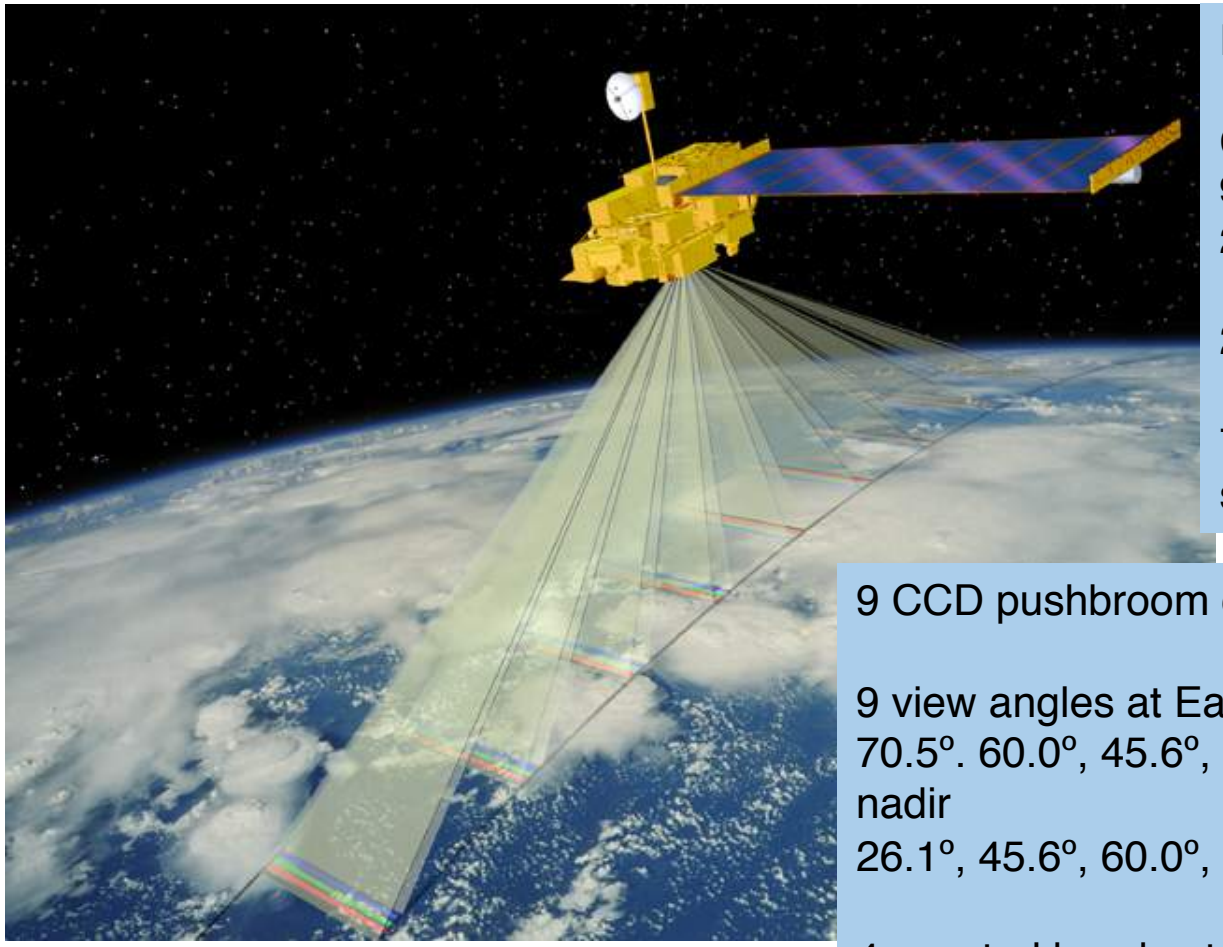
An Overview of MISR Cloud-Top-Heights and Optical Depth Histograms

Roger Marchand
Andrew Geiss
Thomas Ackerman
University of Washington
Dept. of Atmospheric Sciences

Multiangle Imaging SpectroRadiometer (MISR) attributes



Polar Orbit with 400-km swath

Contiguous zonal coverage:
9 days at equator
2 days at poles

275 m sampling

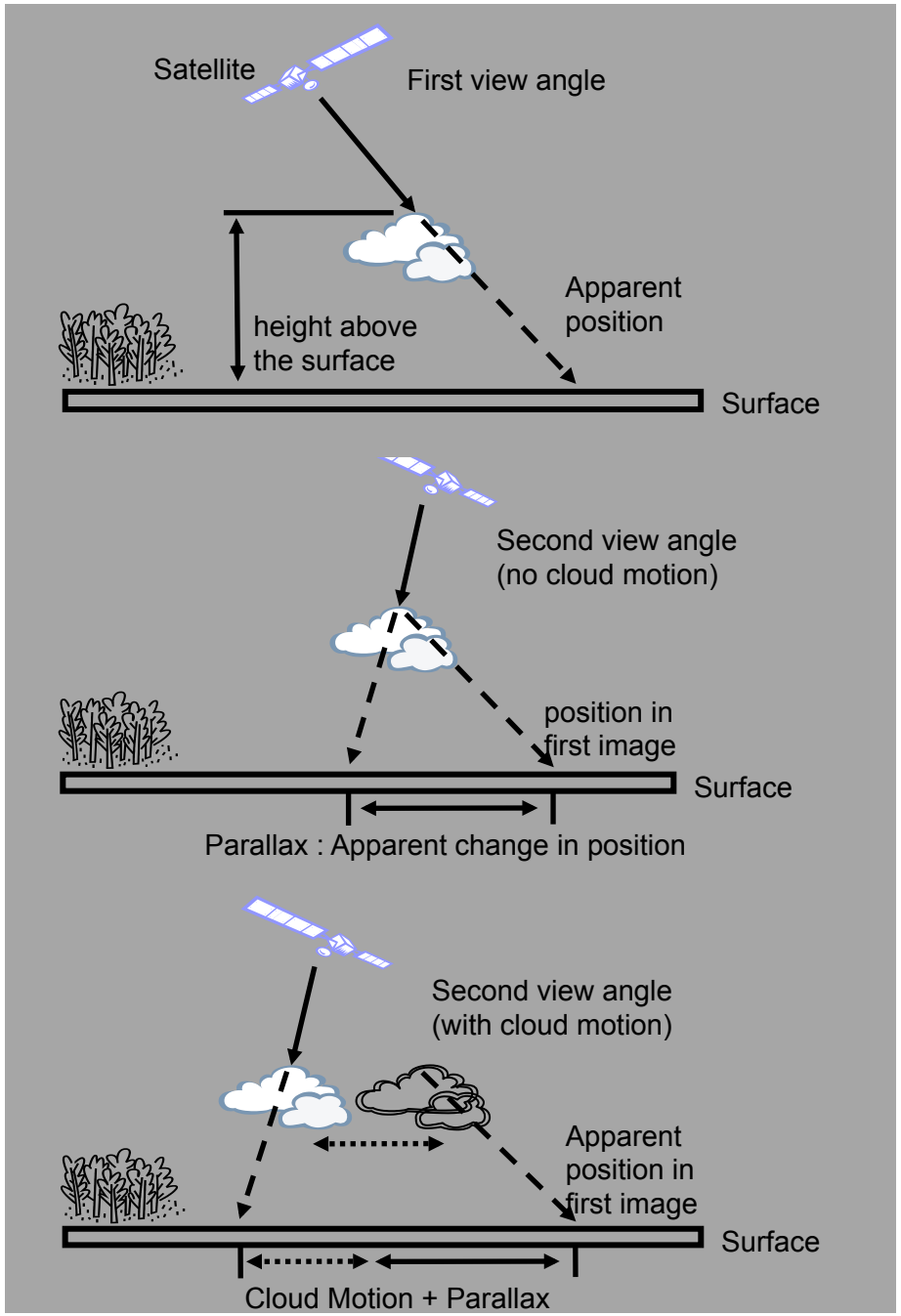
7 minutes to observe each scene at all 9 angles

9 CCD pushbroom cameras

9 view angles at Earth surface:
70.5º. 60.0º, 45.6º, 26.1º forward of nadir
nadir
26.1º, 45.6º, 60.0º, 70.5º backward of nadir

4 spectral bands at each angle
446, 558, 672, 866 nm

14-bit digitization
On-board calibration system



Stereo-imaging

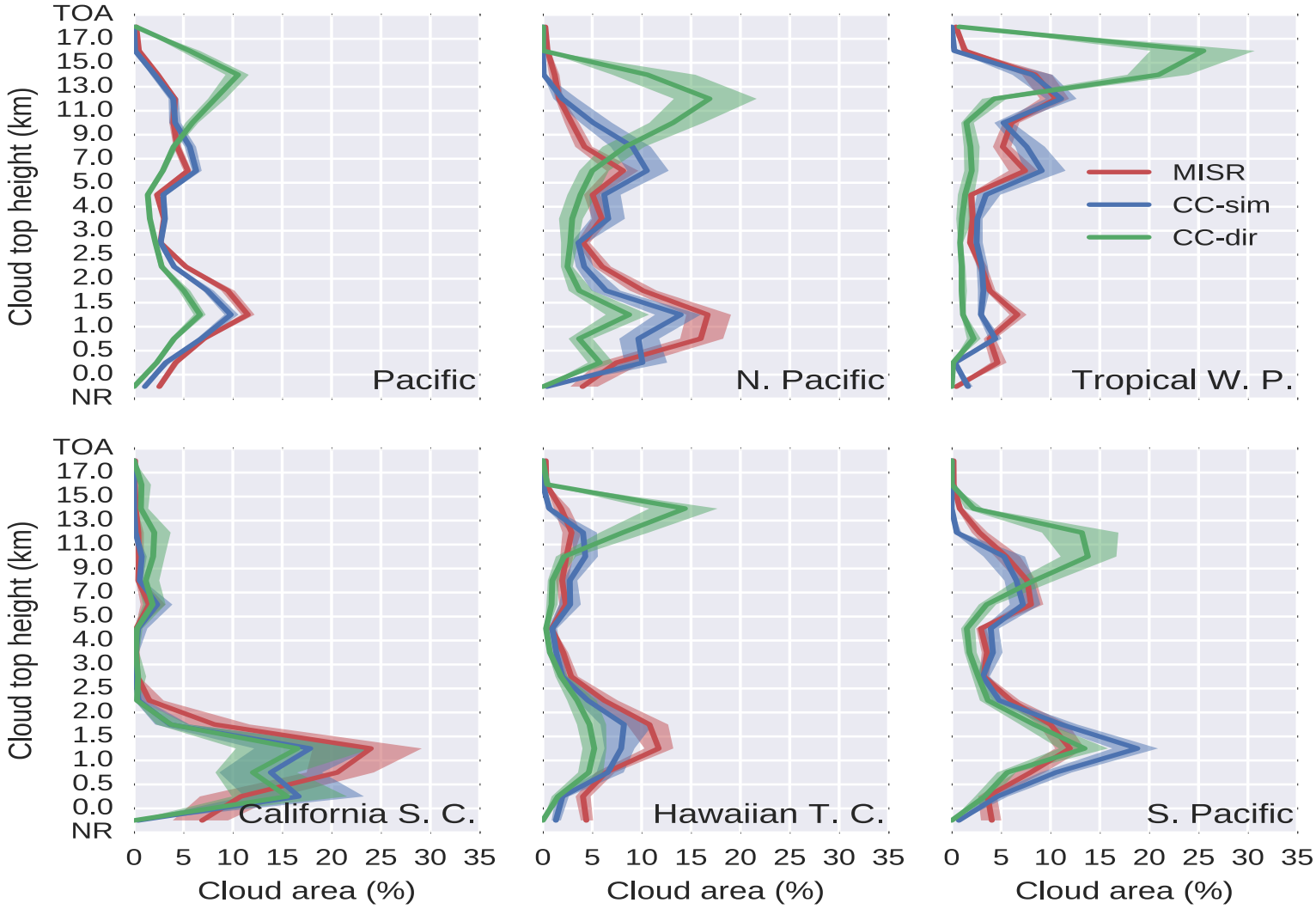
- MISR CTH retrieval is purely geometric and has little sensitivity to the sensor calibration.
- The retrieval has been the focus of several studies including : Hillman et al. (2017), Marchand et al. (2007), Naud et al. (2002, 2004, and 2005a,b), Seiz et al. (2005), Marchand et al. (2001).

