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

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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)

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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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Extended Algorithm

- TWV $>$ 6 to 7 kg/m^2 $\Rightarrow$channel 4 saturated as well:
  No TWV retrieval with the algorithm as is (upper 4 channels)
- Use channels 1 (89 GHz), 2 (150 GHz), 3 (183 $\pm$ 7 GHz), but:
  channel 1 emissivity $\neq$ other emissivities

$\Rightarrow$ Algorithm not independent of emissivity any more:

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

where

$\tilde{\eta}_c = \frac{r_2}{r_1}\left[\frac{T_{b,1}-T_{b,2}-b_{12}}{T_{b,2}-T_{b,3}-b_{23}} + 1\right] - 1$

and $r_i = 1 - \varepsilon_i$ (reflectivity)

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Wanted: Emissivity

- For the $T_b$simulations (for deriving calibration parameters C_0, C_1,b_{12}, b_{23}), ε_{89} as a function of ε_{157} needed
- For the retrieval, only the reflectivity ratio $r_2/r_1 = (1 - \varepsilon_{157})/(1 - \varepsilon_{89})$ needed

$\Rightarrow$ Constant r_2/r_1 would be good (so we don't need emissivity maps)

- If ε_{89} reaches 1.0 before ε_{157}: r_2/r_1 has a singularity ($\rightarrow \infty$) that makes retrieval fail.
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- From SEPOR/POLEX campaign, emission of various surface types in winter was determined for frequencies needed here (89 GHz, 157 GHz)
- Linear regression to get $\varepsilon_{89}(\varepsilon_{157})$, but adding point $(1, 1)$ with large weight to emissivity data to get close to condition $\varepsilon_{89}(\varepsilon_{157} = 1) = 1$

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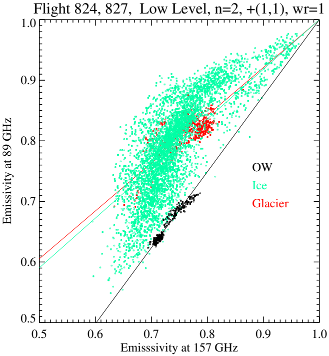

Full Algorithm

- Putting together all 3 sub-algorithms

"low"	ch. 3,4,5 – TWV $< 1.5\,\mathrm{kg/m^2}$
"medium"	ch. 2,3,4 – $1.5\,\mathrm{kg/m^2} <$ TWV $< 7.0\,\mathrm{kg/m^2}$
"high"	ch. 1,2,3 – $7.0\,\mathrm{kg/m^2} <$ TWV $<$ 12.0?? $\mathrm{kg/m^2}$

- Applying "high" algorithm only over sea ice; ice information from, e.g., ASI (ARTIST sea ice) algorithm data.

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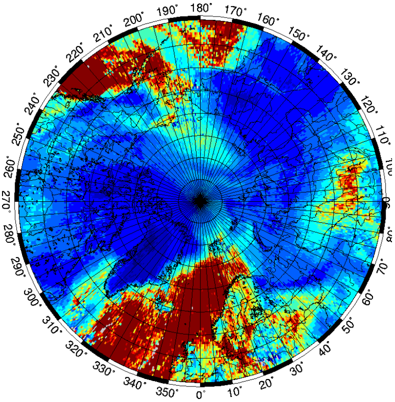
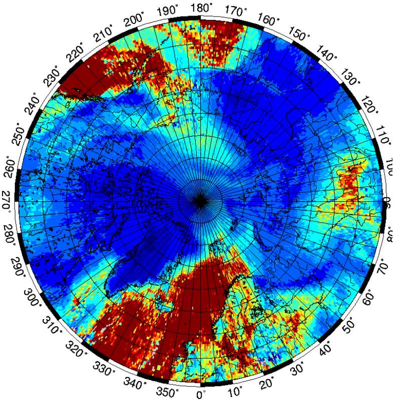
TWV map from Full Algorithm



TWV from AMSU, 18 Feb, 2001

TWV map from Full Algorithm



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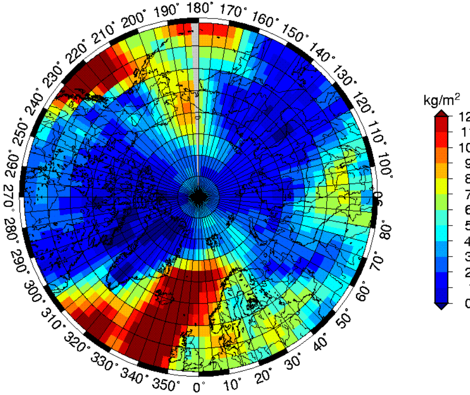

