Analysis of Convectively Coupled Equatorial Kelvin Waves in a GCM with a Modified Entrainment Profile

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Introduction

Convectively coupled Kelvin waves are major weather producers in the tropics, however, they are not well represented in current global climate models (GCMs). In order to improve Kelvin wave simulations, modifications can be made in the way the convection is treated in GCMs. A key feature of convection parameterization is the process of entrainment. Entrainment is the integration of dry, non-turbulent flow into a turbulent (and moist) cloud. Entrainment can limit cloud growth. In this study, the consequences of enhancing the entrainment rate in the lower troposphere of a GCM are investigated. We examine the impact from changes to the entrainment profile on simulated Kelvin waves. Entrainment was enhanced only at low levels in a version of the Relaxed Arakawa-Schubert scheme by Moorthi and Suarez (1997).

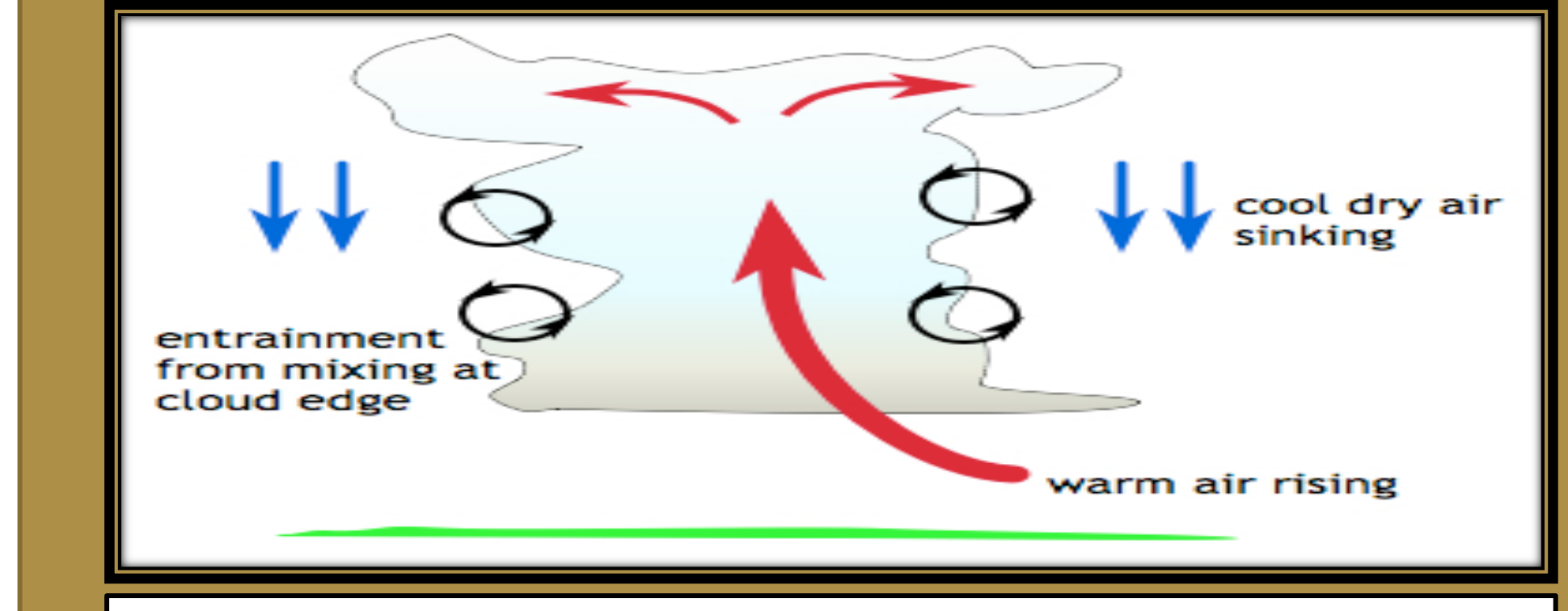

Fig. 1 Integration of dry, non-turbulent flow into a turbulent, preexisting cloud. The larger the entrainment, the less potent and shallower the cloud will be. Picture provided from http://www.cmmap.org/images/learn/clouds/entrainment.jpg

