The Role of Convection in African Easterly Wave Dynamics: A Potential Vorticity Perspective

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1. Background & Research Questions

What propagates and grows AEWs?

Burpee (1972) showed that the AEJ meets the Charney-Stern criterion for a barotropicly and baroclinicly unstable jet. However, Hall et al. (2006) showed that dry dynamics alone cannot explain the observed AEWs. What is the role of convection? How large is it's role relative to adiabatic processes?

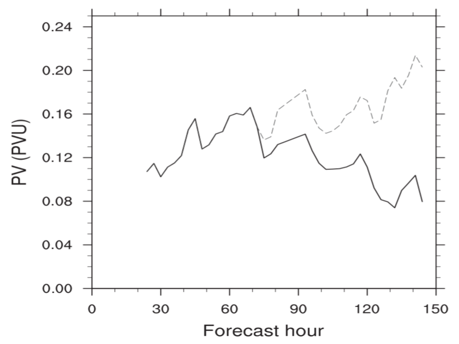


Figure 1: PV in a moist (dashed) and dry (solid) AEW from Berry and Thorncroft (2012).

Potential Vorticity (PV) has been used to describe AEWs before and it has been shown that diabatic processes are important. However this has not yet been put in context, relative to adiabatic sources of PV in AEWs.

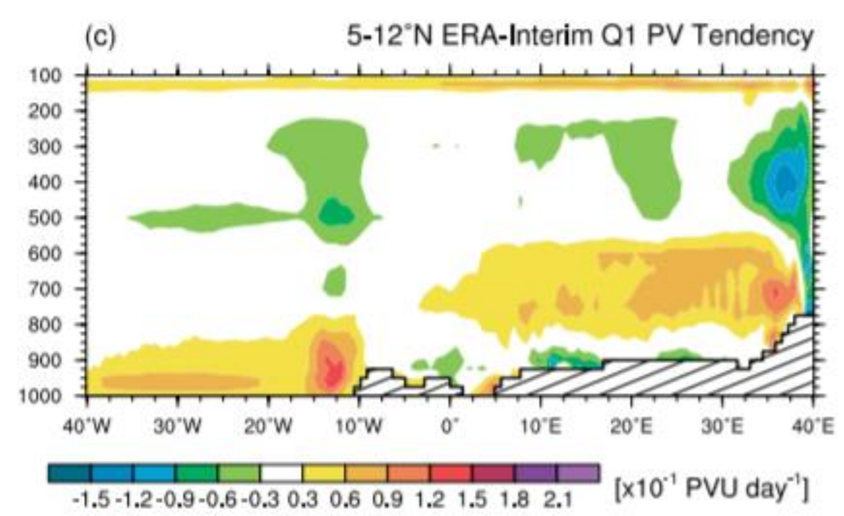


Figure 2: Diabatic PV tendency in various reanalyses from Janiga and Thorncroft (2013).

Theories

1. AEWs can be described as diabatic Rossby waves (DRWs) which are entirely driven by diabatic PV processes.
2. AEWs are partly driven by diabatic and adiabatic PV processes.
3. Convection plays only a minimal role in the dynamics of an average AEWs.

2. Methods

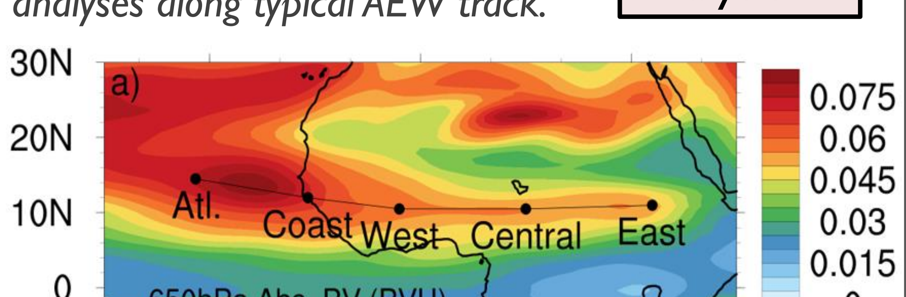
ERA-Interim Reanalysis[3]

