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The Madden-Julian Oscillation in General Circulation Models

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Goals

-evaluate the ability of the AMIP and CMIP models to simulate the bo-
real winter

Madden-Julian Oscillation

- -propagation
- -mechanisms
- -vertical structure
- -role of air-sea interaction

-relationship between mean state error and the MJO

Daily Data (November-March)

-NCEP-NCAR Reanalysis

-CPC Merged Analysis of Precipitation (CMAP)

-Advanced Very High Resolution Radiometer OLR

-20 AMIP Models (1979/80-1994/95)

- 9 Coupled Models (9-19 winters)

Analysis

1) MJO Index

   -intraseasonal variability of the 200hPa tropical zonal mean zonal wind

   -used to identify years of strong MJO variability

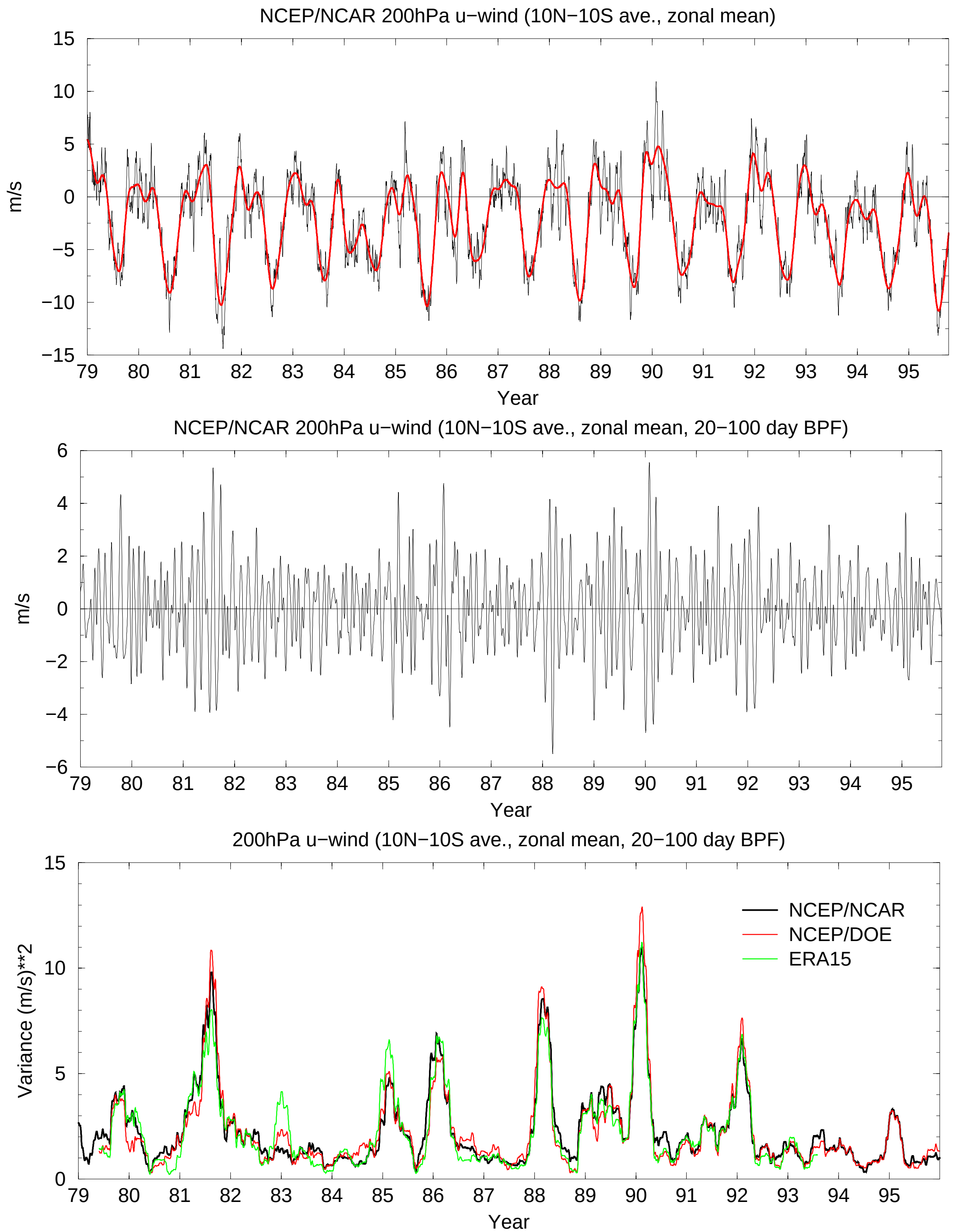
2) EOF analysis of 20-100 day bandpass filtered AVHRR OLR during years of strong MJO variability

   -isolate propagation characteristics of MJO convection

3) Project the 20-100 day bandpass filtered OLR from the observations (1979/80-1994/95) and models onto the observed EOF's to obtain PC's

4) For each model identify years when the simulated lead/lag behavior of the PC's is consistent with observations

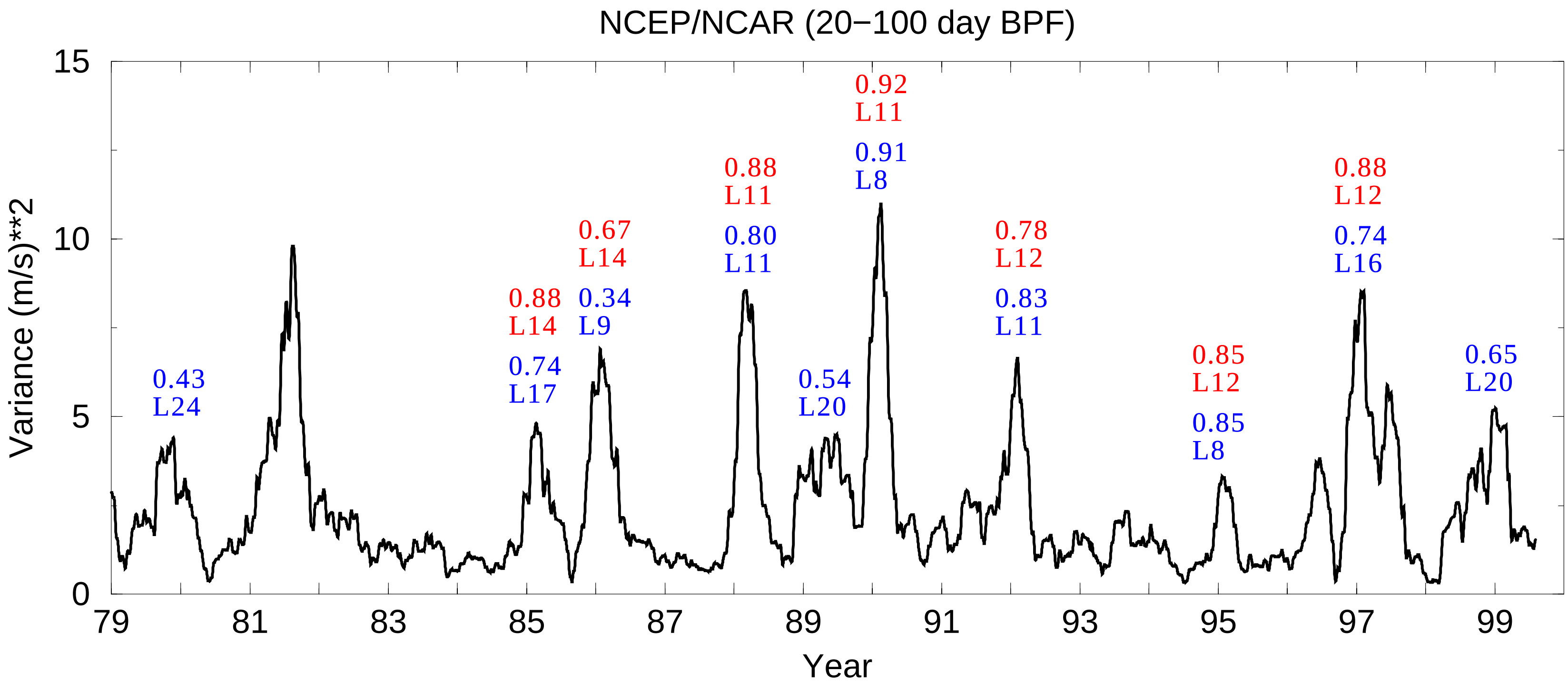
5) For these years, linear regression of PC time series against 20-100 day bandpass filtered OLR, rainfall, winds etc. to evaluate observed/simulated spatio-temporal evolution of the MJO. All regressions have been scaled by a 1 standard deviation perturbation of the PC to return actual units