Cloud-Top-Height Distribution

Calipso + CloudSat

MISR

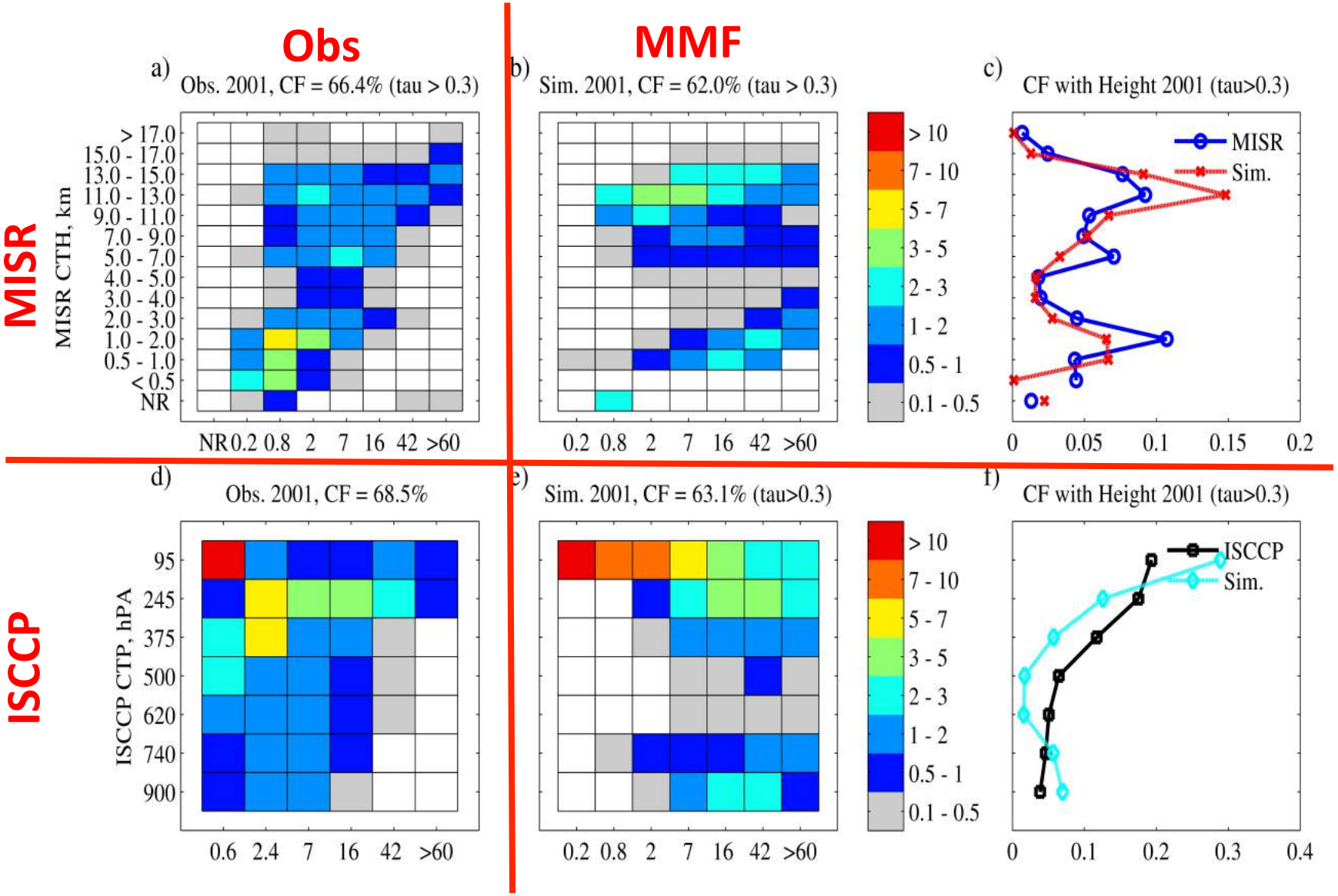
MISR Simulator



Hillman et al. 2017

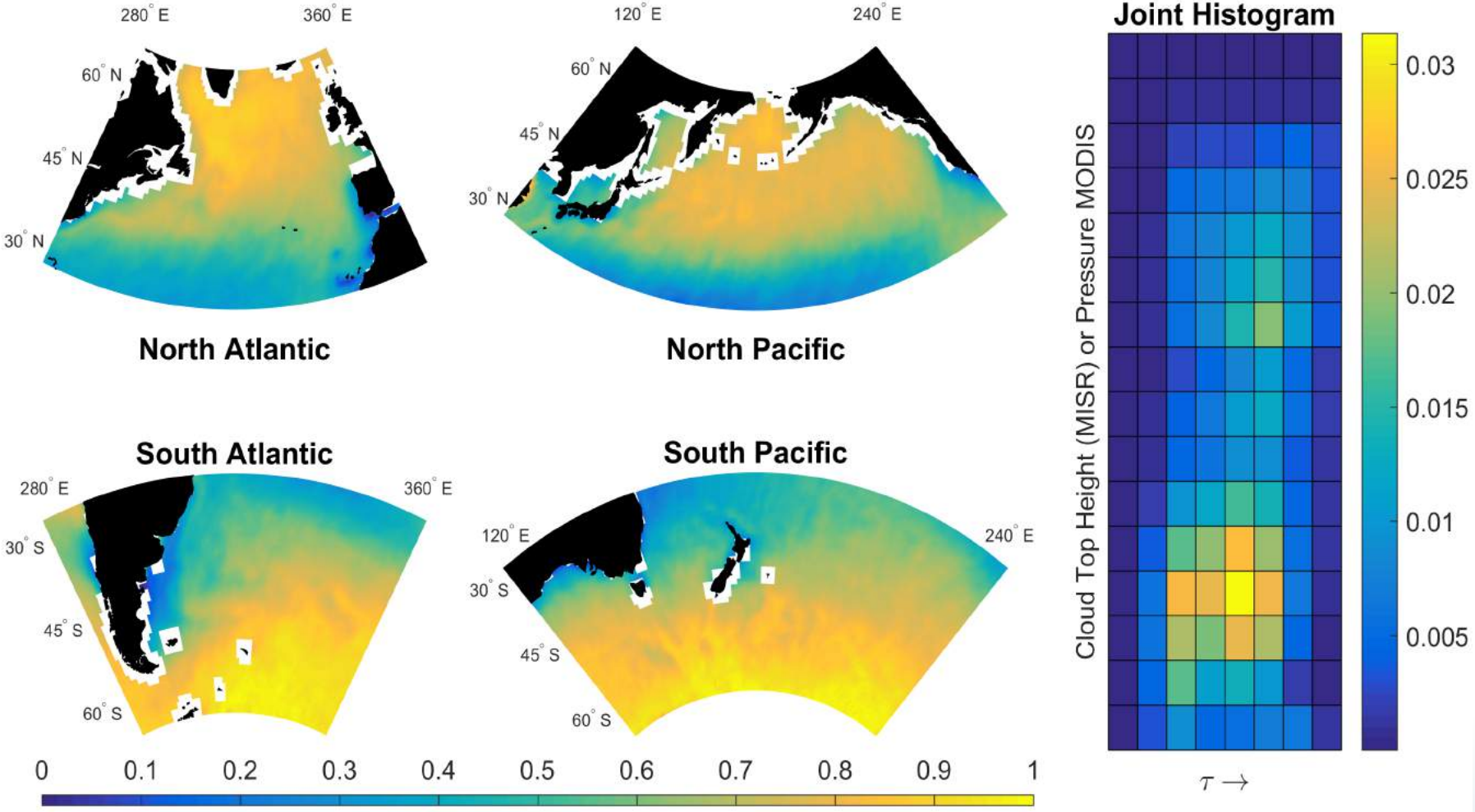
Tropical Western Pacific – Comparison of MMF (4km), ISSCP and MISR

Marchand et al. 2009

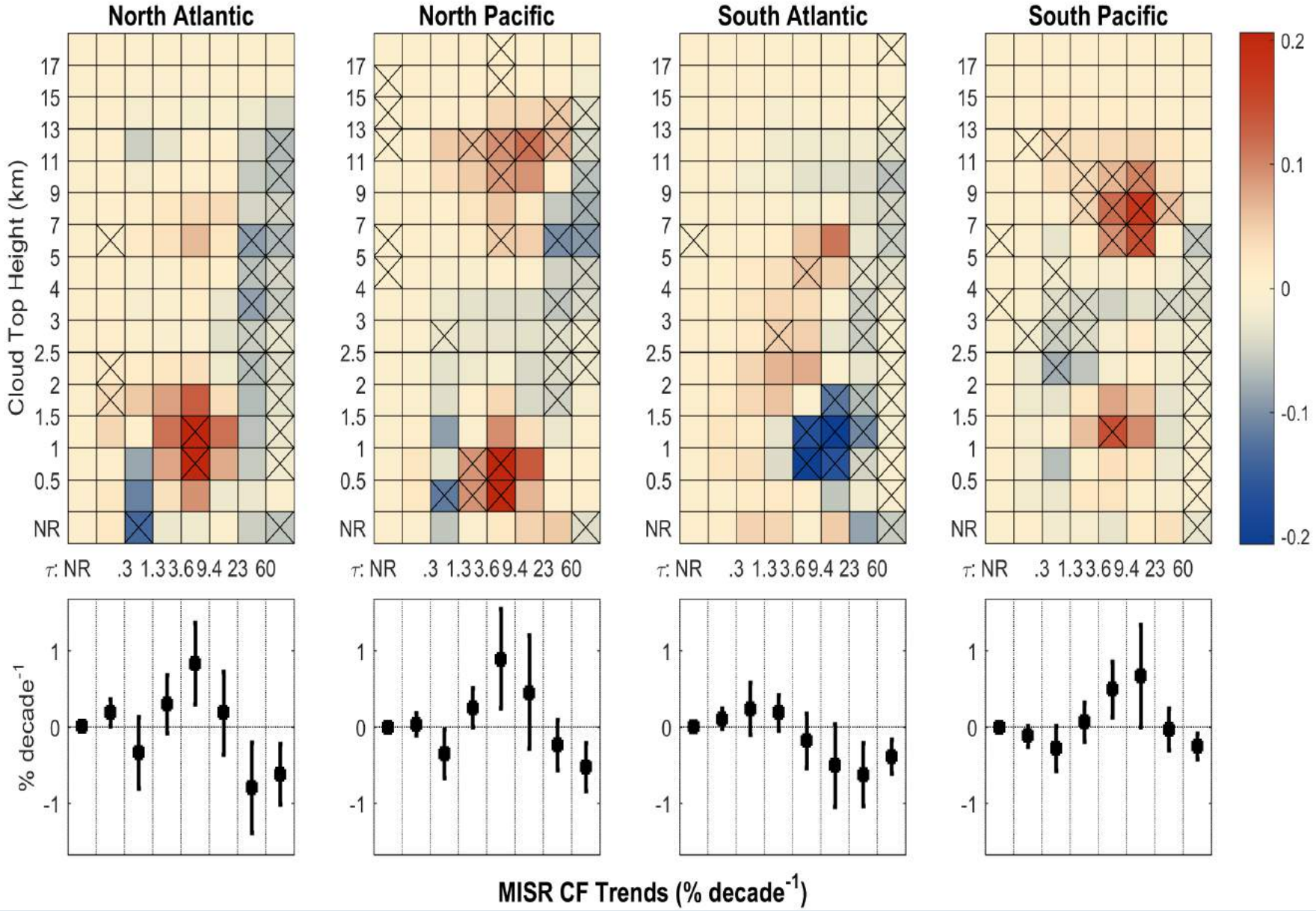


Trends ?

Extratropical Ocean Basins



Trends in MISR Joint-Histograms



Marchand 2013, but for period 2001 to 2013

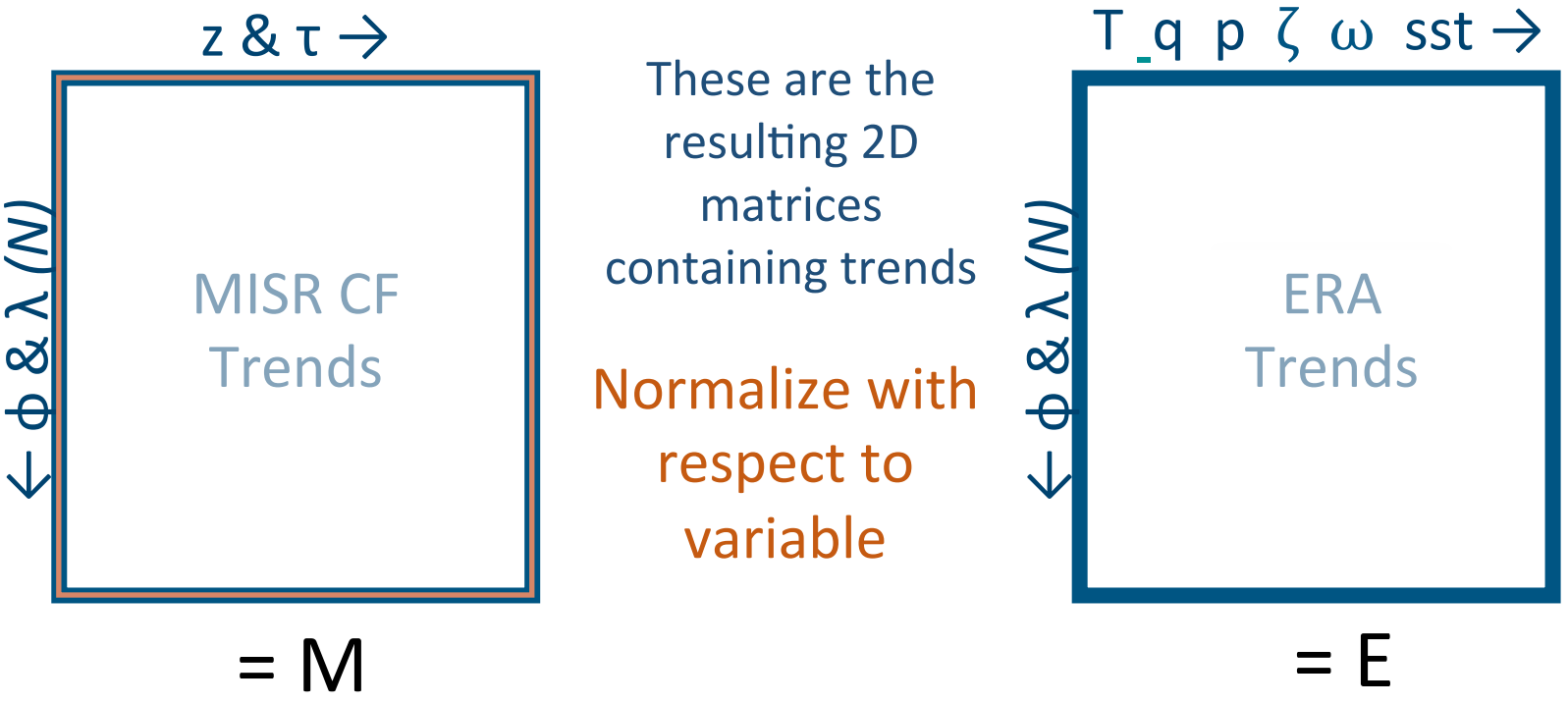
How are these cloud trends related to a changes in large-scale/synoptic activity ?

