The Interactions between Mesoscale Convective Systems and an African Easterly Wave

James Russell[1] and Anantha Aiyyer[1]
[1]**MEAS, North Carolina State University**

1. Background & Research Questions

Laing et al. (2008) showed that convection typically moves at different speeds to the AEW and convection is found in all AEW phases, but is more prominent in the northerlies.

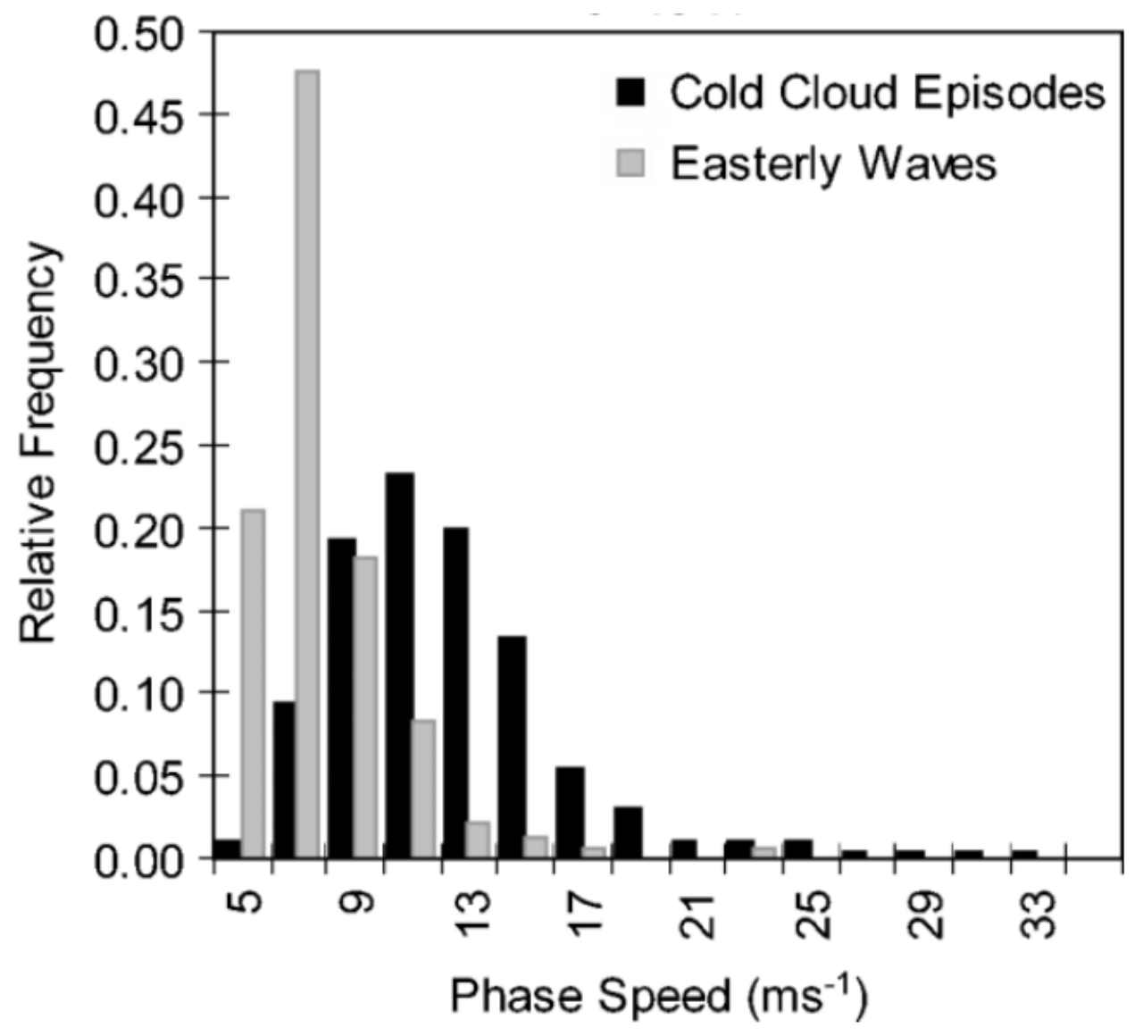
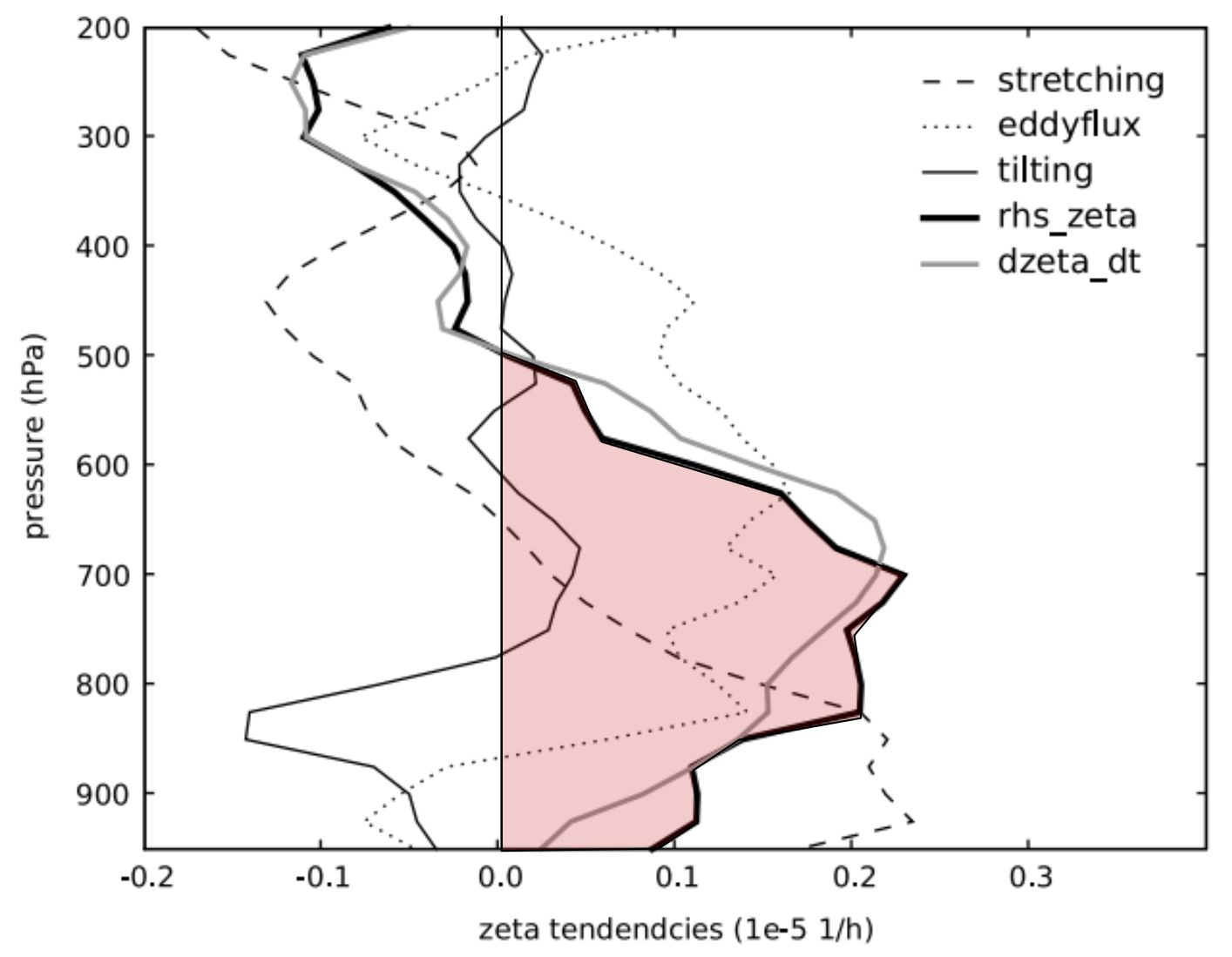


Figure 1: Histograms of zonal phase speed (m/s) for cold cloud episodes (black) and AEWs (grey) averaged between 5-15°N for May–August, 2000–2003 (Laing et al. 2008).



