FINDING ENERGY PATHWAYS FROM A TROPICAL ENERGY BUBBLE TO A MID-LATITUDE JET USING WAVE ACTIVITY FLUX VECTORS

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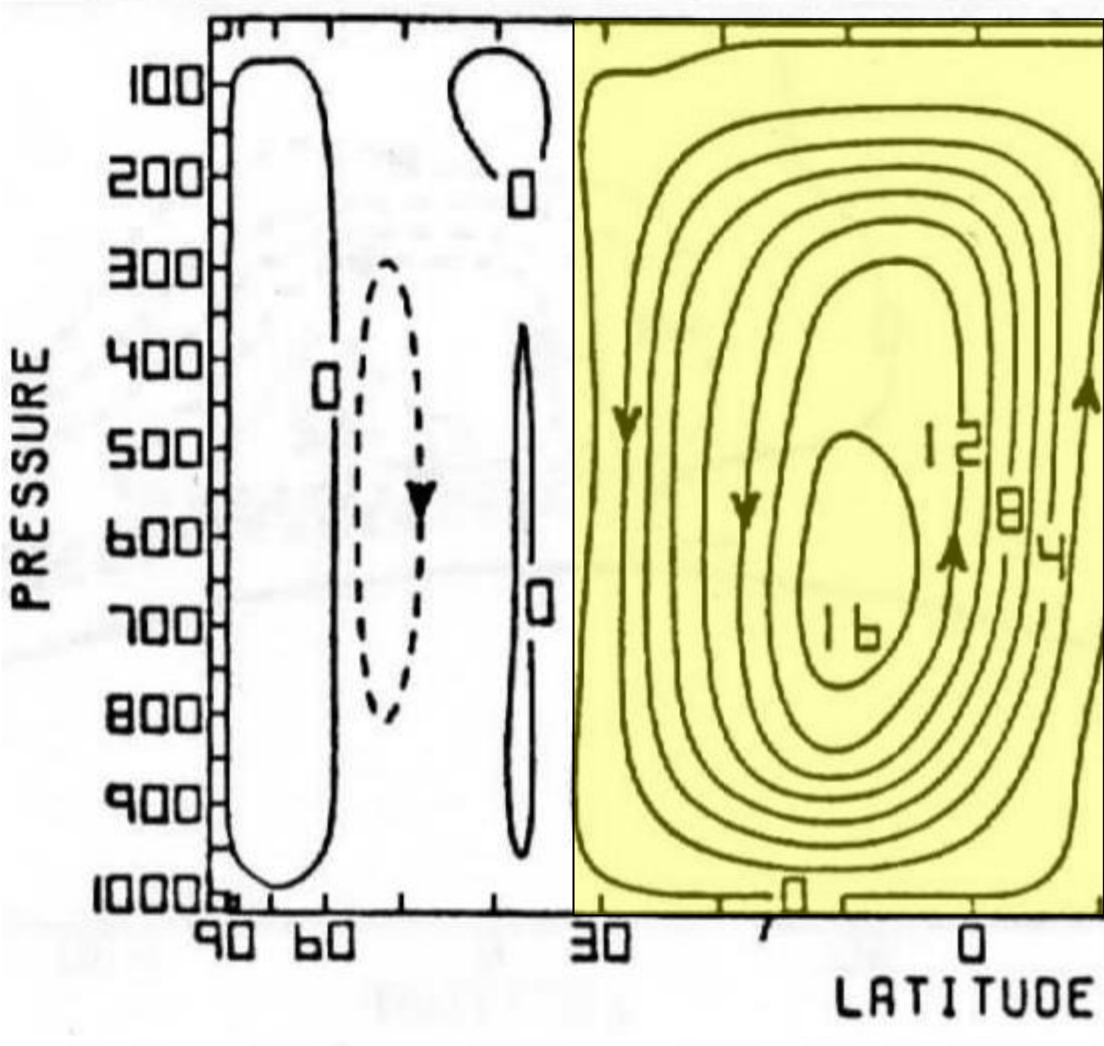
Energy In The Upper Levels

- Energy can be described by the Montgomery streamfunction (dry static energy on isentropic surfaces)
- That value can be subtracted from a standard Montgomery streamfunction*
- The resultant value is Montgomery Available Potential Energy (MAPE)

- *Standard value calculated on same isentropic level in the US Standard Atmosphere (1976)