1) Maximum Covariance Analysis

Geiss and Marchand, submitted

2) Neural Network Classification

MCA Description



Now compute covariance: $C = M^T E$

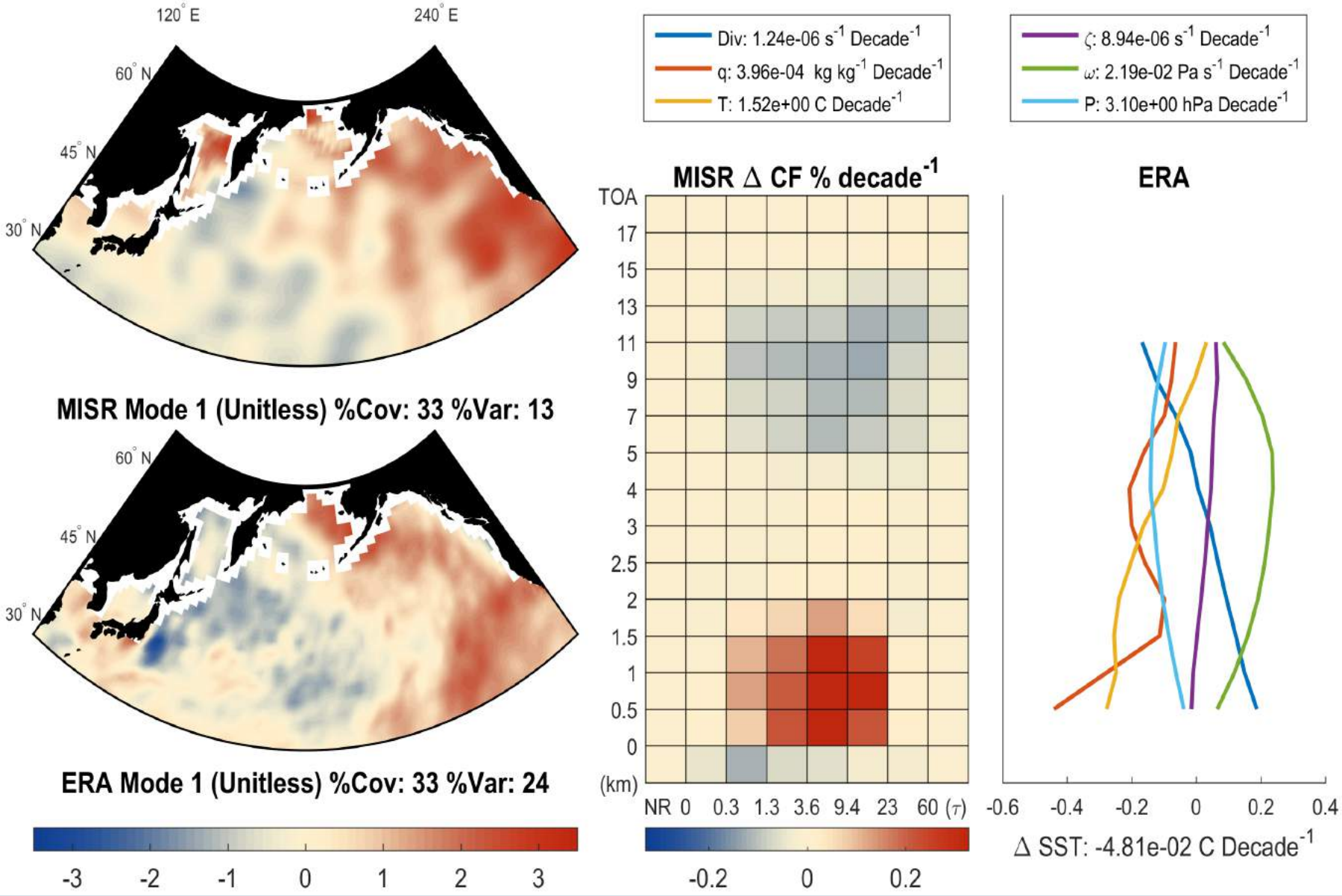
… and perform SVD: $C = U\Sigma V^T$

… so ***U*** contains MISR joint histogram patterns

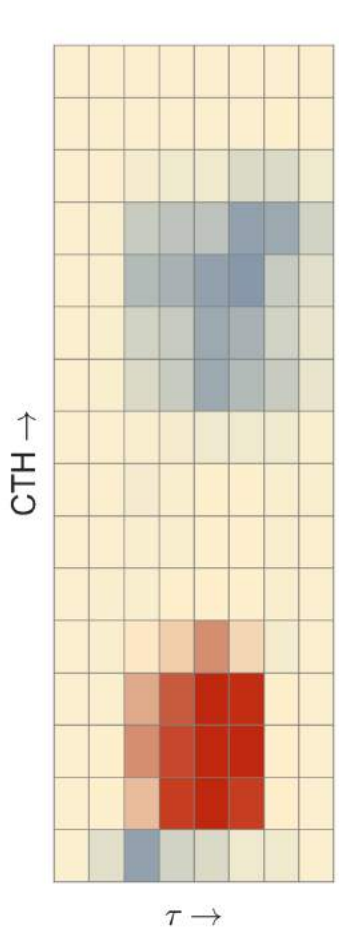
… and ***V*** contains ERA profiles

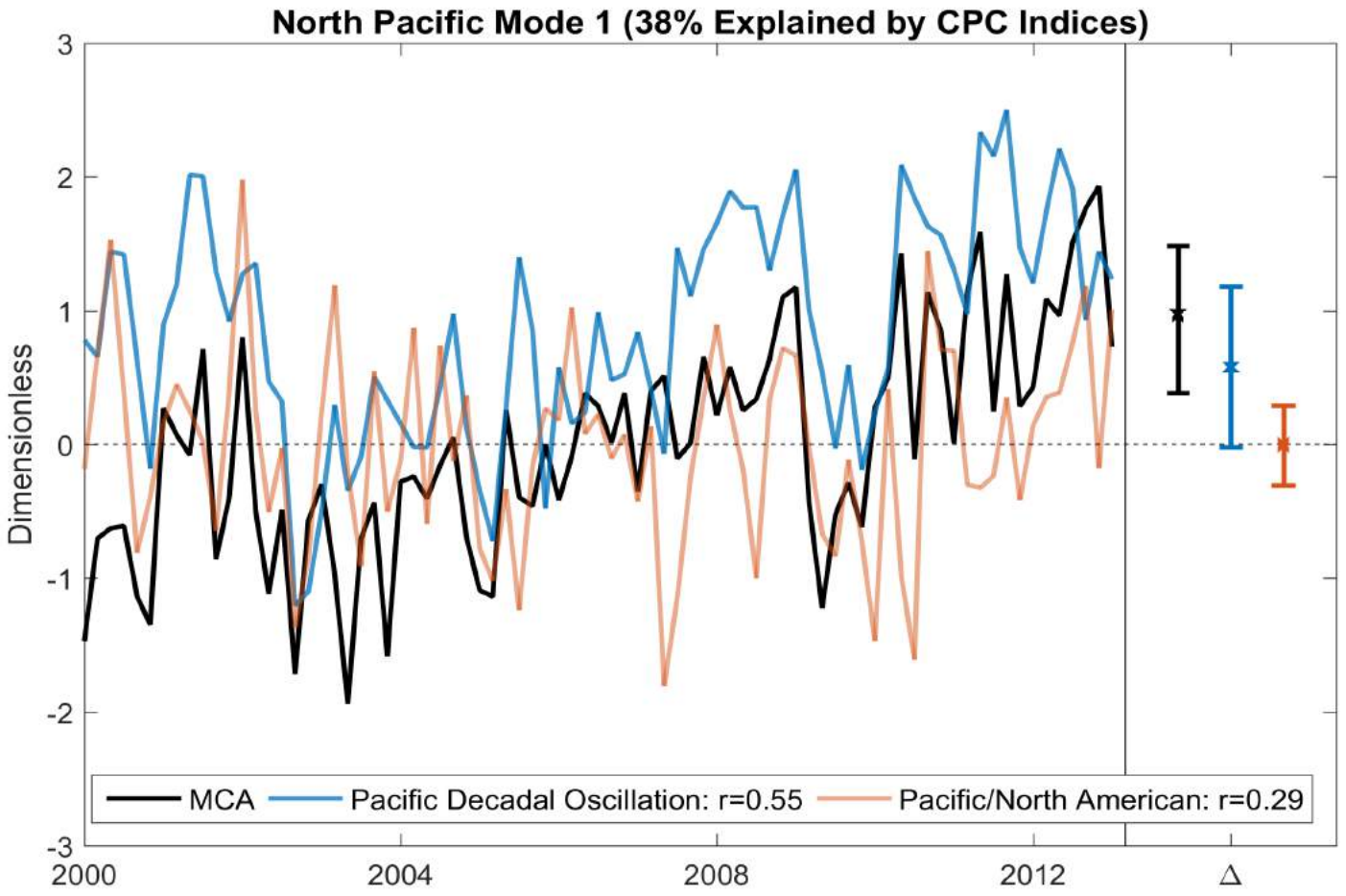
… and **Σ** is a diagonal matrix of the eigen values.

MCA Results: North Pacific (Mode 1)

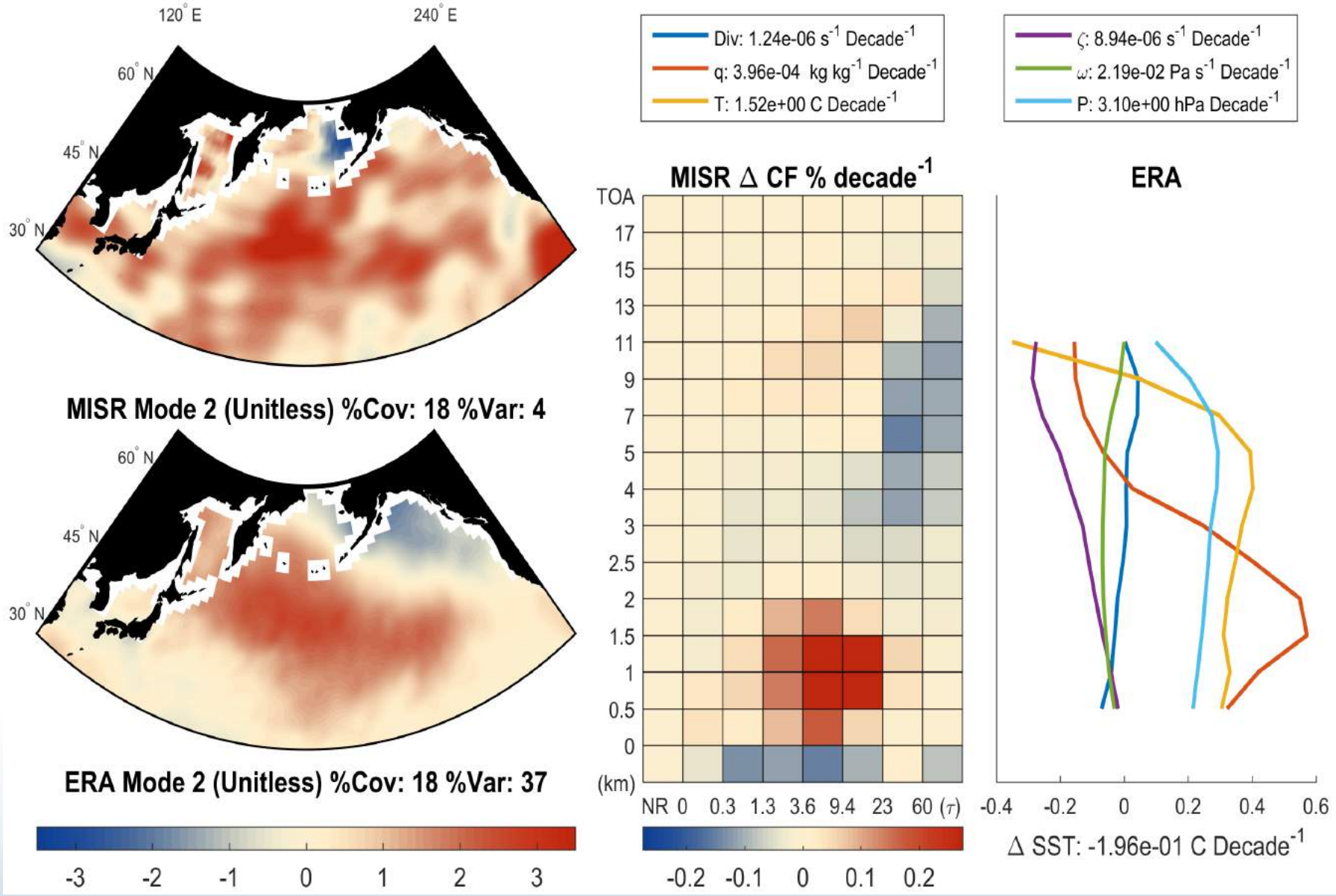


NP1 and **Pacific Decadal Oscillation** (PDO)

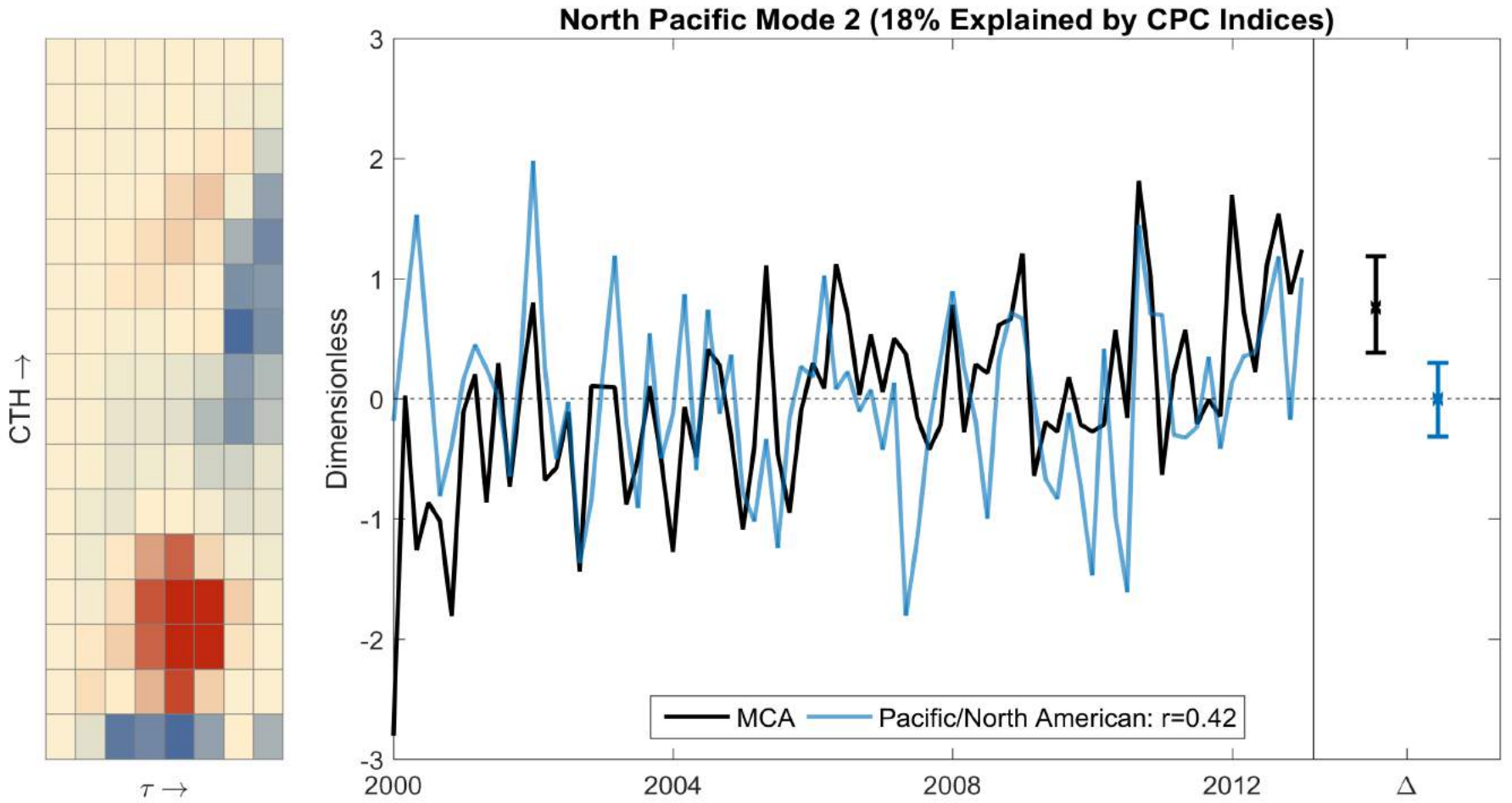




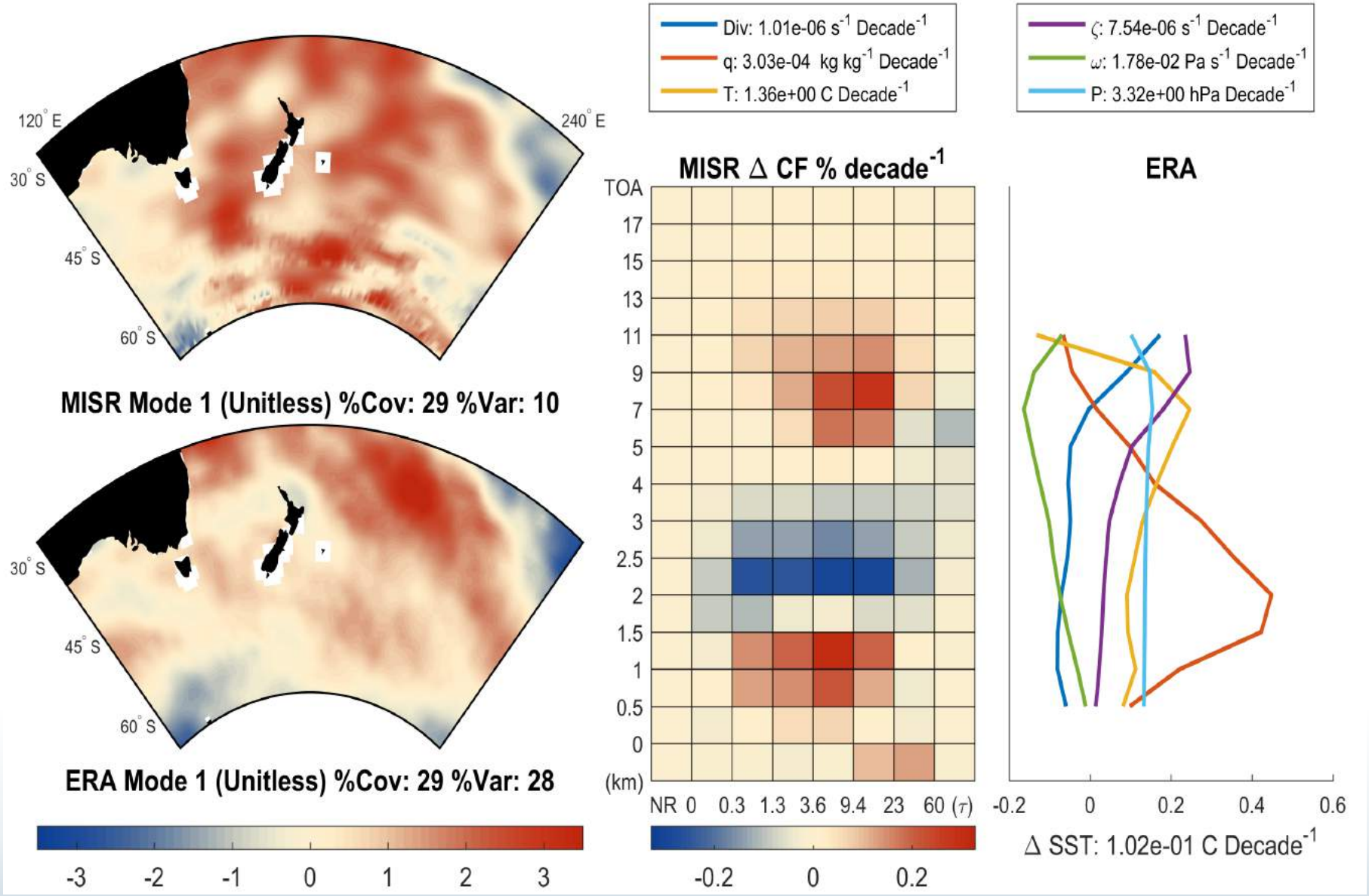
MCA Results: North Pacific (Mode 2)



