Identifying the Origins Of PV Anomalies

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Cyclone Development

- Dominant growth mechanism is generally assumed to be baroclinic instability.

- Parameterized physical processes ("physics") are supposed to be treated as perturbing the basic baroclinic dynamics.

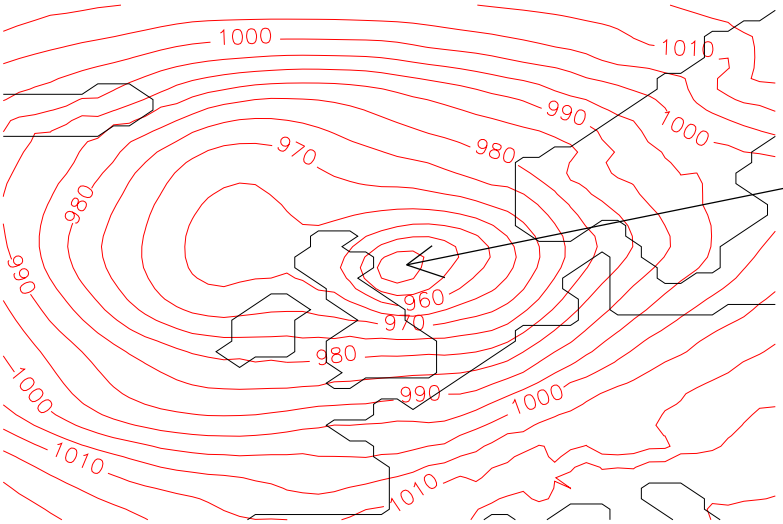
But....

- Some cyclones driven by latent heating (see previous talk).

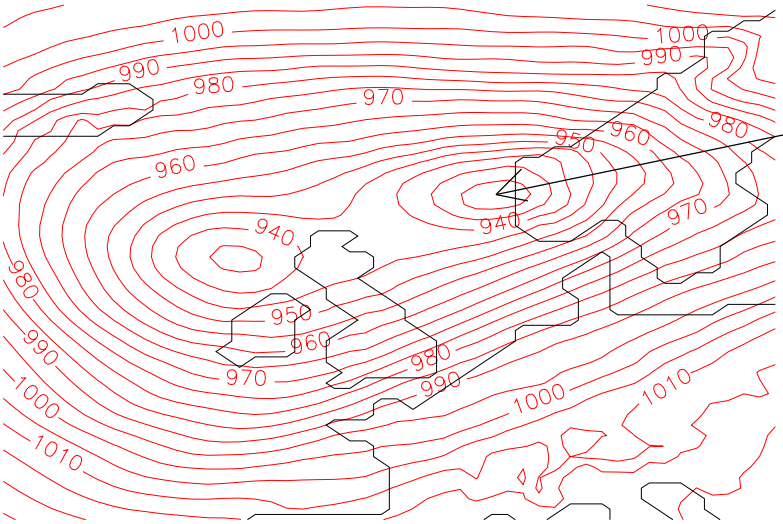
- Other "physics" potentially important too.

Perhaps we should treat physics as an essential element, not as a perturbation.

Control simulation, T+60



Simulation with no boundary layer turbulence, T+60.



Conceptual Models with Physics

- To include physics as a full part of the conceptual framework we need to understand what each bit of physics does.

- Use full physics! Switching things on and off changes the thing we are looking at and is just too cheap and cheerful.

Dynamics conserves PV (the PV just goes with the flow)
but...
Physics generates, destroys and redistributes PV.

- But what PV is due to what physics?

Diagnosing PV Generation in the UM

- At each model timestep, the parameterised physics in the UM is calculated sequentially.

(Each physics process is dealt with in turn and the resultant changes are applied before the next process is taken into account.)

- So, the local PV generation at each timestep by each physics process is just...

Total PV after calculation of this process

–

Total PV before calculation of this process

Check:

$\sum$ processes = overall PV change

What Happens to the Generated PV?

We can split up the full PV field like this....

$PV(t)$ = [$PV(0)$ advected for time t]

+ $\int_0^t$ [PV generated by convection at t′

and advected from t′ to t] dt′

+ [term for friction]

+ ……

Each term represents the current location of PV generated at earlier times through the action of a particular physical process.

What Happens to the Generated PV?

We can handle the advection part by...

(1) Treating each term as a tracer field. (This scheme conserves the PV.)

Or...