Schwendike and Jones (2010) analyzed two convective systems in an AEW. The convective systems generated vorticity in the low- and mid-levels of the environment.

Figure 2: Vorticity tendencies in the environment produced by a West African MCS (Schwendike and Jones et al. 2008).

Research Questions

1. What is the difference between MCS and AEW propagation speeds? In what phase of the AEW are MCSs more frequent?
2. How does the AEW initiate and enhance MCSs?
3. How do MCSs modify the AEW? Are there asymmetries between the effects on the trough and the ridge?

2. Methods

WRF Case Study

AEW simulation (2017)

- 3^{rd} Aug – 12^{th} Aug
- Initialized with 0.25° GFS at Forecast hour 0
- 4km resolution with no convection scheme

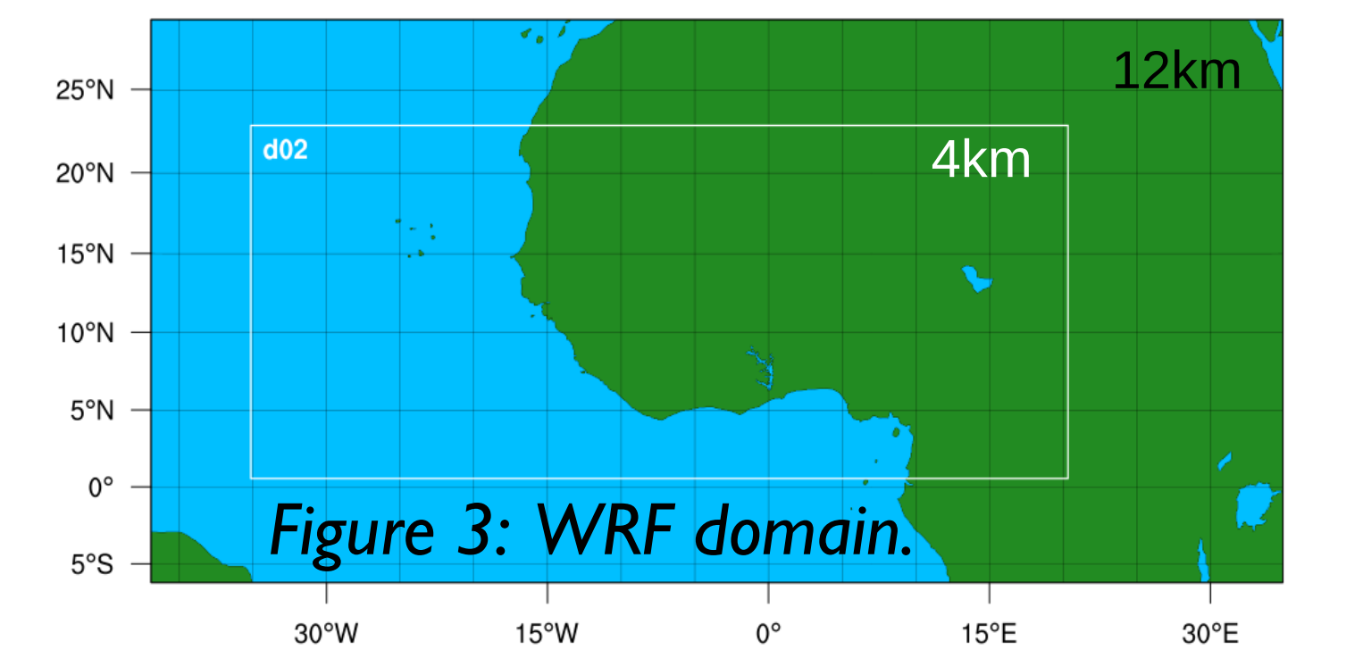


Figure 3: WRF domain.

