IOMASA WP 1.2: Development of algorithms for retrieval of atmospheric parameters

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1. Total water vapor (TWV) from AMSU-B
2. Surface emissivity at temperature sounding frequencies
3. Cloud liquid water

TWV Algorithm

- T_b at 3 different frequencies i, j, k at which ground emissivity ε_s is similar but water vapor absorption different; $\kappa_i < \kappa_j < \kappa_k$:

$$TWV \sec\theta = C_0 + C_1 \ln\left(\frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}}\right)$$

- 4 calibration parameters C_0, C_1, F_{ij}, and F_{jk} determined from regressions with radiosonde data and simulated T_bs
- Channels 3,4,5 for low TWV ($<$ 1.5 kg/m^2)
- Channels 2,3,4 for higher TWV ($<$ 6 to 7 kg/m^2)

our no.	1	2	3	4	5
Freq. [GHz]	89.0	150.0	182.31$\pm$7	182.31$\pm$3	182.31$\pm$1
AMSU channel	16	17	20	19	18

TWV algorithm: Saturation cut-off

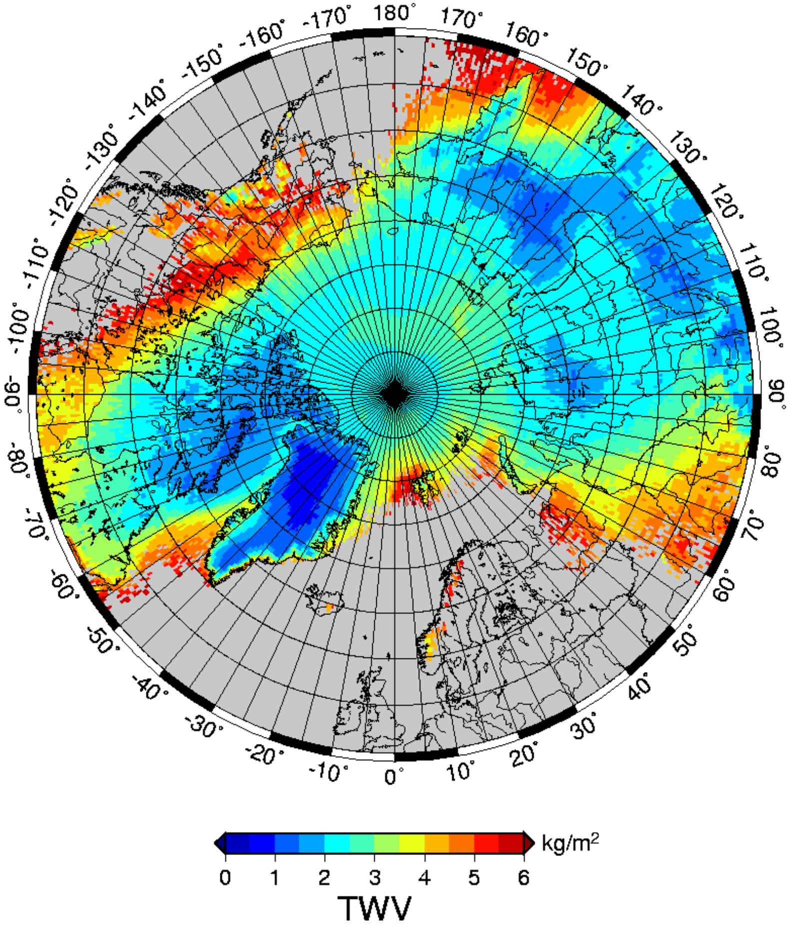
- Condition when algorithm is not applied any more (saturation) was relaxed from
  $T_3 - T_4 \geq 0$ ("saturation cut-off" = 0)
  to
  $T_3 - T_4 \geq F_{3,4}$ ("saturation cut-off" = $F_{3,4}$)
  where the focal point coordinate $F_{3,4}$ is typically a few K
- As long as both numerator and denominator of the $\log$ argument are negative, the algorithm works.

$$\log \frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}}$$

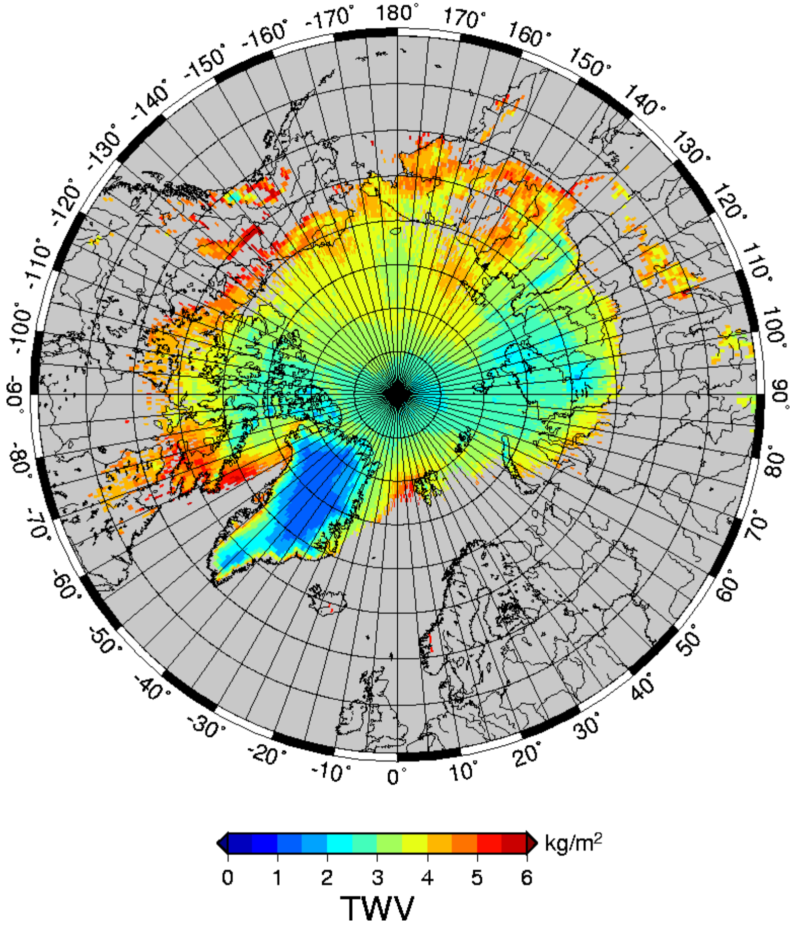
TWV algorithm: Current Status

- TWV can be calculated from AMSU-B swath data in form of
  - swath data (ASCII or binary), i.e. table with 3 columns (longitude, latitude, TWV), one value for each AMSU "pixel"
  - daily averages, monthly averages
    - maps (i.e., images: PostScript, PNG)
    - grid files (GMT output in NetCDF format),
    - more standard NetCDF (can be read, e.g., by GrADS)
- Comparison with NCEP reanalysis data done (not really a validation)
- Comparison with ECMWF reanalysis data planned
- Validation with radiosonde in preparation
- Extension to higher TWV values started