Filter PV for AEWs:
- 2-10 day
- ~1000-4000km
- Westward propagating

$$\frac{\partial P_w}{\partial t} = -\vec{U}_w \cdot \vec{\nabla}\bar{P} - \bar{\vec{U}} \cdot \vec{\nabla}P_w - \vec{U}_w \cdot \vec{\nabla}P_w - \vec{U}_r \cdot \vec{\nabla}P_w - \vec{U}_w \cdot \vec{\nabla}P_r - \vec{U}_r \cdot \vec{\nabla}P_r - g(f+\bar{\zeta}) \cdot \vec{\nabla}Q_w - g\zeta_w \cdot \vec{\nabla}\bar{Q} - g\zeta_w \cdot \vec{\nabla}Q_w - g\zeta_r \cdot \vec{\nabla}Q_w - g\zeta_w \cdot \vec{\nabla}Q_r - g\zeta_r \cdot \vec{\nabla}Q_r + F$$

Composite Analysis

Figure 3: Time-averaged absolute PV and EKE with locations of composite analyses along typical AEW track.



WRF Case Study

AEW that lead to Hurricane Earl (2010): 19th Aug 2010 – 25th Aug 2010

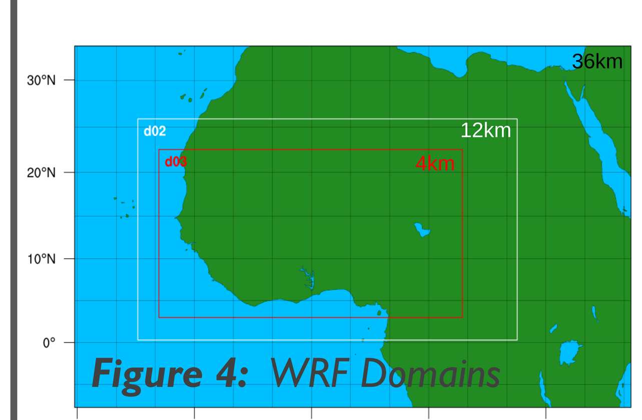


Figure 4: WRF Domains

Simulation	Description
Control	Cu: Tiedtke BL: Shin-Hong Mp: WDM6
90 RH	Control initialized with 90% of initial relative humidity (RH)
70RH	Control initialized with 50% of initial RH
50RH	Control initialized with 50% of initial RH

3. ERA-Interim Composite AEW

Propagation

$-\vec{V} \cdot \vec{\nabla}_p P_w$ is dominant but can only contribute to maintenance and propagation as it does not introduce any new PV. This can be used to develop a "quasi-Lagrangian" framework:

$$\left.\frac{\partial P_w}{\partial t}\right|_L \approx \frac{\partial P_w}{\partial t} + \vec{V} \cdot \vec{\nabla}_p P_w$$

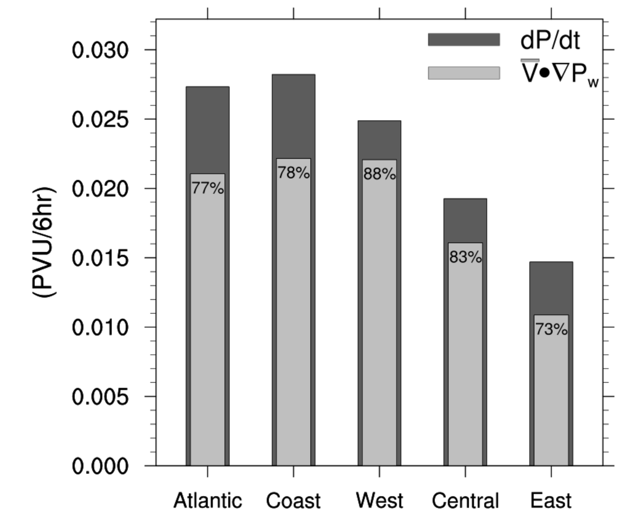


Figure 5: a) Average AEW PV tendency and $-\vec{V} \cdot \vec{\nabla}_p P_w$ in region of strongest PV tendency. Proportion of PV tendency accounted for by $-\vec{V} \cdot \vec{\nabla}_p P_w$ is shown as percentage.

"QL" PV Tendency

Two regimes are evident in the remaining PV tendency. Over West Africa linear dynamics are prevalent with diabatic terms dominating low-levels and advective (adiabatic) terms dominating upper-levels. Over East Africa, linear diabatic processes are large but residual processes play more of a role too.

