GCSS/WGNE Pacific Cross-section Intercomparison (GPCI)

Joao Teixeira (NURC), Sambingo Cardoso (CGUL) and the GPCI group

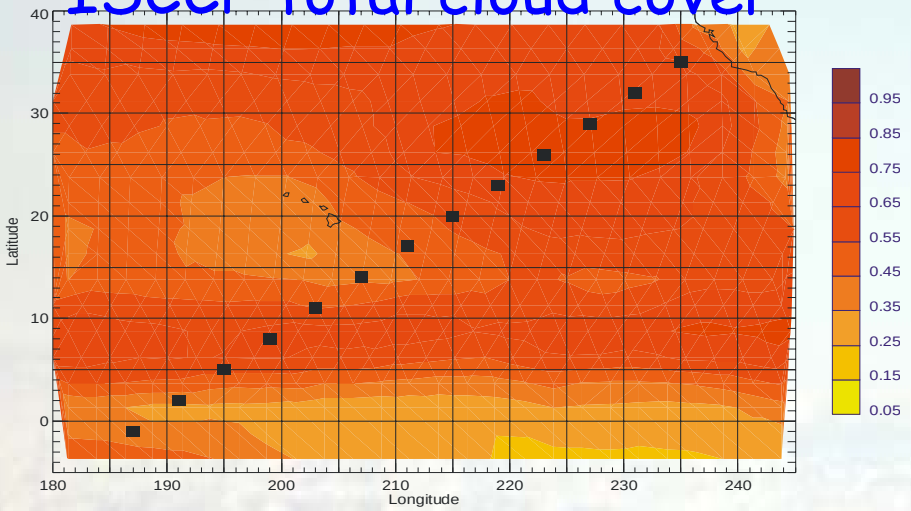
GPCI group also includes: P. Miranda (CGUL), J. Martins (CGUL), C. Jakob (BMRC), P. Soares (CGUL), P. Siebesma (KNMI), R. Neggers (ECMWF), P. Rasch (NCAR), P. Marquet (MF), M. Bonazzola (LMD), T. DelGenio (NASA/GISS), C. DeMott (CSU), C. Franklin (BMRC), C. Hannay (NCAR), Y. Jiao (UQM), H. Kitagawa (JMA), M. Koehler (ECMWF), C. LeDrian (ETH), A. Lock (UKMO), I. Meinke (UCSD), D. Mironov (DWD), B. Ritter (DWD), B. Rockel (GKSS), W. Rossow (NASA/GISS), D. Stokes (NCEP), J. Turk (NRL), P. Vaillancourt (CMC), E. Van Meijgard (KNMI), A. von Engeln (EUMETSAT) and M. Zhao (GFDL)

GCSS-BLC/GPCI workshop at NASA/GISS
New York, 18-21 Sep. 2006

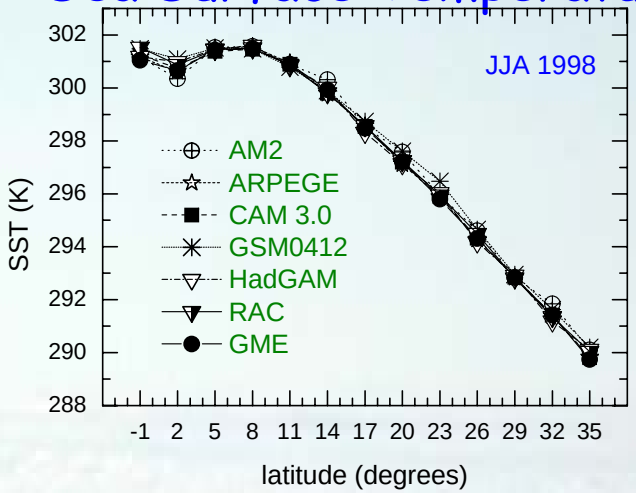
For more info contact Joao Teixeira at: teixeira@nurc.nato.int

GCSS/WGNE Pacific Cross-section Intercomparison (GPCI)

ISCCP total cloud cover



Sea Surface Temperature



GPCI is a working group of the GEWEX Cloud System Study (GCSS)

Models and data are analyzed along a Pacific Crossection from Stratocumulus, to Cumulus and to deep convection

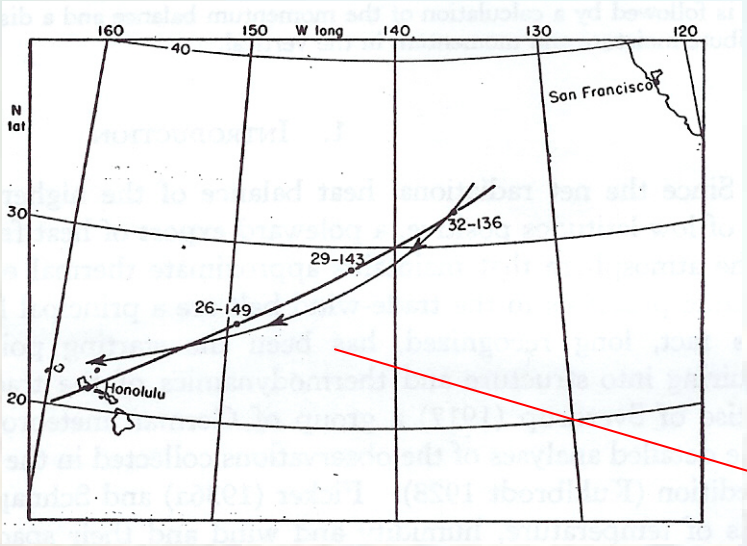
Models: GFDL, NCAR, UKMO, JMA, MF, KNMI, DWD, NCEP, ECMWF, BMRC, NASA/GISS, UCSD, UQM, LMD, CMC, CSU, GKSS

GPCI Motivation

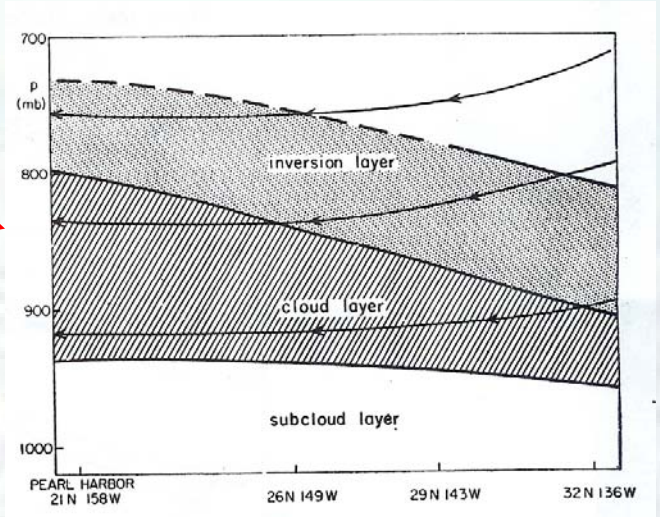
- To evaluate models and observations in the tropics and sub-tropics in terms of the atmospheric hydrologic cycle
- To include 3D NWP/Climate models in the GCSS framework (SCM/LES/CRM intercomparisons have limitations)
- To utilize a new generation of satellite datasets (e.g. AIRS, CloudSat, GPS)
- To create a database of models and observations for future studies of the tropics and sub-tropics
- To try to answer some questions: Can models reproduce the main properties of the diurnal cycle in the (sub)tropics? Can models and observations characterize the humidity structure of the (sub)tropical upper-troposphere?

The 1945 Pacific cross-section

From July to October 1945, 3 weather ships were stationed in a Pacific cross-section from San Francisco to Honolulu.



From Riehl et al. (1951)



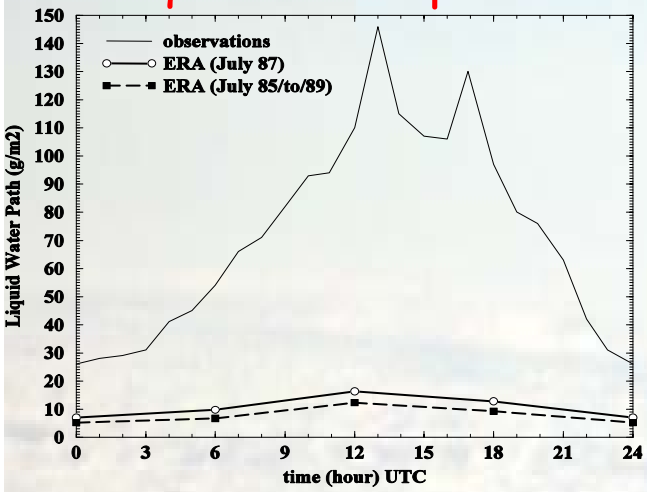
By the end of Word War II, there were 22 Atlantic and 24 Pacific weather ships. After the war 13 weather ships remained in the Atlantic and Pacific until 1980.

Thanks to Bjorn and Anders for historical insight.

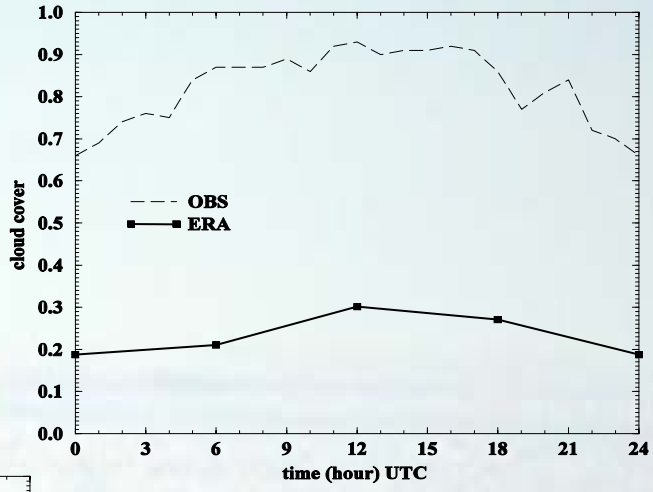
How well are stratocumulus represented? Observations versus ECMWF Re-Analysis (ERA)

July 1987, San Nicolas island, California

Liquid water path

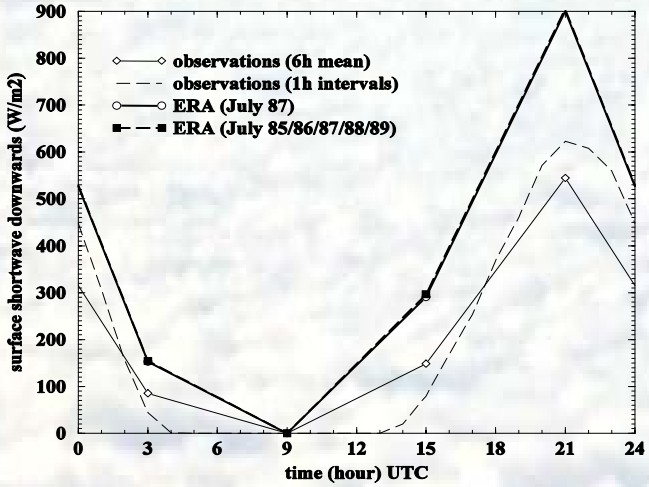


Cloud cover



Severe underestimation of clouds

Surface shortwave



GPCI model data characteristics

When? June-July-August 1998 and 2003

Time resolution: 0, 3, 6, 9, 12, 15, 18, 21 UTC

Boundary Conditions: prescribed sea surface temperature

Remarks: simulation starting May 20th until end of August

Where?

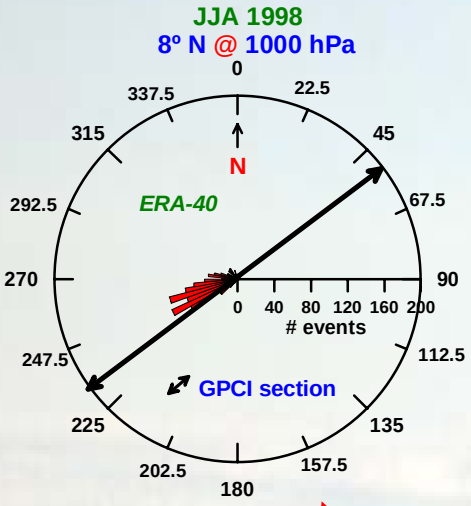
Cross-section: 13 locations starting at 35 N, 125 W and moving southwestwards at 4 deg longitude and 3 deg latitude steps until 1 S, 173 W.

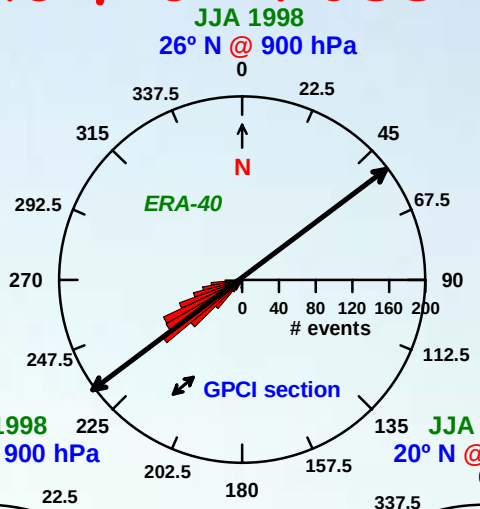
2D map: Locations every 5x5 degrees within the following grid: latitude from 5 S to 45 N, longitude from 160 E to 120 W.

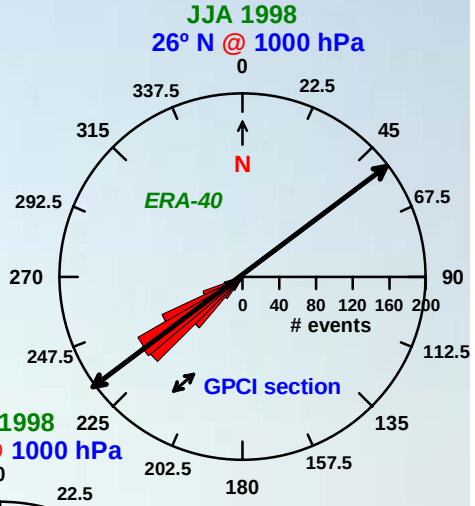
Participating Models

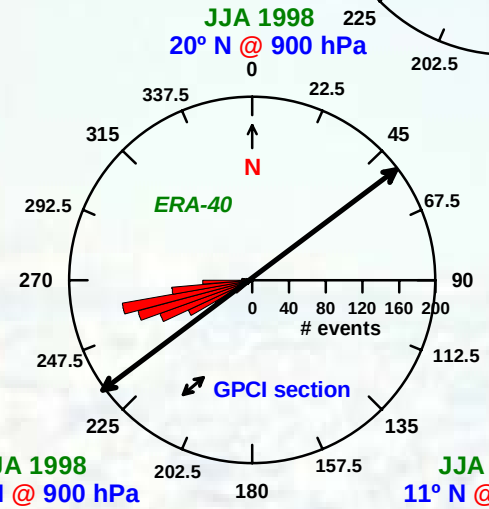
organization	Model type	organization	Model type
BMRC (Aus)	Global	KNMI	Regional
CMC (Can)	Regional	LMD (Fra)	Global
CSU (us)	Global	MeteoFrance	Global
CSU/MMF	Global / MMF	NASA/GISS	Global
DWD (Ger)	Global	NCAR (US)	Global
ECHAM	Global	NCEP (US)	Global/coupl.
GFDL (US)	Global	ECMWF	Global
GKSS (Ger)	Regional	UCSD (US)	Regional
JAMSTEC	Global	UKMO (UK)	Global
JMA (Jap)	Global	UQM (Can)	Regional

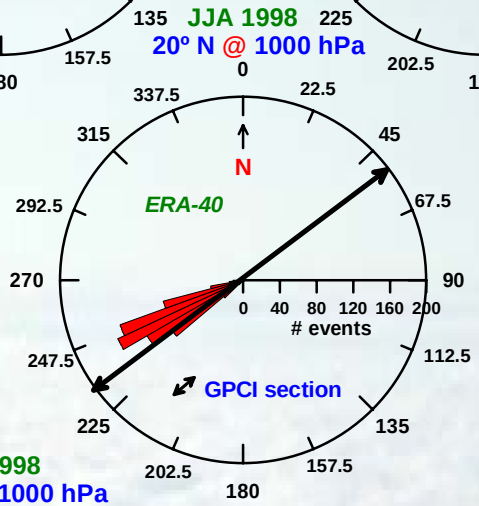
PBL winds in the Pacific Cross-section

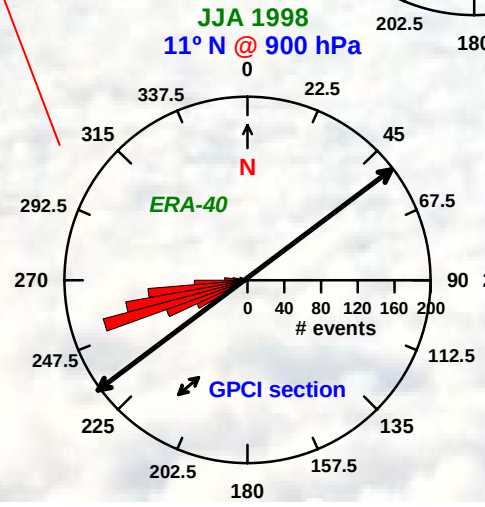


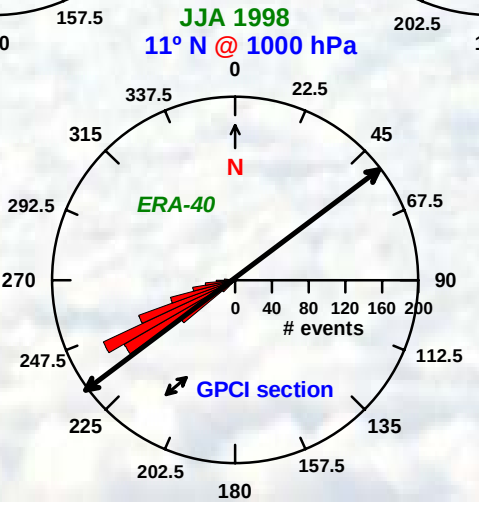






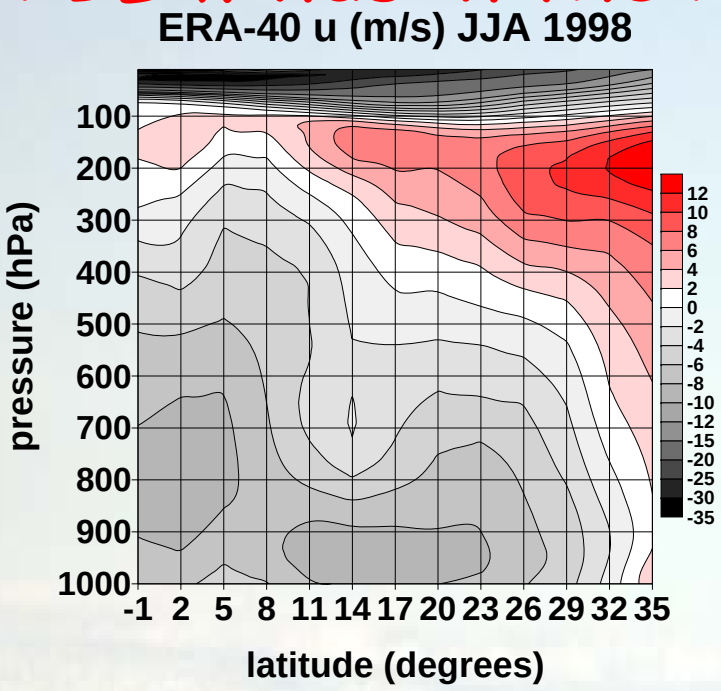


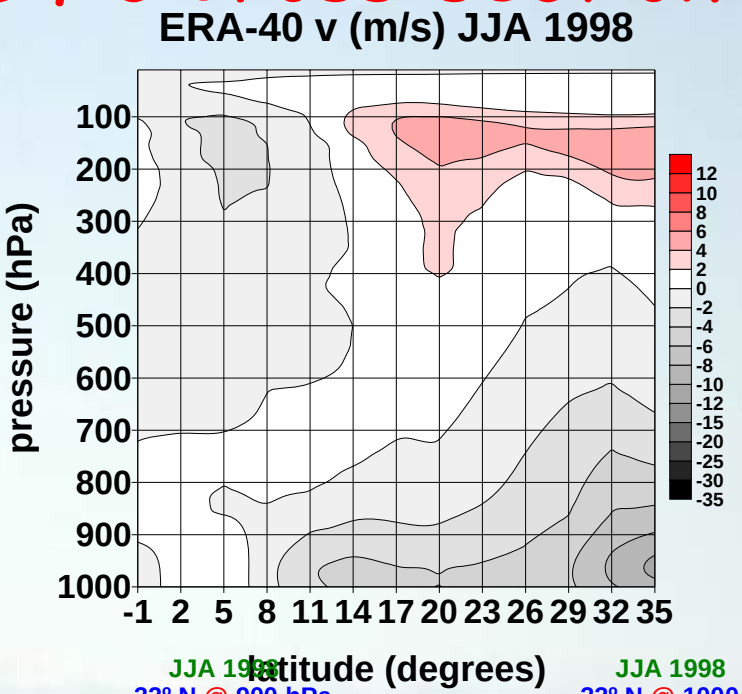


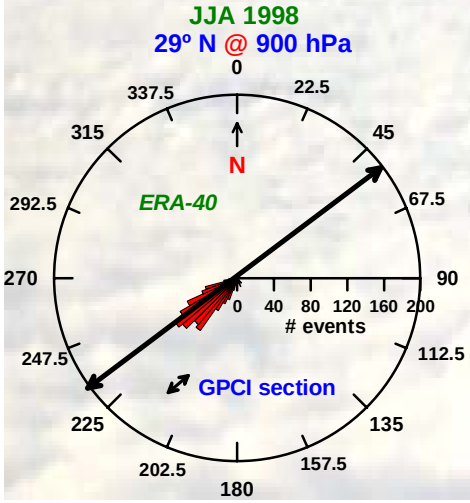


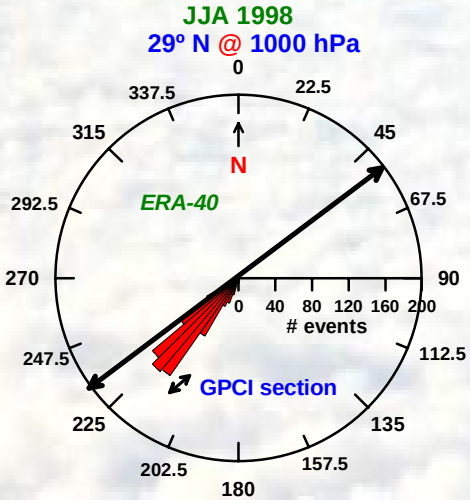
1000 hPa winds are quite parallel to the cross-section

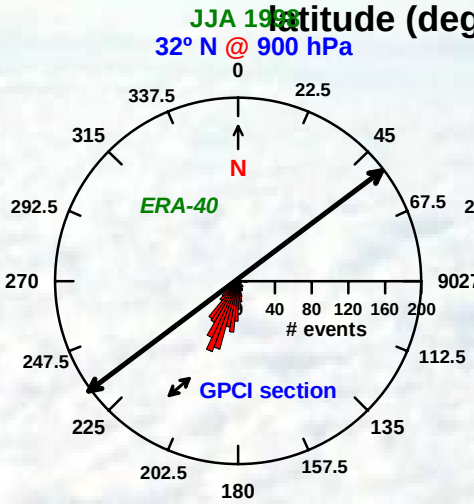
PBL winds in the Pacific Cross-section

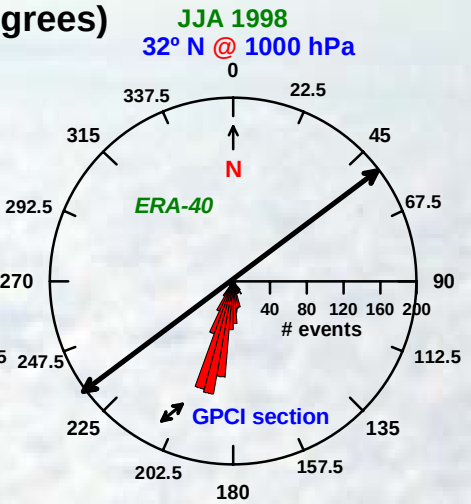






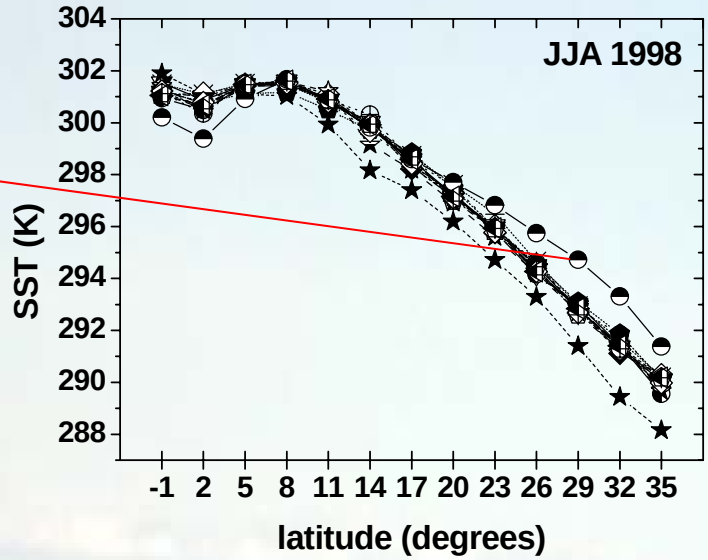






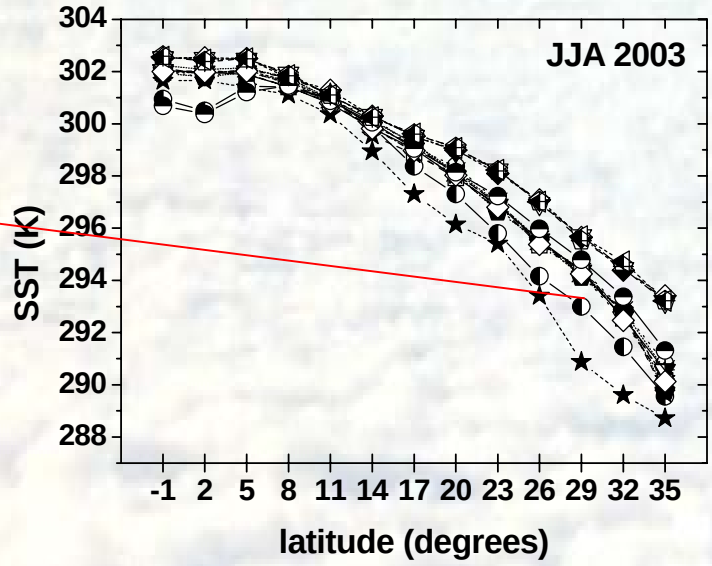
Sea Surface Temperature

NCEP coupled



AM2
ARPEGE
CAM 3.0
GSM0412
HadGAM
RAC
GME
ECMWF
ERA-40
BMRC
CSU MMF
GISS
GKSS
NCEP G&M3
CMC
UQM

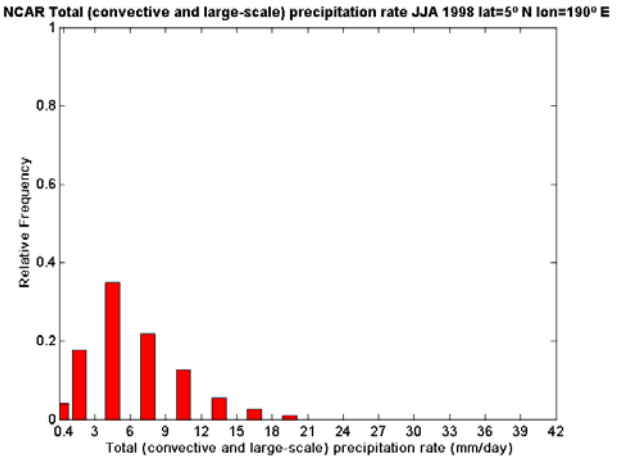
ERA40 1998



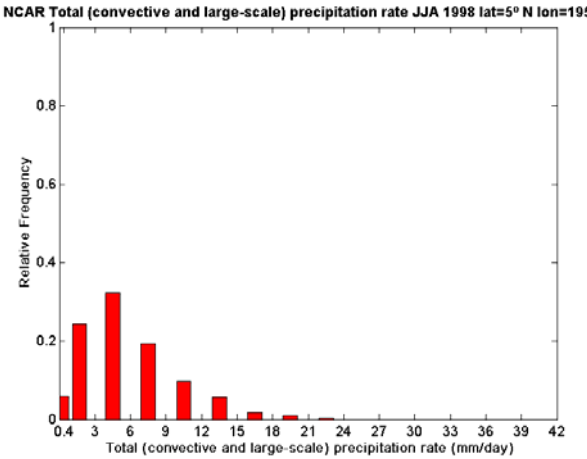
AM2
ARPEGE
CAM 3.0
GSM0412
HadGAM
RAC
GME
ECMWF
ERA-40 (1998)
BMRC
CSU MMF
GISS
GKSS
NCEP G&M3
CMC
UQM

How representative is the cross-section? Precipitation histograms from the 2D maps

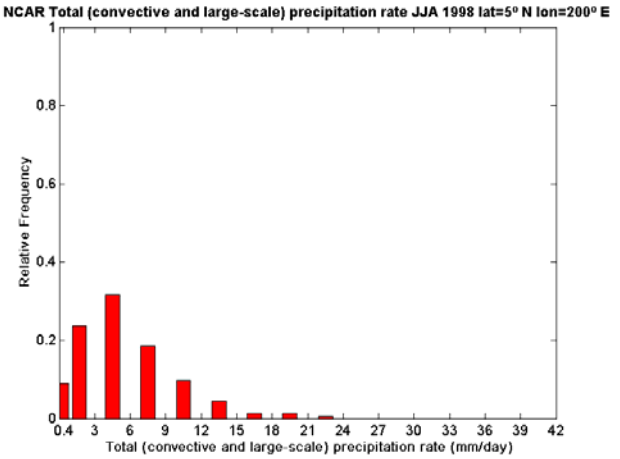
5 N, 190 E



NCAR, 5 N, 195 E

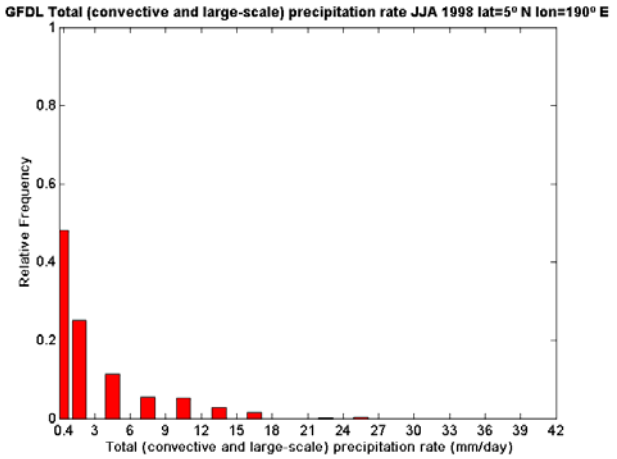


5 N, 200 E

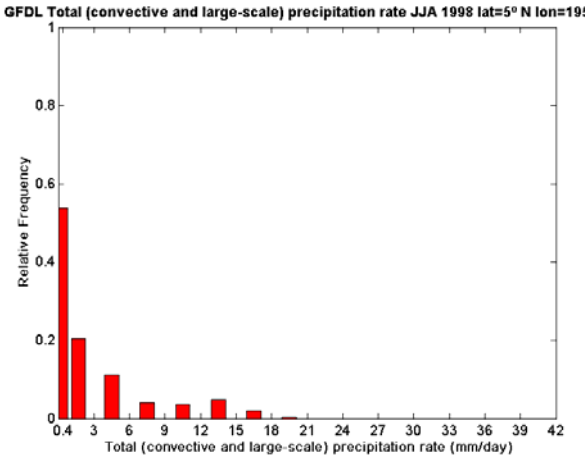


Results from adjacent points are similar. Models are more different.

