National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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DIAMET

DIAbatic influences on MEsoscale structures in extratropical sTorms

Geraint Vaughan

MANCHESTER 1824
The University of Manchester

University of Reading

UNIVERSITY OF LEEDS

UEA
University of East Anglia

Met Office

NATURAL ENVIRONMENT RESEARCH COUNCIL

Storm Risk Mitigation Programme

- NERC strategic research project to improve forecasting of storms and their impacts on catchments and coasts
- £4.9m from 2009-2014
- Three main components:
  - **NWP – DIAMET**
  - Climate science – TEMPEST
  - Impacts – DEMON
- All three involve collaboration between NERC/ University community and the Met Office

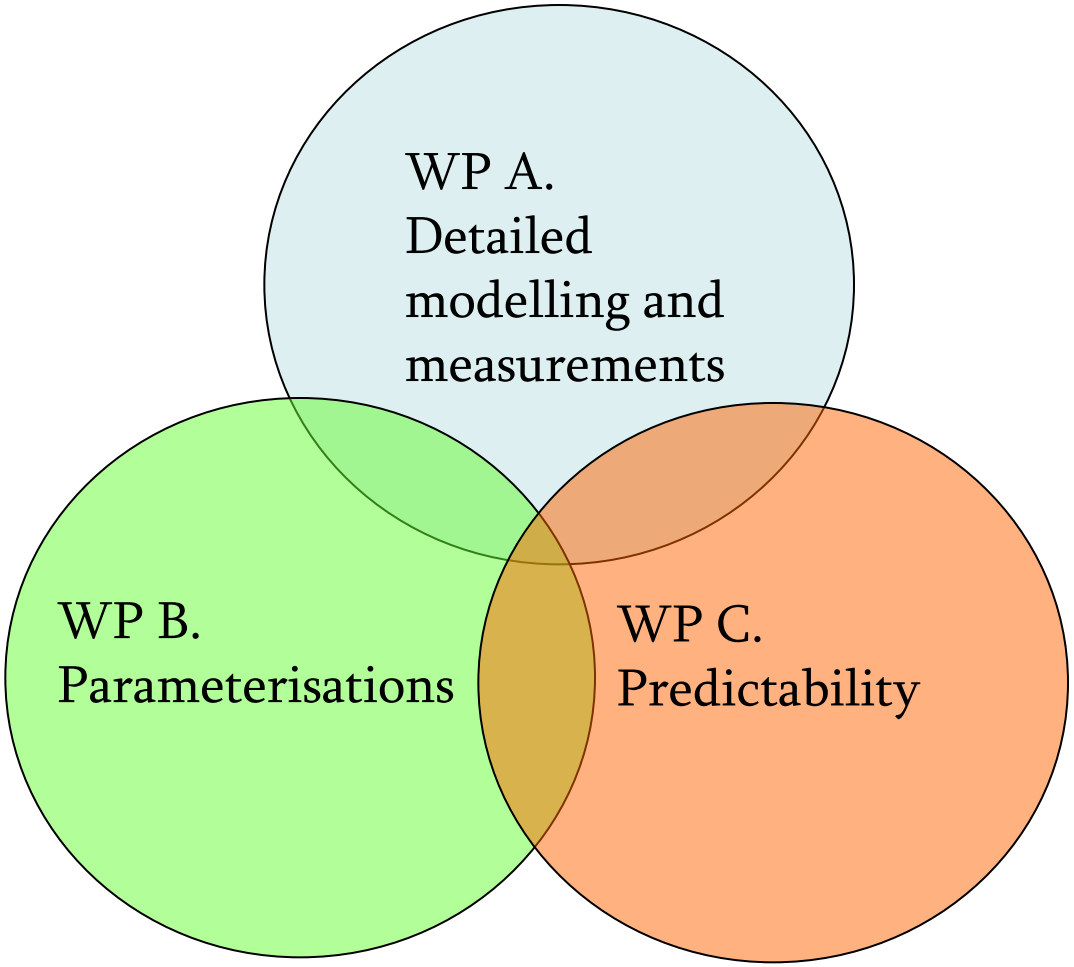
Overarching scientific questions for DIAMET

What is the role of diabatic processes in generating mesoscale potential vorticity (PV) and moisture anomalies in cyclonic storms?, and

What are the consequences of those anomalies for the weather we experience?