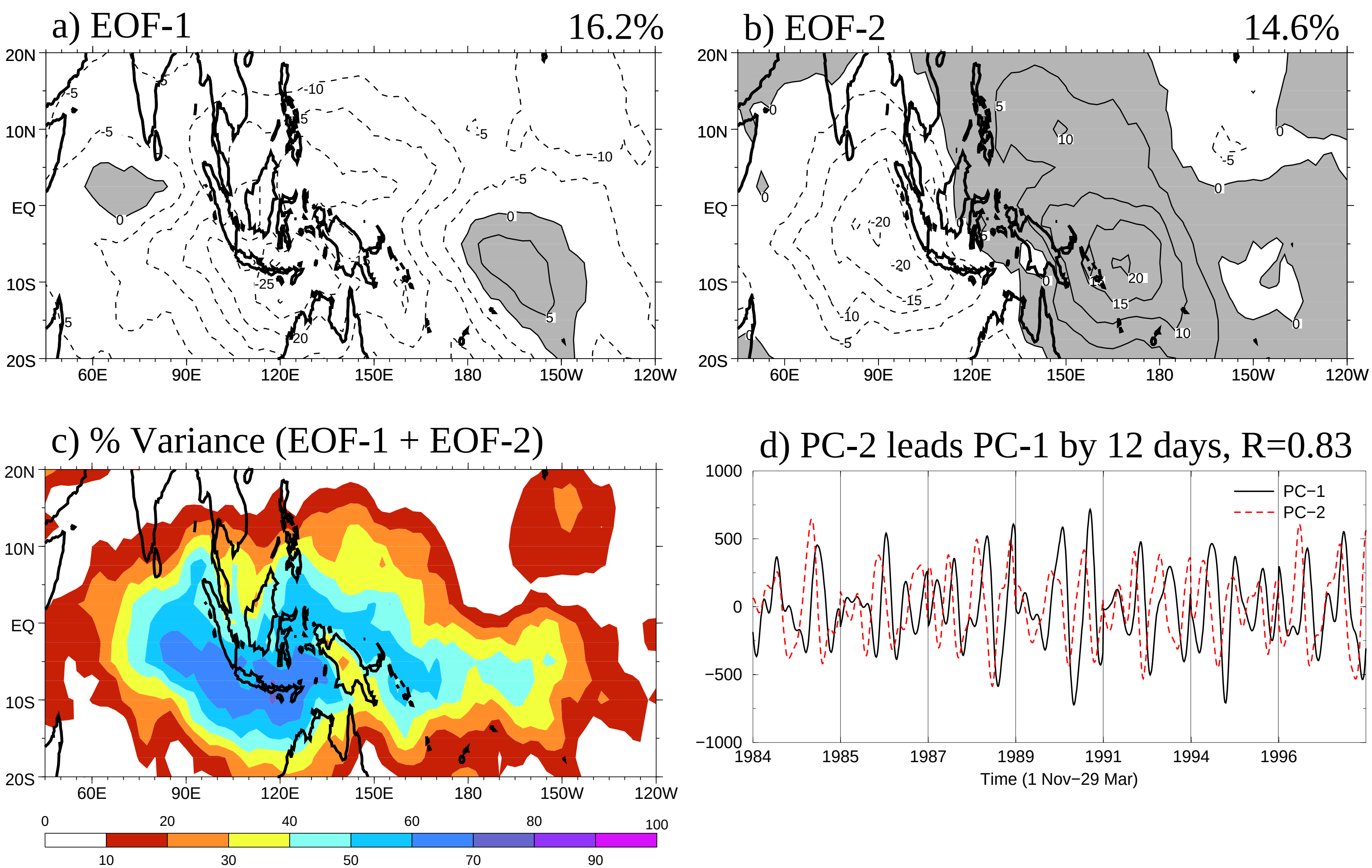
NCEP/NCAR 200hPa u−wind (10N−10S ave., zonal mean)
m/s
Year
NCEP/NCAR 200hPa u−wind (10N−10S ave., zonal mean, 20−100 day BPF)
m/s
Year
200hPa u−wind (10N−10S ave., zonal mean, 20−100 day BPF)
Variance (m/s)**2
Year
NCEP/NCAR
NCEP/DOE
ERA15

The 200hPa zonal mean zonal wind MJO index

Based on EOF analysis of 20-100 day filtered OLR, characteristics of the lead-lag relationship of the 2 leading PC's are also given, including the maximum positive correlation, and the time lag (L'n'; days) at which it occurred. Blue (red) labelling is from the analysis of 10 (7) winters of data.



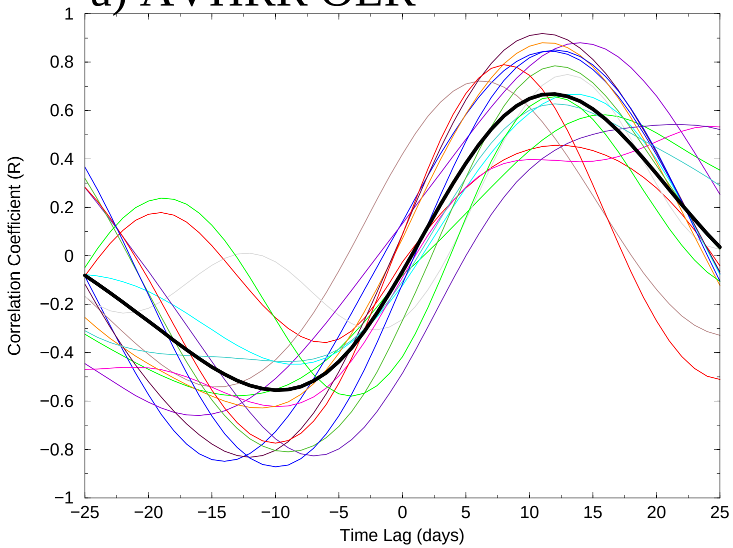
Characteristics of the two leading EOF's/PC's using seven winters of 20-100 day filtered OLR



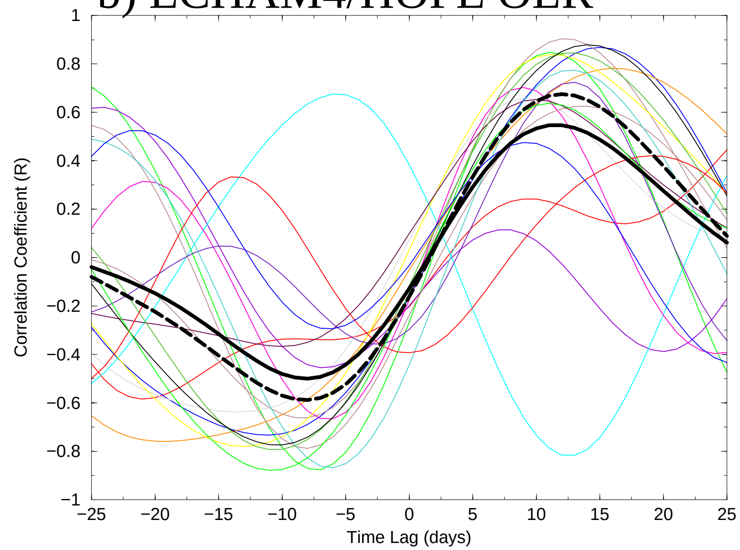
Lead-lag relationship between PC-1 and PC-2

-colored lines: individual winters
-thick solid black line: average over all winters
-thick dashed black line: average of winters in observed phase-space

