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

Christian Melsheimer, *iup* Bremen, Germany

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

Algorithm

- Measure T_b at 3 different frequencies i, j, k at which ground emissivity ϵ_s is similar but water vapor absorption different; $\kappa_i < \kappa_j < \kappa_k$
- Then the following relation can be derived

$$\ln \eta_c = \ln \left(\frac{T_{b,i} - T_{b,j} - b_{ij}}{T_{b,j} - T_{b,k} - b_{jk}} \right) = c_0 + c_1 W \sec\theta$$

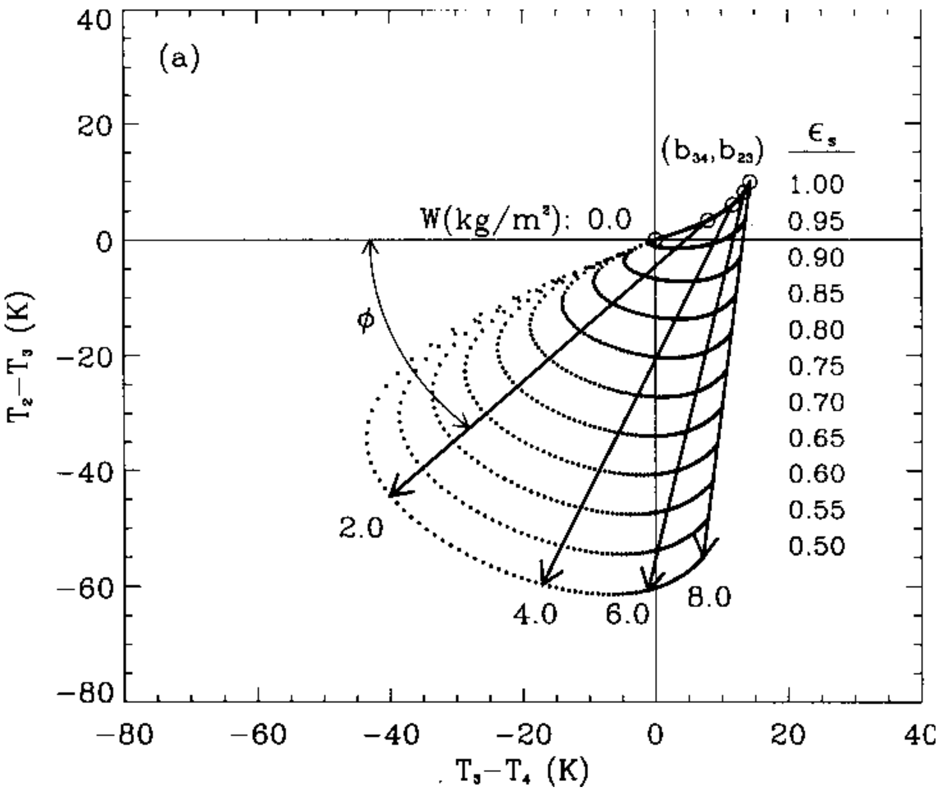
where the "bias" (b_{jk}, b_{ij})

$$b_{ij} \approx \int_0^H \left[\mathrm{e}^{\tau_i(z,H)\sec\theta} - \mathrm{e}^{\tau_j(z,H)\sec\theta} \right] \frac{\mathrm{d}T(z)}{\mathrm{d}z} \,\mathrm{d}z$$

contains the influence of the atmospheric temperature and water vapor profiles

AMSU-B channels (sorted so that $\kappa_2 < \kappa_3 < \kappa_4 < \kappa_5$)

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



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

$\Rightarrow$ 4 calibration parameters: C_0, C_1, F_{ij},F_{jk}

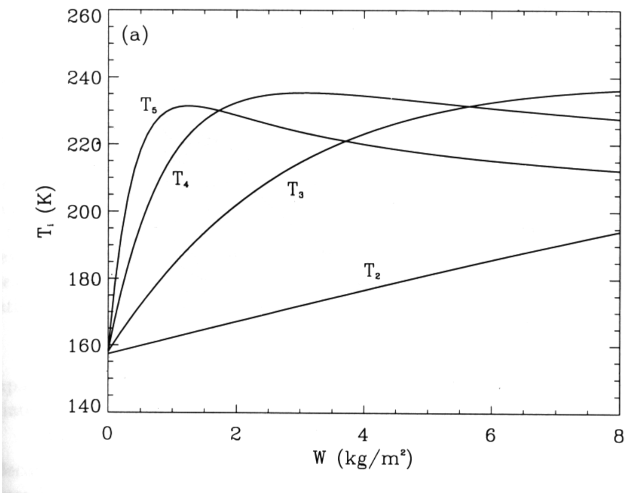
Note: (b_{jk}, b_{ij}) slightly dependent on T and W profile

$\Rightarrow$ find some kind of average $(F_{jk}, F_{ij}) = (\overline{b_{jk}}, \overline{b_{ij}})$ (focal point)

Algorithm Development for AMSU-B

- Use radiosonde (RS) profiles, integrate TWV from them and simulate AMSU-B brightness temperatures T_1, T_2, T_3, T_4, T_5 for a range of ground emissivities ϵ_s for each RS profile
- Several regressions yield the calibration parameters C_0, C_1, F_{ij},F_{jk}
- Two separate sets of calibration parameters, one for $(i, j, k) = (2, 3, 4)$ ("234-algorithm"), one for $(i, j, k) = (3, 4, 5)$ ("345-algorithm")

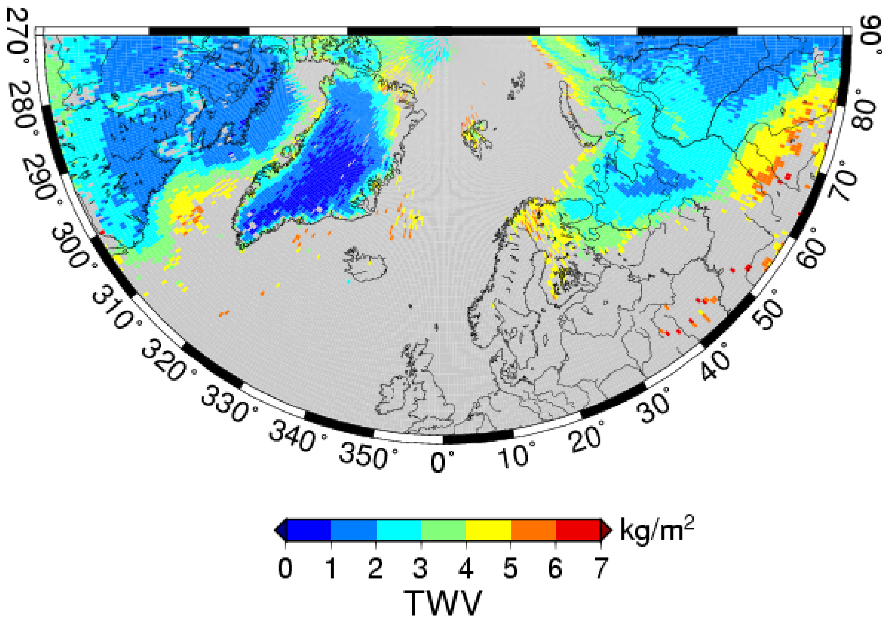
- $T_4 - T_5 < 0$ (low TWV) $\longrightarrow$ use 345-algorithm
- $T_4 - T_5 > 0$ (but still $T_3 - T_4 < 0$, $T_2 - T_3 < 0$) $\longrightarrow$ use 234-algorithm;
- $T_3 - T_4 > 0$ (high TWV, > 6 kg/m2) $\longrightarrow$ no algorithm (yet)