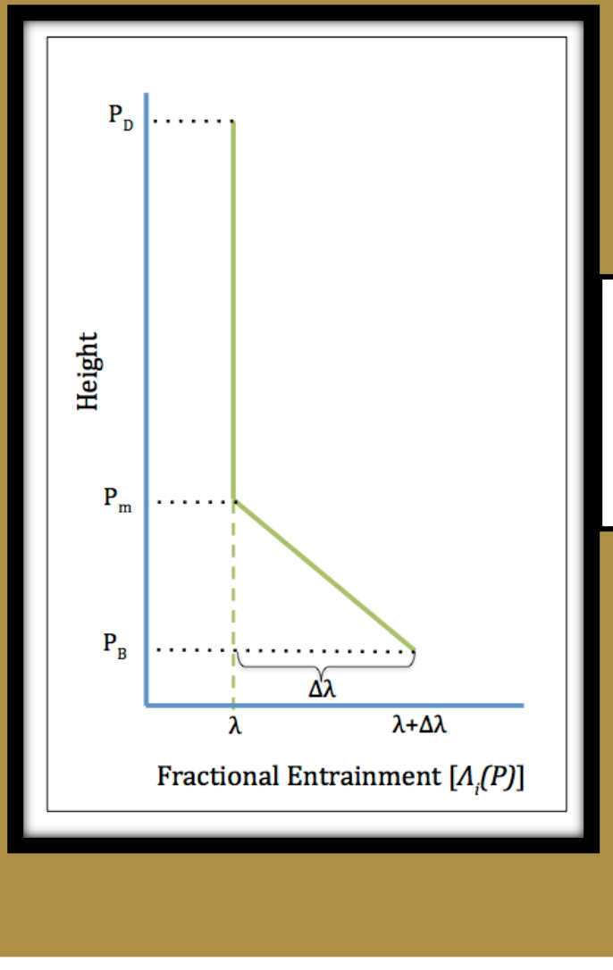

Fig. 2 Schematic of entrainment profile modification. Parameters Pm and Δλ are specified.

Methods

	Model Setup	
	Control	Experiment
Δλ (Entrainment enhancement)	0.0 km^{-1}	0.0008 km^{-1}
Pm	N/A	700 hpa

1. Analyzed daily NCEP2 reanalysis from 1980-2011
2. Space-time spectral analysis (i.e. Wheeler and Kiladis 1999)
3. Backwards FFT used to filter for Kelvin wave signal
4. Lagged linear regression used to produce composite

Variable	Measure of Convection	Temperature	Heights	U&V Winds	Specific Humidity	Omega	Heating
Observation	NOAA interpolated OLR 1980-2011 [W/m^2]	NCEP2 1980-2011 [K]	NCEP2 1980-2011 [mb]	NCEP2 1980-2011 [m/s]	NCEP2 Qv 1980-2011 [kg/kg]	NCEP2 1980-2011 [Pa/s]	N/A
Model Runs: Control/ Experimanet	Total Precip: Large scale, shallow and deep [mm/day]	Daily Temperature [K]	Daily [mb]	Daily [m/s]	Daily Qv [kg/kg]	Daily [Pa/s]	Daily K/day