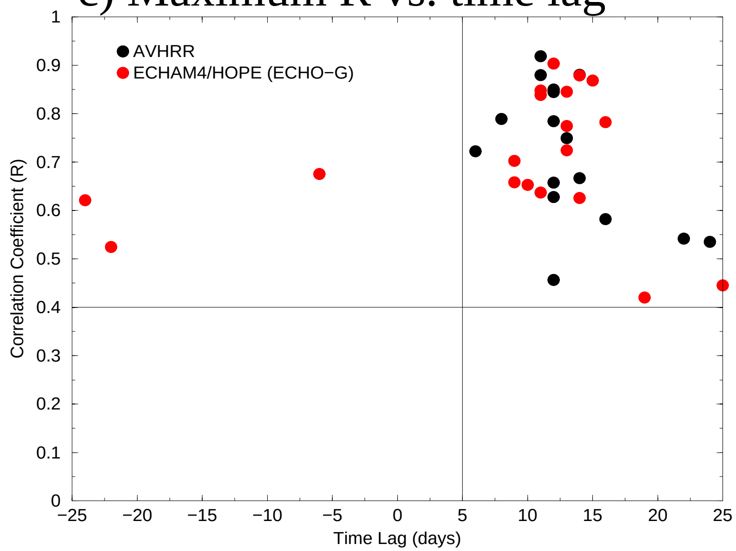
a) AVHRR OLR



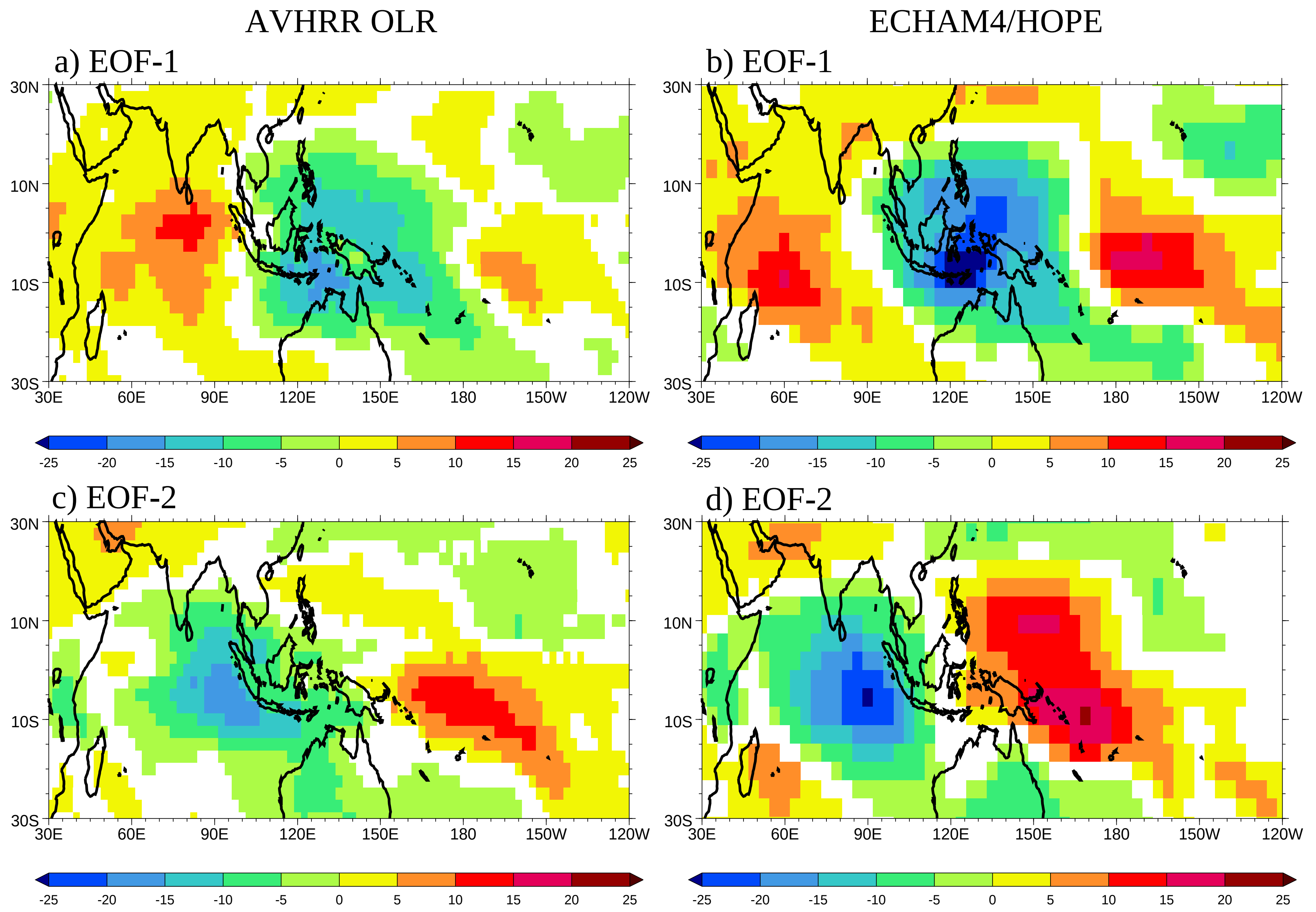
b) ECHAM4/HOPE OLR



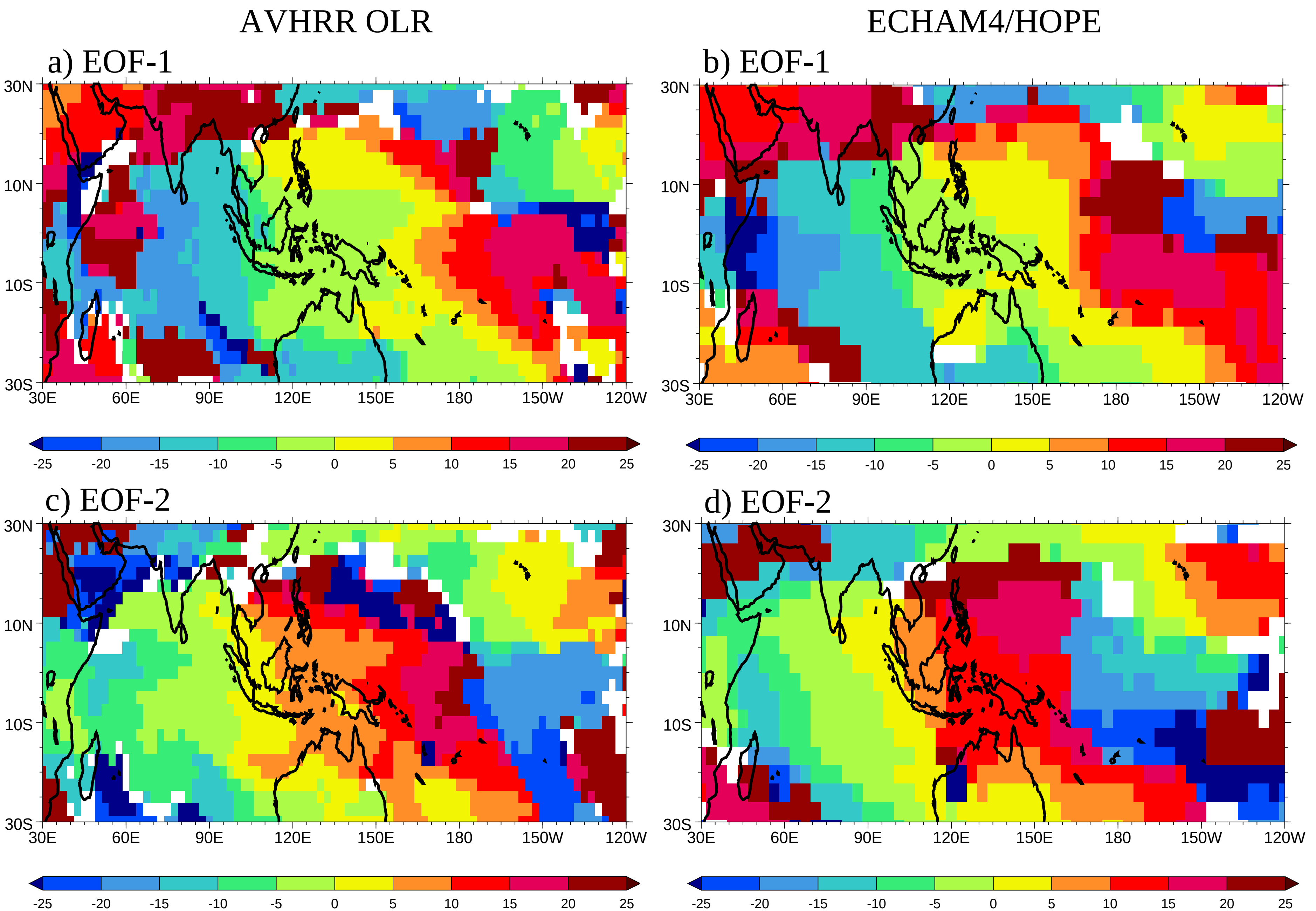
c) Maximum R vs. time lag



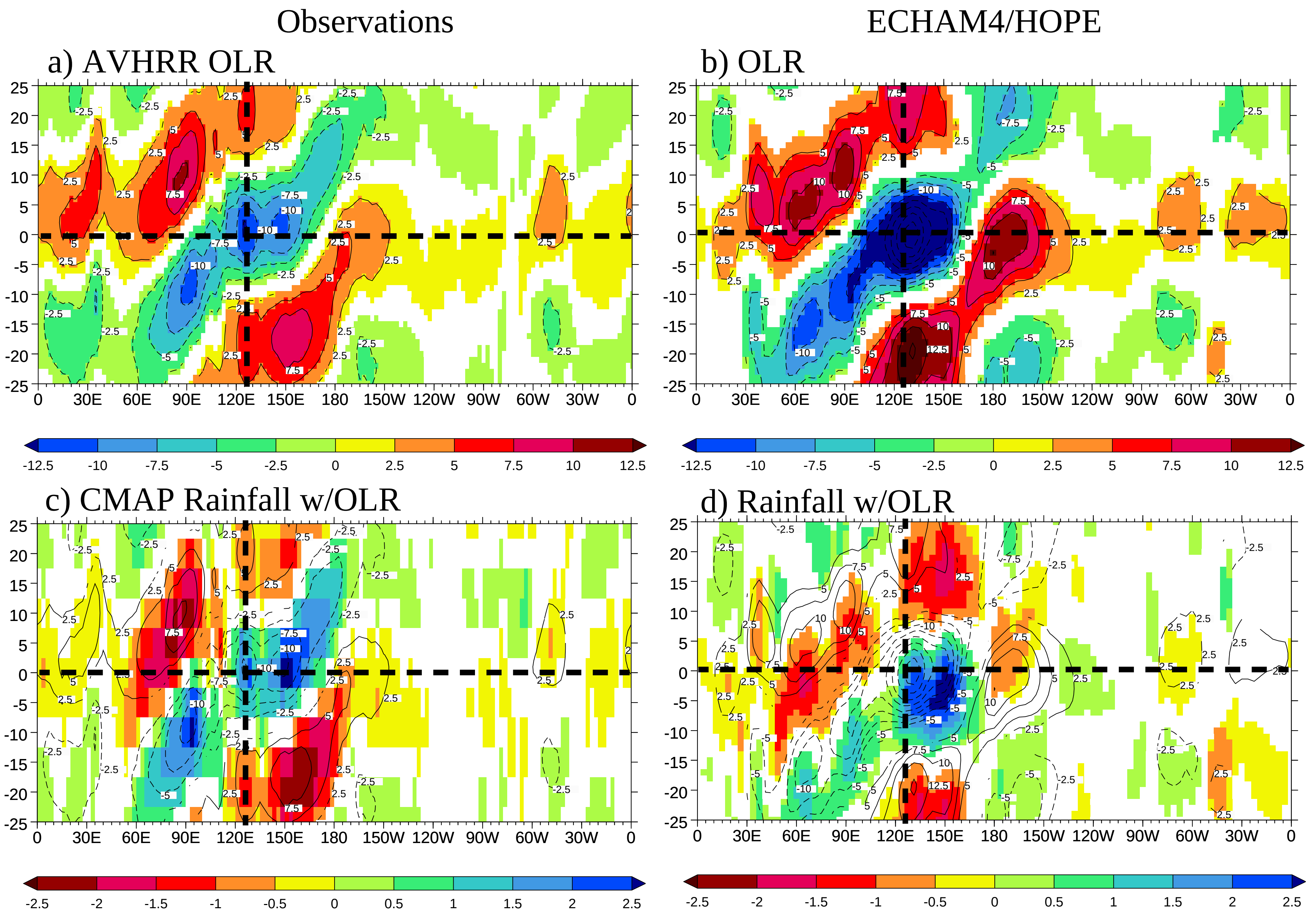
