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AIRS and the GCSS Pacific Cross-section Intercomparison (GPCI): Evaluating the Physics of Climate Models

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Climate Change and the Water Vapor and Cloud feedbacks

IPCC 2007:

- “Water vapor changes represent the largest feedback affecting climate sensitivity and are now better understood”
- “Cloud feedbacks remain the largest source of uncertainty”

Cloud regimes in tropical/sub-tropical regions play a key role

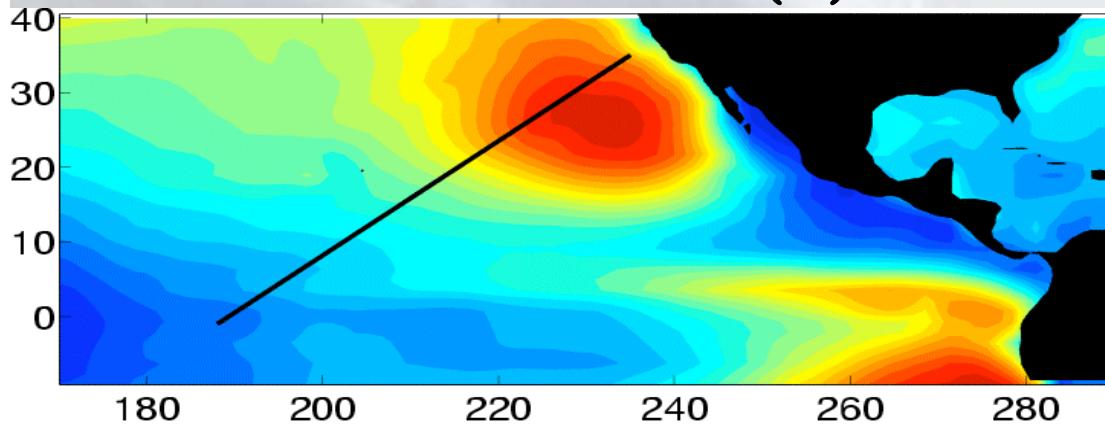


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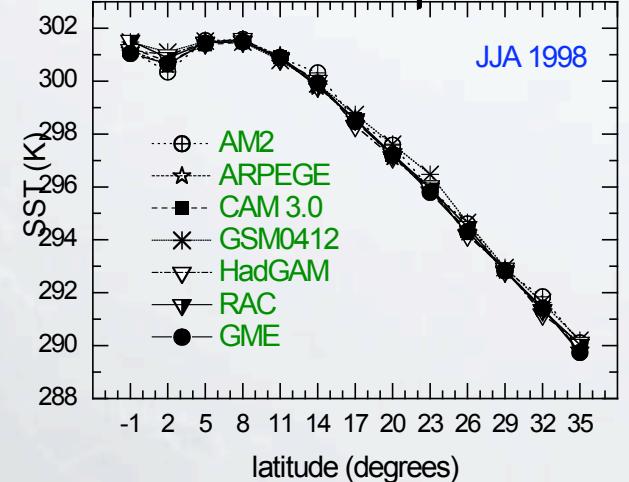
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GCSS/WGNE Pacific Cross-section Intercomparison (GPCI)

ISCCP Low Cloud Cover (%)



Sea Surface Temperature



GPCI is a working group of the GEWEX Cloud System Study (GCSS)
- funded by the NASA MAP Program

Models and observations are analyzed along a transect from
stratocumulus, across shallow cumulus, to deep convection

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



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GPCI Motivation

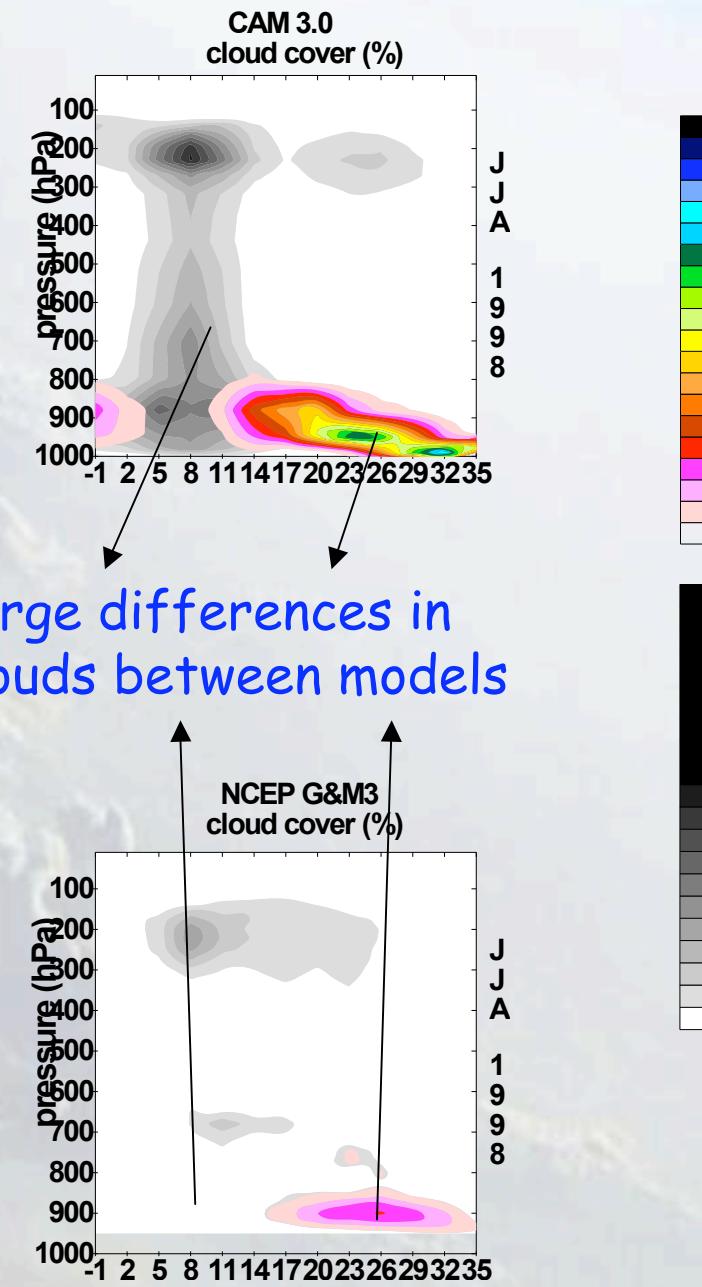
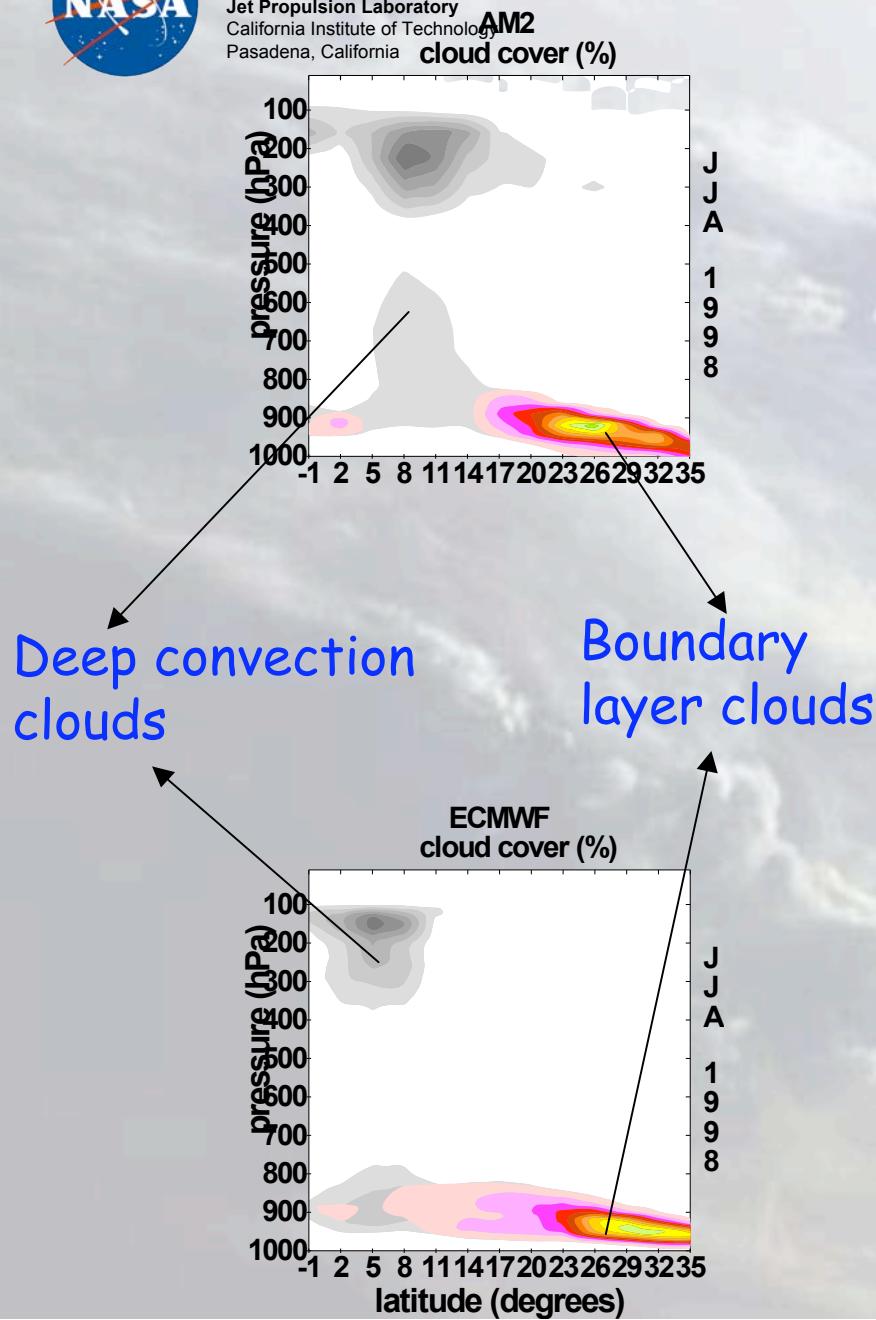
- To study important physical regimes and transitions: stratocumulus, shallow cumulus and deep convection
- To evaluate models and observations in the tropics and sub-tropics in terms of the atmospheric hydrologic cycle
- To utilize a new generation of satellite datasets (e.g. AIRS)
- To help the development of new cloud, convection and turbulence parameterizations in climate/weather models
- To create a database of models and observations for future studies of the tropics and sub-tropics



