(Very) High Res NWP

ECMWF High-resolution modelling developments
(inputs: Nils Wedi, Mats Hamrud, George Mozdzynski, Jean Bidlot, Geir Austad, Sinisa Curic)

Current and planned resolutions:

IFS model resolution	Envisaged Operational Implementation	Grid point spacing (km)	Time-step (seconds)	Estimated number of cores[1]
T1279 H[2]	2010 (L91) 2013 (L137)	16	600	1100 1600
T2047 H	2014-2015	10	450	6K
T3999 NH[3]	*2020-2021*	*5*	*240*	*80K*
T7999 NH	*2025-2026*	*2.5*	*30-120*	*1-4M*

1 - a gross estimate for the number of 'Power7' equivalent cores needed to achieve a 10 day model forecast in under 1 hour (~240 FD/D), system size would normally be 10 times this number.

2 – Hydrostatic Dynamics

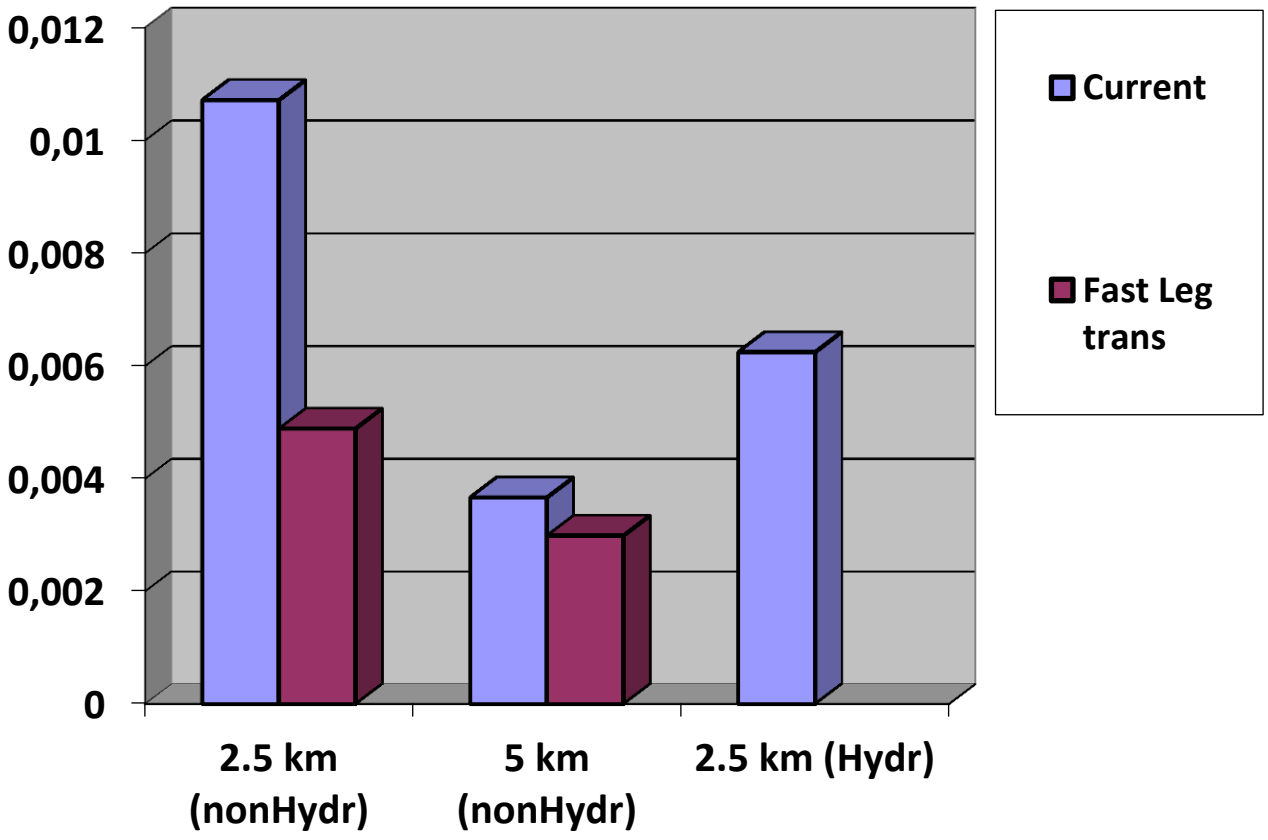
3 – Non-Hydrostatic Dynamics

More speculative: extrapolated capability more than firm plans

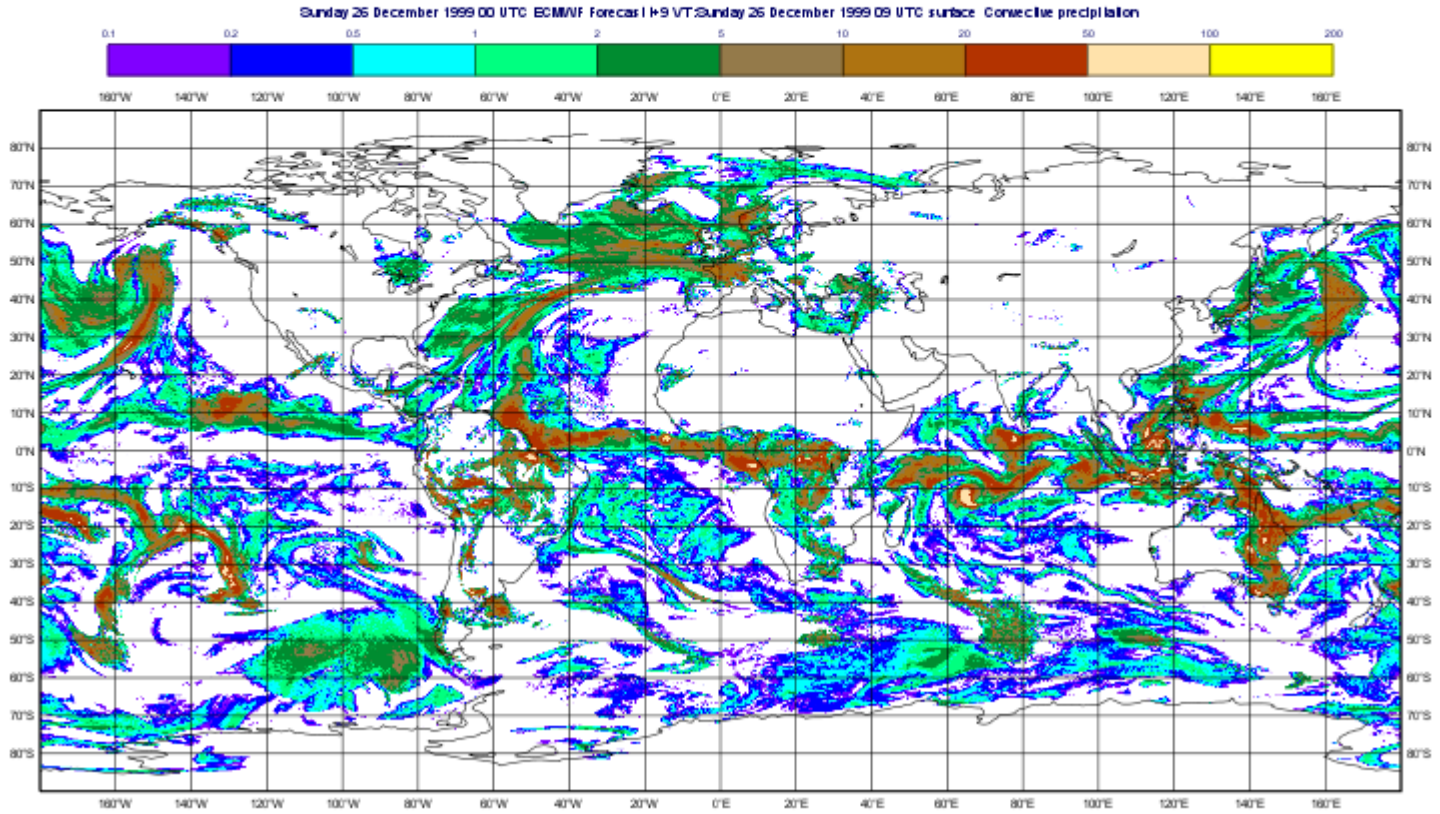
(Wall-clock comp cost)*(N_{ref}/N)^2 in ms