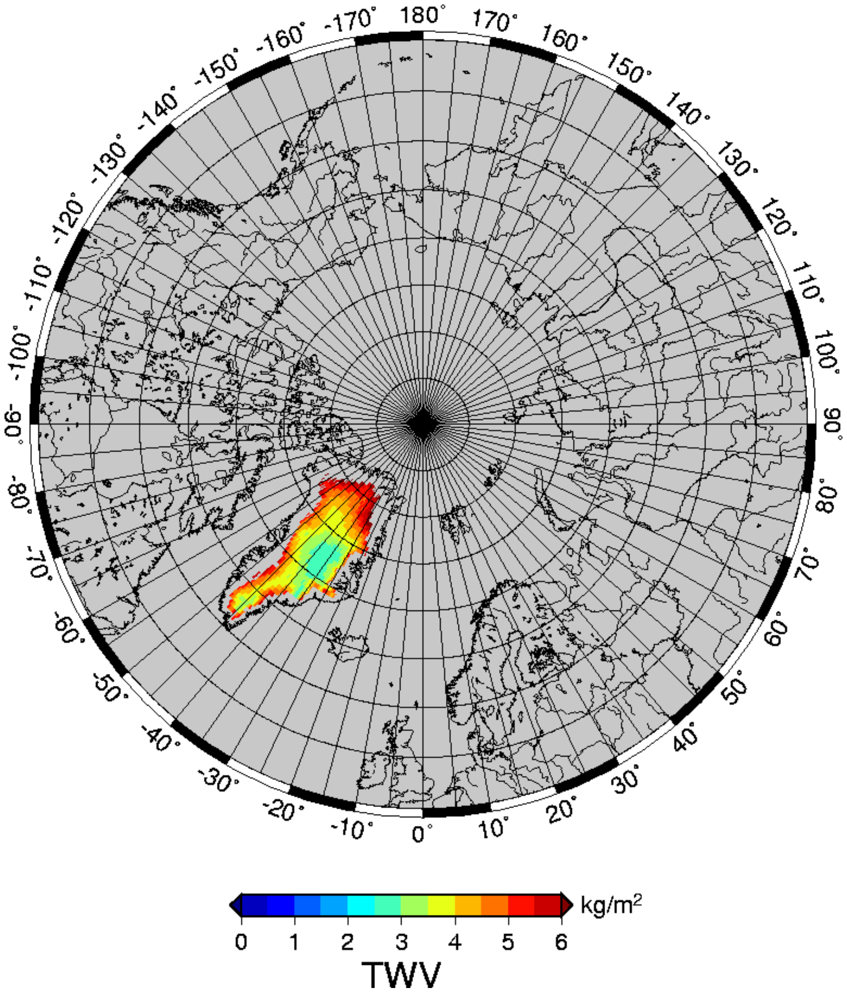
Results



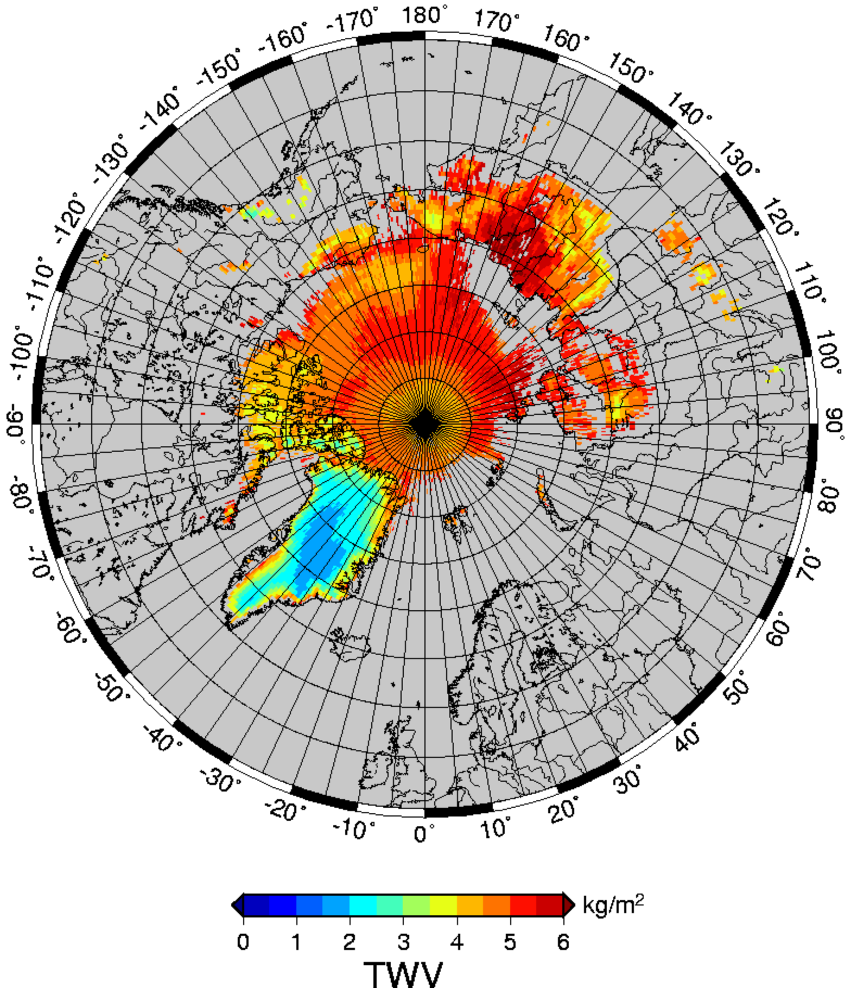
Mean of TWV, January 2001



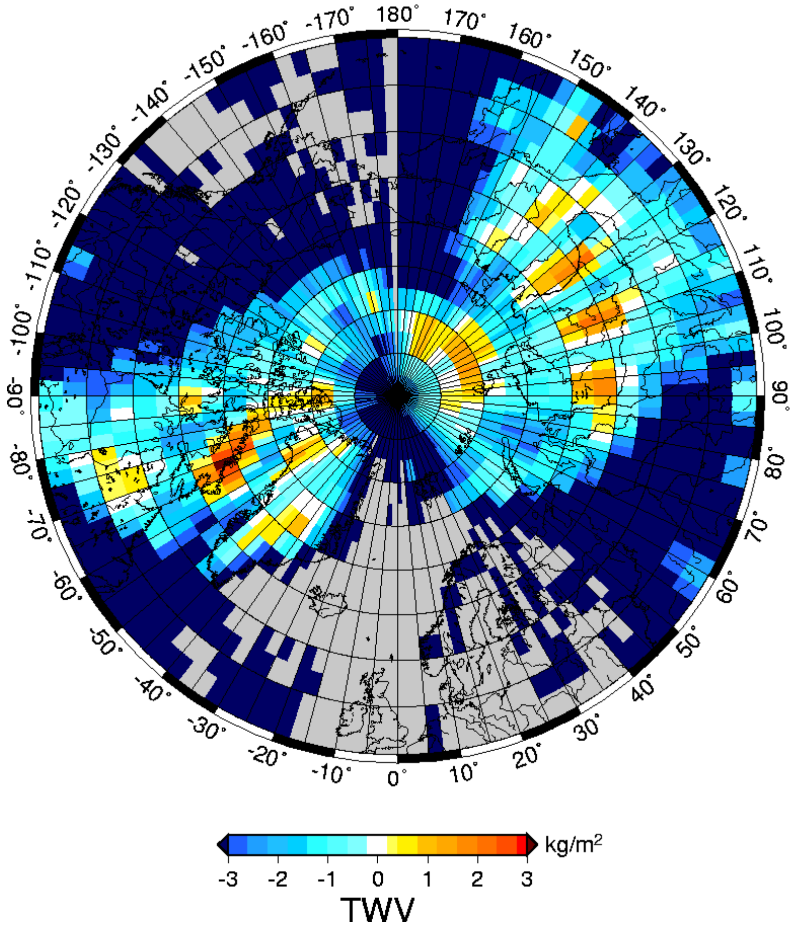
Mean TWV, April 2001



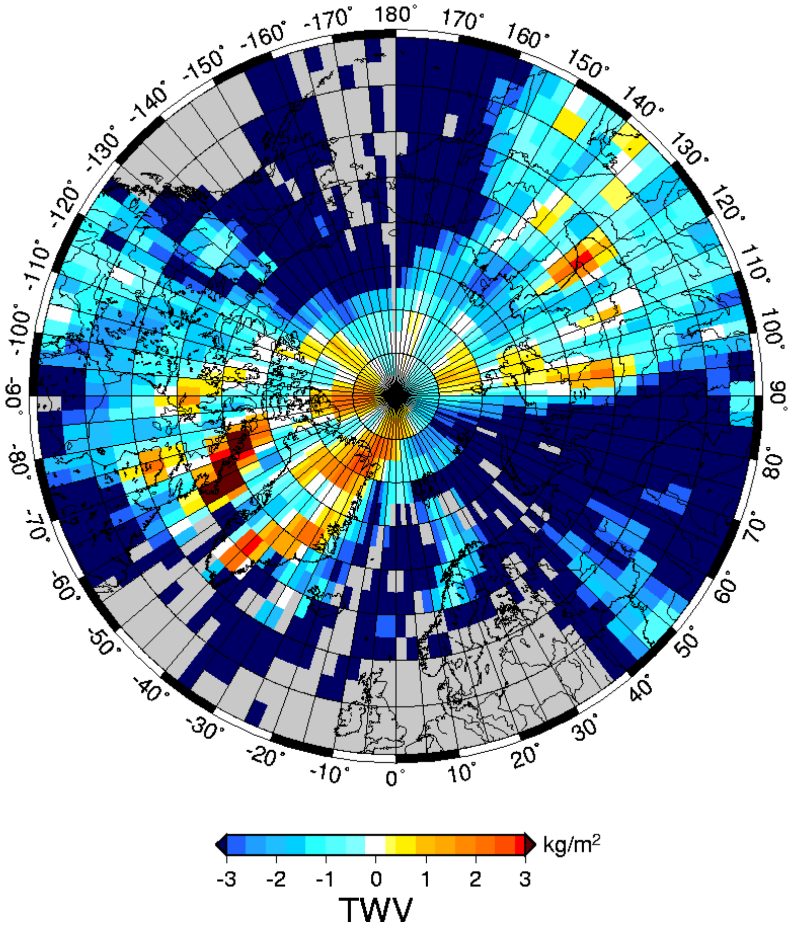
Mean TWV, July 2001



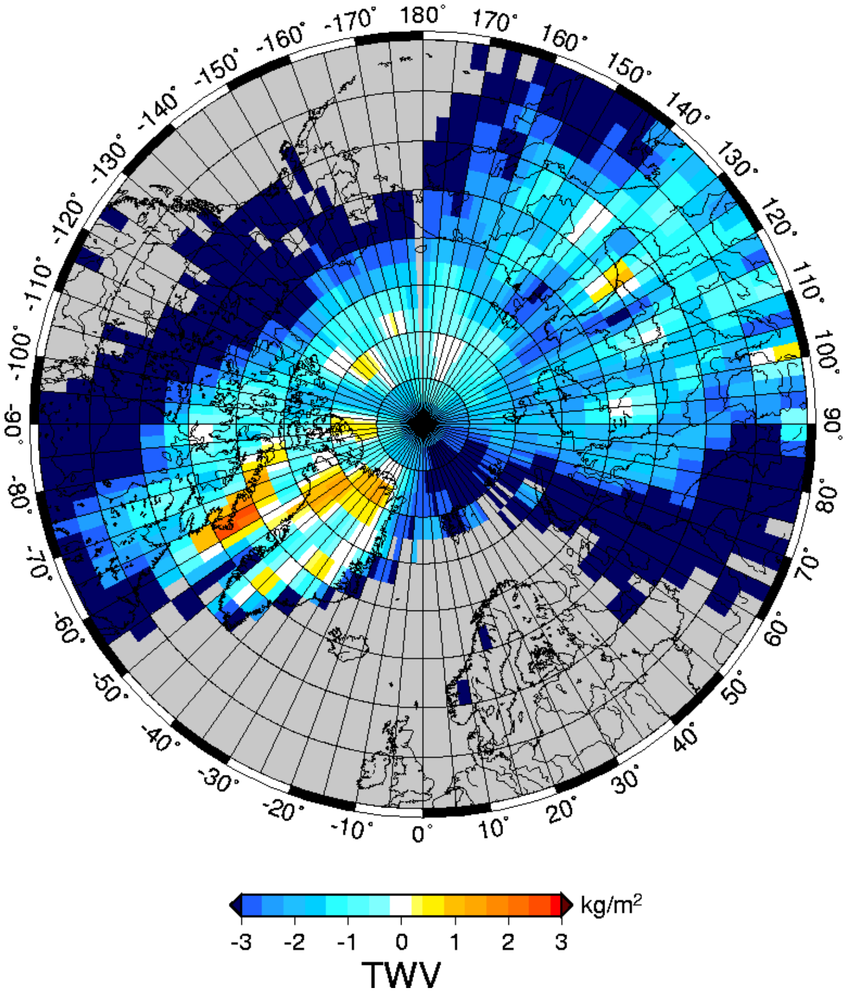
Mean TWV, October 2001



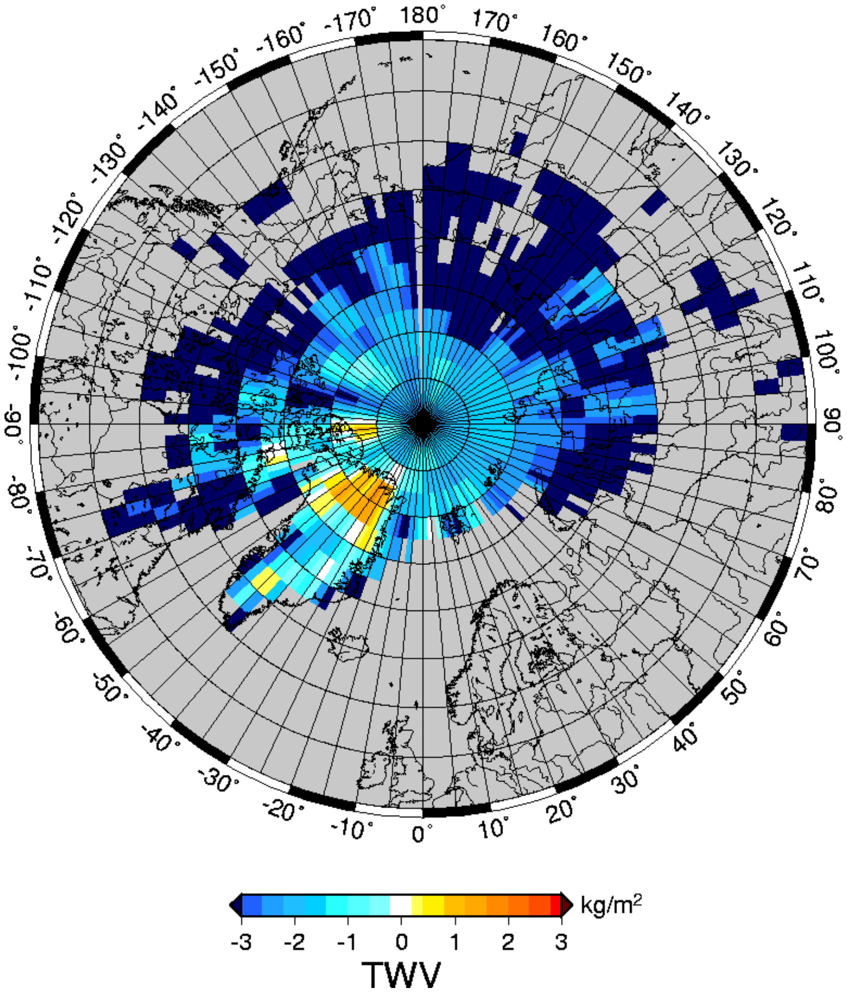