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Cloud Cover along GPCI

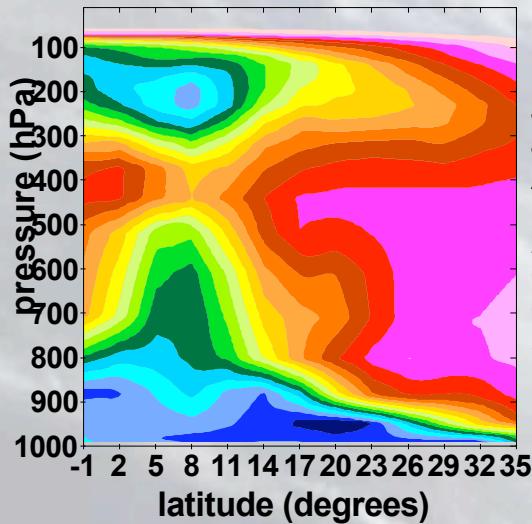




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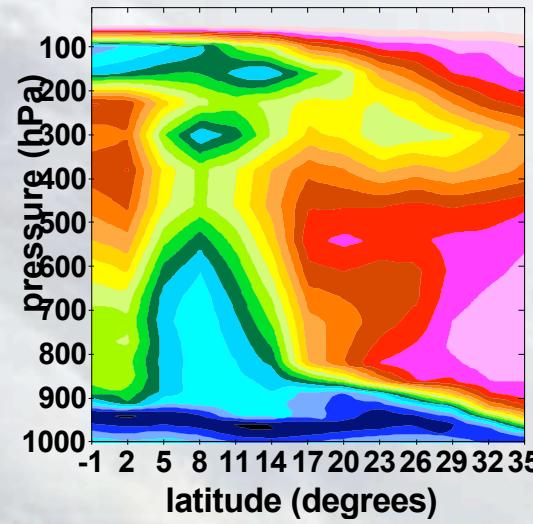
NCARv2

relative humidity (%)

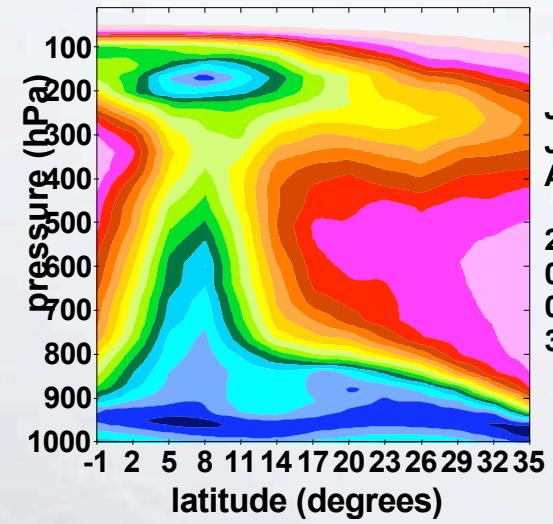


GPCI mean relative humidity - JJA 2003

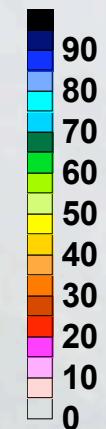
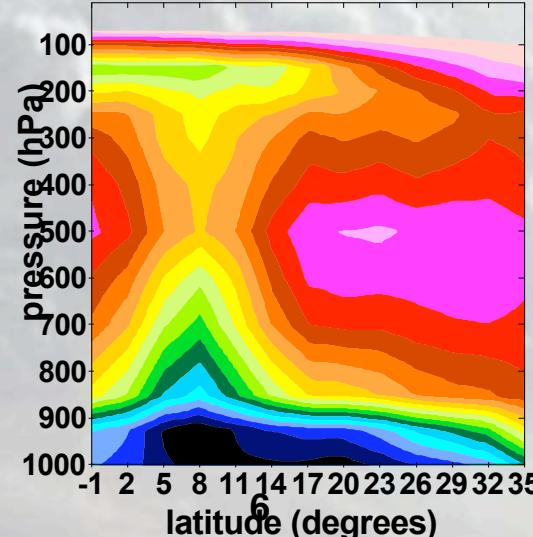
GFDL
relative humidity (%)



METOFF
relative humidity (%)