AEW and MCS tracking

- AEW is manually tracked by following the smoothed maximum in vorticity and minima in meridional wind at 650hPa (AEW peak)
- MCSs are manually tracked in the wave relative framework by following the simulated radar reflectivity

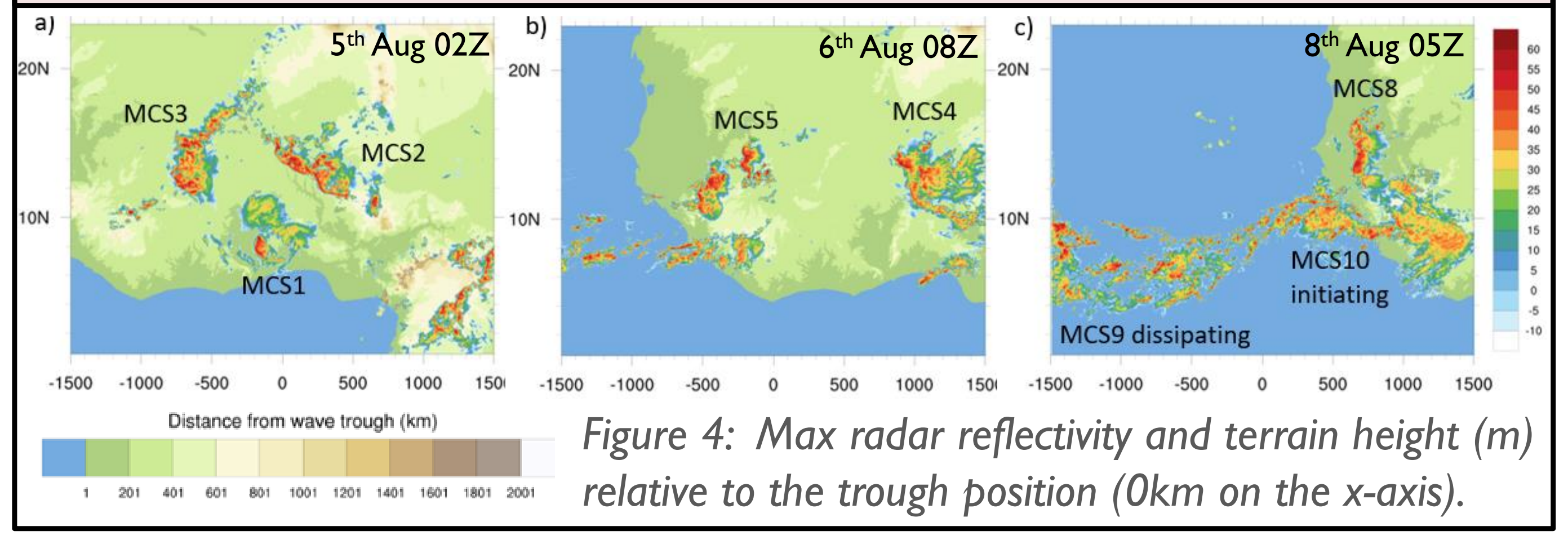


Figure 4: Max radar reflectivity and terrain height (m) relative to the trough position (0km on the x-axis).

