WRF and Application to Dymecs

Raizan Rahmat , Ralph Burton, Alan Gadian,

National Centre for Atmospheric Science (NCAS),
School of Earth and Environment, Leeds' University.

plus contributions from

James Groves, Victoria Smith, Daniel Walker and a host of others.

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- **Summary and conclusions.**

Weather Research and Forecasting Model (WRF)

- Used for research and operational forecasting (adopted by Met. Agencies of China, India, Korea, USA, ...)
- Approximately a third of the world's population get their weather forecast from WRF
- Developed by NCAR, NOAA, AFWA, NRL, etc. etc.
- Open source and supported for almost all countries

Used for:

- Atmospheric physics / parameterisation research
- Case-studies
- Real-time NWP
- Global simulations
- Idealised simulations (convection, orographic flow, etc.)
- Data assimilation

Courtesy NCAR/MMM

Advantages of WRF:

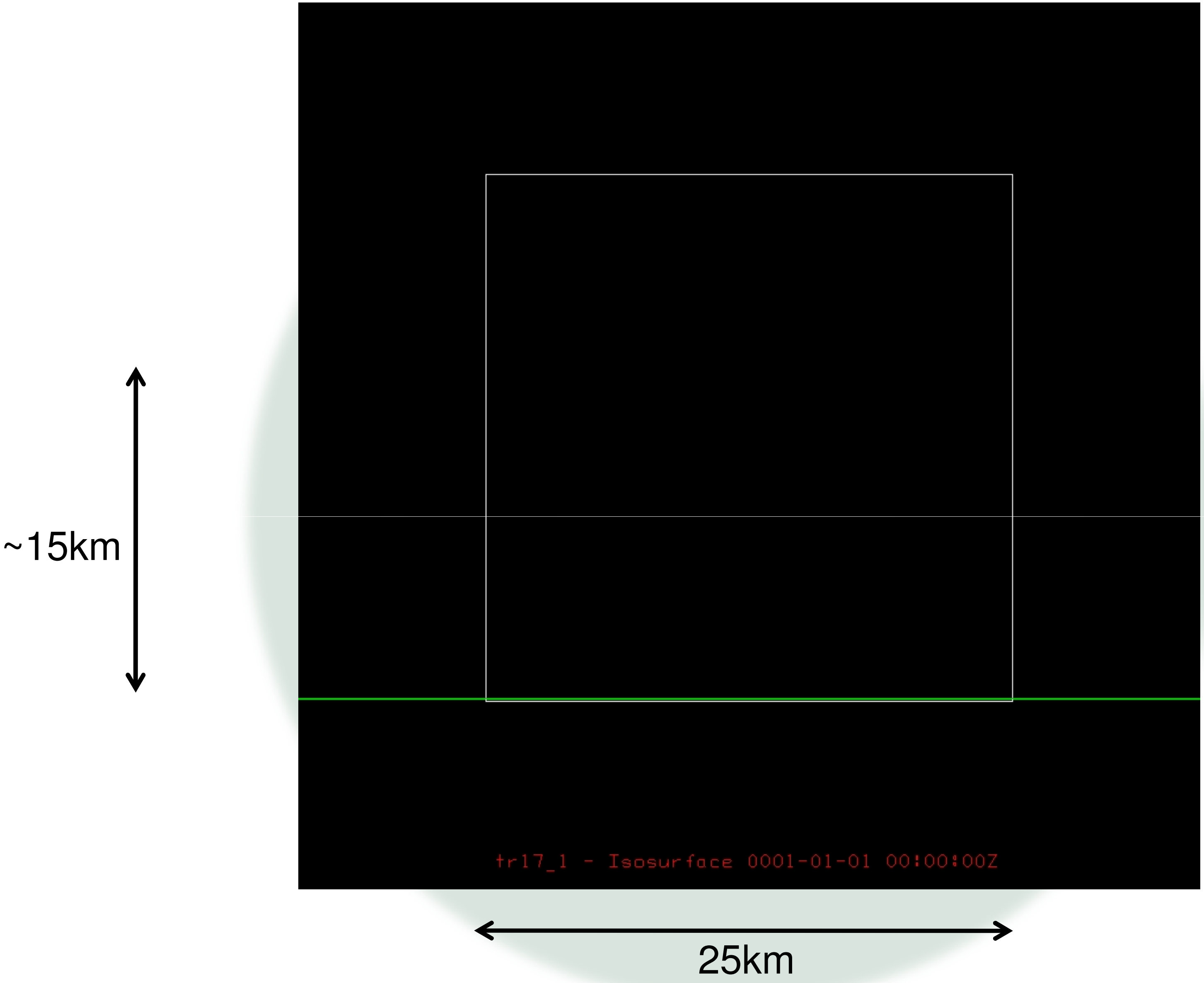
- Easy to learn how to use
- Easy to set up new cases
- Initialisation data easy to acquire
- Written in Fortran/Fortran90
- Wide community support
- Free!

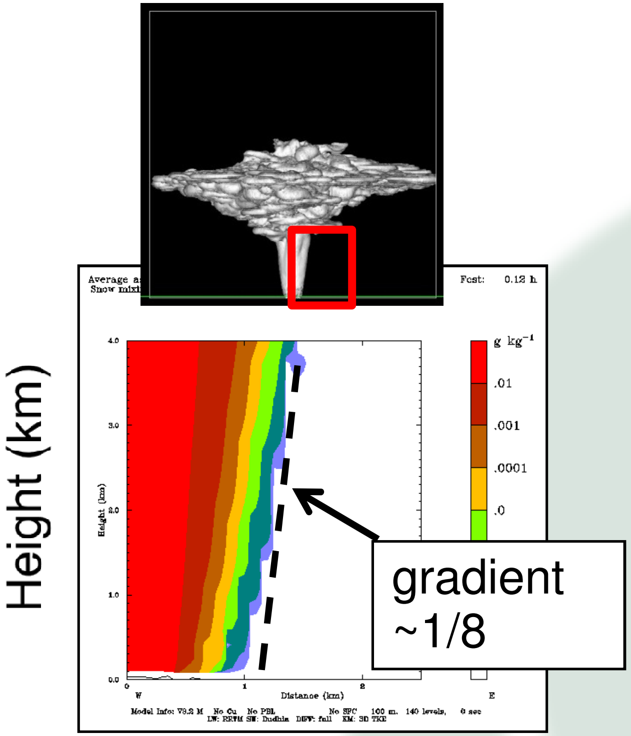
Extreme convection: WRF volcano plume model

WRF configuration: 100m resolution (25km x 25km), 141 vertical levels, 30km top

- Resting atmosphere – U.S. Standard atmosphere; dry;
- Different thermal perturbations at “vent”; order of ~ 100K (requires 0.1s timestep)
- Tracer released at “vent”
- “Circular” vent
- Results look like plumes, but -
- Do they follow various theoretical models of plume behaviour?