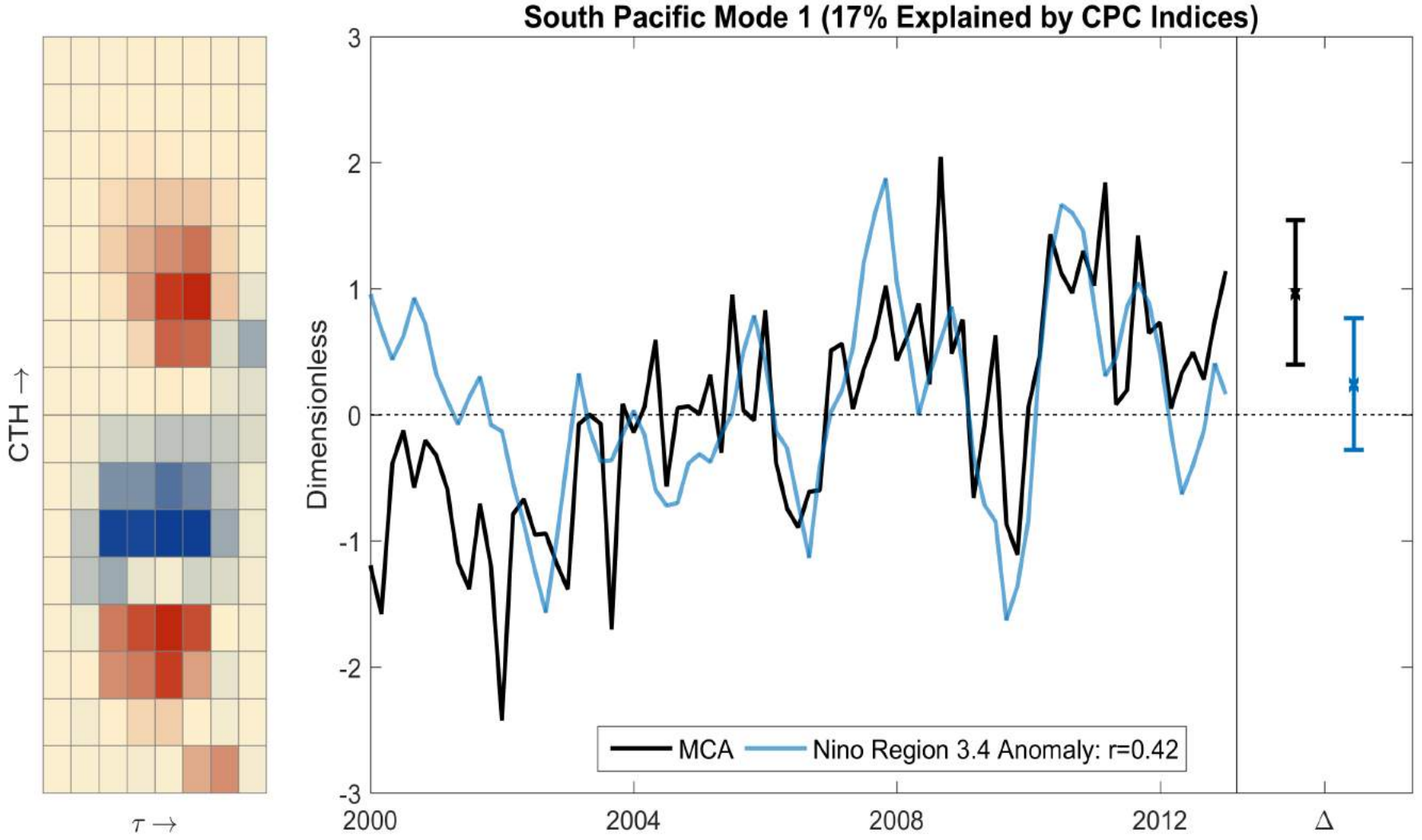
NP2 and **Pacific North America** (PNA) Pattern



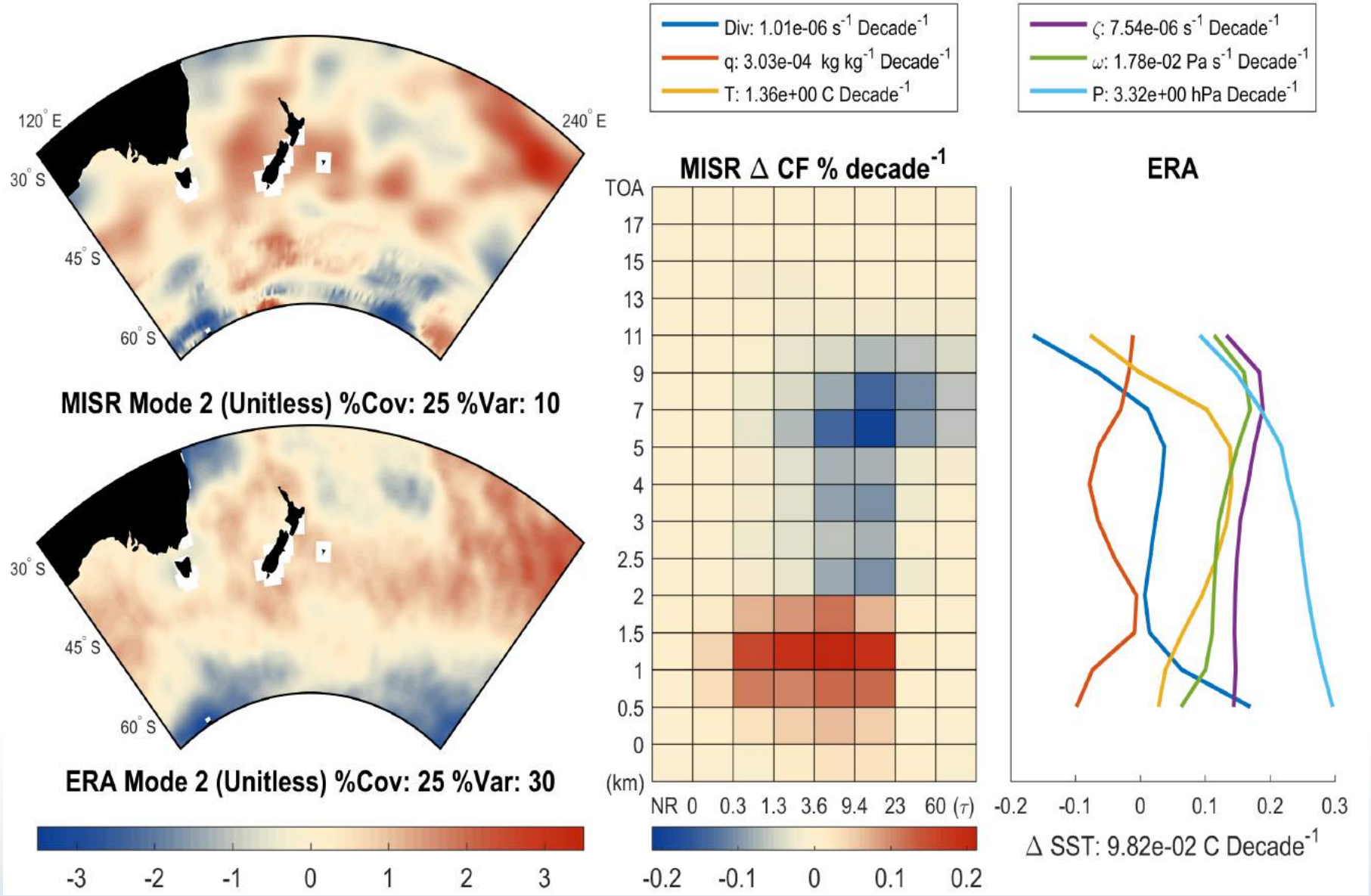
MCA Results: South Pacific (Mode 1)



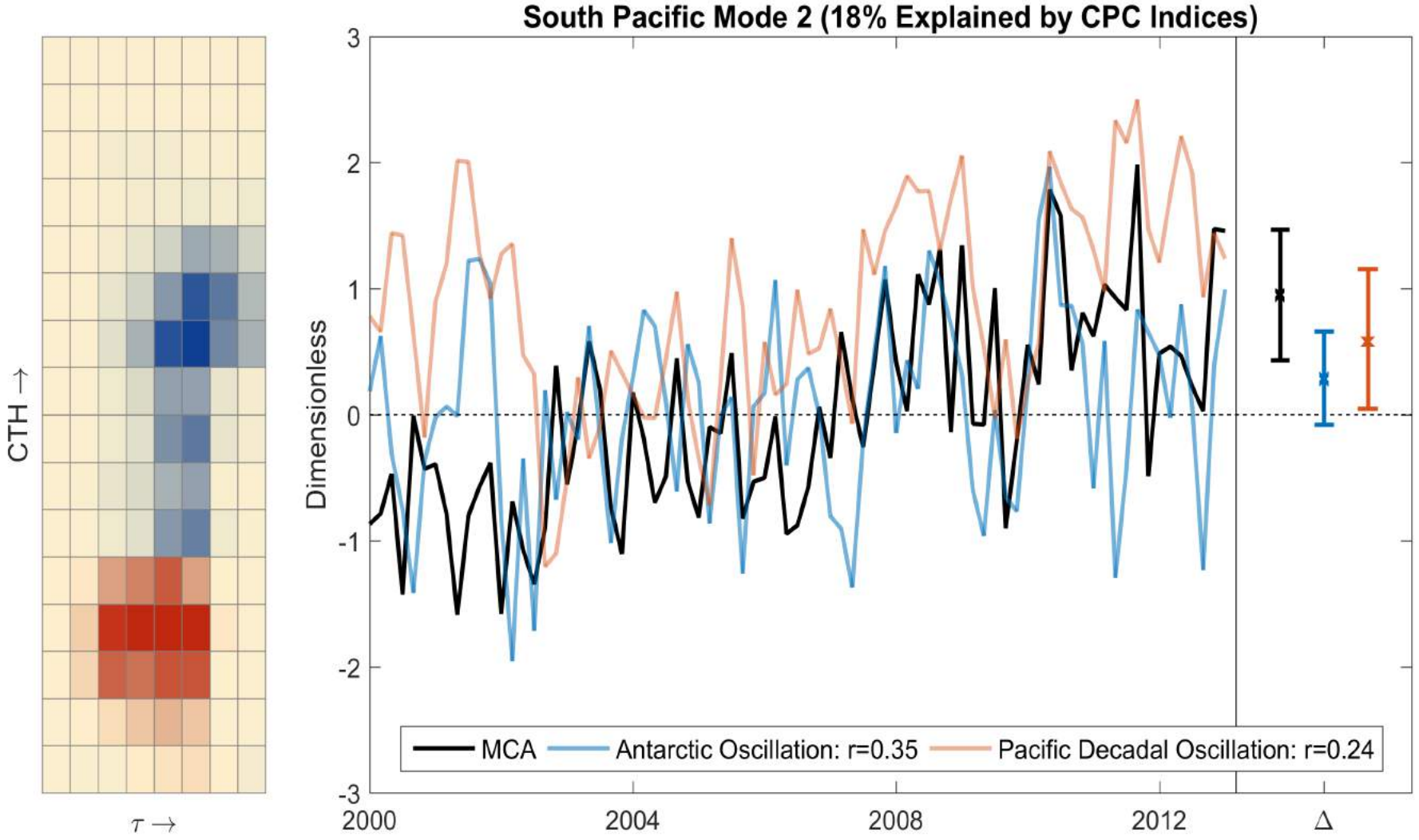
SP1 and **El-Nino Southern Oscillation** (ENSO)



MCA Results: South Pacific (Mode 2)



SP2 and **Southern Annular Mode** (SAM)



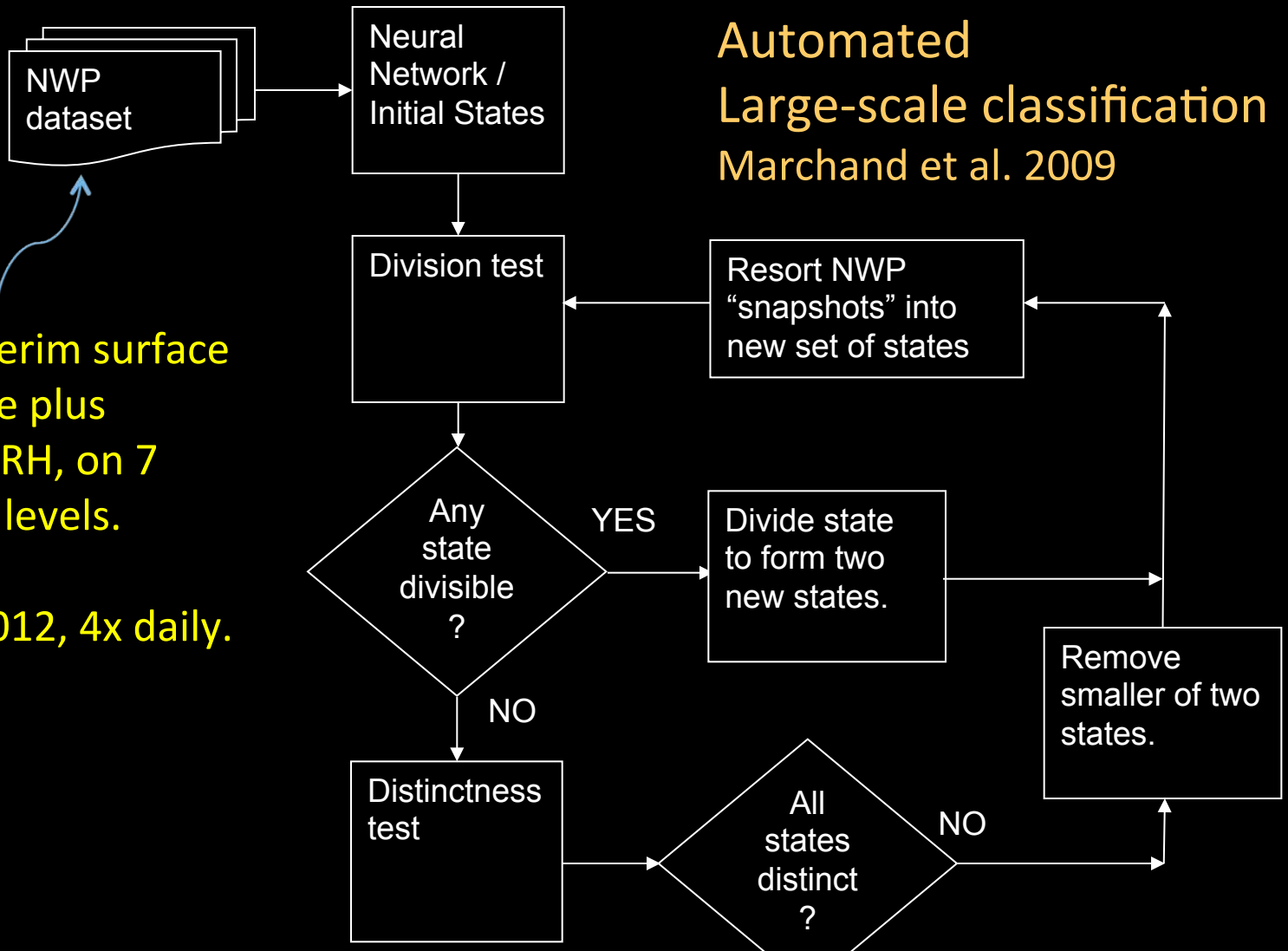
Key points

- Following the path forged by ISCCP … a MISR CTH-OD joint histogram **dataset** & **instrument simulator** exists and provide a **complimentary** view of clouds
- **MISR CTH is based on a Stereo-Imaging technique** :
  - ISCCP CTH (CTP) -> tells us about cloud impact on LW emission.
  - MISR CTH -> tells us where most of the visible photons are being scattered by clouds back toward space.
- MISR CTH -> **insensitive to calibration** -> good for trends
- **Trends exists in the MISR CTH-OD data** (not "boring")
  - North Pacific -> Trends associated with PDO/PNA
  - South Pacific -> Trends associated with ENSO/SAM
  - Mode 1 or 2 in each basin -> shows increasing pressure & anticyclonic motion -> increase in low cloud, less thick OD cloud

Do models show similar relationships ??? … stay tuned !

