OBSERVED CHANGES IN CLOUD COVER FROM MISR AND MODIS OVER THE PAST DECADE : SOUTHERN OCEANS

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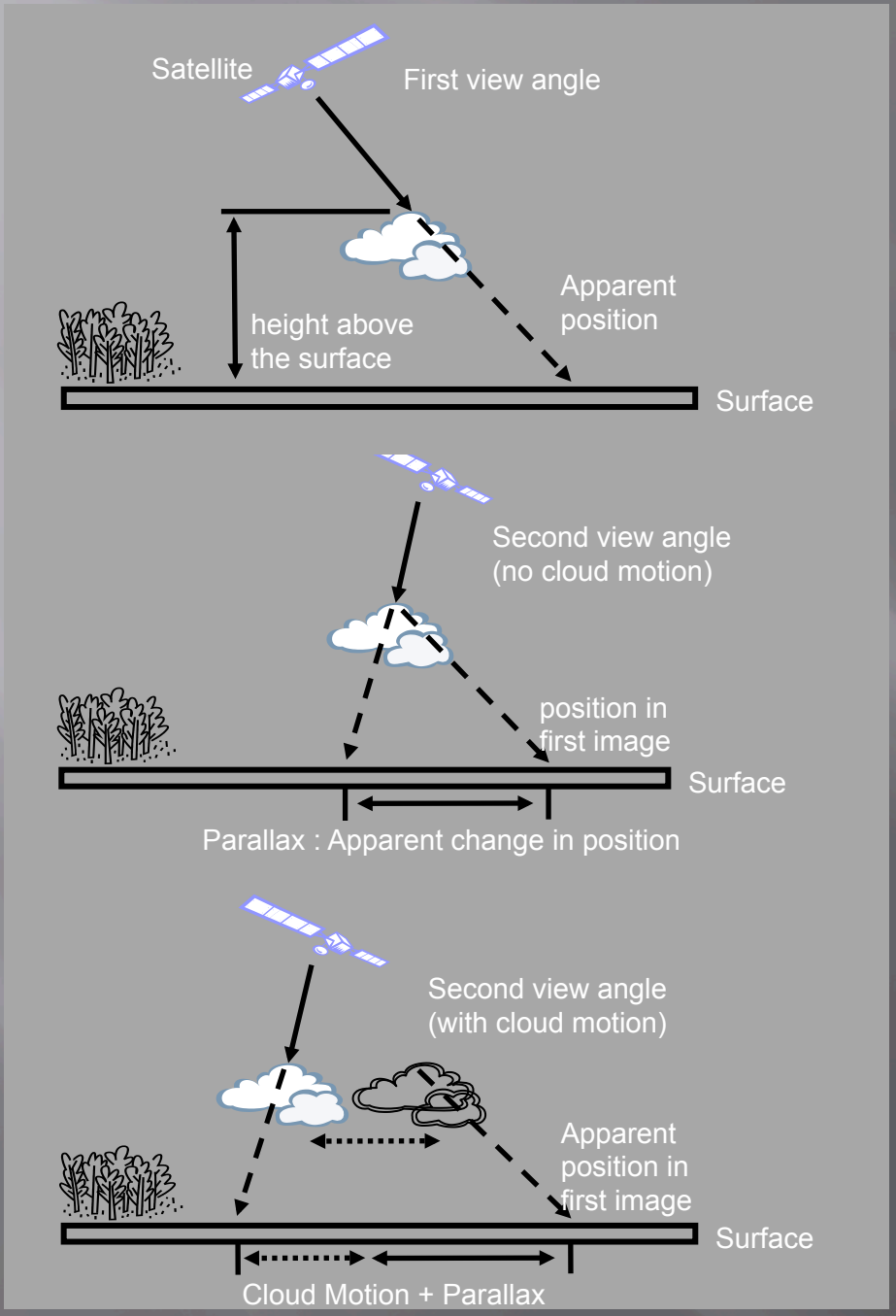


Stereo-imaging

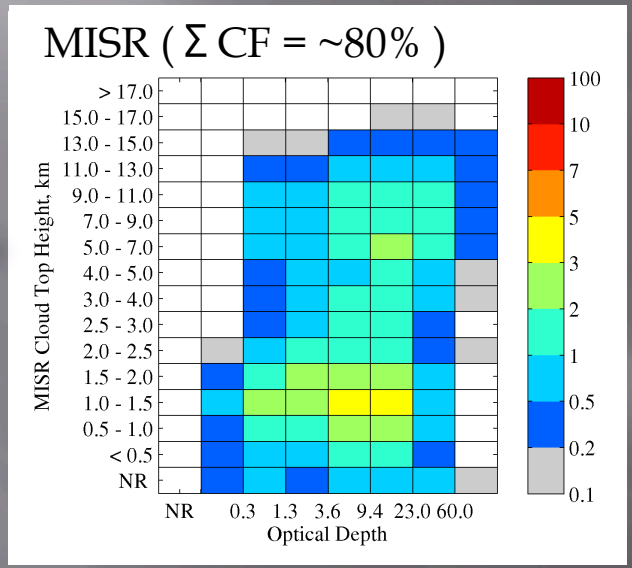
- A significant advantage of the MISR CTH retrieval is that the technique is purely geometric and has little sensitivity to the sensor calibration.
- The retrieval has been the focus of several studies including Marchand et al. (2007), Naud et al. (2002, 2004, and 2005a,b), Seiz et al. (2005), Marchand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

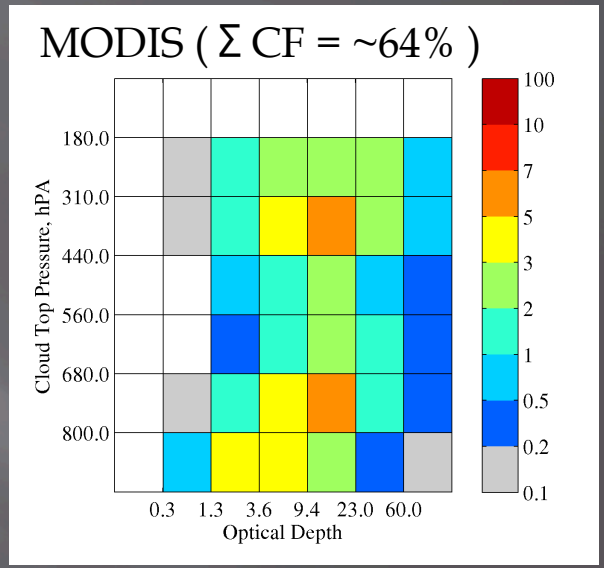
CTH-OD Histograms

- Terra satellite launched December 1999 => We now have more than 13 years of data from MODIS and MISR.

- CTH-OD histograms

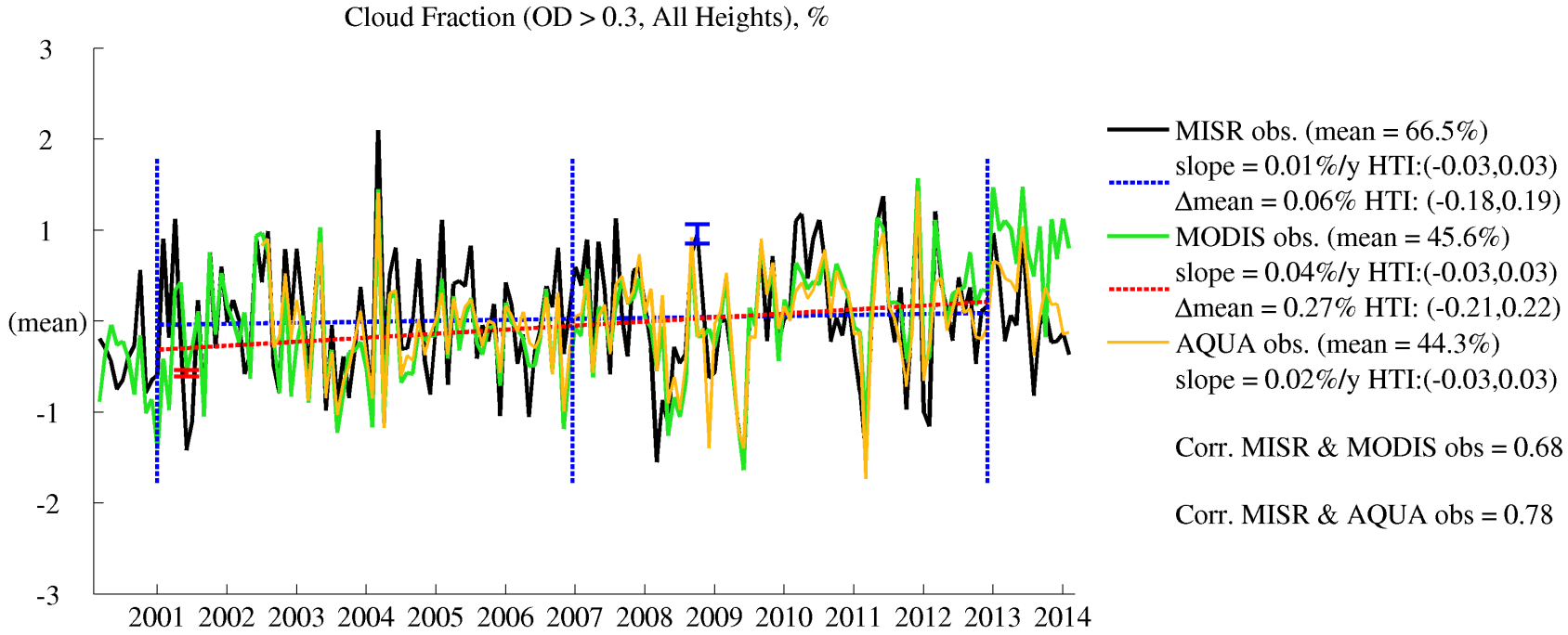
  Example: North Pacific



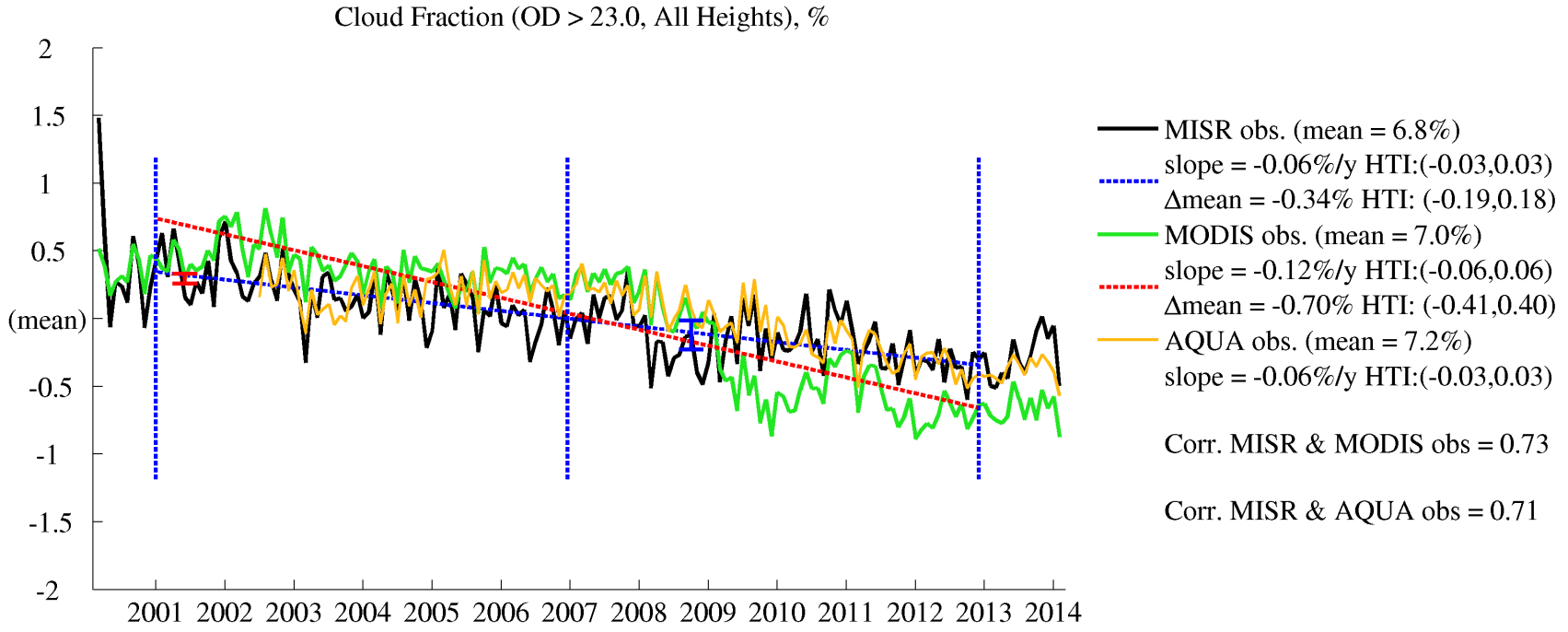


- Do these data show any changes on time-scales longer than a year ?

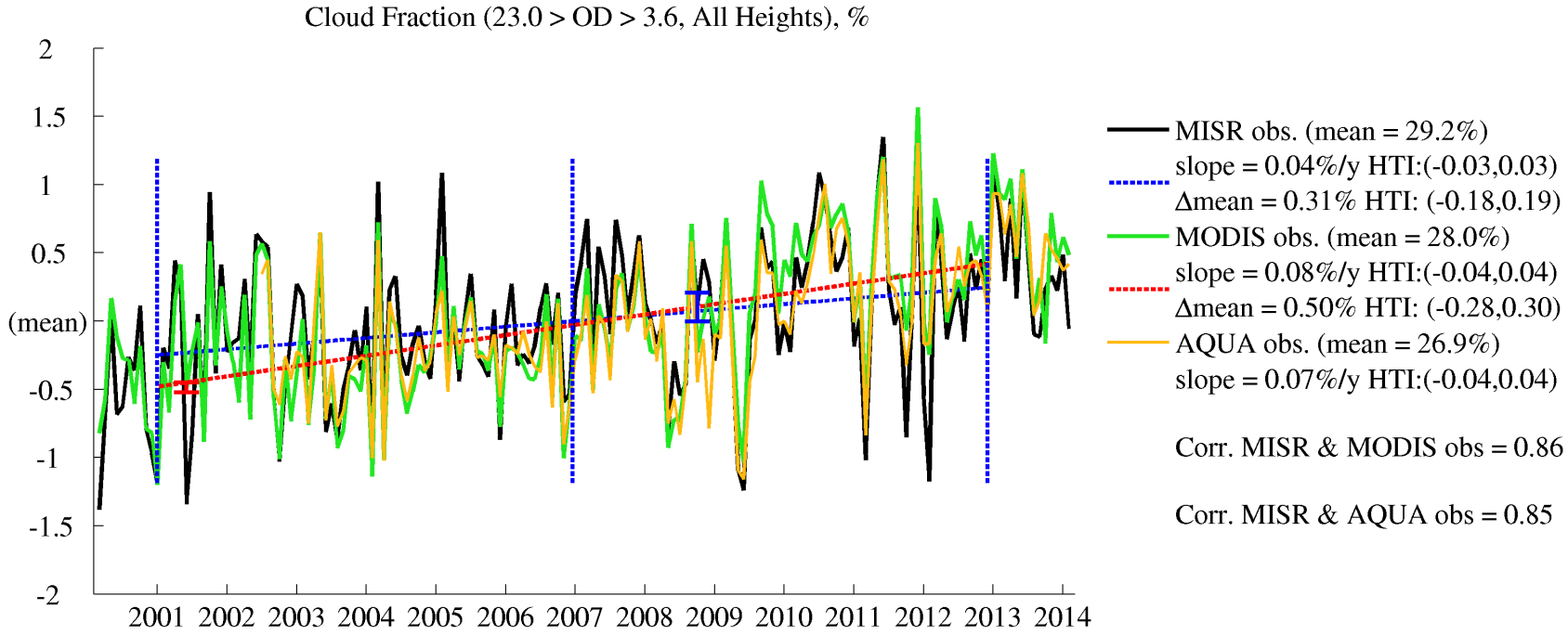
60 N to 60 S
"Total" Cloud Fraction (OD > 0.3)