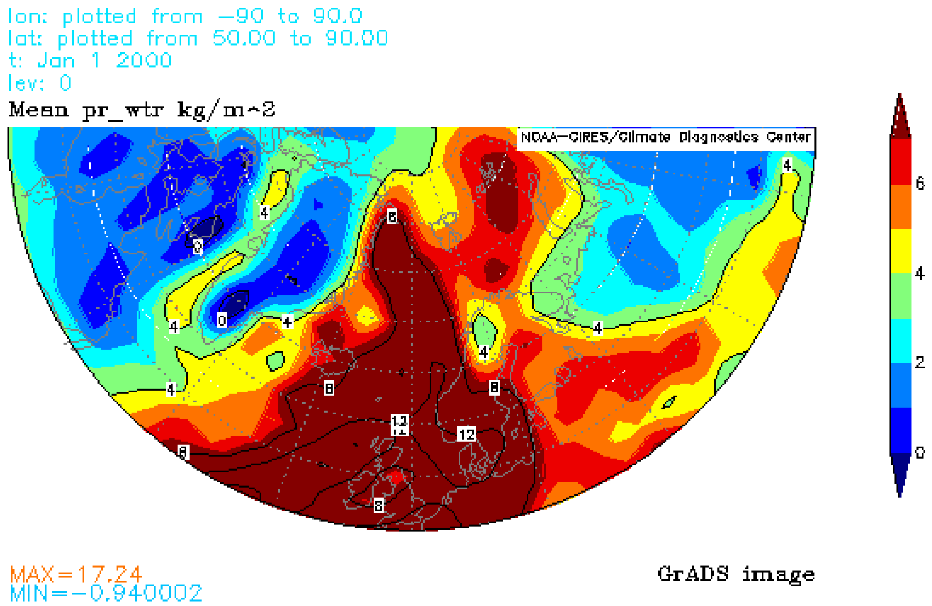
Current Status

- Calibration parameters can be derived for
  - given TWV range of RS data (necessary)
  - regional subset of RS data (station IDs)
  - seasonal subset of RS data (date range regardless of year)
  - temporal subset of RS data (date range including year)
  - any combination thereof
- TWV maps or grid files can be calculated for AMSU-B swath data using any calibration parameter files (from above); gridding and mapping using GMT
  - one or several swaths
  - daily average (all swaths for one day)