NCEP TWV, same day

"Internal" Validation A

- Calibration parameters C_O and C_1 are determined from linear fit of $\log \tilde{\eta}_c$ which contains simulated T_bs based on radiosonde data.
- Plot TWV from radiosonde vs. corresponding $\log \tilde{\eta}_c$ (various emissivities)
- Plot the regression line $C_0 + C_1 \log \tilde{\eta}_c$

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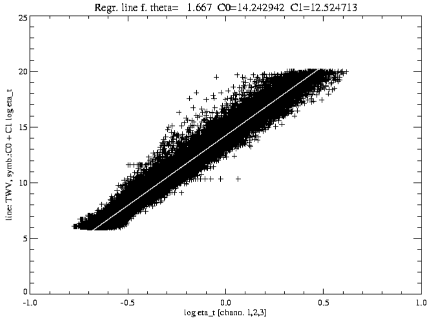

Channels 1,2,3, near-nadir

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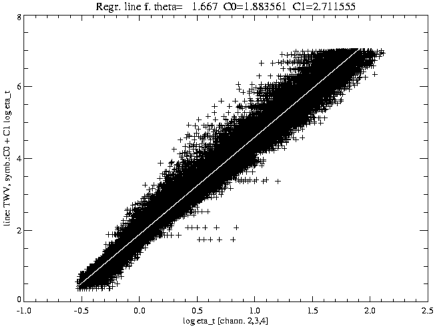
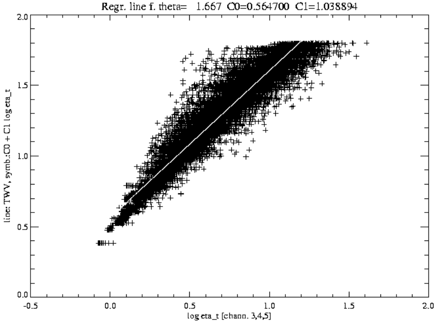


Channels 2,3,4, near-nadir



Channels 3,4,5, near-nadir

“Internal”Validation B

- Divide radiosonde (RS) randomly into two groups: regression group and test group
- from regression group: get calibration parameters
- from test group:
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- Compare simulated-AMSU TWV to RS TWV

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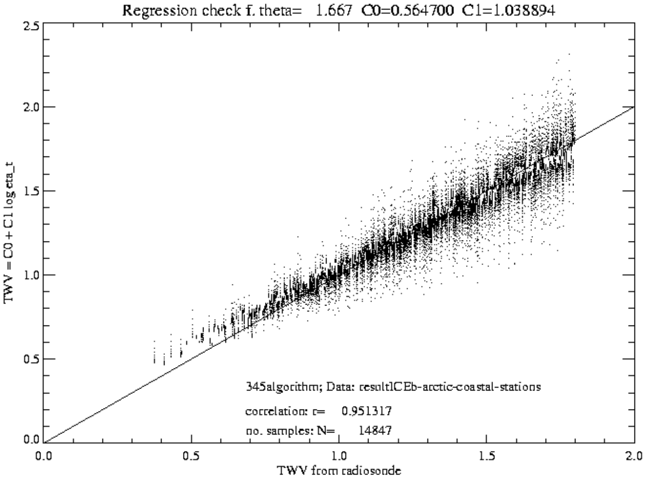
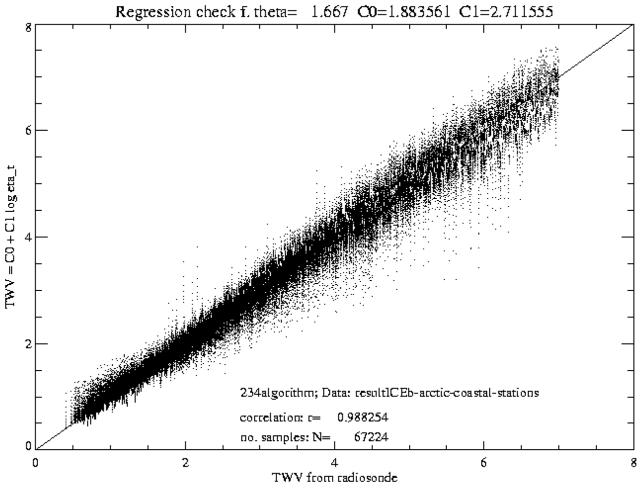