3. MCSs relative to the AEW

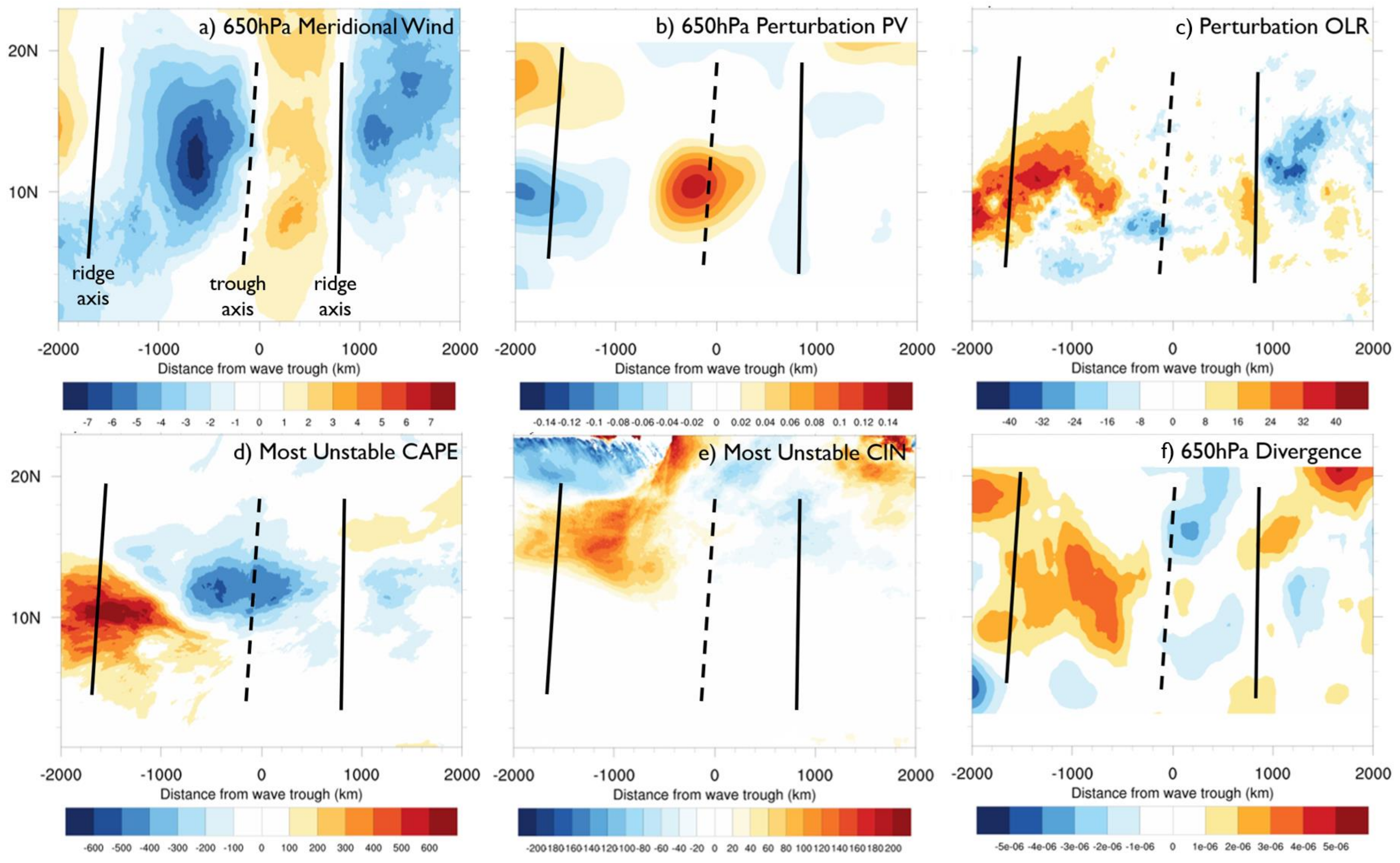
- MCSs move at a variety of speeds relative to the AEW.
- MCSs originate and propagate through all phases of the AEW.
- More, longer-lived MCSs in the northerlies and trough.
- MCSs impact the AEW in all phases.