Aspect ratio = 1:1



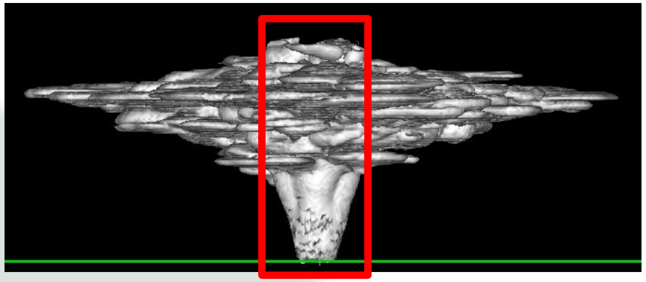


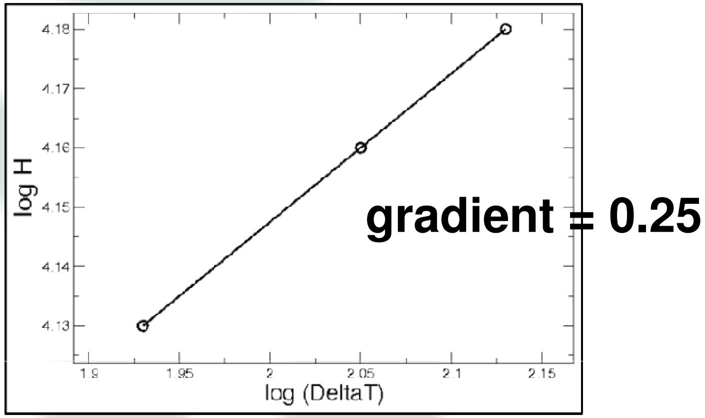
$b = (6/5)\alpha z,$

b = radial lengthscale
α = entrainment constant

$\alpha = 0.10$ (from Turner 1978)

gives $b \sim z/8$
Turner, *Buoyancy effects in Fluids*



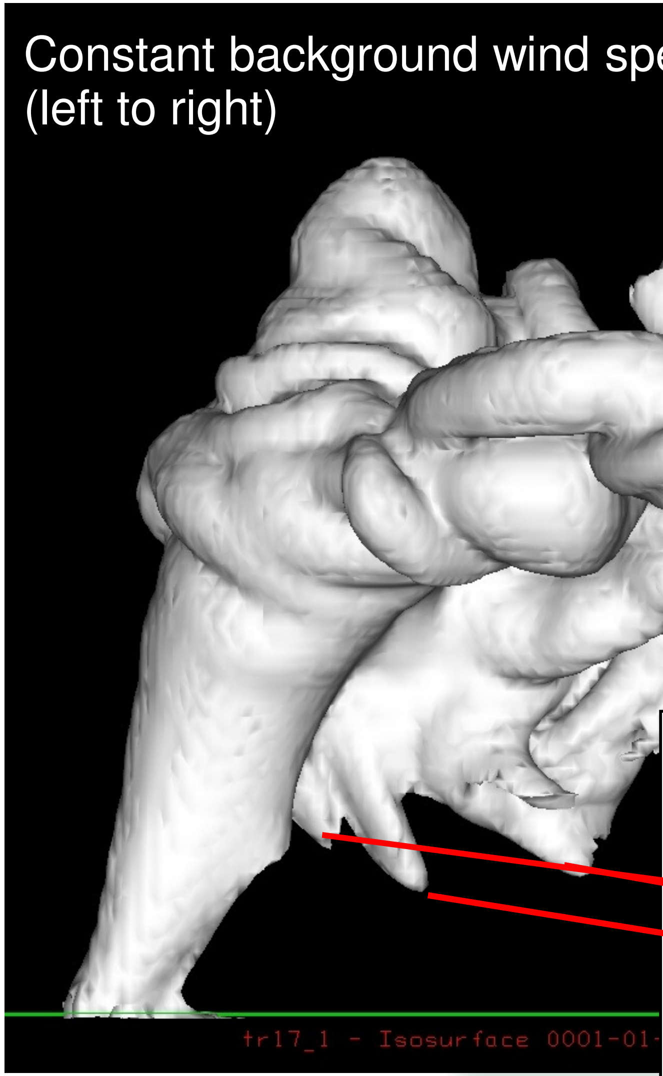


$$H \sim (F_0/\rho_0)^{1/4} N^{-3/4}.$$

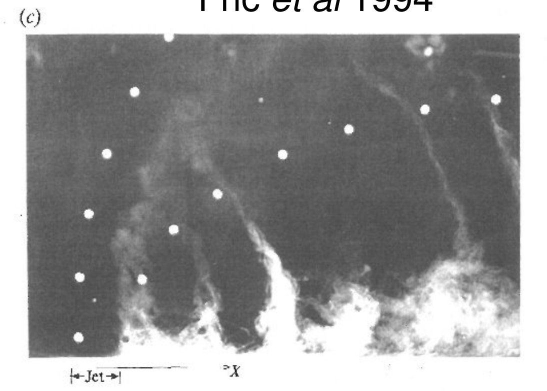
$$\frac{F_0}{\rho_0} = \frac{g}{\rho_0}\left(\frac{\rho_e - \rho}{\rho_0}\right) Q_0 \approx \frac{g}{\rho_0}\left(\frac{T - T_a}{T_a}\right) Q_0,$$

Theory courtesy Mark Woodhouse

Constant background wind speed of 10m/s (left to right)



Fric *et al* 1994



When plume is bent over, “tornado”-type structures can be produced near to plume centreline