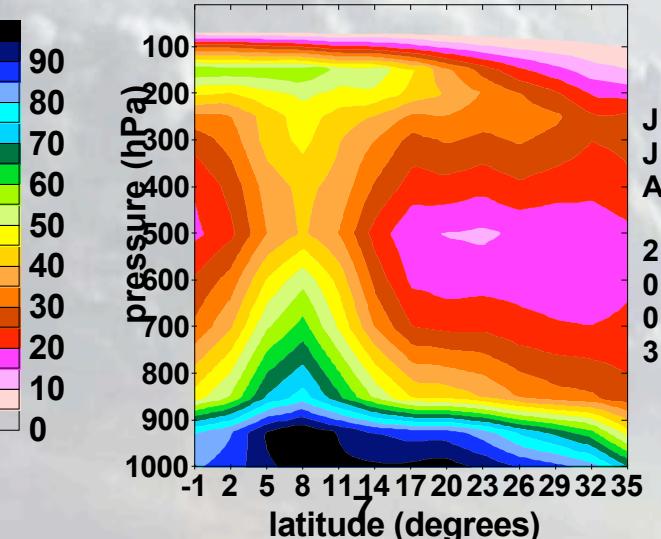
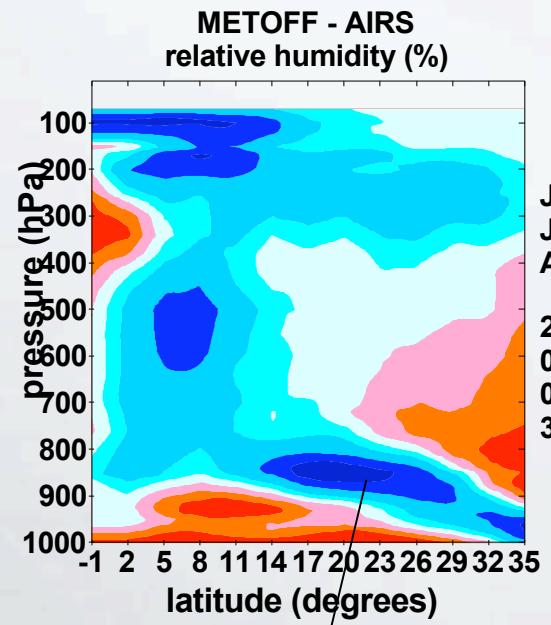
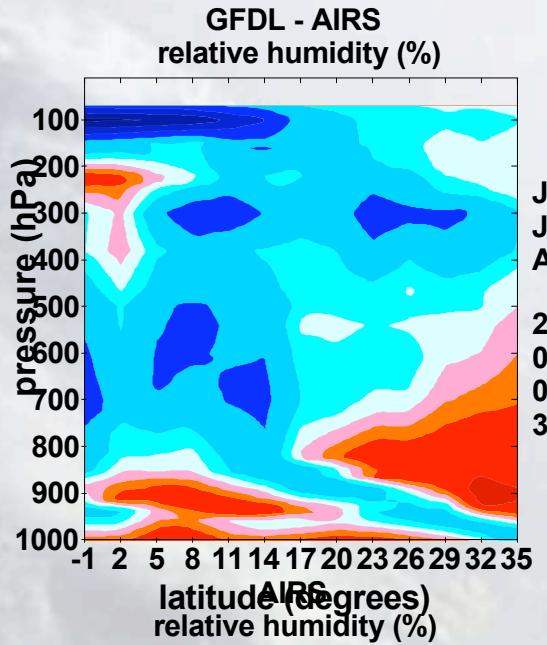
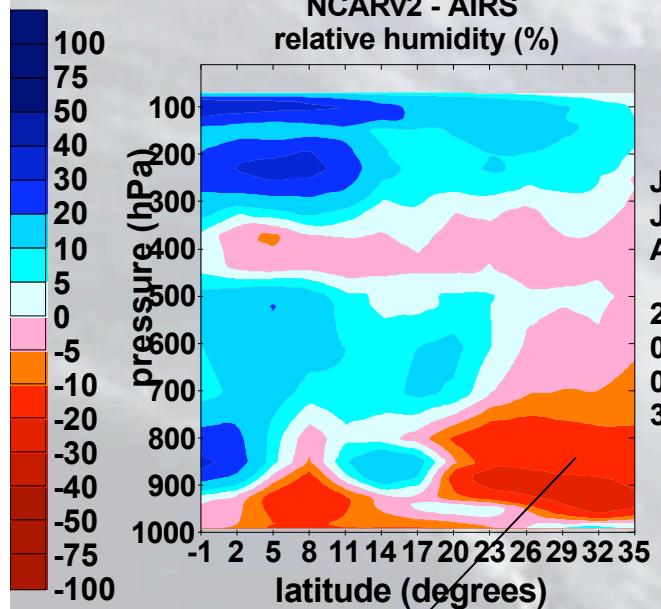
AIRS
relative humidity (%)





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Relative humidity differences: model- AIRS (JJA03)



UKMO PBL is deeper and/or moister/colder

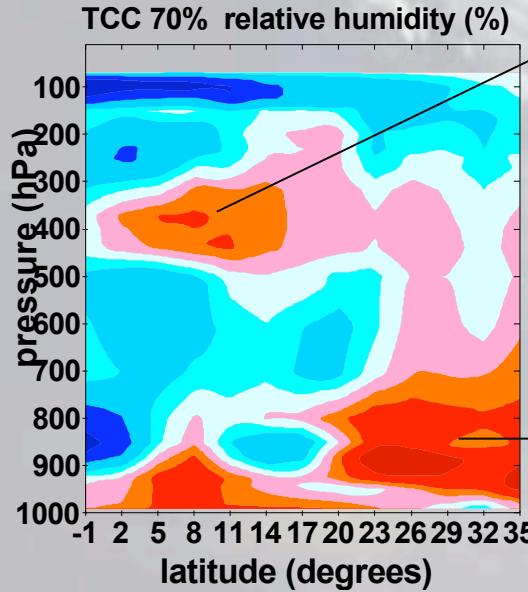
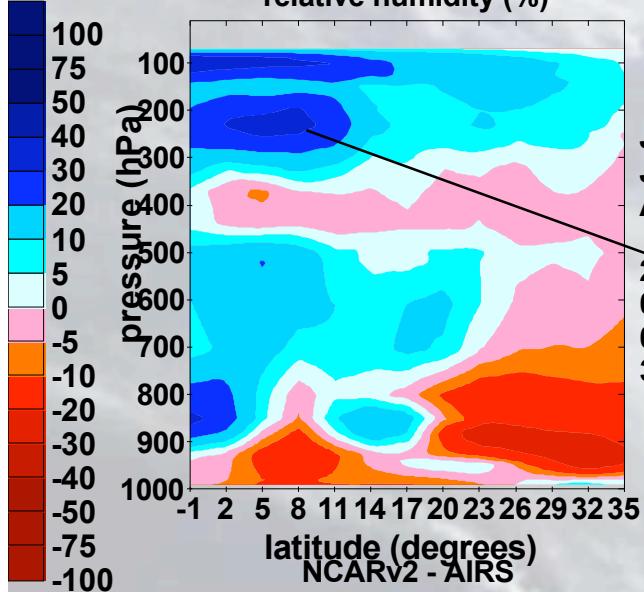


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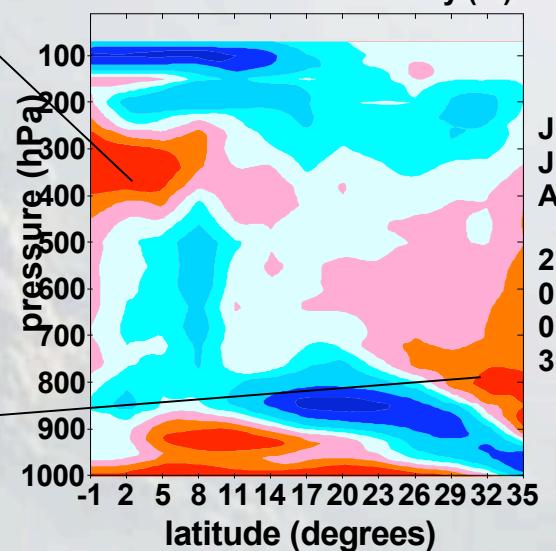
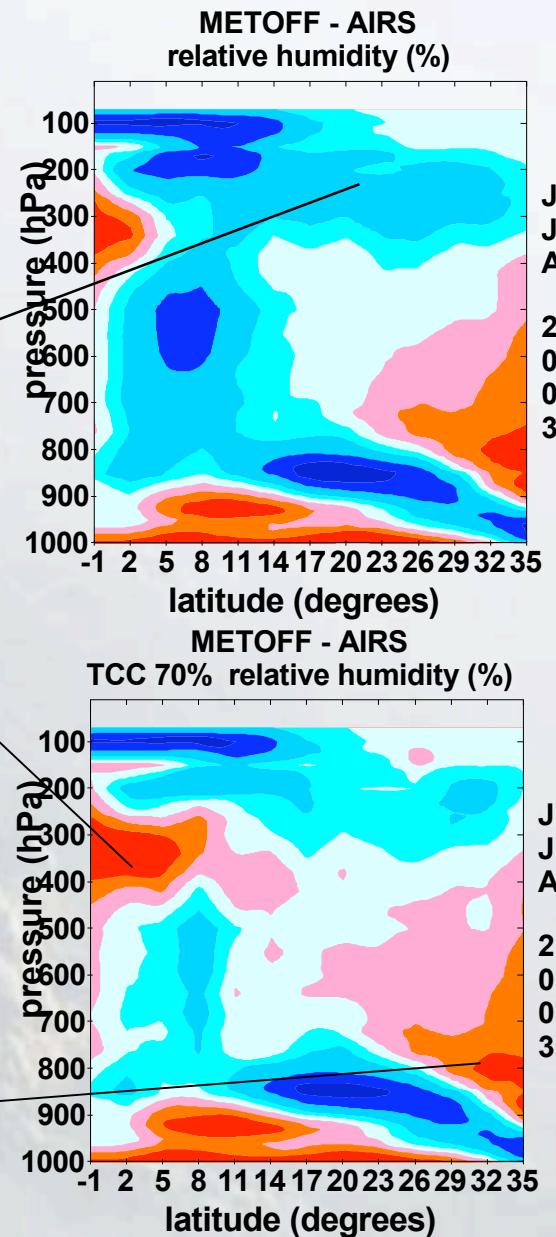
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NCARv2 - AIRS

relative humidity (%)



