Evaluation of radiative properties of low and high clouds in different regimes using satellite measurements

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Introduction

- Clouds:
  - longwave (LW) and shortwave (SW) radiation
  - large global coverage
  - storms: precipitation
- Charicteristics:
  - high clouds –- storms, deep convection
    - anvils: SW (weak-strong); LW (cold)
  - low clouds –- subsidence, BL turbulence (q), inversion, shallow convection
    - straticu.: SW (strong); LW (warm)
- Major uncertainty in GCMs:
  - physical properties and processes of clouds

Introduction (conti.)

- Satellite observations: led by ISCCP and EOS
  - cloud detection -- VIS & IR
  - physical properties – Tc/Pc, OD, LWP/IWP, CC, re
  - BB radiation -- SW & LW

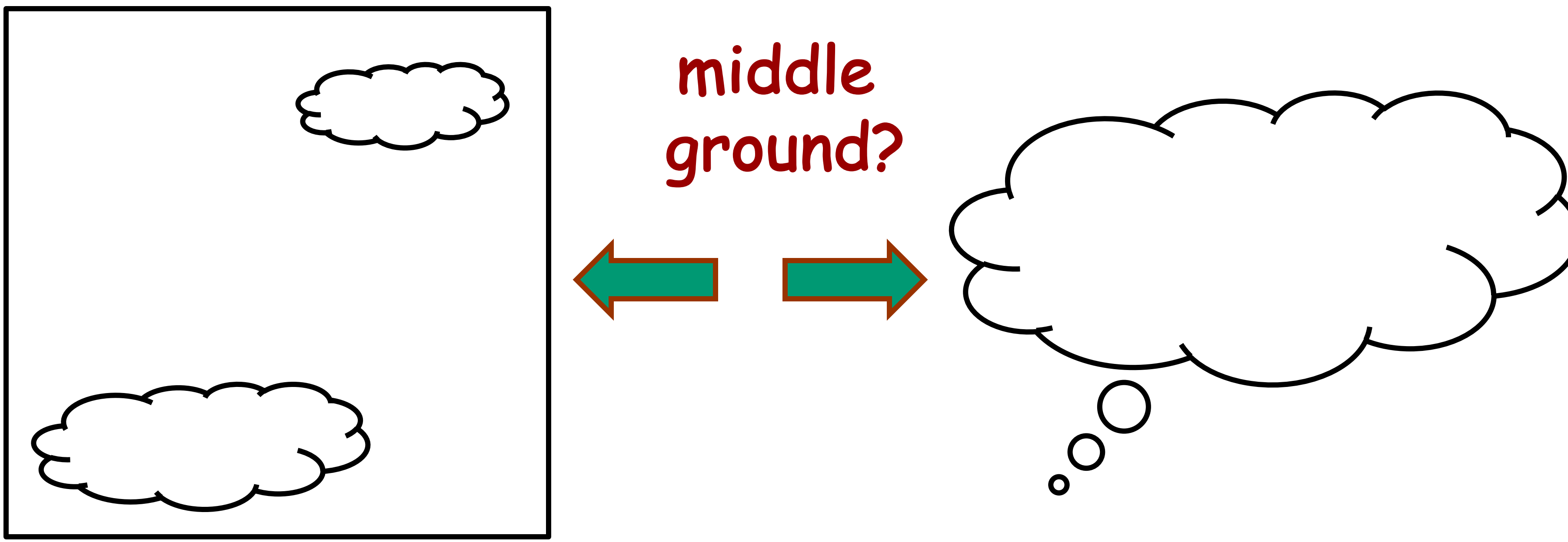
- Cloud classification:
  - temperature (or pressure) & thickness

- Analysis:
  - gridded data or cloud systems (objects)
  - tropical deep convection
  - temperature dependent
    - water clouds: polar, middle & low latitudes

Introduction (conti.)

- Gridded data -- many studies
  - Stephens et al. 1991~1994
  - Tselioudis et al. 1992; Cess et al. 2001
- Cloud systems:
  - Machado et al. 1998; Luo & Rossow 2004
  - DelGenio et al. 2002 & 2005; Lin et al. 2006
  - Xu et al. 2005, 2008
- Advantages and issues
  - gridded data -- GCM applications
  - individual clouds -- physical processes

gridded data & individual cloud systems



easy for GCM to use
but mix different types

physical properties
but scale differences
with GCMs

this effort

- Cloud types
  - identification: low and high clouds in specific regions
- Variability
  - time series of TOA & surface radiation
  - atmospheric radiative characteristics
  - water path distribution
- Potentials
  - testing models, parameterizations
  - (environmental conditions needed)

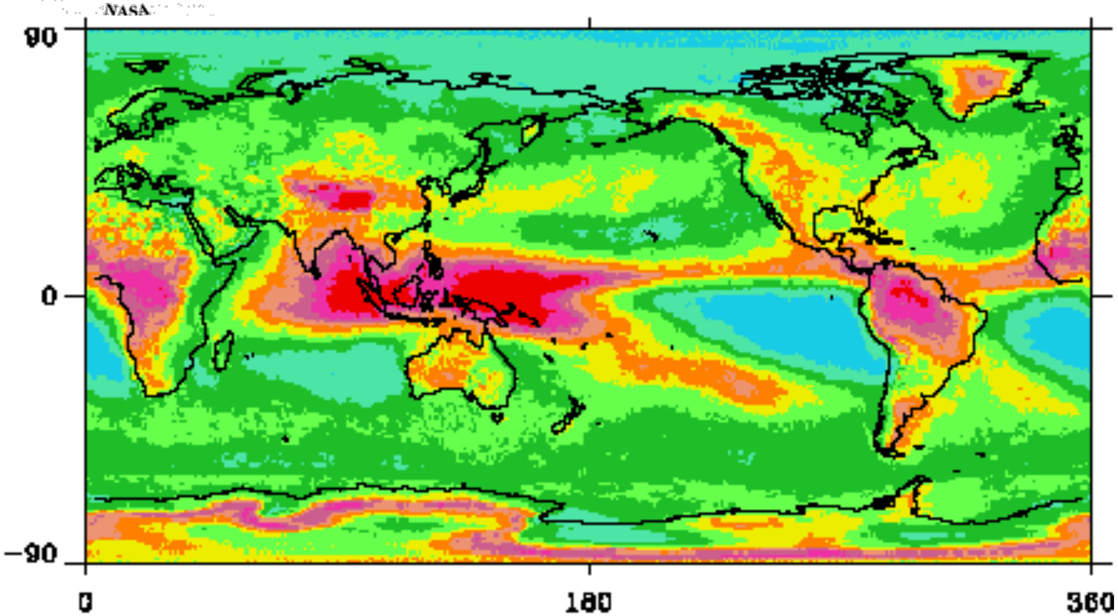
Data Set & Method

- CERES Aqua SSF:
  Jan. 1, 2003 to Dec. 31, 2005 ('normal years')
- TOA fluxes: direct measurements
- Surface fluxes: model B
- Cloud products:
  MODIS/CERES results

- Data selection:
  cloud types in typical areas -- annual mean

- Statistical analysis:
  means, histograms, and time series
  → variability

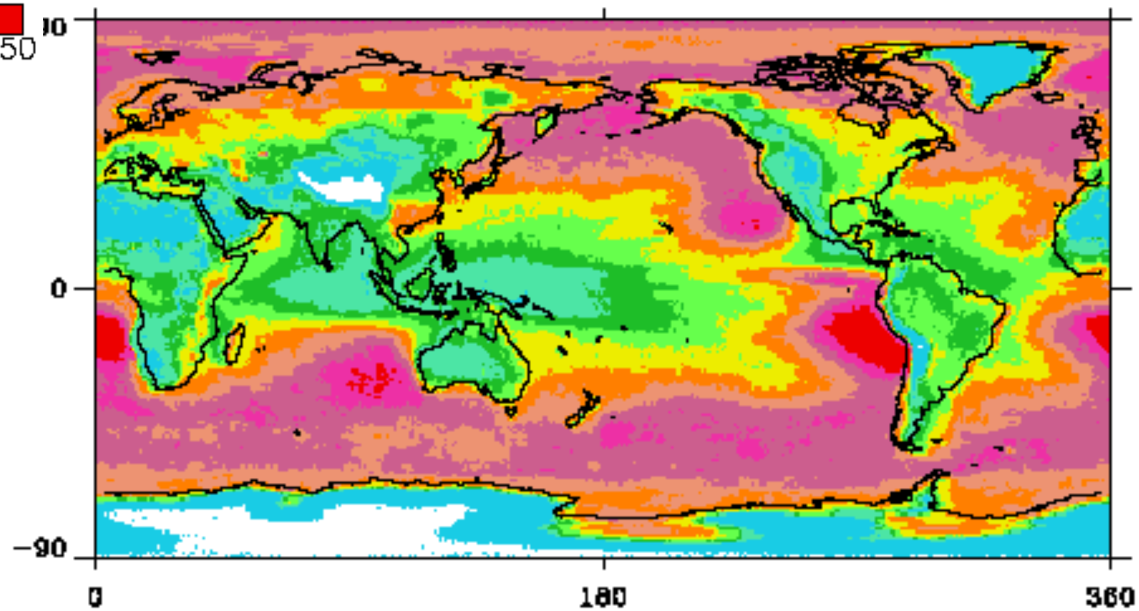
Global distribution (2005)



