Analyzing model water vapor field-patterns by means of satellite remote sensing and *in situ* sonde measurements

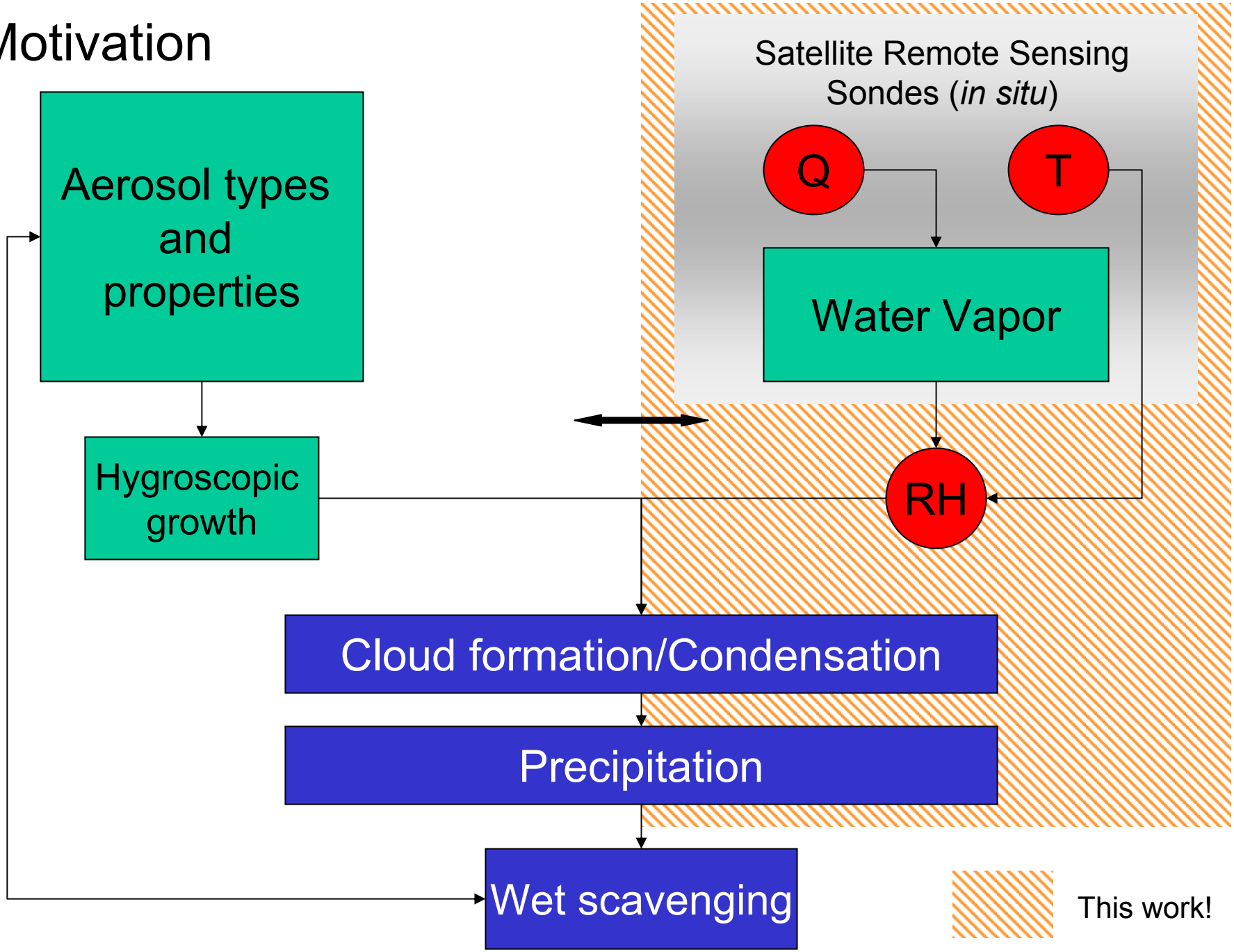
Rüdiger Lang, Swen Metzger and Mark Lawrence

Max-Planck-Institute for Chemistry, Mainz

(Work in progress! Preliminary results!)

AEROCOM meeting, JRC, 2004

Motivation


Satellite Remote Sensing
Sondes (*in situ*)
Q
T
Water Vapor
Aerosol types and properties
Hygroscopic growth
RH
Cloud formation/Condensation
Precipitation
Wet scavenging
This work!

Outline

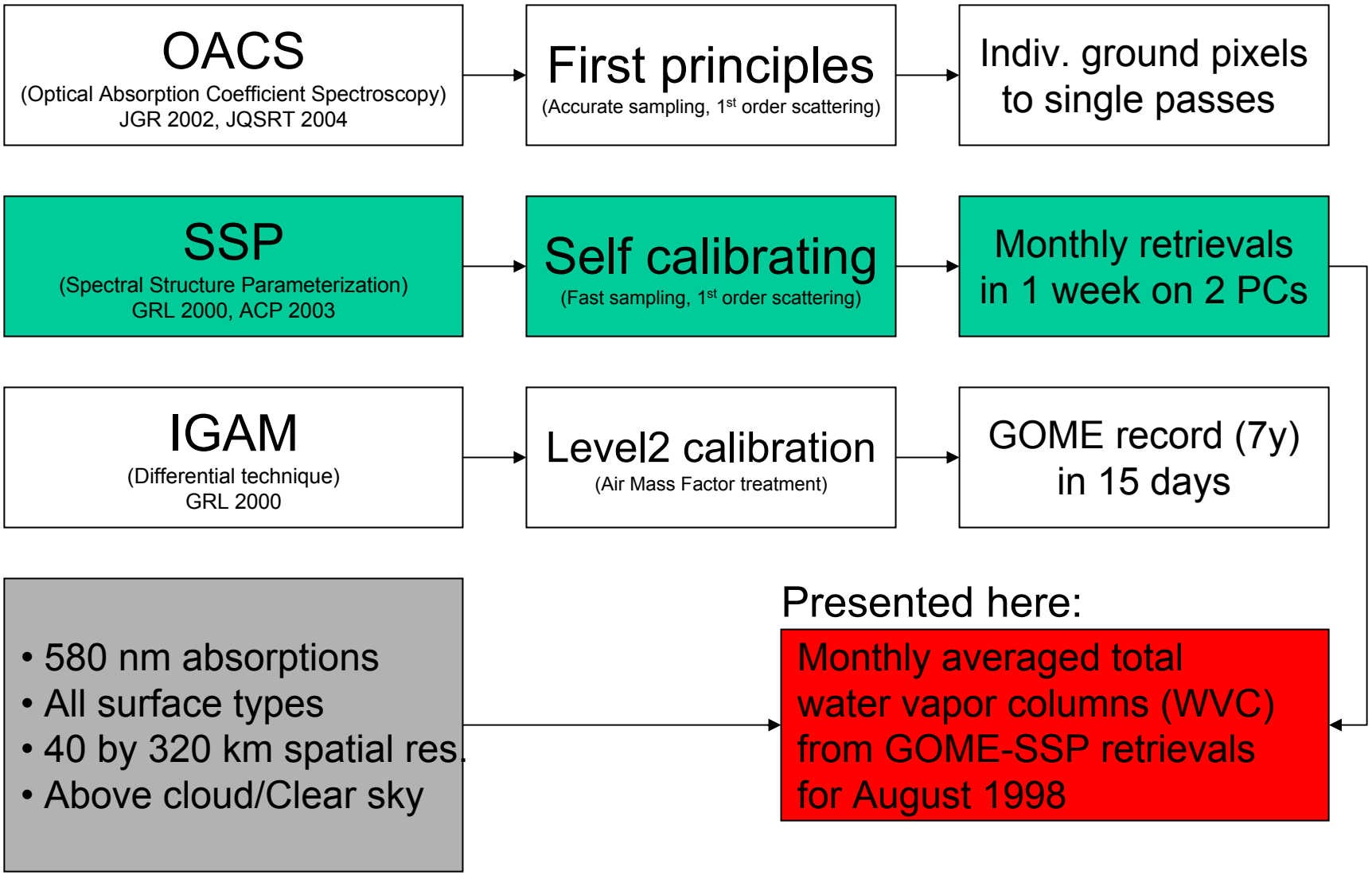
- Motivation and Algorithms
- Comparison monthly averaged WV from GOME with

    1. Radiosondes (land)
    2. SSMI (ocean)
    3. ECMWF
    4. NCEP
    5. MATCH-MPIC
    6. ECHAM 5.2.02

- Comparison of zonal mean Q and RH profiles (MATCH/ECHAM vs radiosondes)
- Preliminary 5 years monthly mean comparisons with ECHAM 5.2.02
- Discussion of resolution and cloud mask problems

Remote sensing of water vapor from GOME and SCIAMACHY

Algorithms:

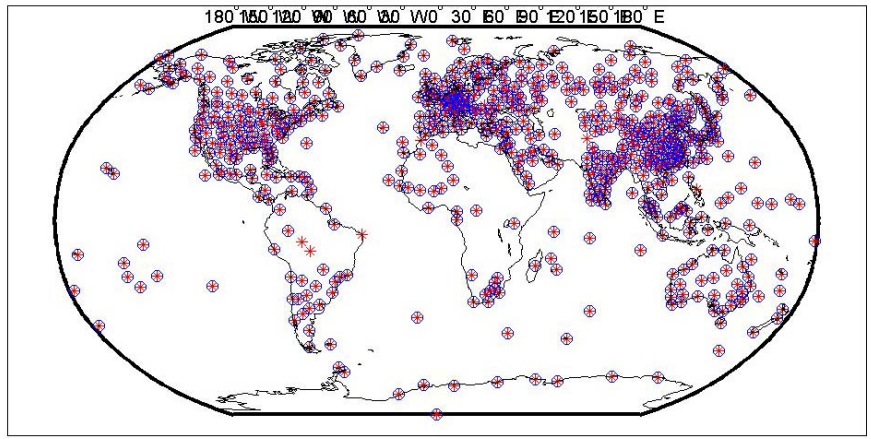


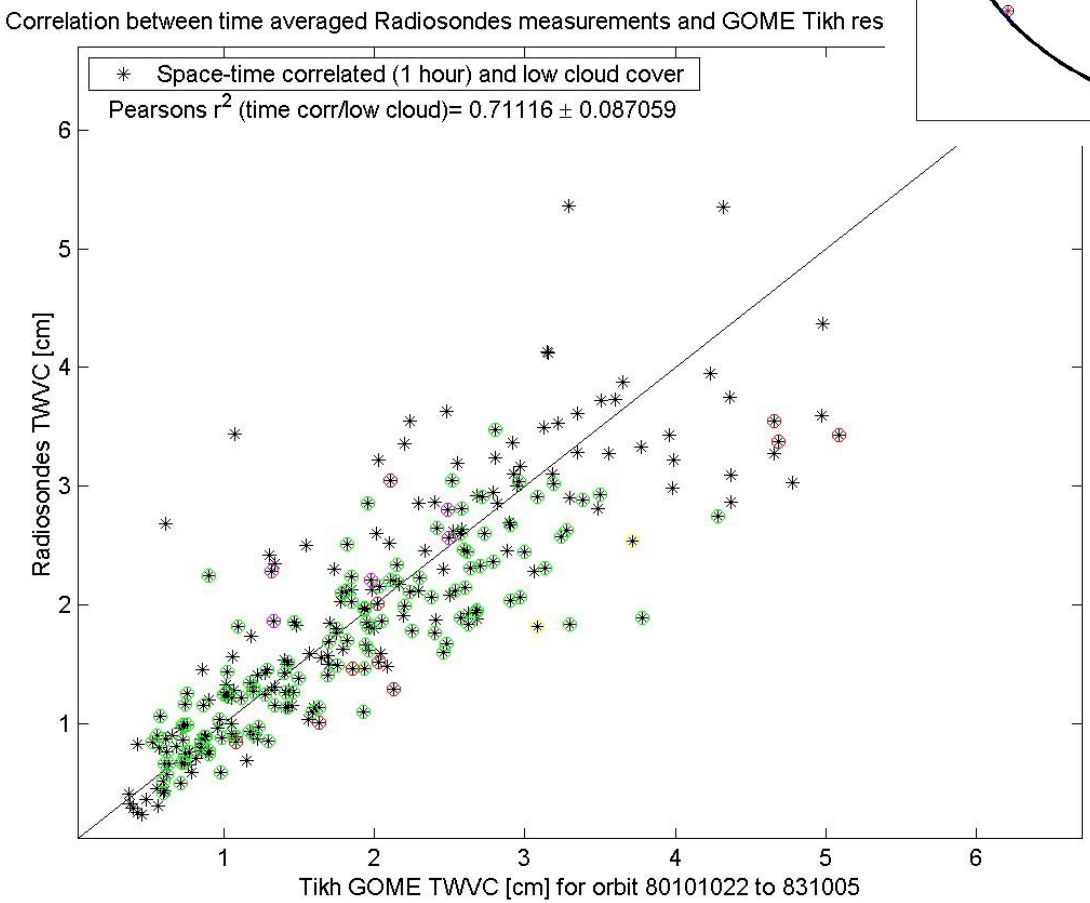
Comparison of TWVC between Radiosondes and GOME TIKH-SSP retrievals

August 1998 and 2000

January 1998 and 2000

Radiosondes vs GOME



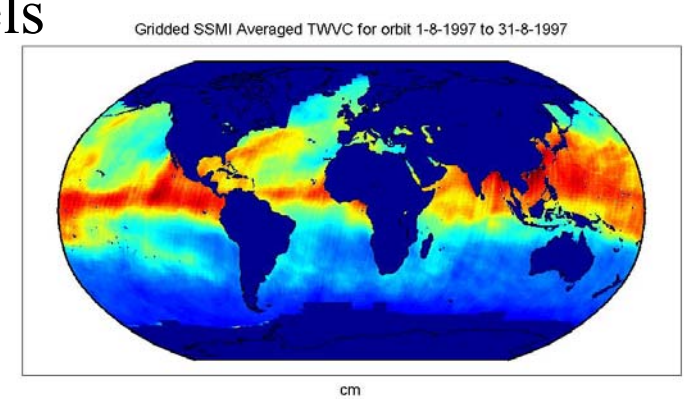


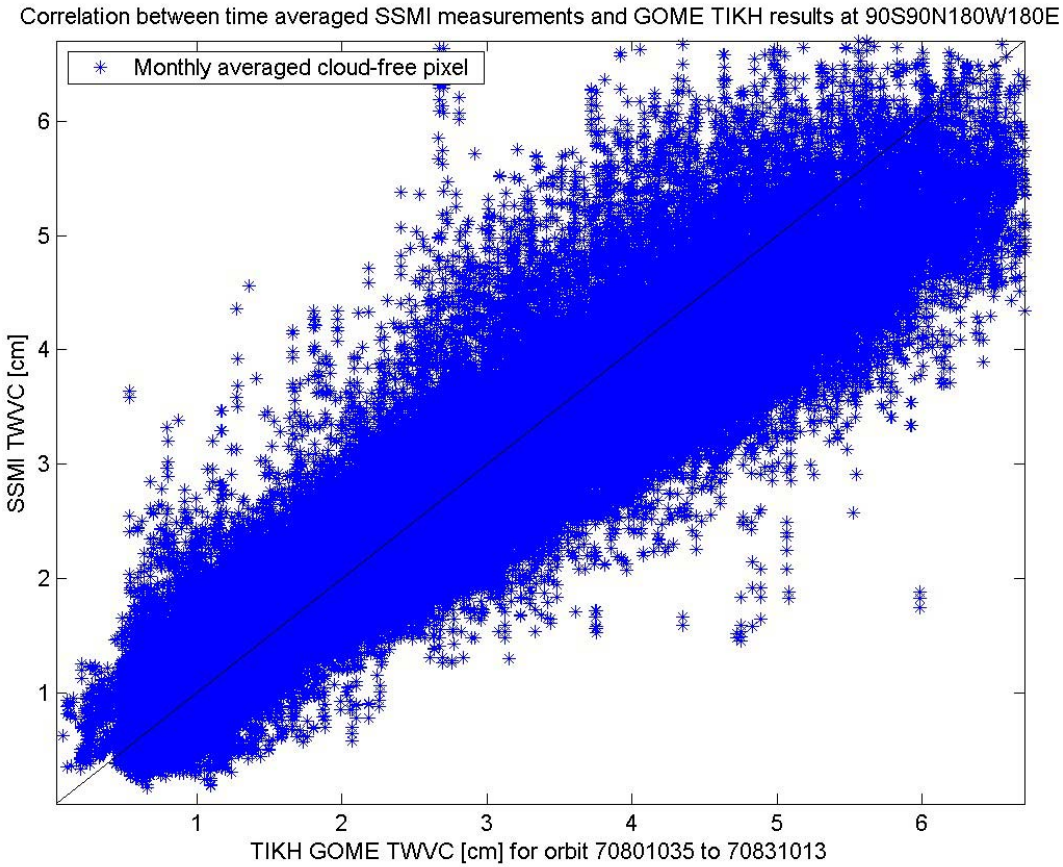
- African sondes
- European sondes
- North American sondes
- Asian sondes

Comparison of TWVC between SSM/I and GOME TIKH-SSP retrievals for ocean pixels

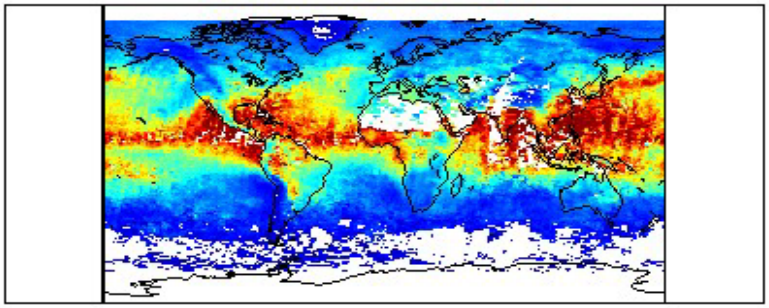
August 1997

SSMI vs GOME





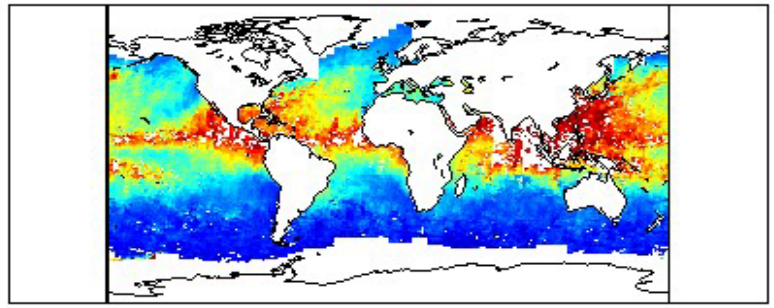
GOME-SSP



0 2 4 6

[cm]

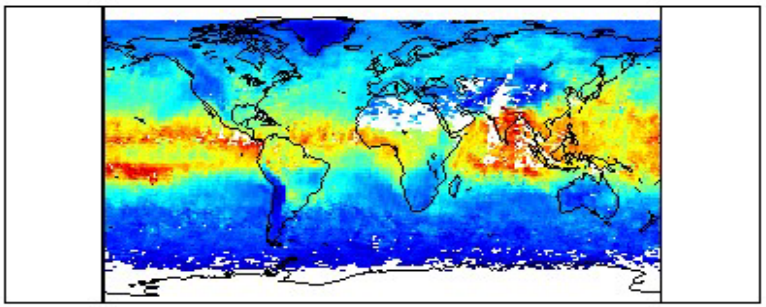
SSMI



0 2 4 6

[cm]

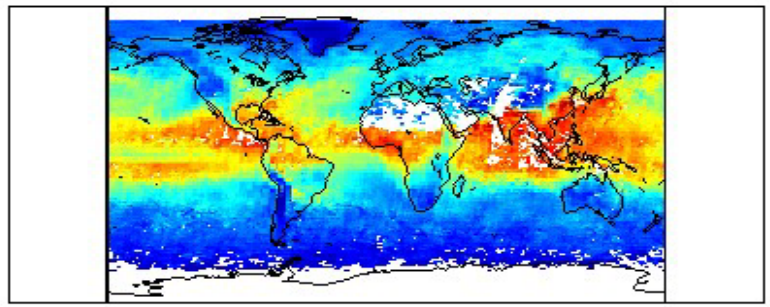
MATCH



0 2 4 6

[cm]

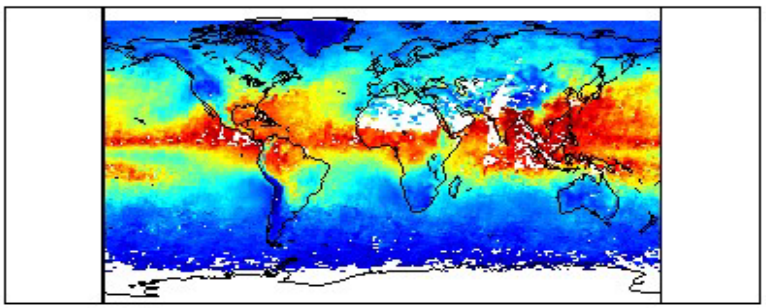
NCEP



0 2 4 6

[cm]

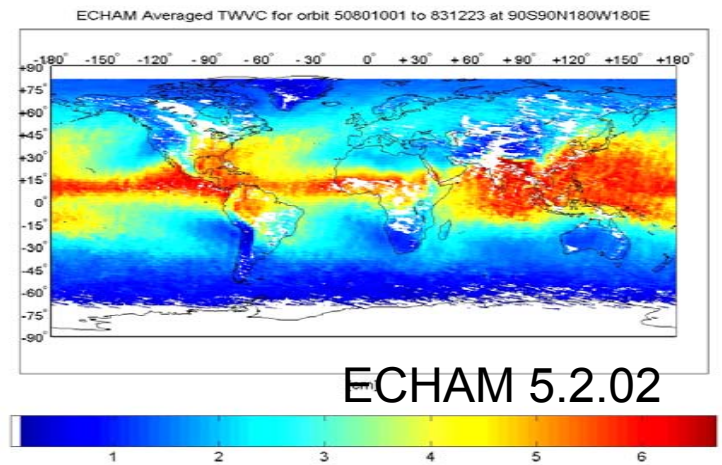
ECMWF



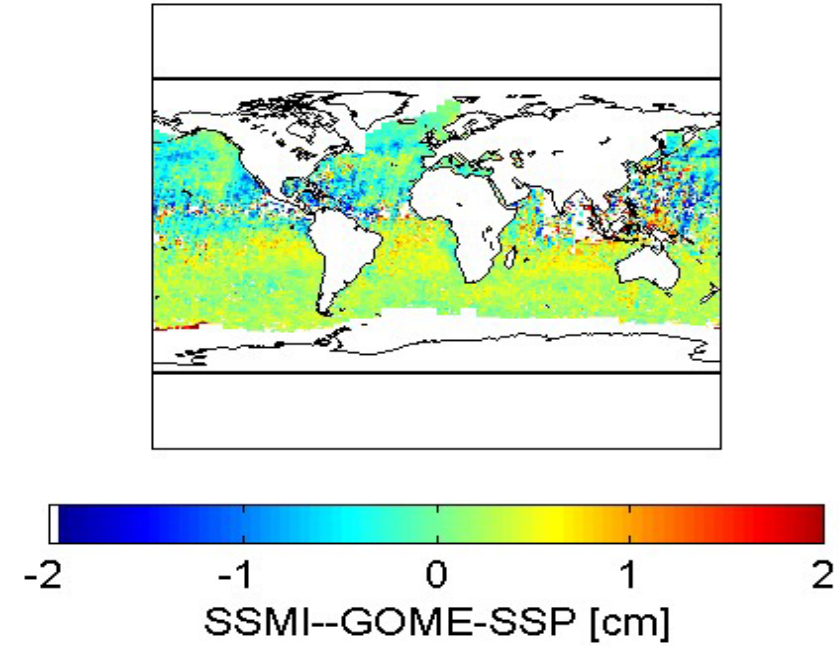
0 2 4 6

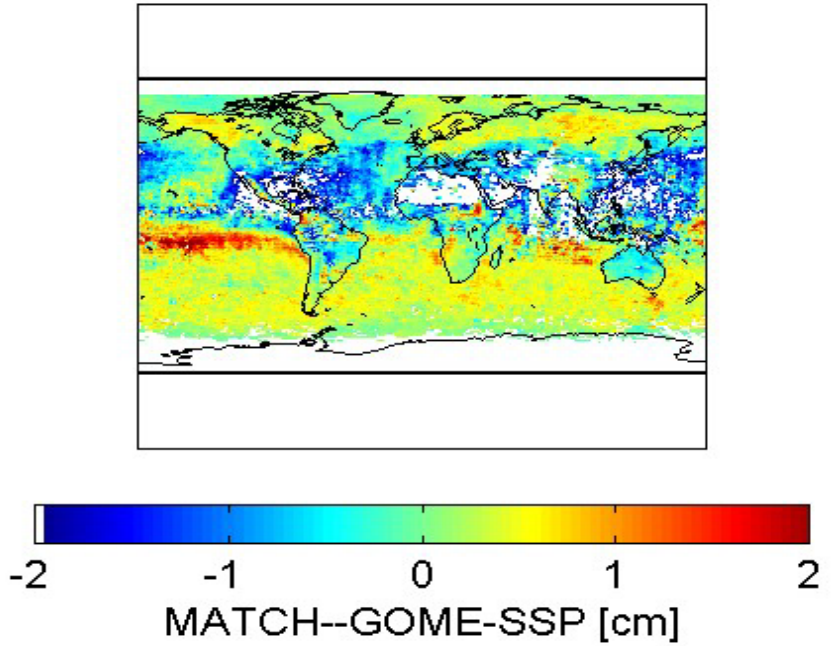
[cm]

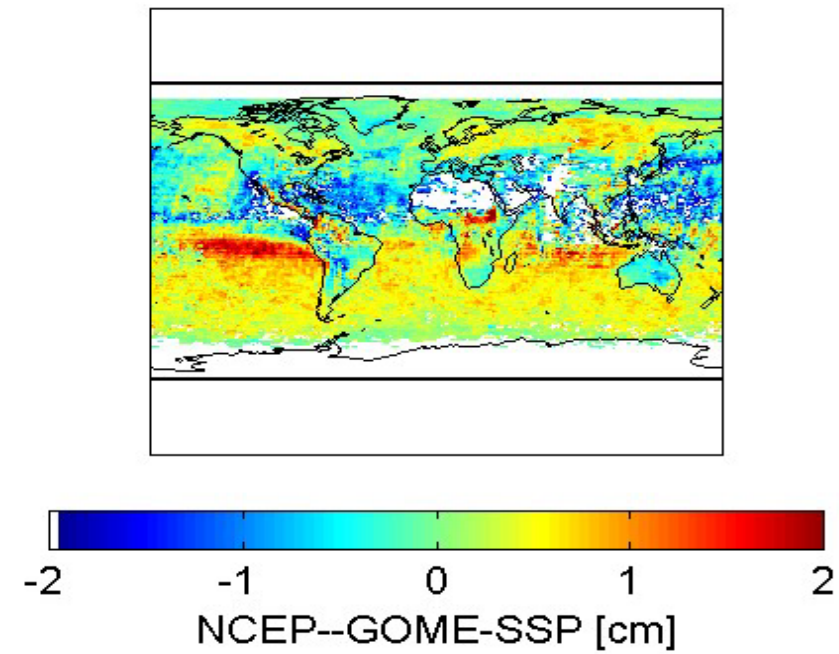
ECHAM 5yr averg.

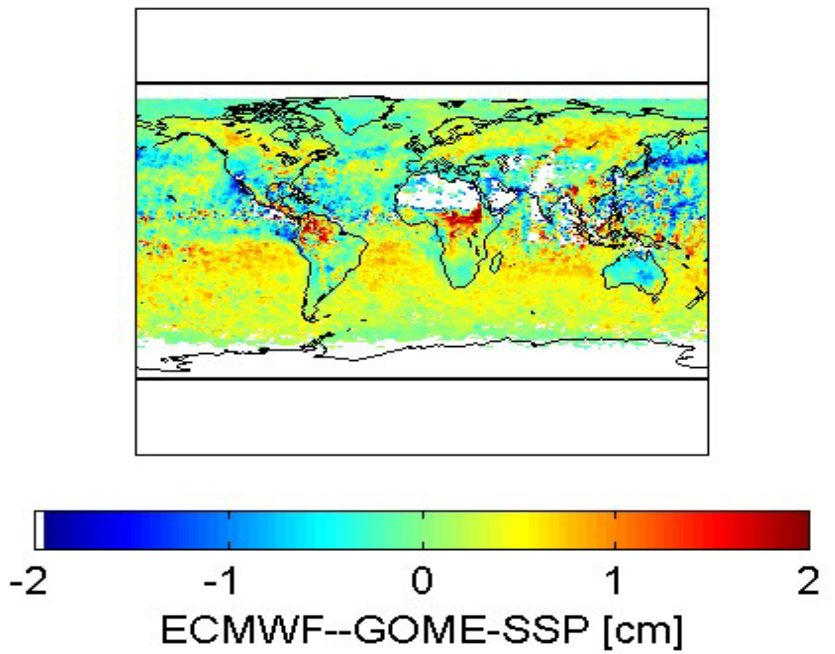


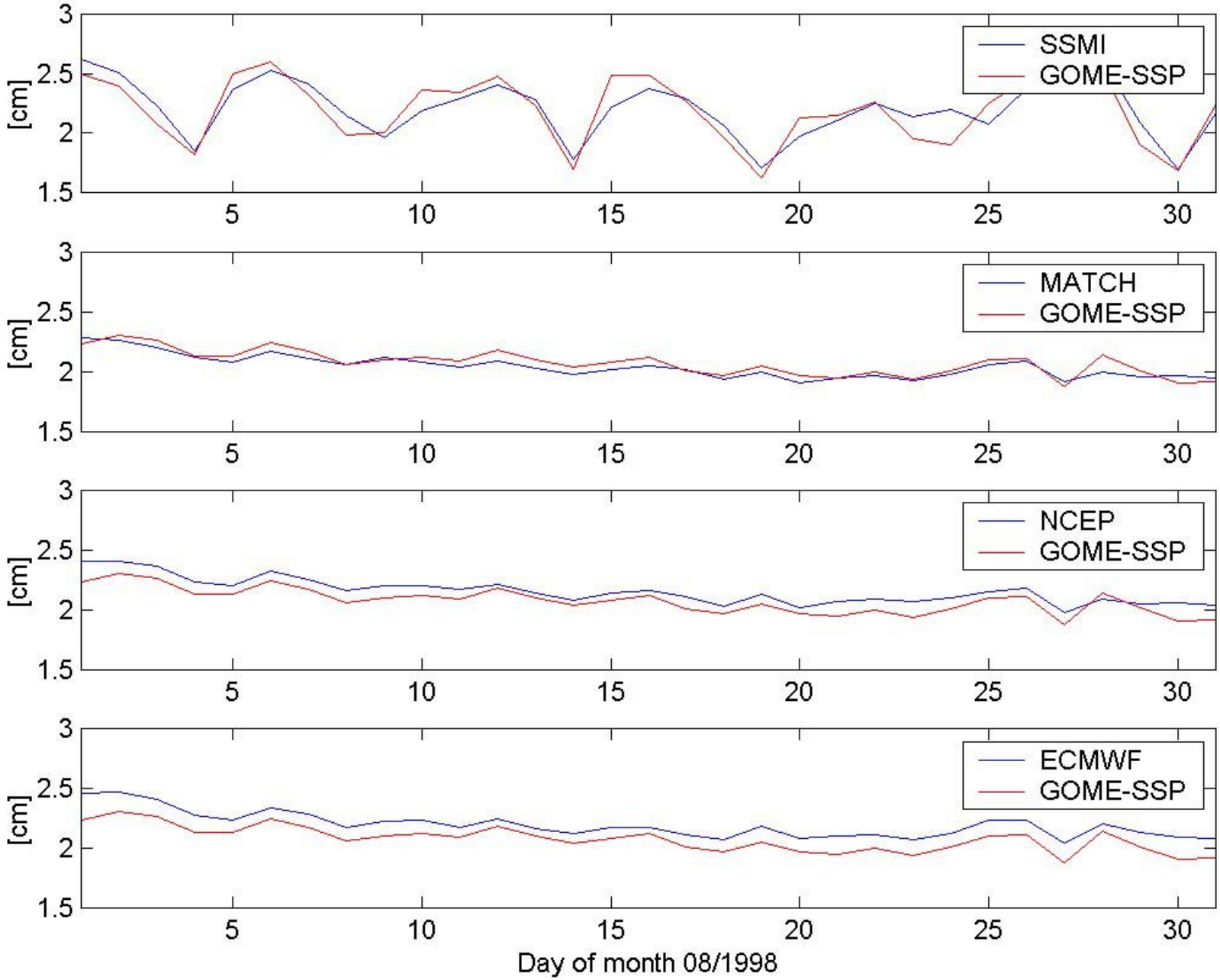
ECHAM 5.2.02

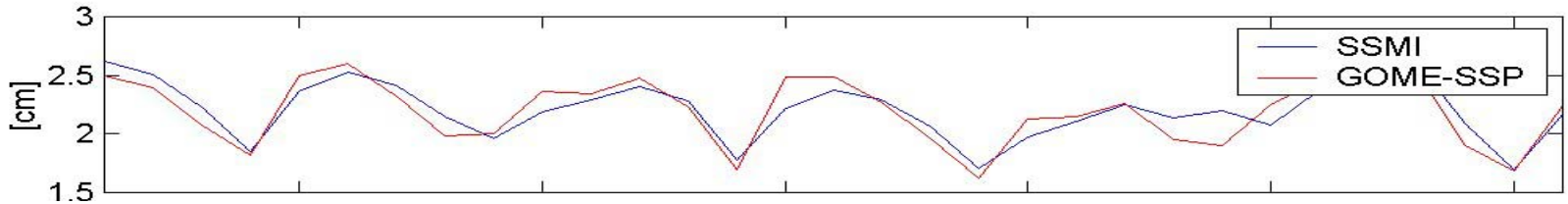

-2
-1
0
1
2
SSMI--GOME-SSP [cm]

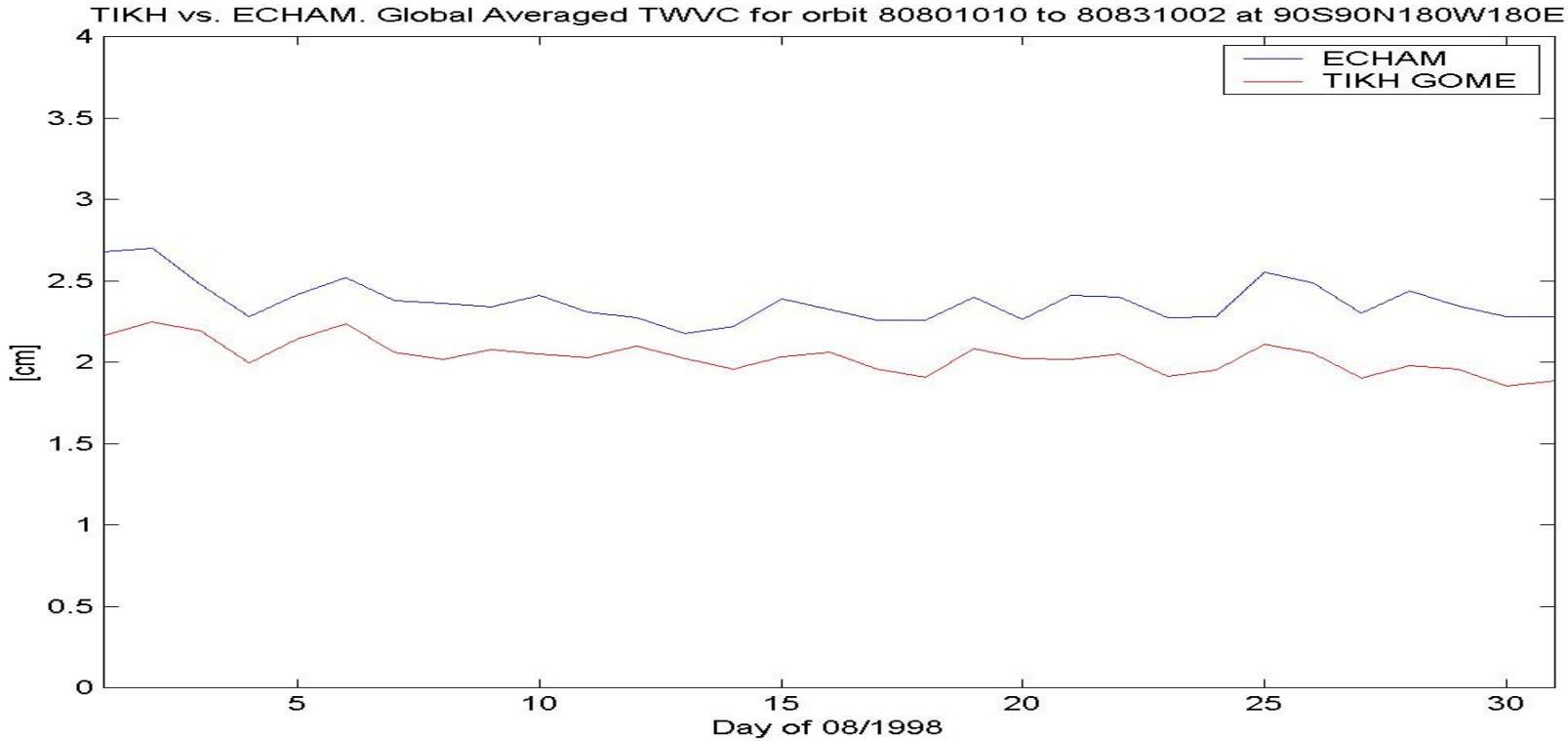

-2
-1
0
1
2
MATCH--GOME-SSP [cm]

