12.804
Project 3
Vortex interaction-atmospheric data

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1 Typhoons and Hurricanes

During February 2005 cyclones Olaf and Nancy formed in the South Pacific near Australia. Fig. 1 shows a satellite image of hurricane Olaf to the north and a weakening cyclone Nancy to the south on Feb 16, 2005, one day before Olaf passed over the island of American Samoa as a Category 5 hurricane. Follow the movement of the two cyclones over few days and study their interaction. The hurricane is anomalous in vorticity and can, for certain purpose, be thought of as a point vortex. In theoretical study the migration of typhoons and hurricanes is often idealized to that of a point vortex in a meridional vorticity gradient.

Is such a theoretical abstraction reasonable? We can find out by studying the data in more details and carrying out vorticity and potential vorticity diagnostic.

1. Compute a series of absolute vorticity at chosen pressure levels during the period of the interaction. How anomalous is the absolute vorticity? Can you see evidence of any vortex interaction or merger? What an idealized point-vortex model does it suggest?

2. Is there a planetary vorticity gradient? Speculate on the role of a background beta effect.

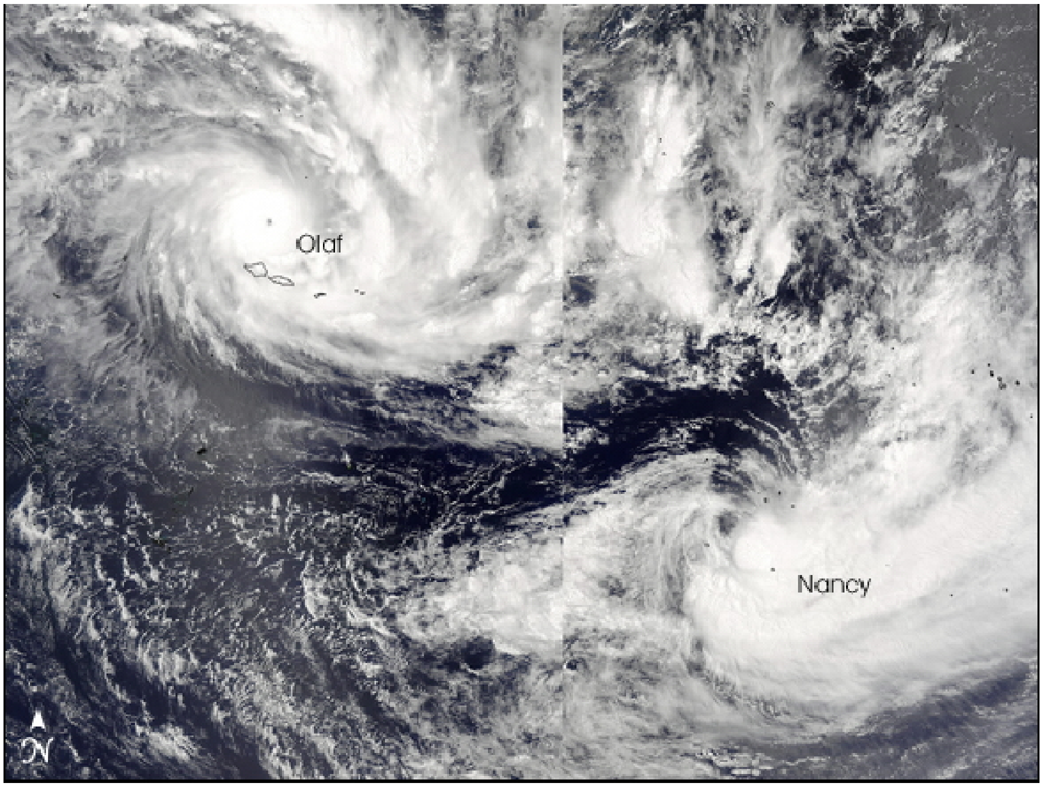

Figure 1: Tropical cyclones Olaf and Nancy on February 16, 2005

3. Plot a north-south section through the cyclones to reveal the distribution of potential temperature in a meridional plane.

4. A more complete 'summary' of the dynamics is revealed through the potential vorticity distribution. Plot Ertel potential vorticity on a chosen theta surface (e.g. 330 K) (guidelines are given in appended notes). Plot meridional sections of PV with potential temperature as the vertical coordinate. Where is PV high and where is it low? Identify and describe the hurricane in relation to the shape of the isentropes. Study its evolution.

