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

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Outline

1. TWV retrieval from AMSU-B
   - Basic TWV Algorithm
   - Current Status
   - Results
   - Extension to higher TWV values, using 89 GHz Channel
   - Results with 89 GHz channel

2. Surface Emissivity at Temperature Sounding Frequencies
   - Emissivity Algorithm
   - Current Status
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Basic Idea of the TWV Algorithm

- T_b at 3 different frequencies i, j, k at which ground emissivity ε is similar but water vapour 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±7	182.31±3	182.31±1
AMSU channel	16	17	20	19	18

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Saturation cut-off

- Condition when algorithm is not applied any more (saturation) was relaxed from
  $T_i - T_j \geq 0$ ("saturation cut-off" = 0)
  to
  $T_i - T_j \geq F_{ij}$ ("saturation cut-off" = F_{ij})
  where the focal point coordinate F_{ij} is typically a few K

- As long as both numerator and denominator of the log argument are negative, the algorithm works.

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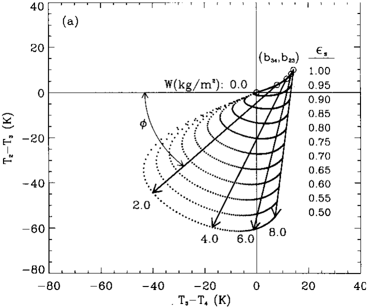

Current Status

- 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
- Validation with radiosonde in preparation
- Extension to higher TWV values ongoing (see later)

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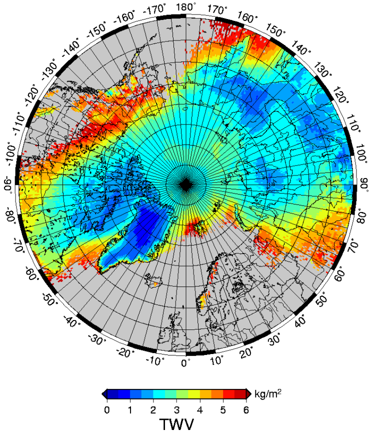
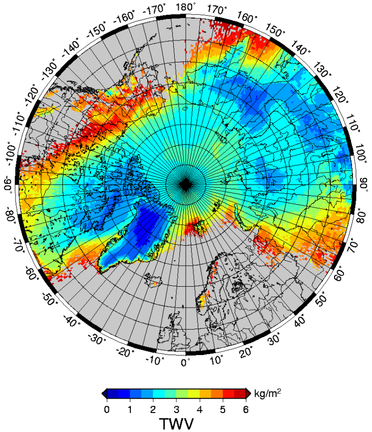


Mean of TWV, January 2001

Monthly means



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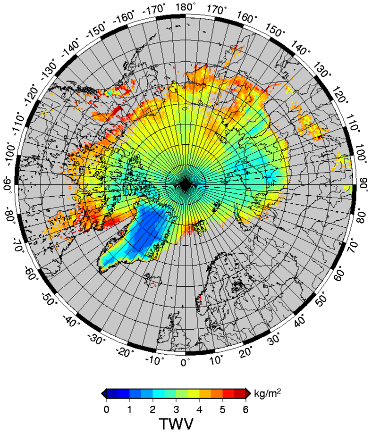
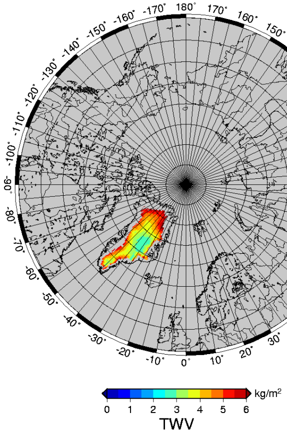


Mean of TWV, April 2001

Monthly means



Mean of TWV, July 2001

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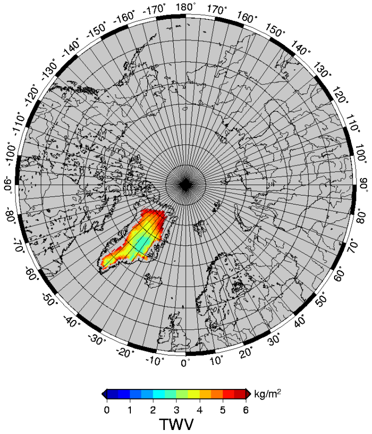