Lag 0 regression of PC-1 and PC-2 with filtered OLR



Day of maximum convection



Lagged linear regression using PC-1 (5^oN-5^oS)



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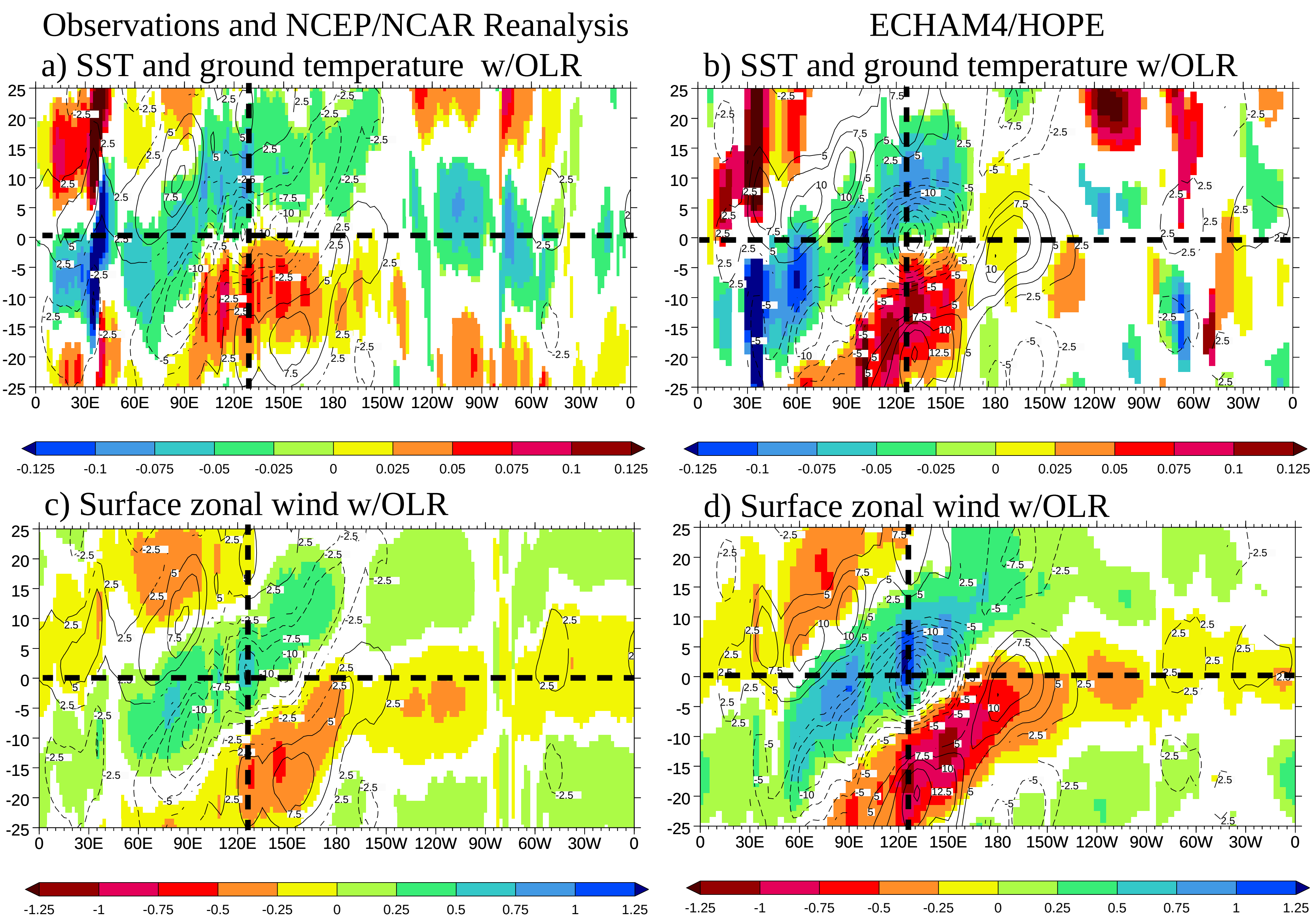

