CREST
REMOTE SENSING OF CLIMATE GROUP

City College of New York

- William Rossow, Fabrice Papa, Cindy Pearl, Eric Tromeur, Ademe Mekonnen,

  Deniz Gencaga, Violeta Golea
- Joe Ferrier (NASA GISS)
- Yuanchong Zhang (Columbia U)

- Johnny Luo, Marco Tedesco

SUMMARY OF PROJECTS

- **International Satellite Cloud Climatology Project**
  - Improvements (Calipso) & Re-processing
  - ISCCP “Research-to-Operations”

- **CloudSat & Calipso**
  - Level 3 Product Development
  - Global & Storm Cloud Vertical Structures

- **Tropical Convection**
  - Convective Processes & Mesoscale Dynamics
  - MJO, Monsoons, AEW & Hurricanes

SUMMARY OF PROJECTS

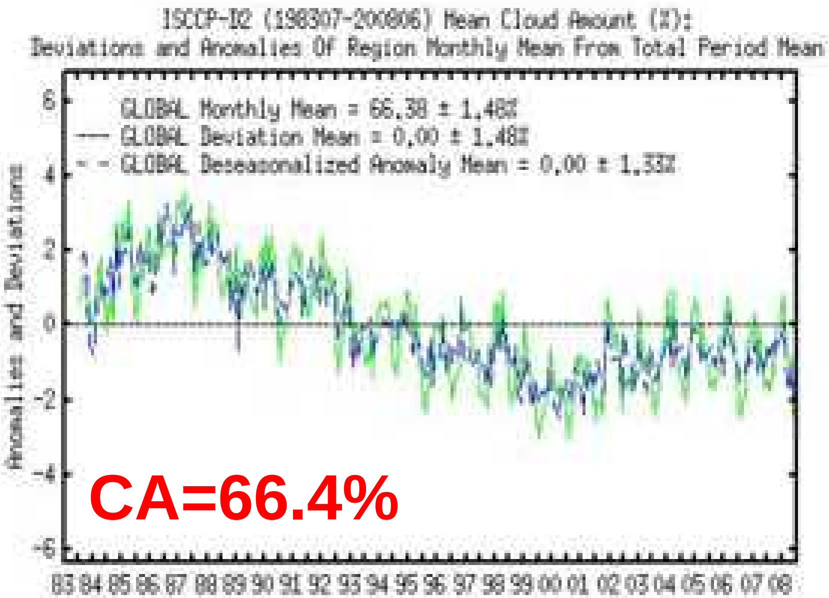
- **Upper Troposphere – Stratosphere Water Vapor**
  - Cirrus
  - Penetrating Convection

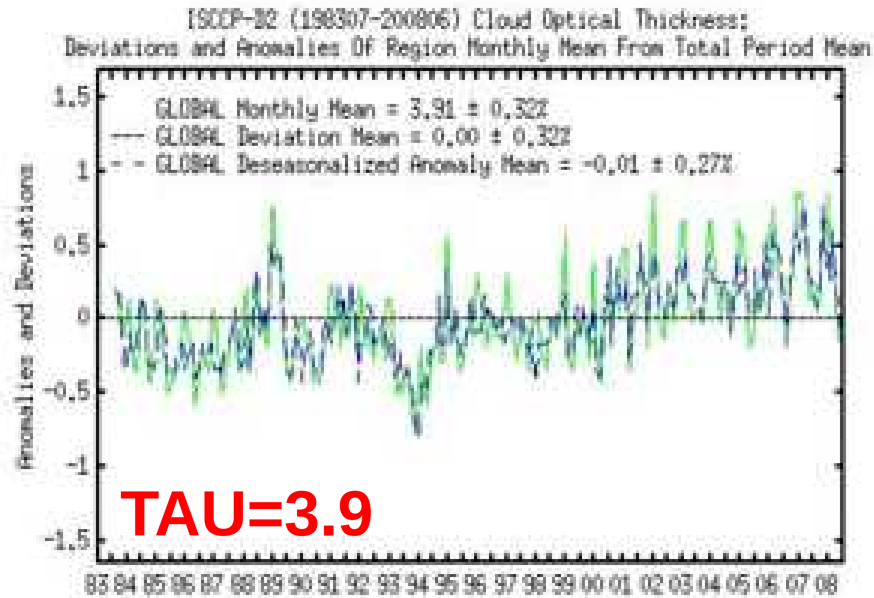
- **Snow**
  - Field Studies of Snow (and Ice)
  - Snow on Surface
  - Snowfall

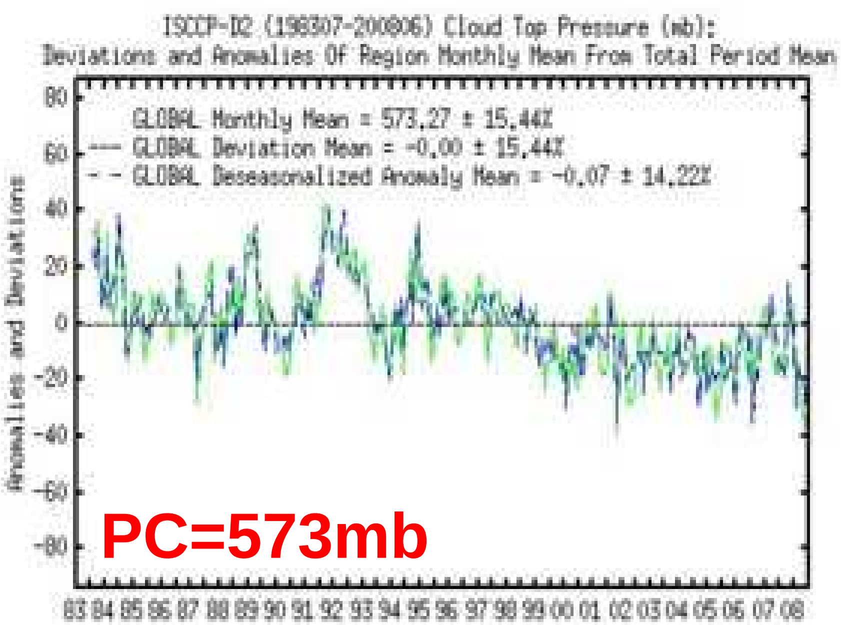
- **Land Surface Fluxes and Hydrology**
  - Surface Turbulent Fluxes
  - Inundation