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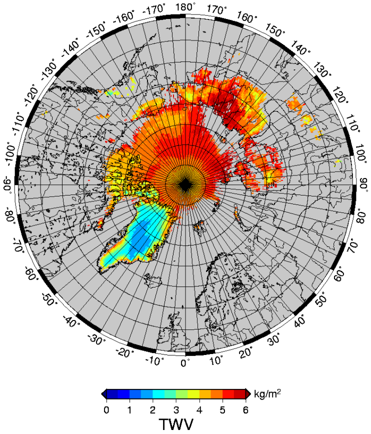
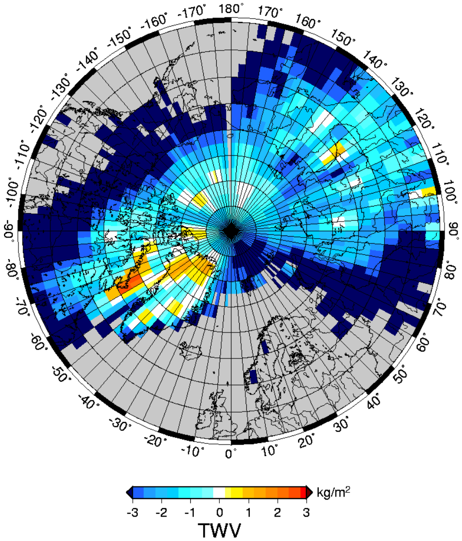


Mean of TWV, October 2001

Difference from NCEP reanalysis data



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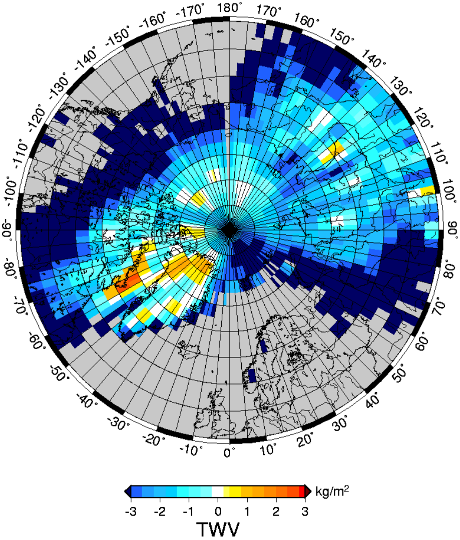

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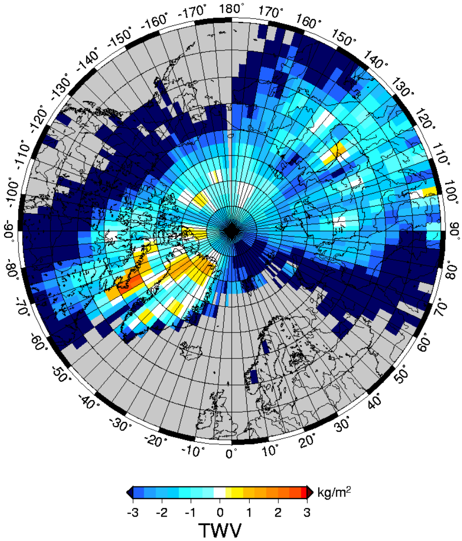

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TWV Algorithm with Different Emissivities

- $\varepsilon_i \neq \varepsilon_j, \varepsilon_j = \varepsilon_k$
- $\varepsilon_i = a + b\varepsilon_j$
- Still valid: $\kappa_i < \kappa_j < \kappa_k$
- i, j, k is 89, 150, and 182 ± 7 GHz

$\Rightarrow$ [. . .]

$$W \sec\theta = C_0 + C_1 \log \tilde{\eta}_c$$

where

$$\tilde{\eta}_c = \frac{r_j}{r_i}\left[\frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}} + C(\tau_j, \tau_k)\right] - C(\tau_j, \tau_k)$$

$r_i = 1 - \varepsilon_i$ reflectivity

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$$C(\tau_j, \tau_k) = \frac{1}{1 - e^{-2(\tau_k - \tau_j)\sec\theta}} \approx 1 \text{ for TWV} > 6\,\mathrm{kg/m^2}$$

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TWV Algorithm with Different Emissivities (ctd.)