Results

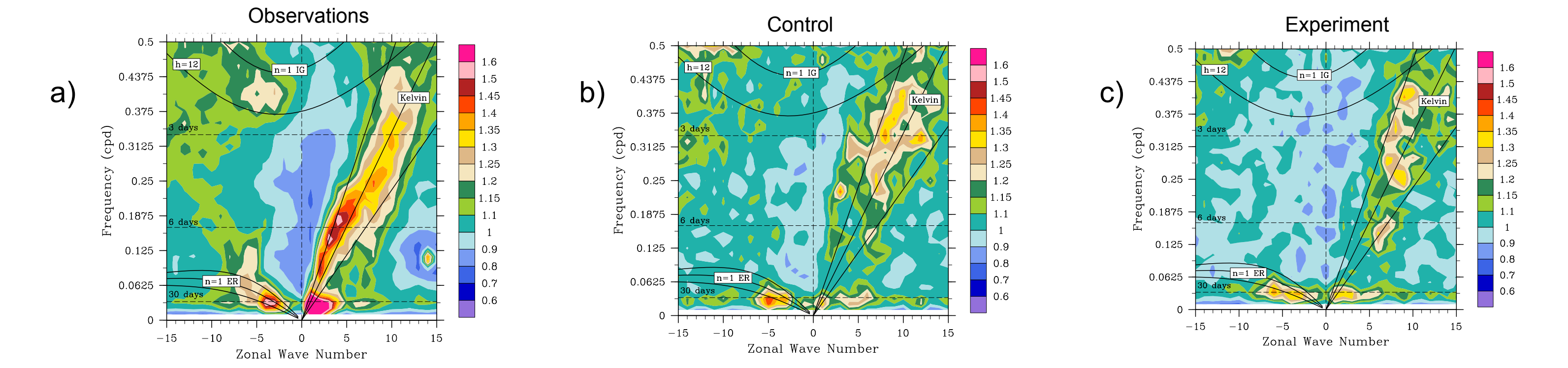

Fig. 3 Symmetric power divided by background power for OLR (a) followed by simulated precipitation from the control (b) and experiment (c) . Overlaid are theoretical dispersion curves for different equivalent depths 12.5 m, 25 m, 50 m, respectively. Note that (c) shows much slower propagation speeds similar to that of the observations.