Automated Large-scale classification

Marchand et al. 2009

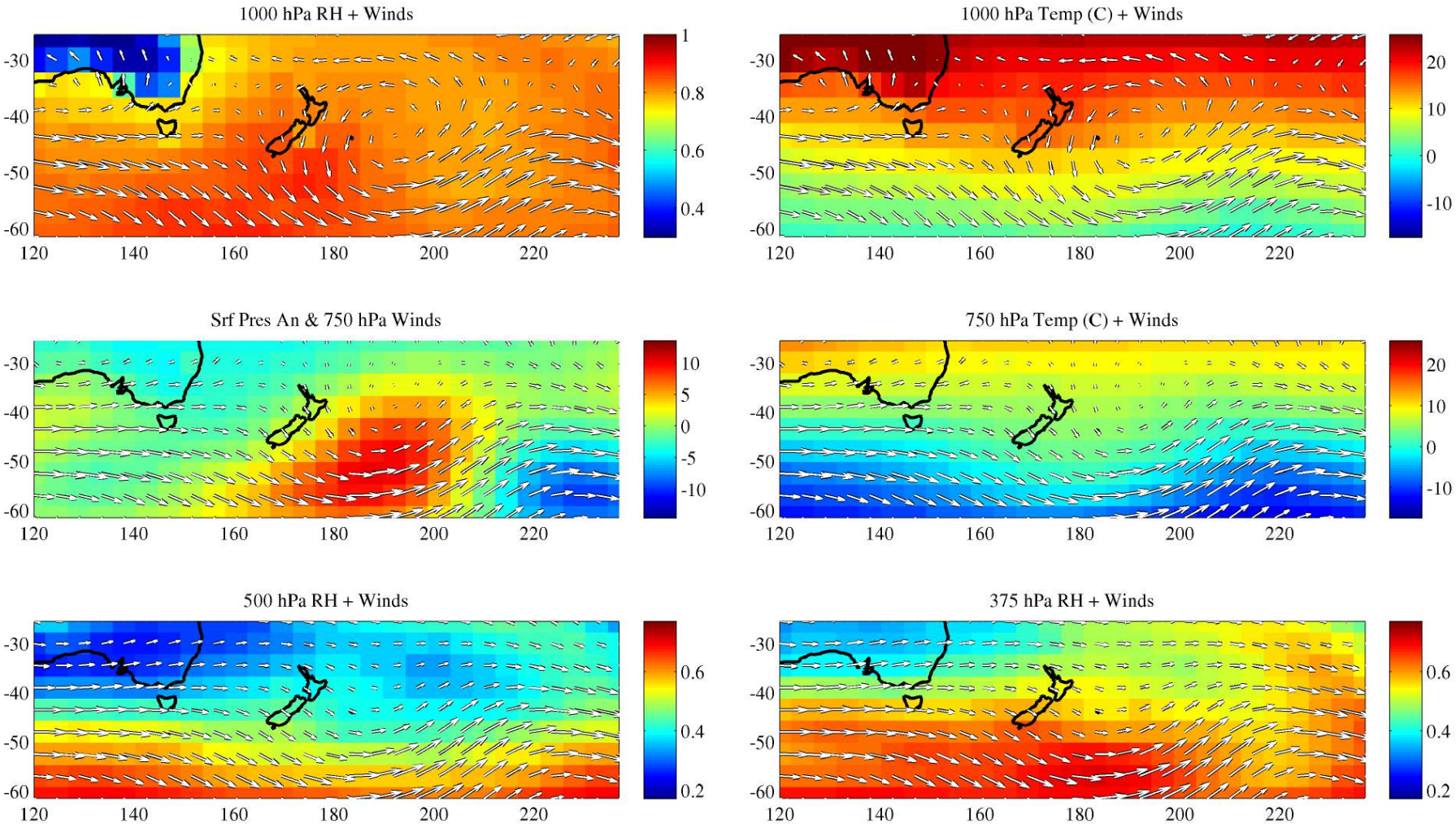


ERA-Interim surface pressure plus T, U, V, RH, on 7 vertical levels.

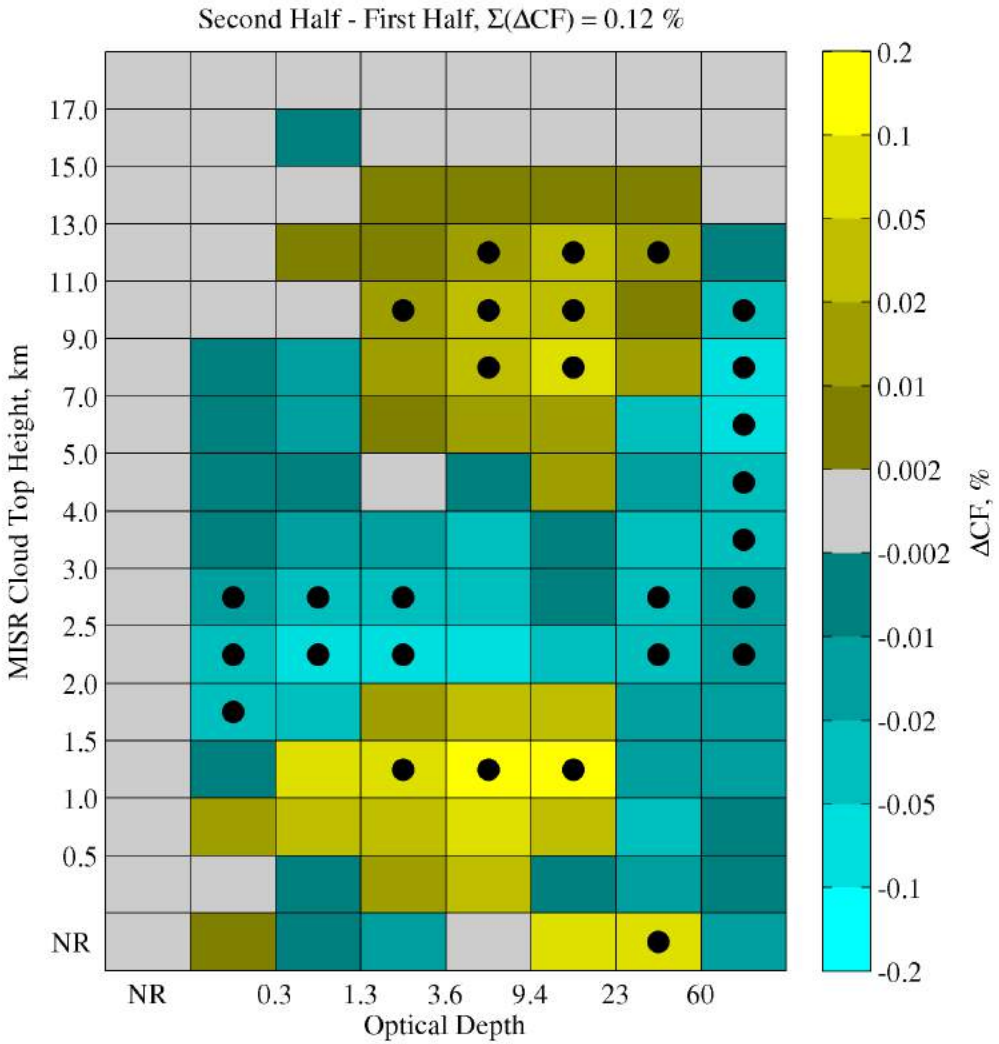
1997-2012, 4x daily.

Objective is to divide the wide range of large-scale weather patterns into a finite set of types with distinct cloud occurrence profiles.

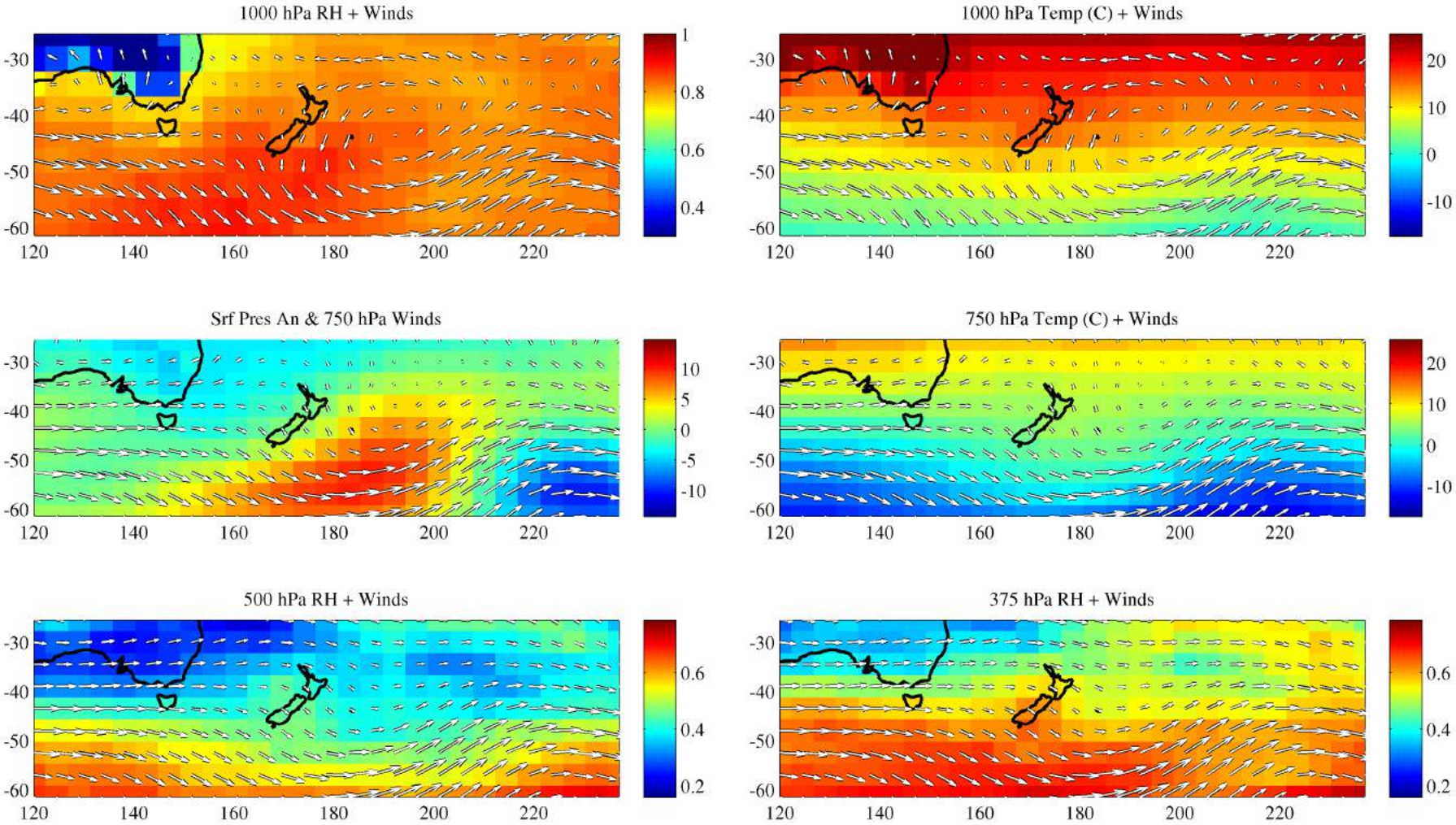
Example, state # 11 of 13



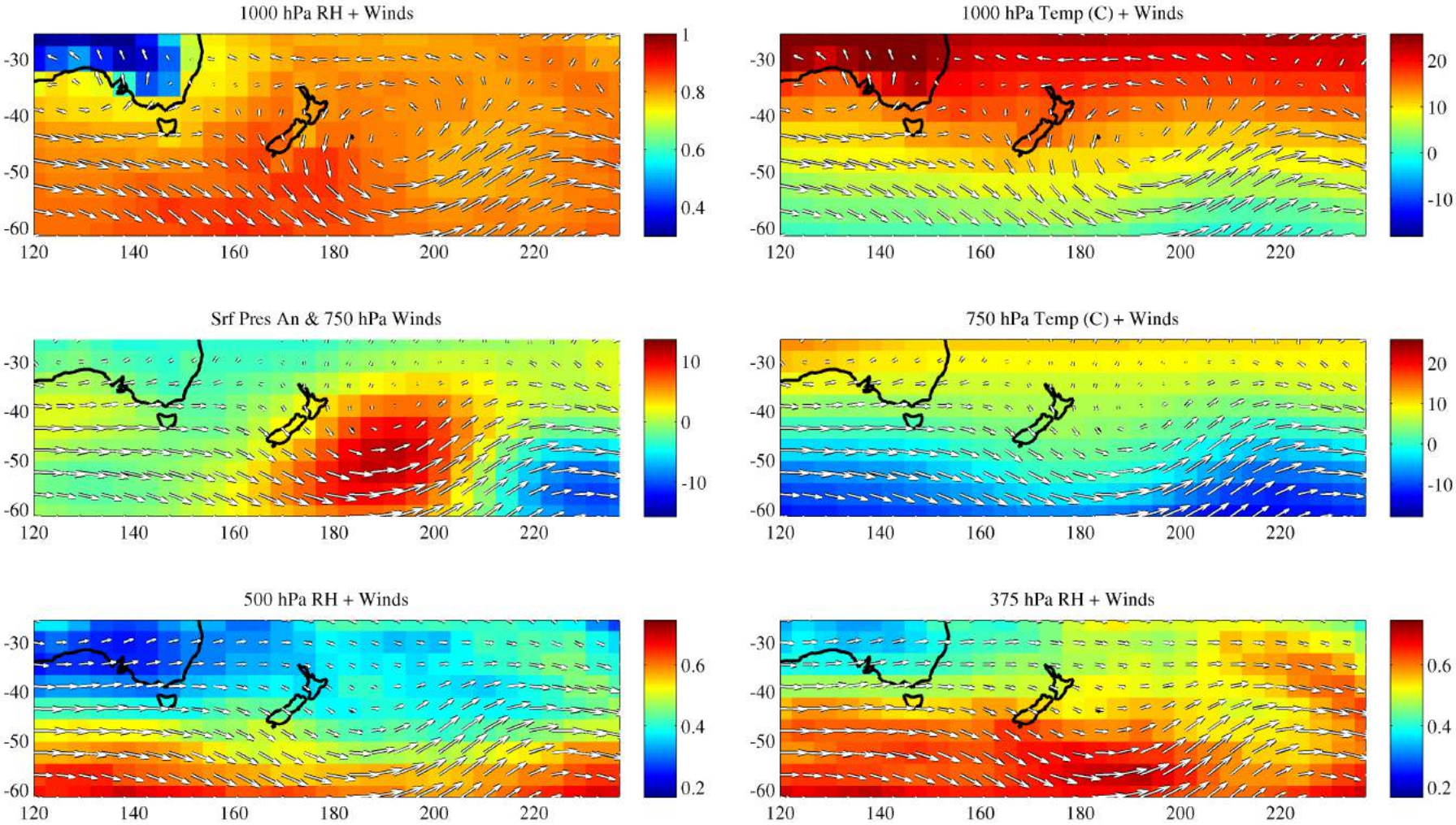
Δmean : (2001-2006) – (2007 – 2012) for each histogram component
(25° - 65° S, 120° – 240° E)