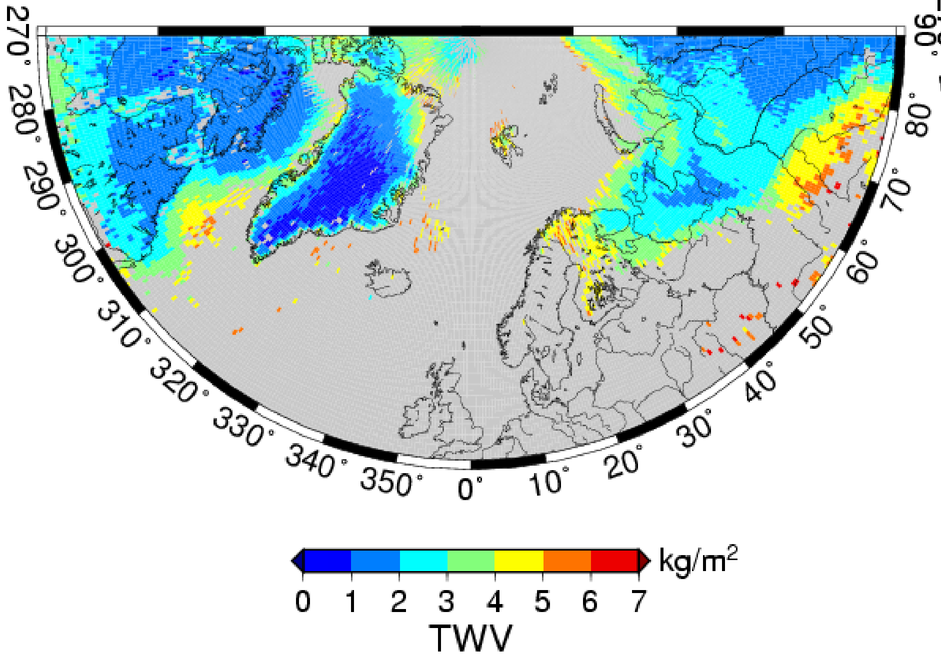
Results



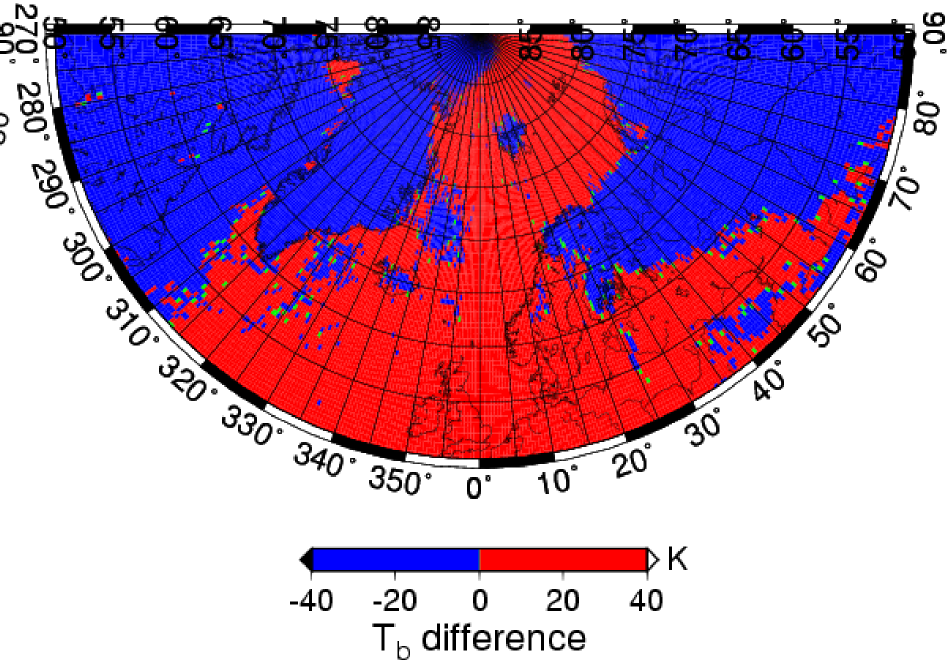
TWV, 1 January, 2000



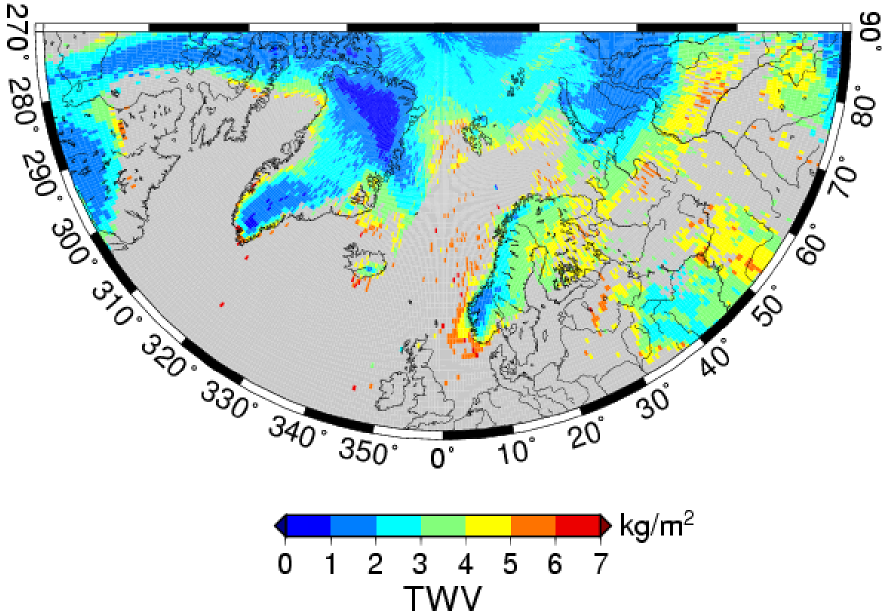
NCEP reanalysis data, same day



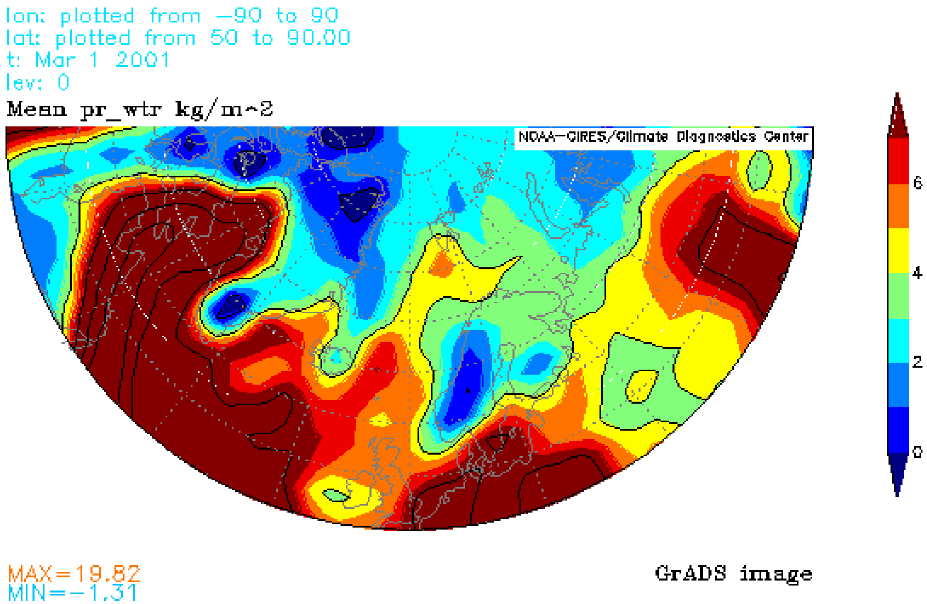
TWV, 1 January, 2000



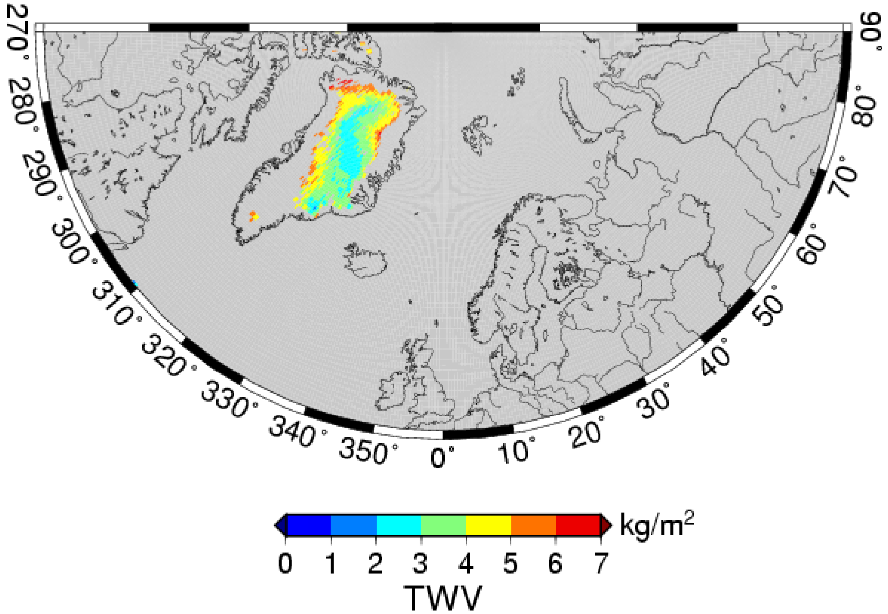
Brightness temperature difference $T_3 - T_4$