Model RH only for TCC < 70%: model- AIRS (JJA03)

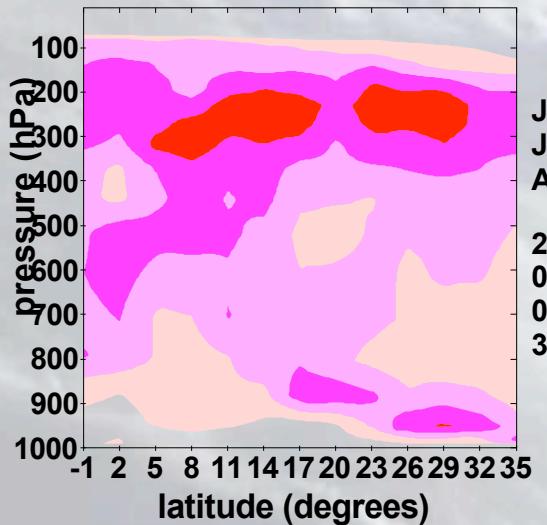




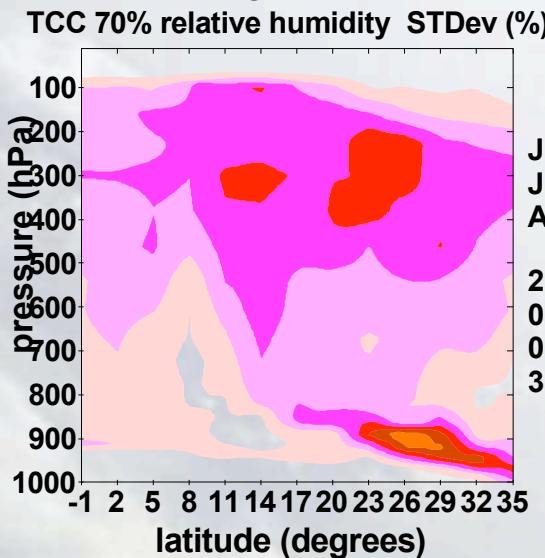
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NCARv2

AIRS and models relative humidity standard deviation

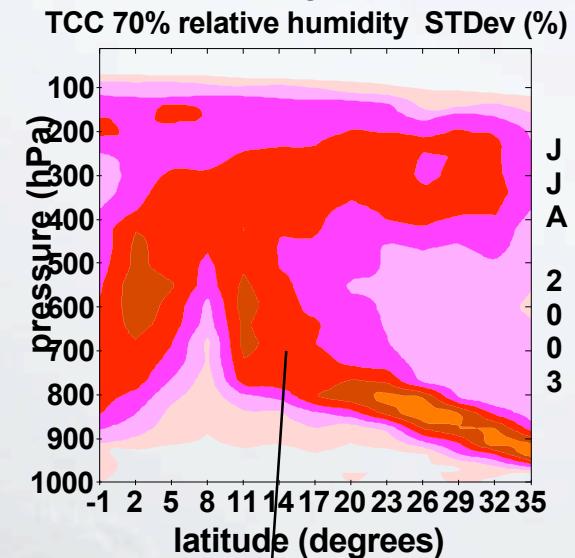
TCC 70% relative humidity STDev (%)



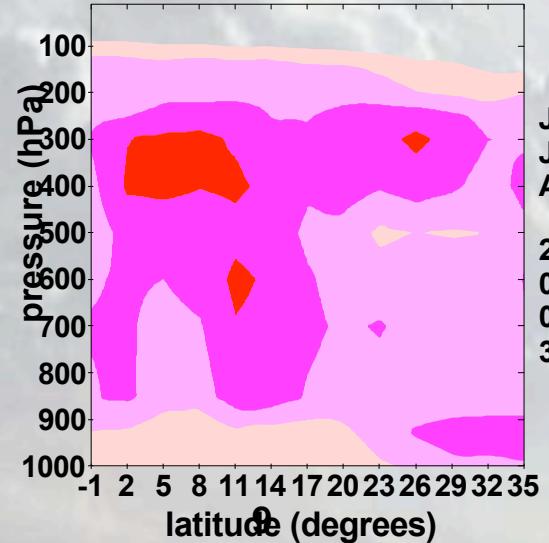
GFDL



METOFF



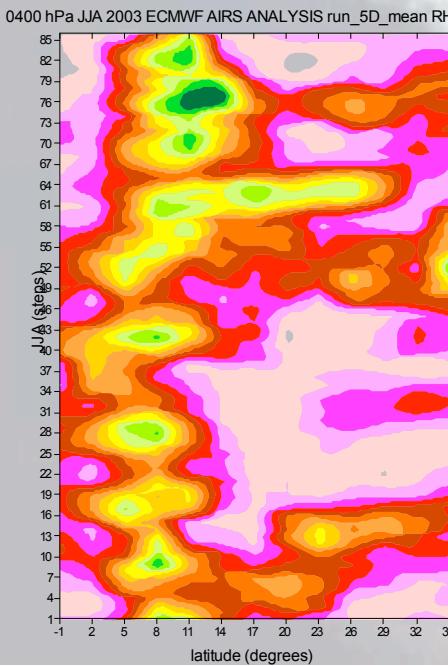
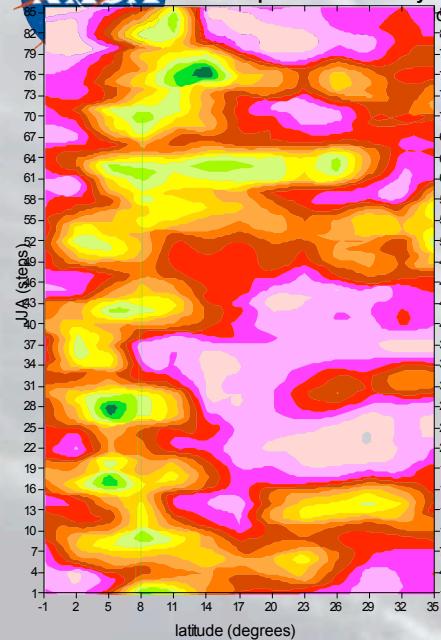
AIRS
relative humidity STDev (%)



UKMO variability
is very different
from AIRS, NCAR
and GFDL



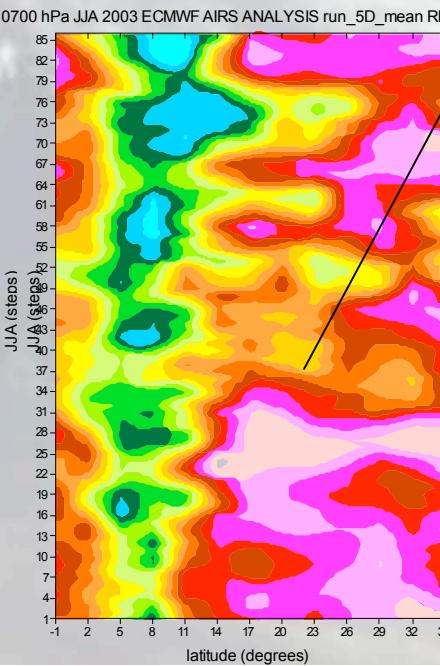
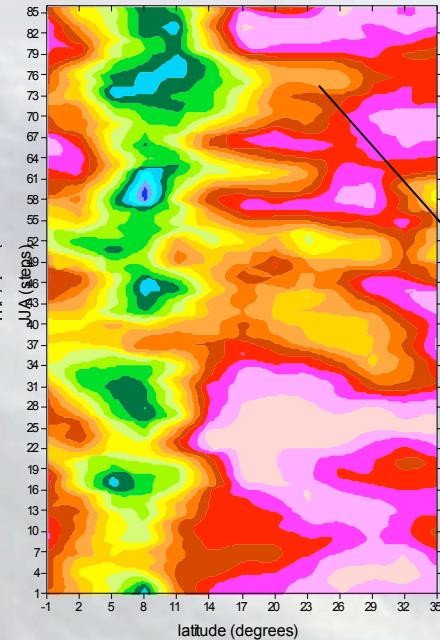
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400 hPa
Atmospheric Reprojection Laboratory