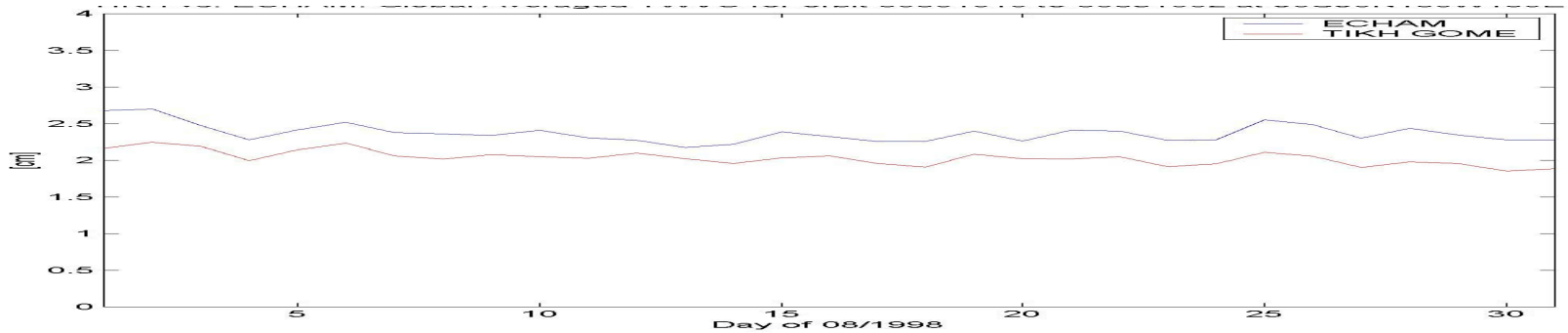

-2
-1
0
1
2
NCEP--GOME-SSP [cm]

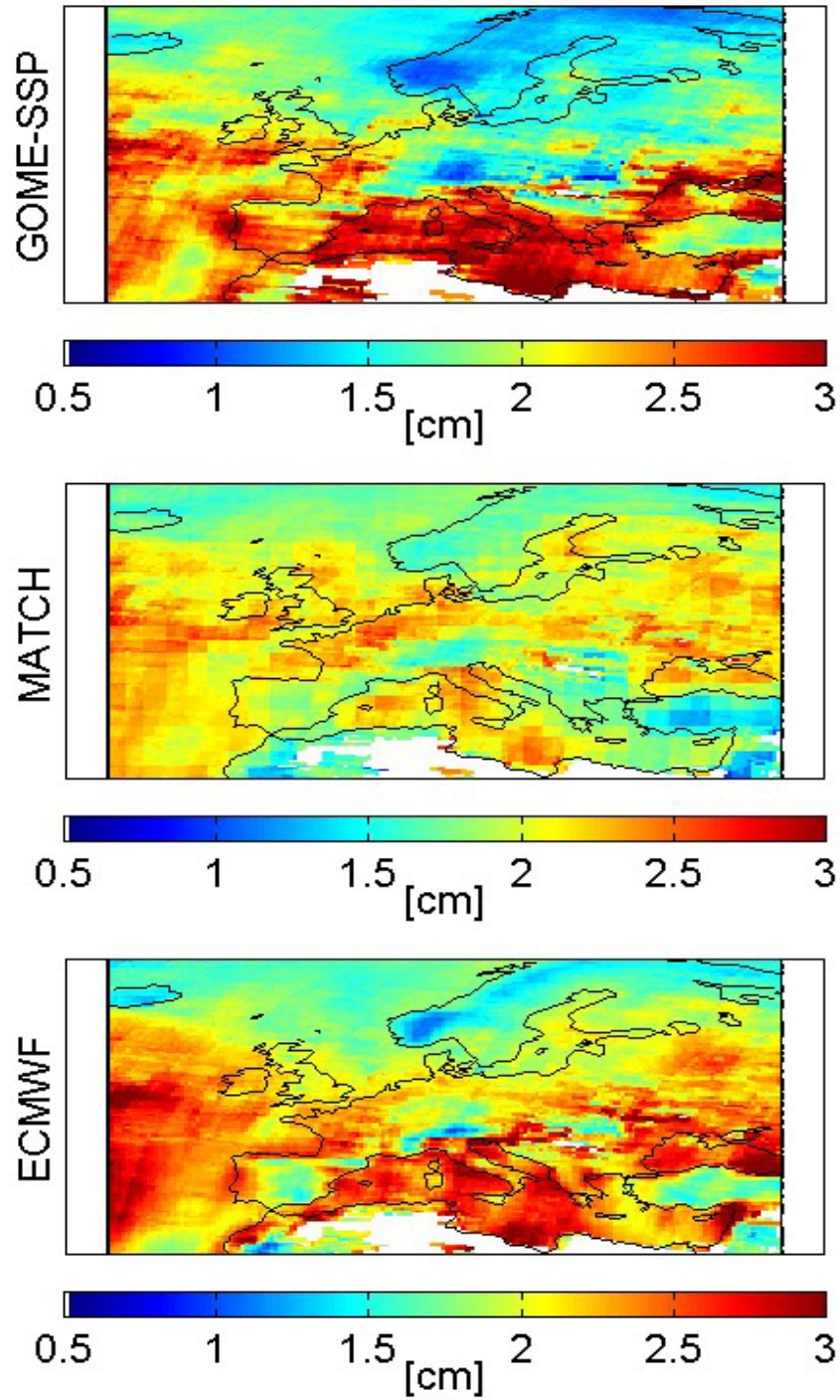

-2
-1
0
1
2
ECMWF--GOME-SSP [cm]

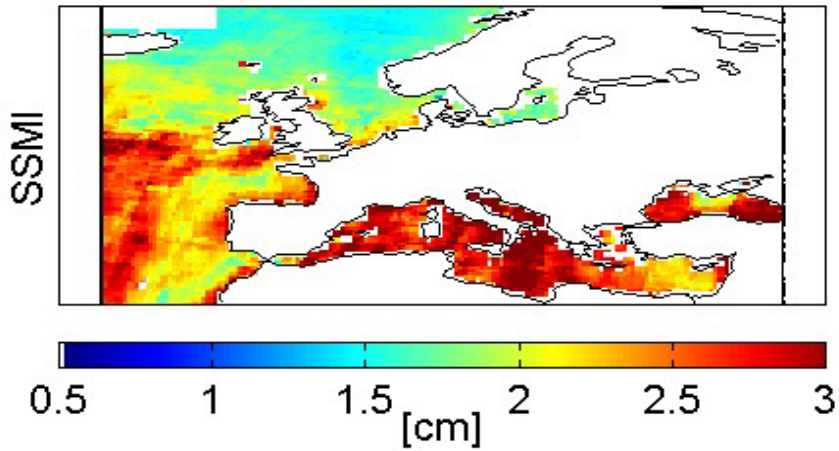

SSMI
GOME-SSP
MATCH
GOME-SSP
NCEP
GOME-SSP
ECMWF
GOME-SSP
[cm]
3
2.5
2
1.5
5
10
15
20
25
30
Day of month 08/1998

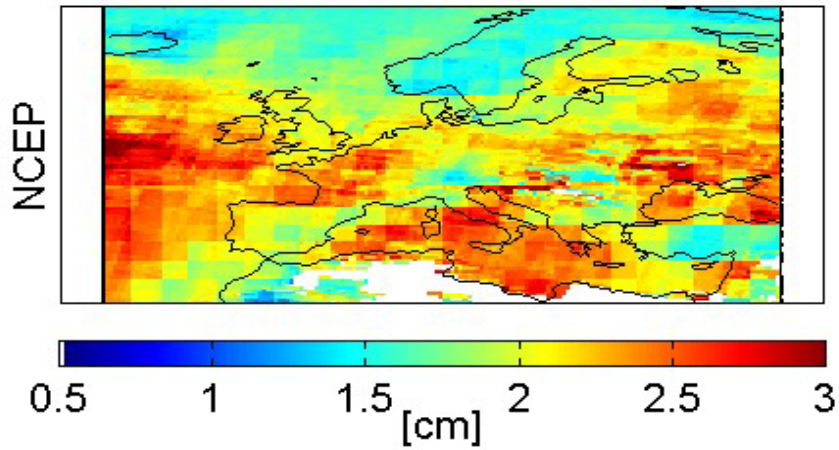

SSMI
GOME-SSP
[cm]
3
2.5
2
1.5


TIKH vs. ECHAM. Global Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
ECHAM
TIKH GOME
[cm]
Day of 08/1998

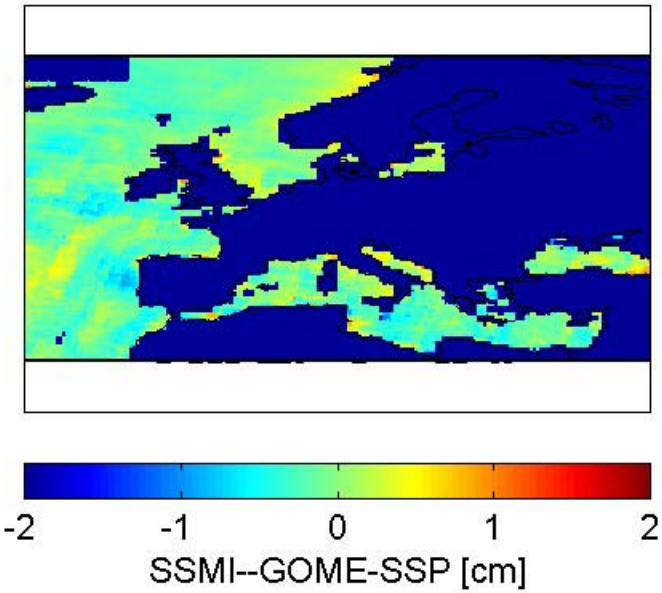

ECHAM
TIKH GOME
[cm]
Day of 08/1998

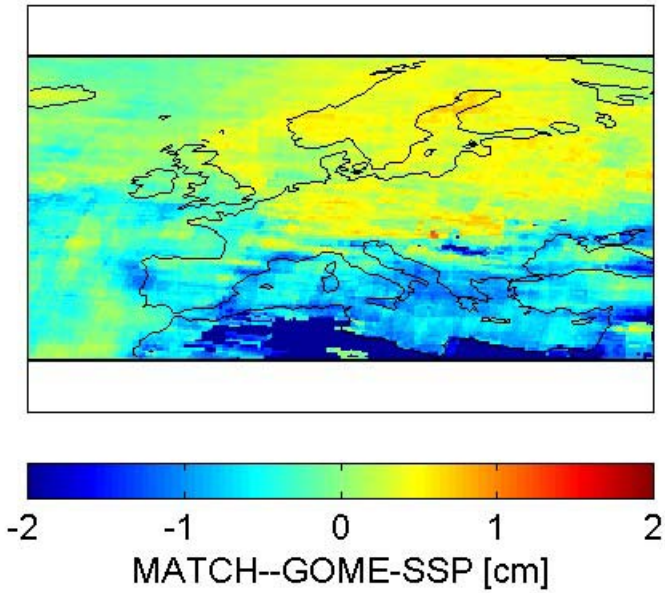


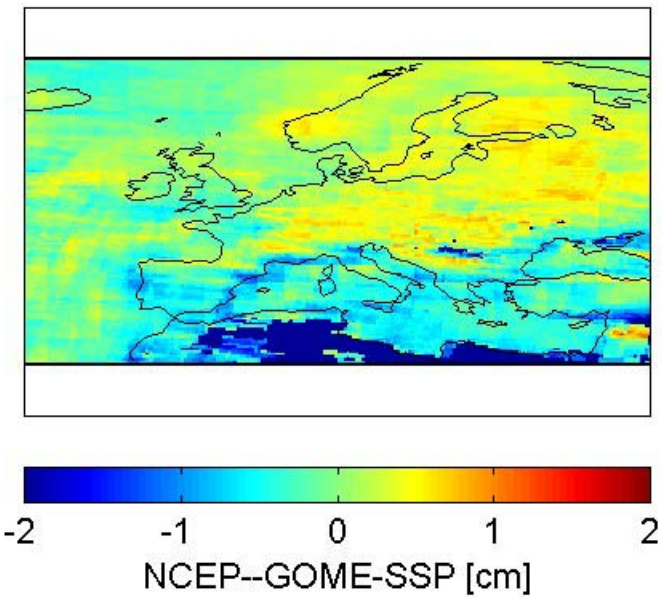


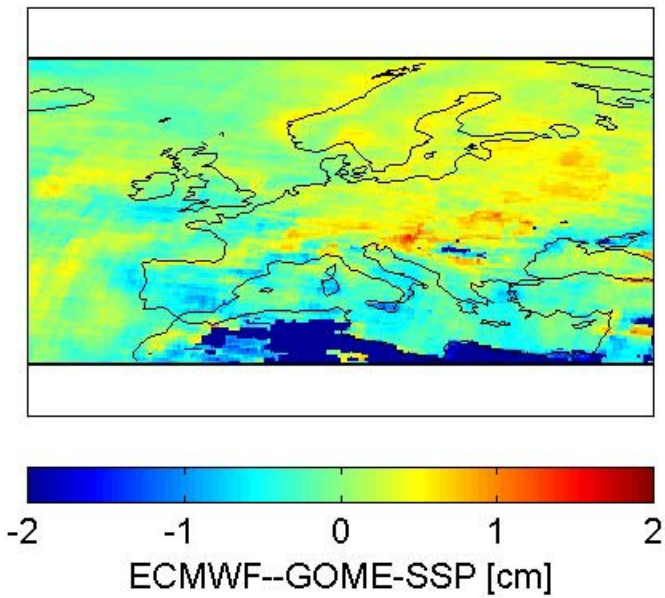


Europe, August 1998

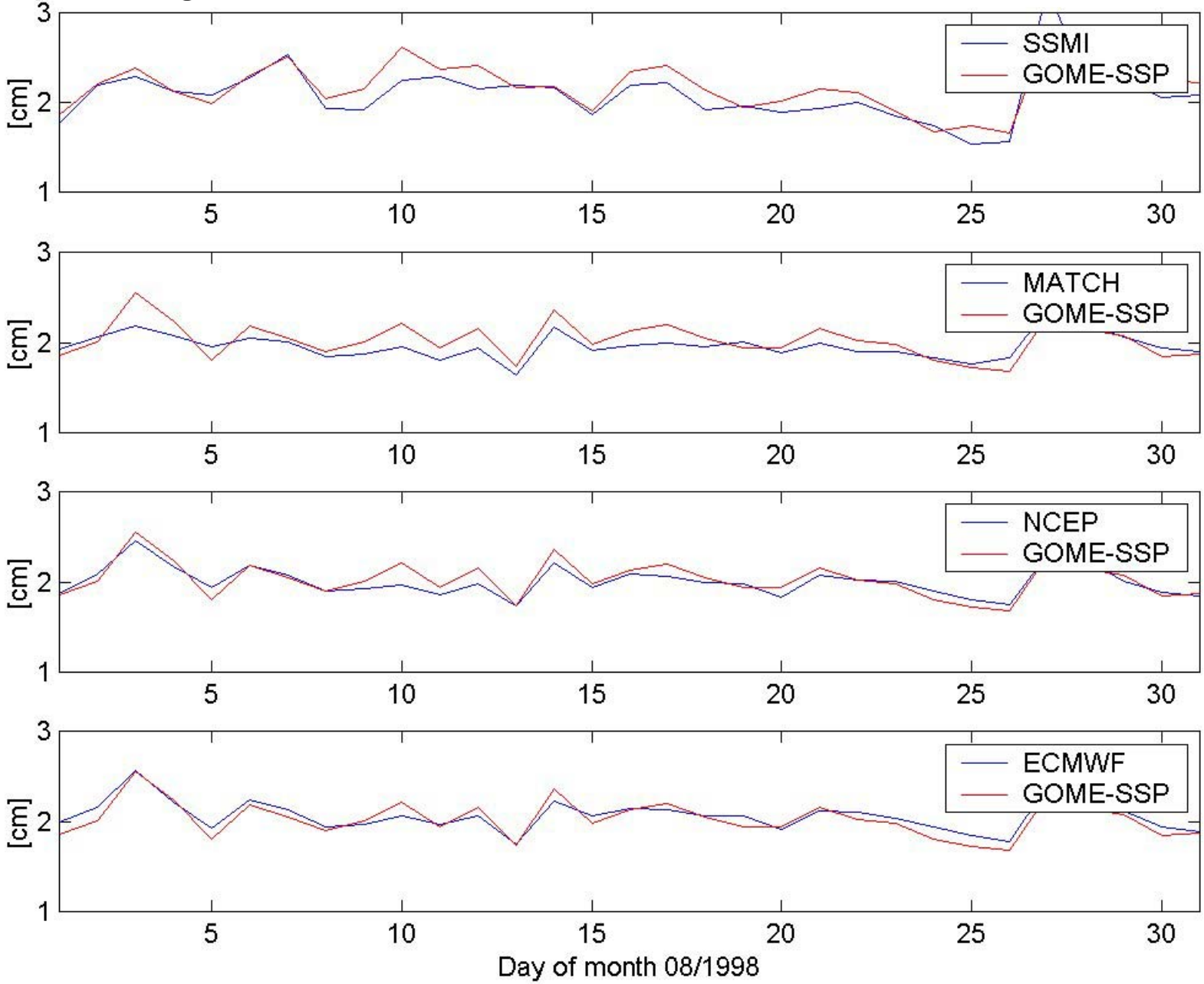

-2
-1
0
1
2
SSMI--GOME-SSP [cm]


-2
-1
0
1
2
MATCH--GOME-SSP [cm]


-2
-1
0
1
2
NCEP--GOME-SSP [cm]

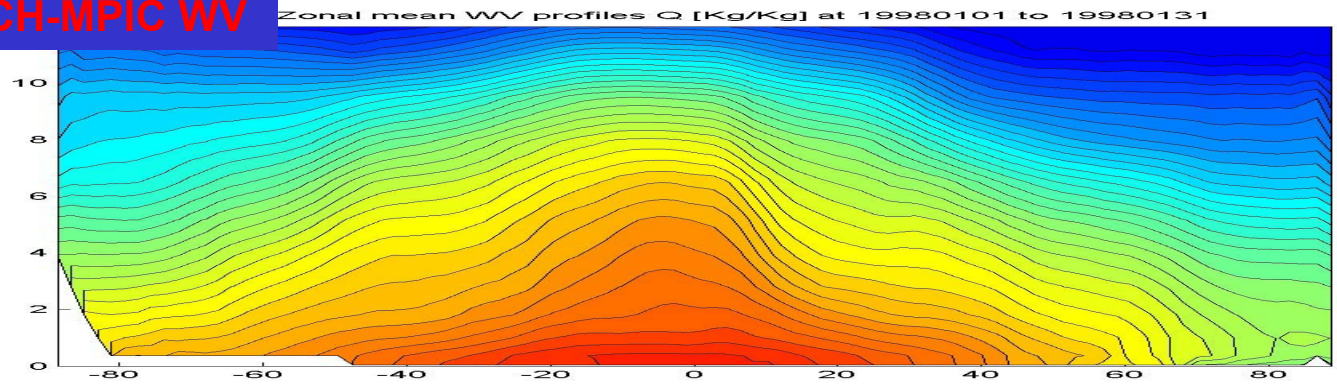

-2
-1
0
1
2
ECMWF--GOME-SSP [cm]

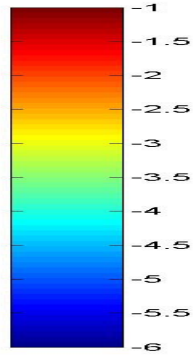
Europe, August 1998



Specific humidity profiles, January 1998 (MATCH 10:30; Sondes 10:00-12:00 lt)

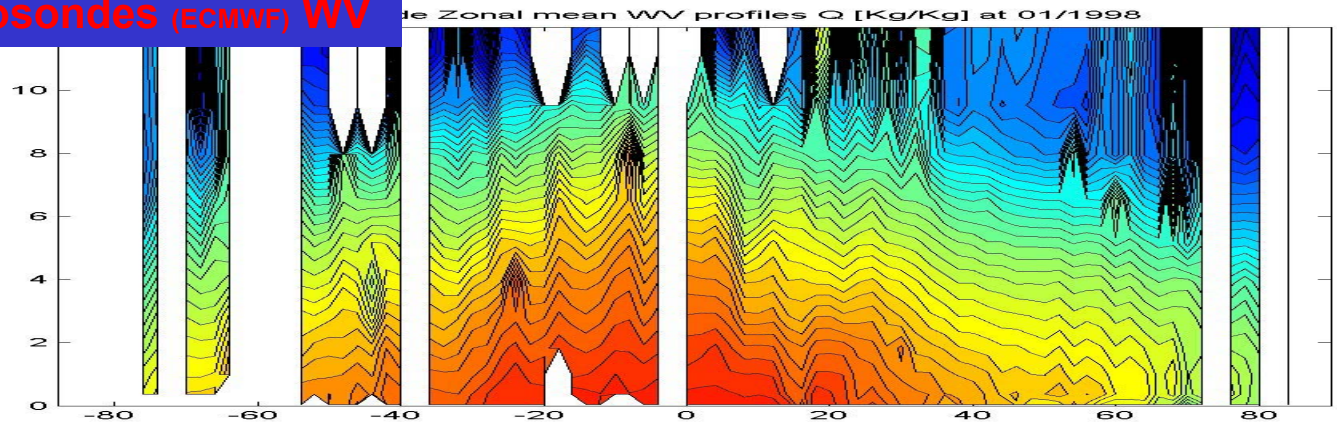
MATCH-MPIC WV

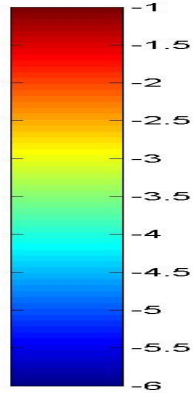




Log_{10}[Kg/Kg]

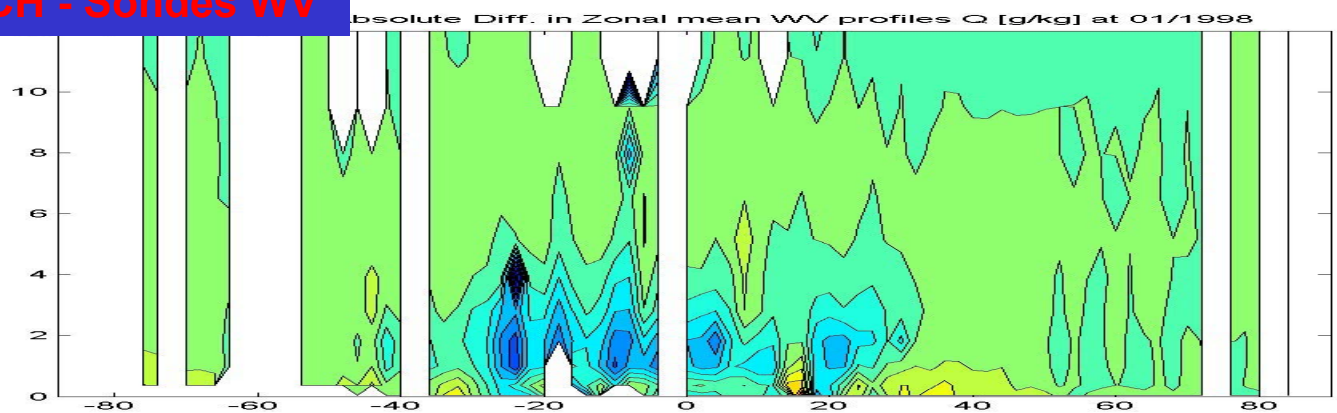
Radiosondes (ECMWF) WV

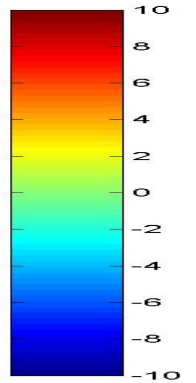




Log_{10}[Kg/Kg]

MATCH - Sondes WV

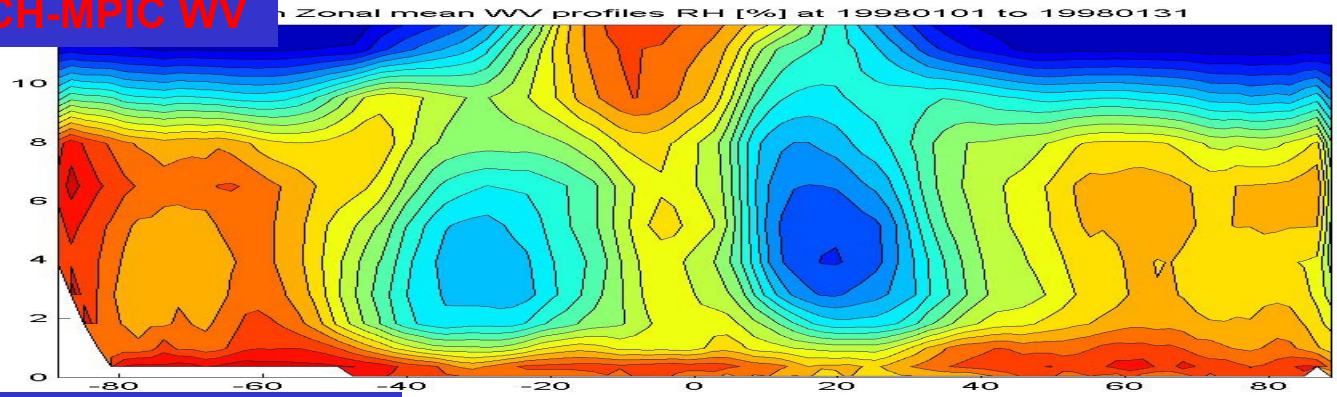


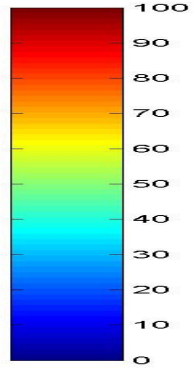


[g/Kg]

Relative humidity profiles, January 1998 (MATCH 10:30; Sondes 10:00-12:00 lt)

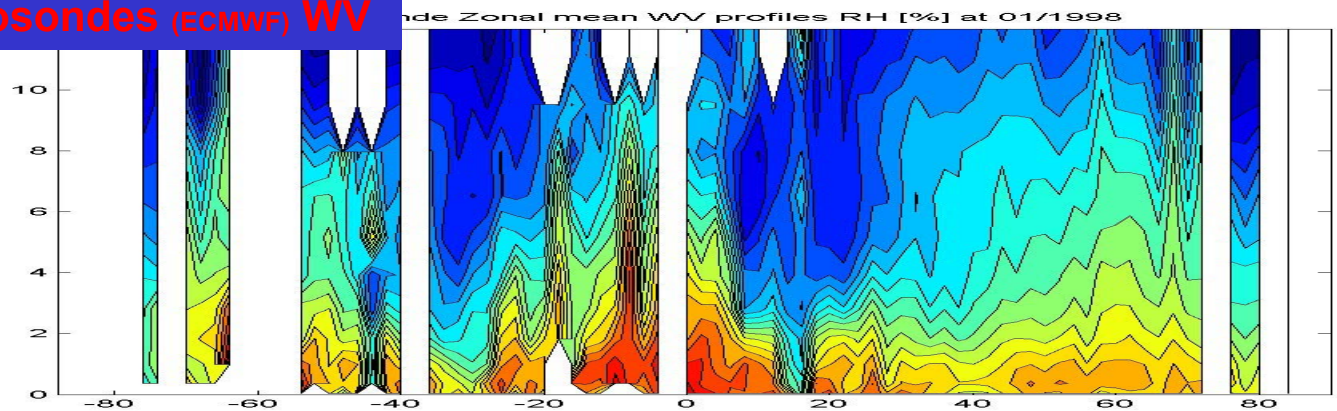
MATCH-MPIC WV

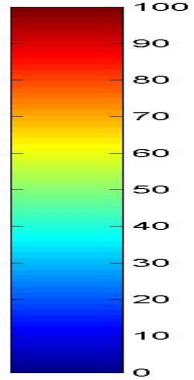




[RH %]

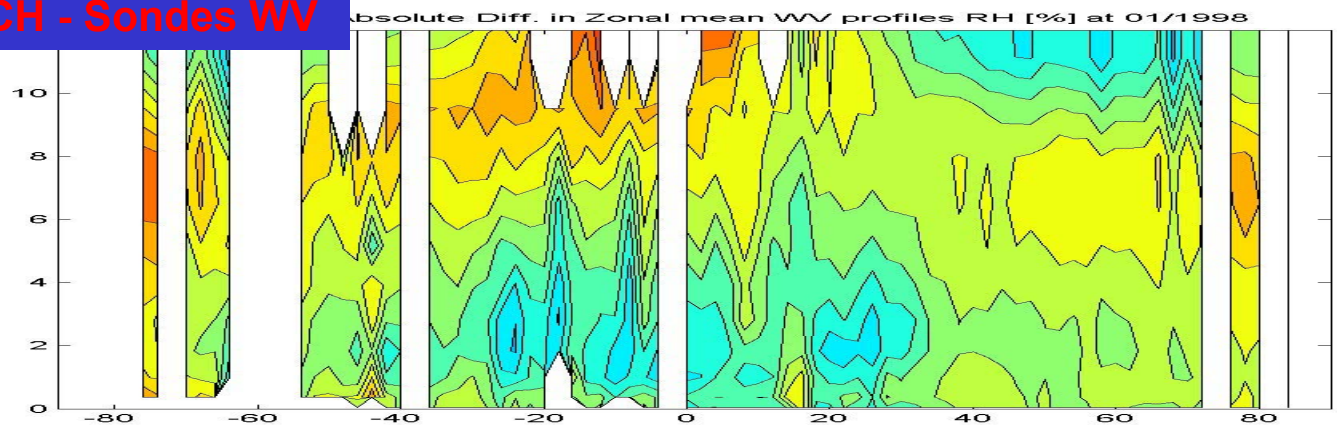
Radiosondes (ECMWF) WV

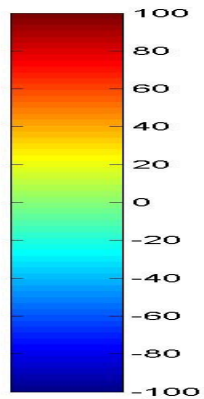




[RH%]

MATCH - Sondes WV

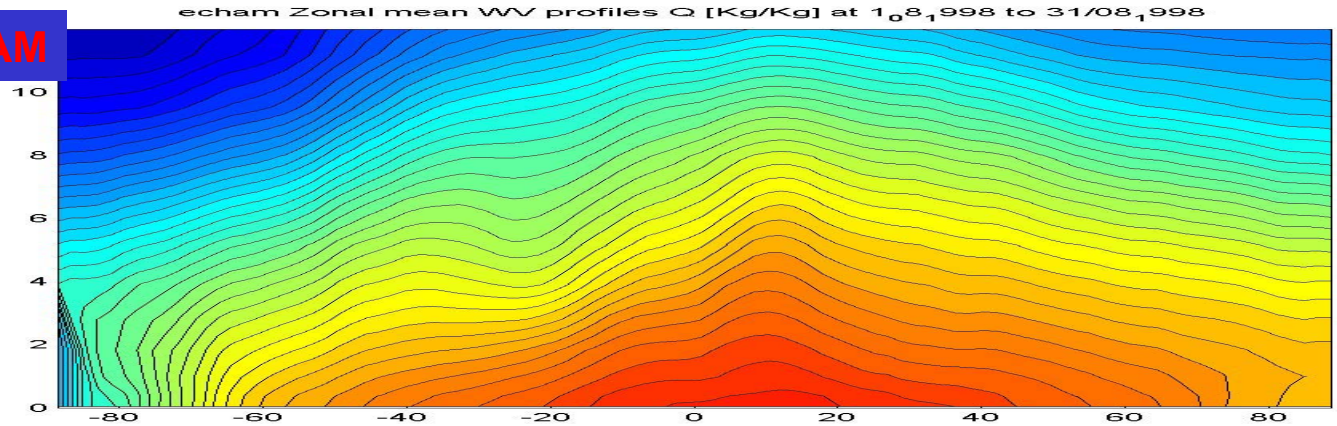


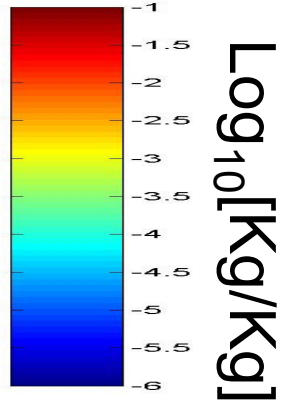


[RH%]

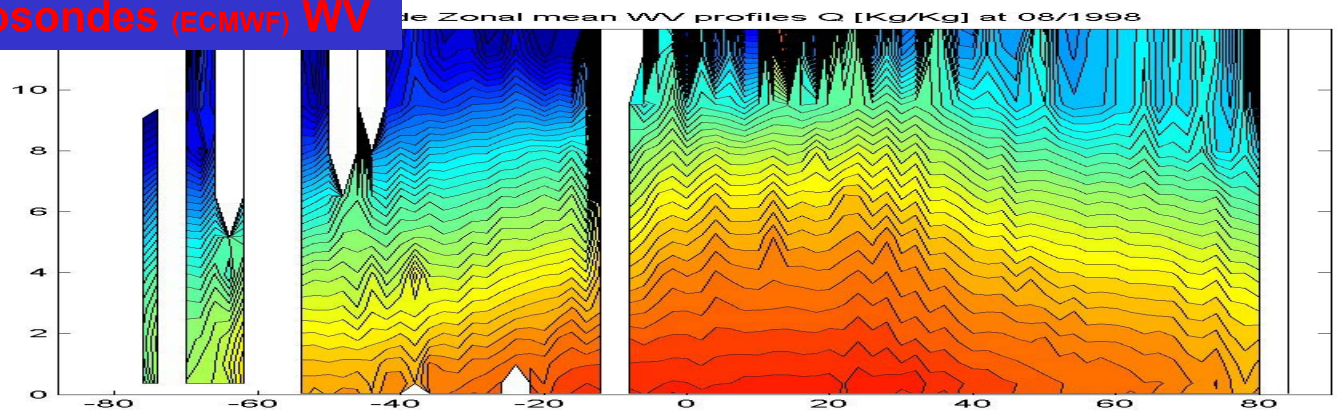
Specific humidity profiles, August 1998 (ECHAM 5.2.02)