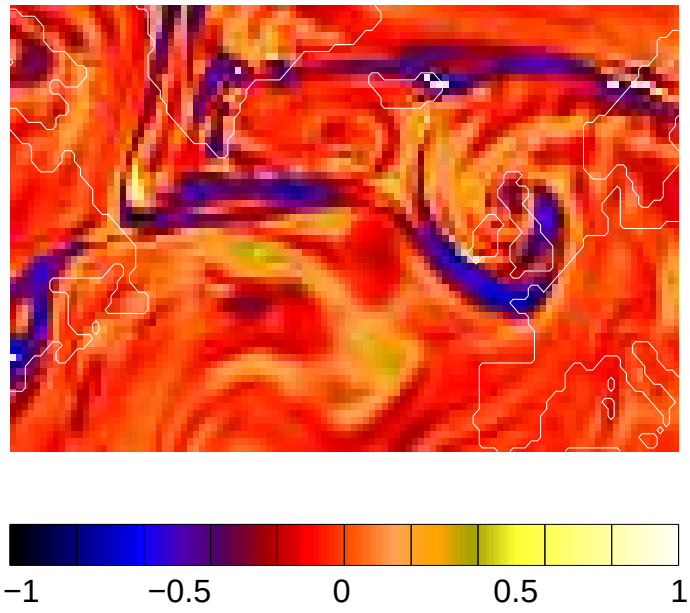
(2) Treating each term as a prognostic scalar (use the model advection scheme for theta.)

The full UM does not conserve PV, due to errors in the advection scheme.

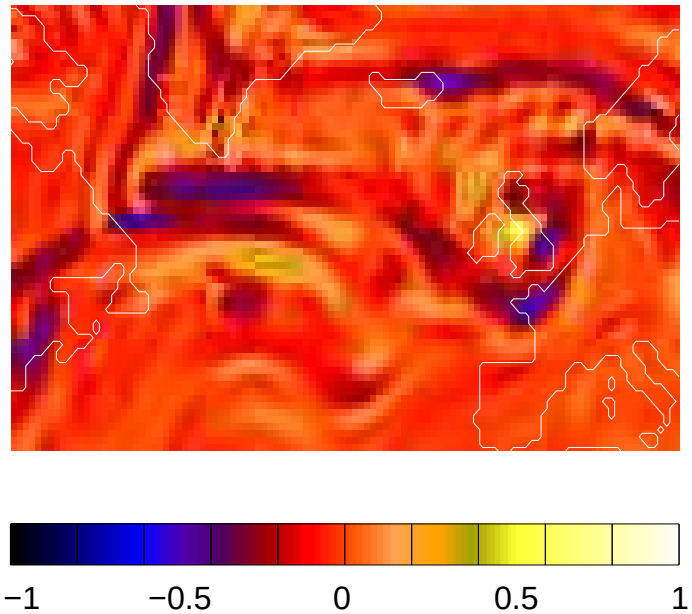
Therefore:

Two methods useful to check that features are robust, and not numerical artefacts.

Error in tracer advection scheme after T+24, sigma=0.45



Error in prognostic advection scheme, T+24, sigma=0.45



Applications

Use advected terms to diagnose action of physics...

- Convective term important in type C?
- Or is the latent heating forced by large-scale dynamics?

(Ahmadi-Givi et al 2001)

- Frictional terms important in cyclone decay?

(Adamson and Belcher 2001)

- Convective term important for strato-sphere-troposphere exchange?

(Gray 2002)

- LW radiation term important for...?

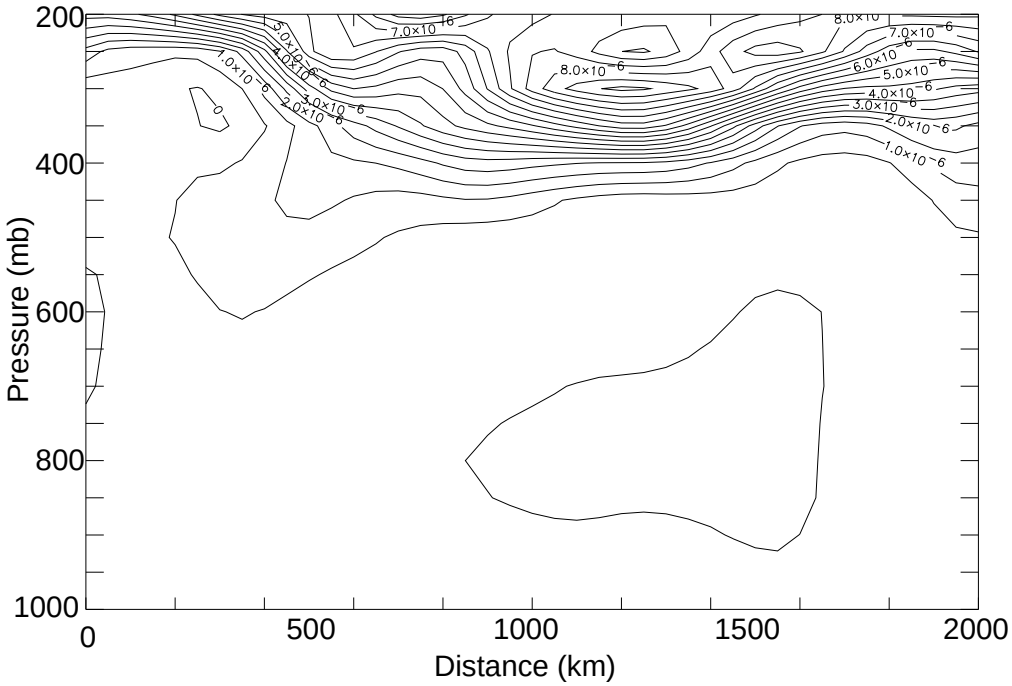
(Well, let's keep an open mind!)

