Sub-seasonal Variability in Climate Models

Joe Tribbia –NCAR

With Rich Neale, Cecile Hannay, Julio Bacmeister,
Haiyan Teng and Paolo Davini

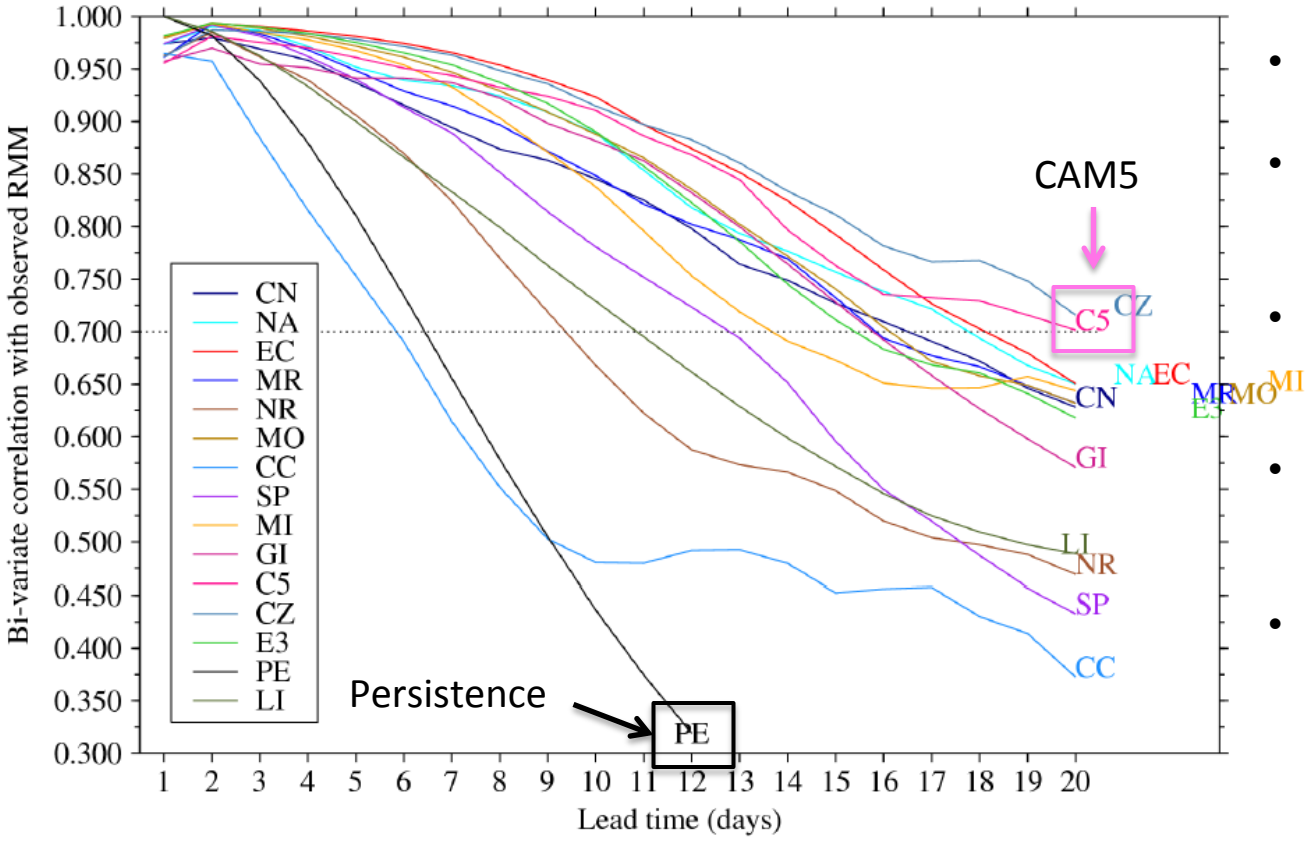
ECMWF Workshop on Subseasonal Predictability
3 November 2015

Outline

- Madden-Julian Oscillation in Climate Models and the NCAR CESM
- Blocking in Climate Models and the NCAR CESM
- Vertical resolution and variability (the Stratosphere's impact)

MJO

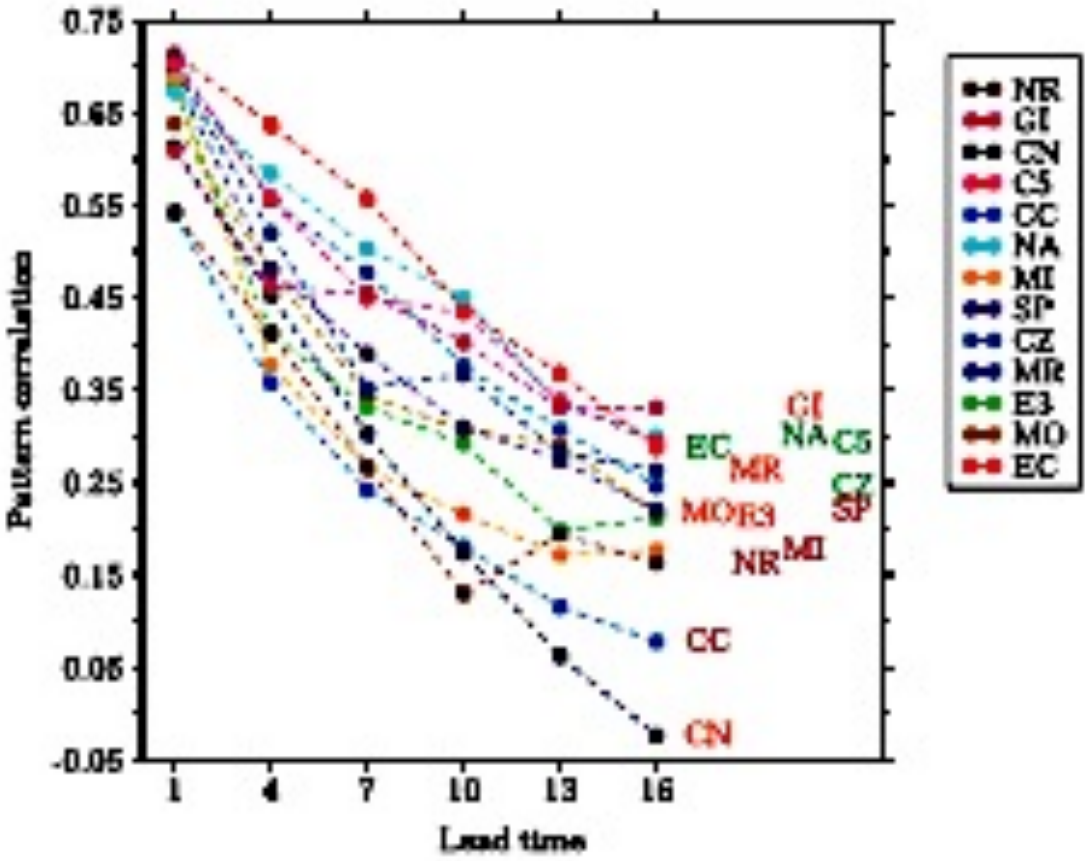
Madden Julian Oscillation (MJO) Hindcasts



- Initial forecast mode (CAPT)
- During MJO-DYNAMO Campaign
- Combined bivariate mode of MJO variability (RMM)
- CAM5 only model to retain skill out to 20 days.
- Top performer among participating CMIP5 models.

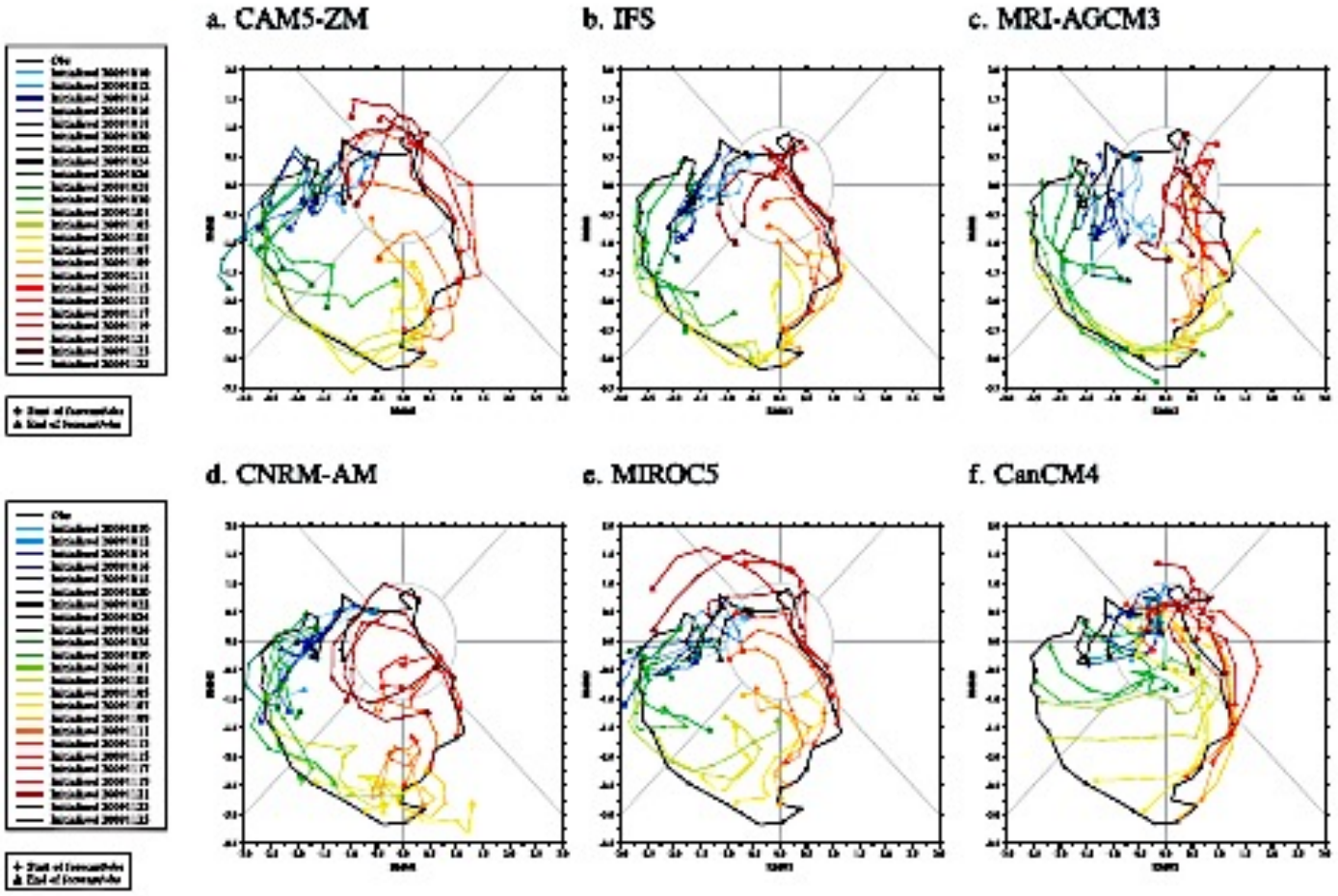
Courtesy: Nick Klingaman, U. Reading, UK