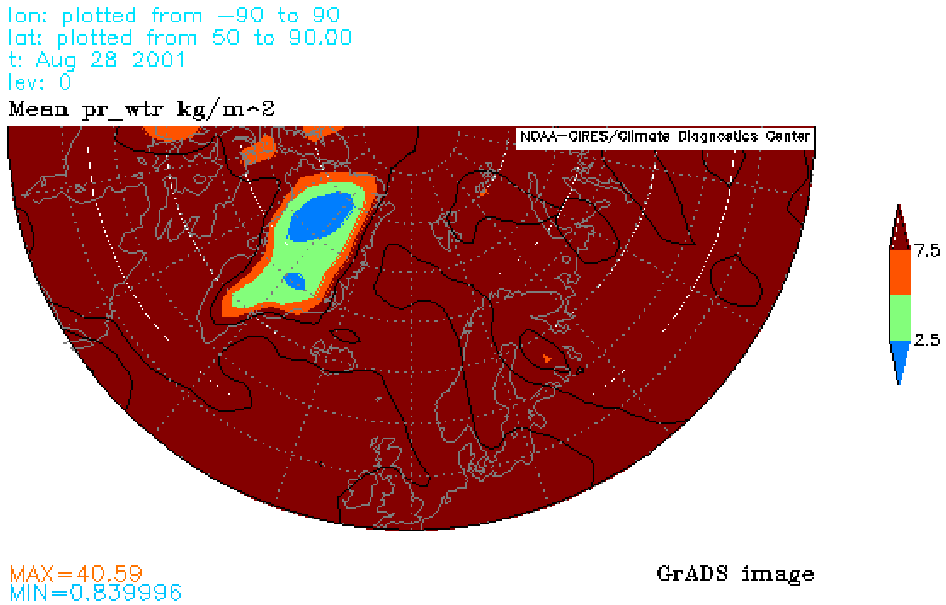


TWV, 1 March, 2001



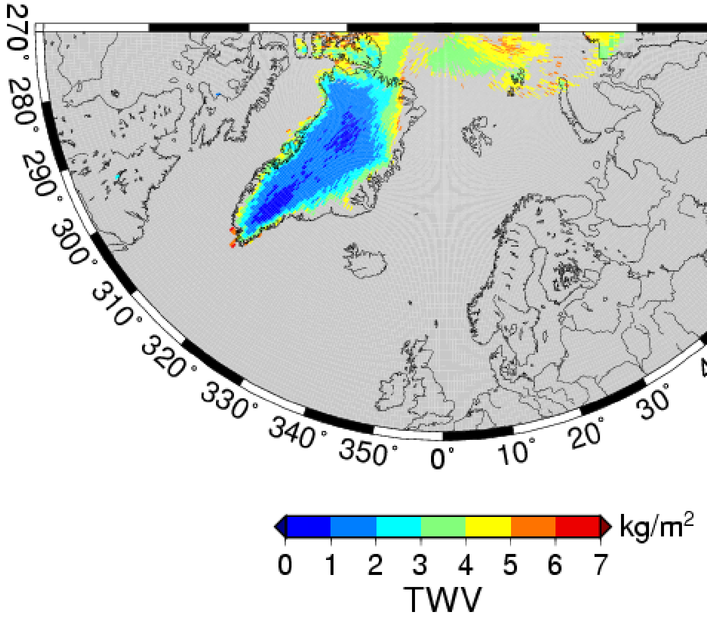
NCEP reanalysis data, same day



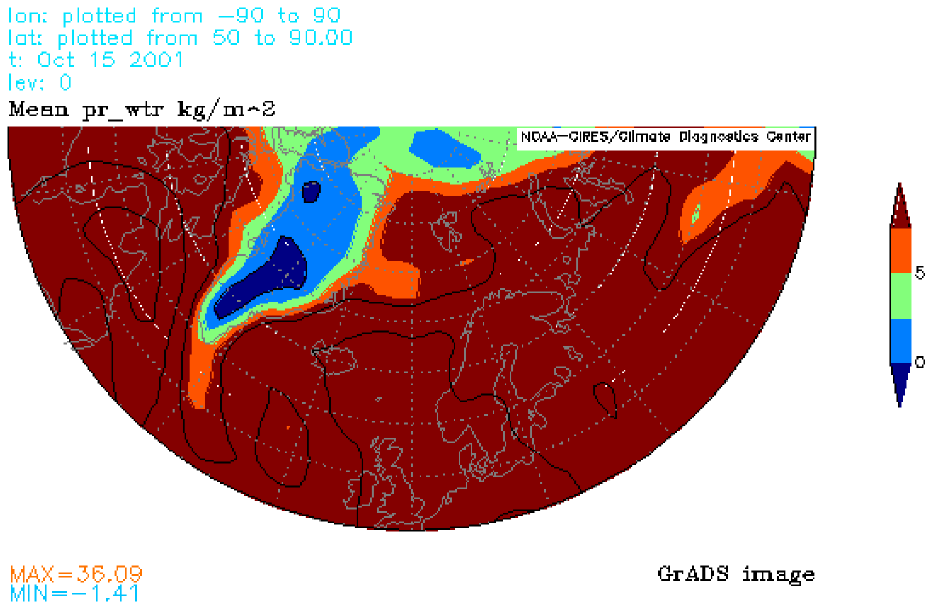


TWV, 28 August, 2001

NCEP reanalysis data, same day



TWV, 15 October, 2001



NCEP reanalysis data, same day

Results: Saturation Cut-Off

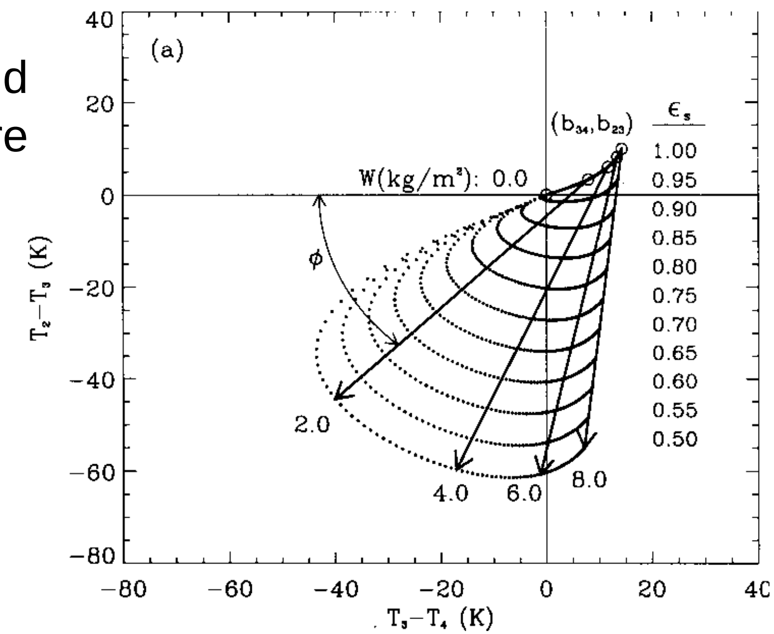
- Condition when algorithm is not applied any more (saturation) is $T_3 - T_4 \geq 0$, the critical value ("saturation cut-off") $S = 0$

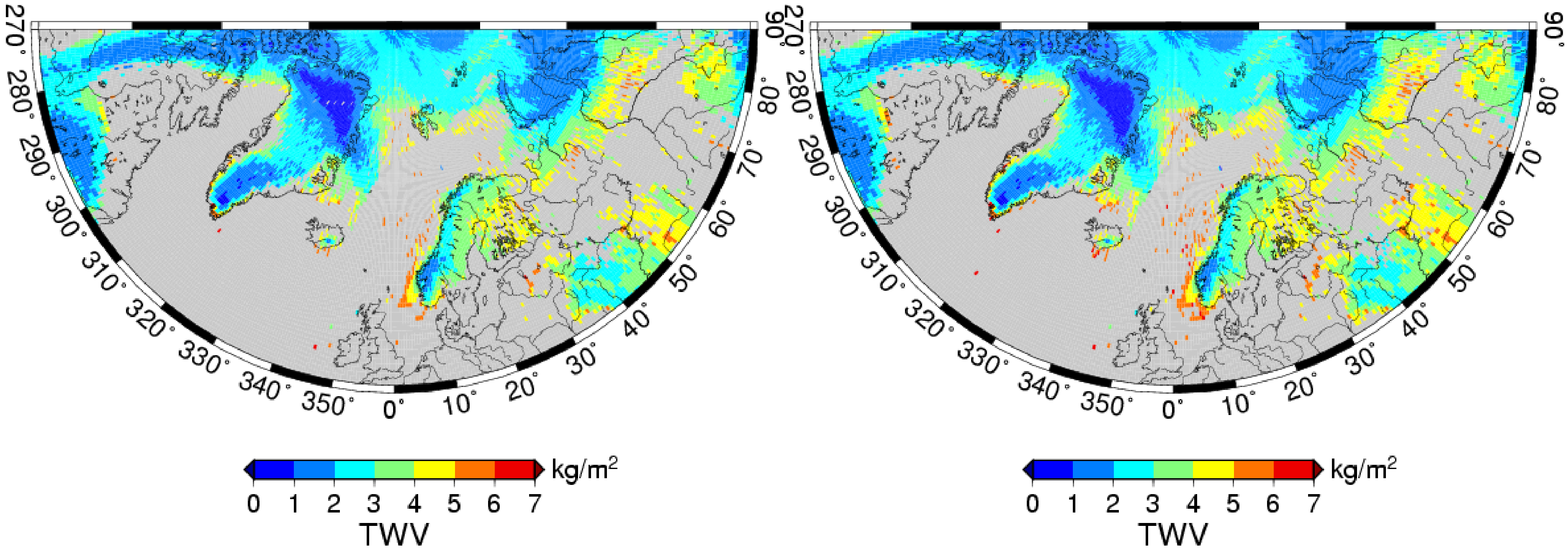
but the focal point coordinates are positive, order of a few K

?? Can we push the saturation cut-off towards positive values?