Depends upon V/V_j

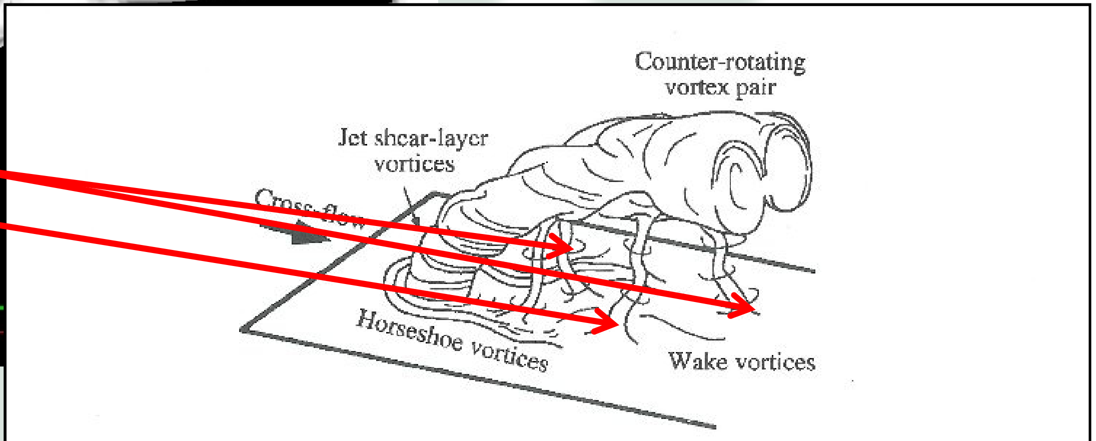
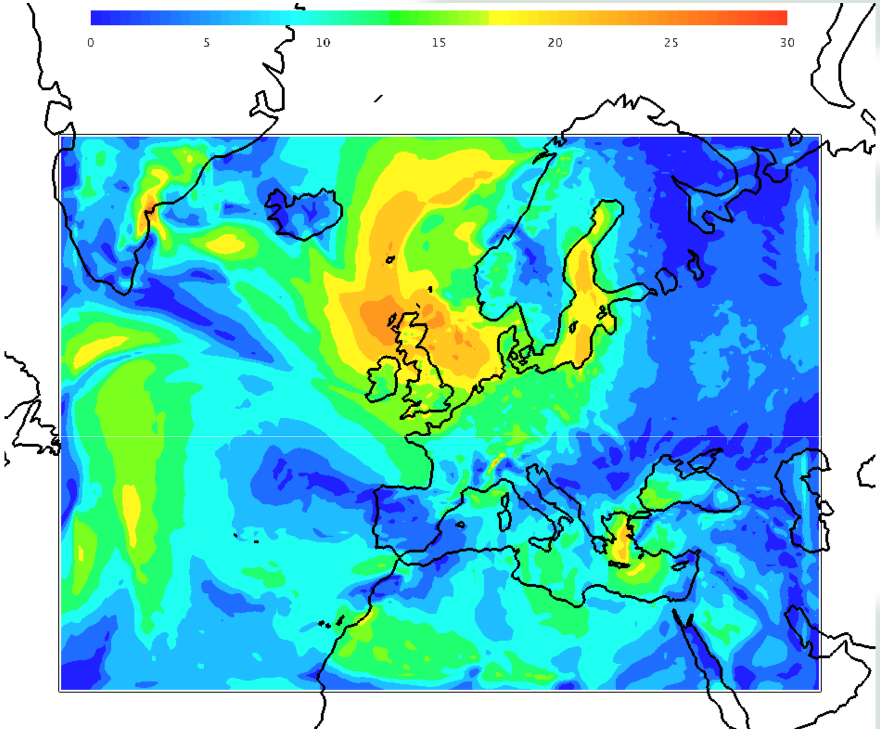


Figure 11.10 Diagram showing four types of vertical vortical structures developed by interaction of a plume or jet with a cross-flow (after Fric and Roshko 1994)

Land-based Renewables Project: downscaling ERA40 data to determine the effect of climate change on crops (willow, miscanthus).

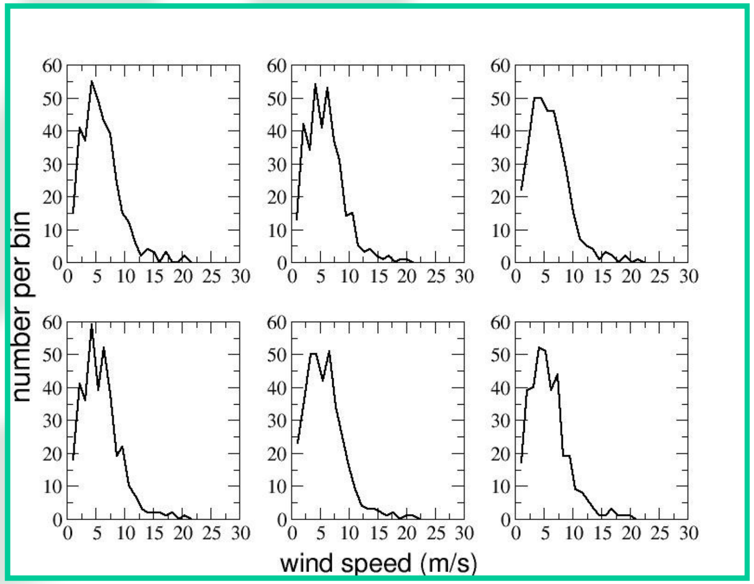
Test case for Dec. 1961-Feb. 1962



Outer domain windspeeds during Feb. 1962 storm (9km resolution). 110,000 houses damaged in Sheffield. ***WRF captures storm very well.***

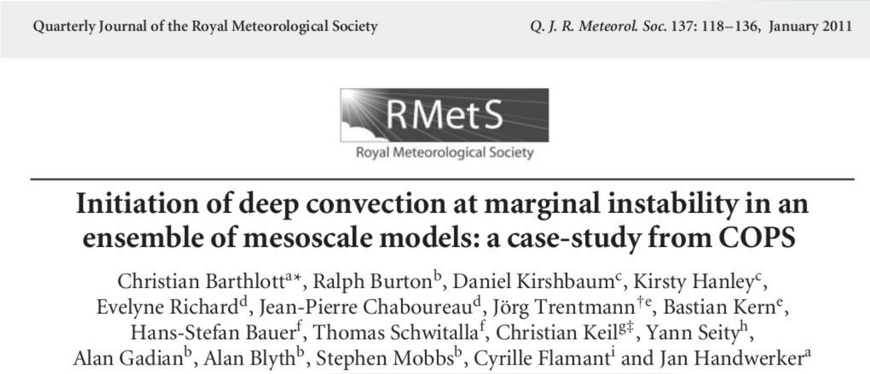
Inner domain (#3 of 3) – 1km resolution

Modelled distribution of wind speeds Dec. 1961 – Feb 1962 for 6 AWS sites in Yorkshire, ~6km apart. N.B. different distributions.