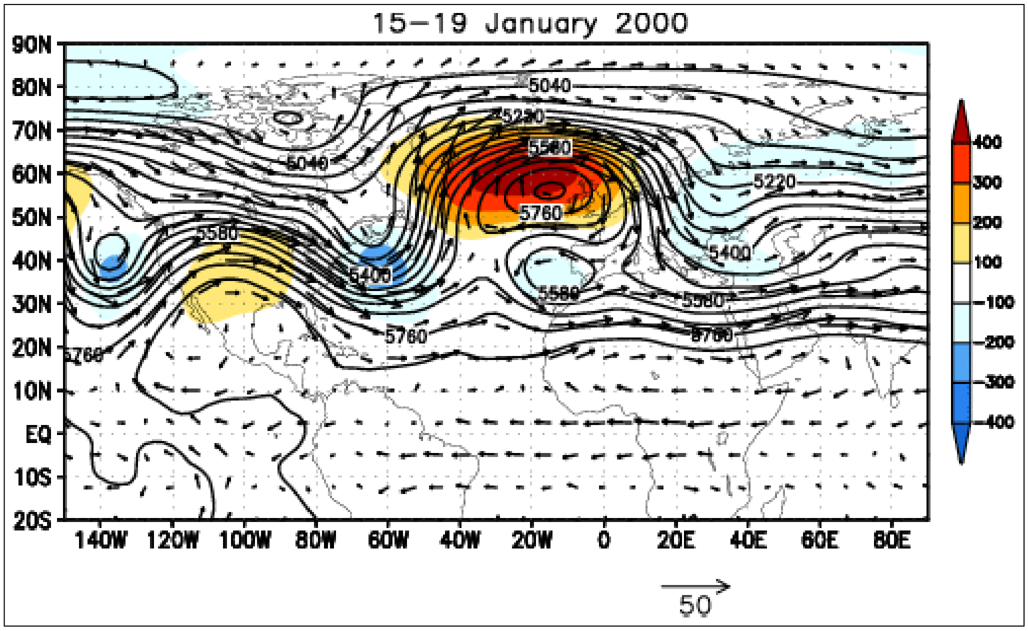

Figure 2: Example of an atlantic blocking dipole from January 2000.

2 Blocking Dipole

Here we continue the study of vortex interaction in a rather characteristic weather regime, that of an atmospheric blocking pattern which tends to affect the Atlantic and Western European regions during late winter and early spring.

The blocking pattern comprises a high pressure (low PV) anomaly to the north of a low pressure (high PV) anomaly. The vortices interact, tending to advect one-another up-stream balancing down-stream advection in the westerlies, see example from January 2000 in Fig.

After inspecting the 500 mb charts over several days during last winter, review the synoptic situation and choose an interesting blocking period.

1. Compute a series of absolute vorticity at selected pressure levels during the blocking episode. How anomalous is the absolute vorticity? Can you see evidence of a north-south dipole. What idealized point-vortex model does it suggest?

2. Plot a north-south section through the high-low dipole to reveal the

distribution of potential temperature in a meridional plane. Can you identify the tropopause? How is it related to the anomalies in absolute vorticity?

3. Try and construct an idealized representation of the blocking dipole using your point vortex model. Choose appropriate vortex strengths and separations guided by your absolute vorticity maps. How quickly does the pair propagate upstream? Is the observed westerly flow strong enough to keep them stationary relative to the ground.

4. Speculate on the role of a background beta effect.

5. A more complete 'summary' of the dynamics is revealed through the potential vorticity distribution. Plot Ertel potential vorticity on a chosen theta surface (e.g. 330 K) (guidelines are given in appended notes). Plot meridional sections of PV with potential temperature as the vertical coordinate. Where is PV high and where is it low? Identify and describe the shape of the tropopause in relation to the shape of the isentropes and the block. Study its evolution.

3 Appendix: Isentropic Potential Vorticity

The isentropic (or Ertel) potential vorticity q is defined as:

$$q = -g(\zeta_\theta + f)\frac{\partial \vartheta}{\partial p} \tag{1}$$

where ζ_θ is the relative vorticity on an isentropic surface, f is the Coriolis parameter, p is pressure and g the acceleration due to gravity. The potential vorticity q is conserved in adiabatic, frictionless motion.

We can evaluate the distribution of potential vorticity on isentropic surfaces using atmospheric data as follows.

3.1 PV on isentropic surfaces

First use GEMPAK program *gdcross* to plot meridional and zonal sections over the US region of the following quantities that will be used to compute PV:

(a) potential temperature - see example file: ~lab/12804/vortex/gdcross.thta_vortex_interac. Identify and describe the shape of the tropopause in relation to the shape of the isentropes

(b) absolute vorticity ($\zeta_\theta + f$) with potential temperature as the vertical coordinate - see example file: ~lab/12804/vortex/gdcross.avor_vortex_interac. Where is the absolute vorticity a maximum?

A more complete 'summary' of the dynamics is revealed through the potential vorticity distribution.

(c) Plot meridional and zonal sections of PV with potential temperature as the vertical coordinate - see example file: ~lab/12804/vortex/gdcross.ipv_vortex_interac. Where is PV high and where is it low? Identify and describe the shape of the tropopause in relation to PV distribution. Mark the PV surface which could be used to identify the tropopause.

3.2 Tropopause maps

Use GEMPAK program *gdcntr* to plot PV on a sequence of isentropic surfaces over the US, starting from 350 K in the stratosphere and moving down to 280 K in the lower troposphere, at 10 K intervals - see example file: ~lab/12804/pvfront/gdcntr.ipv_310.

By identifying the tropopause as the 2 PVU contour, plot the position of the tropopause on each isentropic surface. Tropopause temperature maps are obtained by superimposing many such contours, corresponding to different theta surfaces, on a single map.

Tropopause temperature maps, such as those prepared here, are routinely displayed in the Synoptic Laboratory.