We focus on two key diabatic processes: latent heating/cooling and air-sea fluxes of heat and moisture.

Structure of project

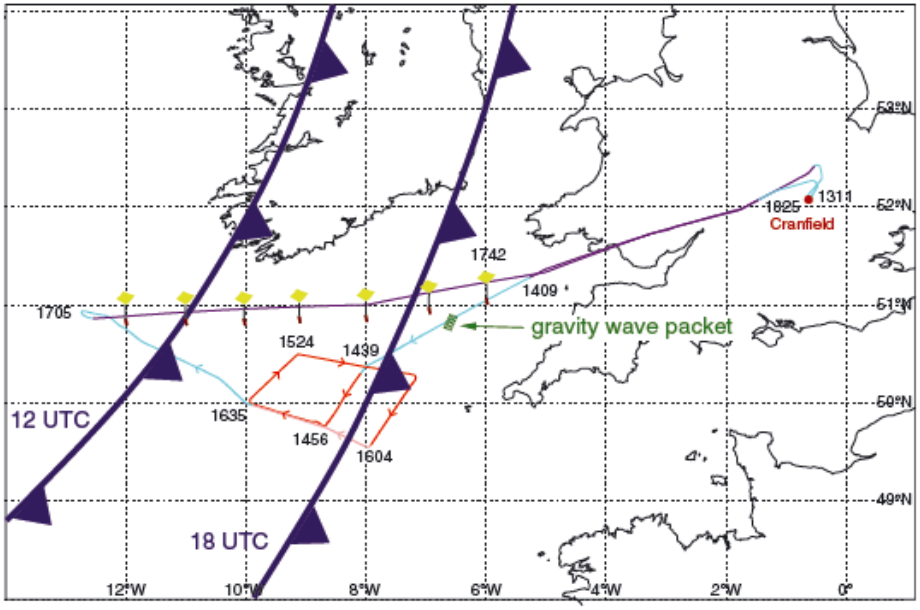


Work Package A
Real-world mesoscale structures

- High-resolution modelling of past cases
- Field campaigns: autumn 2011, summer 2012
- High-resolution modelling of observed cases
- Statistical analysis of precipitation structures observed by radar (student project)
- Modelling microphysical sensitivity of storm dynamics (student project)
- Dynamical consequences of PV and heating anomalies

Exploits novel tracer method for partitioning PV changes by physical process (in a numerical model)