for spectral transforms, 1h simulation

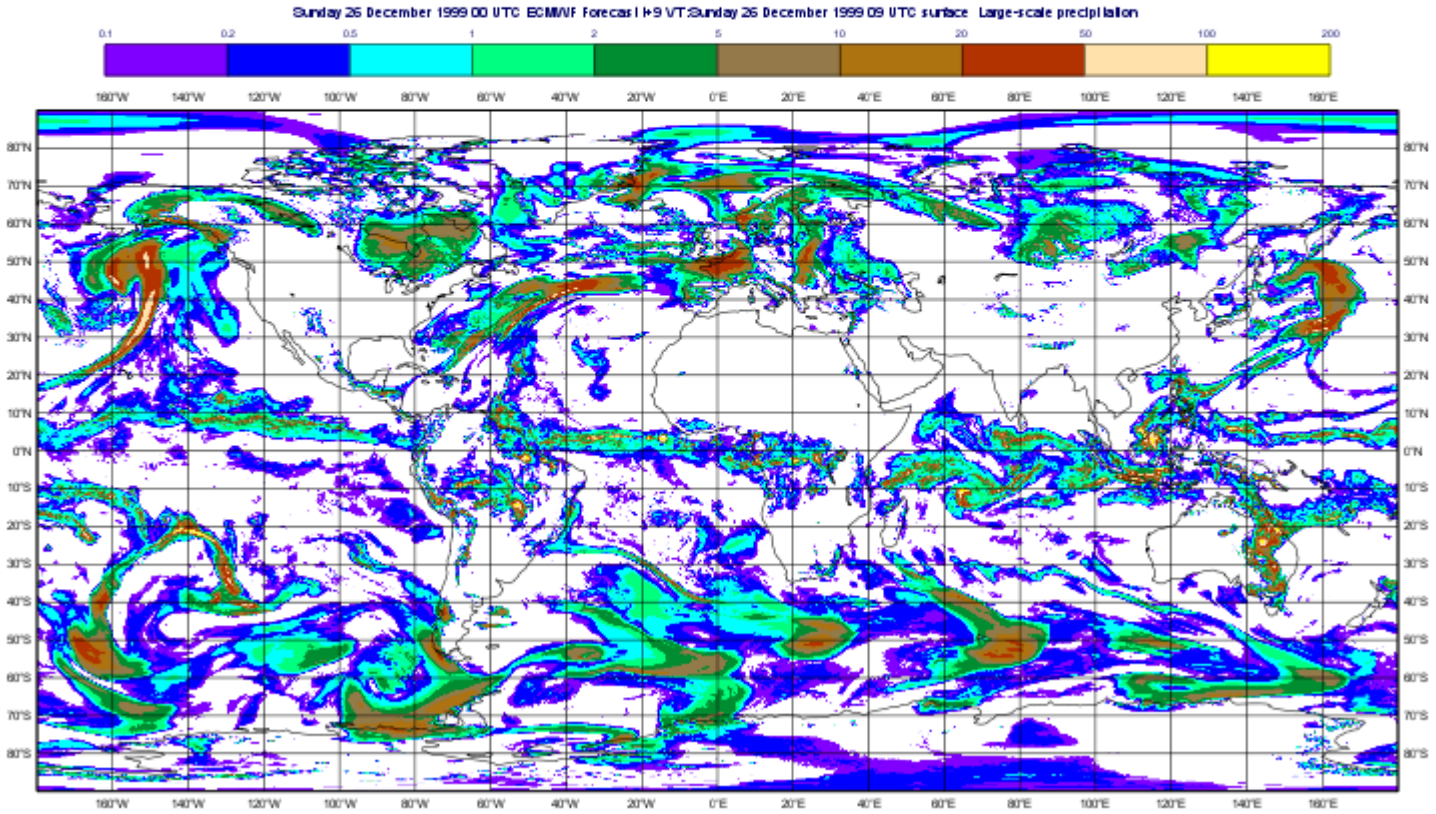
N truncation limit



T1279 convective precipitation



T7999 large-scale precipitation
(ran without deep convection parametrization)



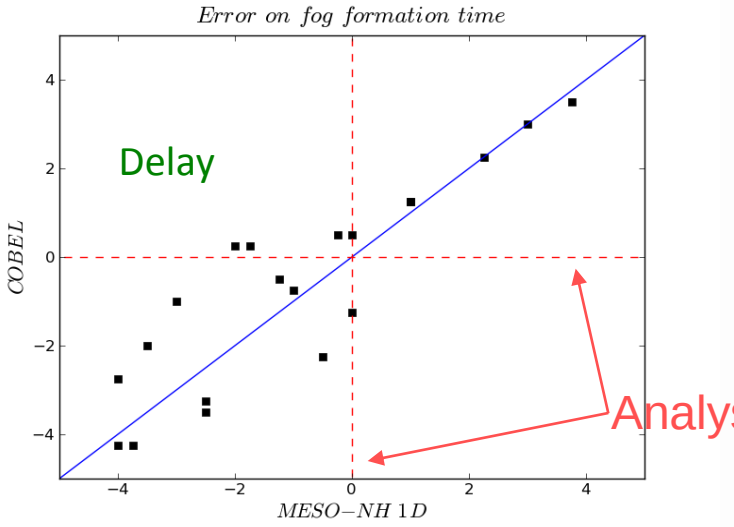
Summary

- Fast Legendre transform is effective.
- Enabled 10-day forecasts at T3999 (~5km)
- Enabled 1st global, convection-permitting, non-hydrostatic IFS forecasts at T7999 (~2.5km)
  - Spectral technique still viable
- Future work:
  - Towards a cheaper non-hydrostatic option
  - Towards a more flexible software infrastructure
  - Vertical discretization aspects and stability
  - Is it technically possible to create a Reduced Gaussian Grid at T20000 (~1km) ?
  - Learn from the Gung-Ho project

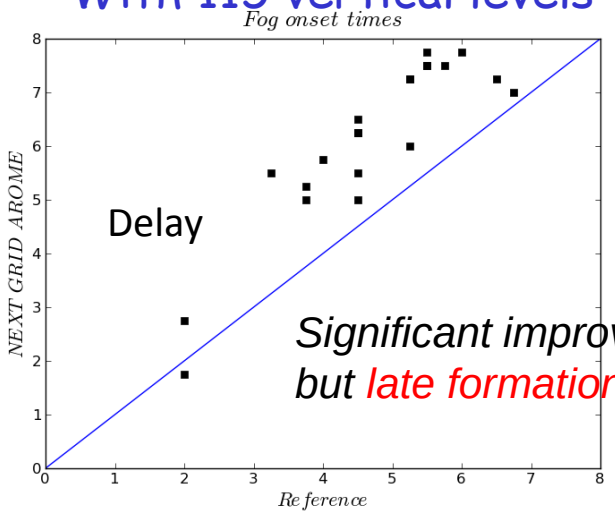
Vertical resolution (fog forecasting)

COBEL (Bergot et al., 2005): 1D oper model for FOG forecast on airports.
Characteristics: - Very high vertical resolution (1st level : 25cm)
- Local assimilation scheme
- Physics adapted to fogs (but warm 1-moment microphysics)

Evaluation of AROME/Méso-NH 1D on radiative fogs on CDG airport for 2 winters :