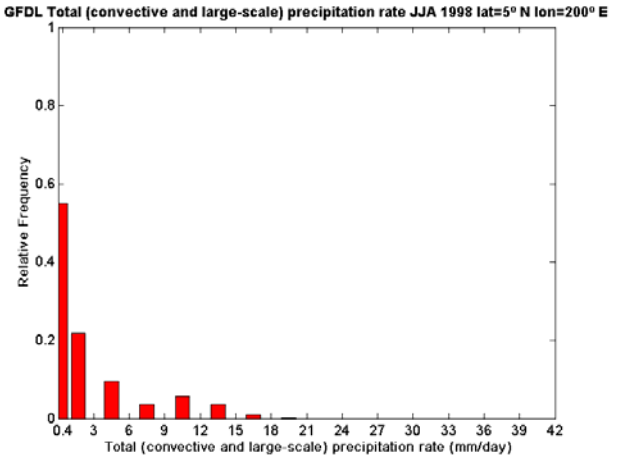
5 N, 190 E



GFDL, 5 N, 195 E

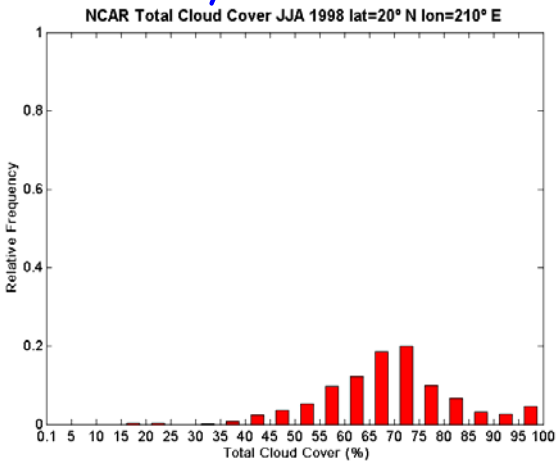


5 N, 200 E

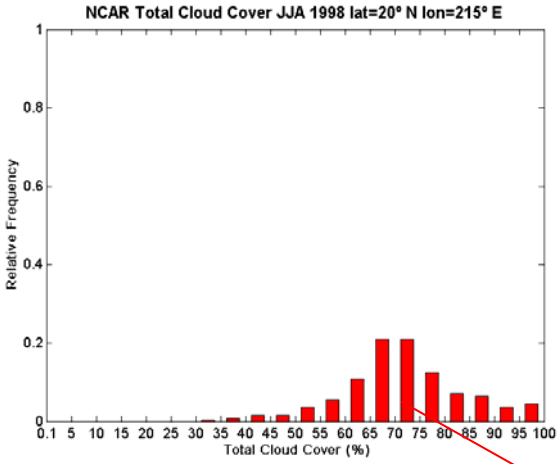


Total cloud cover histograms (2D map)

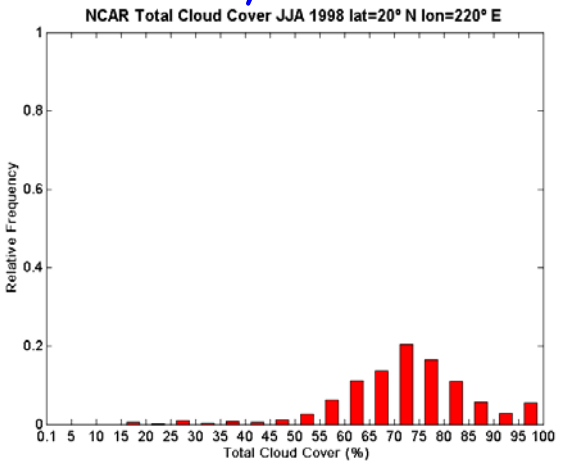
20 N, 210 E



NCAR, 20 N, 215 E

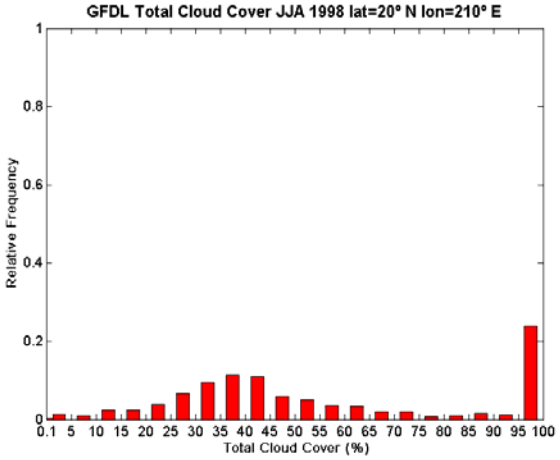


20 N, 220 E

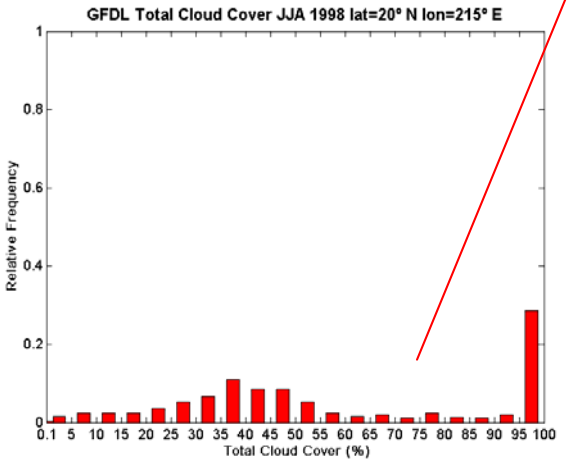


1 peak .vs. 2 peaks

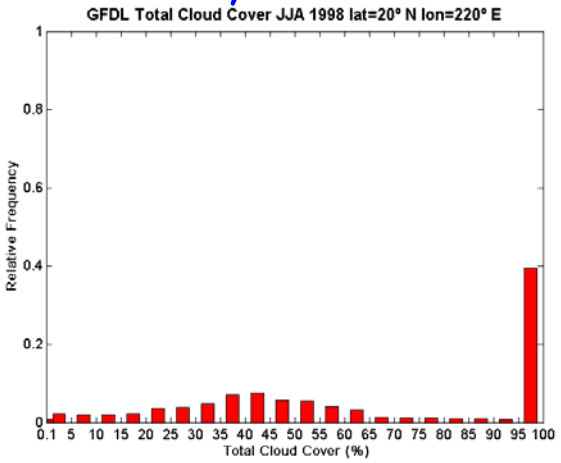
20 N, 210 E



GFDL, 20 N, 215 E

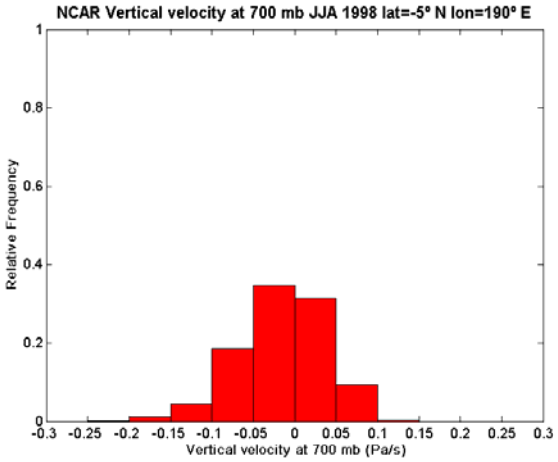


20 N, 220 E

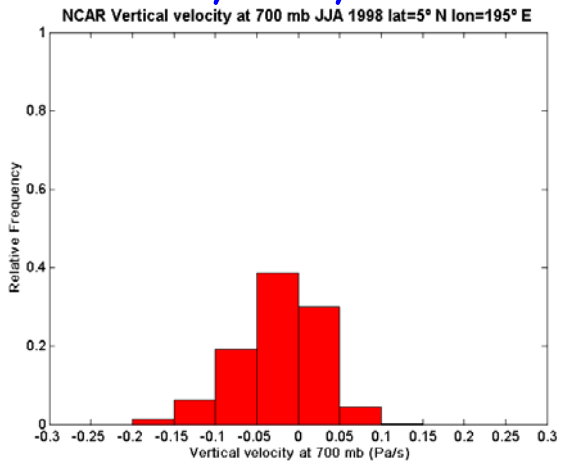


Vertical velocity (700 hPa) histograms

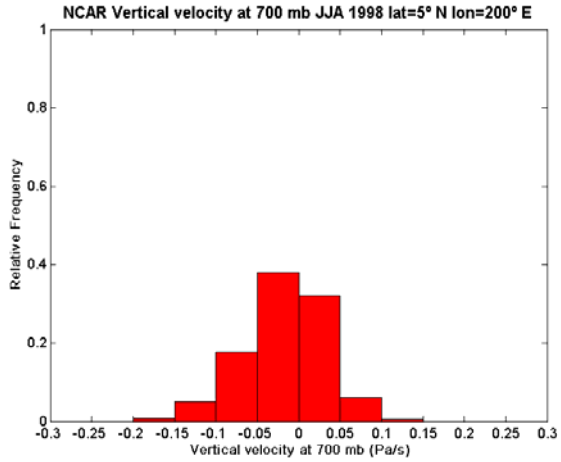
5 N, 190 E



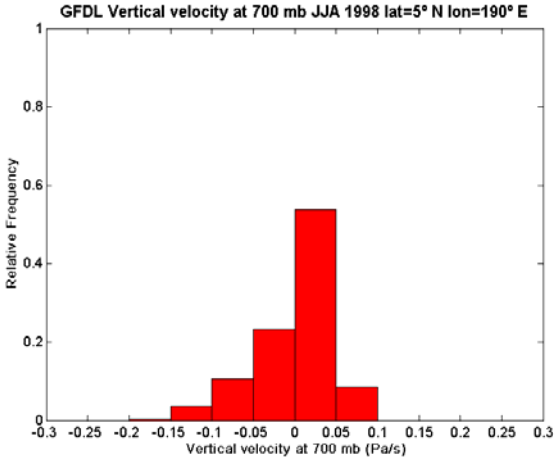
NCAR, 5 N, 195 E



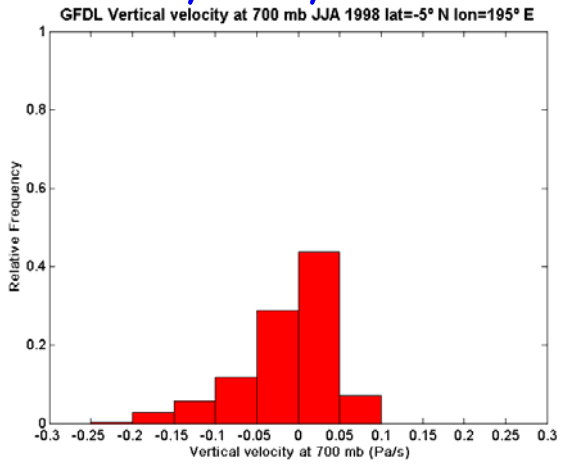
5 N, 200 E



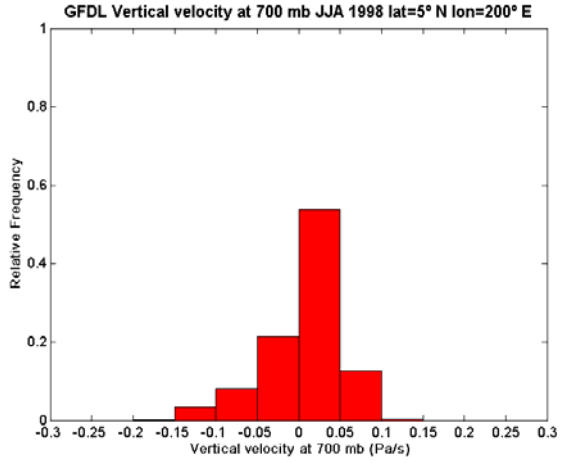
5 N, 190 E



GFDL, 5 N, 195 E

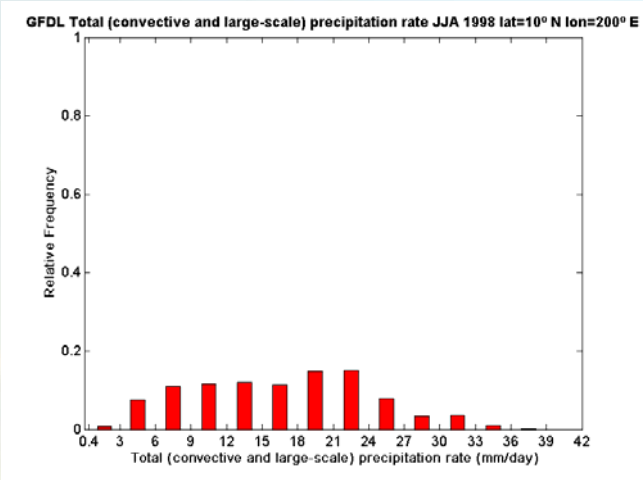


5 N, 200 E

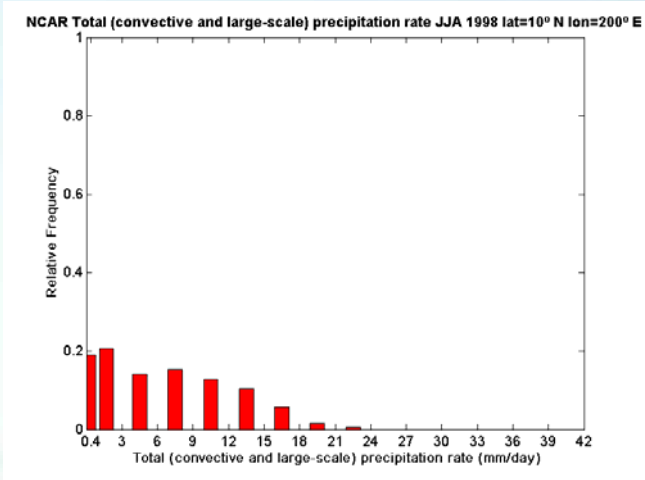


Histograms: regional models tropical precipitation (10 N, 200 E)

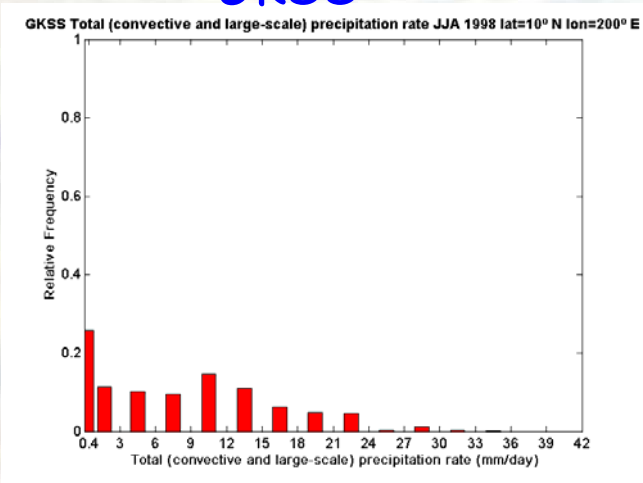
GFDL



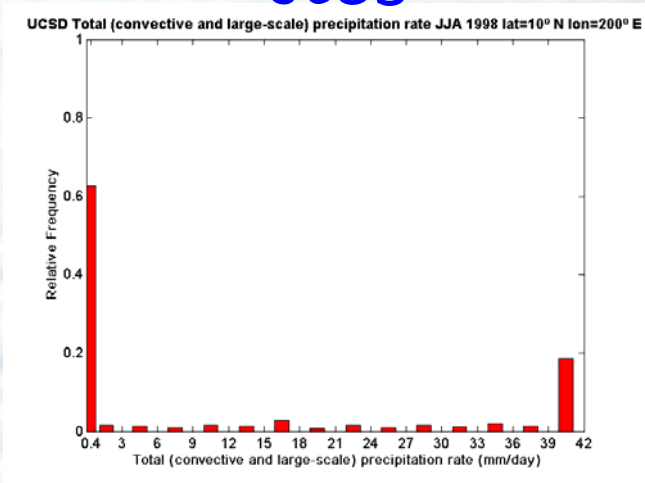
NCAR



GKSS

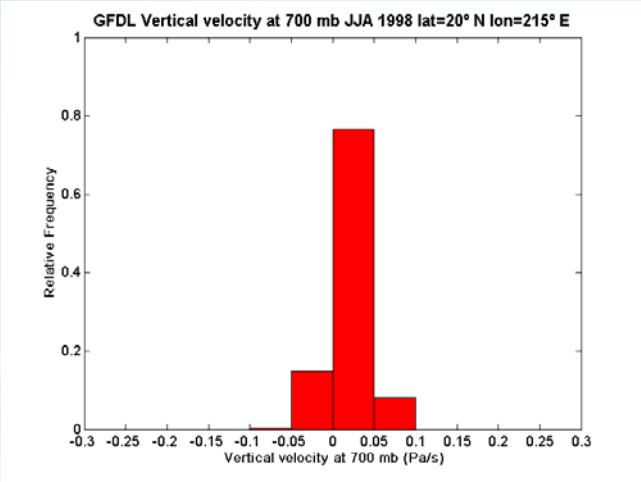


UCSD

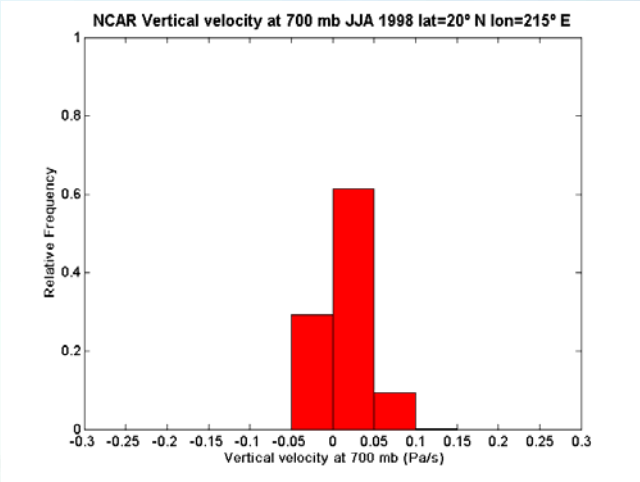


Histograms: regional models vertical velocity 700 hPa (20 N, 215 E)

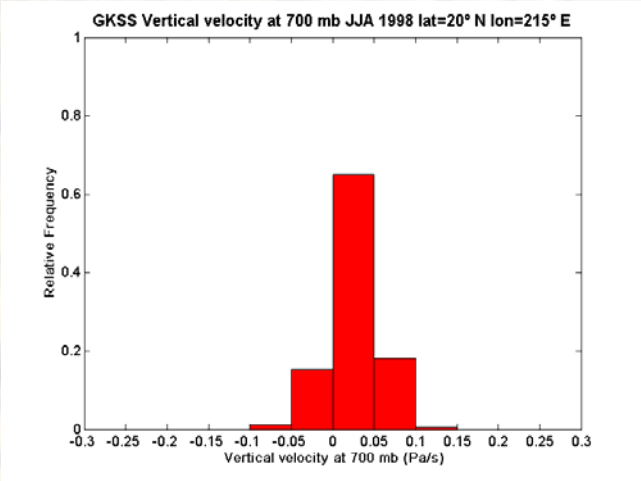
GFDL



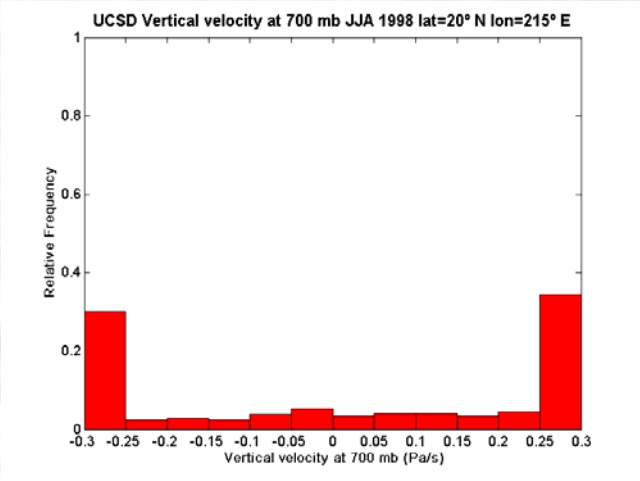
NCAR



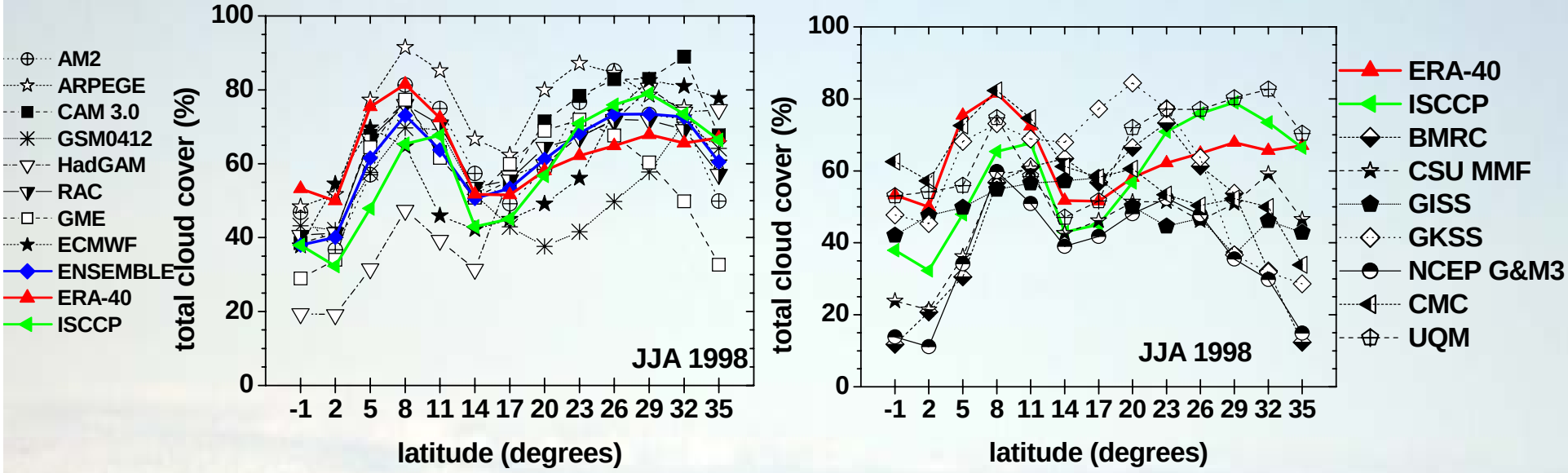
GKSS

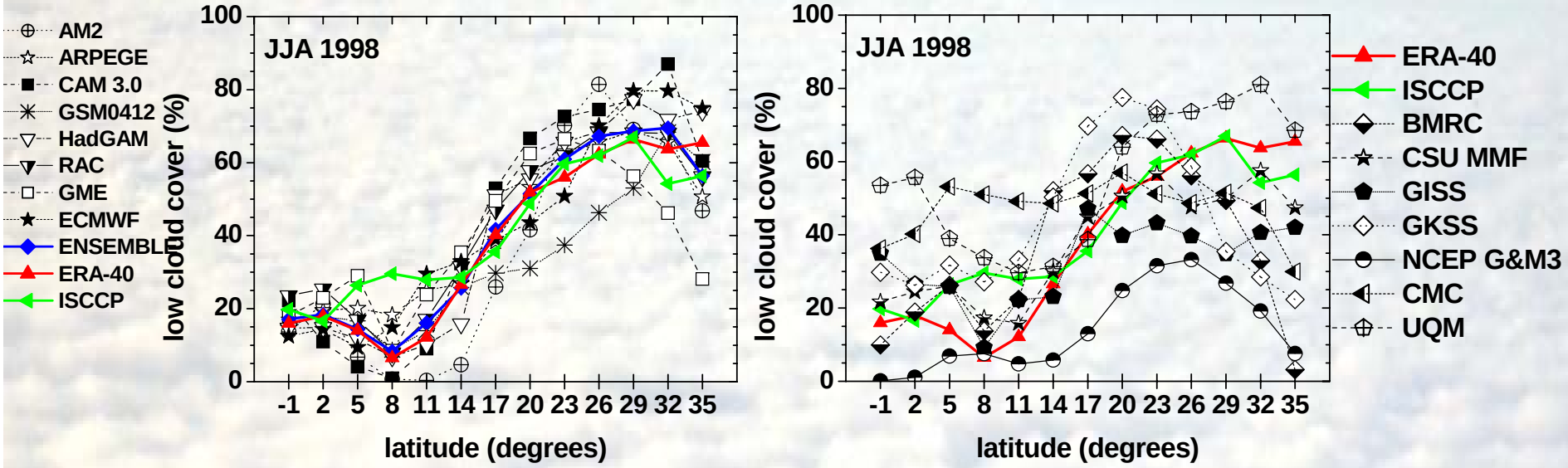


UCSD

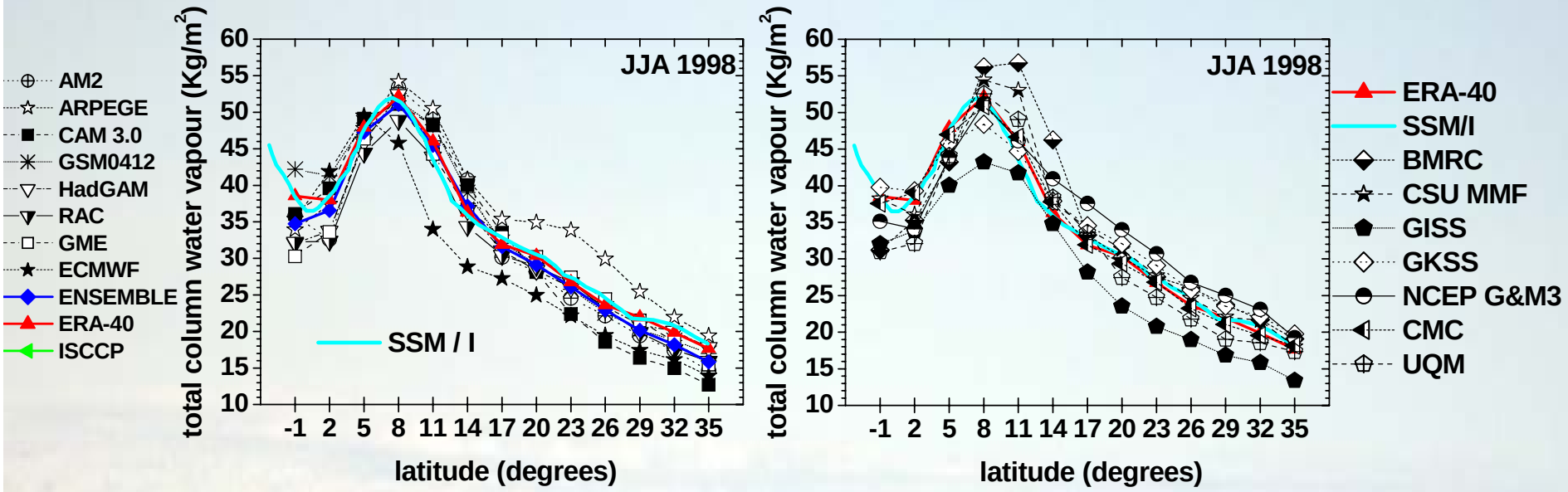


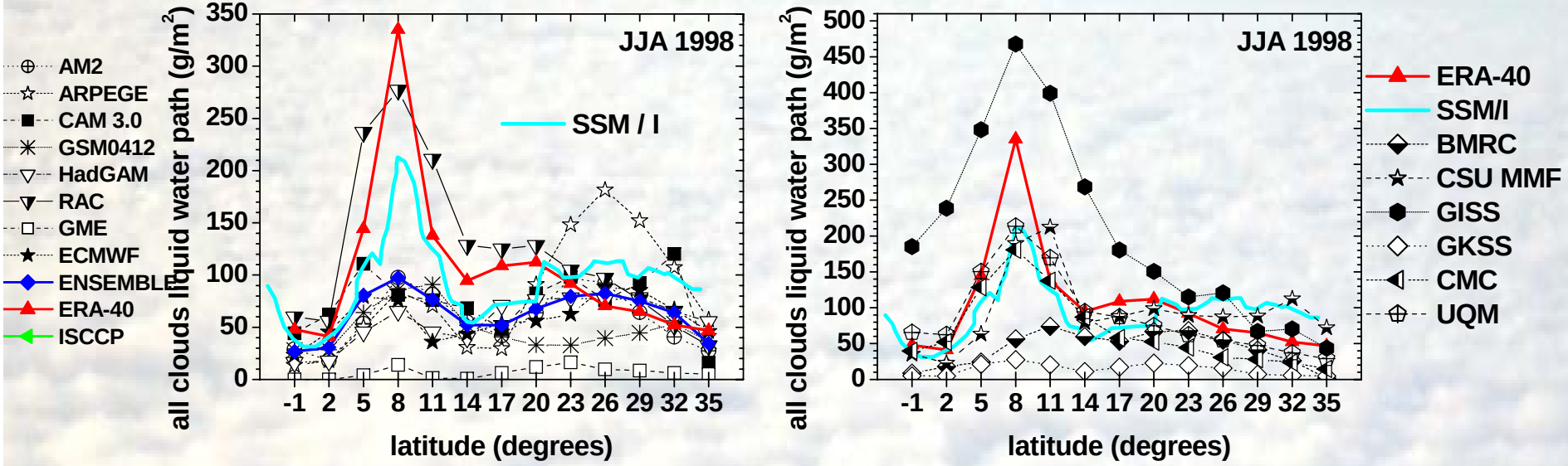
Total and low cloud cover (JJA98)



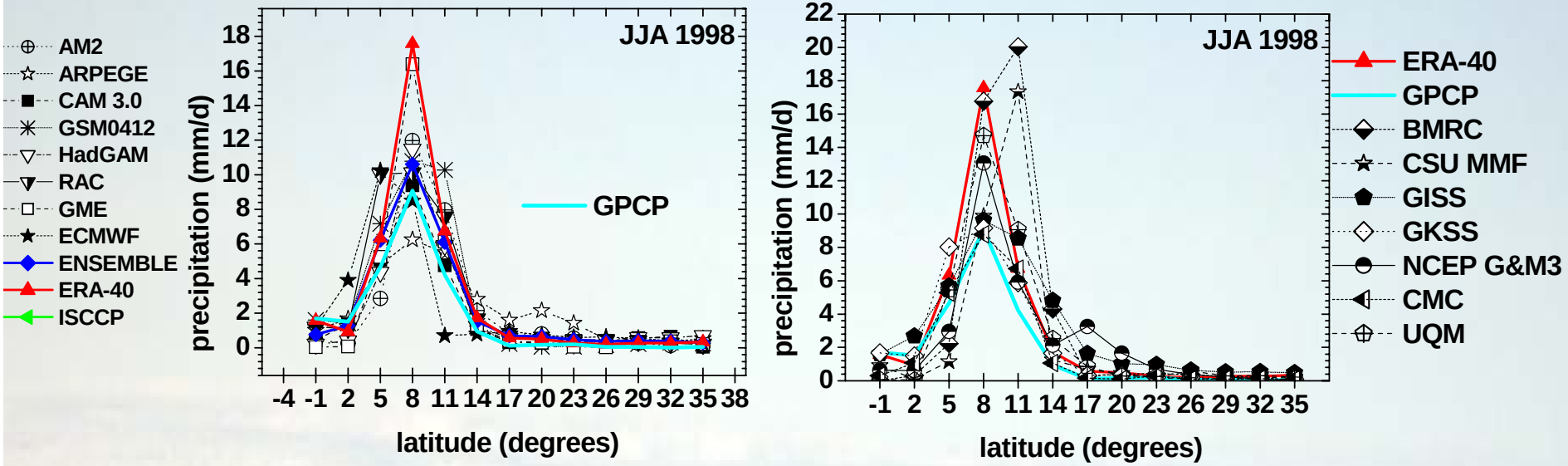


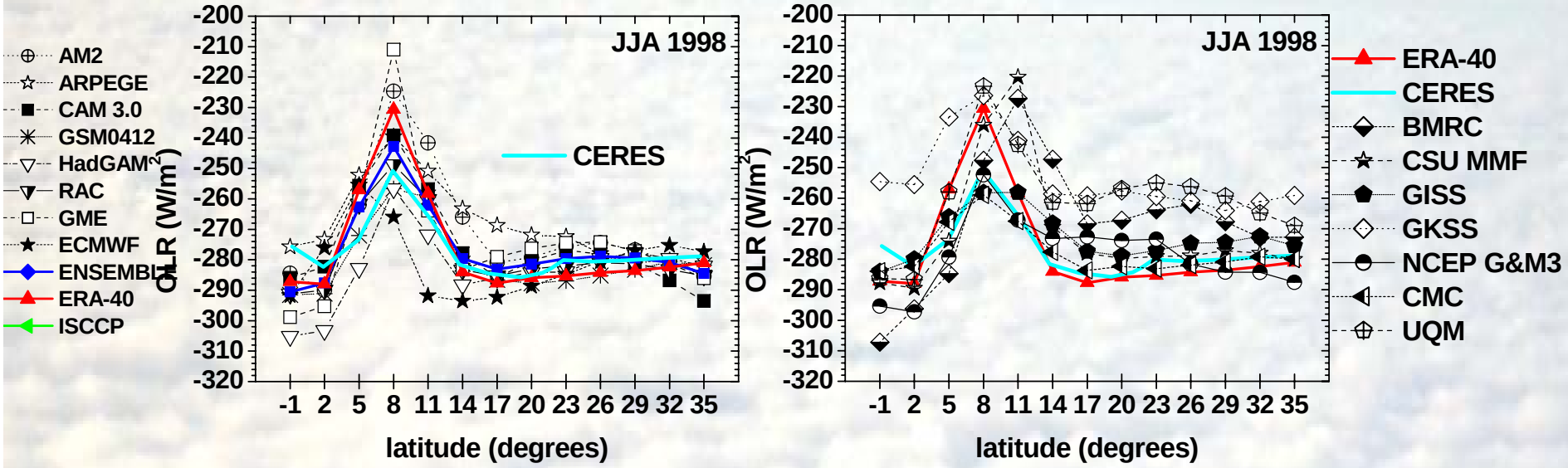
Total column water vapor and liquid water path



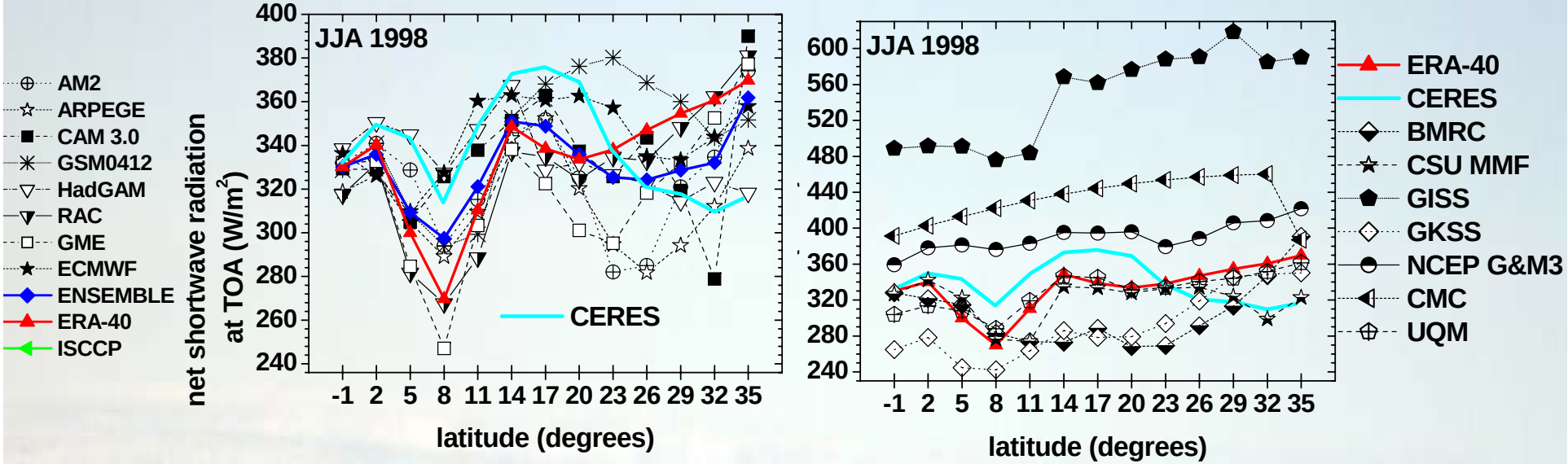


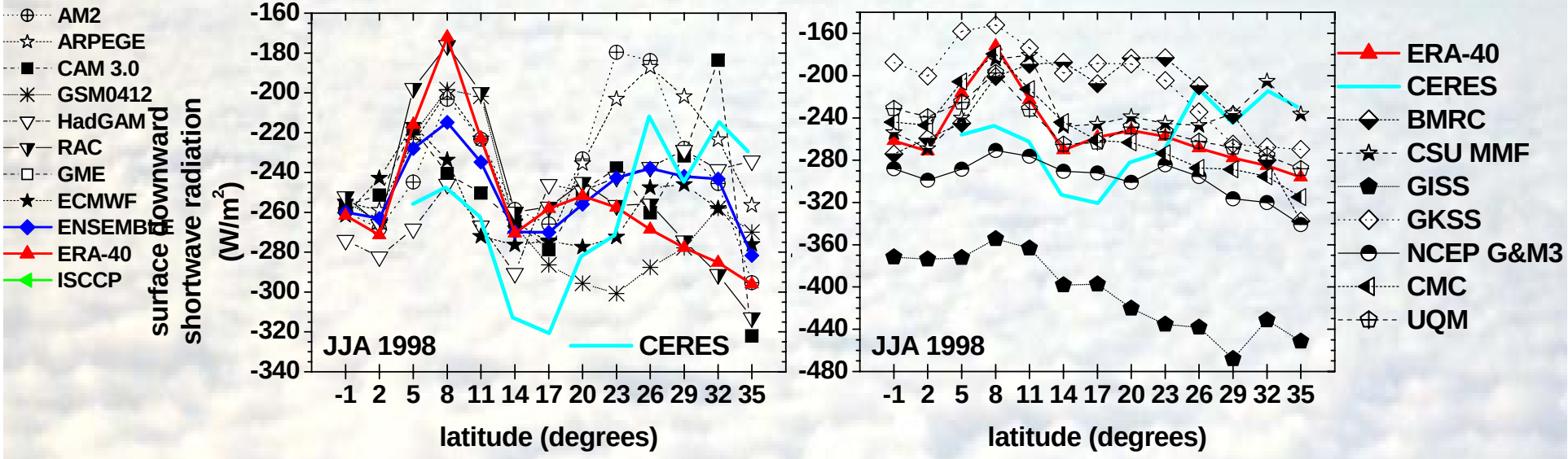
Precipitation and outgoing longwave radiation