AIRS and ECMWF relative humidity Hovmöller

700 hPa

0700 hPa JJA 2003 AIRS run_5D_mean RH (%)

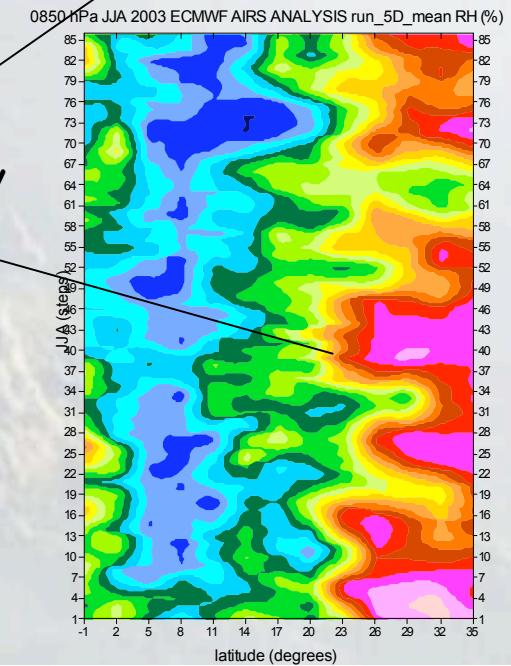
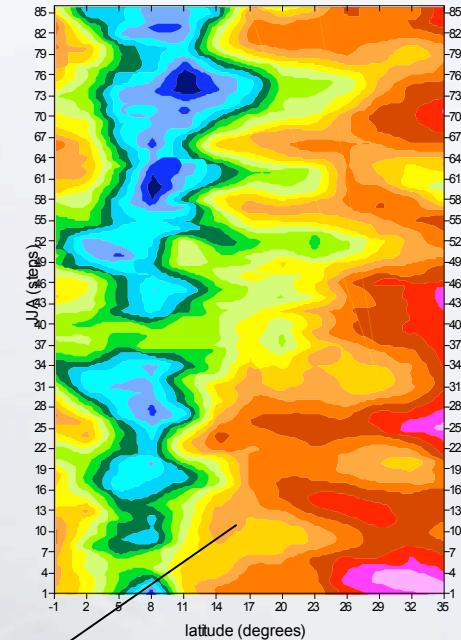


AIRS

ECMWF and
AIRS free
troposphere
is similar

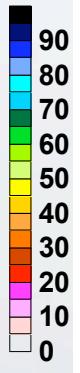
850 hPa

0850 hPa JJA 2003 AIRS run_5D_mean RH (%)



ECMWF

Boundary
layer is very
different





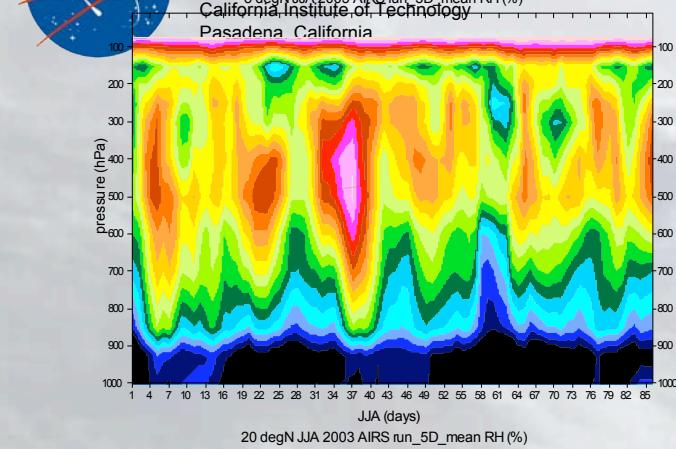
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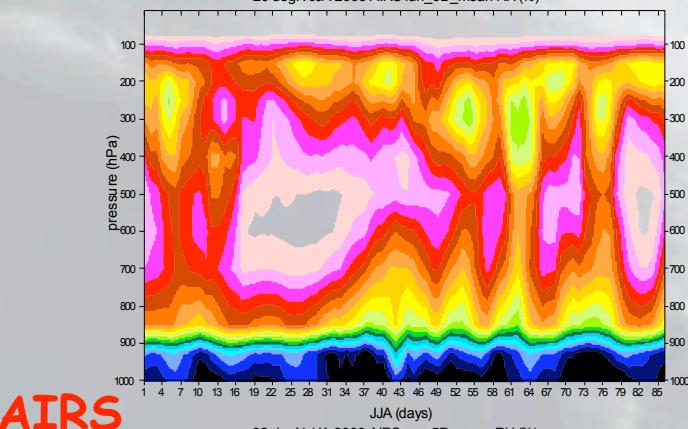
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AIRS and ECMWF RH: pressure versus time



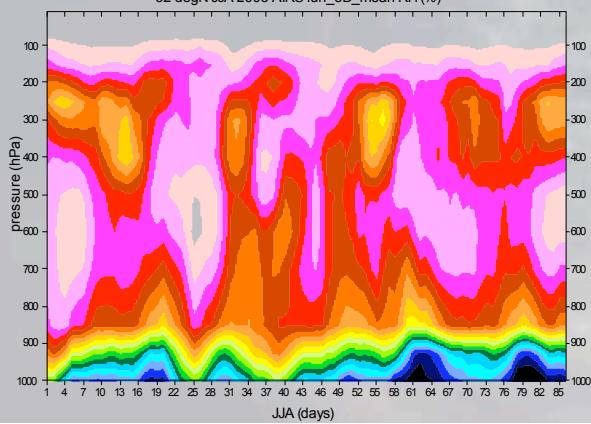
Deep cumulus

Differences
are larger in
deep cumulus
regions

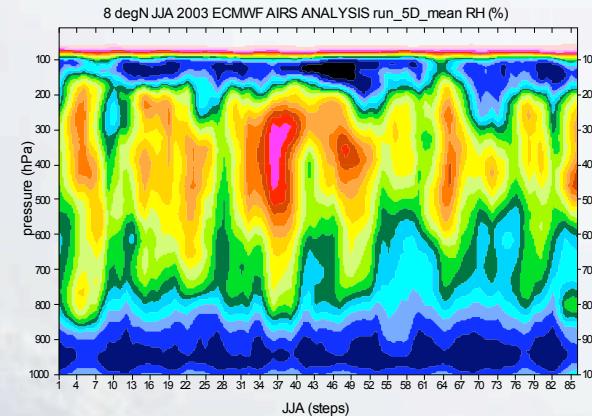


shallow cumulus

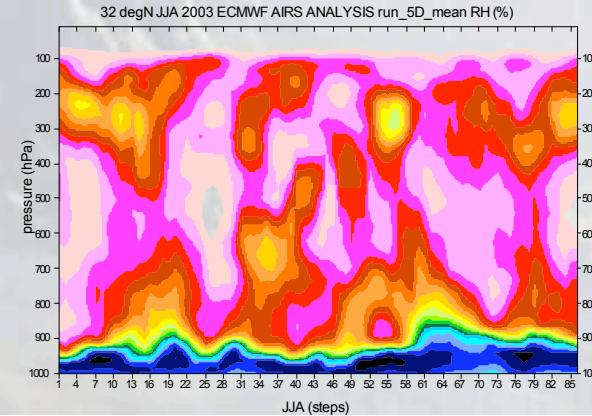
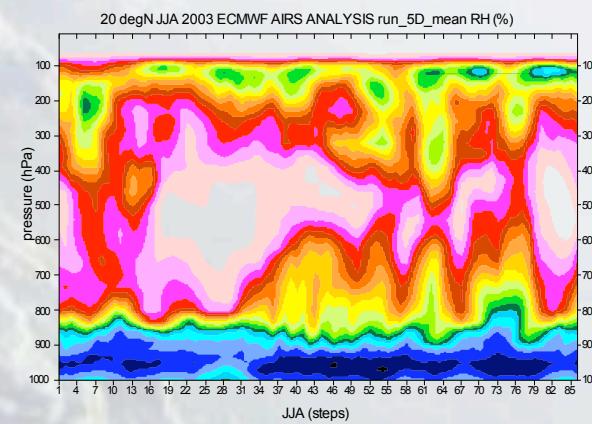
AIRS