Simulated-AMSU TWV vs. RS TWV

Validation 2,3,4-Algorithm



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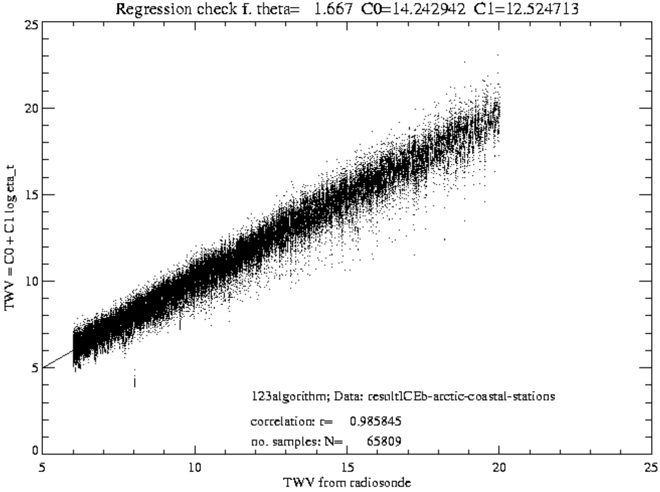
Validation 1,2,3-Algorithm



Simulated-AMSU TWV vs. RS TWV

"External" Validation: GPS-derived TWV)

- Compared GPS-derived TWV data from some Antarctic stations (TU Dresden, *S. Vey*) to AMSU-derived using our algorithm. Here: Casey and Davis:

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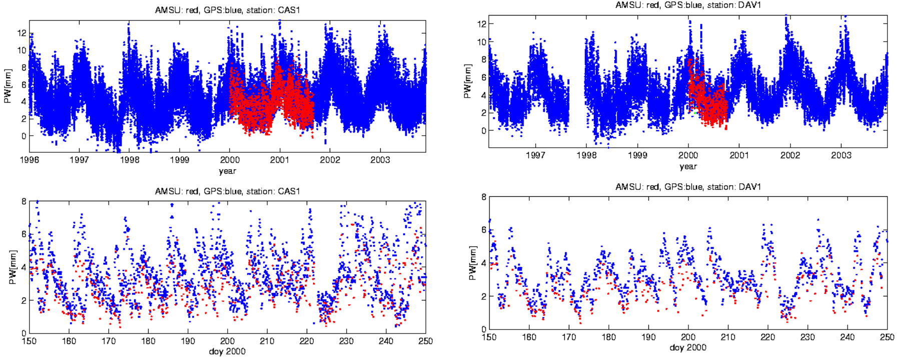

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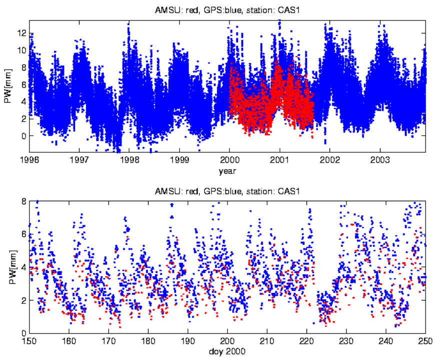
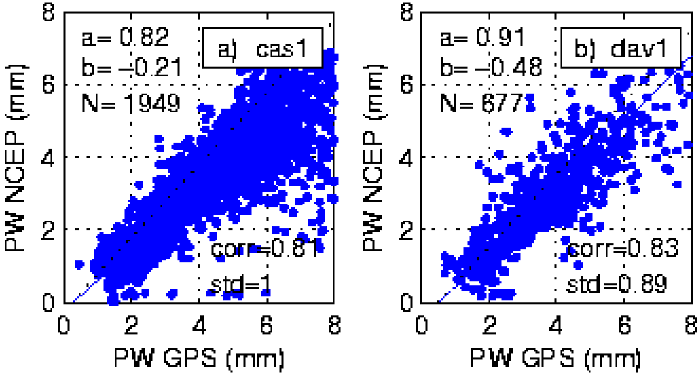