Top and surface shortwave radiation

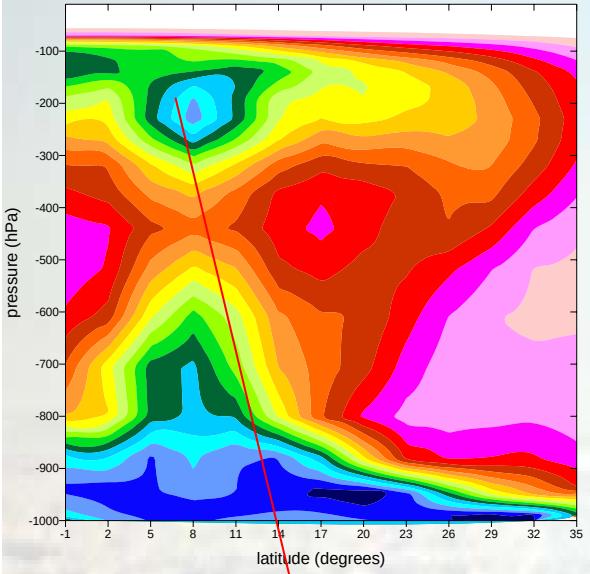




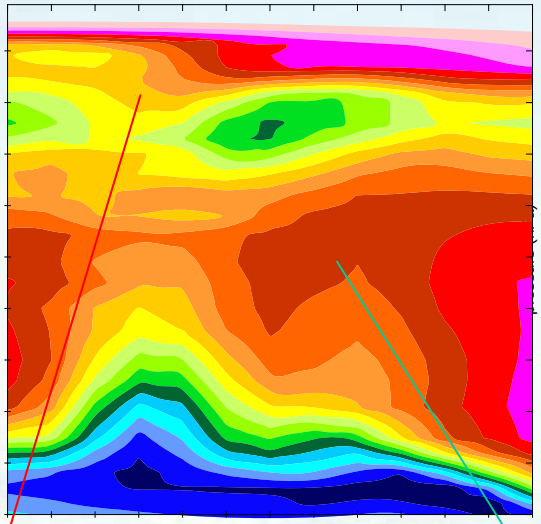
Mean GPCI relative humidity - JJA98

All models exhibit Hadley-circulation-like features…

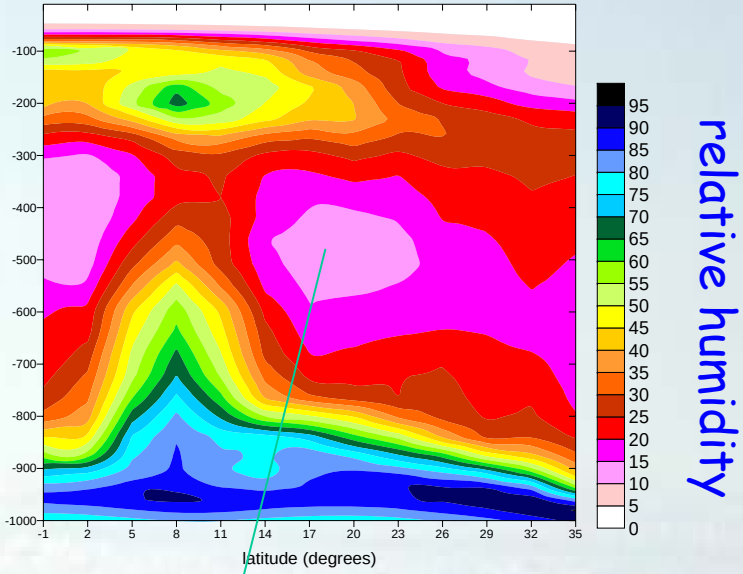
NCAR



MeteoFrance



UKMO

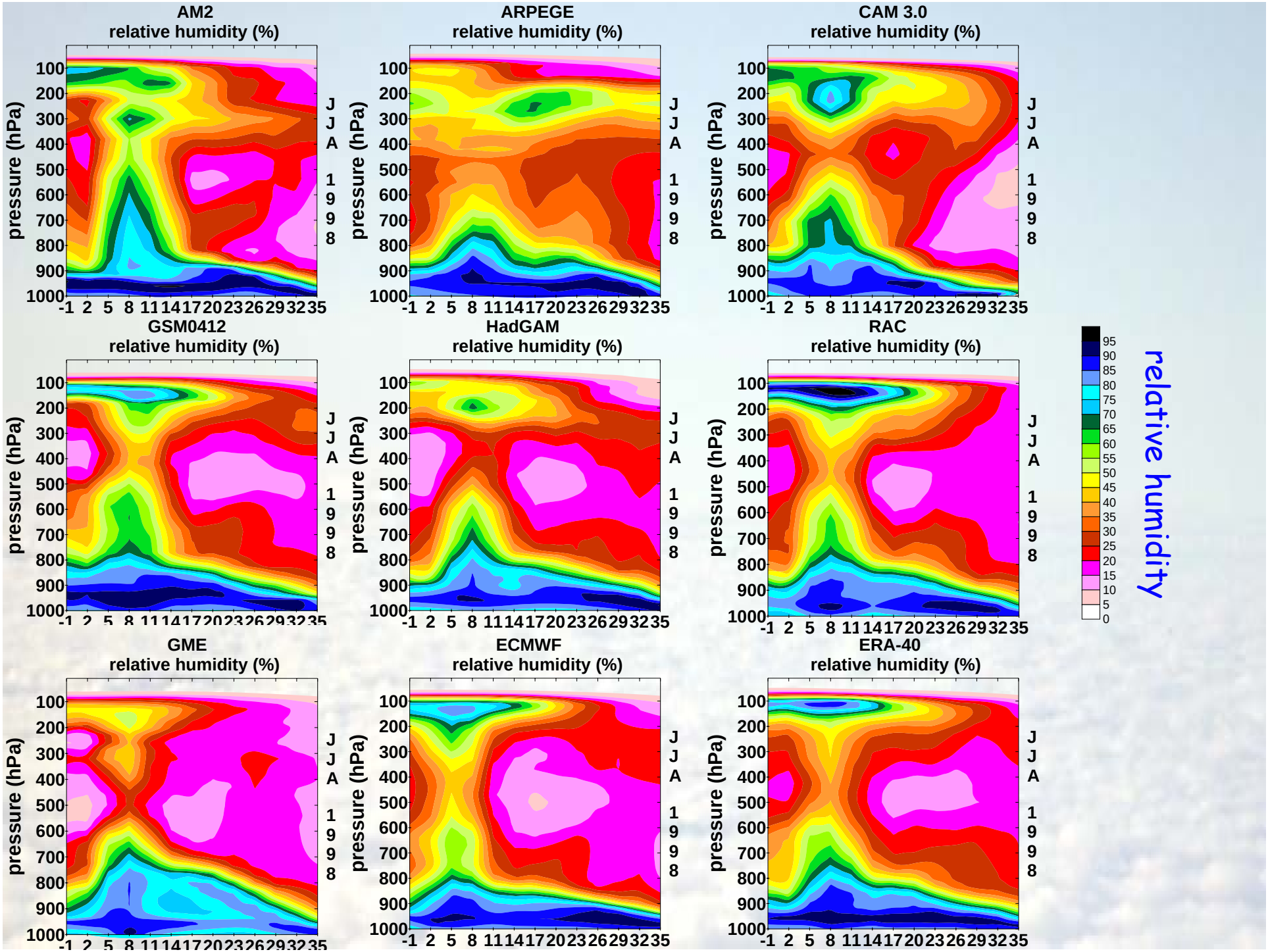


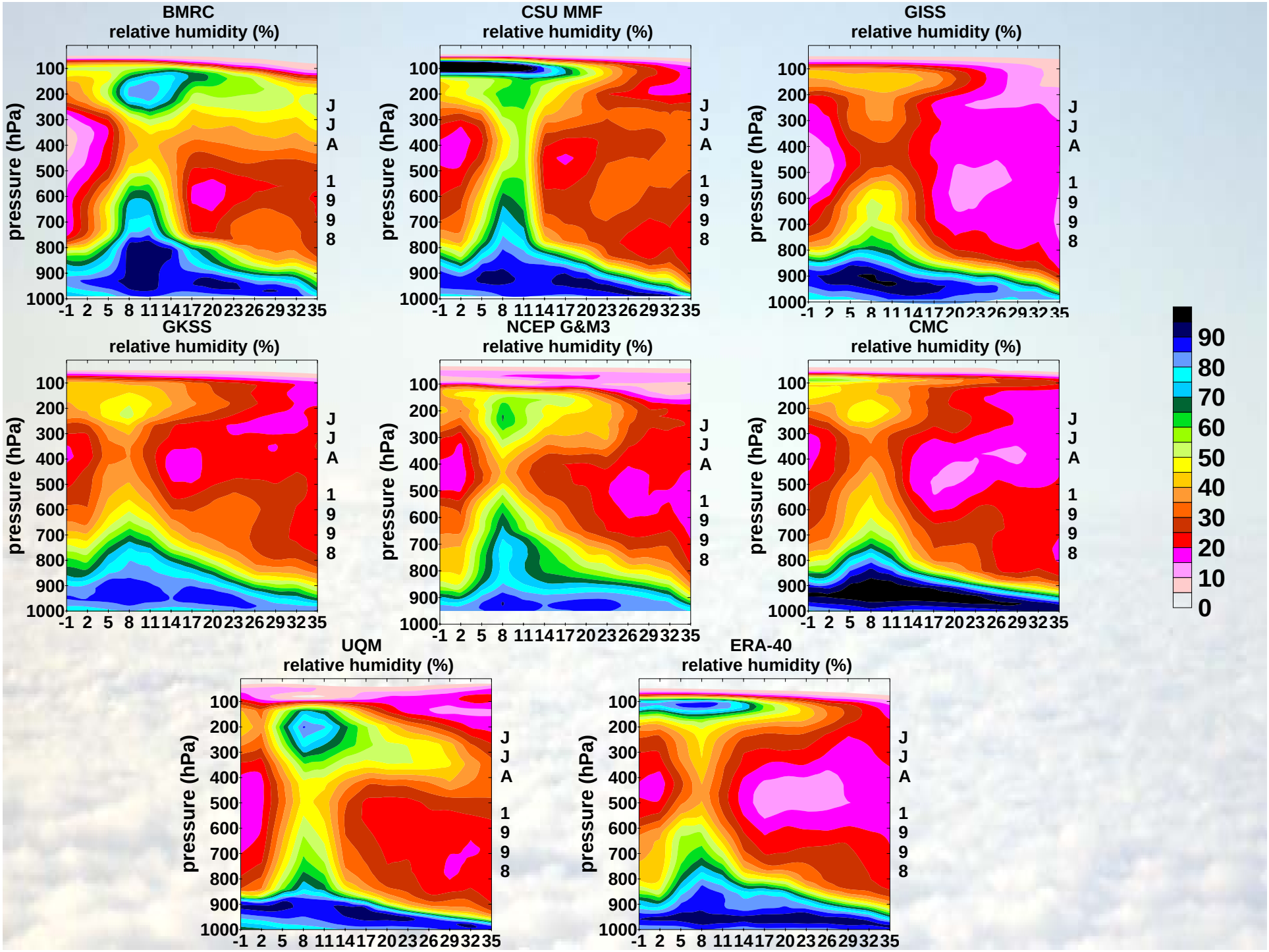
relative humidity

How dry should it be …?

How deep is convection…?

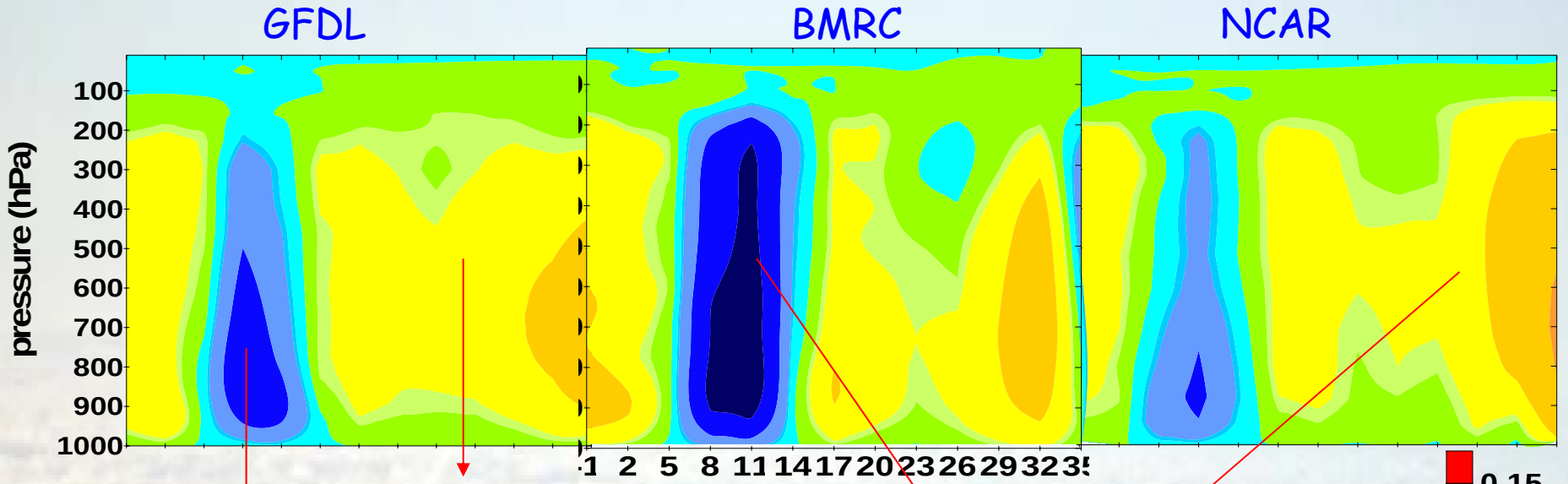
Similar overall model behavior but still some serious differences, but how do we find out how good they are? A lack of observations…


AM2
relative humidity (%)
ARPEGE
relative humidity (%)
CAM 3.0
relative humidity (%)
GSM0412
relative humidity (%)
HadGAM
relative humidity (%)
RAC
relative humidity (%)
GME
relative humidity (%)
ECMWF
relative humidity (%)
ERA-40
relative humidity (%)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J
J
A
1
9
9
8
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
relative humidity


BMRC
relative humidity (%)
CSU MMF
relative humidity (%)
GISS
relative humidity (%)
GKSS
relative humidity (%)
NCEP G&M3
relative humidity (%)
CMC
relative humidity (%)
UQM
relative humidity (%)
ERA-40
relative humidity (%)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J
J
A
1
9
9
8
90
80
70
60
50
40
30
20
10
0

GPCI: JJA98 mean vertical velocity

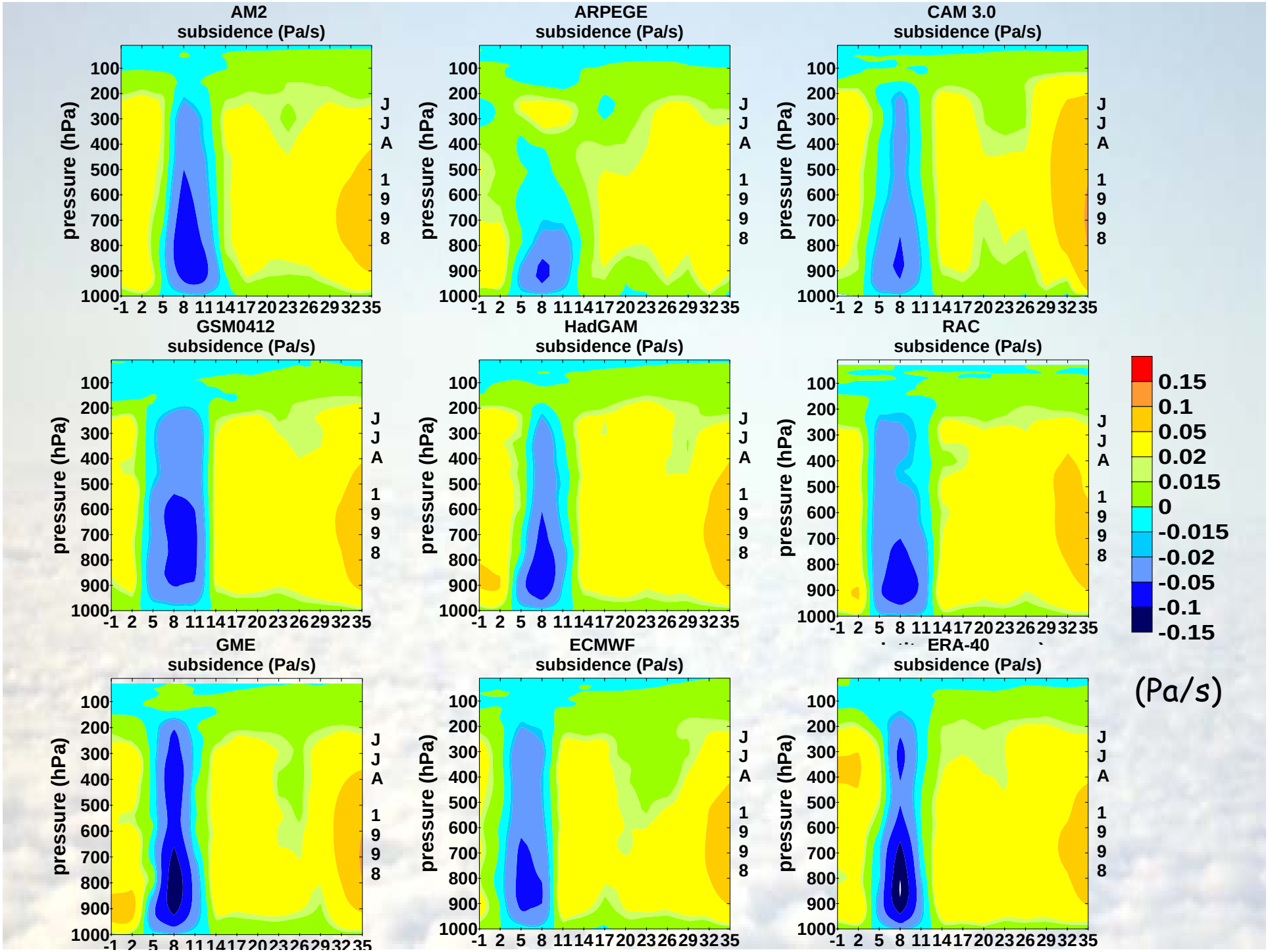
All models exhibit Hadley-circulation-like features…

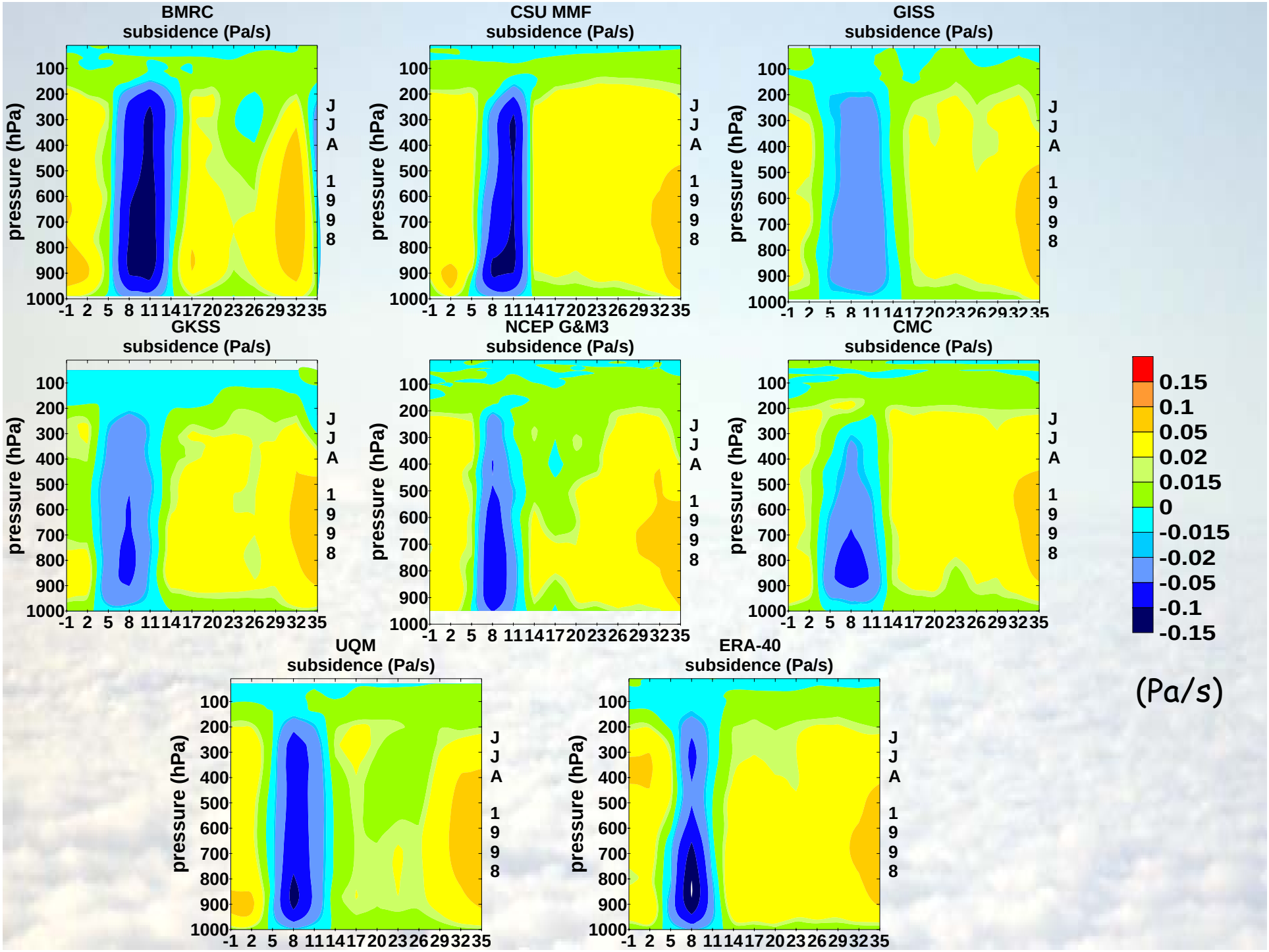


ascending in ITCZ

descending in subtropics

major differences in convection and subsidence


AM2
subsidence (Pa/s)
ARPEGE
subsidence (Pa/s)
CAM 3.0
subsidence (Pa/s)
GSM0412
subsidence (Pa/s)
HadGAM
subsidence (Pa/s)
RAC
subsidence (Pa/s)
GME
subsidence (Pa/s)
ECMWF
subsidence (Pa/s)
ERA-40
subsidence (Pa/s)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J
J
A
1
9
9
8
0.15
0.1
0.05
0.02
0.015
0
-0.015
-0.02
-0.05
-0.1
-0.15
(Pa/s)

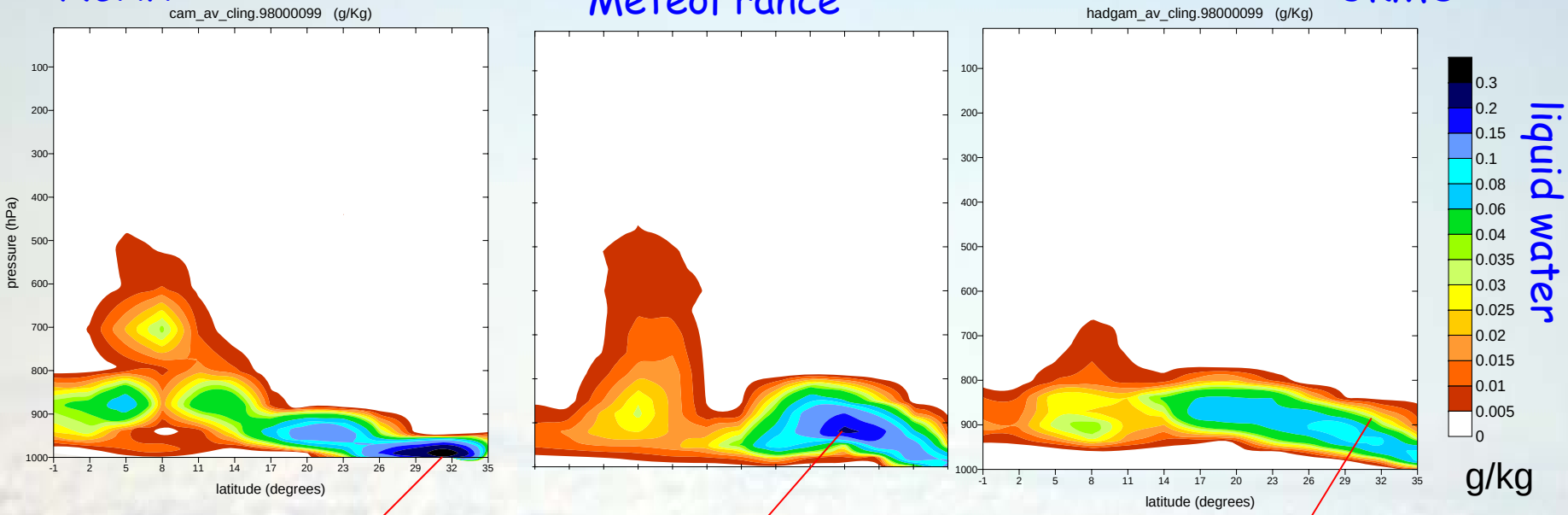

BMRC
subsidence (Pa/s)
CSU MMF
subsidence (Pa/s)
GISS
subsidence (Pa/s)
GKSS
subsidence (Pa/s)
NCEP G&M3
subsidence (Pa/s)
CMC
subsidence (Pa/s)
UQM
subsidence (Pa/s)
ERA-40
subsidence (Pa/s)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J
J
A
1
9
9
8
0.15
0.1
0.05
0.02
0.015
0
-0.015
-0.02
-0.05
-0.1
-0.15
(Pa/s)

Mean GPCI liquid water crossection - JJA98

NCAR

MeteoFrance

UKMO

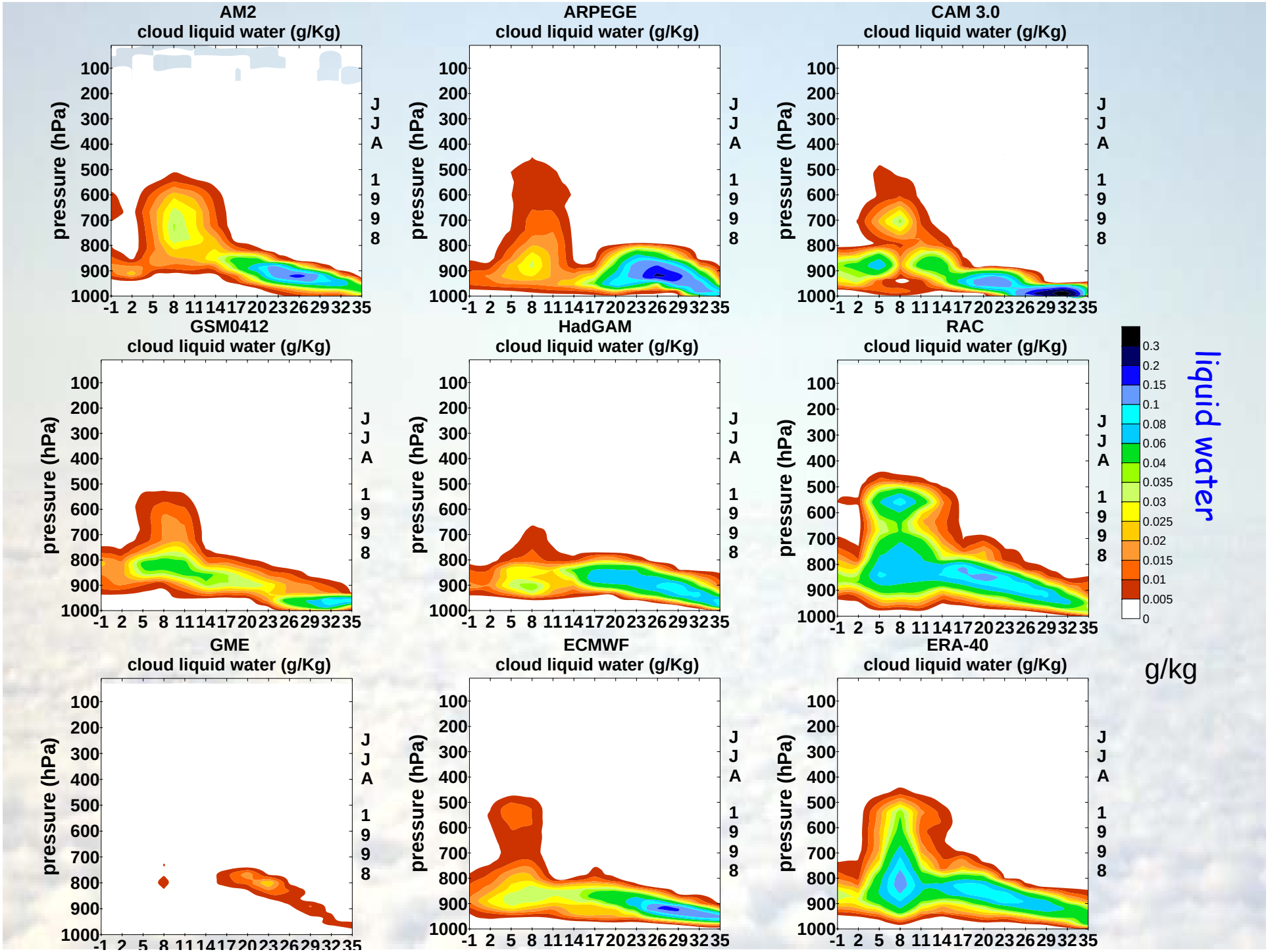


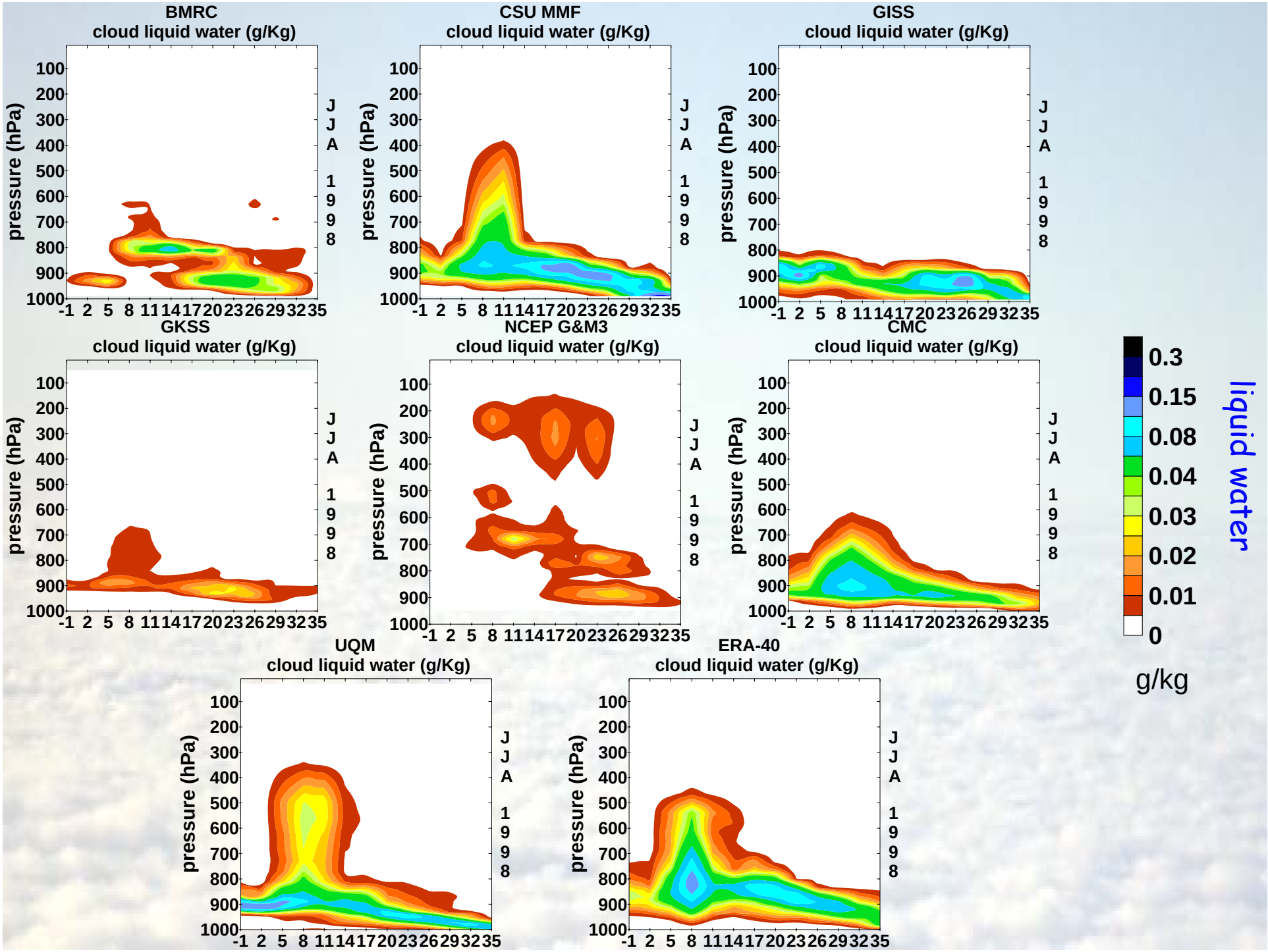
Too shallow -> fog

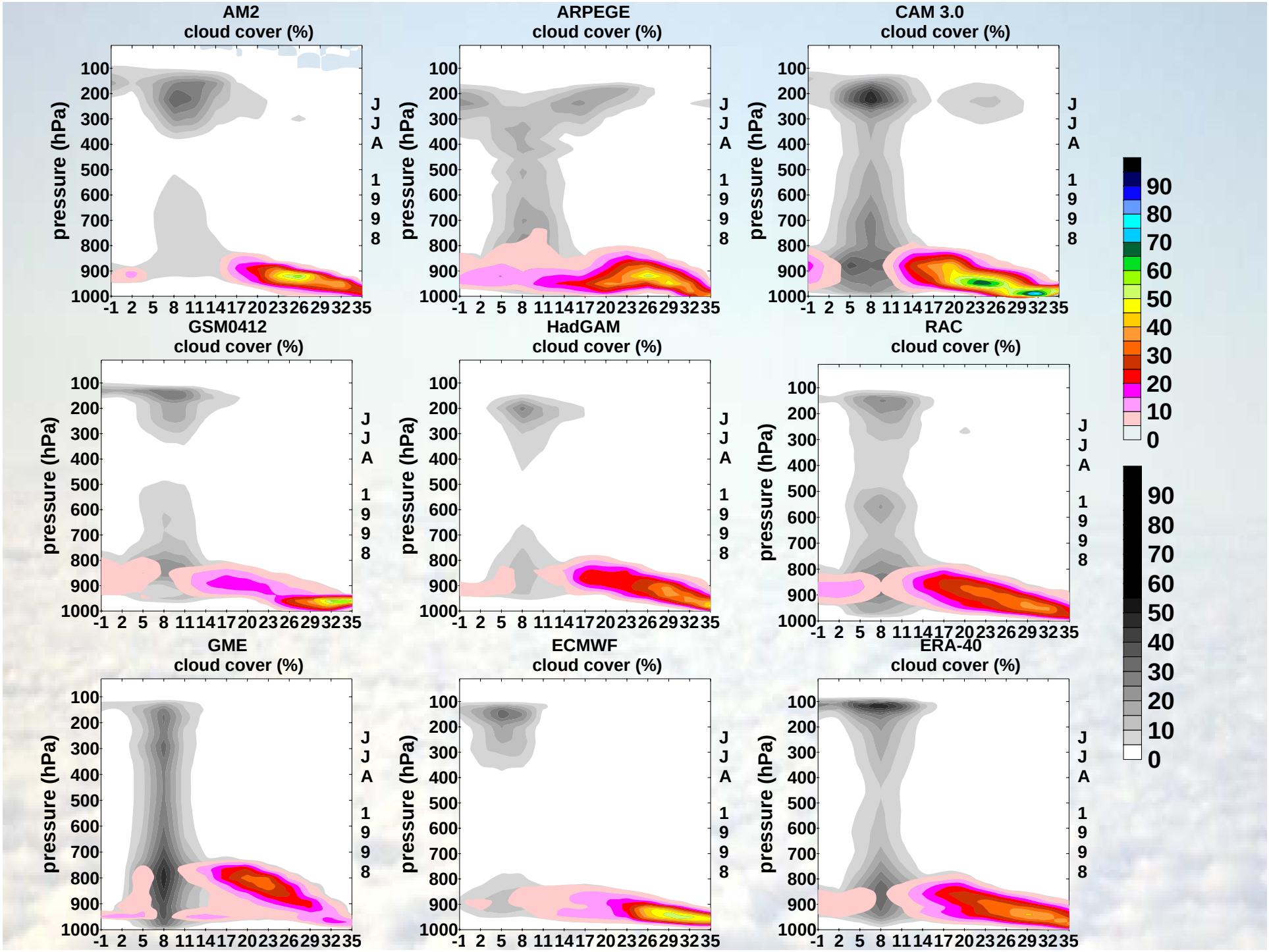
Is this too much liquid water?