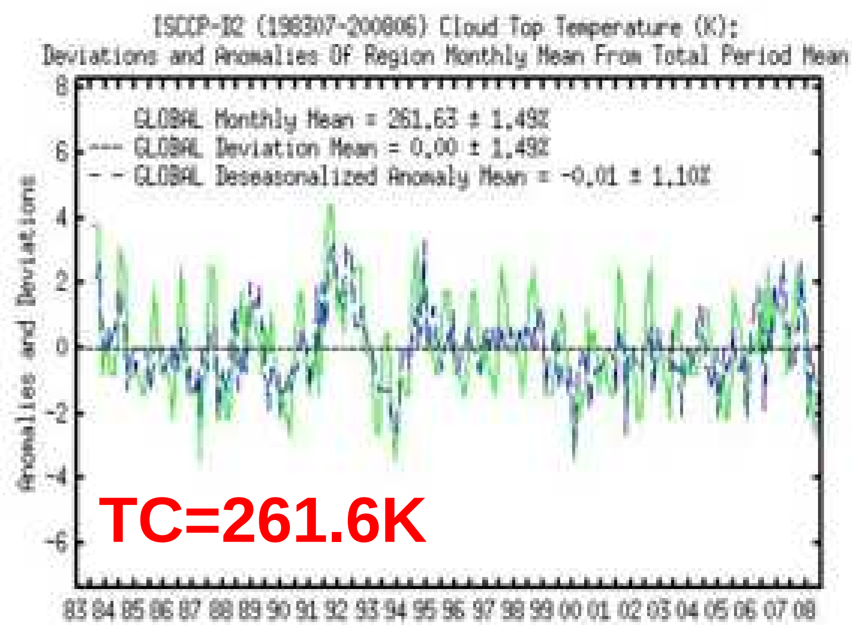
- **Advanced Feedback Analysis**

ISCCP CLIMATOLOGY 2009

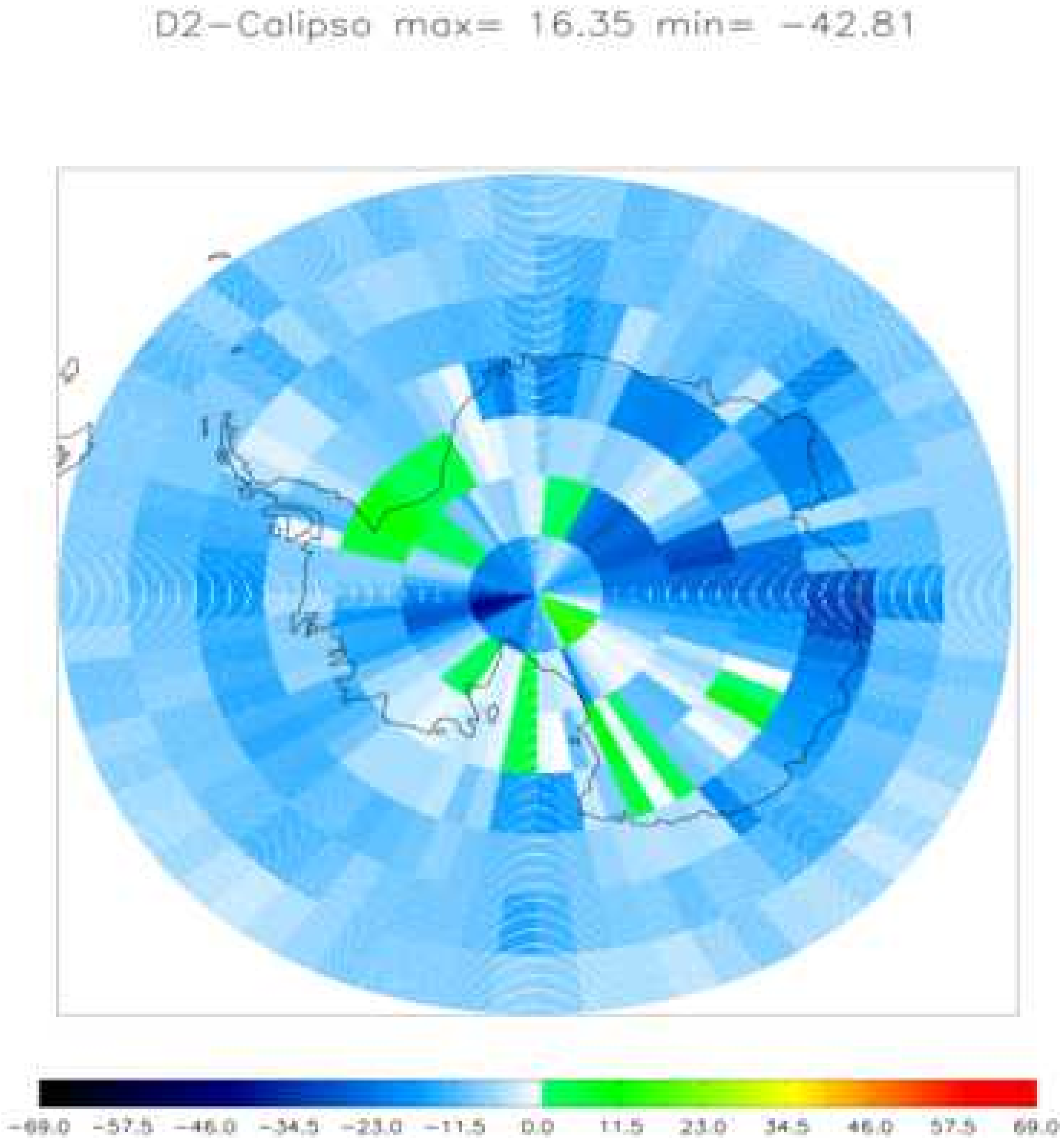






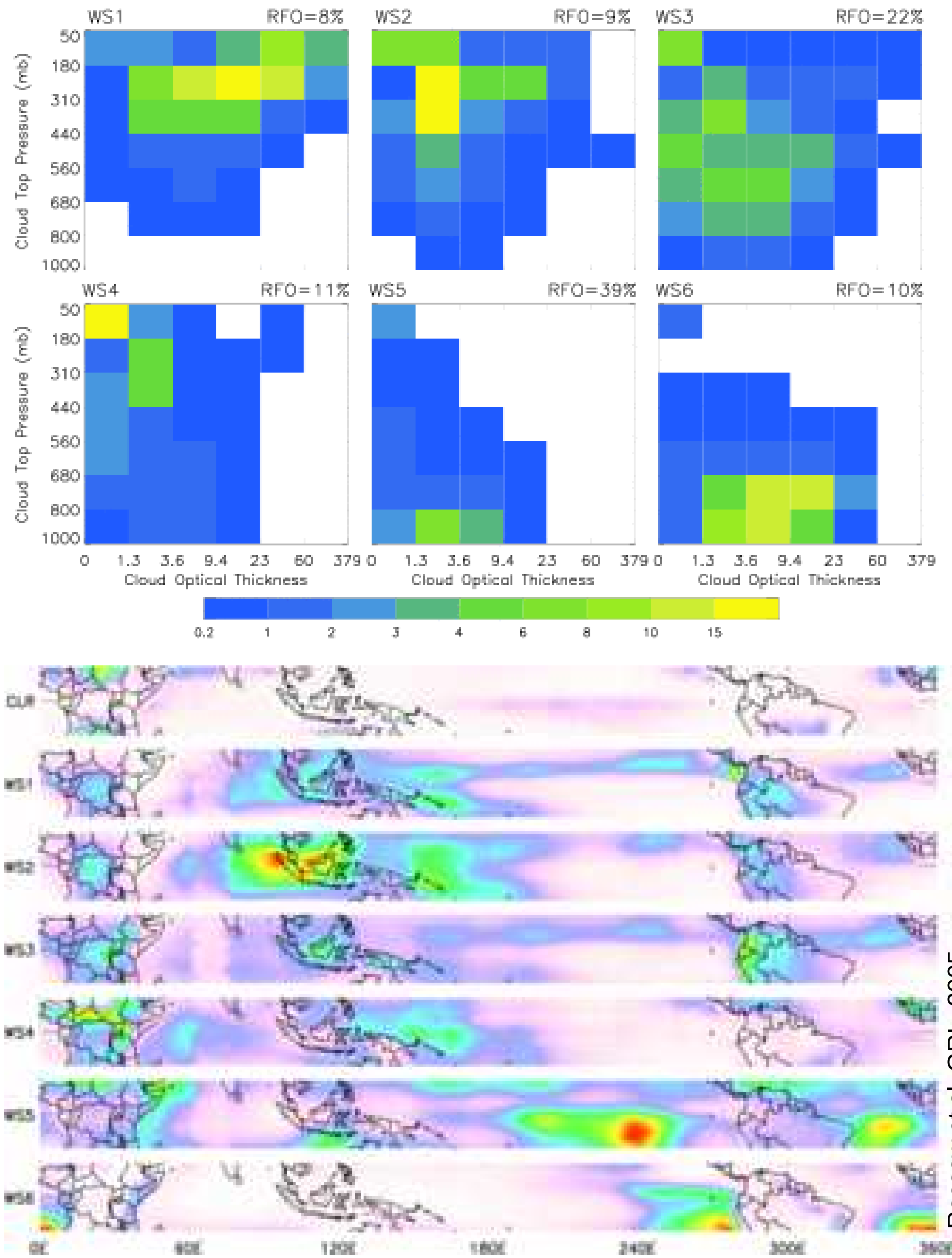


ISCCP MINUS CALIPSO TOTAL CLOUD AMOUNT



ISCCP PC - TAU histogram pattern and Map in Tropics over 21.5 years

1983 - 2004 time period



Rossow et al, GRL, 2005

Cluster Analysis + ISCCP D1 data

WS1 : Deep cumulus clouds

WS2 : Anvils clouds

WS3 : Congestus clouds

WS4 : Cirrus clouds

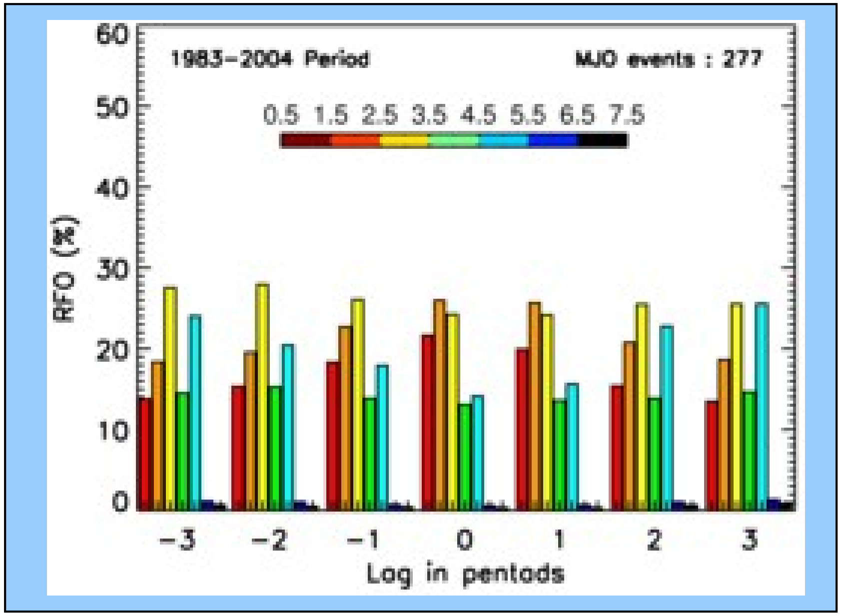
WS5 : Shallow cumulus clouds

WS6 : Stratocumulus clouds

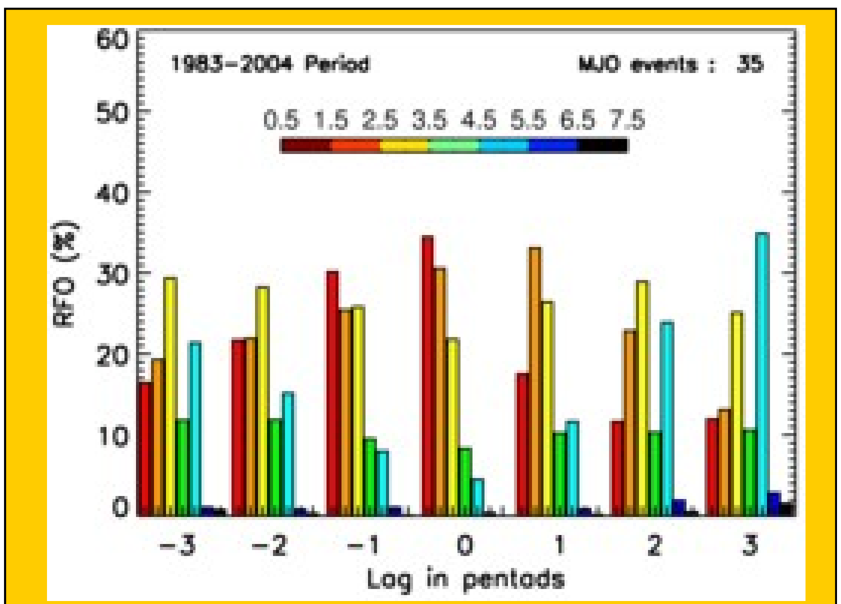
RFO of each cloud regime in 60E-180E region / 5S-5N latitude band

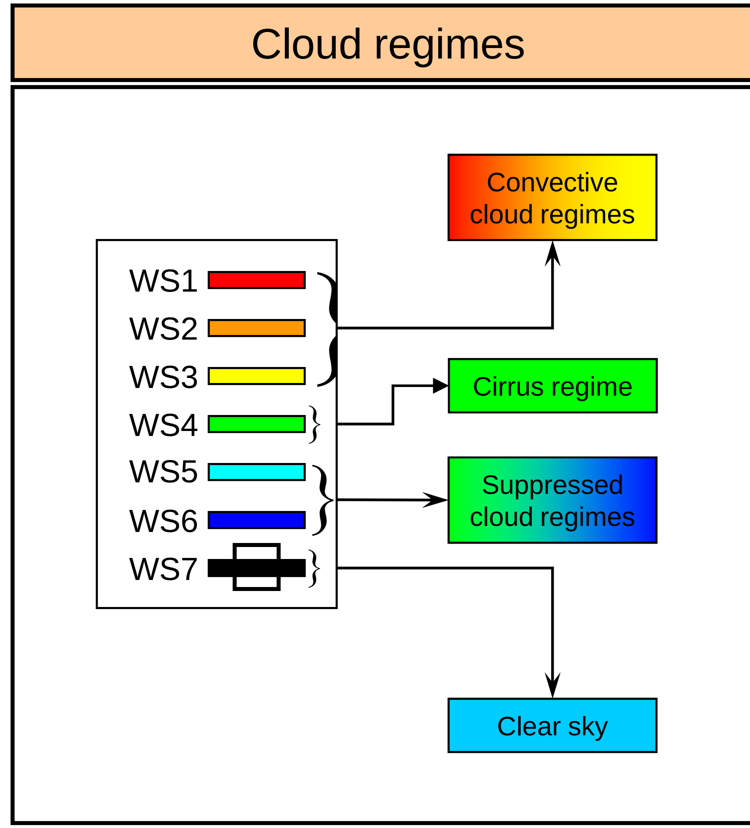
(MJO events in November-April periods from 1983 - 2004)

Weak MJO (index < -1)

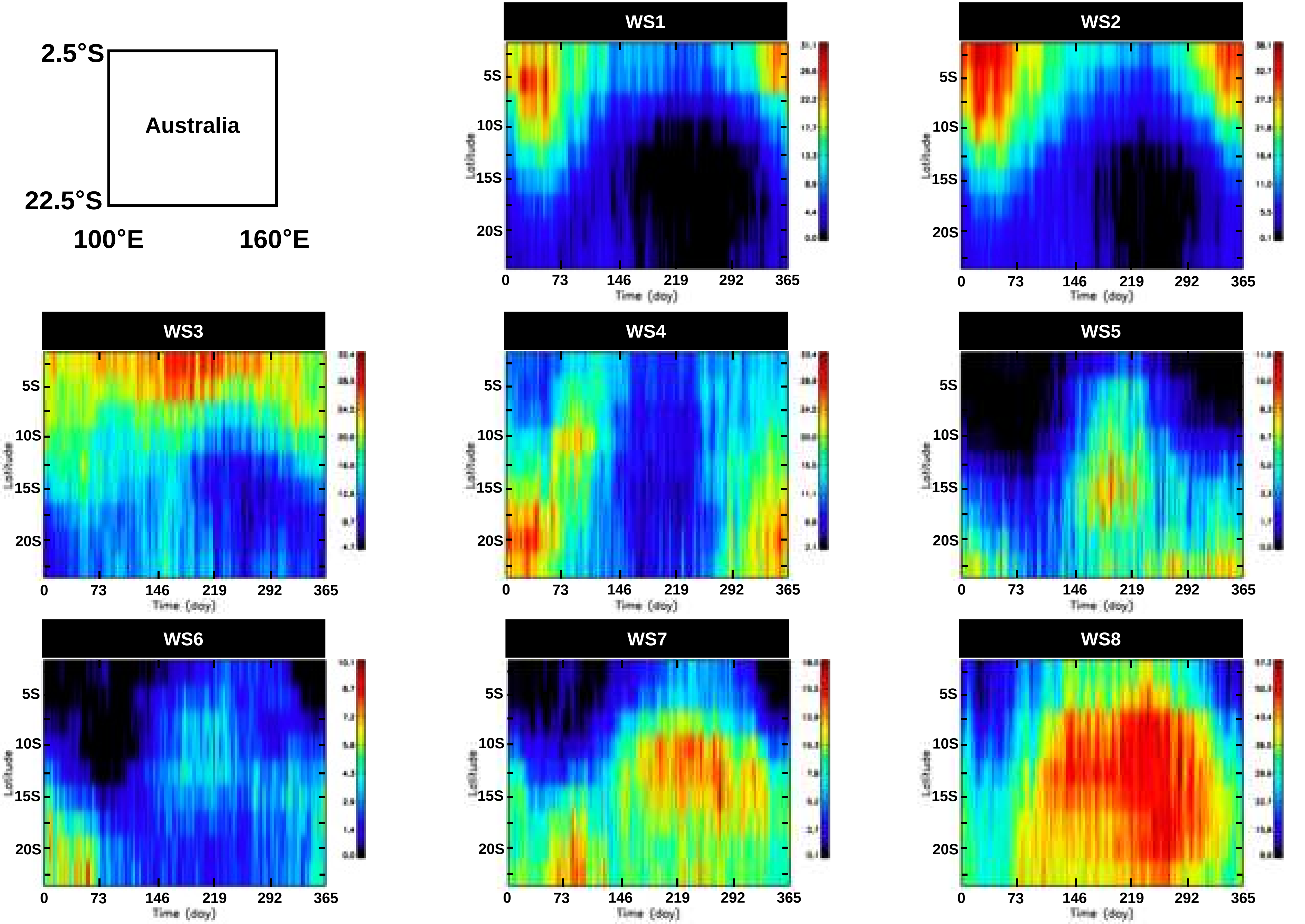


Strong MJO (index < -2.2)





Composite of Annual Cycle of RFO (1984 - 2006)



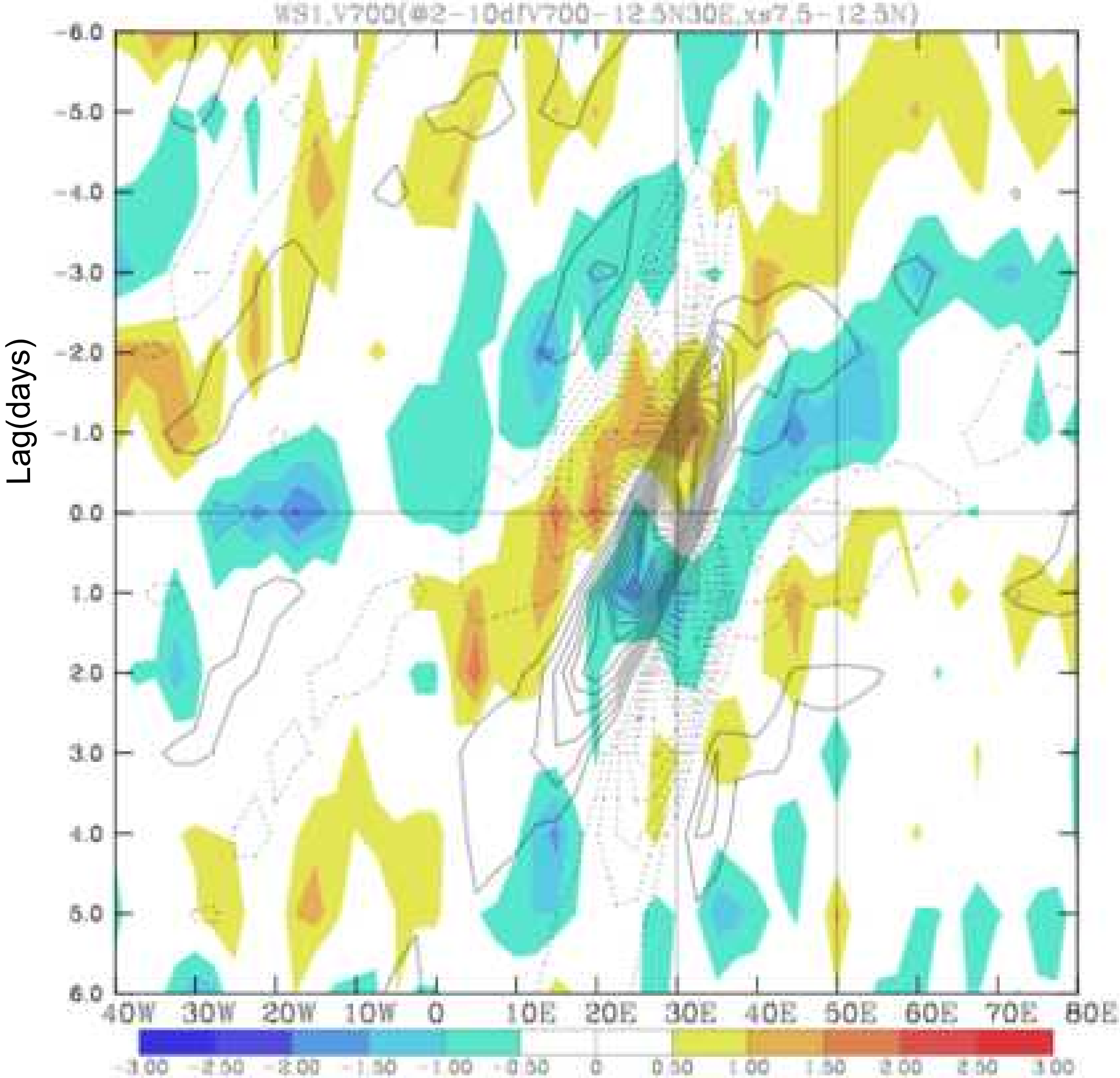
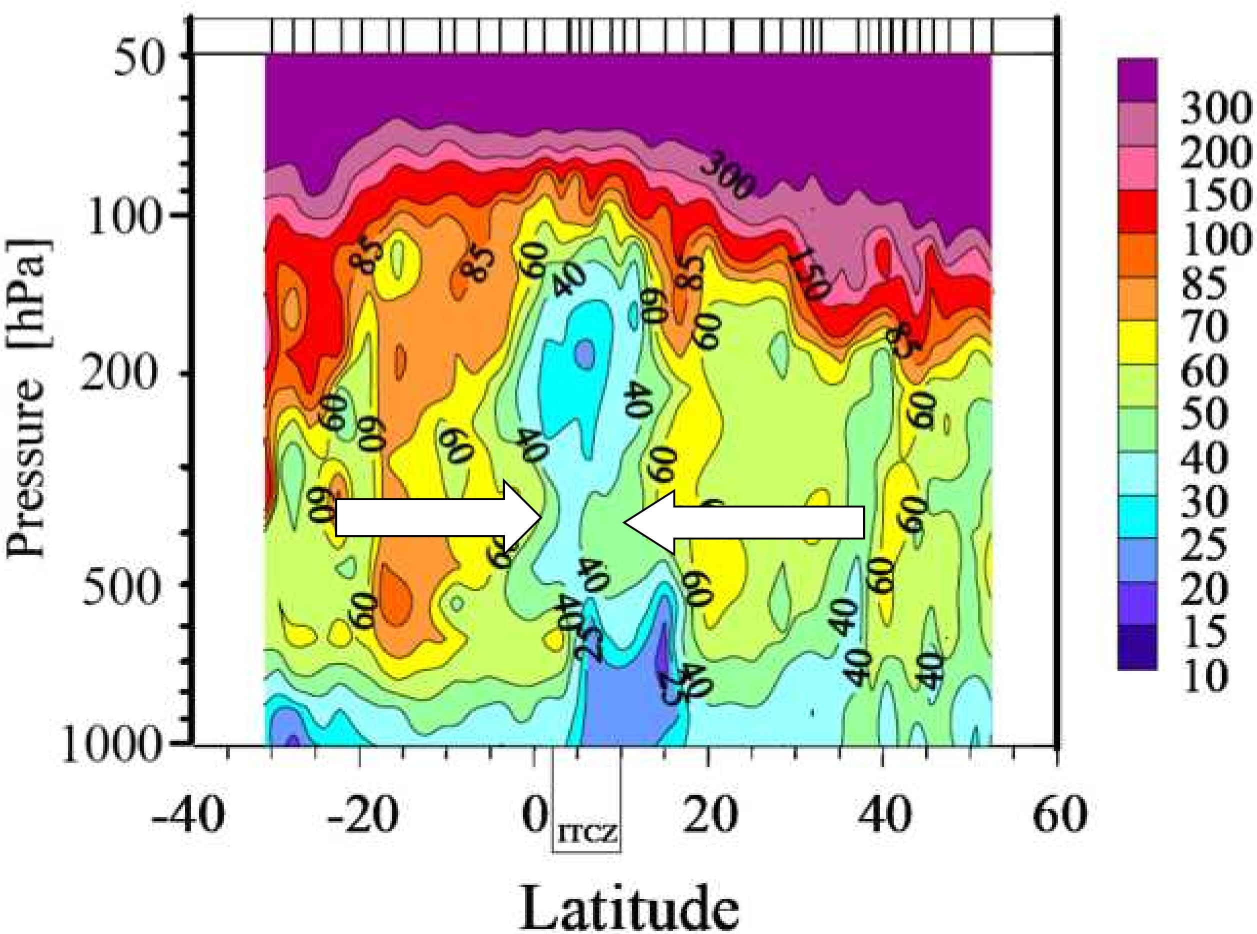
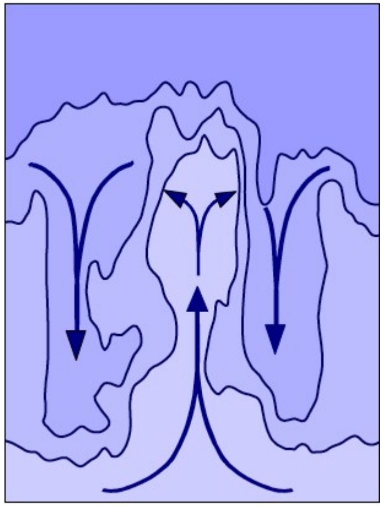


Figure 7a: Frequency of occurrence of WS1 and 700-hPa meridional wind projected onto 2-10day filtered 700-hPa meridional wind at 12.5N, 30E. Anomalous WS1 frequencies are shaded every 0.5 and scaled by 30 (a value at a moderate strong convective event at the chosen basepoint; see also Kiladis et al 2009). Anomalous meridional winds are contoured every 0.1ms^{-1} (positives solid and negatives dashed). The cross-sections are for 7.5-12.5N.