Stratocumulus



ECMWF





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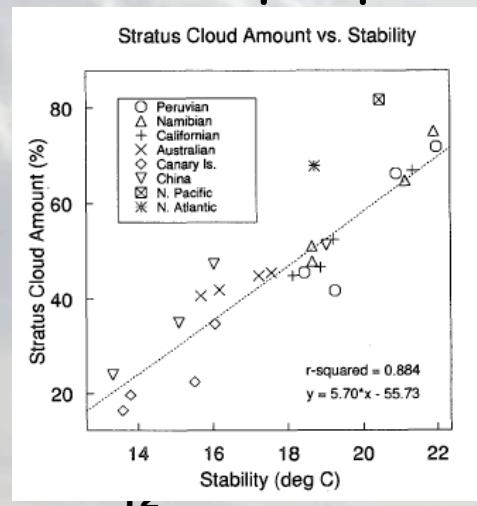
Low cloud climate feedback is a surface/boundary-layer/free-troposphere coupled problem

Boundary layer height function of subsidence + entrainment:

$$\frac{dh}{dt} = w_{LS} + w_{PBL}$$

Cloud cover is function of PBL height: deeper PBL \Rightarrow less cloud

Low cloud cover function of low tropospheric stability $= \theta_{700} - SST$

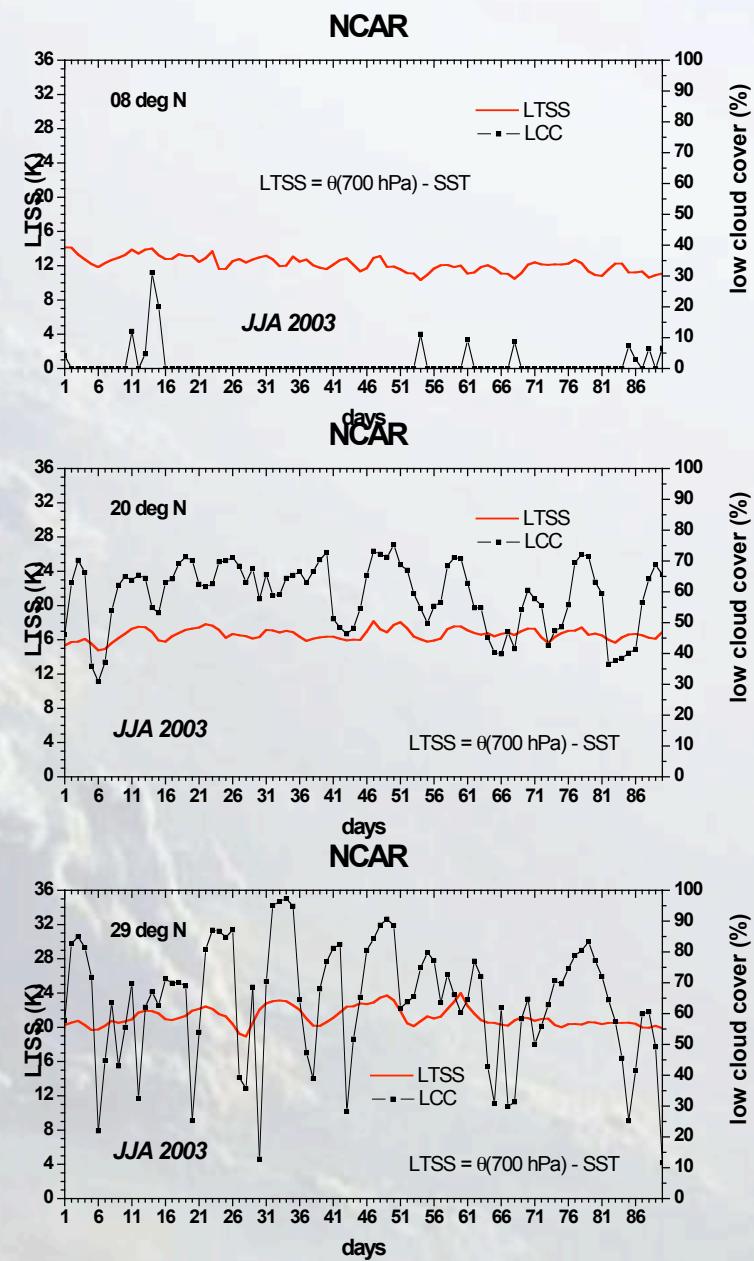
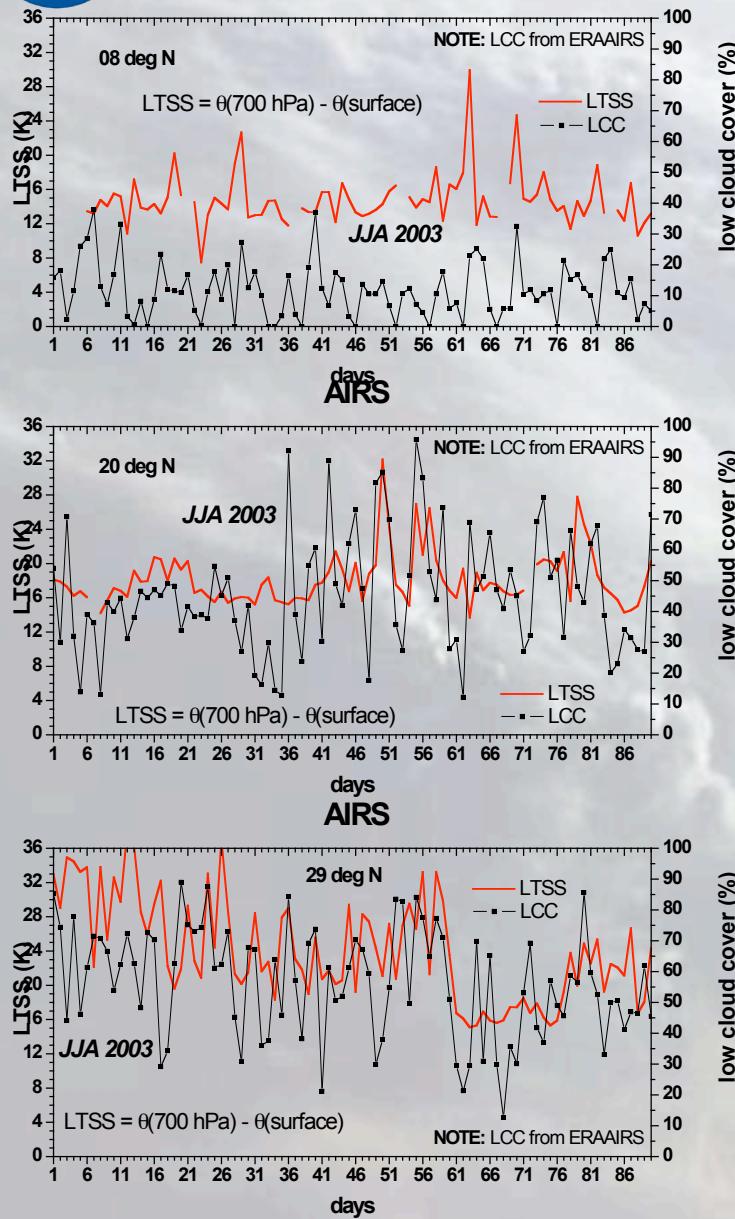


Klein and
Hartman 93



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NCAR exhibits a severe lack of LTS variability compared with AIRS