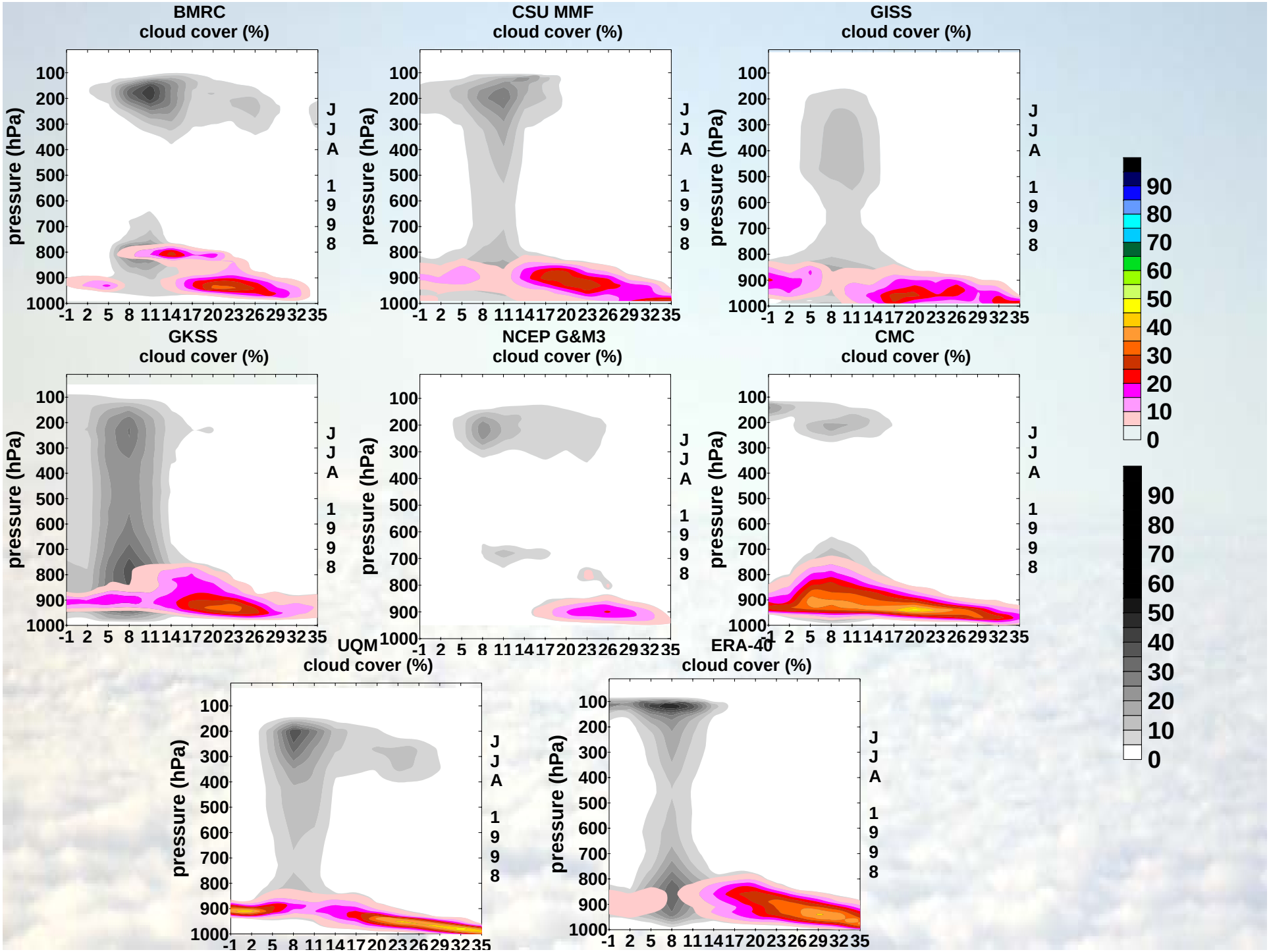
How deep should the PBL be..?

We need observations of cloud and boundary layer (PBL) parameters: PBL height, liquid water,..


AM2
cloud liquid water (g/Kg)
ARPEGE
cloud liquid water (g/Kg)
CAM 3.0
cloud liquid water (g/Kg)
GSM0412
cloud liquid water (g/Kg)
HadGAM
cloud liquid water (g/Kg)
RAC
cloud liquid water (g/Kg)
GME
cloud liquid water (g/Kg)
ECMWF
cloud liquid water (g/Kg)
ERA-40
cloud liquid water (g/Kg)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J J A 1 9 9 8
0.3
0.2
0.15
0.1
0.08
0.06
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
liquid water
g/kg


BMRC
cloud liquid water (g/Kg)
CSU MMF
cloud liquid water (g/Kg)
GISS
cloud liquid water (g/Kg)
GKSS
cloud liquid water (g/Kg)
NCEP G&M3
cloud liquid water (g/Kg)
CMC
cloud liquid water (g/Kg)
UQM
cloud liquid water (g/Kg)
ERA-40
cloud liquid water (g/Kg)
pressure (hPa)
100 200 300 400 500 600 700 800 900 1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J J A 1 9 9 8
0.3
0.15
0.08
0.04
0.03
0.02
0.01
0
g/kg
liquid water


AM2
cloud cover (%)
ARPEGE
cloud cover (%)
CAM 3.0
cloud cover (%)
GSM0412
cloud cover (%)
HadGAM
cloud cover (%)
RAC
cloud cover (%)
GME
cloud cover (%)
ECMWF
cloud cover (%)
ERA-40
cloud cover (%)
pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J J A 1 9 9 8
90
80
70
60
50
40
30
20
10
0


BMRC
cloud cover (%)
CSU MMF
cloud cover (%)
GISS
cloud cover (%)
GKSS
cloud cover (%)
NCEP G&M3
cloud cover (%)
CMC
cloud cover (%)
UQM
cloud cover (%)
ERA-40
cloud cover (%)
pressure (hPa)
100
200
300
400
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600
700
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900
1000
-1 2 5 8 11 14 17 20 23 26 29 32 35
J
J
A
1
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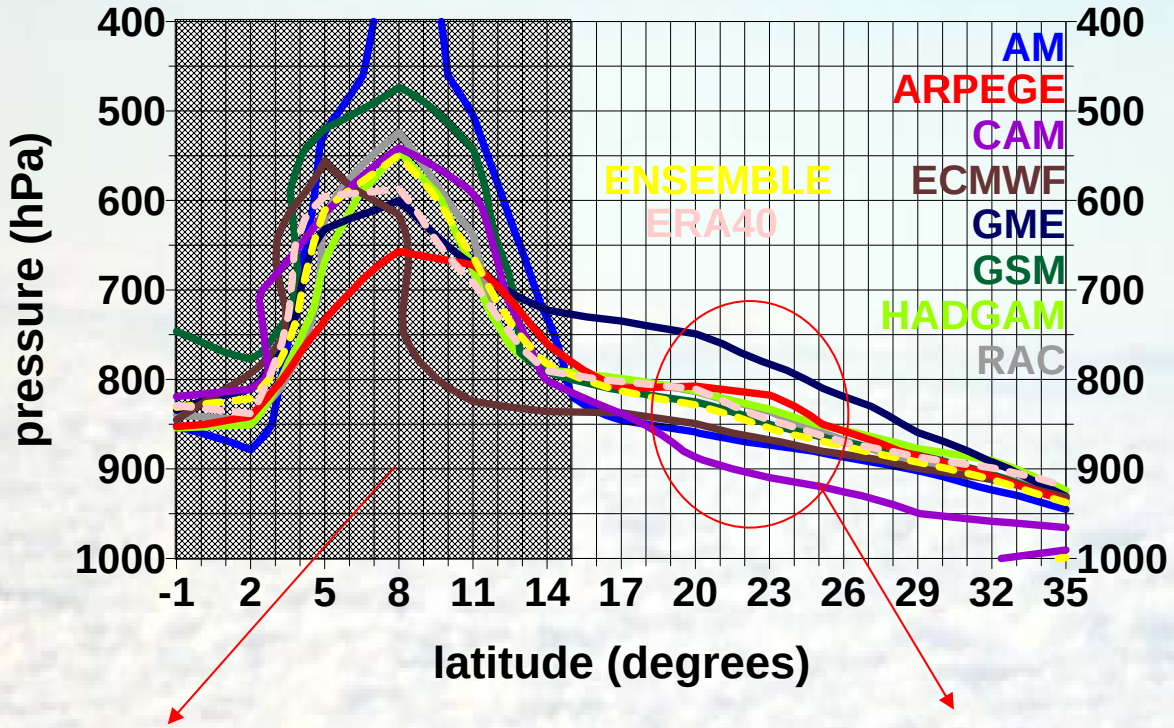
20
10
0

GPCI – Boundary layer height

Boundary layer height defined as RH=50% isoline



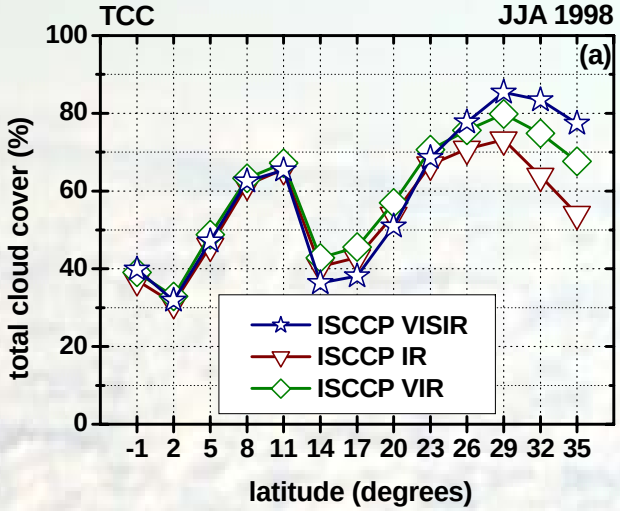
The need for observations

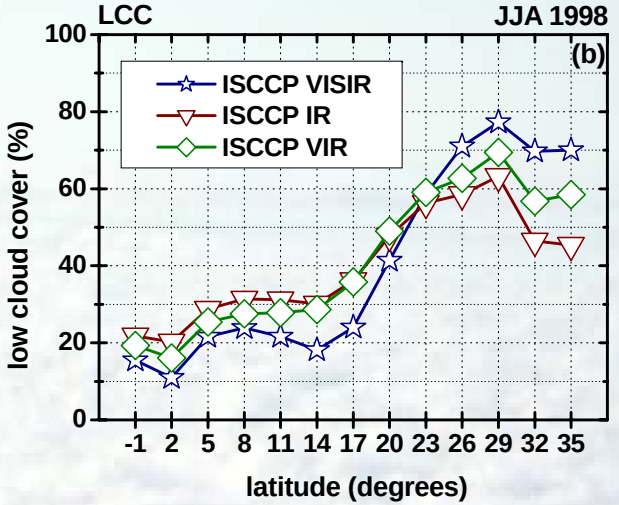
This definition breaks down in tropics

Differences between models of up to 1500 m

ISCCP cloud cover

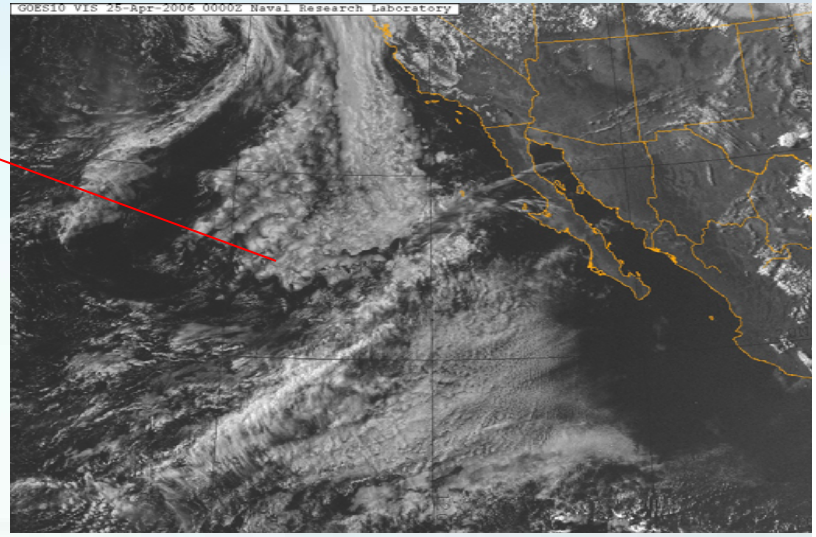
ISCCP PCTAU data from DIME site



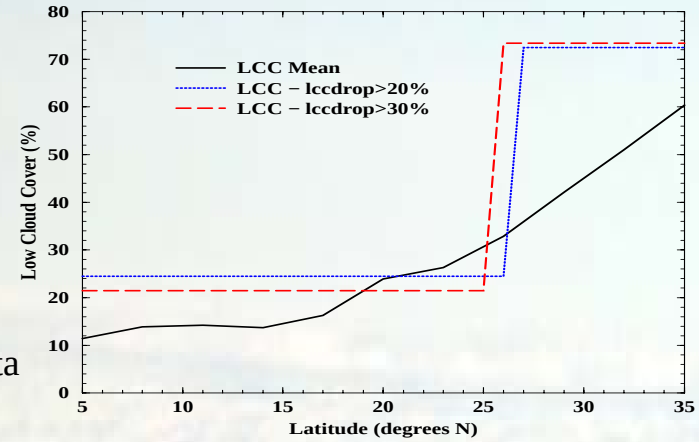


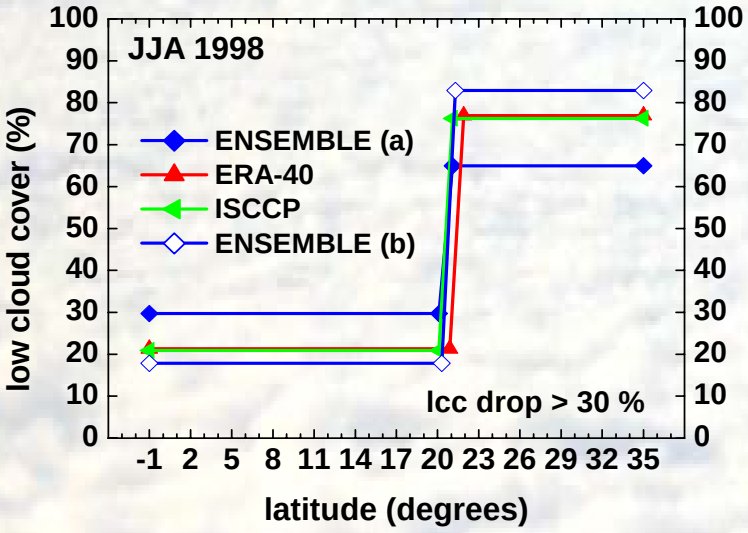
Alternative mean LCC: assume existence of at least 1 sharp gradient of LCC

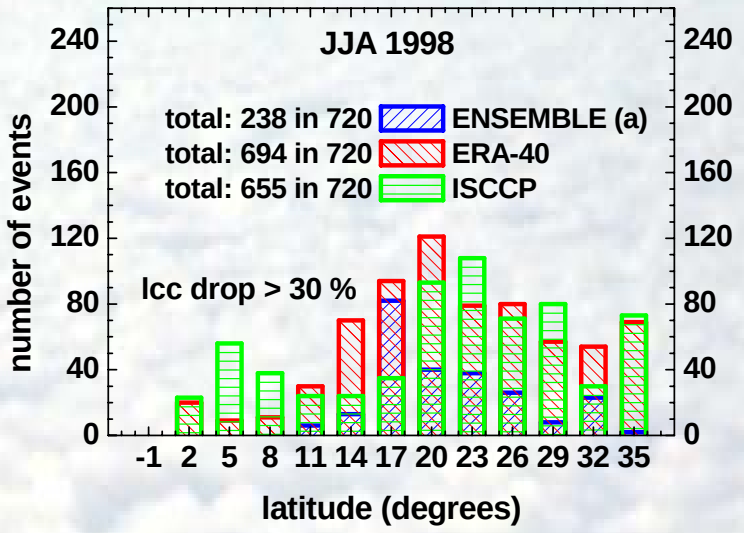
instantaneous clouds have sharp gradients in space



GOES data

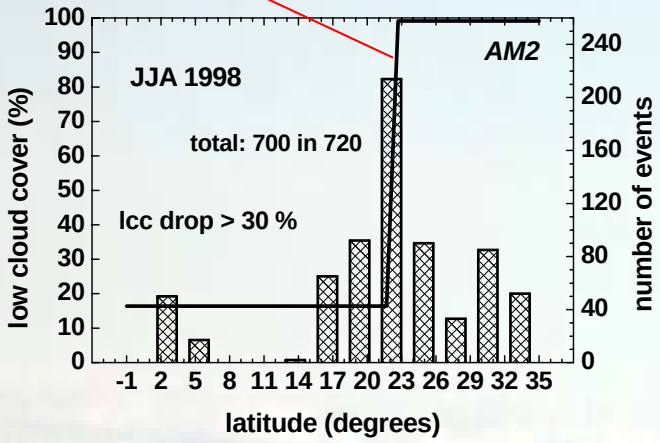


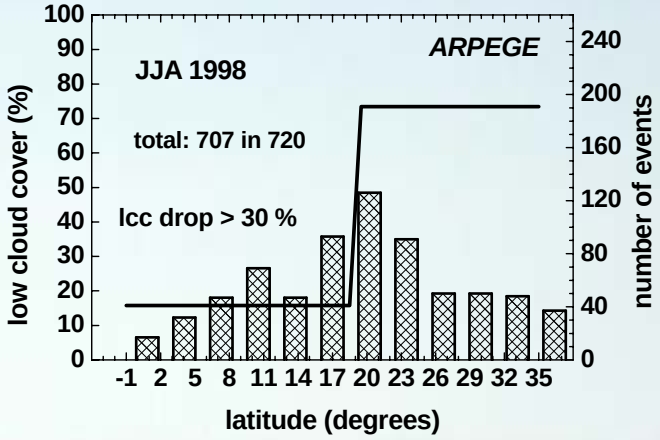


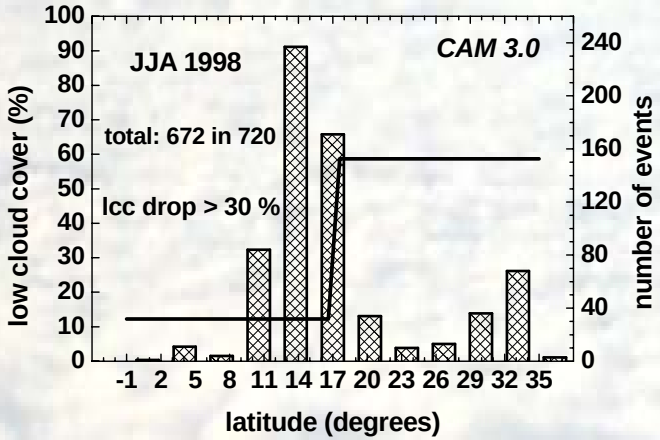


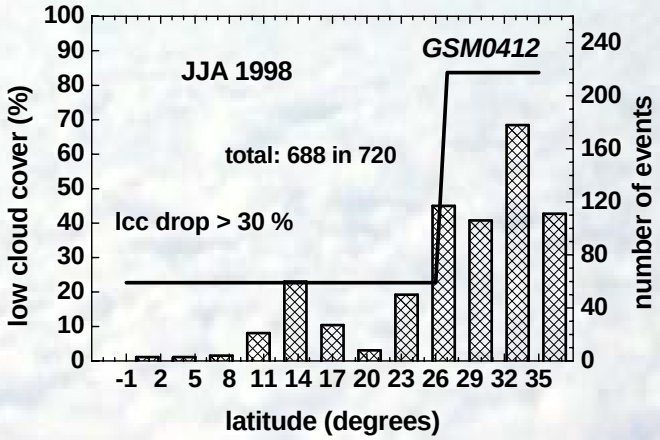
Sharp gradient averaging of LCC

large gradient



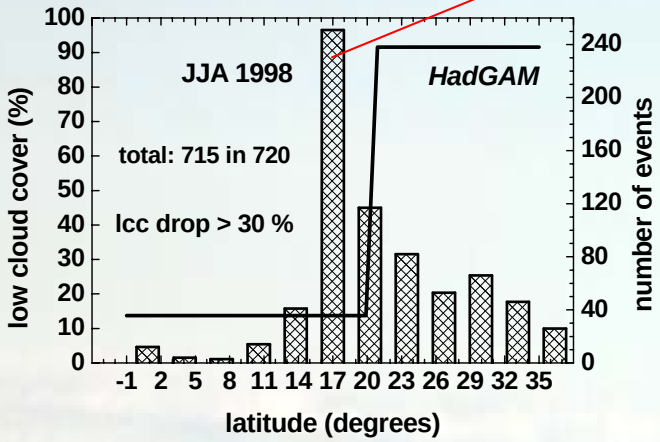


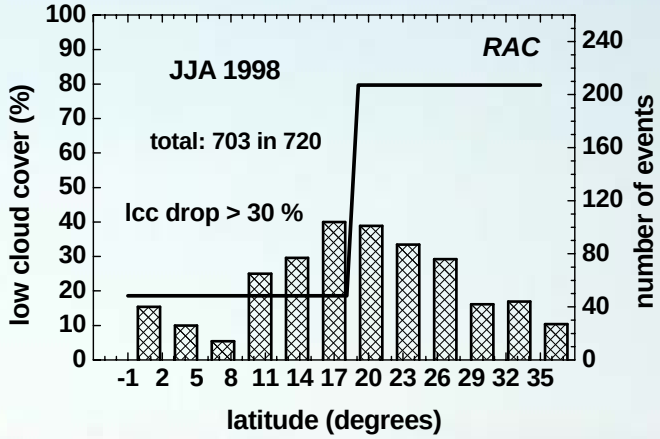


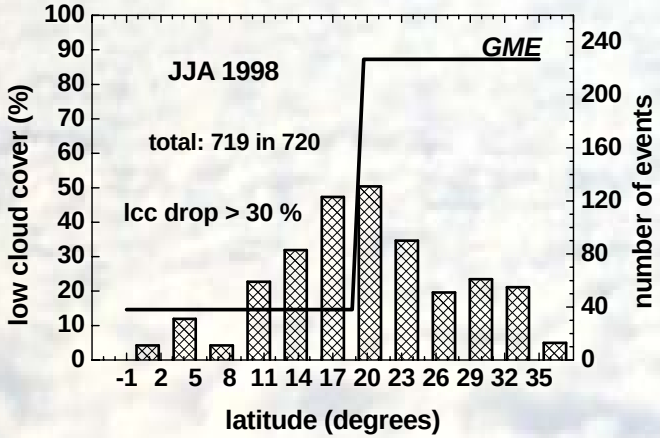


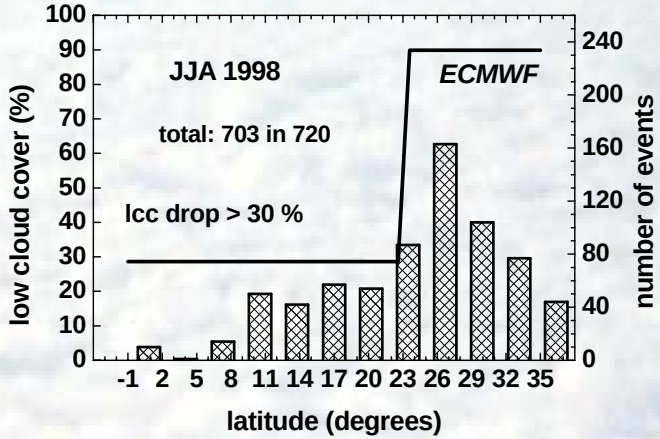
Sharp gradient averaging of LCC

large peak

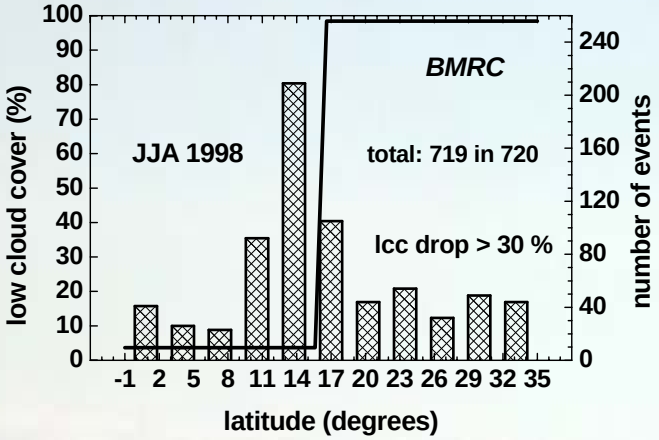


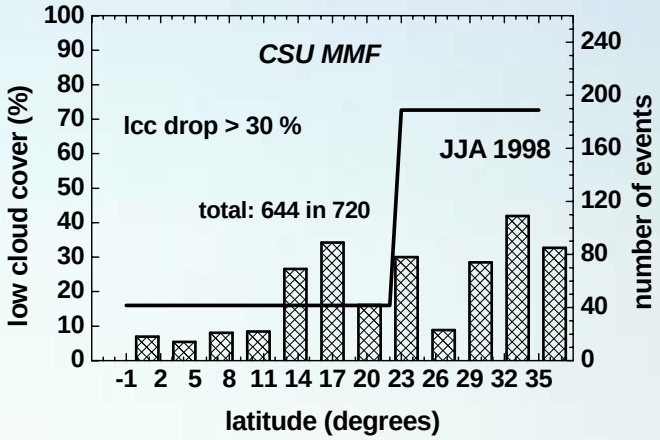


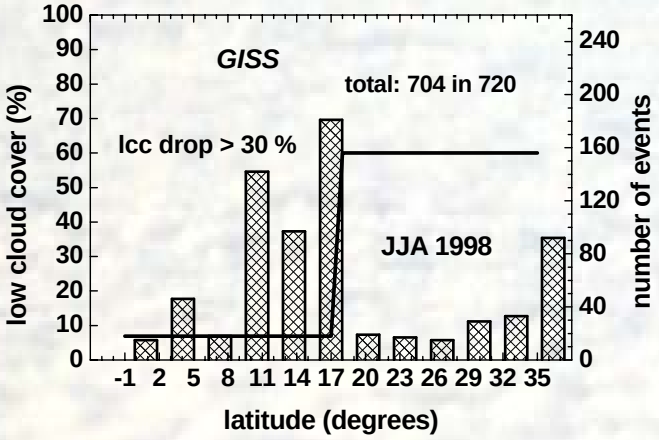


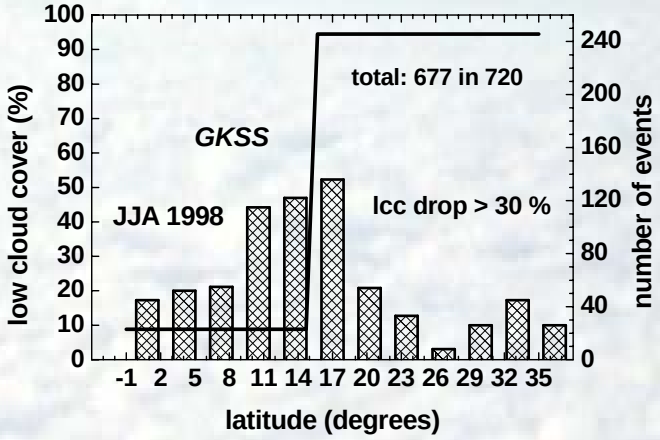


Sharp gradient averaging of LCC

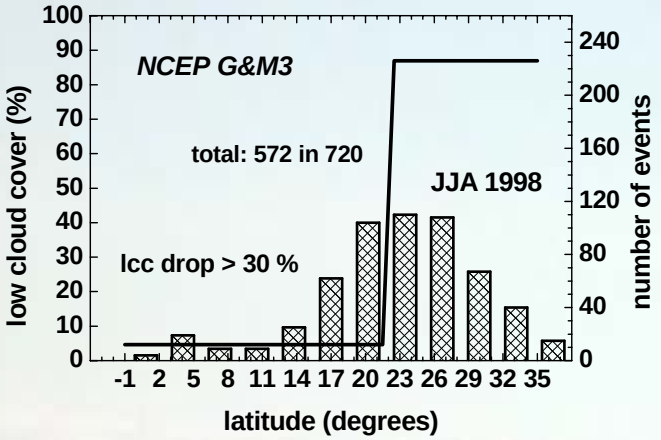


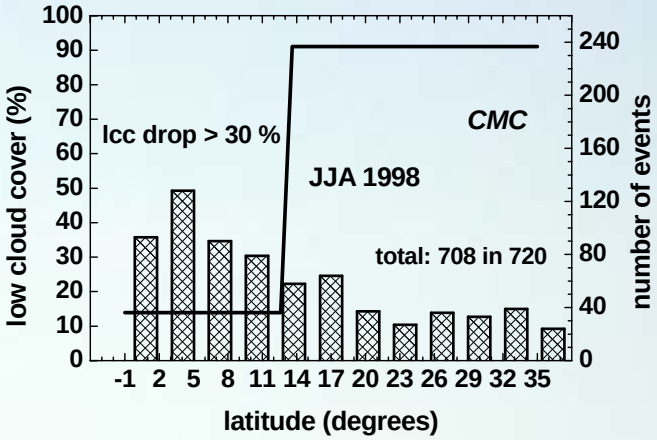


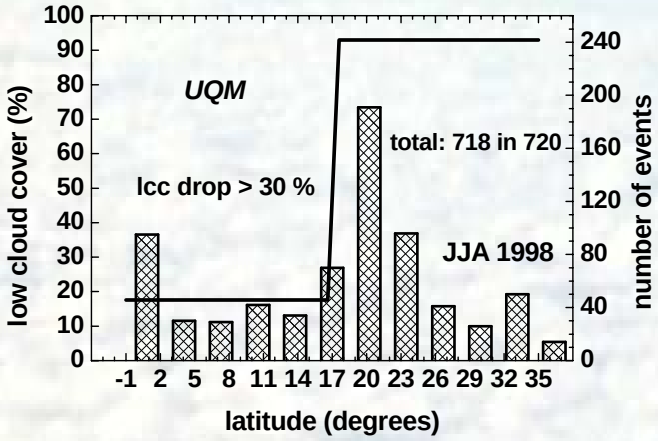




Sharp gradient averaging of LCC

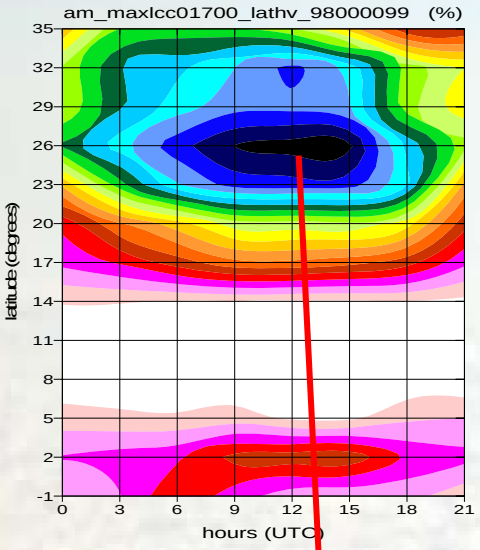




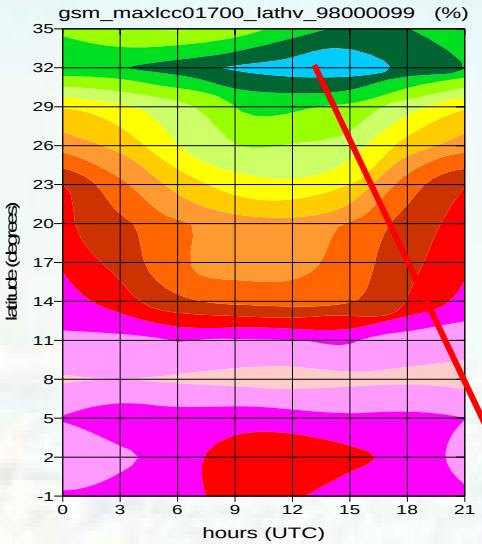


JJA98 mean diurnal cycle: model low cloud cover

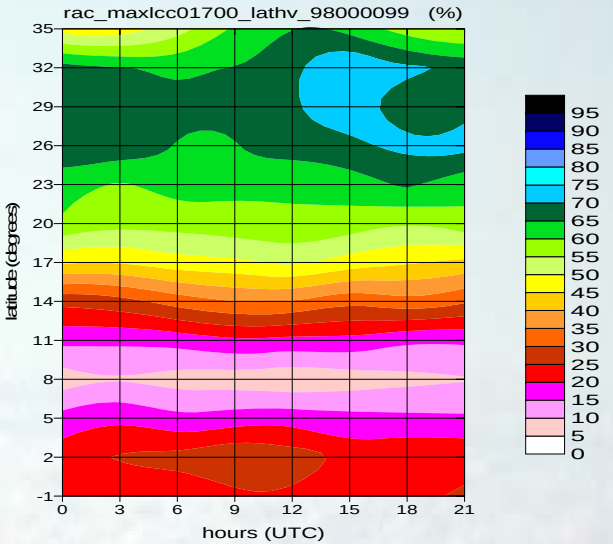
GFDL



JMA



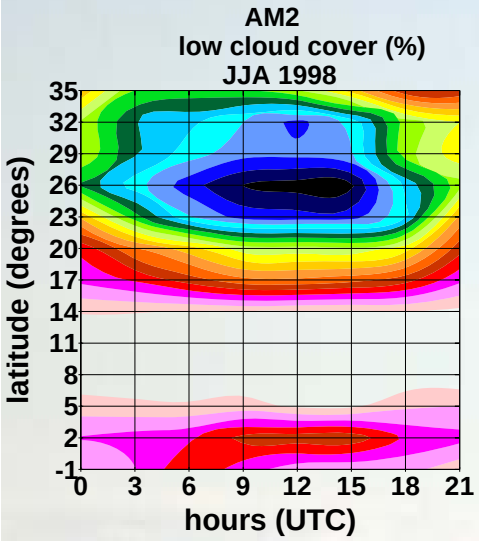
KNMI

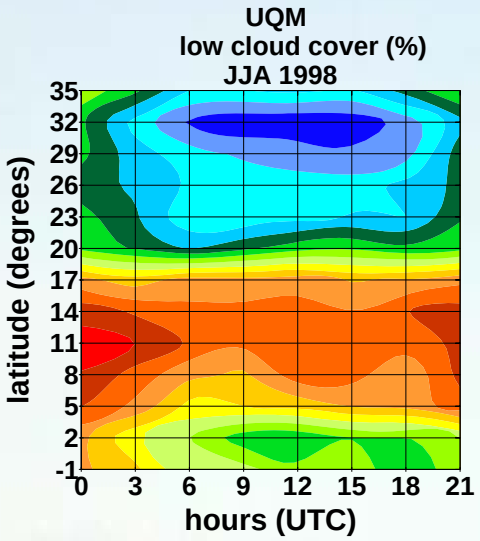


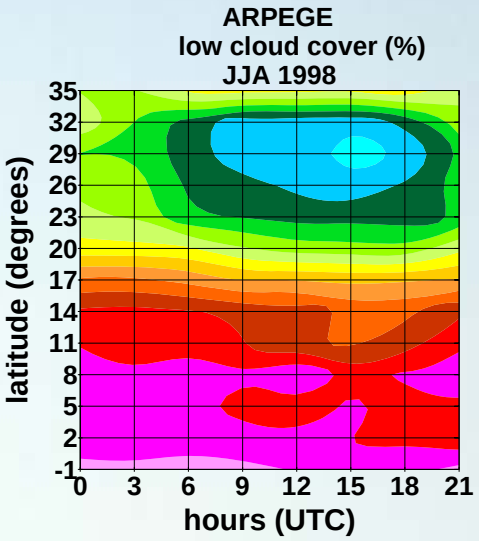
peak values too far to the south (around 26 N)