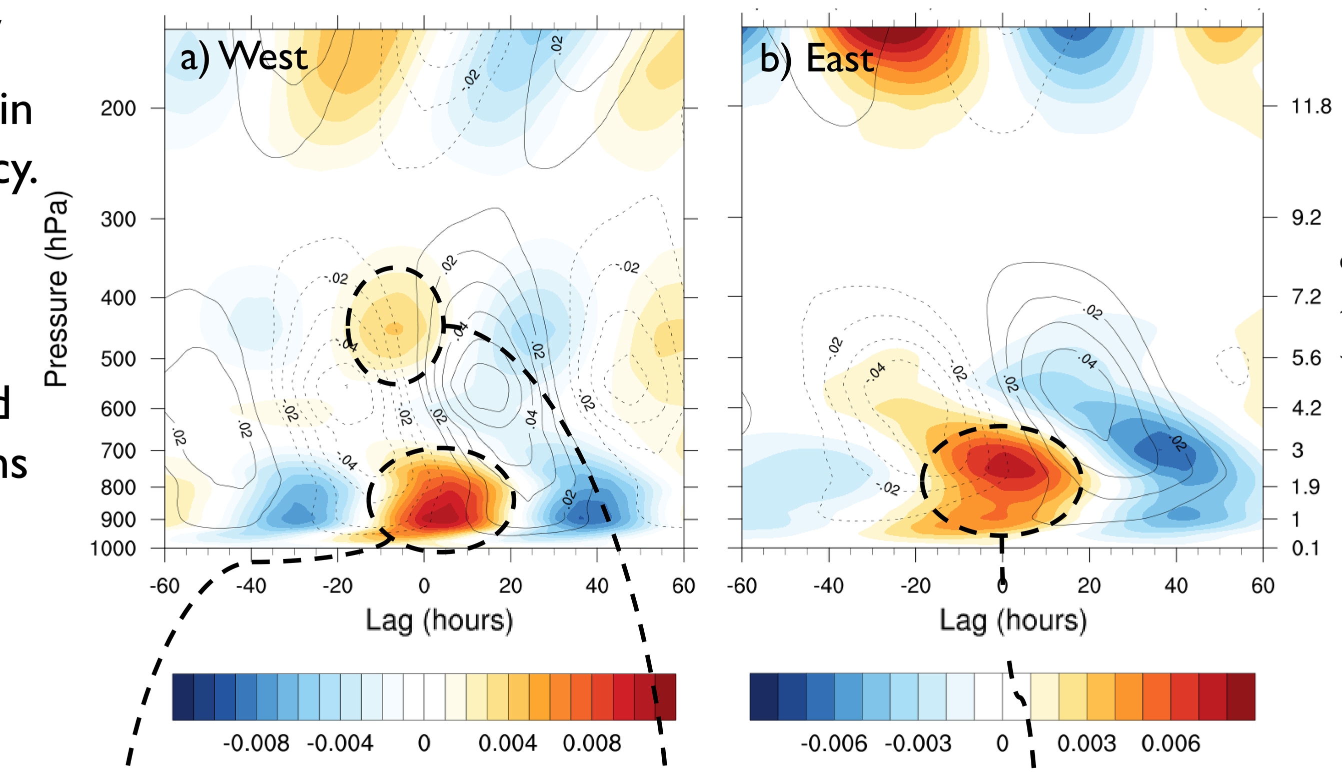


Figure 6: PV (contoured, PVU) and $\left.\frac{\partial P_w}{\partial t}\right|_L$ (filled, PVU/6 hours) averaged between 5-15N at the a) West and b) East composite locations.