Precipitation Pattern Correlation



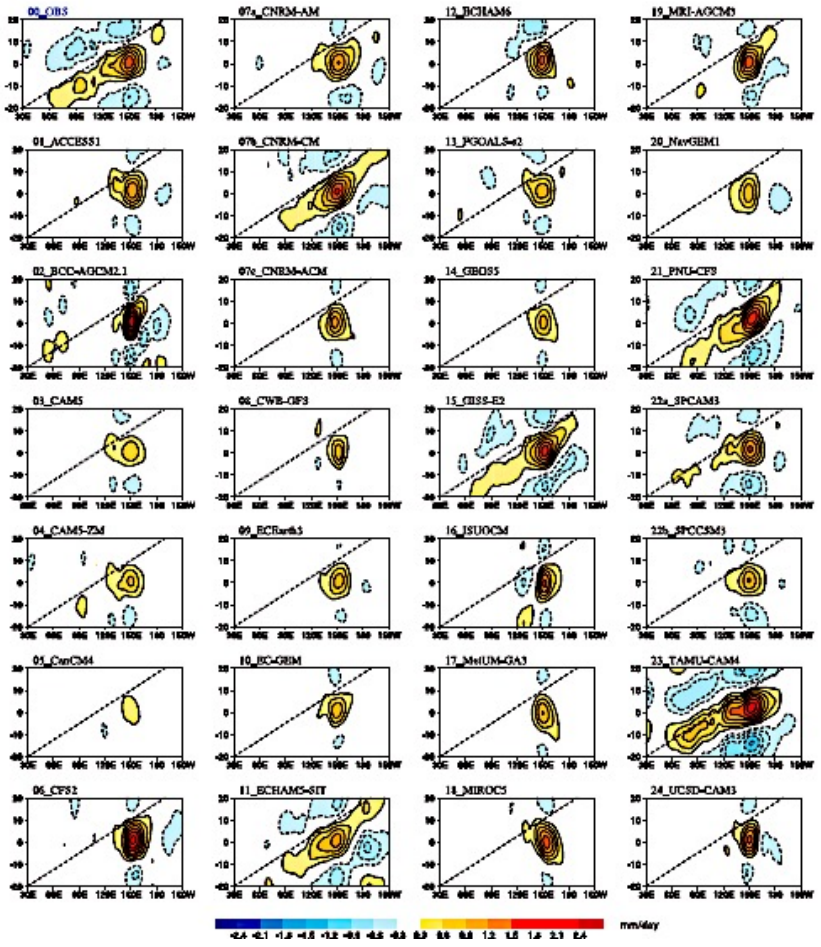
Klingaman et al. 2014

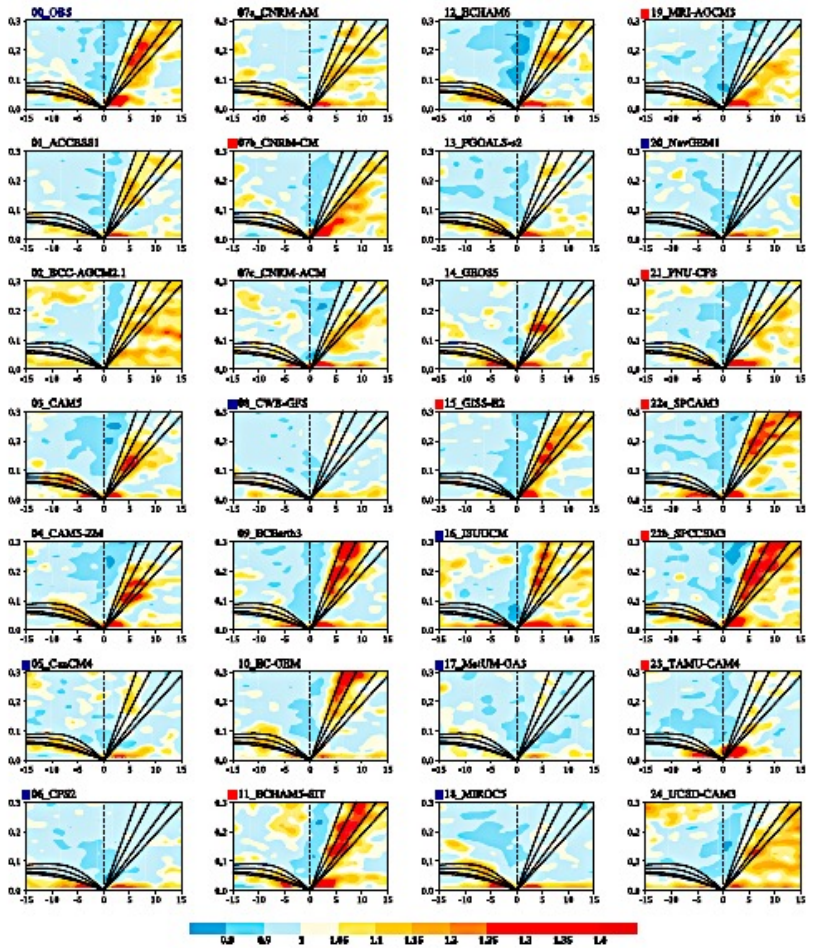
Harmonic Dials in EOF space

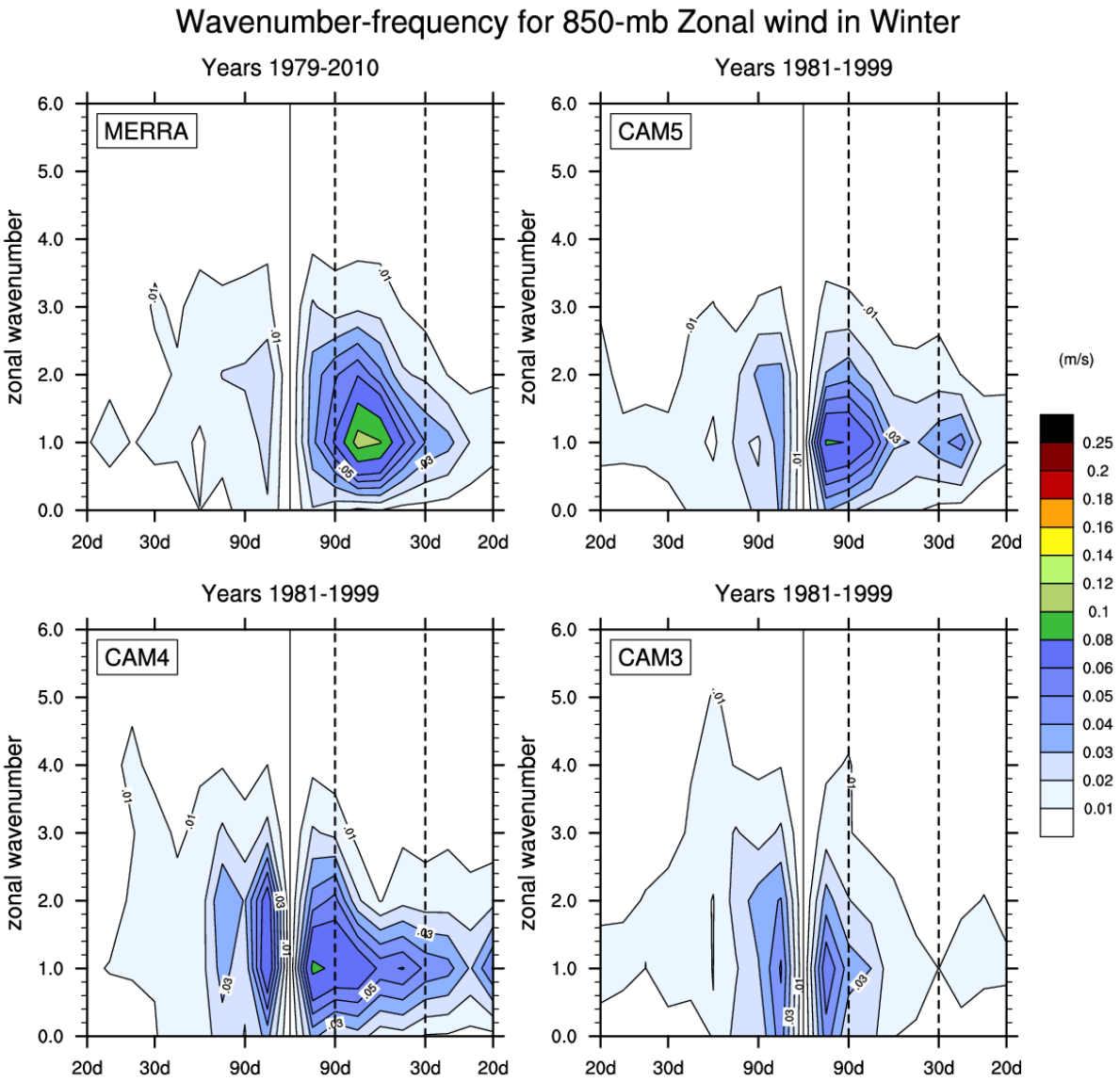


Klingaman et al 2014

Hovemoller and Wheeler-Kiladis Diagram







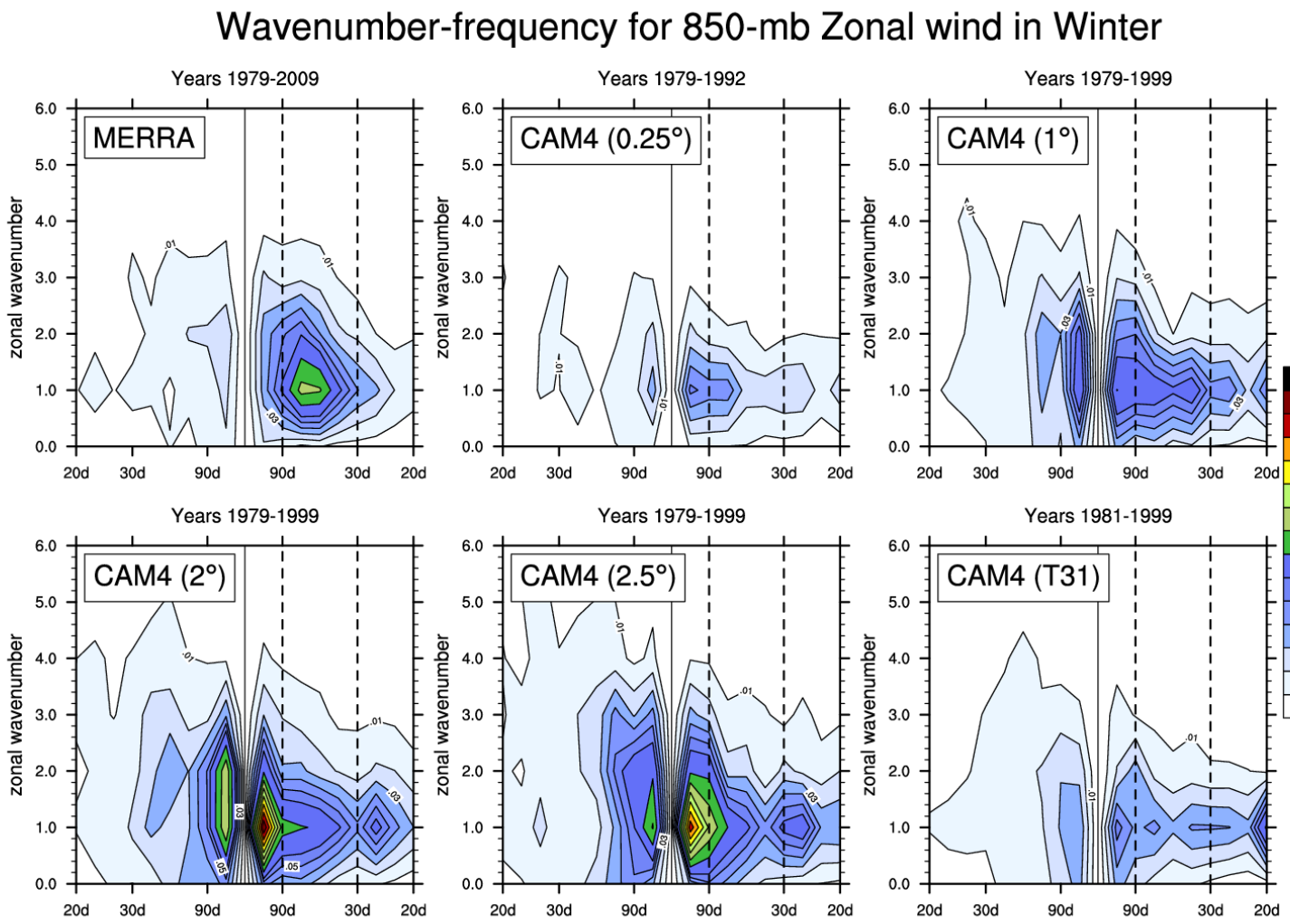
Model Physics

CAM3 poor MJO

CAM4 better MJO (convection changes)

CAM5 degrades MJO (non-convective cloud changes)