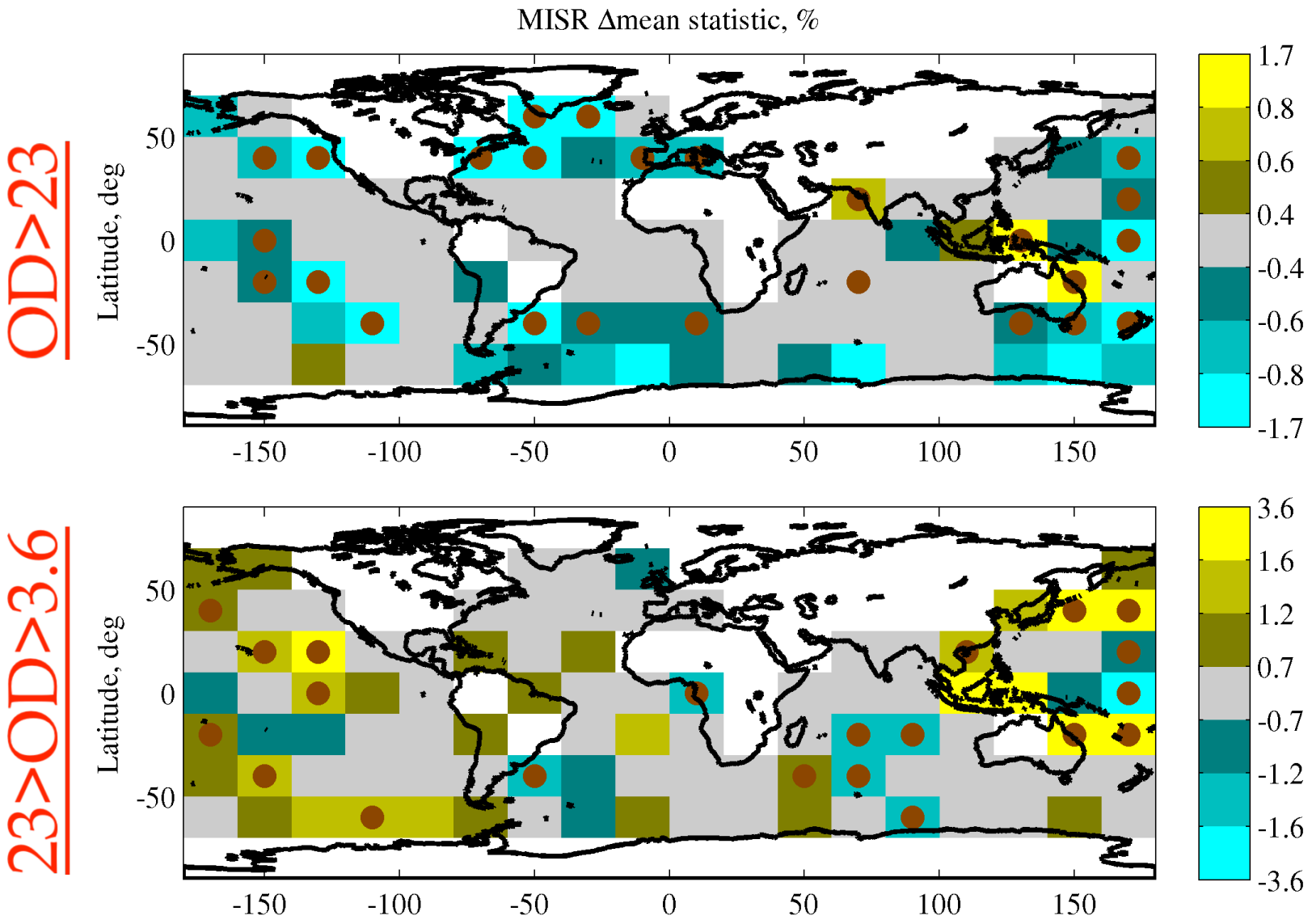
Global Optically-Thick (OD>23) Cloud Fraction



Global Optically-Intermediate (23>OD>3.6) Cloud Fraction

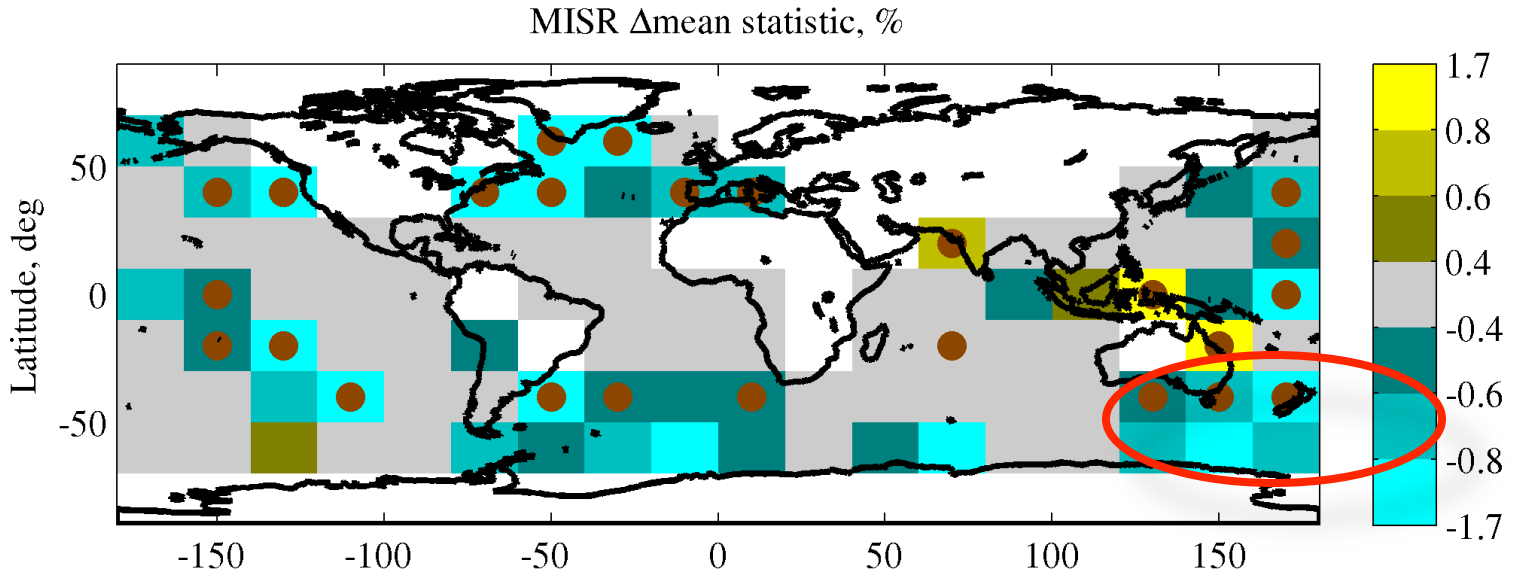


Global Distribution of CF changes

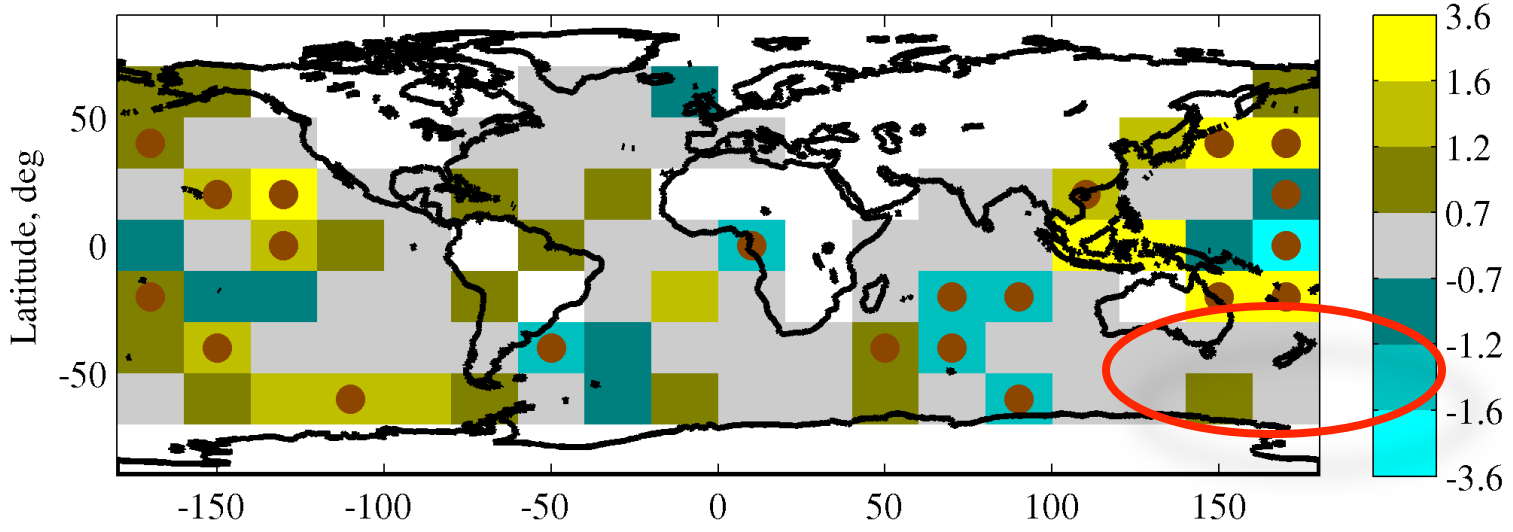


Remainder of Talk … concentrate on Southern Ocean near Australia / New Zeeland

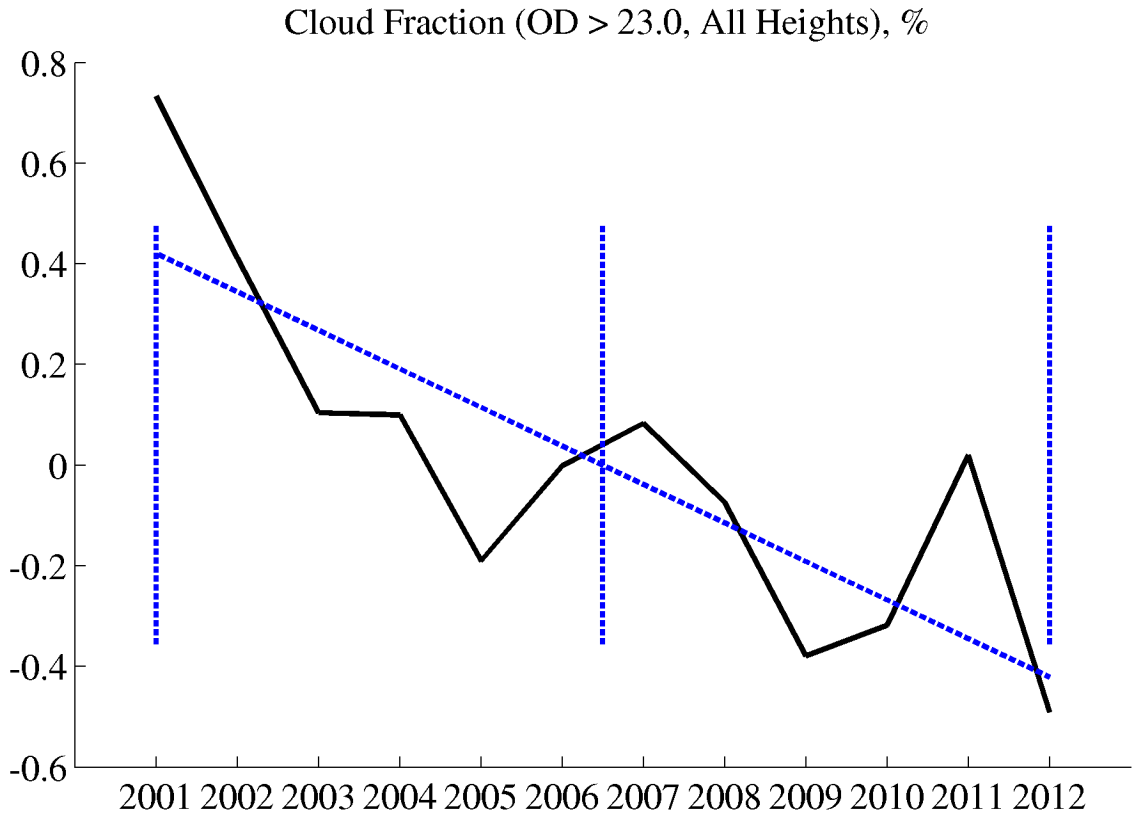
OD>23



23>OD>3.6



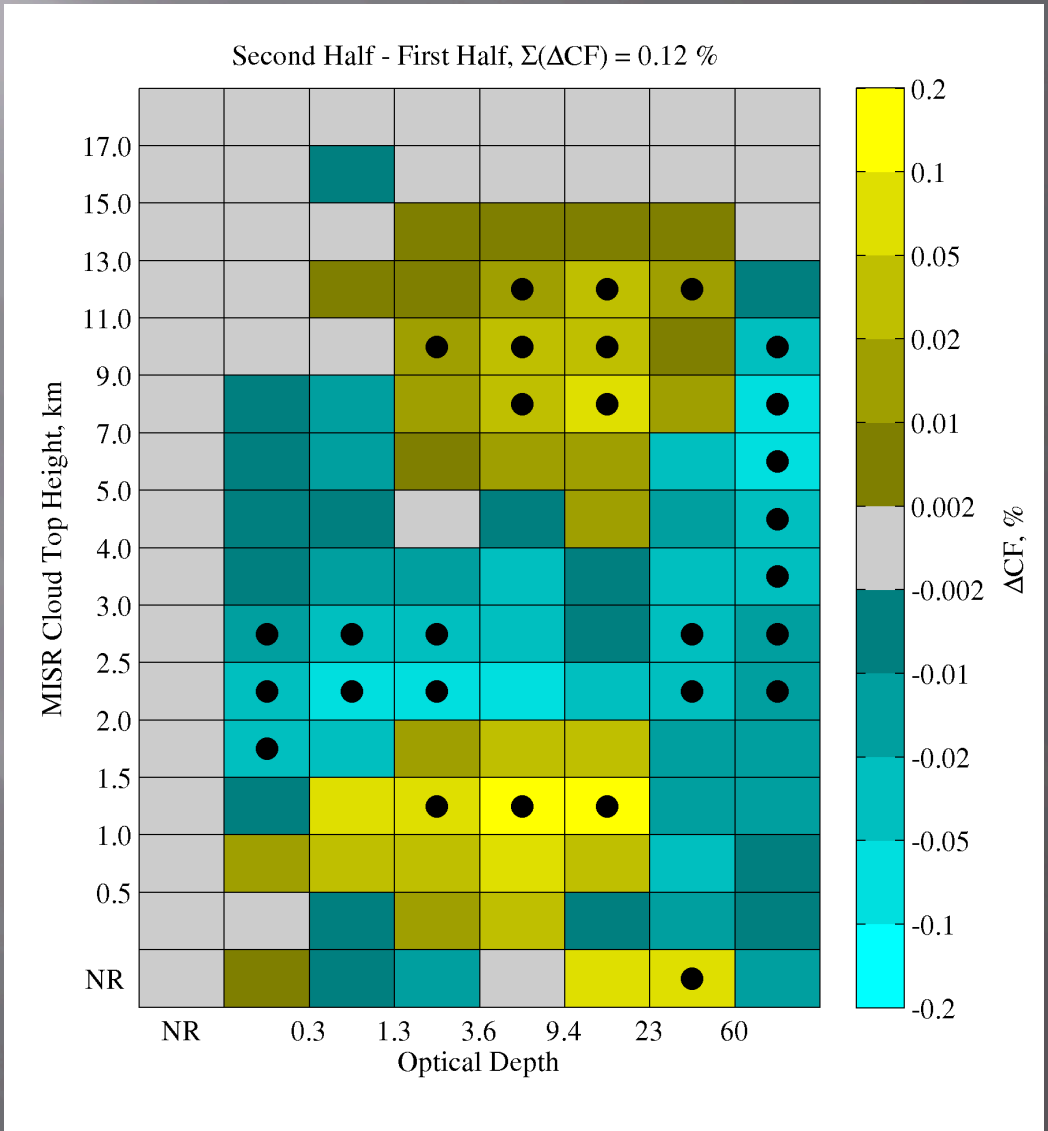
Optically-Thick (OD > 23) CF change
(25° - 65° S, 120° – 240° E)