This figure is from a campaign in 1987 (Polarstern). It shows the ozone cross section, which indicates entrainment near ITCZ.

Ozone cross section is a good illustration of the Hadley Cell.





Kley et al. (2007)

Cryospheric Processes Laboratory

EAS Dept. and NOAA CREST

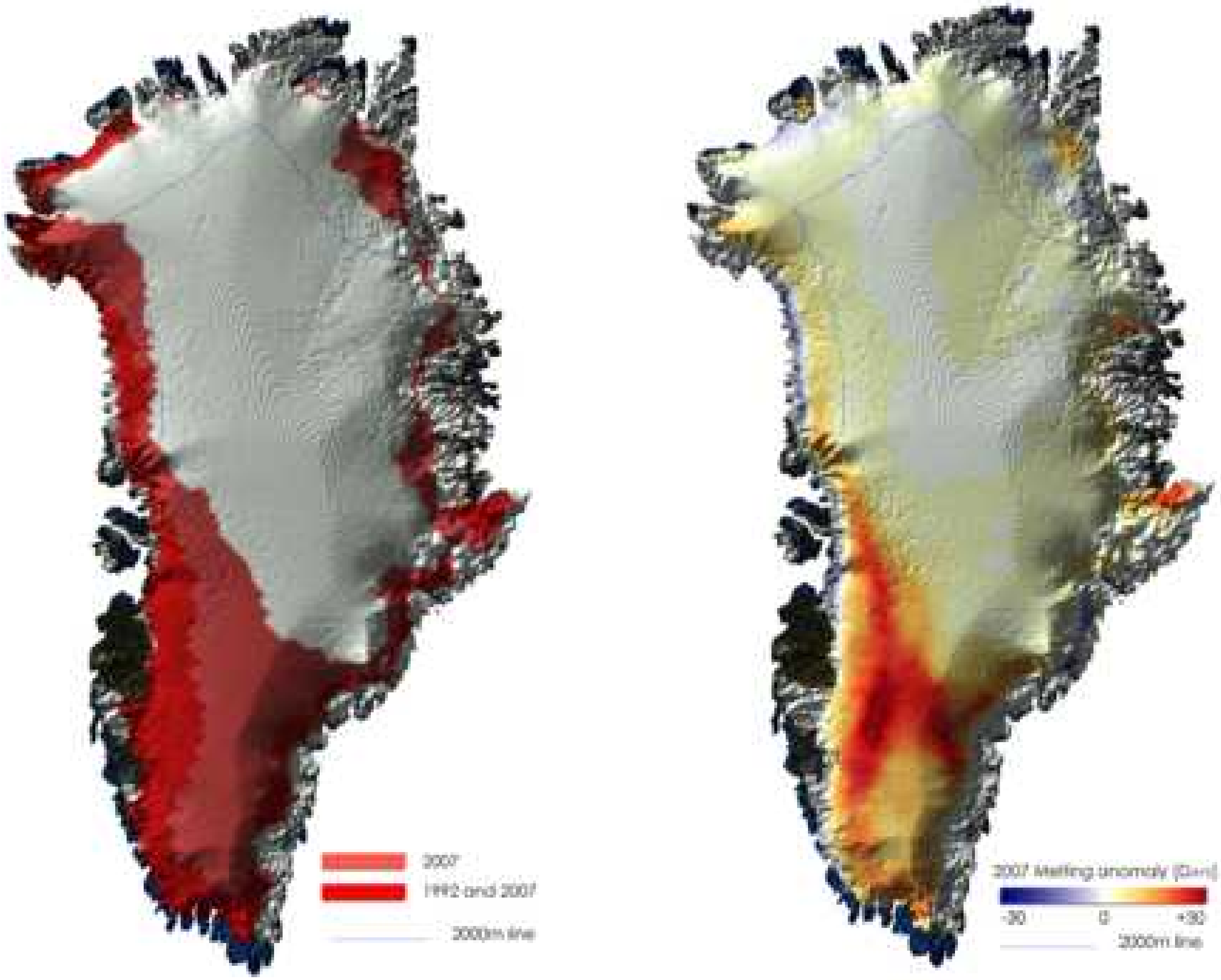
MAIN ACTIVITIES

-Remote sensing of the cryosphere
- Cryosphere/climate interactions
- High latitude field measurements
- Arctic climate change

MAJOR ONGOING PROJECTS:

- Maintenance and refinement of the NASA AMSR-E snow operational product (NASA)
- Combination of active/passive MW data for snow parameters retrieval (NASA)
- Surface mass balance of the Greenland ice sheet (NASA, NSF)
- Investigating glaciers with visible/NIR satellite data
- Investigating supraglacial lakes in Greenland (WWF, NSF)
-Melting in Antarctica and the Arctic and links to climate variability