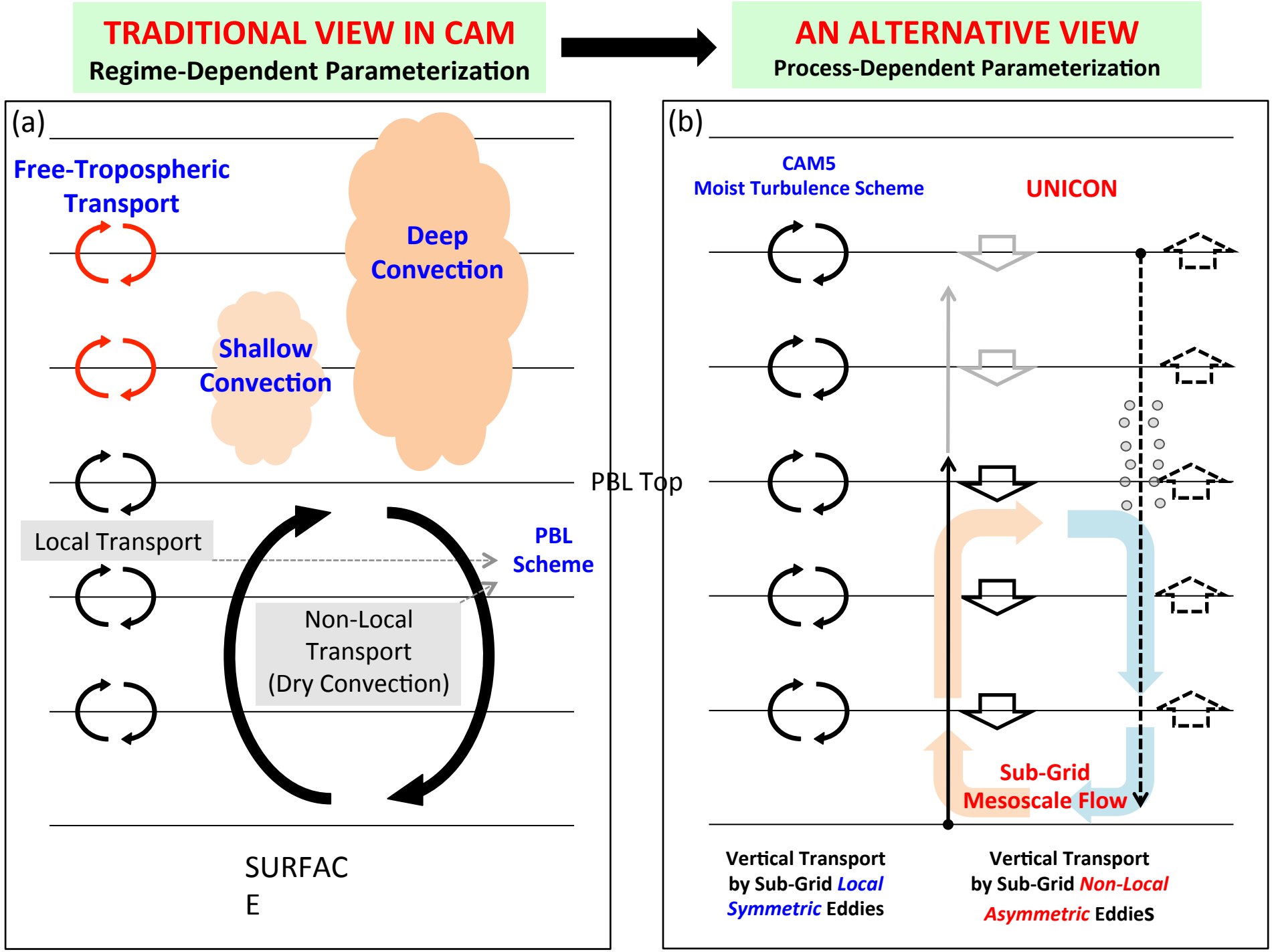
+ Competing priorities



Resolution

'Optimal' resolution of 2-2.5 deg

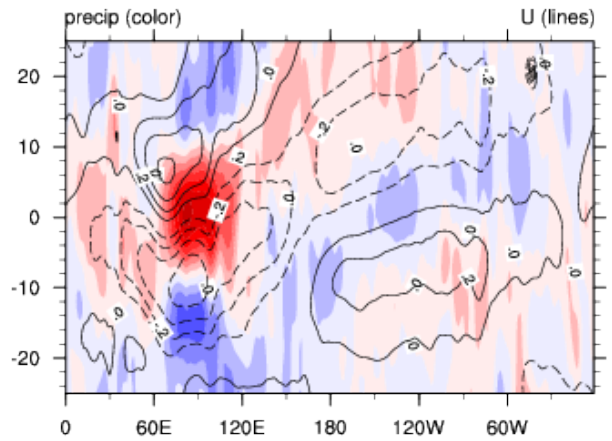
High-res: no natural improvement

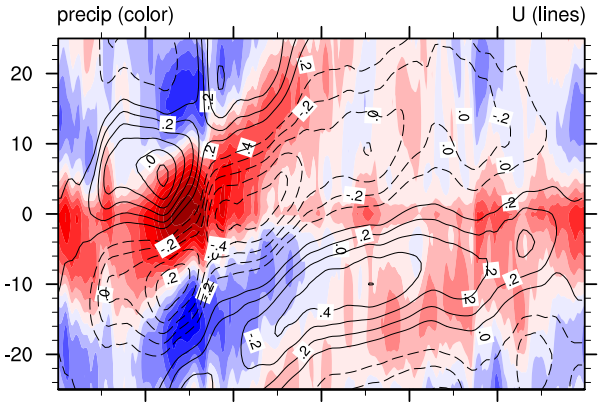

TRADITIONAL VIEW IN CAM
Regime-Dependent Parameterization
AN ALTERNATIVE VIEW
Process-Dependent Parameterization
(a)
Free-Tropospheric Transport
Deep Convection
Shallow Convection
Local Transport
PBL Scheme
Non-Local Transport (Dry Convection)
PBL Top
SURFAC E
(b)
CAM5 Moist Turbulence Scheme
UNICON
Sub-Grid Mesoscale Flow
Vertical Transport by Sub-Grid Local Symmetric Eddies
Vertical Transport by Sub-Grid Non-Local Asymmetric EddieS

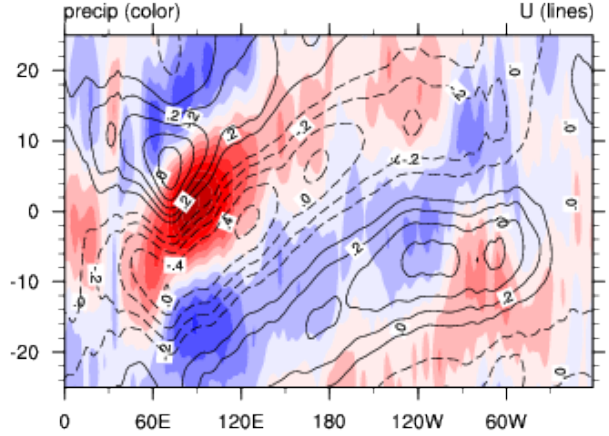
CAM5

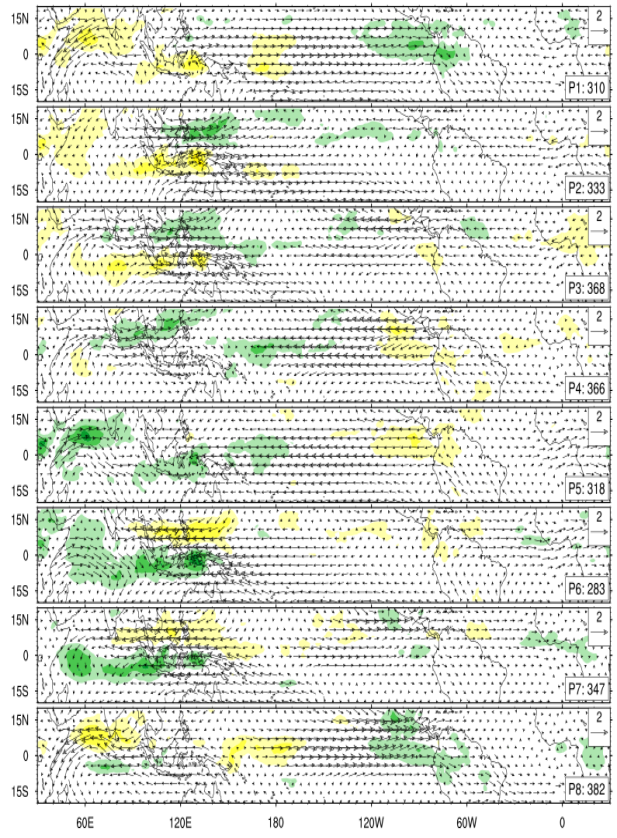
OBS

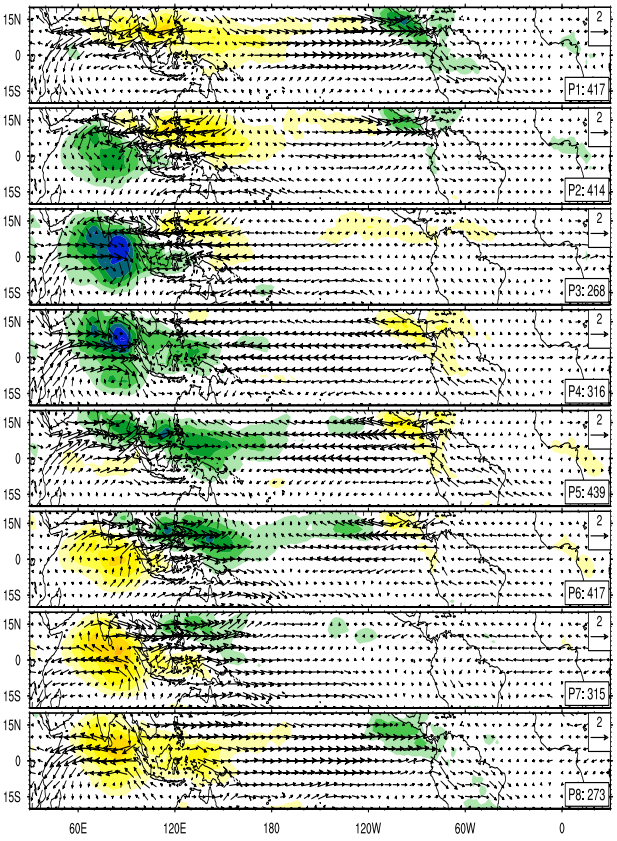
UNICON

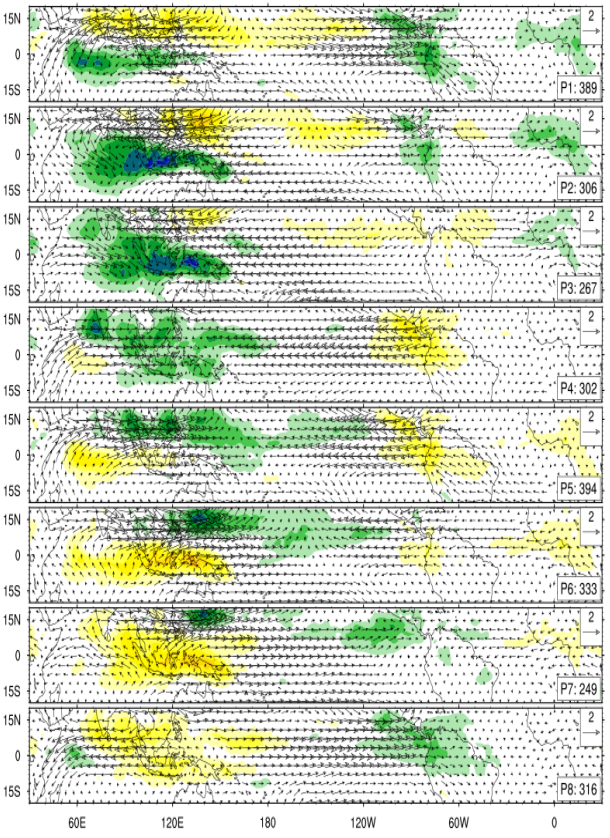


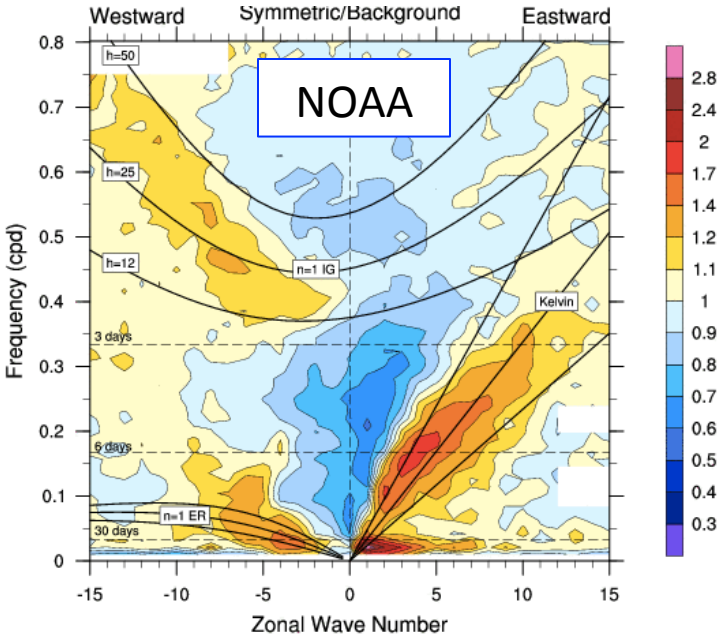


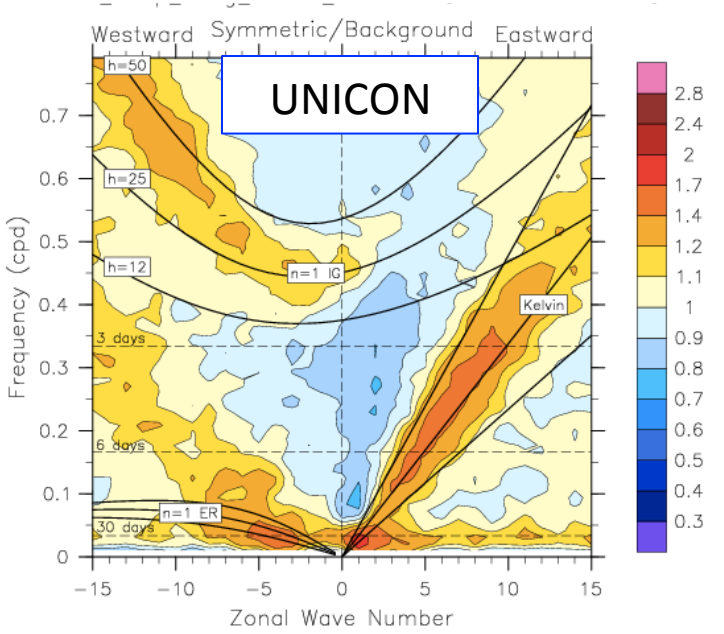









NOAA
Westward
Symmetric/Background
Eastward
h=50
h=25
h=12
n=1 IG
Kelvin
3 days
6 days
n=1 ER
30 days
Frequency (cpd)
Zonal Wave Number
2.8
2.4
2
1.7
1.4
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3