Traditional Mass and Energy Circulation

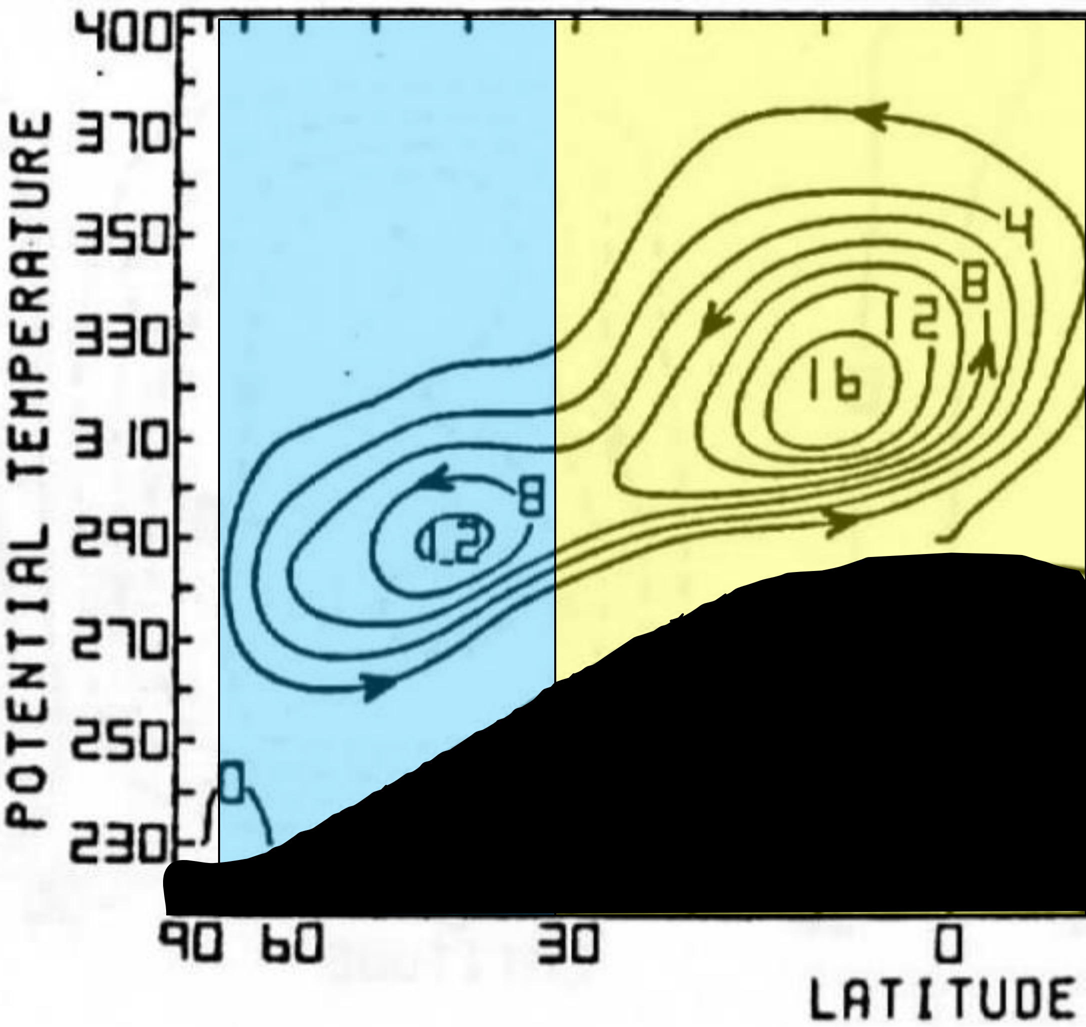
- The traditional **isobaric Hadley cell** extends to the subtropics
- Angular momentum conservation terminates the cell there



From Johnson (1989)

Baroclinic Waves Extend The Circulation