Slight bias

“External” Validation: Regression



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- High correlation
- More comparison ongoing

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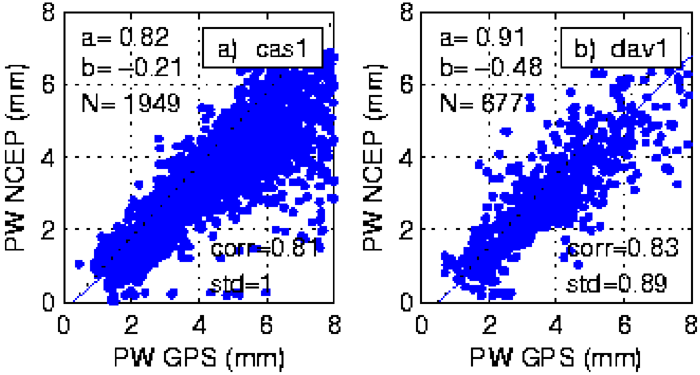

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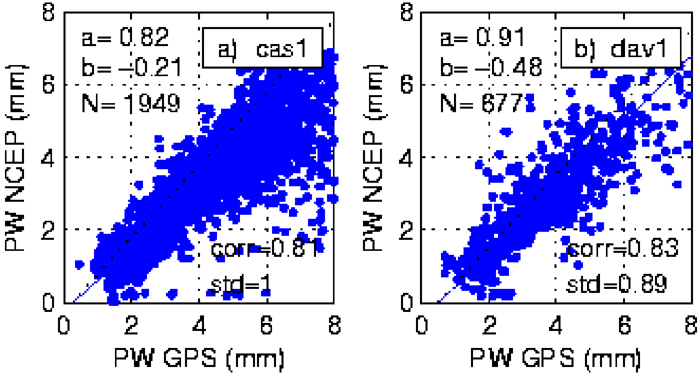

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Data Production

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  - 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)
- Swath TWV data (up to 7 kg/m^2) for investigation period available at IUP and DTU
- TWV being calculated daily from current AMSU data (“real time”) in IIB@DTU

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- Swath TWV data (up to 7 kg/m^2) for investigation period available at IUP and DTU
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  - swath data (ASCII or binary), i.e. table with 3 columns (longitude, latitude, TWV), one value for each AMSU "pixel"
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Outline

1. TWV retrieval from AMSU-B
   - Basic TWV Algorithm
   - Results
   - Validation
   - Data Production
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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$$\begin{aligned} c_1 &= T_u(\nu, \theta), \text{ upwelling radiation from atmosphere} \\ c_2 &= e^{-\tau(0)\sec\theta}, \ \tau(0) = \text{opacity of atmosphere} \\ c_3 &= T_d(\nu, \theta) e^{-\tau(0)\sec\theta}, \text{ downwelling radiation from atmosphere} \\ T_s &= \text{physical temperature of the surface} \\ \varepsilon &= \text{emissivity of the surface} \end{aligned}$$

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Emissivity Algorithm (ctd.)

- $\varepsilon = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$
- For $\varepsilon = 0$: $T_b(\varepsilon = 0) = c_1 + c_3$
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$\Rightarrow$ $\varepsilon = [T_b - T_b(\varepsilon_s = 0)] \,/\, [T_b(\varepsilon_s = 1) - T_b(\varepsilon_s = 0)]$

- 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
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- Alternative algorithm proposed by Leif at PM3 is similar: Uses ratios of differences of measured and modelled T_bs.
- Uses additional approximations:
  - isothermal atmosphere
  - nadir view
  - negligible effect of water vapour

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- Algorithm is implemented and running
- Comparing emissivities of open water retrieved with algorithm and modelled by FASTEM (state-of-the-art sea surface emissivity model
- Emissivity maps etc. being produced
- Correlations between emissivities at different frequencies being investigated