UNICON
Westward
Symmetric/Background
Eastward
h=50
h=25
h=12
n=1 IG
Kelvin
3 days
6 days
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30 days
Frequency (cpd)
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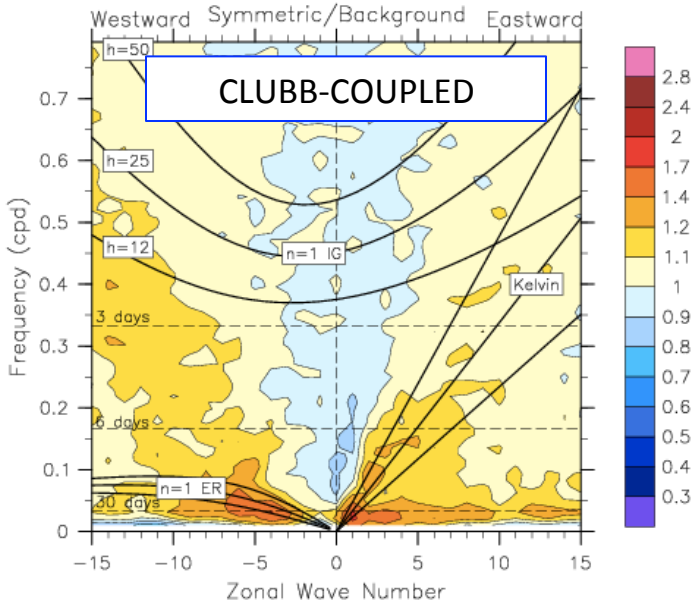
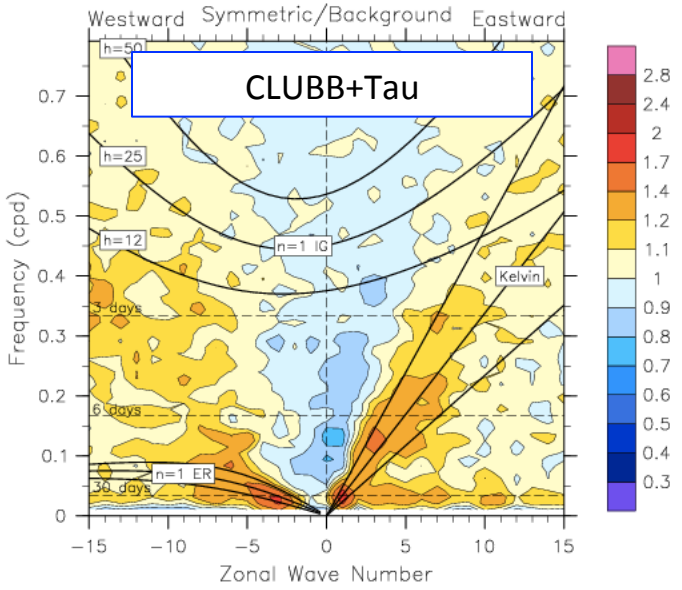
0.6
0.5
0.4
0.3


CLUBB-COUPLED
Westward
Symmetric/Background
Eastward
h=50
h=25
h=12
n=1 IG
Kelvin
3 days
6 days
n=1 ER
30 days
Frequency (cpd)
Zonal Wave Number
2.8
2.4
2
1.7
1.4
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3


CLUBB+Tau
Westward
Symmetric/Background
Eastward
h=50
h=25
h=12
n=1 IG
Kelvin
3 days
6 days
n=1 ER
30 days
Frequency (cpd)
Zonal Wave Number
2.8
2.4
2
1.7
1.4
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3

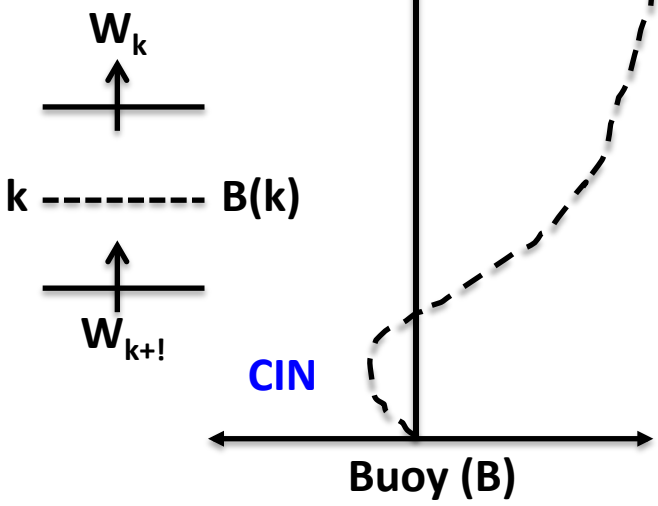
CONVECTIVE PARAMETERIZATION DEVELOPMENT

- Still significant opportunities to improve on existing parameterization that could be applied to newer developments.

$$\frac{w_k^2}{2} = \frac{w_{k+1}^2}{2} + g\int_k^{k+1} B(z)\,dz$$

$$w_k = w_k - Dw_k$$

$$\bar{w}_u^H = \frac{\int_{lcl}^{H} w(z)\,dz}{z(H) - z(lcl)}$$

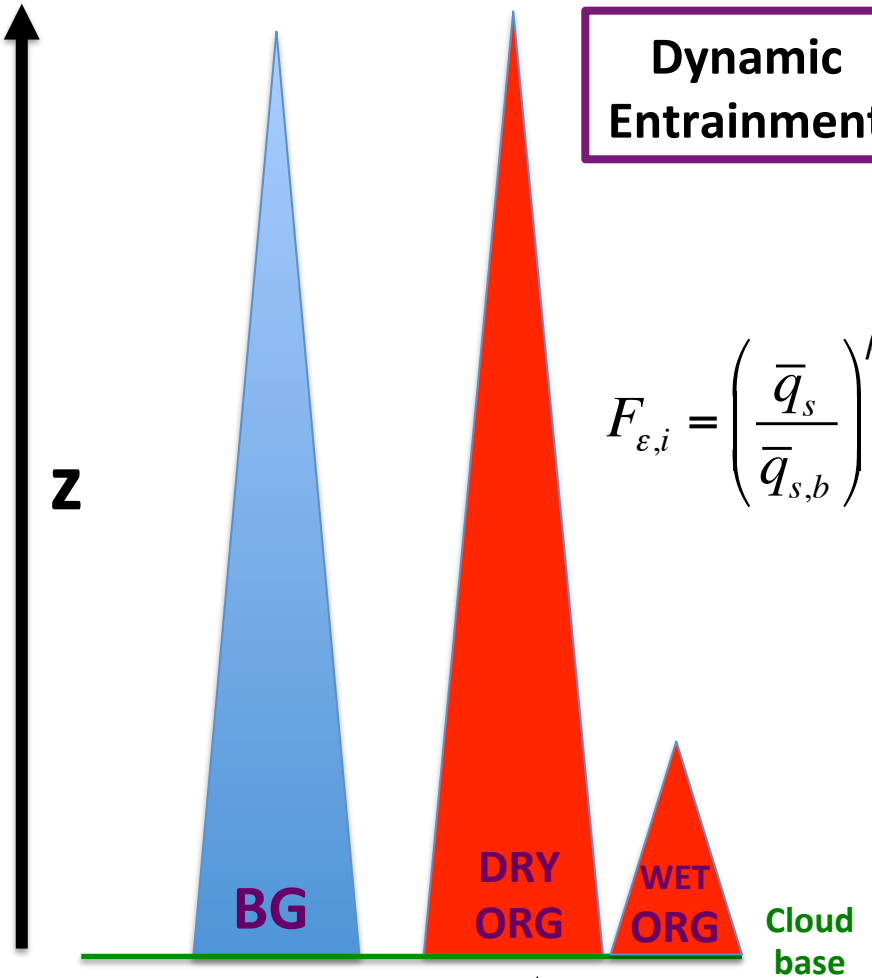


$$\tau = \frac{H}{\bar{w}_u^H}\alpha$$

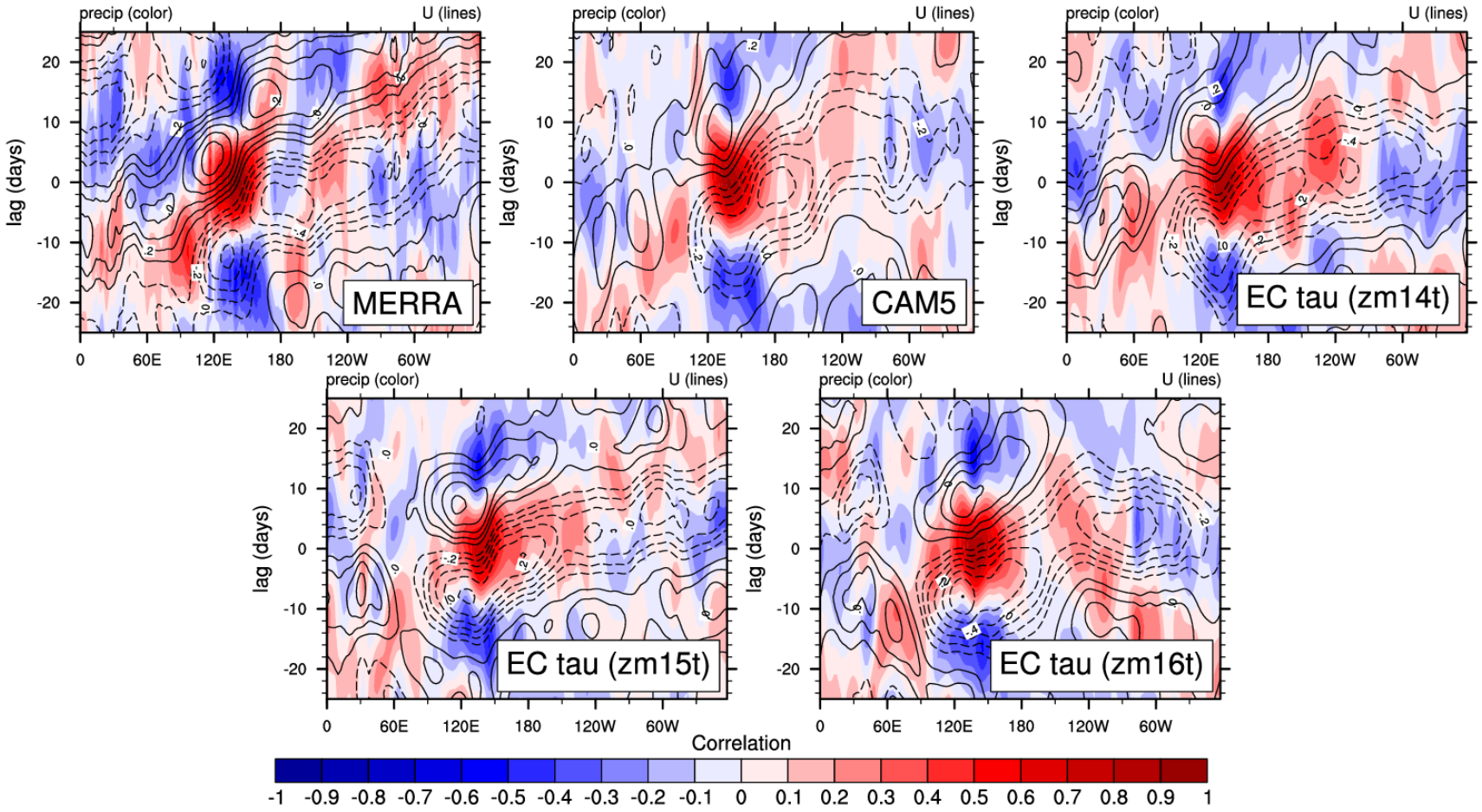
Dynamic Timescale

Dynamic Entrainment

$$F_{\varepsilon,i} = \left(\frac{\bar{q}_s}{\bar{q}_{s,b}}\right)^{\beta i}$$



$$\varepsilon = c_o F_{\varepsilon,0} + c_1 \frac{\bar{q}_s - \bar{q}}{\bar{q}} F_{\varepsilon,1}$$

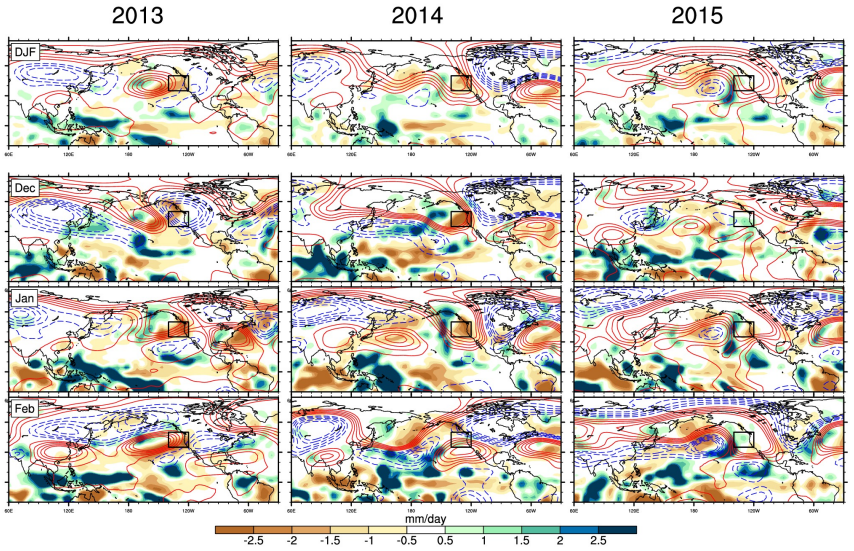


Gets past Maritime Continent Barrier

For S2S choose TELECONNECTIONS

- Reporter: Why do you rob *BANKS?*
- Sutton: That's where the *MONEY* is!