With 115 vertical levels

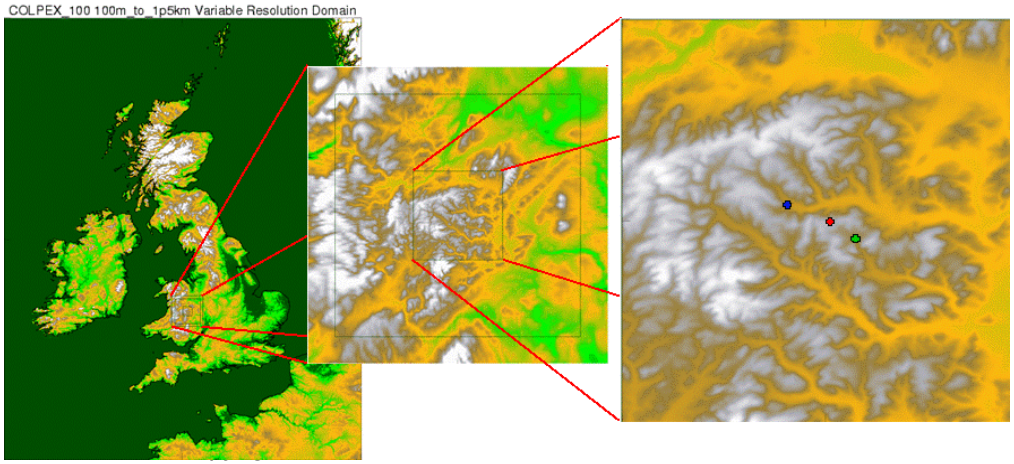


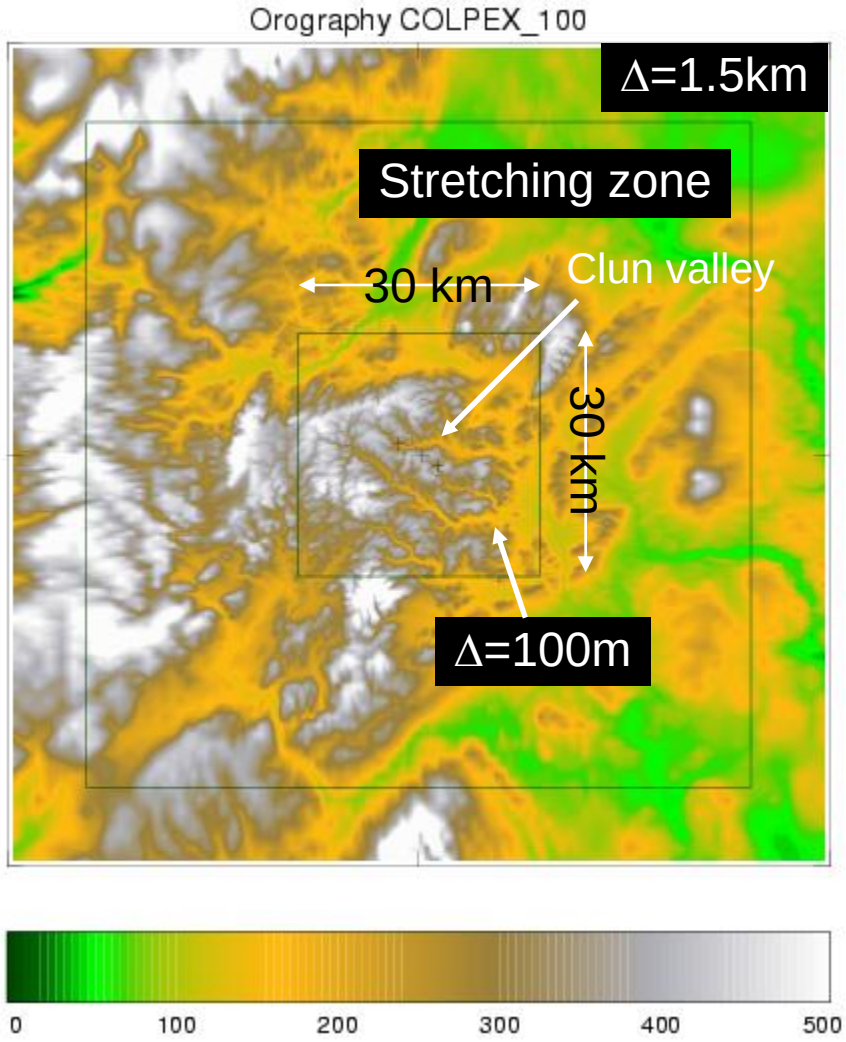
REFERENCE = COBEL GRID

⇒ Same vertical resolution (COBEL grid) and same surface scheme (7 vertical levels) are the the two most important ingredients to include in AROME/Méso-NH 1D to have a comparable fog forecasting skill than COBEL model.