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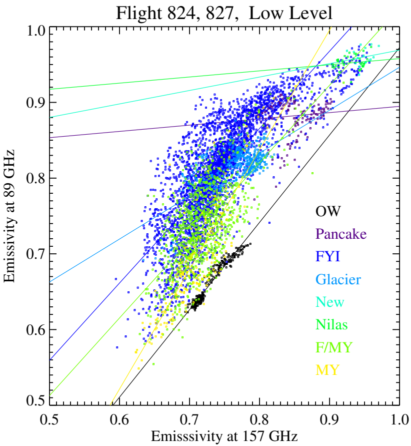
Emissivities at 89 and 157 GHz from SEPOR/POLEX

- Emissivities at 89 and 157 GHz are correlated, for some surface types, $r > 0.8$
- New ice and nilas not very frequent, too small range $\Rightarrow$ no correlation derived
- Open water (OW): good linear fit
- First-year ice (FYI): fair linear fit, but quadratic would be better.



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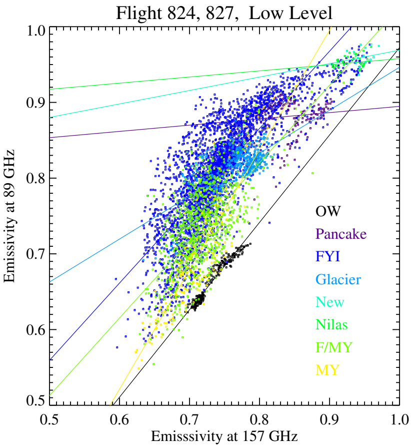

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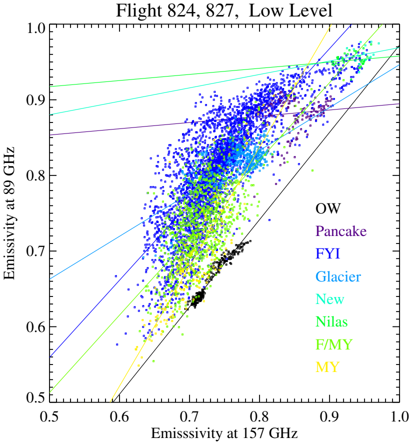

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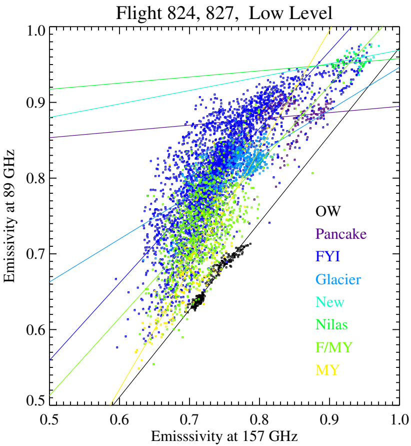

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Reflectivity Ratio at 89 and 157 GHz

Reflectivity ratio $(1-\varepsilon_{157})/(1-\varepsilon_{89})$ *for OW vs.* ε_{157}*(from SEPOR/POLEX data, as above)*

Reflectivity ratio $(1-\varepsilon_{157})/(1-\varepsilon_{89})$ *for FYI vs.* ε_{157}*(from SEPOR/POLEX data, as above)*

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$\Rightarrow$ use constant value for retrieval but dependent on surface type (ice, open water)

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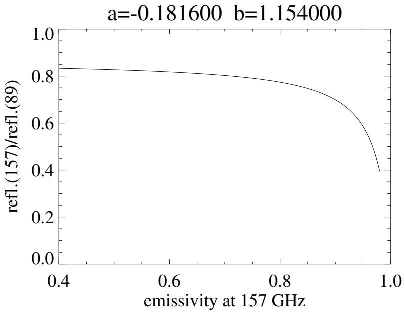