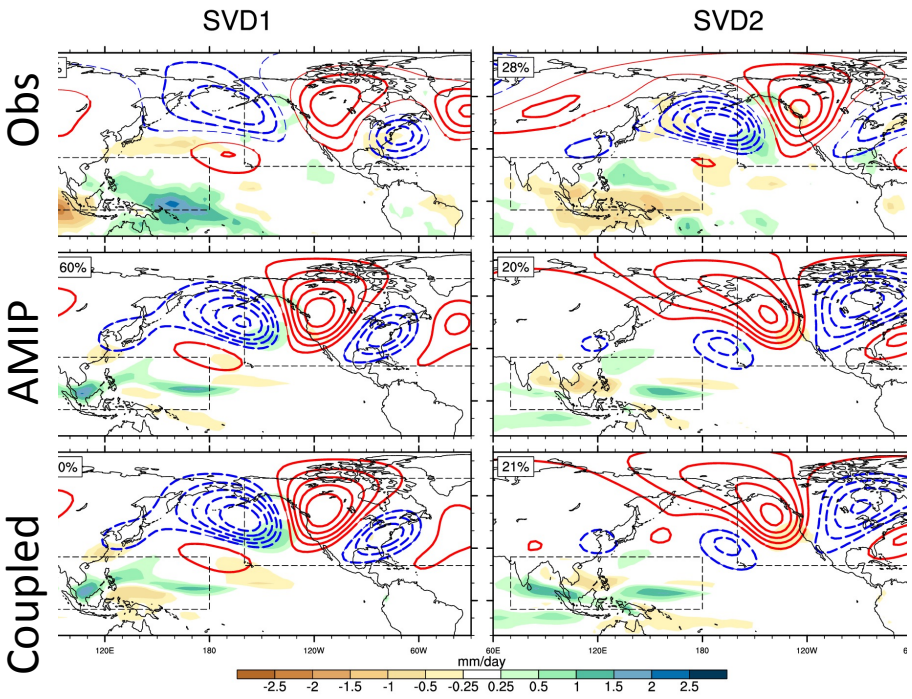
- Reporter: Why worry about *TELECONNECTIONS?*
- Sutton: That's where the *PEOPLE* are!



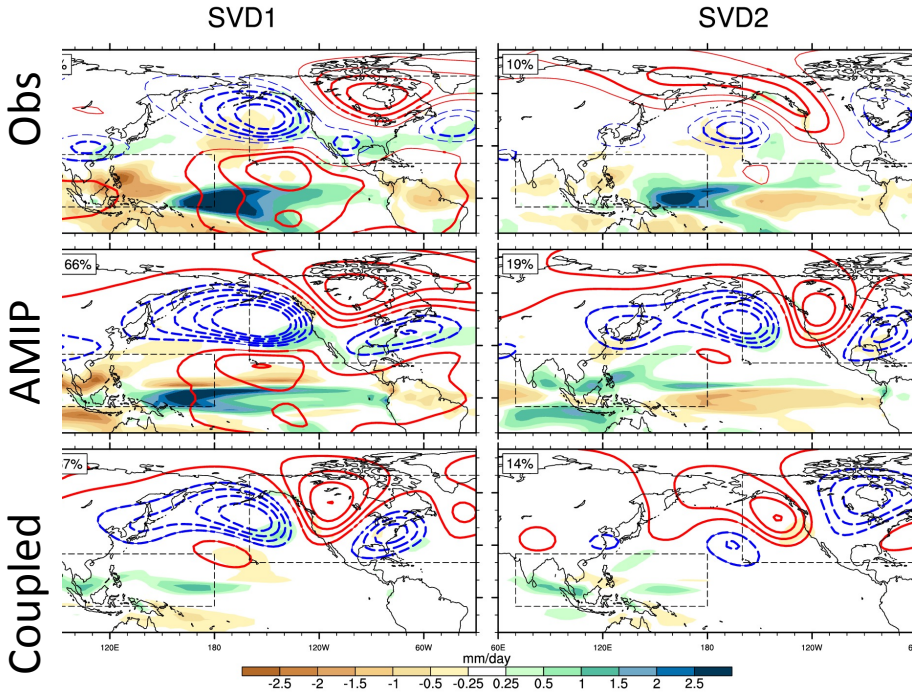
California Drought

Correlations with west Pacific precipitation

Subseasonal Teleconnection



Seasonal Teleconnection



BLOCKING

CMIP5 Models (AMIP simulations: 1979-2005)

Model Name	*Modeling Center*	*Resolution (lon/lat)*
ERA-interim	European Center for Medium Range Forecasting (ECMWF)	0.75° x 0.75°
MERRA	NASA Global Modeling and Assimilation Office (GMAO)	0.67° x 0.5°
CCSM4	National Center for Atmospheric Research (NCAR)	1.25° x 0.9°
CESM1	National Center for Atmospheric Research (NCAR)	1.25° x 0.9°
CESM1-CAM5.3	National Center for Atmospheric Research (NCAR)	1.25° x 0.9°
CESM1-CAM5.3-HR	National Center for Atmospheric Research (NCAR)	0.31° x 0.23°
ACCESS1.0	CSIRO Bureau of Meterology, Australia	1.875° x 1.25°
ACCESS1.3	CSIRO Bureau of Meterology, Australia	1.875° x 1.25°
bcc-csm-1	Beijing Climate Center, China Mete. Administration	2.8° x 2.8°
BNU-ESM	College of Global Change and Earth System Sci., Beijing Normal Univ.	2.8° x 2.8°
CanAM4	Canadian Centre for Climate Modelling and Analysis	2.8° x 2.8°
CMCC-CM	Euro-Mediterranean Center on Climate Change, Italy	0.75° x 0.75°
CNRM-CM5	CNRM/CERFACS, France	1.4° x 1.4°
EC-EARTH	ECMWF European Consortium	1.13° x 1.13°
FGOALS-g2	LASG-CESS, Inst. of Atmospheric Physics, Chinese Academy of Sci	2.8° x 3.0°
FGOALS-s2	LASG-CESS, Inst. of Atmospheric Physics, Chinese Academy of Sci.	2.8° x 1.67°
GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory (GFDL)	2.5° x 2.0°
GFDL-HIRAM-C180	NOAA Geophysical Fluid Dynamics Laboratory (GFDL)	0.63° x 0.5°
GFDL-HIRAM-C360	NOAA Geophysical Fluid Dynamics Laboratory (GFDL)	0.31° x 0.25°
HadGEM2-A	UK Met. Office Hadley Center	1.875° x 1.25°
IPSL-CM5A-LR	Institut Pierre Simon Laplace (IPSL), France	3.75° x 1.875°
IPSL-CM5B-LR	Institut Pierre Simon Laplace (IPSL), France	3.75° x 1.875°
MIROC5	Atmos. and Ocean Research Institute (Univ. Toky), NIES, JAMSTEC	1.4° x 1.4°
MPI-ESM-LR	Max Planck Institute for Meteorology (MPI), Germany	1.875° x 1.875°
MPI-ESM-MR	Max Planck Institute for Meteorology (MPI), Germany	1.875° x 1.875°
MRI-CGCM3	Meteorological Research Institute (MRI,JPA), Japan	1.125° x 1.125°
NorESM1-M	Norwegian Climate Centre (NorClim)	2.5° x 1.875°

Antsey et al 2013

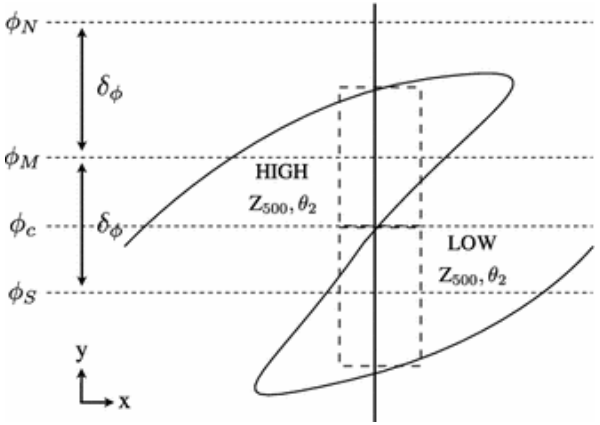
Measures of Blocking

500-mb geopotential height (daily means)

1-dimensional
(D'Andrea et al., 1998)

$$GHGN(\lambda_0) = \frac{Z500(\phi_N) - Z500(\phi_0)}{\phi_N - \phi_0}$$

$$GHGS(\lambda_0) = \frac{Z500(\phi_0) - Z500(\phi_S)}{\phi_0 - \phi_S}$$



$\phi_0 = 50N ... \phi_S = 41N ... \phi_N = 78N$

2-dimensional
(Davini et al., 2012)

$$GHGN(\lambda_0, \phi_0) = \frac{Z500(\lambda_0, \phi_N) - Z500(\lambda_0, \phi_0)}{\phi_N - \phi_0}$$

$$GHGS(\lambda_0, \phi_0) = \frac{Z500(\lambda_0, \phi_0) - Z500(\lambda_0, \phi_S)}{\phi_0 - \phi_S}$$

$\phi_0, \phi_S, \phi_N \ldots \text{var } y$

Lat/lon Blocked if

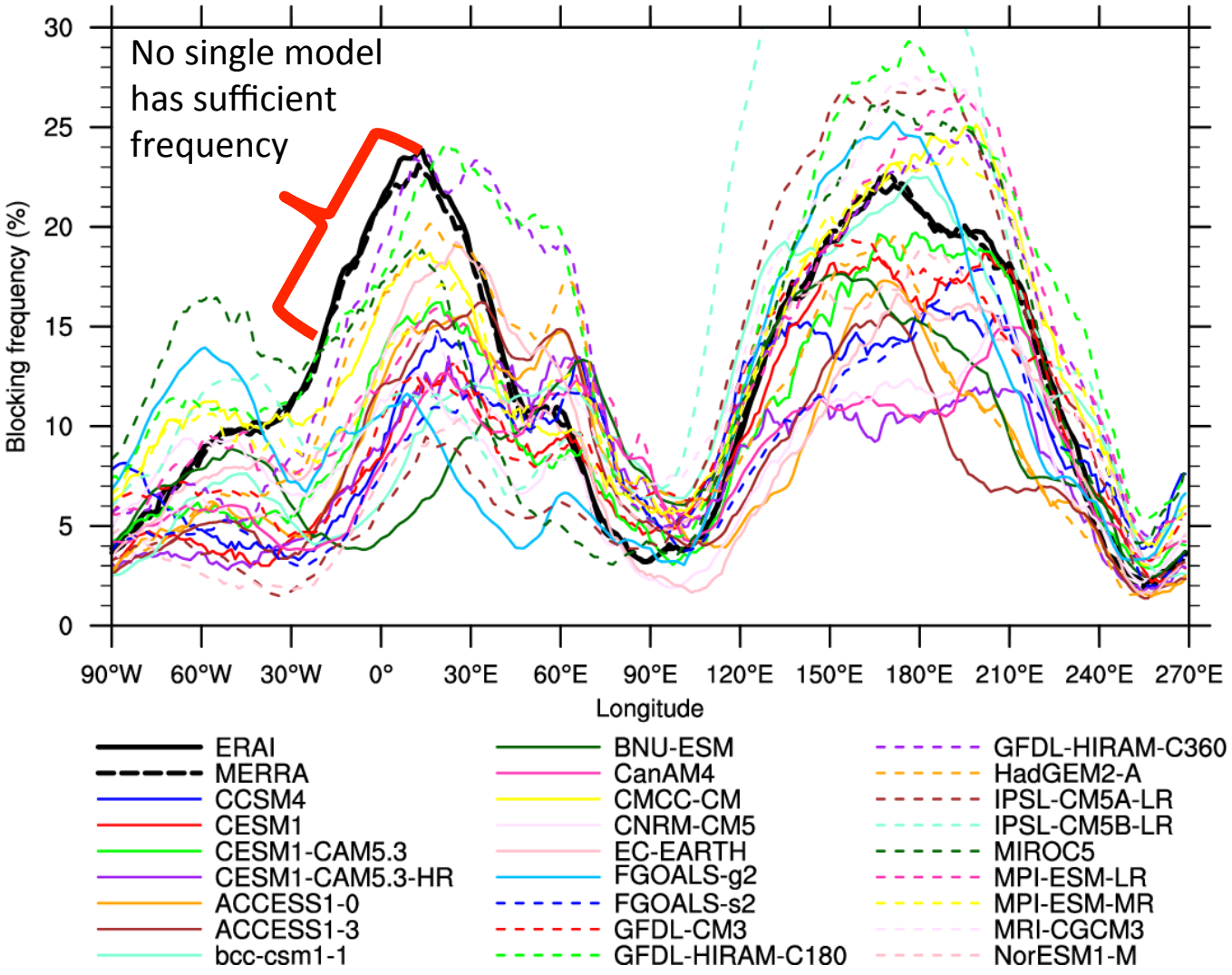
$$GHGN(\lambda_0, \phi_0) < -10m(^o lat)^{-1}$$