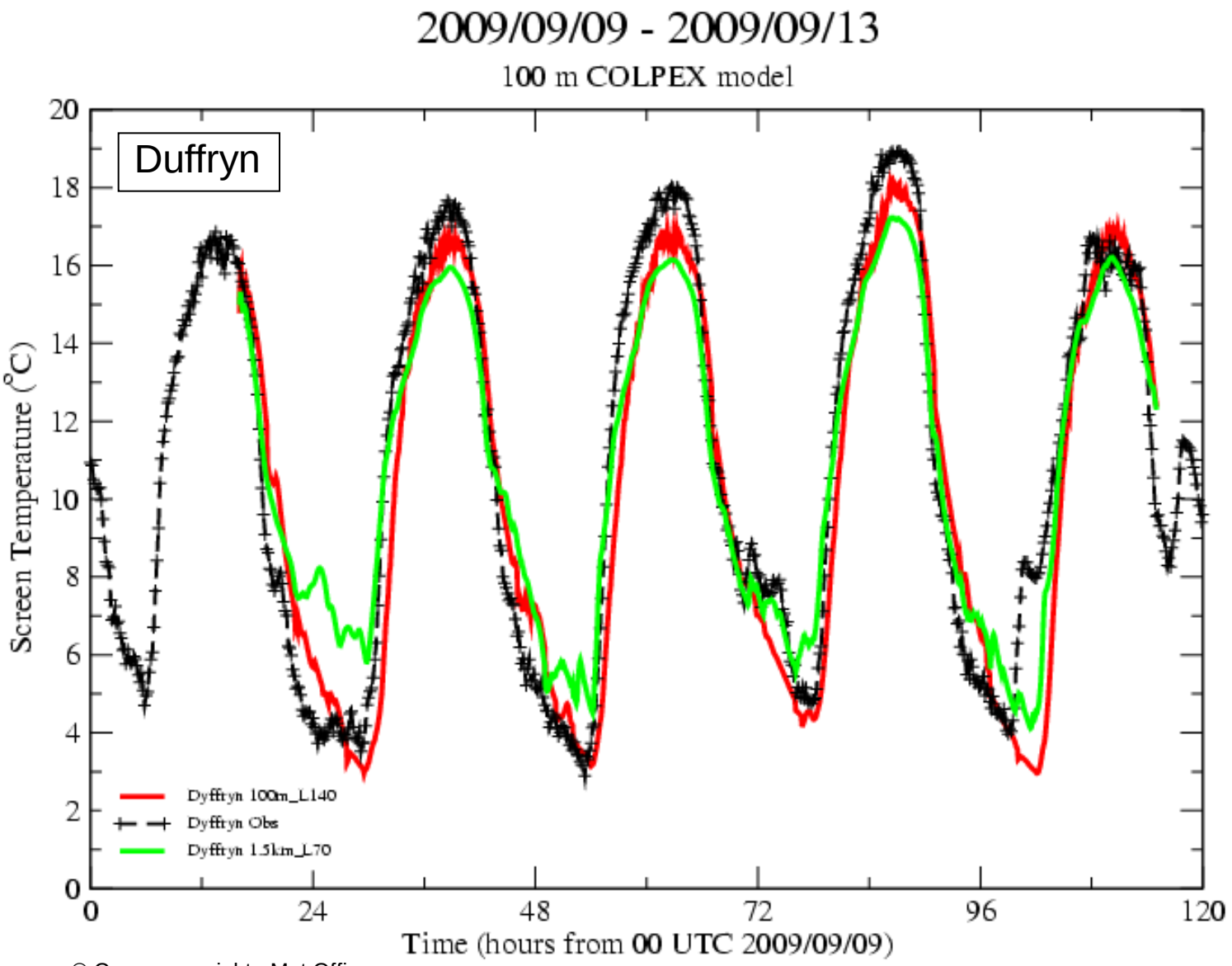
High resolution simulations of cold air pooling in valleys

- Very high resolution simulations using the Met Office Unified Model
- Nested from 4 km resolution domain to 1.5 km, and then 100 m model via a horizontally stretched grid
- Enhanced vertical resolution: 12 levels below 112 m vs 5 levels in operational model