T-NAWDEX pre-frontal wave



Flight of 24th November 2009

Knippertz et al 2010

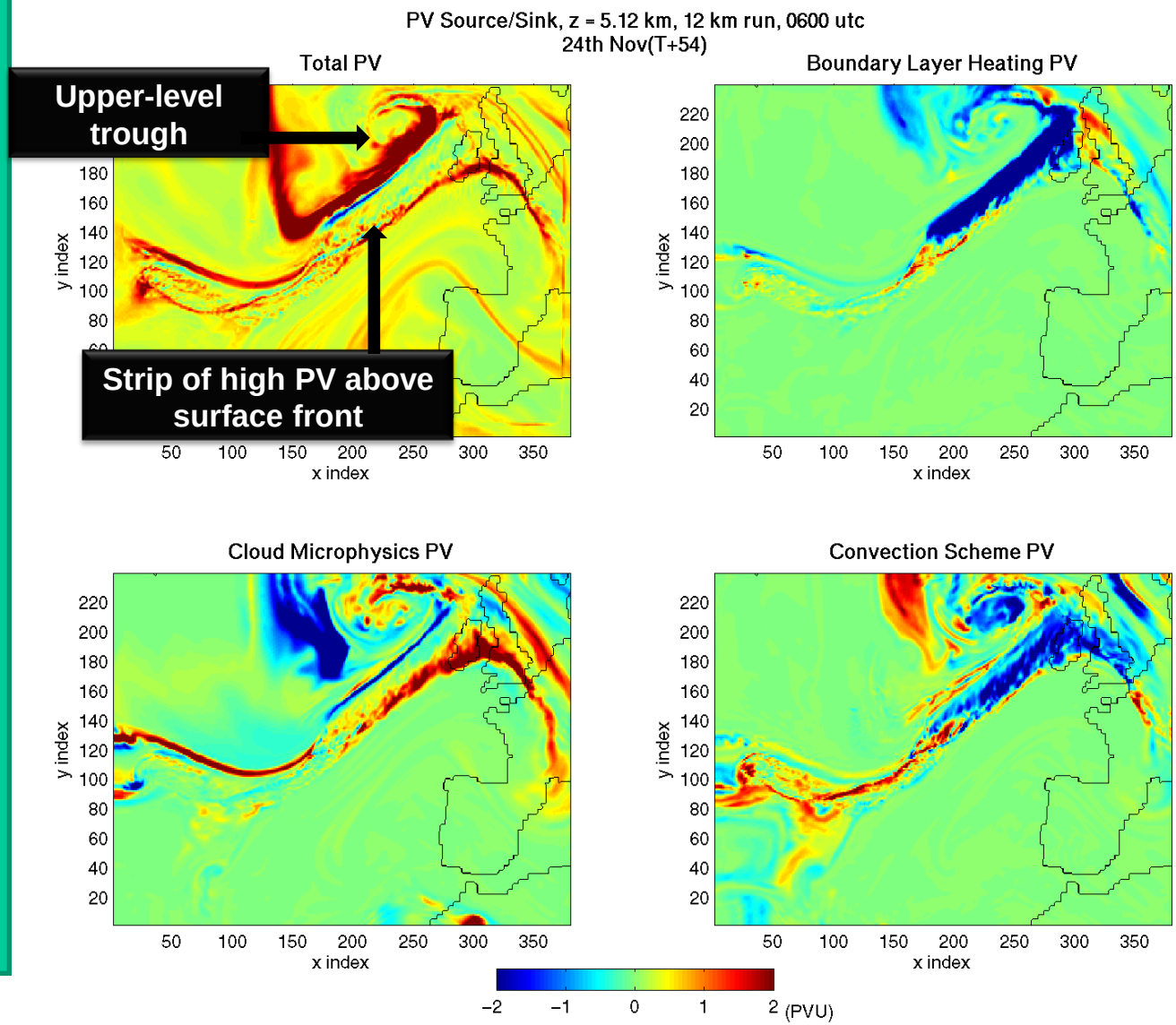
PV SOURCE/SINK ANALYSIS: Pilot project, 24th Nov 2009

- PV sources/sink accumulated from 00 UTC on 22 November 2009, UM 12 km run

- The strip of high PV along the cold front is diabatically generated.