high clouds
Pc < 440mb

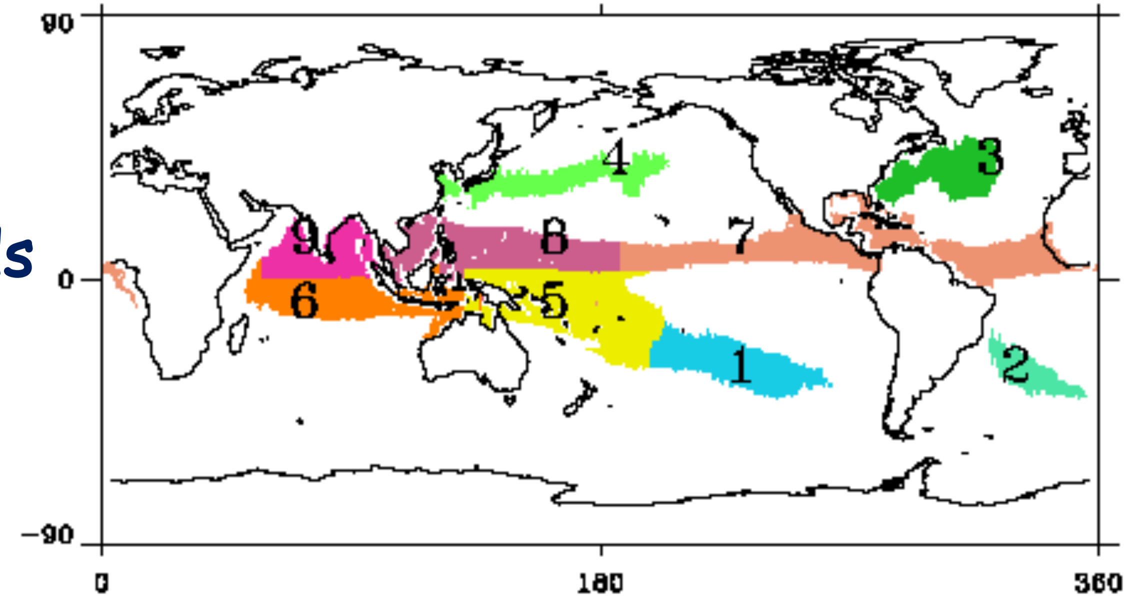
from Aqua

low clouds
Pc > 680mb



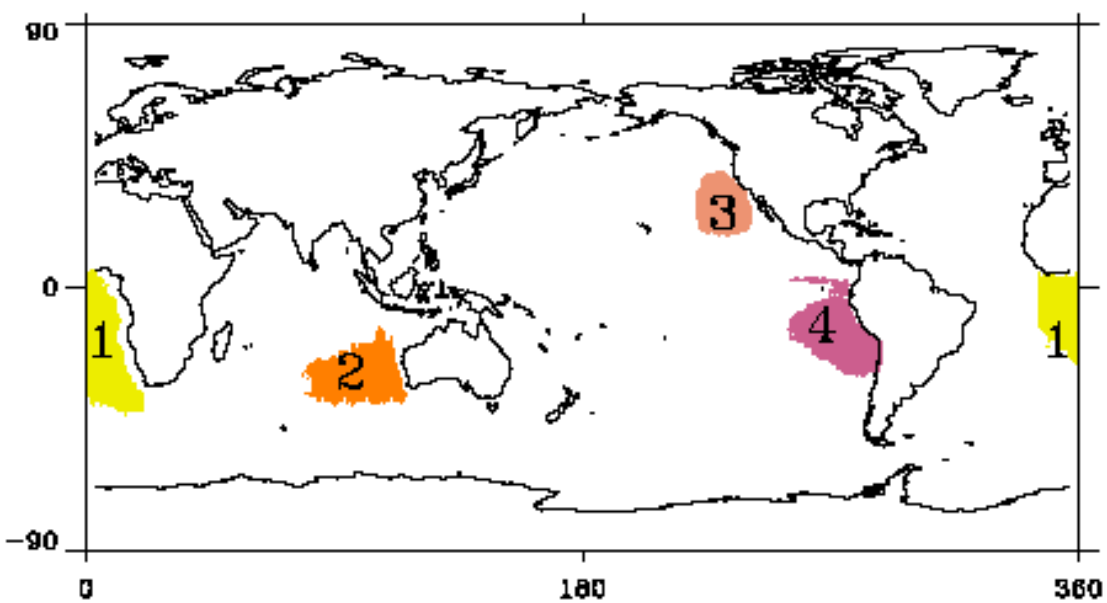
targeted regions

high clouds
>18%

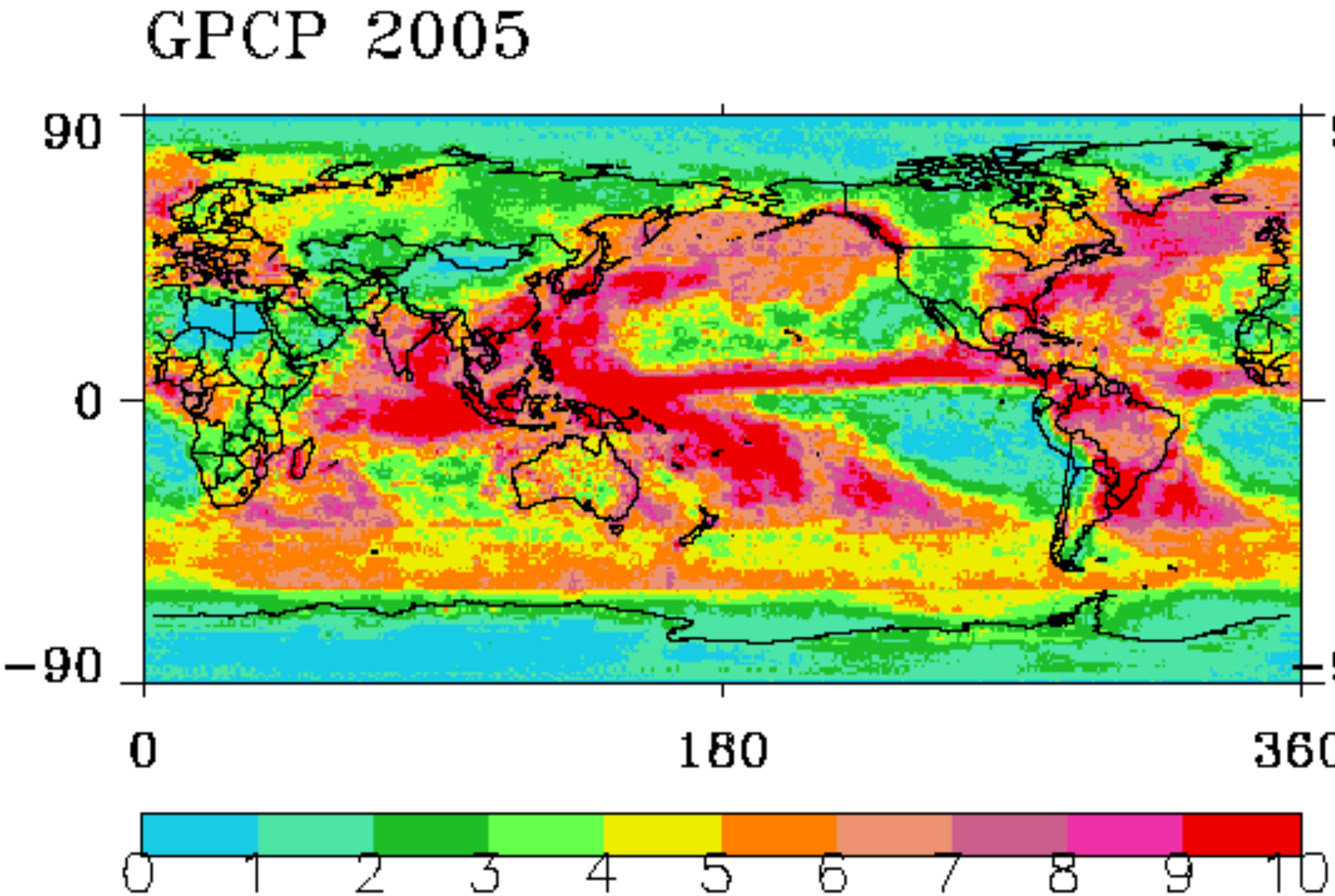


all clouds in
the regions
as long as
in the type

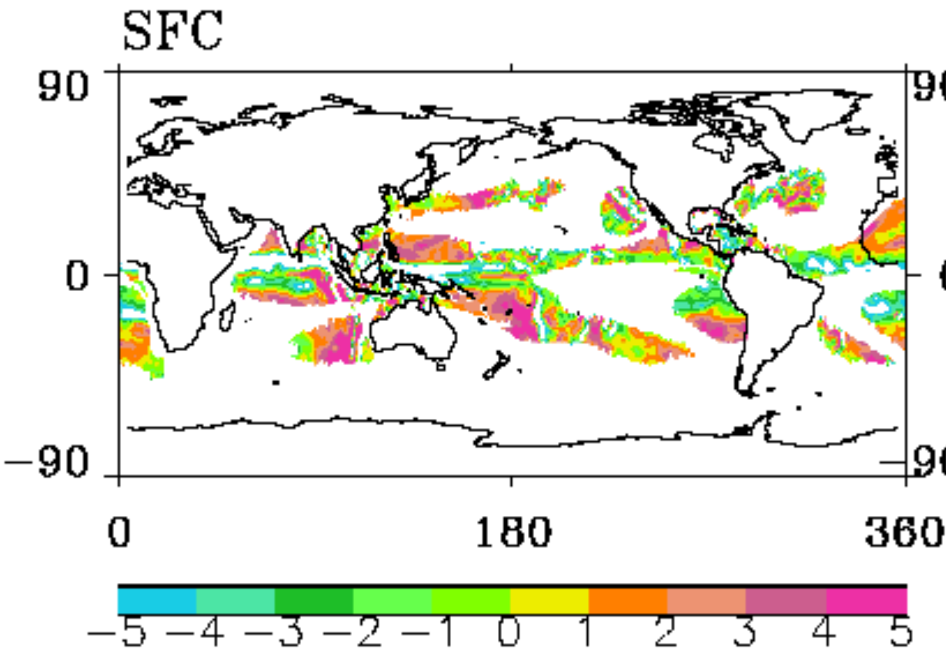
low clouds
>45%



Precipitation (mm/day)



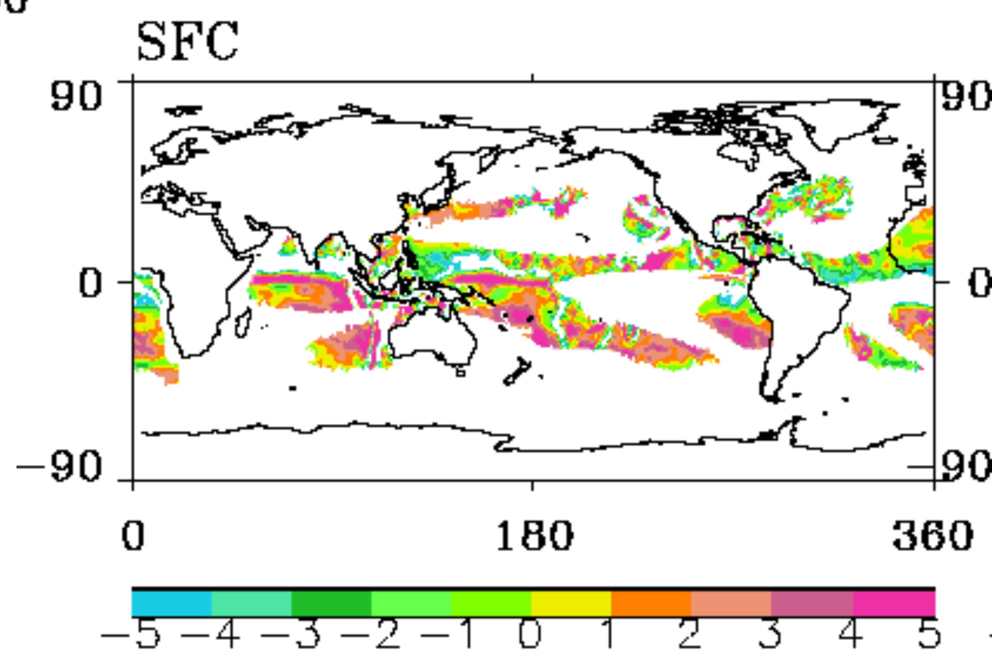
monthly mean div. (10^{-6}/s)