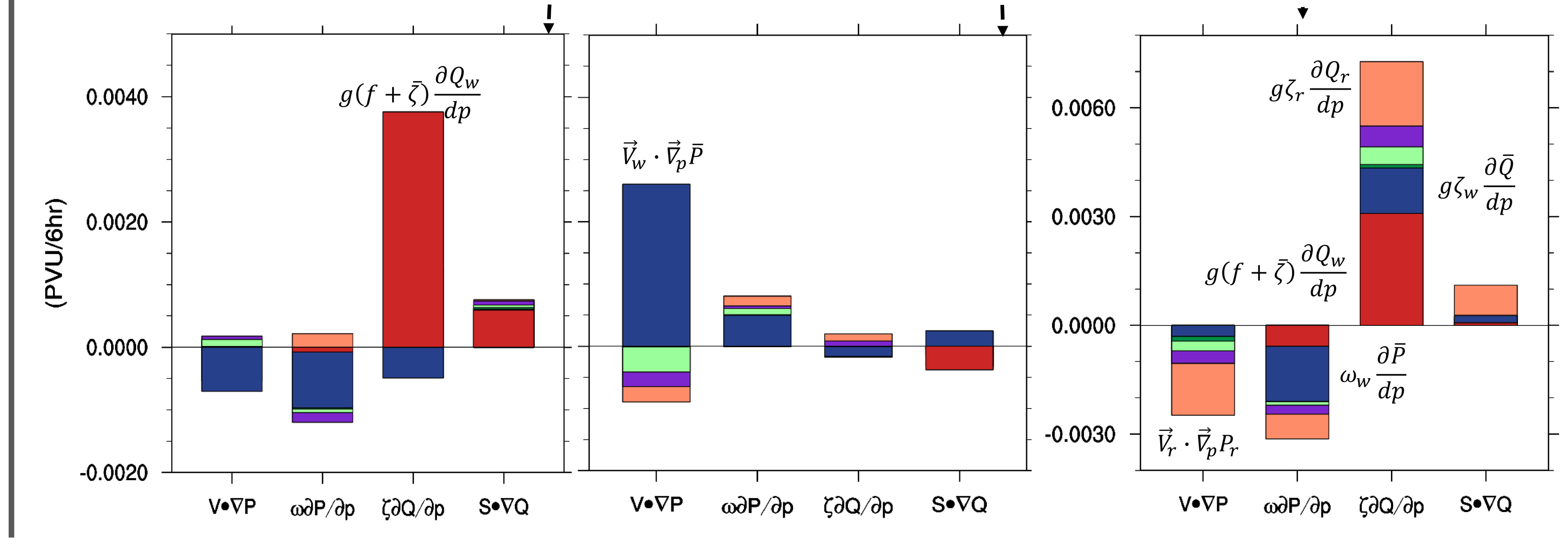


Figure 7: PV budget source terms averaged over the indicated regions.

4. WRF Case Study

- With less moisture and less convection AEW winds are weaker. PV anomalies are also weaker and confined to upper-levels.
- Diabatic PV sources are larger and more organized in the control simulation.

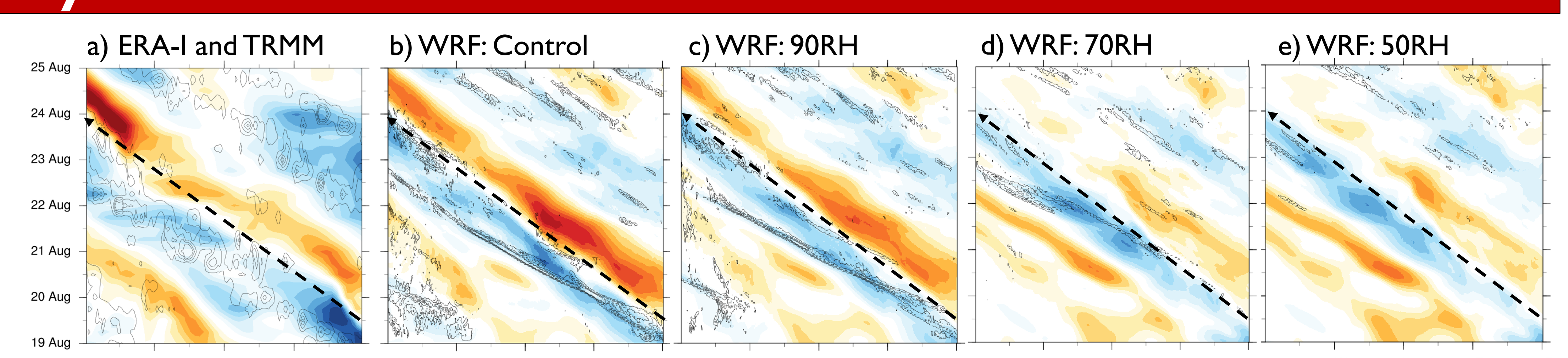


Figure 8: Hovmoller diagrams of the AEW that lead to Hurricane Earl (2010). 5-15N averaged meridional winds (shaded, m/s) and precipitation (contours, mm/hr).