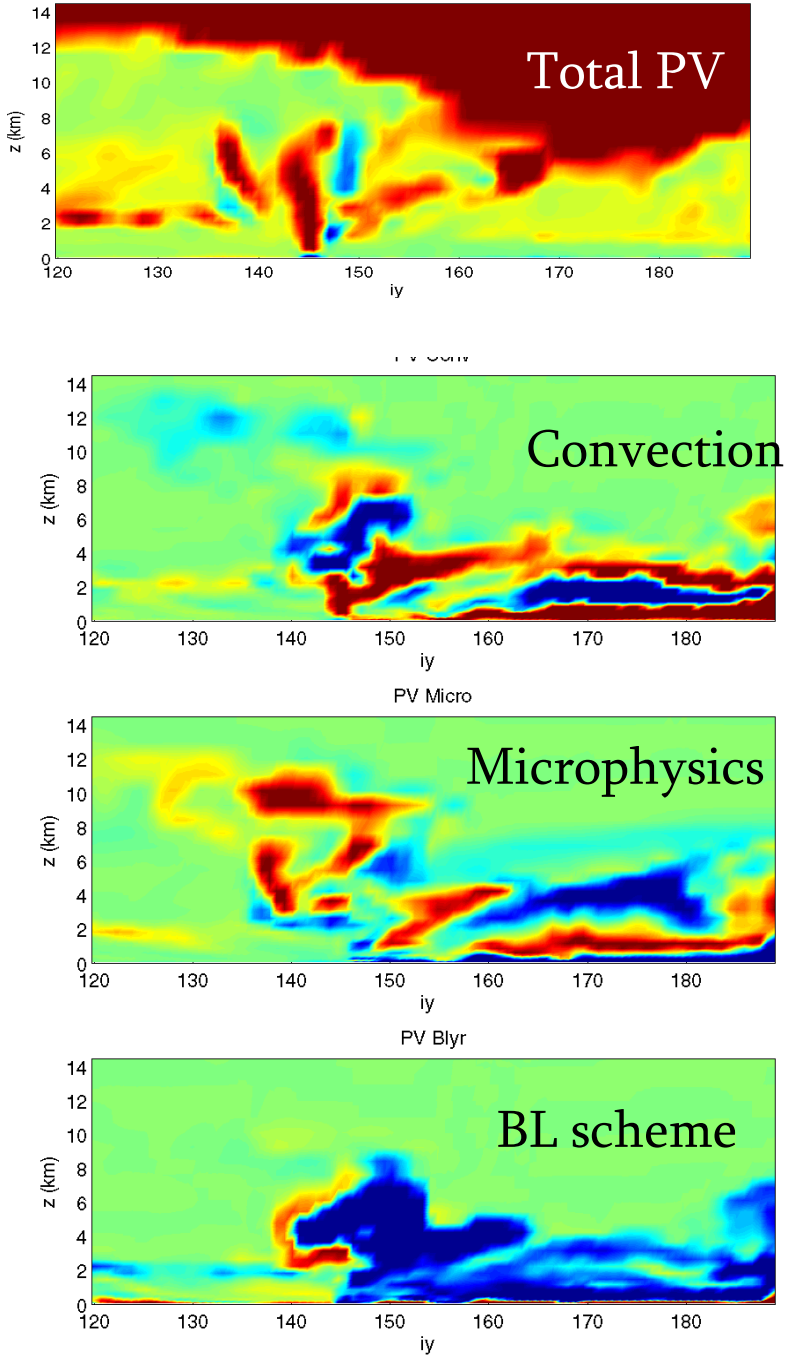
- Main contributions are from boundary-layer heating, cloud microphysics, and convection schemes.

- The high PV strip is involved in the generation of a large-amplitude gravity wave packet.



Source: Jeffrey Chagnon

Latitude-height cross section along 50 N



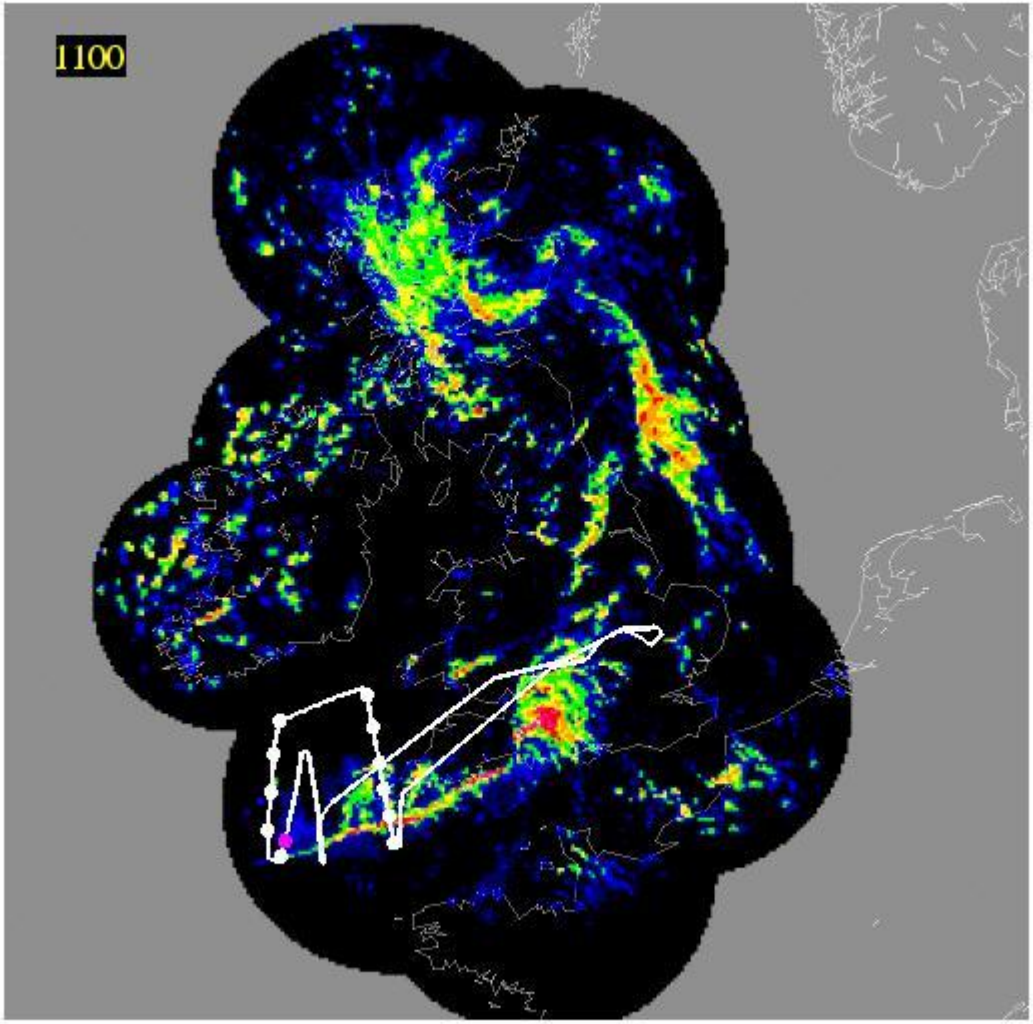
The total potential vorticity [panel (a)] indicates a tropopause fold to the north of front as well as several slantwise-oriented anomalies along the front. The diabatic contributions owing to b) the convection scheme, c) the cloud microphysics scheme, and d) the boundary-layer scheme are integrated and advected over a 36 hour period