Jan. 2005

GEOS-4

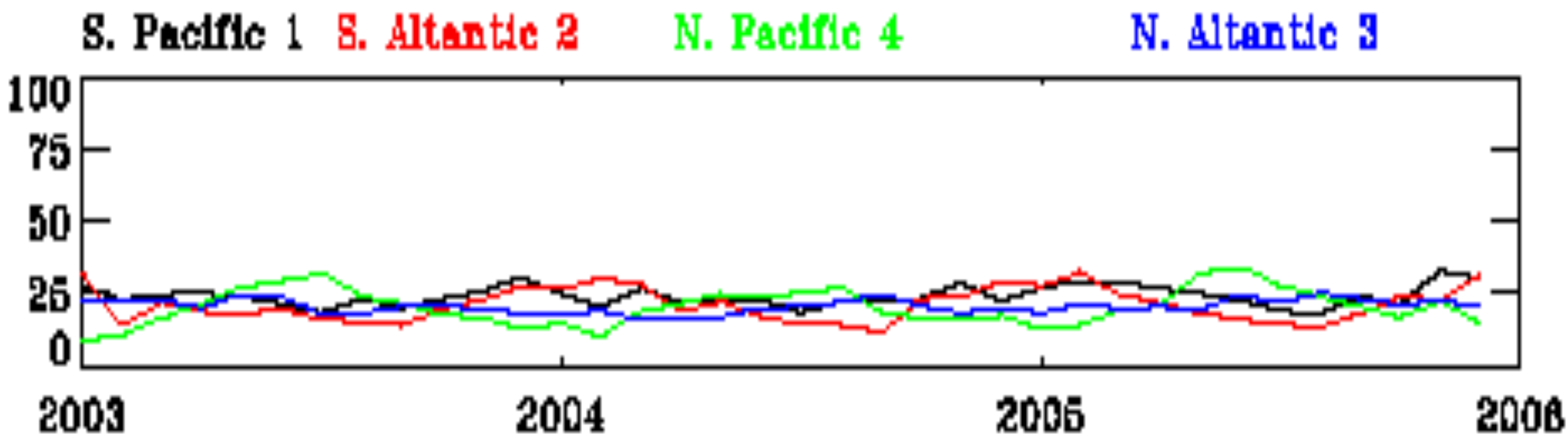
some indications
for cloud formation

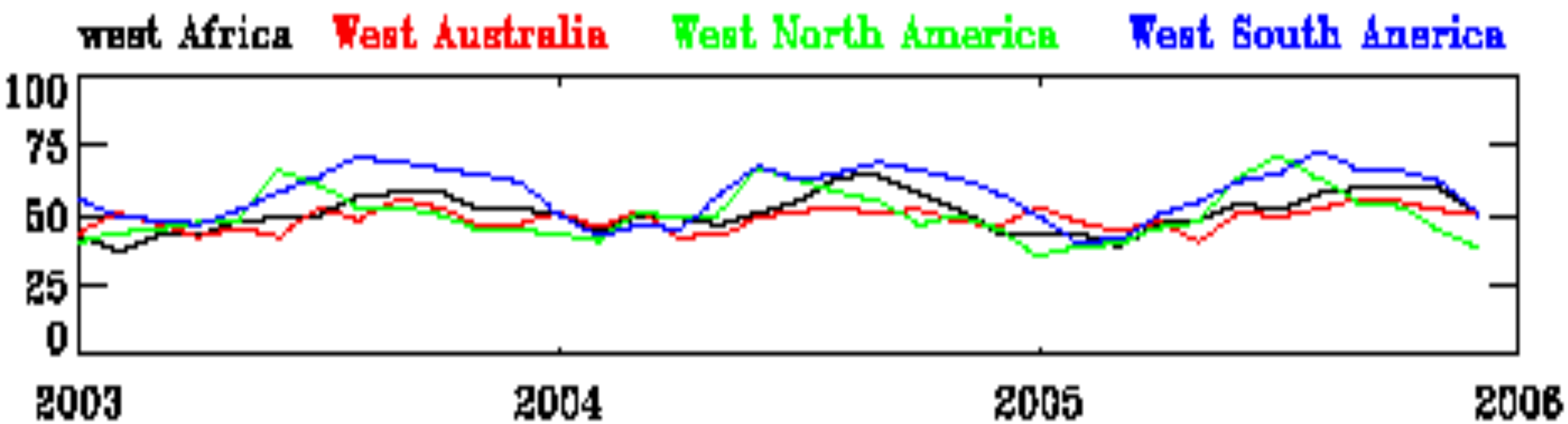


July 2005

Cloud cover

high Clouds in storm tracks

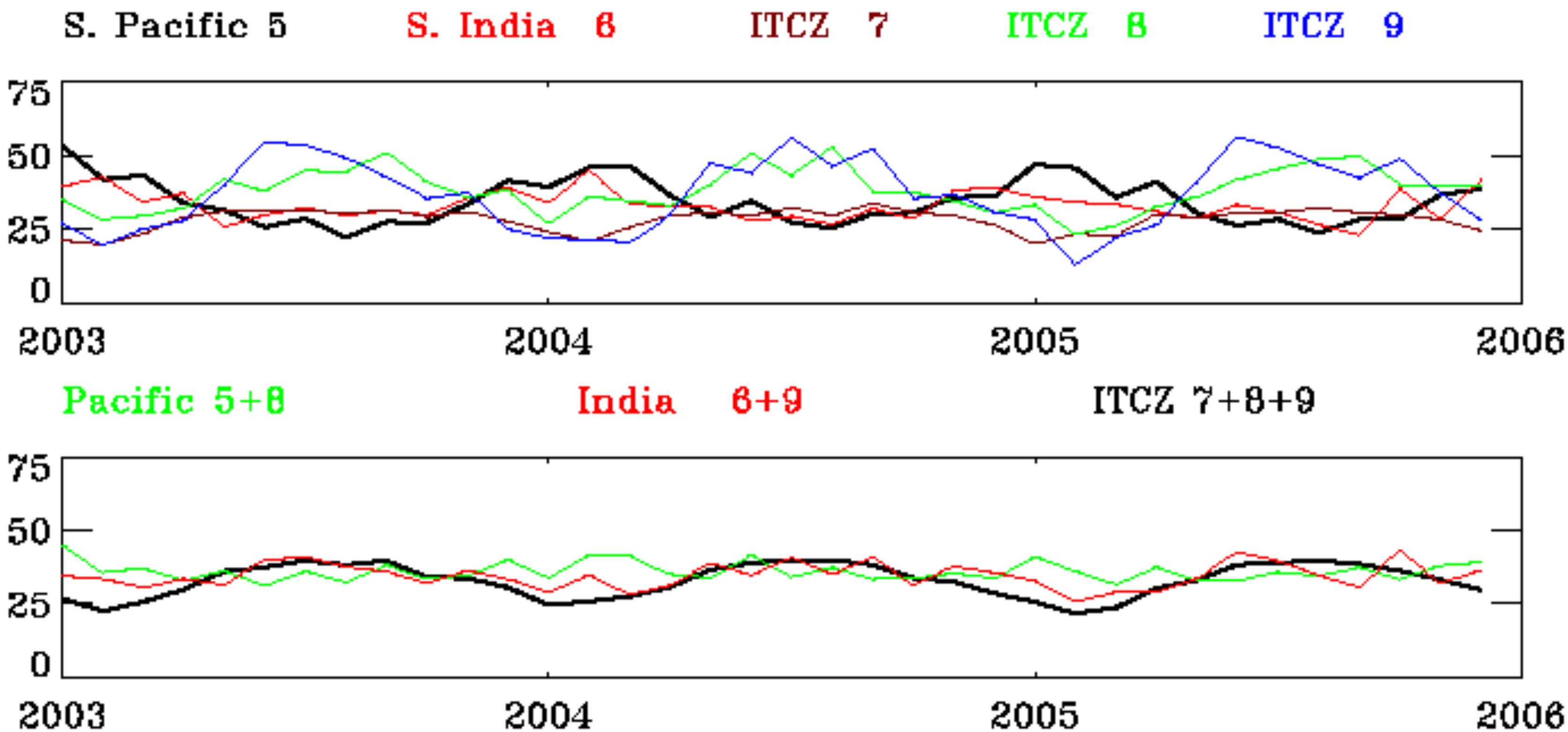




low clouds

CC: pretty large differences

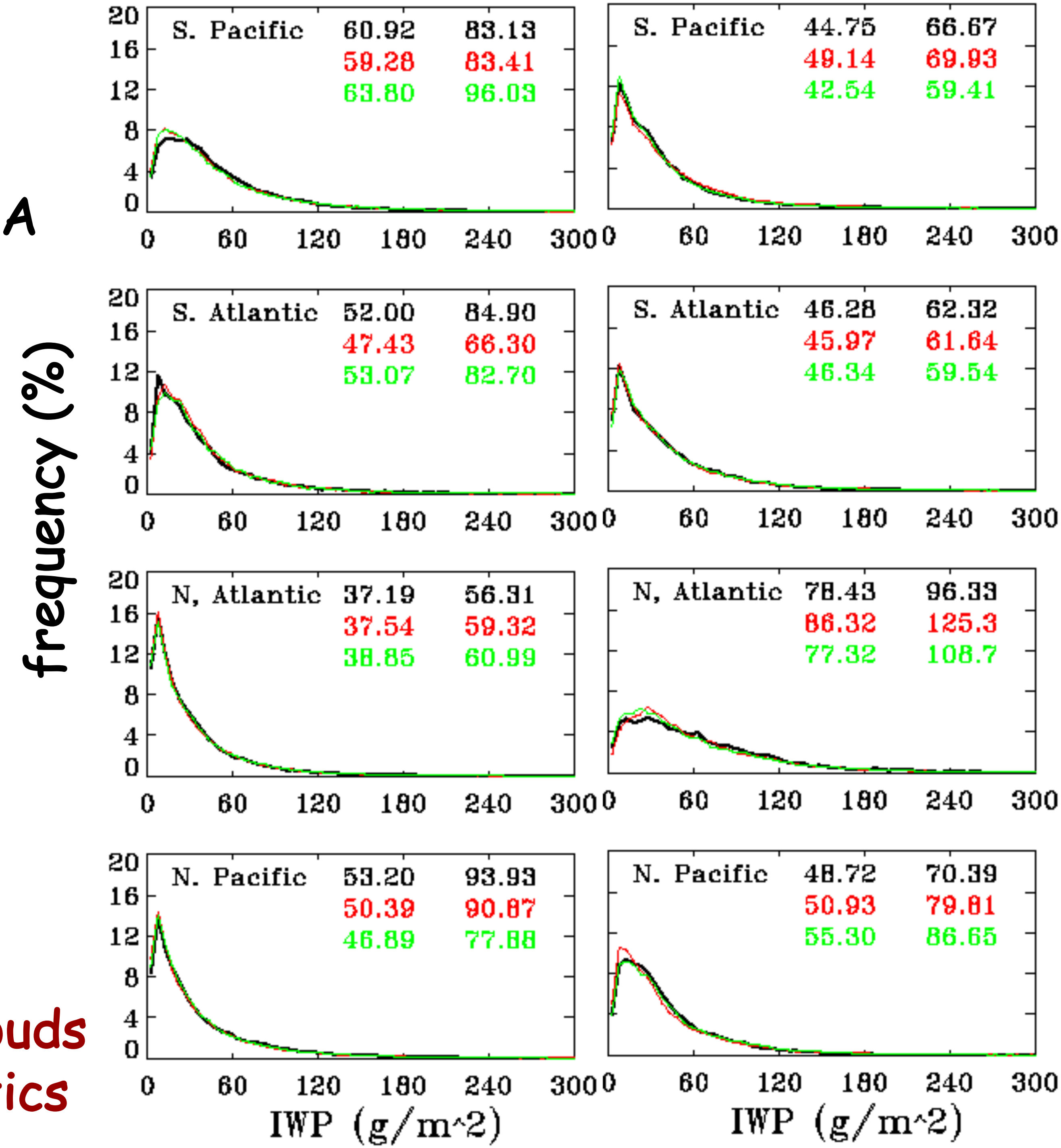
Cloud cover (ITCZ)



large differences for different ITCZ areas (not surprise)
larger areas: differences getting smaller