- **Baroclinic waves** in isentropic coordinates bring mass and energy past the subtropics
- Angular momentum is also removed from the flow via pressure stresses due to jets (Johnson, 1989)



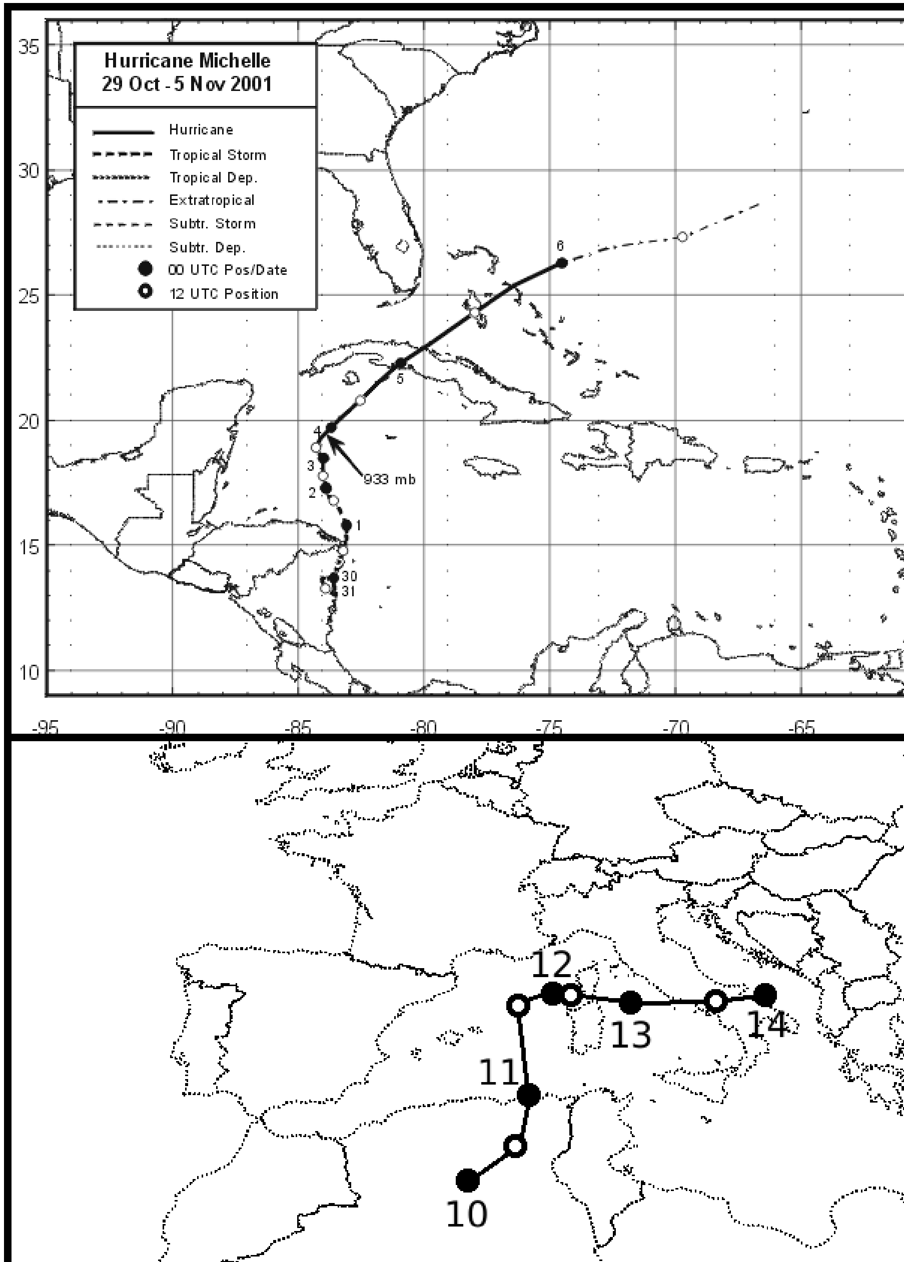
From Johnson (1989)