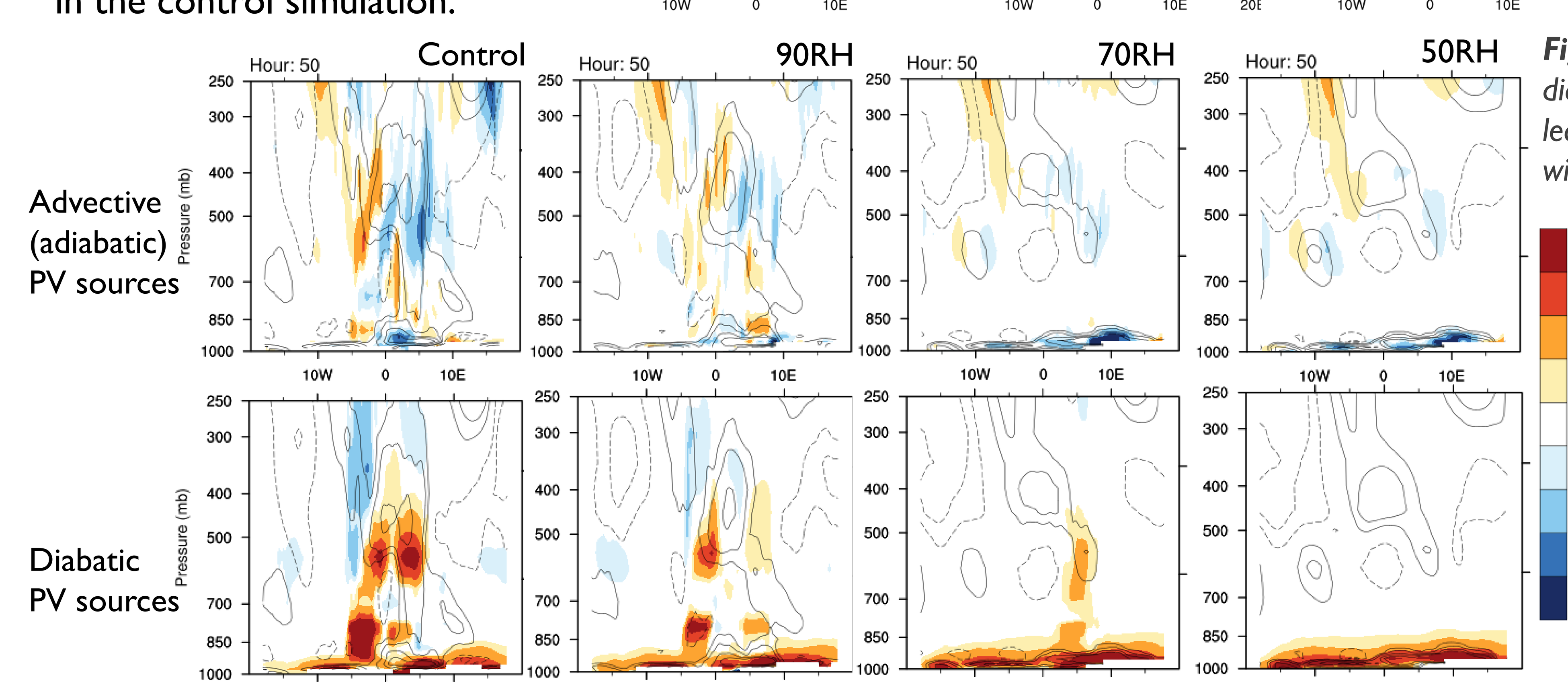


Figure 9: PV (coutours) with PV tendencies (filled) averaged between 5-15N, at simulation hour 50 (2UTC 21st Aug. 2010).

6. Summary and Conclusions

Composite Reanalysis AEW
- At the AEJ level the AEW is maintained and propagated through advection by the AEJ.
- Diabatic processes are strong in the low-levels, similar to that in DRWs but other advective processes are still prevalent.
- Residual processes (e.g. diurnal convection) are prevalent to AEWs in East Africa.

WRF Case Study.
- Consistent with the AEJ controlling propagation, the phase speed remains similar throughout the various simulations.
- With reduced moisture leading to reduced diabatic PV tendencies, PV and meridional wind anomalies weaken below 500hPa.

Conclusions

The AEW cannot be described strictly as a DRW. It may be better described as a hybrid where both adiabatic and diabatic processes play an important role.

Future Work
- Improve sensitivity studies; initializing simulation with limited moisture had detrimental effects on the environment; limiting only latent heating may retain environment.
- Examine balanced dynamics of AEWs through PV inversion.

7. Acknowledgements & References

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References

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