JJA

DJF

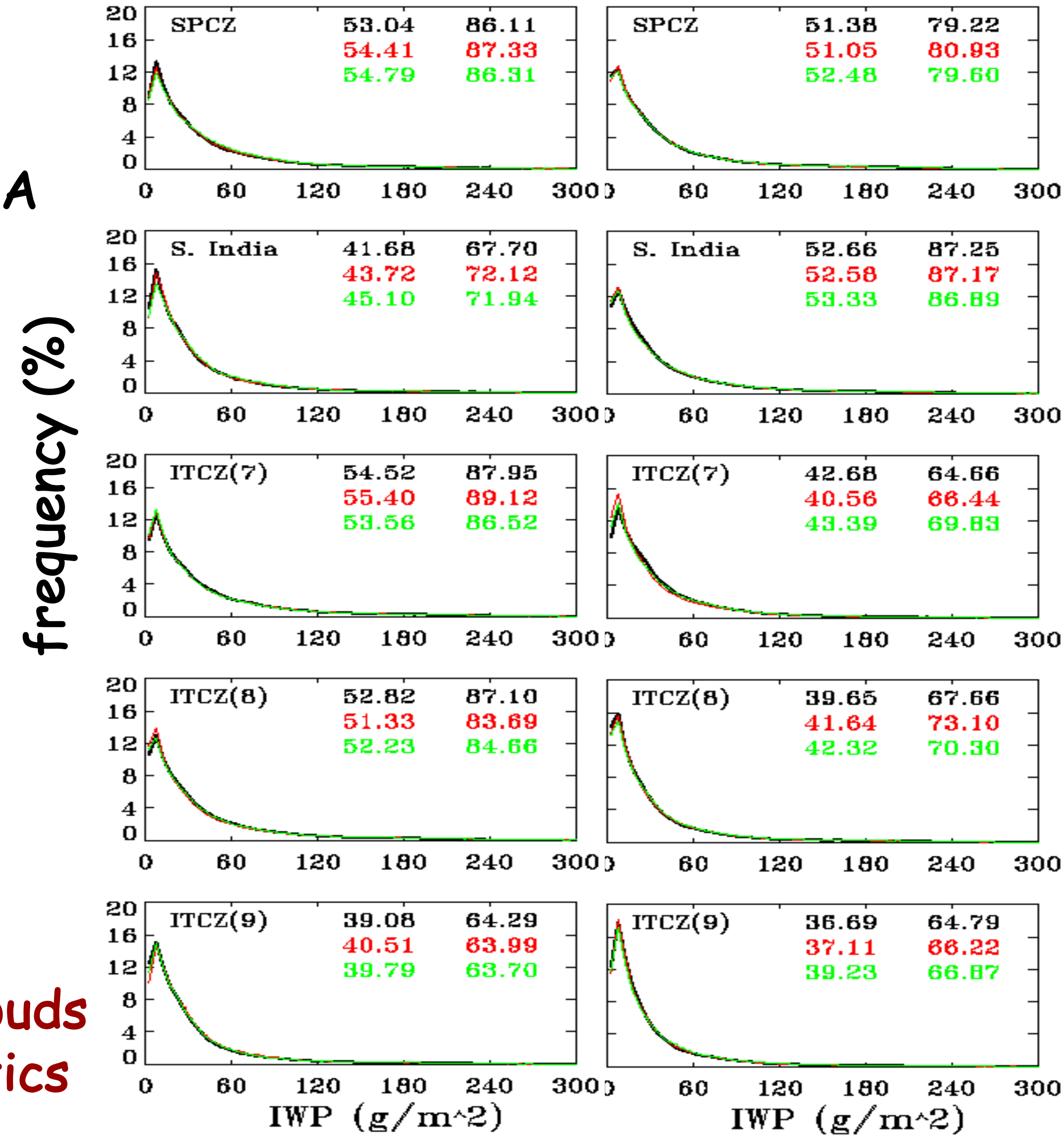


blk: 2003
red: 2004
grn: 2005

high clouds statistics

JJA

DJF

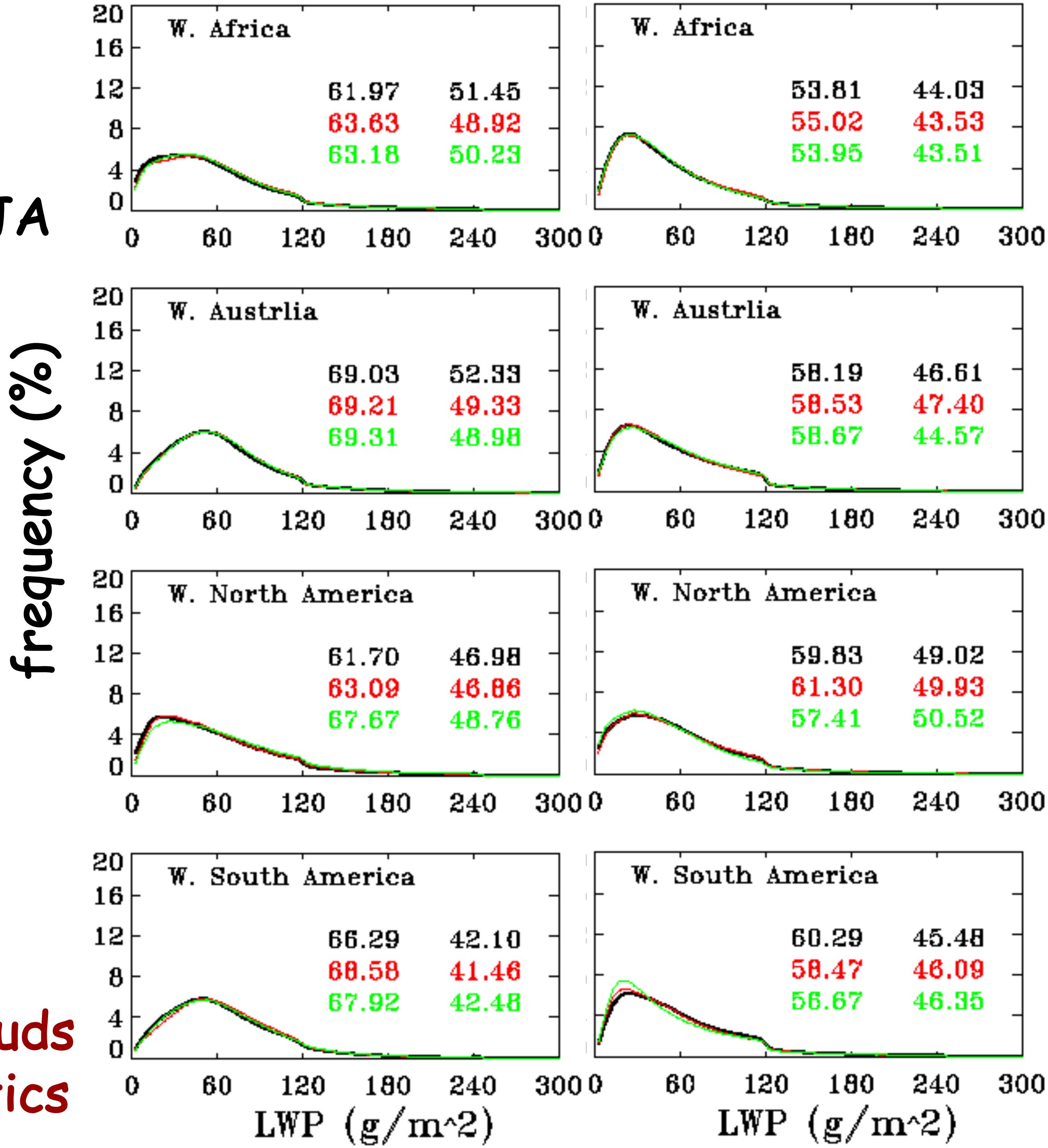


blk: 2003
red: 2004
grn: 2005

high clouds statistics

JJA

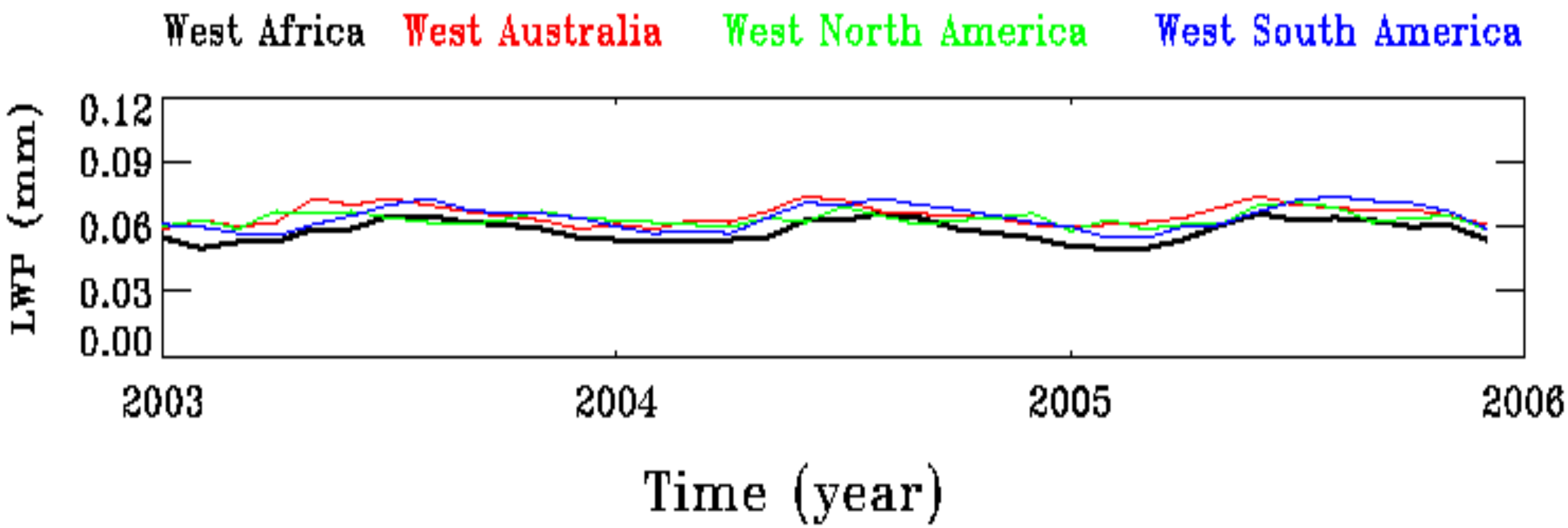
DJF



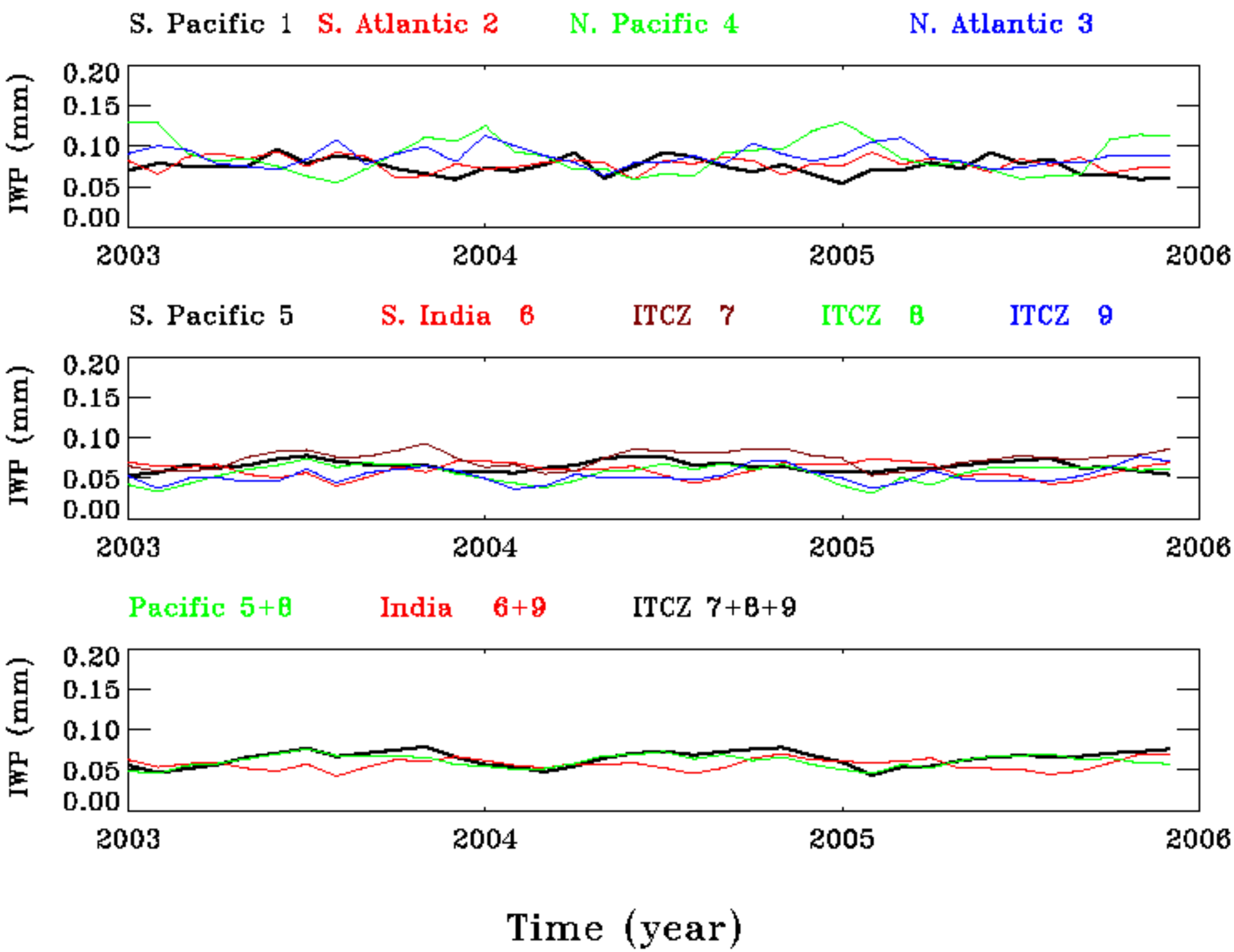
blk: 2003
red: 2004
grn: 2005

low clouds statistics

LWP


West Africa
West Australia
West North America
West South America
LWP (mm)
0.12
0.09
0.06
0.03
0.00
2003
2004
2005
2006
Time (year)

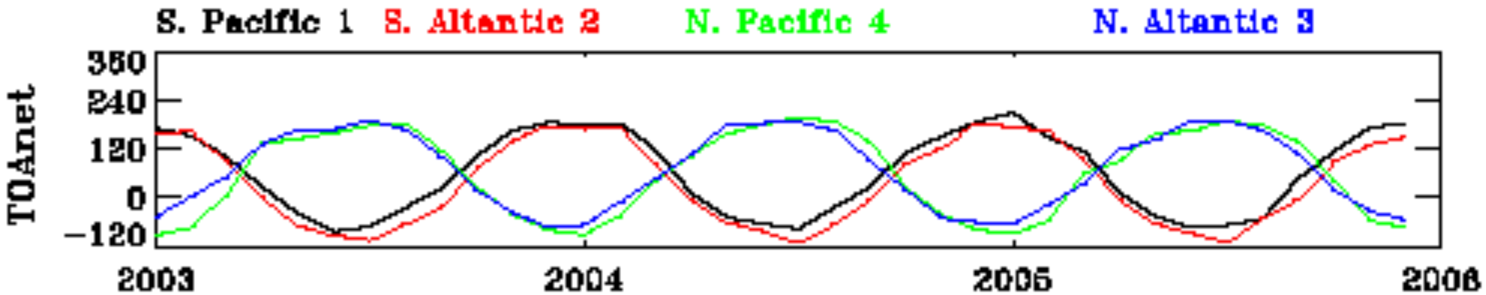
IWP (mm)