MISR obs. (mean = 8.7%)
slope = -0.08%/y HTI:(-0.04,0.04)
Δmean = -0.39% HTI: (-0.33,0.32)

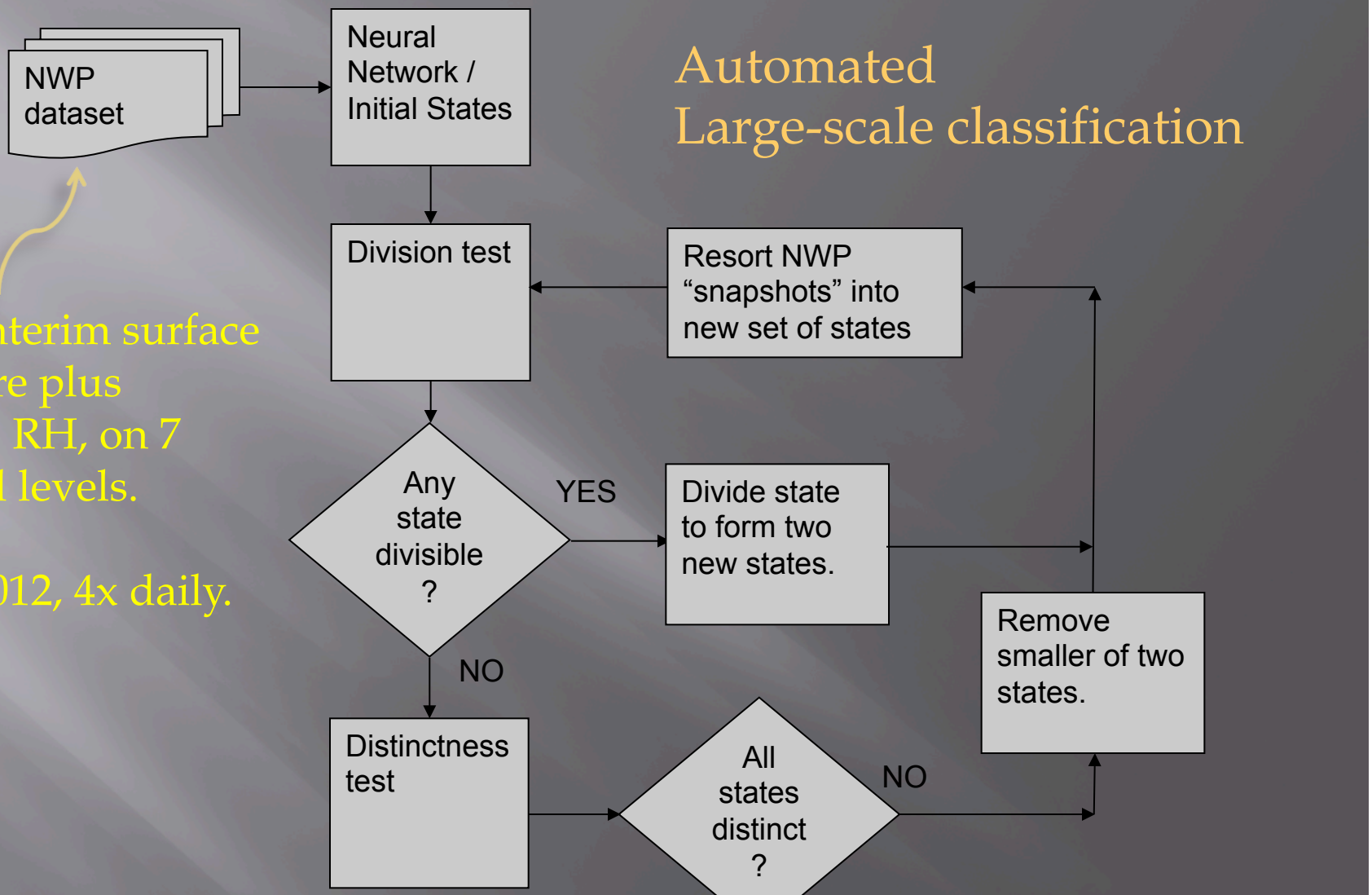
Δmean = -0.39 %

Δmean for each histogram component
(25° - 65° S, 120° – 240° E)



Are these changes due to a change in large-scale/ synoptic activity ?

Automated Large-scale classification

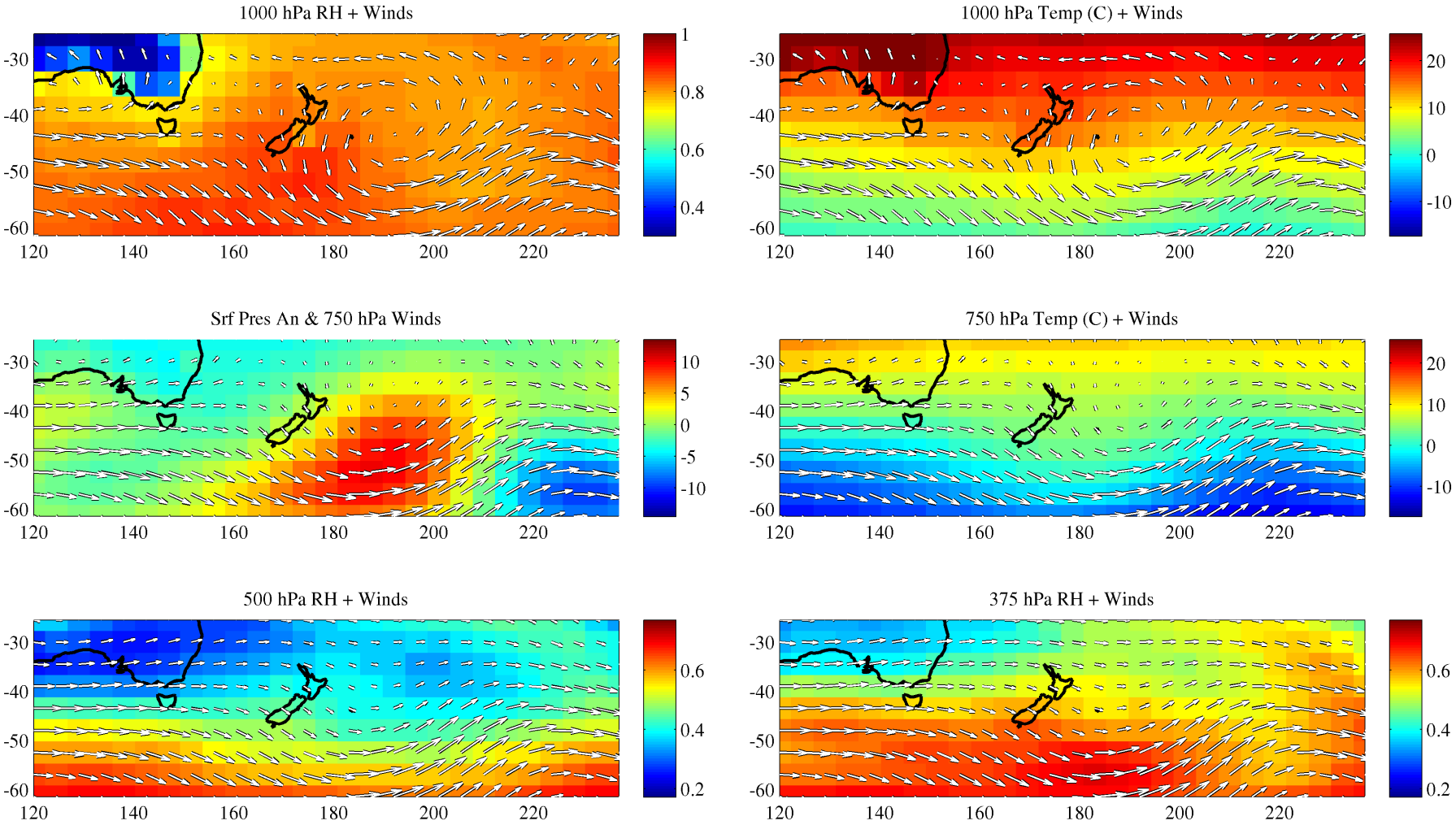


ERA-Interim surface pressure plus T, U, V, RH, on 7 vertical levels.

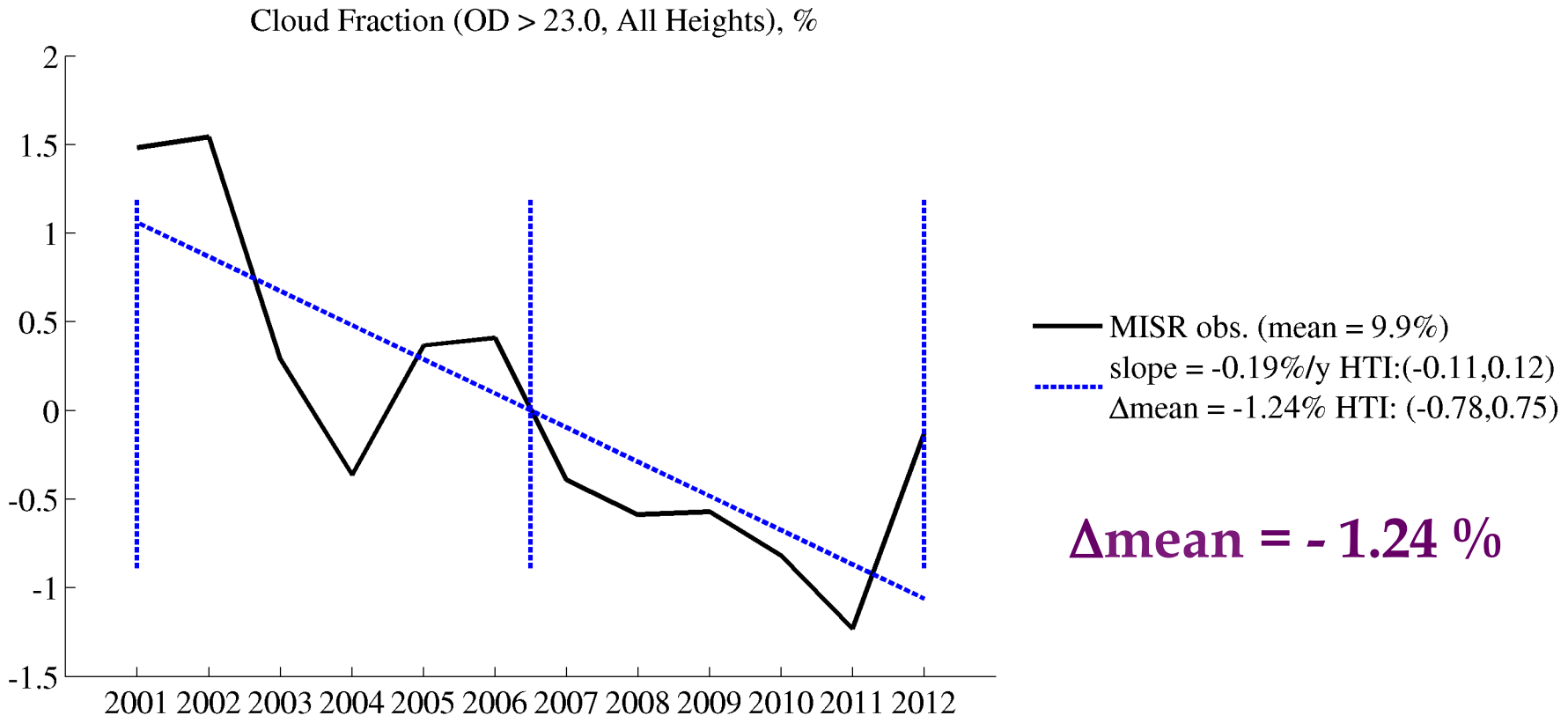
1997-2012, 4x daily.

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 (preliminary result)