Metrics To Track The Circulation

- Eliassen-Palm fluxes ($-\rho u'v'$) track transfer of wave activity and momentum (Gill 1982)
- Increases in wave activity flux represent amplifying waves (Andrews 1987)
- Kinetic energy production term $E=-\rho \mathbf{U}\cdot\nabla_\theta M$
  - ρ is air density, **U** is the wind vector
  - M is Montgomery streamfunction, and
  - $\nabla_\theta M$ is its gradient on isentropic surfaces
- An equation can also be used with Eliassen-Palm flux instead of Montgomery streamfunction

Case Studied

- Hurricane Michelle in late Oct-early Nov 2001
- A strong cyclone in the Mediterranean Sea in mid-Nov 2001 (Tripoli et al., 2005)
- Massless tracers from the eyewall of Michelle end up in the Mediterranean



Tracer Movie

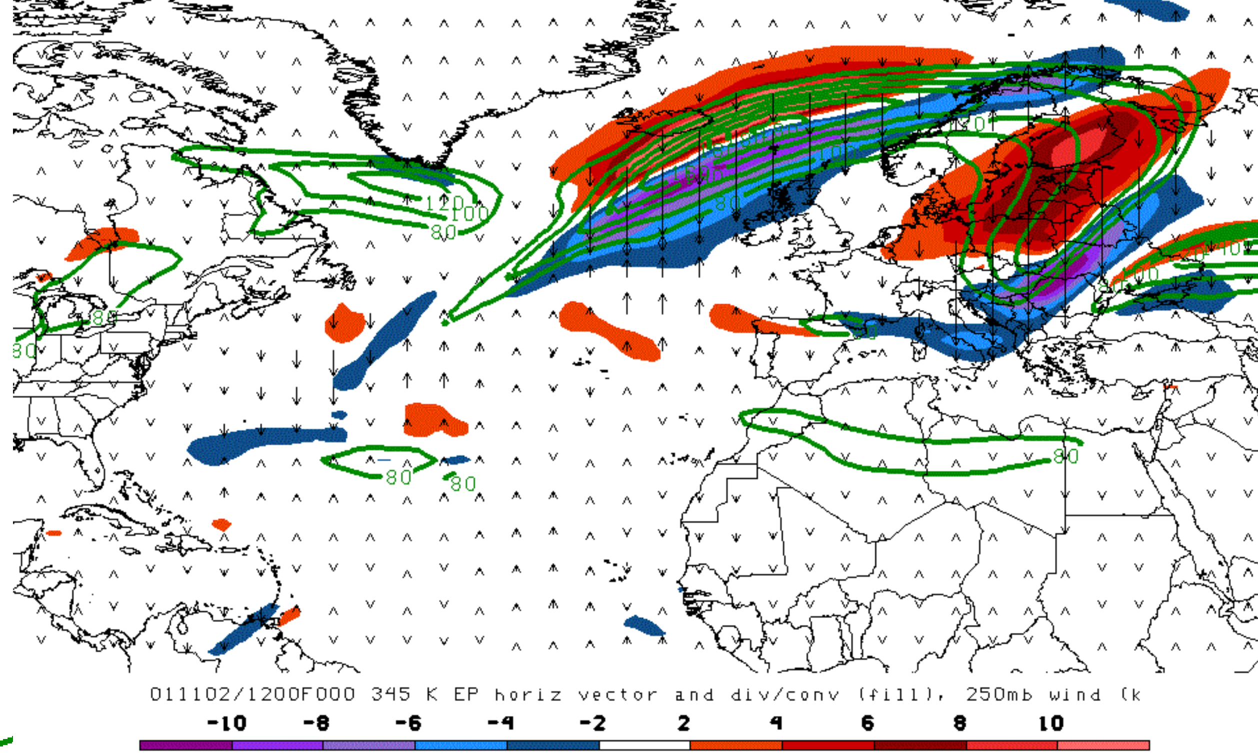
michjet.mov

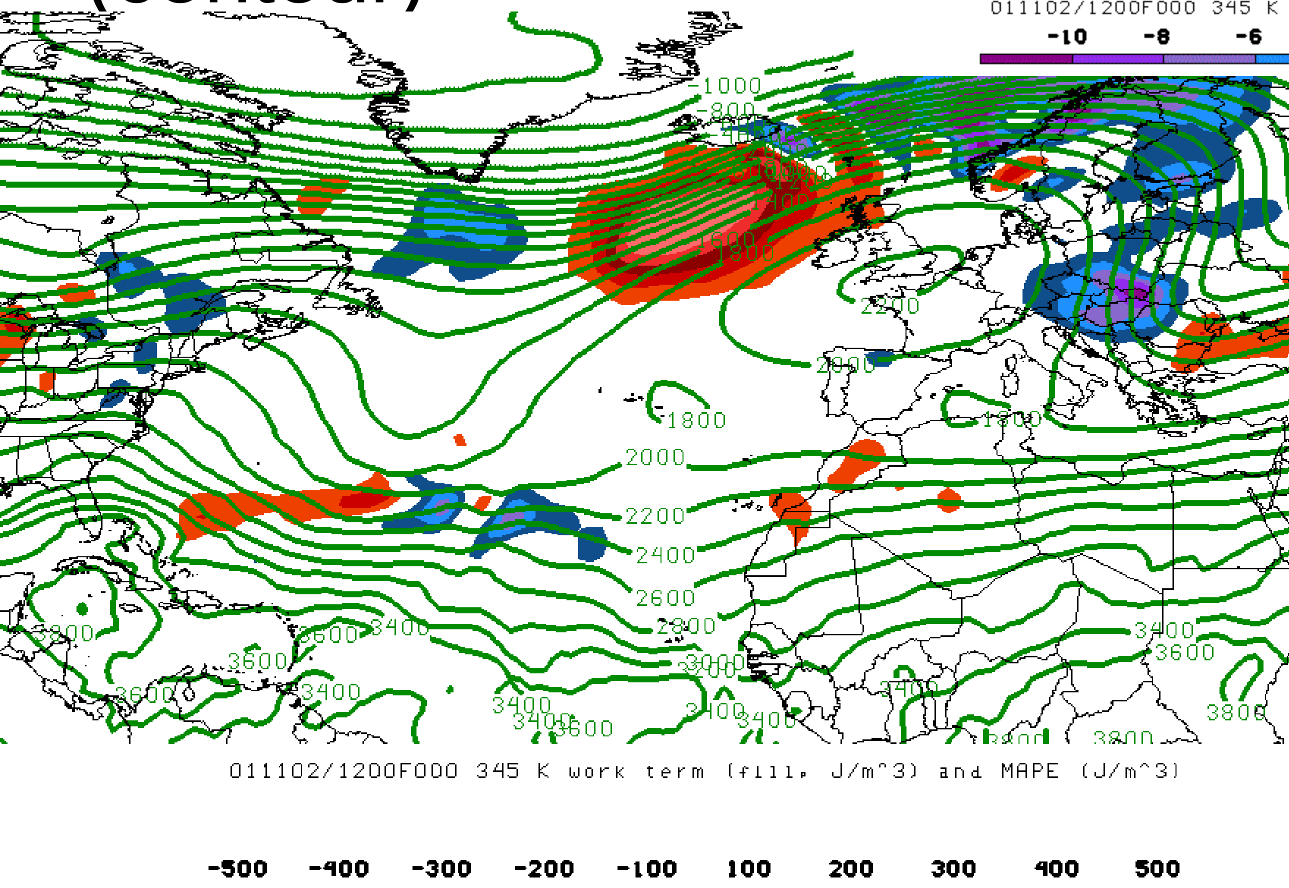
Massless tracers in an explicit UW-NMS simulation, released into the eyewall based on theta-e flux from the surface

Jet Movie

Ztropjet.mpeg

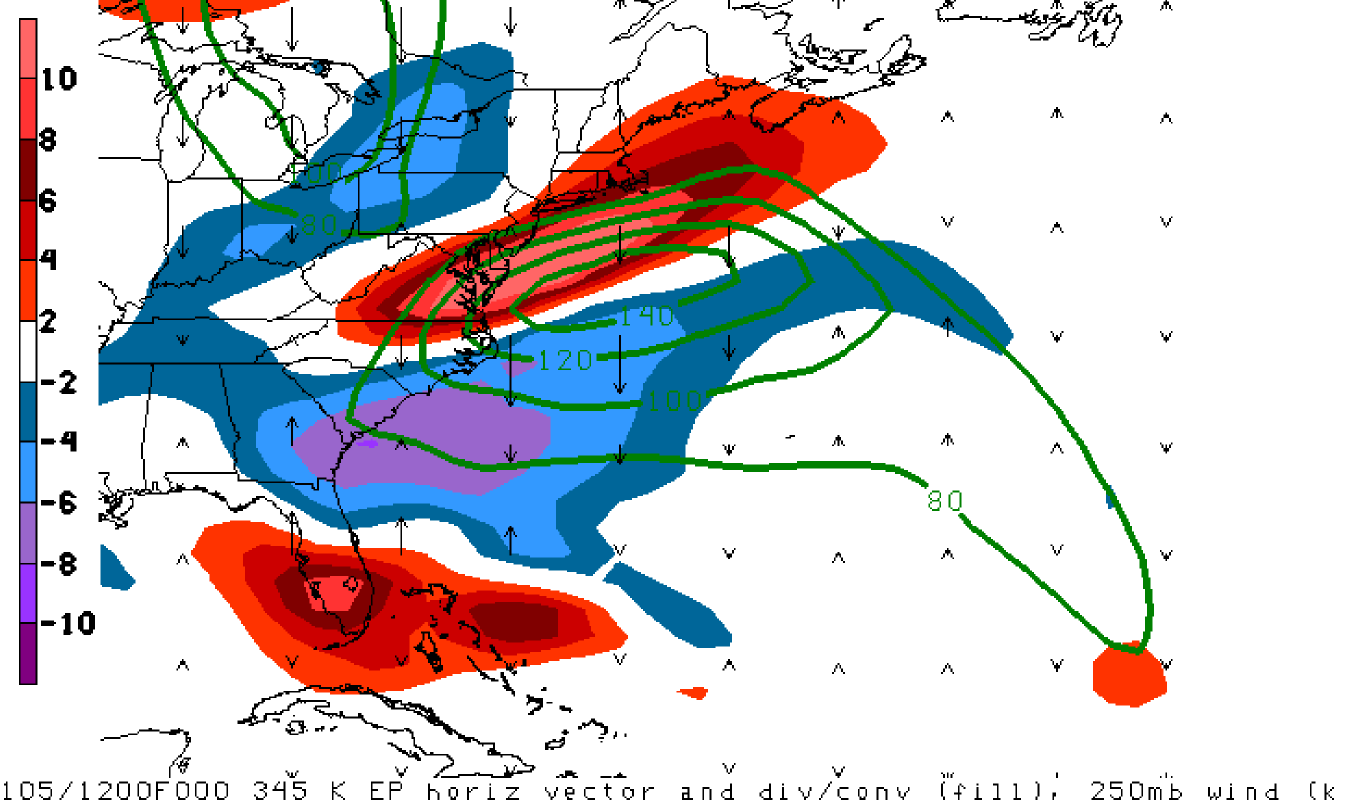
12 UTC 2 Nov Eliassen-Palm flux and divergence (fill) at 345K, 250hPa wind (contour)