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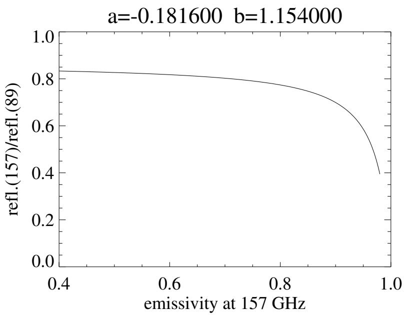

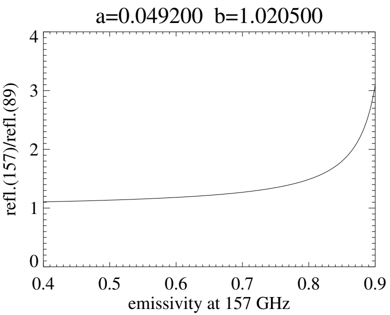

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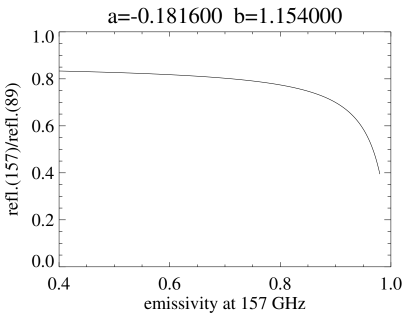

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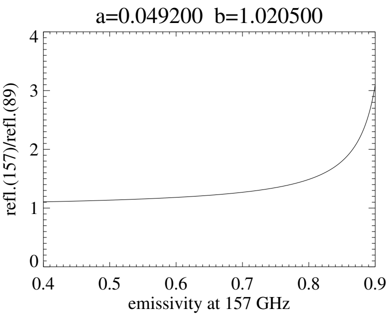

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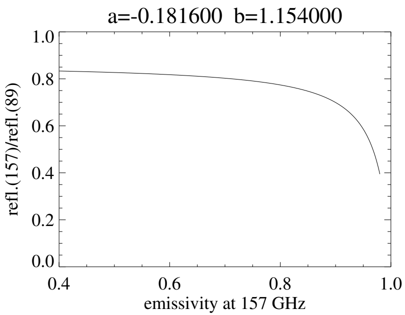

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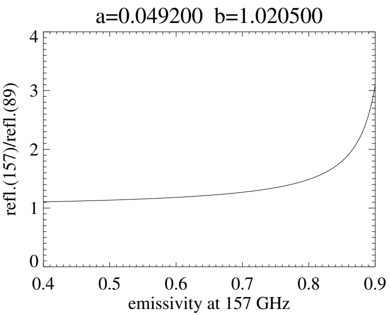
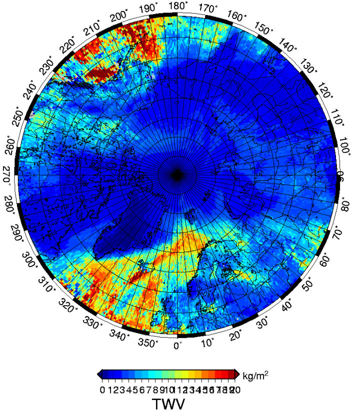


Reflectivity ratio $(1 - \varepsilon_{157})/(1 - \varepsilon_{89})$ *for FYI vs.* ε_{157}*(from SEPOR/POLEX data, as above)*

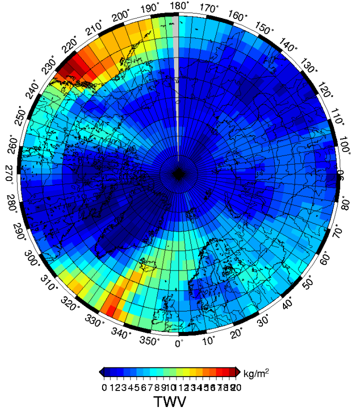
- Reflectivity ratio slowly varying for $\varepsilon_{157} \leq 0.8$