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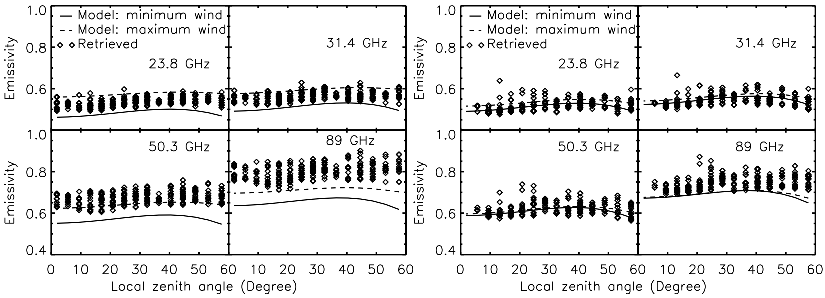
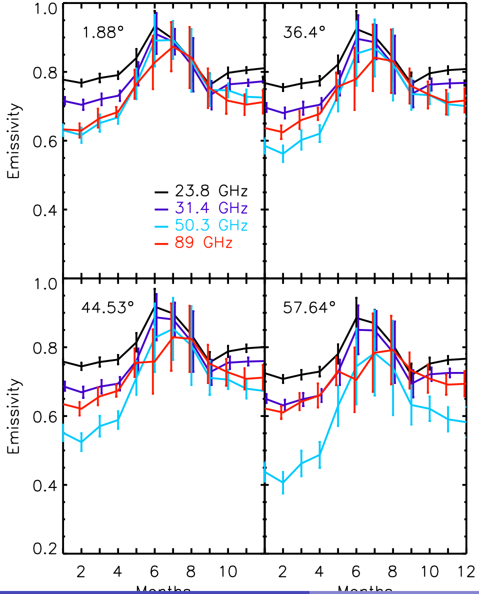
Comaparison with FASTEM



Modelled and retrieved emissivity. Left: Arctic, right: Antarctic

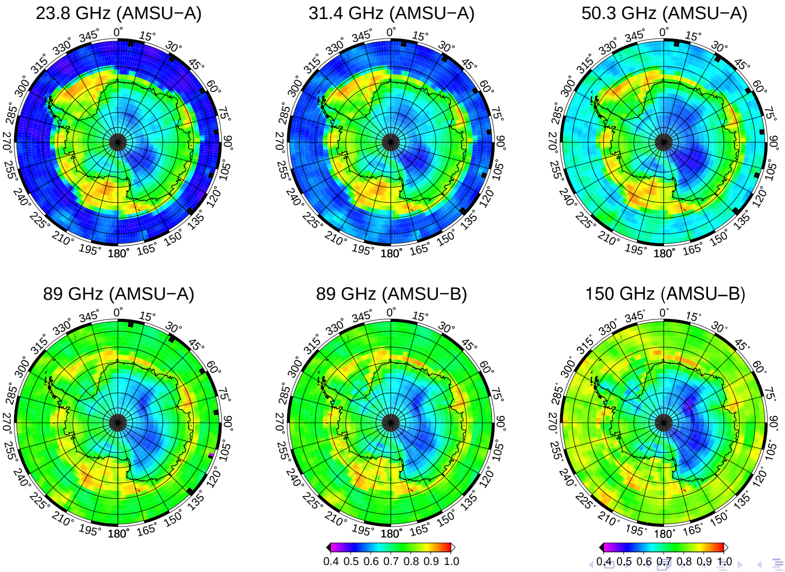
Seasonal Variation



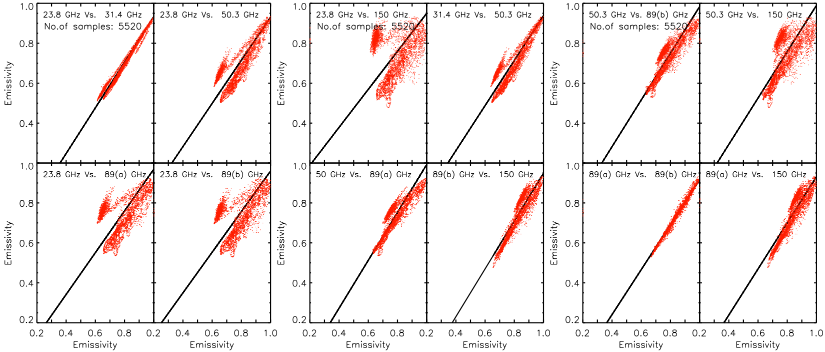
Seasonal variation of emissivity over multi-year ice in the Arctic.

Note: lowest at 50.3 GHz

Emissivity, Antarctic, 25 Apr 2002, AMSU



Correlation of Emissivities



Correlation of emissivity between the various window channel frequencies of AMSU-A and B, one-day average. Up to 3 clouds of data points: open water, sea ice, land ice