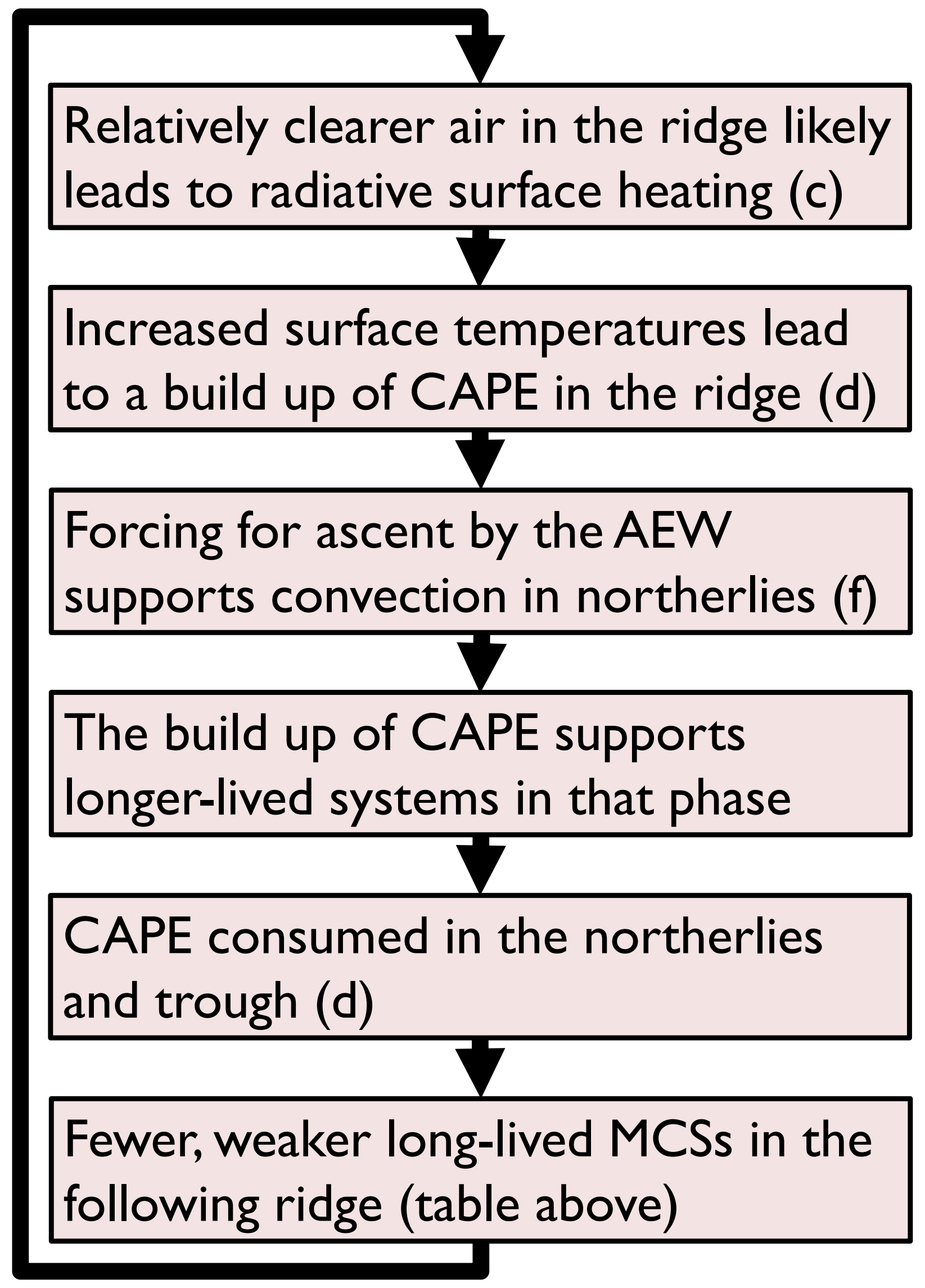
Table 1: Summary of MCSs relative to the AEW. L=Land. O=Ocean. T=Trough. R=Ridge. S=Southerlies. N=Northerlies.