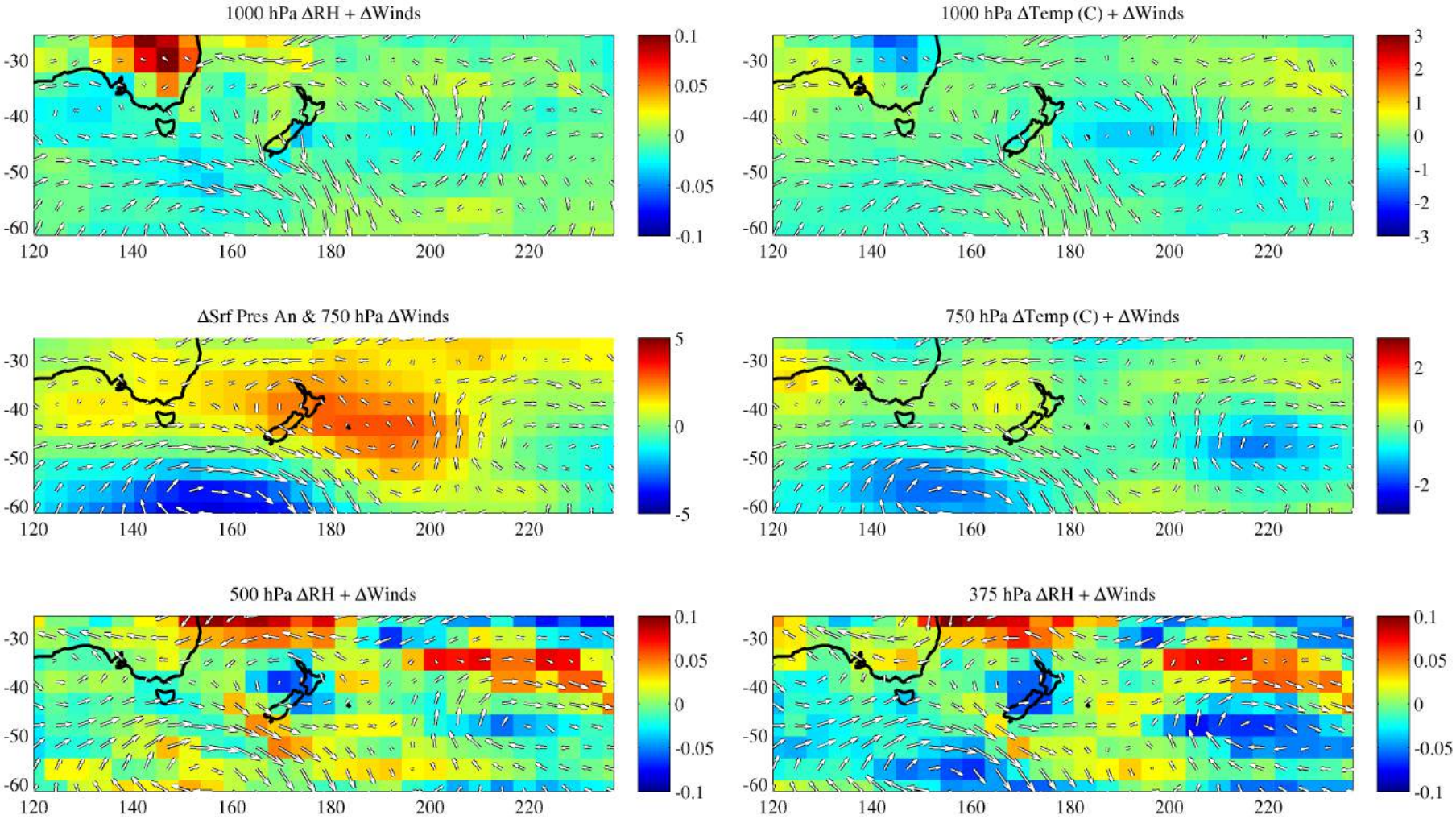
State # 11
Composite 2001 to 2006



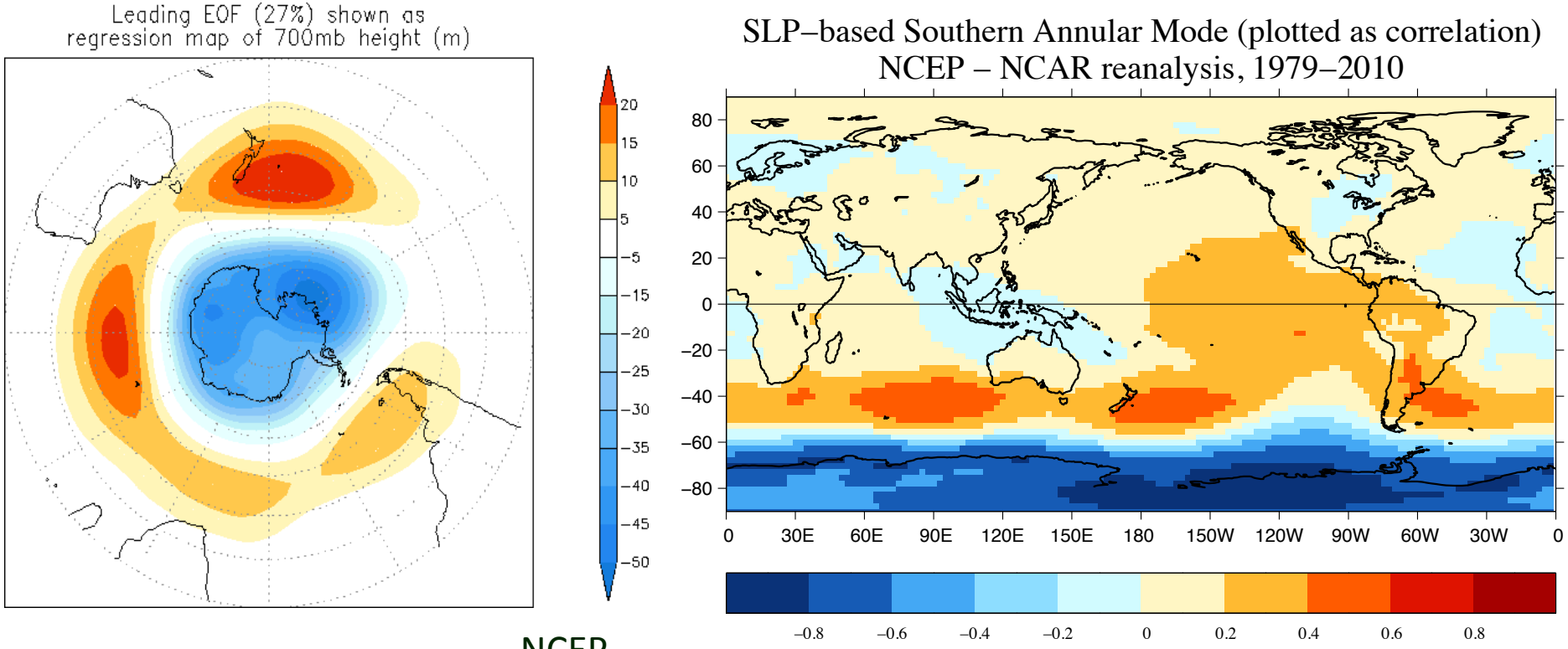
State # 11
Composite 2007 to 2012



State # 11
Difference (2001 to 2006) - (2007-2012)



Antarctica Oscillation (AAO) / Southern Annular Mode (SAM)



NCEP

Todd Mitchell, JISAO

Is total change in cloud fraction due to change in the distribution of states over time ?

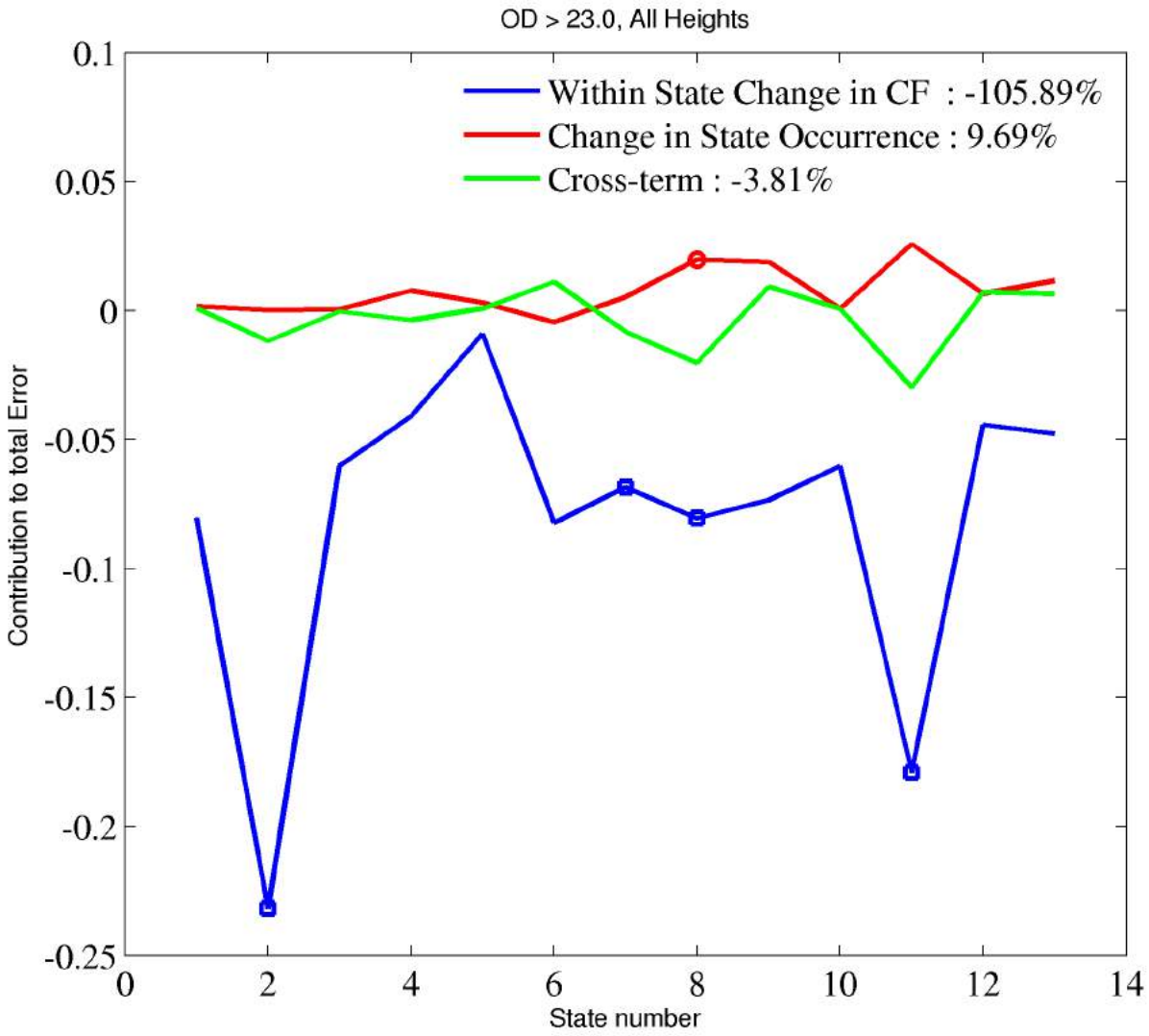
$$\Delta CF_{total} \approx \sum_{i=1}^{states} (\Delta CF_i) * RFO_i + \sum_{i=1}^{states} (CF_i - CF_{total}) * \Delta RFO_i + \sum_{i=1}^{states} \Delta CF_i * \Delta RFO_i$$