Storm seen in tail of distributions

Modelling of deep convection: COPS case study



Quarterly Journal of the Royal Meteorological Society Q. J. R. Meteorol. Soc. 137: 118–136, January 2011

Initiation of deep convection at marginal instability in an ensemble of mesoscale models: a case-study from COPS

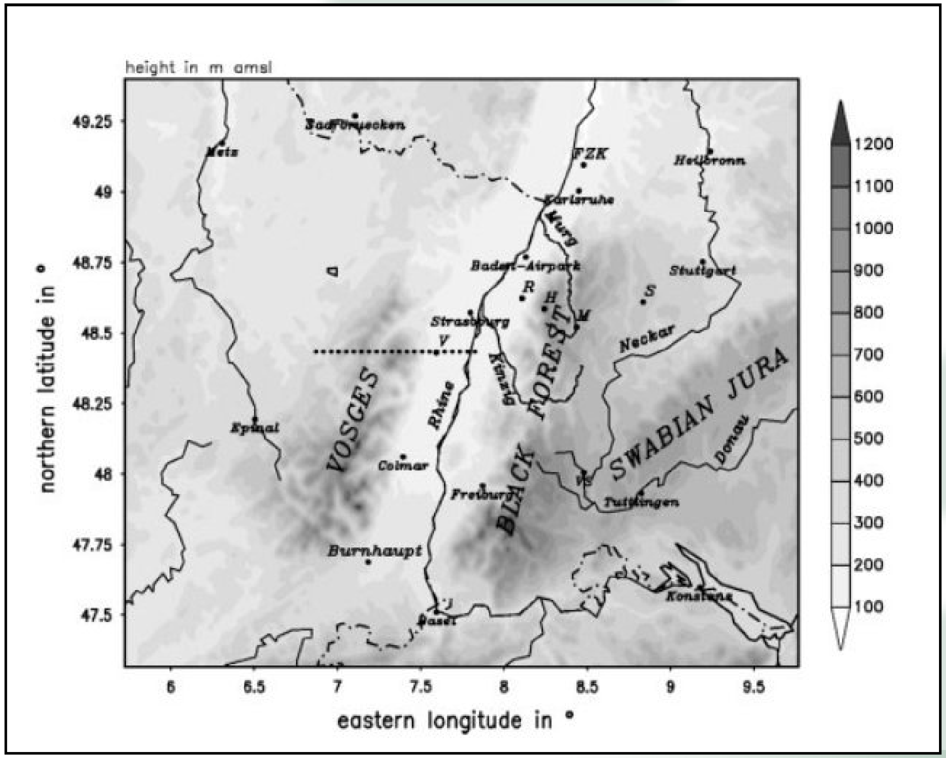
Christian Barthlott[a*], Ralph Burton[b], Daniel Kirshbaum[c], Kirsty Hanley[c], Evelyne Richard[d], Jean-Pierre Chaboureau[d], Jörg Trentmann[†e], Bastian Kern[e], Hans-Stefan Bauer[f], Thomas Schwitalla[f], Christian Keil[g‡], Yann Seity[h], Alan Gadian[b], Alan Blyth[b], Stephen Mobbs[b], Cyrille Flamant[i] and Jan Handwerker[a]

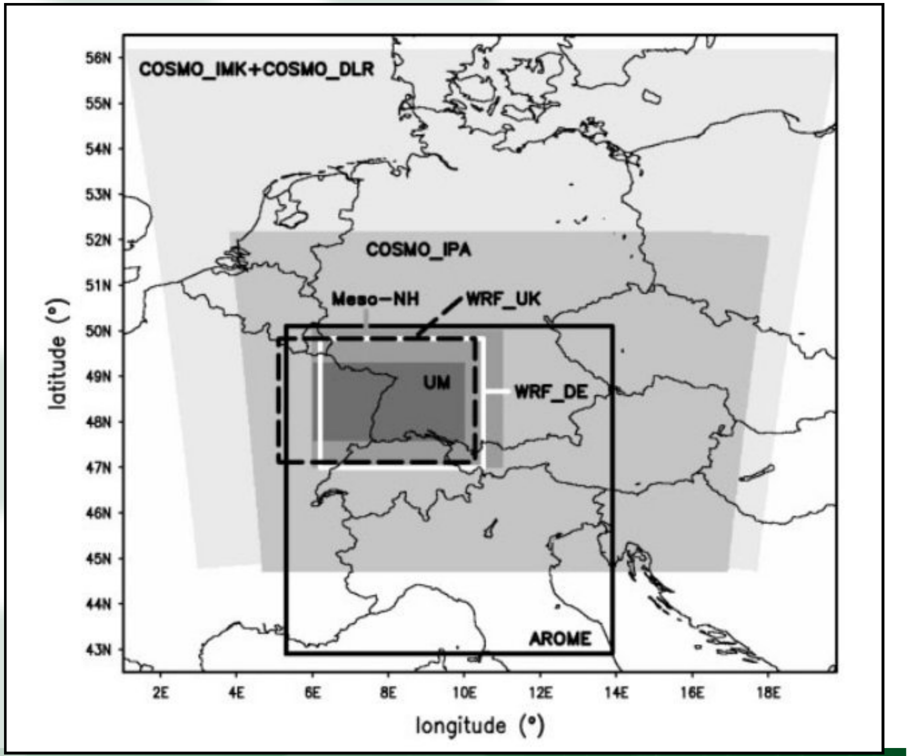
WRF: 2 domains

3.6 & 1.2km resolution,

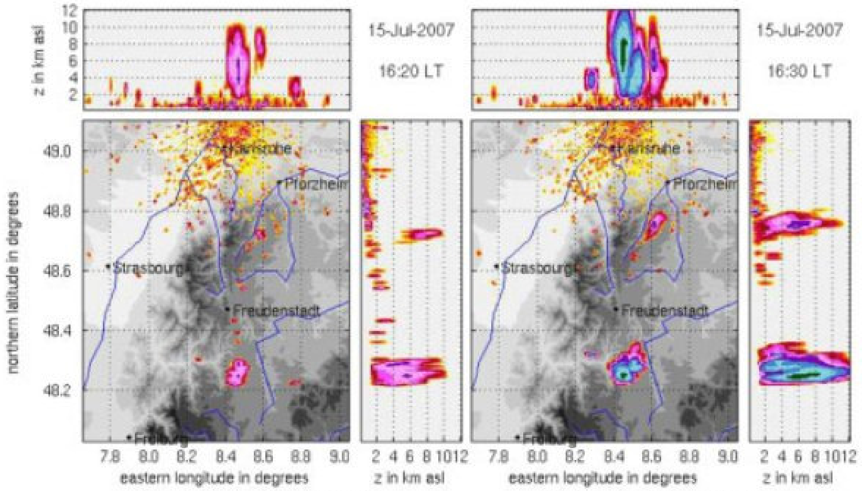
2-way feedback

50 vertical levels

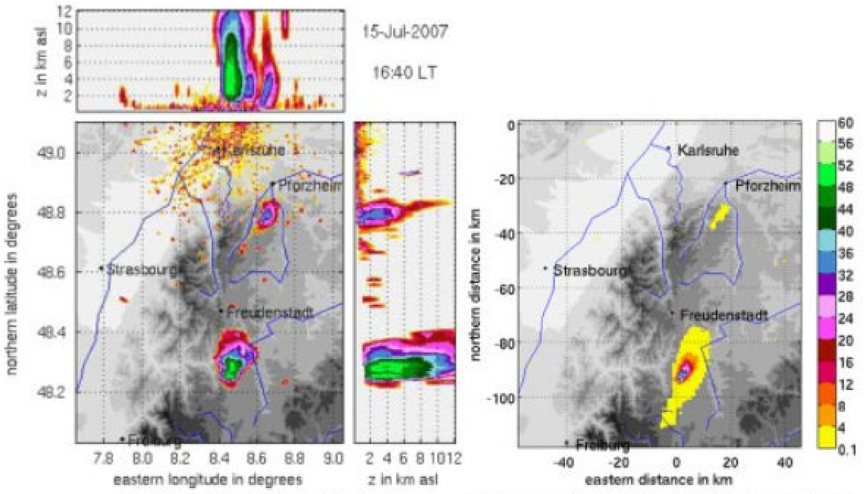




Observations: radar reflect.