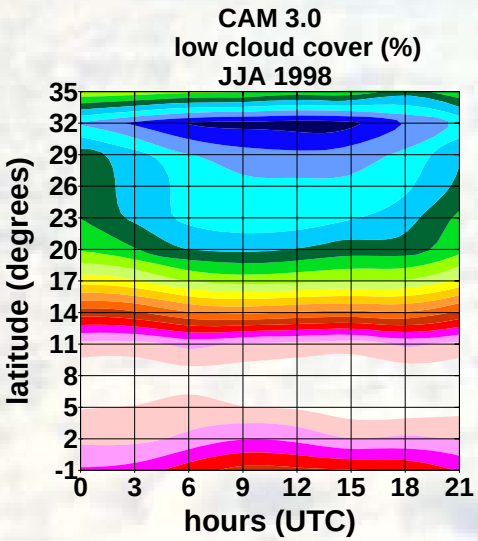
realistic diurnal cycle: morning max

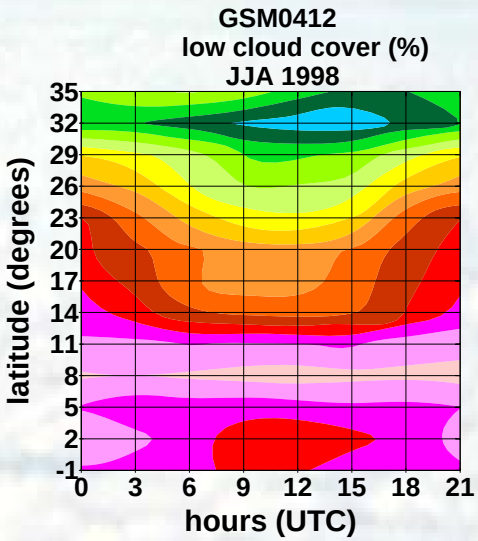
Diurnal cycle: low cloud cover

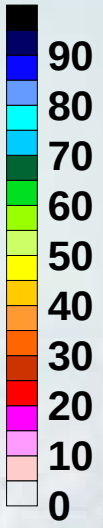




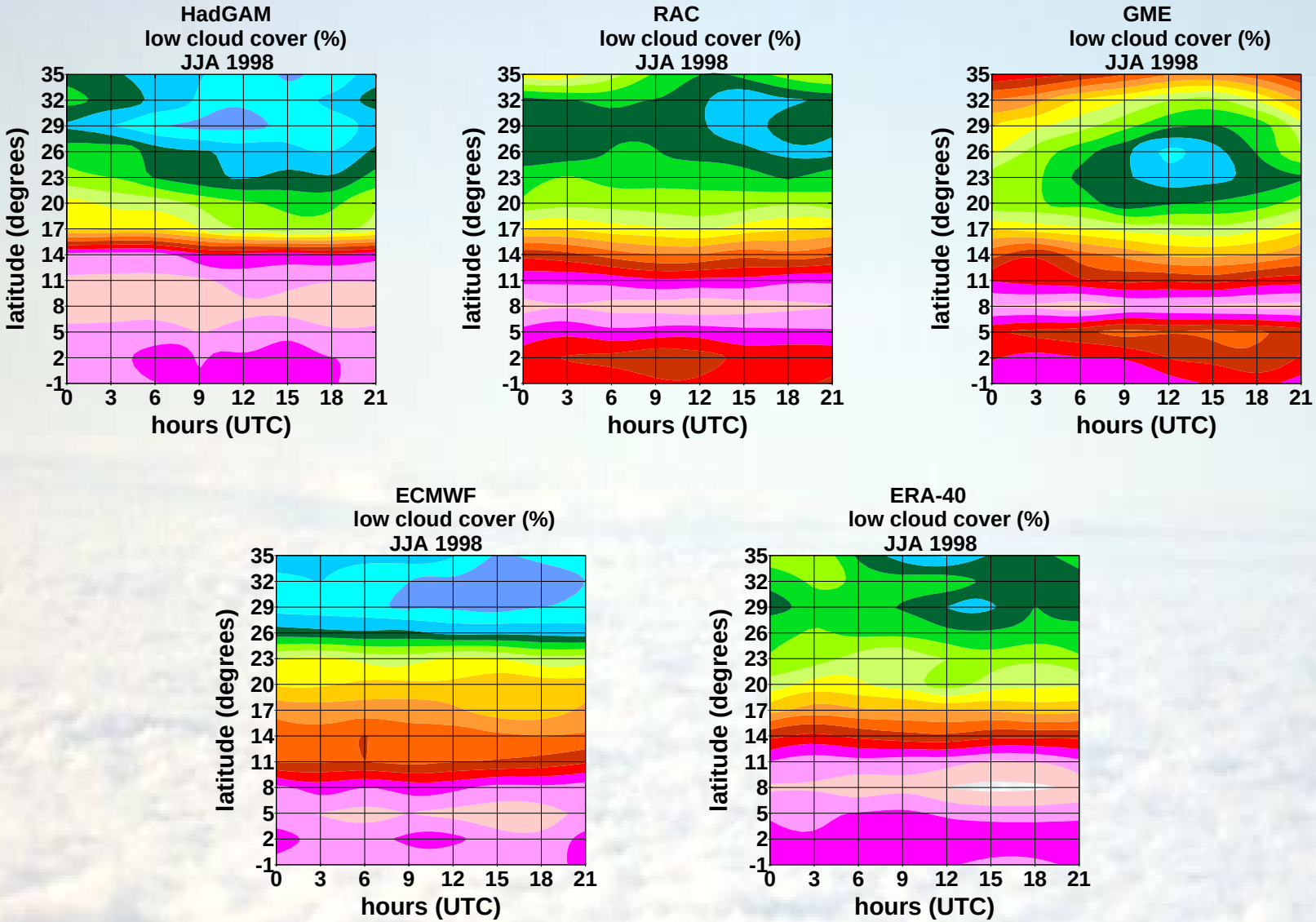




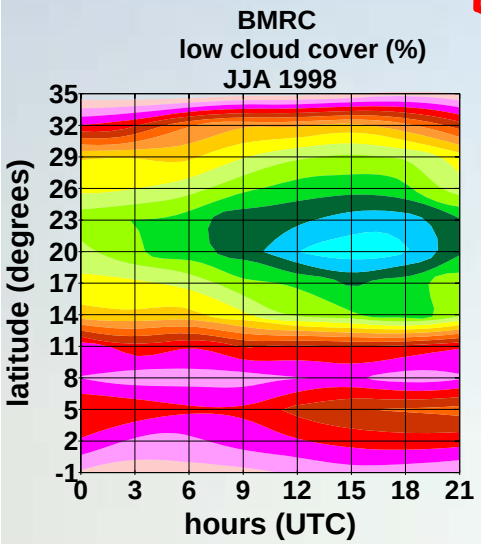


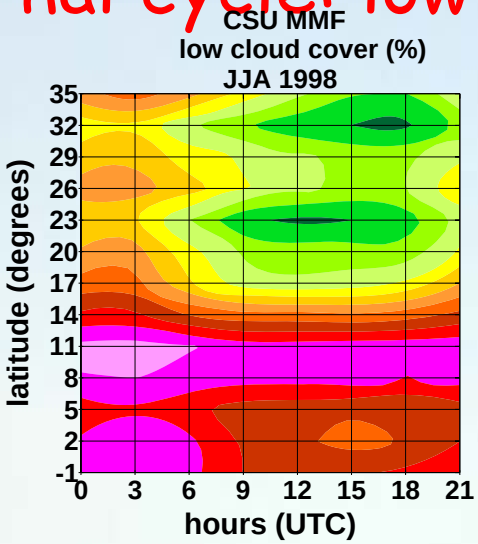


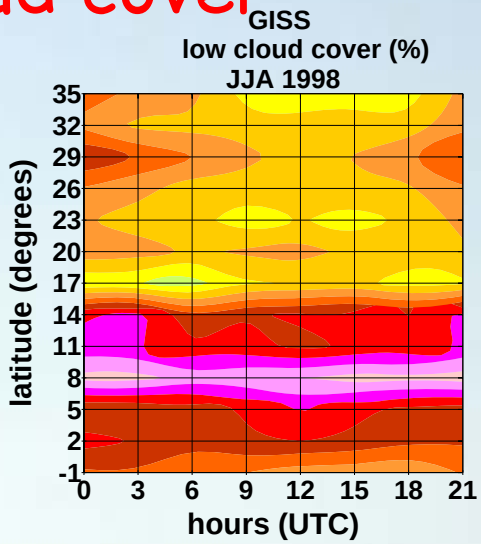
Diurnal cycle: low cloud cover

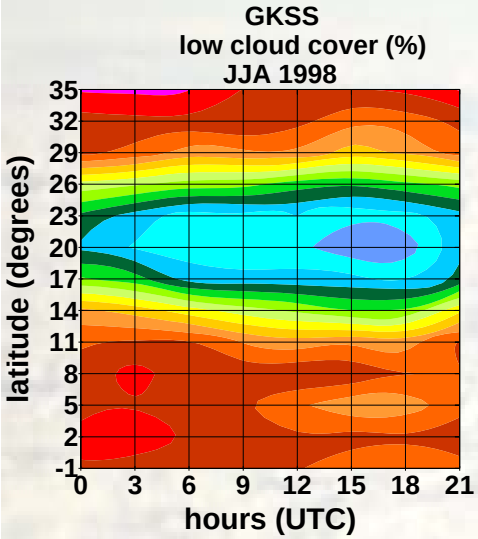


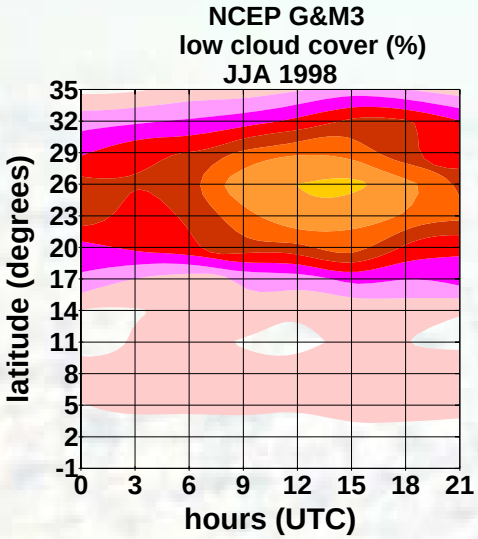
Diurnal cycle: low cloud cover

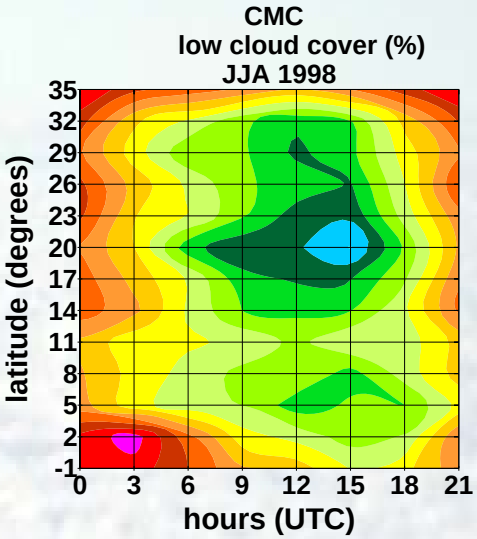


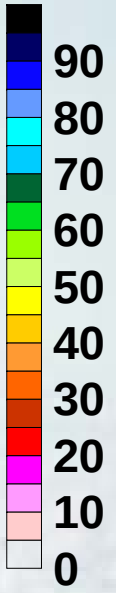






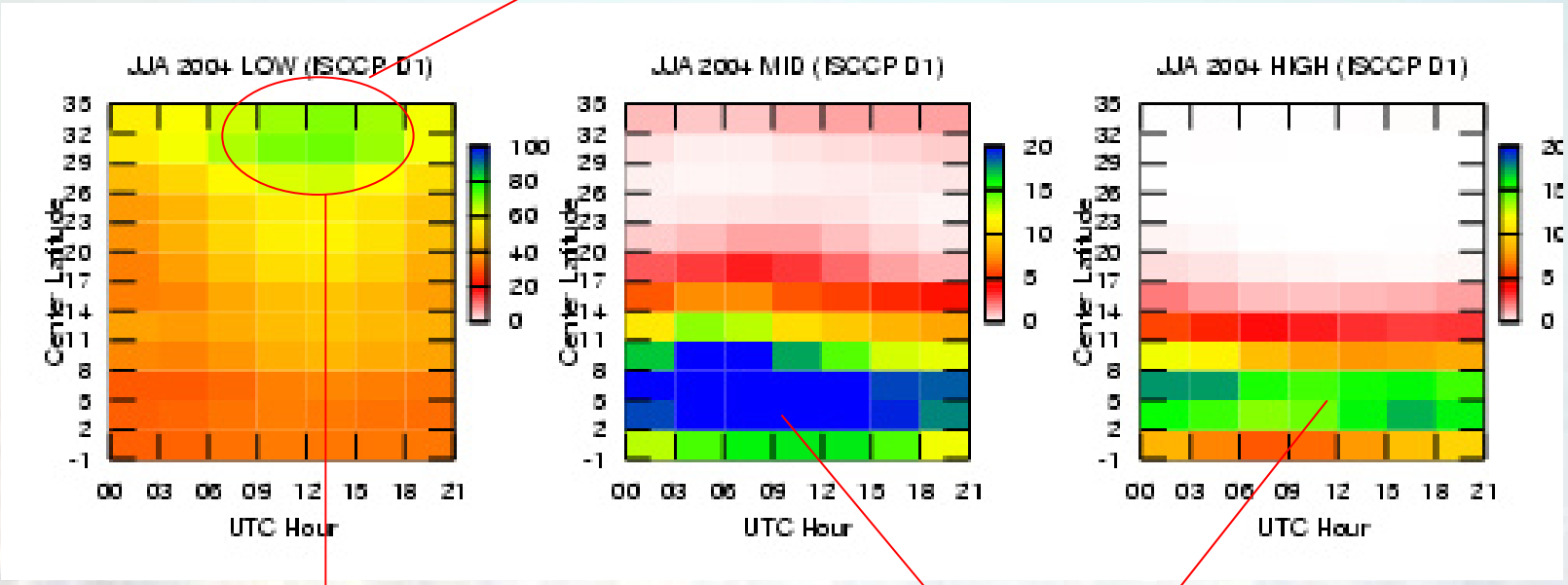






Mean diurnal cycle: ISCCP cloud cover

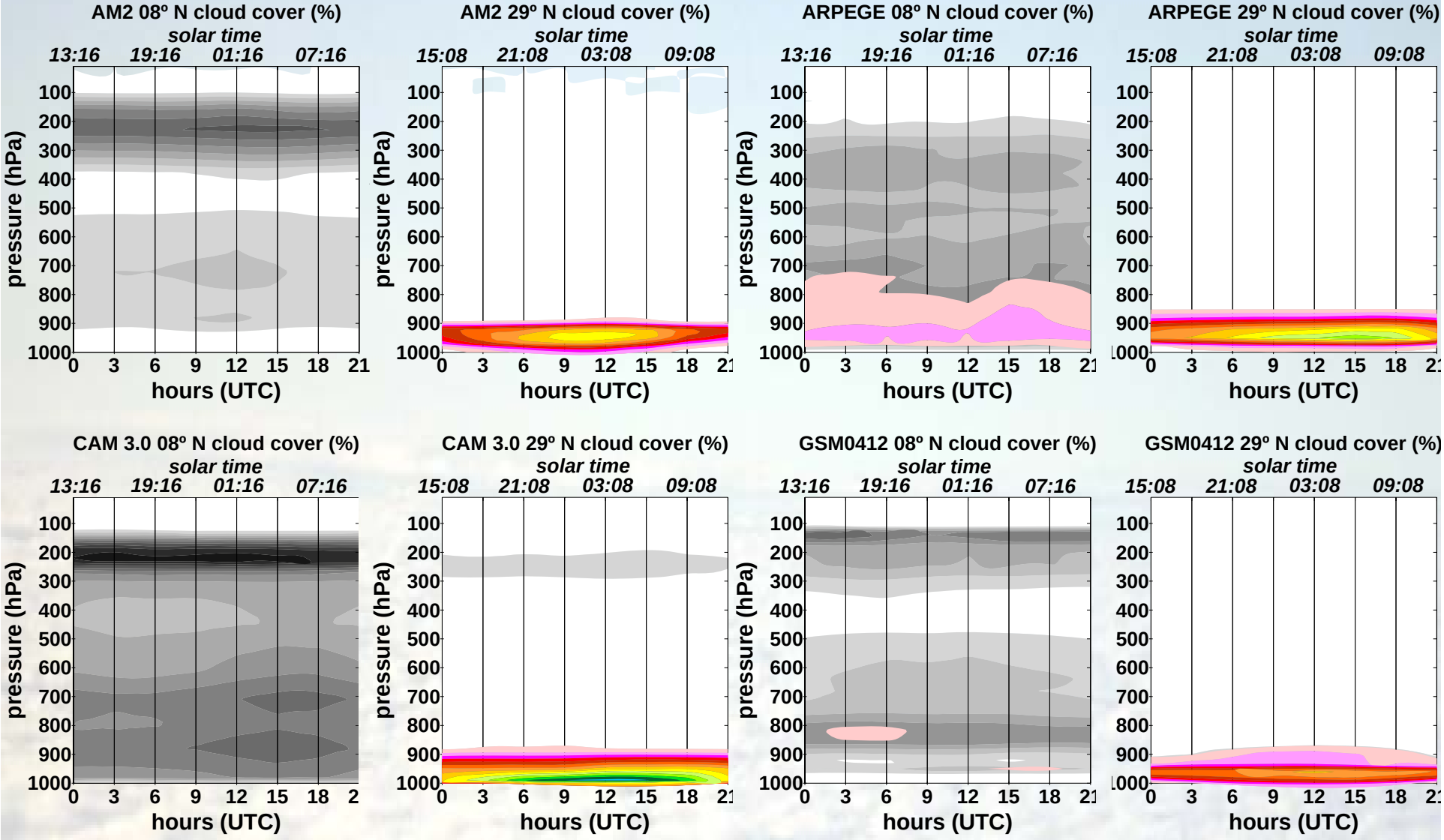
peak values of Sc cloud cover around 32-35 N



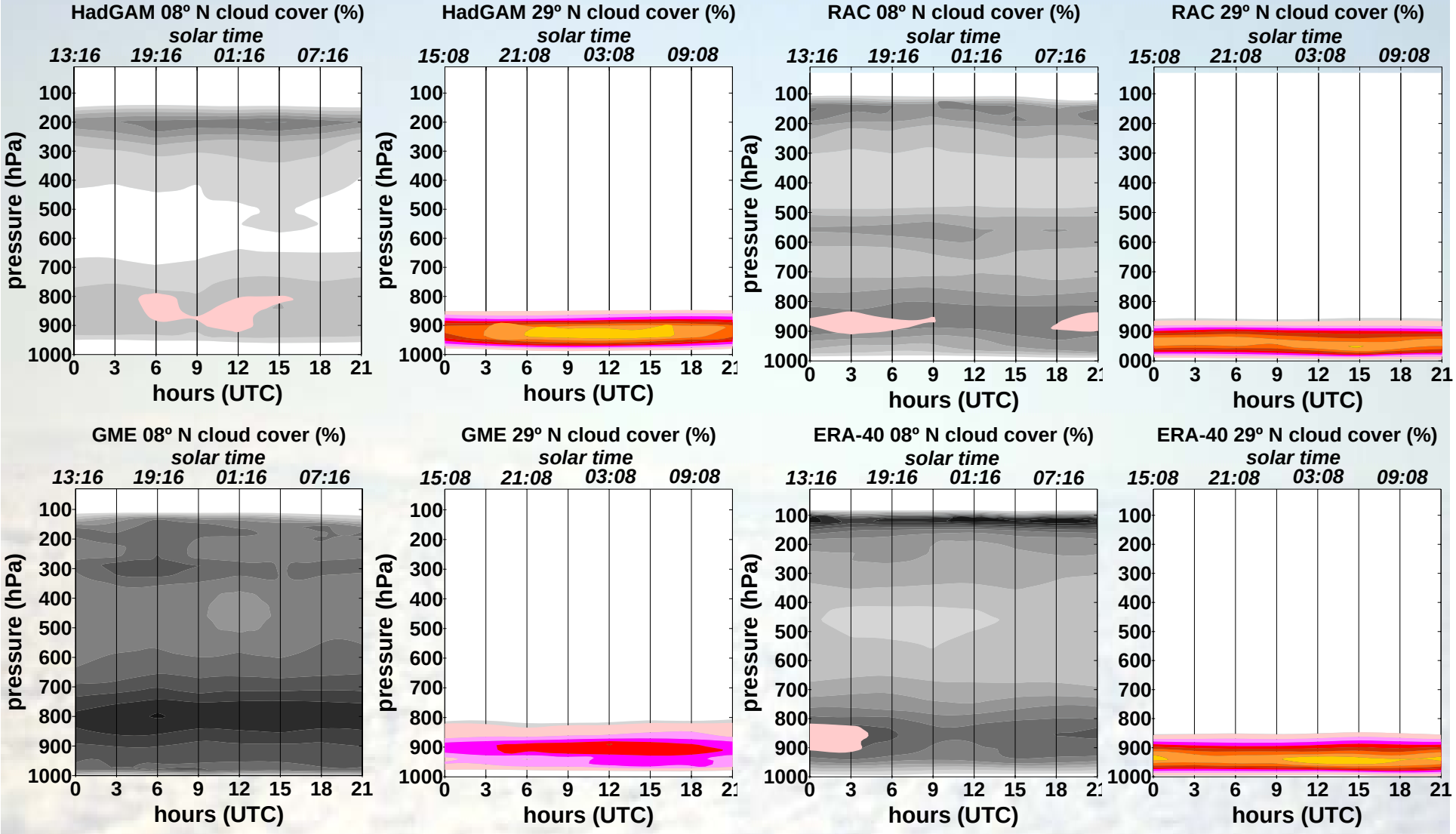
Diurnal cycle: max in (early) morning local time

peak values of mid/high clouds close to ITCZ

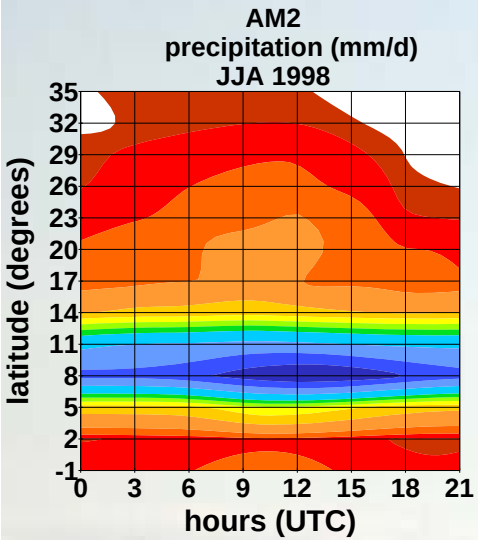
Cloud cover diurnal cycle: 8N, 29N

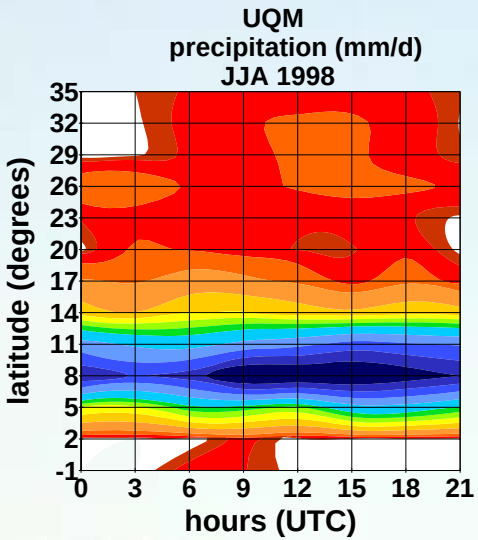


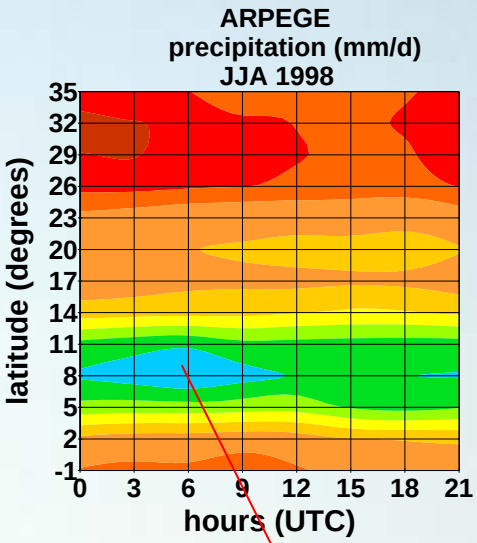
Cloud cover diurnal cycle: 8N, 29N

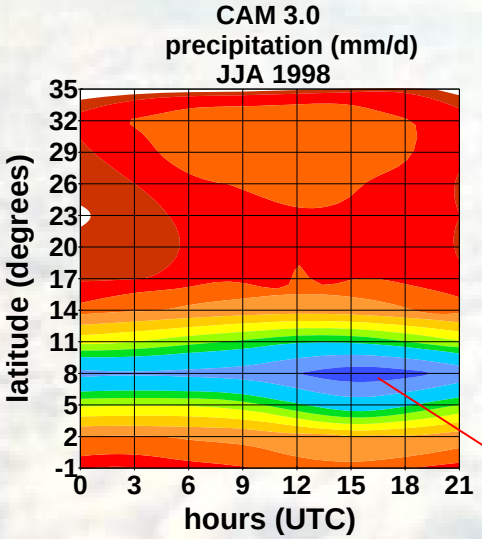


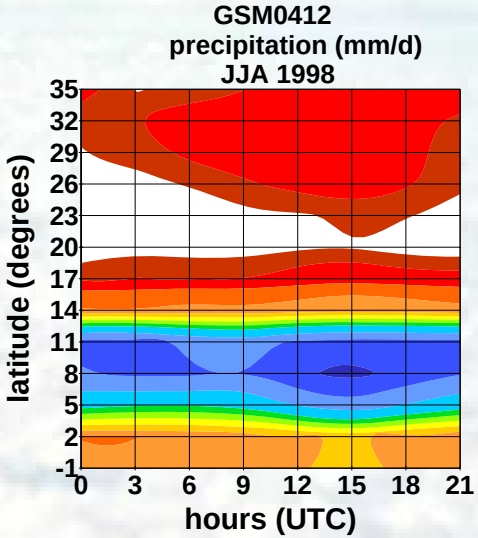
Diurnal cycle: precipitation

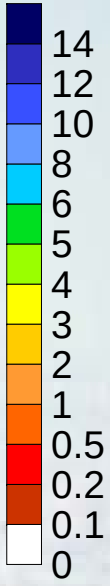








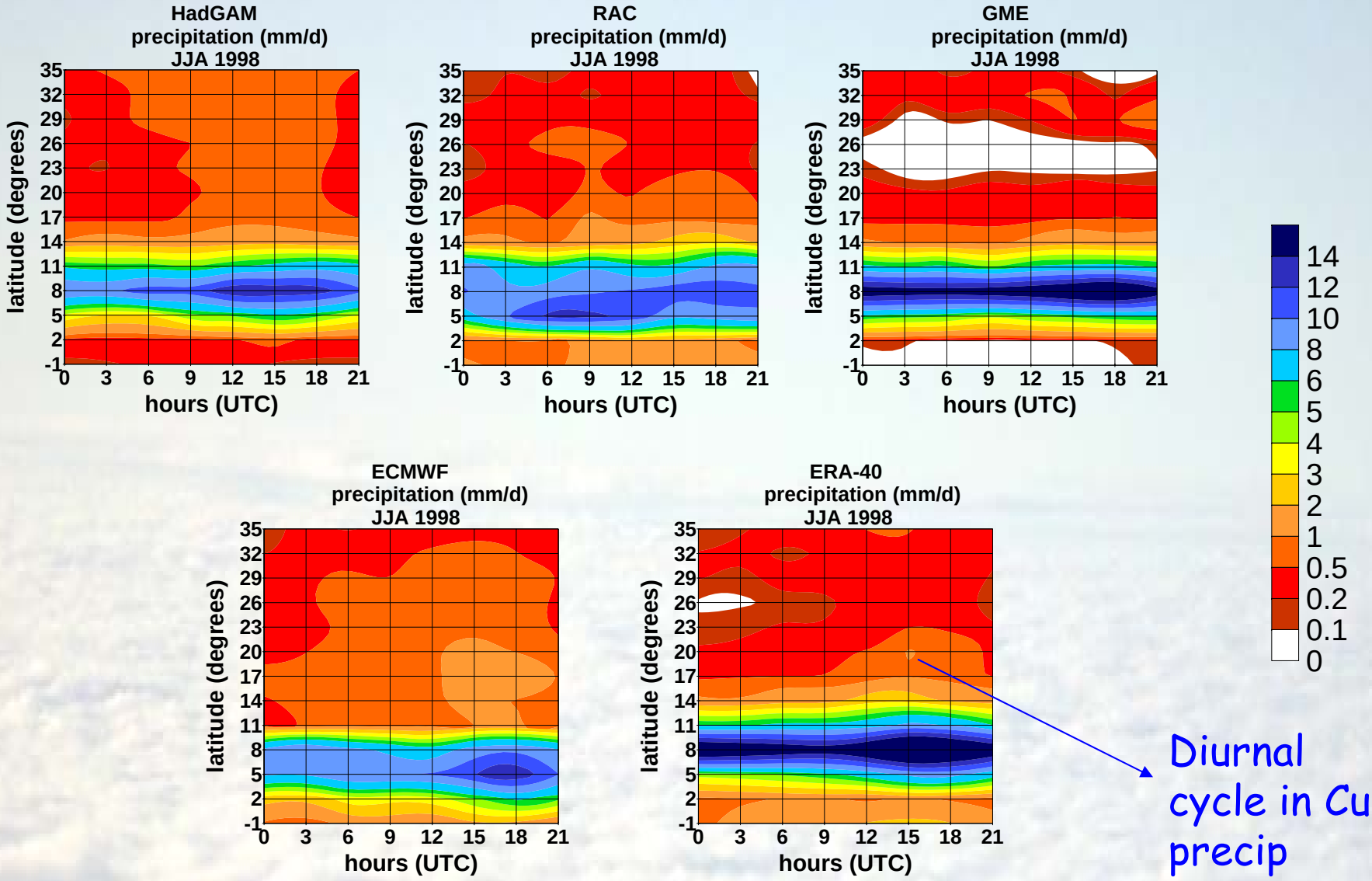




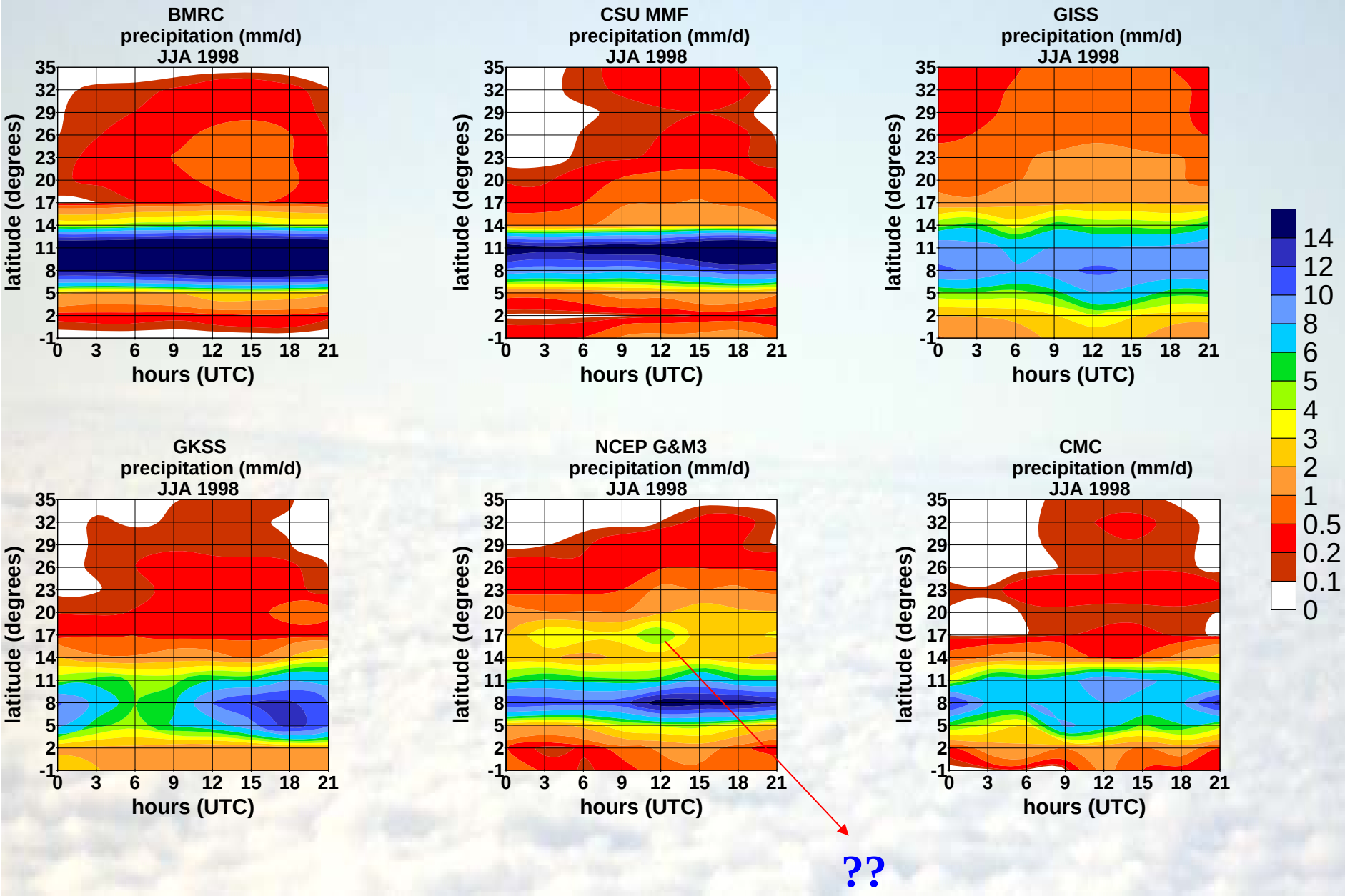
??