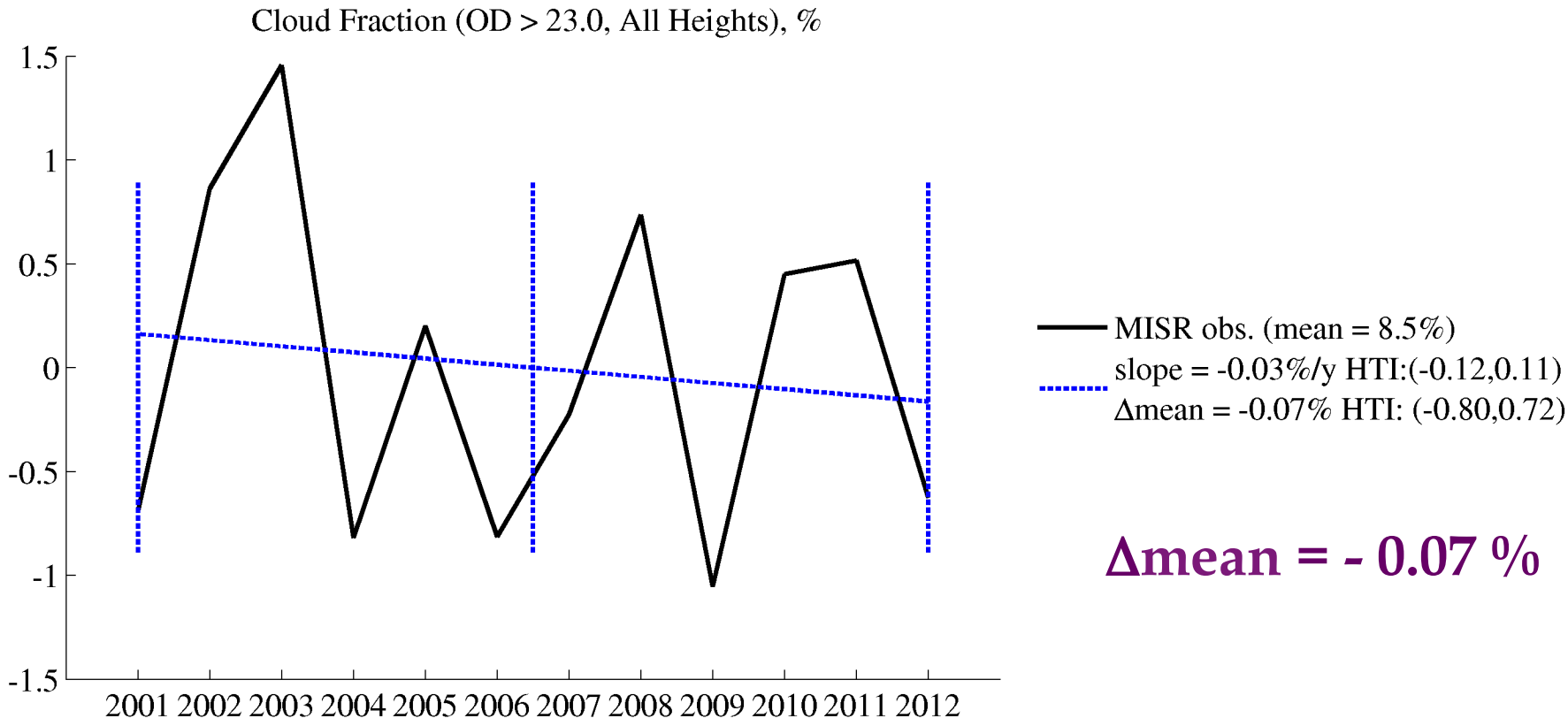


CF OD > 23, State #11



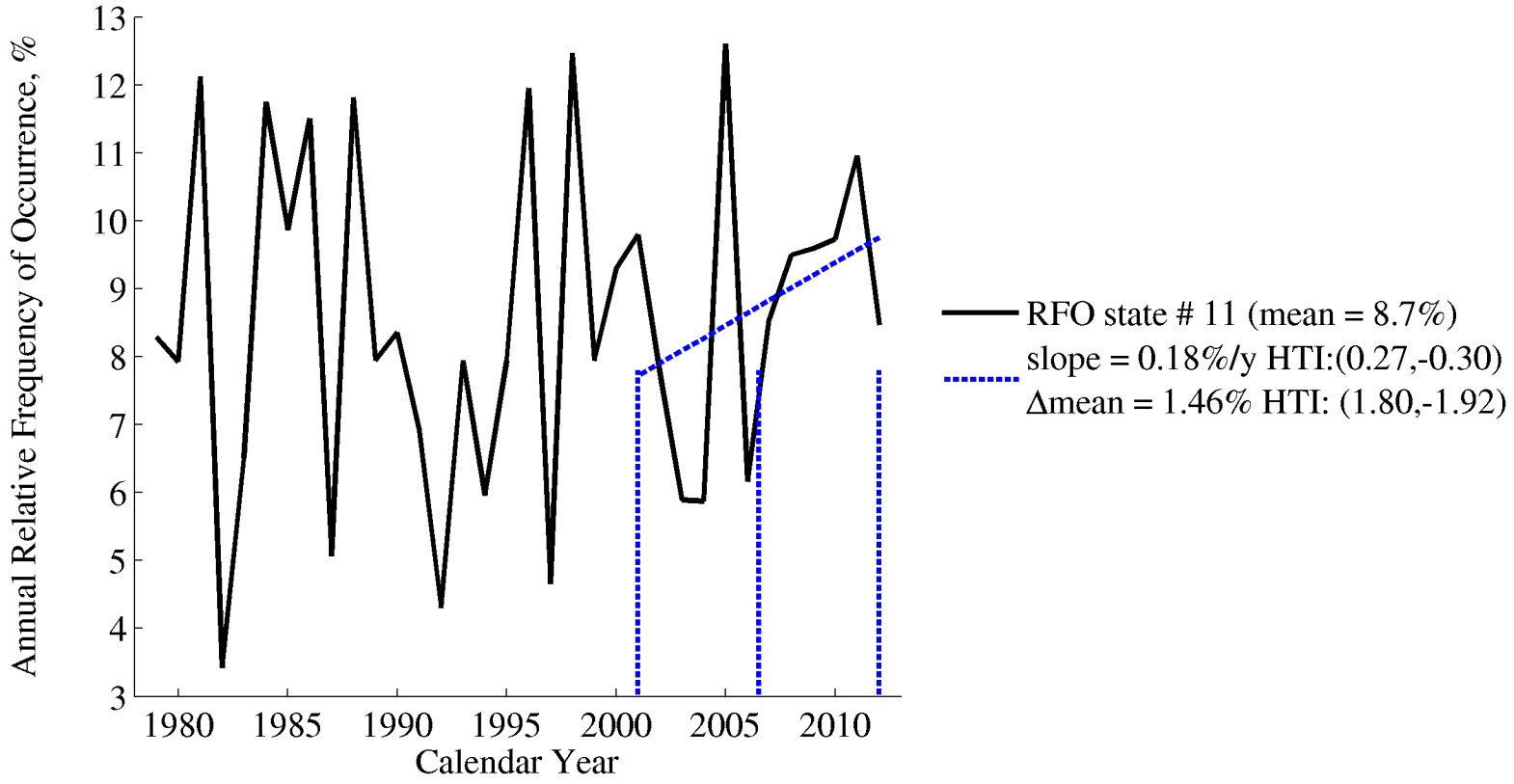
Δmean = - 1.24 %

CF OD > 23, State #5



Δmean = - 0.07 %

Example of Change in Relative Frequency of Occurrence (RFO)



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

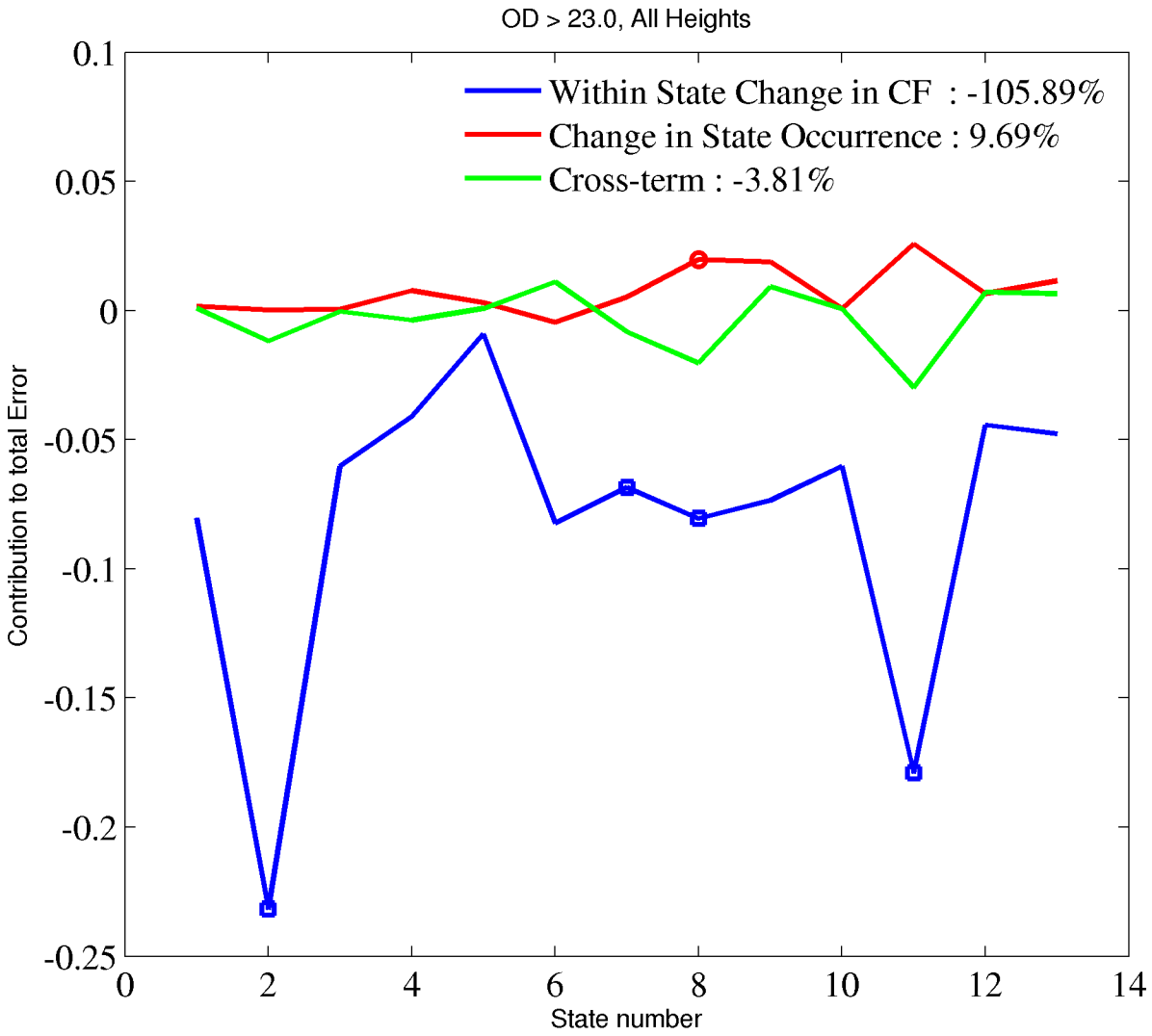
$$\Delta CF_{total} \approx \sum_{i=1}^{states} (\Delta CF_i) * RFO_i + \sum_{i=1}^{states} (CF_i - CF_{total}) * \Delta RFO_i + \sum_{i=1}^{states} \Delta CF_i * \Delta RFO_i$$