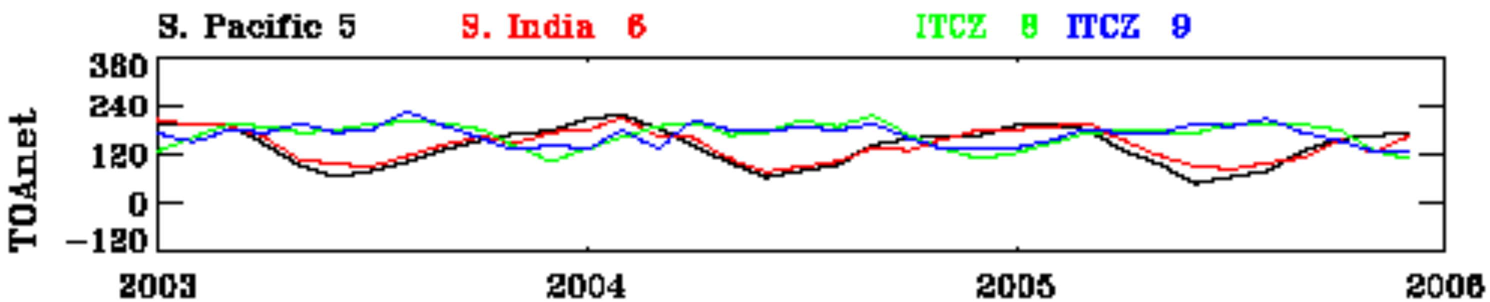


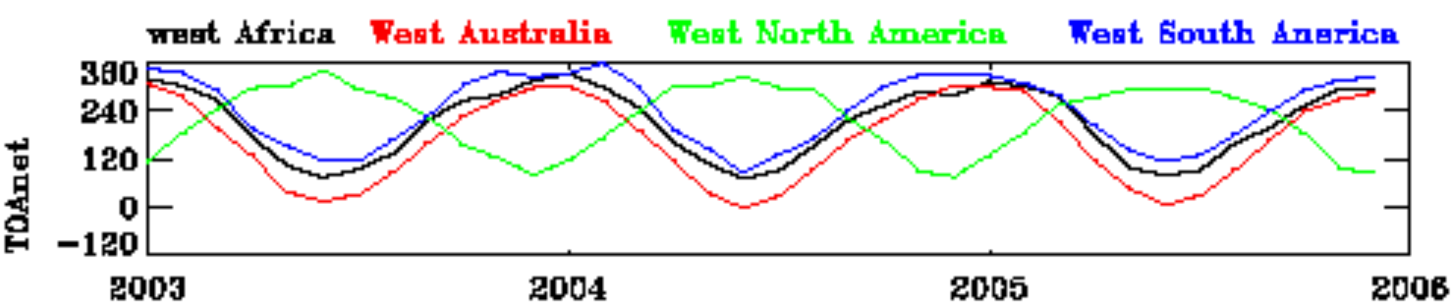
S. Pacific 1
S. Atlantic 2
N. Pacific 4
N. Atlantic 3
IWP (mm)
0.20
0.15
0.10
0.05
0.00
2003
2004
2005
2006
S. Pacific 5
S. India 6
ITCZ 7
ITCZ 8
ITCZ 9
IWP (mm)
0.20
0.15
0.10
0.05
0.00
2003
2004
2005
2006
Pacific 5+8
India 6+9
ITCZ 7+8+9
IWP (mm)
0.20
0.15
0.10
0.05
0.00
2003
2004
2005
2006
Time (year)

TOA radiation

high clouds similarity: diff. areas



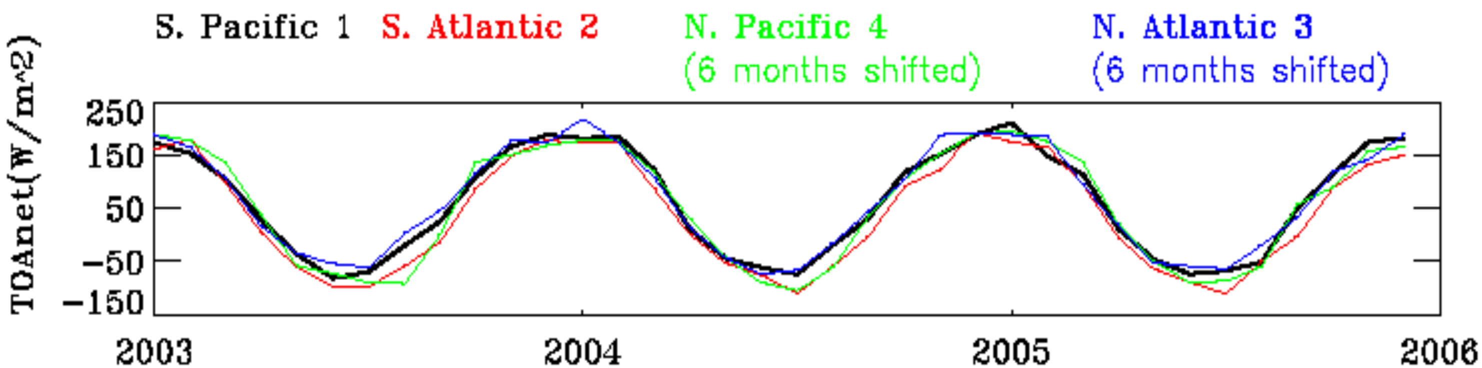




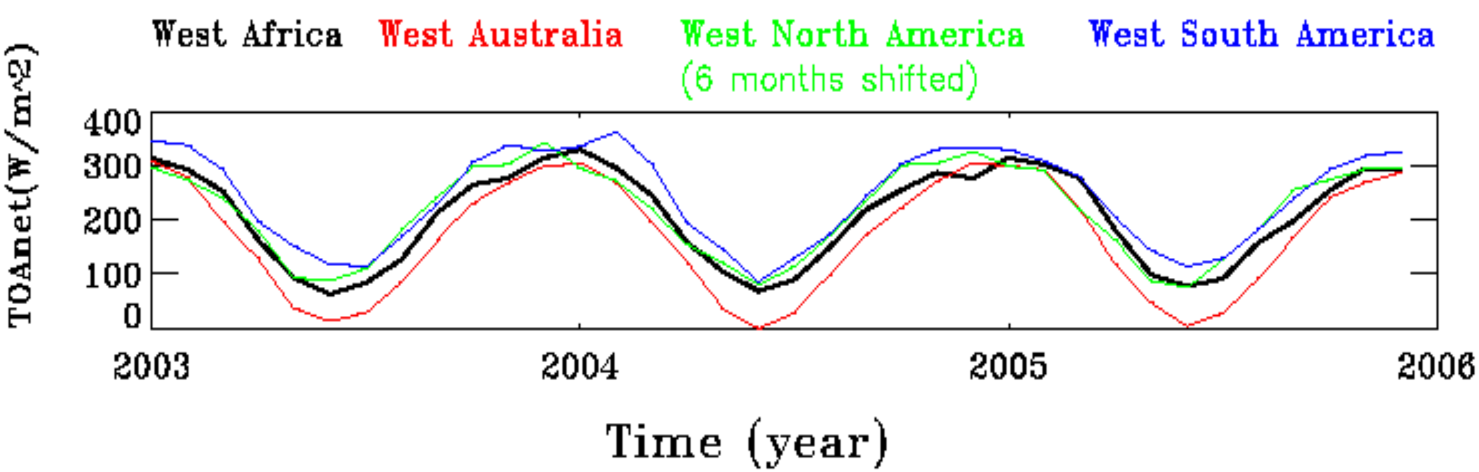
low clouds

TOA radiation (plotted by season)