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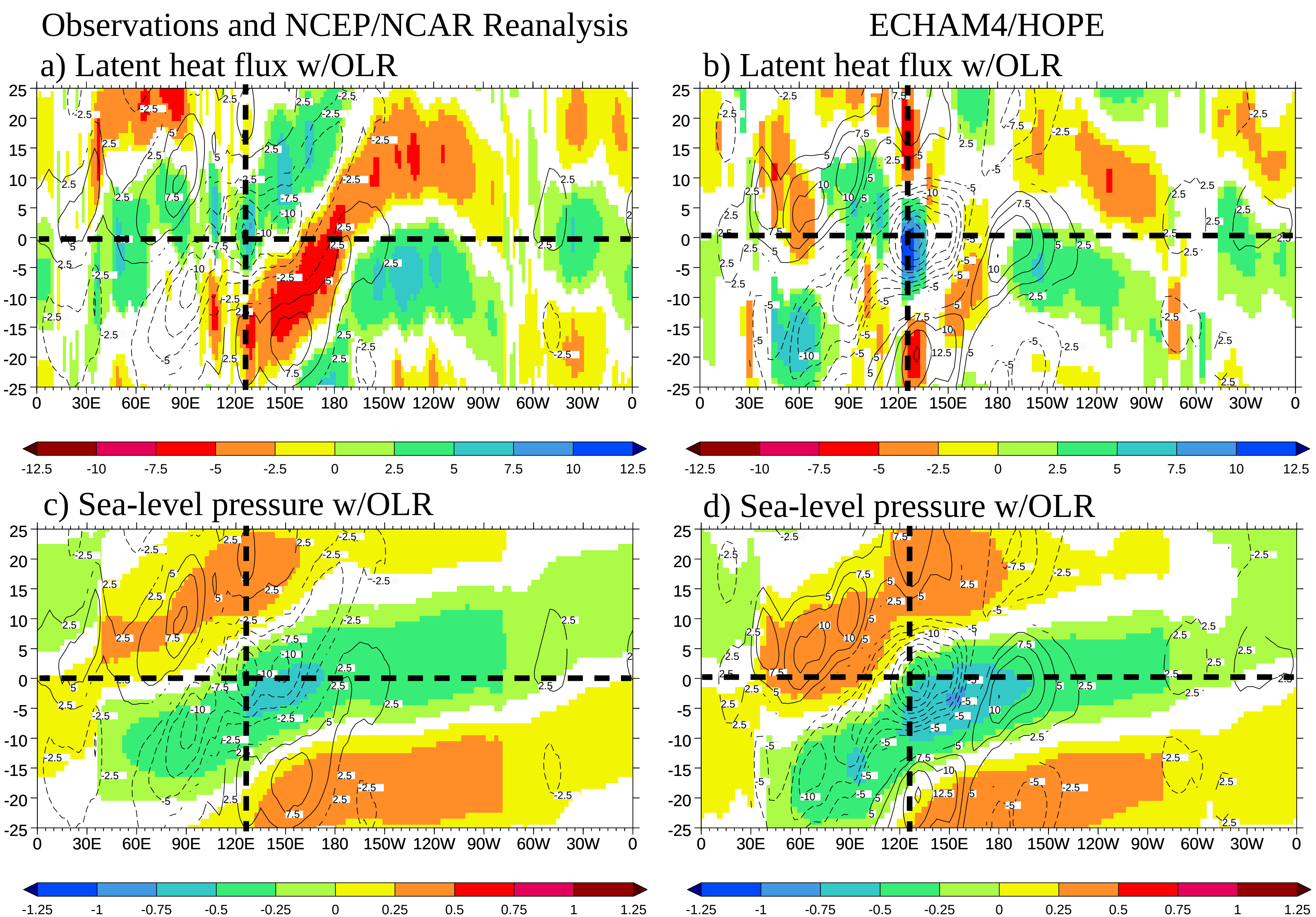
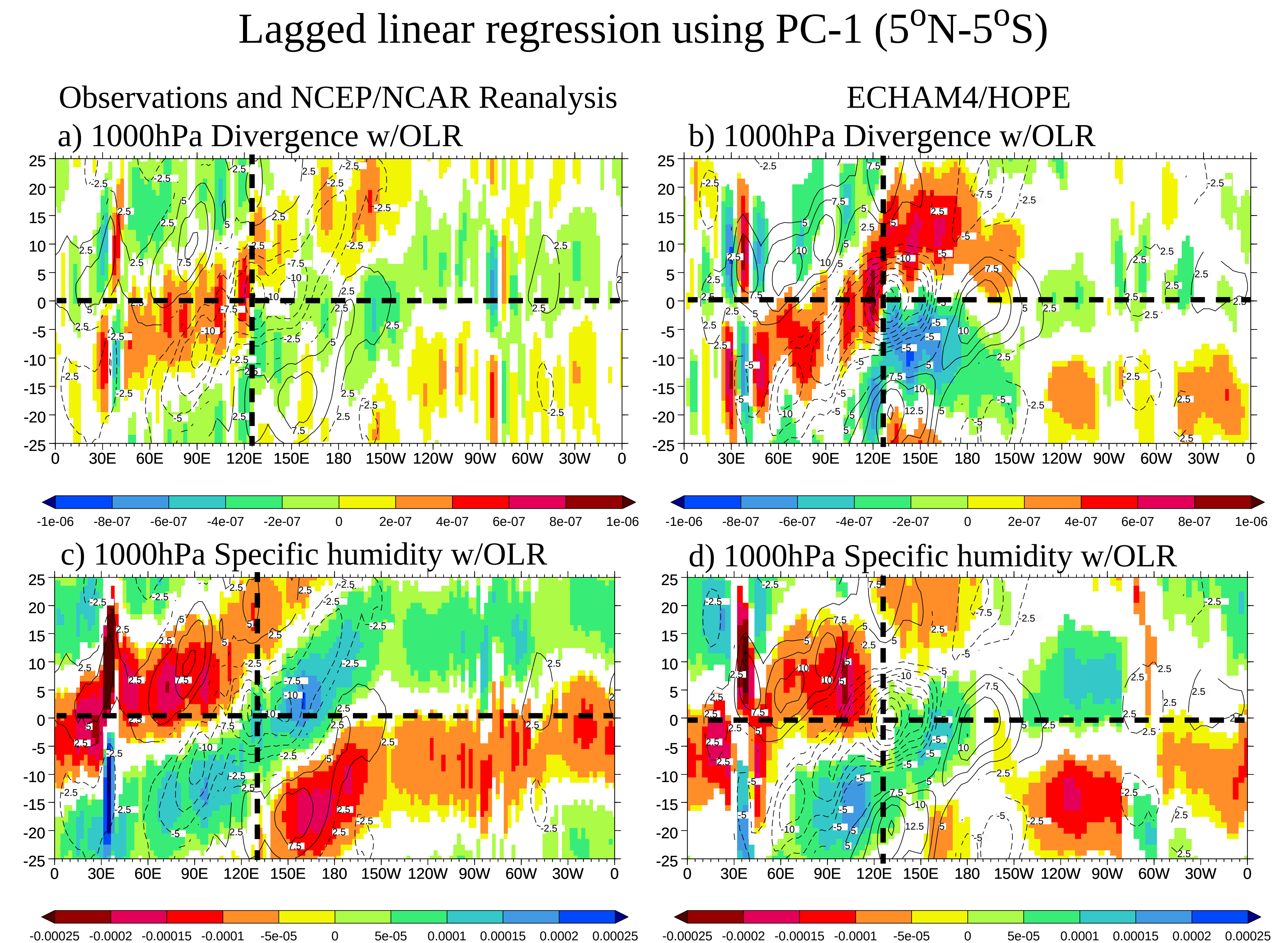
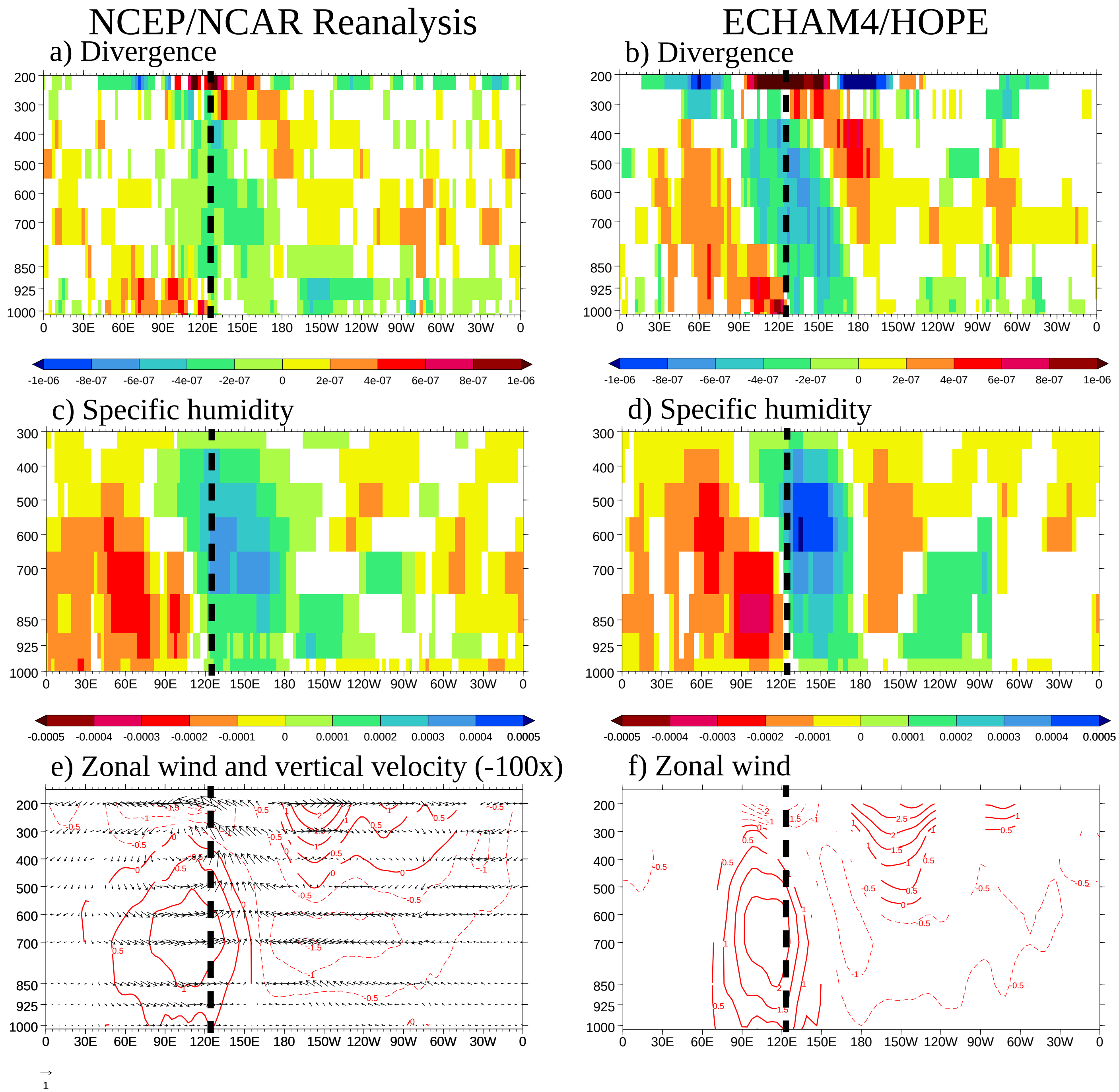