TWV from AMSU-B minus TWV from NCEP, 27 January, 2001



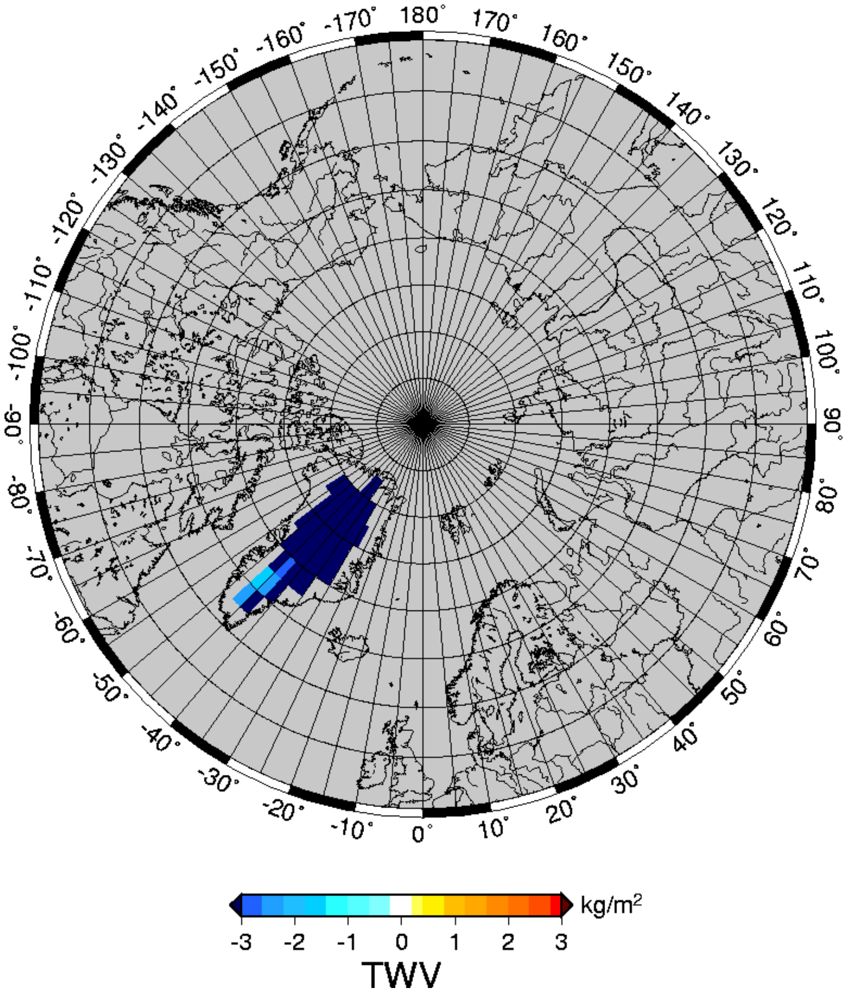
TWV from AMSU-B minus TWV from NCEP, 7 February, 2001



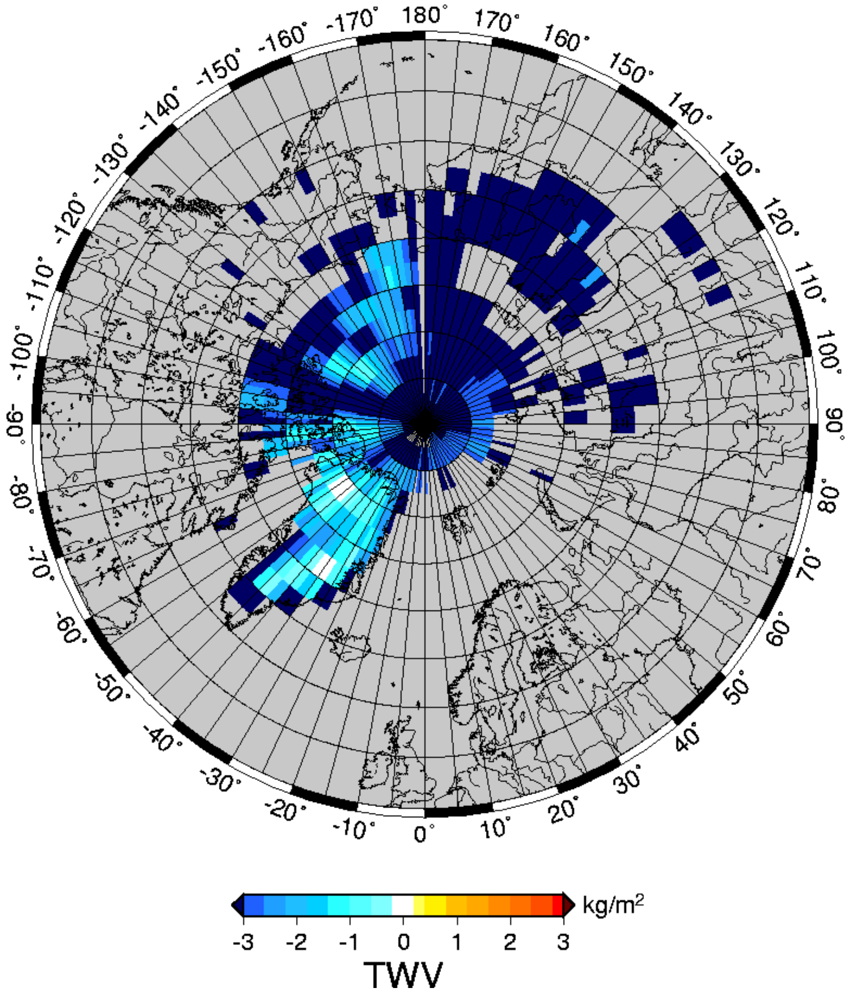
Mean of difference AMSU–NCEP TWV, January 2001



Mean of difference AMSU–NCEP TWV, April 2001



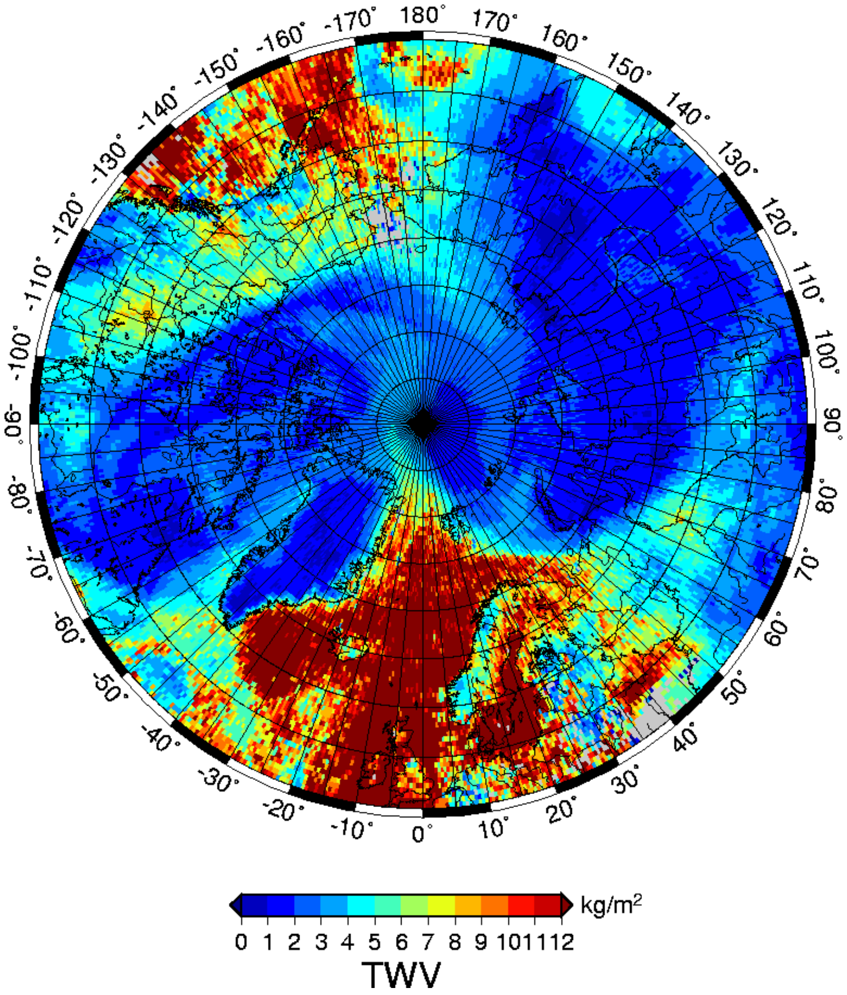
Mean of difference AMSU–NCEP TWV, July 2001