high clouds

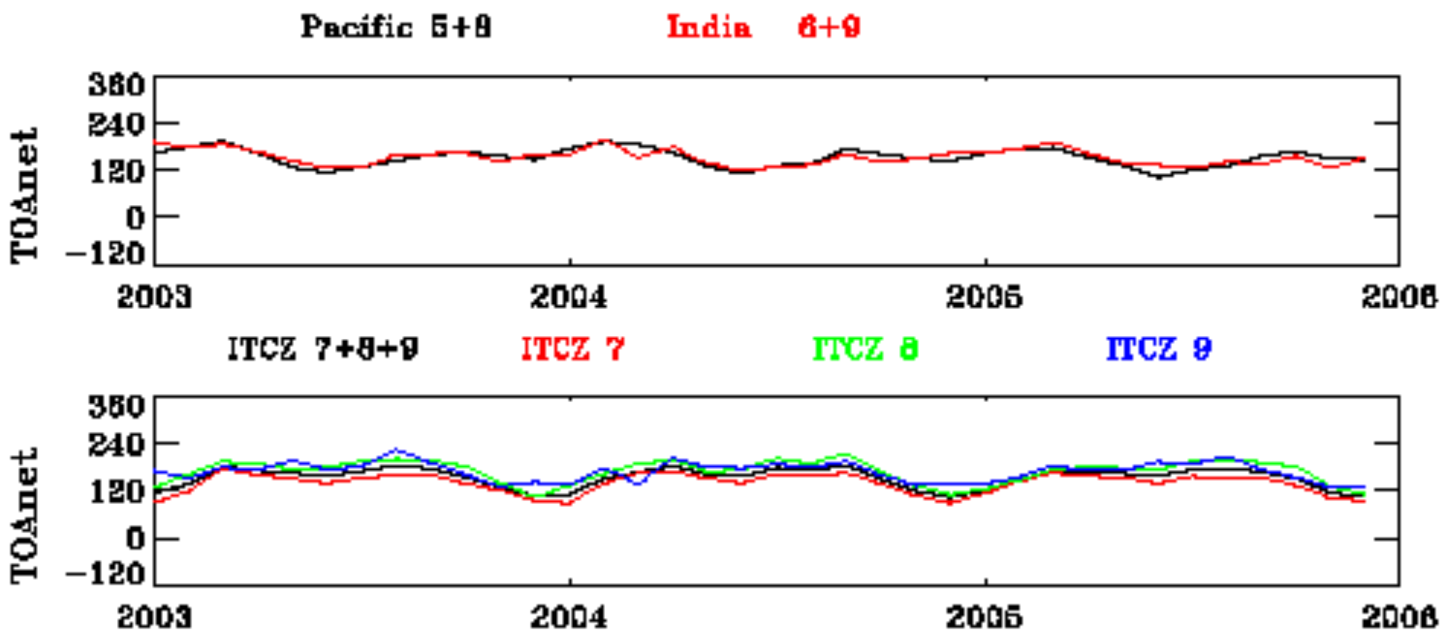


6-months-shifted data: N.P. & N.A.



low clouds

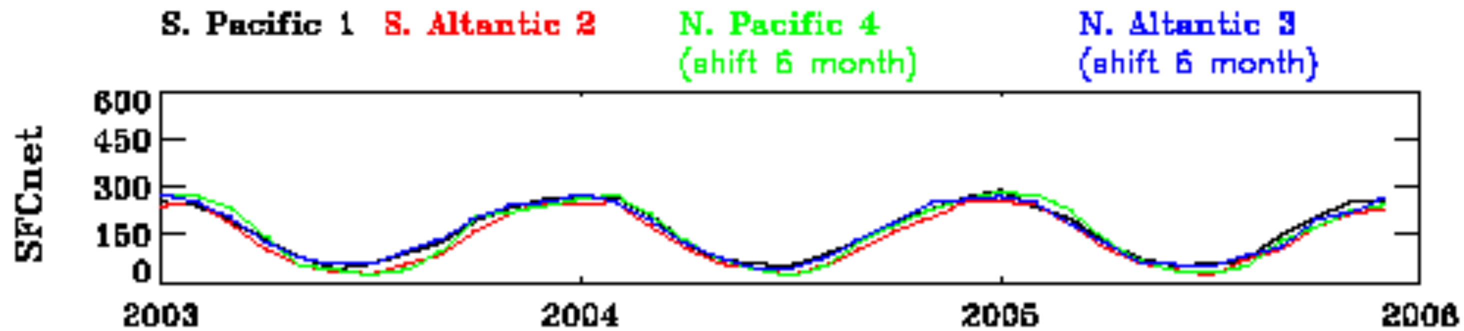
TOA radiation

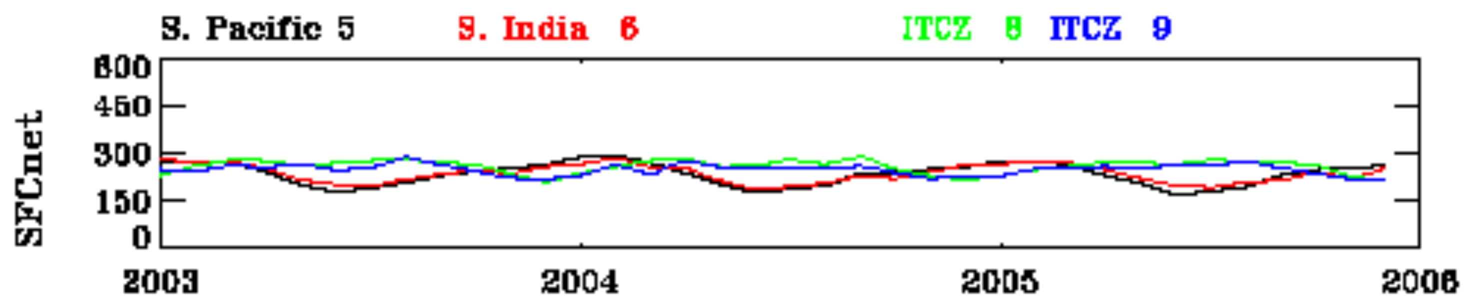


high similarity between western Pacific and India Ocean and among ITCZ areas

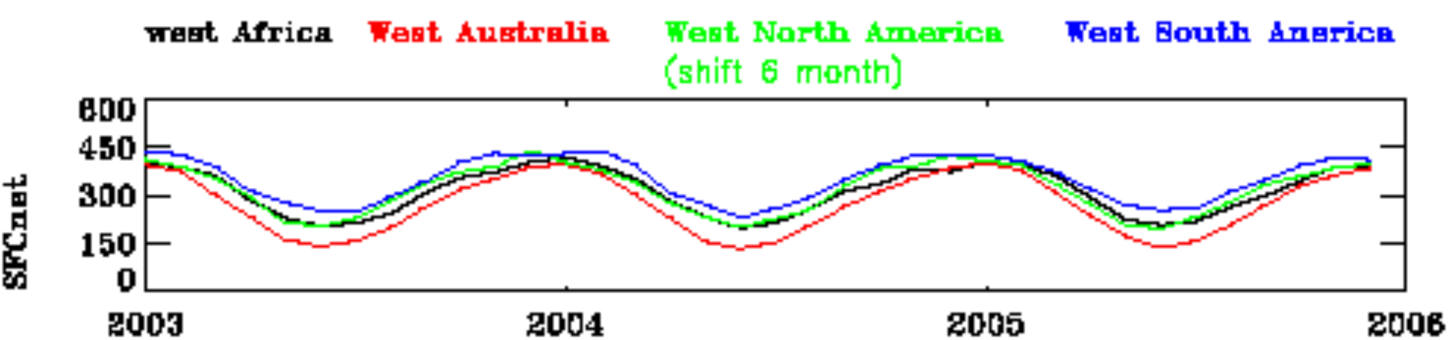
SFC radiation

high clouds





6 months shifted data: N.P. & N.A.