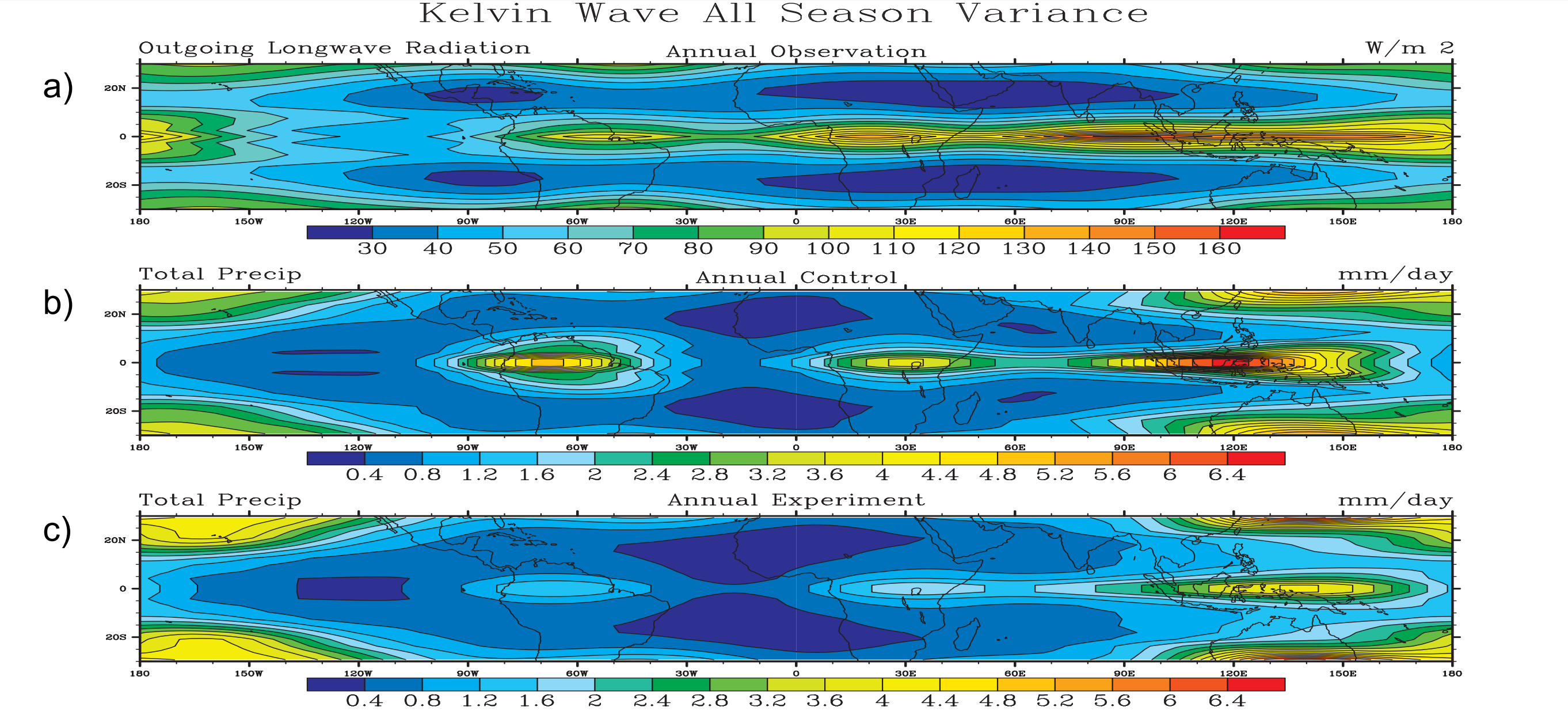

Fig. 4 Kelvin wave filtered variance for observed OLR(a), followed by simulated precipitation from the control (b) and experiment(c). In (a), maximum variance near 90E is observed. Both control and experiment (b&c) indicate maximum variance near 120E.

