A new mechanism of ocean-atmosphere coupling in midlatitudes

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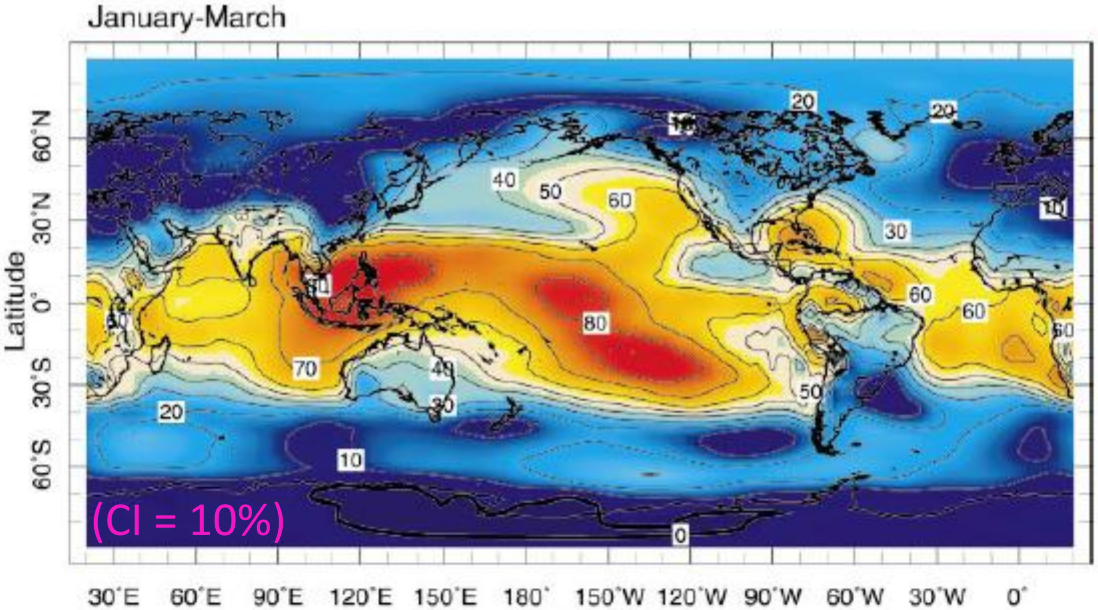
1. Motivation

Two key questions

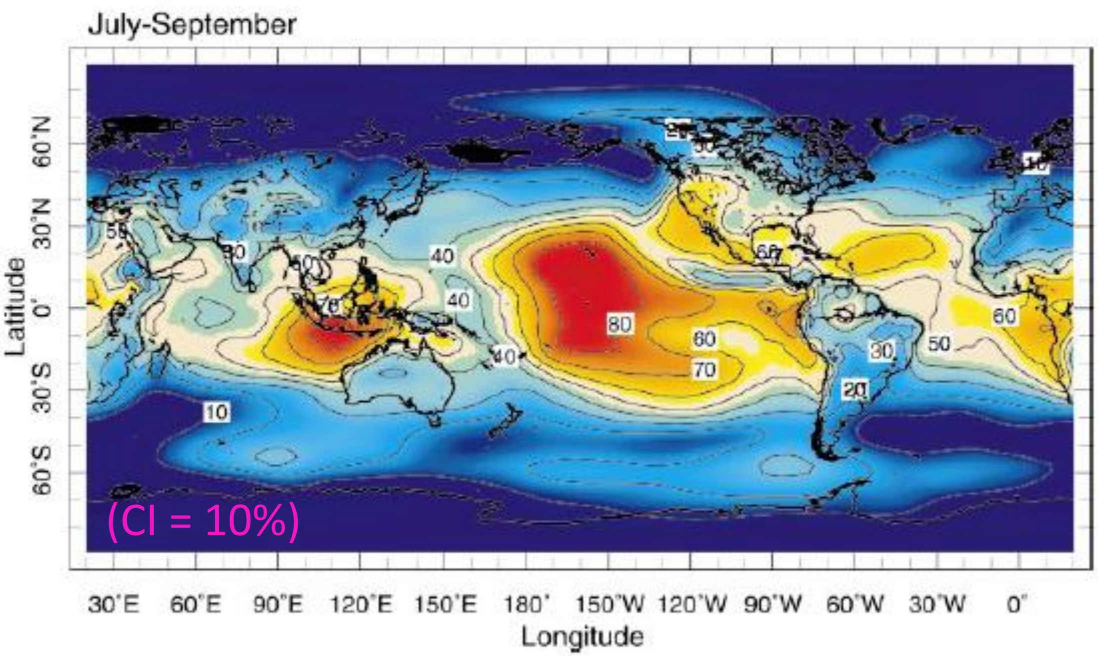
- By which mechanism(s) do extra-tropical SST anomalies interact with the atmosphere?
- Might the extra-tropical oceanic influence be larger in Nature than in AGCMs?

(NB: SST anomalies referred as spatial non uniformity)

"Potential predictability" in models



Seasonal mean sea level pressure



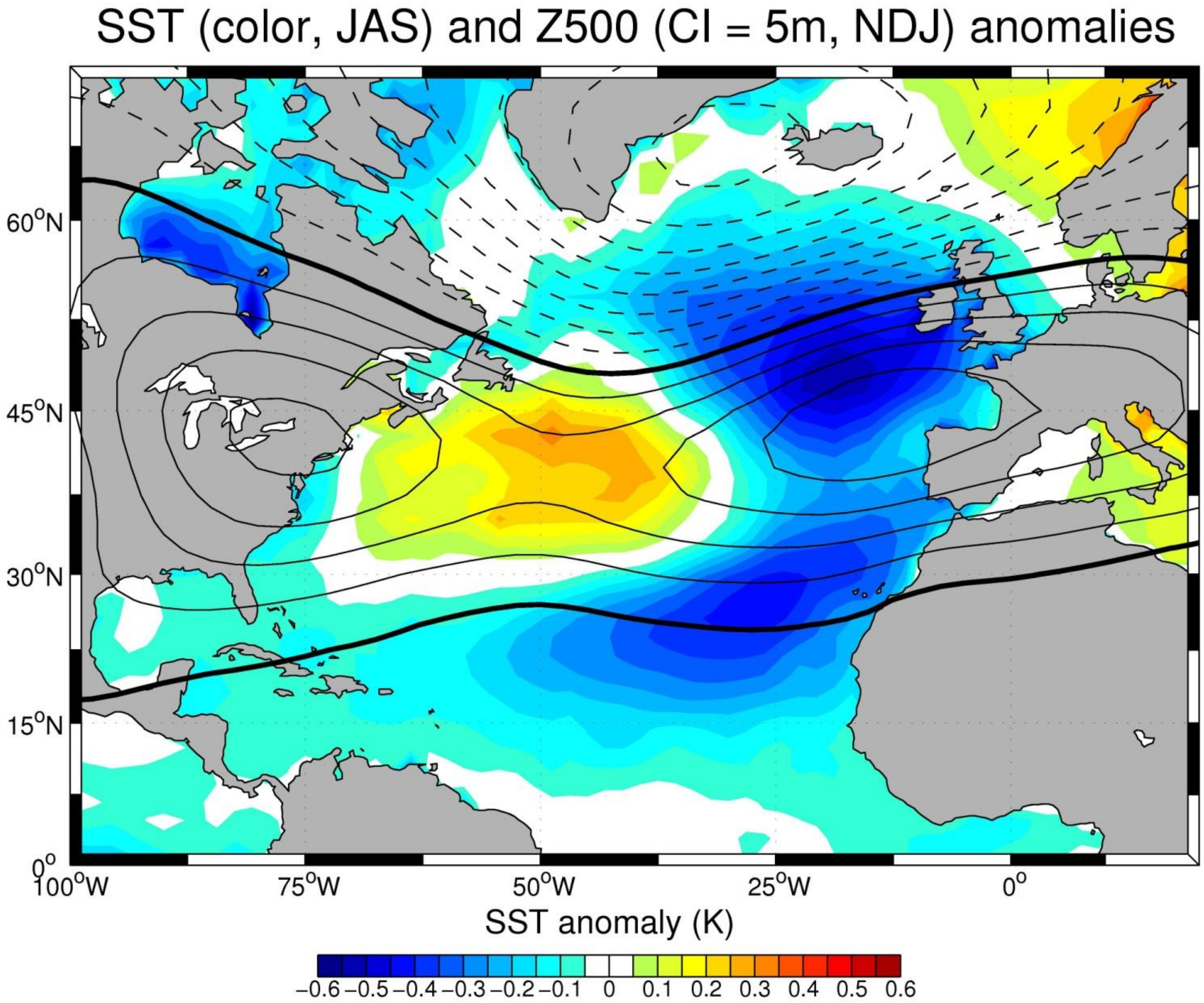
$$R = \frac{\sigma^2_{forced}}{\sigma^2_{internal} + \sigma^2_{forced}}$$

$\sigma^2_{internal}$: Variance existing in absence of SST and sea ice time variations

σ^2_{forced}: Variance originating from SST and sea ice time variations

Roeckner et al. (1992)

Predictability in Reanalysis datasets

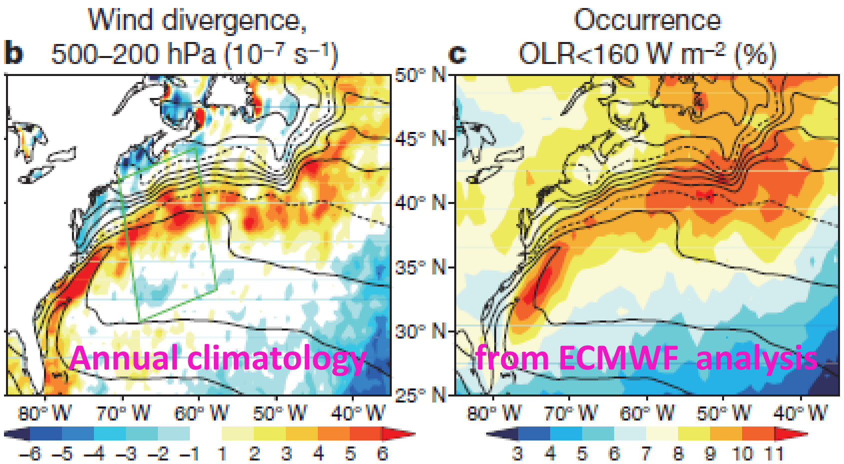


Positive feedback of SST tripole onto NAO

Czaja & Frankignoul (2002)

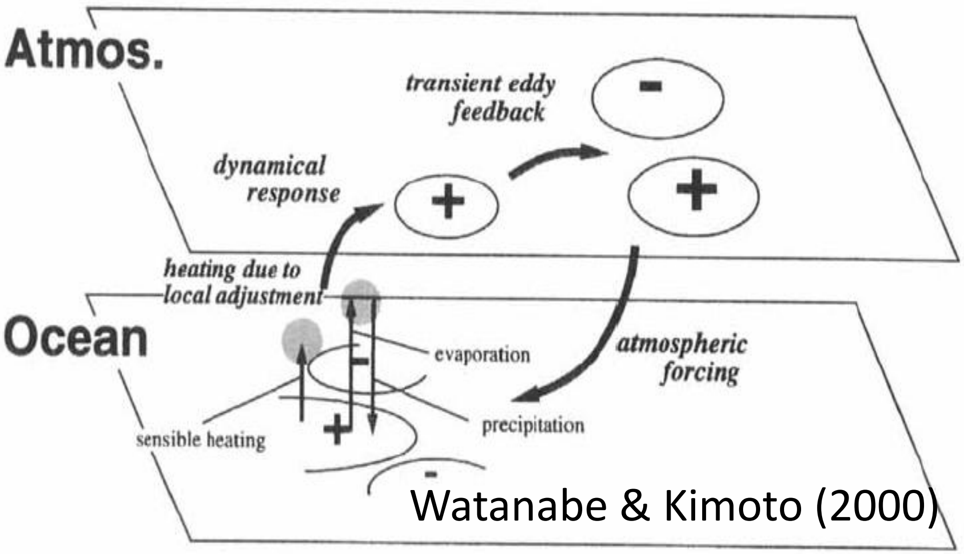
Prevalent paradigm for extra-tropical SST forcing: two steps

- Heating (deep or shallow) induced by SST anomalies.