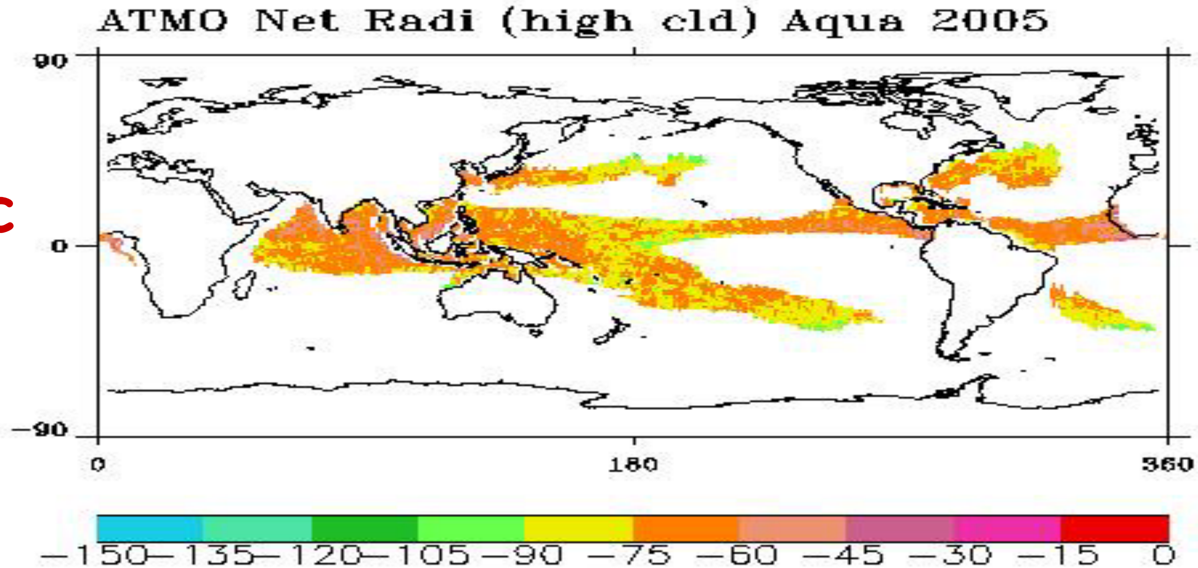
low clouds

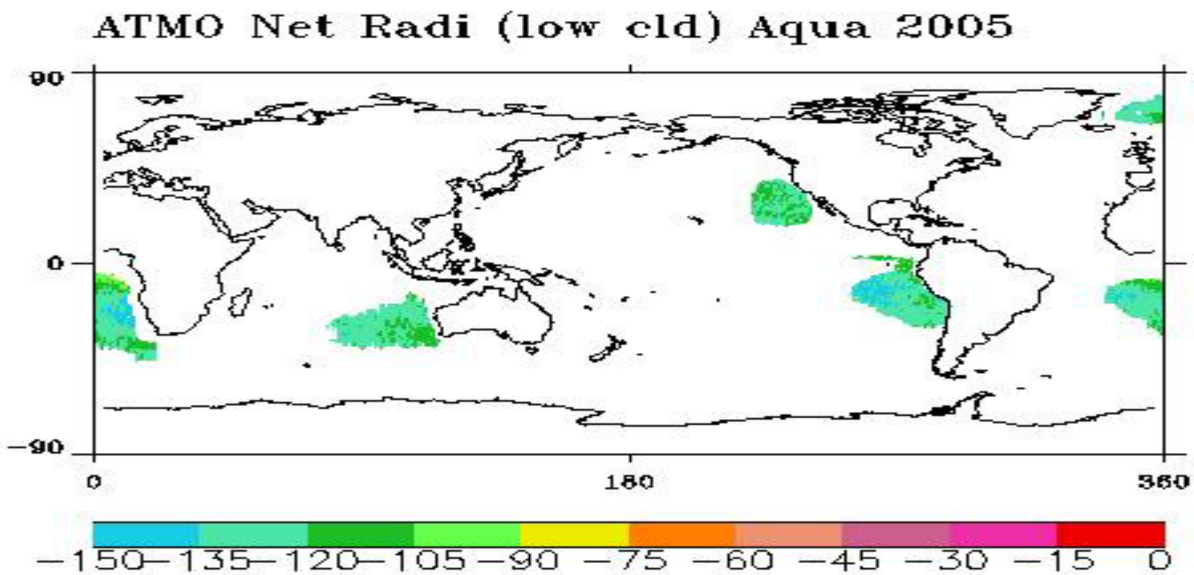
Annual mean atmos. heating

Atmospheric cooling

LW↓, LW↑ & weak SW

low cloud LW↑

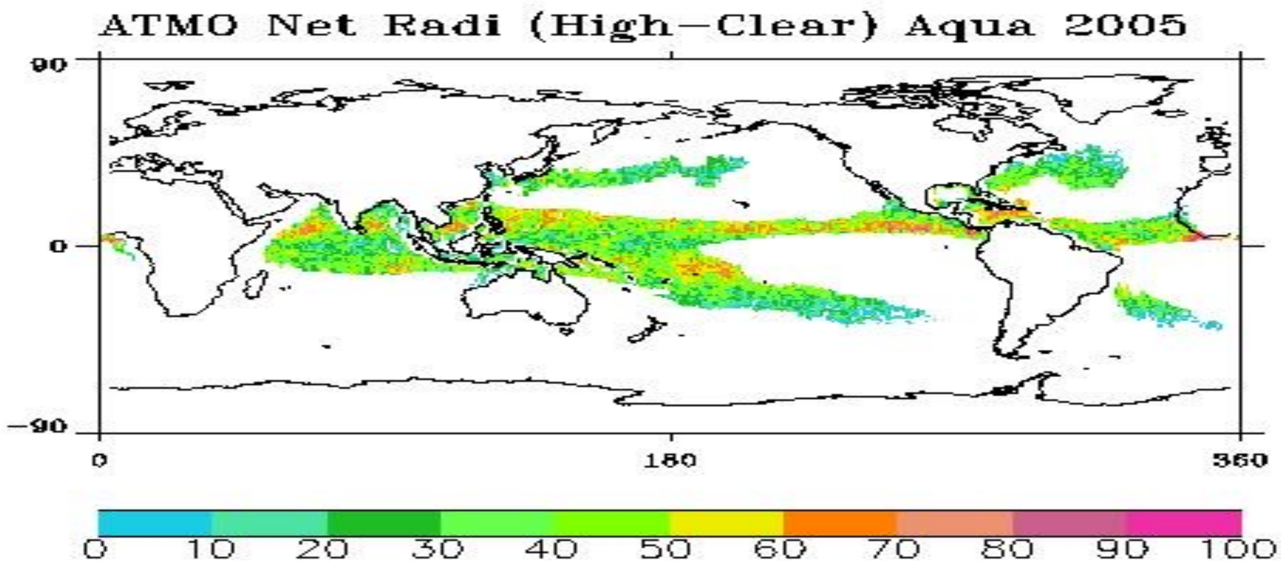




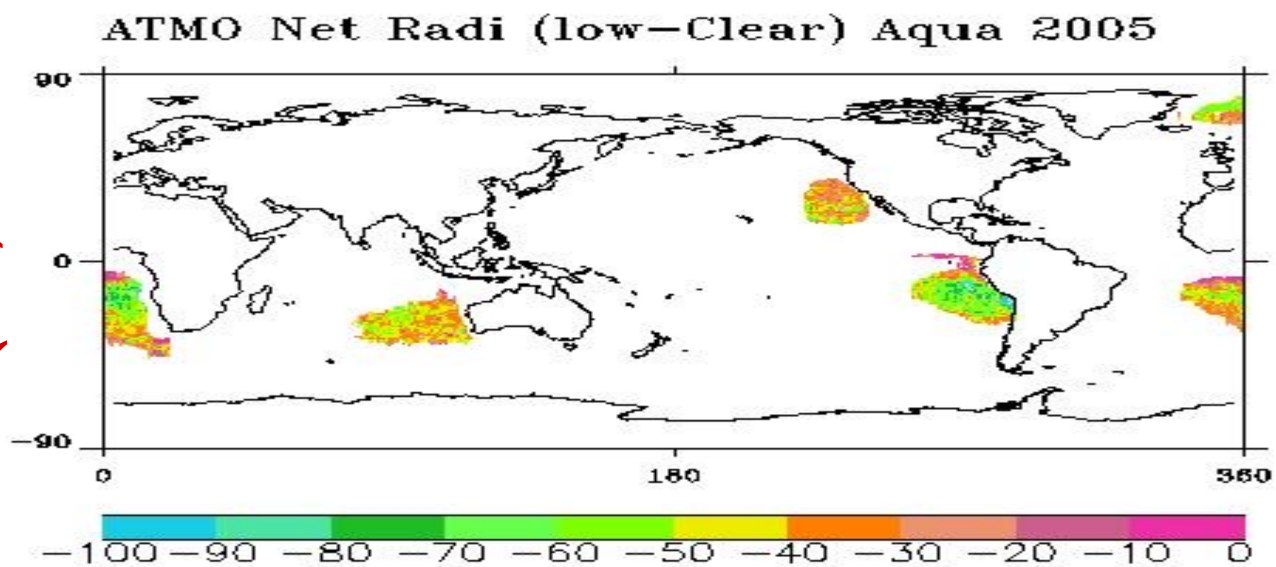
Atmos. radiative contrast

high cloud
warming

weak LW↑

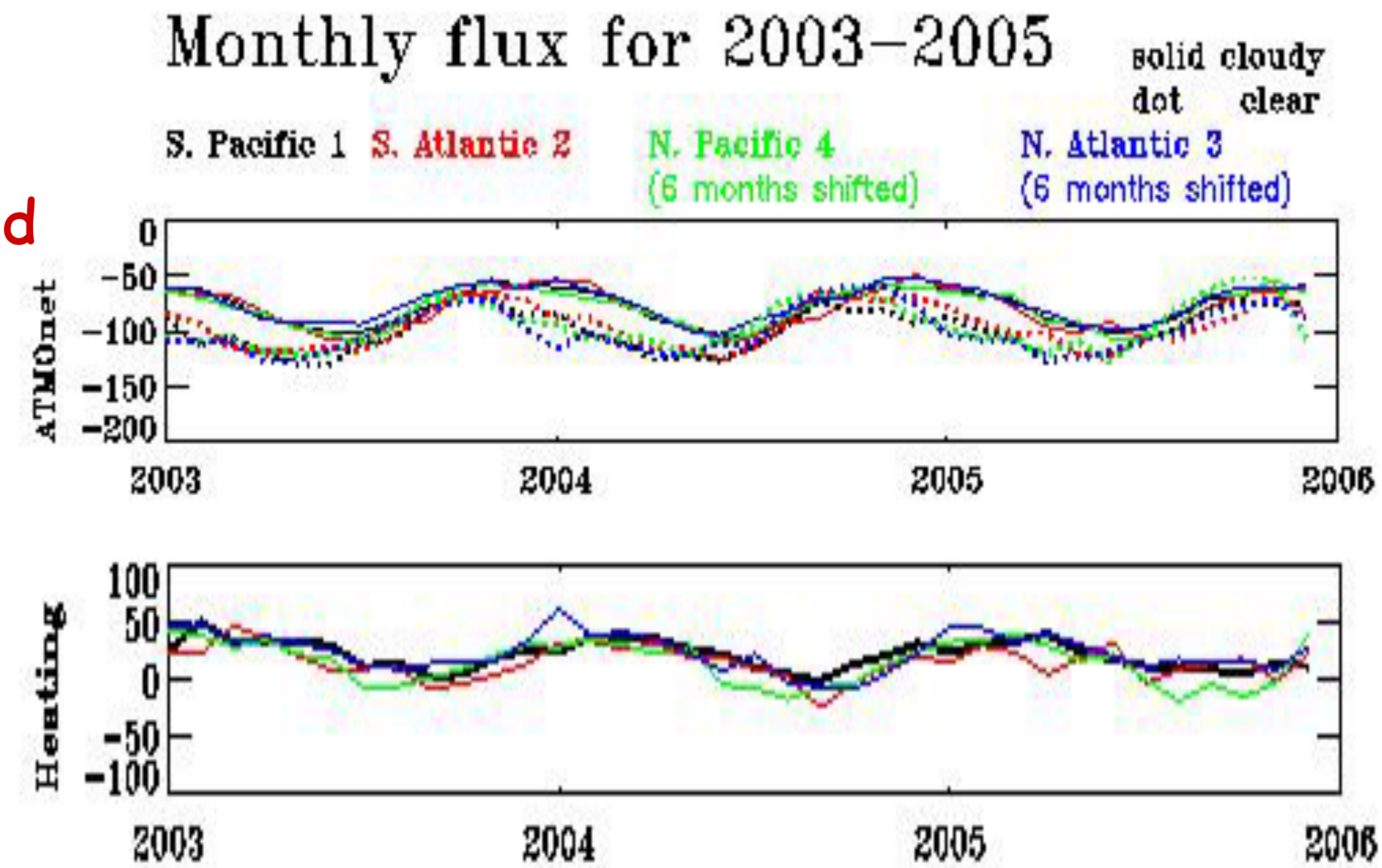


low cloud
similar LW↑
Strong LW↓



Midlatitude storm tracks

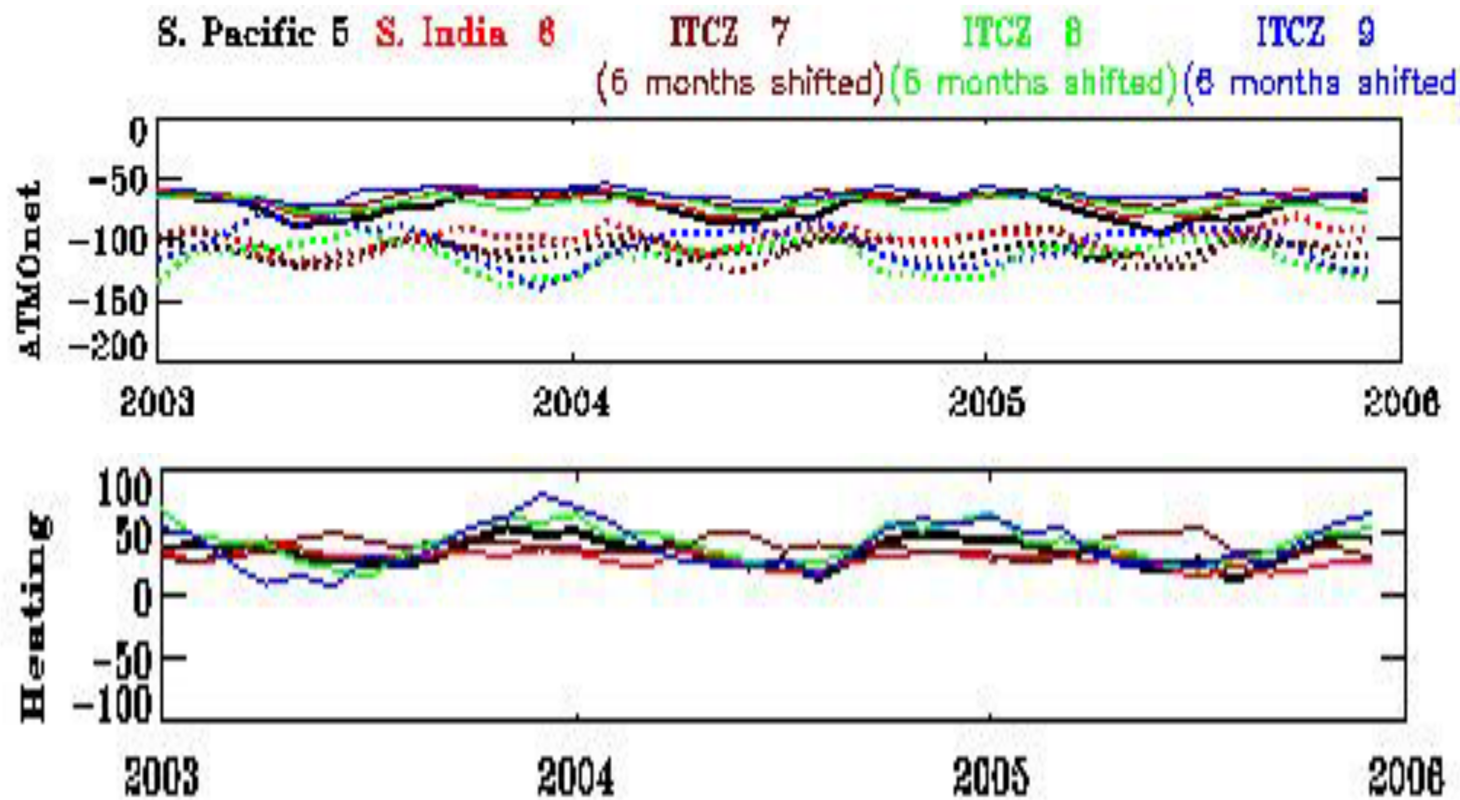
Clr: dot
Cld: solid



radiative heating within atmosphere:
tendency to reduce instability

tropical convergence zones

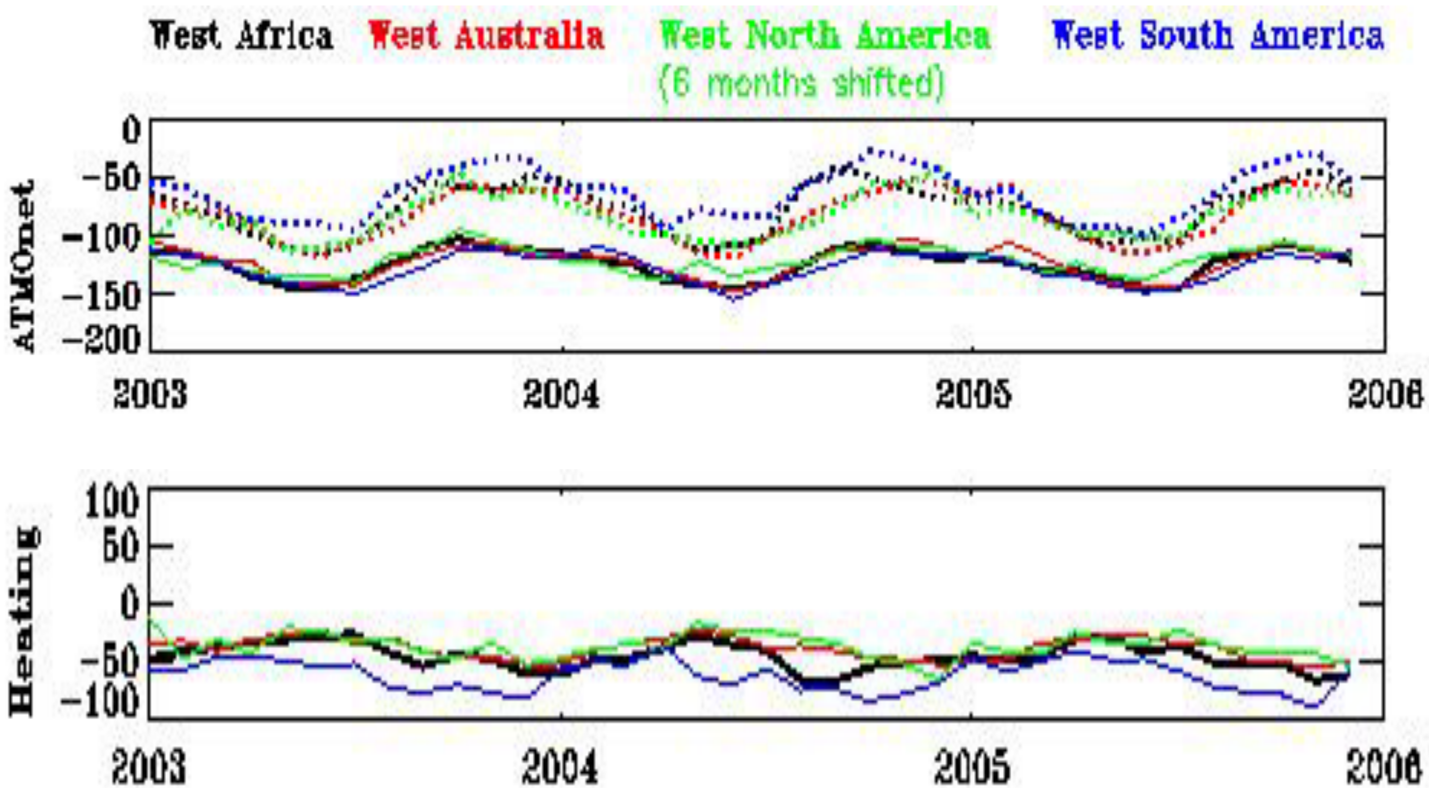
Clr: dot
Cld: solid



Similar story as those in storm tracks
except slightly stronger heating
Larger clear sky differences

Low clouds

Clr: dot
Cld: solid



Radiative cooling at MBL cloud layer:
enhance subsidence and large-scale circulation

Summary

- For marine high and low clouds, they persistently occur in certain areas due to the combined local and large scale meteorological conditions.

- The same types of clouds from different preferred areas generally have different radiative fluxes due mainly to the differences in solar insolation and local temperature.