Source: Jeffrey Chagnon

DIAMET flying programme

- Autumn 2011
  - 14-30 September, flying from Cranfield
  - detachment to Exeter 24 Nov – 14 Dec
  - 12 IOPs planned, 4 double and 4 single flights
- July-August 2012
  - Cranfield-based
  - Focus on high-impact rainfall
  - 2 double, 3 single flights

Field campaign: example flight



Pilot flight 3/11/09 overlain on 11UTC radar image.

Strong cold front propagating to SE

Heavy precipitation beginning to break out over England under tropopause fold behind surface front

Heavy precip was not forecast. Case of mid-level destabilisation of convection?

White dots: dropsondes; Pink dot: aircraft location, 11.00

Work Package B
Physical Processes and Parameterisations

- Tracer method applied to moisture in the UM
- Approaches to parameterising mid-level and embedded convection within cyclones
- Air-sea fluxes and impact on storm development
- Distribution of latent heating from microphysical processes (ice and liquid water)
- Improvements to microphysical schemes in idealised model, motivated by new aircraft observations

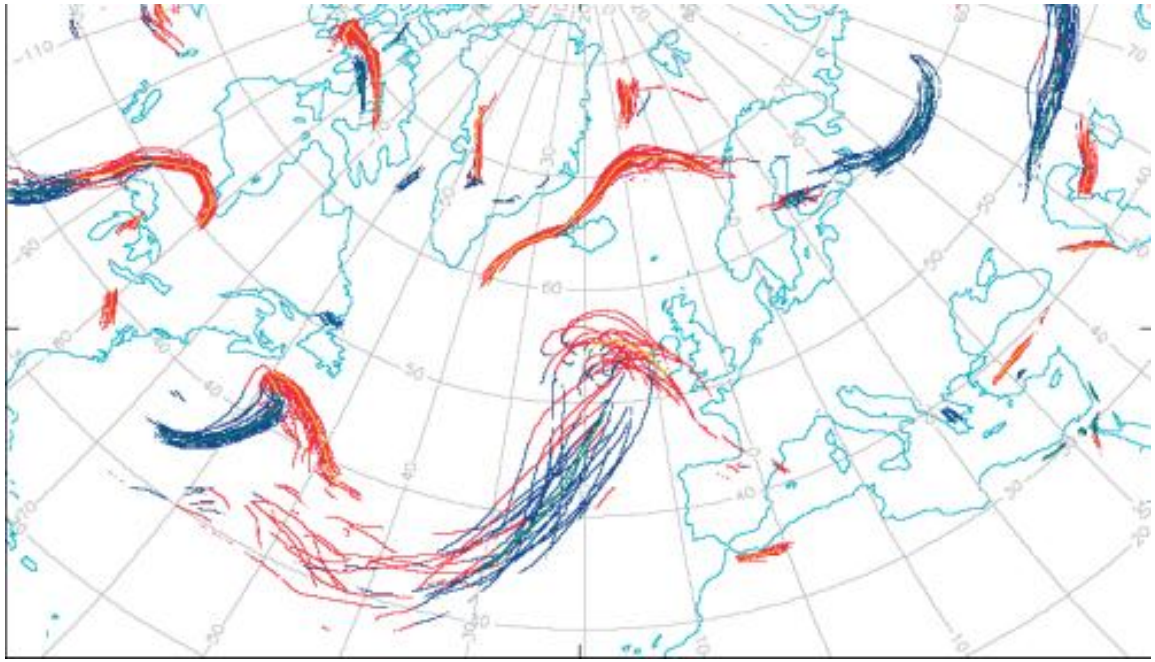
Work Package C
Predictability

Use ensemble forecasts at varying resolution to determine:

- Predictability of mesoscale features within cyclones
- Association of forecast skill for high-impact weather variables (precipitation and high surface winds) with mesoscale features
- Sources of model error on the mesoscale/ convective scale, and error covariance structures
- Alternatives to geostrophic and hydrostatic balance in data assimilation, valid at finer scales (<50km)
- Investigate the benefits of an ensemble 4-D var assimilation system (student project)

WPC1: UKMO Cyclone database

contains feature tracking data for ensemble forecasts dating back to October 2006.



T+36 fronts

RED= warm front
BLUE=cold front

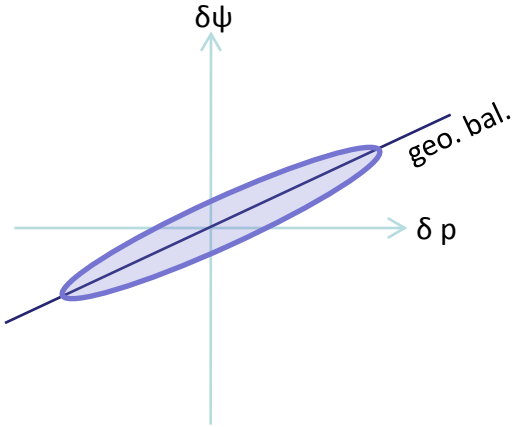
1. How do statistics of mesoscale features embedded within cyclones vary with lead time?
2. How well does the 'best' ensemble member shadow the observed (analysis) evolution?
3. Use this shadow member as initial conditions in high resolution simulations and in determining balance for smaller scales
4. How does the forecast skill for weather variables depend on the skill of forecasts of mesoscale features, stratified by feature type?

C.3: The changing nature of multivariate relations in high-resolution models

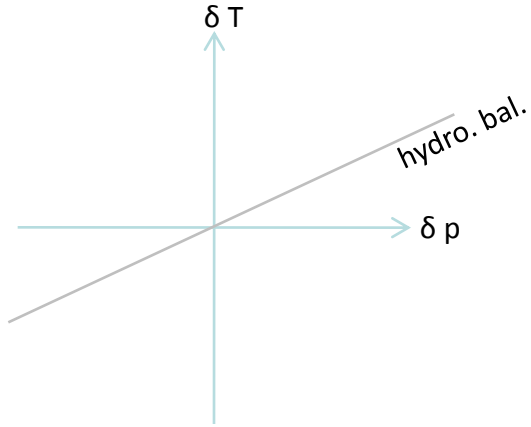
Objective: To use ensembles of forecasts to assess the changing nature of multivariate relations at high-resolution and to understand their sensitivity to different sources of error (initial and boundary conditions, and model error), and study the feasibility of incorporating these relations in operational data assimilation systems.