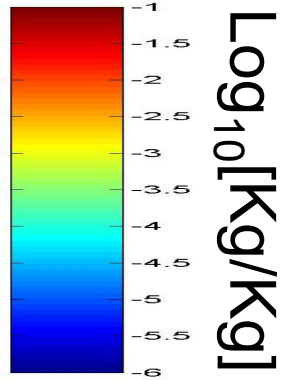
ECHAM



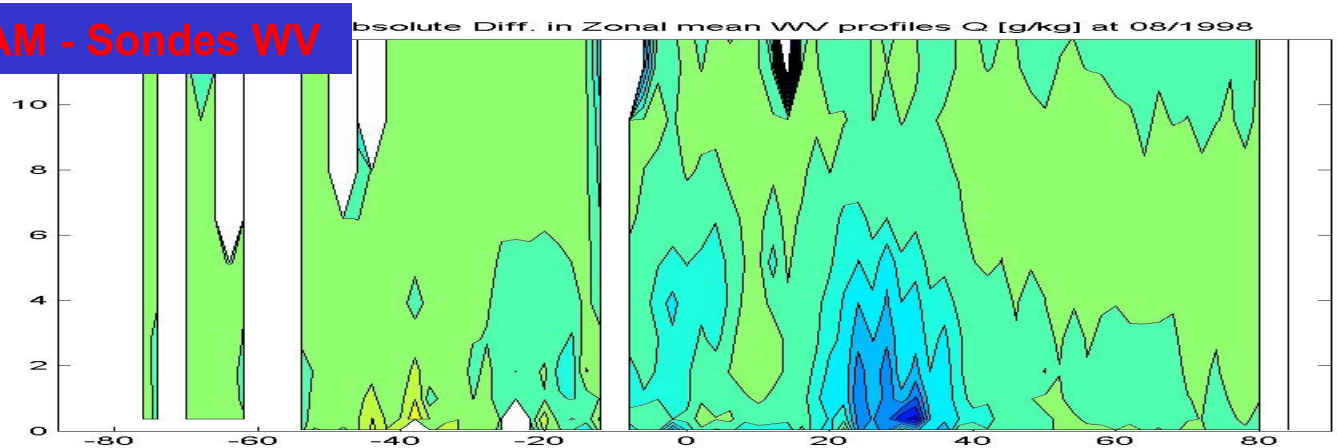


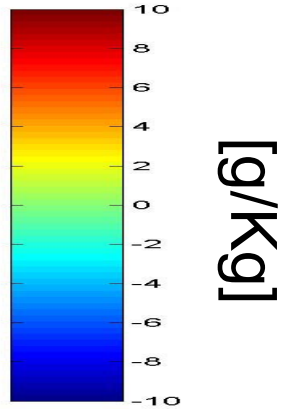
Radiosondes (ECMWF) WV





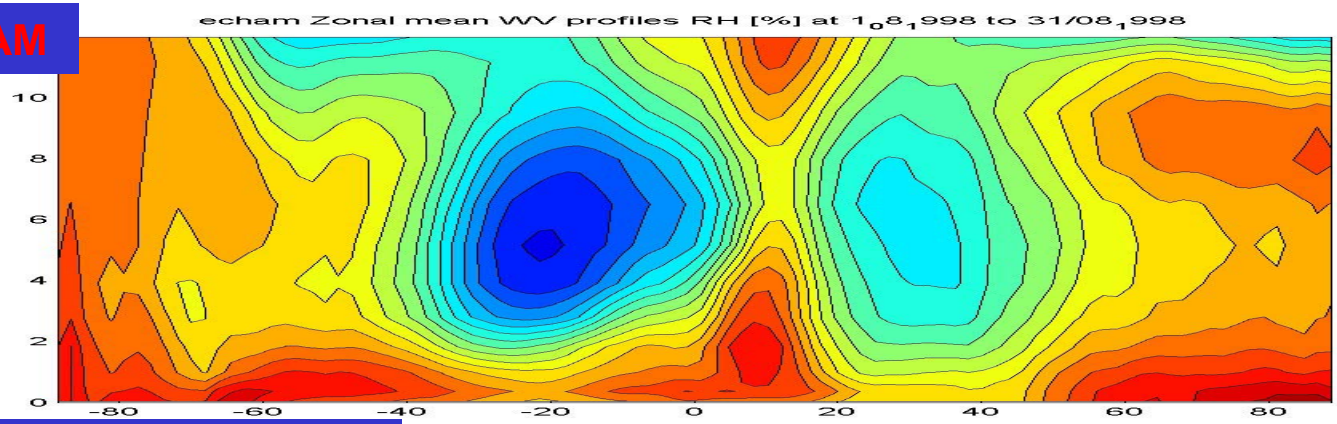
ECHAM - Sondes WV

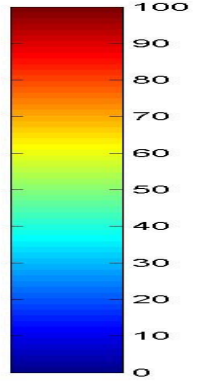




Relative humidity profiles, August 1998 (ECHAM 5.2.02)

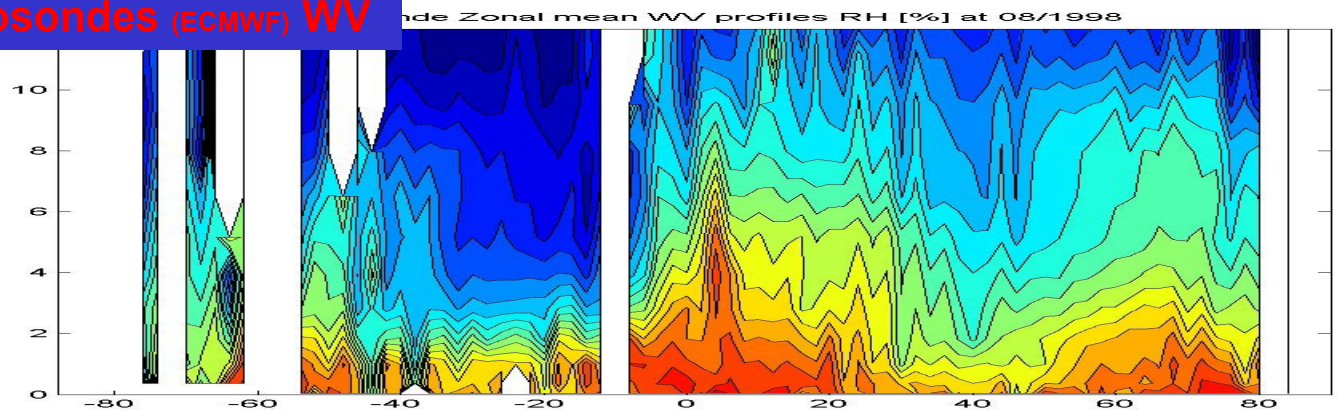
ECHAM

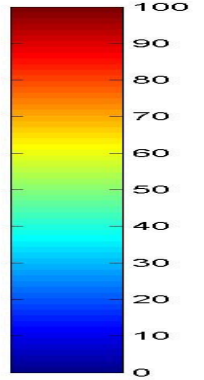




[RH %]

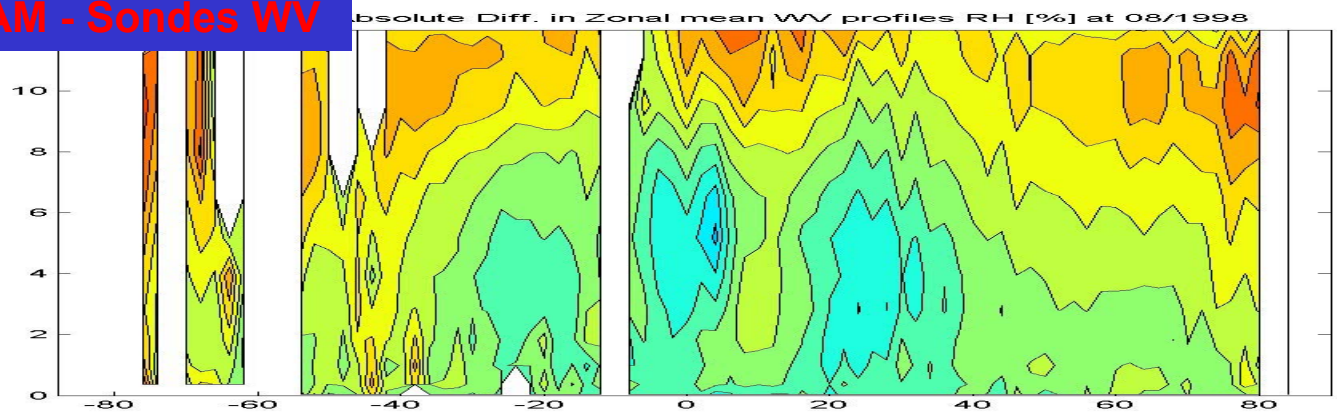
Radiosondes (ECMWF) WV

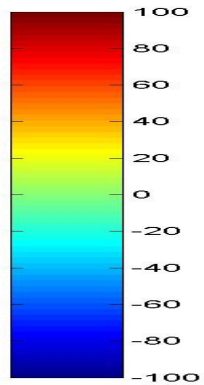




[RH%]

ECHAM - Sondes WV

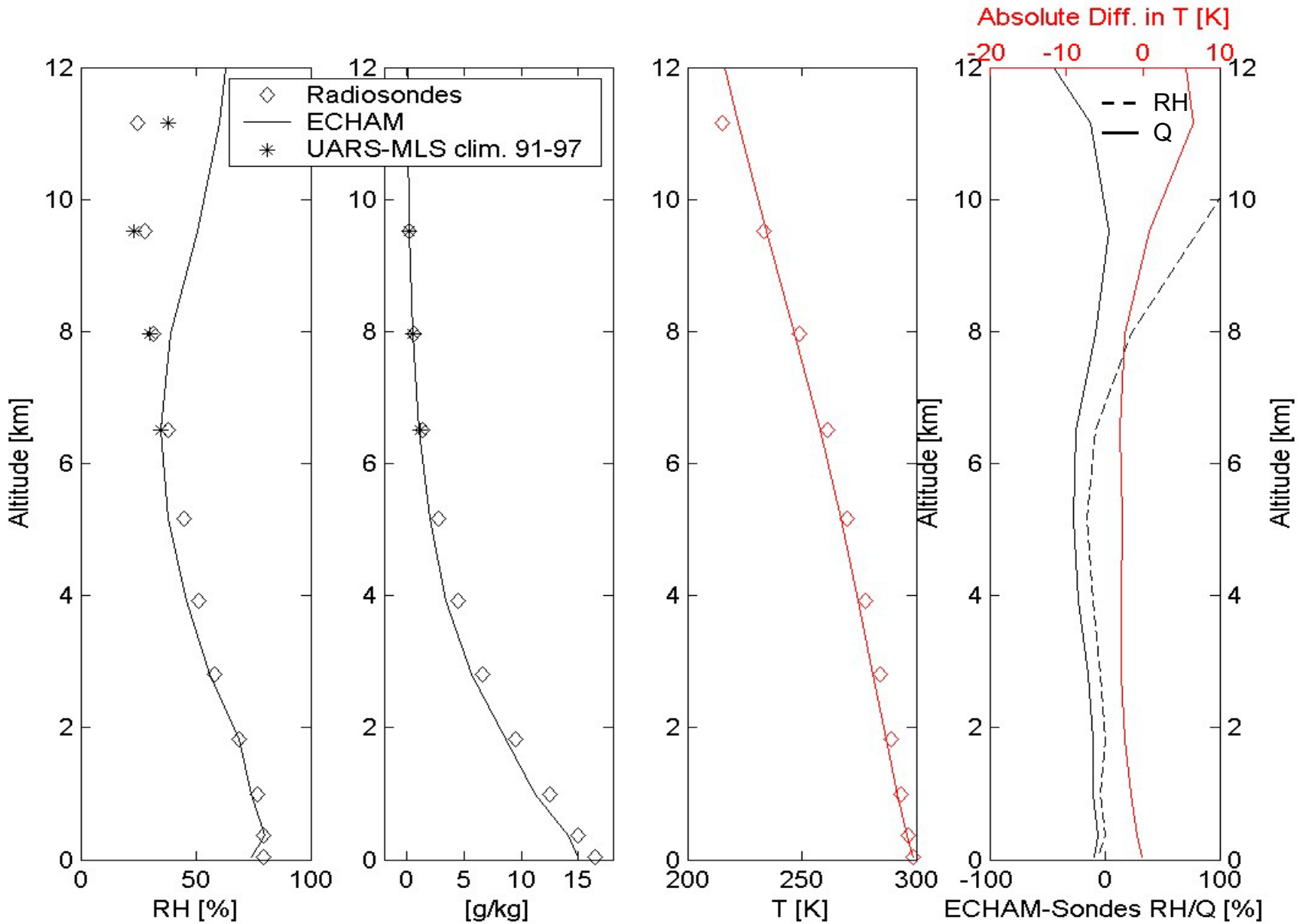




[RH%]

Average tropical RH/Q profiles, August 1998, 25S-25N
(ECHAM)

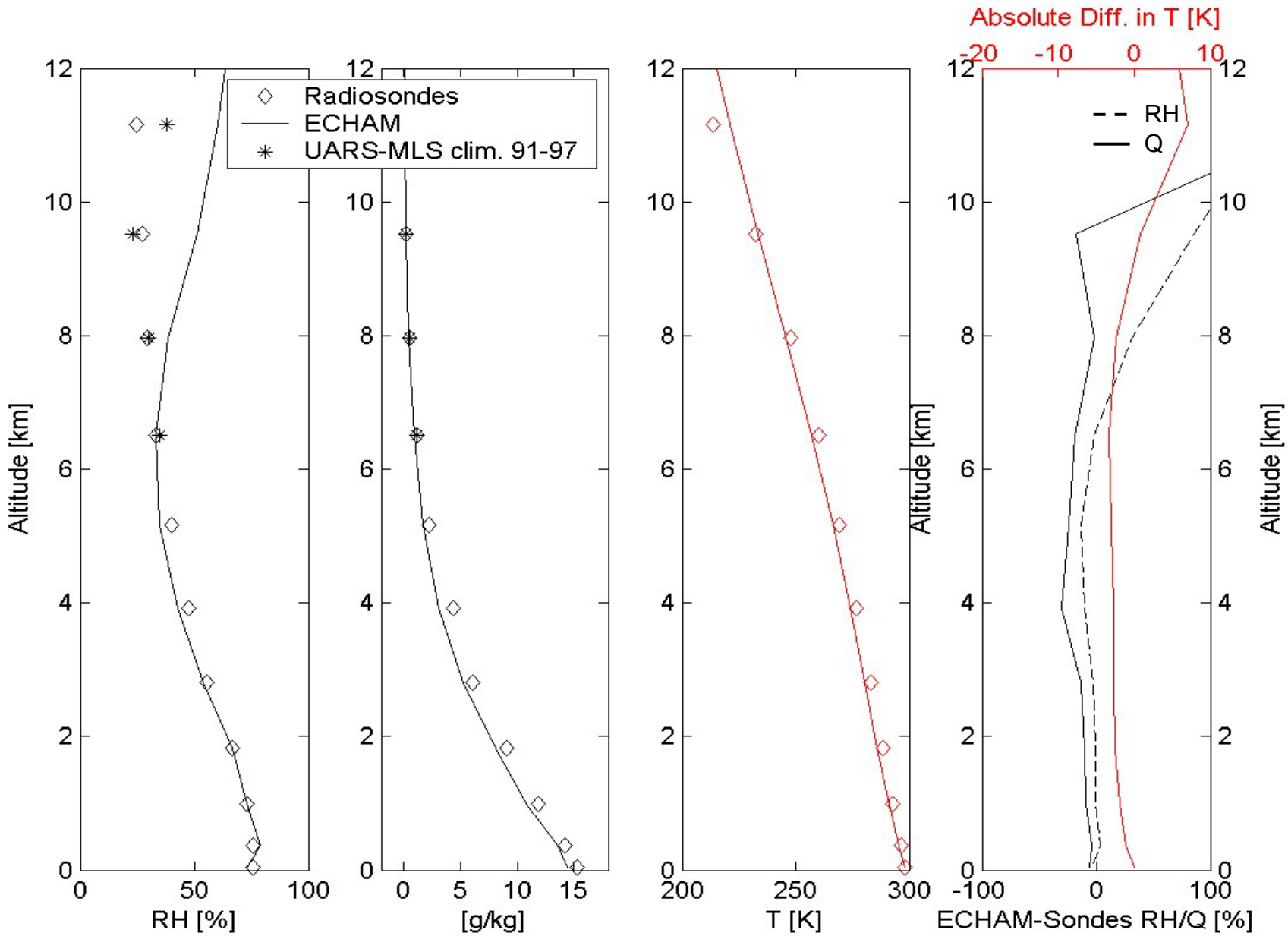
ECHAM



Average tropical RH/Q profiles, January 1998, 25S-15N

(ECHAM 10:30; Sondes 10:00-12:00 lt)

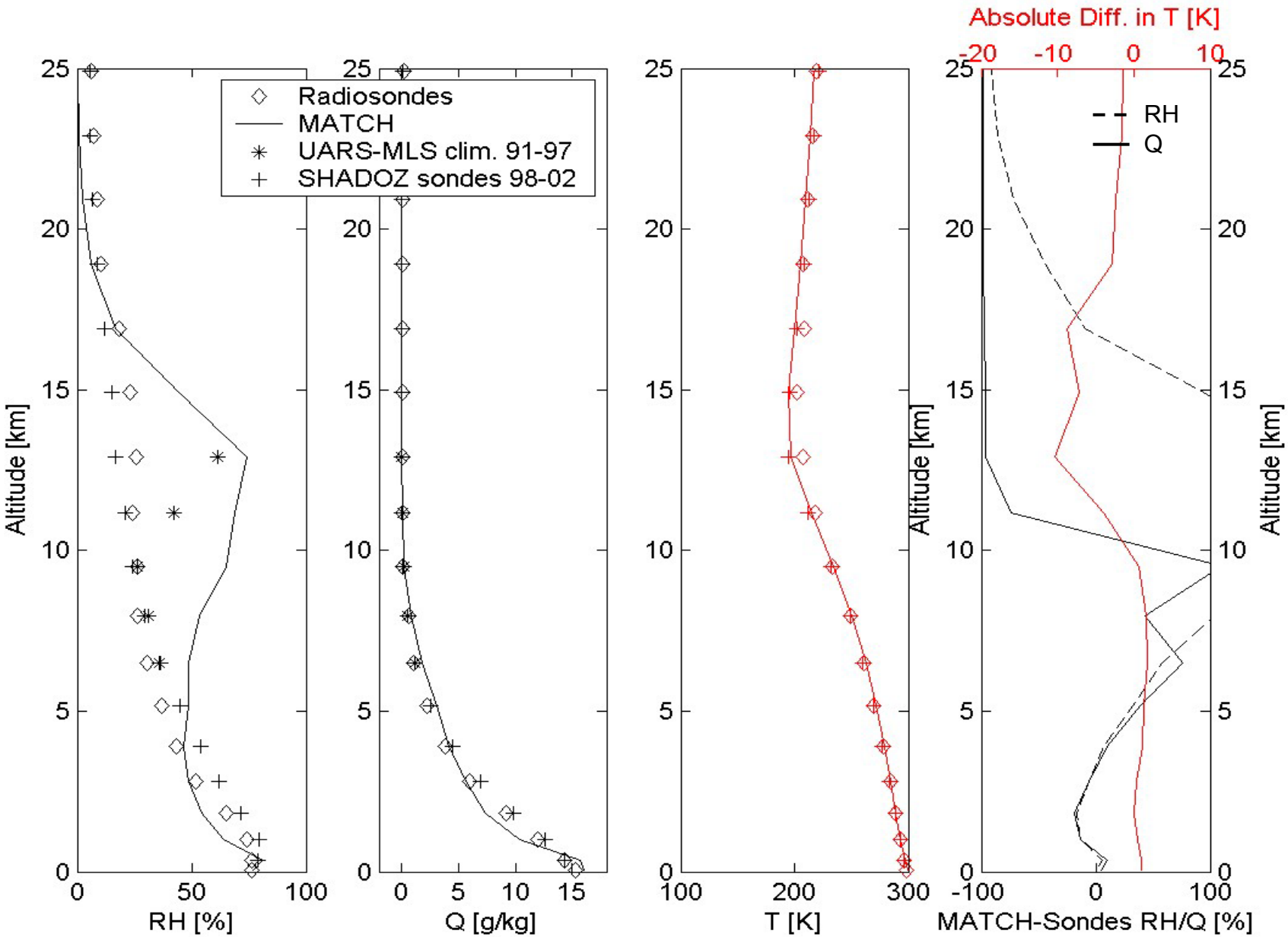
ECHAM



Average tropical RH/Q profiles, January 1998, 25S-15N

(MATCH 10:30; Sondes 10:00-12:00 lt)

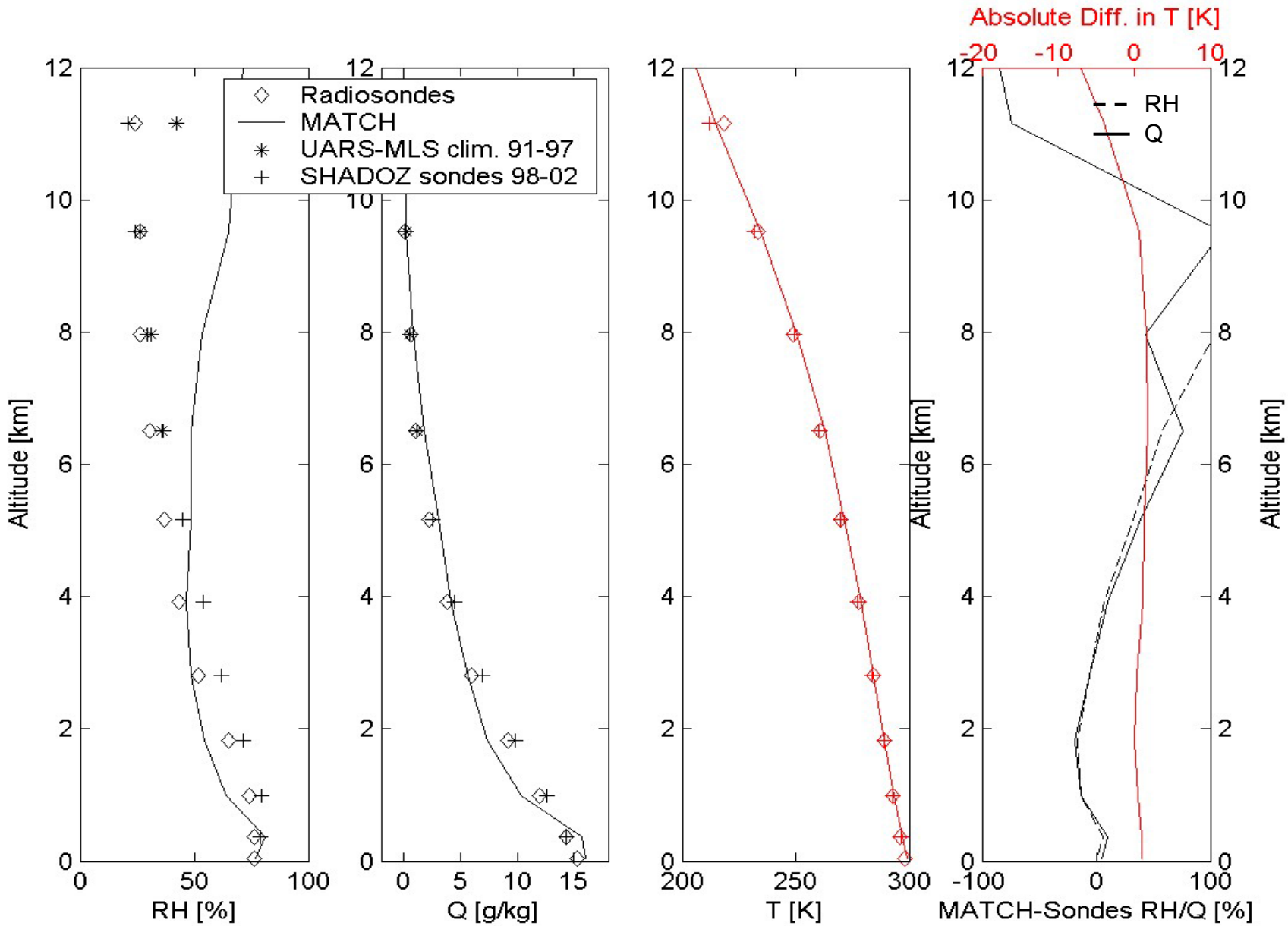
MATCH



Average tropical RH/Q profiles, January 1998, 25S-15N

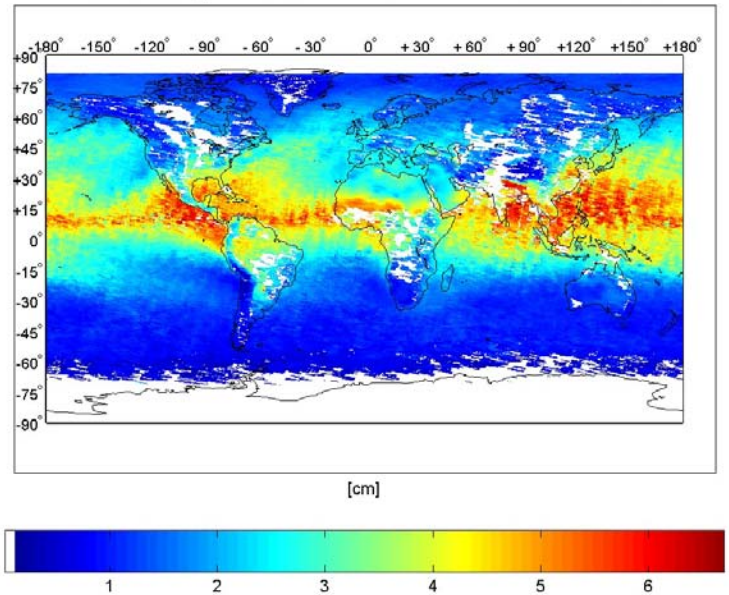
(MATCH 10:30; Sondes 10:00-12:00 lt)

MATCH

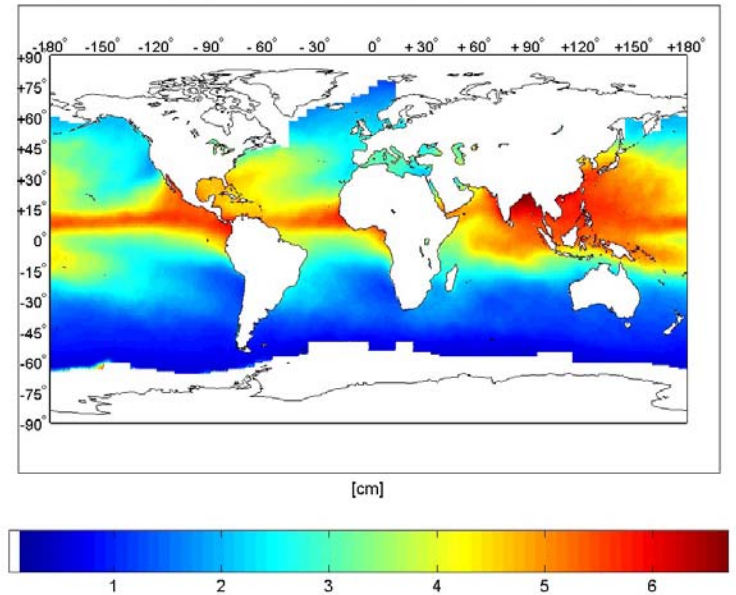


Some subtleties concerning statistics

GOME

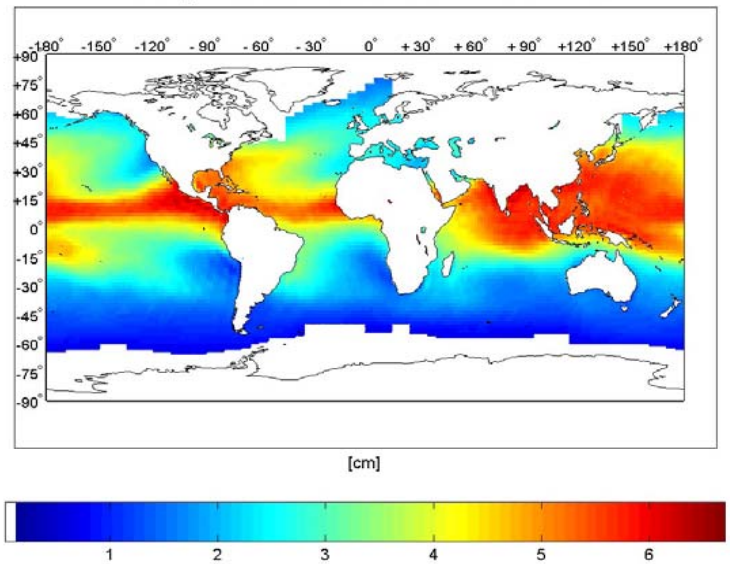


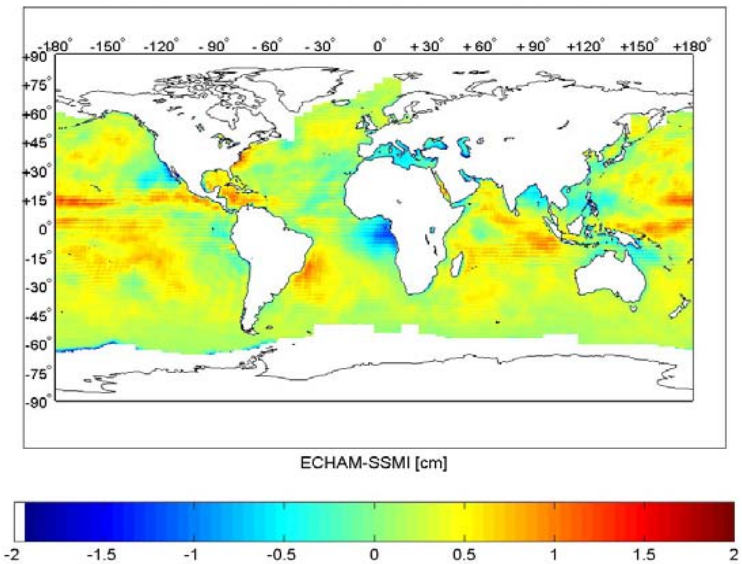
SSMI



5 year averages August 1995-2000

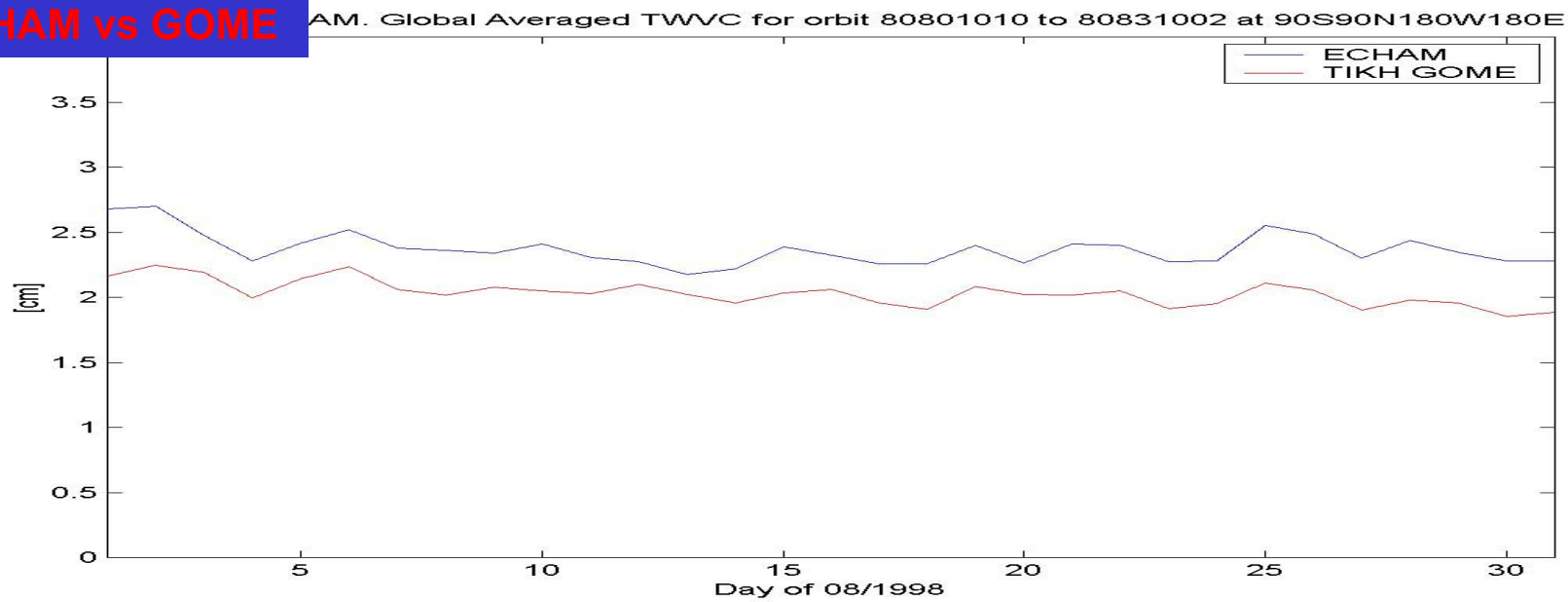
ECHAM 5.2.02



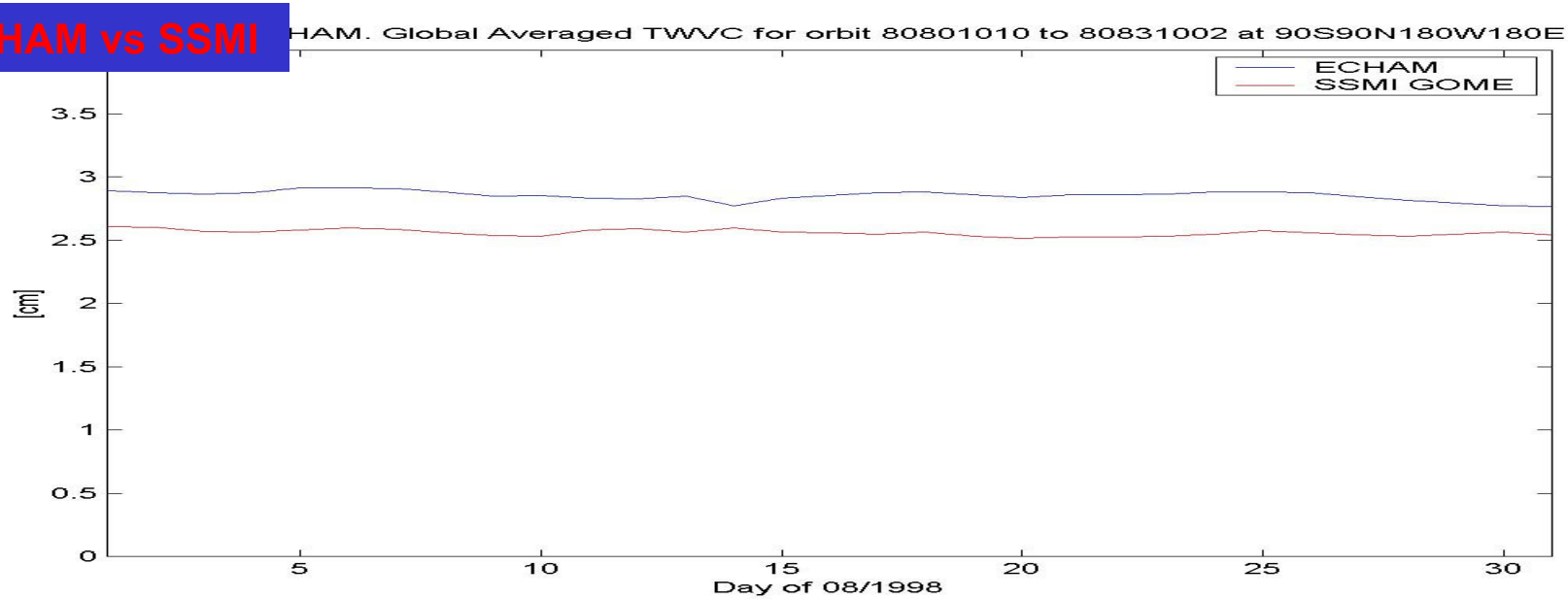


ECHAM-SSMI

ECHAM vs GOME



ECHAM vs SSMI



Conclusions

- There can be serious regional differences between satellite observations and model total water vapor columns of up to 50%.
- Global and regional averages compare usually quite well (diff. <10%)
- Measurement resolution issues significantly influences the residual amplitudes.
- Impact of the GOME cloud mask on the comparisons has to be investigated in more detail: bias of the model?

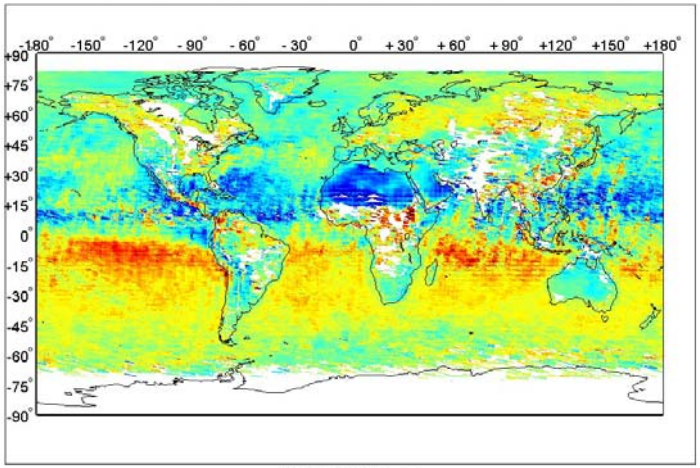
Outlook

- Planned time series 1995 to 2004. (GOME-1 period)
- Data for 2000 (will be) available: Inter-comparison studies with AEROCOM models and AERONET measurements possible.
- Sensitivity studies on the impact of relative humidity on aerosol optical properties.