With in State

Distribution of States

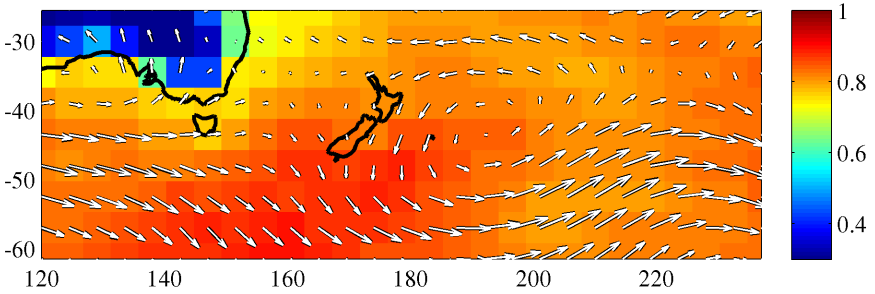
Cross-term

Comparison of terms for each atmospheric state

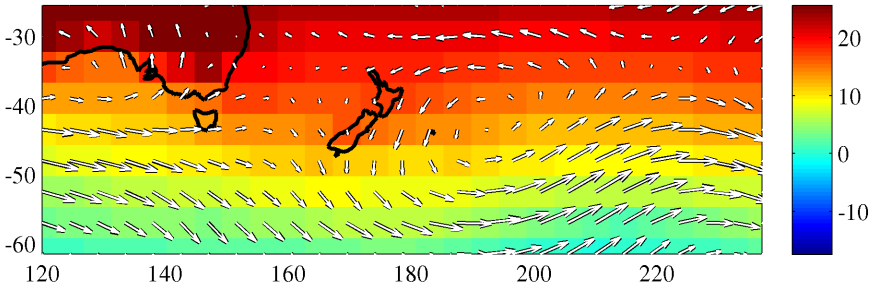


State # 11
Composite 2001 to 2006

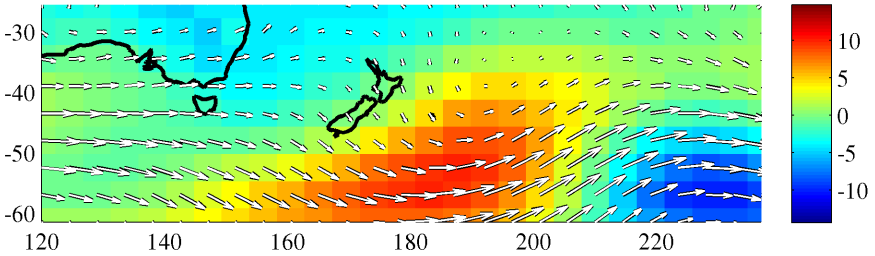
1000 hPa RH + Winds



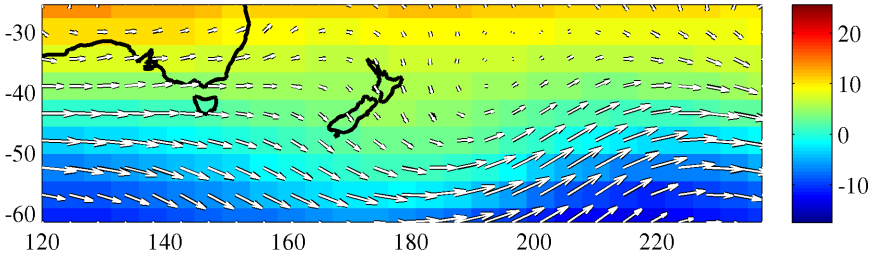
1000 hPa Temp (C) + Winds



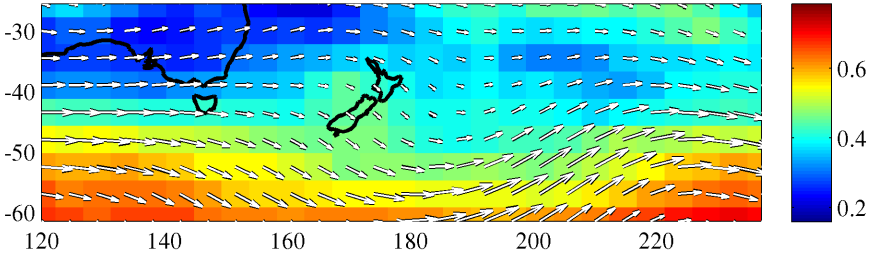
Srf Pres An & 750 hPa Winds



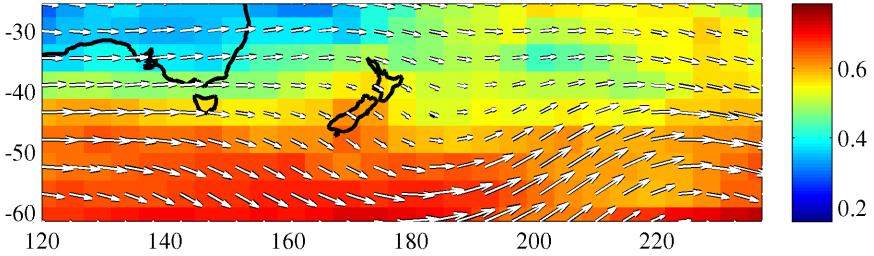
750 hPa Temp (C) + Winds



500 hPa RH + Winds

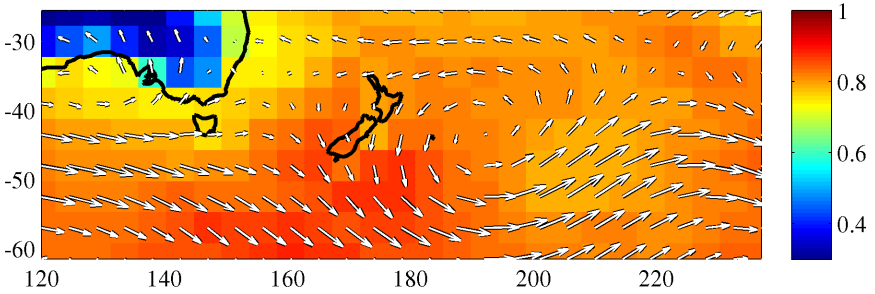


375 hPa RH + Winds

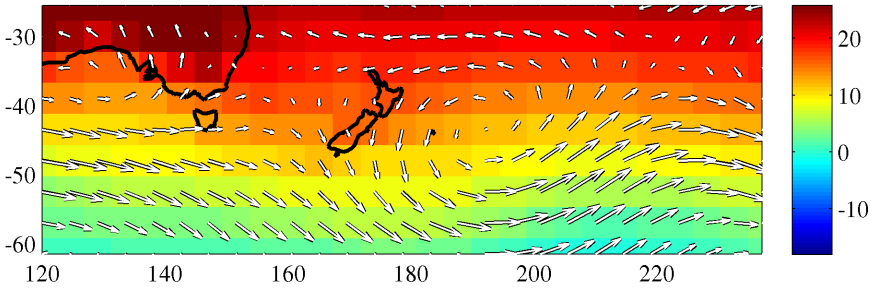


State # 11
Composite 2007 to 2012

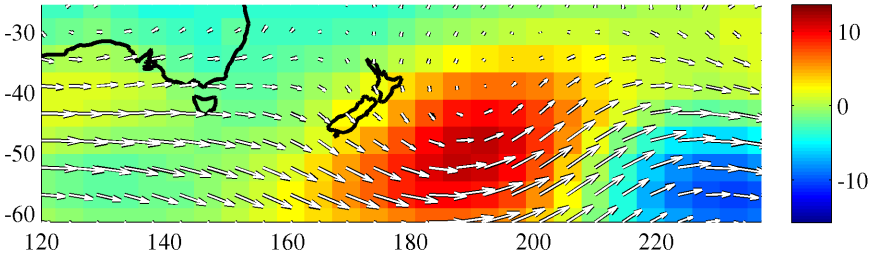
1000 hPa RH + Winds



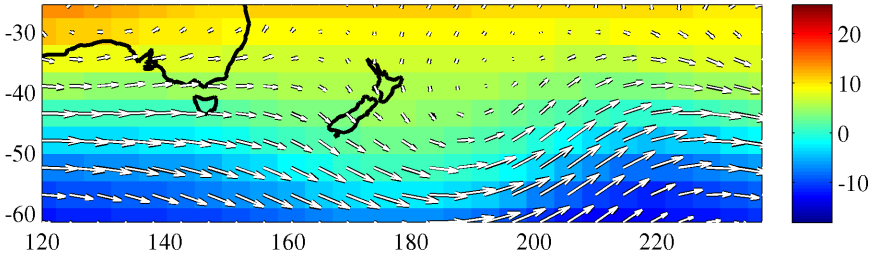
1000 hPa Temp (C) + Winds



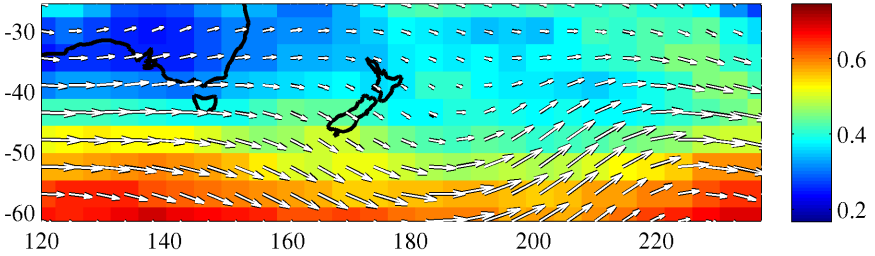
Srf Pres An & 750 hPa Winds



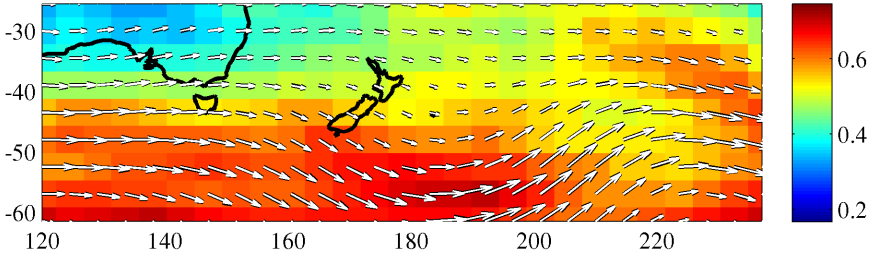
750 hPa Temp (C) + Winds



500 hPa RH + Winds

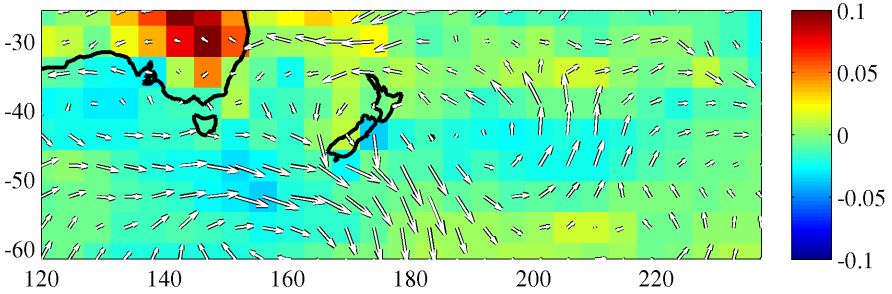


375 hPa RH + Winds

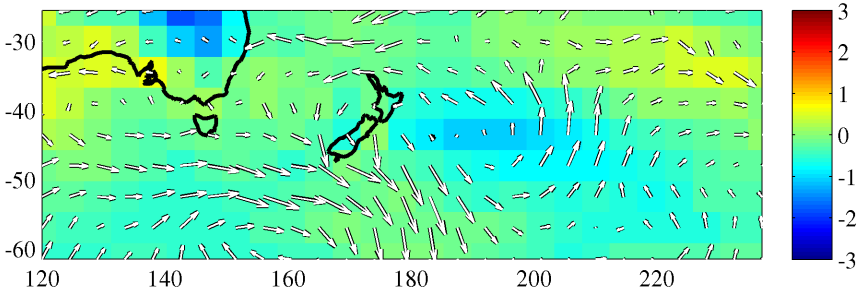


State # 11
Difference (2001 to 2006) - (2007-2012)