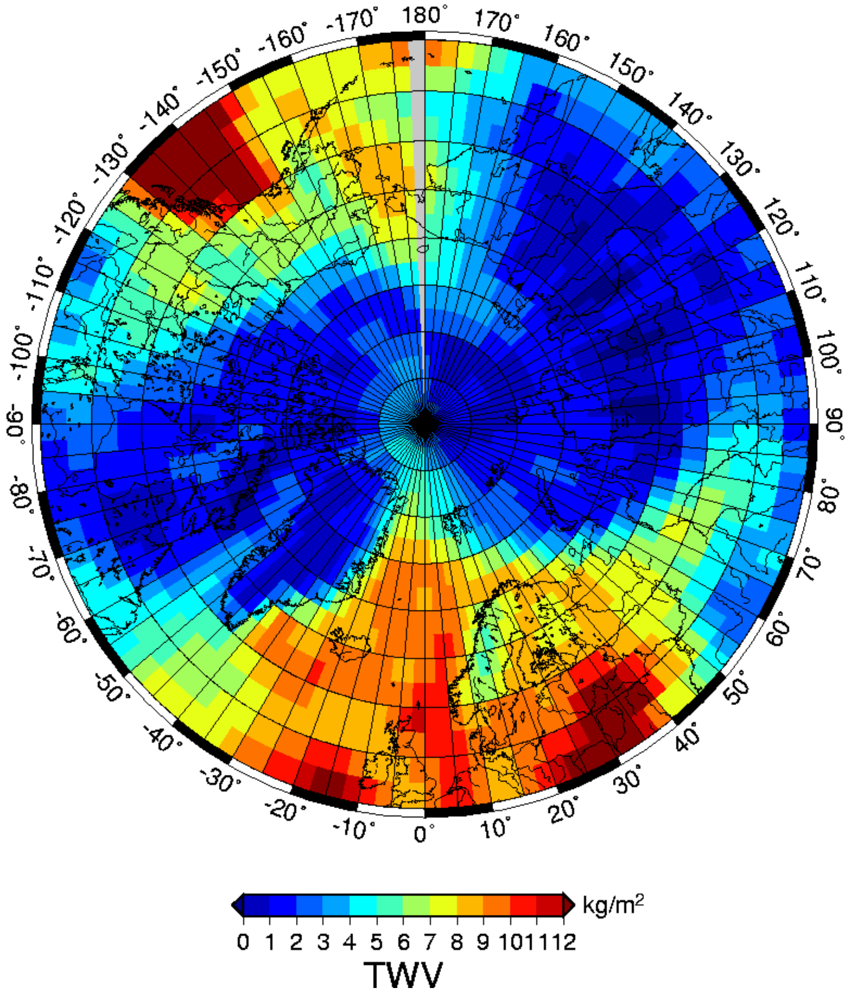
Mean of difference AMSU–NCEP TWV, October 2001

Extension to higher TWV values

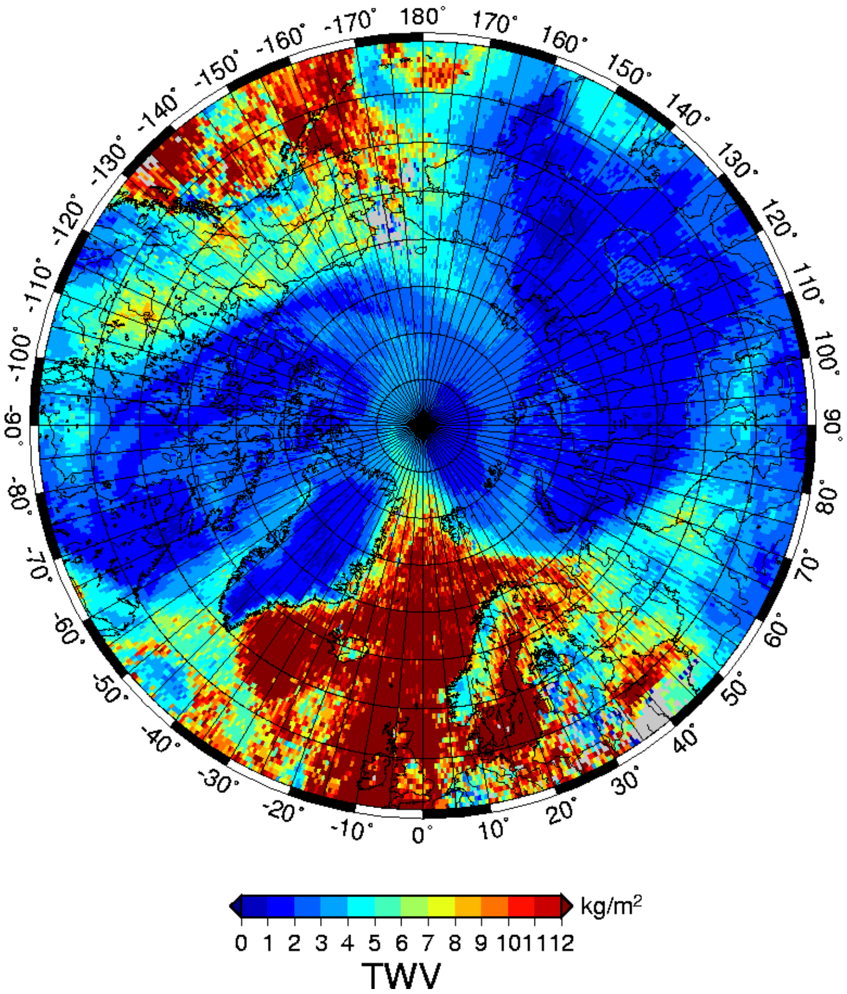
- TWV $>$ 6 to 7 kg/m^2 $\Rightarrow$channel 4 saturated as well
- Try channels 1,2,3, but: channel 1 emissivity $\neq$ other emissivities
- Nevertheless: Deriving calibration parameters (it works), applying algorithm (eyes closed. . .)