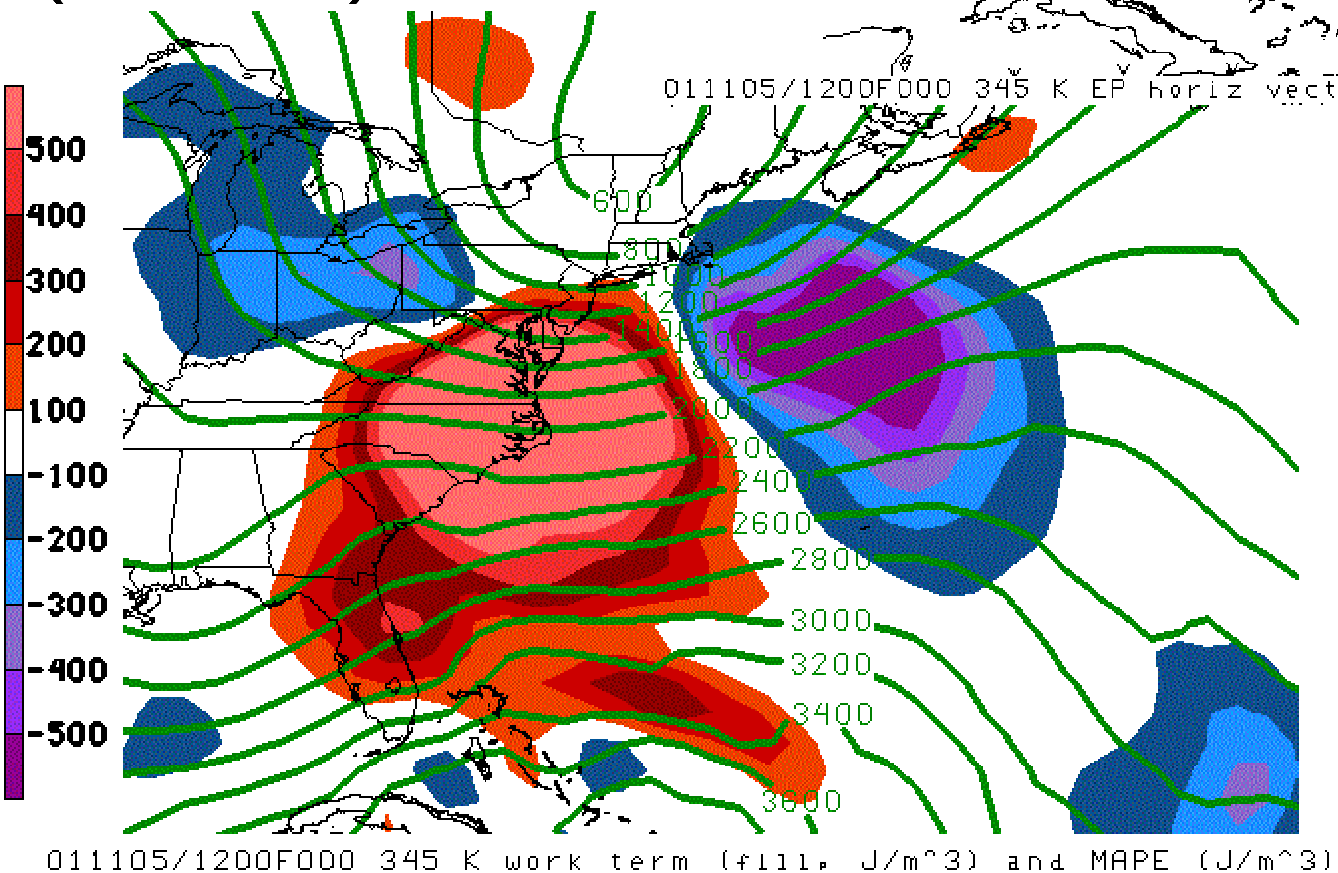




12 UTC 2 Nov Energy conversion (fill) and MAPE (contour)

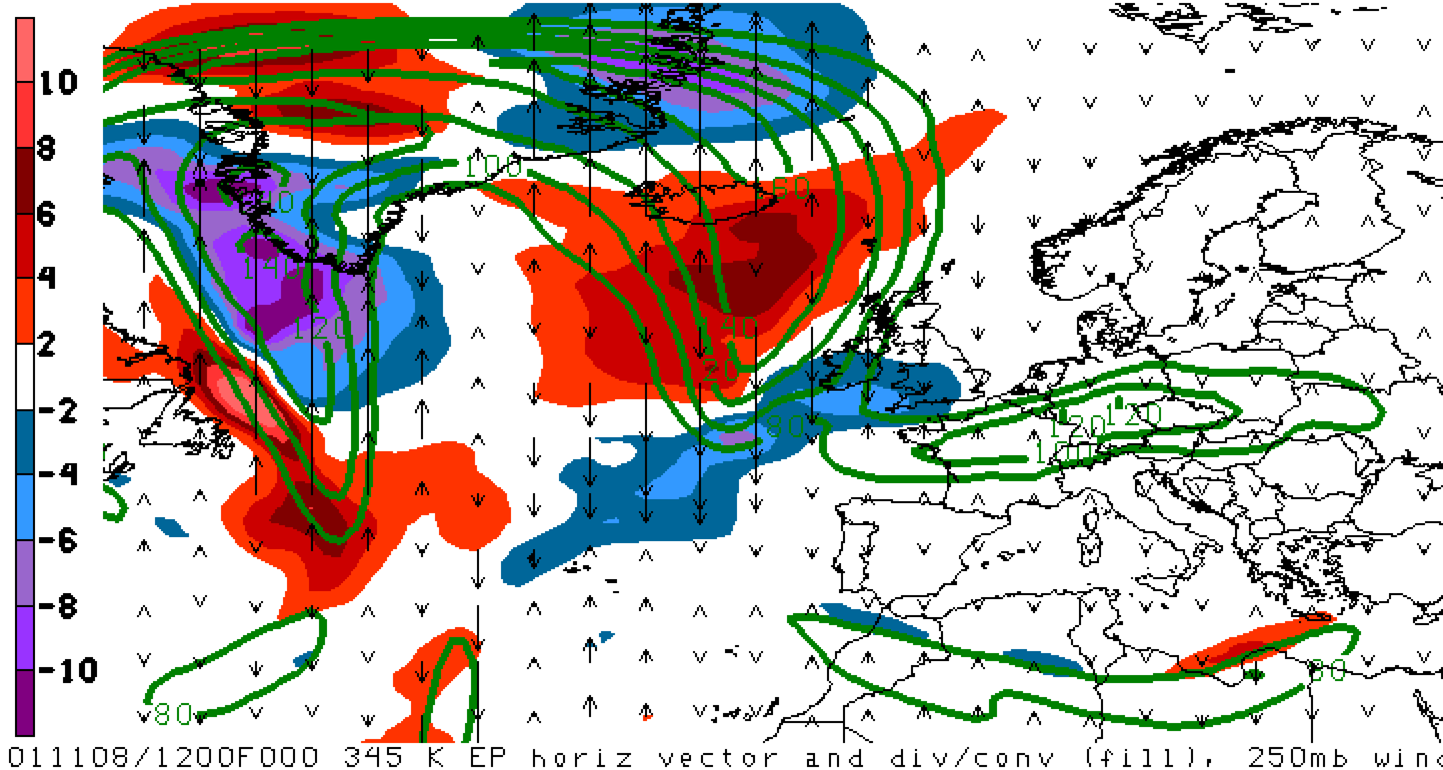
12 UTC 5 Nov Eliassen-Palm flux and divergence (fill) at 345K, 250hPa wind (contour)