Model screen temperature: Δ=100m L140 vs Δ=1.5km L70



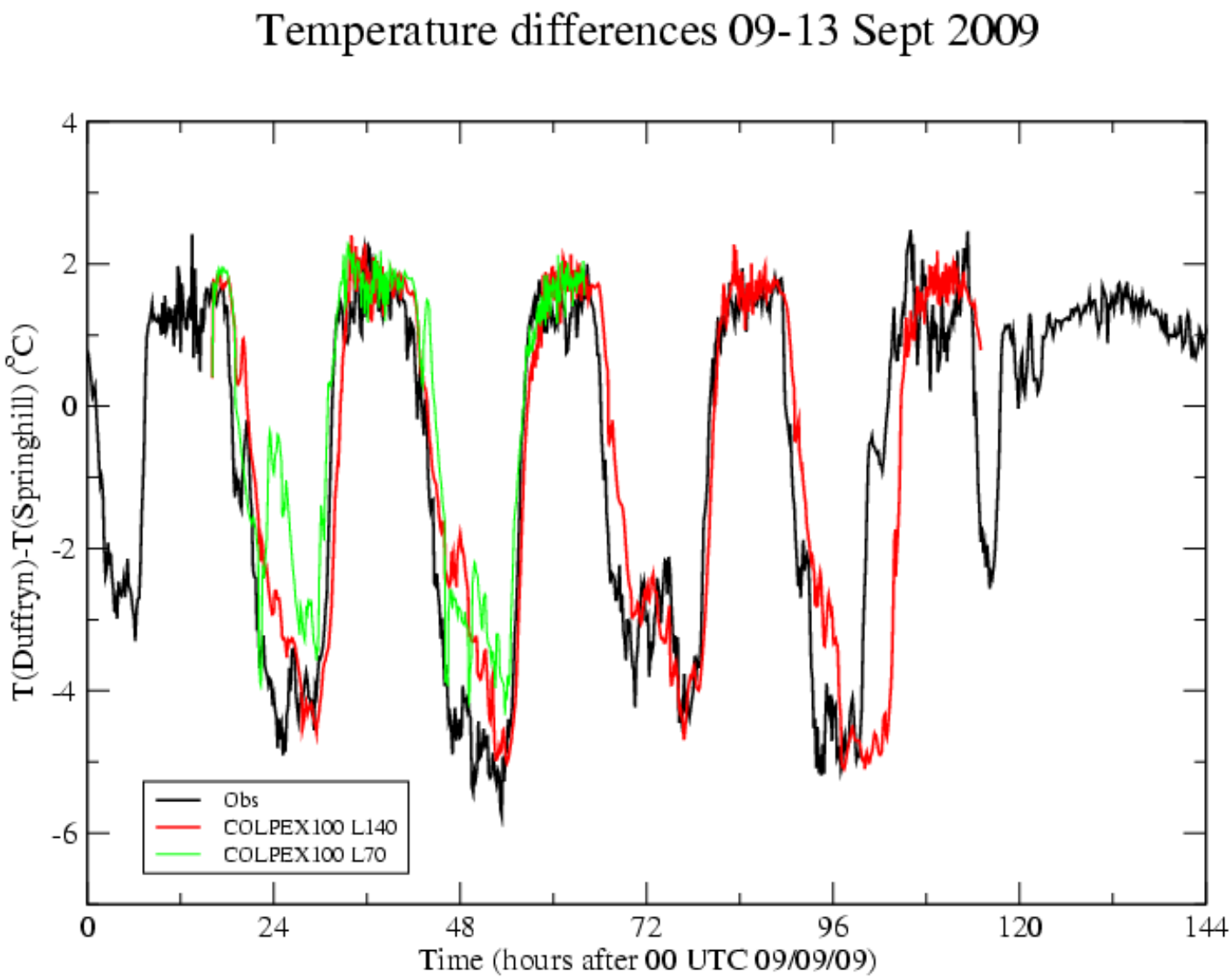
Temperature minima well represented

Daytime temperatures too cold

Clear benefit of 100m resolution over 1.5km

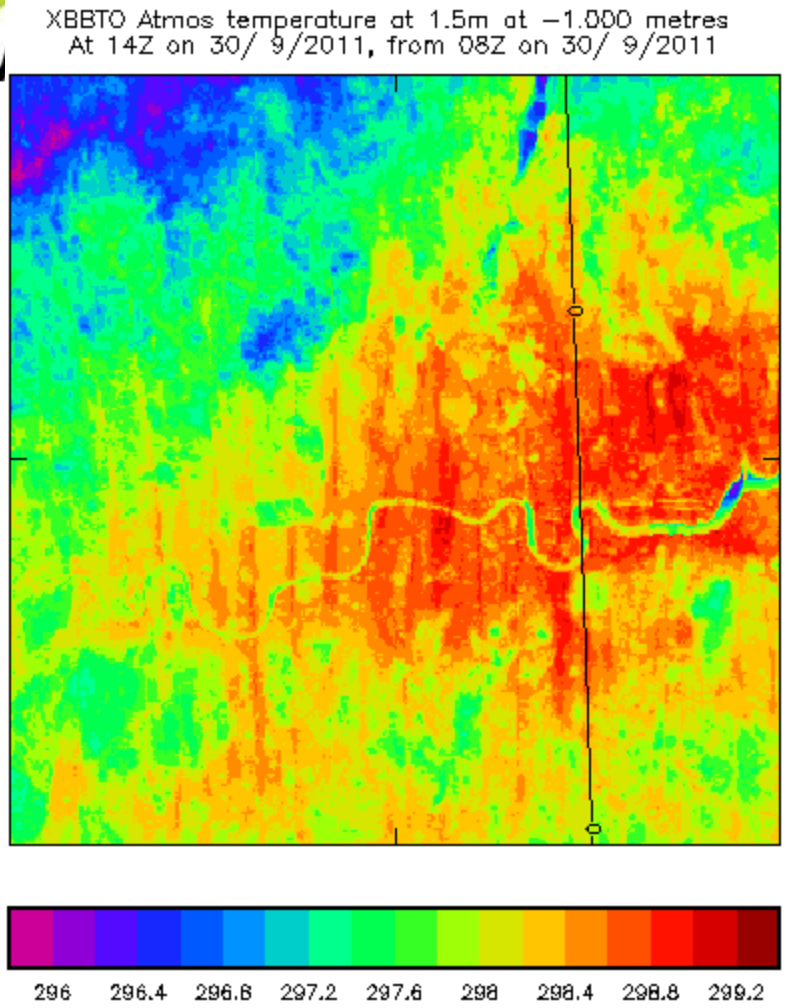
Cold pool strength

- Repeatable night-time ΔT of approx. -4 K
- L140 (12 levels in lowest 100m) model gives good prediction of ΔT amplitude
- Coarser vertical resolution (L70, 5 levels in lowest 100m) results in weaker cold pools