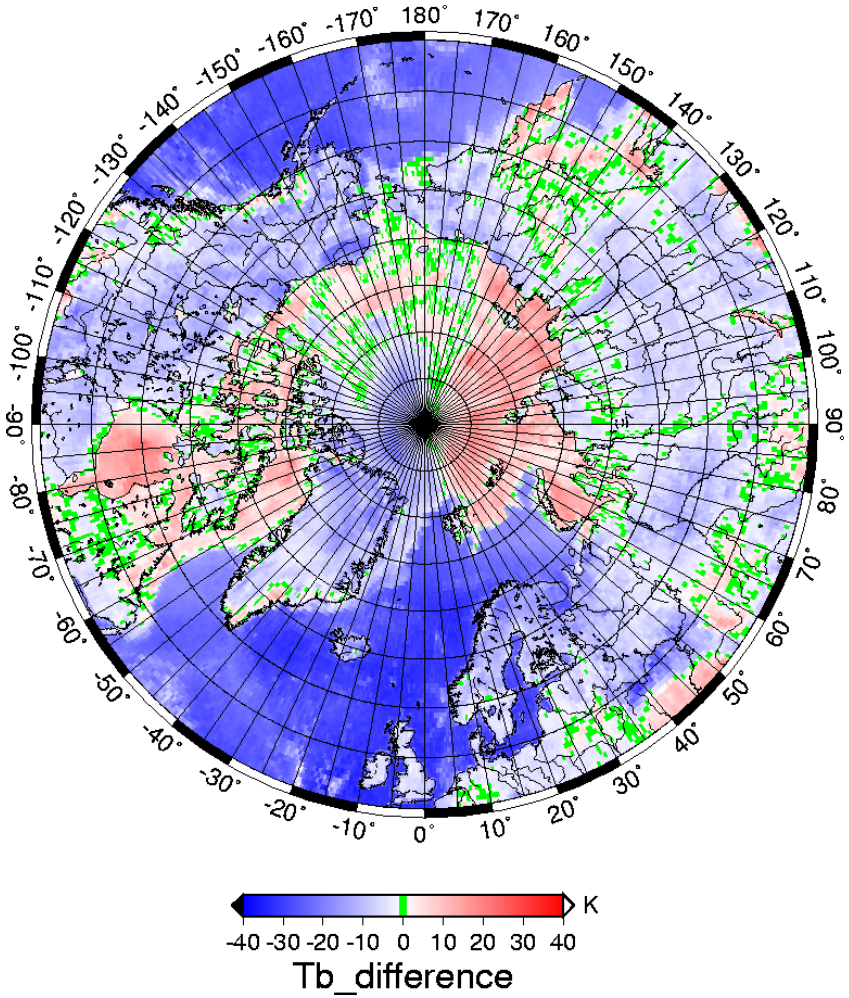


“TWV” with channel 1,2,3 and 2,3,4; 27 January, 2001



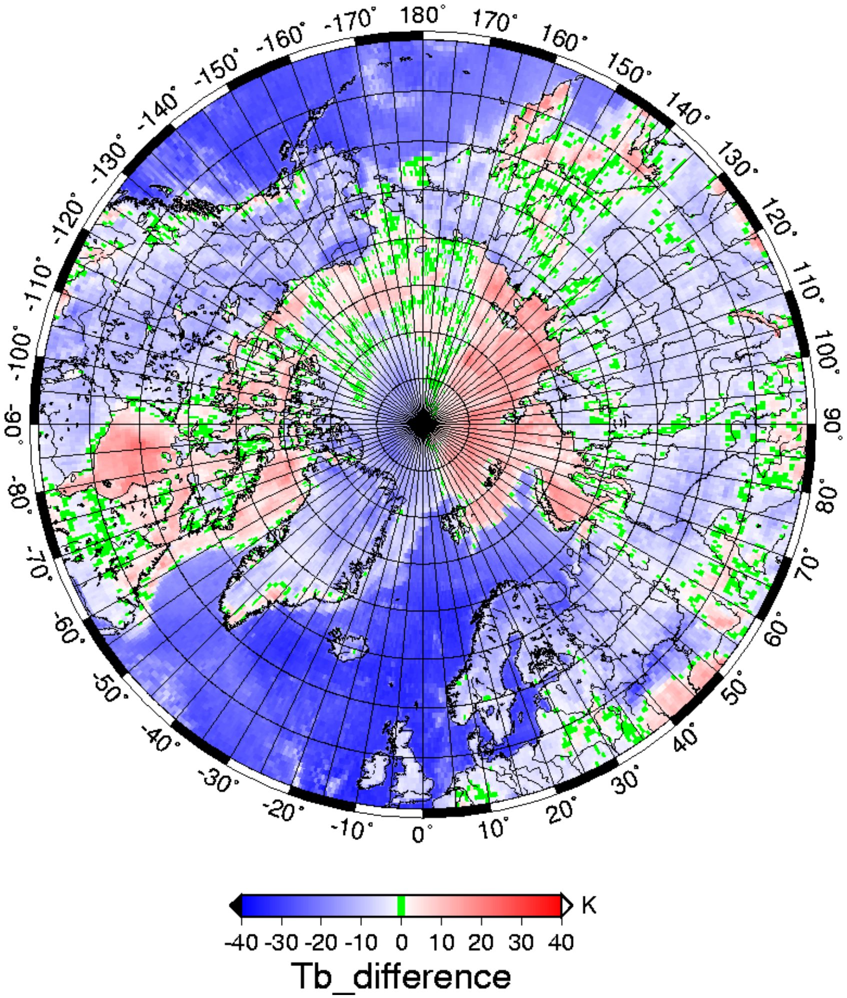
NCEP TWV, same date



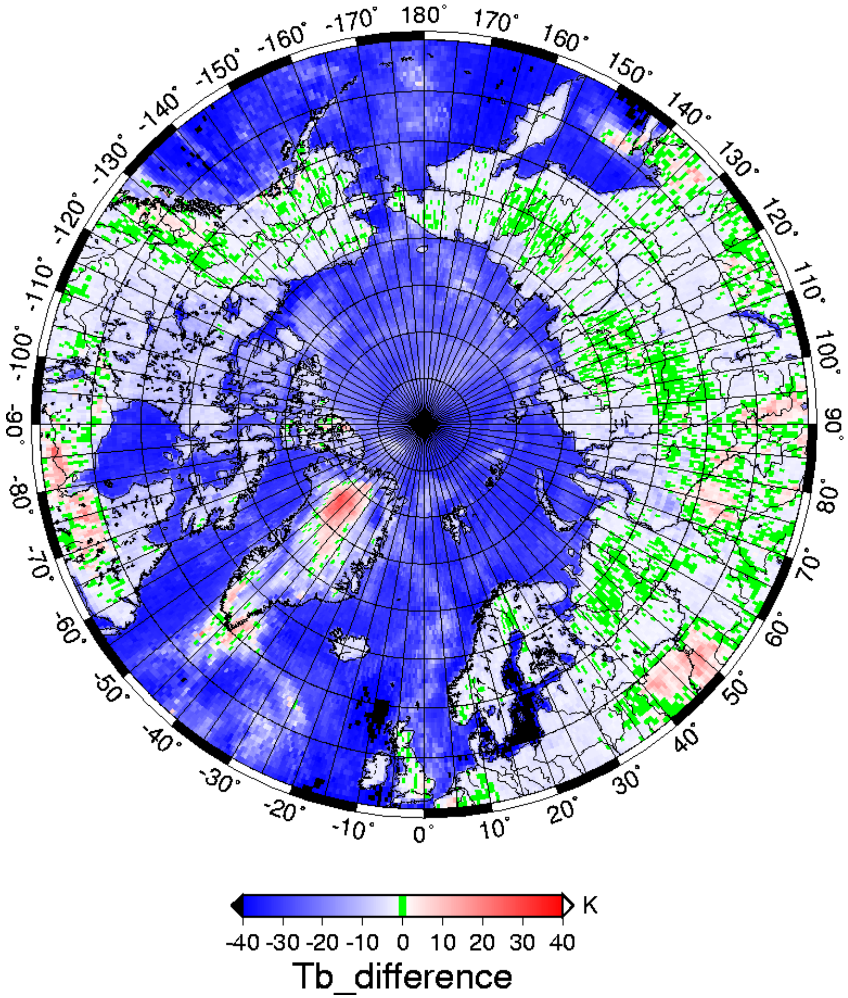


"TWV" with channel 1,2,3 and 2,3,4; 27 January, 2001

T_b difference (same day): ch. 1 (89 GHz) $-$ ch. 2 (150 GHz)



T_b difference (27 Jan 2001):
ch. 1 (89 GHz) $-$ ch. 2 (150 GHz)



T_b difference (30 Aug 2001):
ch. 1 (89 GHz) $-$ ch. 2 (150 GHz)

Extension to higher TWV values (ctd.)

- Extension of algorithm (1st order correction) as derived by *Selbach* [2003, PhD Thesis@IUP]:

$$TWV \sec\theta = \left(C_0 + C_1 \ln \frac{r_j}{r_i}\right) + C_1 \ln \left(\frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}} + C_2 \frac{r_j - r_i}{r_j}\right)$$

  where

  $r \;= 1 - \varepsilon_s$ (reflectivity)

  $C_2 \;= \frac{1}{1 - \mathrm{e}^{-2(\kappa_k - \kappa_j) TWV \sec\theta}}$

  κ_i water vapour absorption coefficient at channel i

- $(i, j, k) = (1, 2, 3)$ $\Rightarrow$information needed on
  - κ at 150 GHz(ch. 2) and 183.31$\pm$7 GHz (ch. 3)
  - ε_s (ground surface emissivity) at 89 GHz (ch. 1) and 150 GHz (ch. 2)
  - TWV (first guess)
- use correlation of ε_s at 150 and 89 GHz from SEPOR/PolEX campaign, parameterize $\varepsilon_s(150)$ with $\varepsilon_s(89)$
- get $\varepsilon_s(89)$ from “other sources”

Extension to higher TWV values (ctd.)

- Moreover: extended algorithm only needed for high TWV, i.e.,
  - mainly over open water,
  - rarely over sea ice (except for late summer),
  - practically never over the interior of Greenland

$\Rightarrow$ can mostly rely on “well-known” ε_s of ocean surface

- Alternatively/Additionally: implement and test algorithms proposed by *Grody et al.* [2000], *Weng et al.* [2003], based on AMSU-A channels at 23.8 and 31.4 GHz.

Surface emissivity at temperature sounding frequencies: Algorithm

- work by *Nizy Mathew*

- Total brightness temperature measured by satellite sensor like AMSU-A (viewing angle θ, frequency ν):

$$T_b(\theta, \nu) = c_1 + c_2 \varepsilon_s T_s + (1 - \varepsilon_s) c_3$$

where

$$\begin{aligned} c_1 &= T_u(\nu, \theta), \text{ upwelling radiation from atmosphere} \\ c_2 &= \mathrm{e}^{-\tau(0)\sec\theta}, \ \tau(0) = \text{opacity of atmosphere} \\ c_3 &= T_d(\nu, \theta)\mathrm{e}^{-\tau(0)\sec\theta}, \text{ downwelling radiation from atmosphere} \\ T_s &= \text{physical temperature of the surface} \\ \varepsilon_s &= \text{emissivity of the surface} \end{aligned}$$

$\Rightarrow \quad \varepsilon_s = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$

Surface emissivity: Algorithm (Ctd.)

- $\varepsilon_s = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$
- For $\varepsilon_s = 0$:

$$T_b(\varepsilon_s = 0) = c_1 + c_3$$

- For $\varepsilon_s = 1$:

$$T_b(\varepsilon_s = 1) = c_1 + c_2 T_s$$

$\Rightarrow$

$$\varepsilon_s = [T_b - T_b(\varepsilon_s = 0)] \,/\, [T_b(\varepsilon_s = 1) - T_b(\varepsilon_s = 0)]$$

- This means: Emissivity at given ν can be determined from measured (AMSU-A) T_b if we simulate $T_b(\varepsilon_s = 0)$ and $T_b(\varepsilon_s = 1)$ for ν
- Here: MWMOD (MicroWave radiative transfer MODel). Input: Atmospheric profile from
  - Measurements during Polarstern cruises; Problem: only in summer
  - ECMWF model profiles

Surface emissivity: Algorithm (Ctd.)