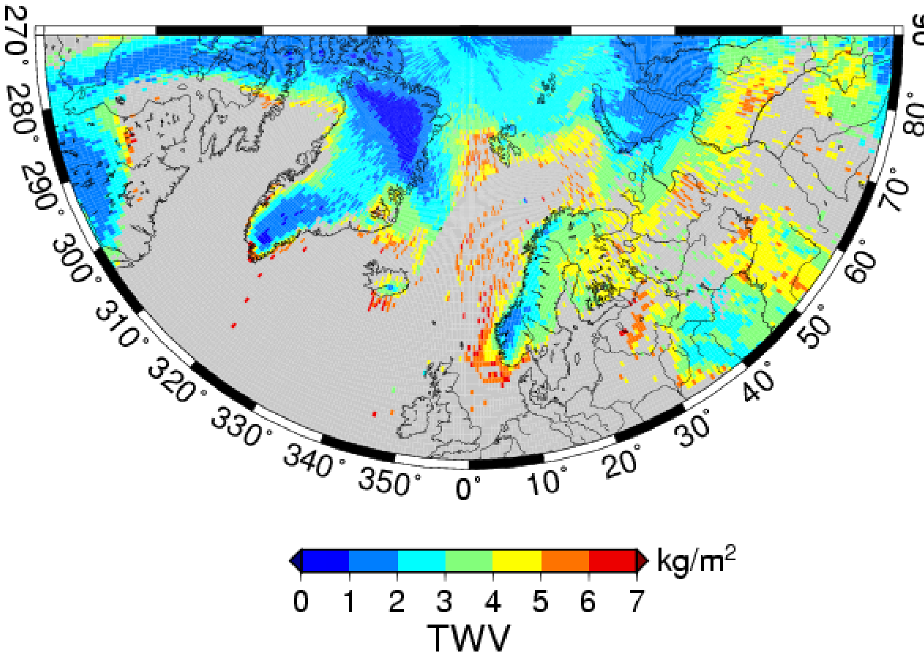
- As long as both numerator and denominator of the $\log$ argument are negative, the algorithm should work.

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

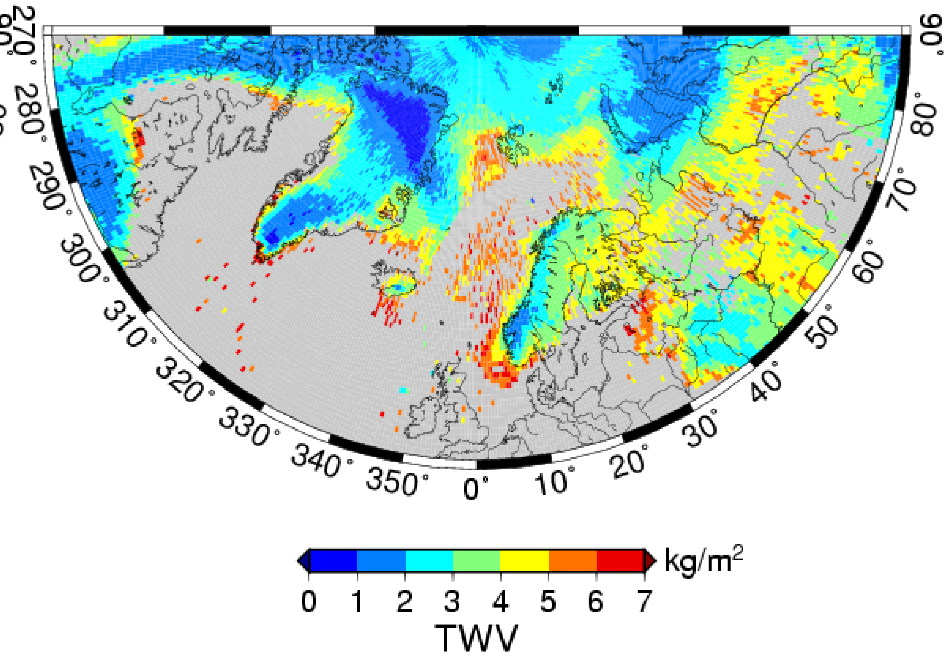




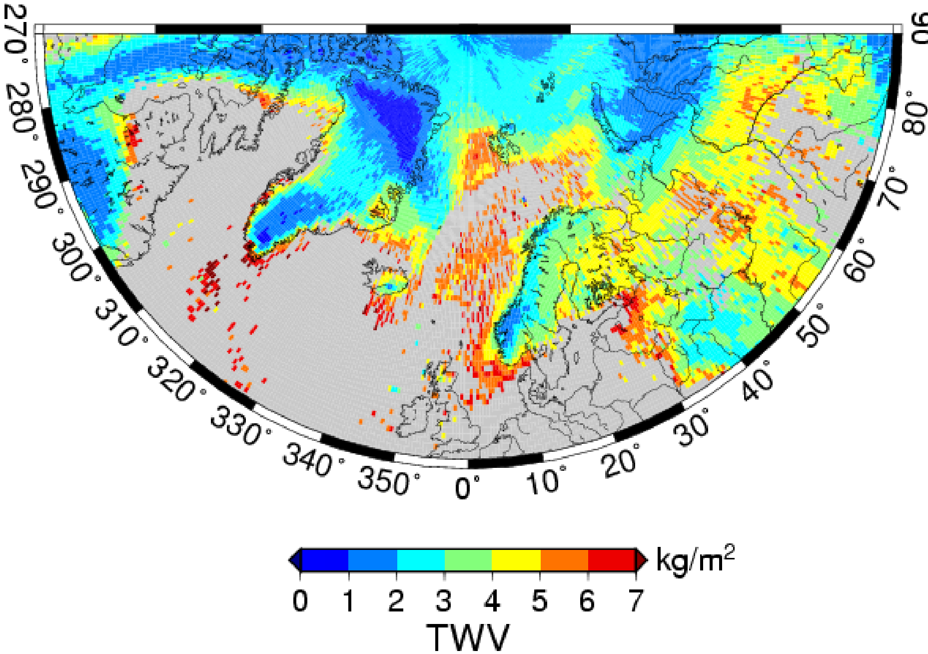
TWV, 1 March, 2001: Saturation cut-off $S = 0$as before, but $S = 1$