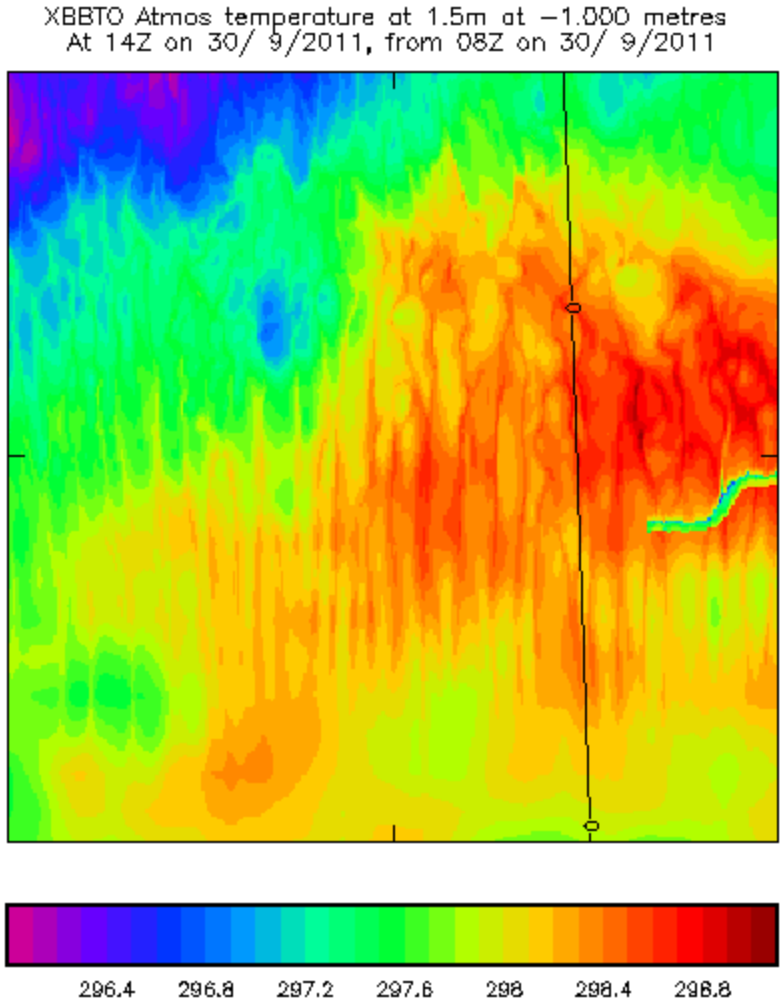


London 100m model (140 levels)

1.5m temperature



100m

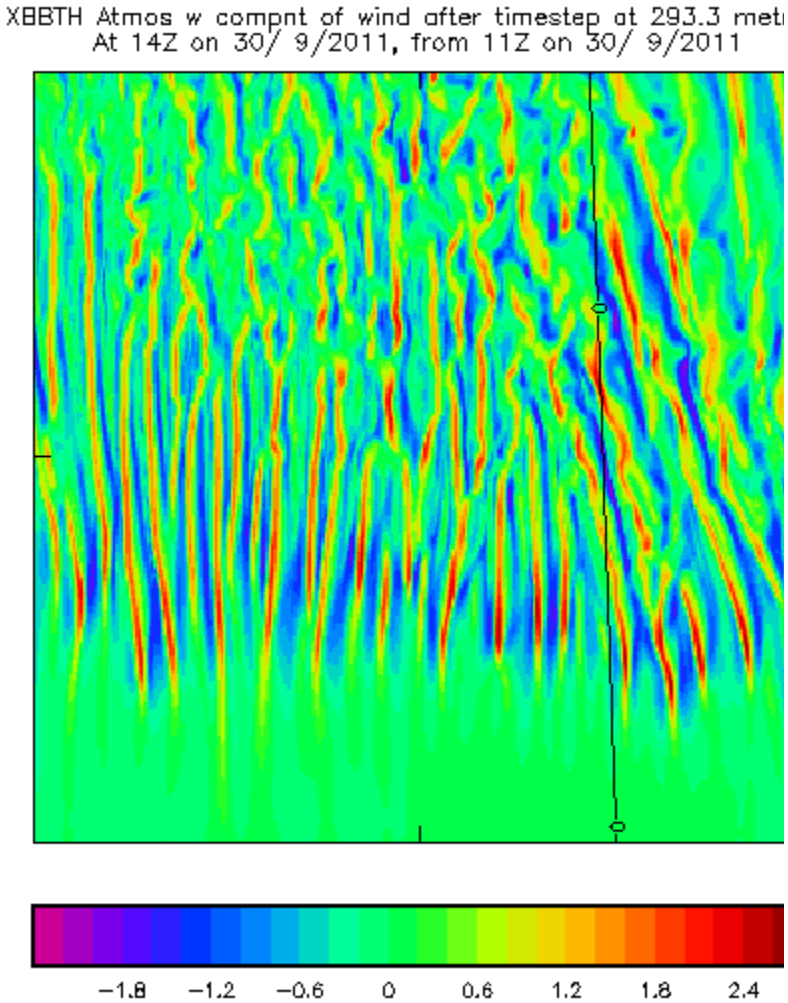


100m with 1.5km surface data

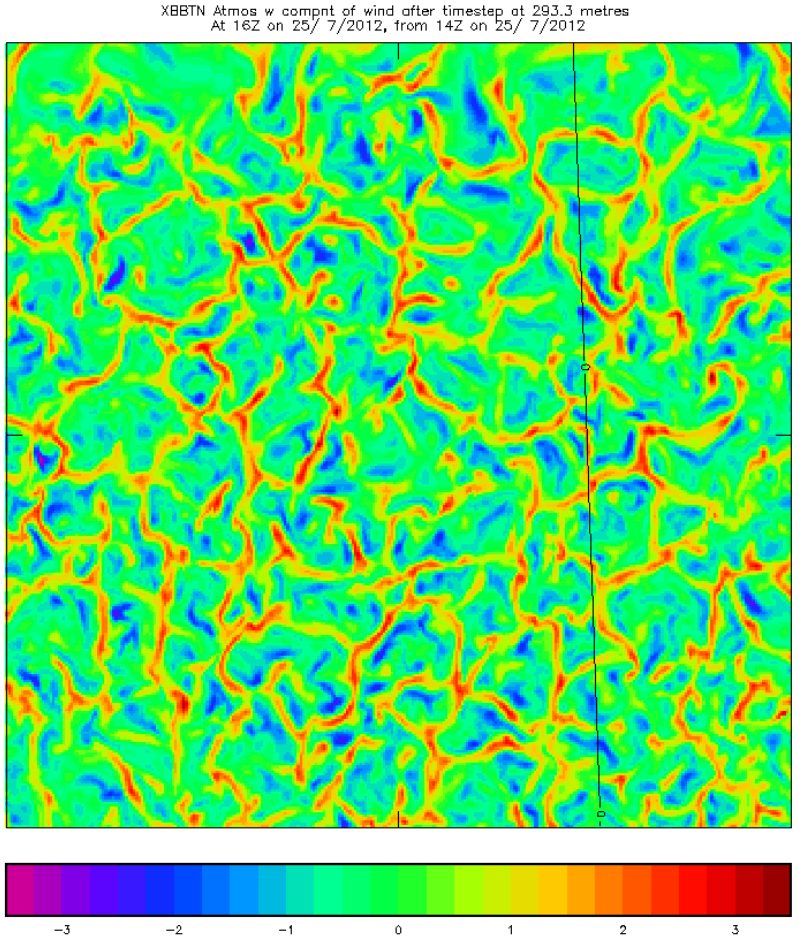
14 UTC 30/09/2011 Cloud free day

Explicit overturning in boundary layer.