Lagged linear regression using PC-1 (5oN-5oS)
Observations and NCEP/NCAR Reanalysis
ECHAM4/HOPE
a) 1000hPa Divergence w/OLR
b) 1000hPa Divergence w/OLR
c) 1000hPa Specific humidity w/OLR
d) 1000hPa Specific humidity w/OLR
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
-1e-06 -8e-07 -6e-07 -4e-07 -2e-07 0 2e-07 4e-07 6e-07 8e-07 1e-06
-0.00025 -0.0002 -0.00015 -0.0001 -5e-05 0 5e-05 0.0001 0.00015 0.0002 0.00025

Lag 0 linear regression using PC-1 (5^oN-5^oS)



Lagged linear regression using PC-1 (5^oN-5^oS)

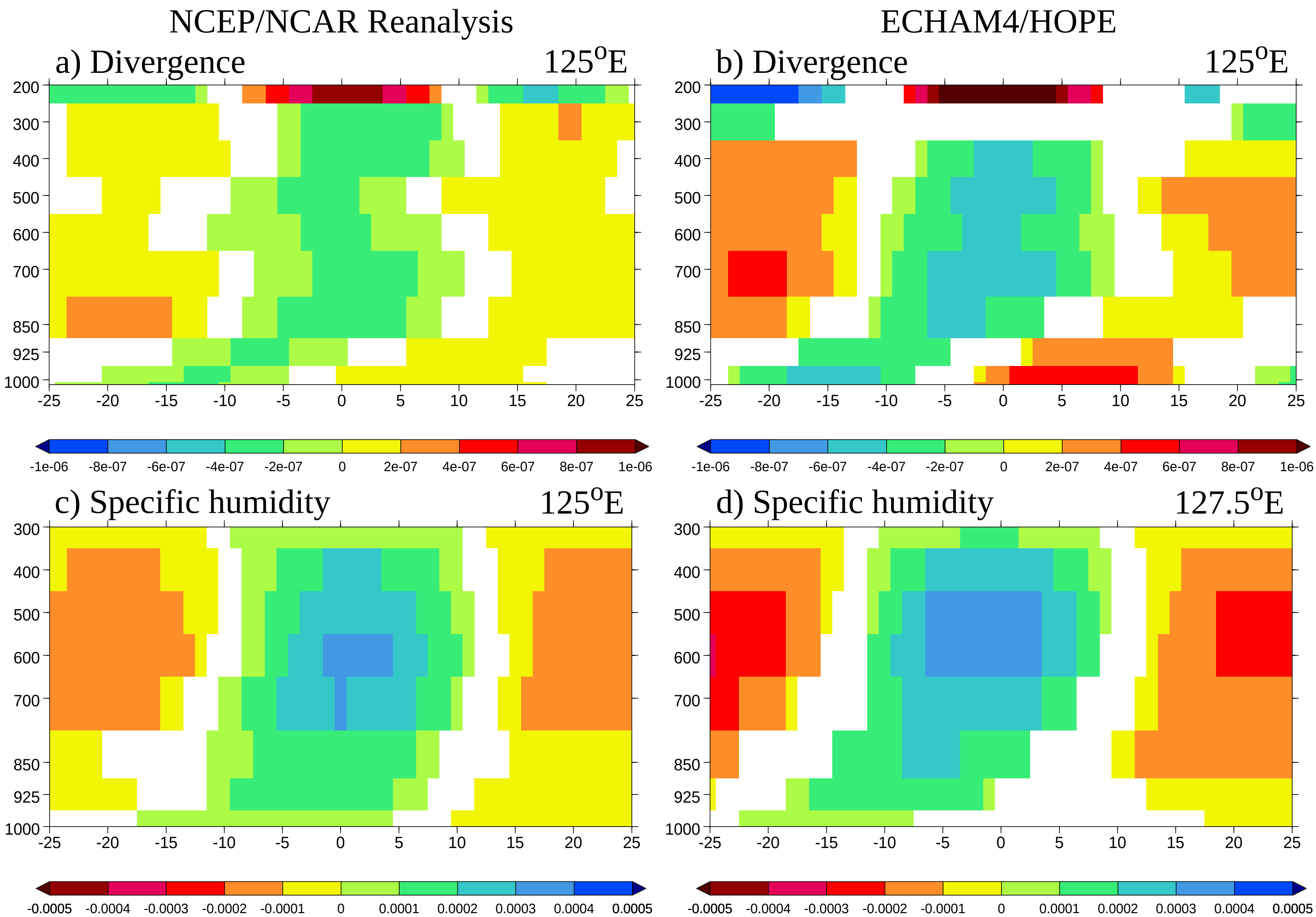


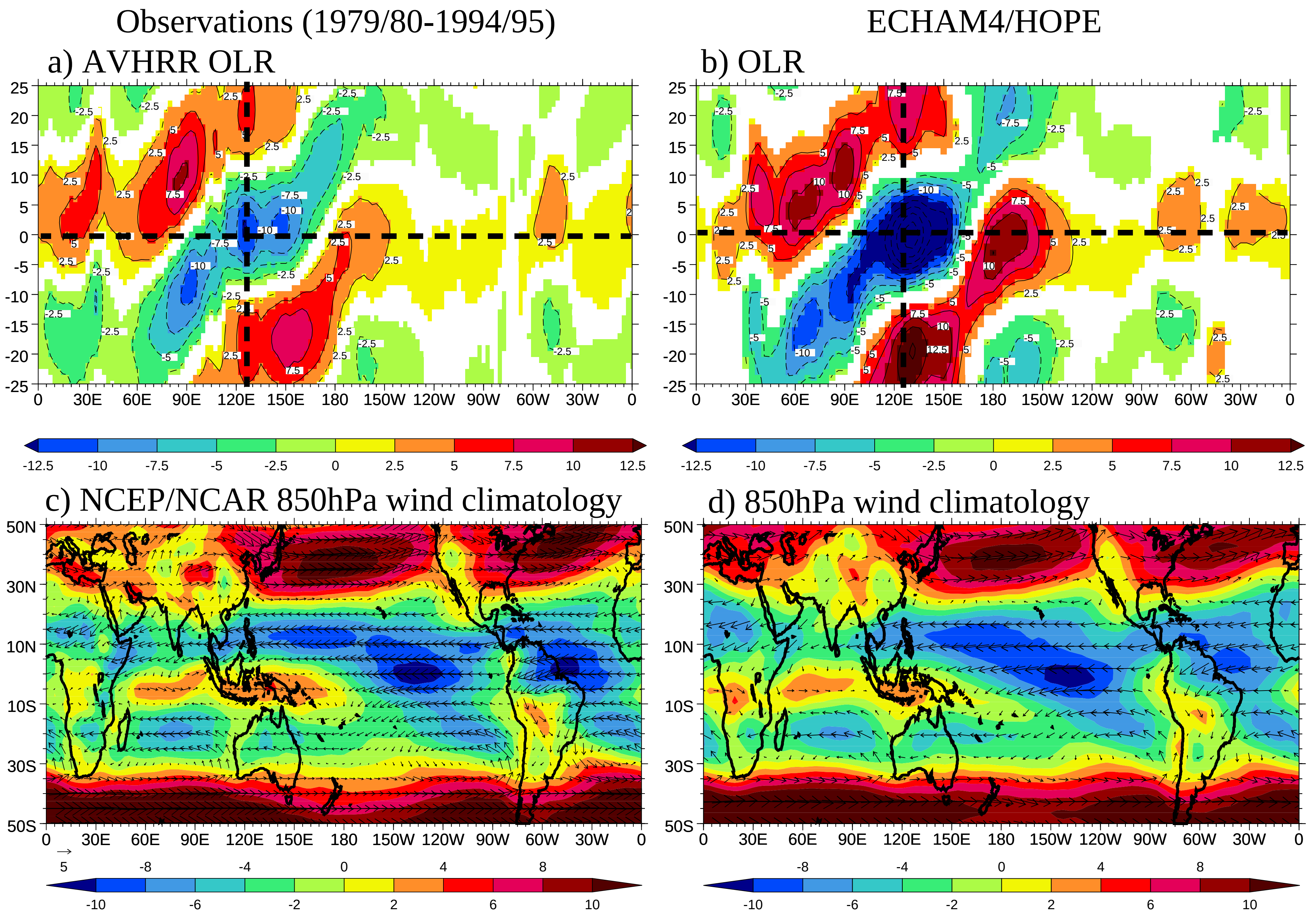
Table 1: Observed, reanalyzed, and AMIP Model MJO-eastward characteristics. Given are the standard deviations of PC-1 and PC-2, the maximum positive correlation, R, the time lag (days) at which it occurred, and the fraction of years for which the PC's had a lead-lag relationship consistent with the observations. Shaded models used the same atmospheric component in their coupled integration (see Table 2).