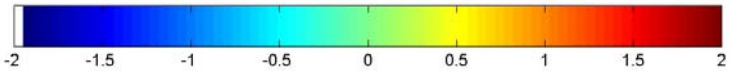
Acknowledgements

We would like to thank,
• Swen Metzger (MPI-CHEM, Mainz) for providing ECHAM 5 data.
• Michael Traub (MPI-CHEM, Mainz) and Peter van Veldthoven (KNMI, de Bilt, Netherlands) for providing ECMWF data.
• Marc Allaart (KNMI, de Bilt, The Netherlands) for providing radiosonde (ECMWF network) data.
• Ahilleas Maurellis (SRON, Utrecht, The Netherlands) for providing GOME level 1 data.
• NVAP data were obtained from the NASA Langley Research Center Atmospheric Sciences Data Center.

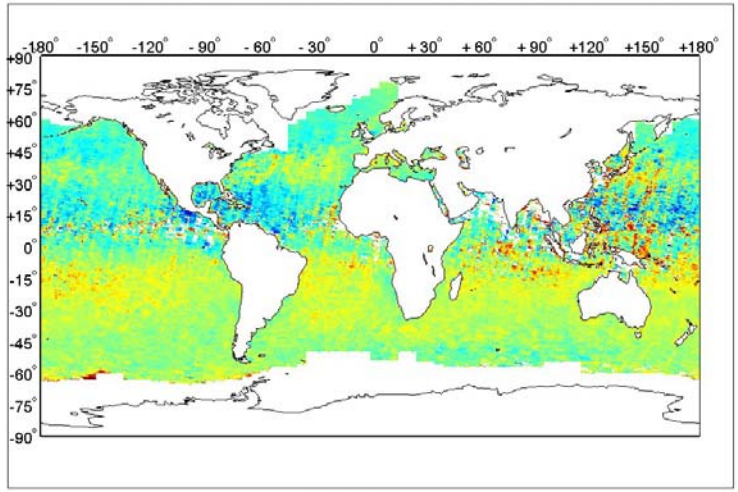
NCEP vs. TIKH. Diff TWVC for orbit 50801001 to 831223 at 90S90N180W180E



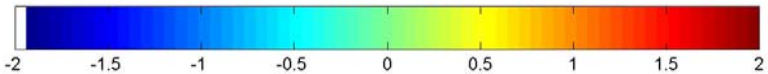
NCEP-TIKH [cm]



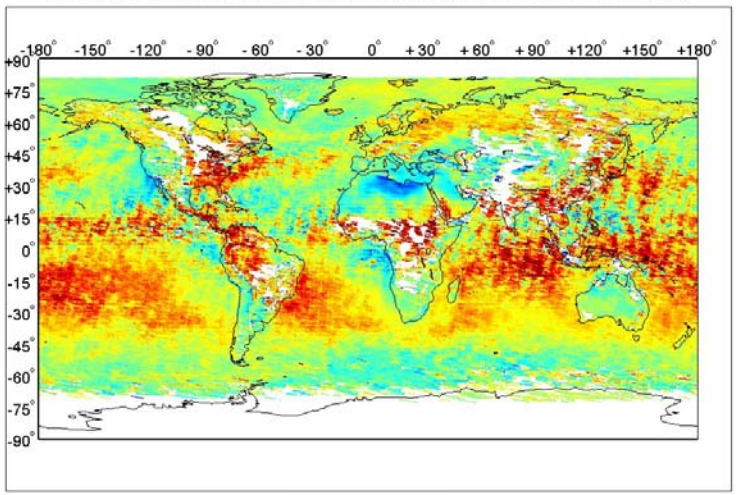
SSMI vs. TIKH. Diff TWVC for orbit 50801001 to 831223 at 90S90N180W180E



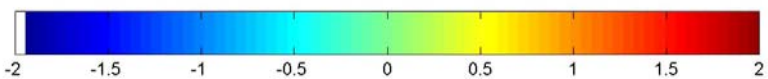
SSMI-TIKH [cm]



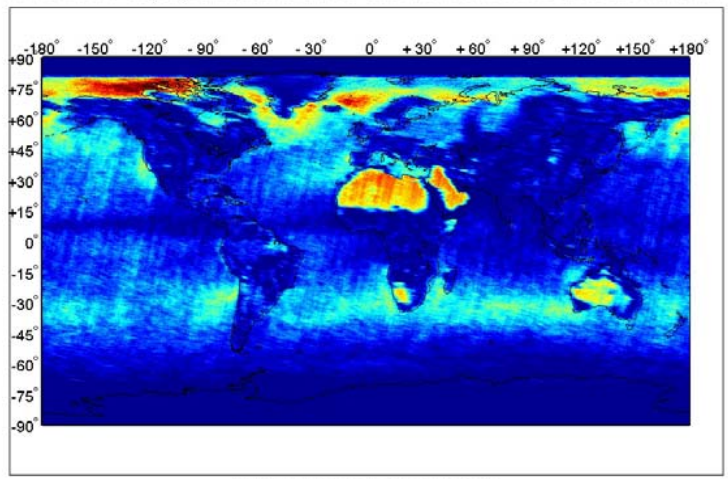
ECHAM vs. TIKH. Diff TWVC for orbit 50801001 to 831223 at 90S90N180W180E



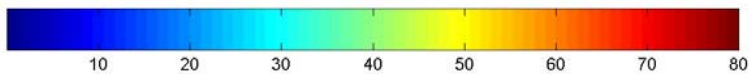
ECHAM-TIKH [cm]

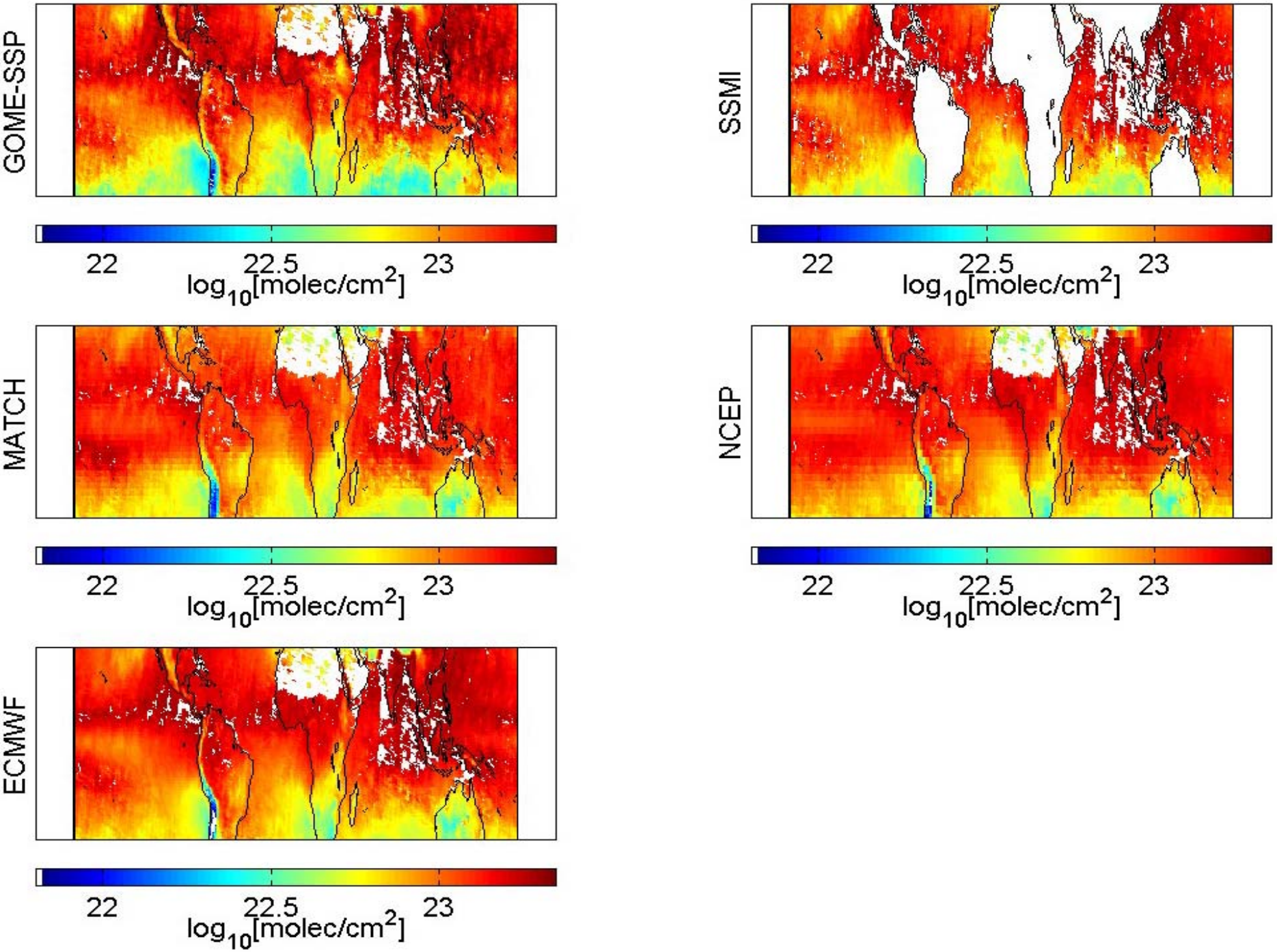


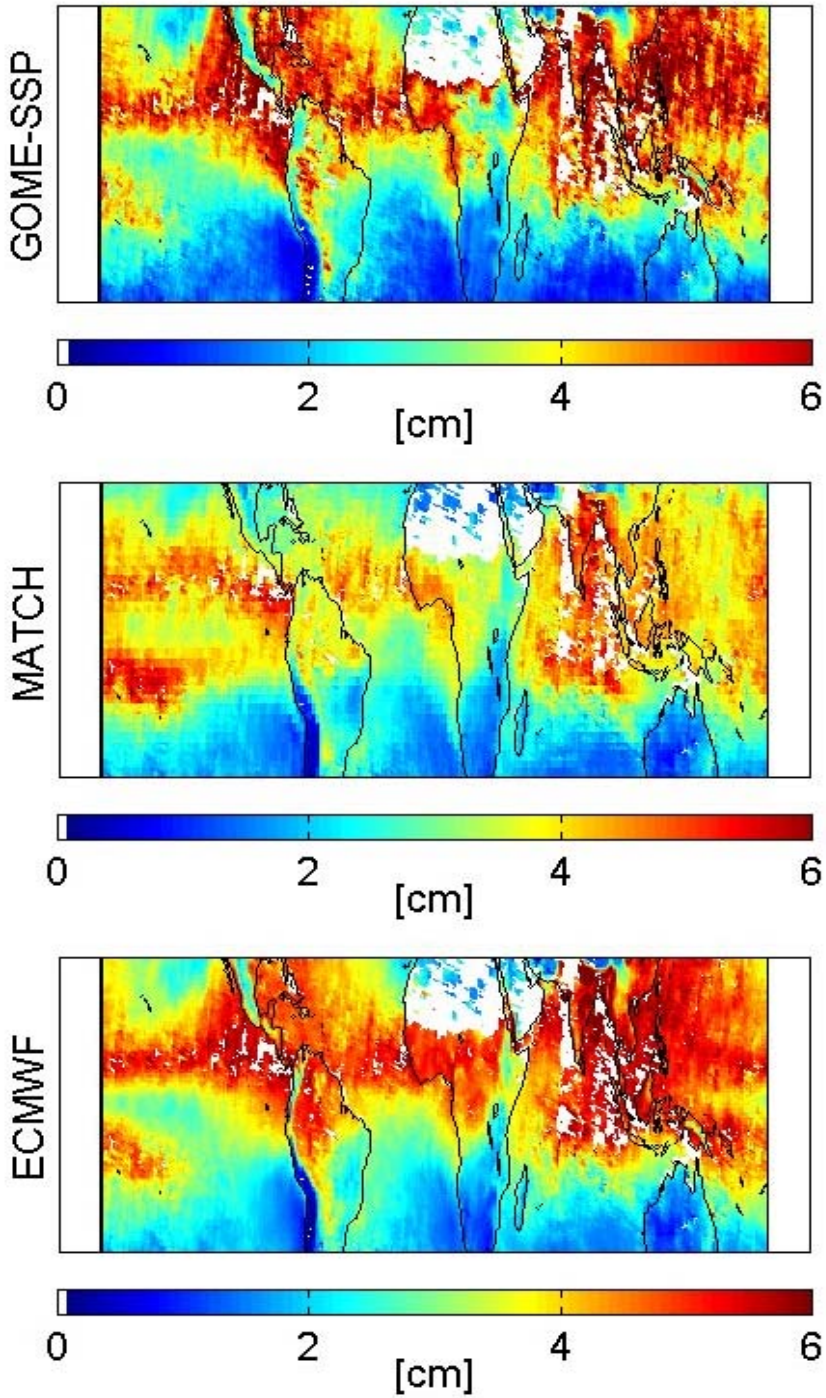
TIKH GOME Averaged ground-pixel number for orbit 50801001 to 831223 at 90S90N180W180E



Number of averaged ground pixels




GOME-SSP
SSMI
MATCH
NCEP
ECMWF
22
22.5
23
log10[molec/cm2]


GOME-SSP
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2
4
6
[cm]
SSMI
1
2
3
4
5
6
[cm]
MATCH
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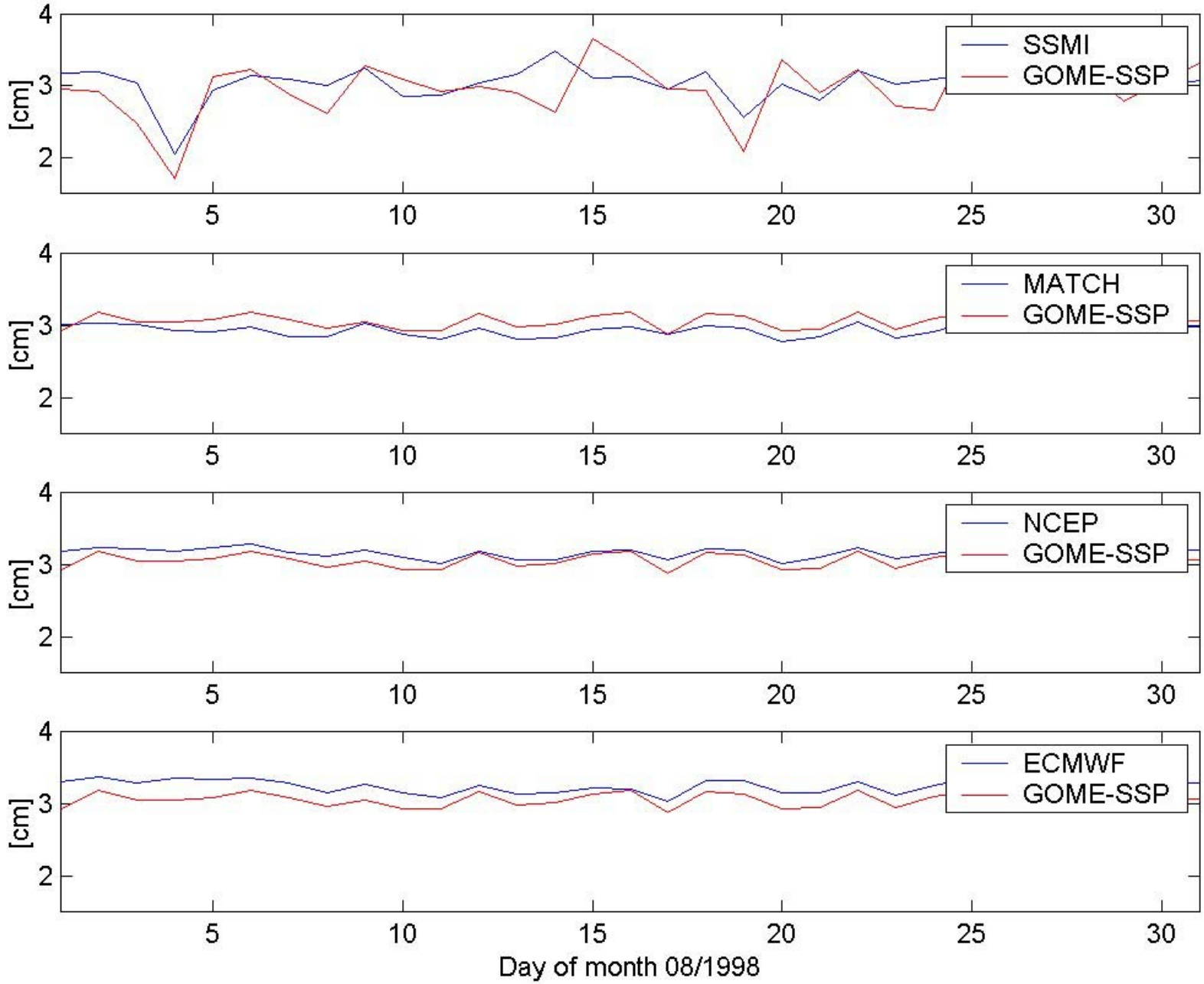
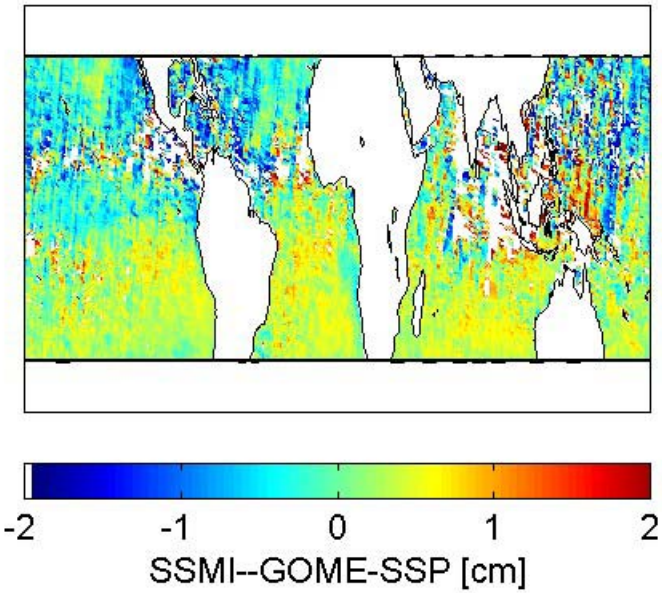
2
4
6
[cm]
NCEP
0
2
4
6
[cm]
ECMWF
0
2
4
6
[cm]


SSMI
GOME-SSP
MATCH
GOME-SSP
NCEP
GOME-SSP
ECMWF
GOME-SSP
[cm]
2
3
4
5
10
15
20
25
30
Day of month 08/1998


-2
-1
0
1
2
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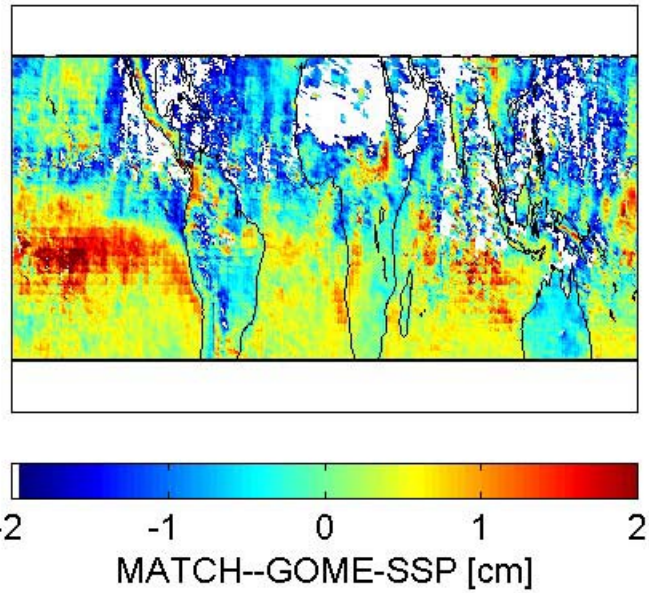
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2
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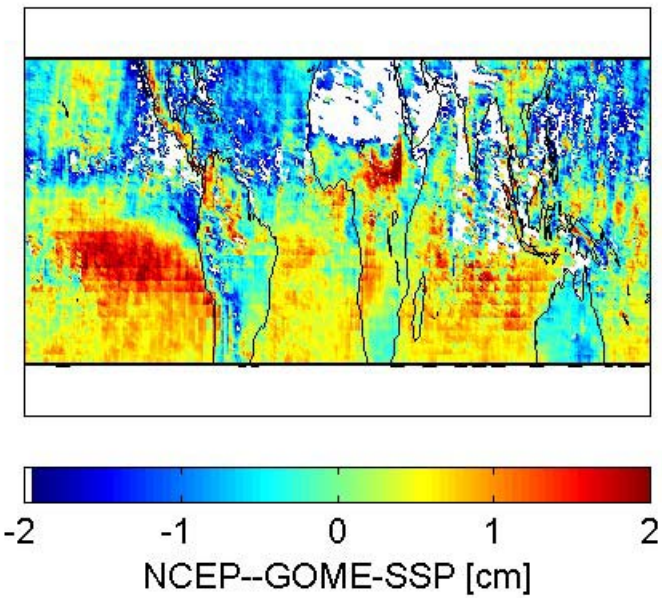
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1
2
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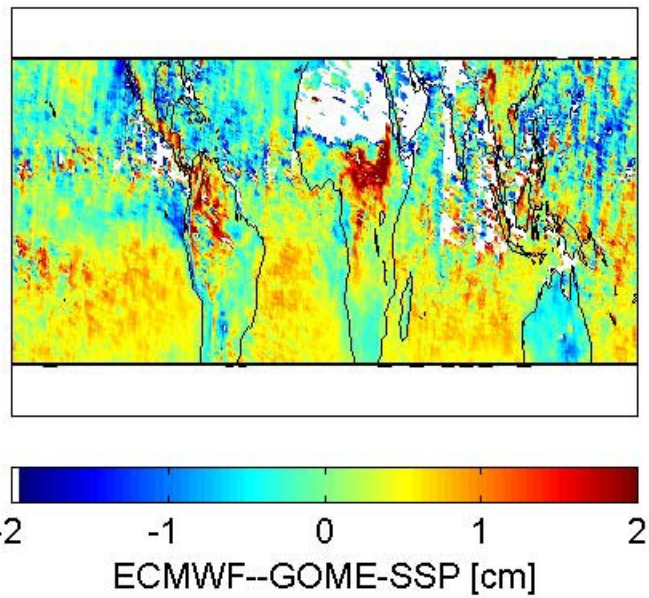
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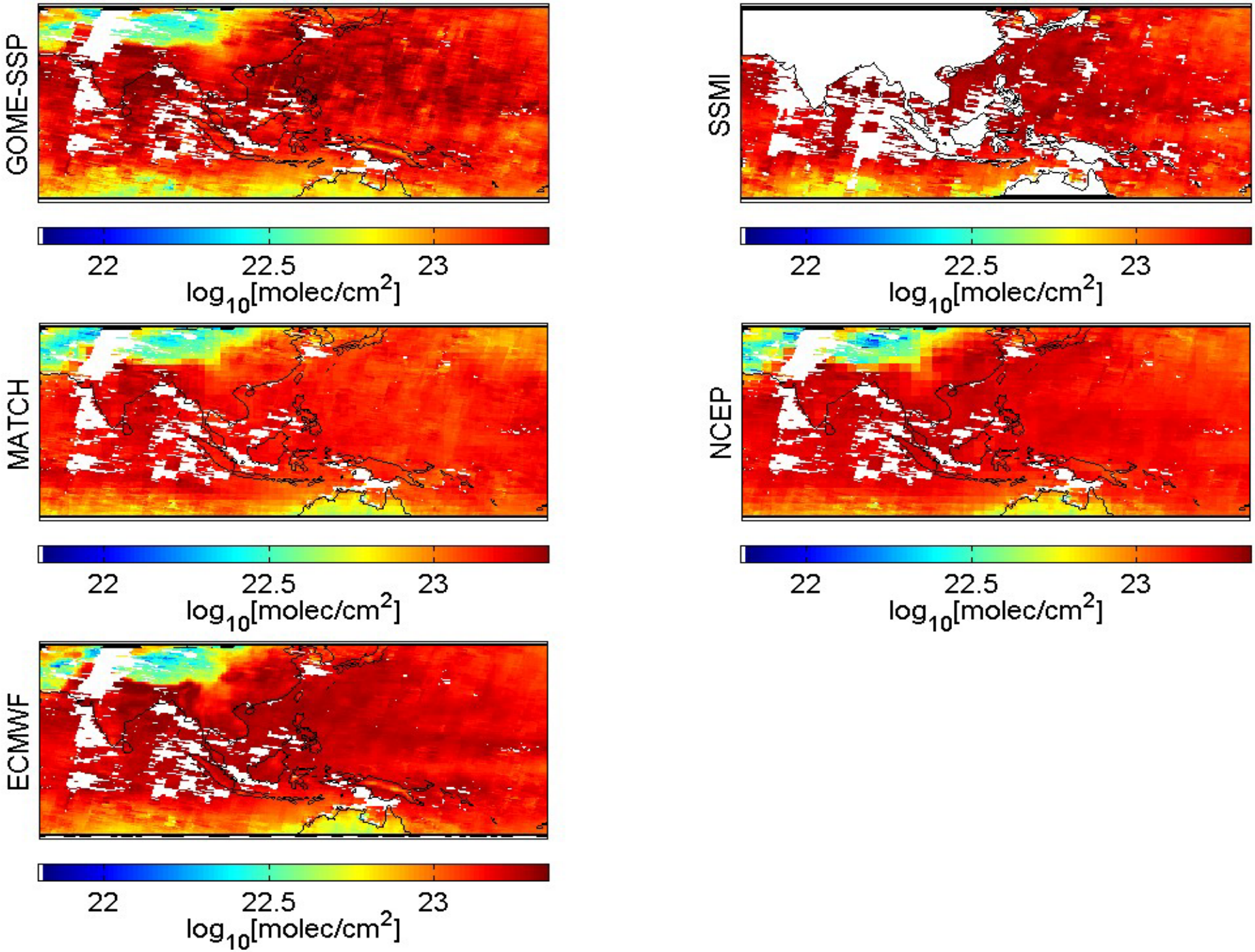
1
2
ECMWF--GOME-SSP [cm]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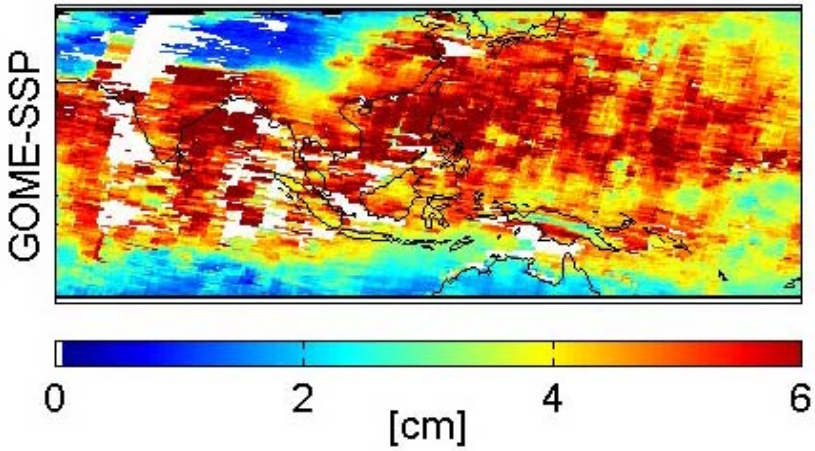
SSMI
MATCH
NCEP
ECMWF
22
22.5
23
log10[molec/cm2]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4
6
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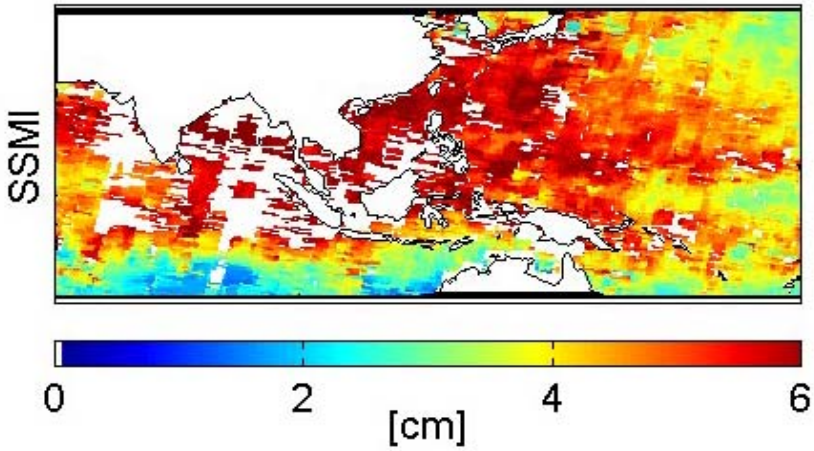
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6
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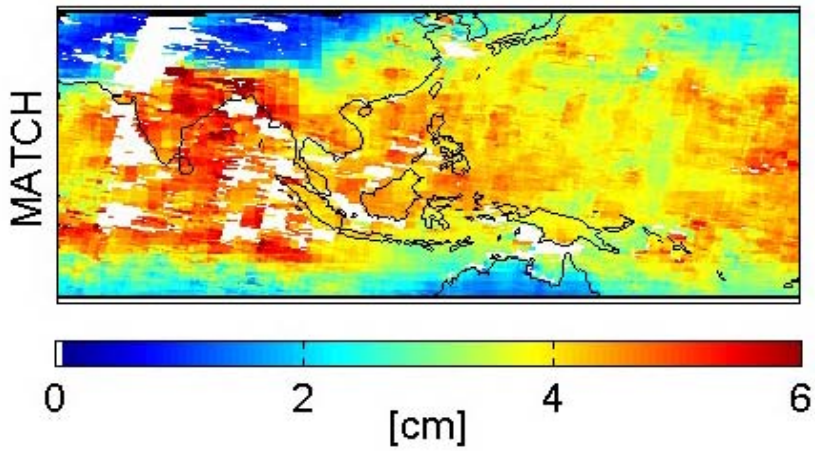
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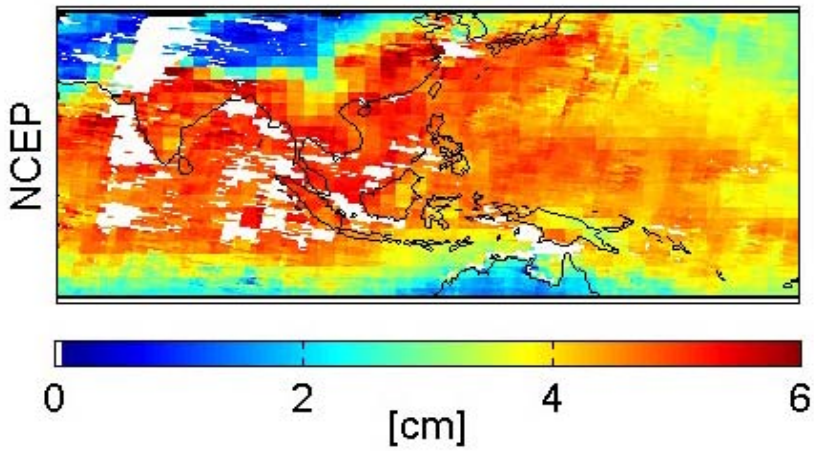
4
6
[cm]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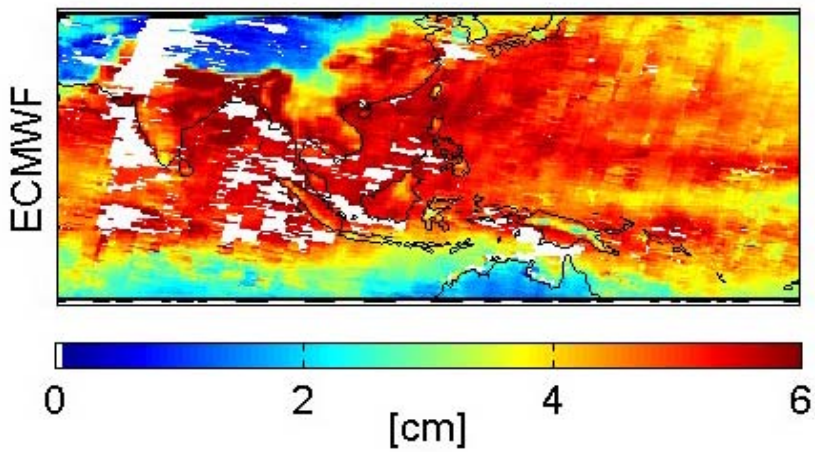
ECMWF
0
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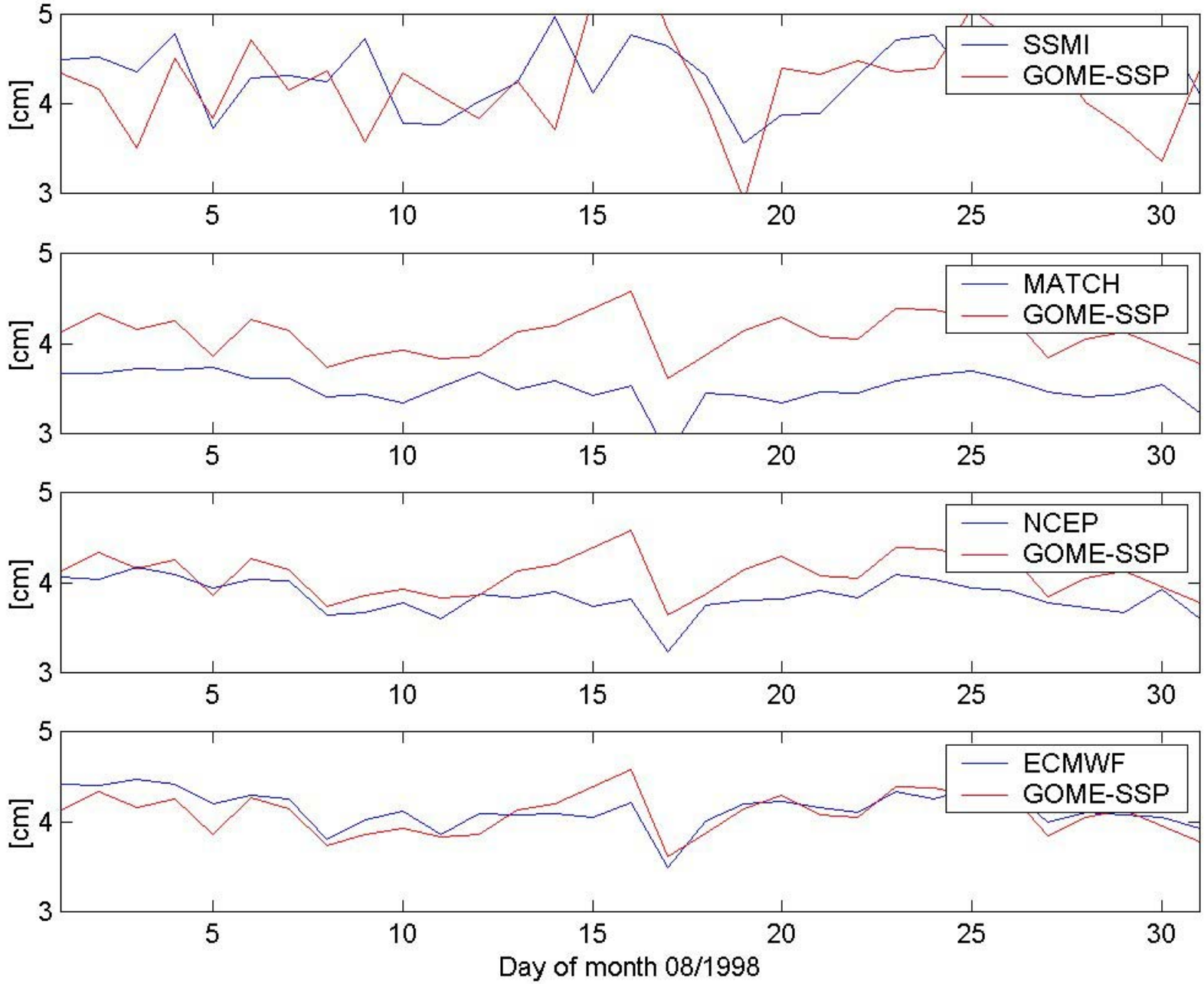
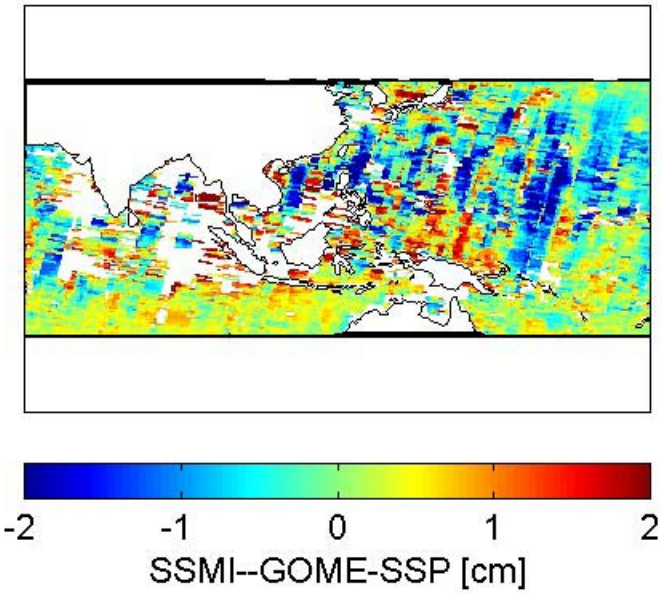
4
6
[cm]