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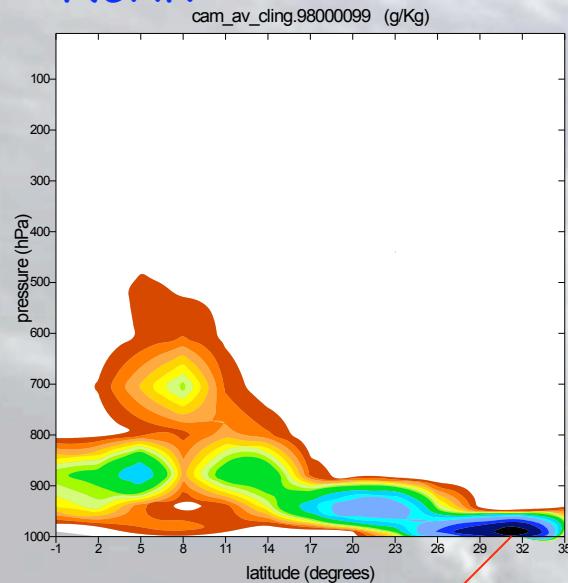
Summary

- Water vapor and cloud feedbacks remain large sources of uncertainty in climate prediction
- Cloud regimes in tropics/sub-tropics play a key role
- GCSS Pacific Cross-section Intercomparison (GPCI) allows for in-depth study of tropics and sub-tropics
- AIRS is a key instrument for model evaluation
- Clouds and thermodynamic variability can be very different between models and observations
- Differences between AIRS and models are larger in deep tropics and boundary layer



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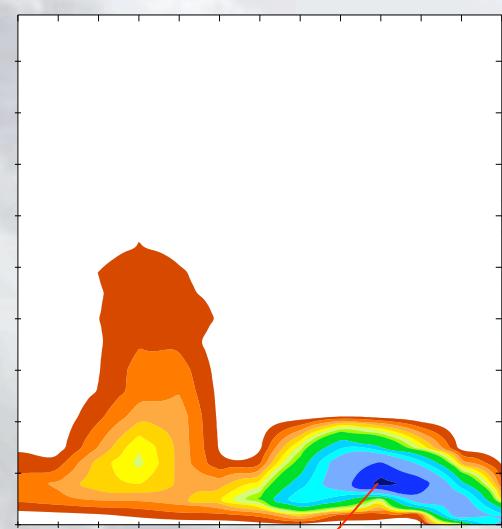
NCAR



Too shallow -> fog

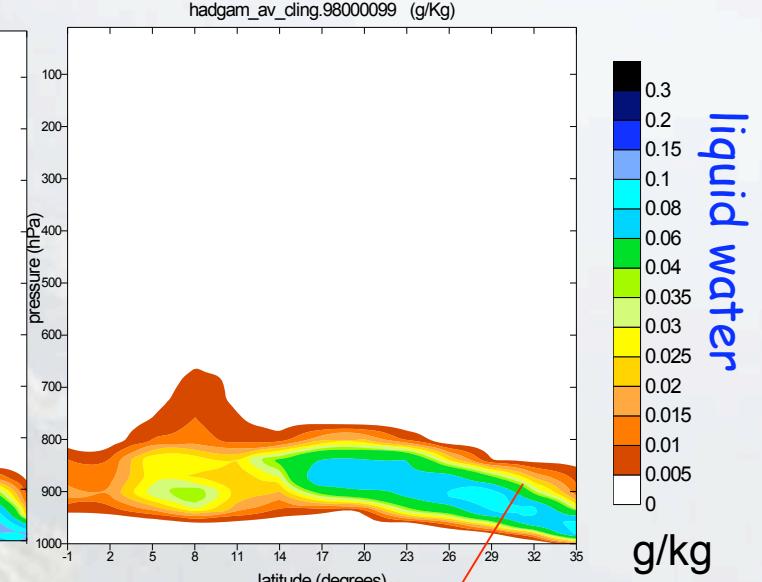
Mean liquid water content - JJA98

MeteoFrance



Is this too much
liquid water?

UKMO



How deep should
the PBL be..?

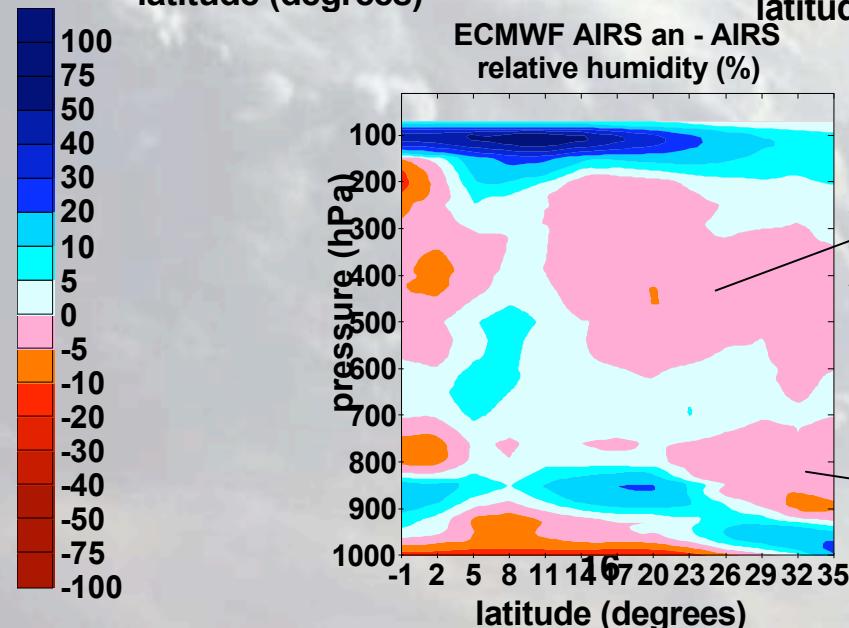
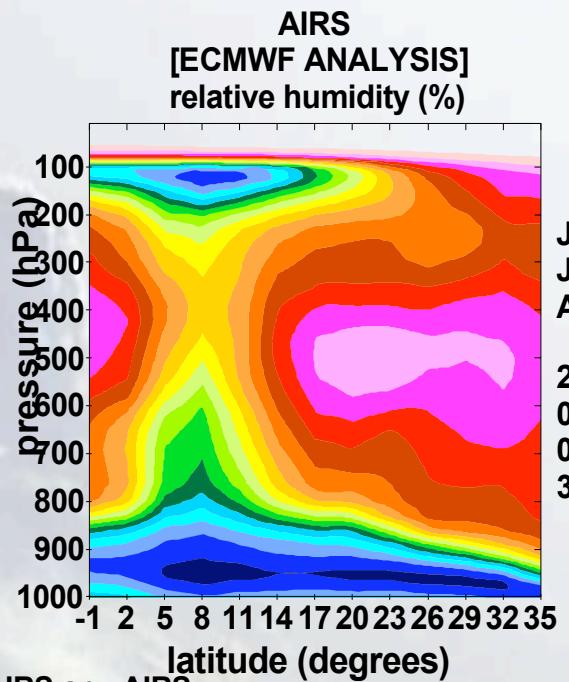
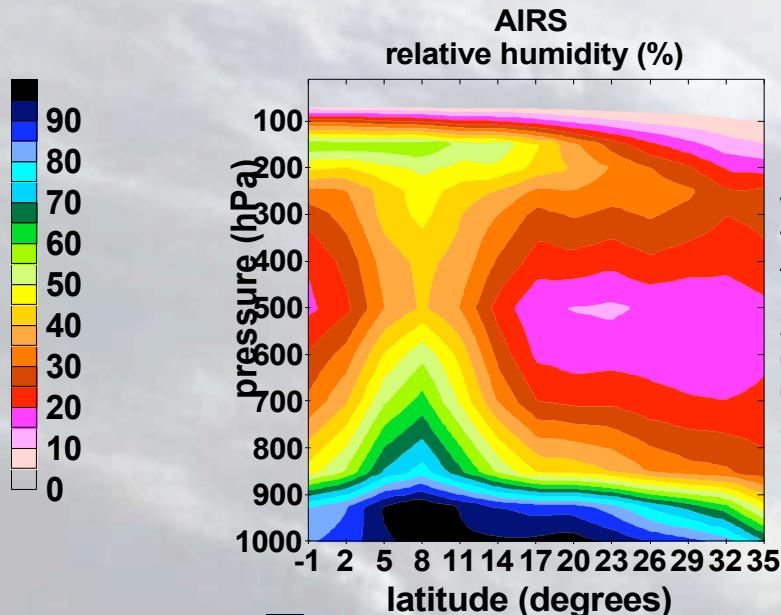
There is a need for observations of cloud and boundary layer
(PBL) parameters: PBL height, liquid water, ...