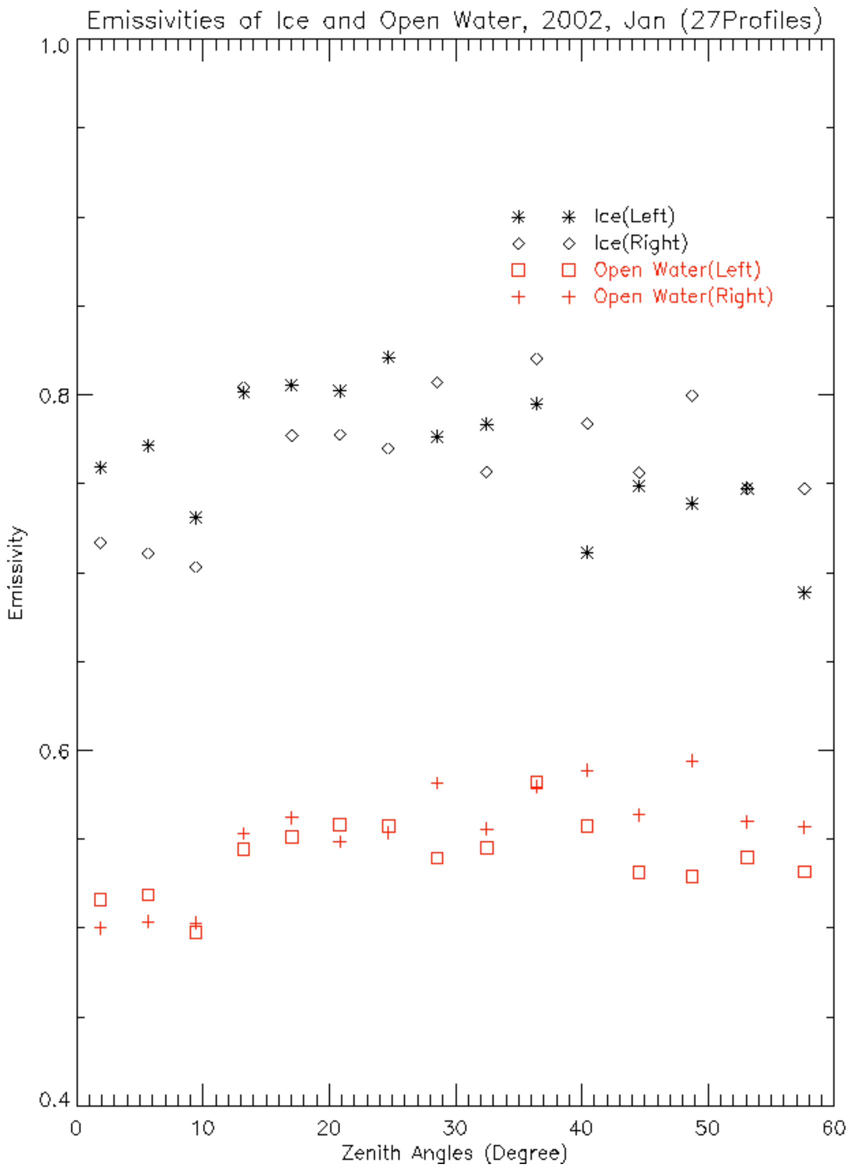
- Using ASI (ARTIST Sea Ice algorithm) sea ice concentration data, derive open water and sea ice emissivities (ε_{w}, ε_{i}) from emissivity of one AMSU-A footprint (diameter $\approx$ 50 km):

$$\varepsilon_s(\nu, \theta) = \sum_{i,j} \sum_k (A_{i,j} P_{i,j,k} \varepsilon_k)$$

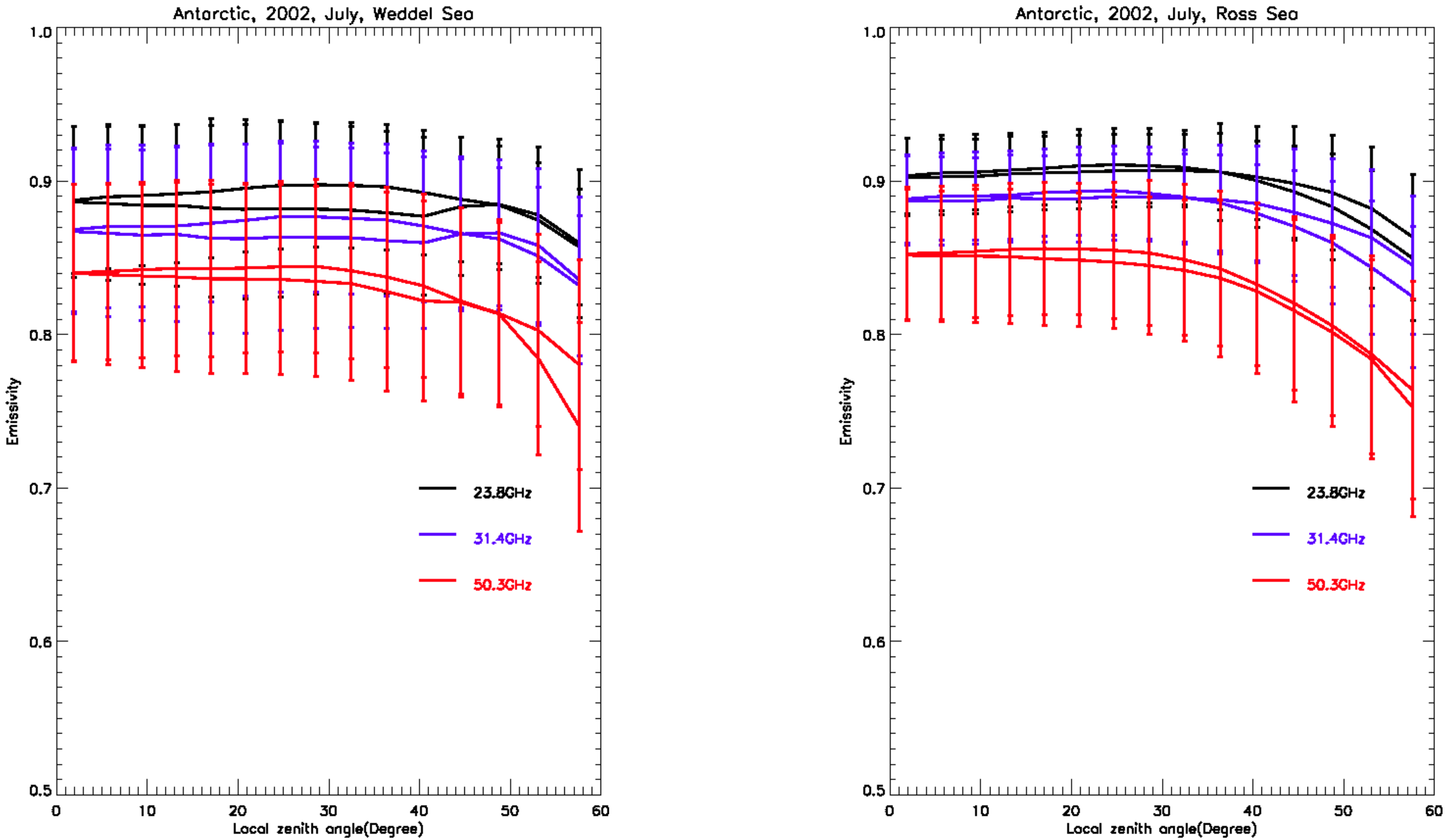
where

$A_{i,j}$ – antenna weight at pixel (i, j)

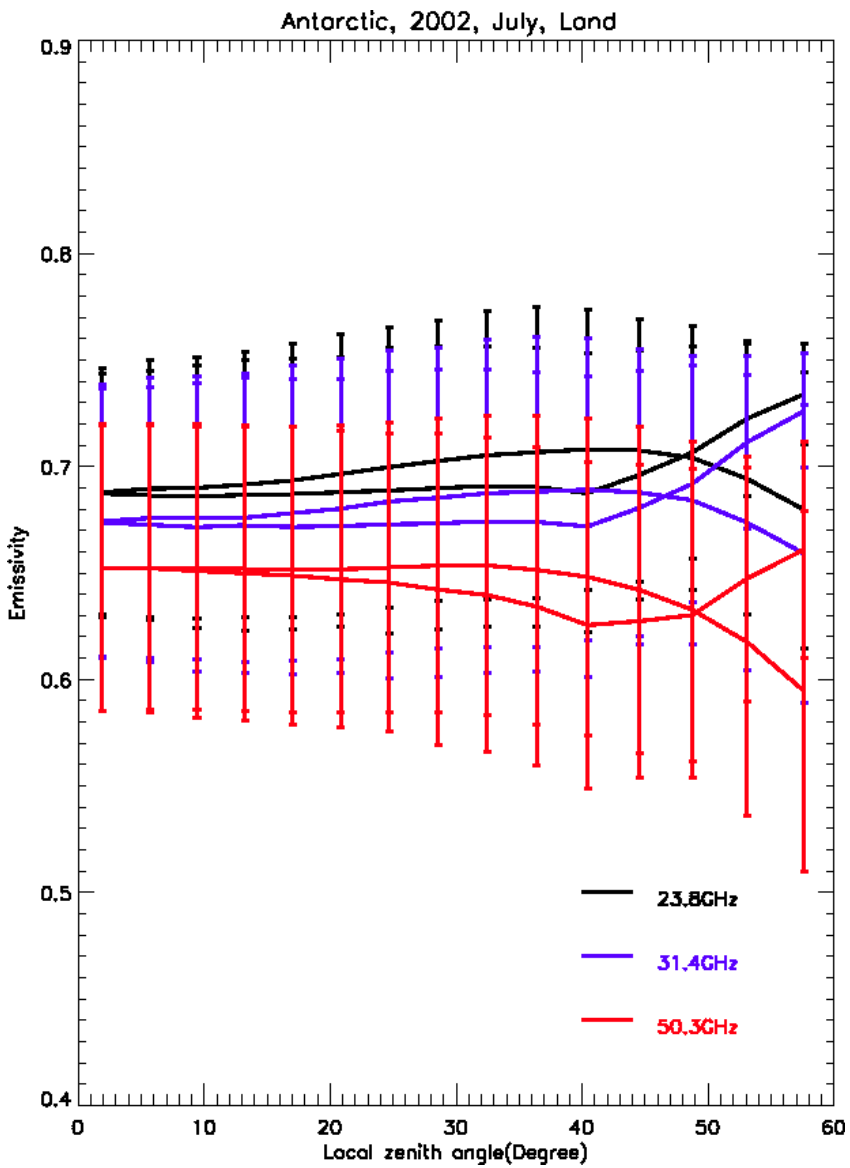
$P_{i,j,k}$ – fraction of the constituent k ($k = \mathrm{i}, \mathrm{w}$ for sea ice and open water) at pixel (i, j)