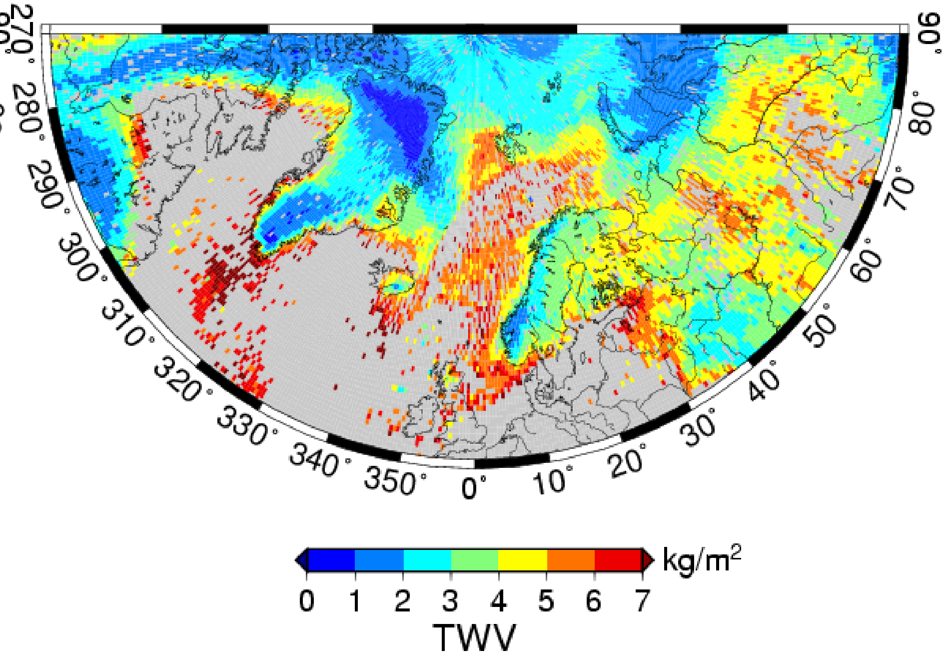
as before, but $S = 2$



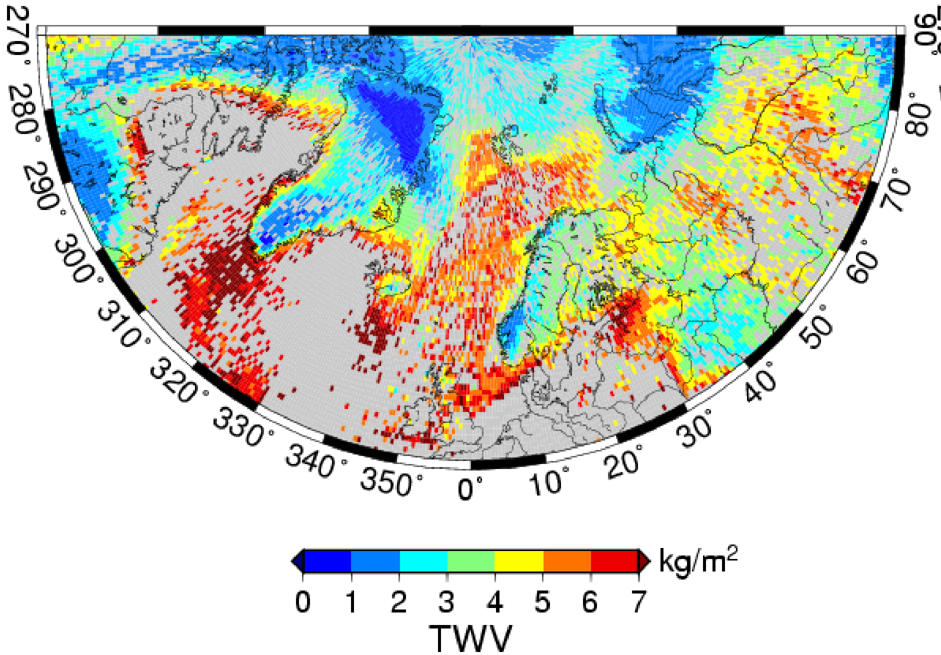
as before, but $S = 3$



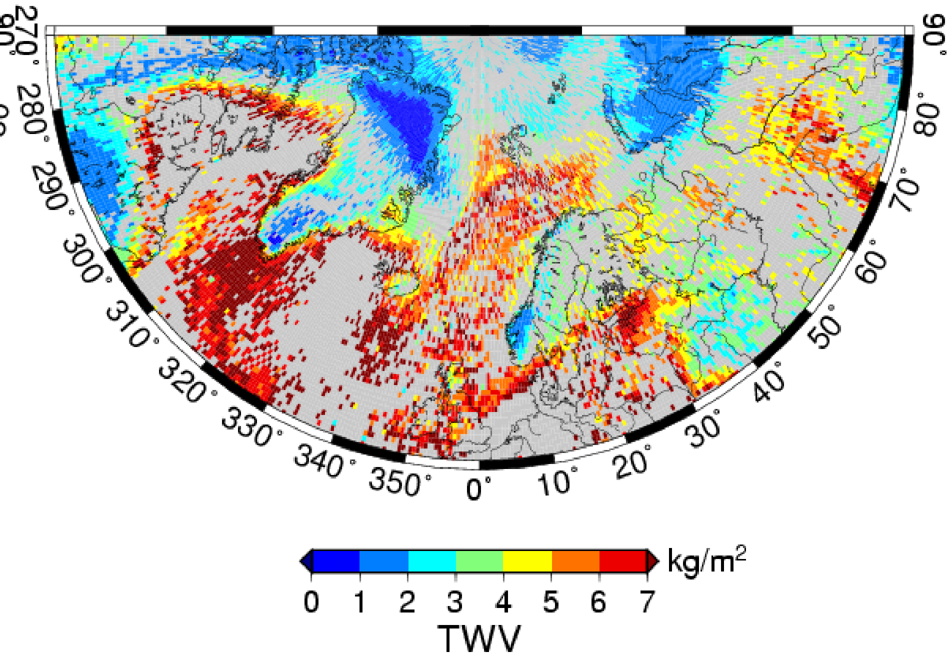
as before, but $S = 4$



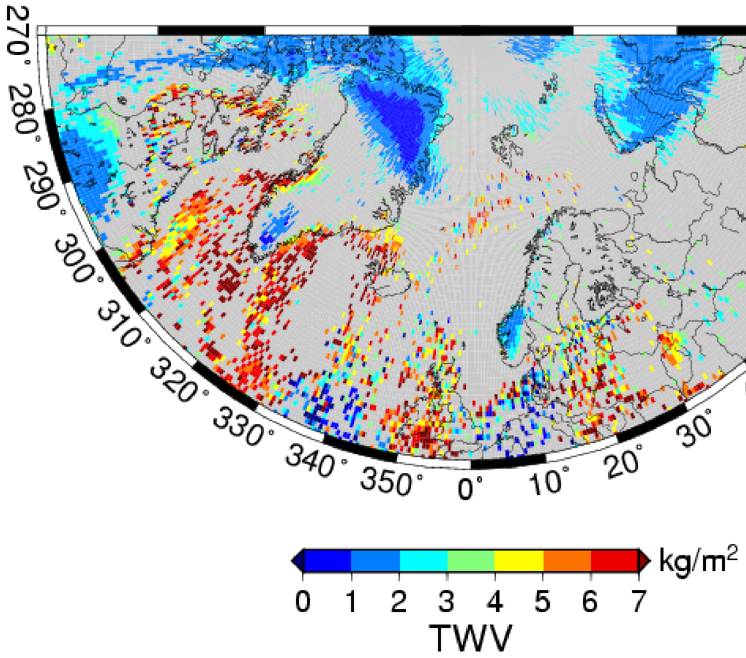
as before, but $S = 5$



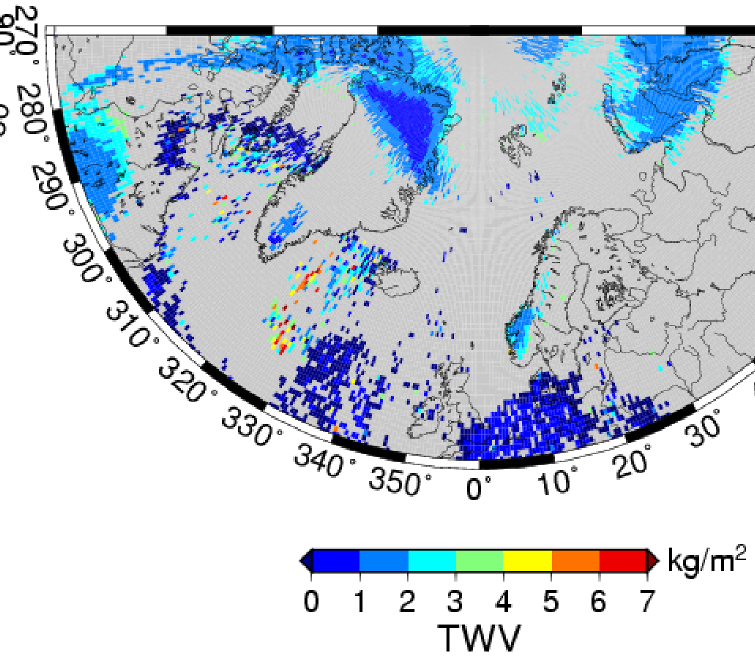
as before, but $S = 6$



as before, but $S = 7$



as before, but $S = 10$



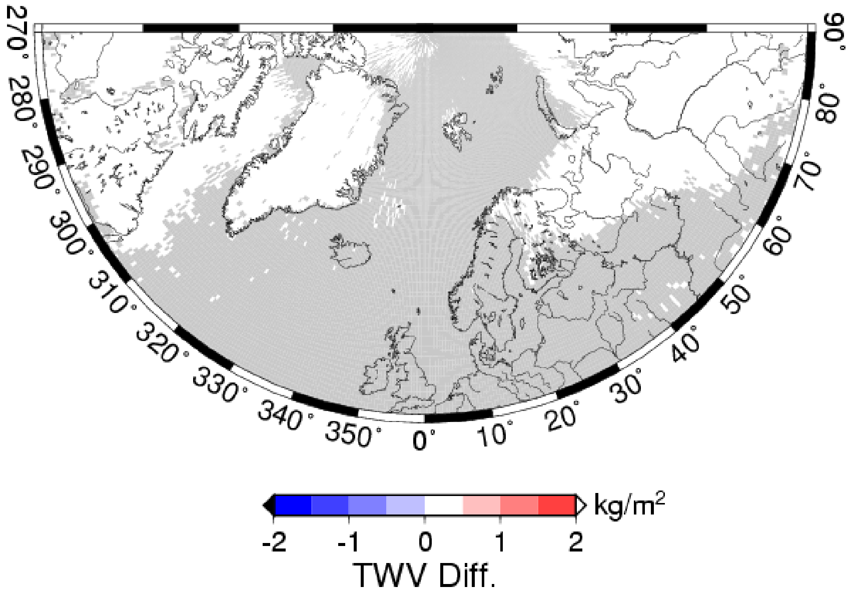