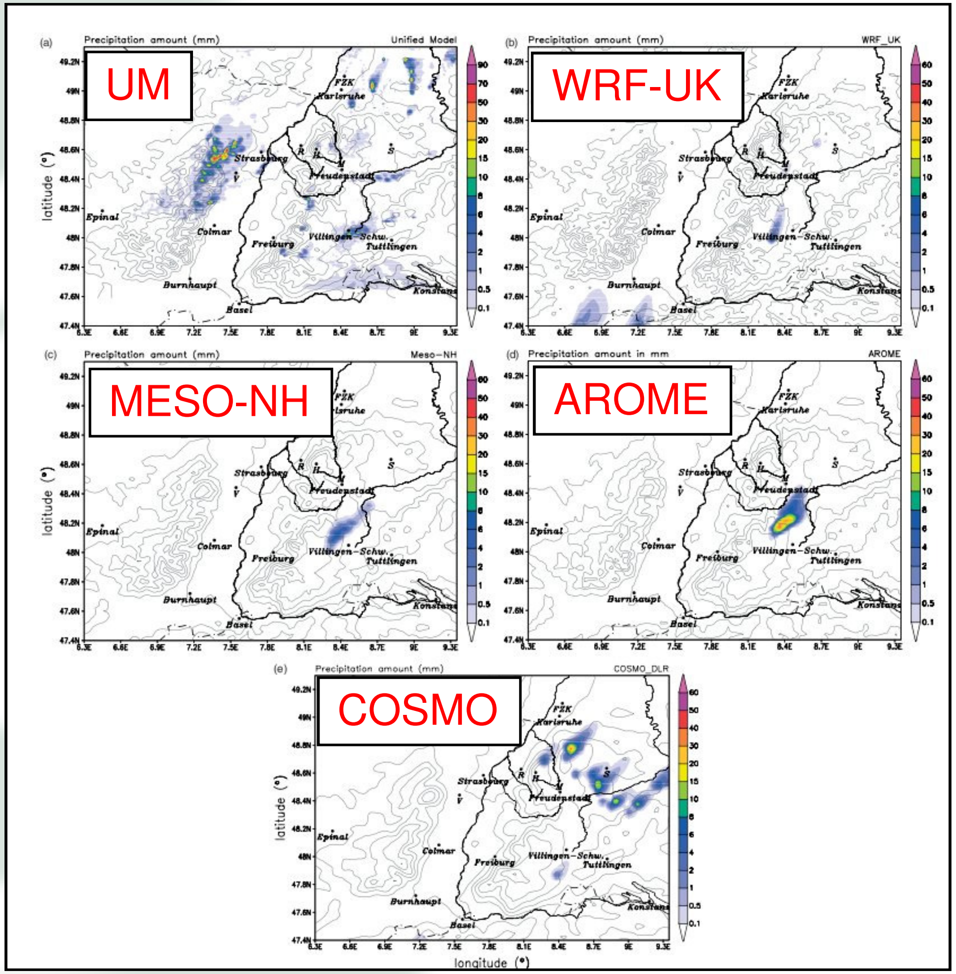


(a) Radar reflectivity 1420 UTC (b) Radar reflectivity 1430 UTC



(c) Radar reflectivity 1440 UTC (d) Radar-derived 24 h accumulated precipitation

Models: precip. amount



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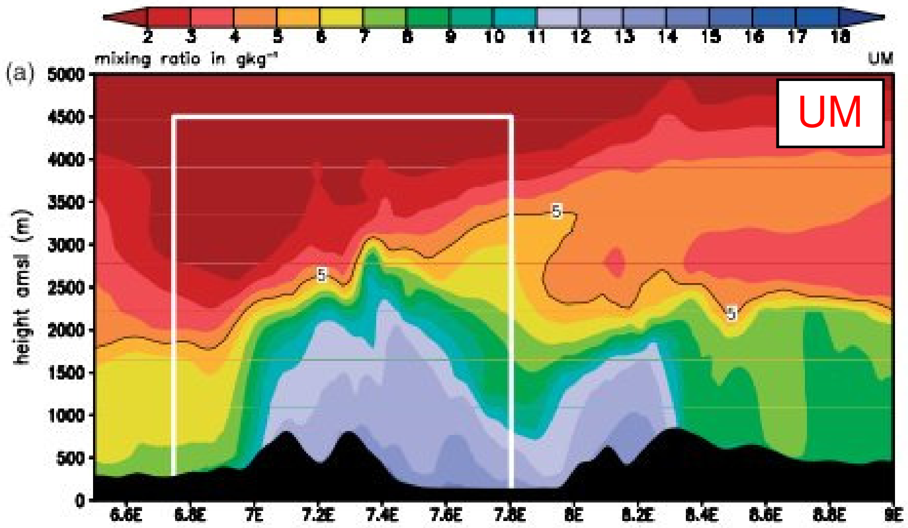
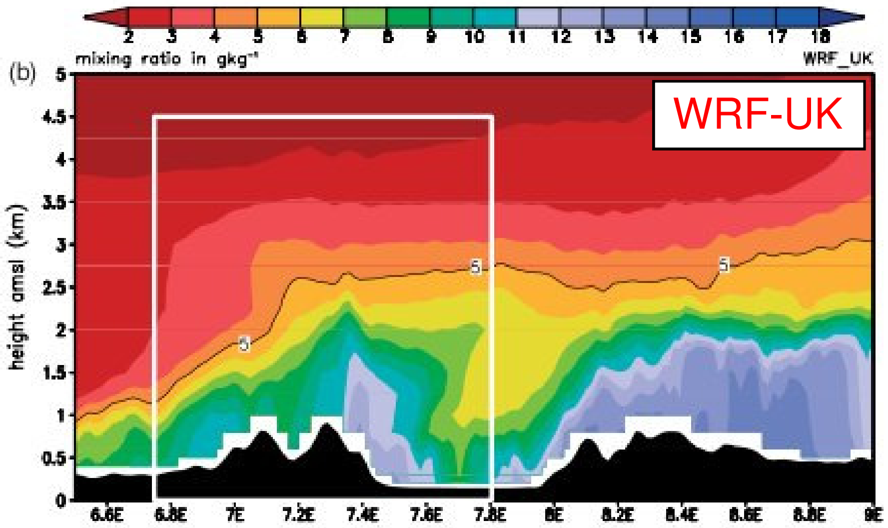
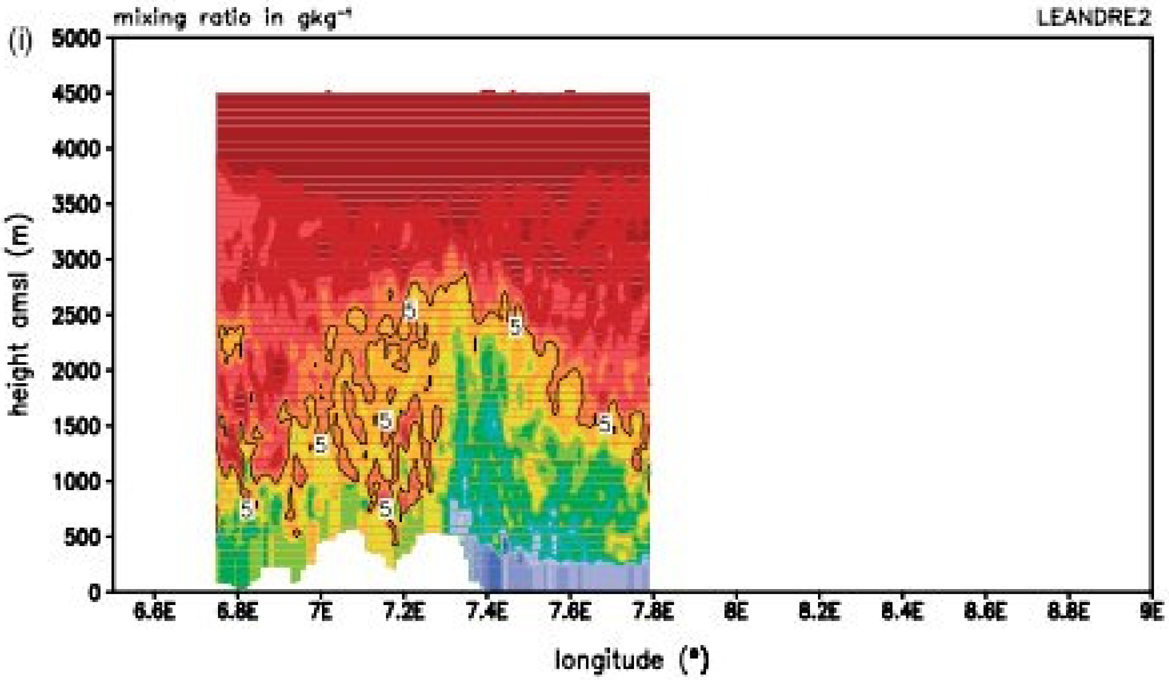




Mixing ratios:

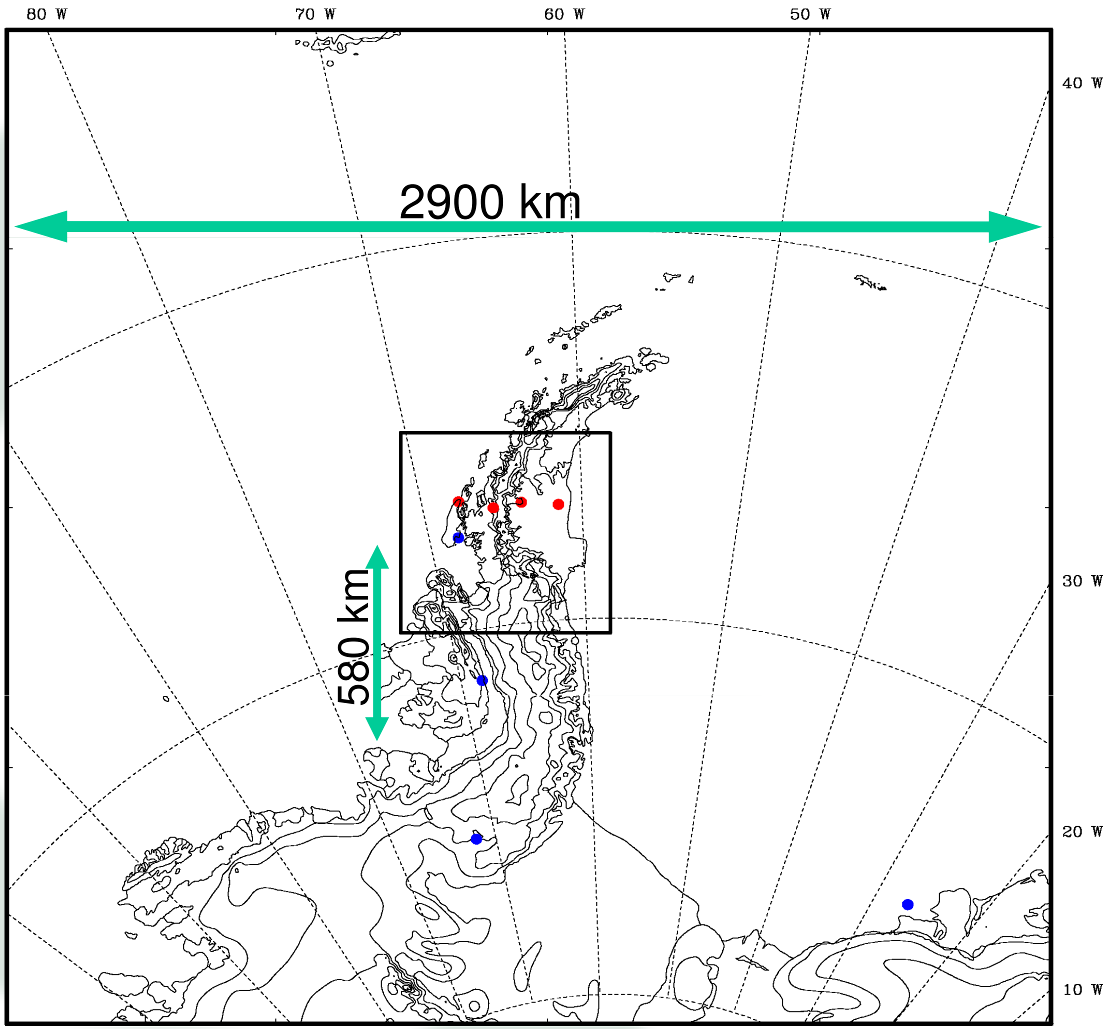
Models

Observation



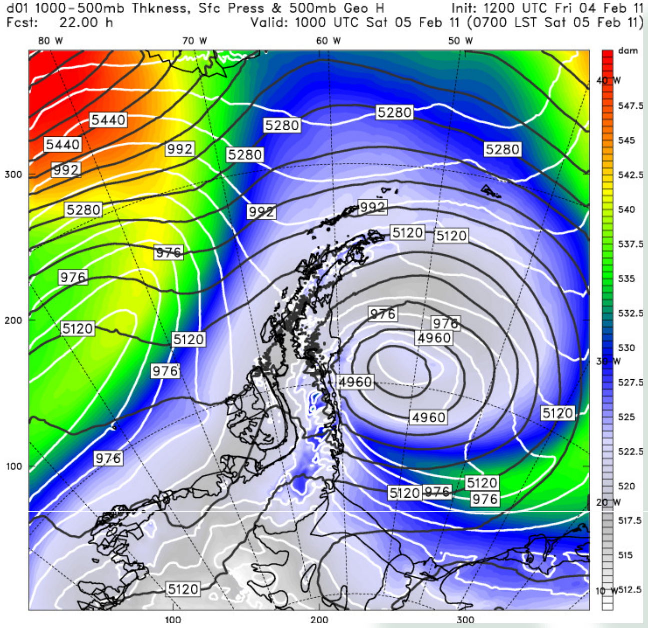
WRF Model Setup

- WRFV3.2
- 2 Domains
- d01 – 7.5 km resolution
- d02 – 1.5 km resolution
- 90 vertical levels
- Δz 64 m (surface)→ 370 m (top)
- Polar WRF configuration
- Fractional sea ice
- Seasonal sea ice albedo
- Optimal surface energy balance & heat transfer for permanent / seasonal ice
- Initial and boundary conditions from 6hr 0.5° GFS analysis / forecast

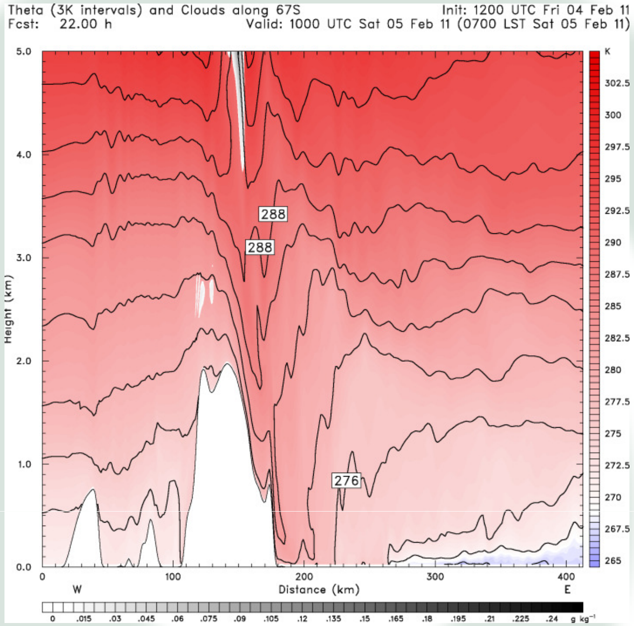


Run using 144 cores on Leeds University cluster ARC1. 12 hours wall time achieved 60 hr forecast from 12 UTC each day. Effective forecast was therefore valid until 18 UTC of today + 1 during morning planning meeting.

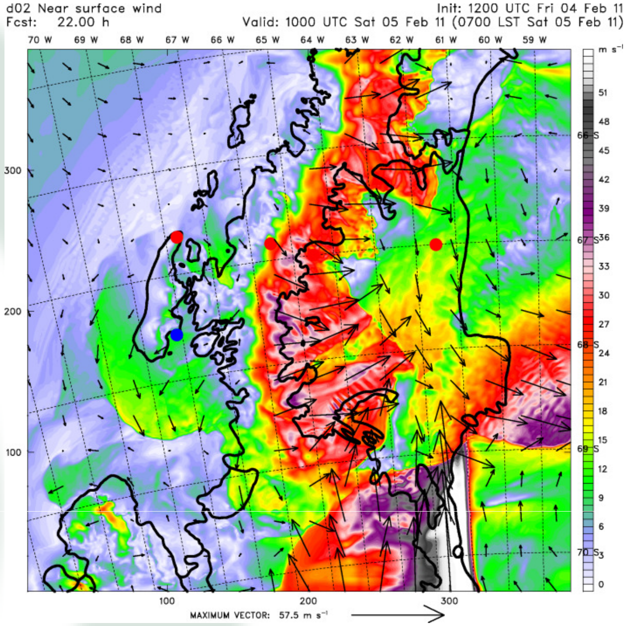
Westerly flow over case – 5th Feb 2011, 2 research flights undertaken



1000-500 hPa thickness, surface pressure and 500 hPa height. Isobars suggest westerly cross-peninsula flow across 67°



Contours of potential temperature show high θ air plunging down the lee (eastern) side of the Antarctic Peninsula at 67 ° S. Textbook case of a warm (and dry) Föhn downslope wind removing cold stable air over Larsen ice shelf and generating ΔT of 6K across Peninsula



Near surface wind speed and direction show the increased strength of winds co-located with orography and glaciers .
We did however find that WRF mostly overestimated the strength of winds.

Intro Summary

- WRF has been run at variety of scales (100m to several kms)
- Reproduces theoretical concepts of volcanic plume behaviour
- Reproduces well a case of isolated deep convection, with caveats:

- Modelled results very sensitive to choice of BL scheme (**MYJ** scheme needed to get deep convection)
- Modelled results very sensitive to choice of land surface scheme (**NOAH** scheme needed to get deep convection)

Uniweather ---- website

This teaching tool is operating daily.

http://ncasweather.ncas.ac.uk

Demonstration of:

(a) Precipitation
(b) Skew T
(c) Radar Reflectivity

Dymecs

Two domain set up for the Dymecs project.

Preliminary model configuration:-:

Outer and inner domains.