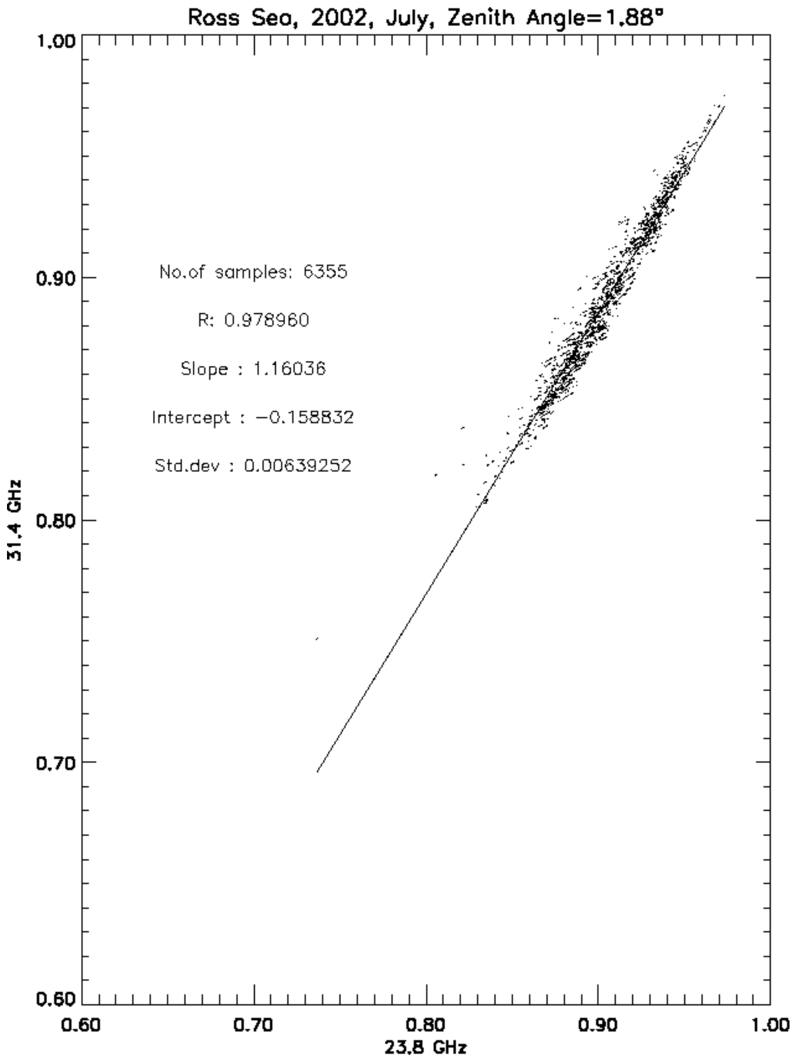
Emissivities of ice and open water using Polarstern data for different local zenith angles at 31.4GHz. Jan. 2002

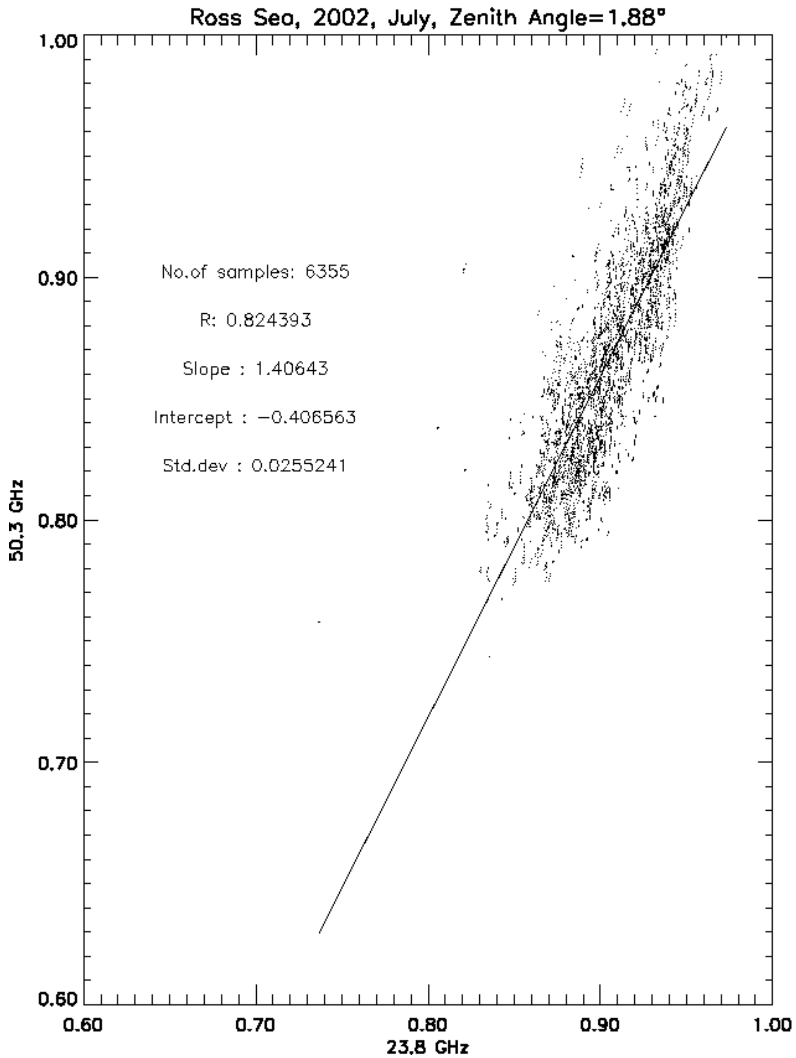


Variation of surface emissivity, Weddell Sea region (left) and Ross Sea region (right), with local zenith angle (AMSU-A window frequencies). July 2002

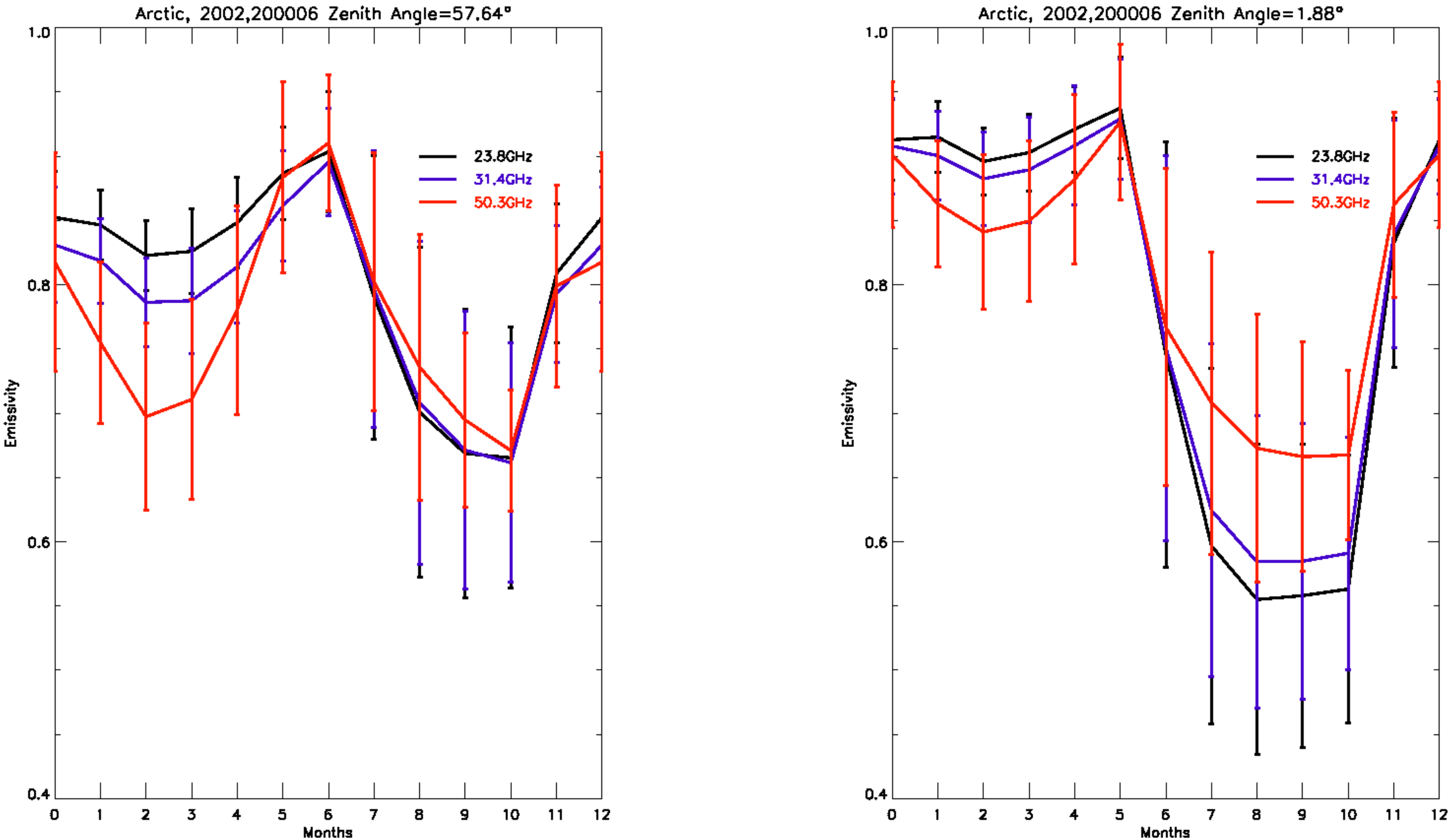


Variation of surface emissivity of land (Antarctica) with local zenith angle (AMSU-A window frequencies). July 2002.