as before, but $S = 15$

Seasonal calibration parameters

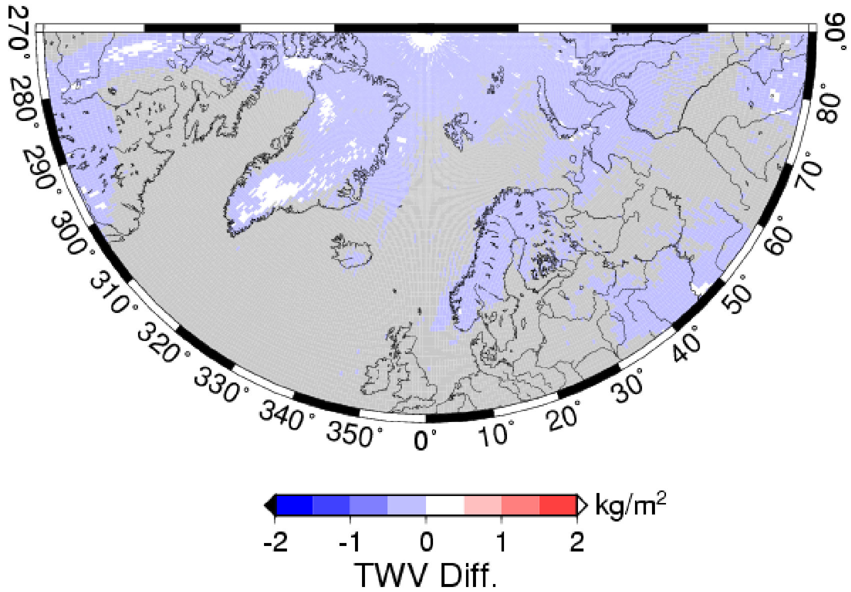
Calibration parameters from RS data from all year round

vs.

Calibration parameters from RS data from one month



TWV with calibr. parameters whole year *minus* TWV with calibr. parameters January: 1 Jan 2000



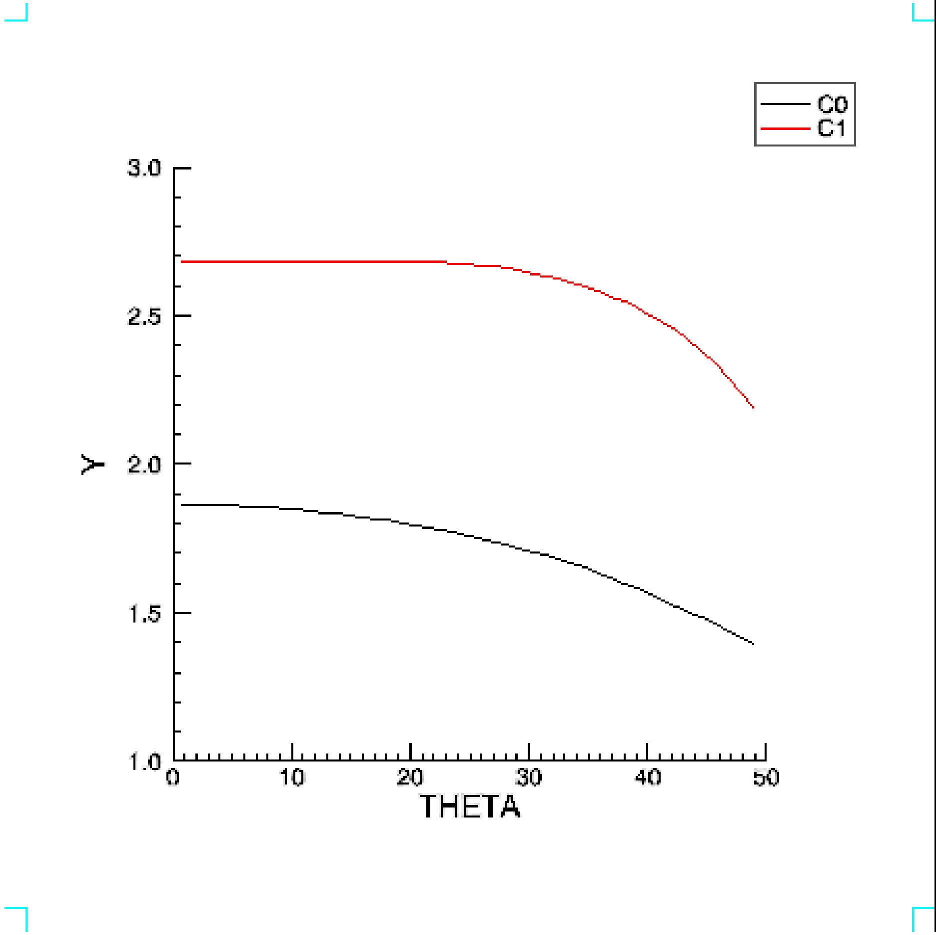
TWV with calibr. parameters whole year *minus* TWV with calibr. parameters March: 1 Mar 2001