MCS	Date & Time	(UTC)	Duration (hrs)	AEW Phase	Surface Type	Speed	
	Start	End				Actual	AEW-rel.
1	4th 12:00	5th 18:40	30	T	L	9.5	0.0
2	4th 12:40	6th 06:20	42	S to N	L	15.5	4.7
3	4th 15:20	6th 06:20	39	N	L to O	13.5	2.1
4	5th 11:20	6th 21:20	34	R to S	L	10.2	0.0
5	5th 23:20	6th 19:40	20	N	L to O	9.6	-4.2
6	6th 13:00	6th 22:20	9	S	L	9.9	-6.2
7	6th 21:20	7th 10:40	13	S	L	14.6	2.1
8	7th 19:00	8th 13:20	18	R to S	L	13.3	7.7
9	6th 14:40	8th 01:40	35	N	O	12.2	0.8
10	8th 01:40	9th 14:20	37	S	O	8.3	-0.8

4. Modulation of Convection by the AEW

Figure 5: Wave relative average a) V-wind, b) PV', c) divergence, d) CAPE, e) CIN, and f) OLR'.





Relatively clearer air in the ridge likely leads to radiative surface heating (c)

Increased surface temperatures lead to a build up of CAPE in the ridge (d)

Forcing for ascent by the AEW supports convection in northerlies (f)

The build up of CAPE supports longer-lived systems in that phase

CAPE consumed in the northerlies and trough (d)

Fewer, weaker long-lived MCSs in the following ridge (table above)

5. Modulation of the AEW by MCSs

A PV budget: $\frac{Dq}{Dt} = -g(\vec{\zeta}_a \cdot \vec{\nabla}\dot{\theta}) - g\vec{\nabla}\theta \cdot (\vec{\nabla} \times \vec{F})$, is used to assess the role of the MCSs on the AEW. The diabatic term is compared to the PV, $q = -g(\vec{\zeta}_a \cdot \vec{\nabla}\theta)$ to generate four categories of amplification or decay of the positive or negative PV.

Due to diabatic processes associated with the MCSs, there is:

a) Amplification of the positive PV in and ahead of the trough.
b) Decay of negative PV in and around the ridge