Minobe et al. (2008)

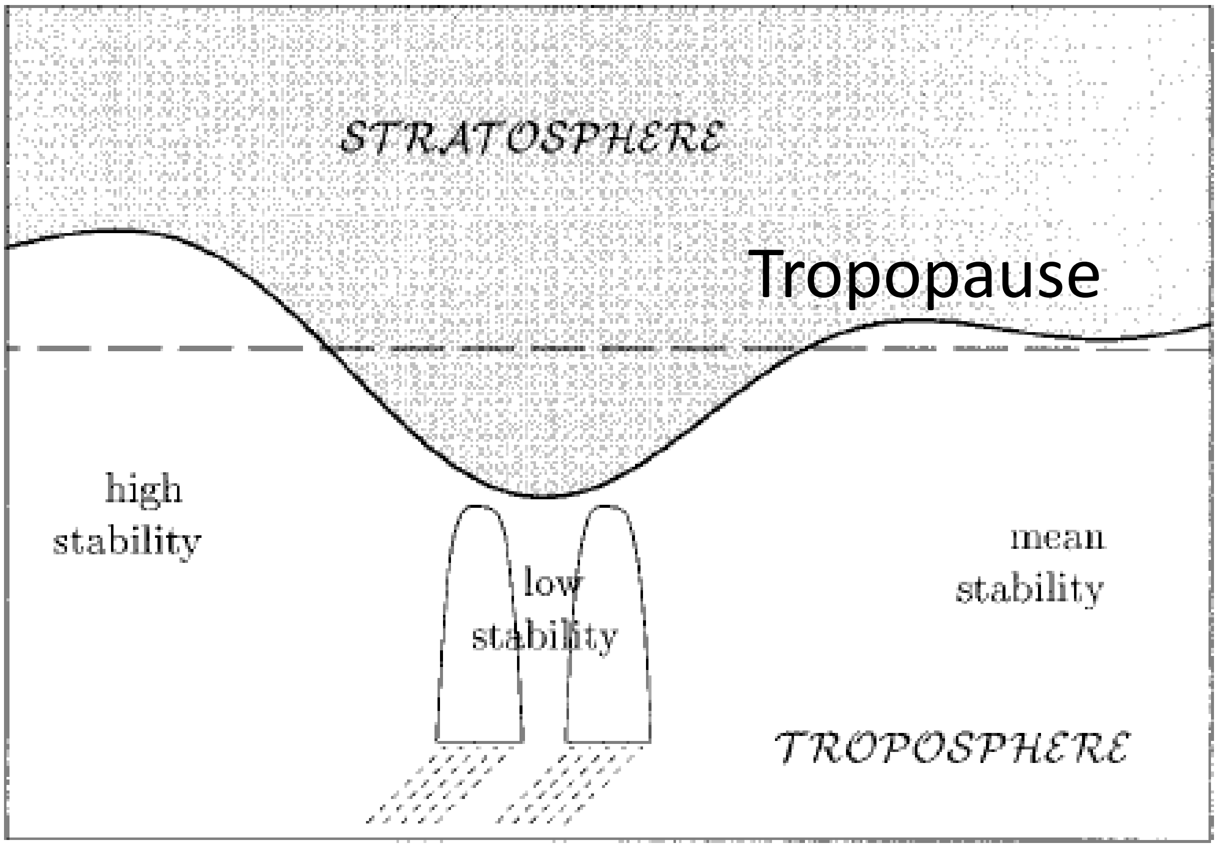
- Interaction between the direct baroclinic response to this heating and eddy PV fluxes.



Watanabe & Kimoto (2000)

Alternative paradigm: SST anomalies "set" the atmospheric lapse-rate

(building upon Juckes 2000)



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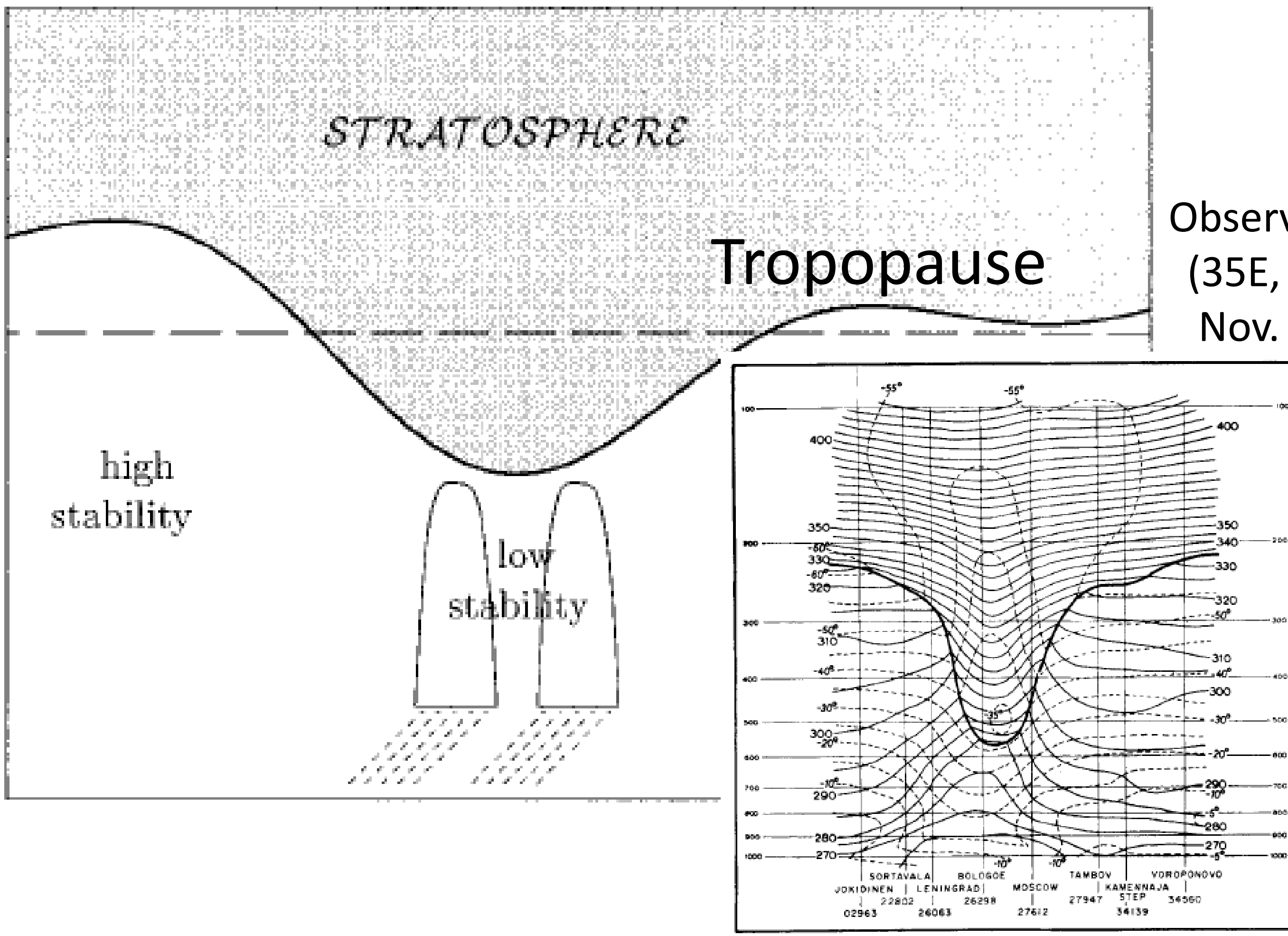

Observations at (35E, 58N) on Nov. 16 1958

Alternative paradigm: SST anomalies “set” the atmospheric lapse-rate

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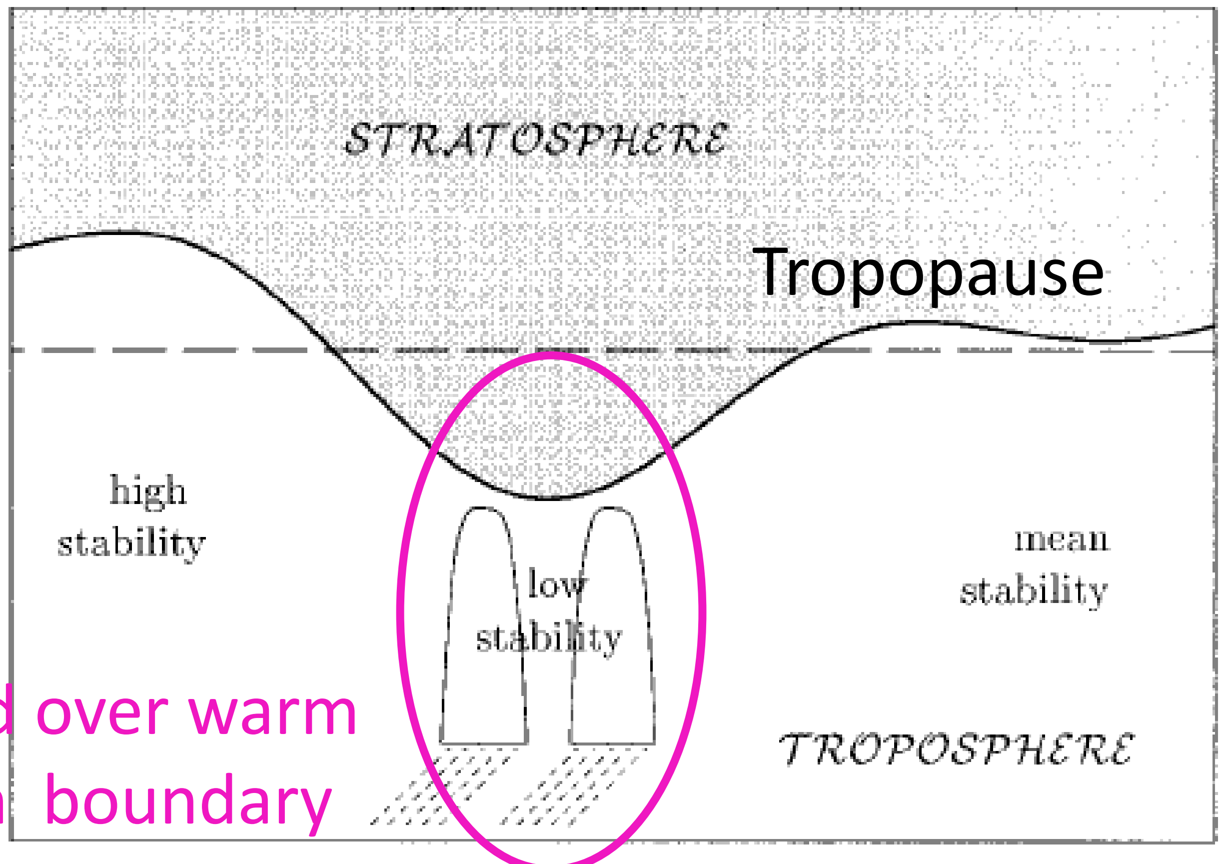