$\Rightarrow$ use constant value for retrieval but dependent on surface type (ice, open water)

Results with 89 GHz channel



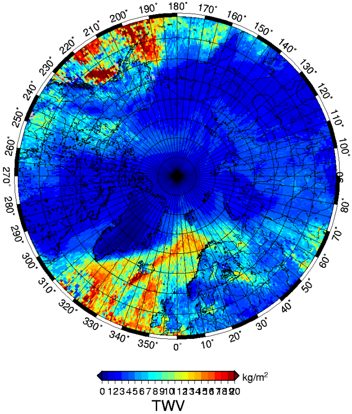
TWV form AMSU, using 150 and 183 GHz channels (2,3,4) for TWV < 6 kg/m^2, and 89, 150, 183 GHz (1,2,3), $r_j/r_i = 1.22$ (appropriate for ice)

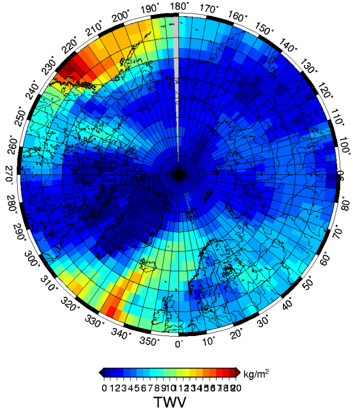


TWV from NCEP reanalysis data.

- Seems reasonable over ice

Results with 89 GHz channel





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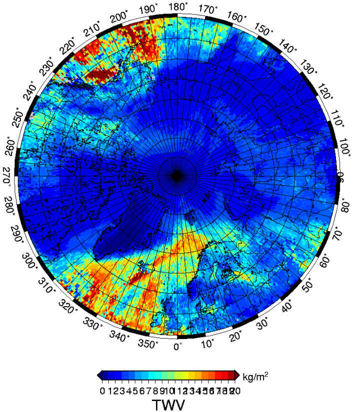
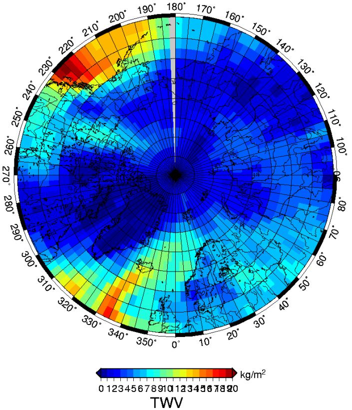
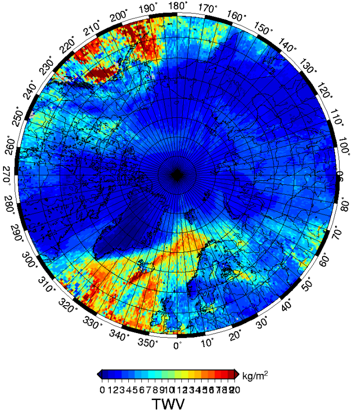
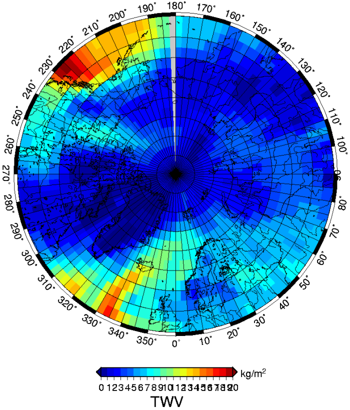




- Seems reasonable over ice
- Does not work over open water: $r_j/r_i = 1.22$ obviously wrong.