early morning max

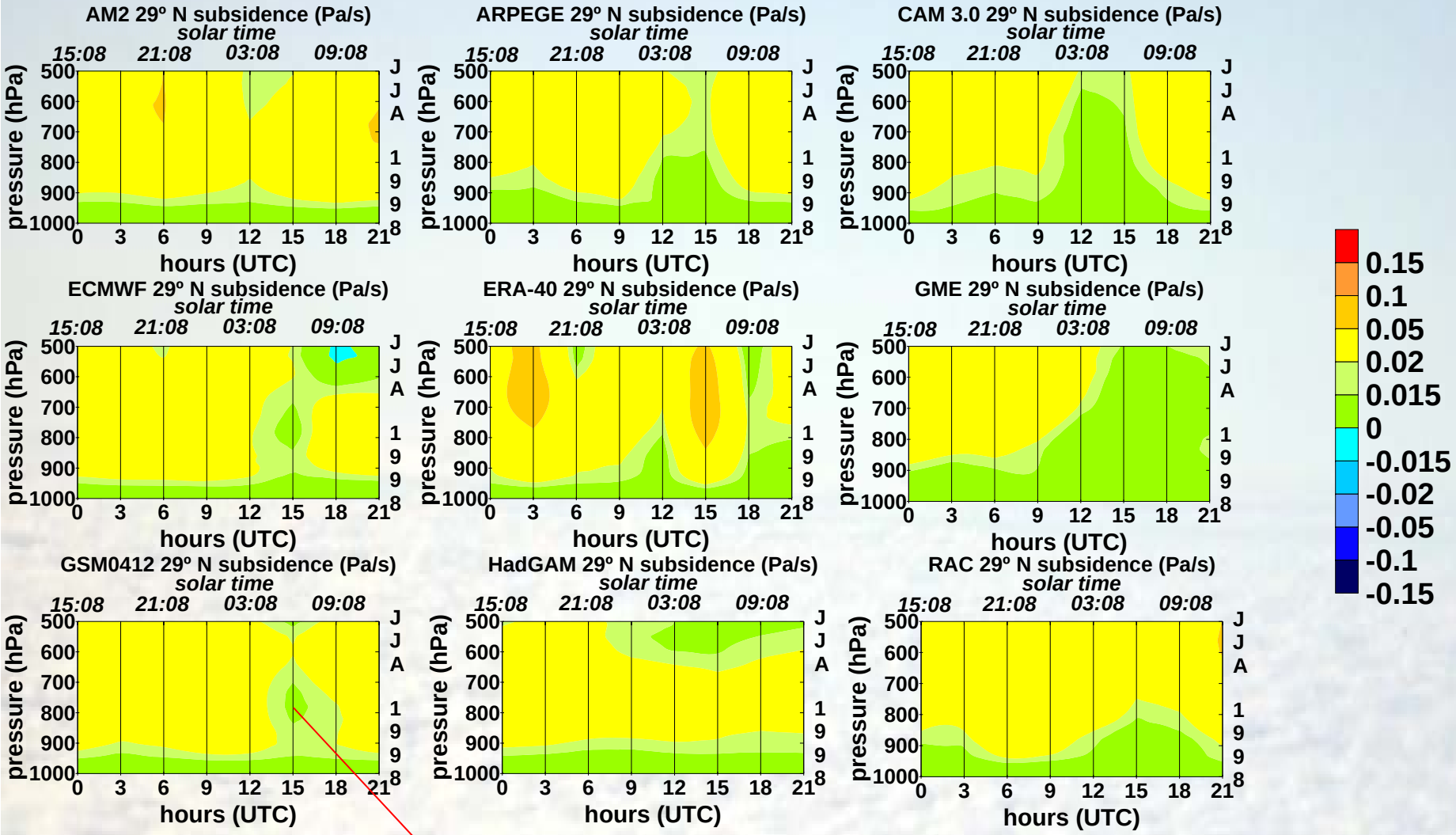
Diurnal cycle: precipitation



Diurnal cycle: precipitation

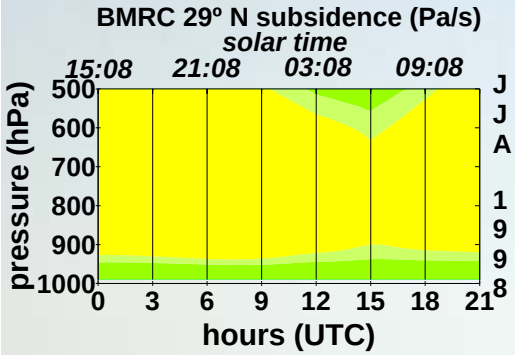


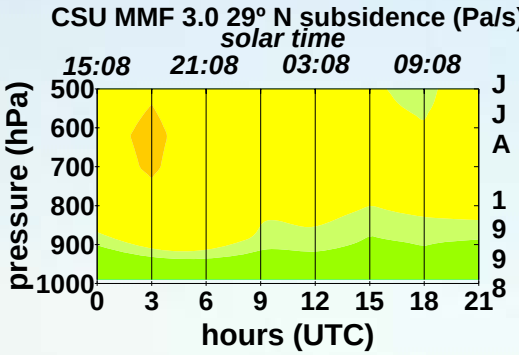
Diurnal cycle of subsidence: 29N

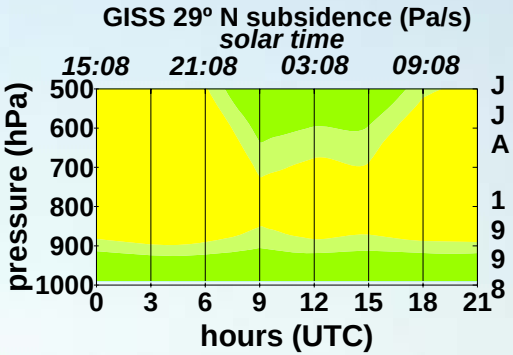


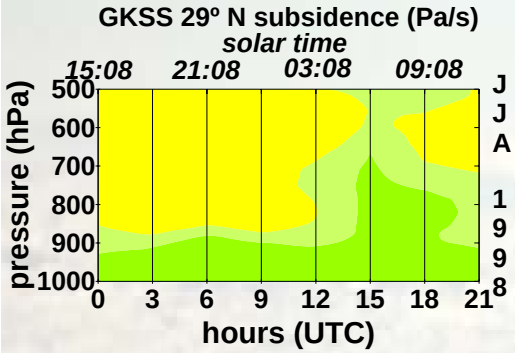
Early-morning min
in most models

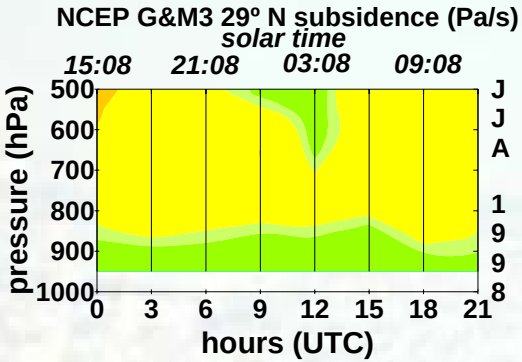
Diurnal cycle of subsidence: 29N

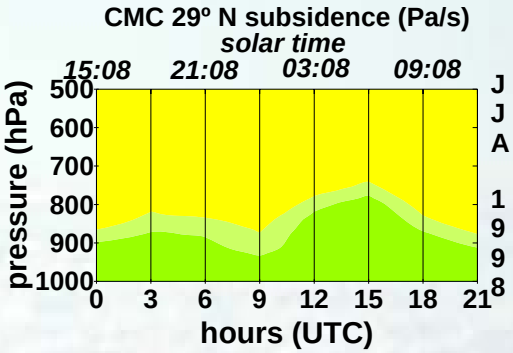


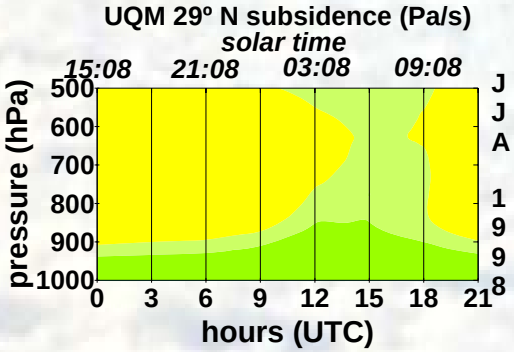


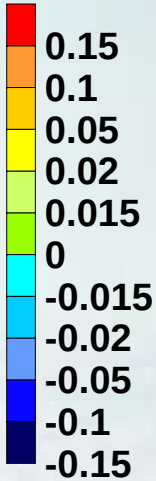




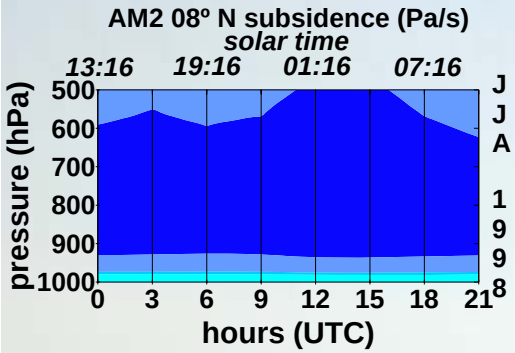


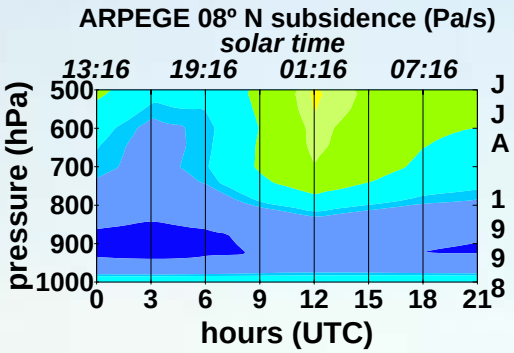


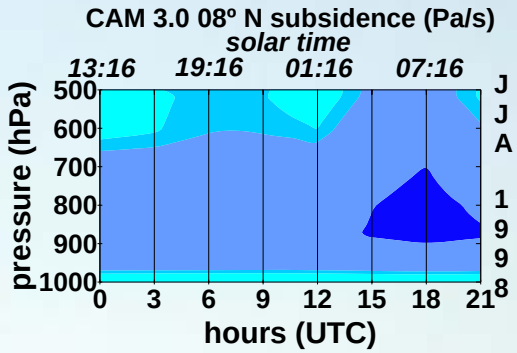


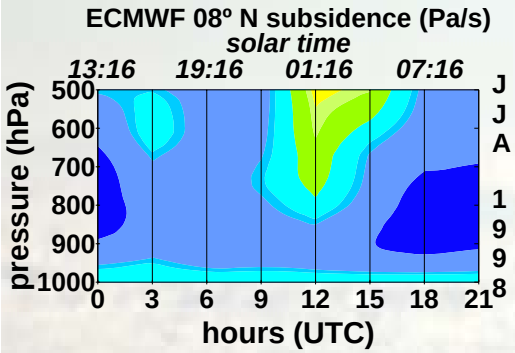


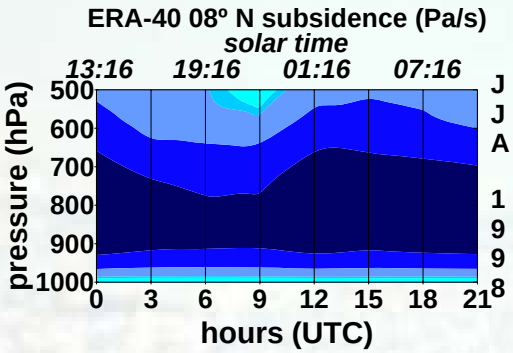
Diurnal cycle of subsidence: 8 N

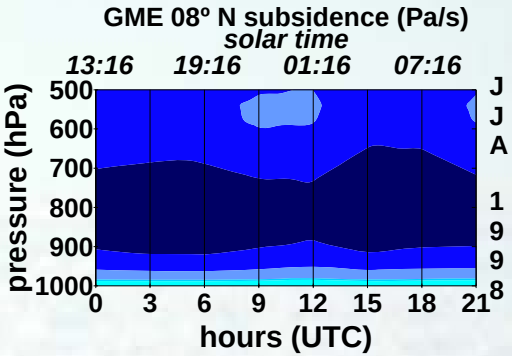


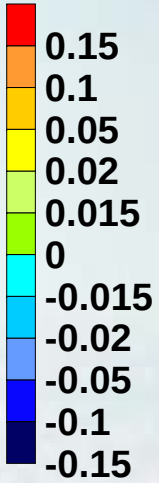


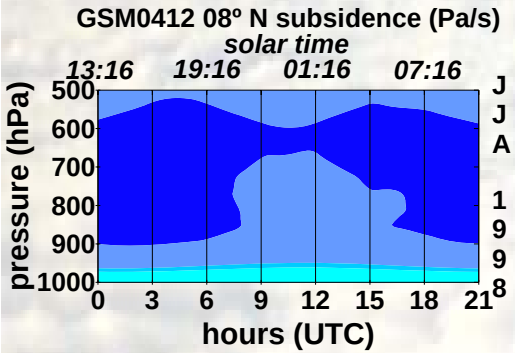


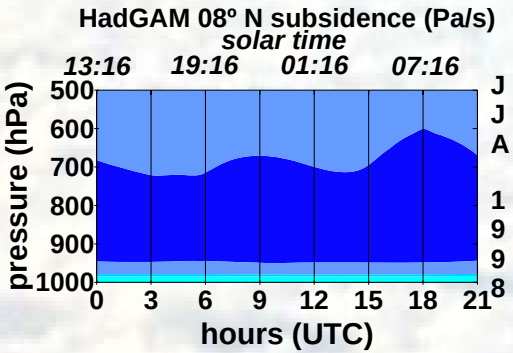


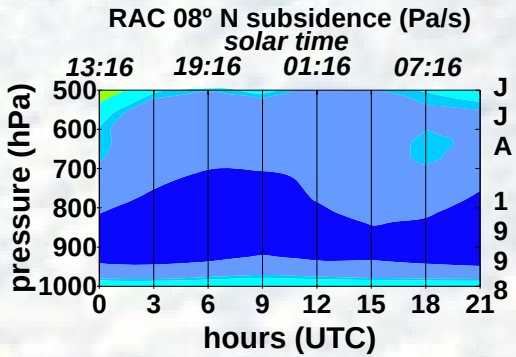






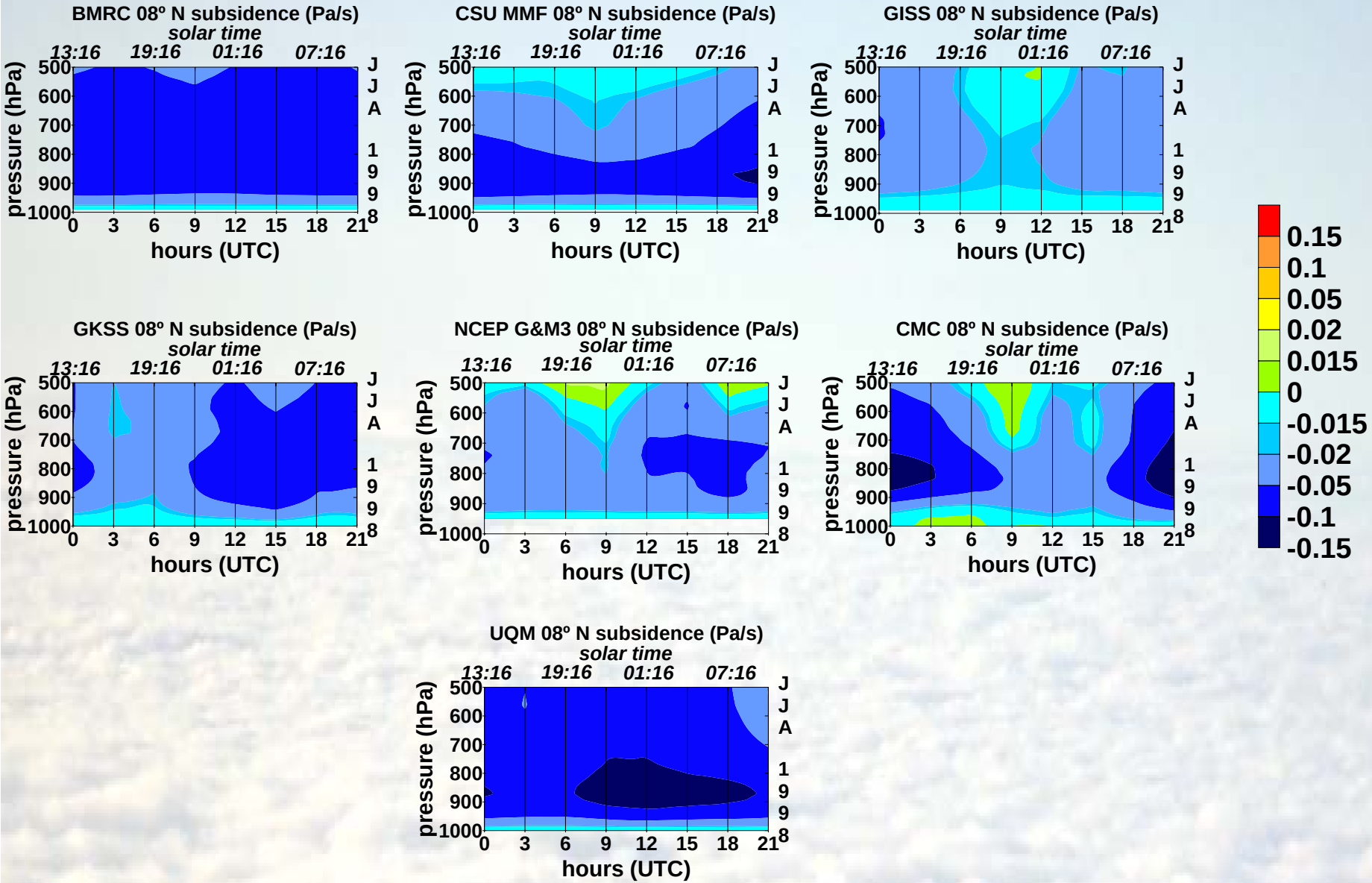






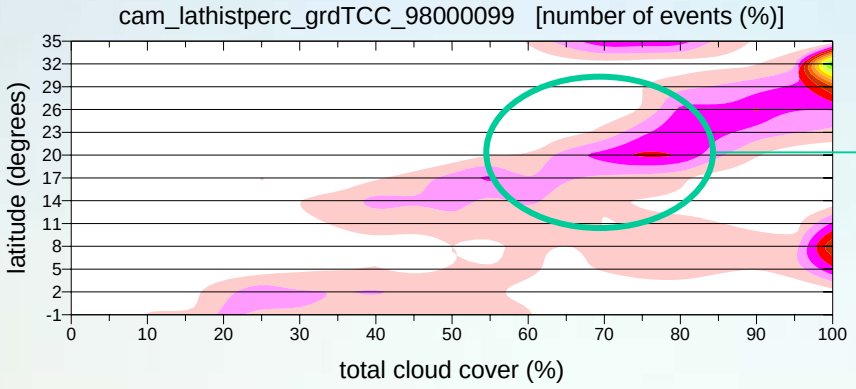
Diurnal cycle not so clear

Diurnal cycle of subsidence: 8 N



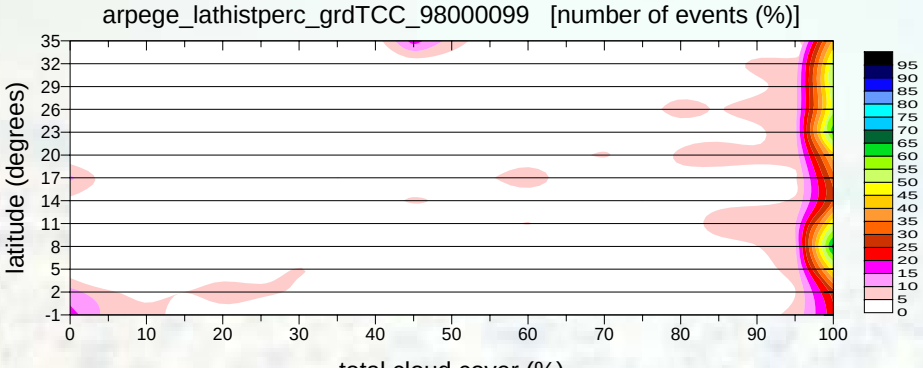
Histograms of total cloud cover (JJA 98)

NCAR



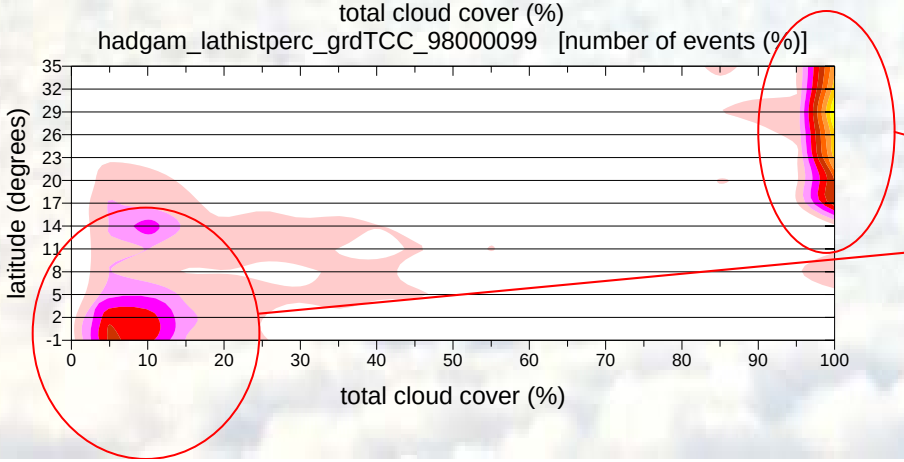
Continuous distribution

MeteoFrance



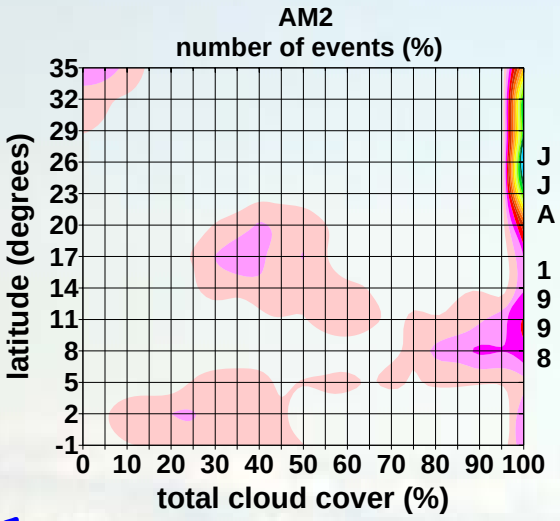
How does it look like in reality?