Conventional variational data assimilation assumes certain 'balances' in the forecast error stats (and hence analysis error stats) …

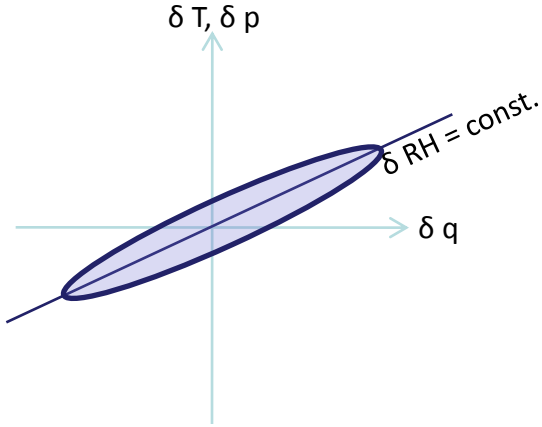
Weak geostrophic balance



Strong hydrostatic balance



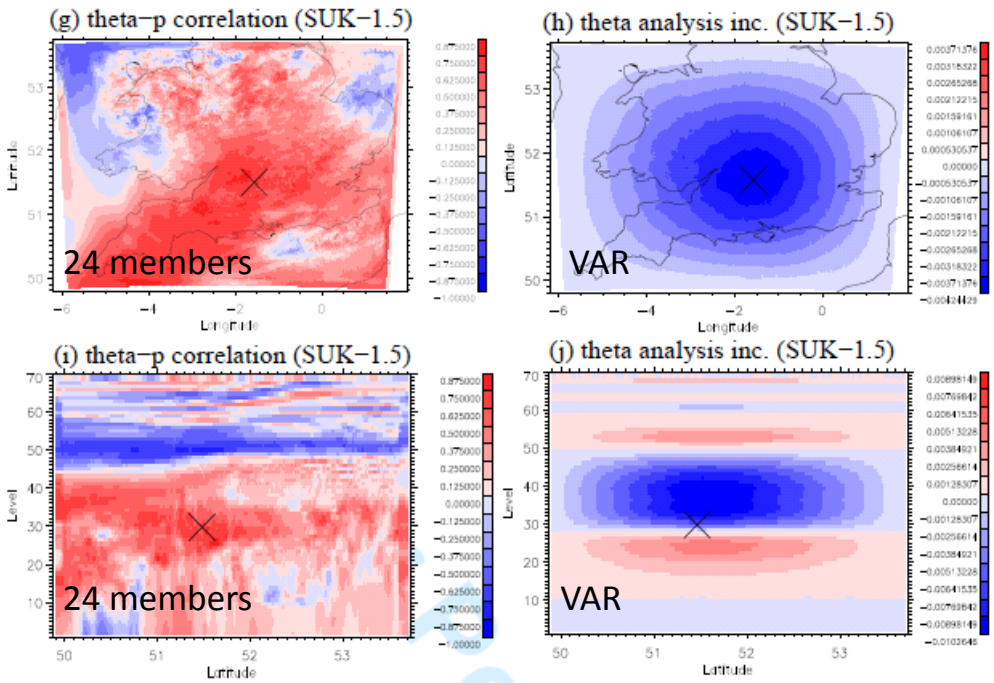
Moisture assumptions



Source: Ross Bannister

Many of these balances break down at small-scales

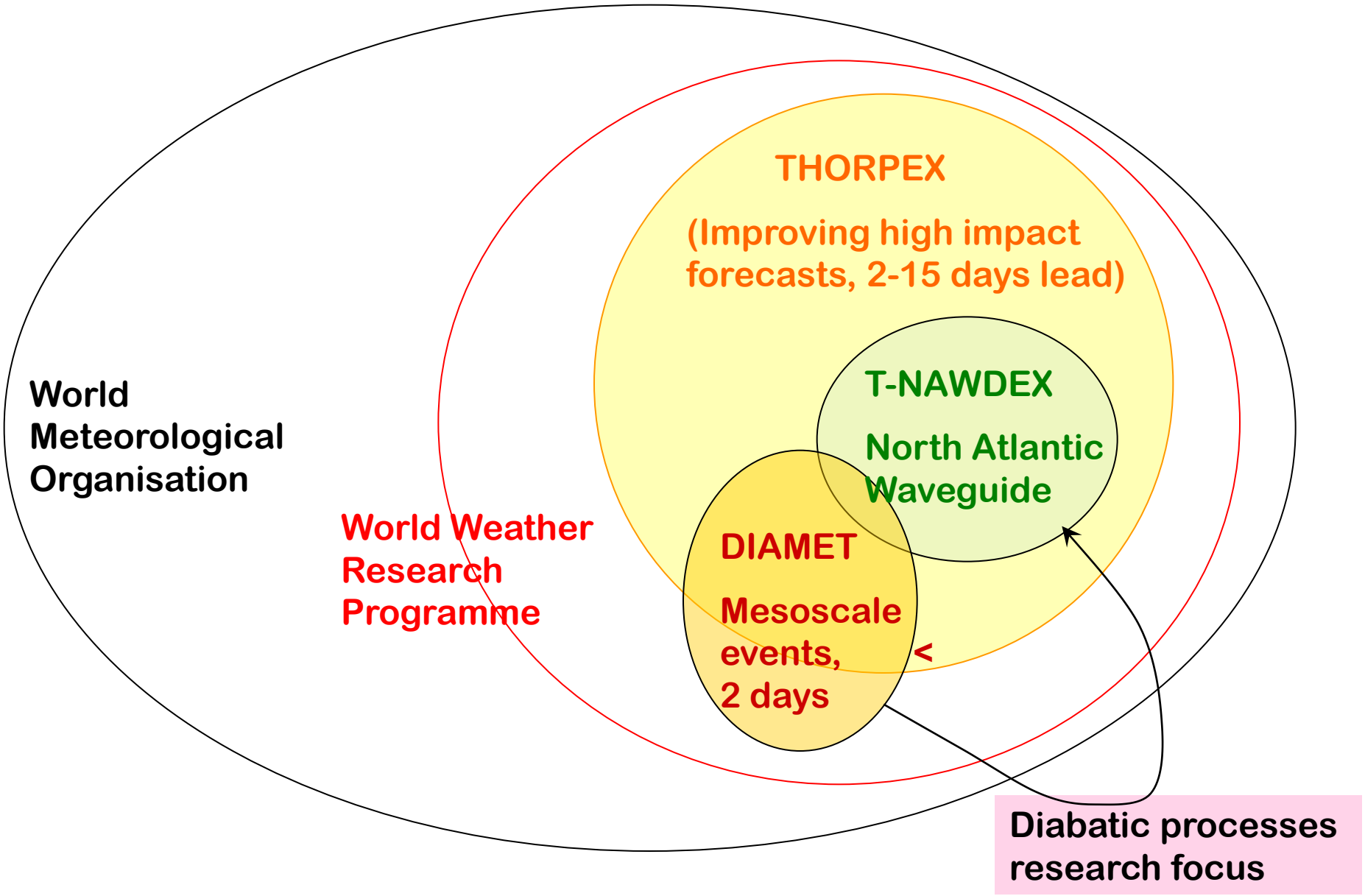
- This approach assumes that for analysis increments (e.g.):
  - all rotational wind is in geostrophic balance,
  - all pressure is in hydrostatic balance with temperature.
- These effects show-up especially at small scales (large Ro).



1. What scales do geostrophic and hydrostatic balances break down?
2. Do the moisture assumptions hold?
3. Can these assumptions affect accurate forecast of storms?
4. How valid is anelastic balance?
5. What is the role of each source of error (init. cond. err, model err. – strong connection with C.2)?
6. What is an alternative model of forecast error stats valid for hi-res models?
7. How robust are these statistics?

Source: Ross Bannister

Partnership with Met Office

- Participation in field campaigns (staff time, dropsondes, extra instruments)
- Data assimilation at high resolution and new data streams
- Surface fluxes, microphysical parameterisation and access to high resolution forecasts
- Radar group– high resolution radar data
- Microphysical parameterisation
- Ensemble Forecasting Group - feature tracking and forecast skill
- Data Assimilation Group - co-supervision of studentship and DA experiments on Met Office computer.

International Collaboration