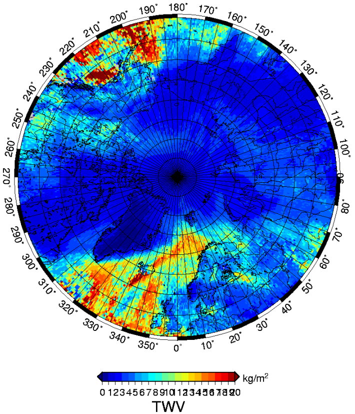
Results with 89 GHz channel

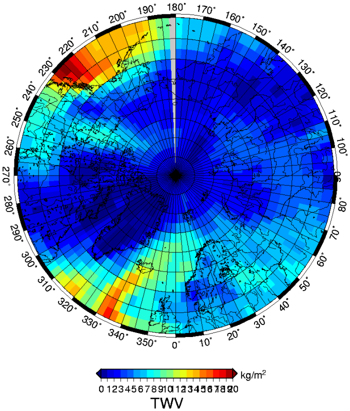




- Seems reasonable over ice
- Does not work over open water: $r_j/r_i = 1.22$ obviously wrong.
- Possibly other problems over open water (e.g., large difference of surface temperature and air temperature at the surface)

Results with 89 GHz channel





- Seems reasonable over ice
- However, main concern is TWV over ice

Outline

1. TWV retrieval from AMSU-B
   - Basic TWV Algorithm
   - Current Status
   - Results
   - Extension to higher TWV values, using 89 GHz Channel
   - Results with 89 GHz channel

2. Surface Emissivity at Temperature Sounding Frequencies
   - Emissivity Algorithm
   - Current Status
   - Results

Emissivity 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

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

$\Rightarrow$

$$\varepsilon = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$$

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Emissivity Algorithm (ctd.)

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

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

- For $\varepsilon = 1$:

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

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

- This means: Emissivity at given ν can be determined from measured (AMSU-A) T_b if we simulate $T_b(\varepsilon = 0)$ and $T_b(\varepsilon = 1)$ for ν
- Here: MWMOD (MicroWave radiative transfer MODel). Input: Atmospheric profile from
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Current Status

- Algorithm is implemented and in principle running
- Behaviour of 22 and 37 GHz channel ⇐Clouds (liquid water) ?
- Comparing emissivities of open water retrieved with algorithm and modelled by MWMOD (specular reflection model modified for the effects of wind on roughness [*Wisler and Hollinger*,1977][1]), for checking if use of ECMWF atmospheric profiles gives reasonable results.

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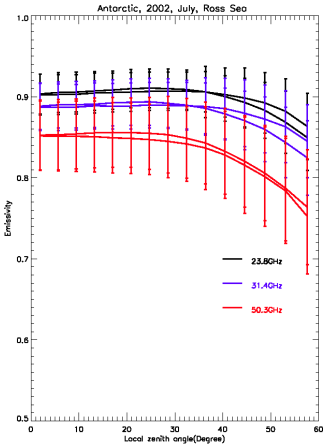
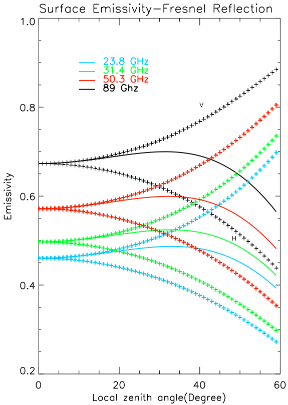
Angular Dependence



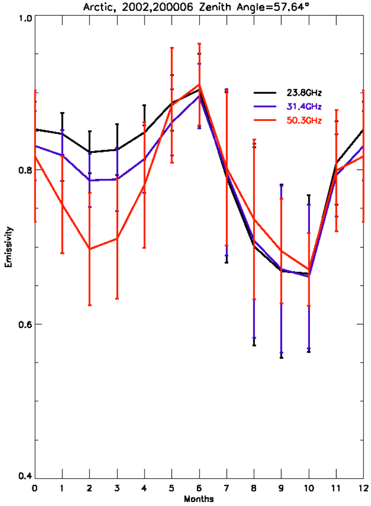
Viewing angle dependence of retrieved emissivity over open water (Ross sea, Antarctic, July 2002)



Viewing angle dependence of a specular water surface, based on Fresnel coefficients and AMSU "polarisation mixing"