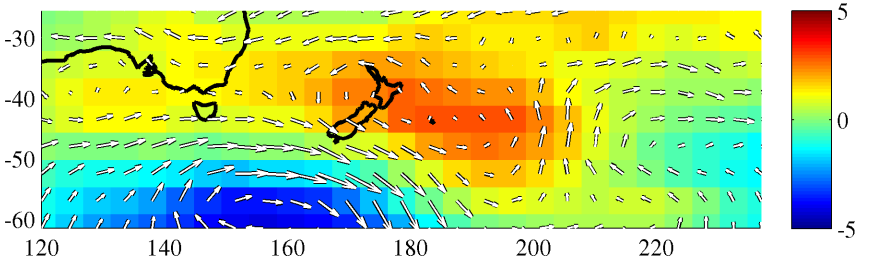
1000 hPa ΔRH + ΔWinds



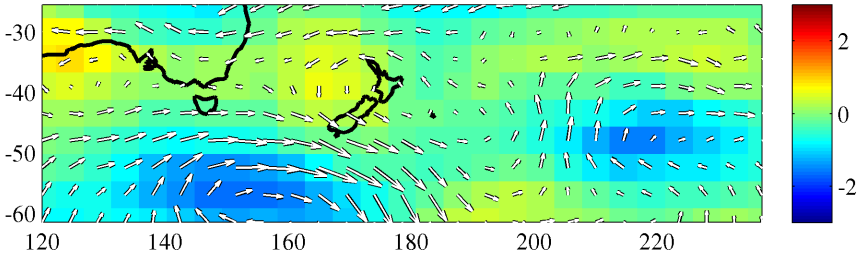
1000 hPa ΔTemp (C) + ΔWinds



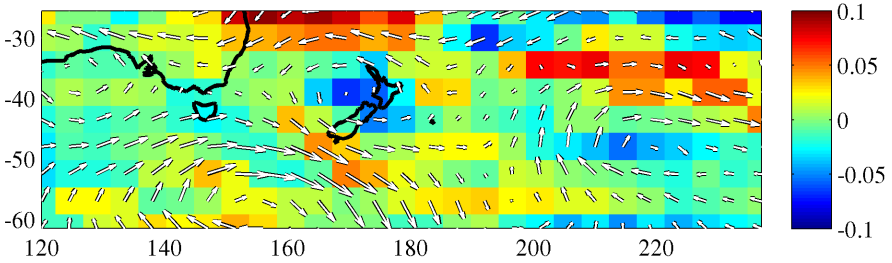
ΔSrf Pres An & 750 hPa ΔWinds



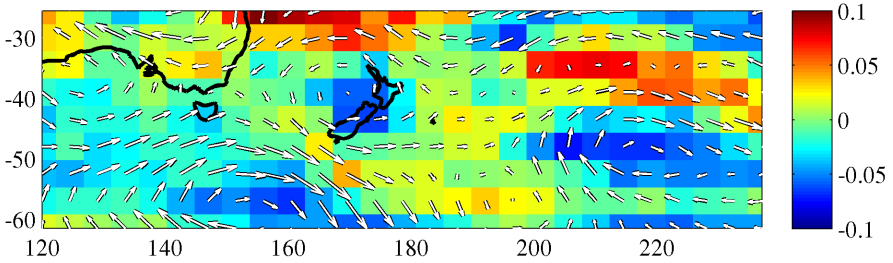
750 hPa ΔTemp (C) + ΔWinds



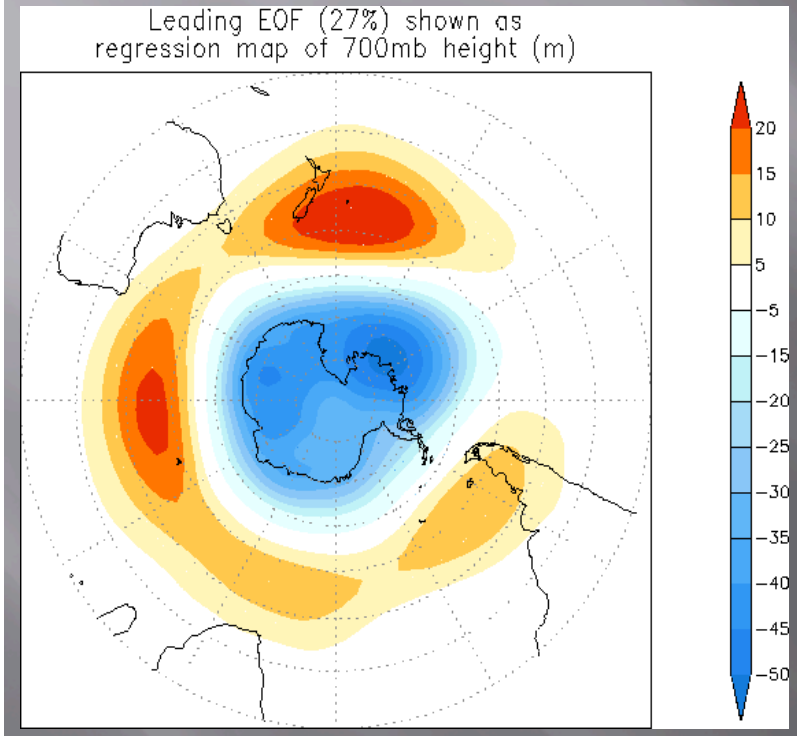
500 hPa ΔRH + ΔWinds



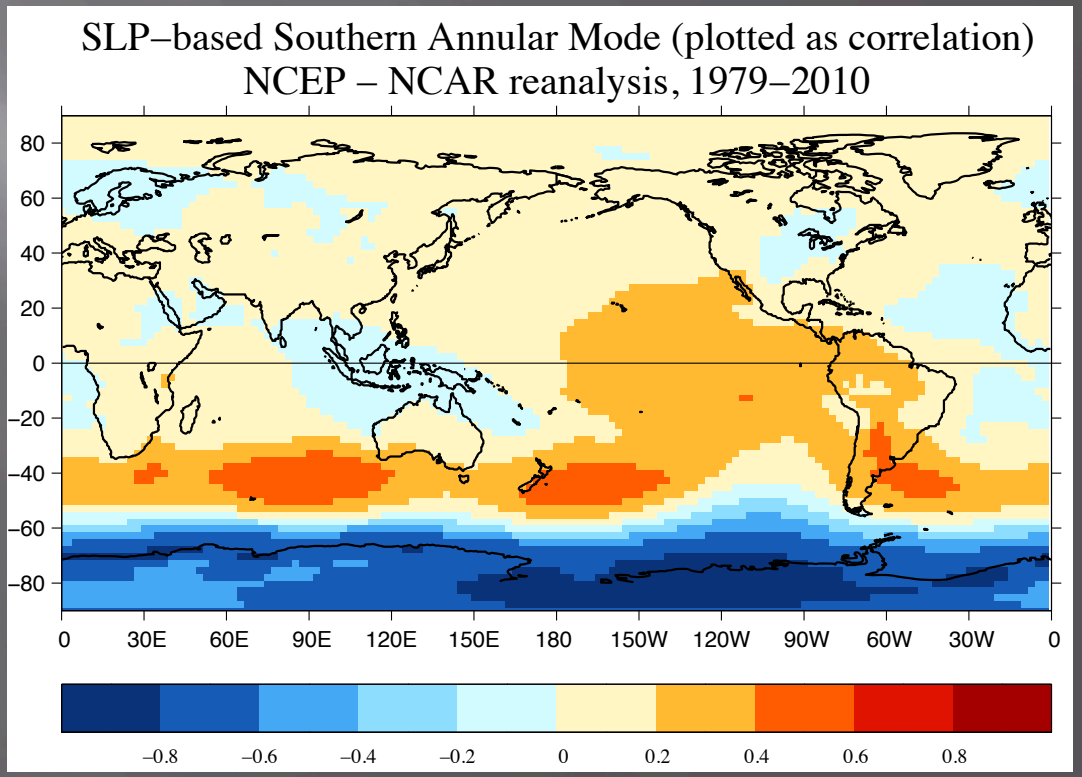
375 hPa ΔRH + ΔWinds



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

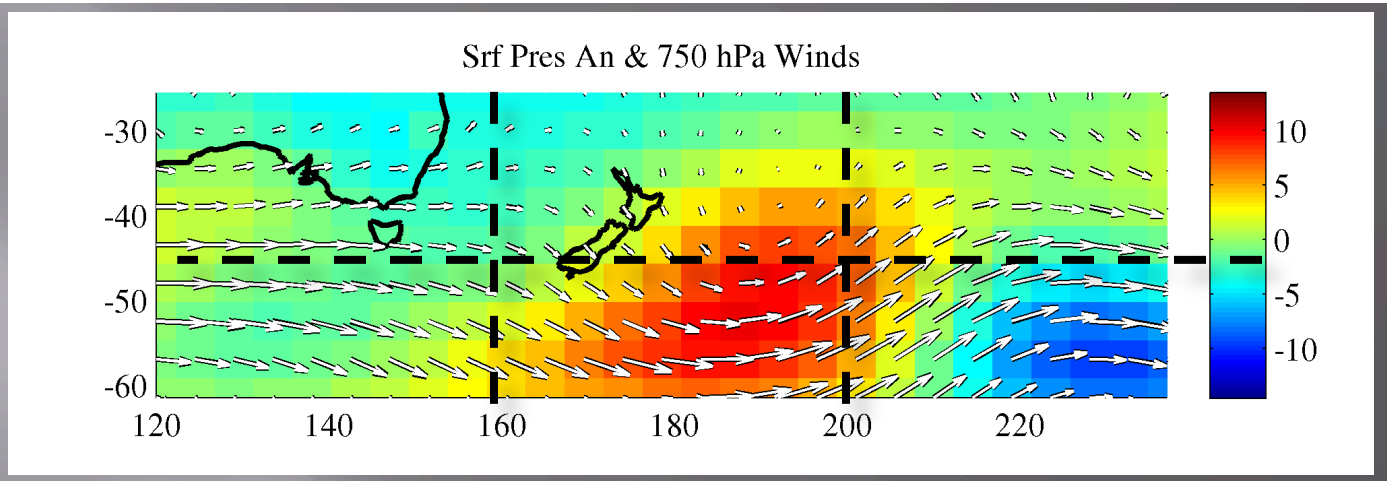


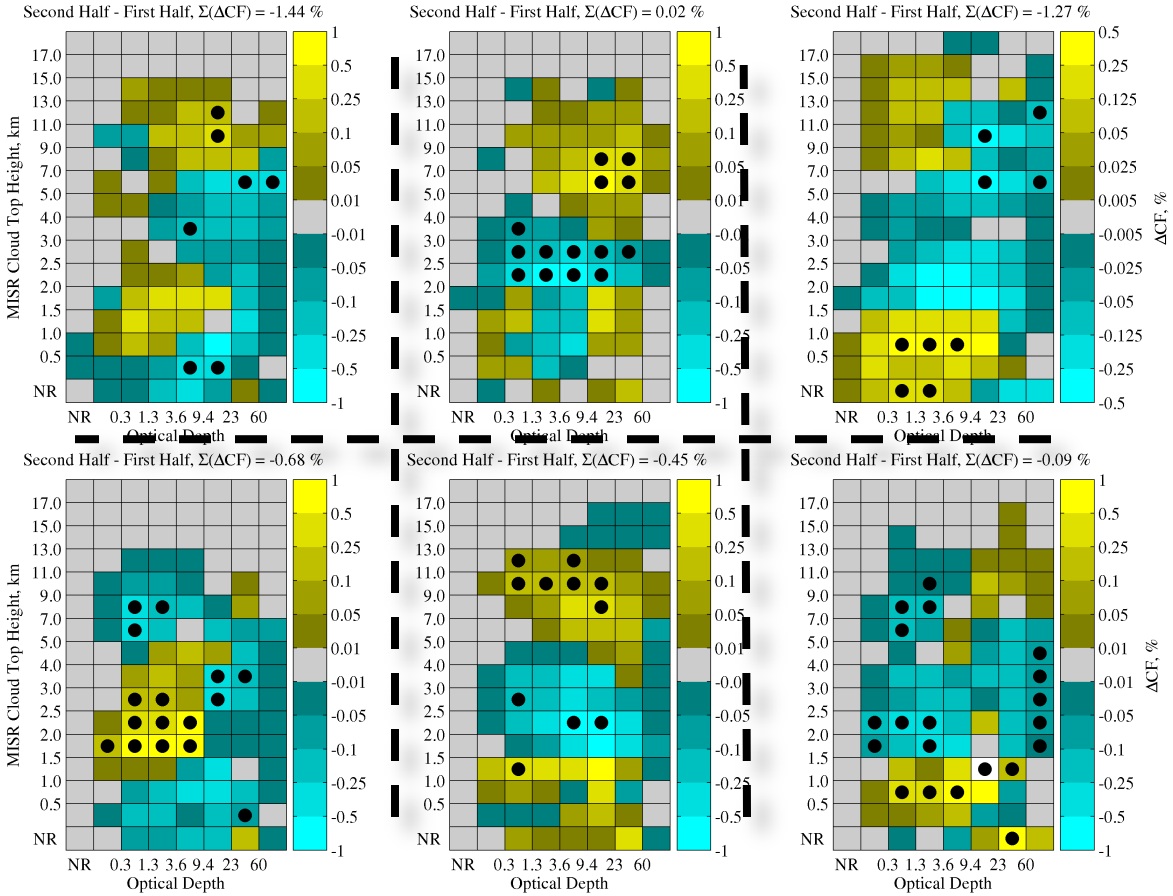
NCEP



Todd Mitchell, JISAO

State # 11

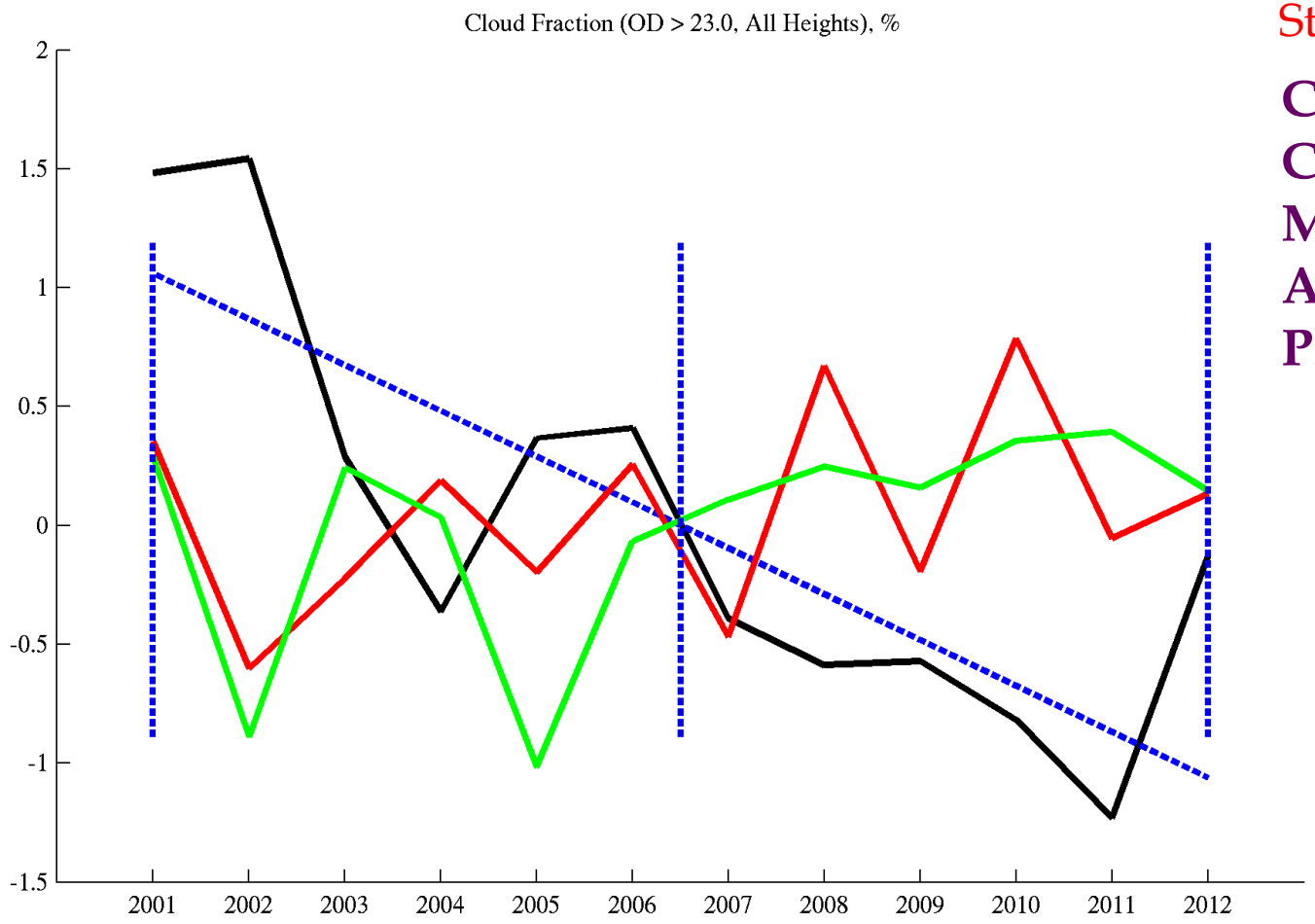

Srf Pres An & 750 hPa Winds
-30
-40
-50
-60
120
140
160
180
200
220
10
5
0
-5
-10


Second Half - First Half, Σ(ΔCF) = -1.44 %
Second Half - First Half, Σ(ΔCF) = 0.02 %
Second Half - First Half, Σ(ΔCF) = -1.27 %
Second Half - First Half, Σ(ΔCF) = -0.68 %
Second Half - First Half, Σ(ΔCF) = -0.45 %
Second Half - First Half, Σ(ΔCF) = -0.09 %
MISR Cloud Top Height, km
Optical Depth
NR 0.3 1.3 3.6 9.4 23 60
ΔCF, %

Summary

- There has been a reduction in optically thick (OD > 23) cloud amount over much of the NH & SH extratropics over the past decade.
  - Not likely due to calibration drift.
  - This means a reduction in "Bright Pixels"
  - Not necessarily climate change … could be low frequency variability
- This change does NOT is not due to a change in the distribution of large-scale dynamical states (as identified by an atmospheric classification), but relatively subtle changes in position and strength of baroclinic systems.
  - These changes are consistent with an overall strengthening of the Sothern Annular Mode, and consistent with an expansion of subtropical belts.
- Looking Forward
  - Is there a detectable radiative impact ?
  - Correlation with monthly SAM indexes.
  - Examine MODIS AQUA by state → wider swath → more samples.
  - Are there changes in other cloud properties (e.g. Effective Radius) ?
  - Examine structure of CloudSat observations by atmospheric state.
  - Other extratropical regions.
  - Do climate models capture this trend ? (NEED MISR simulator output!)

Extra-slides



State #11

Correlation Coefficient MISR w/ AAO = - 0.30
Ps anom = -0.54

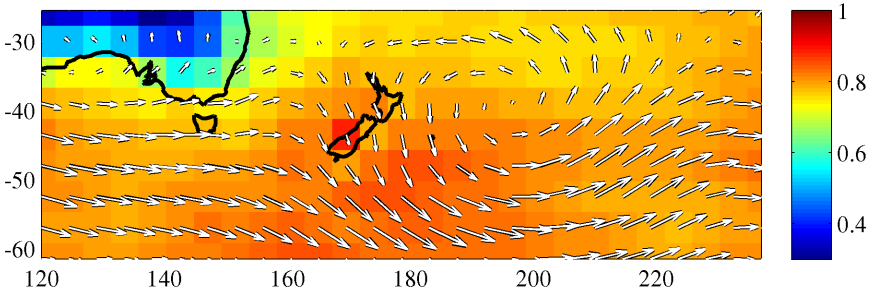
MISR obs.

AAO index (-0.30)

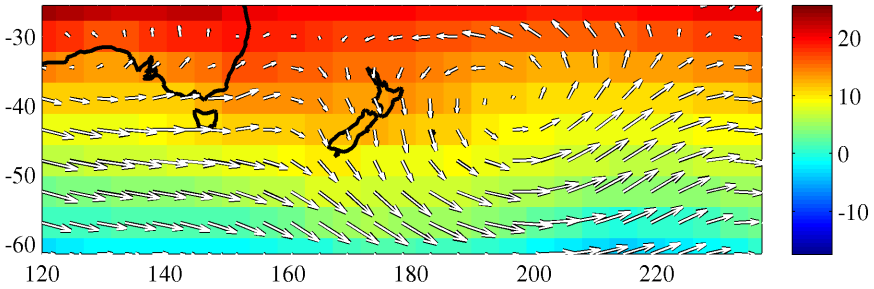
local Ps Anom. (-0.54)