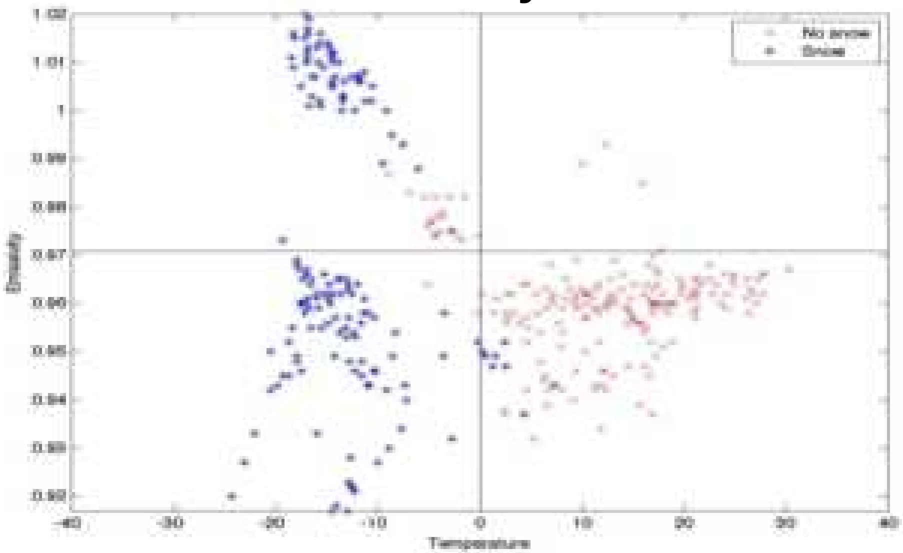
Greenland melting anomaly in 2007



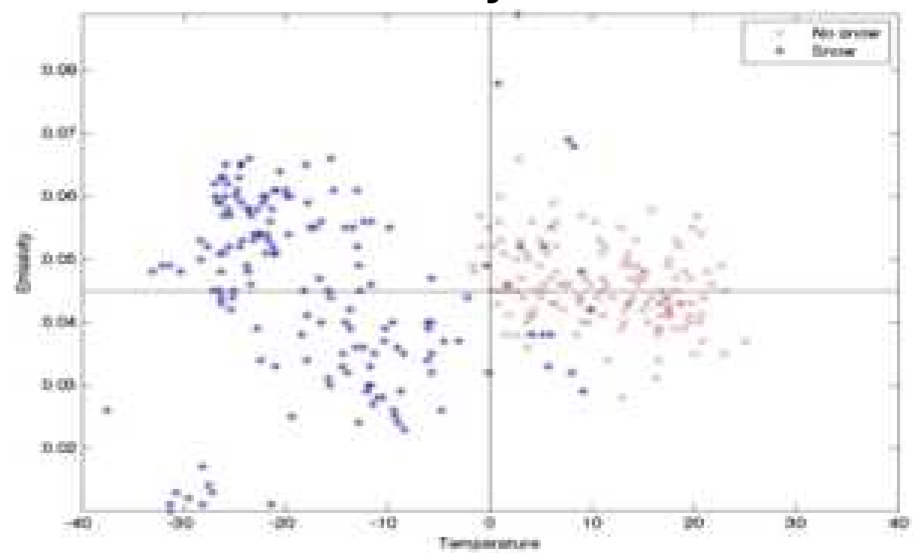
Tedesco, EOS, 2007 b

MICROWAVE EMISSIVITY VERSUS TEMPERATURE

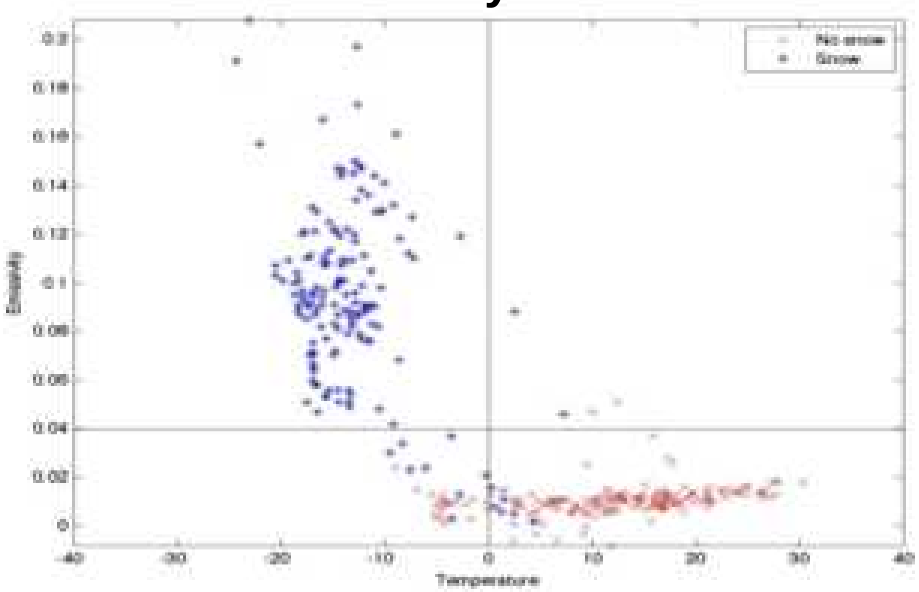
Emissivity 19V



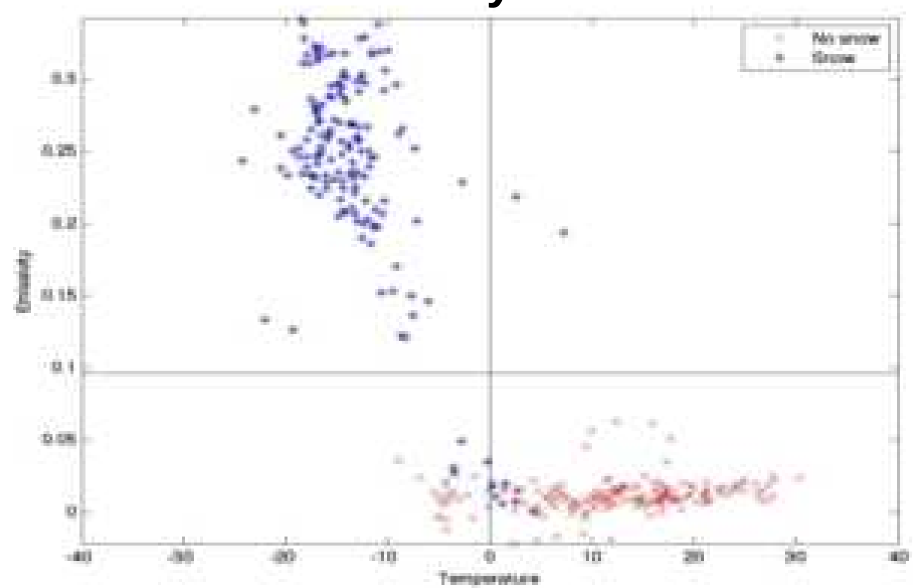
Emissivity 19V-19H



Emissivity 19V-37V



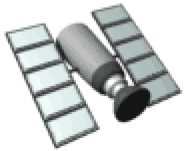
Emissivity 19V-85V



Snowfall Rate Estimation from Multi-Spectral Satellite Based Information

Student: Cecilia Hernández-Aldarondo, PhD

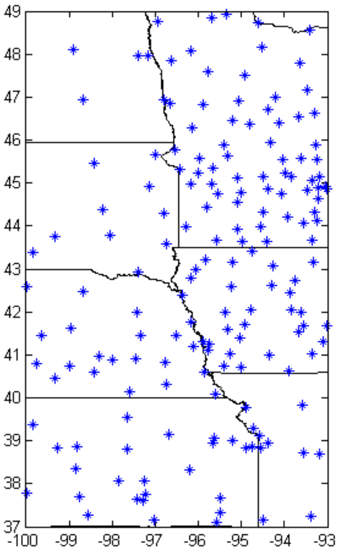
Study Areas & Data used

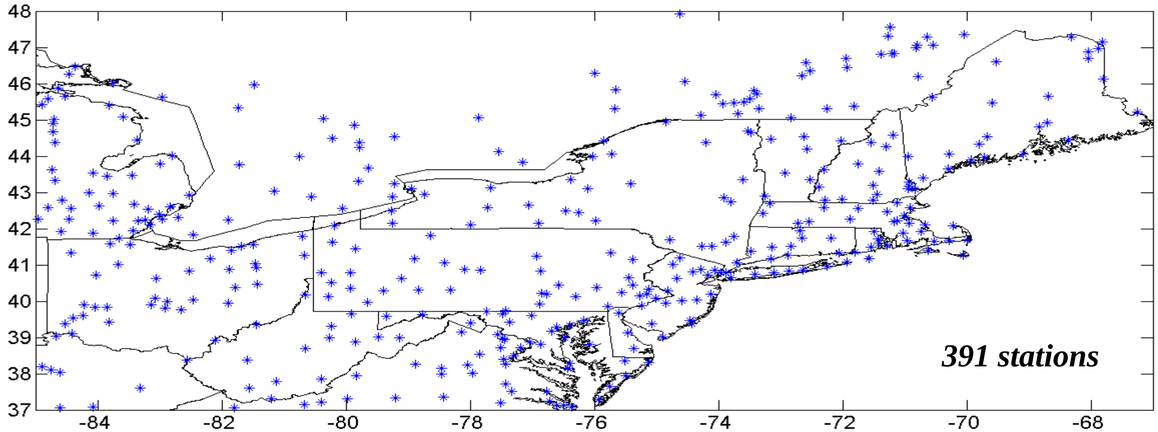


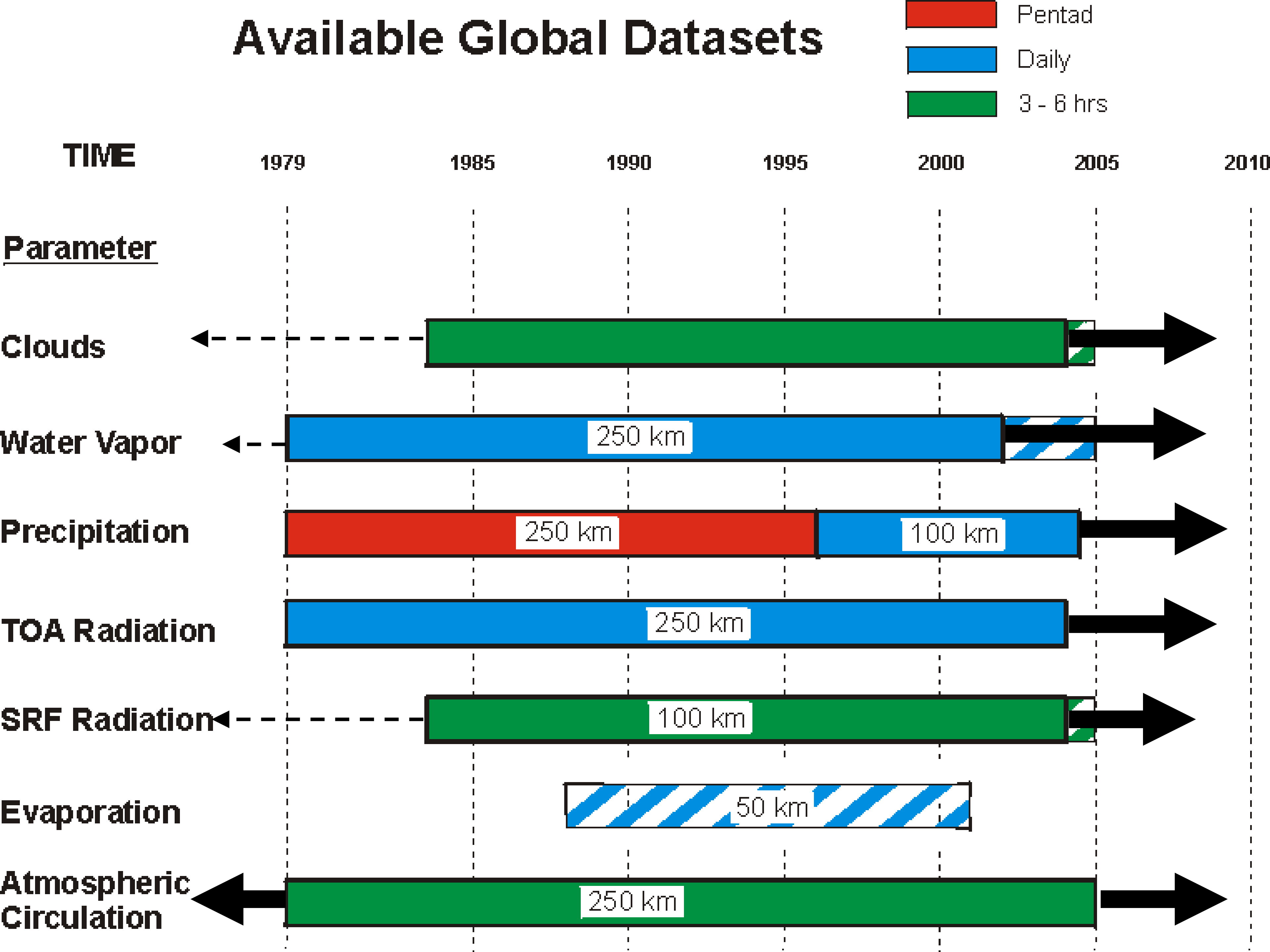
- Input data
  - AMSU-B channels: 89-, 150-, 183±1-, 183±3-, 183±7 – GHz
- Calibration and validation data
  - Ground-based snowfall rate observations
    - Quality Controlled Local Climatological Data (QCLCD) product from the National Climatic Data Center (NCDC)

NCDC Stations

188 stations



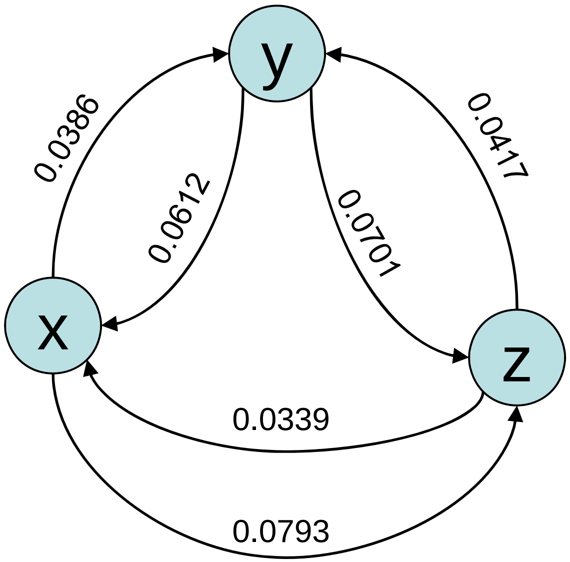




Available Global Datasets
Pentad
Daily
3 - 6 hrs
TIME
1979
1985
1990
1995
2000
2005
2010
Parameter
Clouds
Water Vapor
250 km
Precipitation
250 km
100 km
TOA Radiation
250 km
SRF Radiation
100 km
Evaporation
50 km
Atmospheric Circulation
250 km

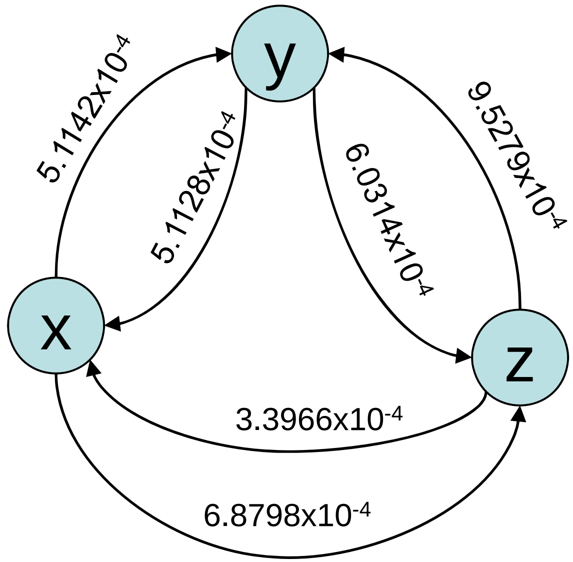
Normalized Transfer Entropy (TE) estimates between Lorenz variables

Chaotic regime

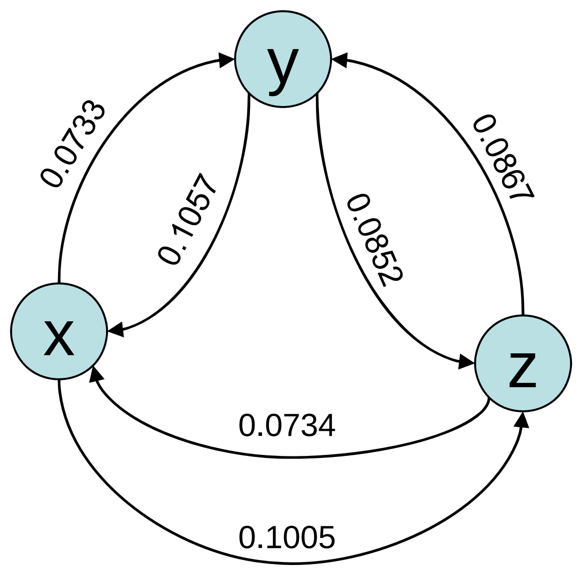


$$TE \in [0,1]$$

Periodic regime



Stable regime



ISCCP Improvements

- **Switch to B1U** – code re-write **completed**, now testing smaller-scale spatial contrast test & sliding time windows & revised thresholds

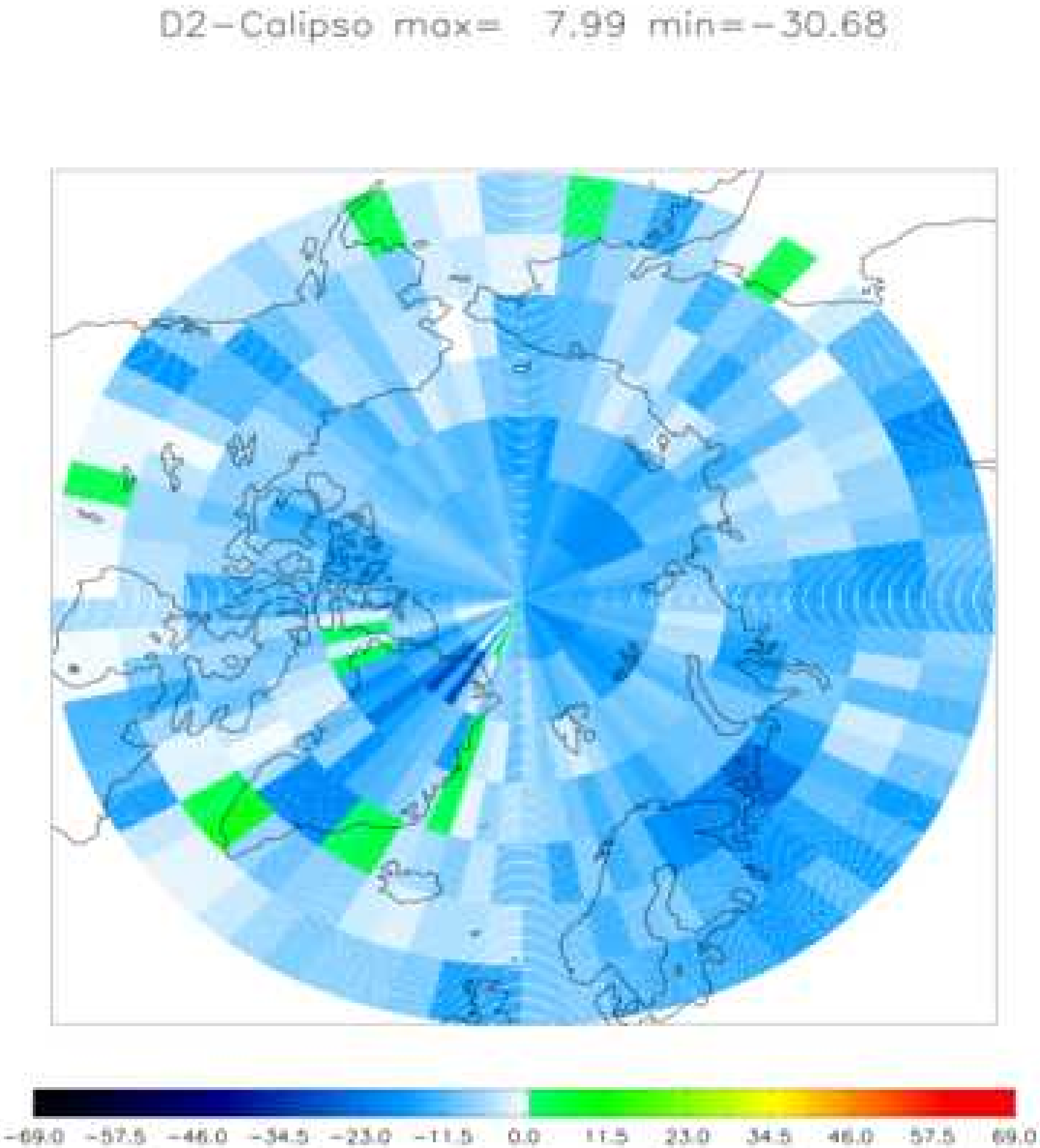
- **Polar Cloud Detection** – testing ideas from J. Key's AVHRR algorithm: daytime TB45 test helps but nighttime TB45 test does not, old TB3 test may be dropped, increased TB4 threshold with alternate TB45 nighttime test may help

- **Surface skin temperature –** More realistic surface emissivities **implemented**

- **Planned VIS changes** -- better tau precision, better ice treatment (aspect ratio, correct error), included aerosol effects, better land surface reflectances

- **Possibilities** -- particle sizes

ISCCP MINUS CALIPSO TOTAL CLOUD AMOUNT



Preparations for Re-Processing in 2010

- Code adapted to newer computers
- Code adapted to B1U
- Testing finer spatial test and sliding time window
- Testing new polar cloud detection
- IR retrieval code revised for better treatment of surface
- Starting on VIS retrieval code revisions
- Beginning tests of new products

CLOUDSAT L3 PRODUCT

Part A – Basic Cross-Sections

Twice-daily, Reduced Resolution (50 km - 500 m)