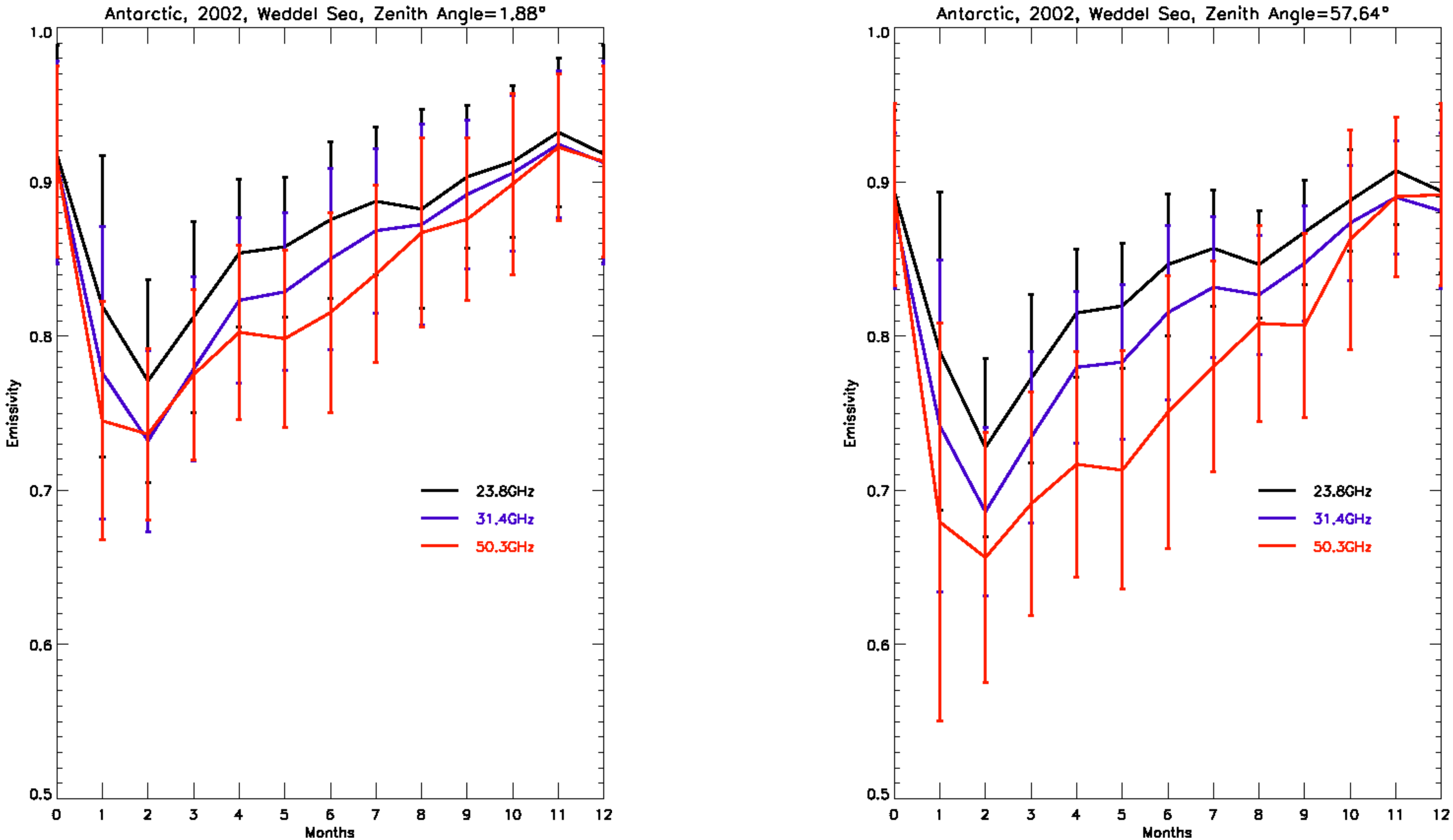




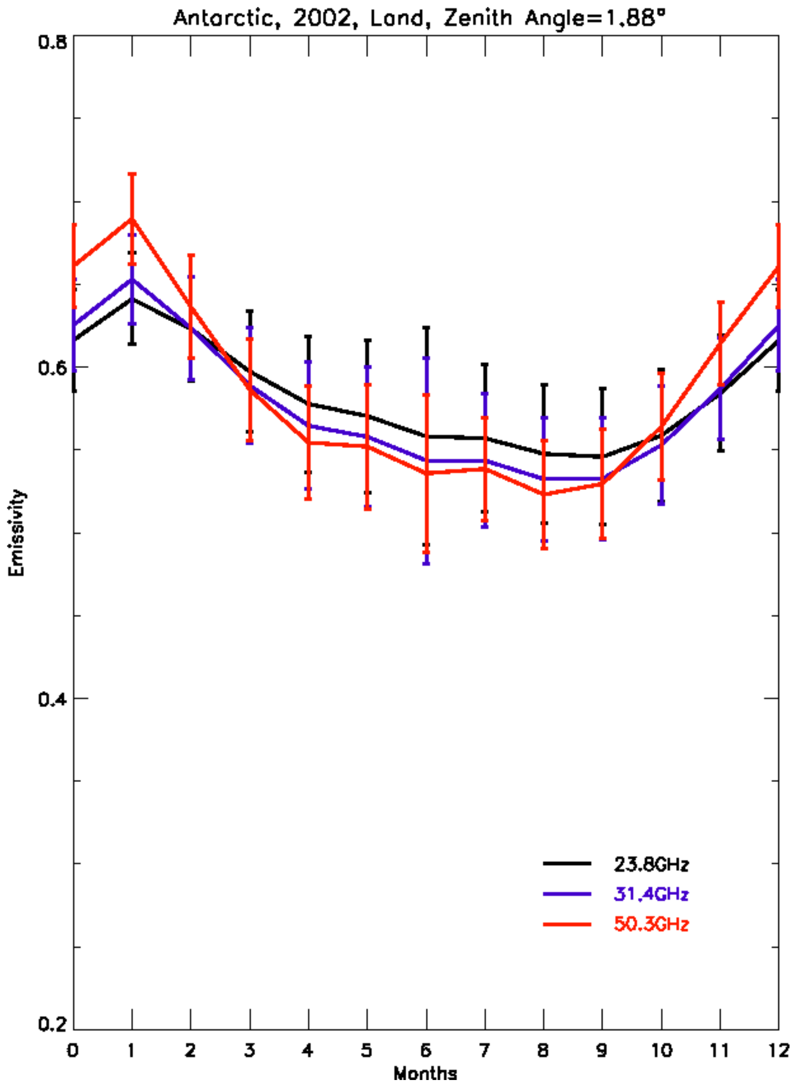
Correlation of emissivities of Ross Sea region at 23.8 GHz and 31.4 GHz (left) and at 23.8 GHz and 50.3 GHz (right). July 2002.

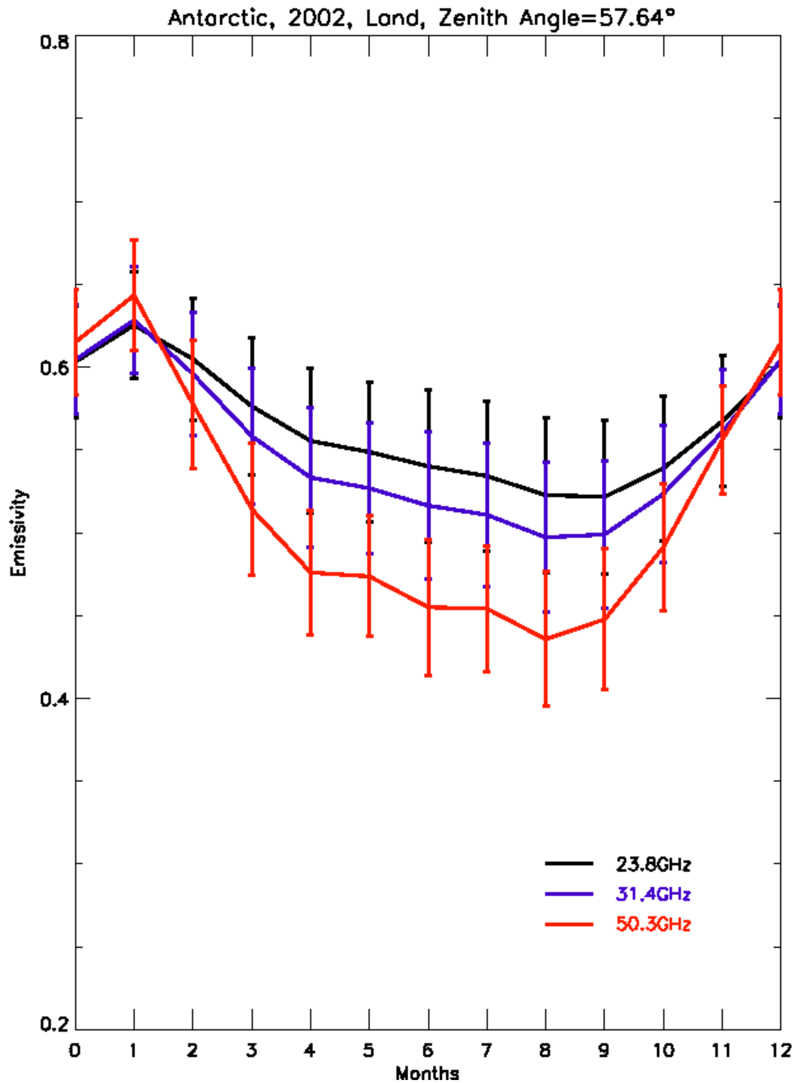


Seasonal variation of emissivity in the Arctic at different frequencies. Zenith angle 1.88°(left) and 57.64°(right). July 2002.



Seasonal variation of emissivity in Antarctic at different frequencies. Zenith angle 1.88°(left) and 57.64°(right). July 2002.





Seasonal variation of emissivity of land in Antarctic at at different frequencies. Zenith angle 1.88°(left) and 57.64°(right). July 2002.