State # 2
Composite 2001 to 2006

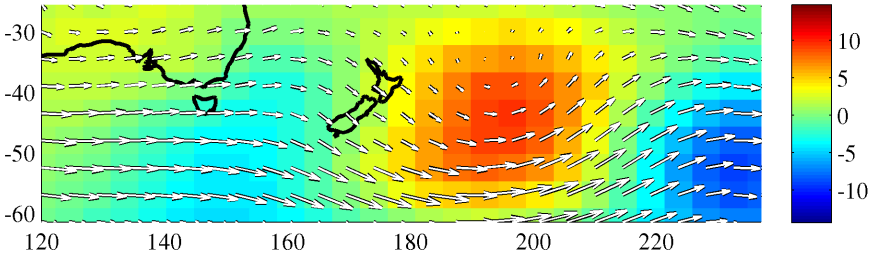
1000 hPa RH + Winds



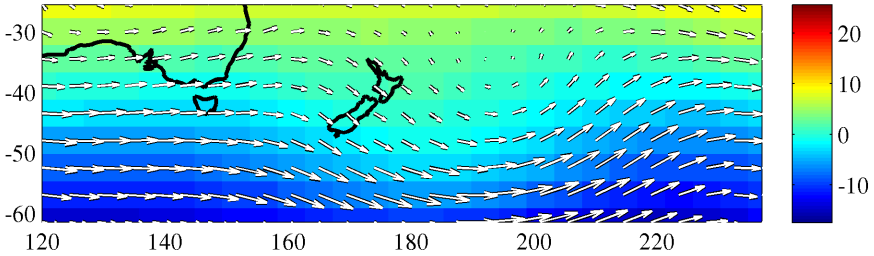
1000 hPa Temp (C) + Winds



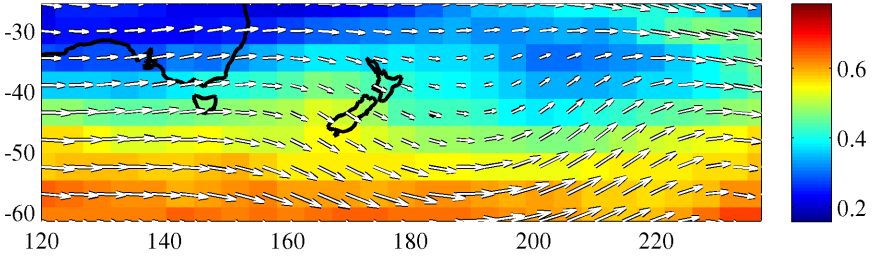
Srf Pres An & 750 hPa Winds



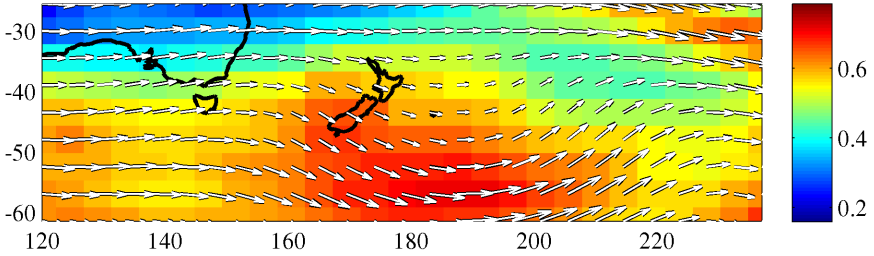
750 hPa Temp (C) + Winds



500 hPa RH + Winds

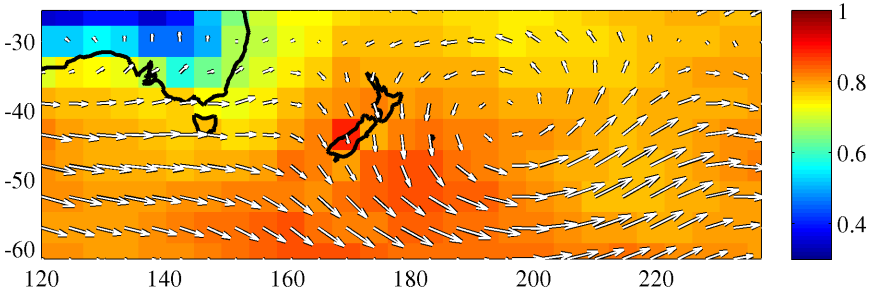


375 hPa RH + Winds

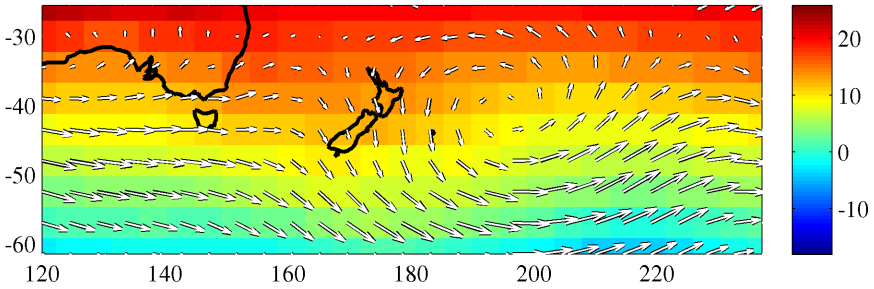


State # 2
Composite 2007 to 2012

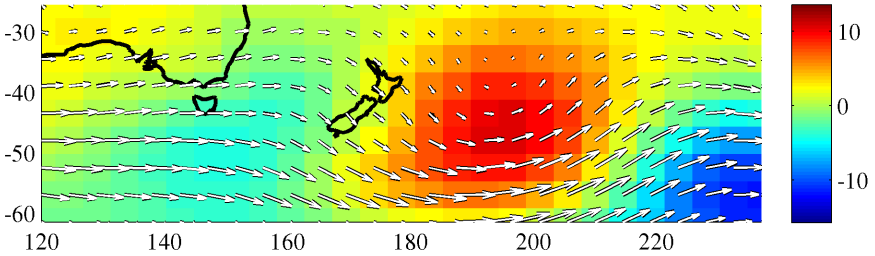
1000 hPa RH + Winds



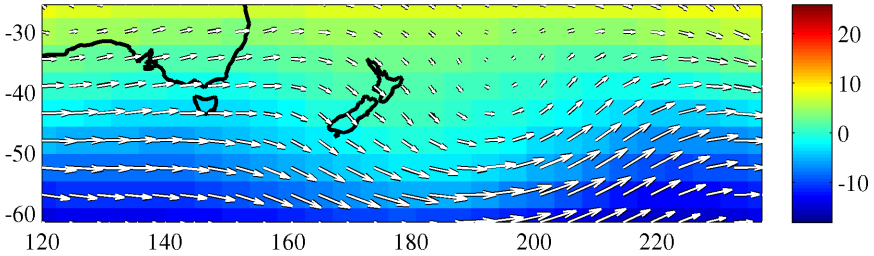
1000 hPa Temp (C) + Winds



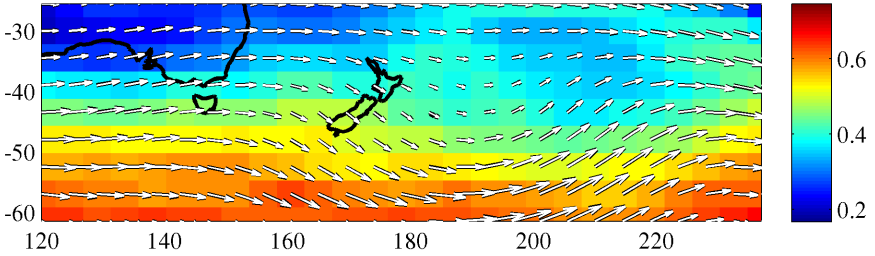
Srf Pres An & 750 hPa Winds



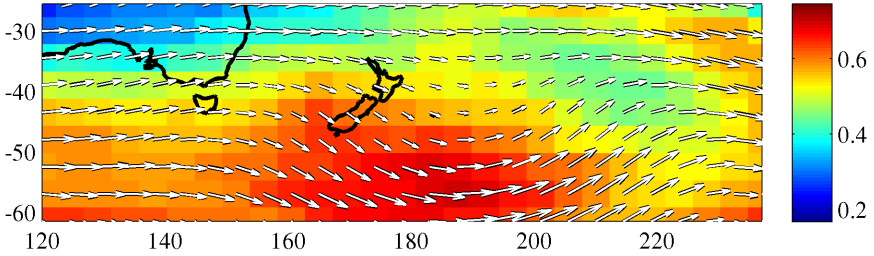
750 hPa Temp (C) + Winds



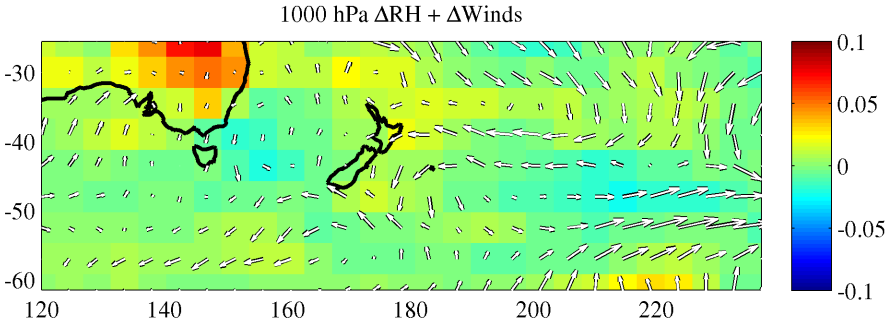
500 hPa RH + Winds

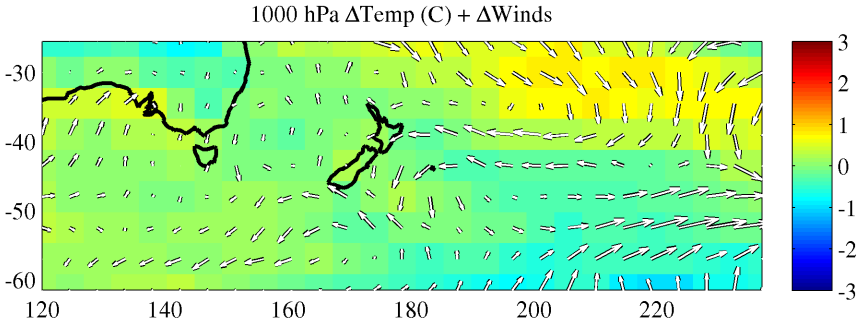


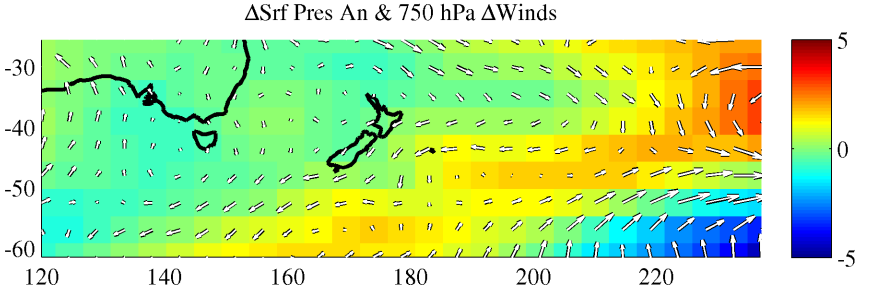
375 hPa RH + Winds

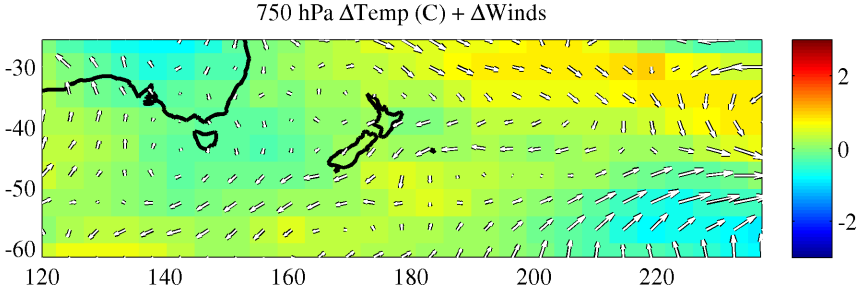


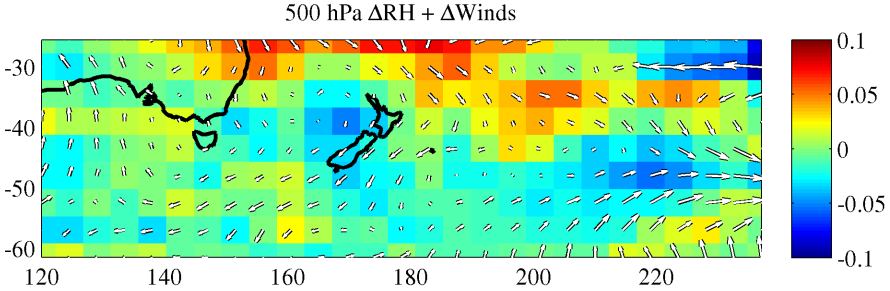
State # 2
Difference (2001 to 2006) - (2007-2012)

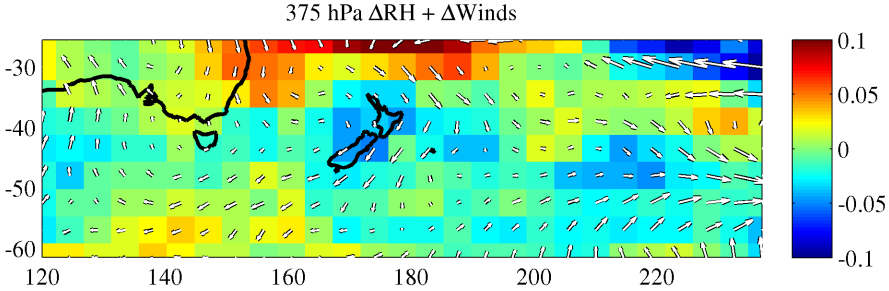








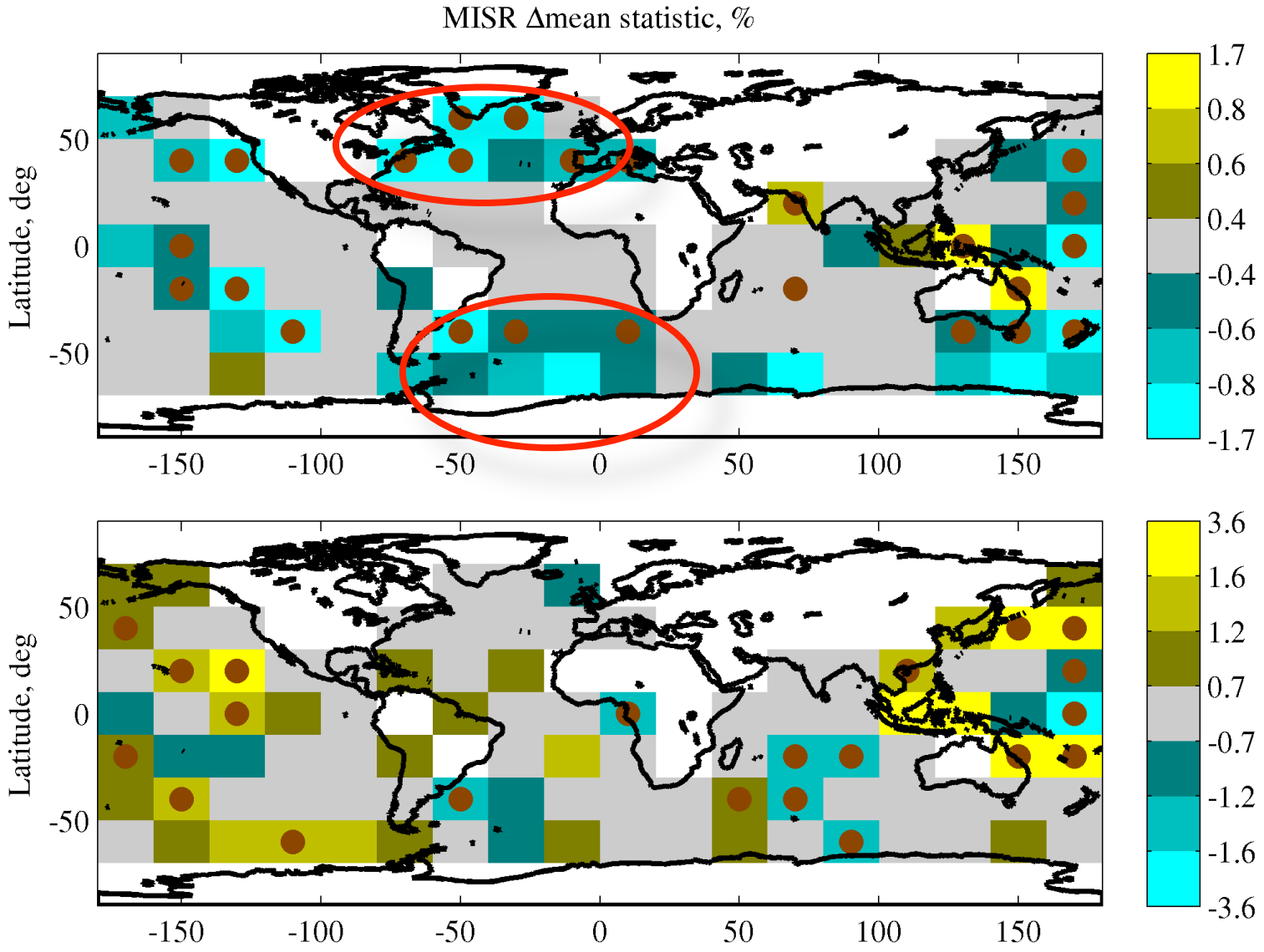




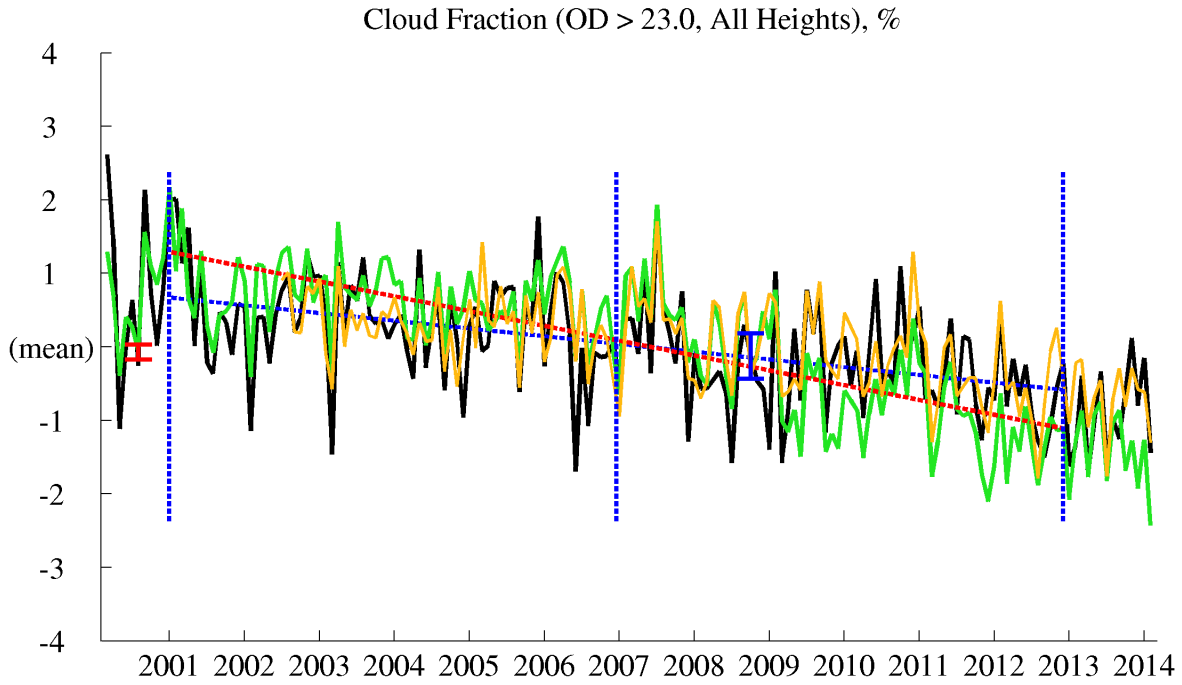
Changes in the extratropical Atlantic …

OD>23

23>OD>3.6



Extratropics

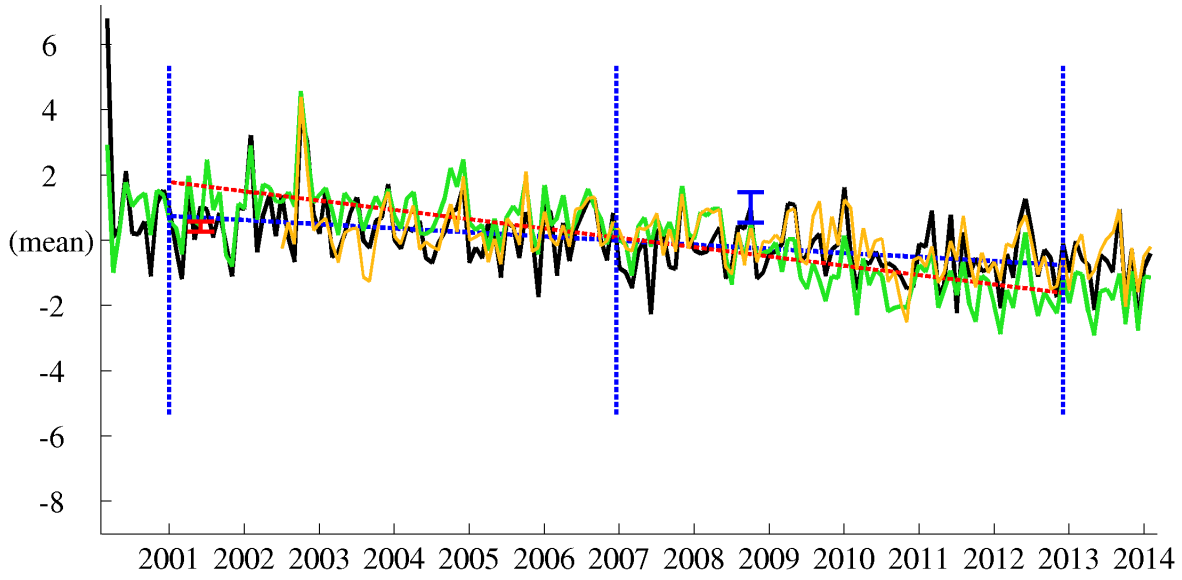


North Atlantic

MISR obs. (mean = 10.5%)
slope = -0.11%/y HTI:(-0.05,0.05)
Δmean = -0.61% HTI: (-0.32,0.31)
MODIS obs. (mean = 11.0%)
slope = -0.20%/y HTI:(-0.10,0.10)
Δmean = -1.18% HTI: (-0.65,0.60)
AQUA obs. (mean = 11.6%)
slope = -0.10%/y HTI:(-0.05,0.05)