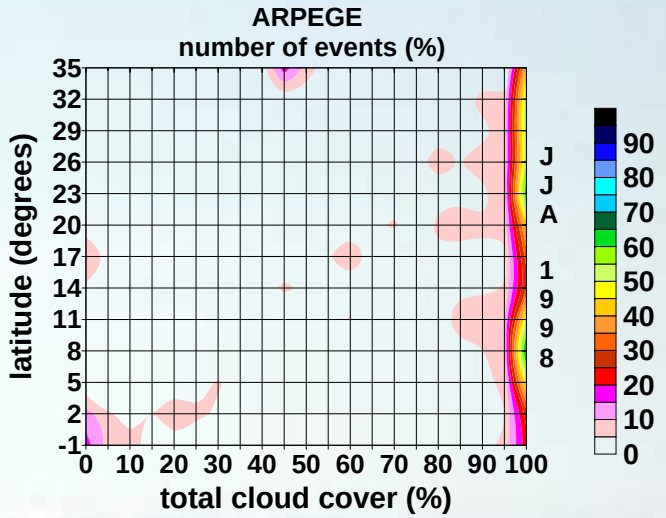
UKMO



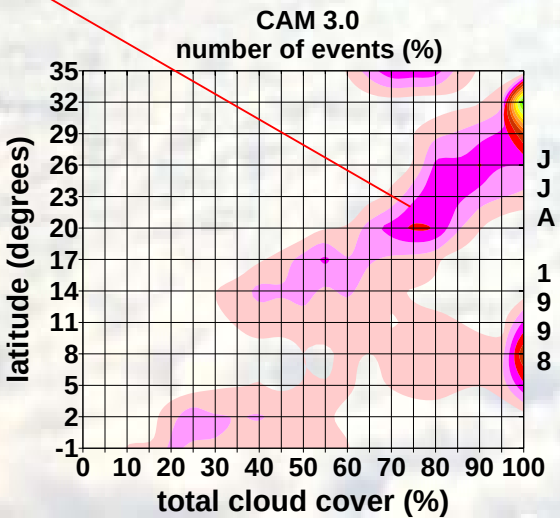
Bimodal distribution

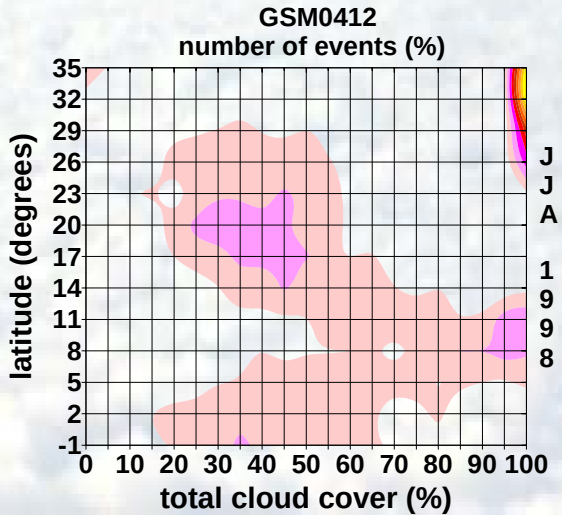
Histograms of total cloud cover



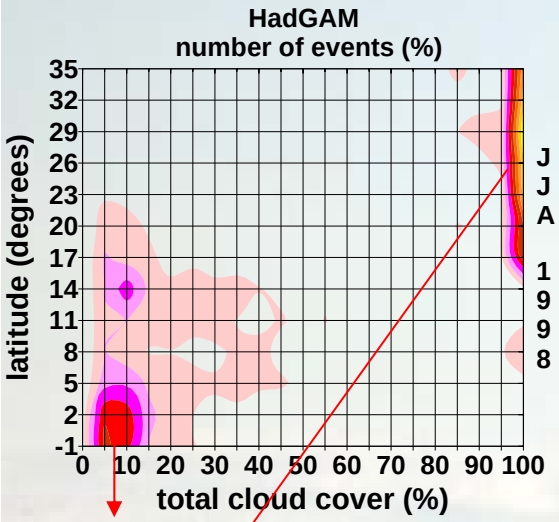


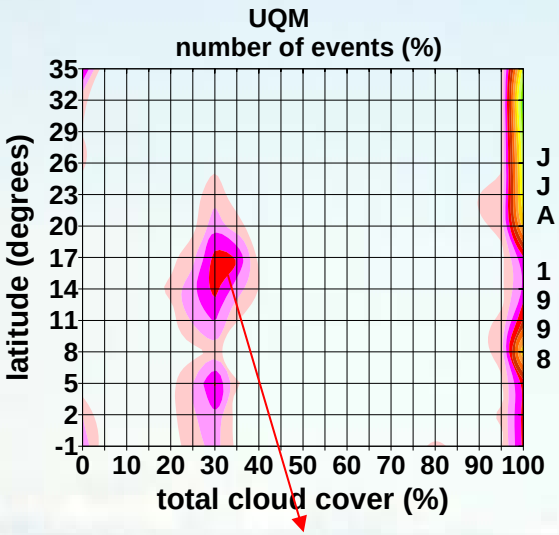
Continuous distribution

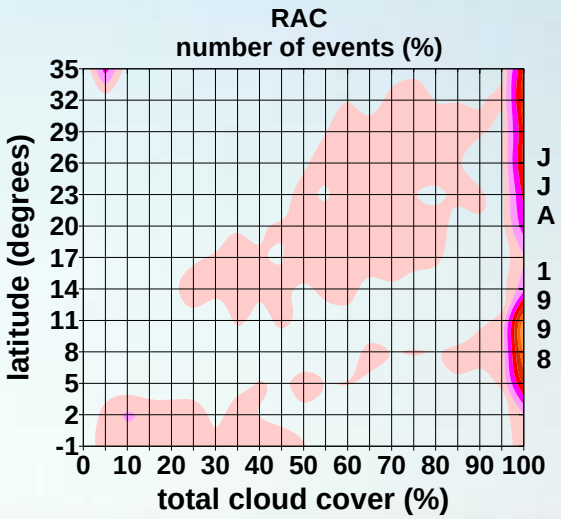




Histograms of total cloud cover

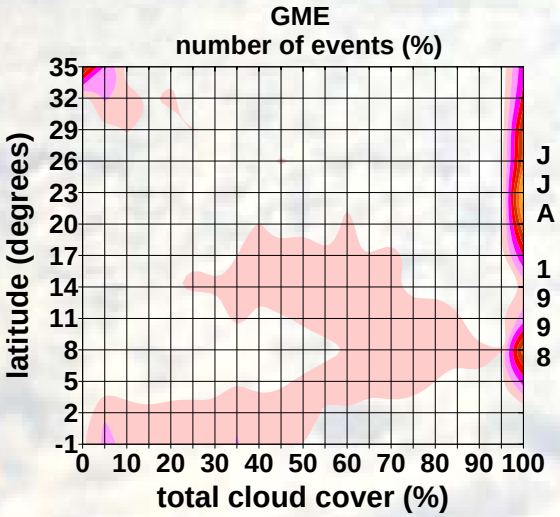


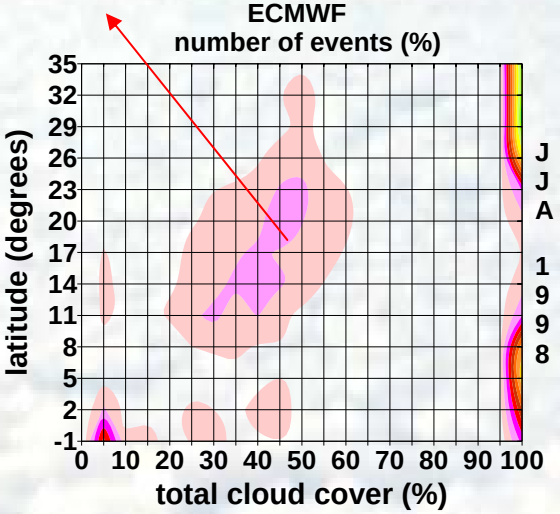


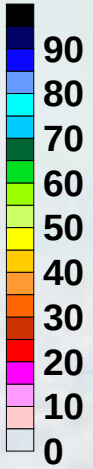


bimodal

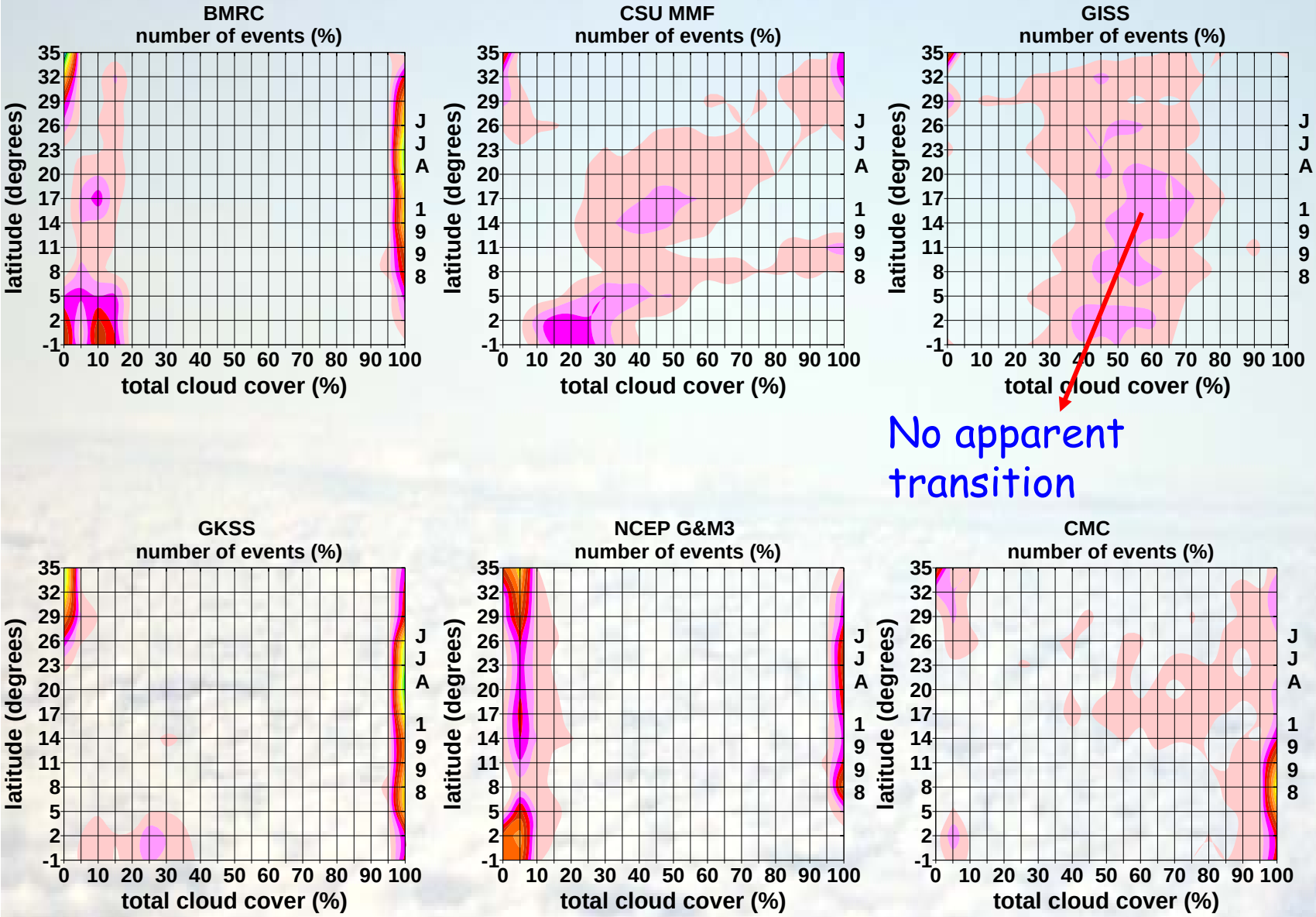
Third peak





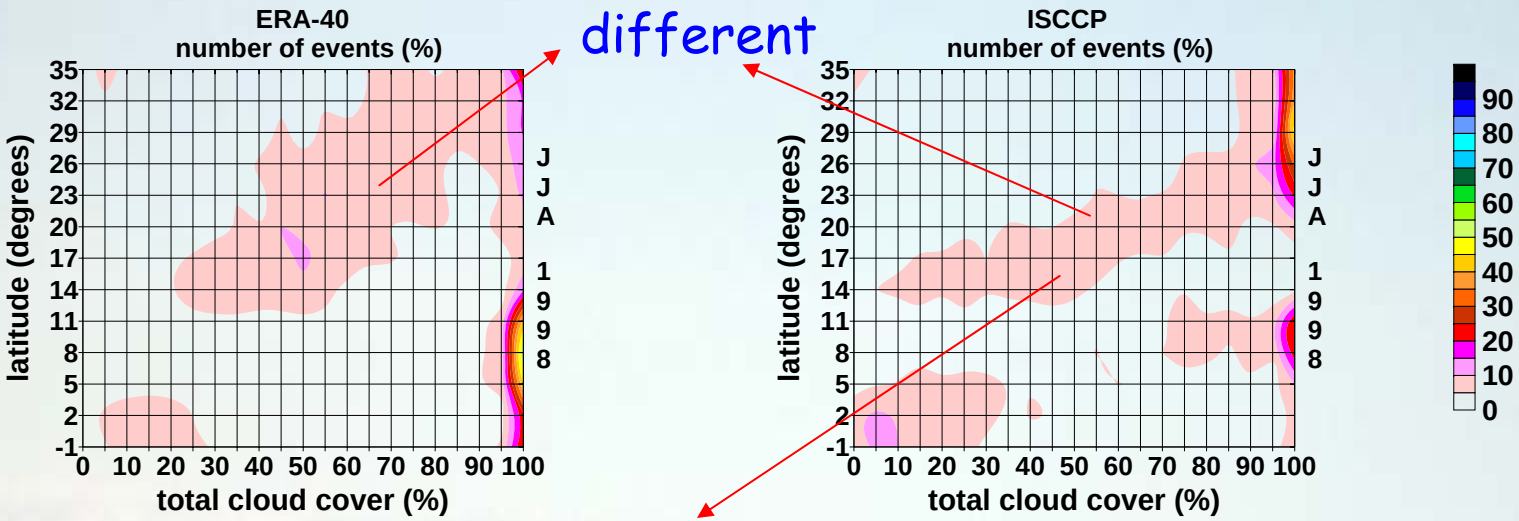


Histograms of total cloud cover

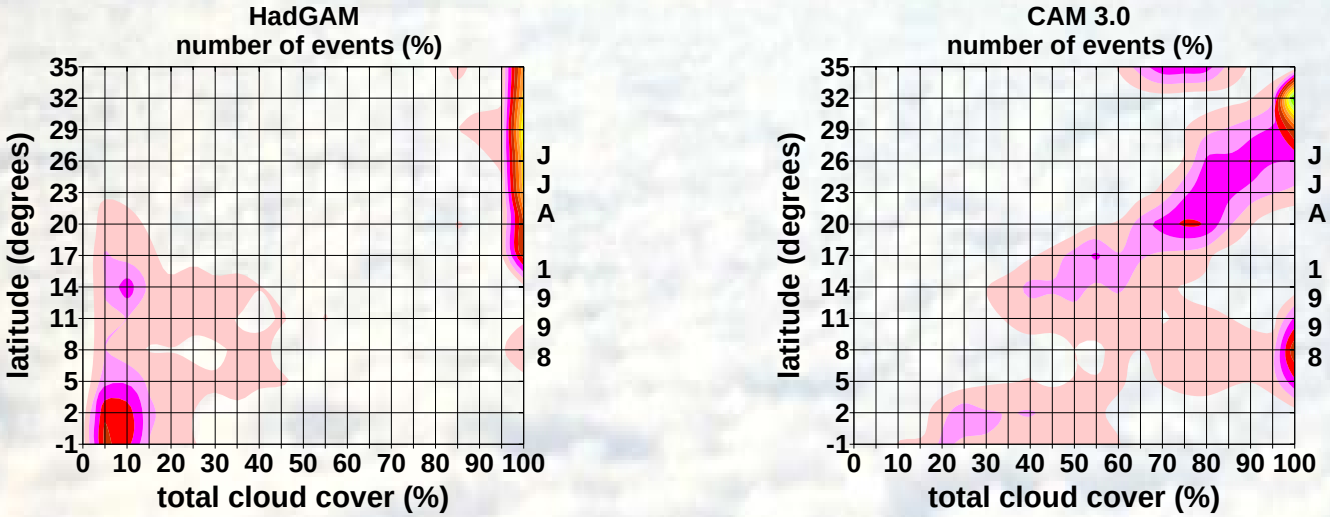


Histograms of TCC: ISCCP and ERA40

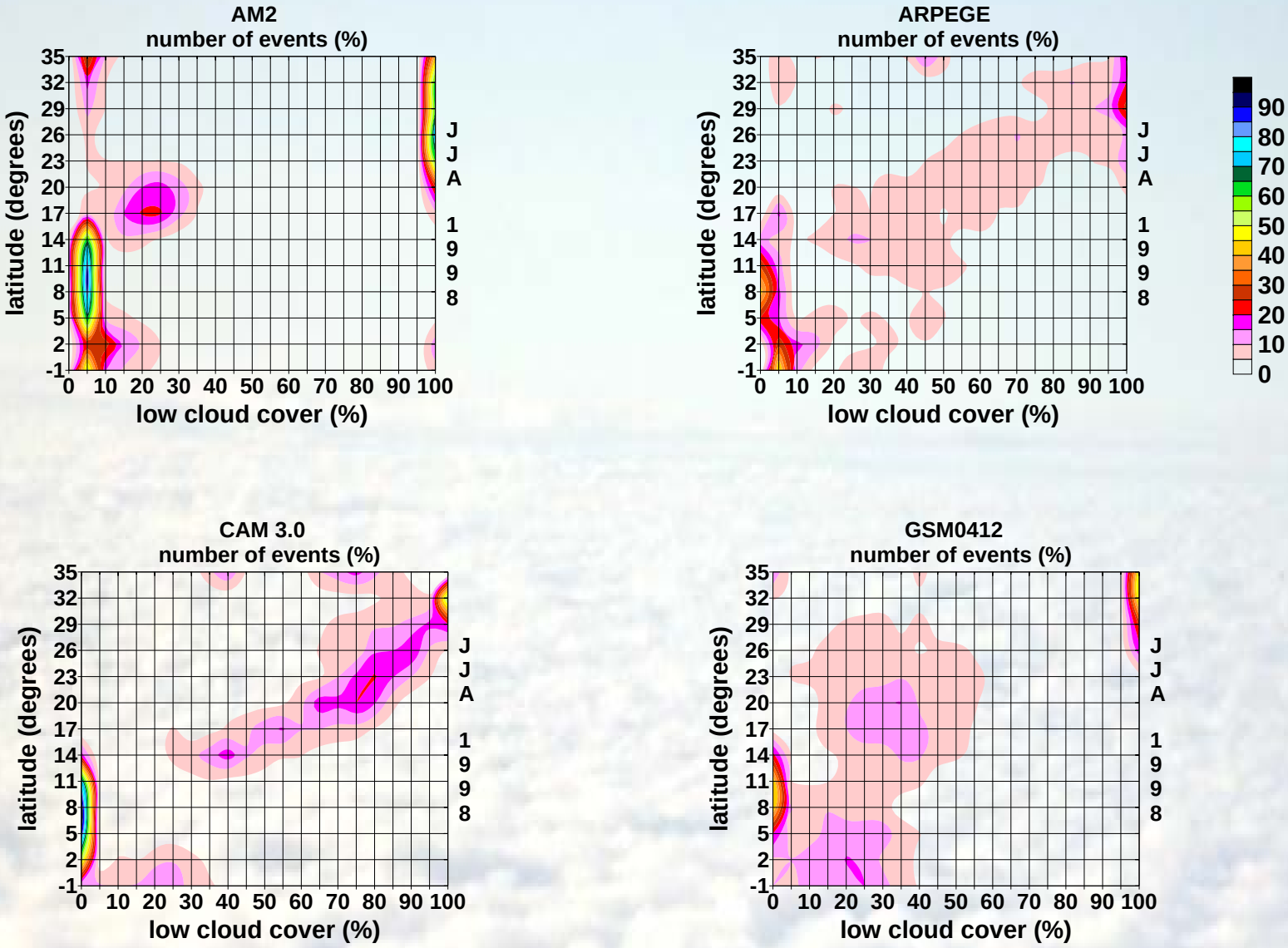
Not so different



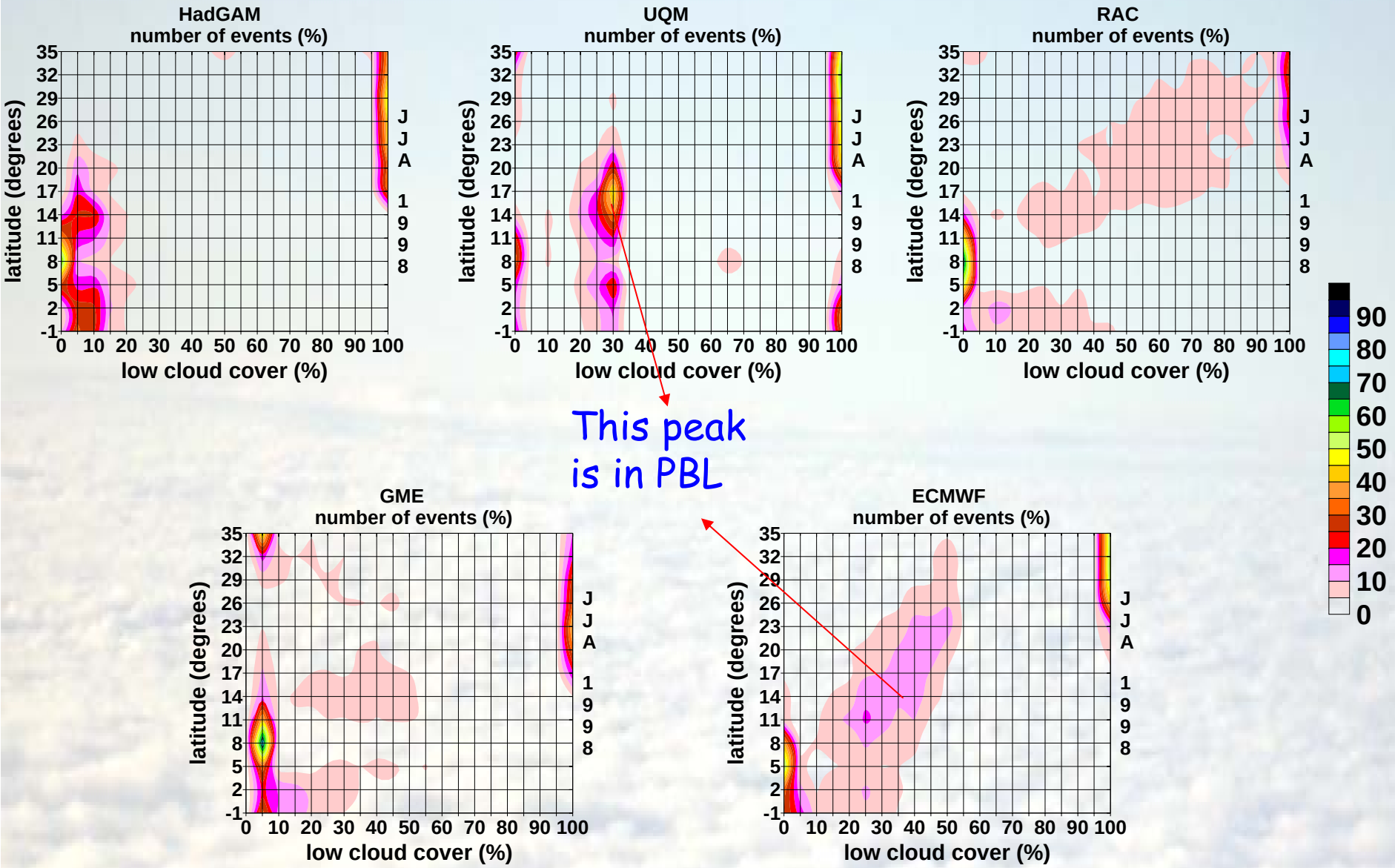
ISCCP is between continuous and bimodal



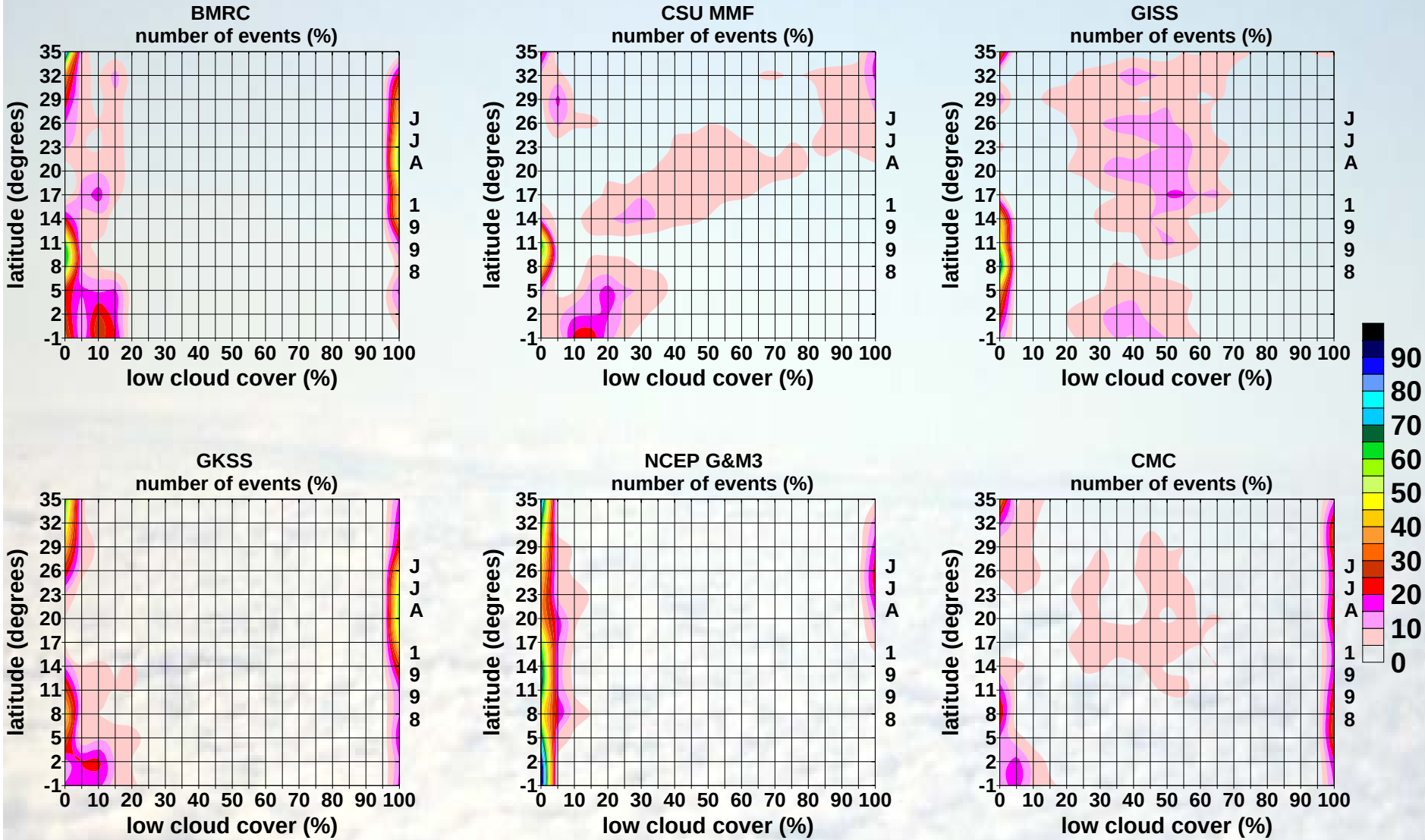
Histograms of low cloud cover



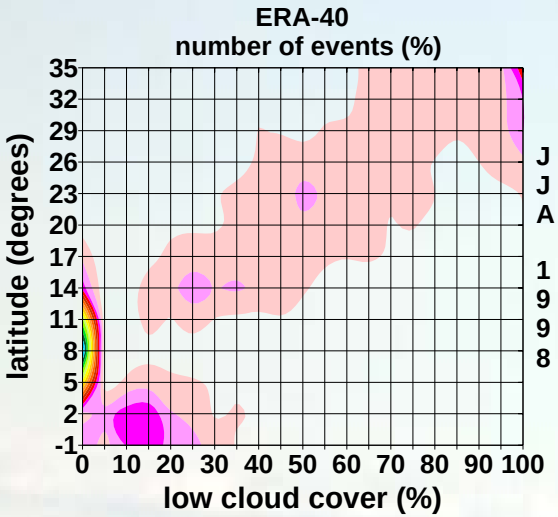
Histograms of low cloud cover

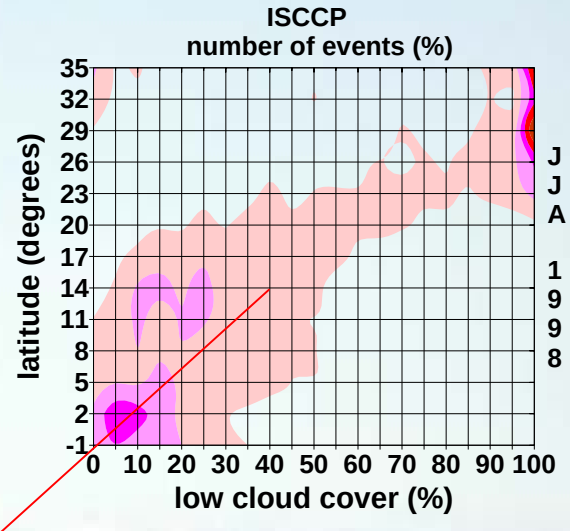


Histograms of low cloud cover

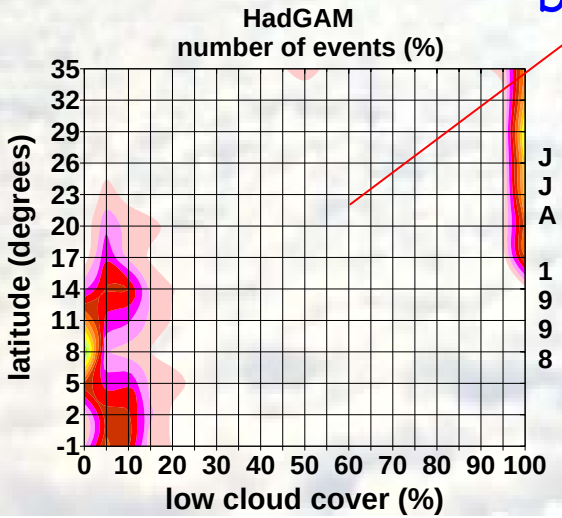


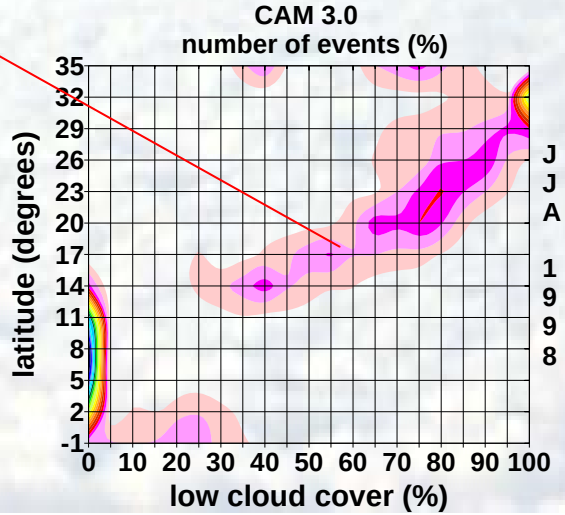
Histograms of LCC: ISCCP and ERA40



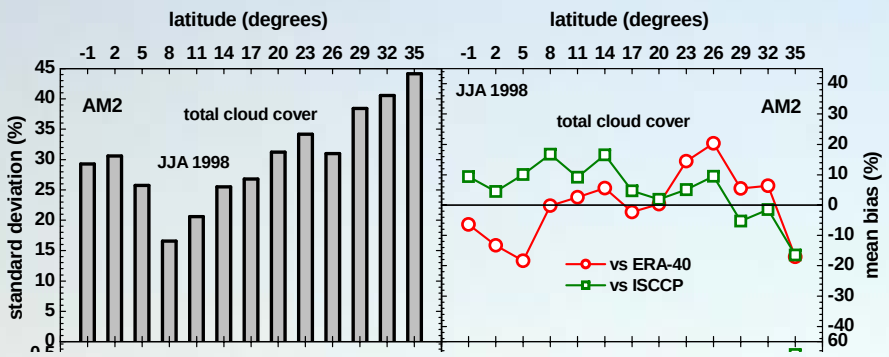


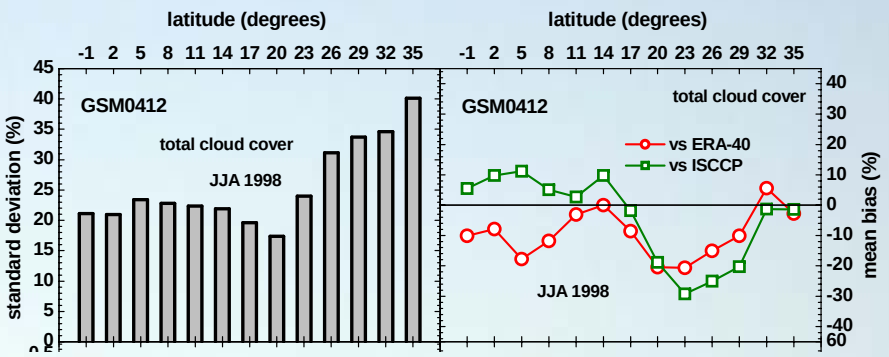
ISCCP is in between

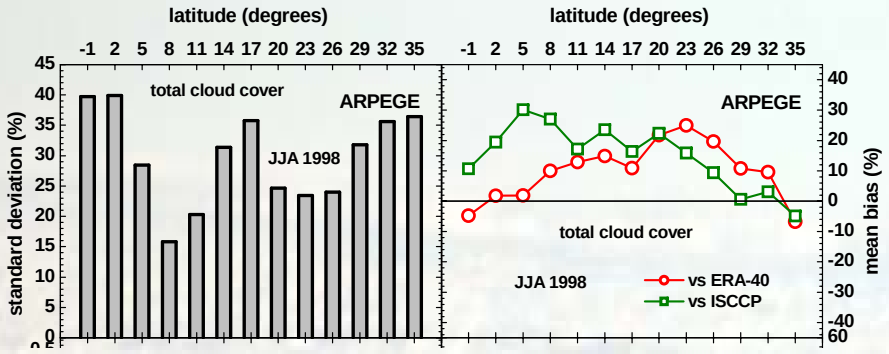


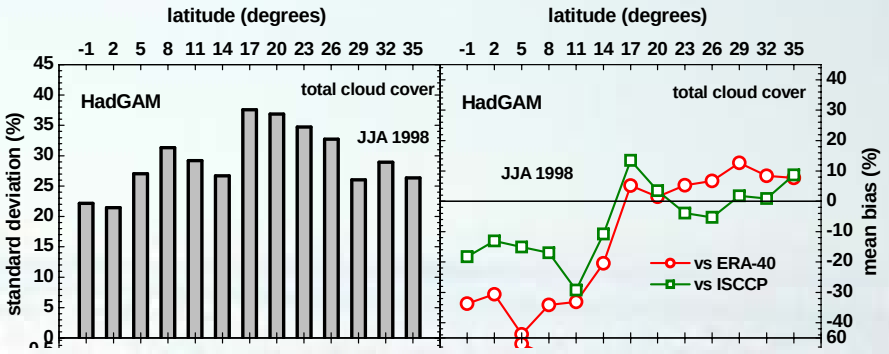


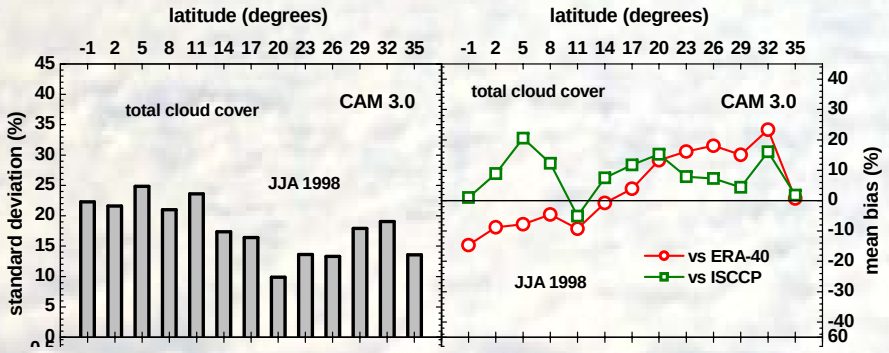
Model total cloud cover versus ISCCP and ERA40

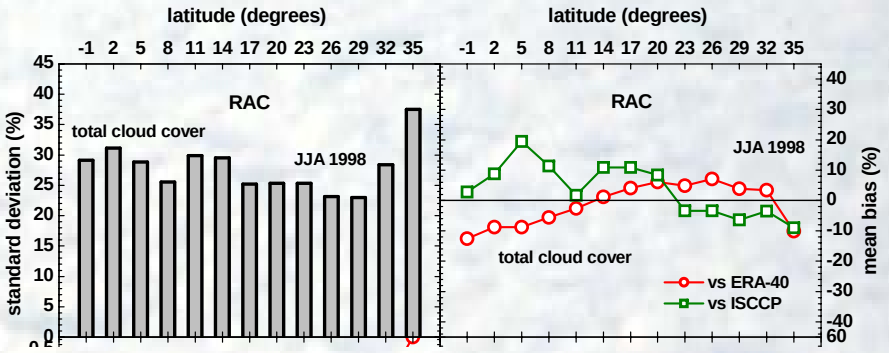




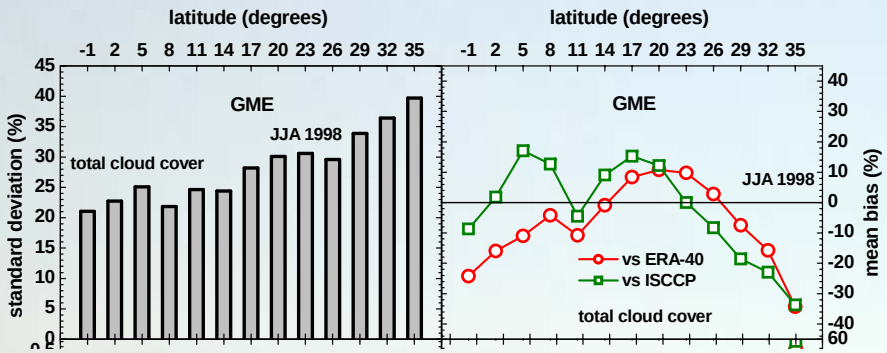


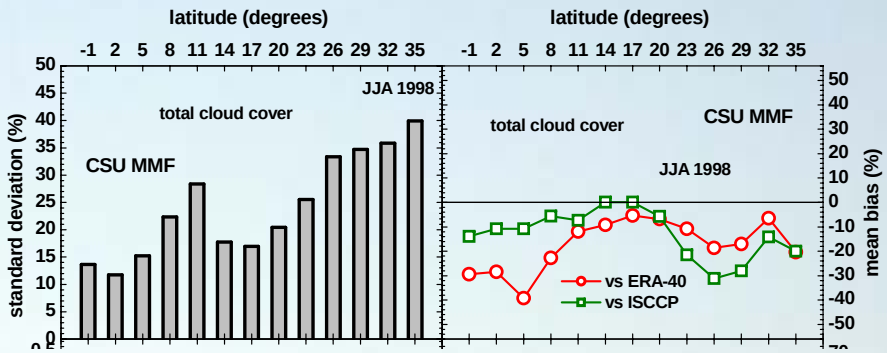


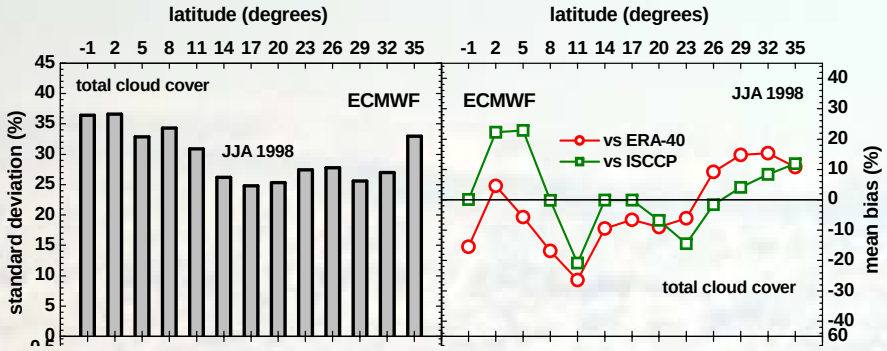


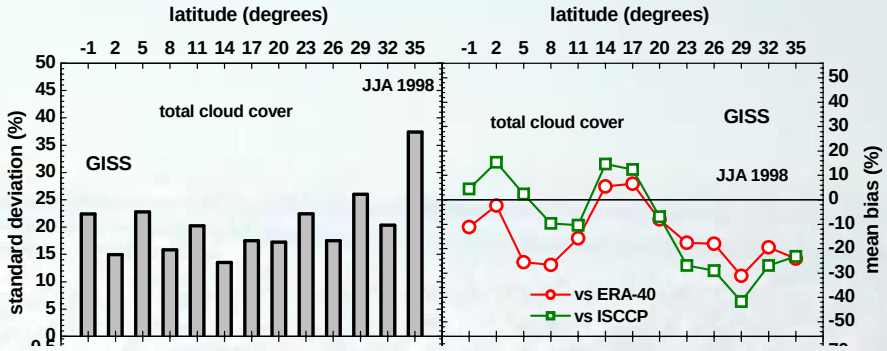


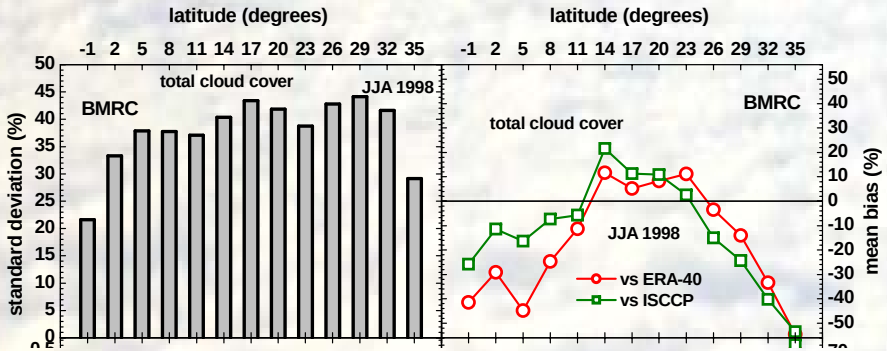
Model total cloud cover versus ISCCP and ERA40