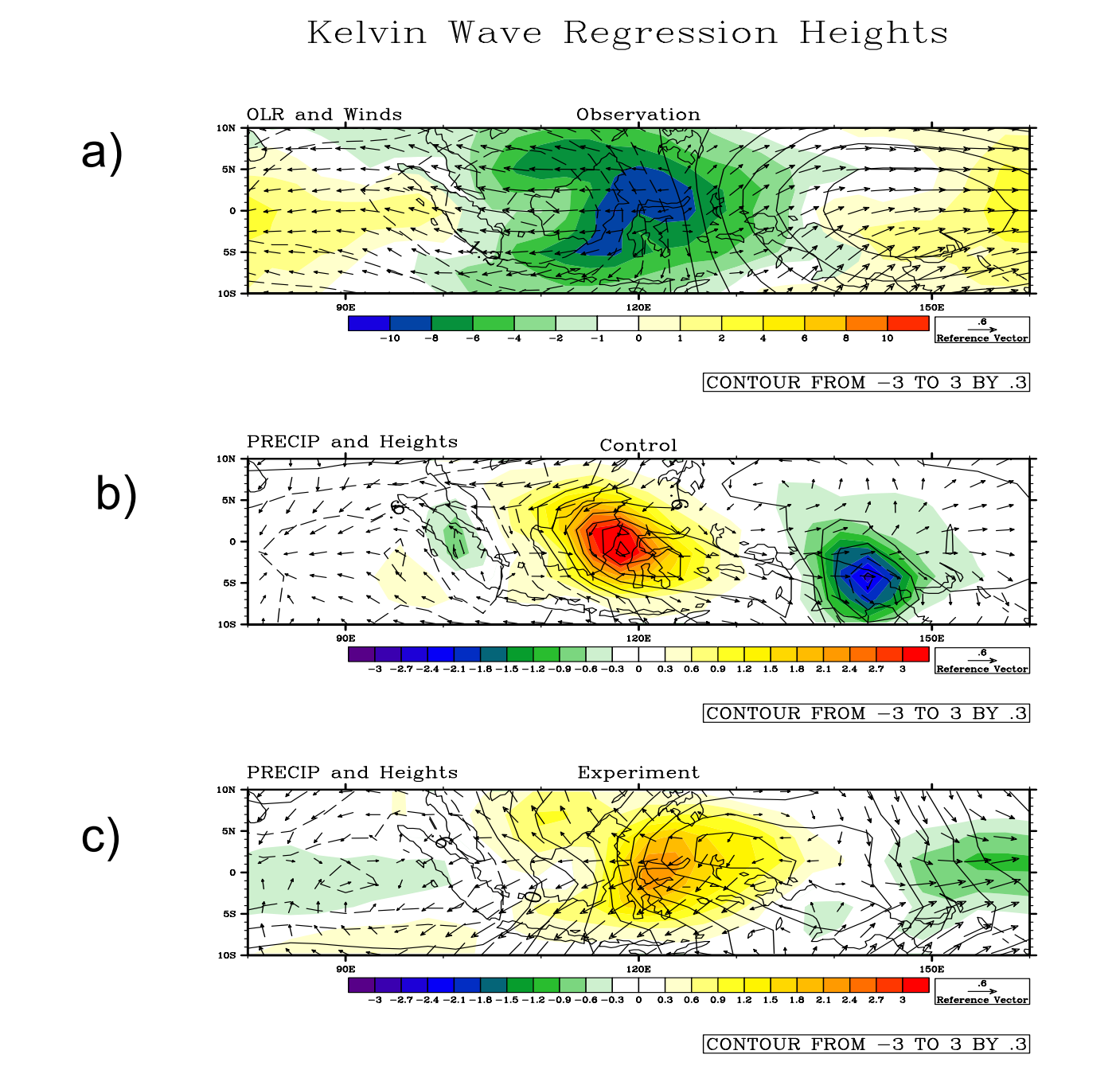

Fig. 5 Regressed OLR (a) and simulated precipitation from control (b) and experiment (c) runs with contours of 200-mb heights contour and 850hpa vector winds overlaid. Contour dashing indicates decreasing heights. Note OLR units are W/m^2 while simulated precipitation is in mm/day.

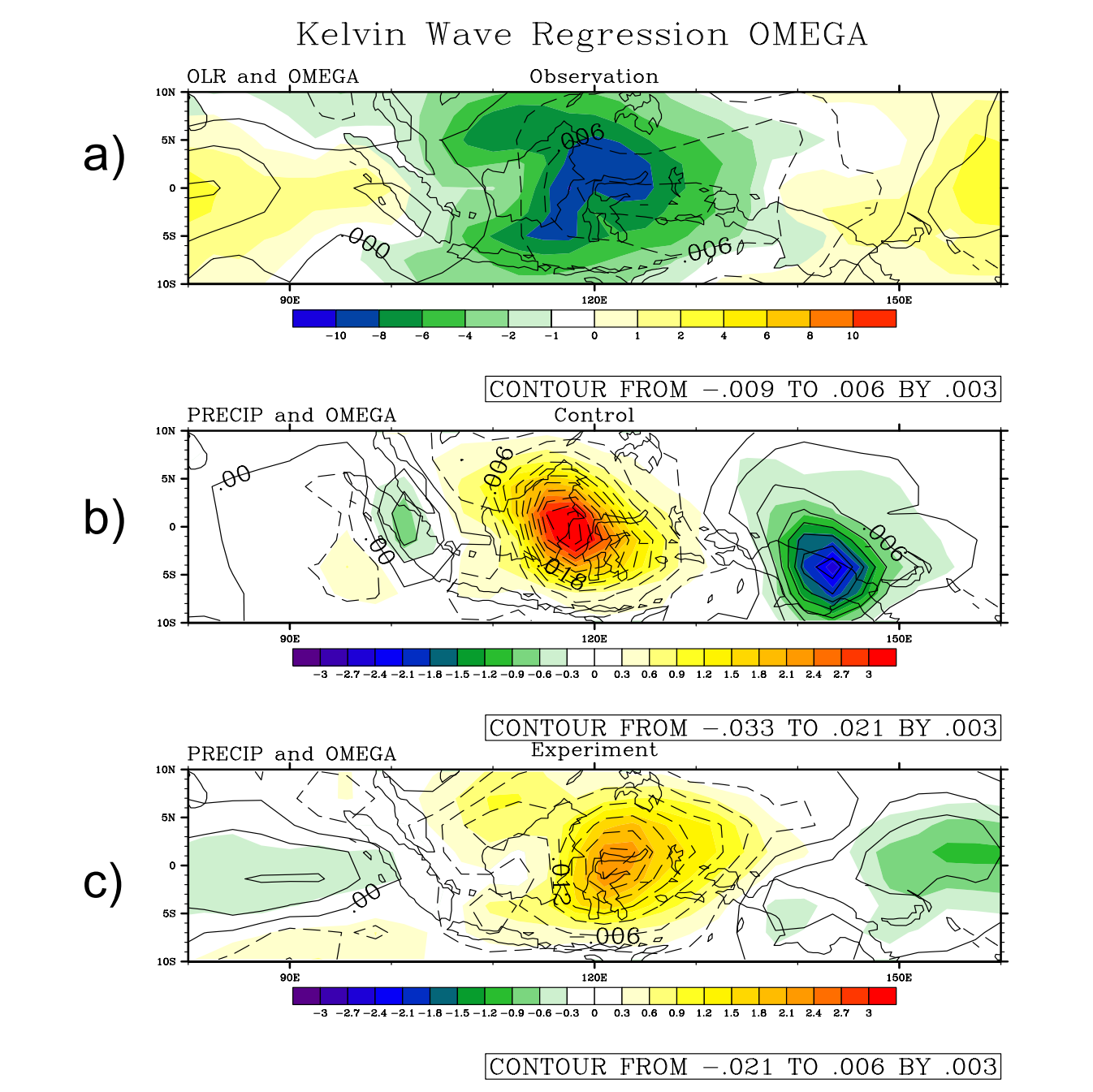

Fig. 6 Regressed OLR (a) and simulated precipitation from control (b) and experiment (c) runs overlaid with omega contours. Contour dashing indicates negative omega values (rising vertical motion). Note unit of omega is Pa/s.