Favoured over warm western boundary current regions

Alternative paradigm: SST anomalies "set" the atmospheric lapse-rate

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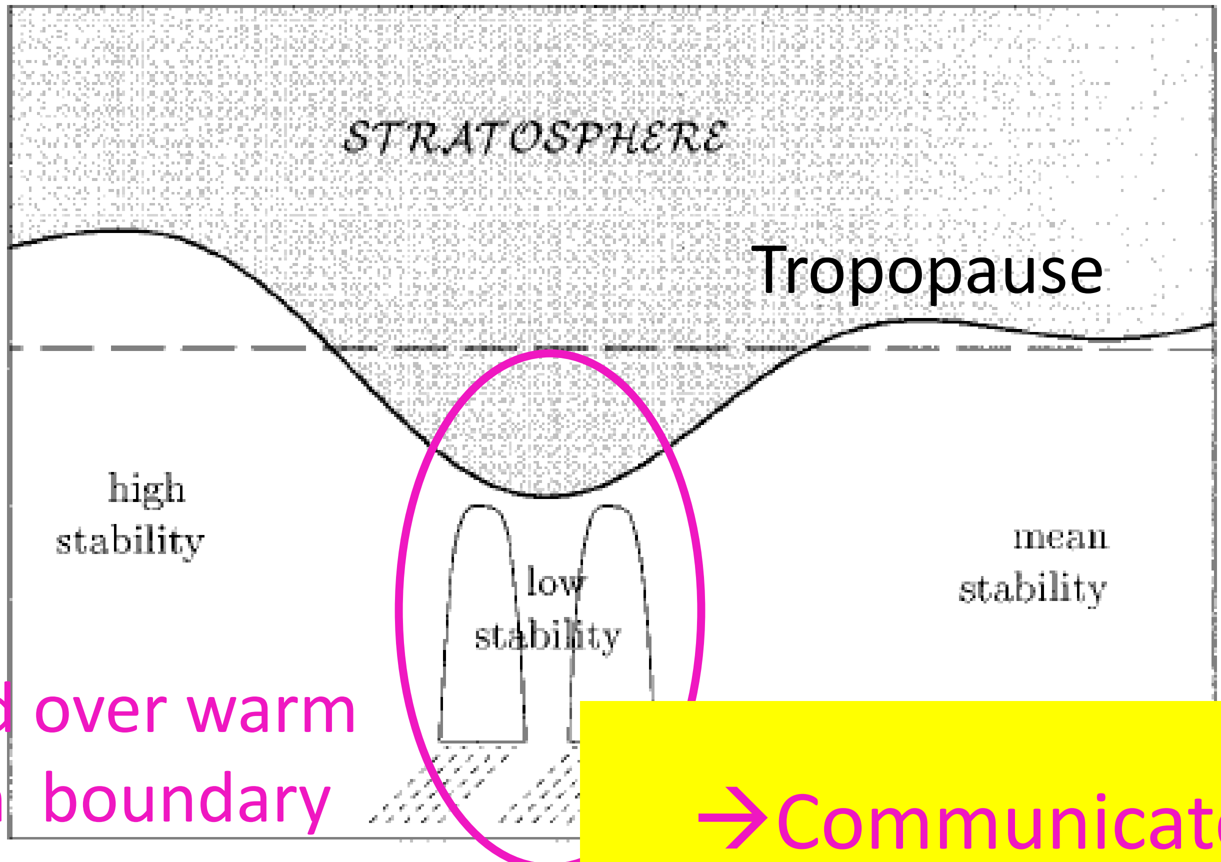


Favoured over warm western boundary current regions

→Communicates SST throughout troposphere

2. Analysis of ***extra-tropical*** moist convection in the ERA interim data

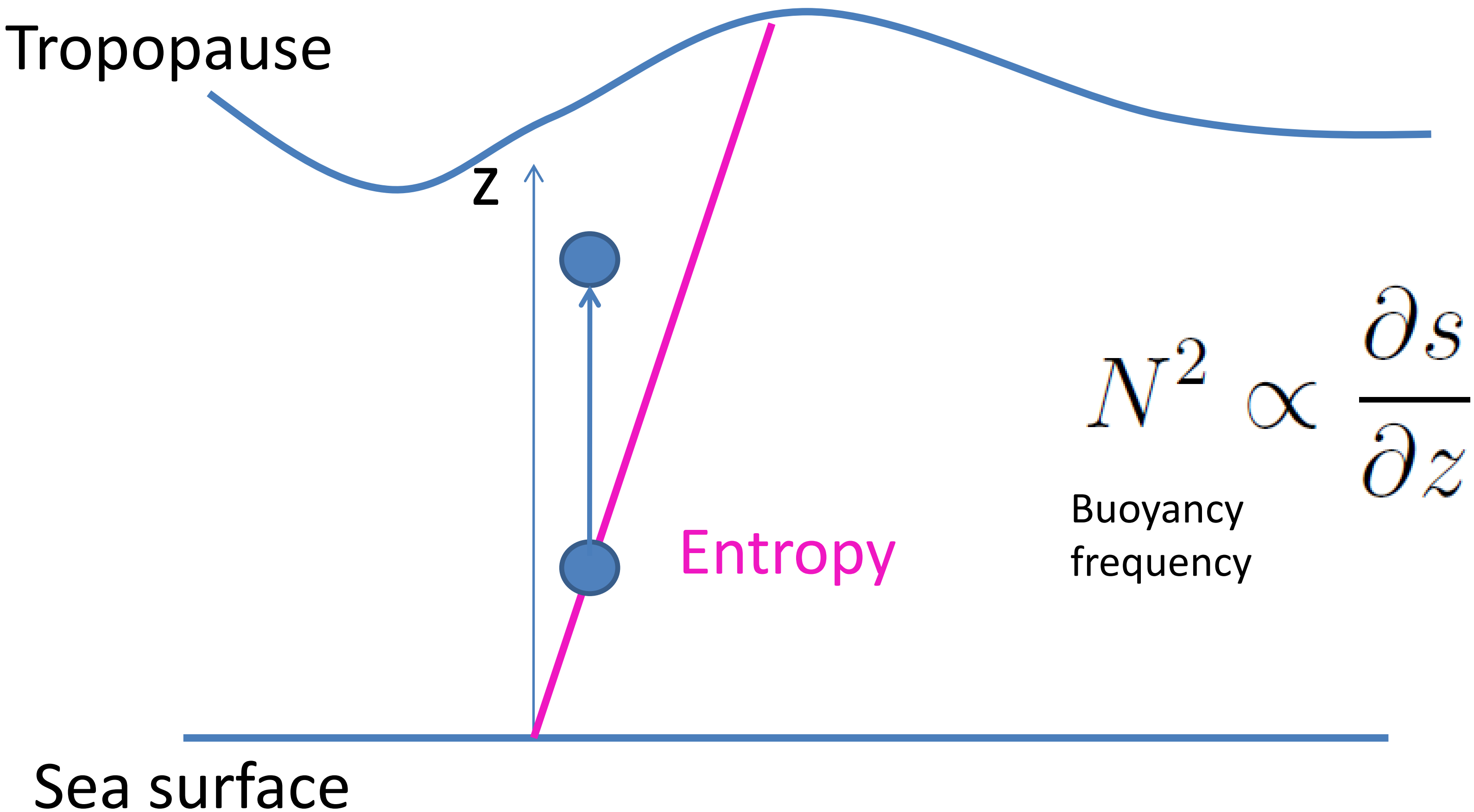
- Data and method
- Global maps of moist convective potential
- Mechanisms controlling when the moist convective potential is realized

ERA interim data

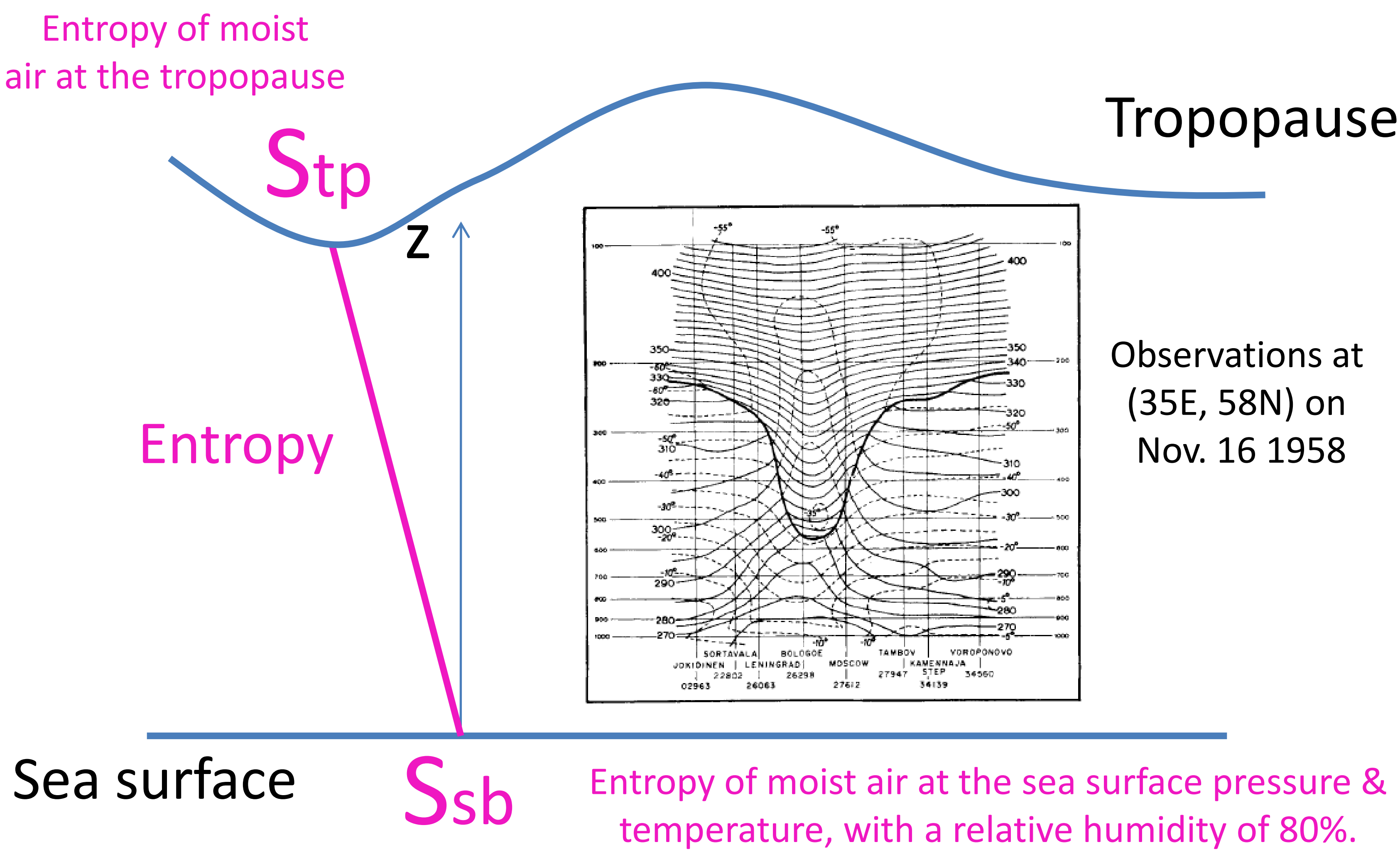
- This is an *atmospheric model* constrained to be close to observations (1989-present).
- 60 levels in the vertical, with the top level at 0.1 hPa.
- T255 spherical-harmonic representation for the basic dynamical fields.
- a reduced Gaussian grid with approximately uniform 79 km spacing for surface and other grid-point fields.
- Tropopause tracked as the 2 PVU surface.

NB: At this resolution convection is parameterized.