Within State

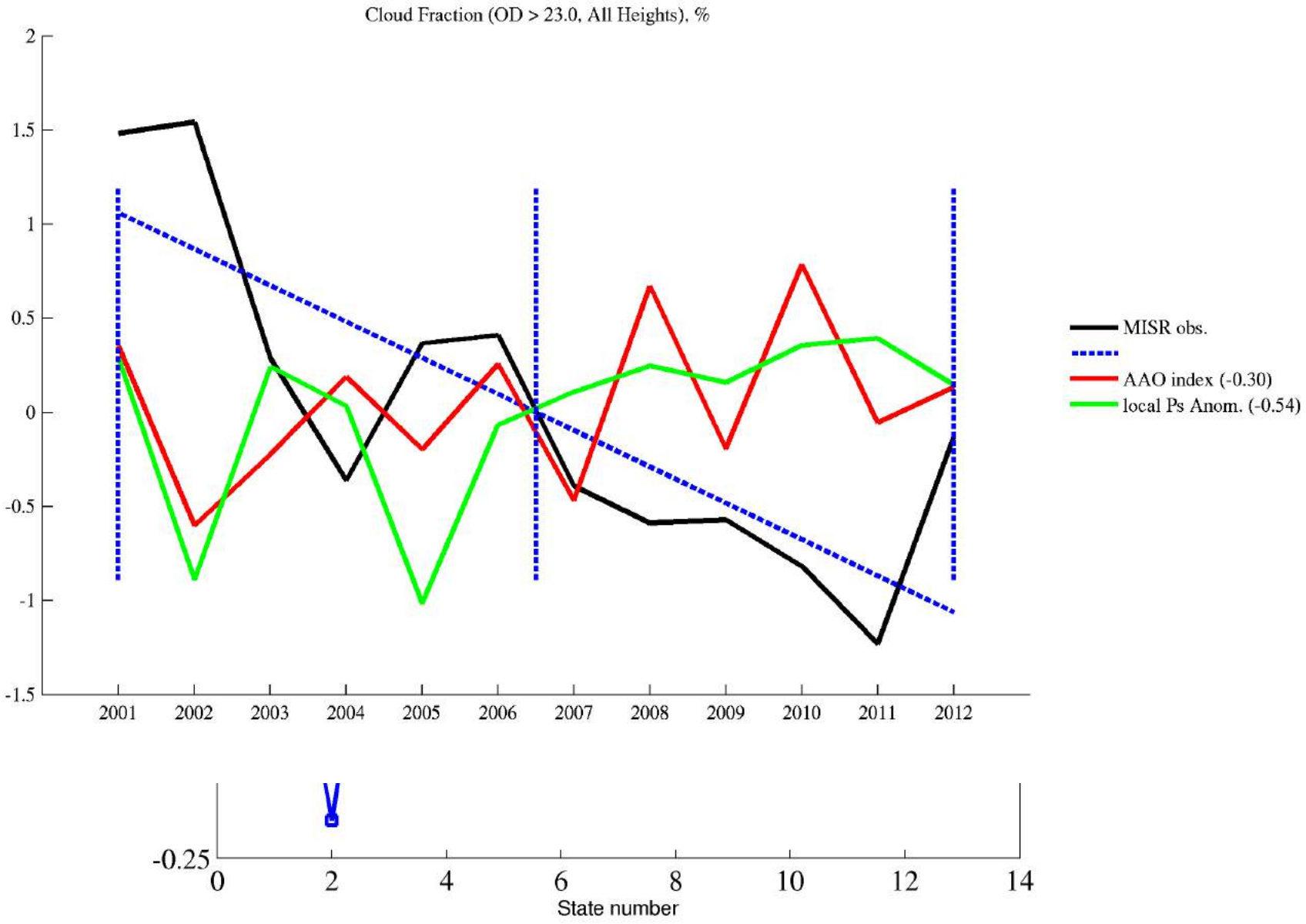
Distribution of States

Cross Term

Comparison of terms for each atmospheric state



Comparison of terms for each atmospheric state



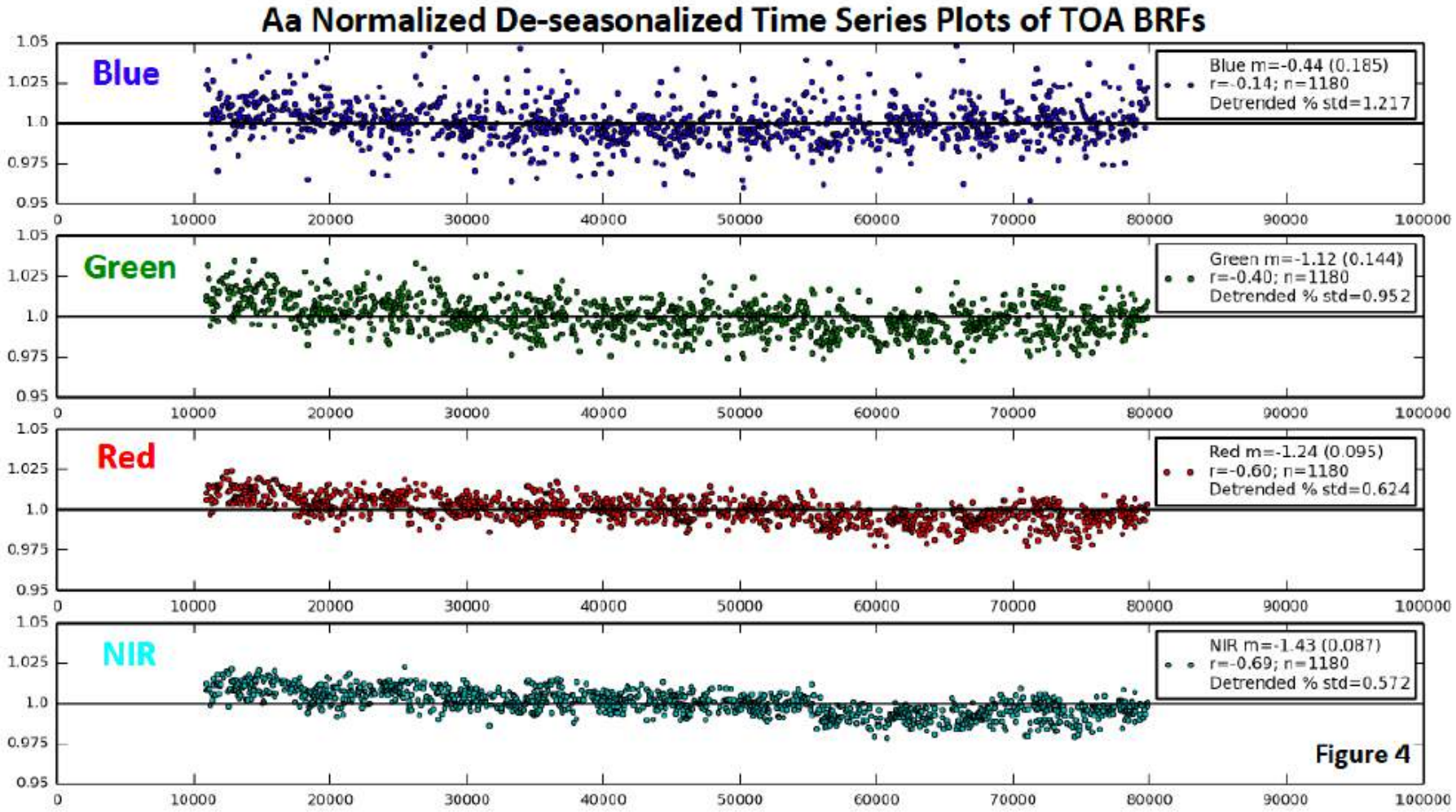


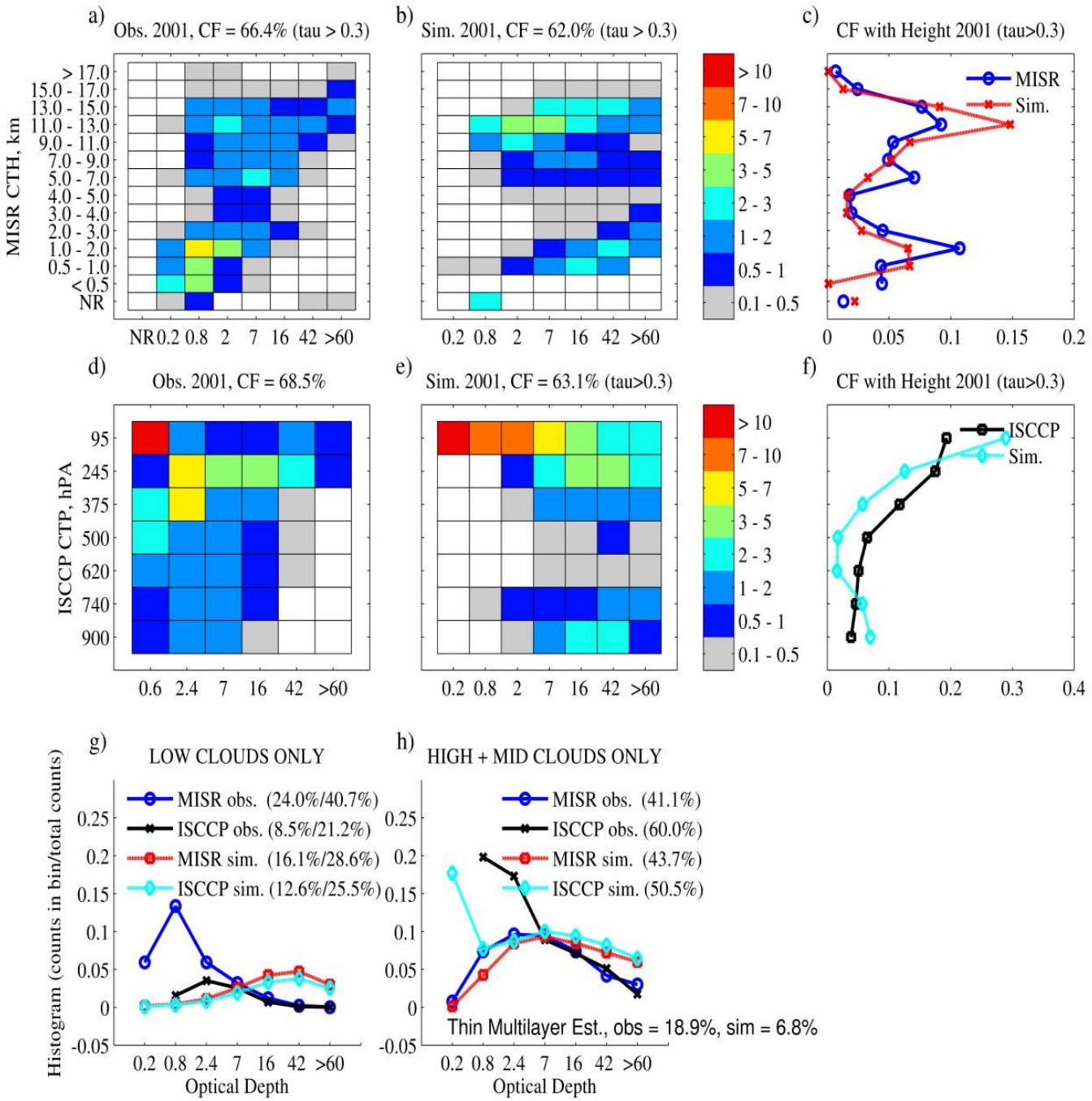
Figure 4. Normalized, de-seasonalized TOA BRF time series plots, for the four spectral bands of the MISR Aa camera. Data are normalized such that the mean value is unity. These data present all of the data for the three desert sites used (Libya-1, Libya-4, and Egypt-1), excluding outliers, processed through Step 4b of Section 3.

Limbacher and Kahn 2016

Tropical Western Pacific, 2001

Comparison of MMF (4km) ISSCP and MISR

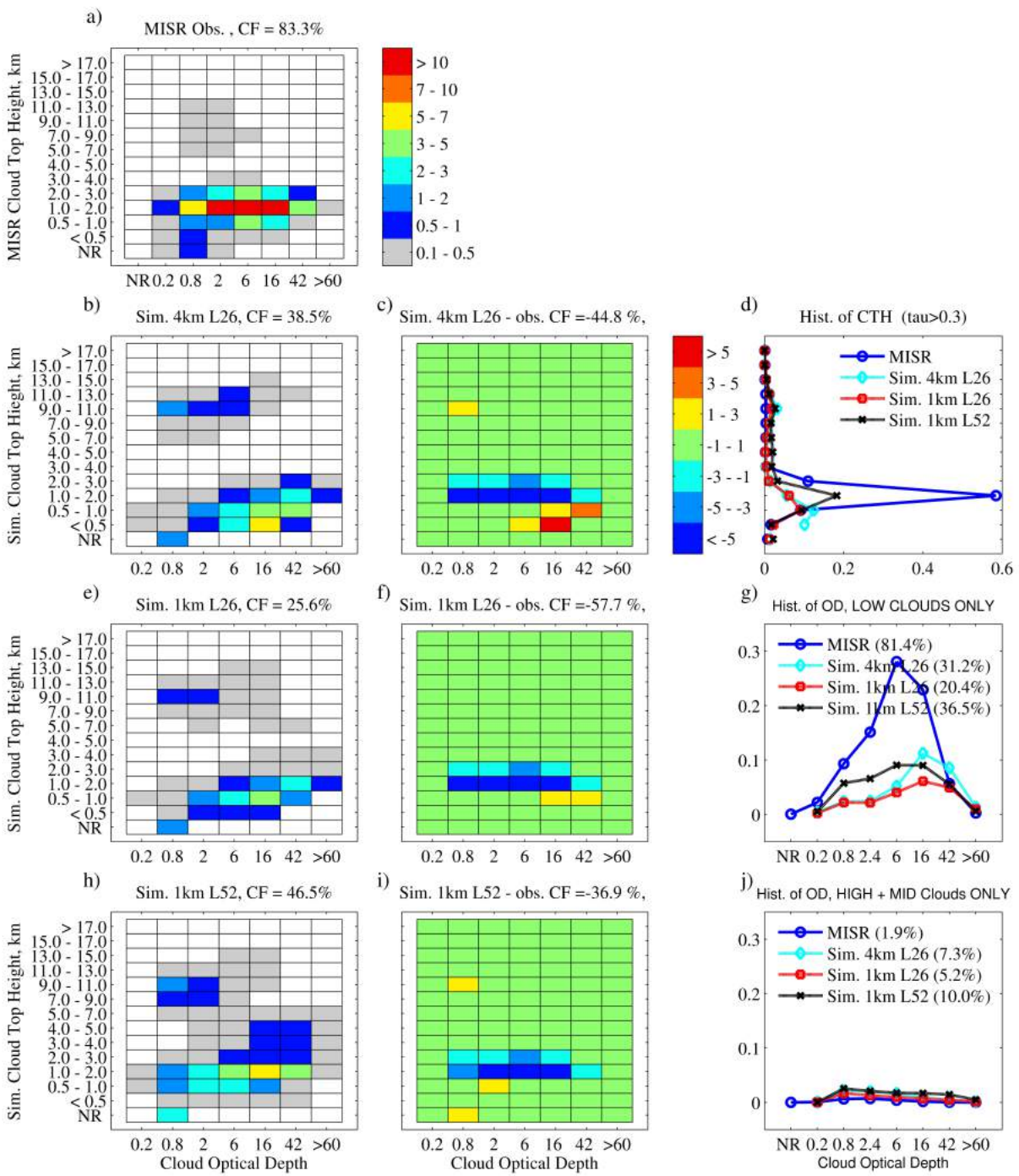
Marchand et al. 2009



Comparison of MMF Simulations with differing CRM grid-spacing

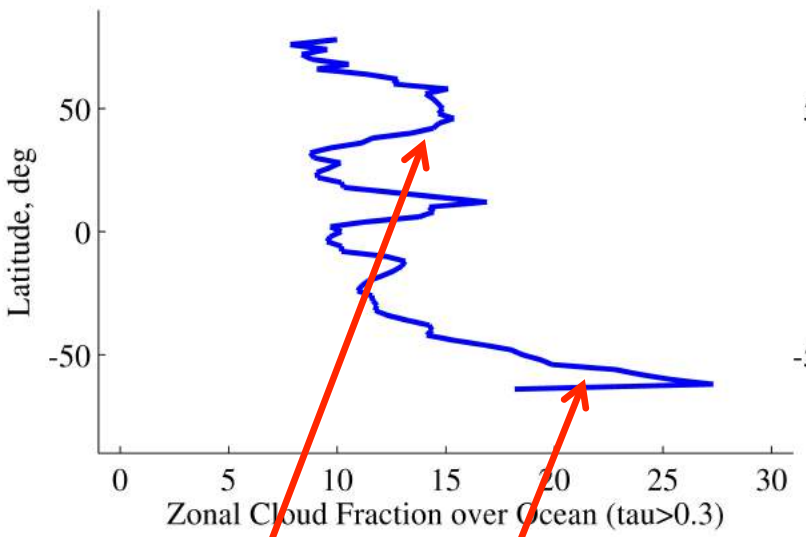
South American Stratocumulus

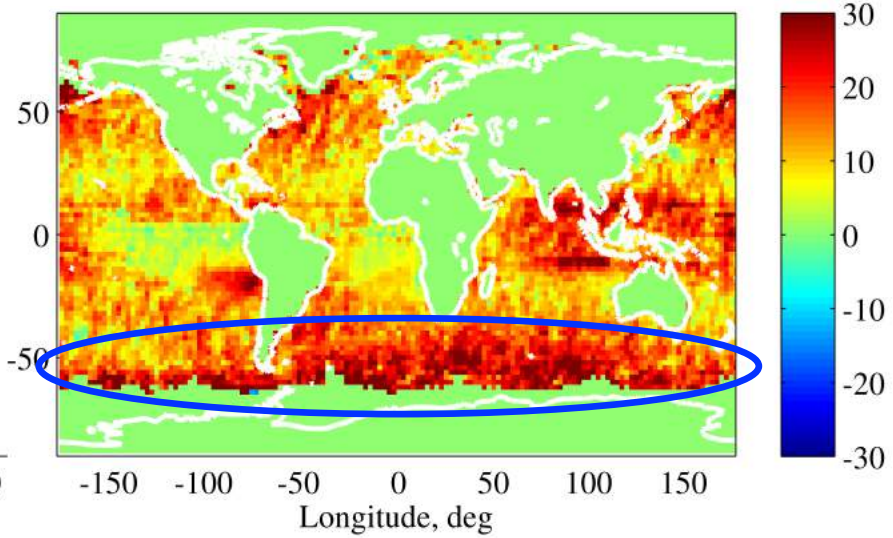
Marchand et al. 2007



Multilayer Cloud Amount

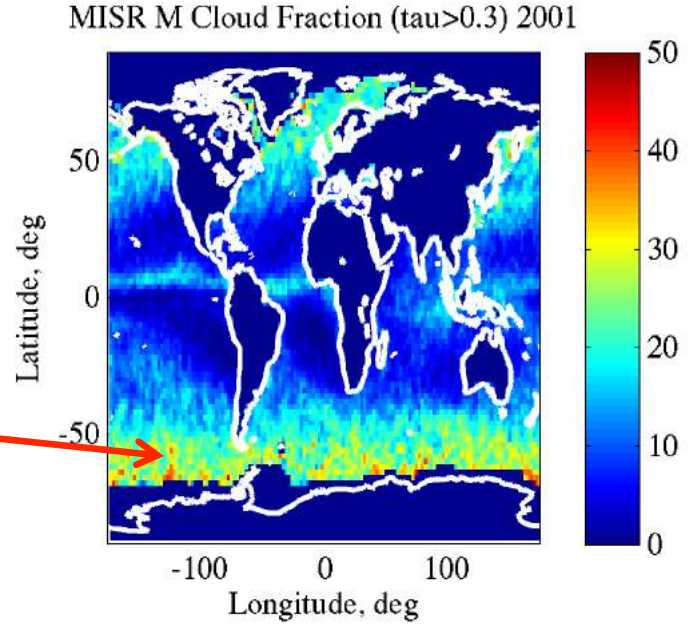
ISCCP/MISR Multilayer Cloud Amount, 2001 (12.9%)