SSMI
GOME-SSP
MATCH
GOME-SSP
NCEP
GOME-SSP
ECMWF
GOME-SSP
[cm]
5
4
3
5
10
15
20
25
30
Day of month 08/1998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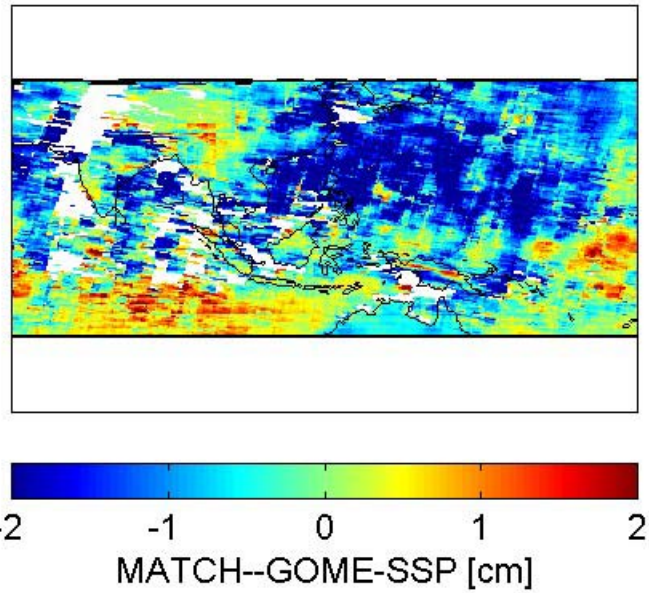
0
1
2
SSMI--GOME-SSP [cm]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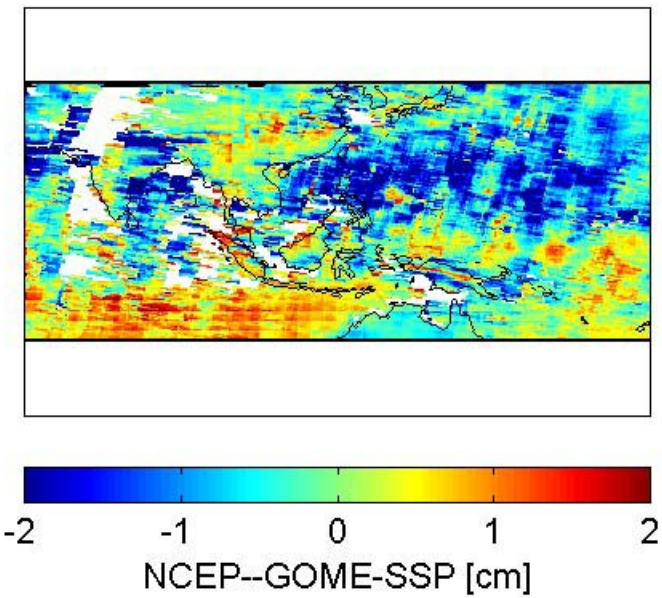
MATCH--GOME-SSP [cm]


-2
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0
1
2
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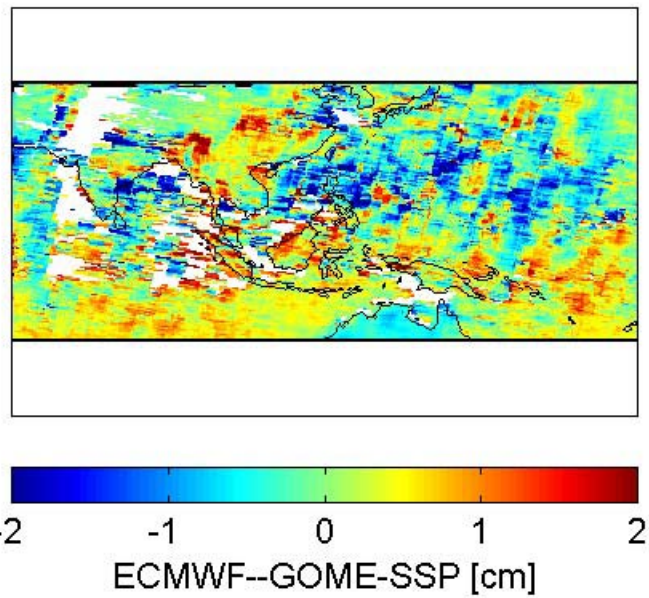
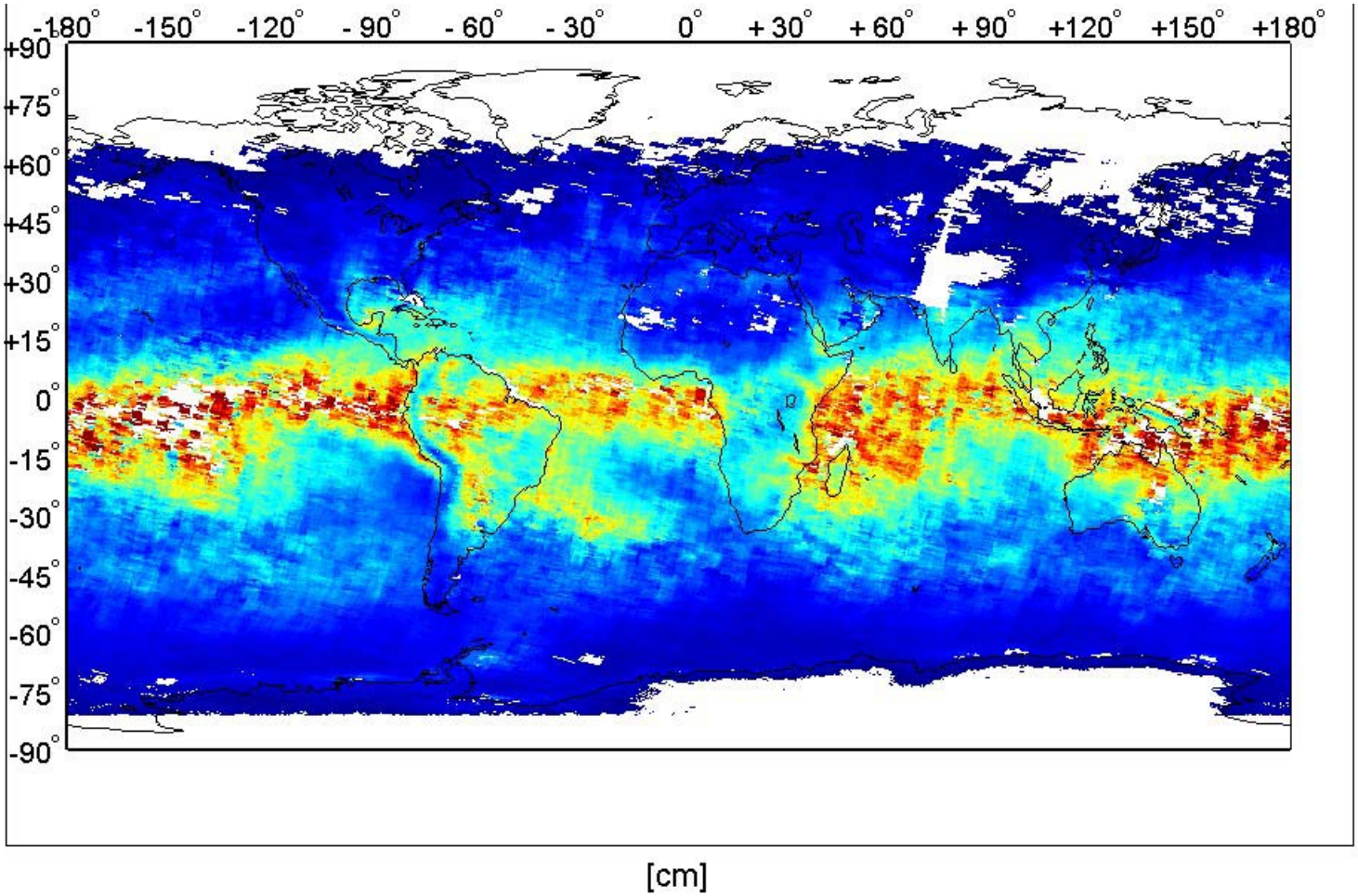

-2
-1
0
1
2
ECMWF--GOME-SSP [cm]

January 1998

Monthly averaged DATA, January 1998

(O4-cloud screening)

GOME

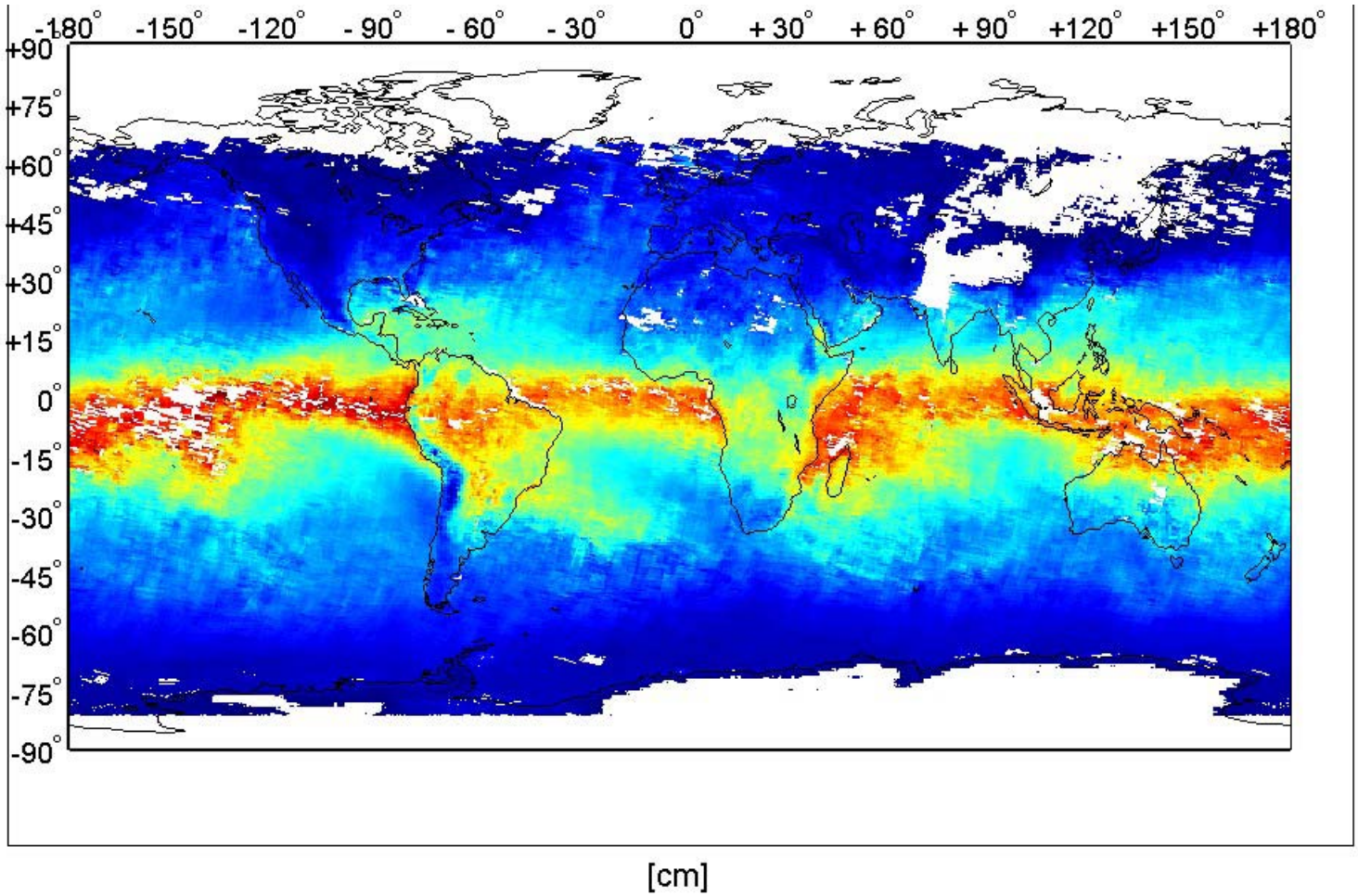


Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.

Monthly averaged DATA, January 1998

(O4-cloud screening)

NVAP



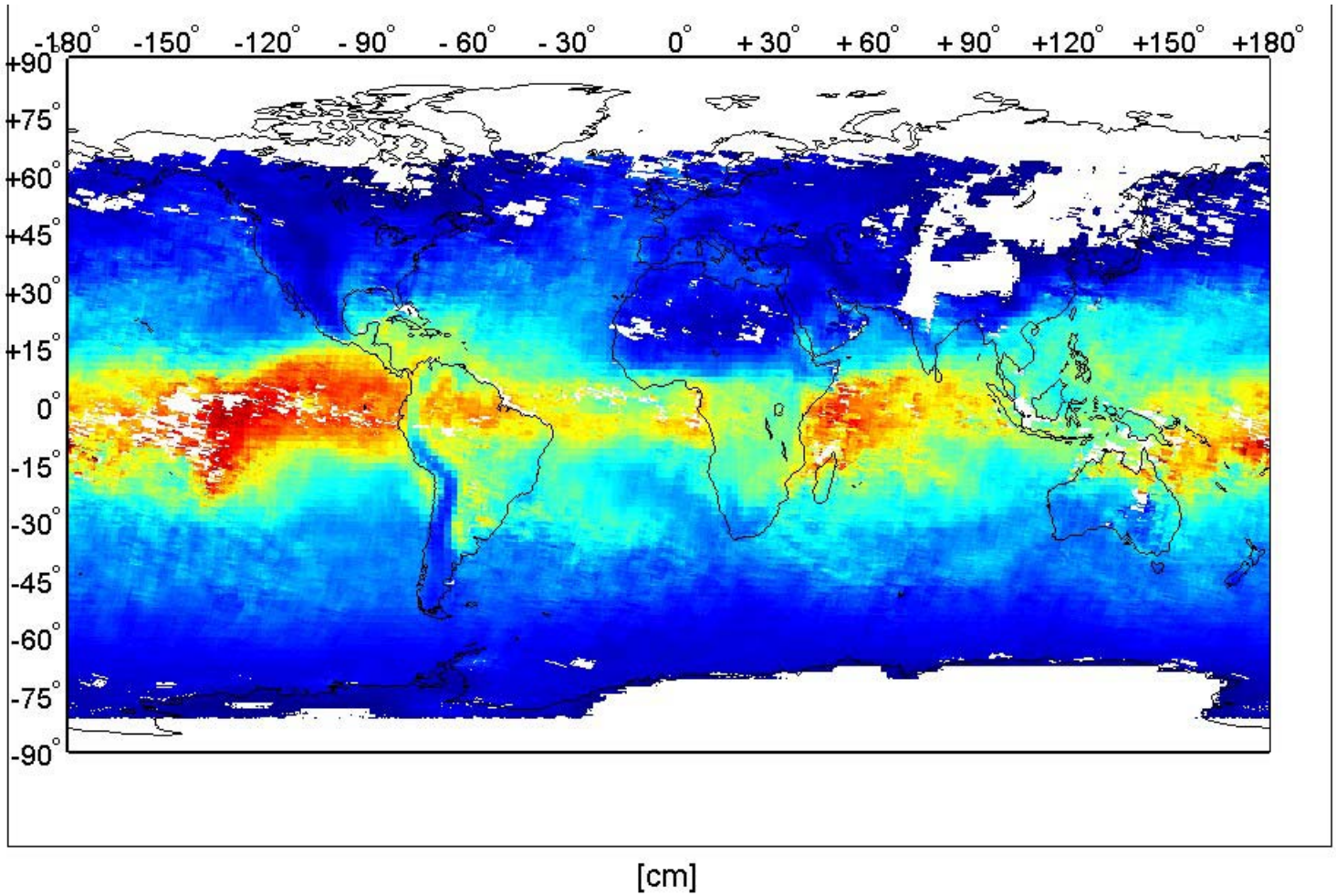
NVAP total water vapor column based on SSM/I, TOVS and Sondes,

(same averaging statistics applied as for GOME)

Monthly averaged DATA, January 1998

(O4-cloud screening)

MATCH



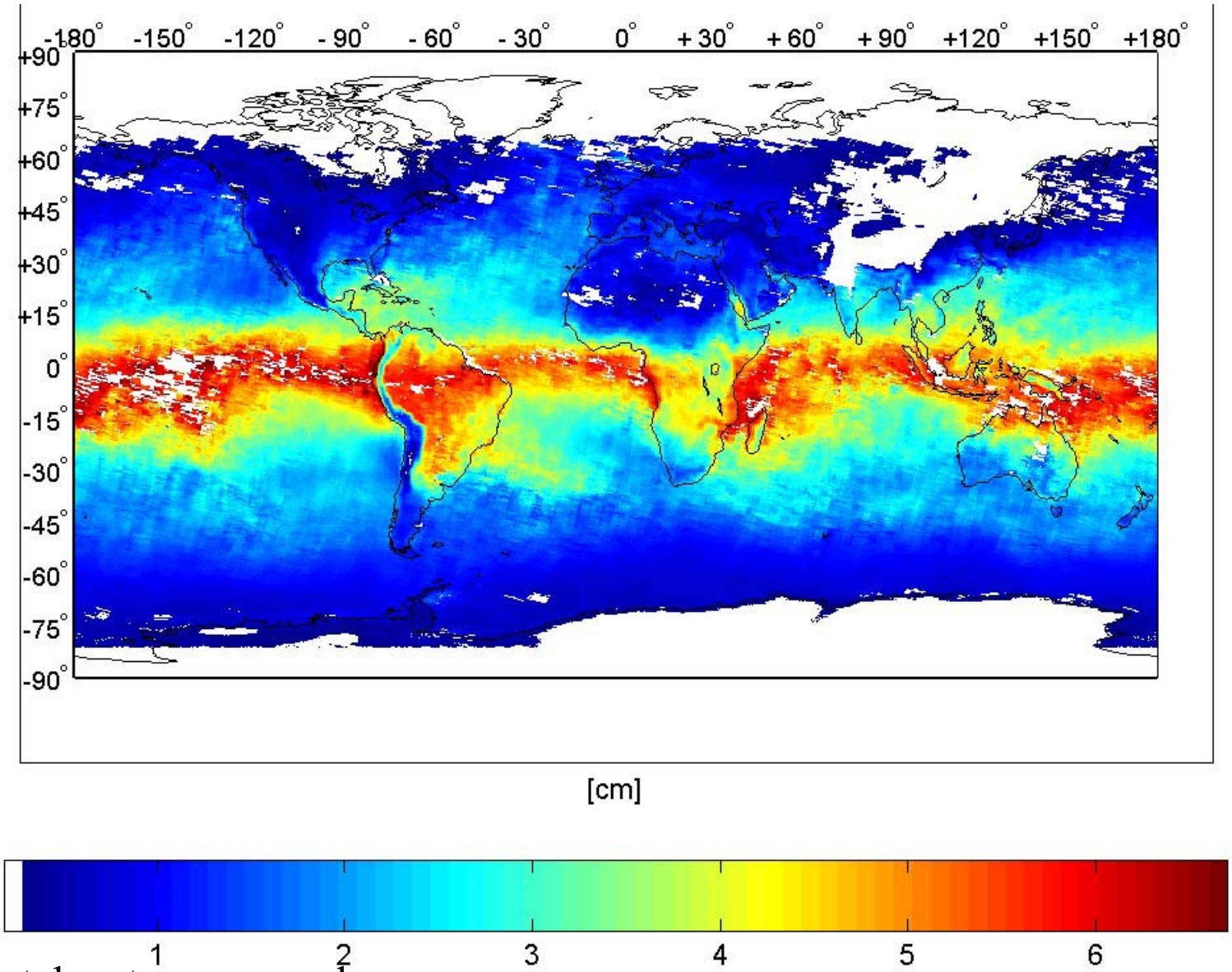
MATCH-MPIC total water vapor column,

(same averaging statistics applied as for GOME)

Monthly averaged DATA, January 1998

(O4-cloud screening)

ECMWF



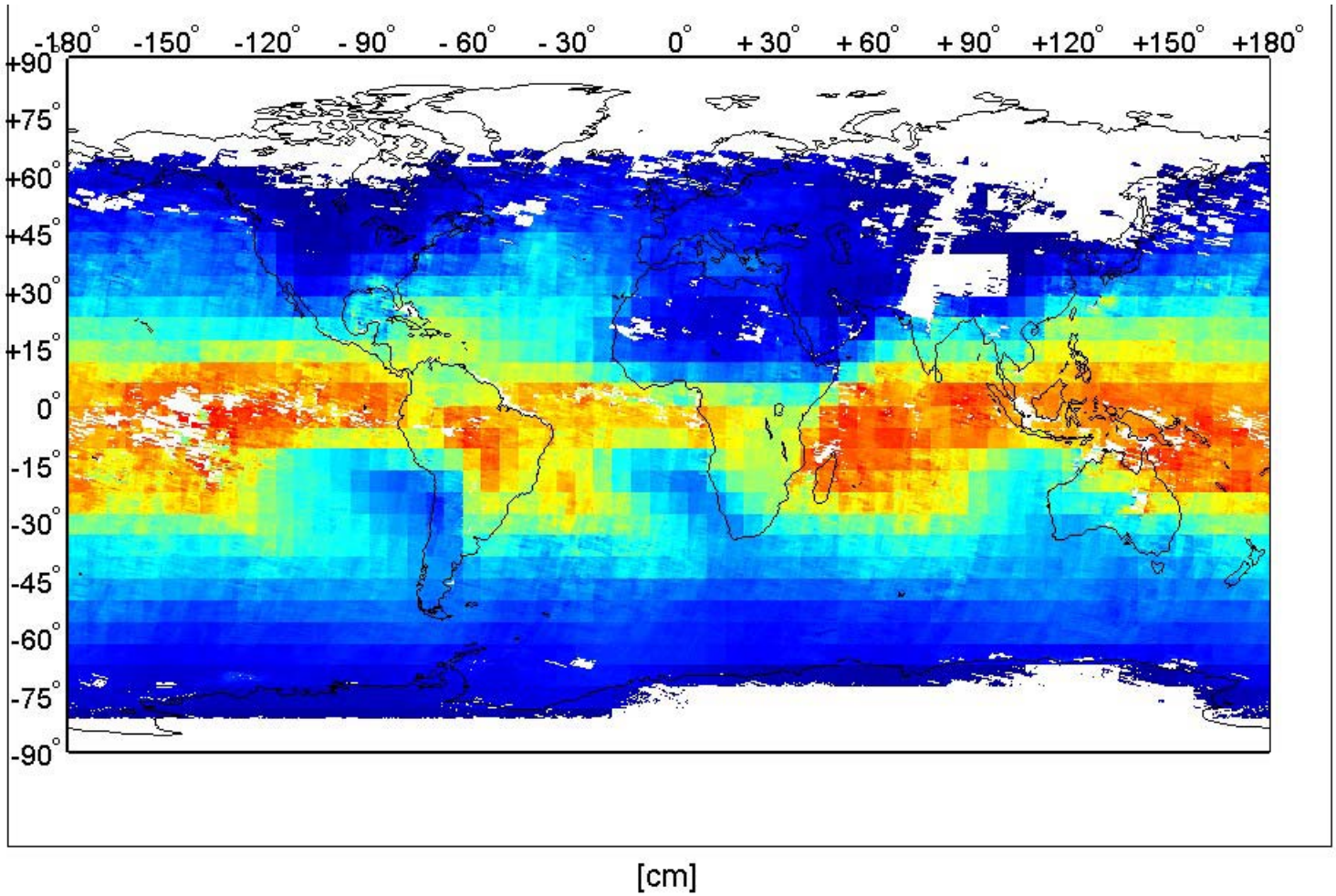
ECMWF total water vapor column,

(same averaging statistics applied as for GOME)

Monthly averaged DATA, January 1998

(O4-cloud screening)

ECHAM



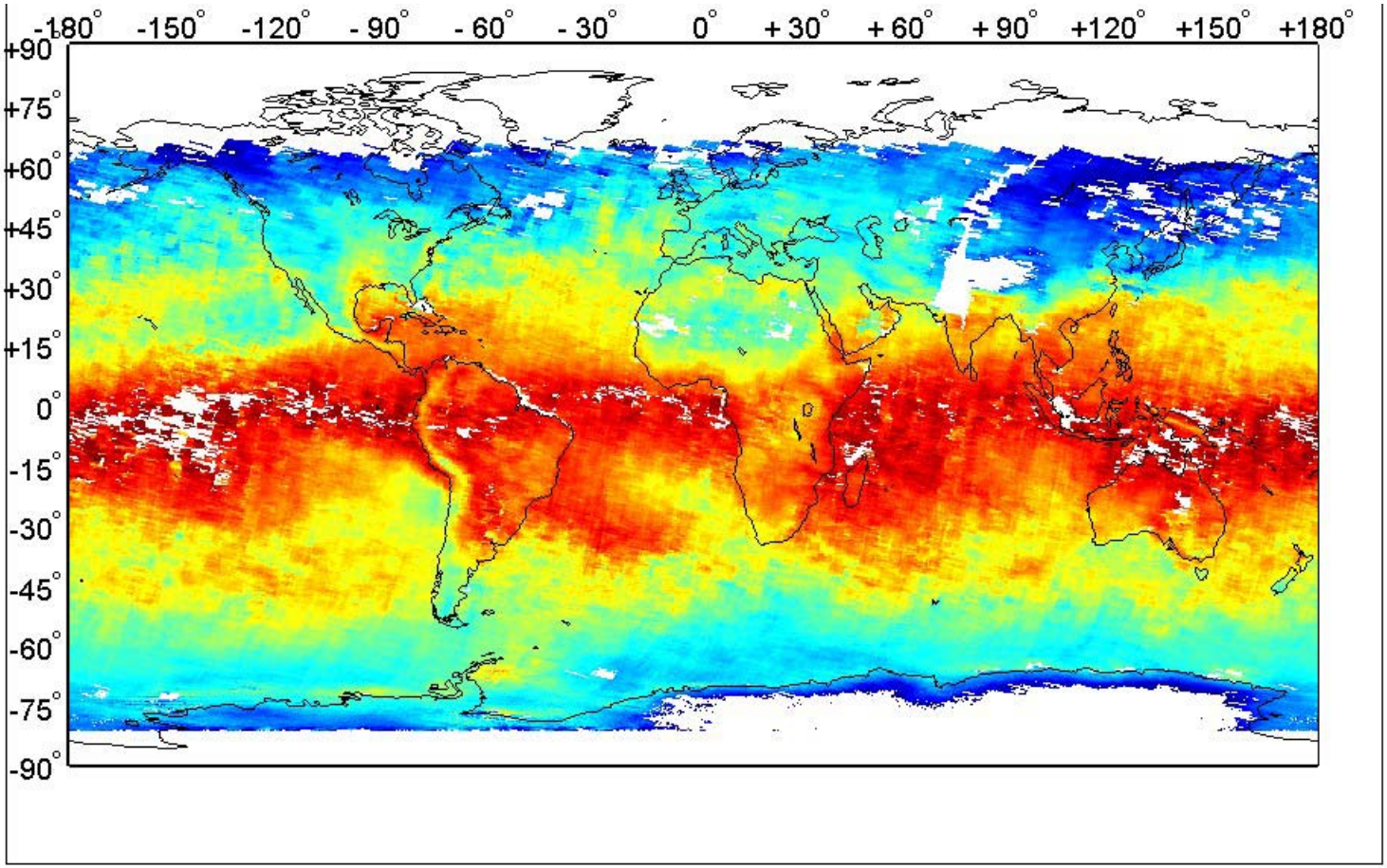
ECHAM 5.1.07_mz09i total water vapor column,

(same averaging statistics applied as for GOME)

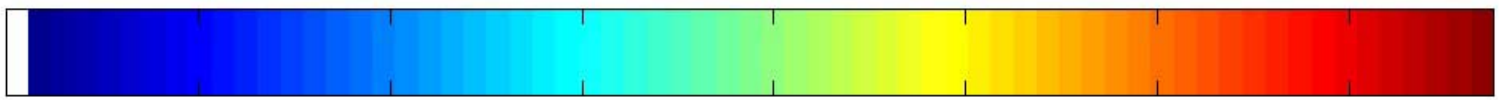
Monthly averaged DATA, January 1998

(O4-cloud screening)

GOME



log10[molec/cm^2]

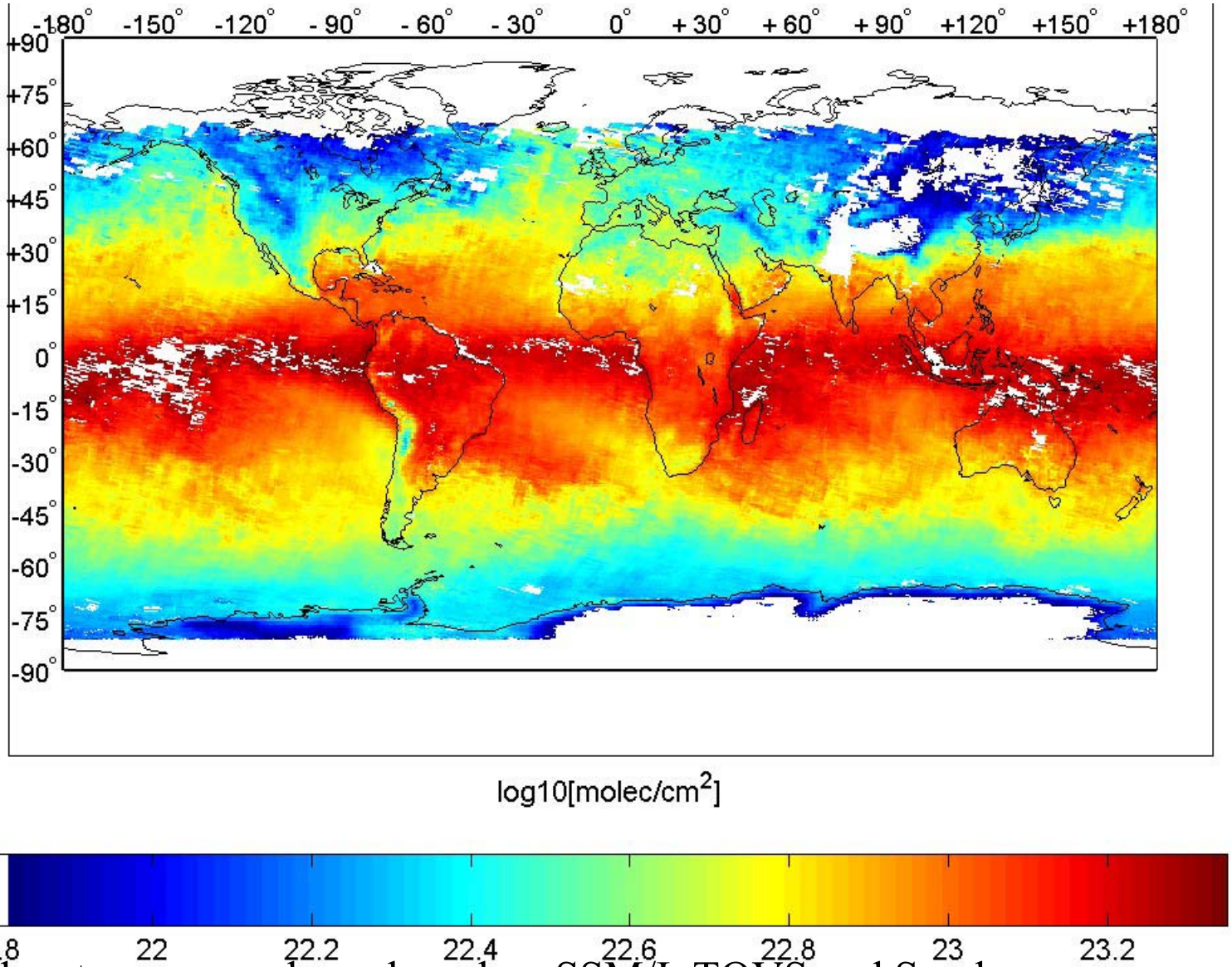


Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.