Stability to vertical displacements: vertical entropy gradient



Simple measure of convective instability = Stp – Ssb < 0



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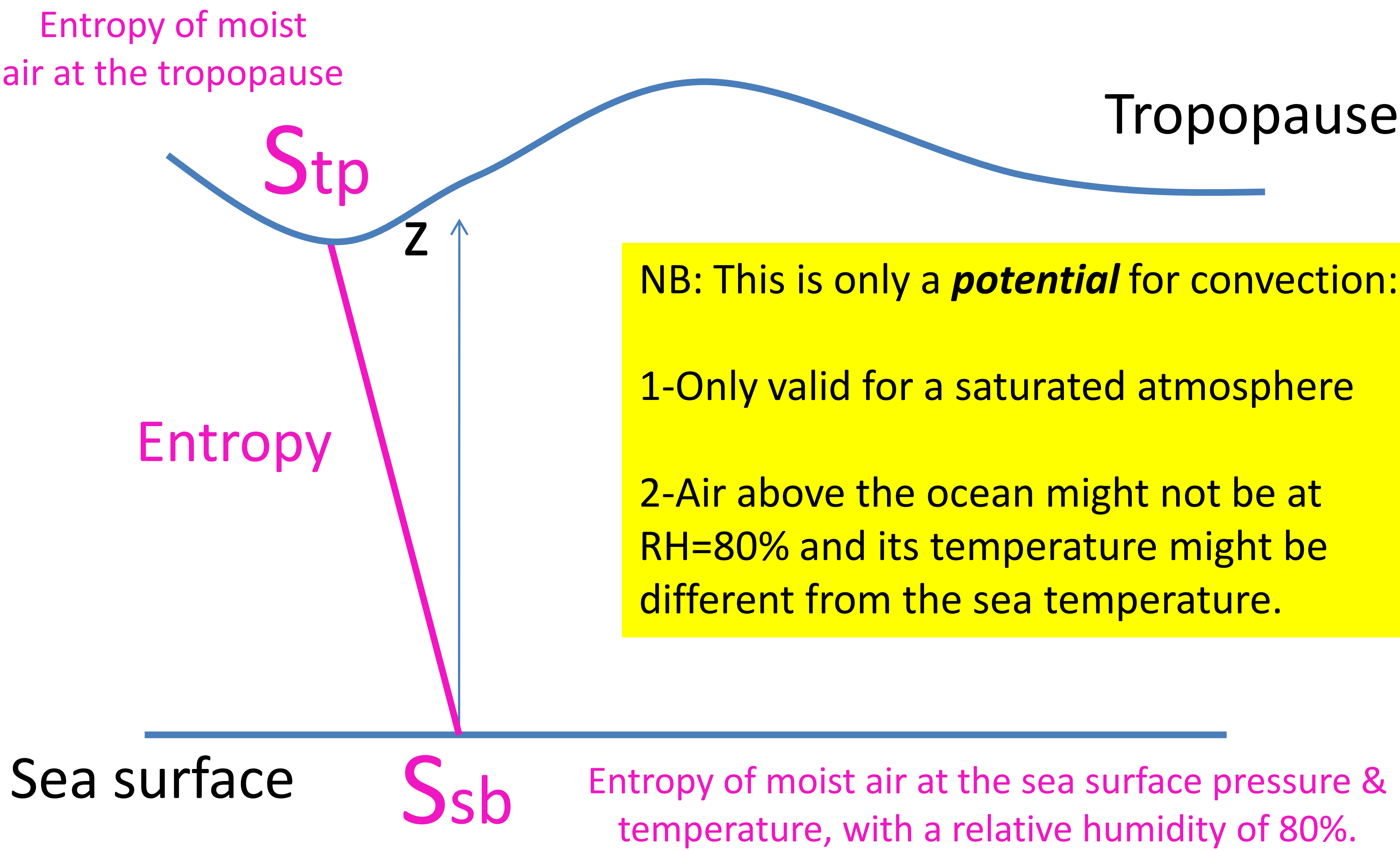
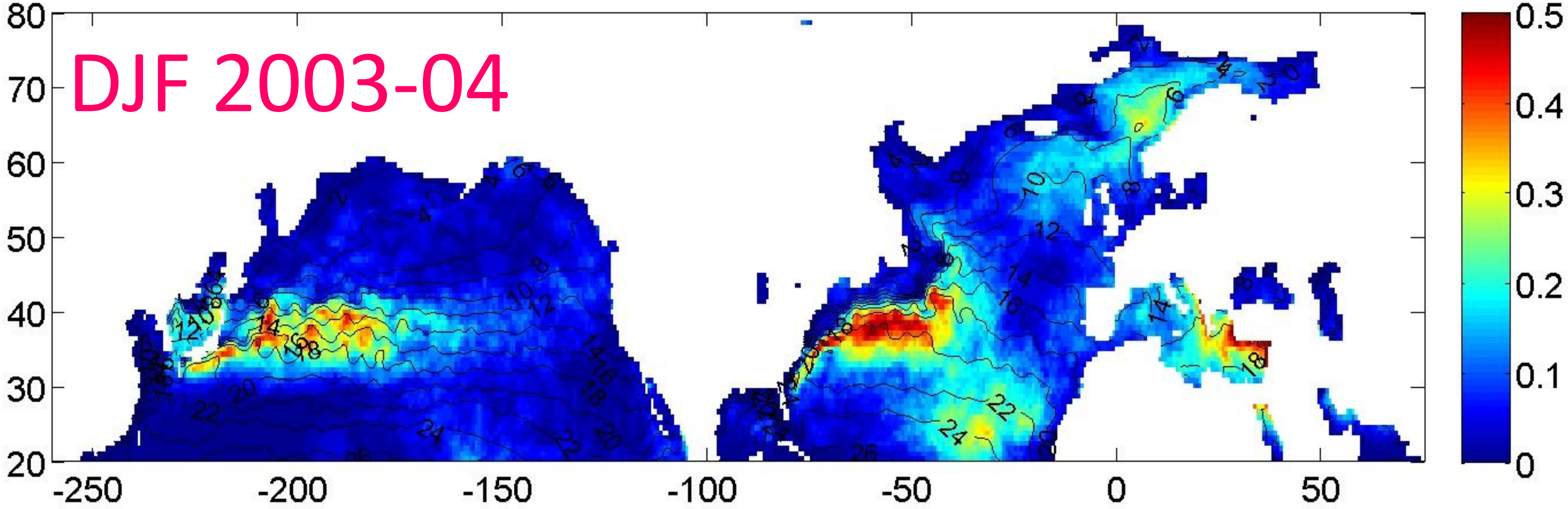


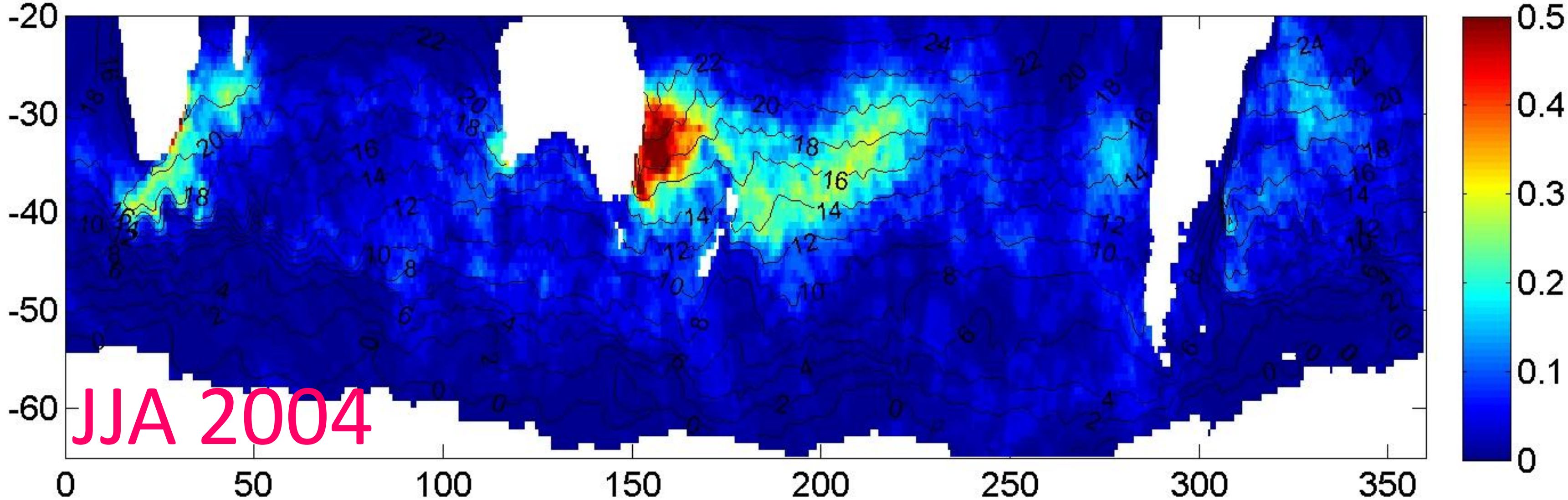
NB: This is only a ***potential*** for convection:

1-Only valid for a saturated atmosphere

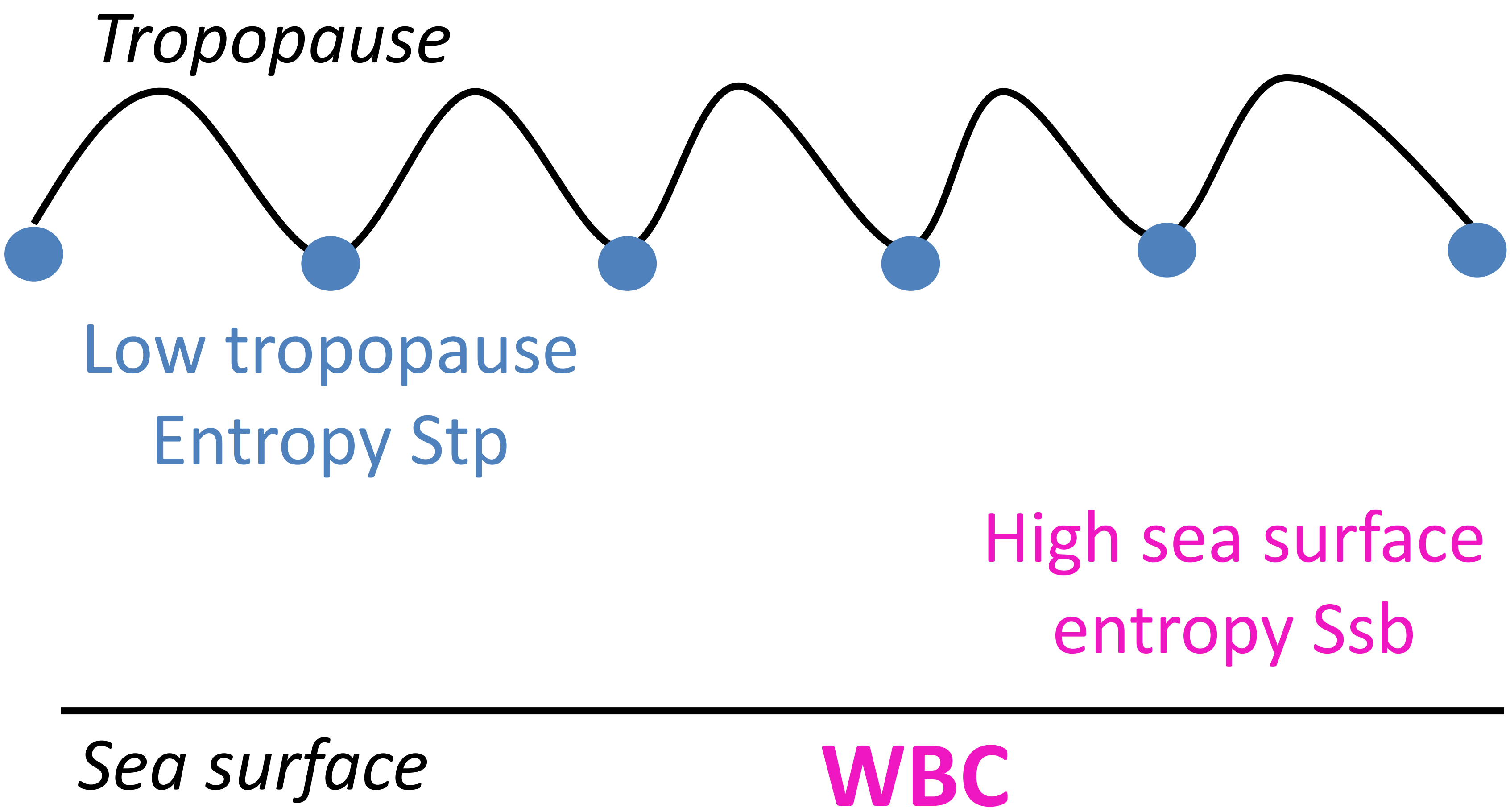
2-Air above the ocean might not be at RH=80% and its temperature might be different from the sea temperature.