Merged, Averaged L2 Variables at Each Location

CLOUDSAT L3 PRODUCT

Part B -- Statistical Histograms

Reflectivity vs Particle Size

Optical Thickness vs Particle Size

Water Content vs Particle Size

Water Content vs Precipitation

CLOUDSAT L3 PRODUCT

PART C – Gridded Monthly Statistics

Gridded at 4.5^o x 4.5^o with Cloud Fraction

Cloud Layer (Type) Properties from Part A

Vertical Structure Statistics from Part A

Accumulated Histograms from Part B

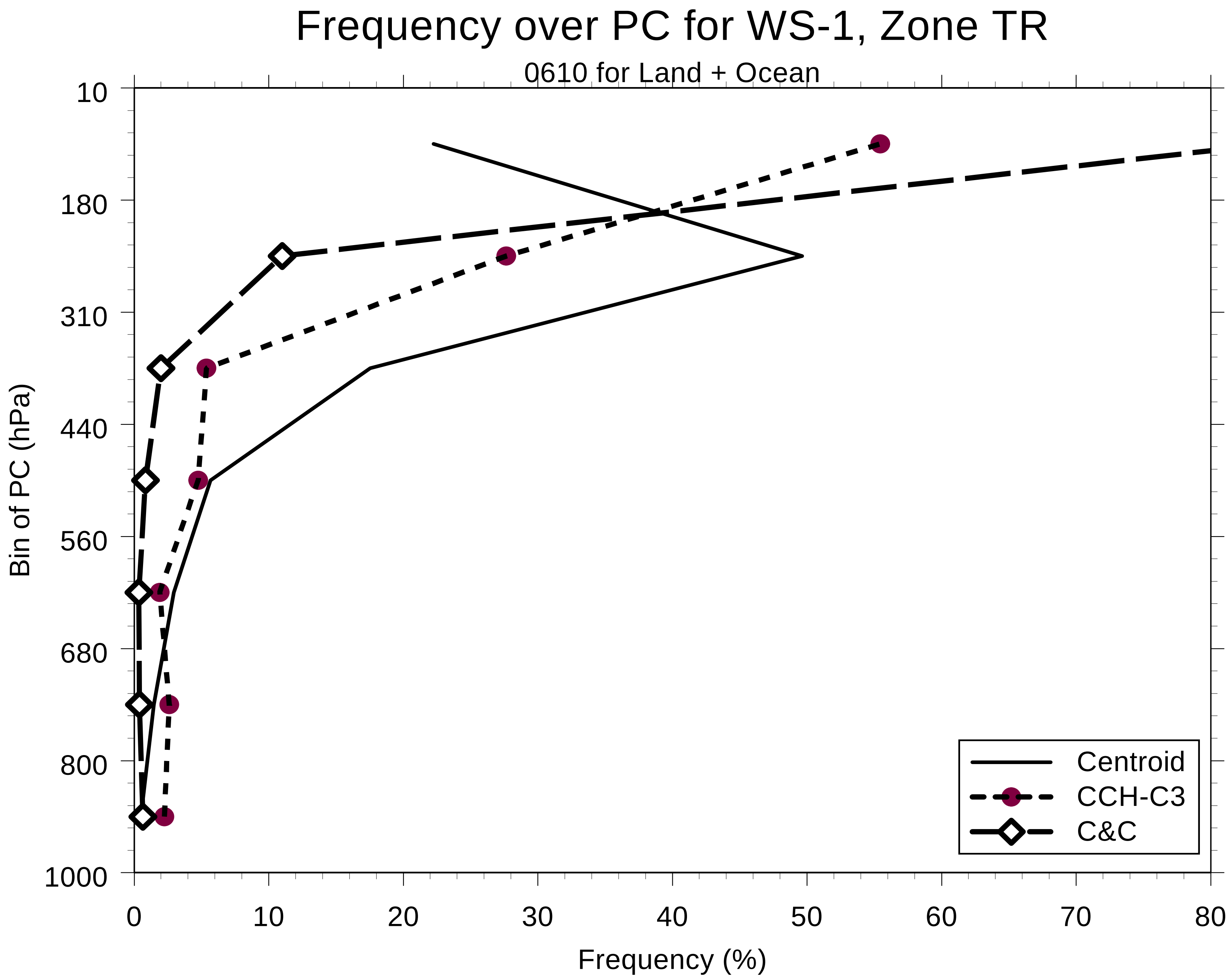
Additional Histograms

Water Content– Particle Size– Temperature

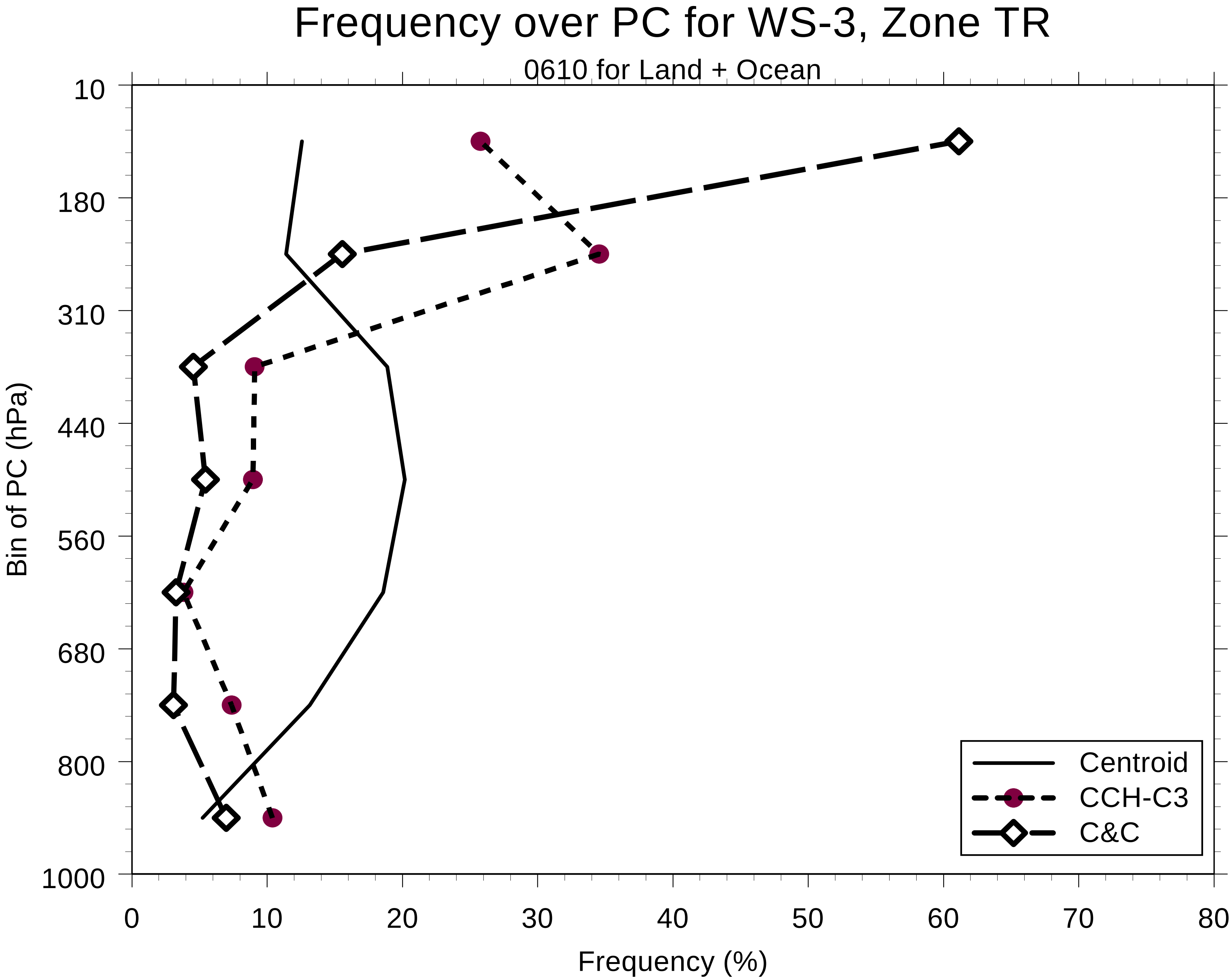
Water Content—Particle Size—Relative Humidity

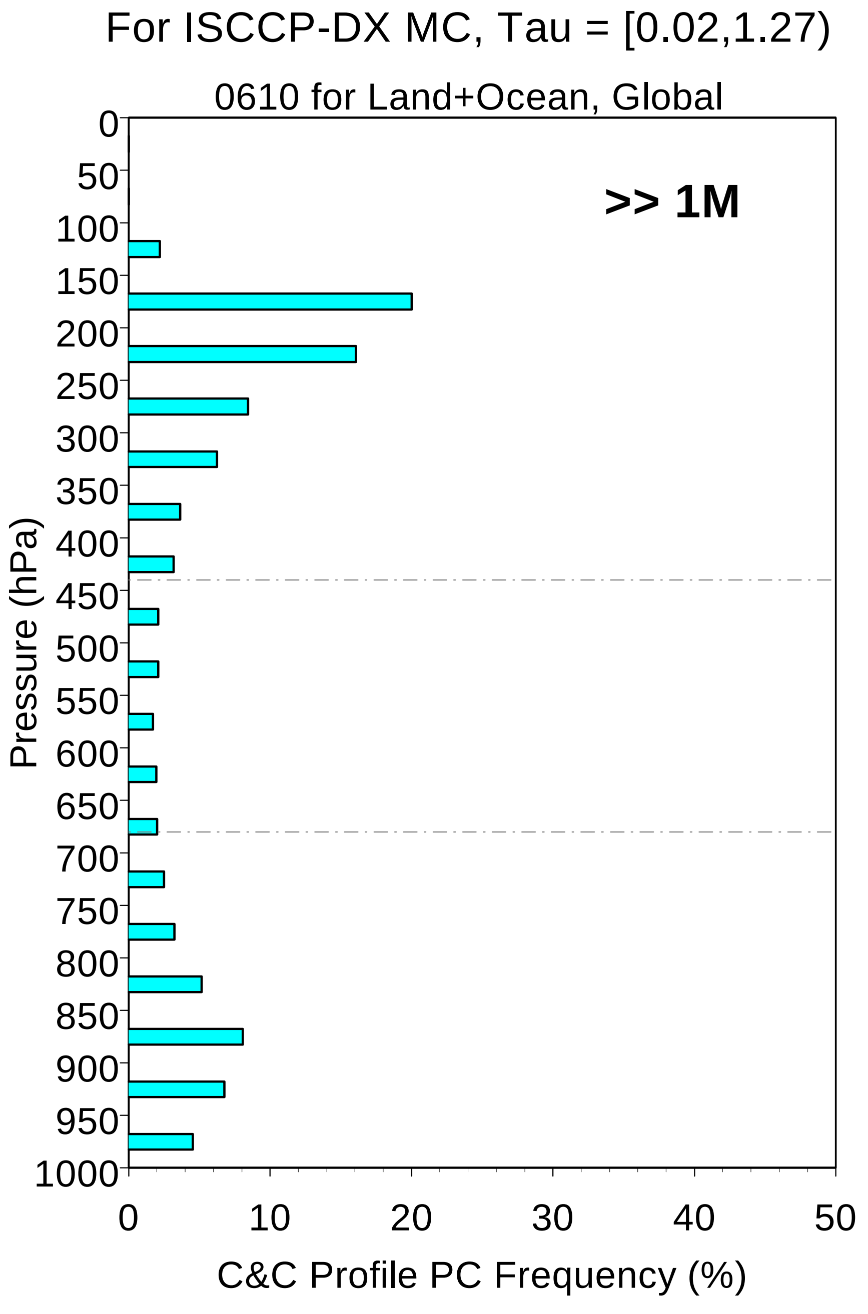
Cloudy Alpha & Beta Parameters

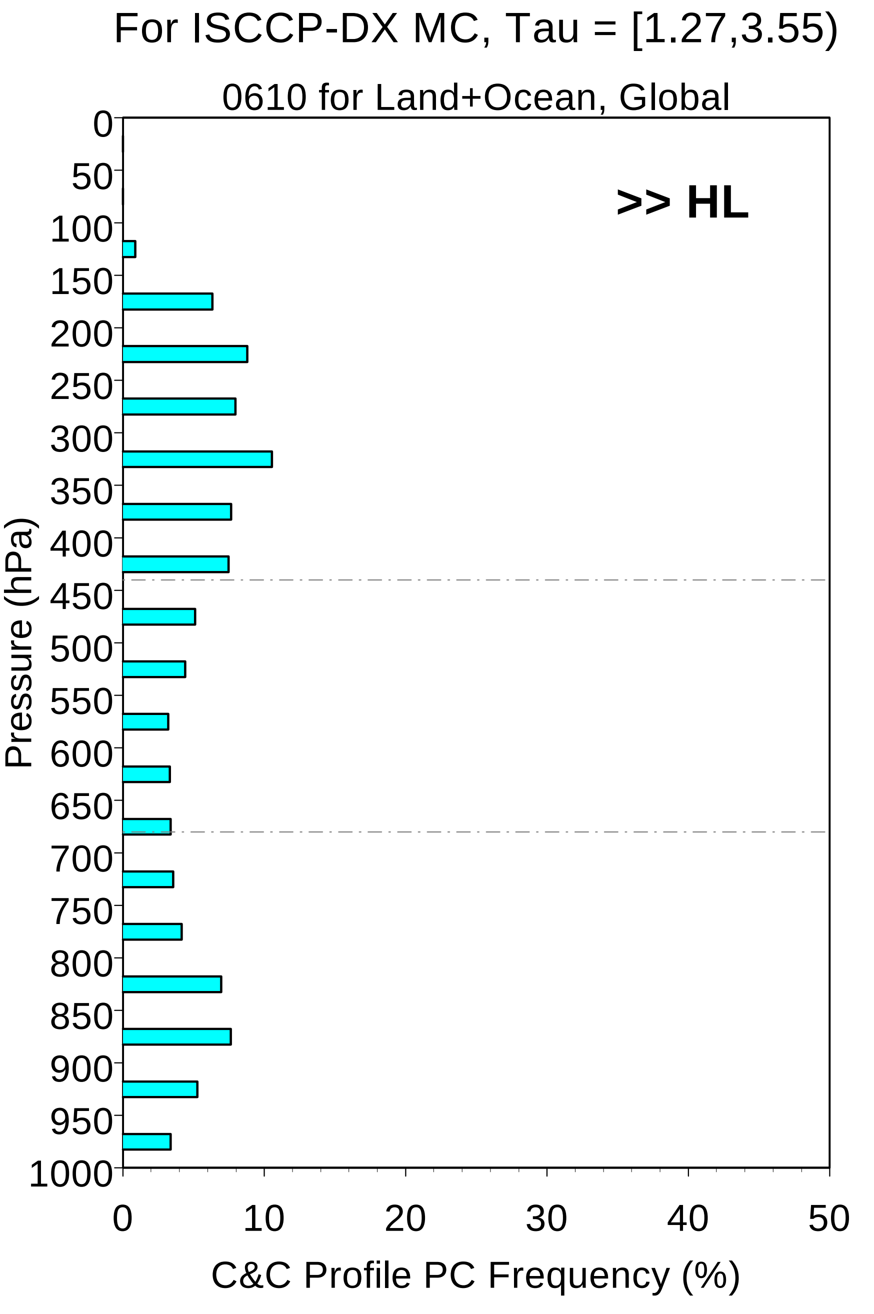
Clear Alpha & Beta Parameters



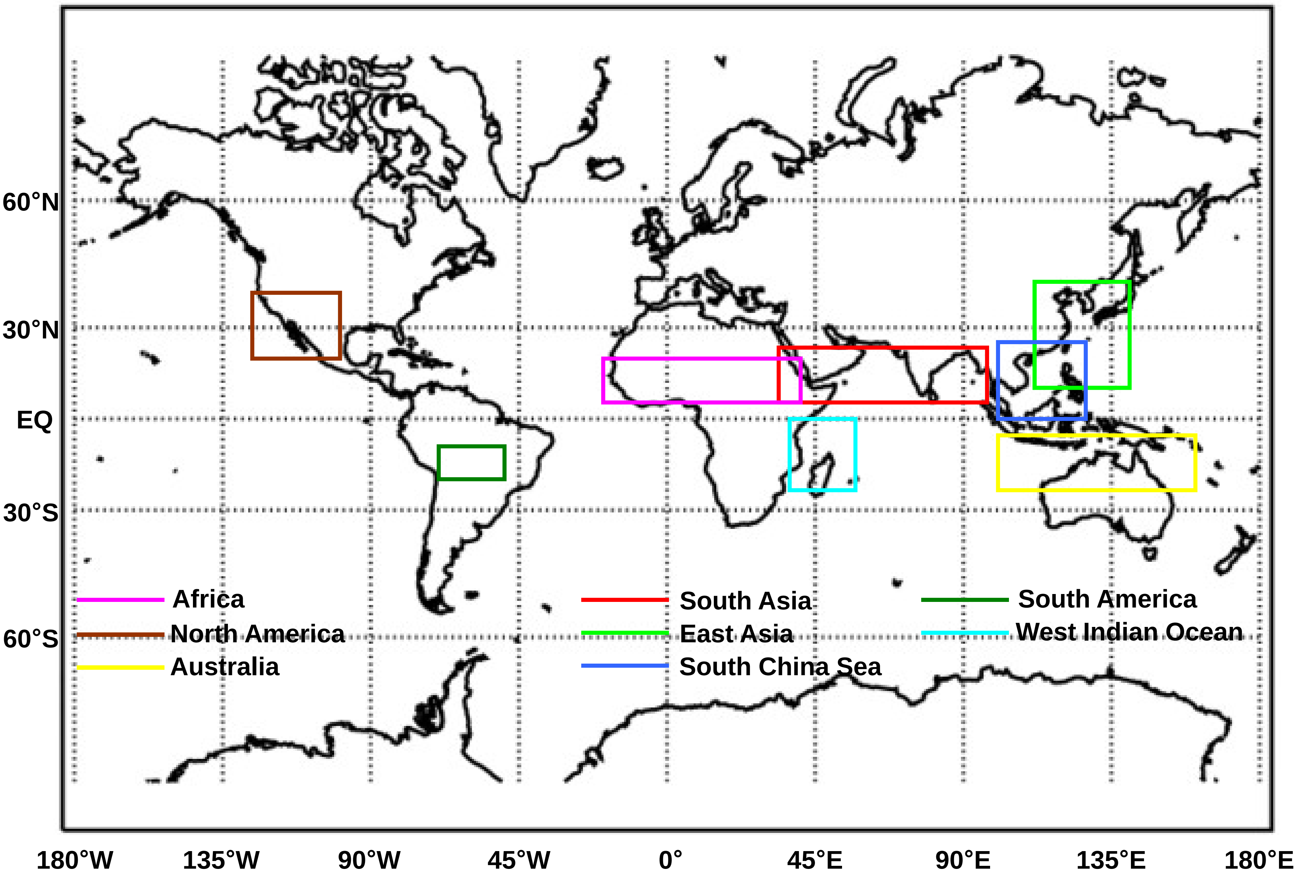
Frequency over PC for WS-1, Zone TR
0610 for Land + Ocean
Bin of PC (hPa)
10
180
310
440
560
680
800
1000
0
10
20
30
40
50
60
70
80
Frequency (%)
Centroid
CCH-C3
C&C


Frequency over PC for WS-3, Zone TR
0610 for Land + Ocean
Bin of PC (hPa)
10
180
310
440
560
680
800
1000
0
10
20
30
40
50
60
70
80
Frequency (%)
Centroid
CCH-C3
C&C

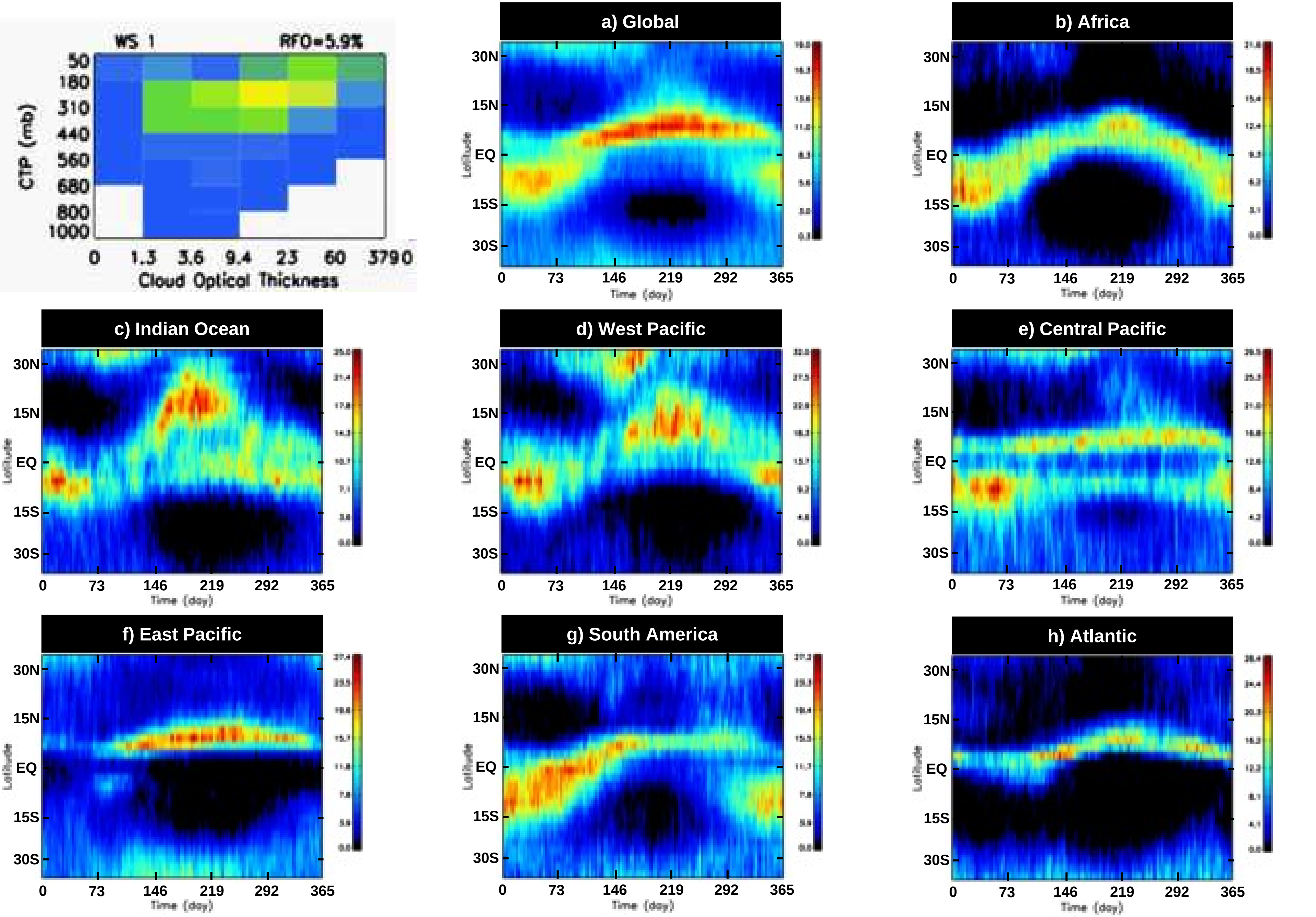

For ISCCP-DX MC, Tau = [0.02,1.27)
0610 for Land+Ocean, Global
>> 1M
Pressure (hPa)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
0
10
20
30
40
50
C&C Profile PC Frequency (%)