Monthly averaged DATA, January 1998

(O4-cloud screening)

NVAP



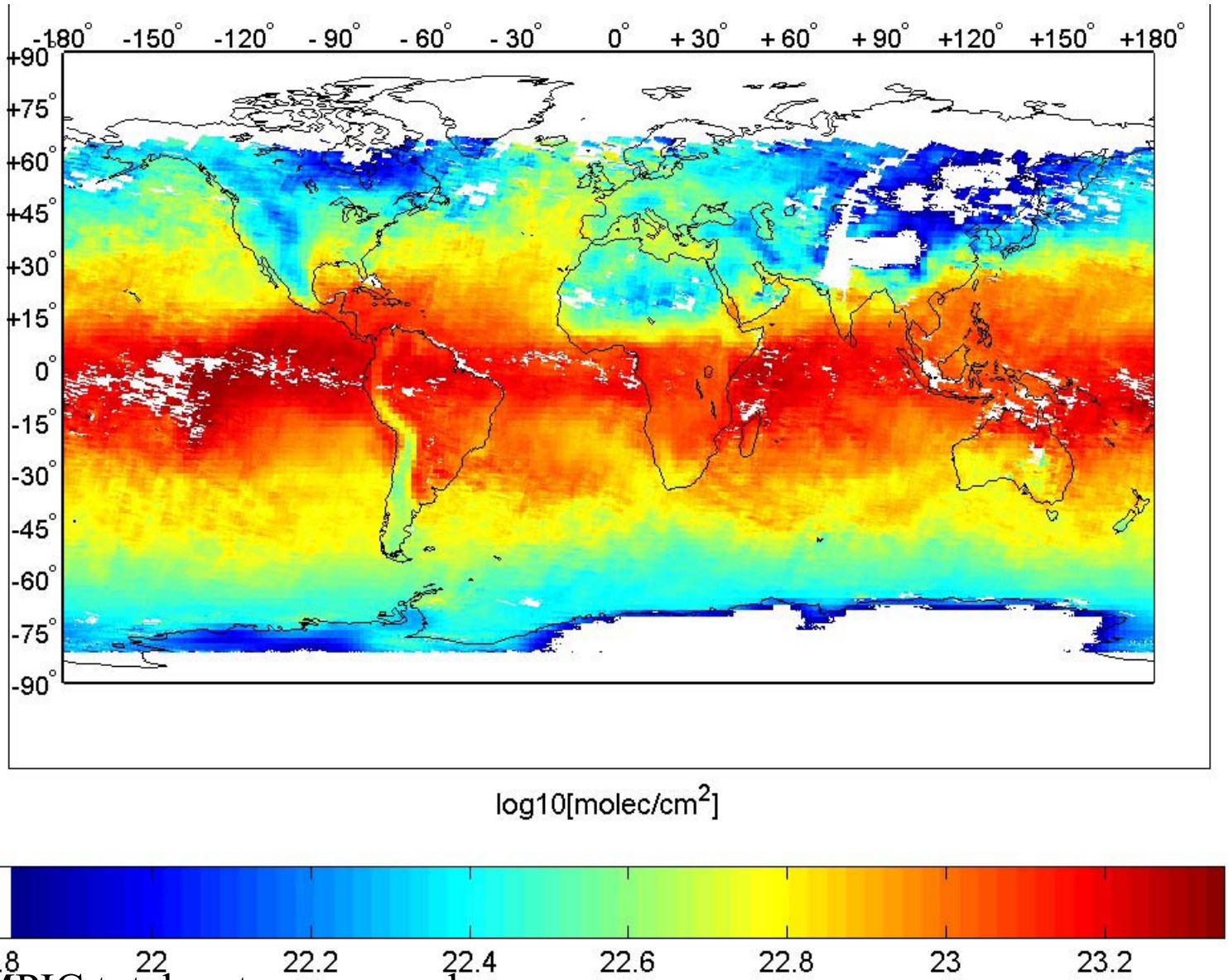
NVAP total water vapor column based on SSM/I, TOVS and Sondes,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, January 1998

(O4-cloud screening)

MATCH



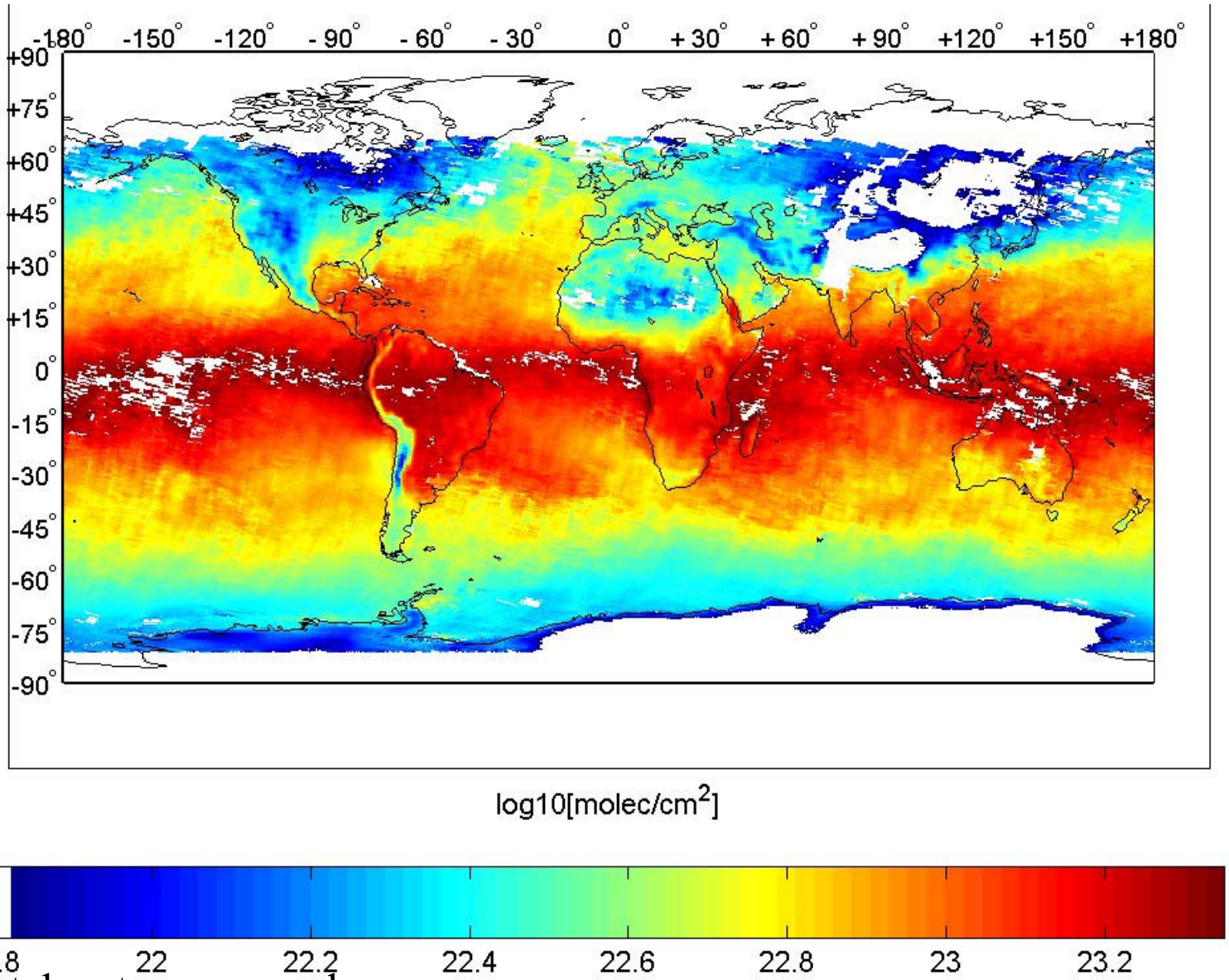
MATCH-MPIC total water vapor column,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, January 1998

(O4-cloud screening)

ECMWF



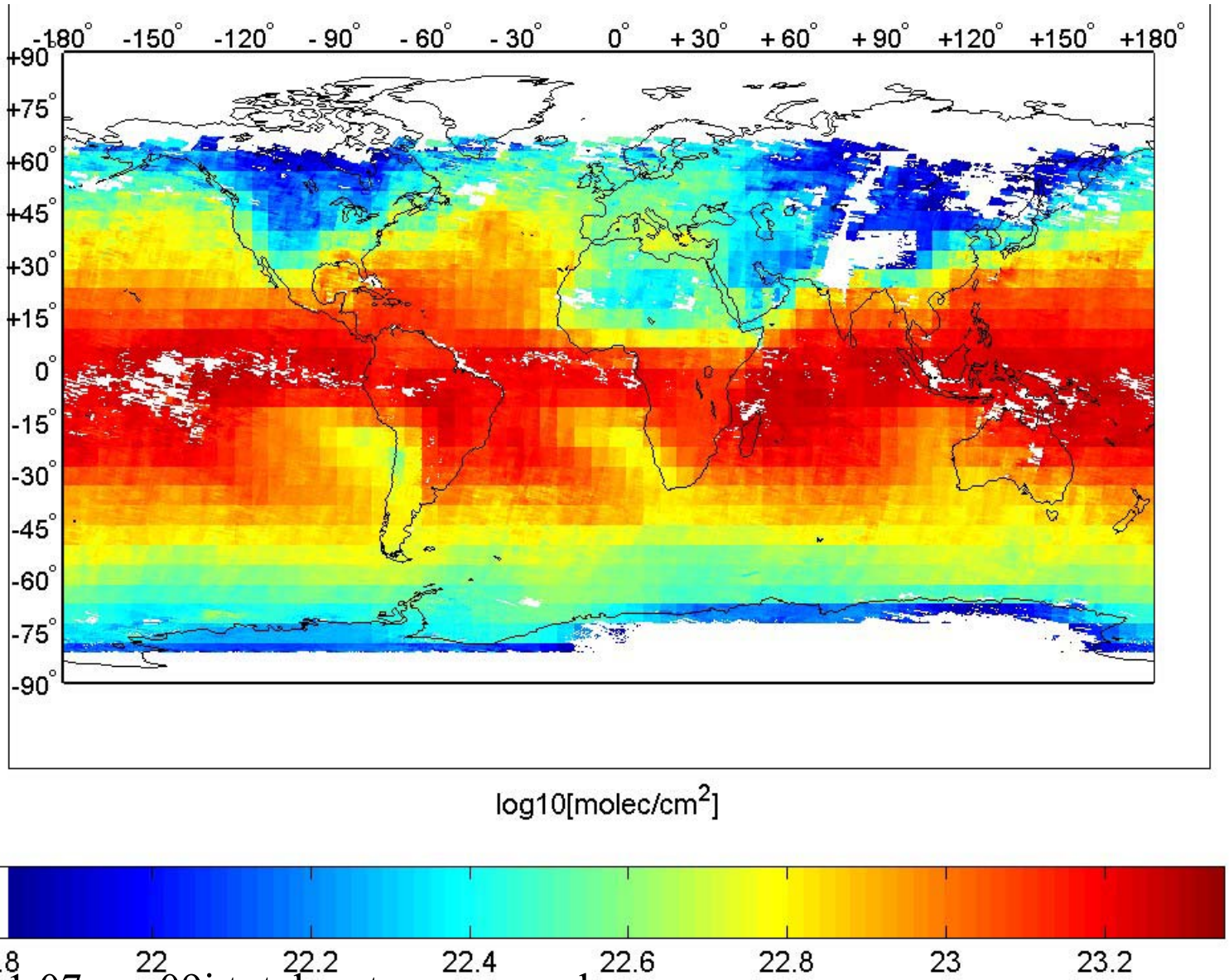
ECMWF total water vapor column,

(same averaging statistics applied as for GOME)

Monthly averaged DATA, January 1998

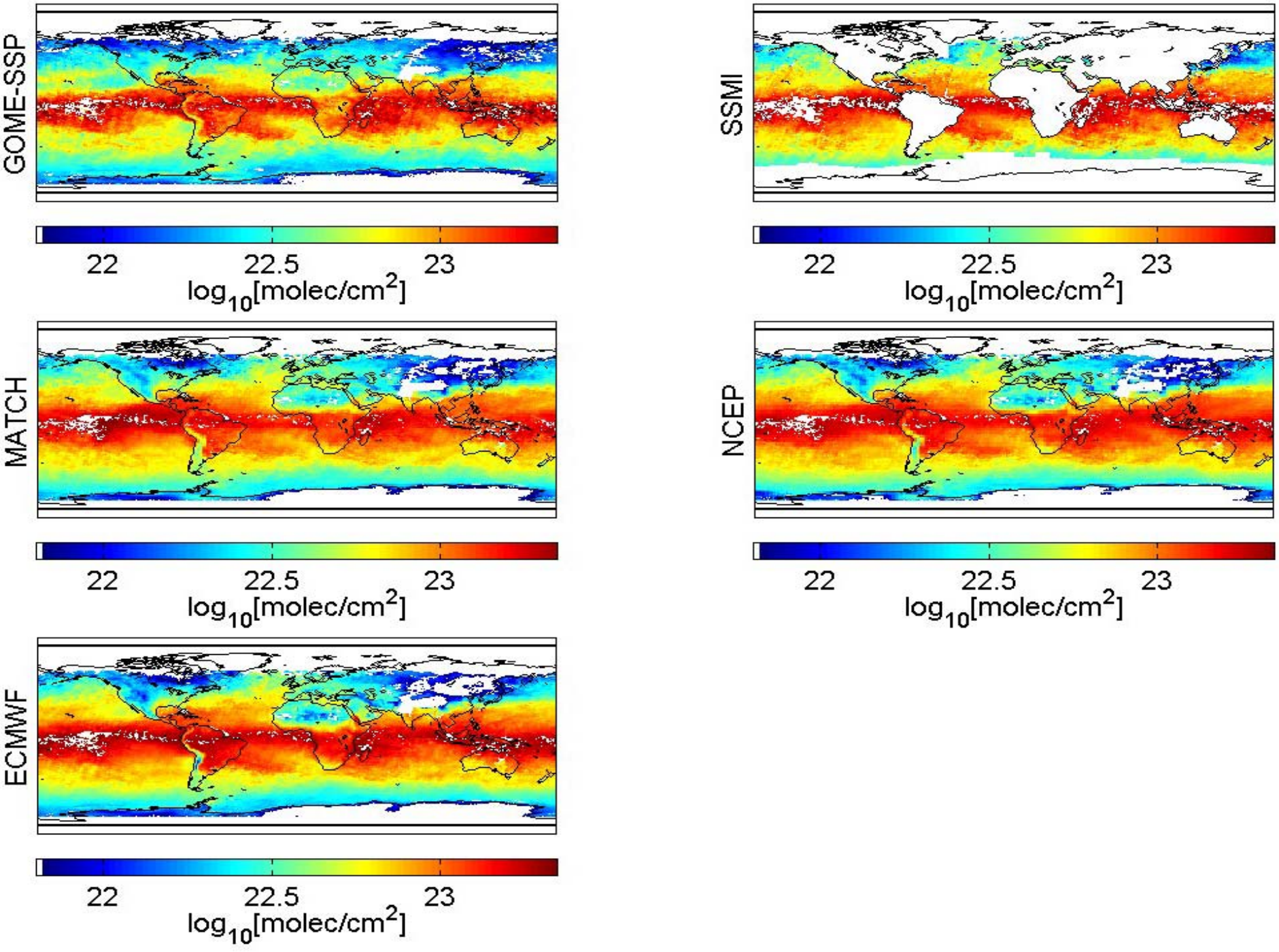
(O4-cloud screening)

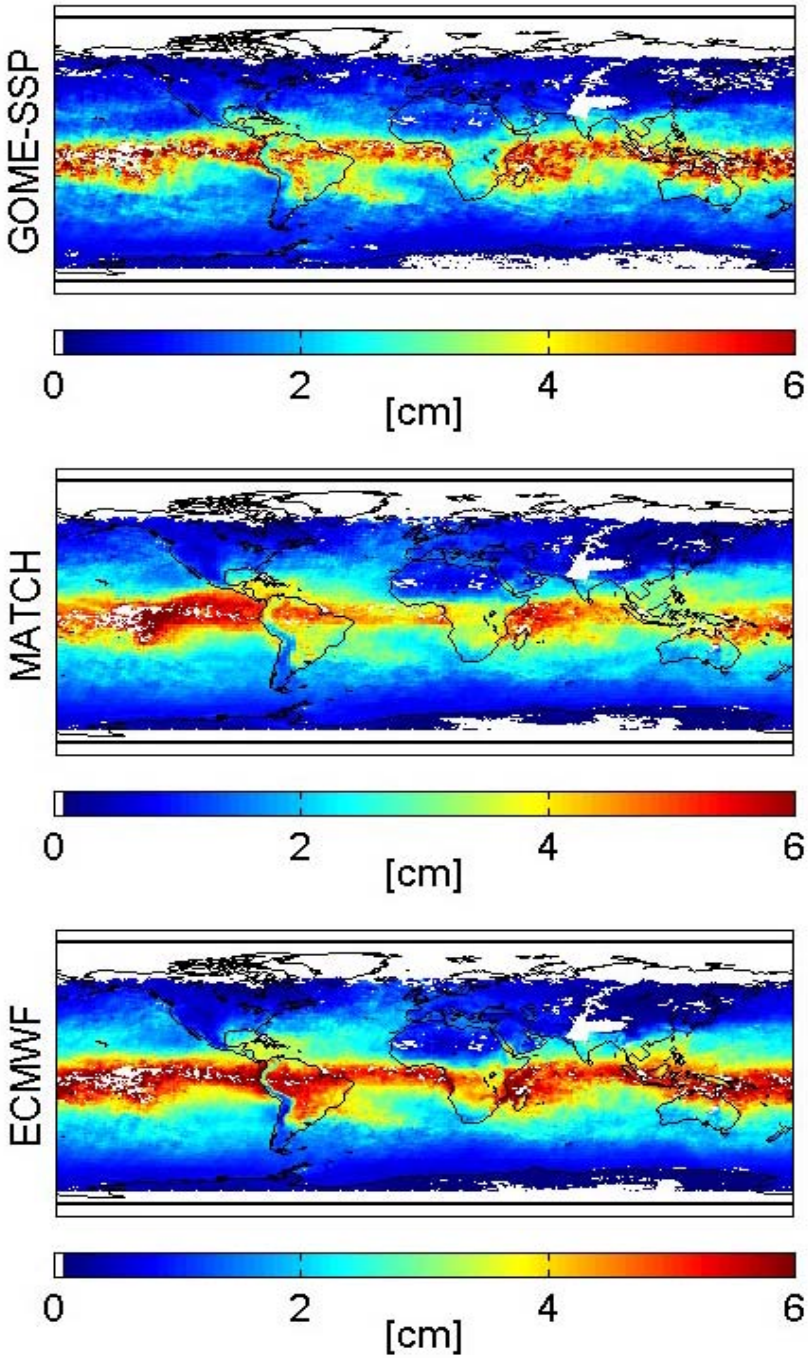
ECHAM



ECHAM 5.1.07_mz09i total water vapor column,

(same averaging statistics applied as for GOME)


GOME-SSP
SSMI
MATCH
NCEP
ECMWF
22
22.5
23
log10[molec/cm2]


GOME-SSP
0
2
4
6
[cm]
SSMI
0
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4
6
[cm]
MATCH
0
2
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NCEP
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ECMWF
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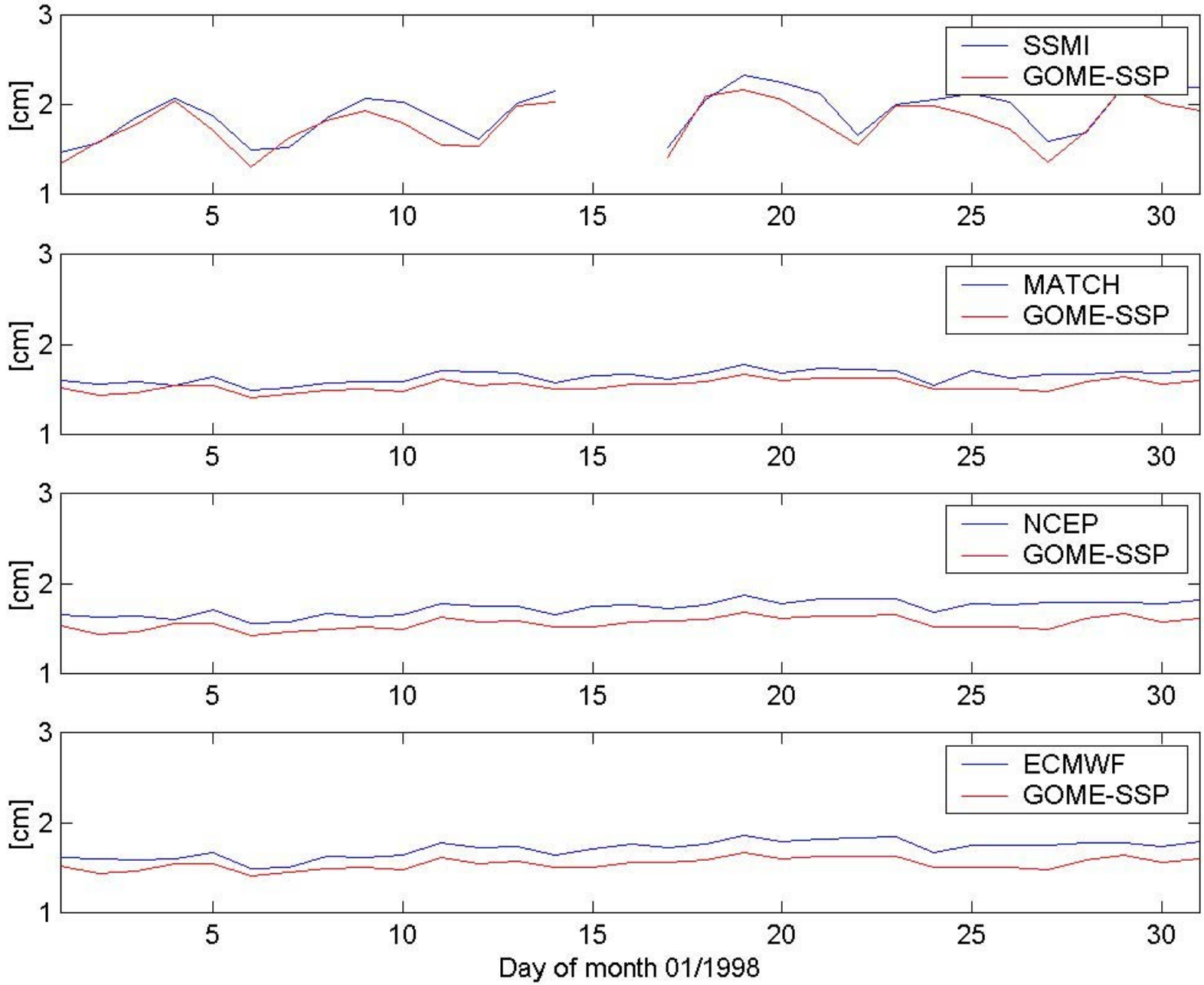
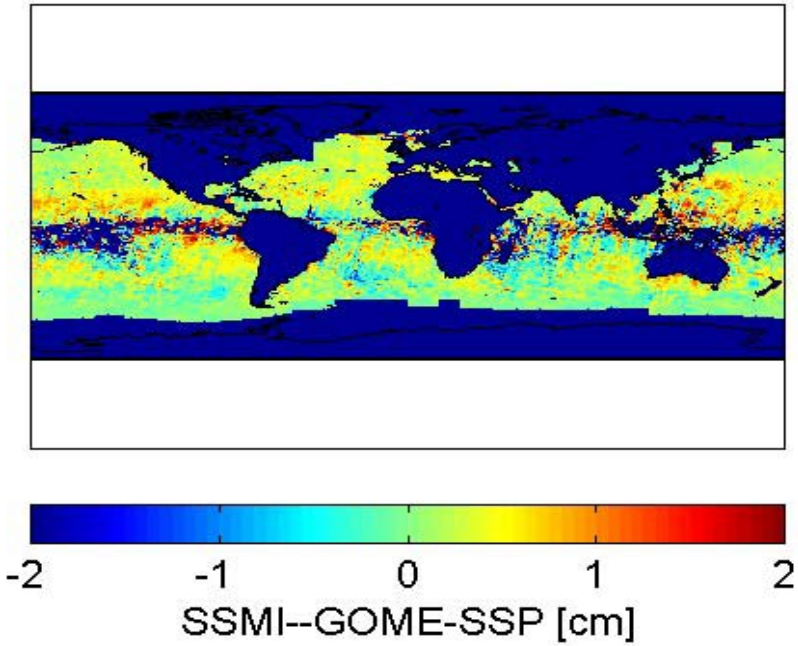
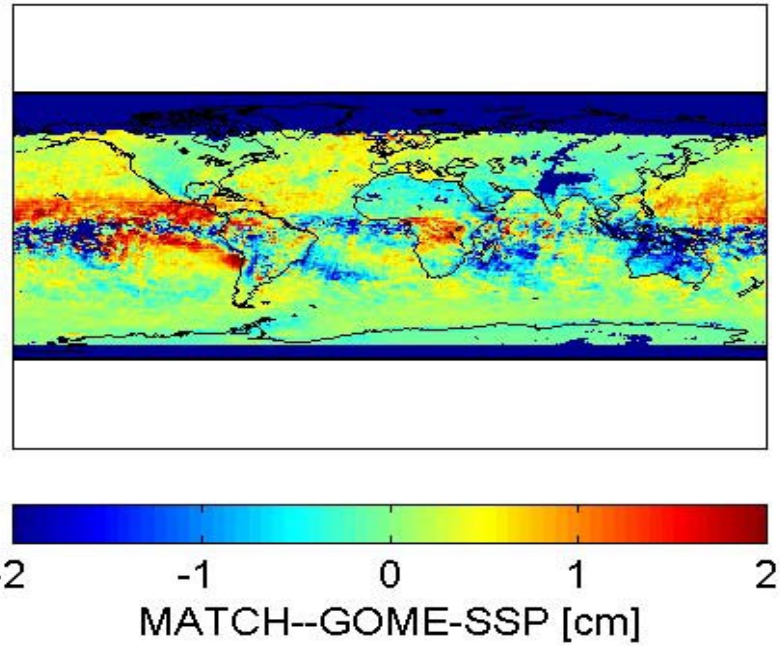
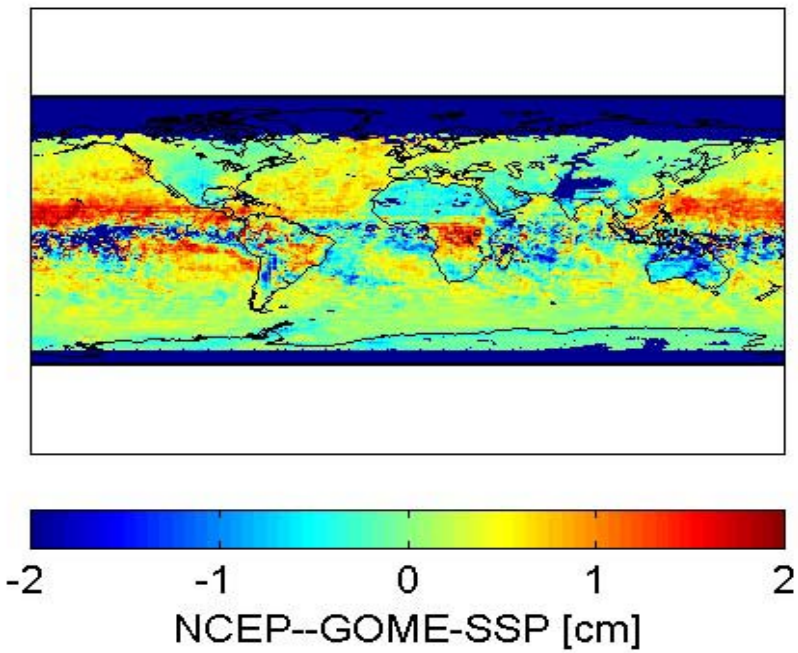
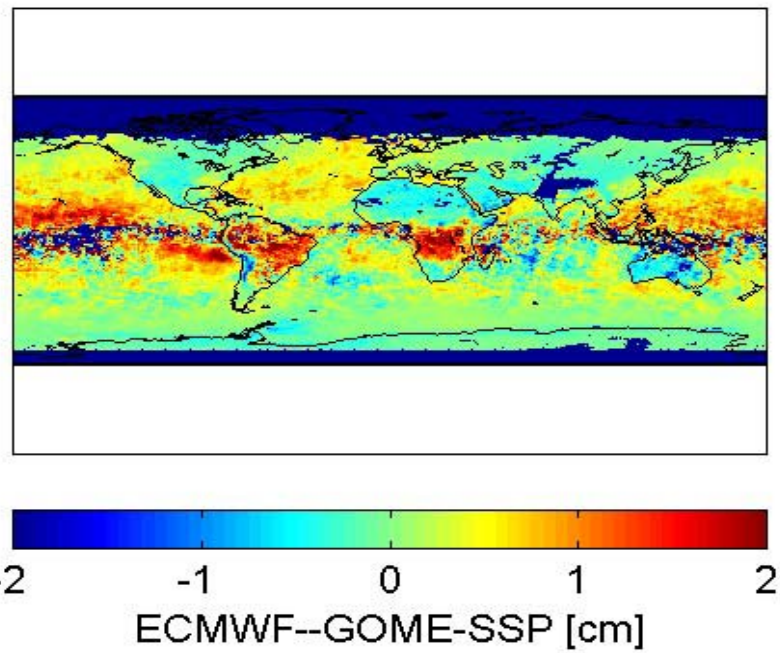

SSMI
GOME-SSP
MATCH
GOME-SSP
NCEP
GOME-SSP
ECMWF
GOME-SSP
[cm]
1
2
3
5
10
15
20
25
30
Day of month 01/1998


-2
-1
0
1
2
SSMI--GOME-SSP [cm]

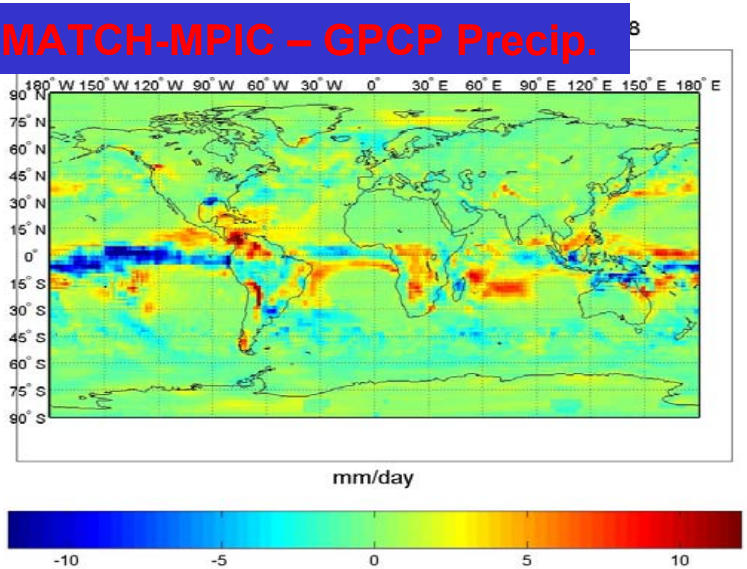

-2
-1
0
1
2
MATCH--GOME-SSP [cm]


-2
-1
0
1
2
NCEP--GOME-SSP [cm]

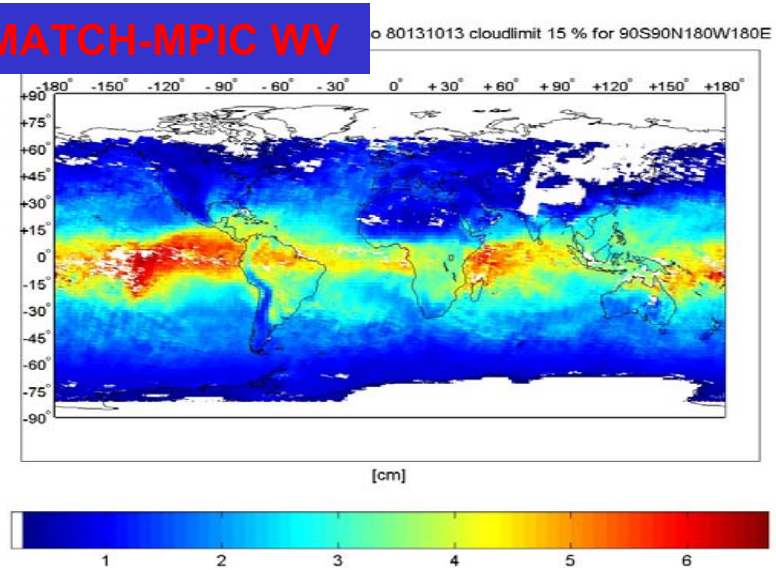

-2
-1
0
1
2
ECMWF--GOME-SSP [cm]

Precipitation and Water Vapor, January 1998

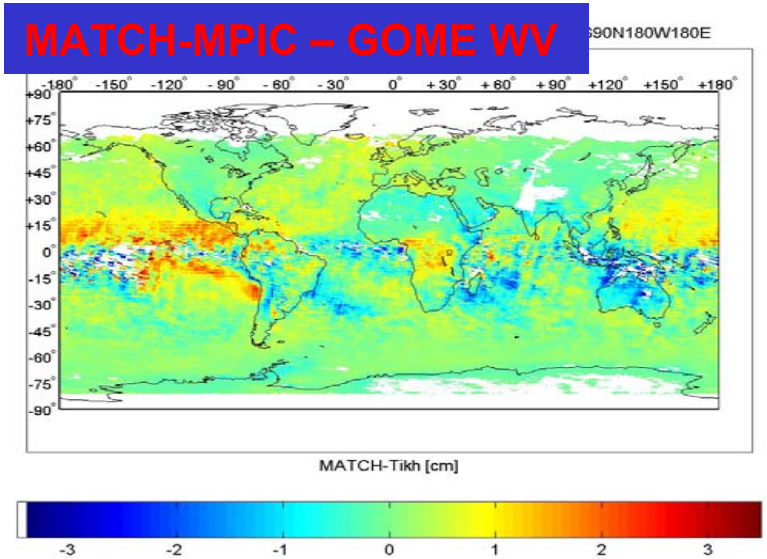
MATCH-MPIC – GPCP Precip.



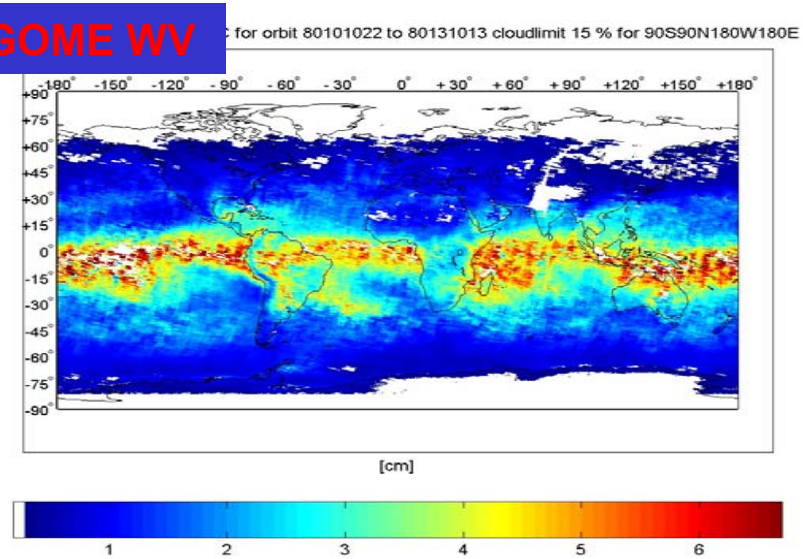
MATCH-MPIC WV



MATCH-MPIC – GOME WV



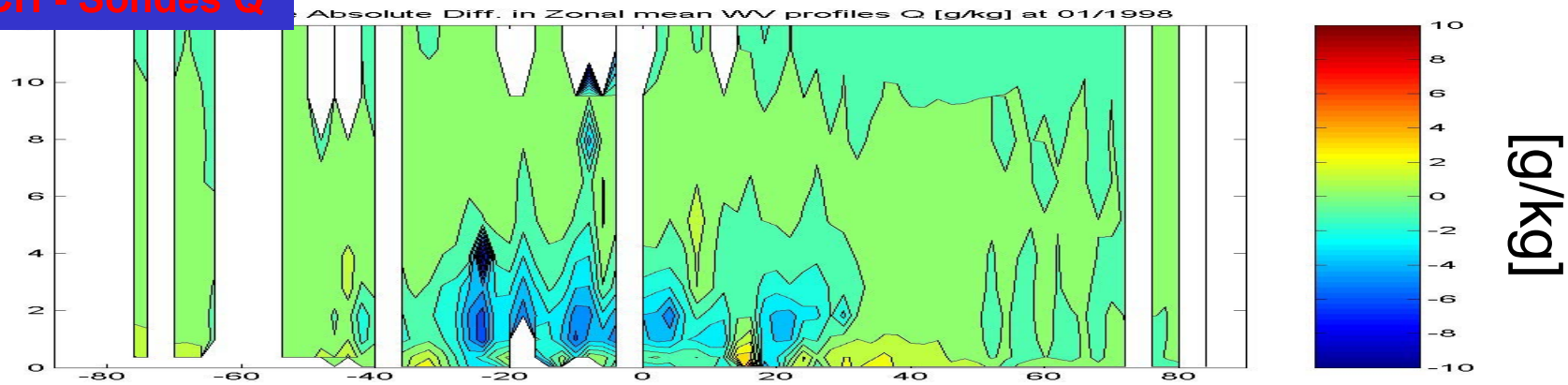
GOME WV



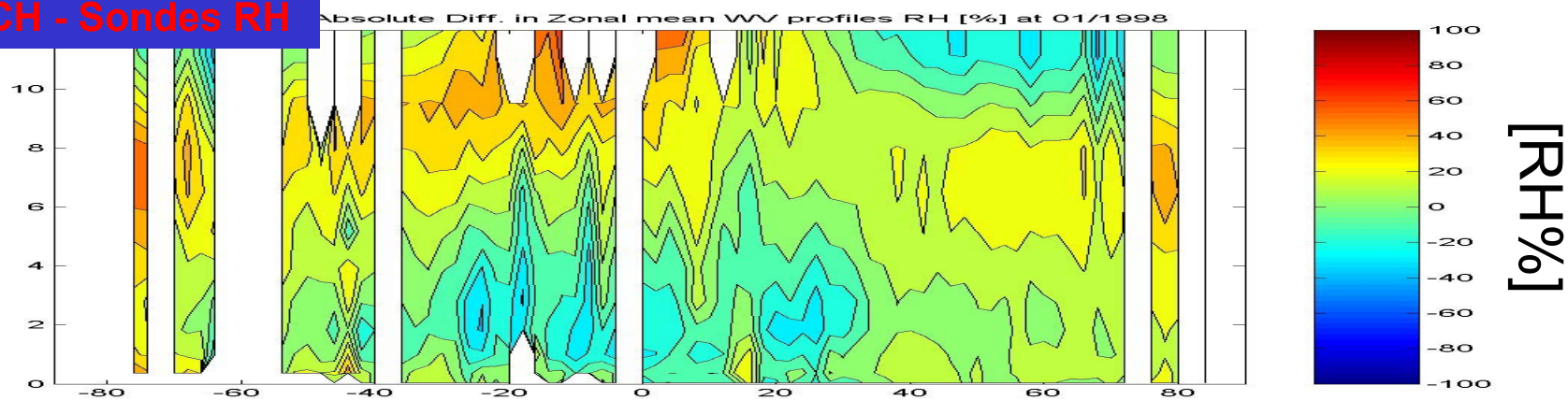
Comparison Absolute Differences RH/Q profiles, January 1998

(MATCH 10:30; Sondes 10:00-12:00 lt)

MATCH - Sondes Q

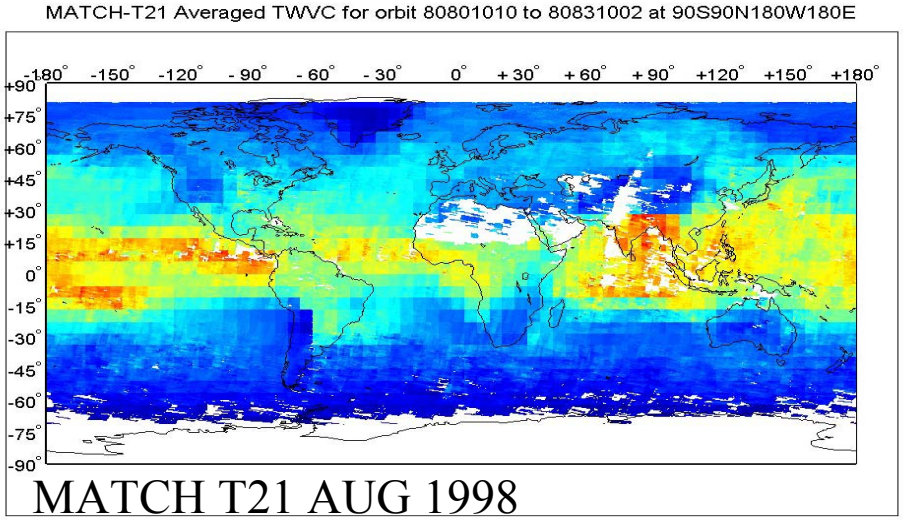


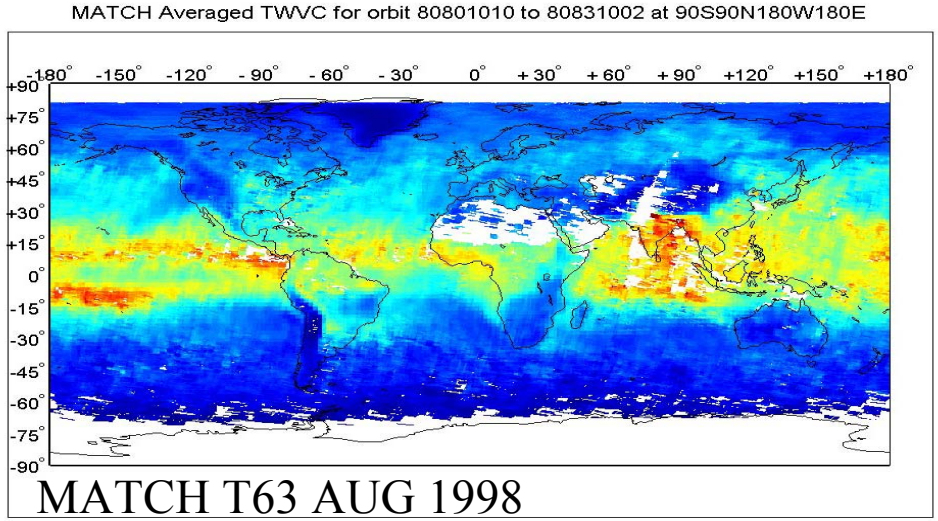
MATCH - Sondes RH

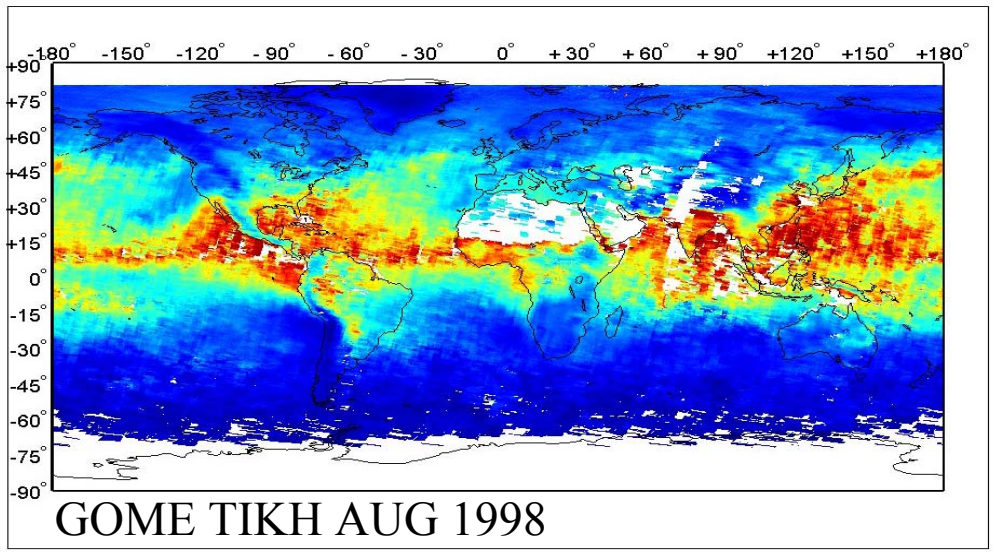


?