Fraction of days with (S_{tp}-S_{sb} < 0) in color & time mean SST (CI = 2^{o}C)





30-50% of days are potentially unstable over western boundary current regions: why?



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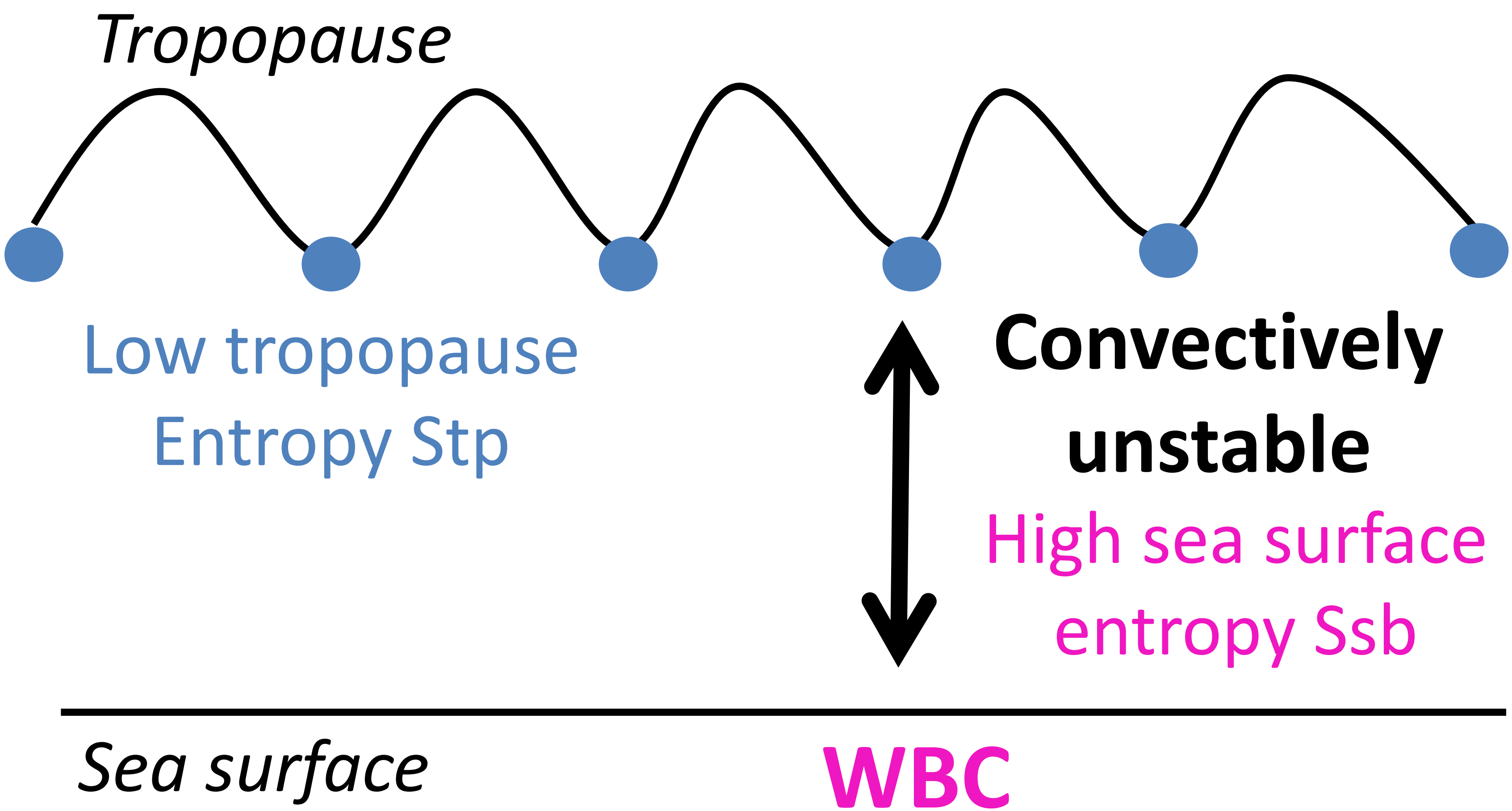
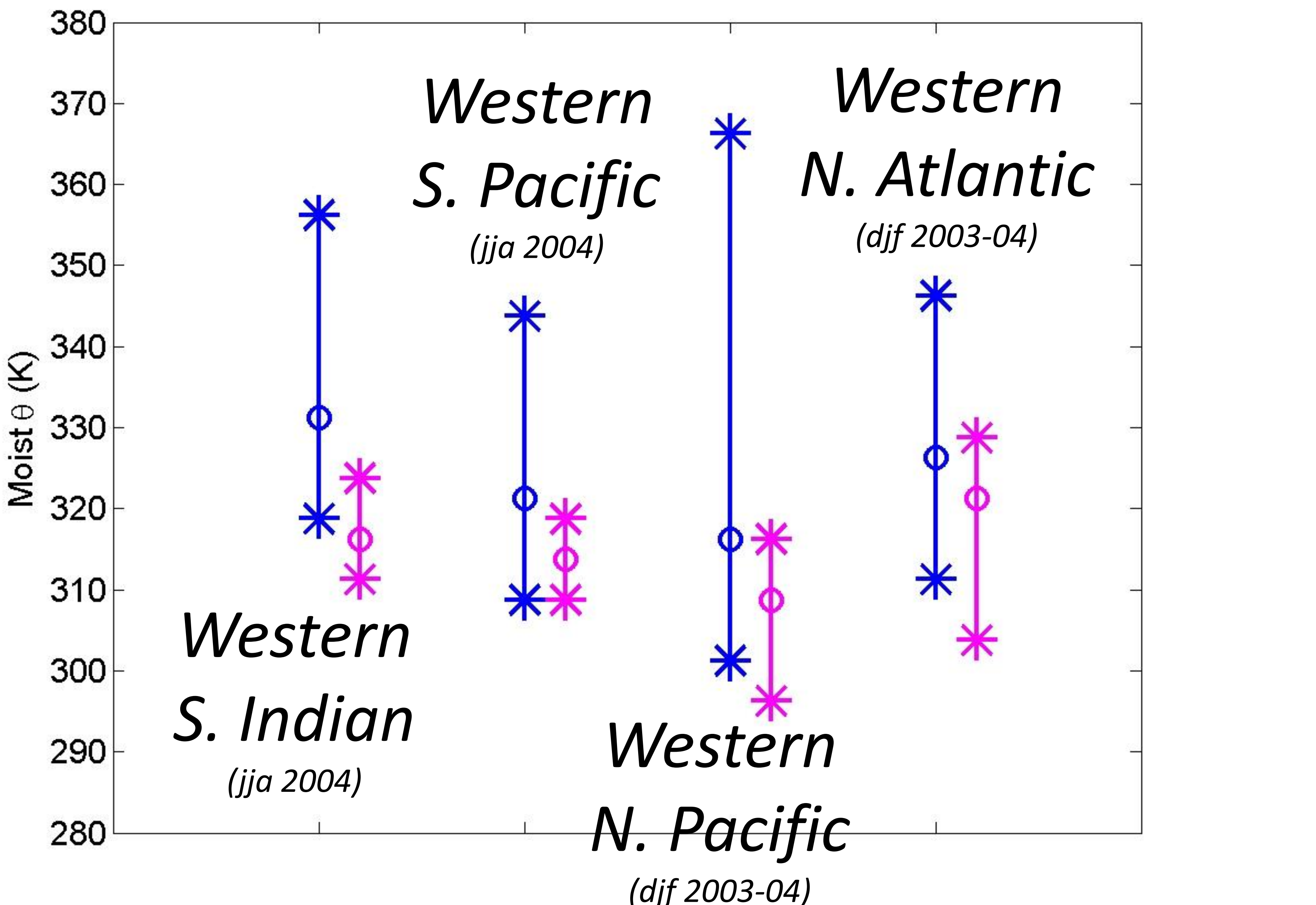
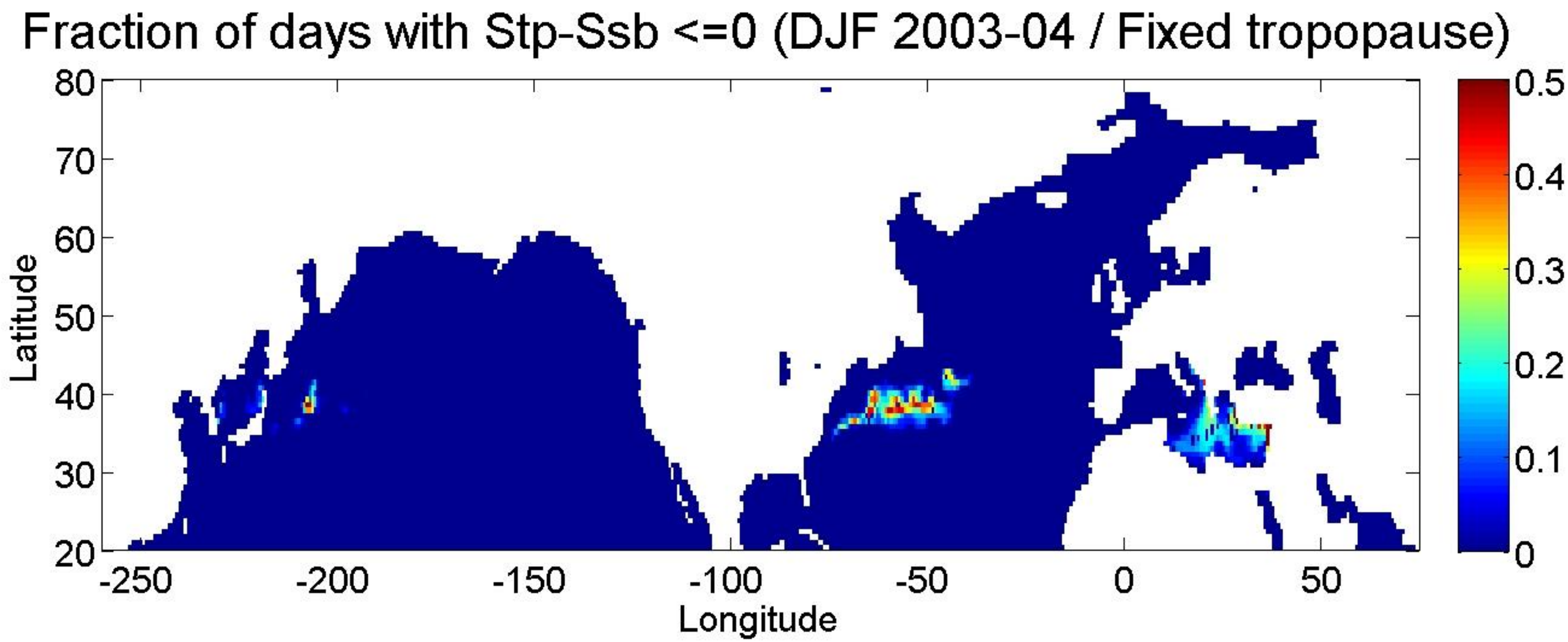
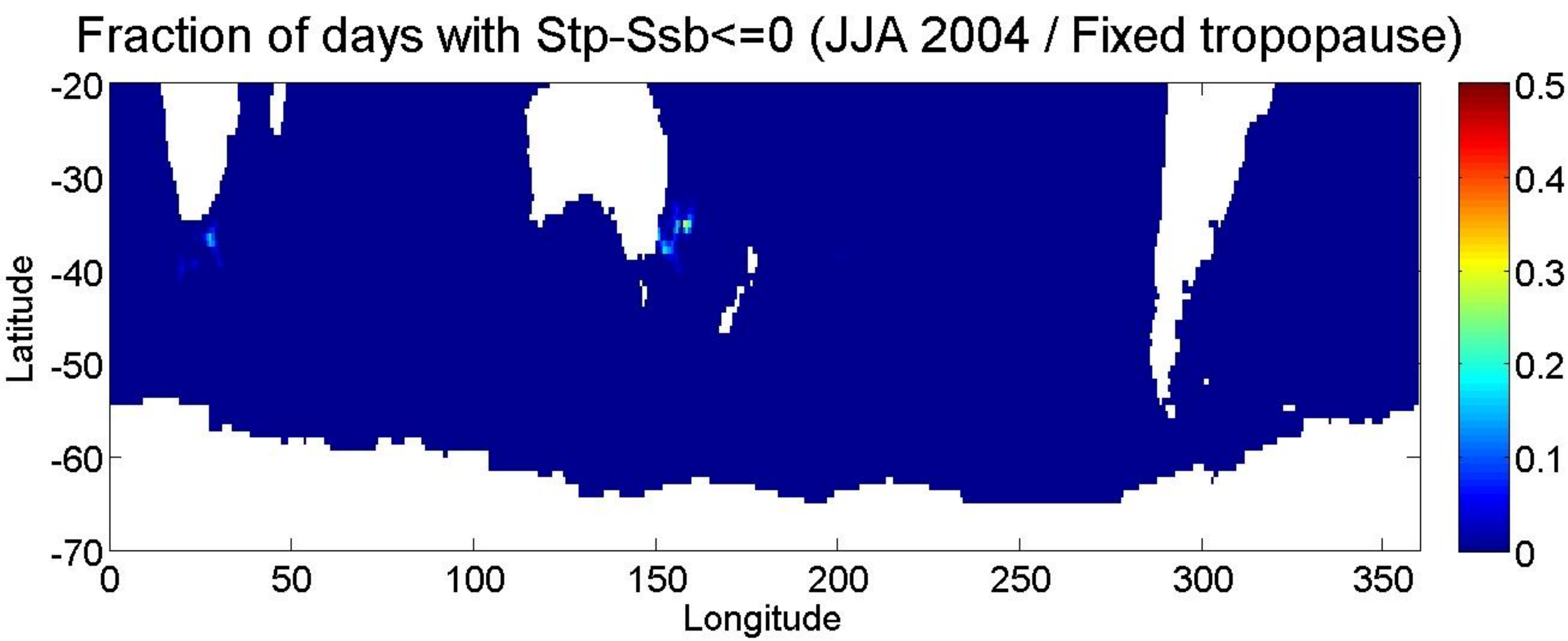
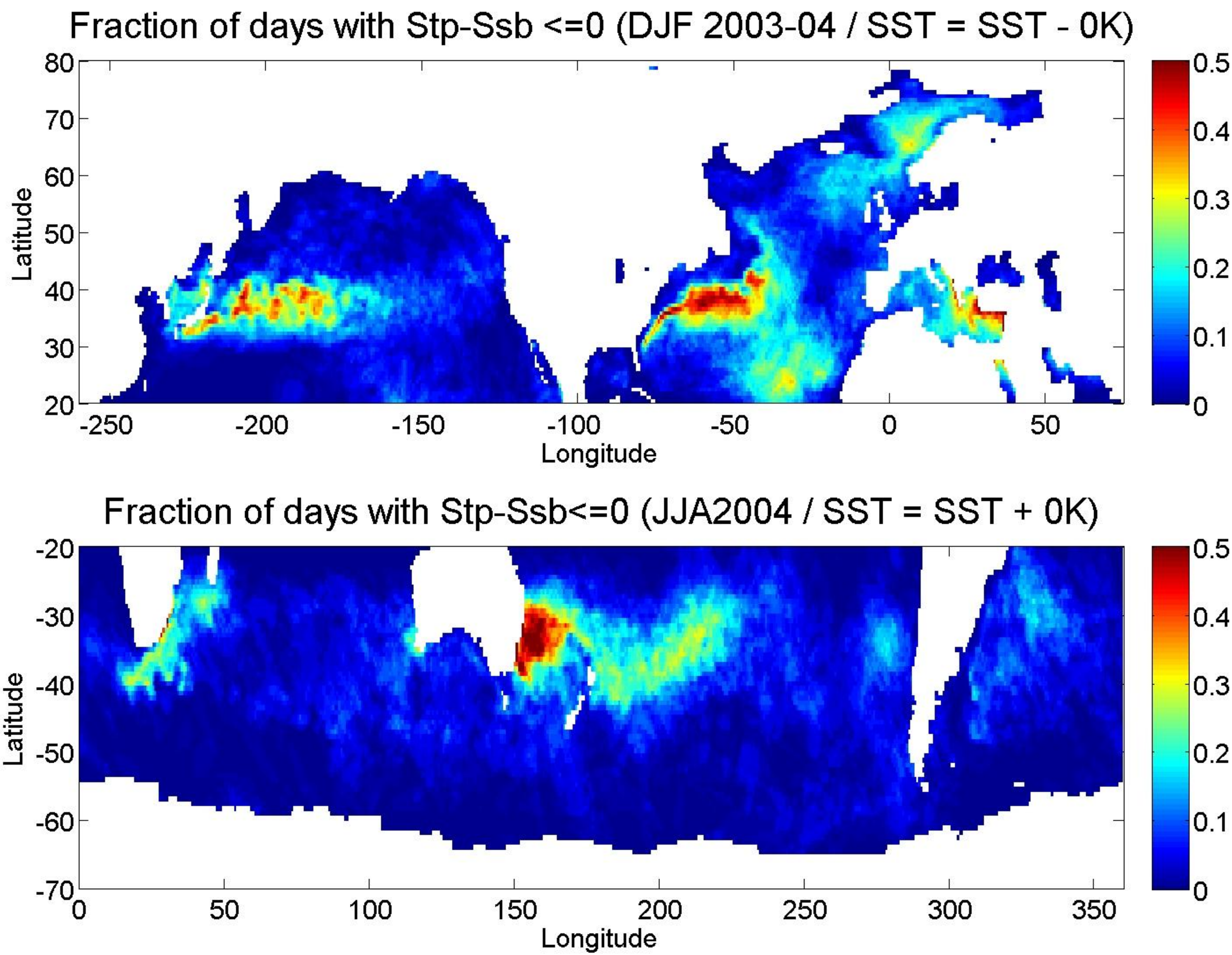


