and downward facing; Scan period 3 s; Integration time 100 ms)*

Frequency [GHz]	Beamwidth (FWHM) [°]	Calibration Accuracy [K]
89	11.8	0.9
157	11.0	1.1
183 ± 1	6.2	1.0
183 ± 3	6.2	0.9
183 ± 7	6.2	0.8

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:

$$\mathrm{TWV} = C_0 + C_1 \ln \frac{T_i - T_j - Y_0}{T_j - T_k - X_0}$$

- For TWV $< 2\,\mathrm{kg/m^2}$ three 183 GHz channels are used
- For $2\,\mathrm{kg/m^2} < \mathrm{TWV} < 6\,\mathrm{kg/m^2}$ the 157 GHz and the two wider 183 GHz channels are used

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Algorithm Modification

- Radiative transfer model MWMOD run to derive coefficients
- Using a dataset of 400 arctic profiles (NESDIS rocketsonde dataset)
- Modelled brightness temperatures (T_B) at 89, 157, 183 ± 7, 183 ± 3 and 183 ± 1 GHz using dual side band
- Derived set of coefficients for each channel combination. Fig. 3 shows a plot of brightness temperature differences and focal point (X_0, Y_0) for the 157 GHz and the two wider 183 GHz channels
- Fig. 2 (bottom) shows a typical timeseries of TWV derived from high level data using this set of coefficients

Results

- In flight A827 $T_B(89\,\mathrm{GHz}) < T_B(157\,\mathrm{GHz})$ for MY ice (Fig. 2 top) and
- Channel at 183 ± 1 GHz saturated over open water, i.e. cannot 'see' surface due to strong atmospheric absorption
- 183 GHz algorithm shows good agreement with dropsonde data for TWV $< 2\,\mathrm{kg/m^2}$ (Fig. 2 bottom, Fig. 4),
- But fails for higher humidity because 183 ± 1 GHz channel saturates
- Algorithm including 157 GHz has systematic offset over FY ice, due to emissivity difference from 183 GHz, and even more bias over open water due to greater emissivity difference

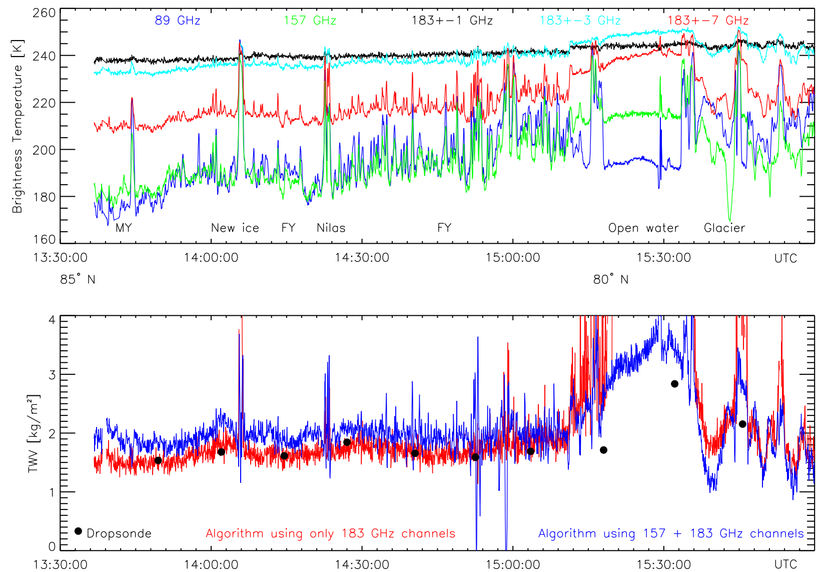

Fig. 2: *Timeseries of nadir brightness temperatures from 9 km altitude (top) and derived TWV (bottom) for A827 (Fig. 1)*

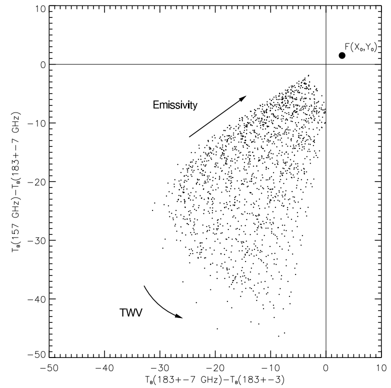

Fig. 3: *Brightness temperature differences and focal point for 157 GHz and the two wider 183 GHz frequencies*

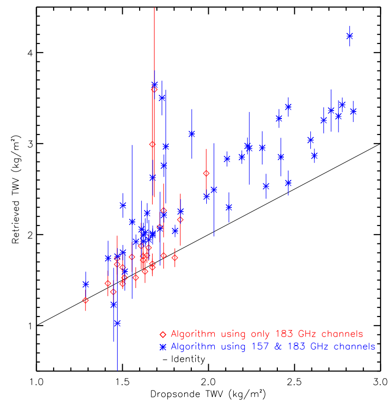

Fig. 4: *TWV from dropsonde and microwave radiometer data for all SEPOR-POLEX flights*

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

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