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Rel. humidity: AIRS and ECMWF analysis (with AIRS)



Small differences
in subtropical
upper troposphere

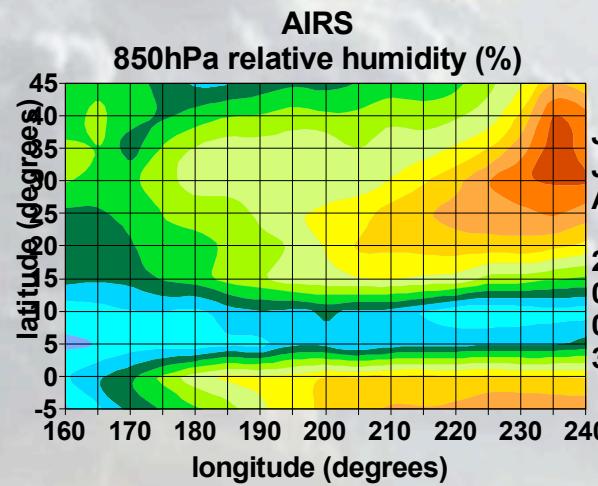
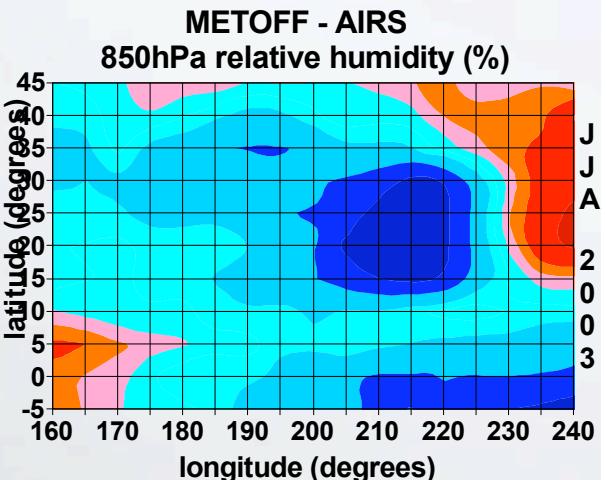
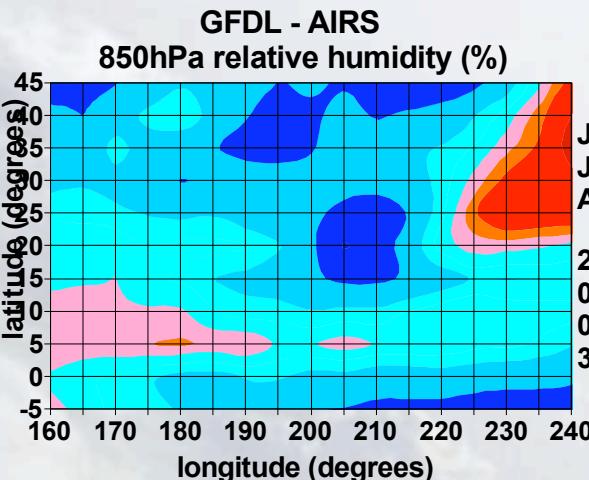
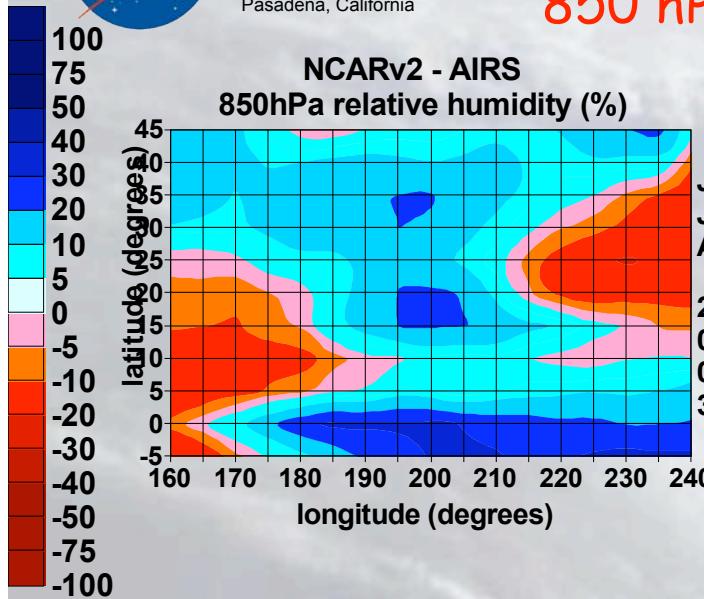
Smaller bias above
stratocumulus



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North-East Pacific tropics and sub-tropics

850 hPa RH - climate models versus AIRS



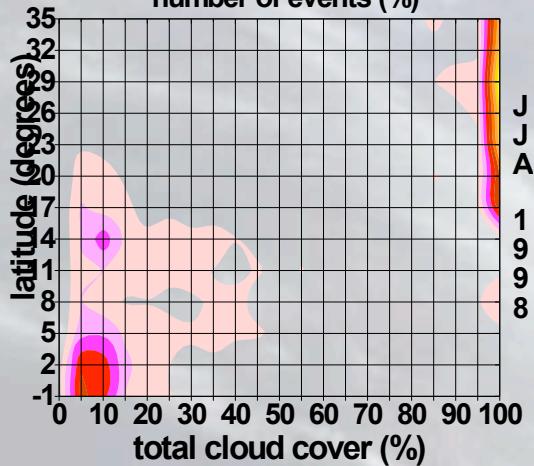


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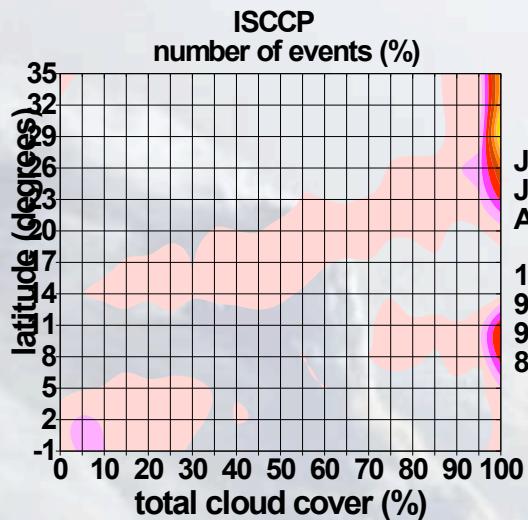
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UKMO

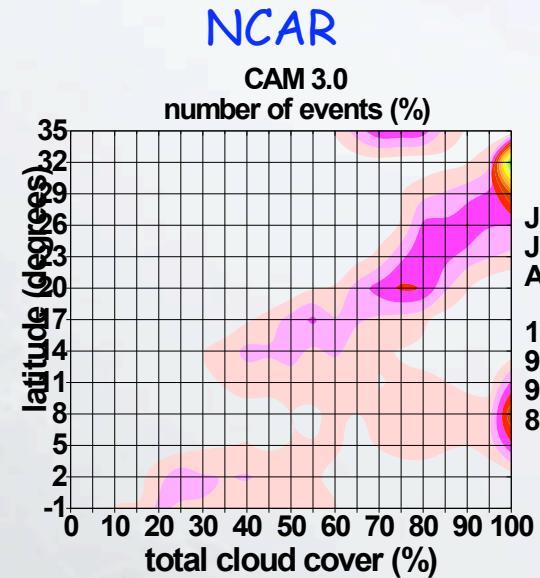
HadGAM
number of events (%)



Histograms of TCC: ISCCP versus models



ISCCP is between
continuous and bimodal



- NCAR low cloud parameterization is based on climatology => continuous transition
- UKMO (and partly GFDL) cloudy-PBL parameterizations are based on the idea of distinct-regimes => discontinuous transition
- ISCCP suggests that none of these two "extreme" concepts is fully valid => relevant for parameterization development