Model	PC-1	PC-2	R	Lag (days) PC-2 leads PC-1 (positive)	#Years Eastward/ Total
AVHRR	211.3	205.6	0.67	12	16/16
NCEP/NCAR	119.4	103.4	0.60	12	14/16
CCCMA	105.8	102.3	0.41	12	8/16
CCSR	109.7	91.0	0.41	12	10/16
CNRM	161.8	141.1	0.57	14	12/16
COLA	104.0	77.9	0.30	25	7/16
DNM	73.7	70.3	0.42	17	5/16
ECHAM4	221.2	232.2	0.43	12	11/16
ECMWF (T63)	100.7	97.5	0.42	19	4/16
ECMWF (T159)	130.8	84.8	0.58	21	4/16
GFDL	107.1	79.7	0.28	14	6/16
GFDL/DERF	158.4	186.4	0.41	12	13/16
GISS (A170)	36.2	36.2	0.27	20	3/16
GISS (Model II)	58.8	59.2	0.54	22	1/16
HADAM3 (L58)	125.4	99.0	0.42	13	9/16
HADAM2 (AMIP I)	182.6	137.9	0.48	18	6/9
JMA	165.0	159.3	0.35	10	10/16
MRI	185.0	159.6	0.46	9	7/16
NCAR CAM2	93.8	97.2	0.17	25	6/16
NCAR CCM3	83.7	82.8	0.37	16	7/16
NCEP (T42)	111.0	103.1	0.46	11	8/16
NCEP (T62)	102.7	96.1	0.41	21	7/16

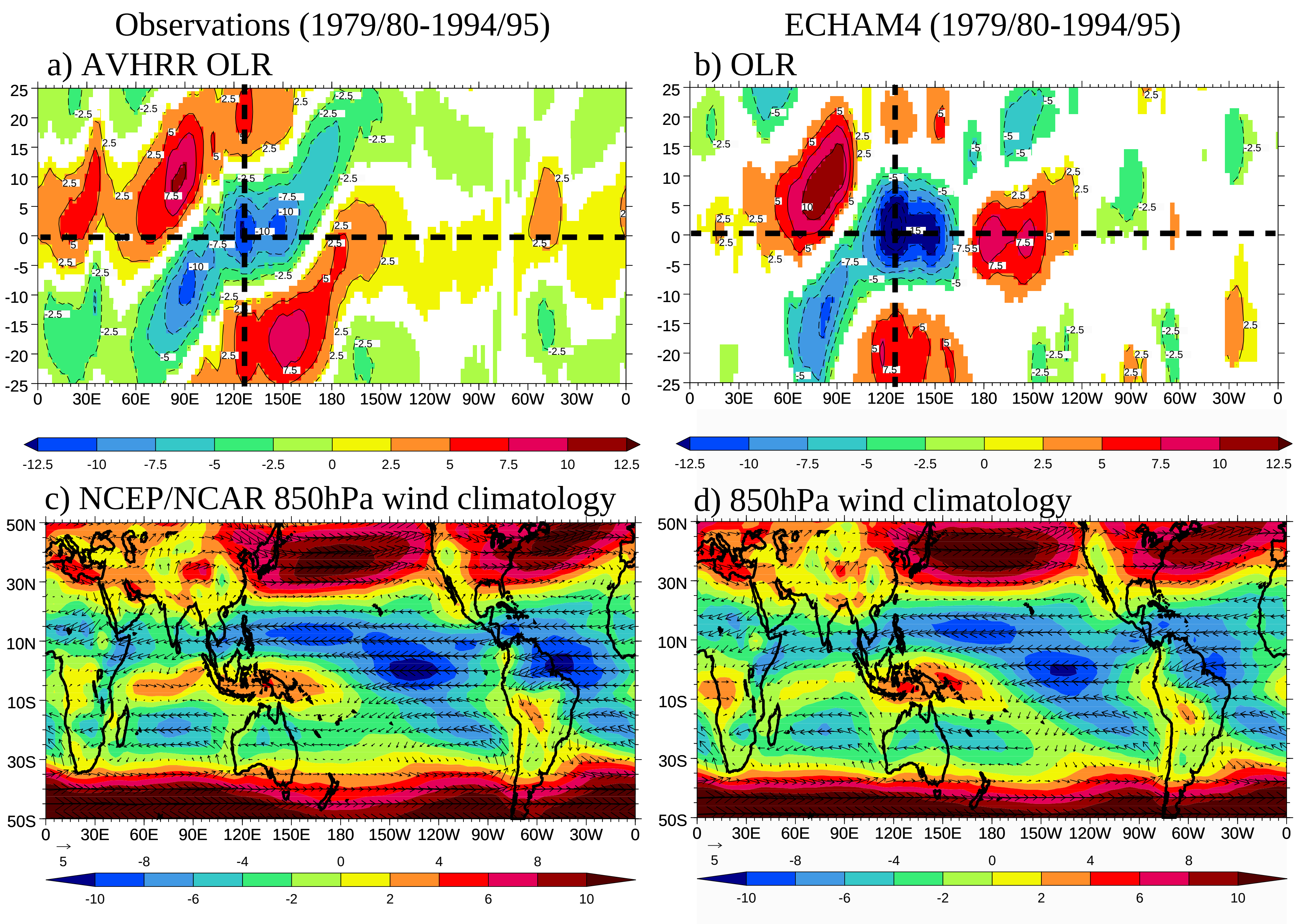
Table 2: Observed, reanalyzed, and coupled model MJO-eastward characteristics. Given are the standard deviations of PC-1 and PC-2, the maximum positive correlation, R, the time lag (days) at which it occurred, and the fraction of years for which the PC's had a lead-lag relationship consistent with the observations. Shaded models used the same atmospheric component in their AMIP integration (see Table 1).

Model	PC-1	PC-2	R	Lag (days) PC-2 leads PC-1 (positive)	#Years Eastward/ Total
AVHRR	211.3	205.6	0.67	12	16/16
NCEP/NCAR	119.4	103.4	0.60	12	14/16
CSIRO	143.6	165.7	0.49	16	13/19
ECHAM4.6/HOPE (ECHO-G)	293.8	267.1	0.68	12	16/19
ECHAM4/OPA8.1 (SINTEX)	240.8	207.6	0.50	12	15/19
ECHAM4/OPYC3	245.8	217.9	0.71	11	19/19
GFDL R30	221.4	198.9	0.48	10	16/19
HADCM3 (L30)	105.5	99.8	0.51	8	14/19
IAP/LASG GOALS	127.4	132.8	0.47	10	7/9
NCAR CCSM2	103.6	119.8	0.40	16	5/9
NCAR PCM	109.4	94.9	0.42	15	10/15

MJO OLR propagation vs. the 850hPa wind climatology (Nov.-Mar.)