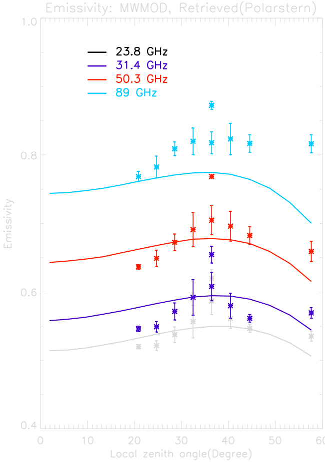
$\varepsilon_{\mathrm{AMSU}} = \varepsilon_{\mathrm{H}} \sin^2\theta + \varepsilon_{\mathrm{V}} \cos^2\theta$

Time Series

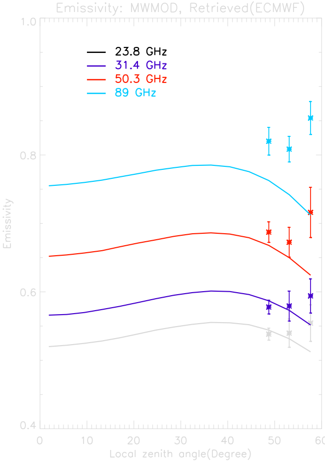


Seasonal variation of emissivity in the Arctic (July 2002) at different frequencies. Zenith angle 1.88°.

Open Water: Modelled vs. retrieved emissivity



Modelled (solid) and retrieved emissivity, using atmospheric profiles from Polarstern.



Modelled and retrieved emissivity, using ECMWF atmospheric profiles.

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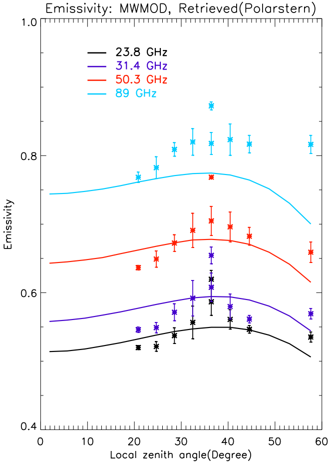

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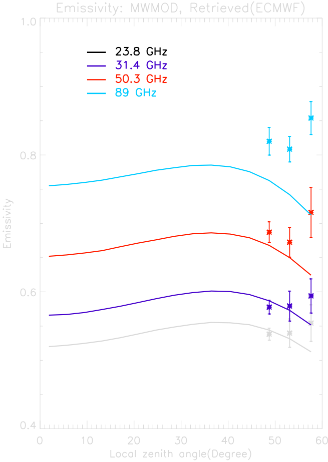

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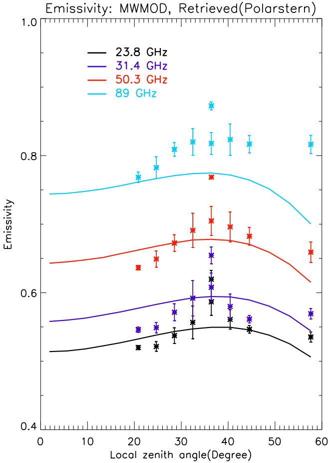

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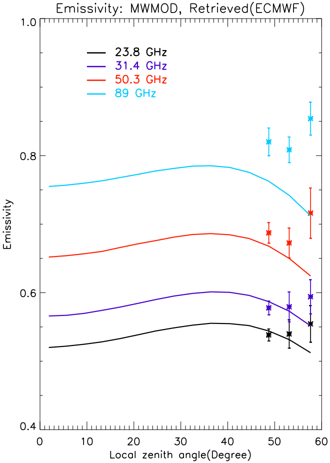

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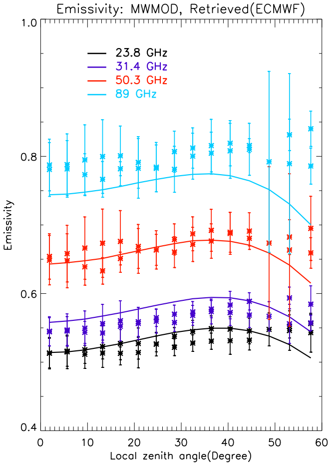

Modelled and retrieved emissivity, using ECMWF atmospheric profiles. June 2002, open water east of Iceland.