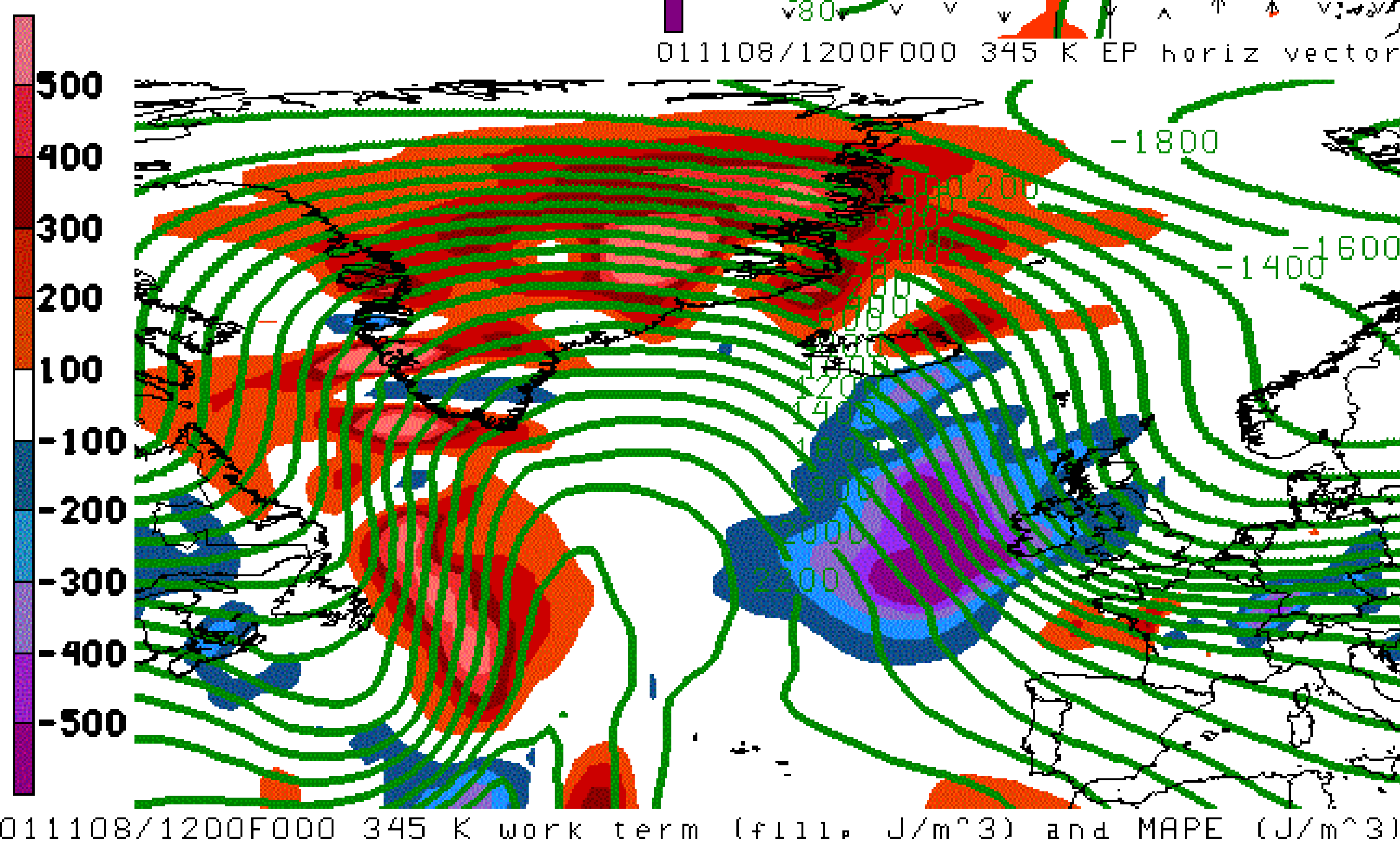




12 UTC 5 Nov Energy conversion (fill) and MAPE (contour)

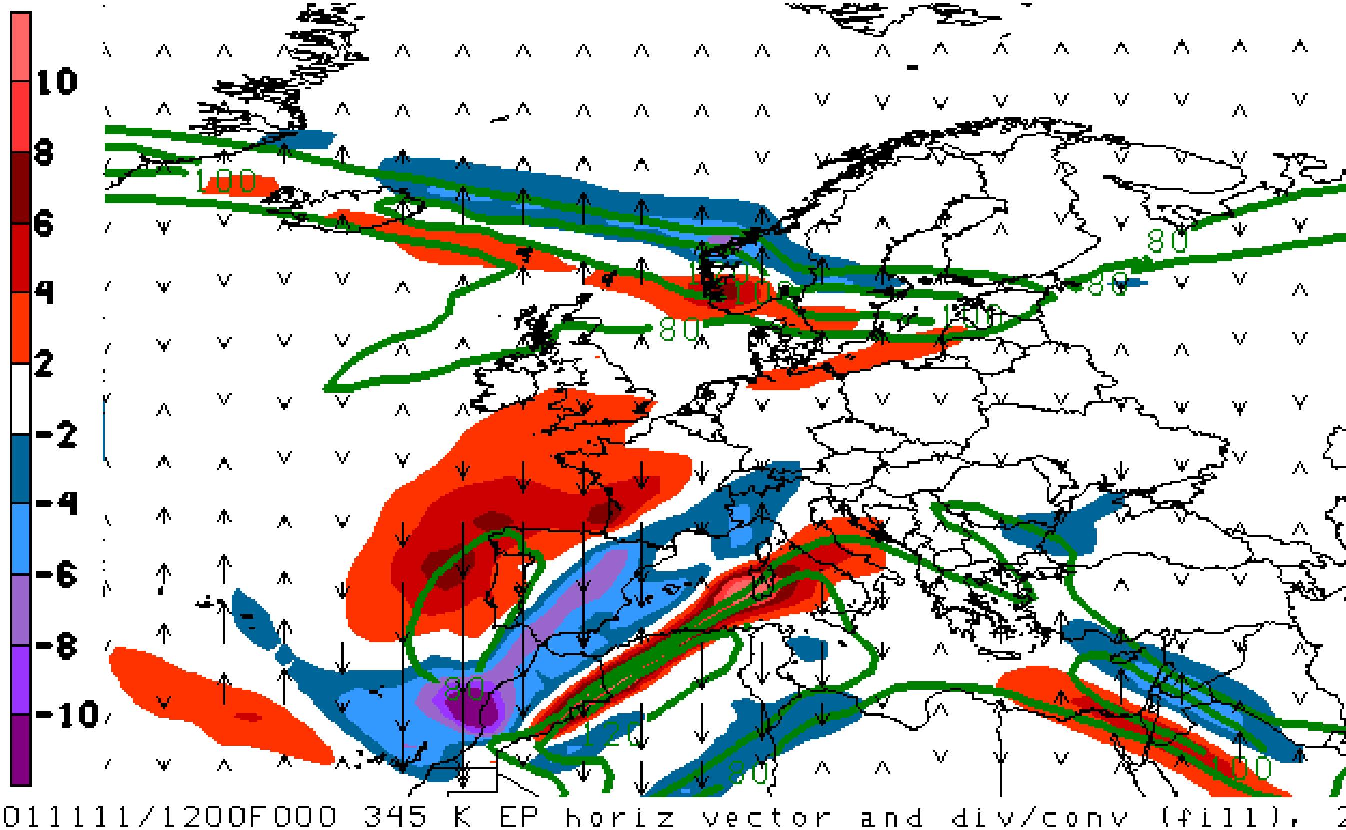
12 UTC 8 Nov
Eliassen-Palm flux and divergence (fill) at 345K, 250hPa wind (contour)