Lower 10th, upper 90th and median for moist θ distribution at 35S & 37N: Tropopause & Sea surface

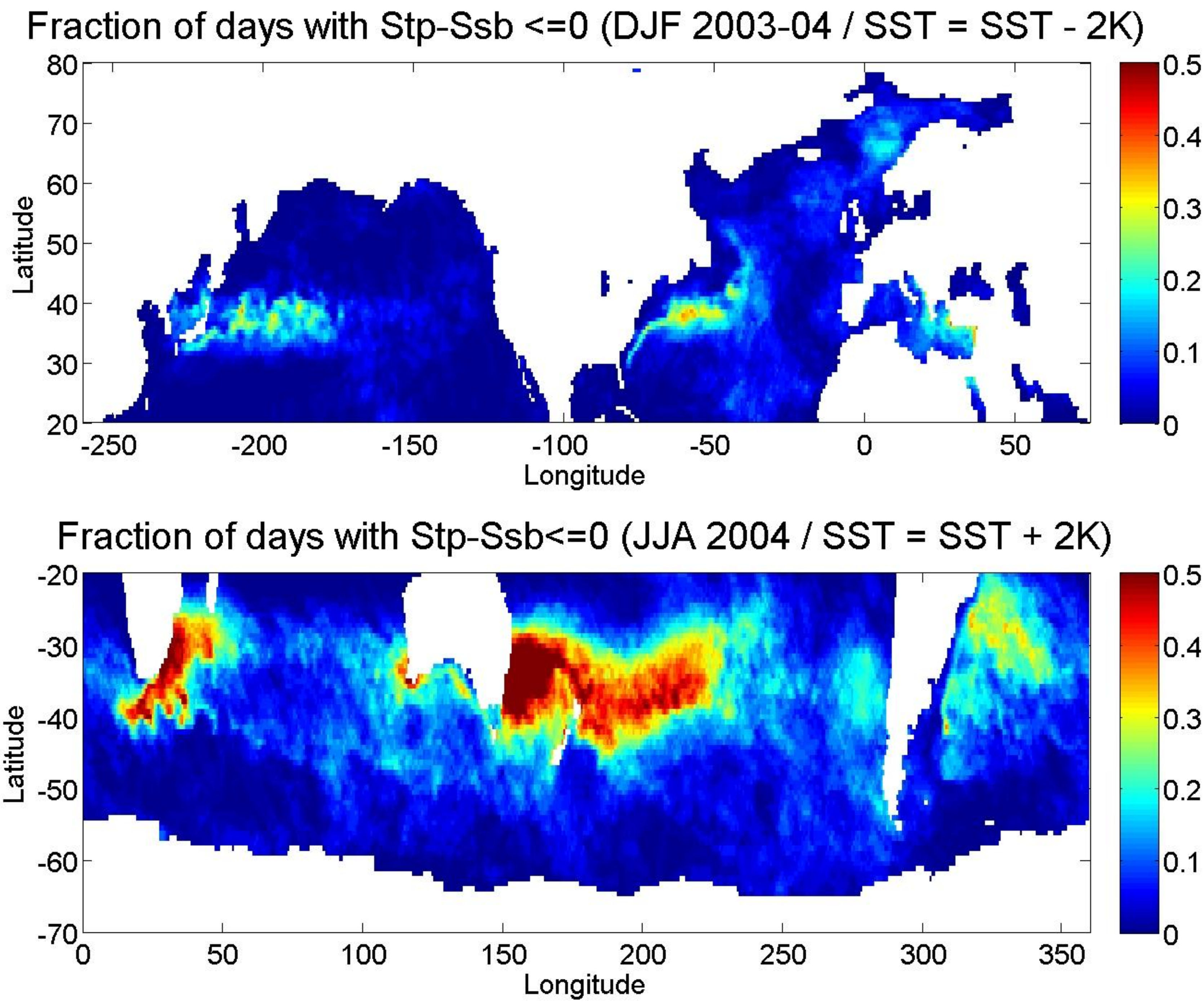



Fraction of days with Stp-Ssb <=0 (DJF 2003-04 / Fixed tropopause)
Latitude
Longitude
80
70
60
50
40
30
20
-250
-200
-150
-100
-50
0
50
0.5
0.4
0.3
0.2
0.1
0


Fraction of days with Stp-Ssb<=0 (JJA 2004 / Fixed tropopause)
Latitude
Longitude
-20
-30
-40
-50
-60
-70
0
50
100
150
200
250
300
350
0.5
0.4
0.3
0.2
0.1
0



Fraction of days with Stp-Ssb <=0 (DJF 2003-04 / SST = SST - 0K)
Latitude
Longitude
80
70
60
50
40
30
20
-250
-200
-150
-100
-50
0
50
0.5
0.4
0.3
0.2
0.1
0
Fraction of days with Stp-Ssb<=0 (JJA2004 / SST = SST + 0K)
Latitude
Longitude
-20
-30
-40
-50
-60
-70
0
50
100
150
200
250
300
350
0.5
0.4
0.3
0.2
0.1
0