For ISCCP-DX MC, Tau = [1.27,3.55)
0610 for Land+Ocean, Global
>> HL
Pressure (hPa)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
0
10
20
30
40
50
C&C Profile PC Frequency (%)

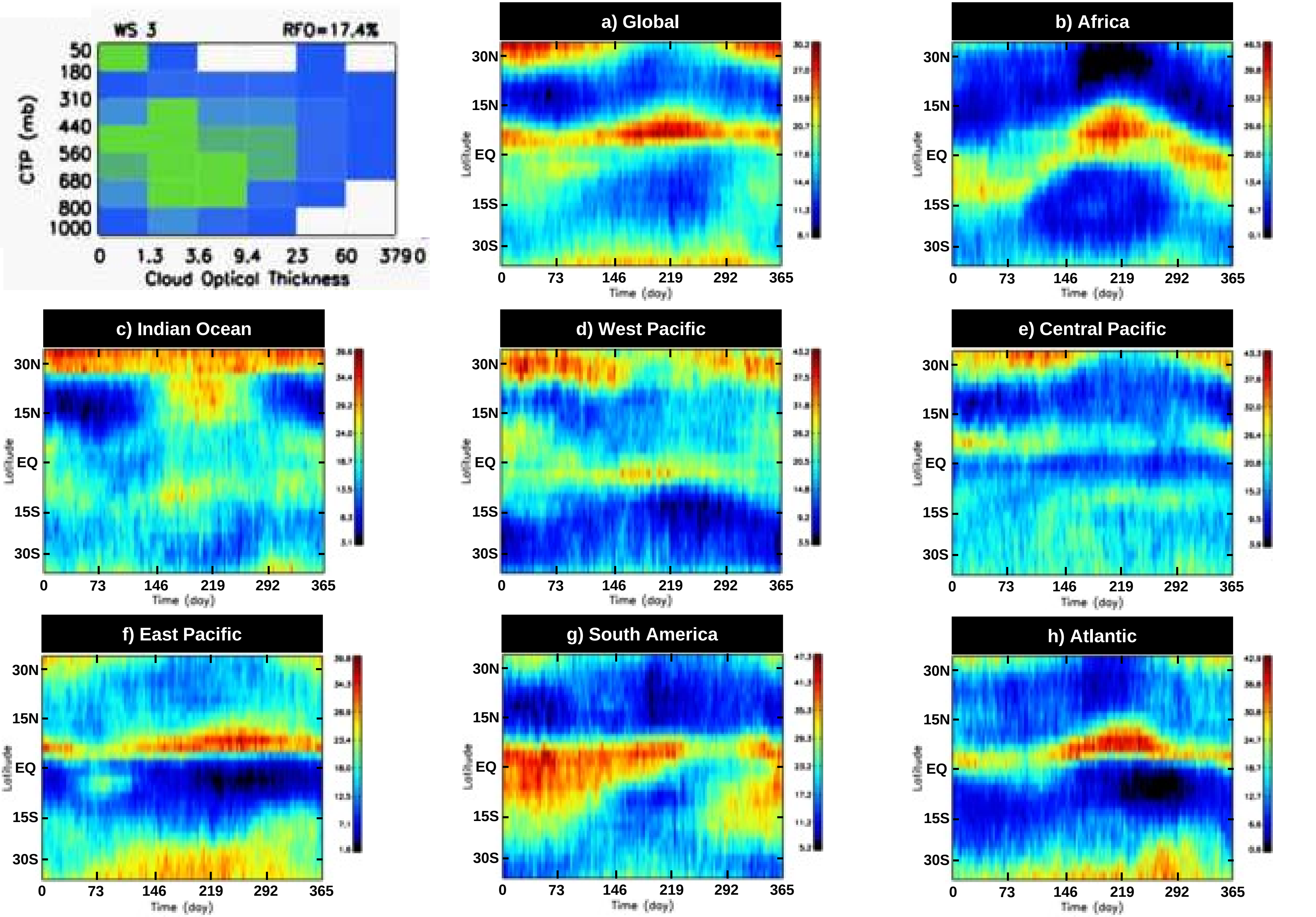
8 Monsoon Sectors



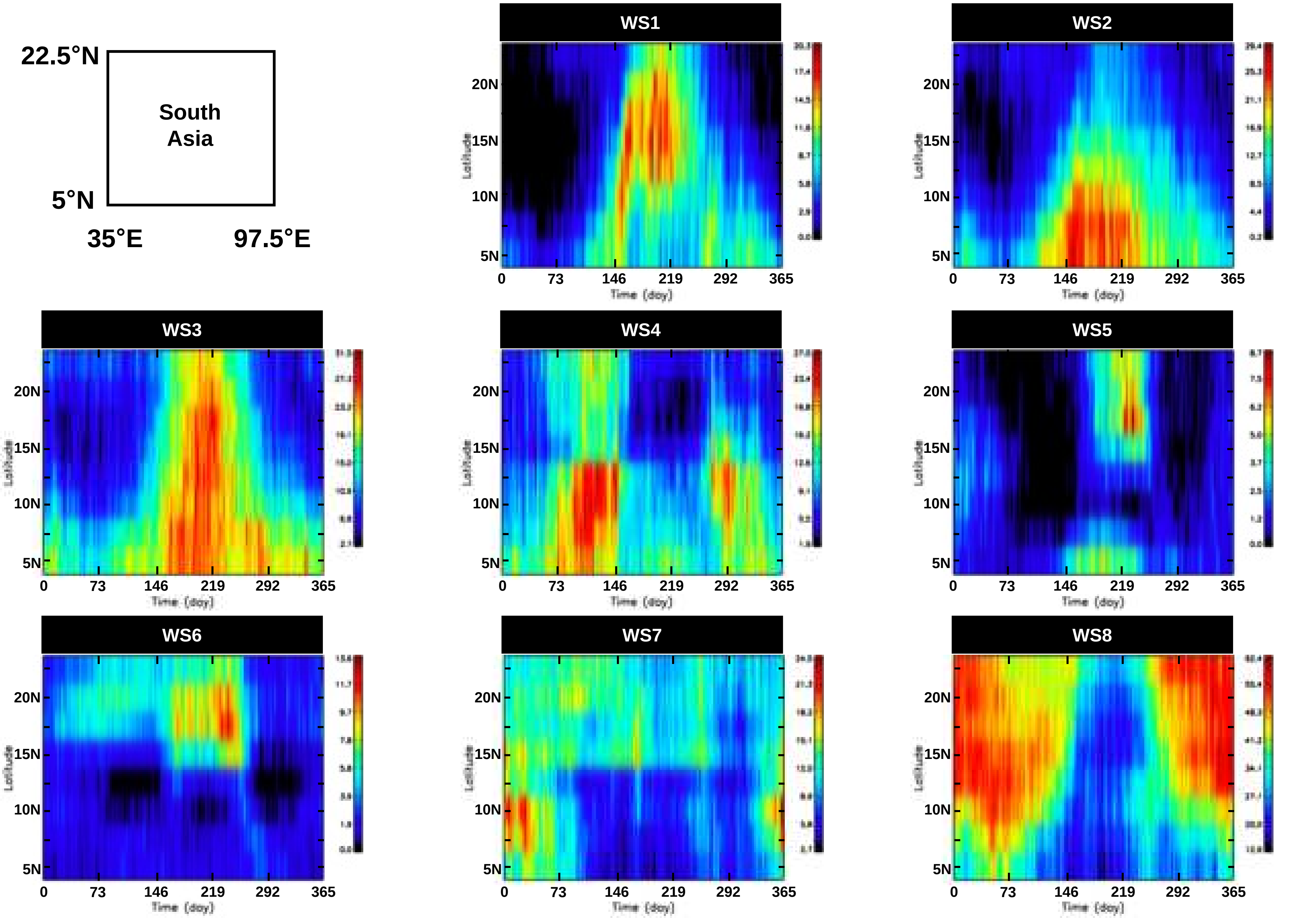
Composite of Annual Cycle of WS1 RFO (1984 - 2006)



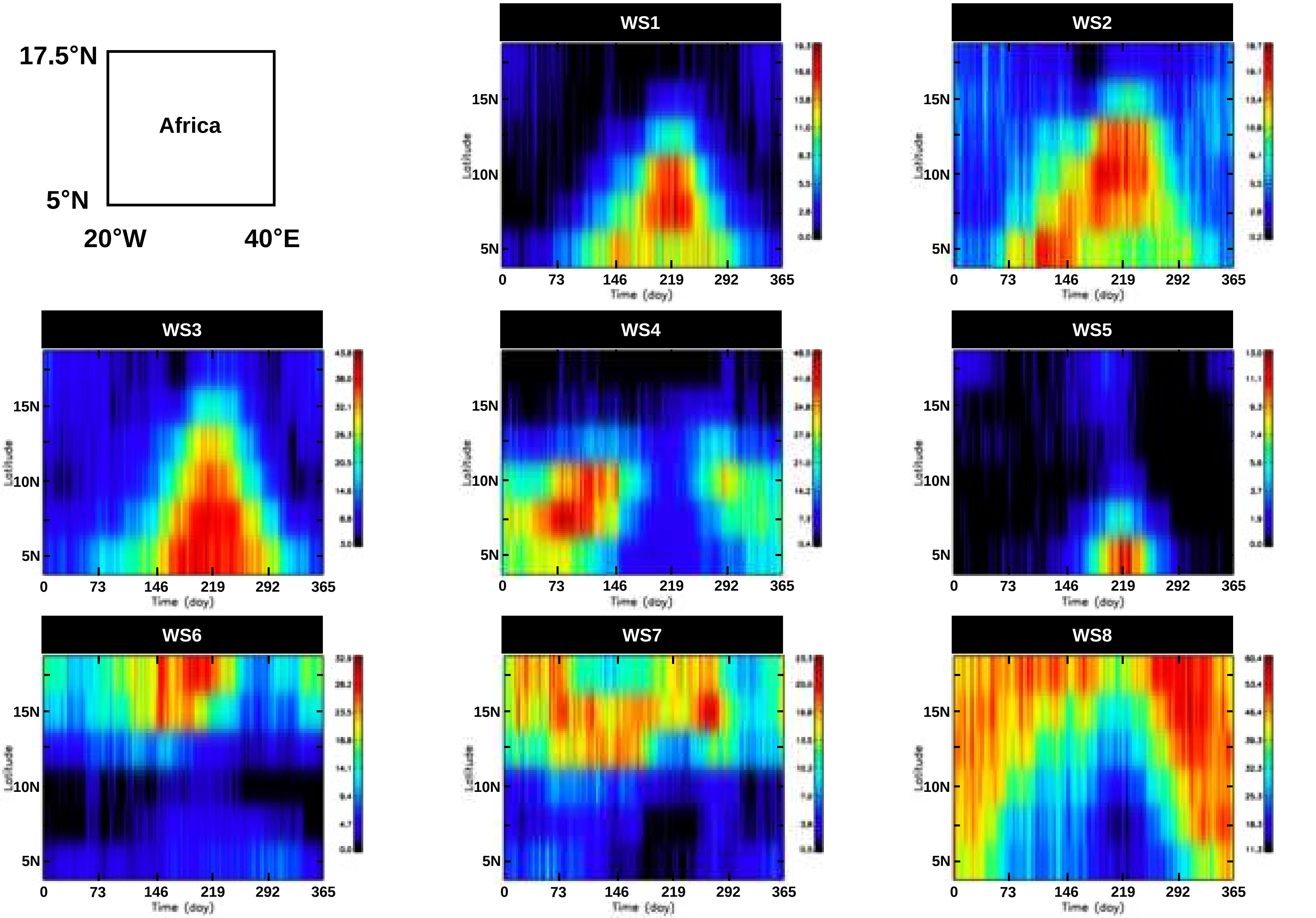
Composite of Annual Cycle of WS3 RFO (1984 - 2006)



Composite of Annual Cycle of RFO (1984 - 2006)



Composite of Annual Cycle of RFO (1984 - 2006)