Corr. MISR & MODIS obs = 0.75

Corr. MISR & AQUA obs = 0.72



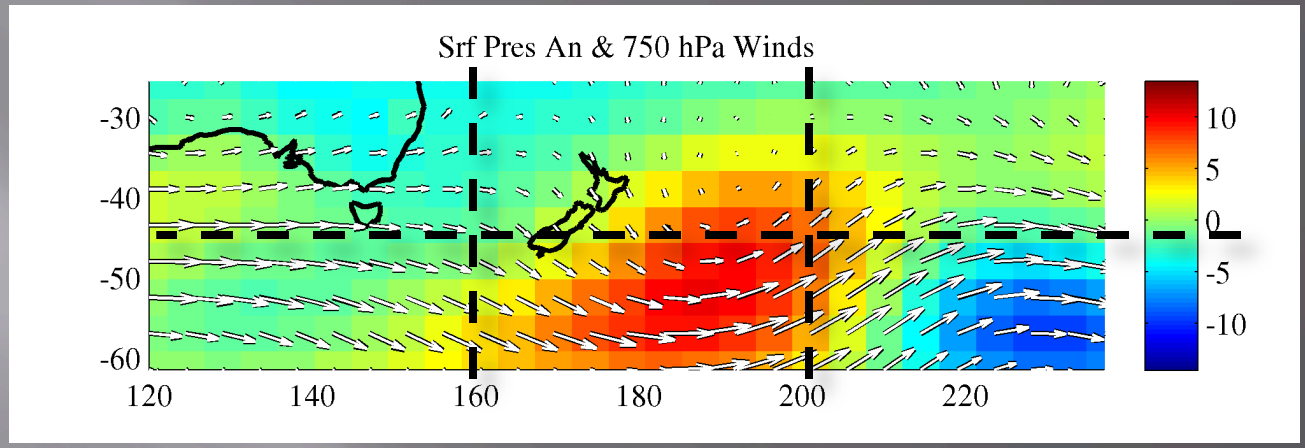
South Atlantic

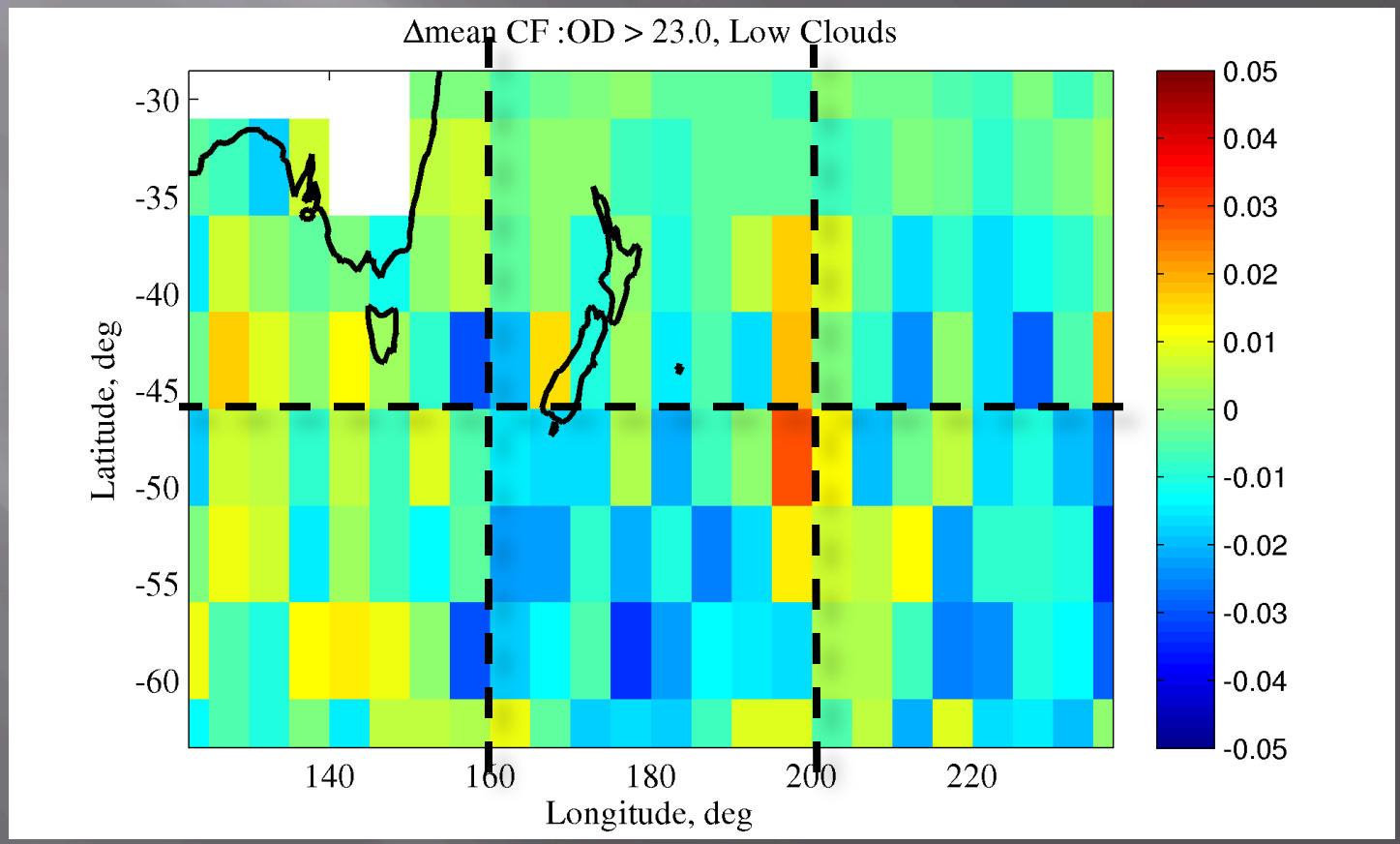
MISR obs. (mean = 10.5%)
slope = -0.13%/y HTI:(-0.07,0.06)
Δmean = -0.85% HTI: (-0.47,0.45)
MODIS obs. (mean = 12.0%)
slope = -0.29%/y HTI:(-0.13,0.14)
Δmean = -1.79% HTI: (-0.97,1.02)
AQUA obs. (mean = 12.5%)
slope = -0.12%/y HTI:(-0.07,0.06)

Corr. MISR & MODIS obs = 0.74

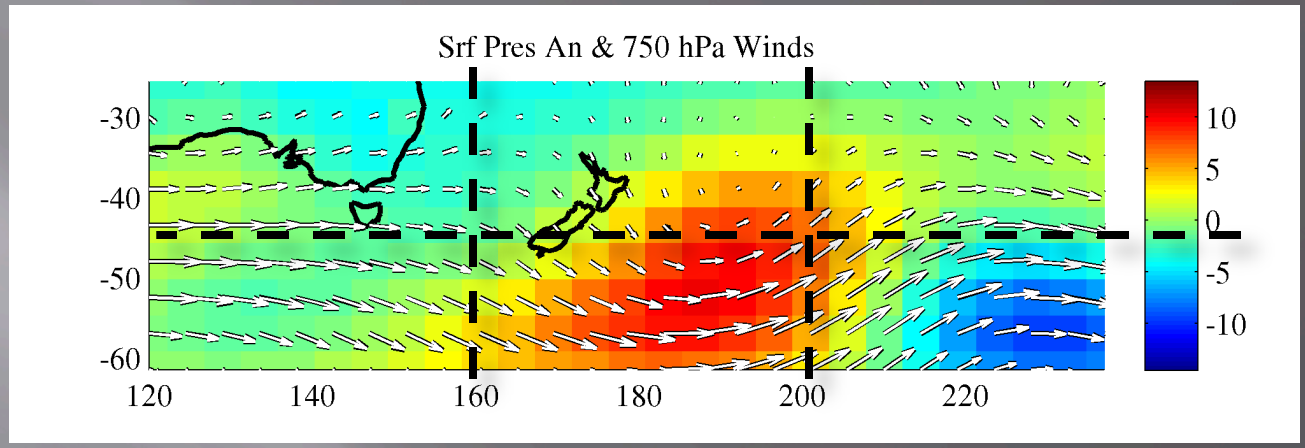
Corr. MISR & AQUA obs = 0.74

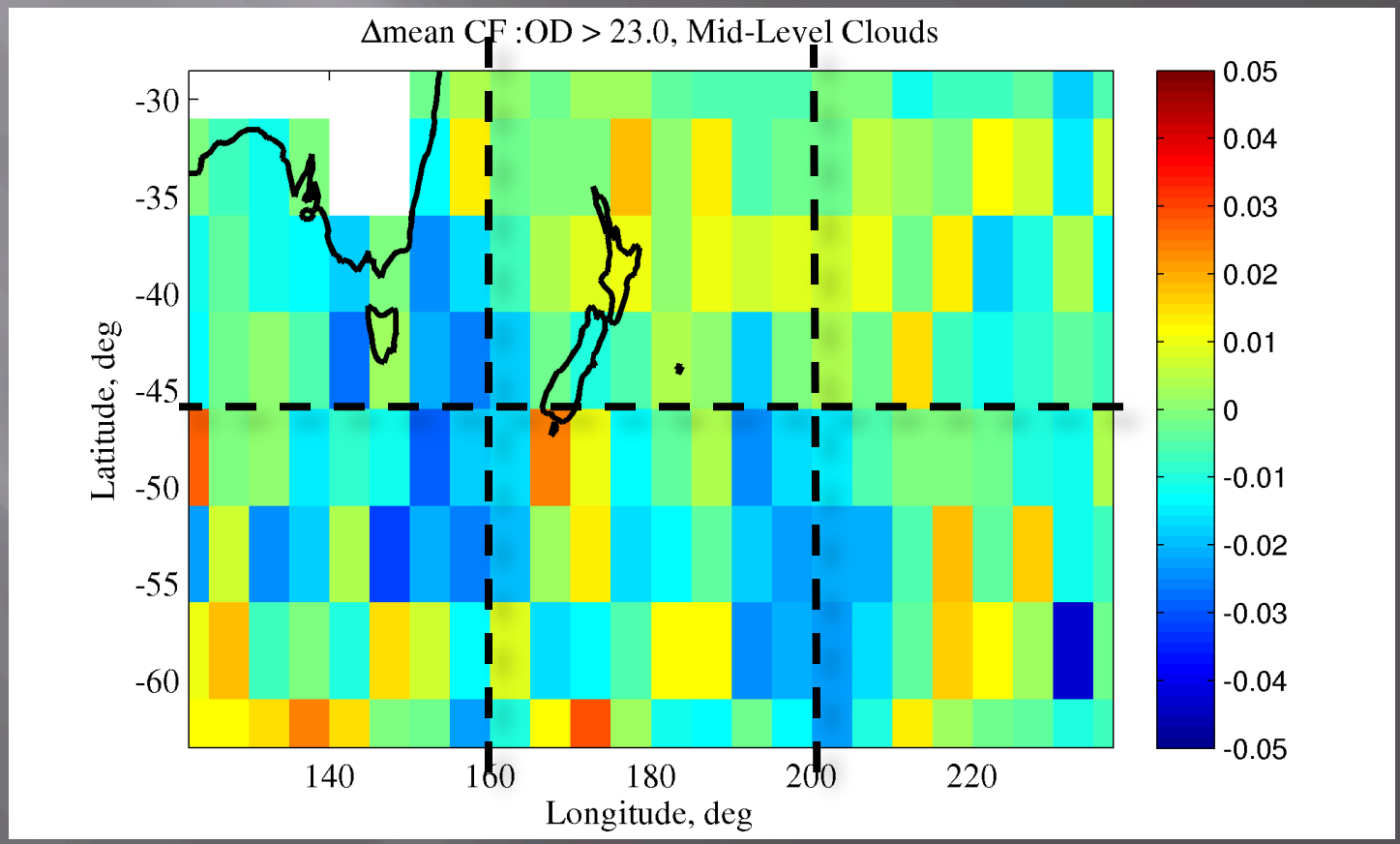
State # 11


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

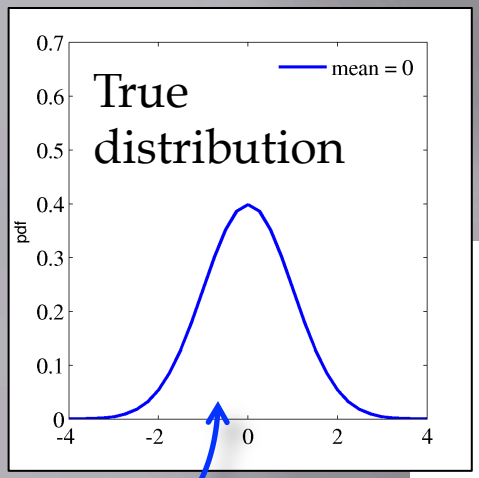

Δmean CF :OD > 23.0, Low Clouds
Latitude, deg
-30
-35
-40
-45
-50
-55
-60
140
160
180
200
220
Longitude, deg
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05

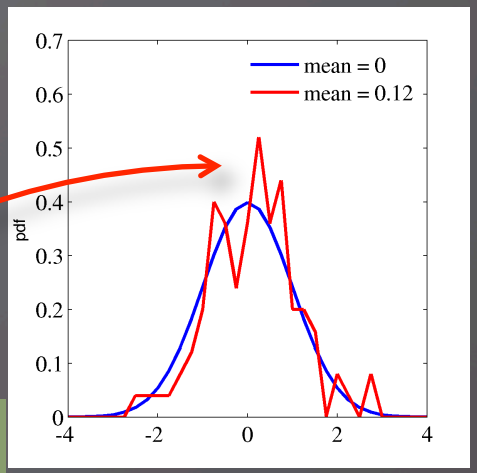
State # 11


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


Δmean CF :OD > 23.0, Mid-Level Clouds
Latitude, deg
-30
-35
-40
-45
-50
-55
-60
140
160
180
200
220
Longitude, deg
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05

Moving Blocks Bootstrap Resampling (zero-mean test)





Parent Population

Sample can be a scalar or vector

1	2	3	4	5	6	7	8	9	10	11	12
2	3	4	5	8	9	10	11	7	8	9	10
9	10	11	12	7	8	9	10	5	6	7	8
3	4	5	6	8	9	10	11	4	5	6	7

Statistic/ Mean

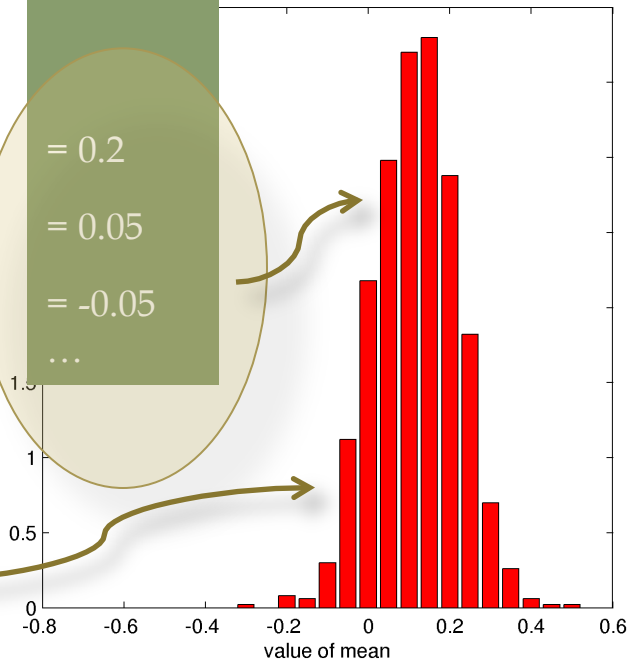
= 0.12

= 0.2

= 0.05

= -0.05

…



Requirement: sufficient "independent" samples in original samples to represent the true distribution !

Distribution of Mean values from resamples