- When the same types of clouds are analyzed in the same seasons, although there are large differences in cloud covers, the differences in radiation fluxes of these clouds are remarkably reduced.

Summary (conti.)

- Year-to-year variations in LWP/IWP statistical distributions are very small for each season in a given selected area. The area-to-area changes for the same types of clouds are also small.

- The difference in net atmospheric radiative fluxes between high clouds and clear sky cases are positive, which would increase atmospheric stability and reduce convection.

- The net atmospheric radiative fluxes under MBL clouds are smaller compared to clear sky cases, which would increase atmospheric subsidence and enhance general atmospheric circulation in the tropics.

- The results may have great potentials in testing models.

Acknowledgements

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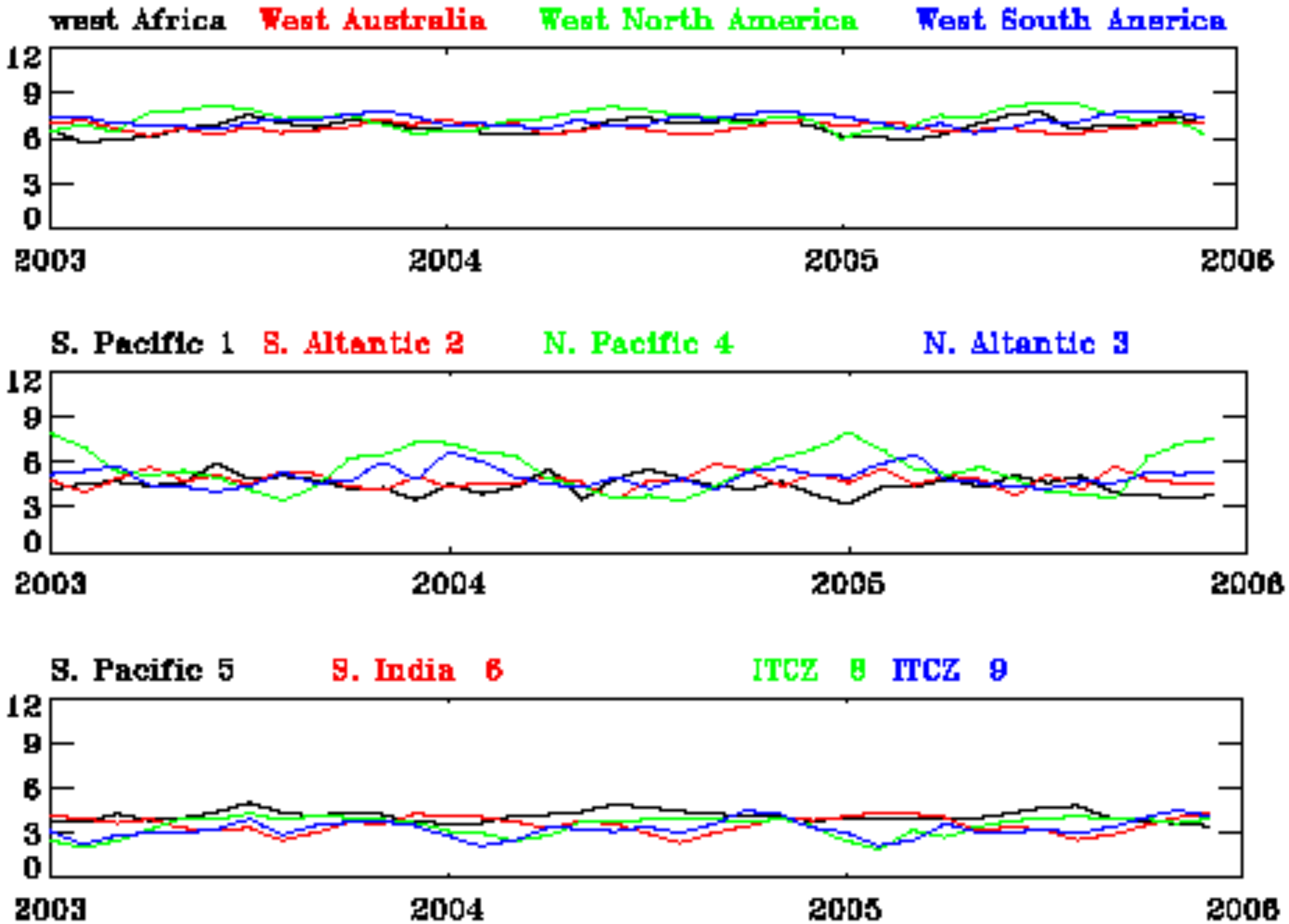
OD



west Africa
West Australia
West North America
West South America
12
9
6
3
0
2003
2004
2005
2006
S. Pacific 1
S. Altantic 2
N. Pacific 4
N. Altantic 3
12
9
6
3
0
2003
2004
2005
2006
S. Pacific 5
S. India 6
ITCZ 8
ITCZ 9
12
9
6
3
0
2003
2004
2005
2006