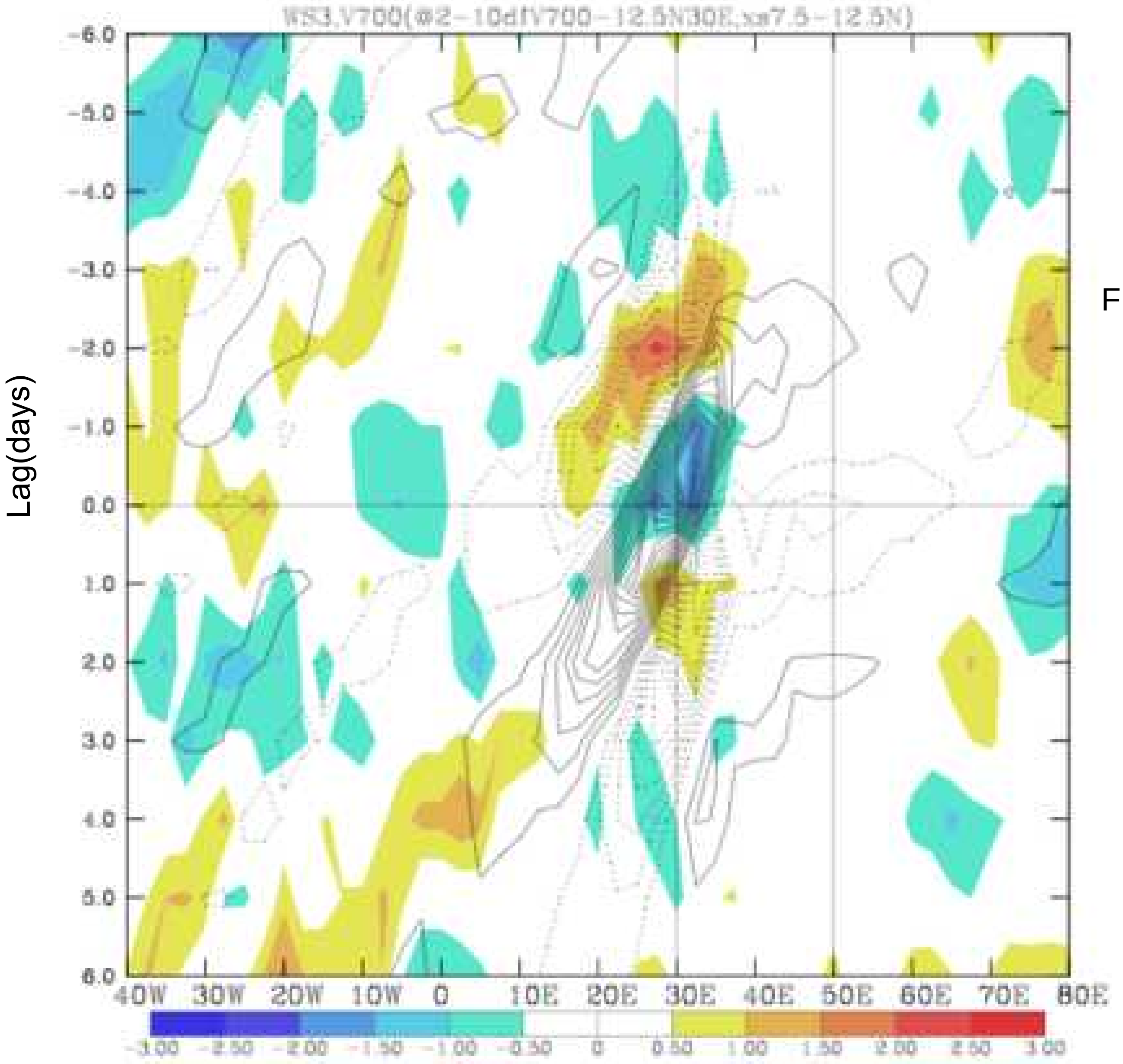


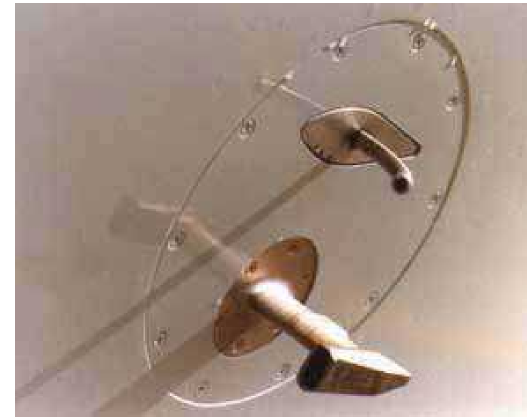
Fig. 7b: as in Fig. 7a but for WS3

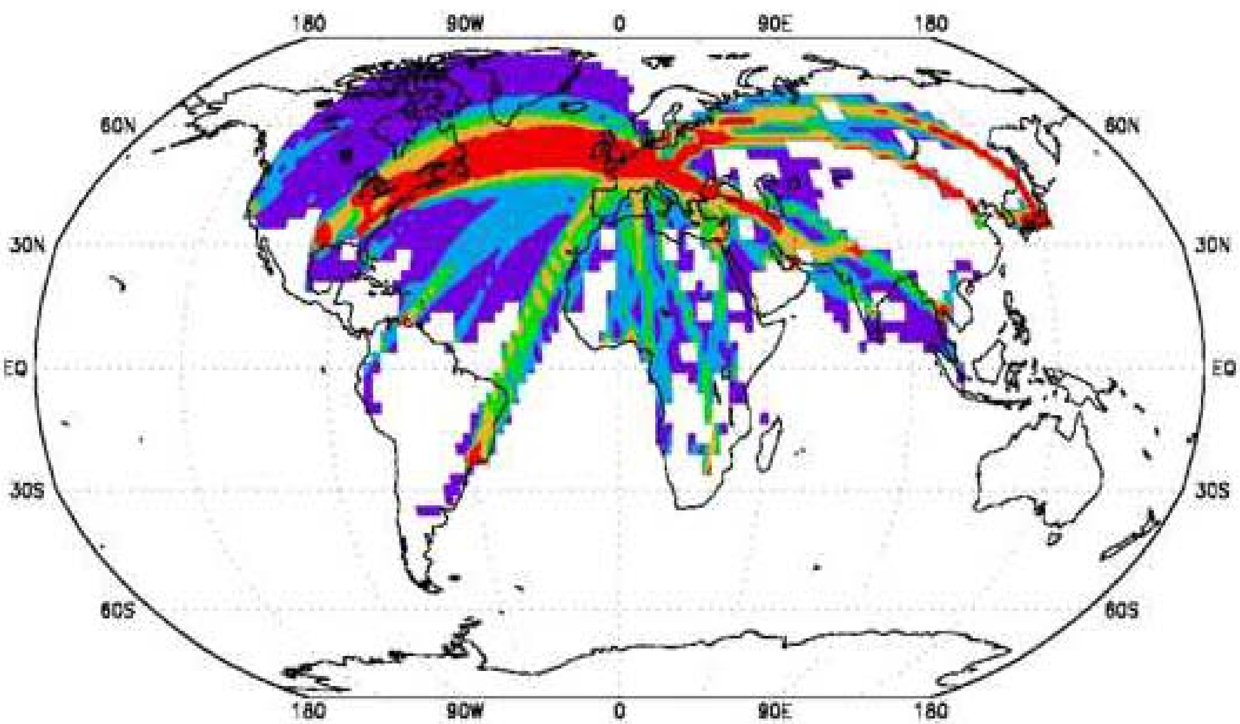
$\vec{u}$

Founded by the EU in 1993;

Five long-range commercial aircraft;

Operational since 08/94 with ~ 2500 flights/yr

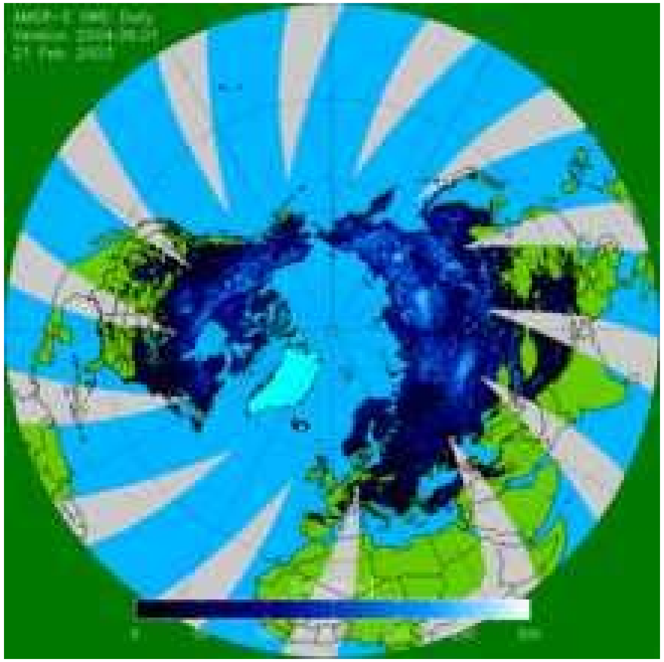


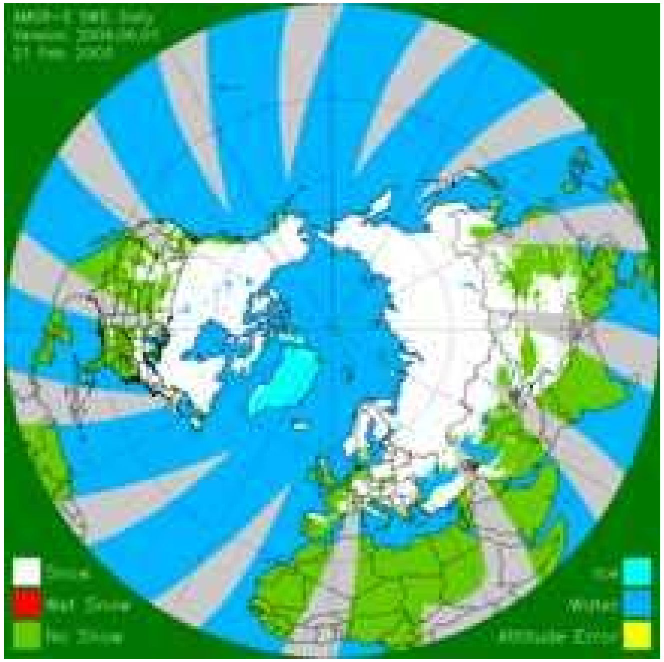


MOZAIC FACTS:

1. Measuring RH, T, *p, u, v*, and O_3 (NO_x and CO since 2000);
2. 1 min & 15 km;
3. Flight levels: ~ 300-200 hPa;
4. RH ~ 5% accuracy
5. O_3~2 ppb accuracy

NASA AMSR-E product





- PI – Tedesco (CUNY)
- co-PI – Kelly (U. Waterloo)
- co-I’s J. Foster (NASA)
- Collaborators: M. Hallikainen, C. Derksen
- Support Specialist: J. Miller

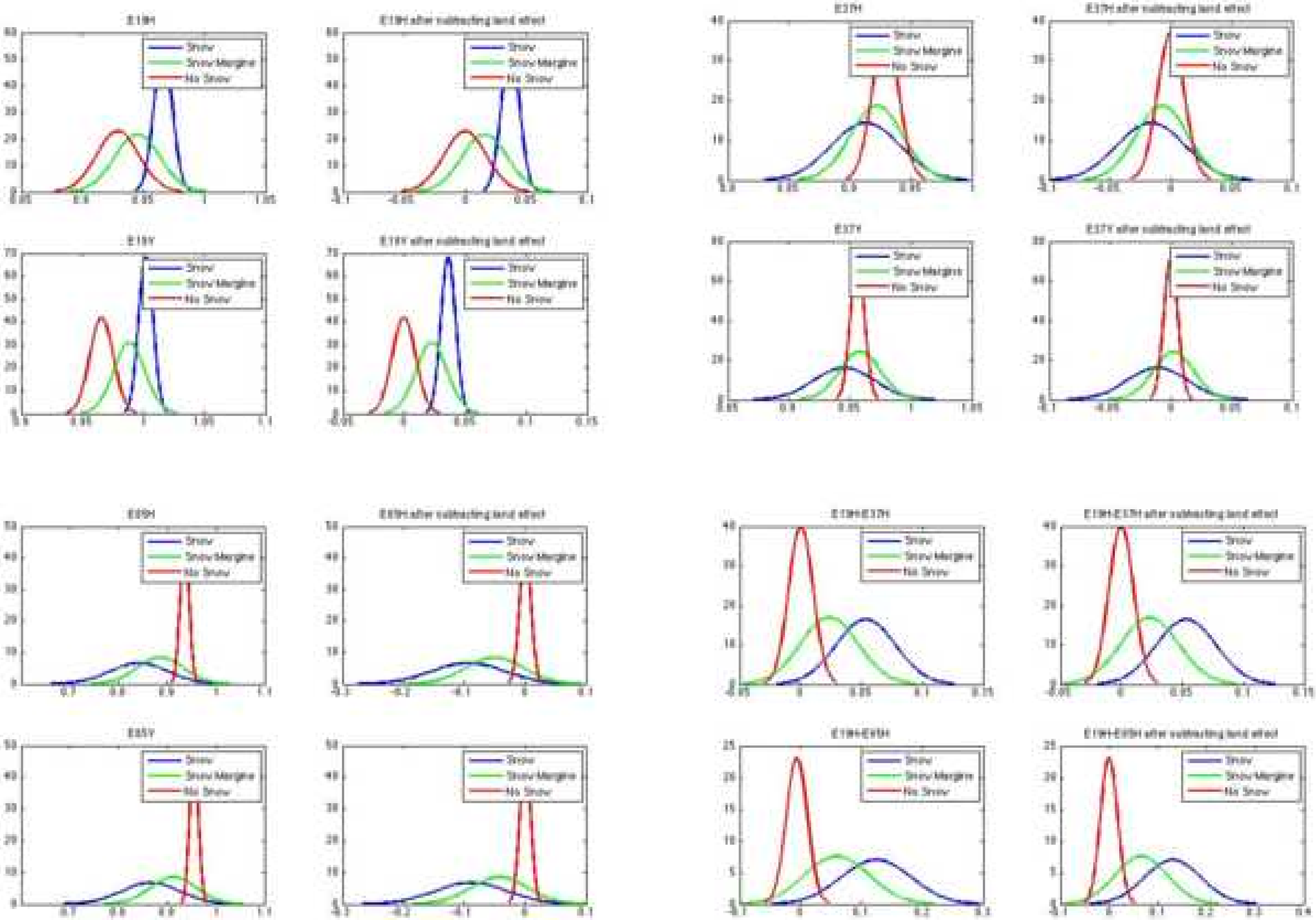
- **Planned field activities:**

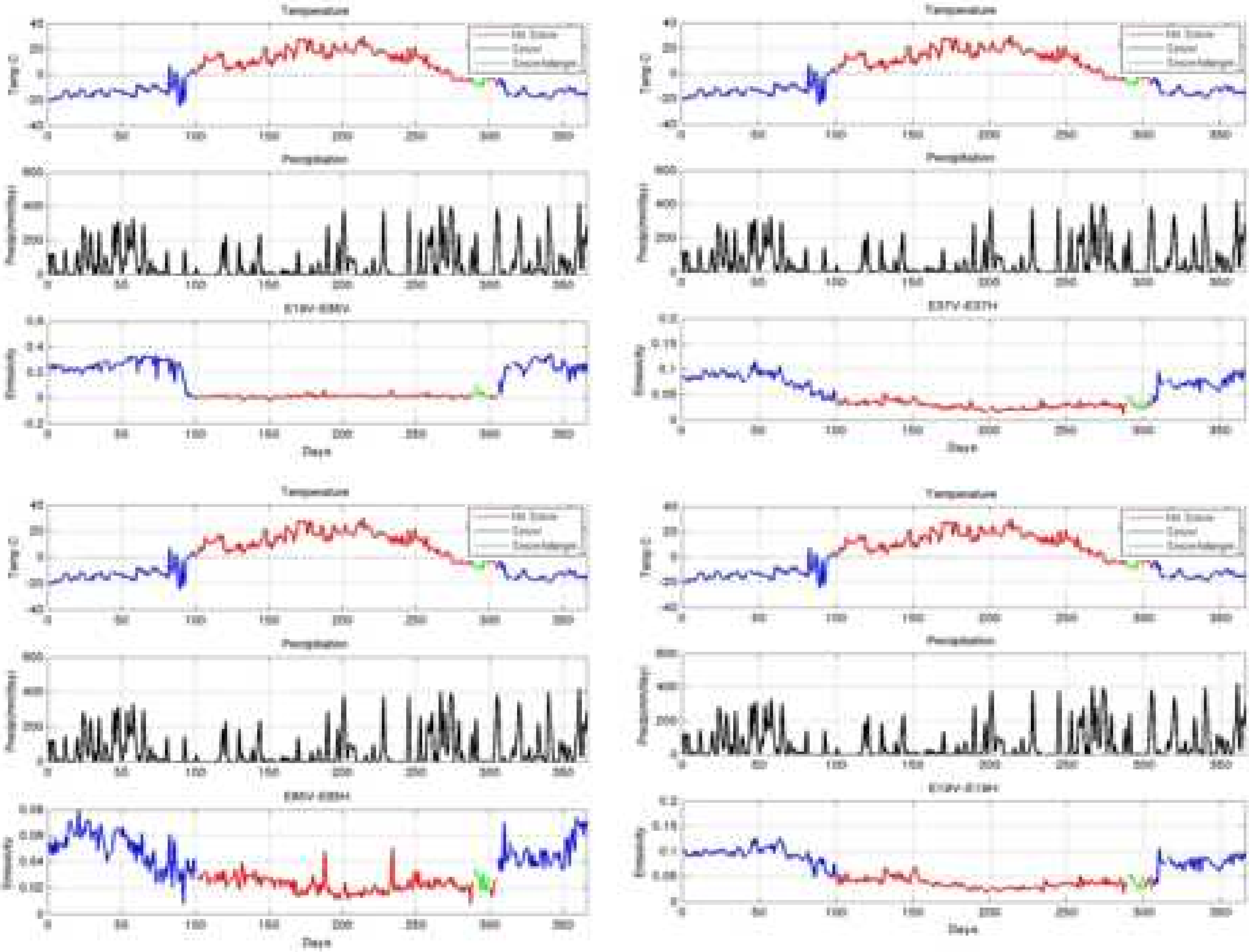
- GAPS10 - Idaho , February 2010
- Fieldwork in Vermont, January , April 2010
- Sodankyla, Finland, March 2010
- Greenland, June 2010

Preliminary Conclusions

Model Input

- AMSU-B
  - Snow product, 183±1, 183±3 GHz
- AMSU-A
  - ATs near 50 GHz (4, 5, 7, 8) and 89GHz
  - Products: Emis@50 GHz, Tsurf
- GOES @ 25 km
  - Mean @ 25 km: Band 3, Band 6
  - Min. - 25 km window: Band 3, Band 6
  - Std. dev – 25 km window: Band 6
- SNODAS @ 25 km – previous day
  - Snow water equivalent (SWE)
  - Snow depth (average)
  - Snow melt (average)
  - Maximum in 25 km window of Non-snow (liquid) precipitation
  - Snow pack sublimation std dev in the 25 km window
- RUC Data
  - TMP @ 675, 600, 575, 550, 525 mb
  - u wind @ 975, 850, 825, 725, 625, 600, 575, 500 mb
  - v wind @ 925 mb
  - Surface lifted index (LFTX) - sfc anl
  - Best lifted index (BLI - to 500 hPa) - sfc anl
  - Storm relative helicity (HLCY) - sfc anl
  - Pressure (PRES) isotherm
  - Geopotential height (HGT) isotherm
  - Temperature (TMP) - tropopause


E19H
E19H after subtracting land effect
E37H
E37H after subtracting land effect
E19V
E19V after subtracting land effect
E37V
E37V after subtracting land effect
E85H
E85H after subtracting land effect
E19H-E37H
E19H-E37H after subtracting land effect
E85V
E19H-E85H
E19H-E85H after subtracting land effect
Snow
Snow Margins
No Snow


Temperature
Precipitation
Days
Temperature
Precipitation
Days
Temperature
Precipitation
Days
Temperature
Precipitation
Days

Information-Theoretic quantities to estimate information flow between different variables □

Mutual information: If we have some knowledge about one variable X, how much information do we also have about another variable Y (amount of information shared between two variables)

$$I(X;Y)=\sum_{x\in X}\sum_{y\in Y} p(x,y)\frac{p(x,y)}{p(x)q(y)}$$

Joint probability

Marginal probabilities

Kullback-Leibler divergence between p(x,y) and p(x)p(y):
Measure of difference of Joint probability from the product of their marginals (thus measure of (in)dependency)

Note that I(X;Y)=I(Y;X), I.e. symmetric. Only provides information shared between X and Y.
No information about the directionality: Does X cause Y; or does Y cause X?