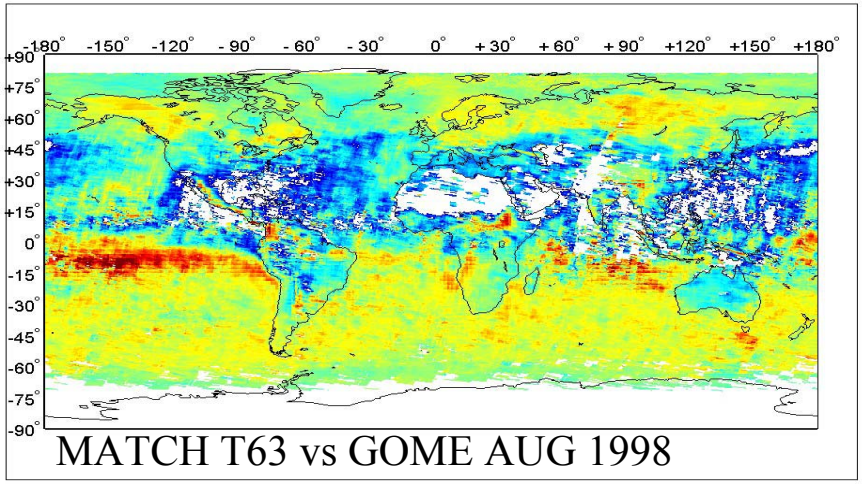
MATCH T63 vs MATCH T21


MATCH-T21 Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
-180° -150° -120° - 90° - 60° - 30° 0° + 30° + 60° + 90° +120° +150° +180°
+90° +75° +60° +45° +30° +15° 0° -15° -30° -45° -60° -75° -90°
MATCH T21 AUG 1998
[cm]
1 2 3 4 5 6

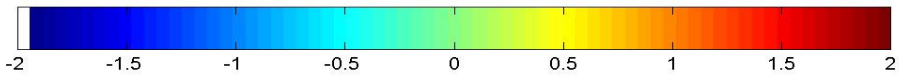

MATCH Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
-180° -150° -120° - 90° - 60° - 30° 0° + 30° + 60° + 90° +120° +150° +180°
+90° +75° +60° +45° +30° +15° 0° -15° -30° -45° -60° -75° -90°
MATCH T63 AUG 1998
[cm]
1 2 3 4 5 6


Tikh GOME Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
-180° -150° -120° - 90° - 60° - 30° 0° + 30° + 60° + 90° +120° +150° +180°
+90° +75° +60° +45° +30° +15° 0° -15° -30° -45° -60° -75° -90°
GOME TIKH AUG 1998
[cm]
1 2 3 4 5 6

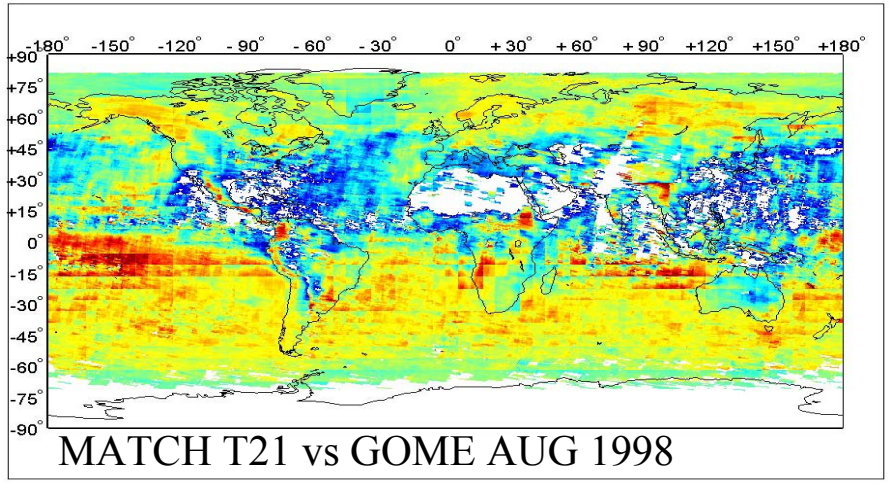
MATCH vs. Tikh. Diff TWVC for orbit 80801010 to 80831002 at 90S90N180W180E



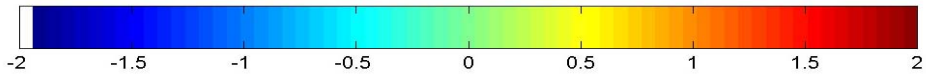
MATCH-Tikh [cm]



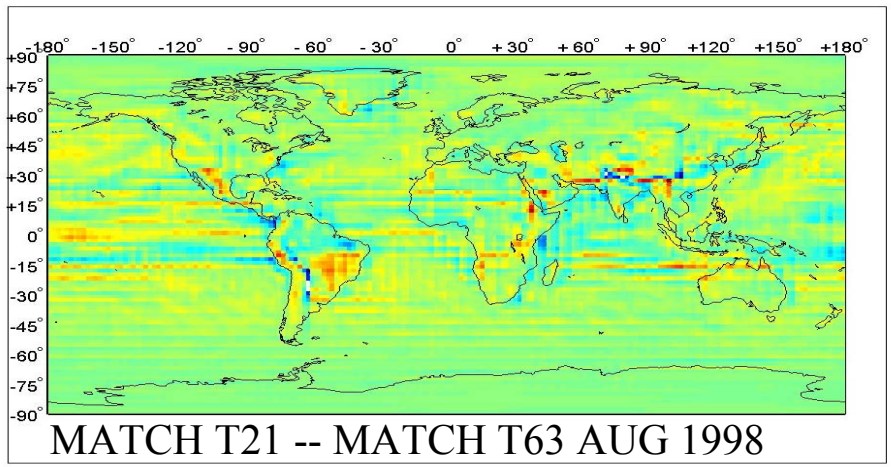
MATCH-T21 vs. TIKH. Diff TWVC for orbit 80801010 to 80831002 at 90S90N180W180E



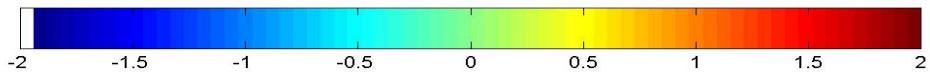
MATCH-T21-TIKH [cm]

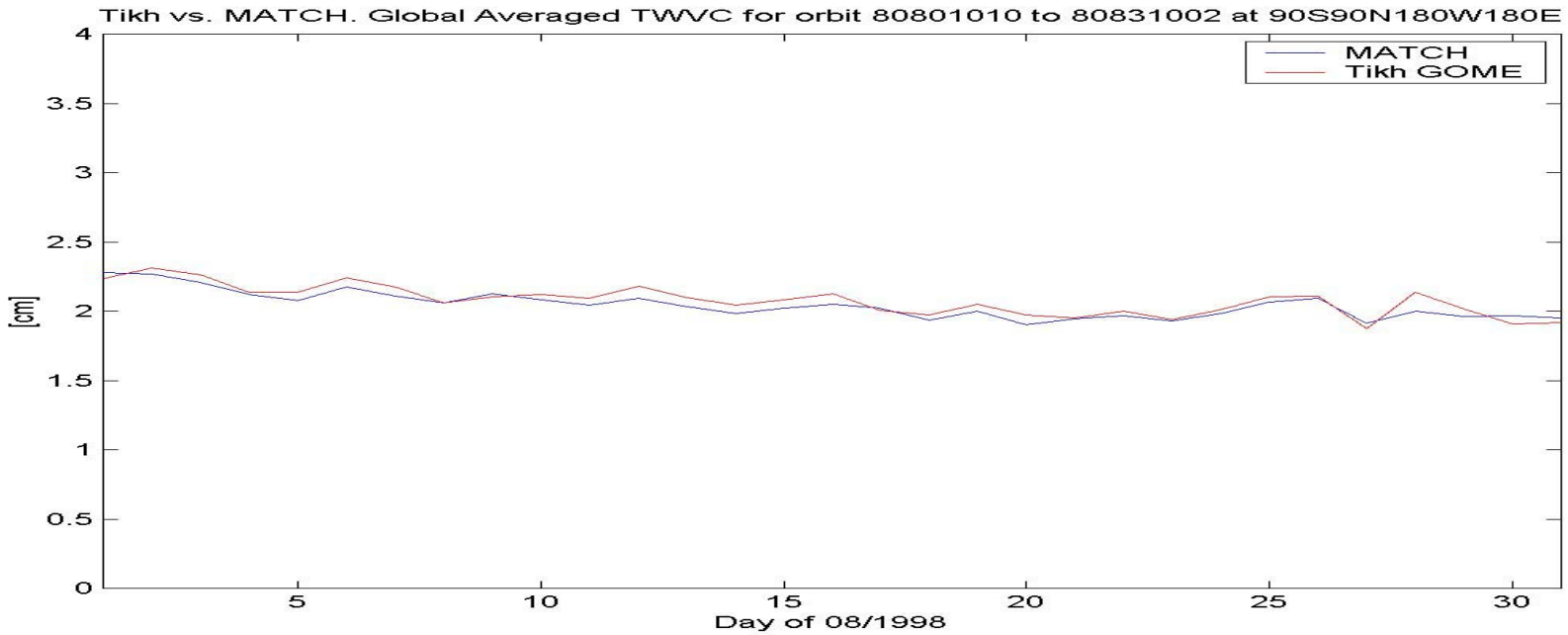


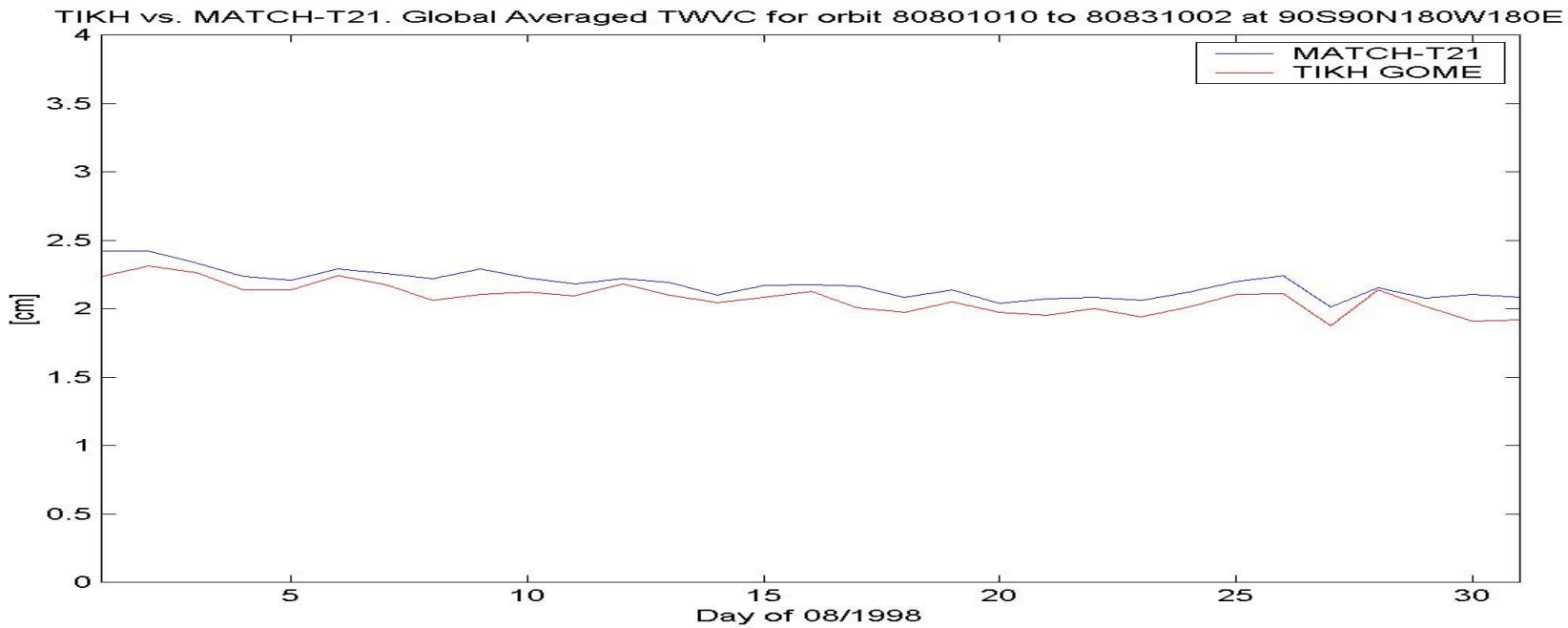
MATCH-T21 vs. MATCH. Diff TWVC for orbit 80801010 to 80831002 at 90S90N180W180E



MATCH-T21-MATCH [cm]

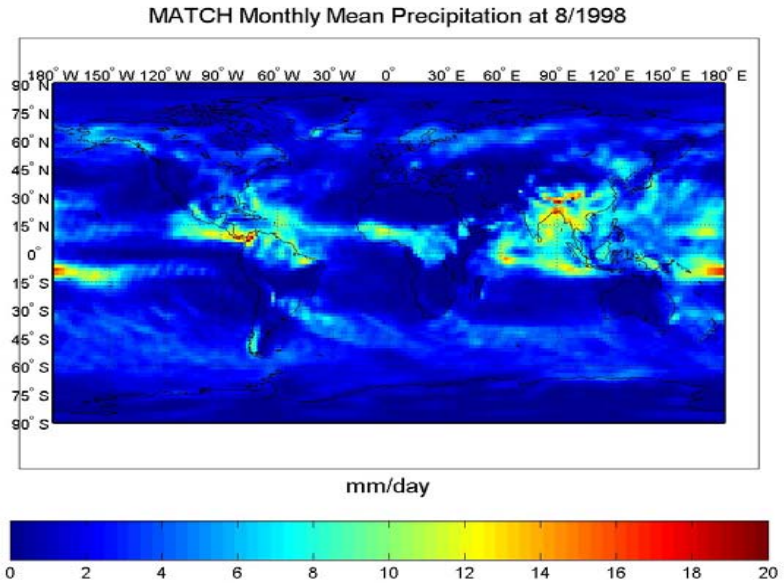



Tikh vs. MATCH. Global Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
MATCH
Tikh GOME
[cm]
Day of 08/1998

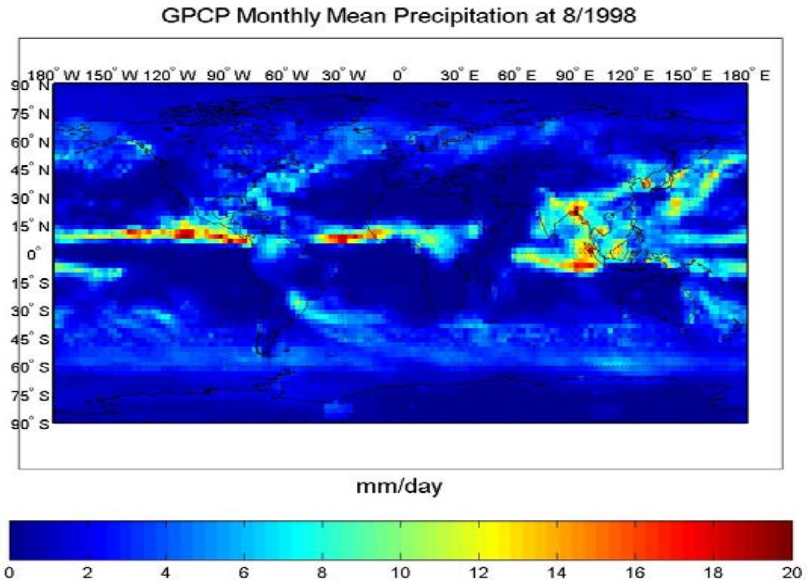

TIKH vs. MATCH-T21. Global Averaged TWVC for orbit 80801010 to 80831002 at 90S90N180W180E
MATCH-T21
TIKH GOME
[cm]
Day of 08/1998

Motivation II: Precipitation differences between MATCH-MPIC and GCPC

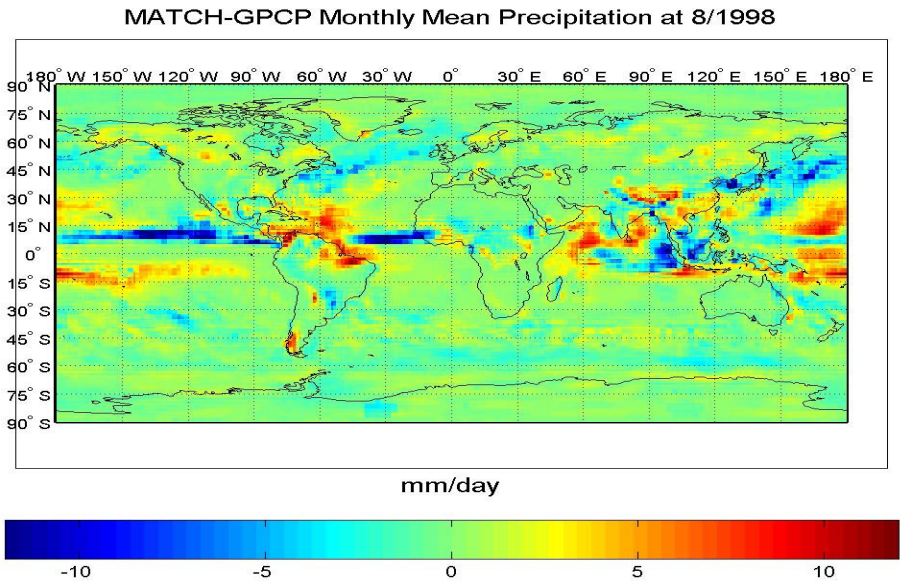
MATCH-MPIC



GPCP



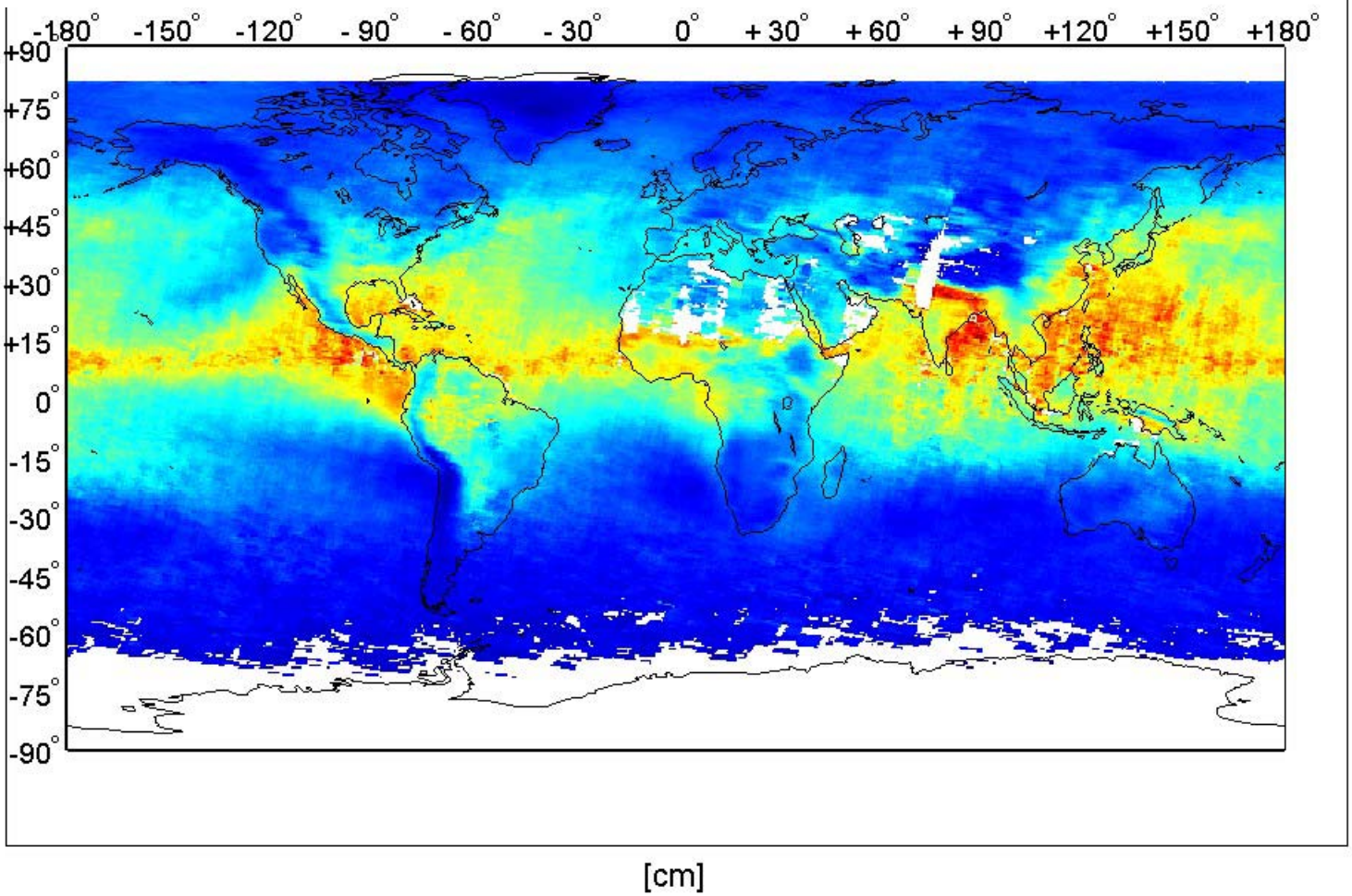
MATCH-MPIC-GPCP



Monthly averaged DATA, August 1998-2000

(O4-cloud screening)

GOME

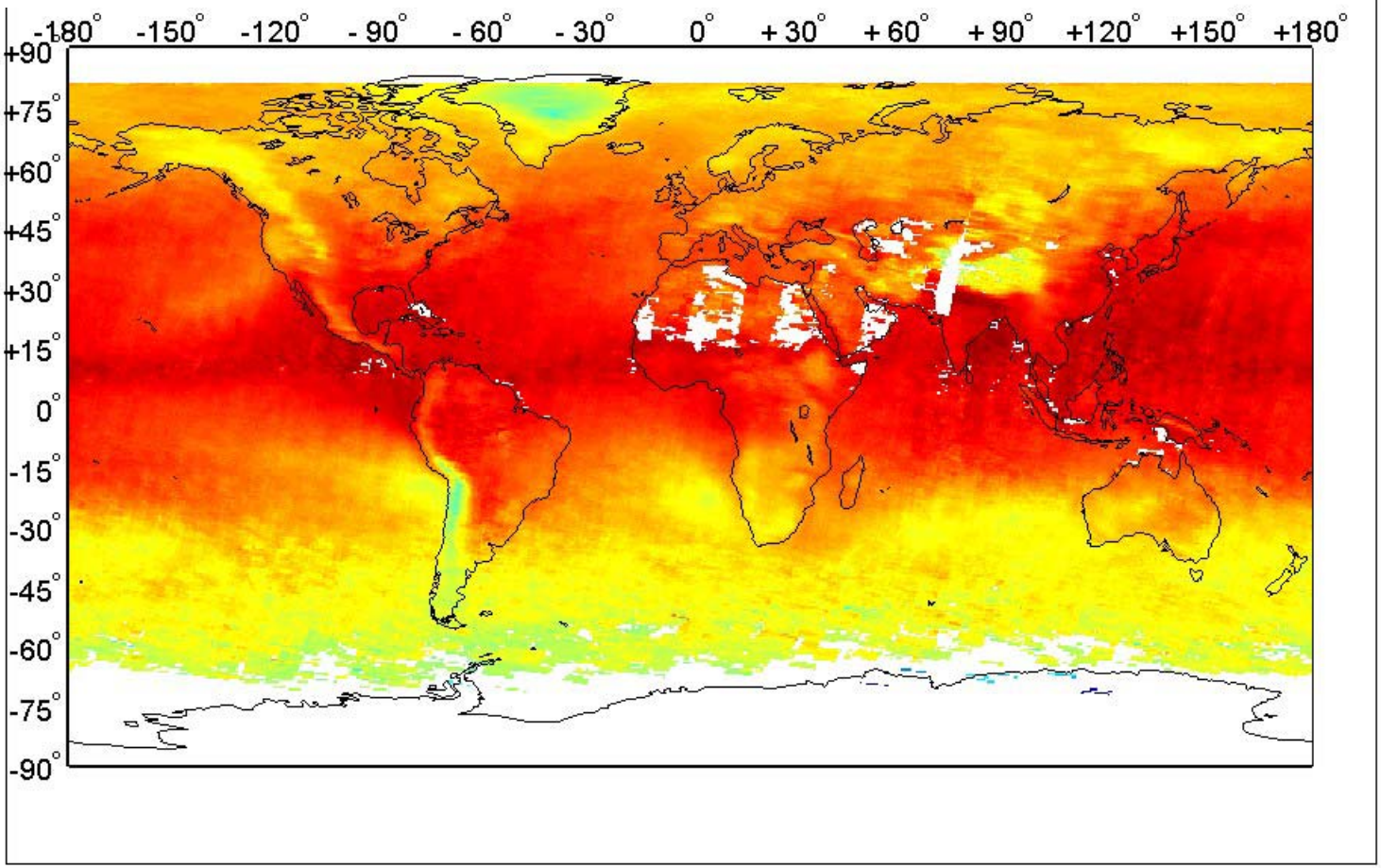


Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.

Monthly averaged DATA, August 1998-2000

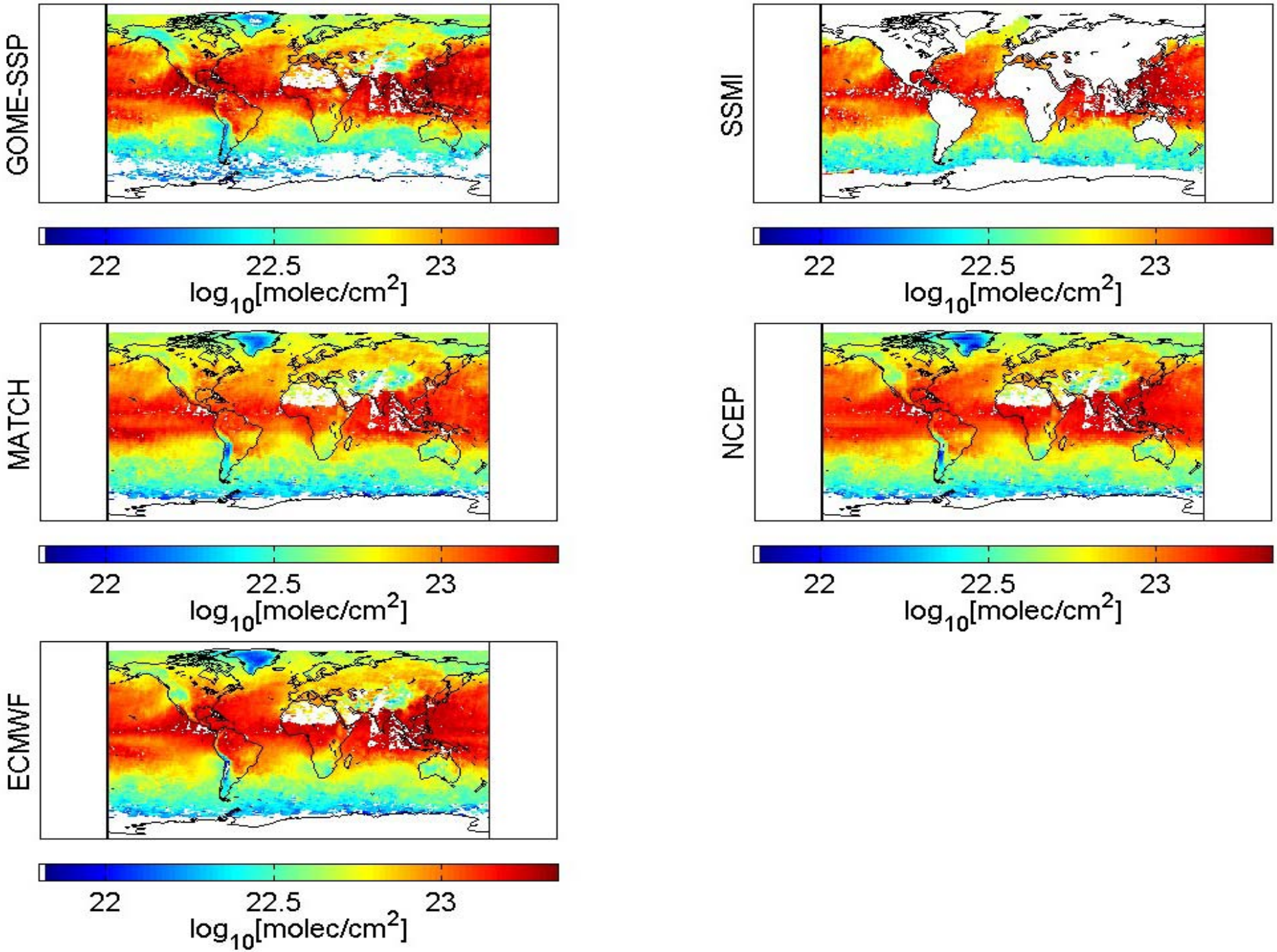
(O4-cloud screening)

GOME



log10[molec/cm^2]

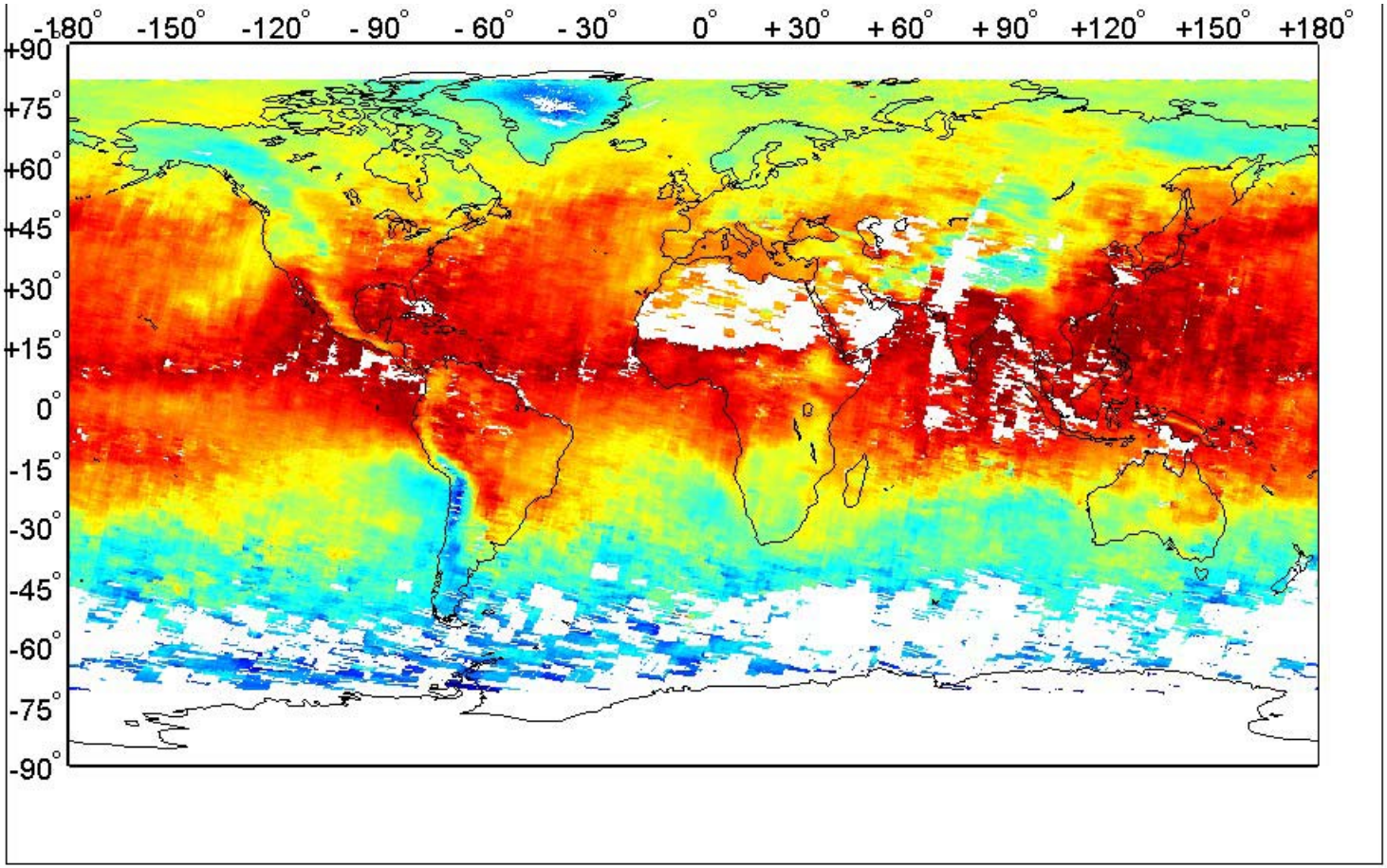
Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.