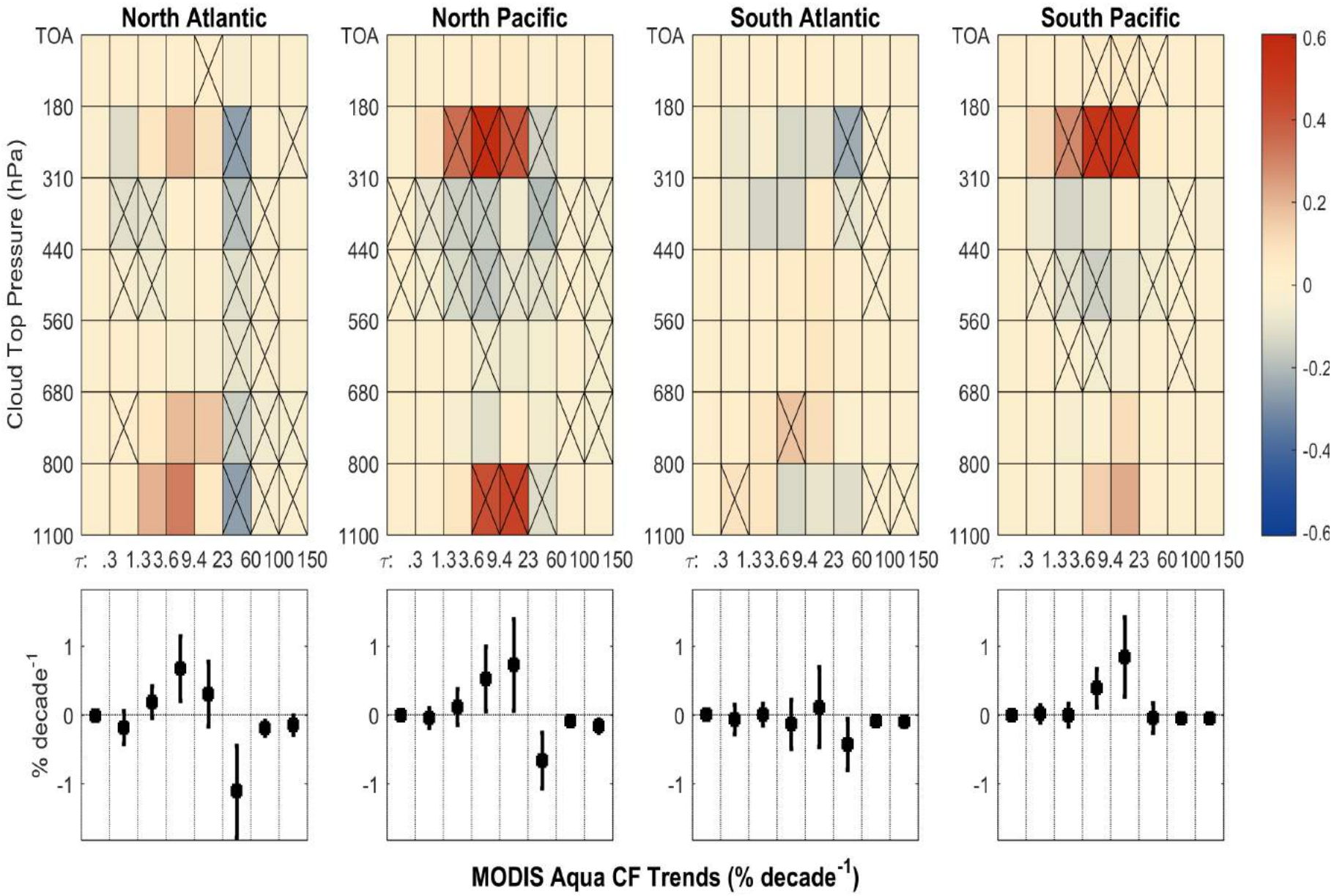


More multi-layer cloud in southern hemisphere beyond 50° S

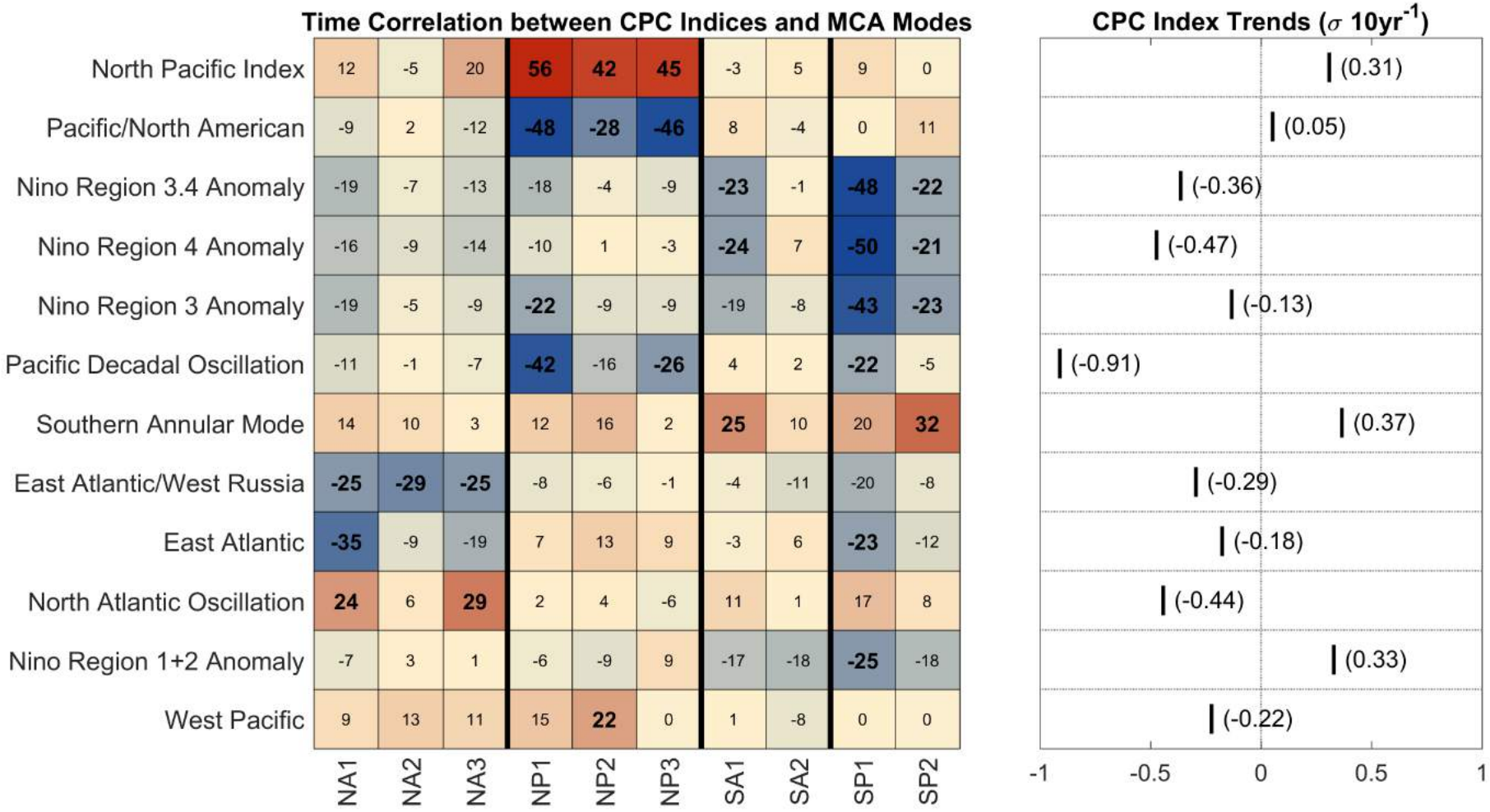
So some of the ISCCP "mid-level" here is not real … which is not say there isn't ALSO more mid-level cloud in SH than NH.



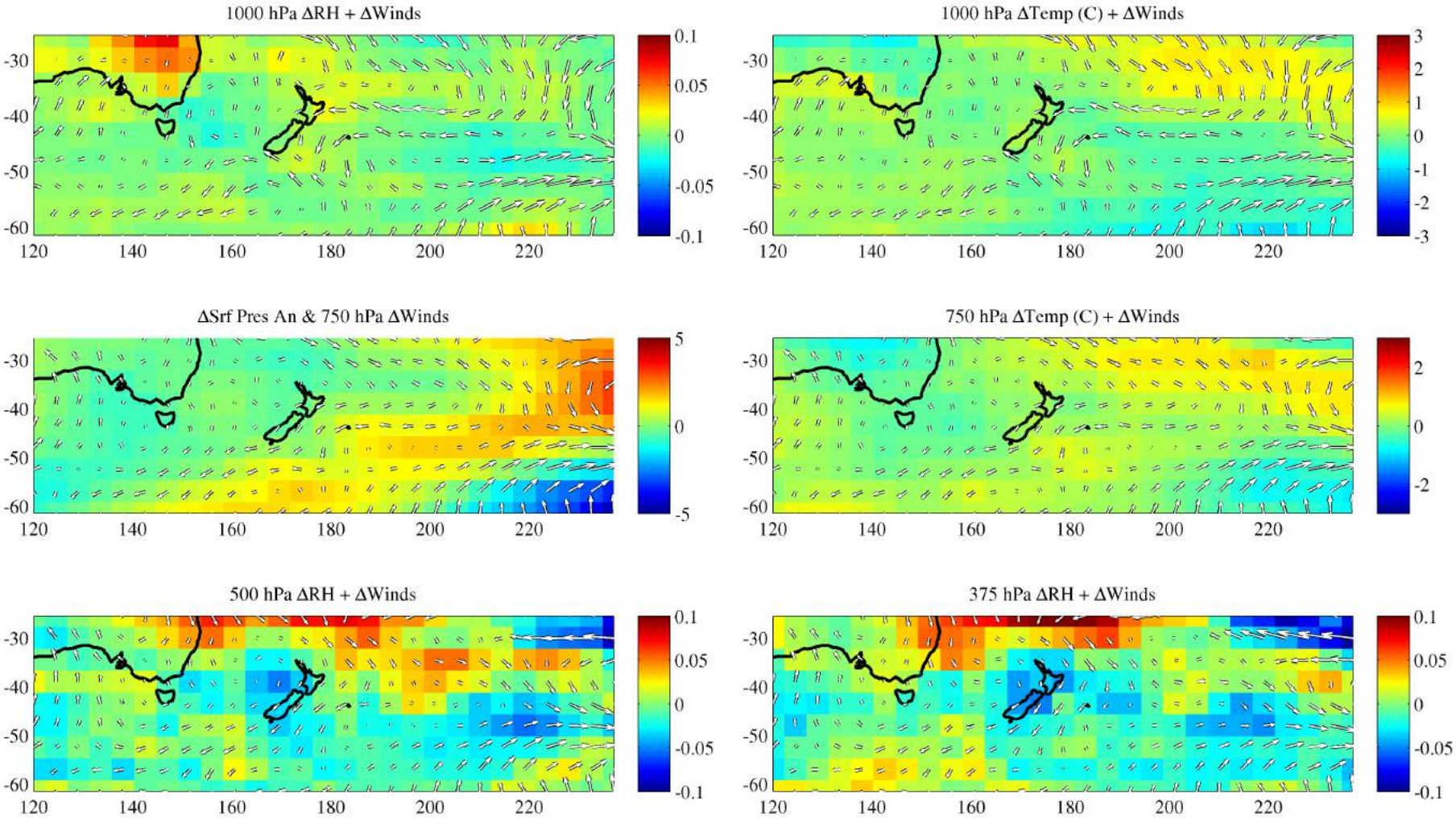
Trends in MODIS (AQUA) Joint-Histograms



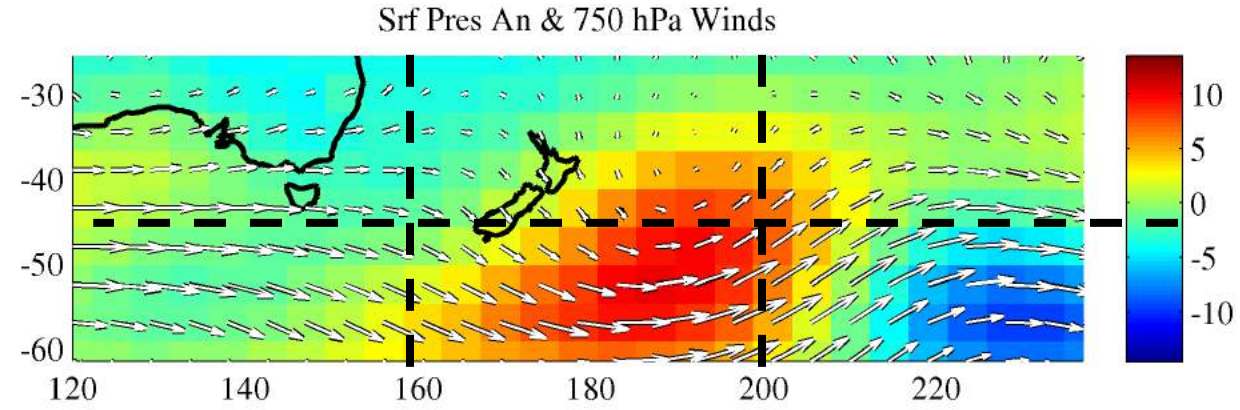
Correlations with “known” modes of climatic variability

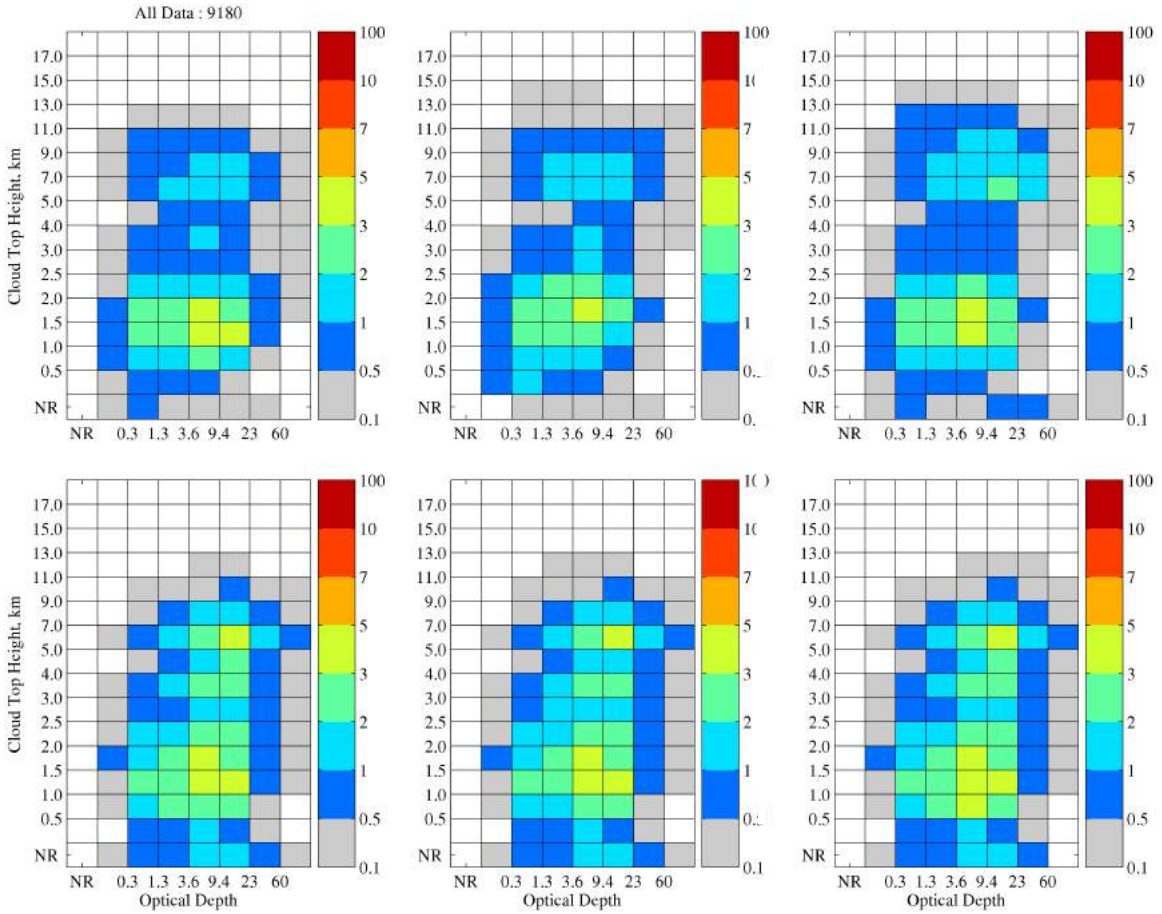


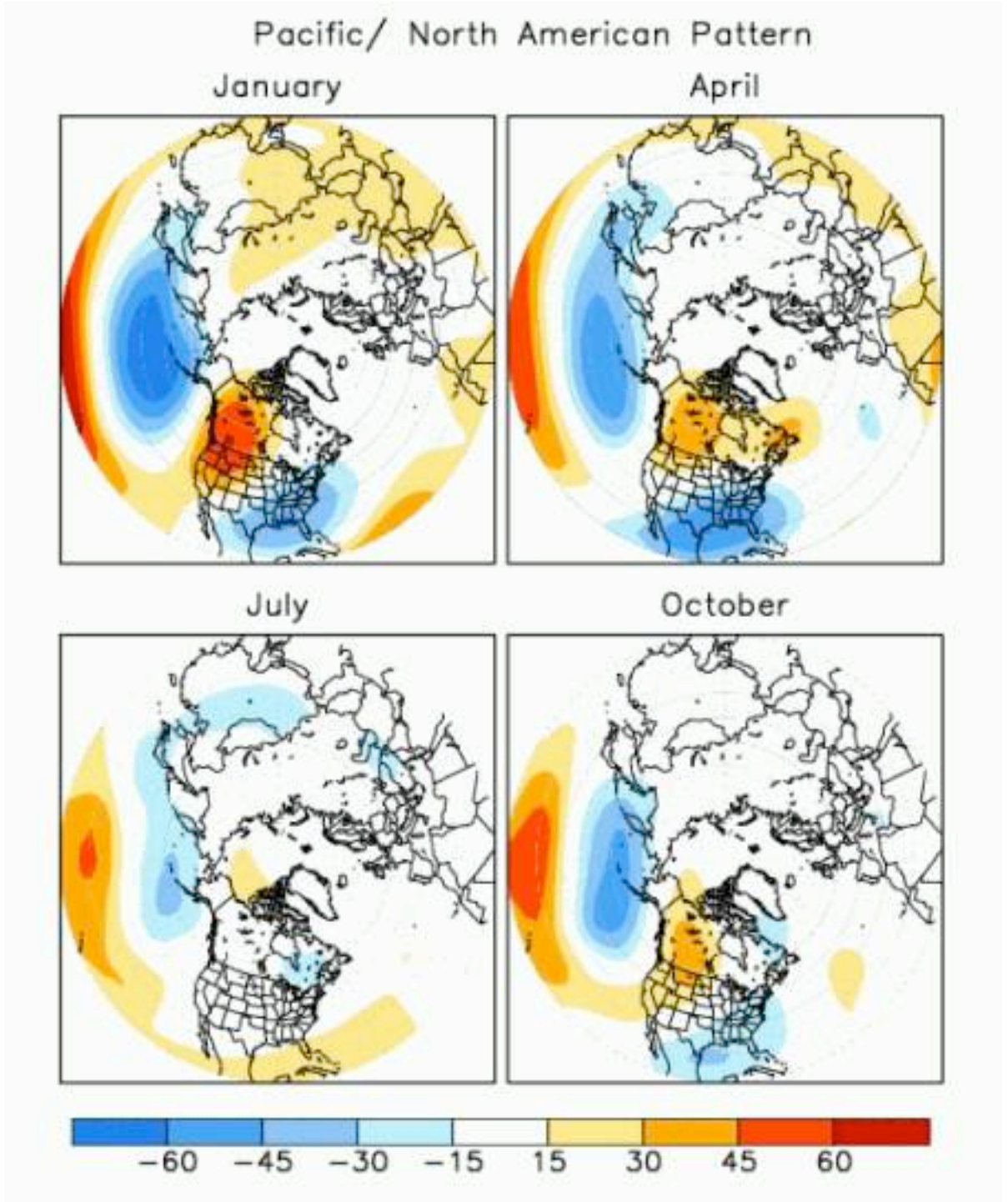
State # 2
Difference (2001 to 2006) - (2007-2012)



State # 11


Srf Pres An & 750 hPa Winds
-30
-40
-50
-60
120
140
160
180
200
220
10
5
0
-5
-10


All Data : 9180
Cloud Top Height, km
Optical Depth
NR
0.3
1.3
3.6
9.4
23
60


Pacific/ North American Pattern
January
April
July
October
−60
−45
−30
−15
15
30
45
60