$$GHGS(\lambda_0, \phi_0) > 0$$

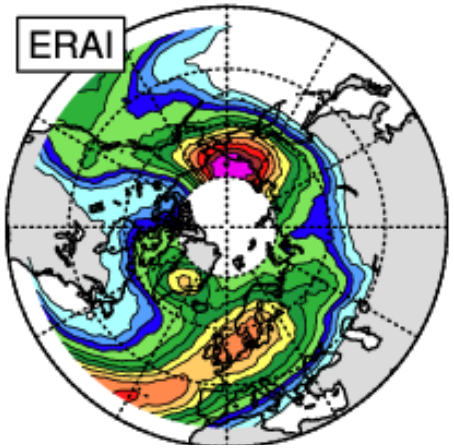
Lon Blocked strength

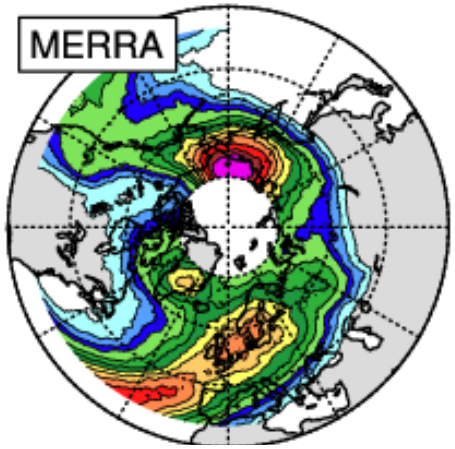
$$GHGS(\lambda_0) - GHGN(\lambda_0)$$

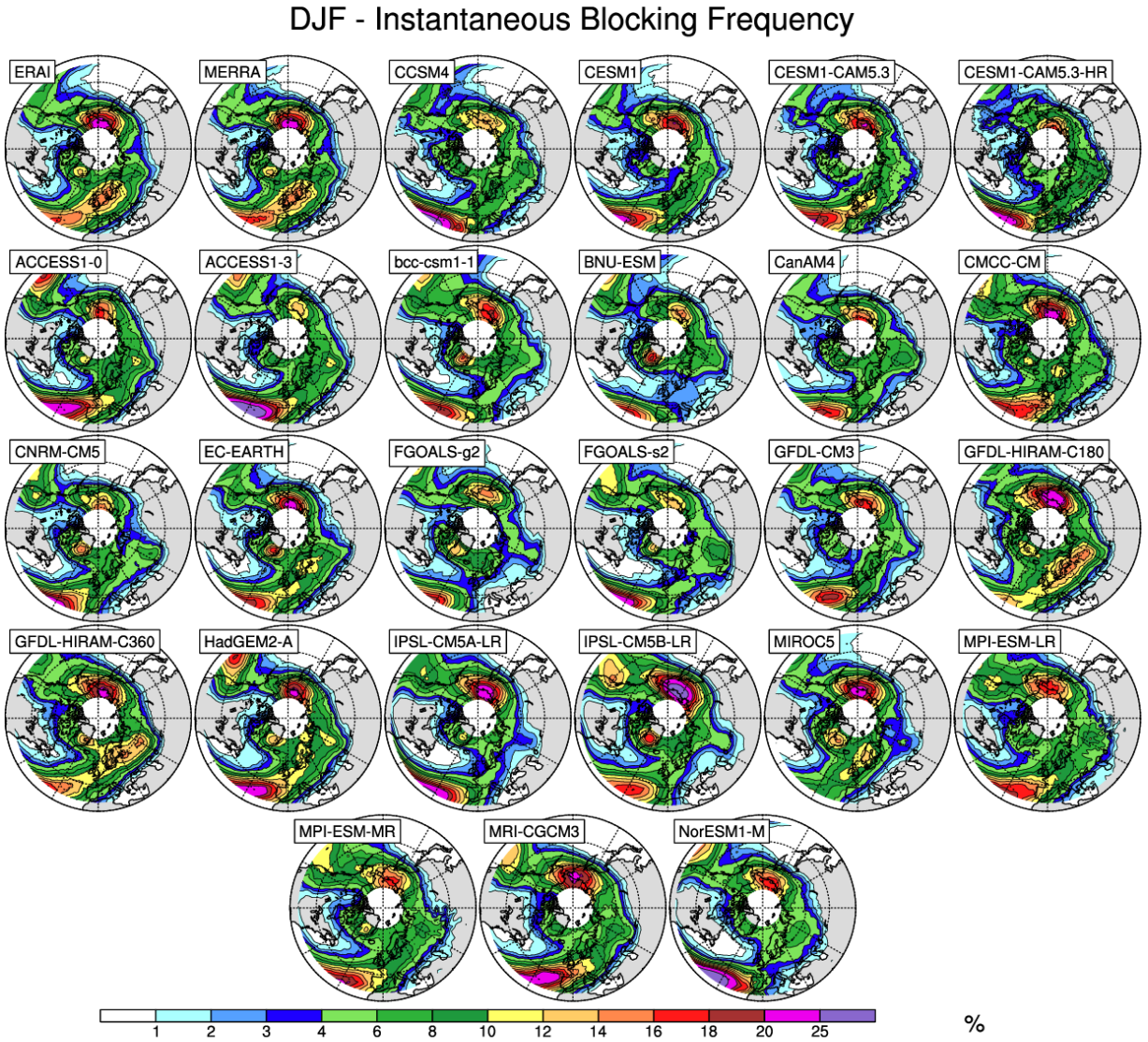
DJF Blocking



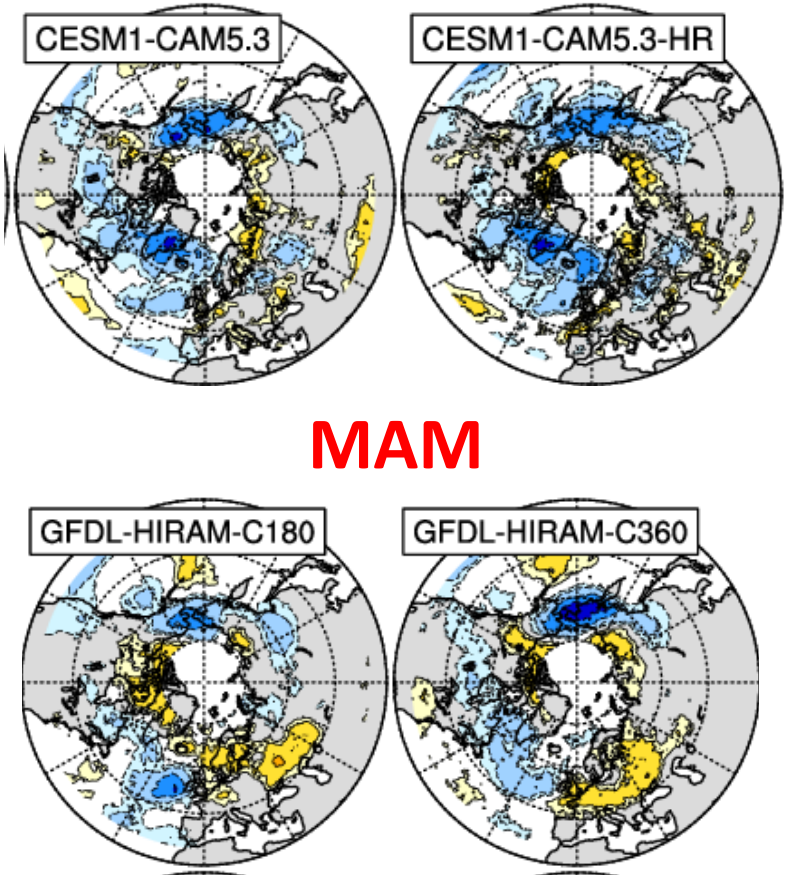
2D Mean Blocking

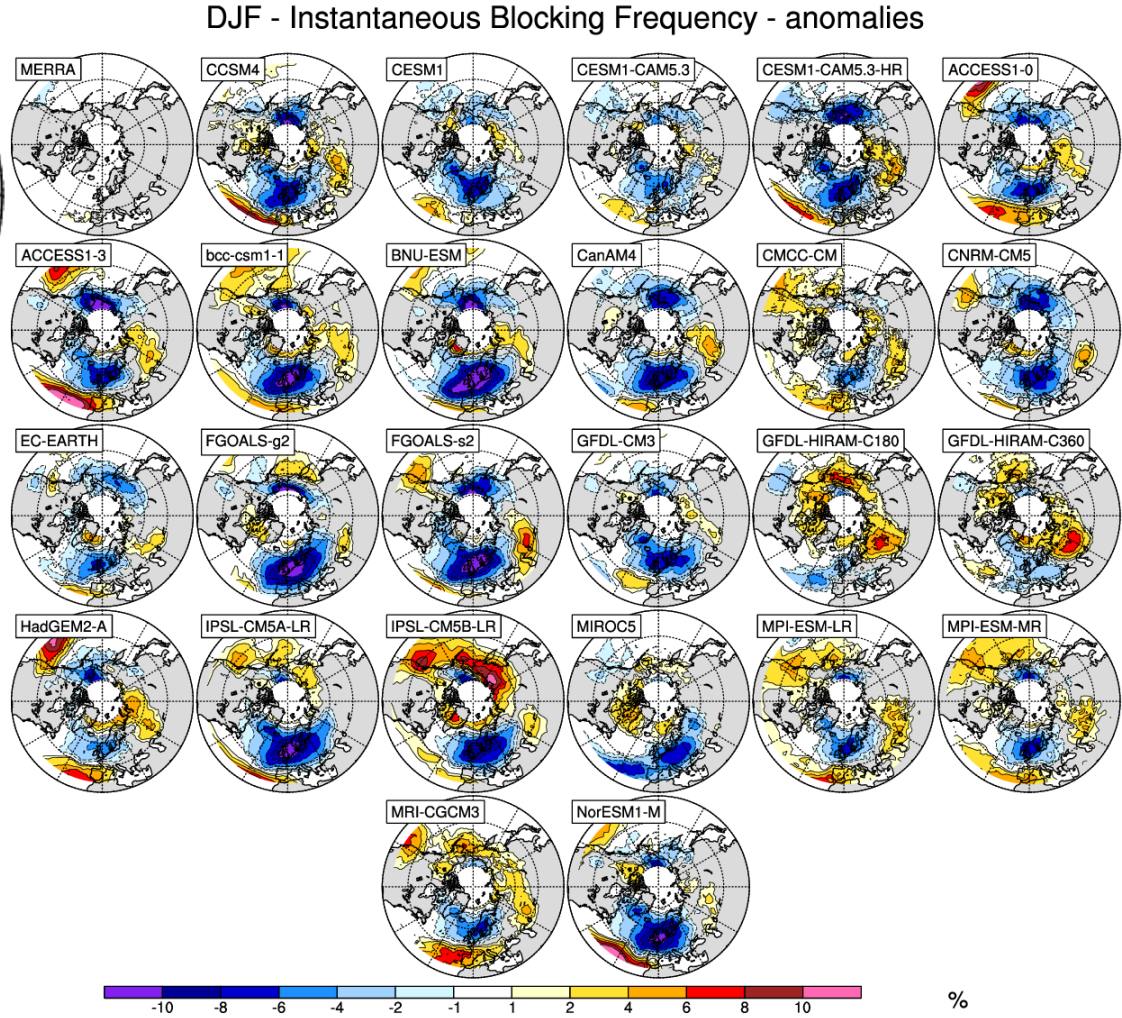




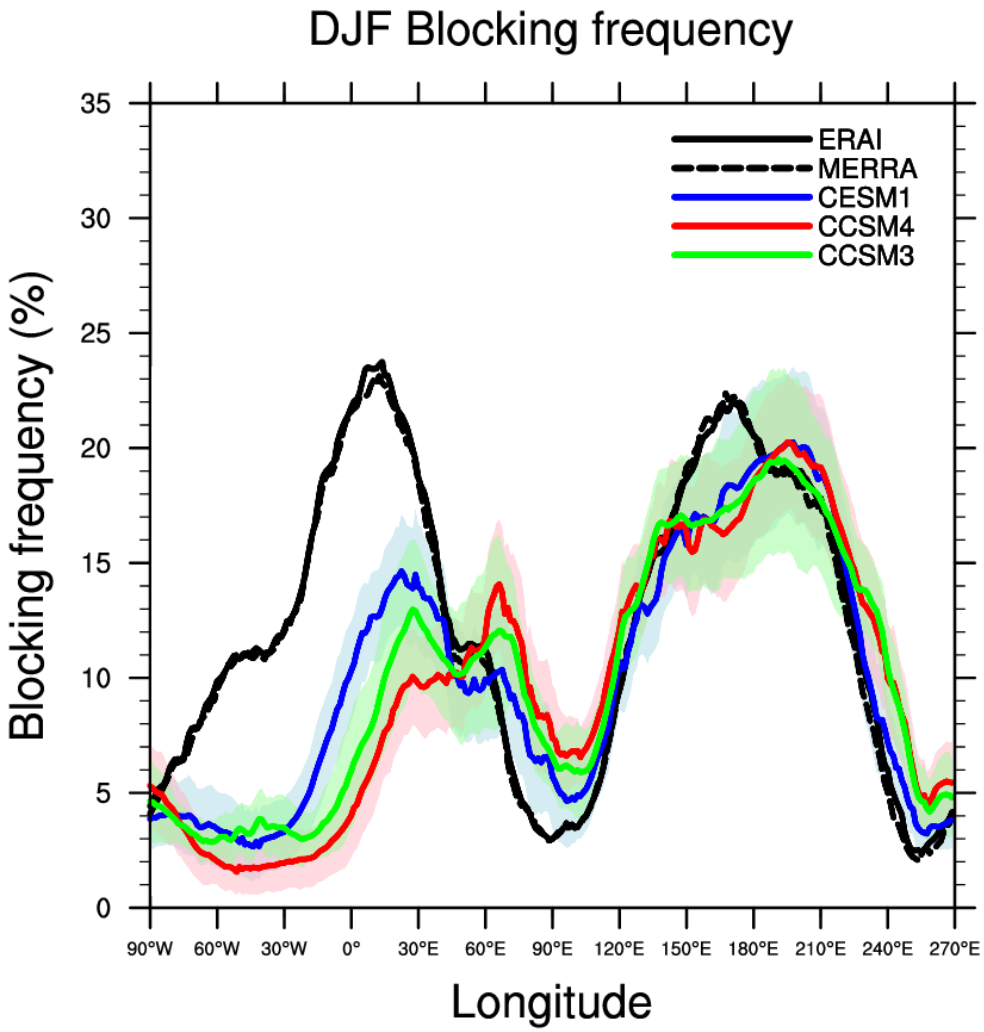


2D Mean Blocking





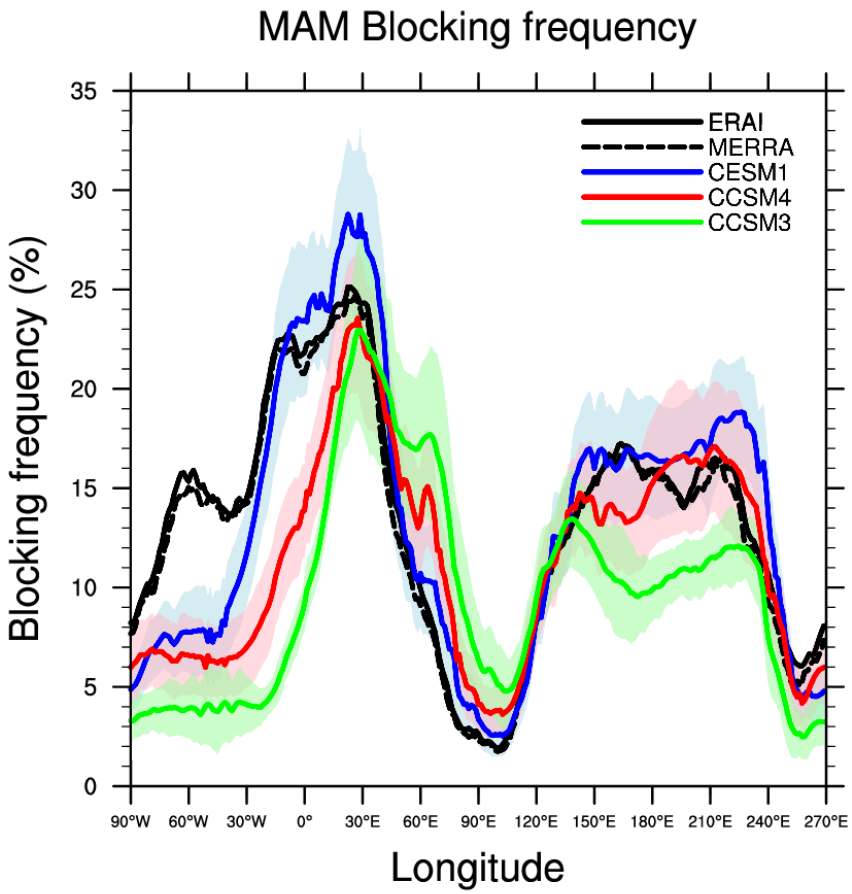