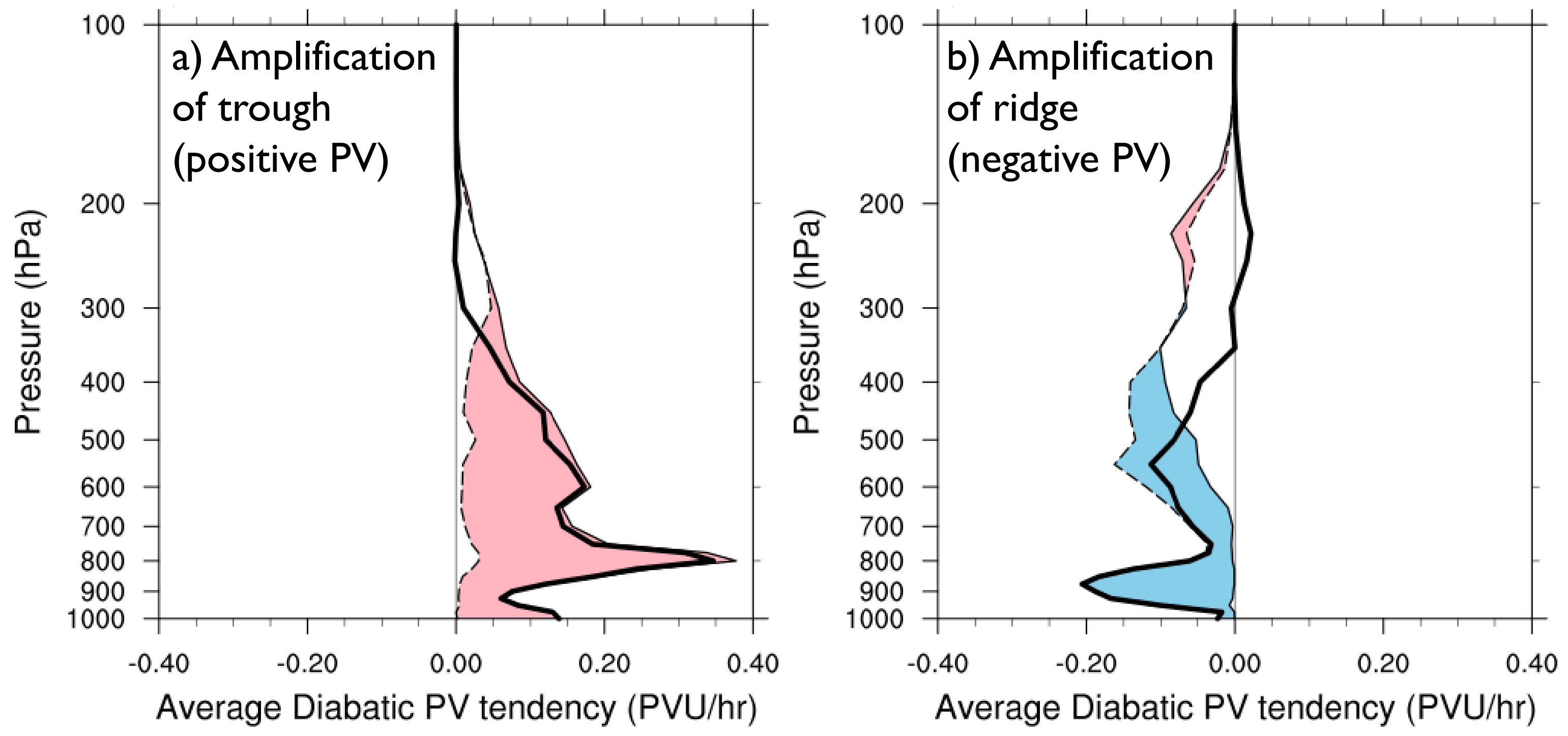


Figure 8: Average vertical profiles of amplification (solid black lines) and decay (dashed black lines) of a) positive and b) negative perturbation PV by diabatic processes associated with the 10 MCSs. Red shading indicates where amplification is larger than decay and blue shading indicates where decay is larger than amplification. Thick black lines indicate the actual value of the difference between amplification and decay in each case.

6. Summary and Conclusions

Summary

- MCSs exist in all phases of the AEW.
- Synoptic scale forcing for ascent in the northerlies and enhanced CAPE in the ridge lead to longer-lived MCSs in the trough and northerlies.
- Consumption of CAPE and passing of the forcing for ascent begins the cycle again.
- MCSs asymmetrically enhance the PV in the trough and decay the PV in the ridge.

Conclusions

The generation and consumption of CAPE combine with forcing for ascent in AEWs to produce a cycle of convective enhancement and suppression that couples the AEW and convection. Further, the asymmetries in diabatically generated PV support growth of the trough but decay of the ridge. Thus, due to the prevalence of MCSs in all phases of the AEW, MCSs push the AEW toward a more vortex-like system than a wave. This could have implication for tropical cyclogenesis from AEWs.

Future Work/Research Questions

- Why does CAPE preferentially build up in the ridge?
- How does CAPE combine with shear in the AEW to support convection?
- Why does convection still exist in all phases of the AEW?
- What is supporting the AEWs wave-like structure if diabatic processes are not?

7. Acknowledgements & References

This research was sponsored by NSF through award #1433763.

References

1. Laing, A. G., R. Carbone, V. Levizzani, and J. Tuttle, 2008: The propagation and diurnal cycles of deep convection in northern tropical africa. Quart. J. Roy. Meteor. Soc., 134 (630), 93–110.
2. Schwendike, J., and S. C. Jones, 2010: Convection in an African Easterly Wave over West Africa and the eastern Atlantic: A model case study of Helene (2006). Quart. J. Roy. Meteor. Soc., 136, 364–396