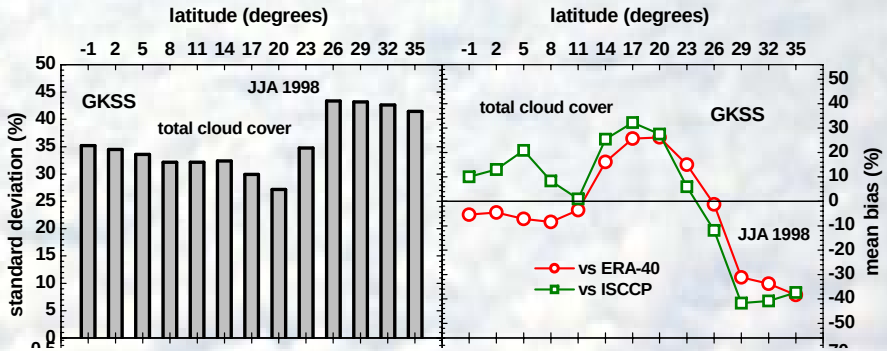




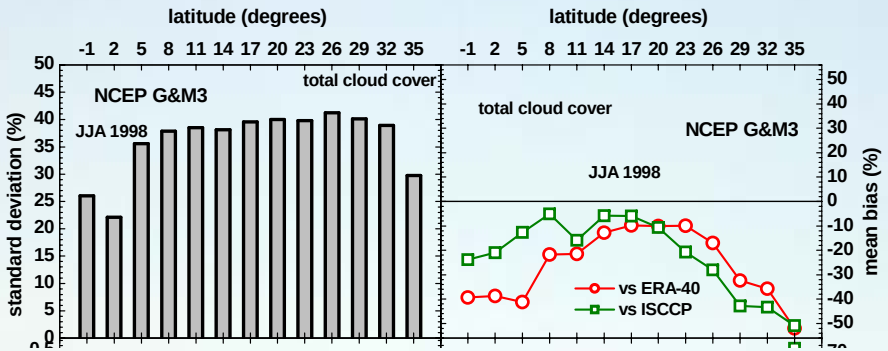


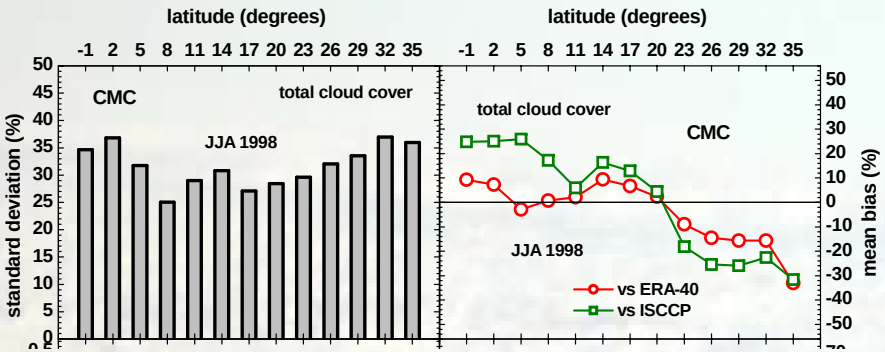


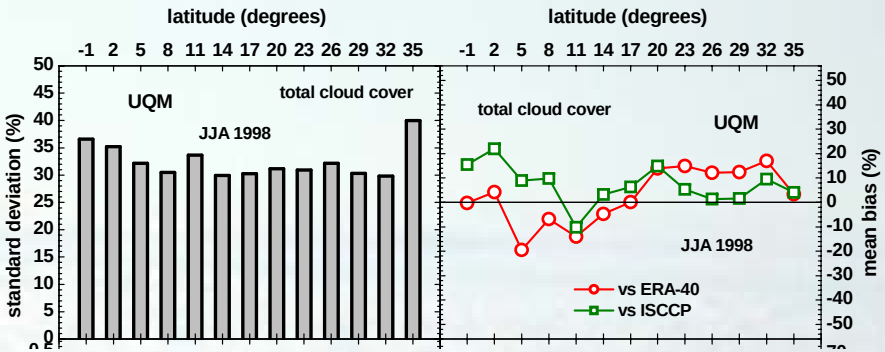


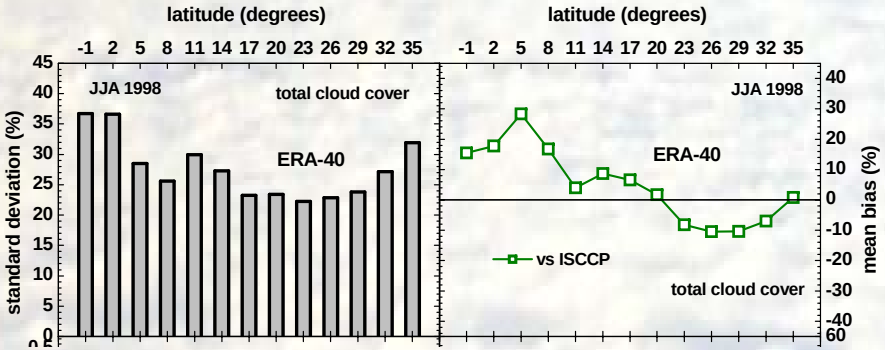


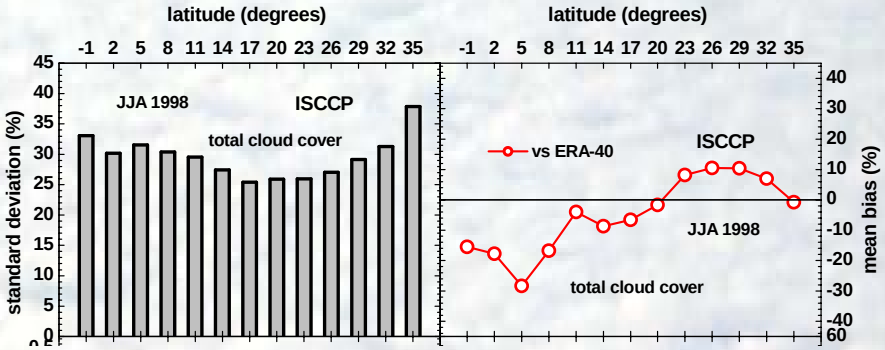
Model total cloud cover versus ISCCP and ERA40



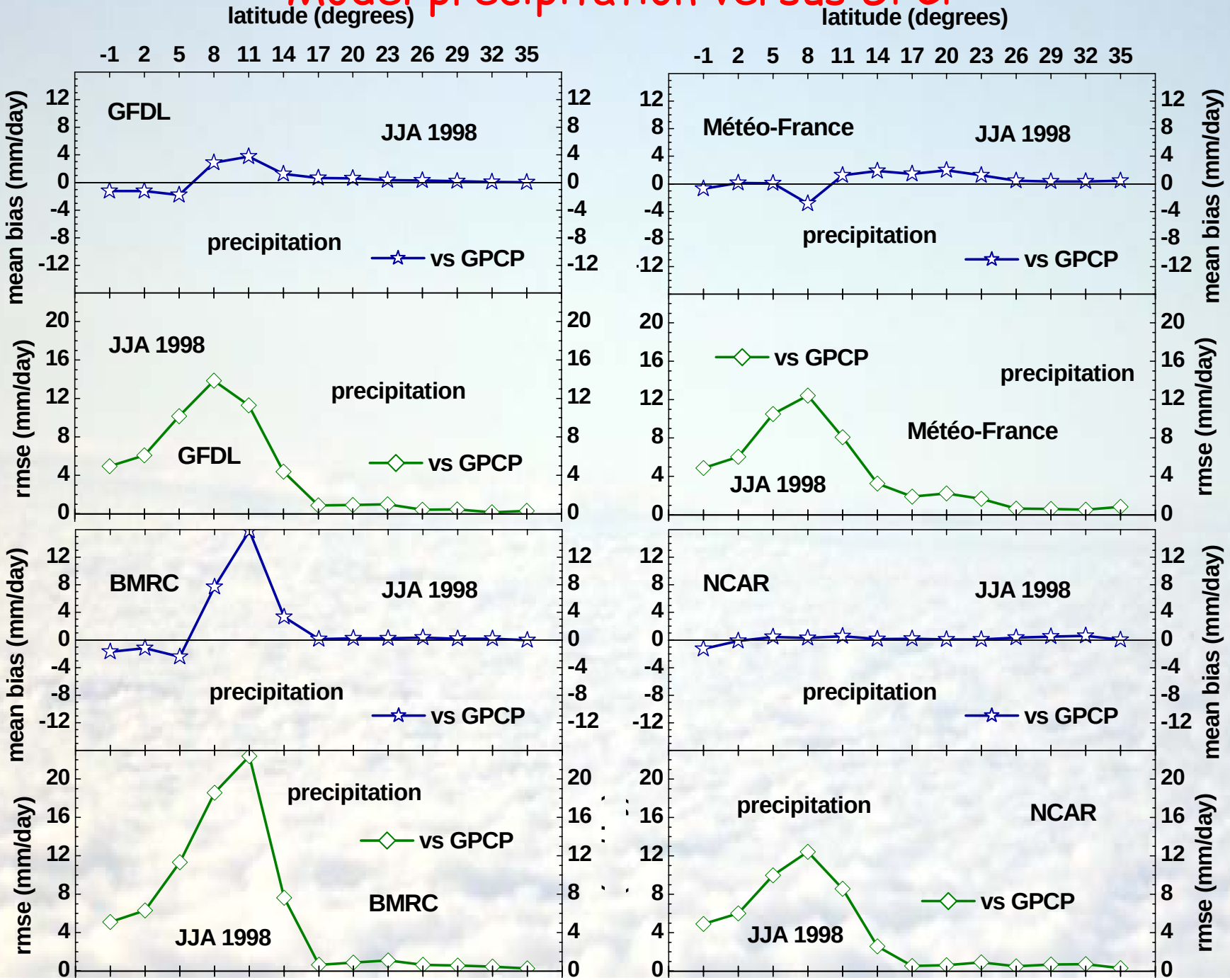




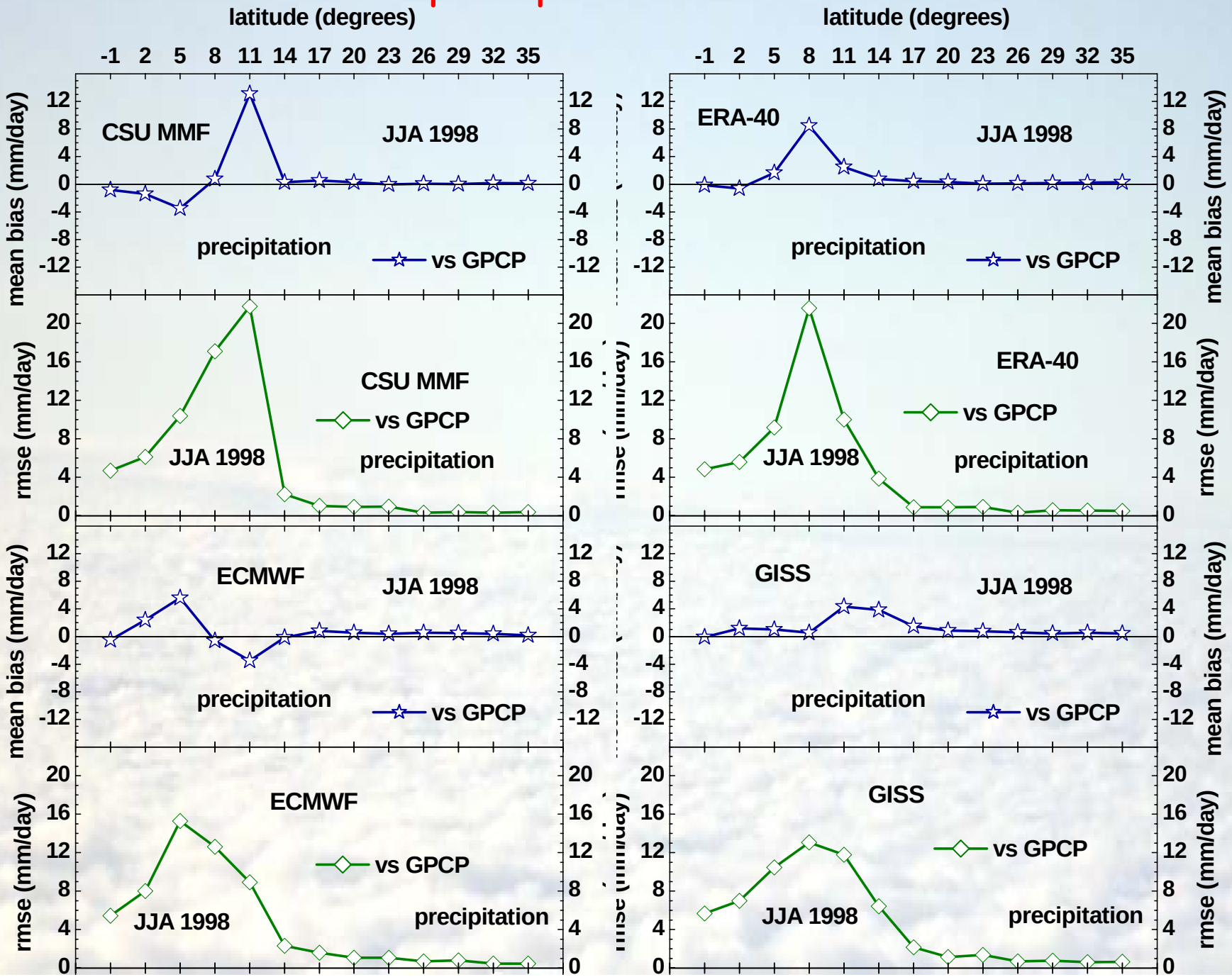




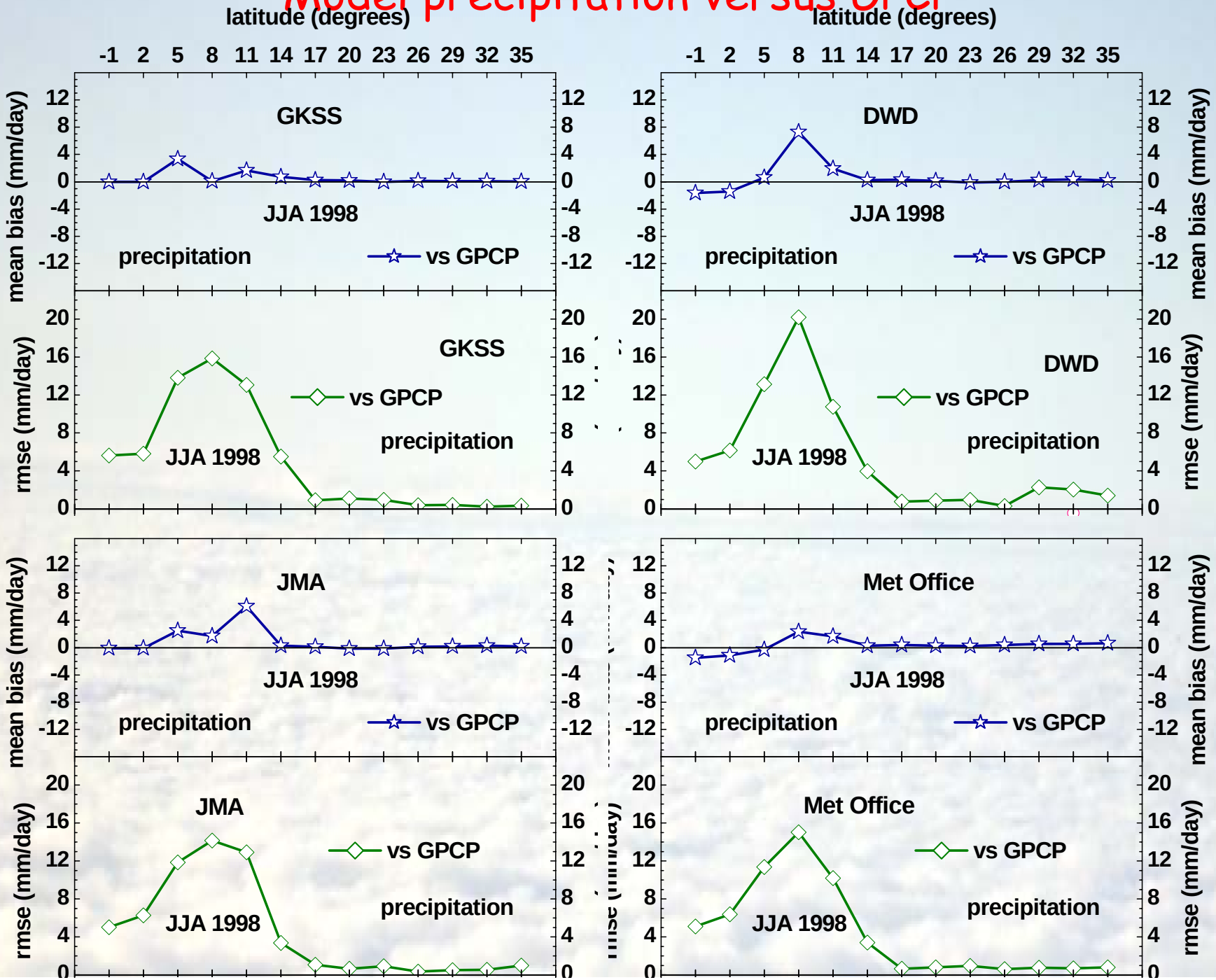
Model precipitation versus GPCP



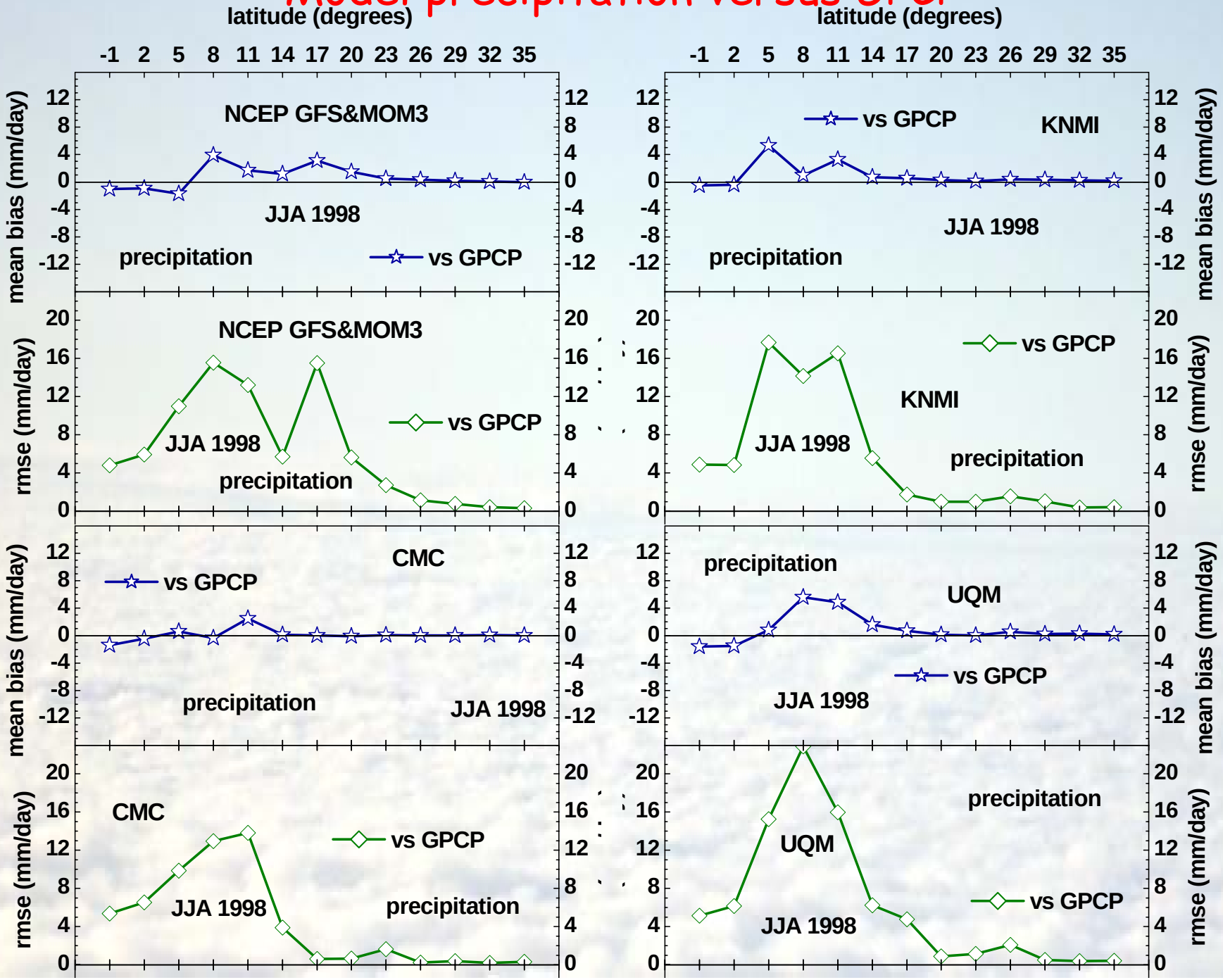
Model precipitation versus GPCP



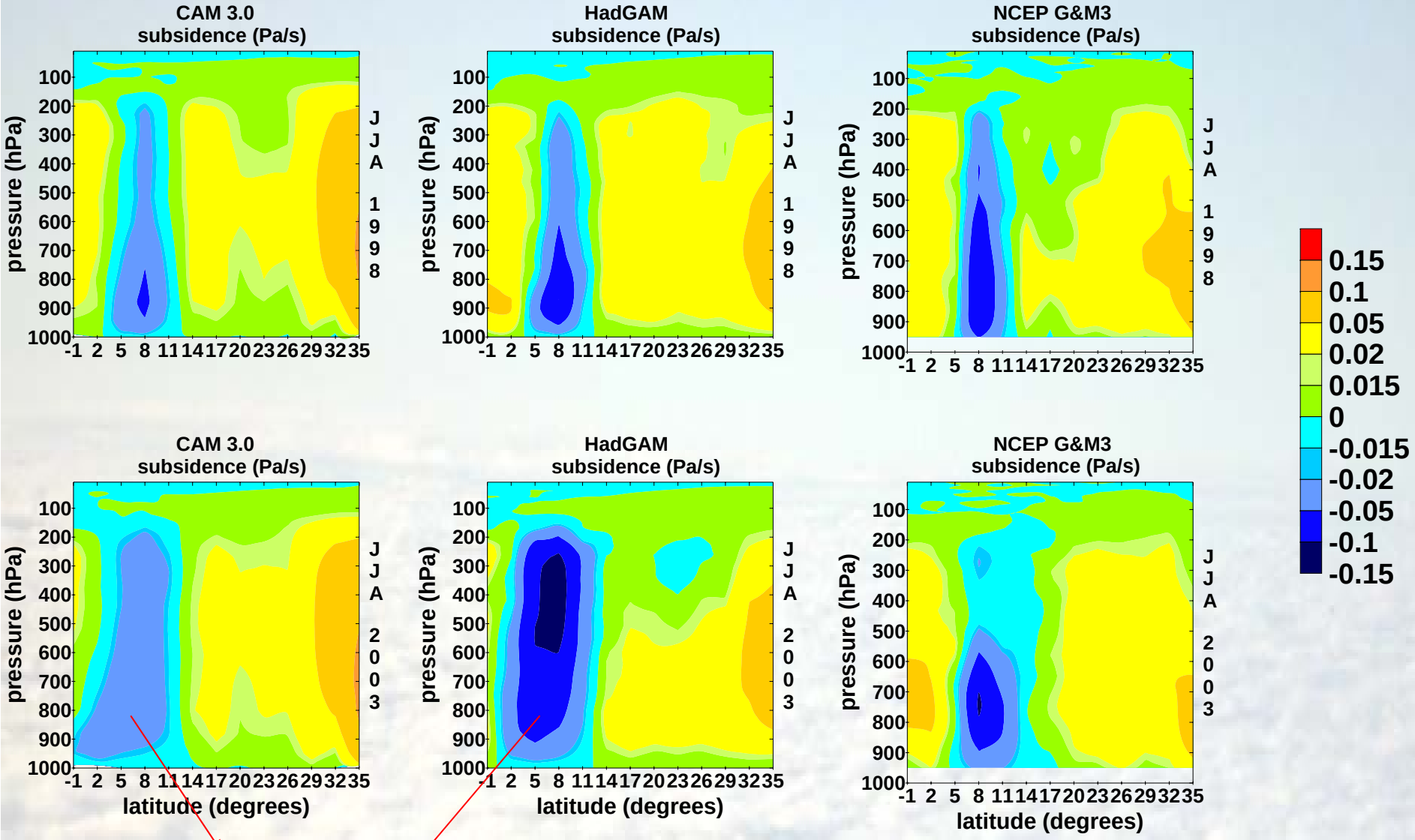
Model precipitation versus GPCP



Model precipitation versus GPCP



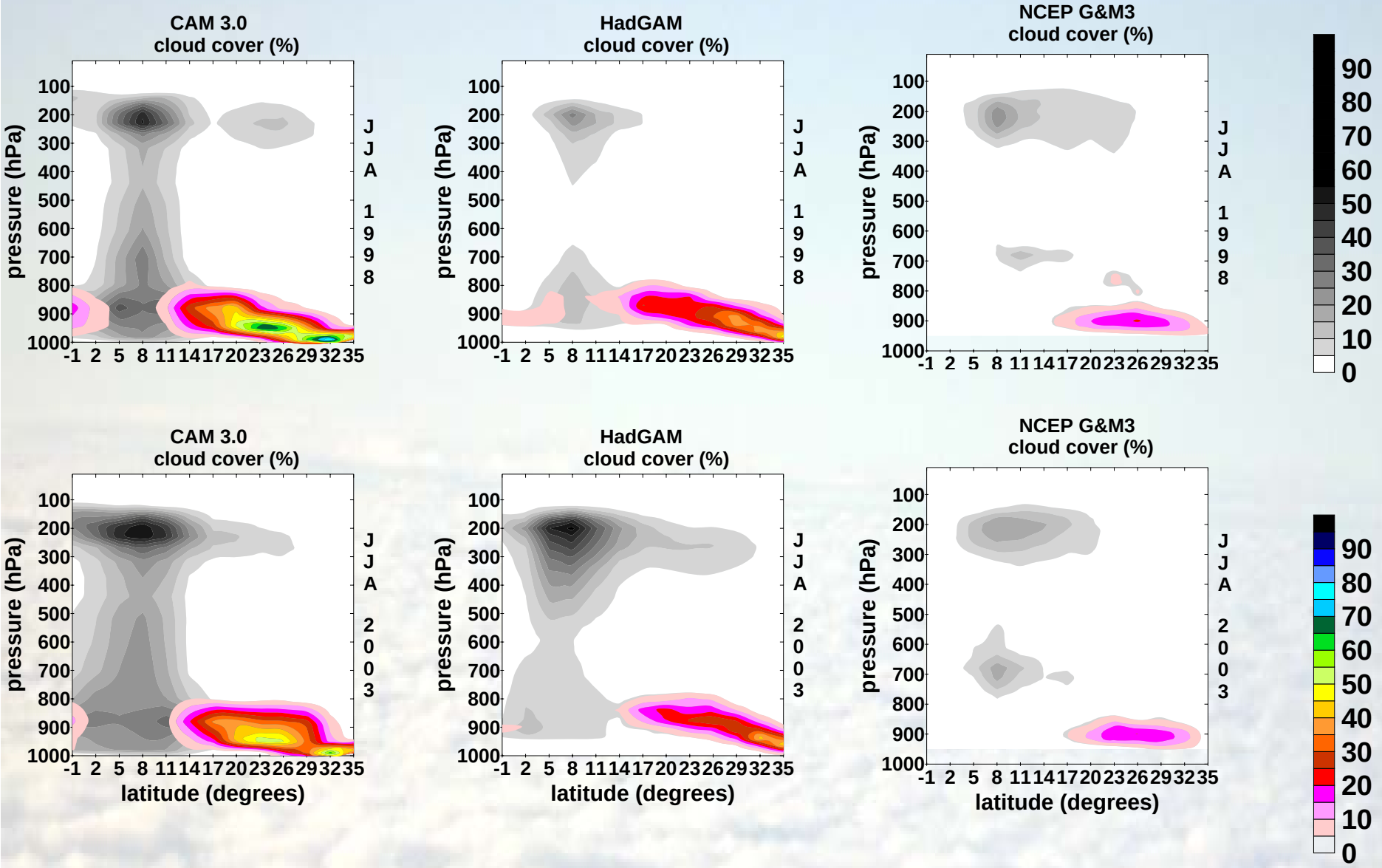
1998 versus 2003: subsidence



Wider convection area in 2003

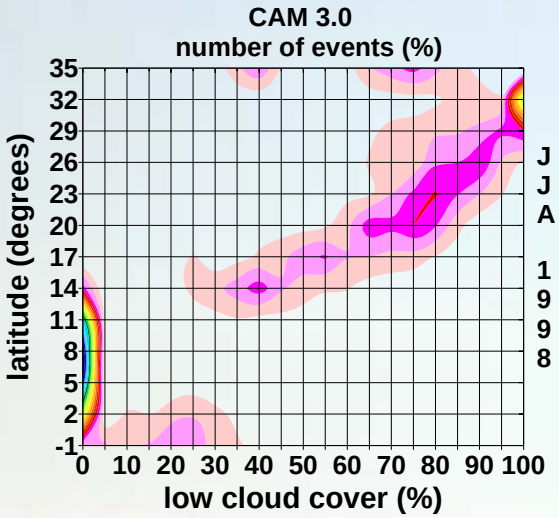
Coupled model does not produce wider convection area

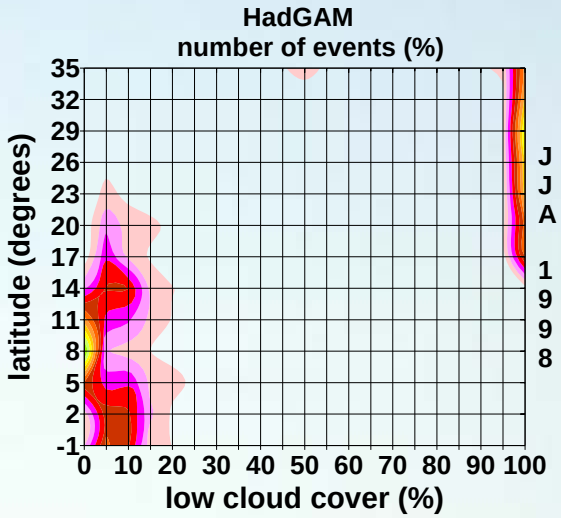
1998 versus 2003: cloud cover

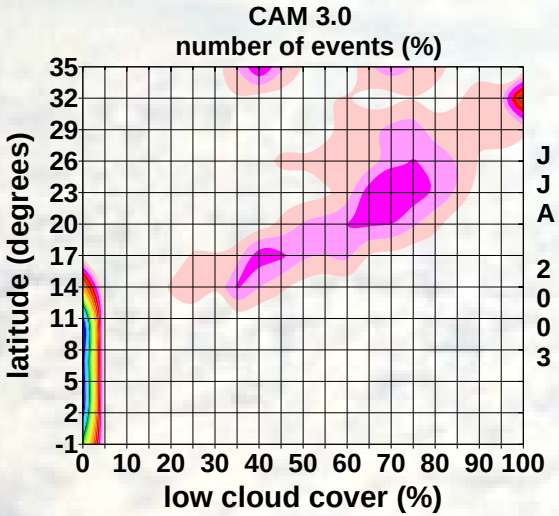


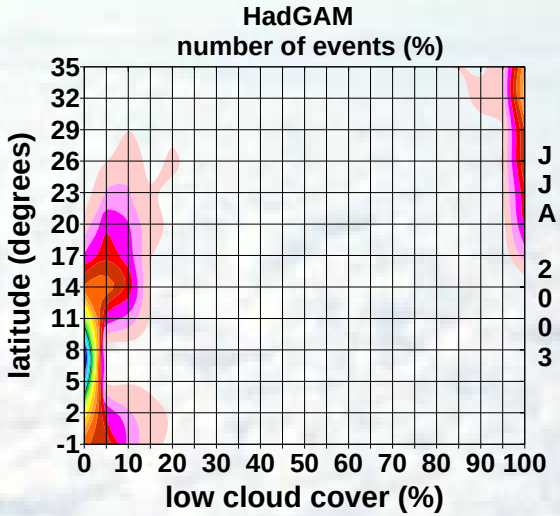
Slightly less … and deeper low clouds

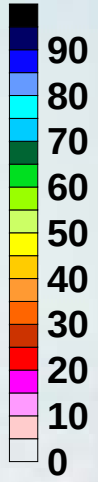
1998 versus 2003: LCC histograms









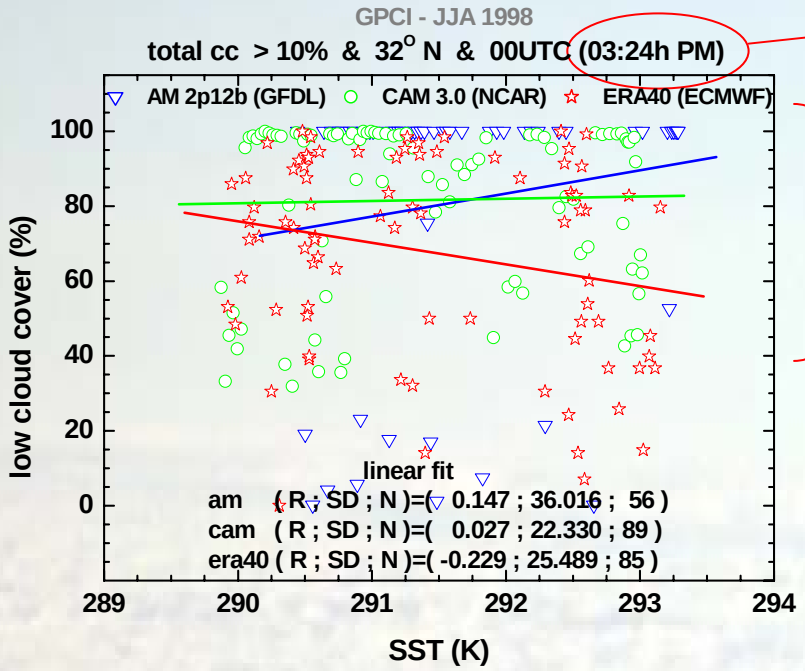


Similar histograms in 2003

Sensitivity to SST: low clouds and TOA SW

NCAR, GFDL and ERA40 Stratocumulus (32 N)

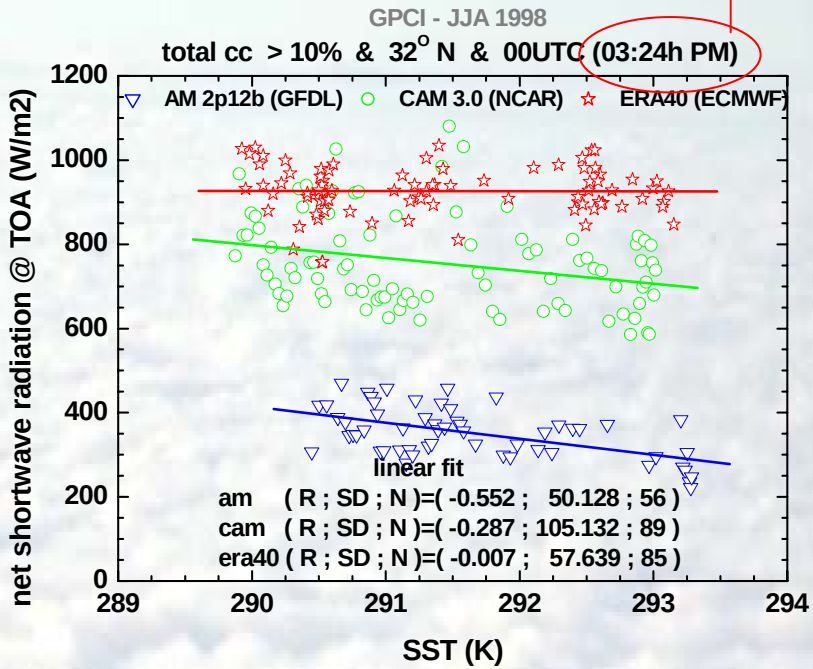
local time



GFDL: low cloud increases with SST – negative feedback

ERA40: low cloud decreases with SST – positive feedback

Strangely large differences between models in netSW@TOA



GPCI – Summary

- The lack of Sc problem (getting better)
- Too much cloud in ITCZ (impact on OLR)
- PBL vertical structure different between models
- How deep is the PBL? PBL observations…
- How dry is the sub-tropical upper troposphere?
- Need for detailed observations of vertical structure…
- Subsidence diurnal cycle in sub-tropics.
- Histograms: how are clouds distributed?
- How smooth is the cloud transition from Sc to Cu?
- Sharp gradient LCC cross-section
- ISCCP is in-between continuous and bi-modal
- …