An Example

- Latent heat release dominates the intensification of FASTEX IOP4.
- The latent heat seems to erode an upper level PV anomaly.
- Perhaps this occurs because of PV destruction above a region of heating?

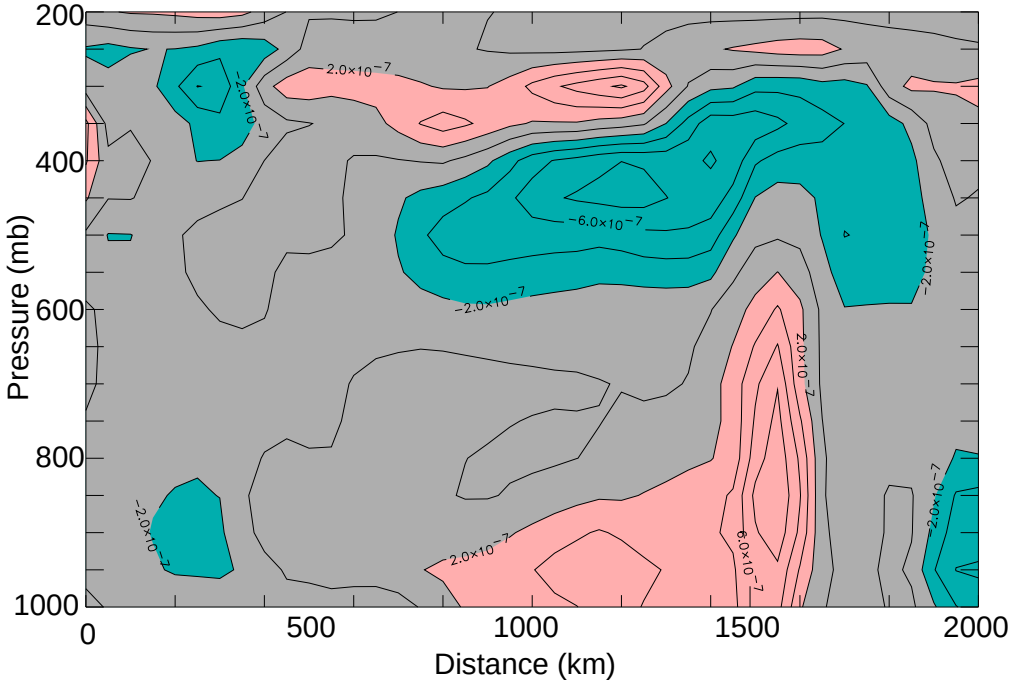
PV field, T+24

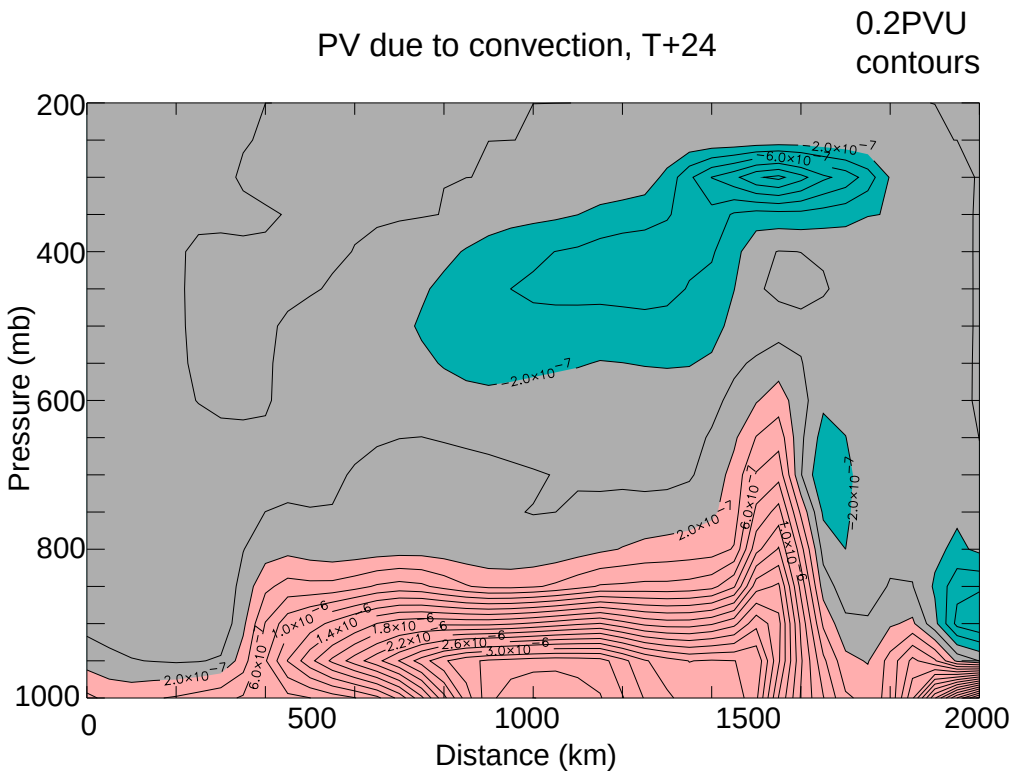
0.5PVU contours

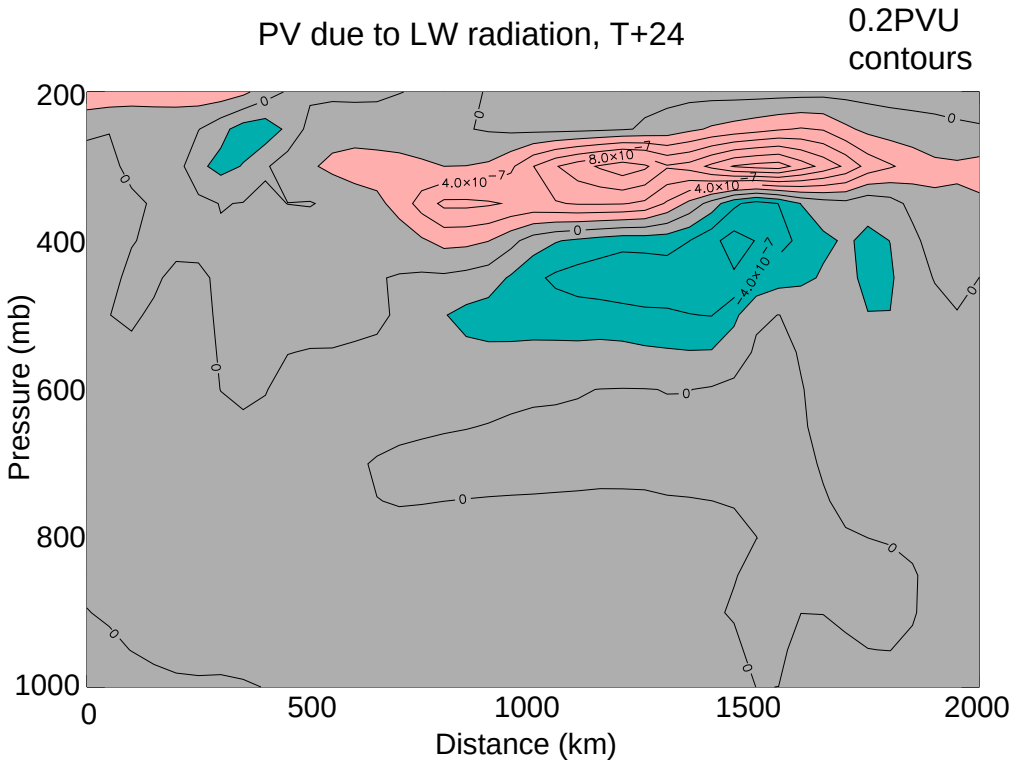


PV due to all parameterised physics, T+24

0.2PVU contours




PV due to convection, T+24
0.2PVU
contours
Pressure (mb)
200
400
600
800
1000
0
500
1000
1500
2000
Distance (km)


PV due to LW radiation, T+24
0.2PVU
contours
Pressure (mb)
200
400
600
800
1000
0
500
1000
1500
2000
Distance (km)

Conclusions

- Cyclone development often viewed in terms of the formation of regions with particularly high and low values of PV.
- Such regions may form due to dynamics.
- Or due to parameterised physical processes (the “physics”).
- We have a method for determining how much of the PV field is due to the action of each process.
- This is an exciting new gadget for helping us to figure out what the role of each process is.