Dependence of calibration parameters on scan angle

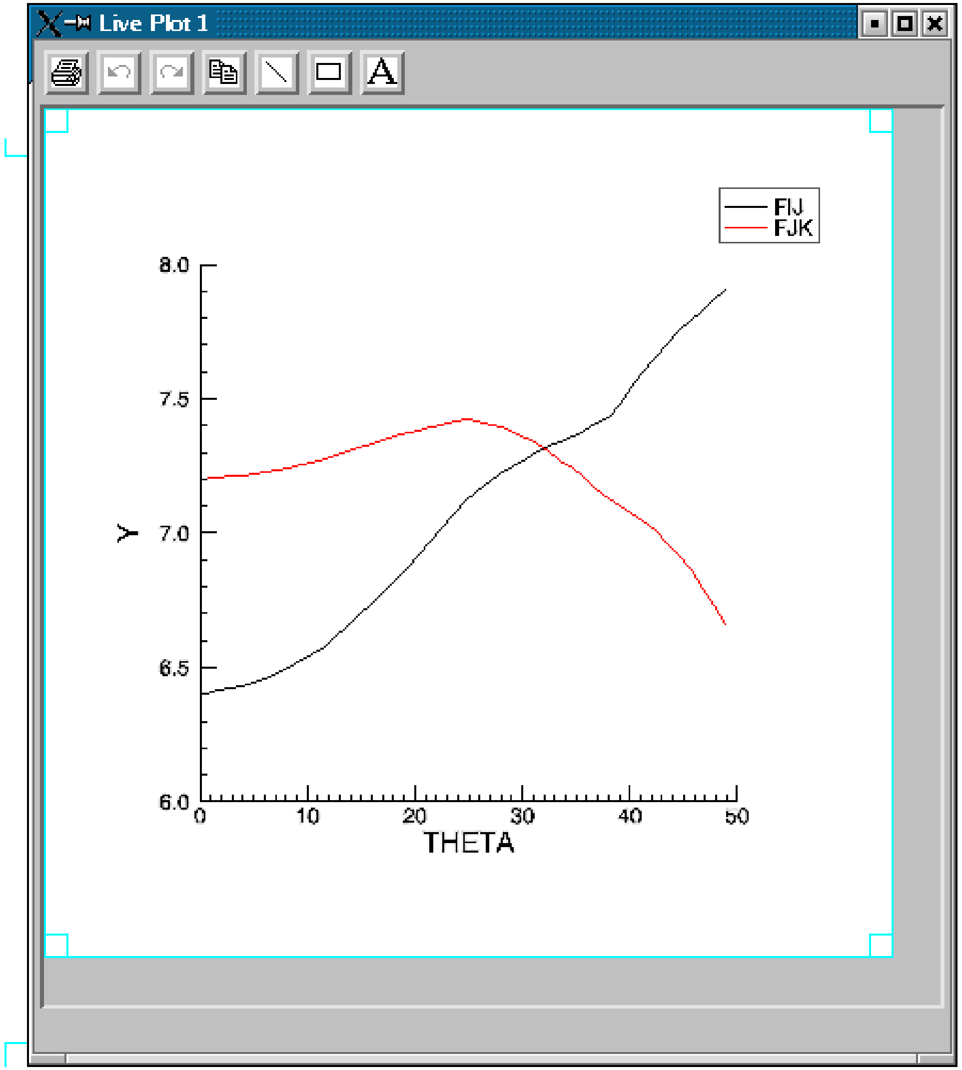
- Bias terms b_{ij}, b_{jk} depend on scan angle (incidence/zenith/looking angle) in complicated way – not just by the path length factor $\sec\theta$:

$$b_{ij} \approx \int_0^H \left[e^{\tau_i(z,H)\sec\theta} - e^{\tau_j(z,H)\sec\theta} \right] \frac{\mathrm{d}T(z)}{\mathrm{d}z}\,\mathrm{d}z$$

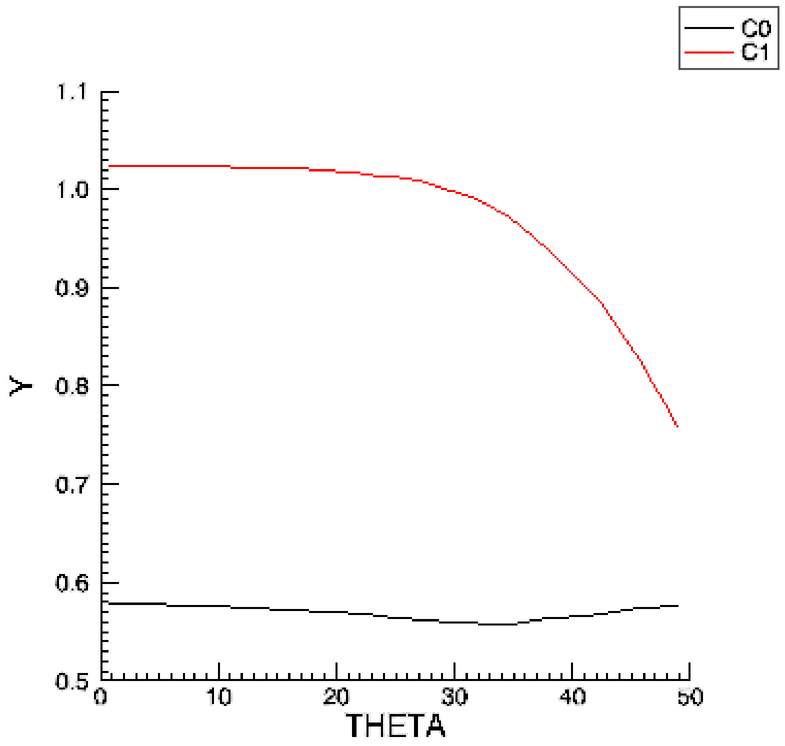
- Calibration parameters were derived and applied for each scan angle (incidence/zenith/looking angle) separately

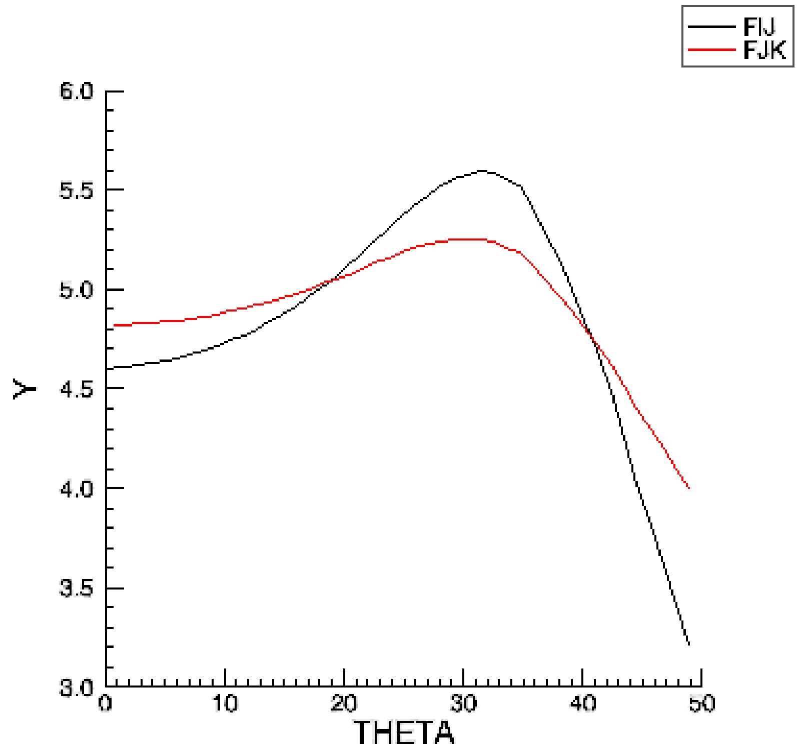


Constants C_0, C_1 for 234-algorithm



Focal point coordinates for 234-algorithm





Constants C_0, C_1 for 345-algorithm

Focal point coordinates for 345-algorithm

Ongoing Work, Ideas

- Implement sub-ranges, two-step algorithm:
  - Derive calibration constants for TWV sub-ranges $[0, 0.5]$, $[0.5, 1.0]$, $[1.0, 1.5]$, etc.
  - calculate TWV once, using simple 234-/345-algorithm
  - Based on the resulting TWV values, apply the algorithms derived for the matching sub-range.
- Investigate seasonal variations of calibration parameters
- Gridding/interpolation issues
- Optimize the saturation cut-off (link to focal point coordinates, i.e., 2 values for each algorithm?)
- Estimate error (mainly from fuzziness of focal point?)
- More validation besides NCEP data; other sensors