Climatological Blocking (1D) - DJF

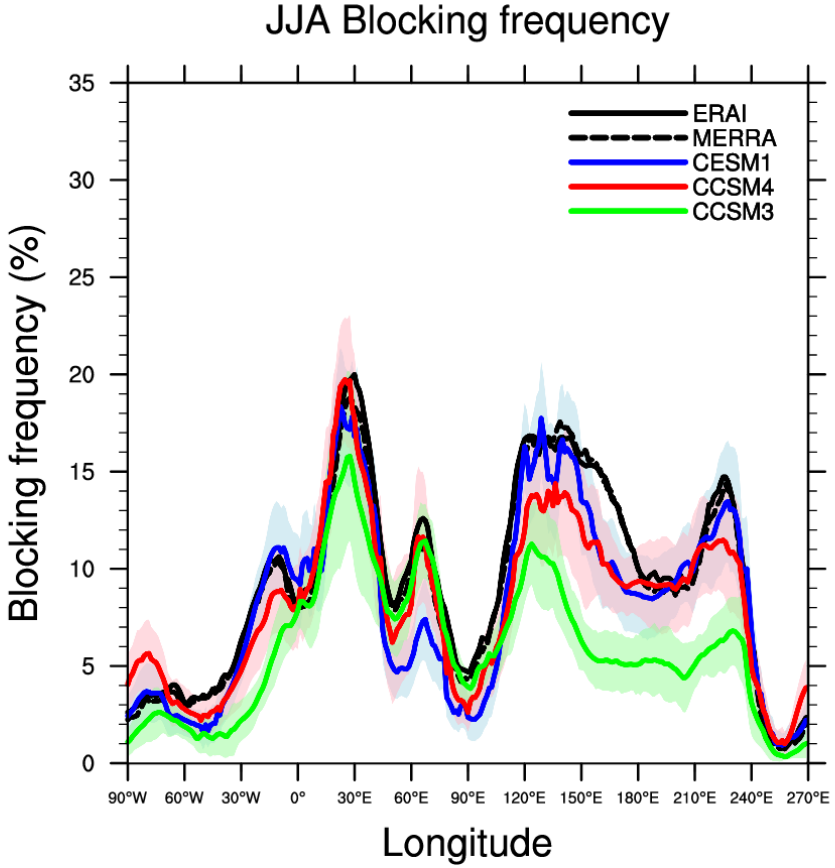


Blocking frequency

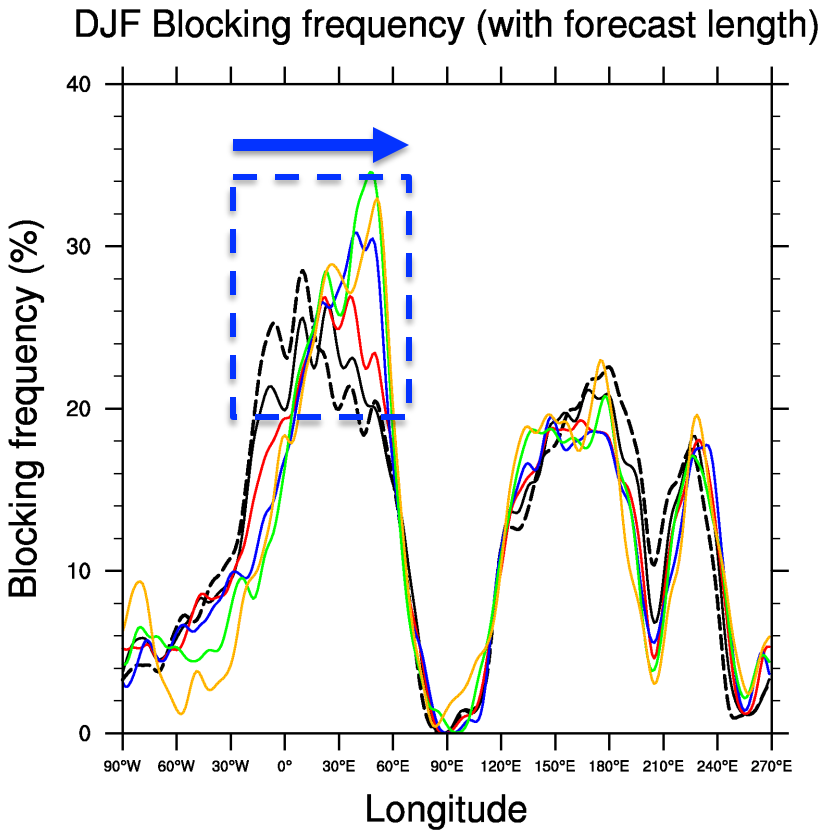
- 1979-2005 - Daily instantaneous blocking frequency
- Models +/- 2 std: All ens. Members.
- 2 maxima: Western Europe and North Pacific
- Max blocking ~20%
- Minimum over Central US/Canada and Central Russia
- Model captures Pacific blocking
- Poor representation of Western Europe; Atlantic blocking
- Some improvements in CESM1 (CAM5)