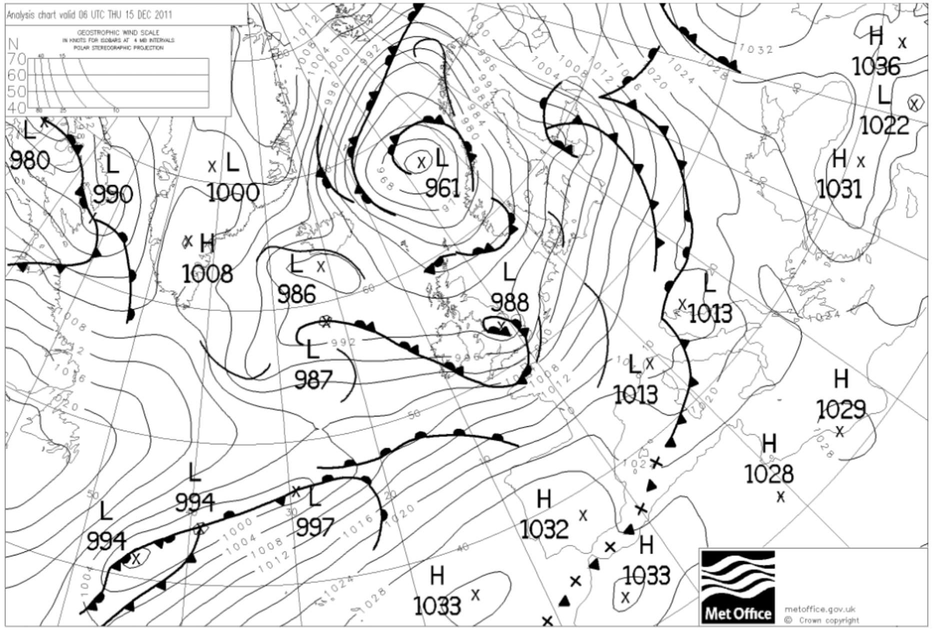
Outer domain nx=ny=181 and dx = 2.16 km resolution

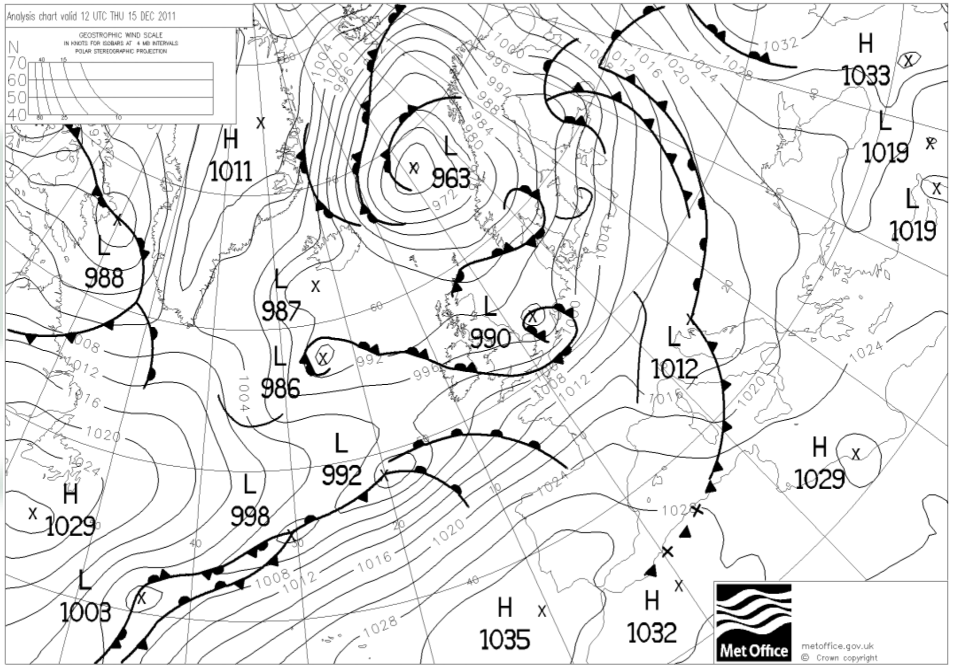
Inner domain with nx=ny=121 and dx = 432 m resolution.

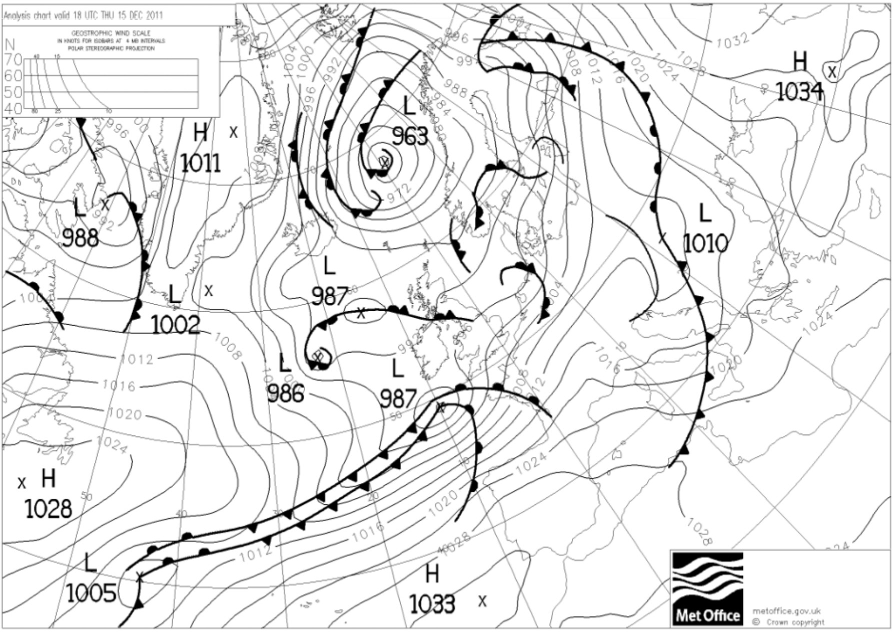
nz = 51 levels, a stretched vertical grid

The Chilbolton radar is horizontally to the right of the centre (51.7N, -3.0E) of the outer domain. The designs of the two domains are such that it is aimed to correspond to a westward looking radar.

- The WRF model run will be initialised using the Global Forecast System (GFS) model's 0.5 deg analyses data.
- The model start time will be at 06 UTC and it will run for 36 hours. Tests have shown that the process will take approximately 12 hours to complete. (48 core machine). The runs will start at noon, day 1 allowing enough spin-up time for the physical processes of interest.
- The physics and dynamics options are modelled after the UniWeather system, and for a start the following configurations will be used: Morrison Double-moment scheme for the microphysics, Eta Similarity scheme for the surface layer physics, Mellor-Yamada-Janjic scheme for the planetary boundary layer physics, Noah Land Surface Model for the land surface physics, and none for the cumulus physics so as to explicitly resolve the convective processes. Other setups will be used, if necessary, as the work progresses.







15th December Met Office Surface analysis charts.

06:00Z Top left
12:00Z. Top right
18:00Z. Bottom left

Application to Dymecs: Setup and Results
14th December 2011

Demonstration of:

(a) Weather Maps
(b) Precipitation
(c) Radar Reflectivity

link

Discussion.

- Domain sizes
- Resolution and horizontal extent
- Diagnostics. What can be shown
- An outer domain at 10.8km would be of advantage.

Practicalities

- Can it be run for DYMECS?
- Is it of use?
- What can be achieved?

Questions please?