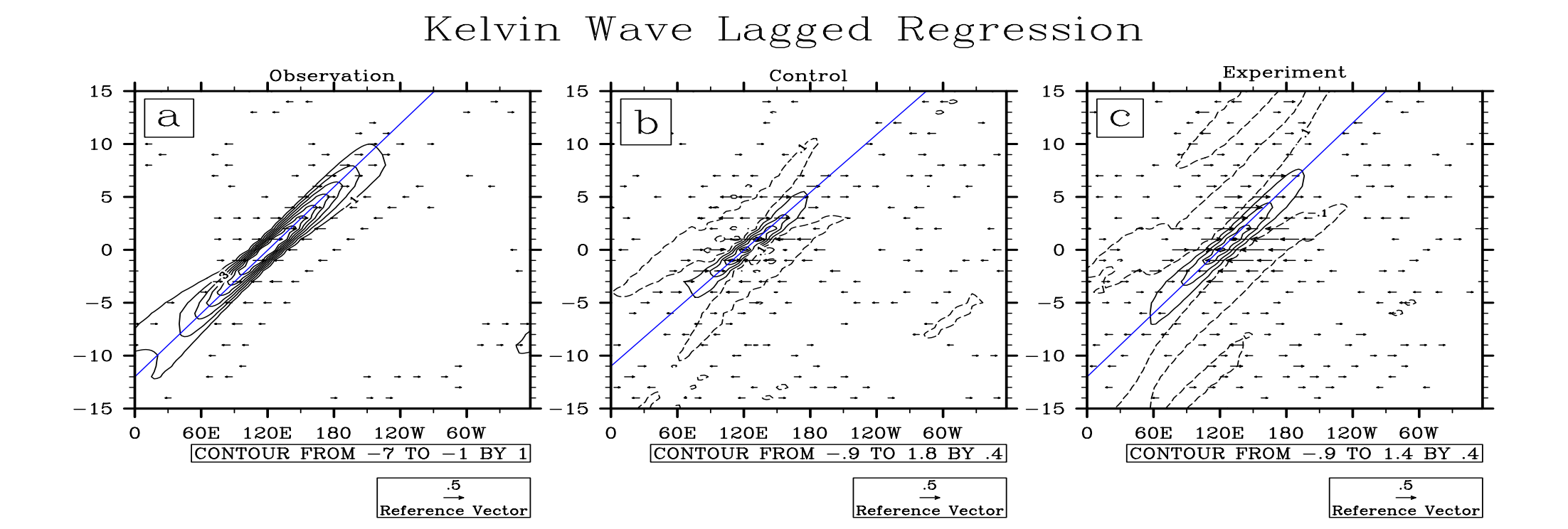

Fig. 7 Longitude versus lag time plot of OLR (a) and simulated precipitation from control (b) and experiment (c) averaged from 5 °S to 5 °N (contours), and zonal 850hpa winds (vectors). Eastward propagation is observed. OLR/precipitation and zonal wind patterns represent the behavior of such variables relative to fluctuations in a convection intensity time series centered on (0°N, 120°E; the region of maximum Kelvin wave variance). Sloped line signifies wave propagation speed.