Fraction of days with Stp-Ssb <=0 (DJF 2003-04 / SST = SST - 2K)
Latitude
Longitude
80
70
60
50
40
30
20
-250
-200
-150
-100
-50
0
50
0.5
0.4
0.3
0.2
0.1
0
Fraction of days with Stp-Ssb<=0 (JJA 2004 / SST = SST + 2K)
Latitude
Longitude
-20
-30
-40
-50
-60
-70
0
50
100
150
200
250
300
350
0.5
0.4
0.3
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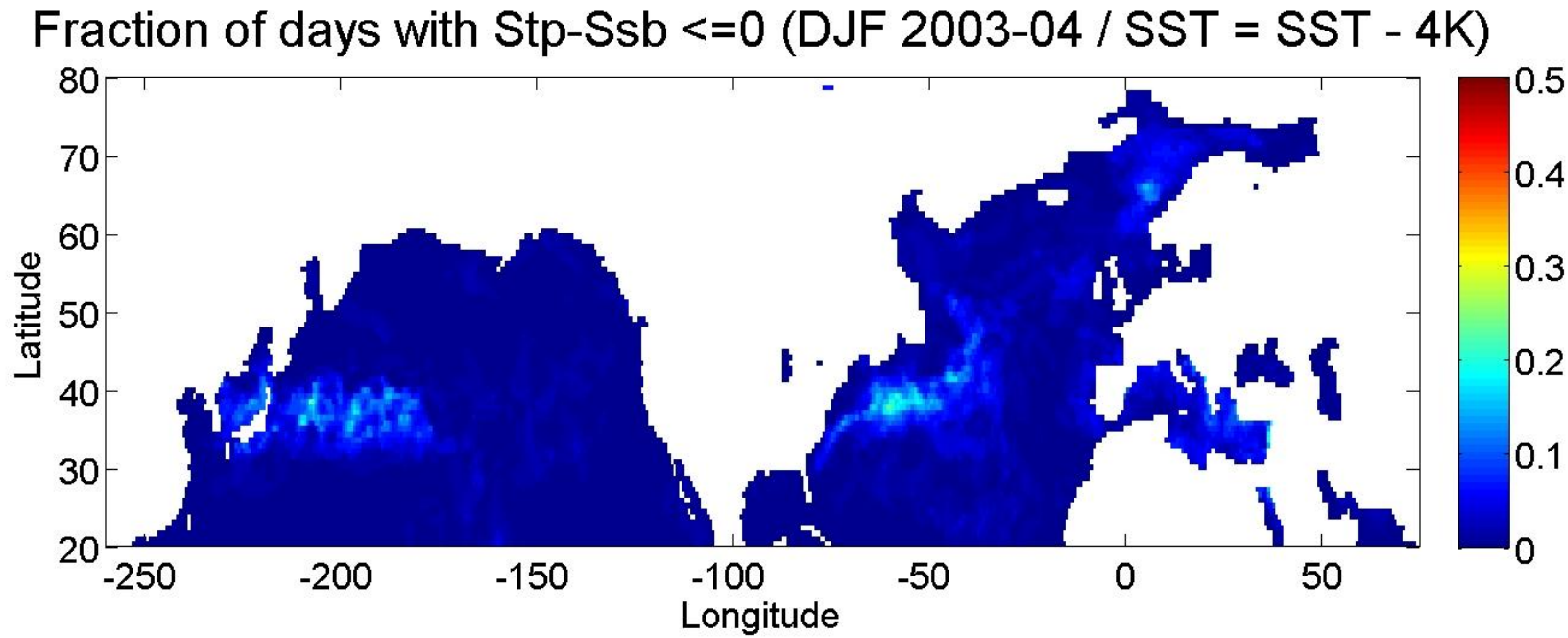
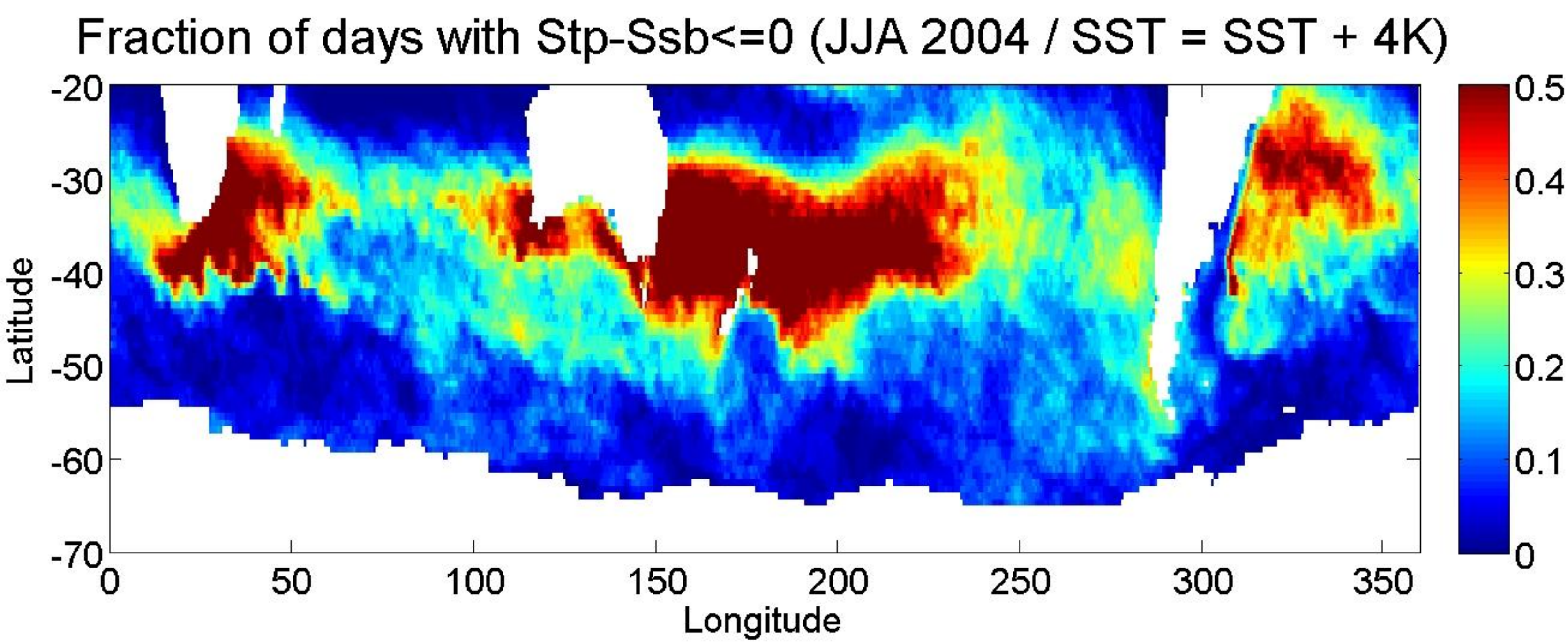
0.1
0



Fraction of days with Stp-Ssb <=0 (DJF 2003-04 / SST = SST - 4K)
Latitude
Longitude
80
70
60
50
40
30
20
-250
-200
-150
-100
-50
0
50
0.5
0.4
0.3
0.2
0.1
0



Fraction of days with Stp-Ssb<=0 (JJA 2004 / SST = SST + 4K)
Latitude
Longitude
-20
-30
-40
-50
-60
-70
0
50
100
150
200
250
300
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0.5
0.4
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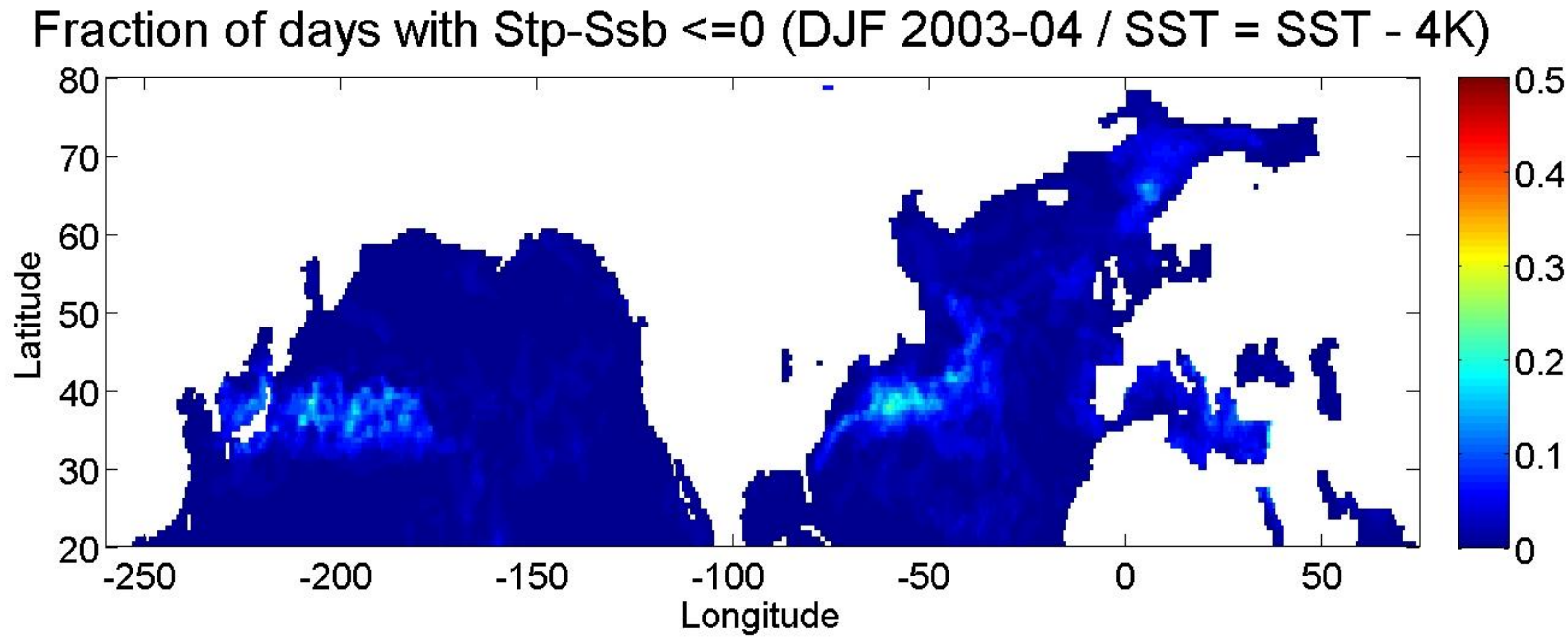
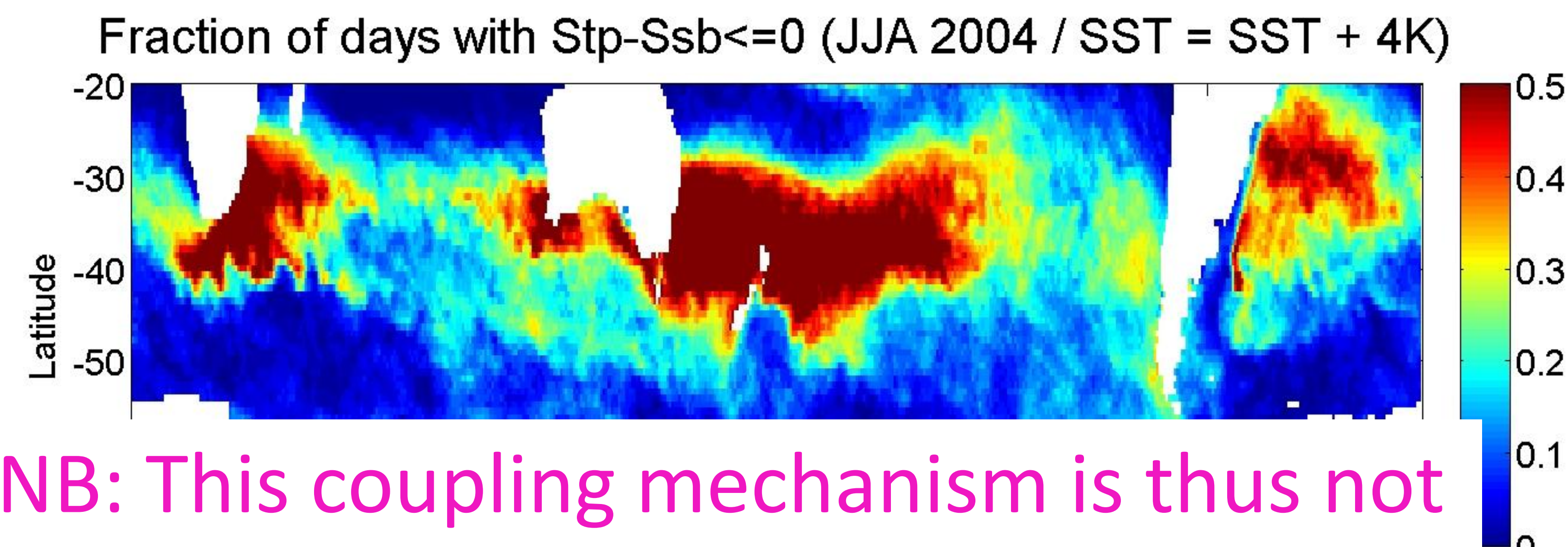
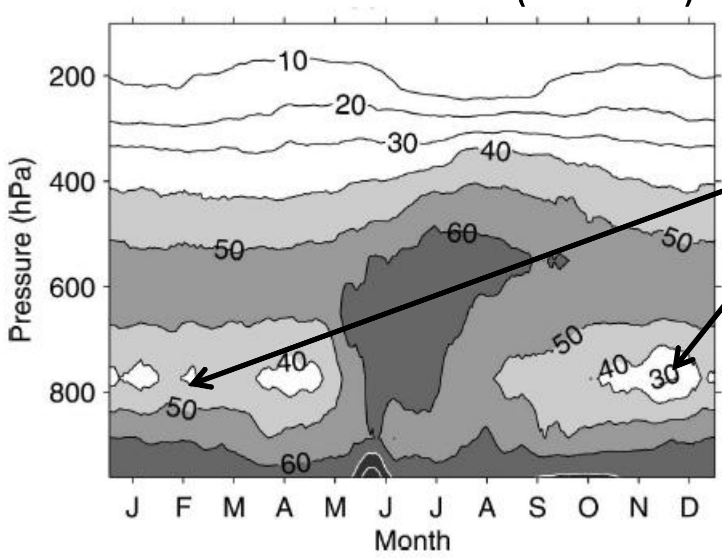