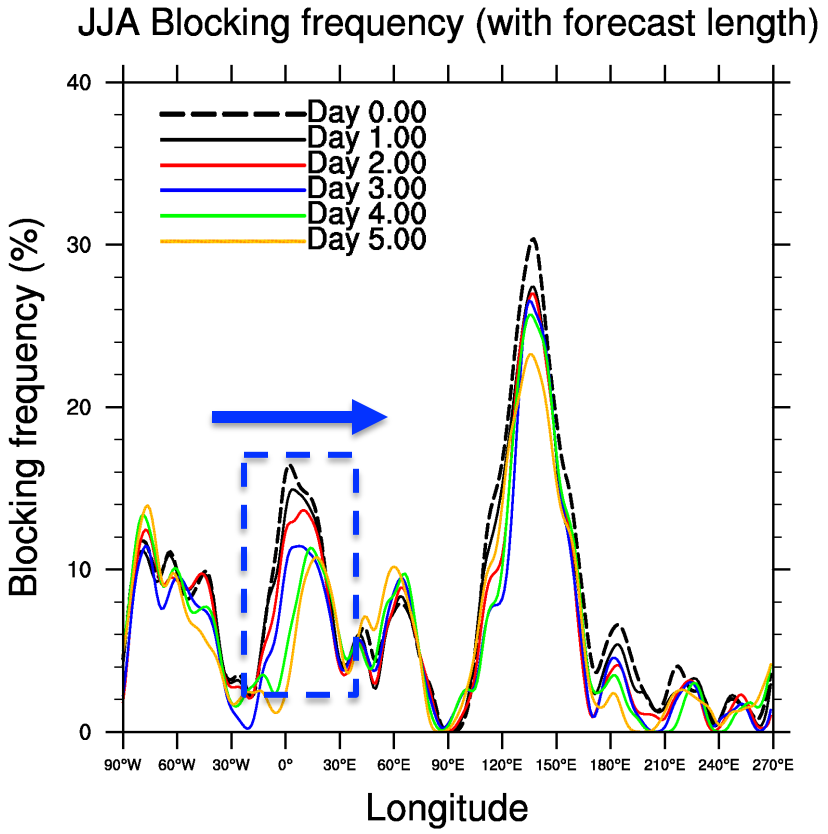
Climatological Blocking (1D) – MAM/JJA



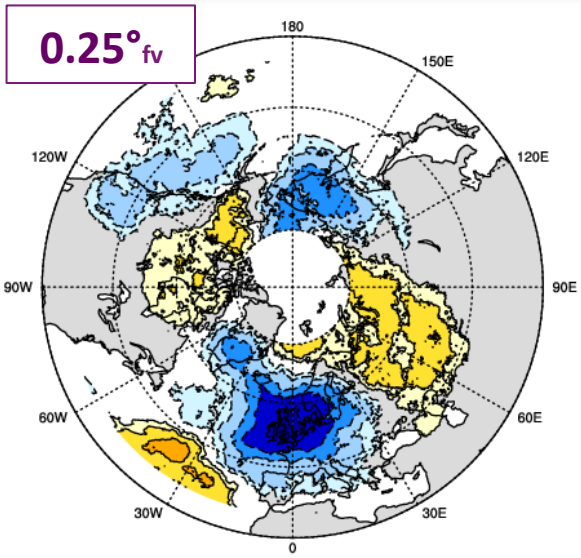


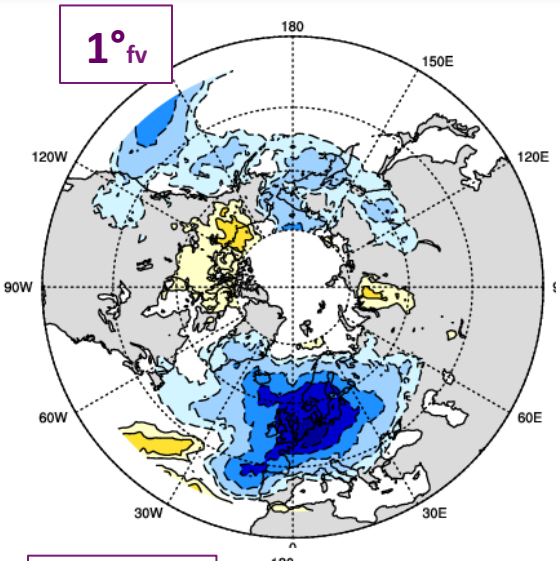
Seasonal Hindcasts: CAPT/YOTC 2008/09

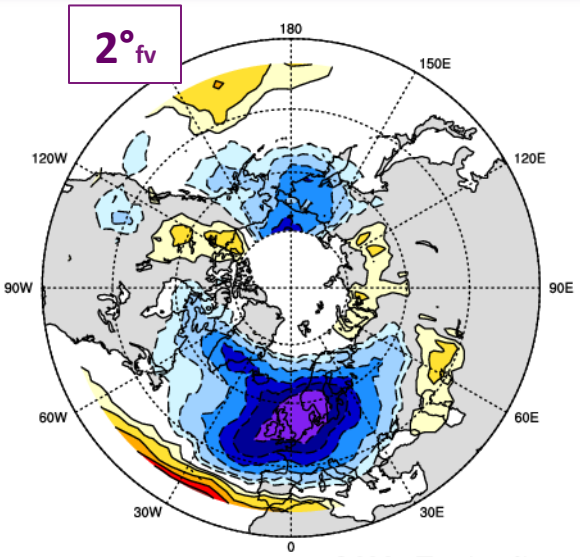


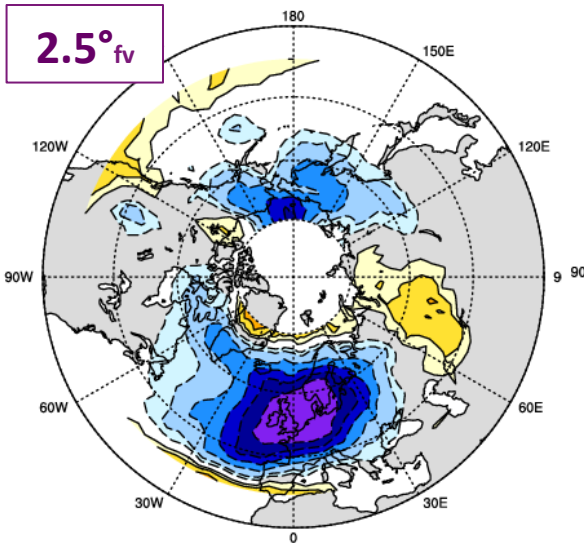


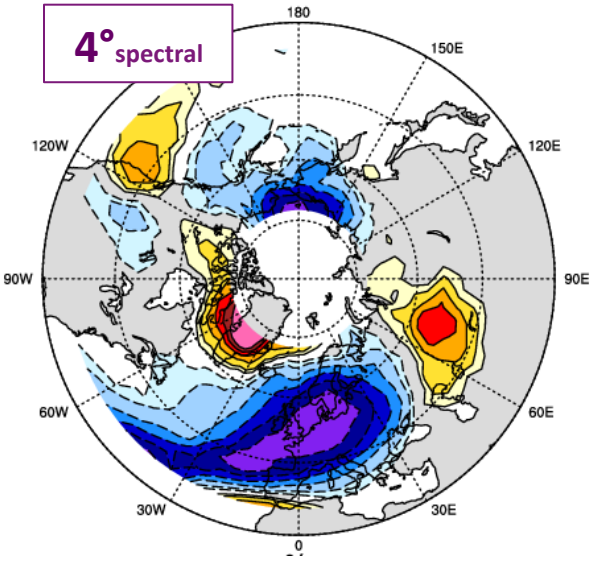
Evolution of Blocking Simulation in CESM - Resolution











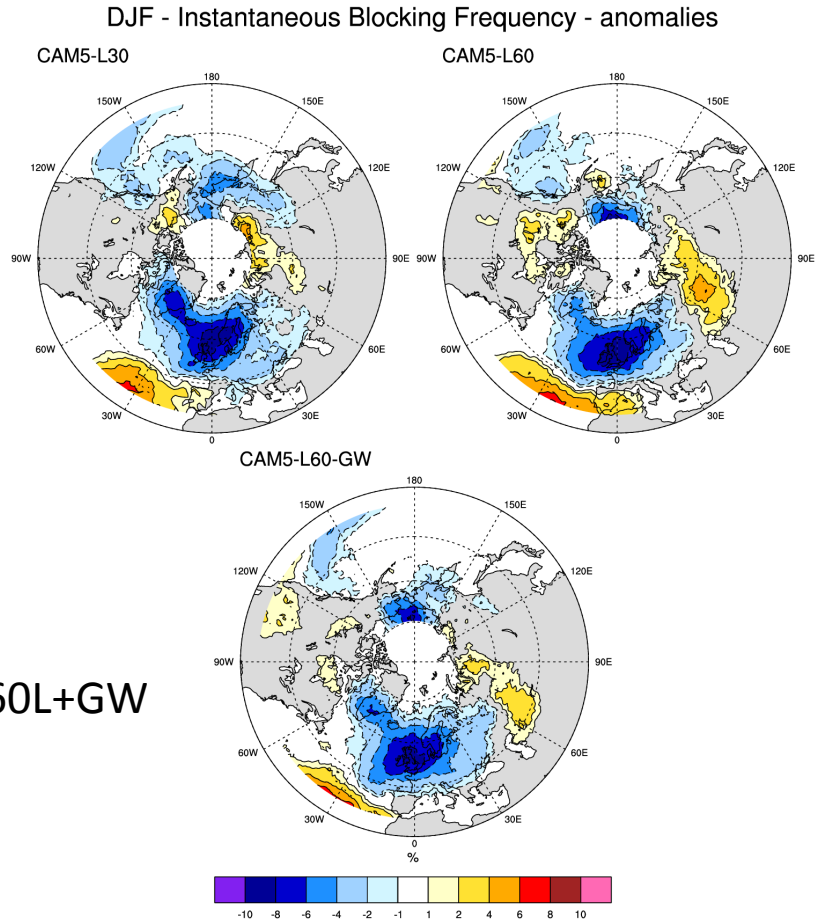
CAM4 Resolution Differences

DJF

AMIP: 1979-1999

Evolution of Blocking Simulation in CESM - Resolution

Effect of Vertical Resolution



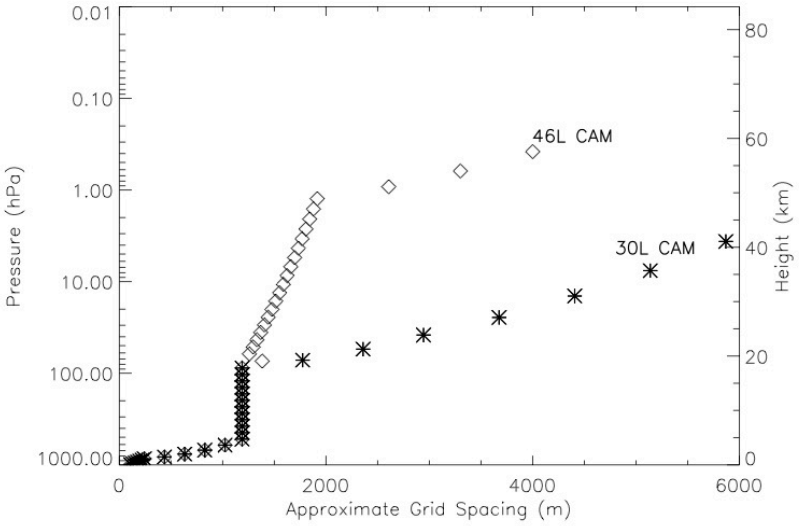
30L

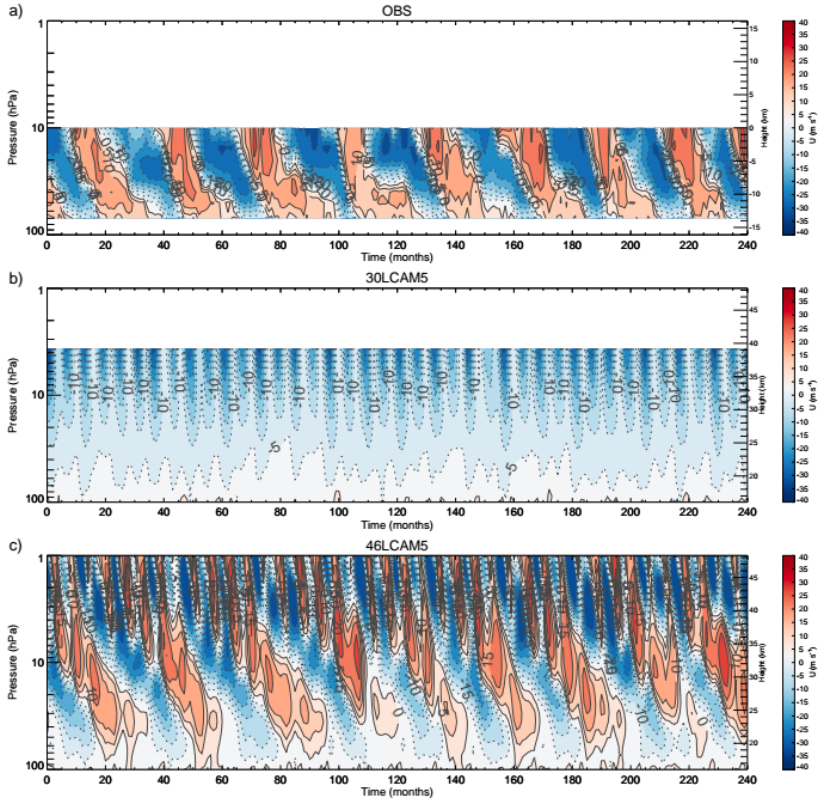
60L

60L+GW

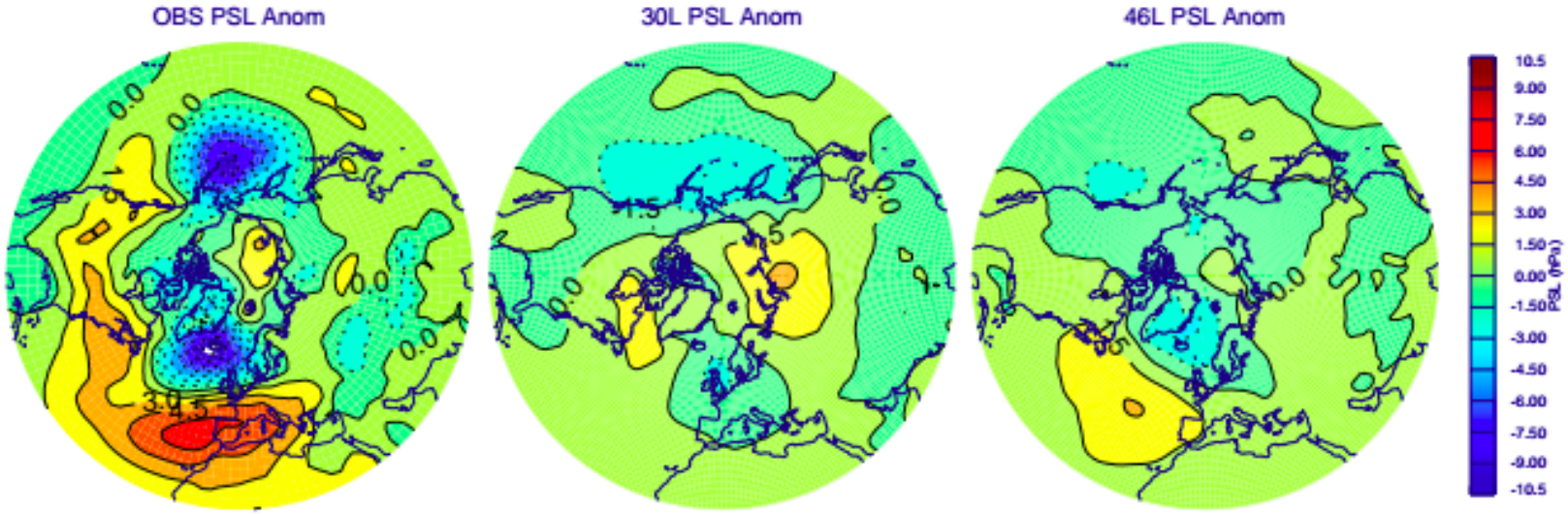
INFLUENCE OF THE STRATOSPHERE

Resolved vertical wavelength: QBO





Higher vertical resolution->
Better horizontal anomaly structure



Conclusions

Climate matters in S2S

1. Climate mean matters because teleconnections depend on mean state
2. S2S Variability determines teleconnection forcing

Resolution

1. Not the (only) solution but can be a large part of the problem in climate
2. Sensitivity to physics and resolution

S2S is a testing ground for SEAMLESS prediction