GOME-SSP
SSMI
MATCH
NCEP
ECMWF
22
22.5
23
log10[molec/cm2]

Monthly averaged DATA, August 1998

(O4-cloud screening)

GOME

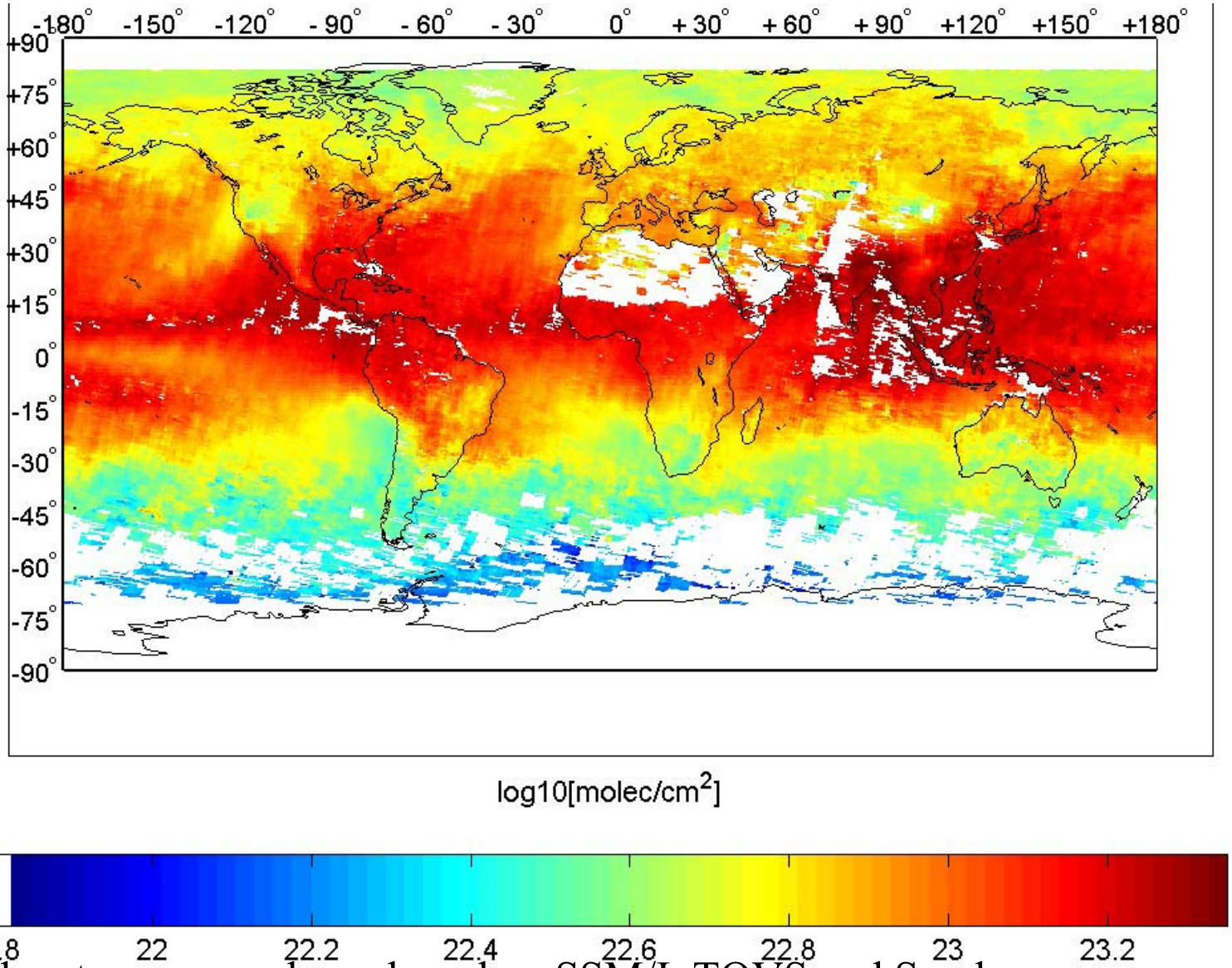


Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.

Monthly averaged DATA, August 1998

(O4-cloud screening)

NVAP



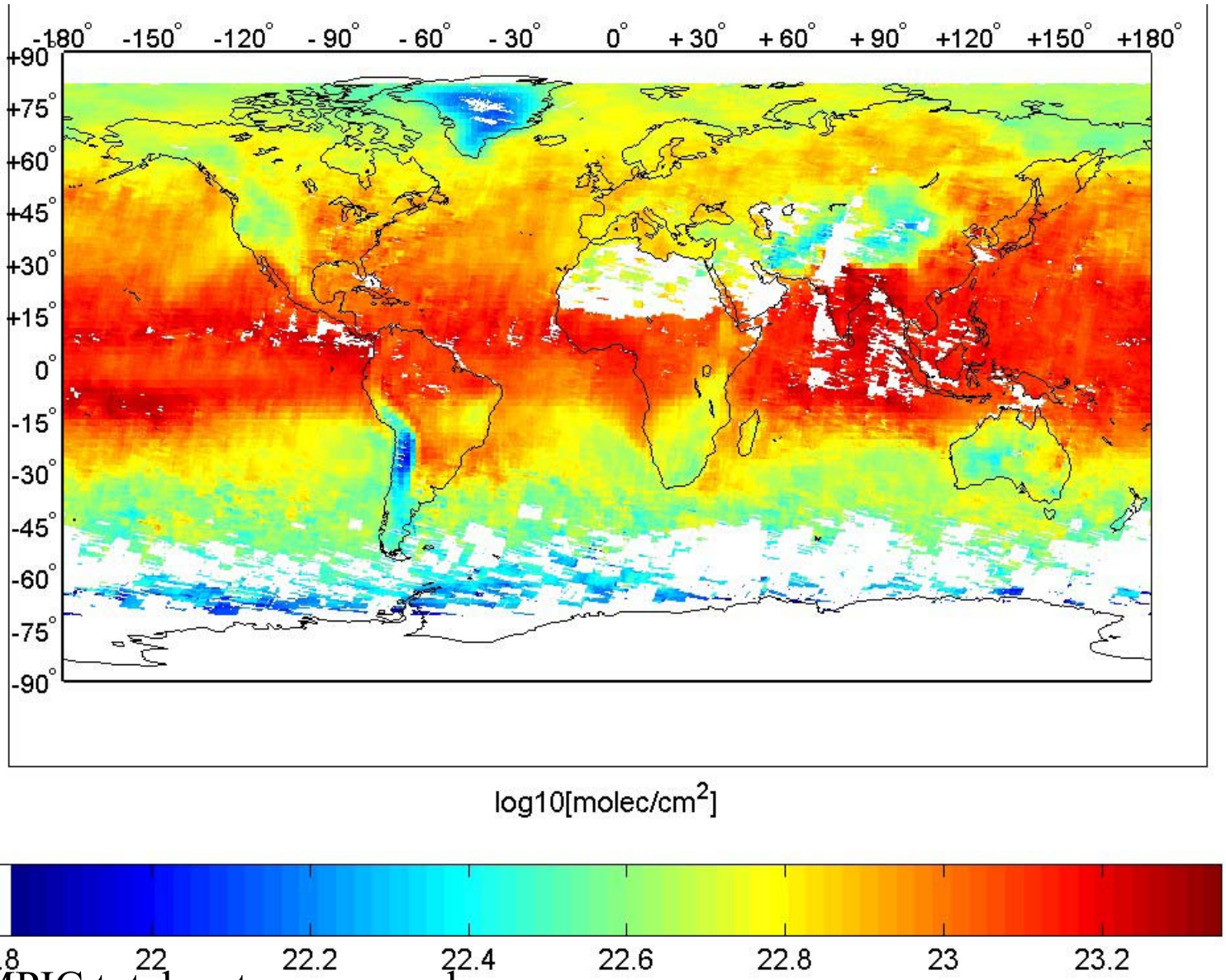
NVAP total water vapor column based on SSM/I, TOVS and Sondes,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, August 1998

(O4-cloud screening)

MATCH



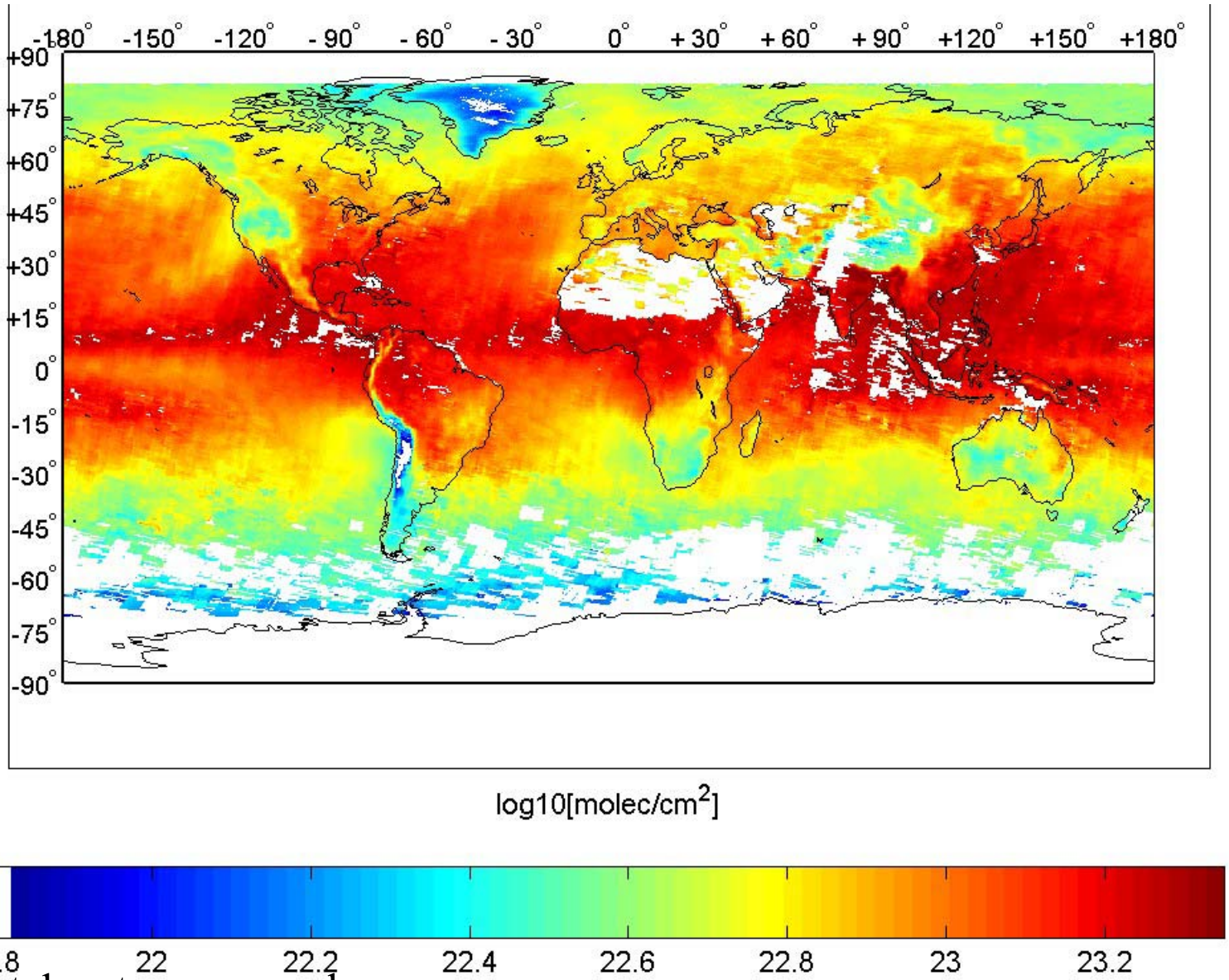
MATCH-MPIC total water vapor column,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, August 1998

(O4-cloud screening)

ECMWF



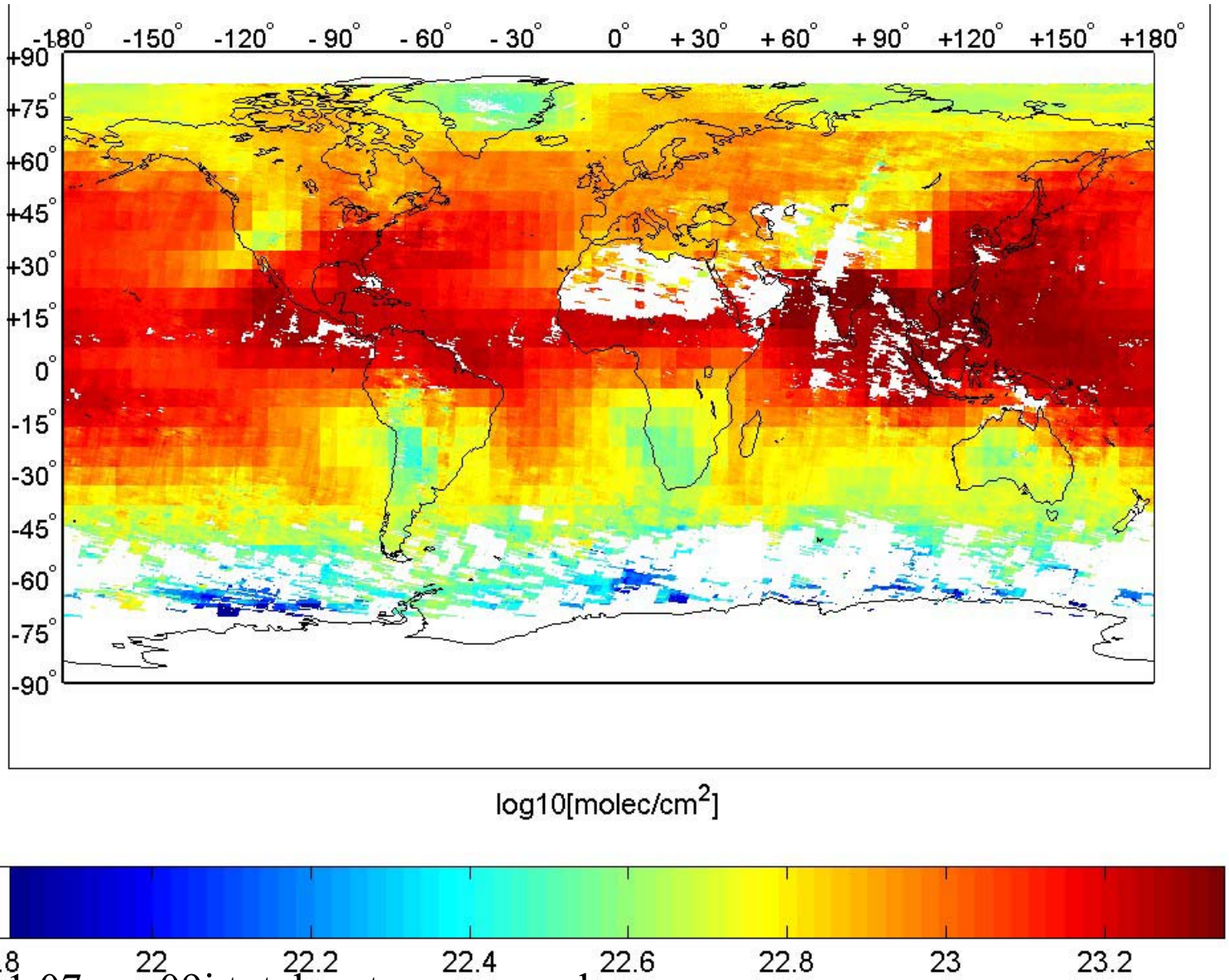
ECMWF total water vapor column,

(same averaging statistics applied)

Monthly averaged DATA, August 1998

(O4-cloud screening)

ECHAM



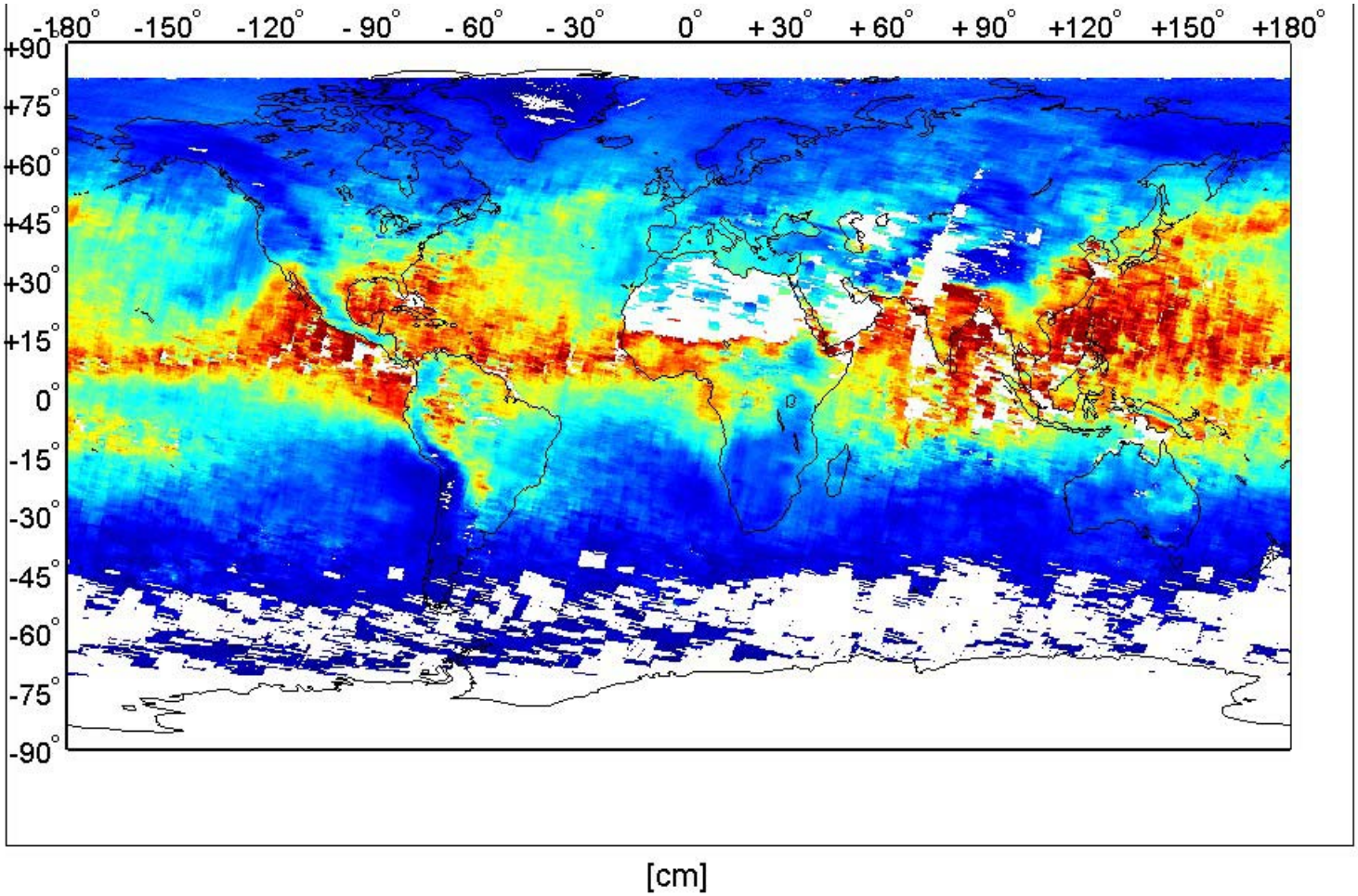
ECHAM 5.1.07_mz09i total water vapor column,

(same averaging statistics applied as for GOME)

Monthly averaged DATA, August 1998

(O4-cloud screening)

GOME

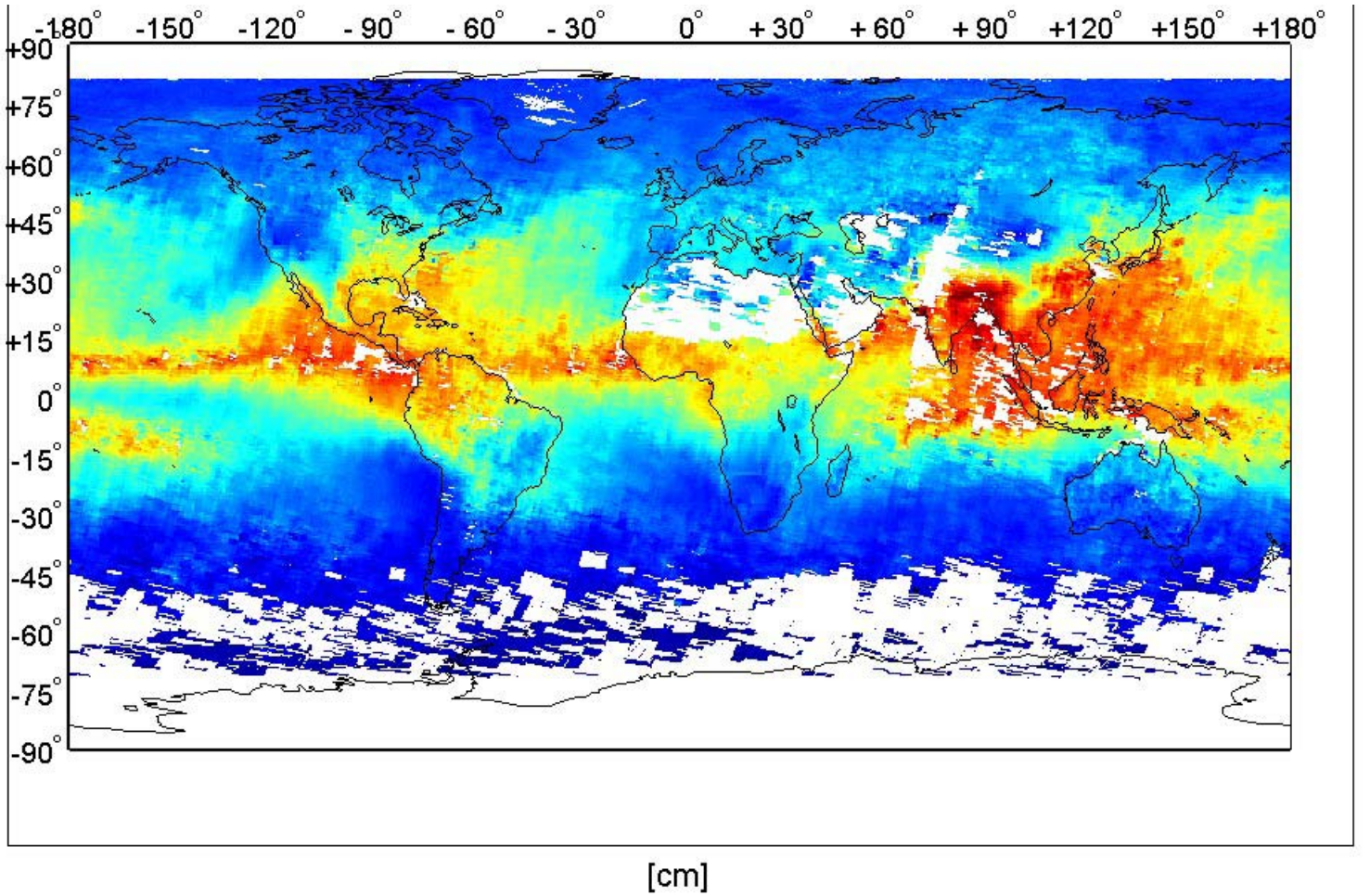


Efficient Phillips-Tikhonov-Twomey regularization using SSP, PTTR-SSP, (590 nm absorption band), MPI-Chemistry, Mainz, *Maurellis et al.,* GRL 2000, *Lang et al.*, ACP 2003.

Monthly averaged DATA, August 1998

(O4-cloud screening)

NVAP



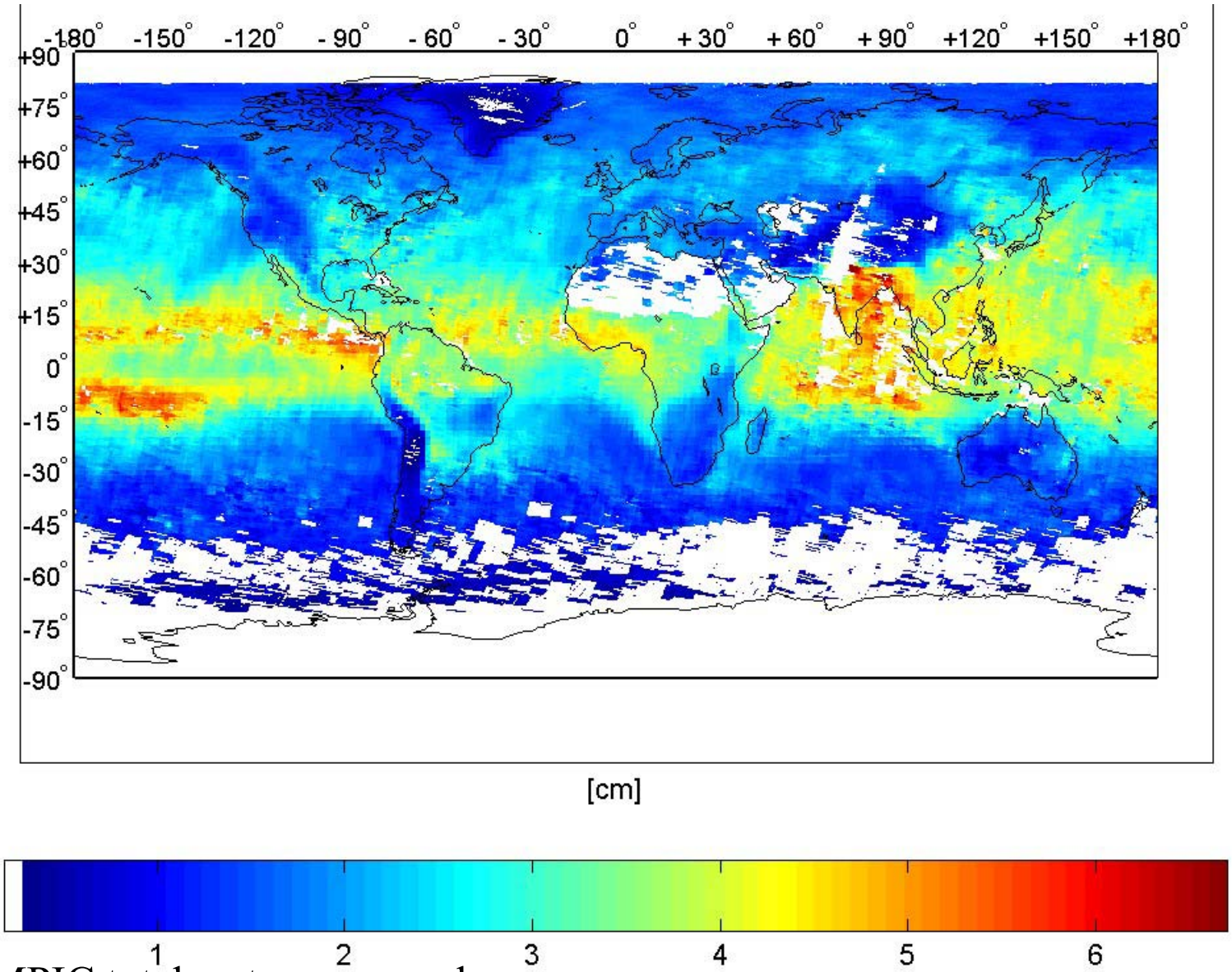
NVAP total water vapor column based on SSM/I, TOVS and Sondes,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, August 1998

(O4-cloud screening)

MATCH



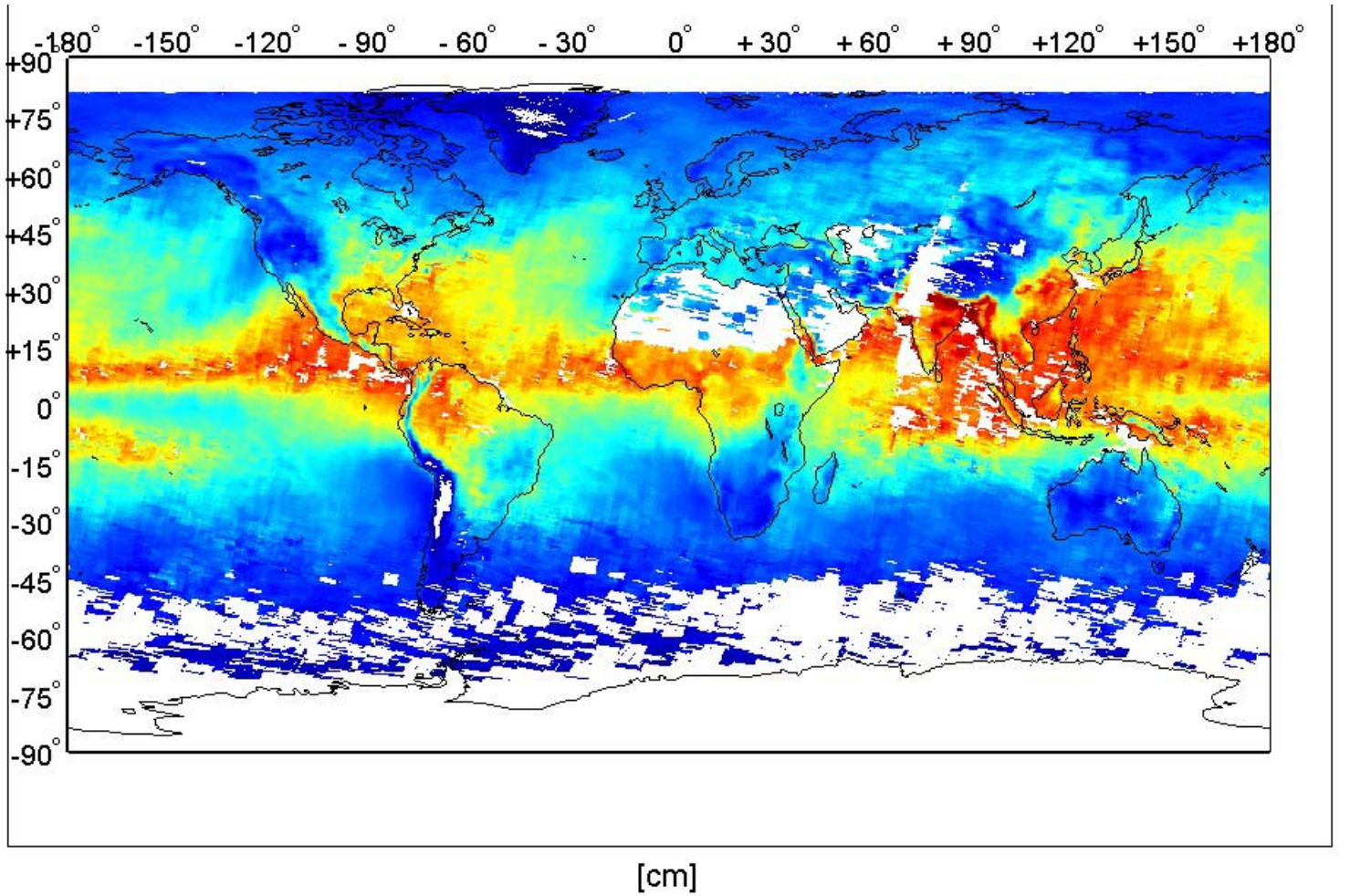
MATCH-MPIC total water vapor column,

(same averaging statistics applied as for GOME-TIKH)

Monthly averaged DATA, August 1998

(O4-cloud screening)

ECMWF



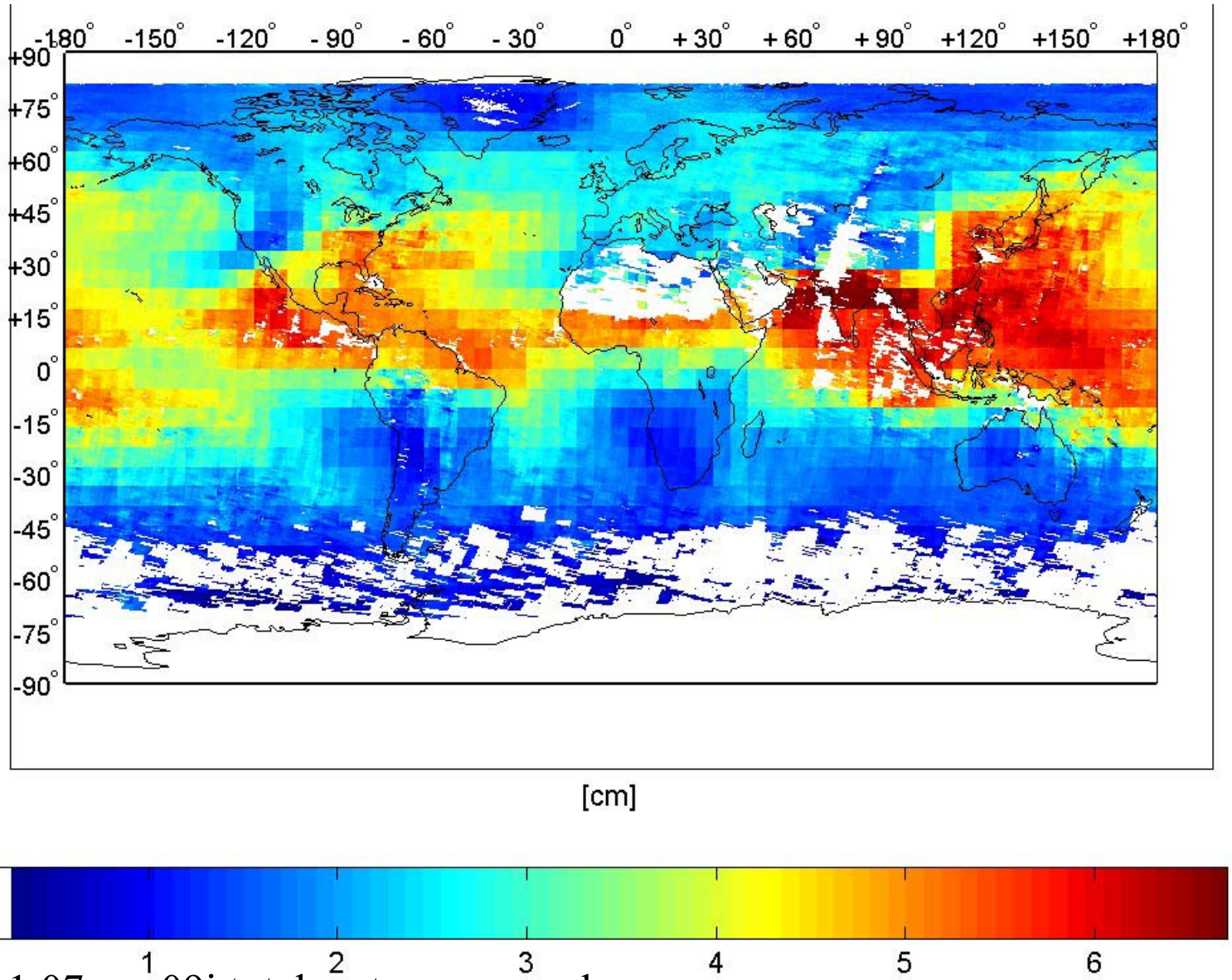
ECMWF total water vapor column,

(same averaging statistics applied)

Monthly averaged DATA, August 1998

(O4-cloud screening)

ECHAM



ECHAM 5.1.07_mz09i total water vapor column,

(same averaging statistics applied as for GOME)

Global and regional comparison

GOME
SSMI
MATCH
NCEP
ECMWF