Solution: Make use of the generalized Markov property: Test if future sample X_{i+1} depends only on its past *k* samples $\left(\mathbf{X}_i^{(k)}\right)$ but not on past *l* samples of variable Y $\left(\mathbf{Y}_j^{(l)}\right)$: Measure the Kullback divergence between

$$p\left(x_{i+1}\middle|\mathbf{x}_\mathbf{i}^{(\mathbf{k})},\mathbf{y}_\mathbf{j}^{(\mathbf{l})}\right) \quad \text{and} \quad p\left(x_{i+1}\middle|\mathbf{x}_\mathbf{i}^{(\mathbf{k})}\right)$$

$$TE_{Y\to X}=T\left(X_{i+1}\middle|\mathbf{X}_\mathbf{i}^{(\mathbf{k})},\mathbf{Y}_\mathbf{j}^{(\mathbf{l})}\right)=\sum_{i=1}^{N} p\left(x_{i+1},\mathbf{x}_\mathbf{i}^{(\mathbf{k})},\mathbf{y}_\mathbf{j}^{(\mathbf{l})}\right)\log_2\frac{p\left(x_{i+1}\middle|\mathbf{x}_\mathbf{i}^{(\mathbf{k})},\mathbf{y}_\mathbf{j}^{(\mathbf{l})}\right)}{p\left(x_{i+1}\middle|\mathbf{x}_\mathbf{i}^{(\mathbf{k})}\right)}$$

Similarly, in the other direction:

$$TE_{X\to Y}=T\left(Y_{i+1}\middle|\mathbf{Y}_\mathbf{i}^{(\mathbf{k})},\mathbf{X}_\mathbf{j}^{(\mathbf{l})}\right)=\sum_{i=1}^{N} p\left(y_{i+1},\mathbf{y}_\mathbf{i}^{(\mathbf{k})},\mathbf{x}_\mathbf{j}^{(\mathbf{l})}\right)\log_2\frac{p\left(y_{i+1}\middle|\mathbf{y}_\mathbf{i}^{(\mathbf{k})},\mathbf{x}_\mathbf{j}^{(\mathbf{l})}\right)}{p\left(y_{i+1}\middle|\mathbf{y}_\mathbf{i}^{(\mathbf{k})}\right)}$$

TRANSFER ENTROPY

$$\mathbf{x}_\mathbf{i}^{(\mathbf{k})}=\{x_i,\ldots,x_{i-k+1}\}$$

Application: Lorenz equations

$$\frac{dx}{dt} = \sigma(y - x)$$

$$\frac{dy}{dt} = -xz + rx - y$$

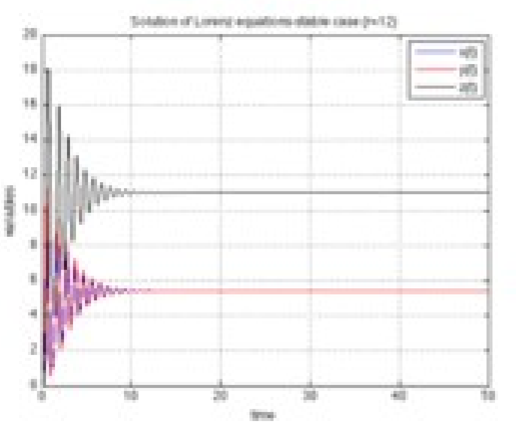
$$\frac{dz}{dt} = xy - bz$$

Parameters: $\sigma = 10; \quad b = 8/3; \quad r$: *Rayleigh number*

Initial conditions: $x = 0, y = 1, z = 0$

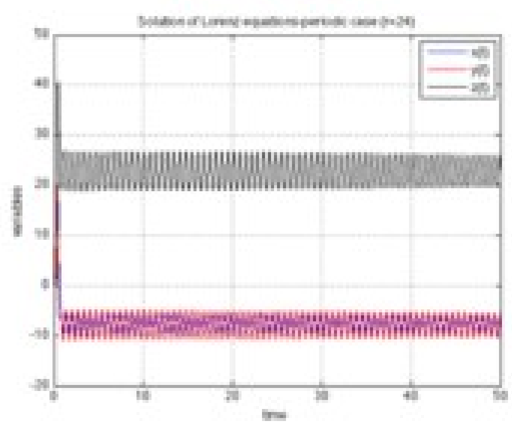
r = 12

Stable Regime



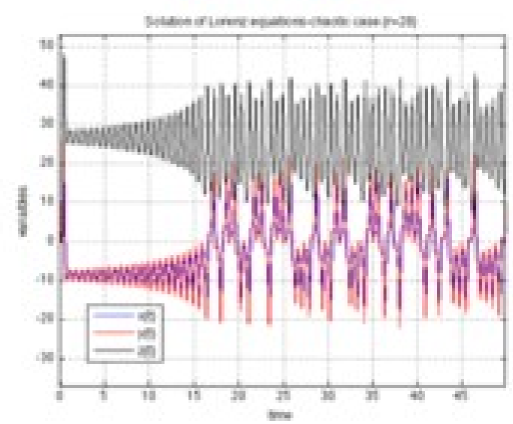
r = 24

Periodic Regime



r = 28

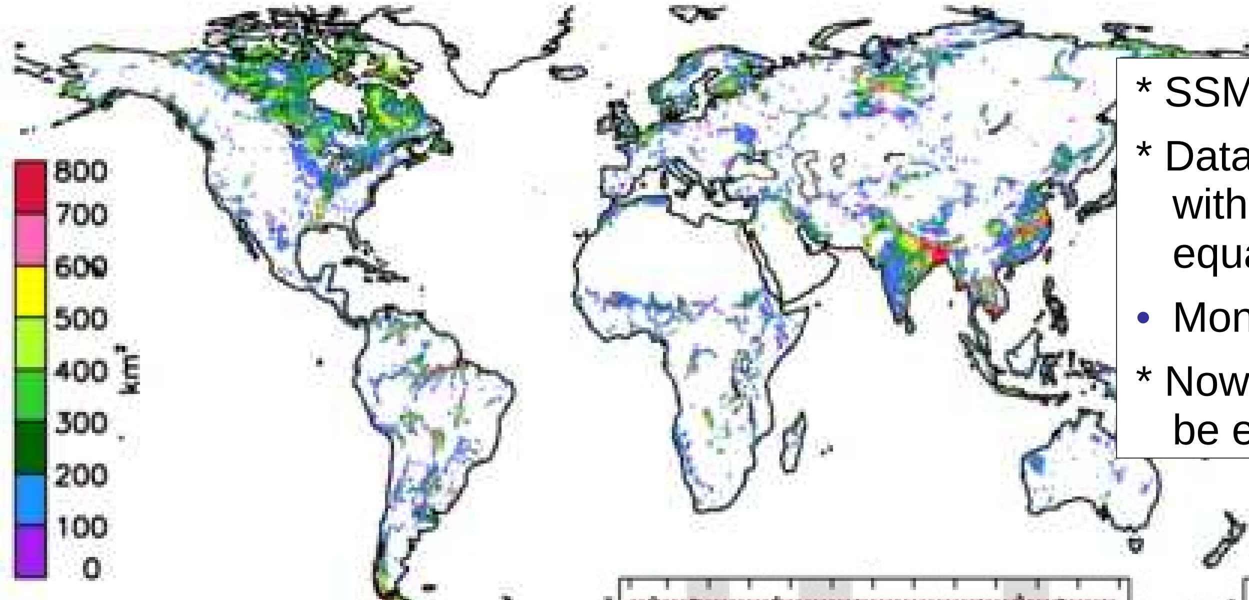
Chaotic Regime



FABRICE’S SLIDES

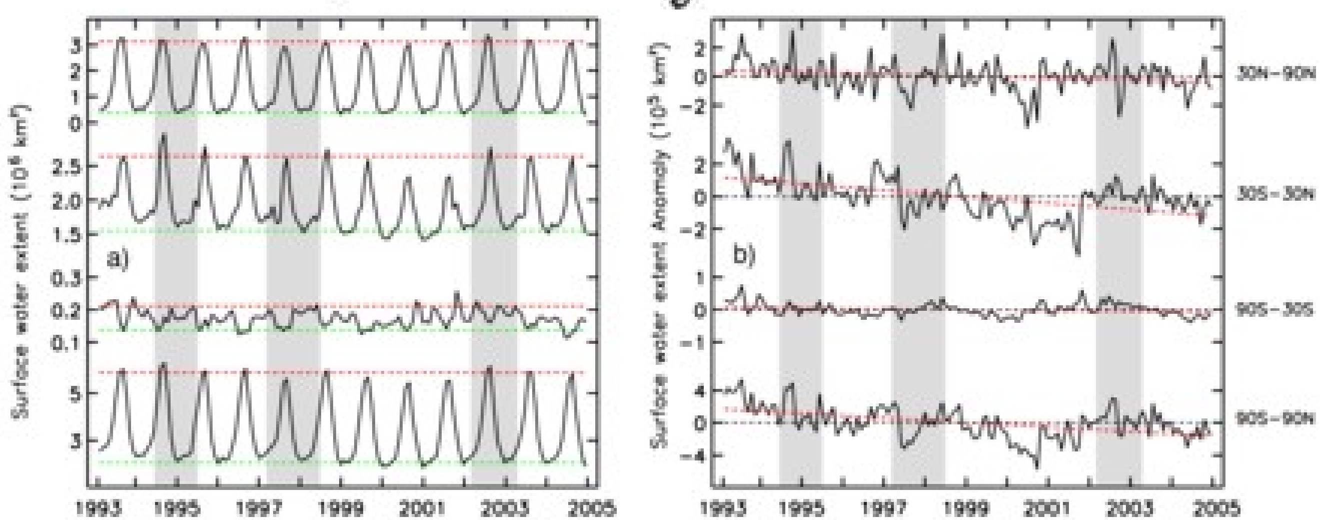
Dynamic of global surface water from multi-satellite observations (Papa, Rossow, Prigent)

Mean surface water extent (km²) at annual maximum



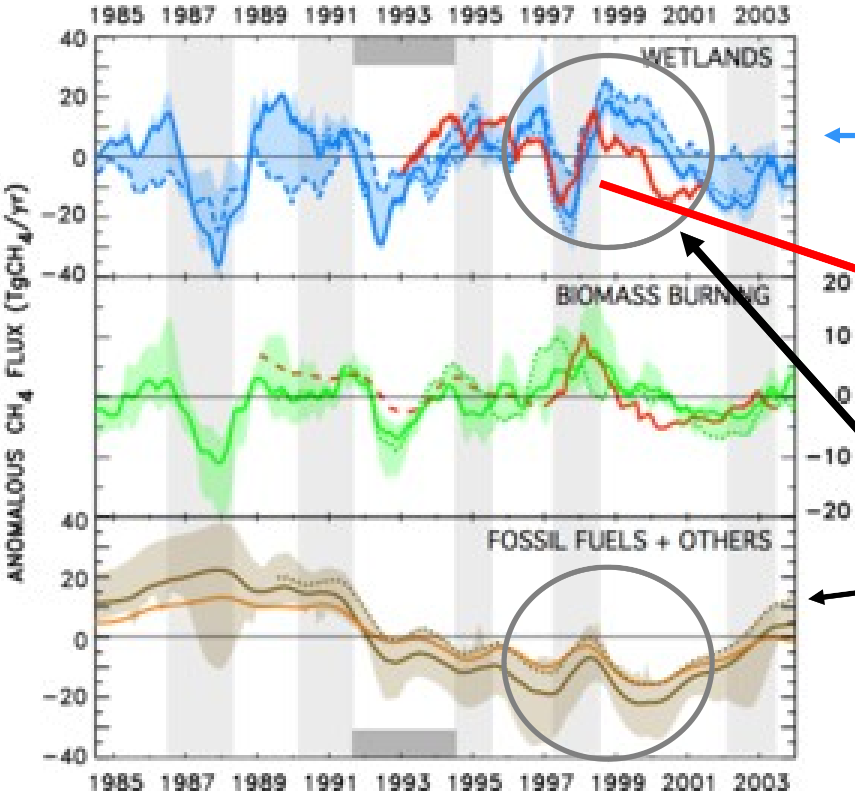
* SSM/I emis, ERS scatt, AVHRR
* Data mapped on equal-area grid with 0.25°x0.25° resolution at equator (773 km²)
- Monthly resolution, soon daily
* Now for 1993-2004 and at least to be extended to 2012 and longer

1993-2004, monthly surface water extent variations by latitude zones: decrease of ~6% in the Tropics



Direct Applications:

- **Understanding hydrological processes and floods dynamic**
- **Validation/ Improvement of hydrological models**
- **Surface waters are the largest natural sources of CH4: this data is used in CH4 models or to help separate the different contributions (anthropogenic, fire, wetlands…)**



Wetlands are the bigger contributors to the interannual variability in methane emissions

CH4 emissions from wetlands estimated from multi-sat. method

Since 1999, compensation between an increase in anthropogenic emission and a decrease in CH4 emissions from wetlands

Bousquet et al, *Nature*, 2006

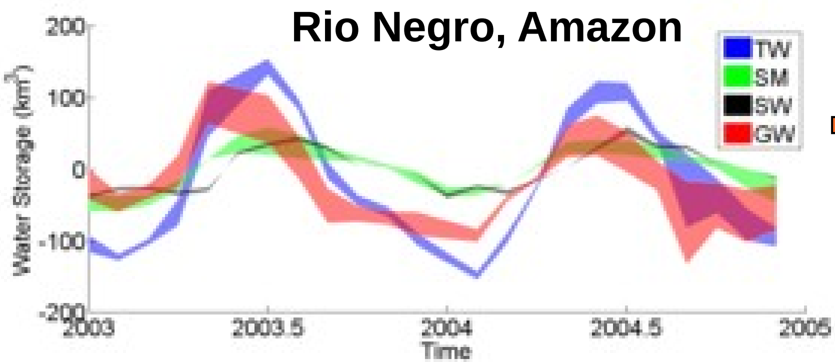
Combining this dataset with other observations:

With radar altimetry and DEM, it provides land surface water volume change

Decomposition of water falling on land into the different components of the water balance equation

GRACE(Total water storage)= Surface water storage+Soil Moisture+Groundwater

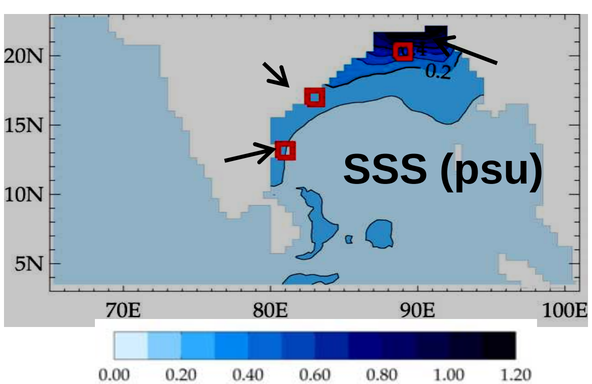
SMOS/SMAP



Contribution of terrestrial surface water to sea level change?

Impact of terrestrial hydrology to other climatic components:

Ex: Impact of river discharge on ocean circulation, sea surface salinity….:



Large impact of fresh water fluxes from rivers into the Bay of Bengal in terms of salinity and ocean stratification

Impact on SST, **cyclogenesis**, monsoon variability