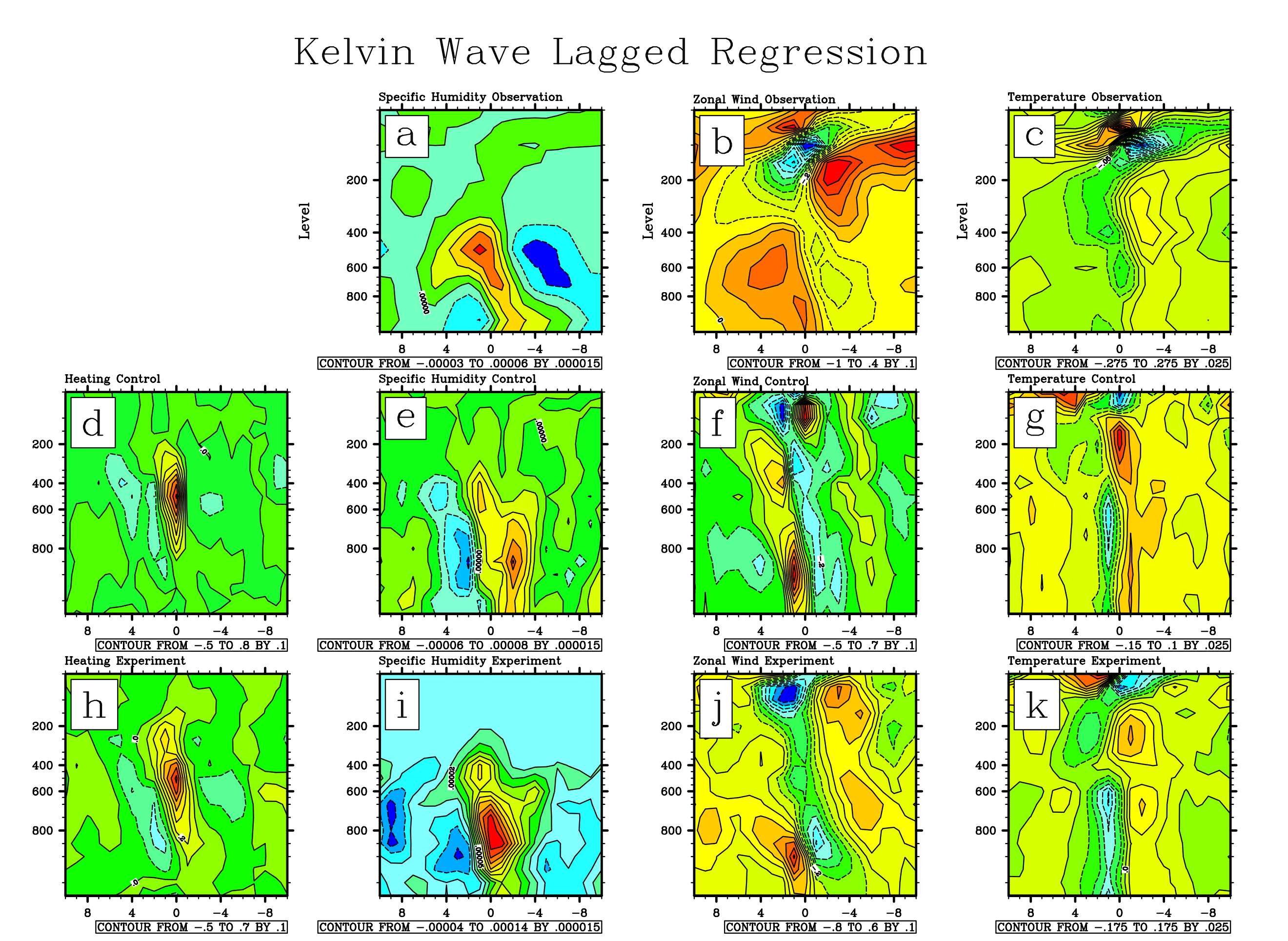

Fig. 8 Vertical lagged regression analysis for NCEP2 reanalysis (a-c; "observations"), control simulation (d-g) and experiment (h-k). Note that negative lag days appear to right of each plot to mimic a west-to-east cross section for eastward-moving Kelvin waves.

Conclusion

1. The modified entrainment relationship results in slower (more realistic) Kelvin waves. This is indicated by a decrease in spectral power at large equivalent depths.
2. A westward shift of Kelvin wave variance is observed for both the control and the modified scheme.
3. Propagation becomes more coherent as low level entrainment is increased (Fig. 7c).
4. The modified scheme in Fig. 8 (h-j) shows improved vertical structure with a noticeable westward tilt with height.
5. Overall, results reveal improved Kelvin wave signal in the model representation. However, the reasons for these improvements require further investigation.

References

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