MJO OLR propagation vs. the 850hPa wind climatology (Nov.-Mar.)



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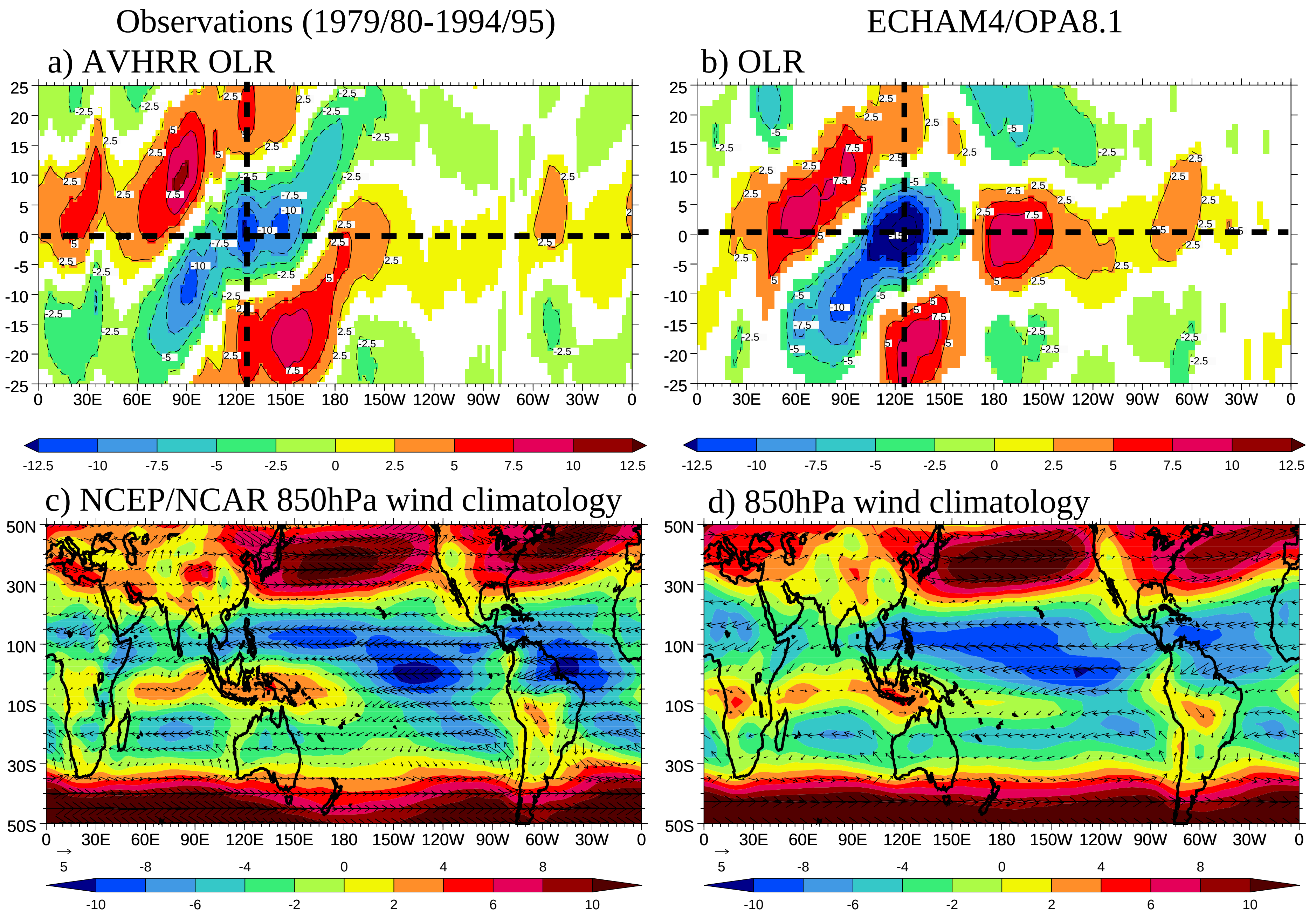

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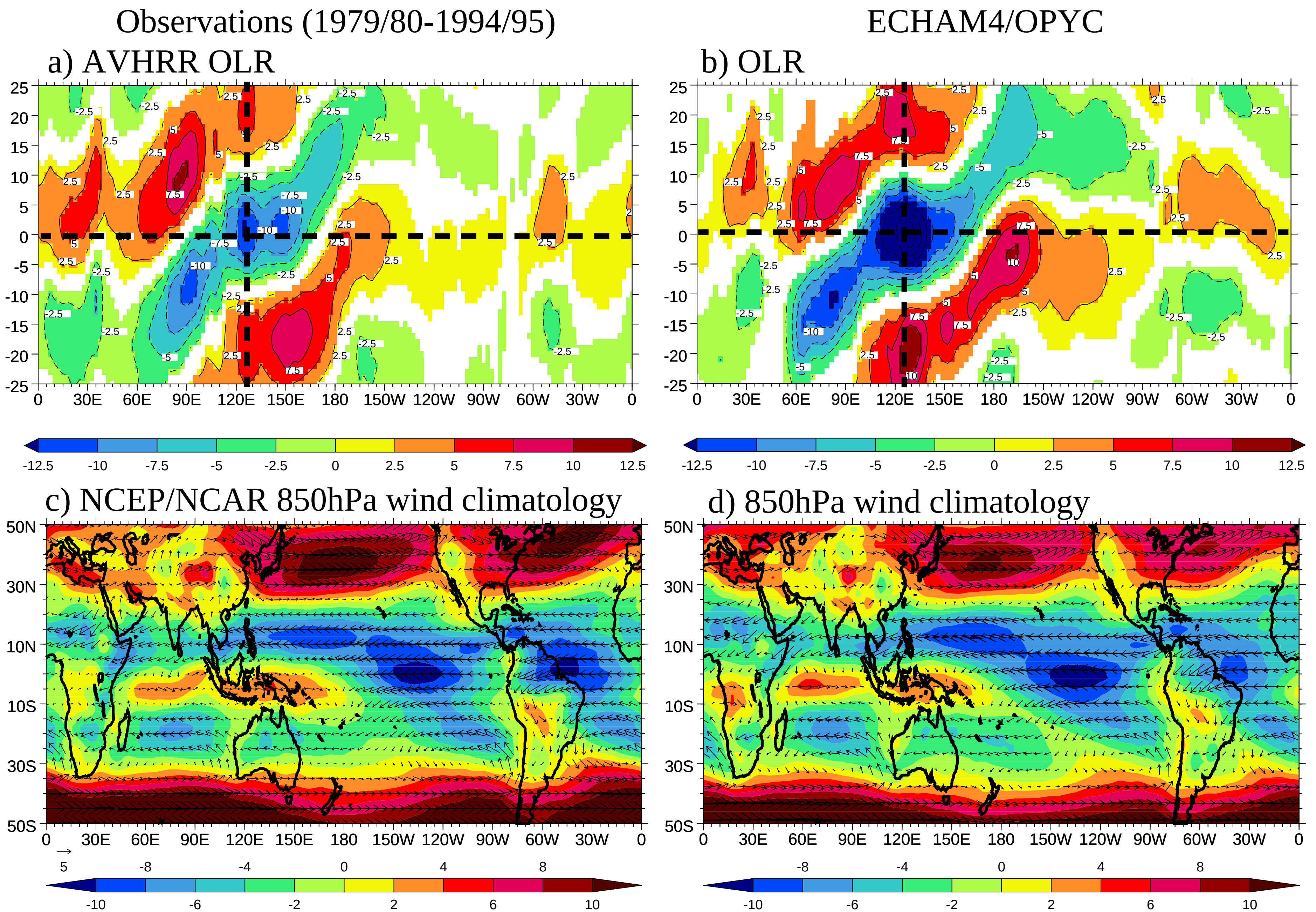

Results

1) The MJO is a very stringent test of a models ability to simulate tropical variability

2) The models still fail to represent the intraseasonal dominance of the large-scale circulation

3) Within a family of models, ocean-atmosphere coupling leads to an improved lead/lag structure of the MJO

4) The ECHAM family of models produces a realistic representation of the MJO, though some problems exist (e.g., latent heat flux relation to MJO convection, details of the vertical structure)

Results (con't)

5) The propagation of convection into the western/central Pacific tends to be limited by systematic error of the lower-tropospheric zonal wind (e.g., eastward propagation impeded in presence of easterly winds)

6) For the other models a more comprehensive diagnosis of the MJO mechanism will require daily data:

   latent heat flux

   winds (standard pressure levels)

   vertical velocity (standard pressure levels)

   specific humidity (standard pressure levels)

   diabatic heating profiles (pressure or model levels?)