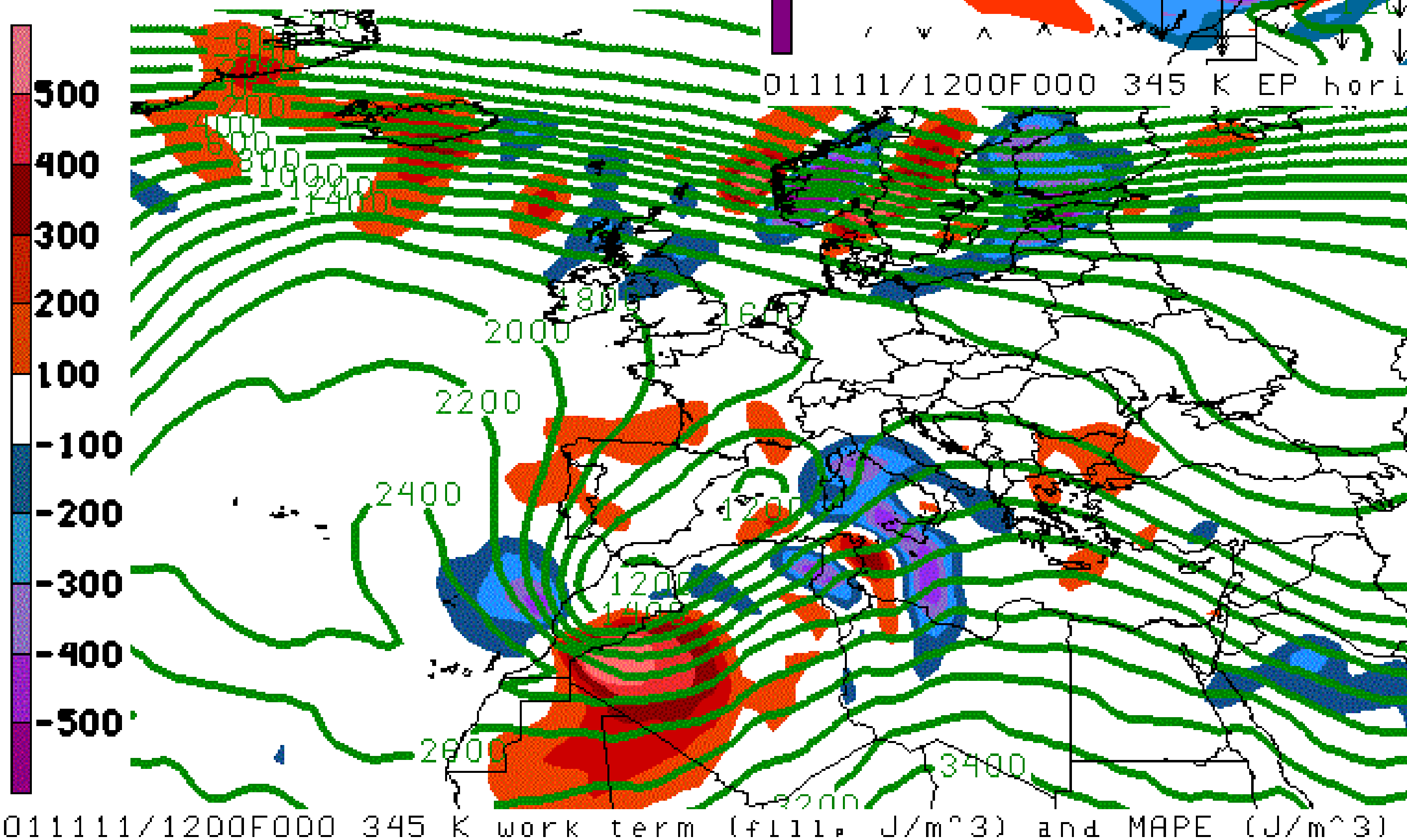




12 UTC 8 Nov
Energy conversion (fill) and MAPE (contour)

12 UTC 11 Nov Eliassen-Palm flux and divergence (fill) at 345K, 250hPa wind (contour)





12 UTC 11 Nov Energy conversion (fill) and MAPE (contour)

Results

- The total MAPE in the vicinity of the hurricane at 12 UTC 2 Nov was **6.4x10^20J**
- The total positive energy converted in jet formation from Montgomery streamfunction between 12 UTC 2 Nov-18 UTC 11 Nov was **7.5x10^20J**
- The total positive energy converted in wave-wave interaction during that time was **5.0x10^20J**
- Wave-wave interactions grew in importance as the MAPE decayed, reaching parity by 11 Nov

Results/Conclusions

- A check of the anomalous potential energy at 250 hPa in the mid-latitude wave affected shows an increase from 4414 J/kg to 4535 J/kg between 12 UTC 2 Nov and 12 UTC 9 Nov
- A large fraction of the energy converted in the jets originated in the hurricane
- **Baroclinic waves** are important in releasing tropical energy

References

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Gill, A. E., 1982: Atmosphere-Ocean Dynamics, Vol. 30. Academic Press.

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