NB: This coupling mechanism is thus not relevant to ACC related SST anomalies

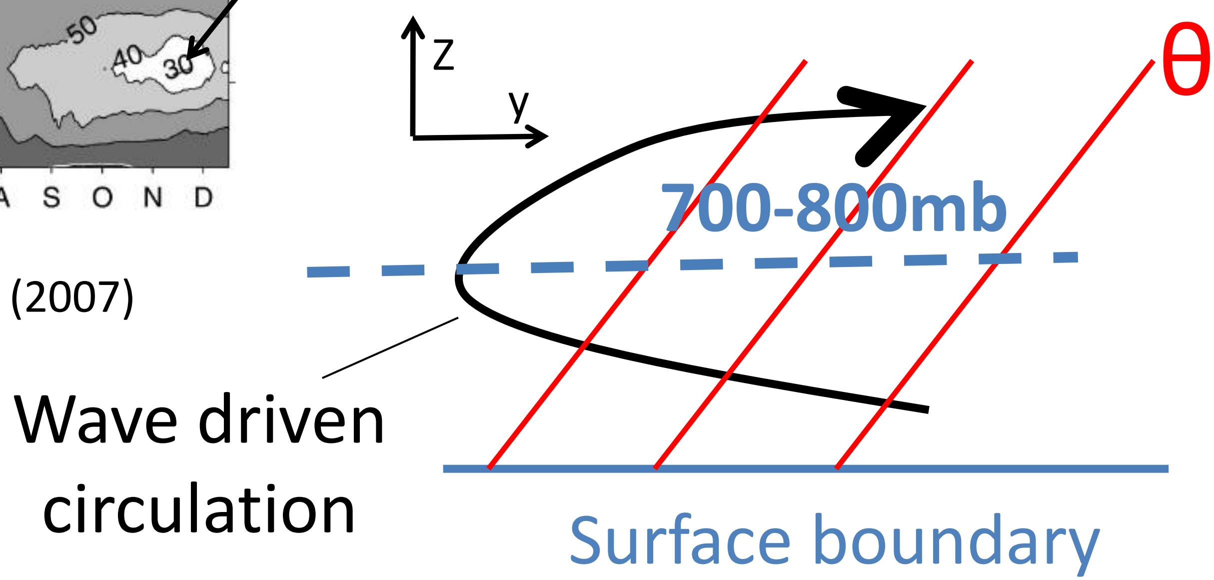
The potential cannot be achieved 30-50% of the times because of a "low level brake" effect...

Poleward extent of moist neutral air over Atlantic sector (60-15W)

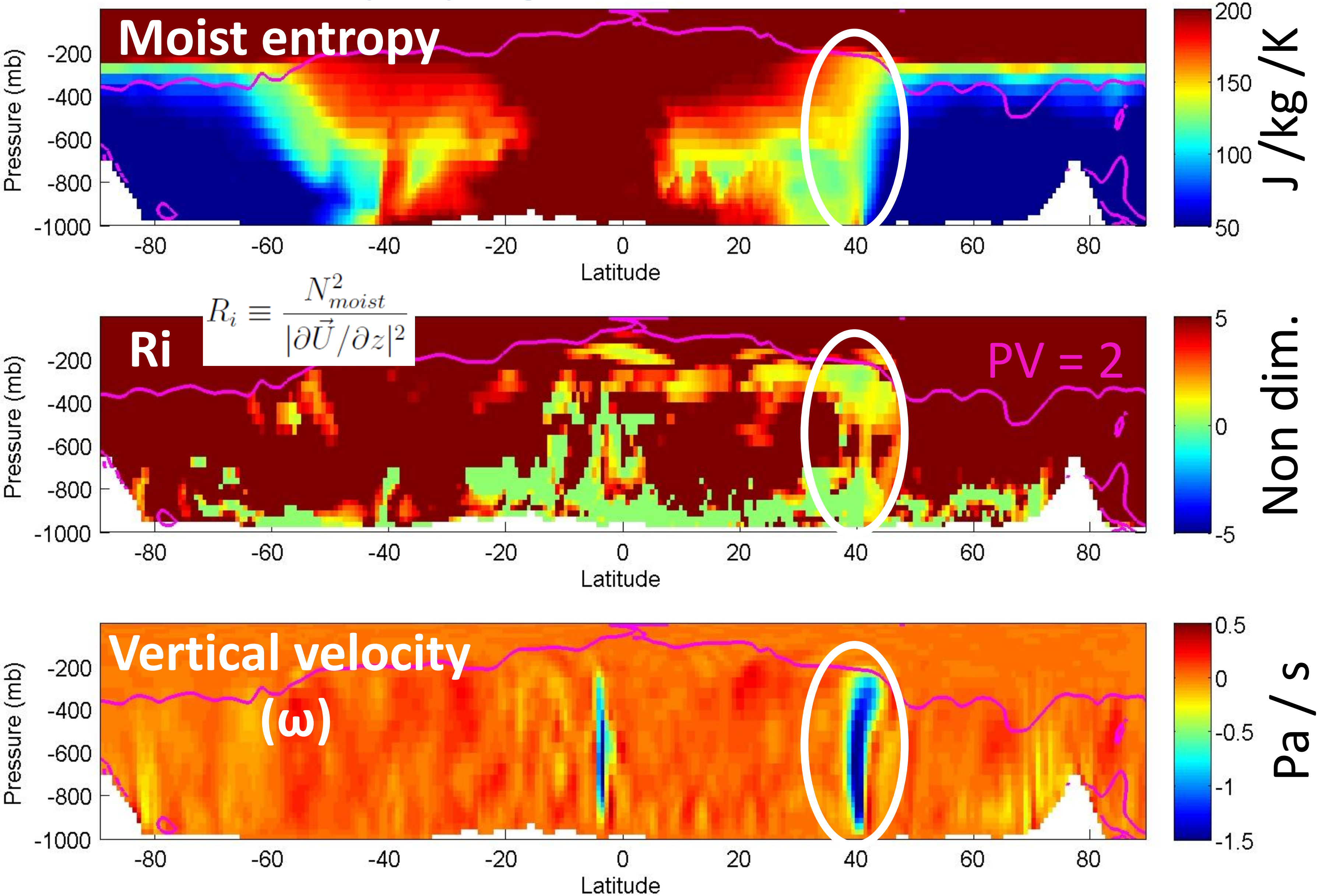


Korty & Schneider (2007)

Baroclinic waves stratify efficiently the 700-800mb layer in winter

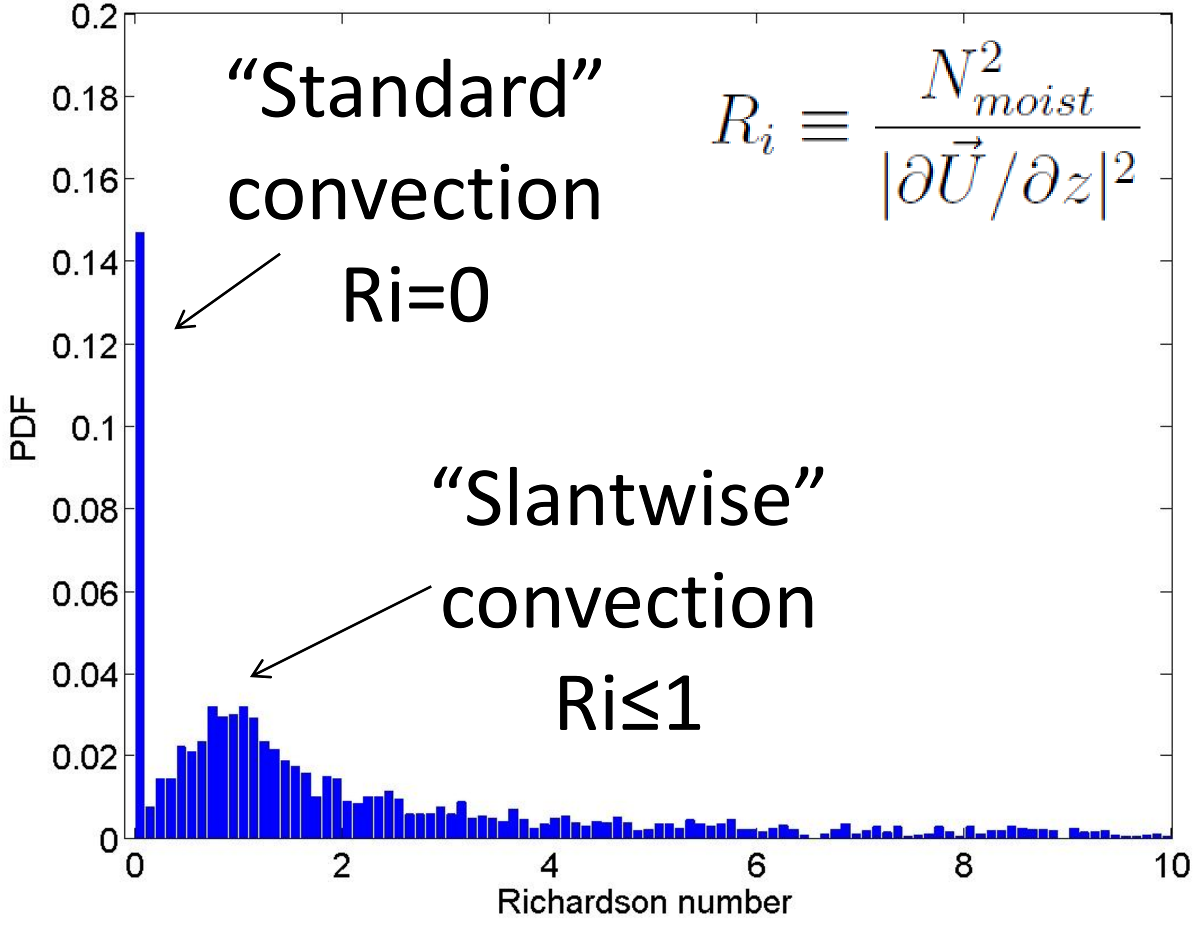


Meridional sections at 55W on a given day displaying S_{tp}-S_{sb}<0 at (40N,55W)



Distribution of the Richardson number over the Gulf Stream for moist profiles

Ri(700mb) for column averaged RH>80%



Summary

- A focus on lapse-rate rather than on heating and eddy mean flow interaction provides an alternative framework to investigate the impact of the extra-tropical oceans on climate.

- The interplay of warm surface water advection and low tropopause events highlights the western boundary currents as regions where moist neutrality can be most frequently achieved.

Implications

- Mechanisms by which moist neutrality is reached are low Ri mechanisms. These are currently not parameterized in AGCMs.

- Predictability associated with low frequency changes in western boundary current regions might thus not have been fully invistigated.