W component at 293m



With wind rolls form which break up downstream



Light winds- cellular structure

Preparation of AROME future configurations

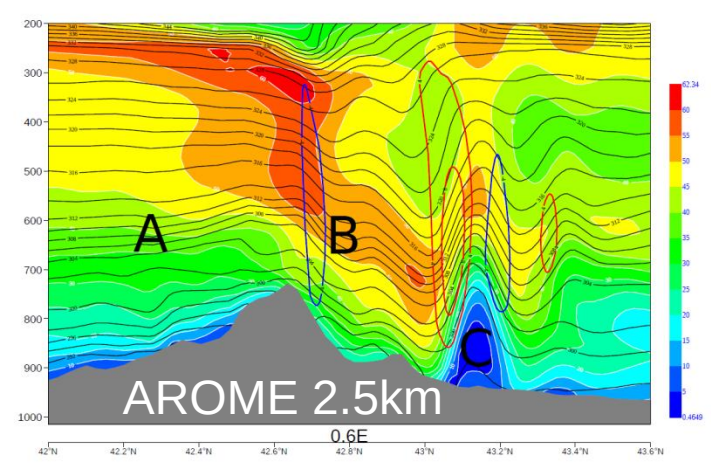
- Increase of spatial resolution planned for AROME-France NWP system : ~1.3 km and ~90 vertical levels. On-going studies to define the future vertical resolution: simulation of low level clouds (fog, stratocumulus), time-step, assimilation of satellite observations, etc.

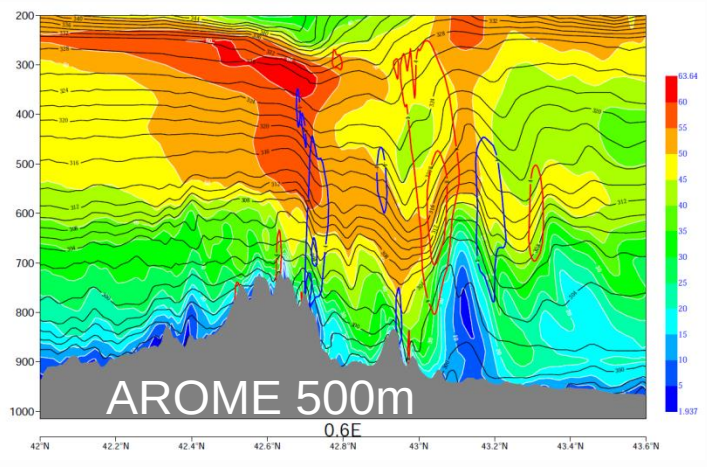
- Development of a nowcasting system based on AROME NWP model at 2.5km with hourly assimilations and short range forecasts (few hours)

- Evaluation of AROME-500m over dedicated areas (airports, mountains, ...) : case studies of heavy precipitation and mountains waves, wake vortex dissipation over airport (SESAR European project), research on thermals parameterization in the grey-zone of turbulence

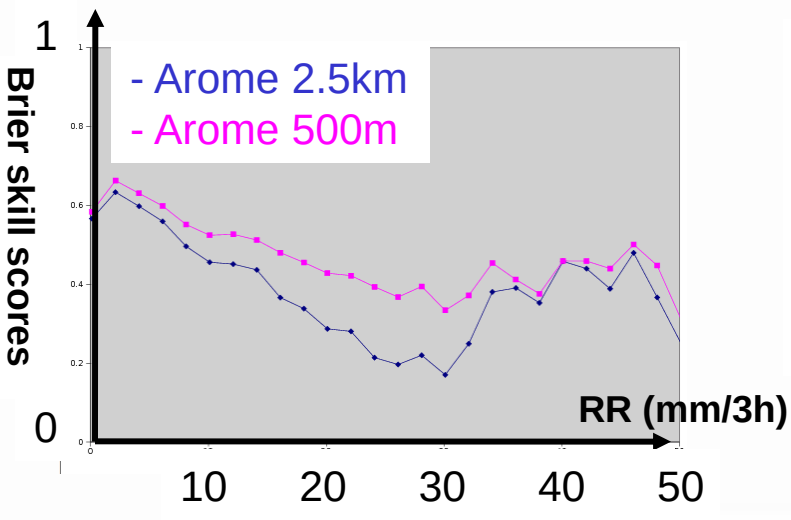
AROME 500m configuration

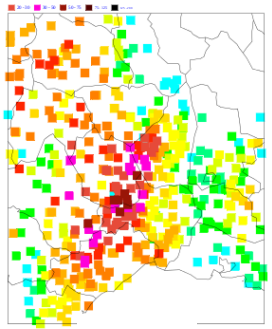
Cross section over the Pyrenees for the Xynthia storm case.
Small scales Trapped Lee waves well captured at 500m res.



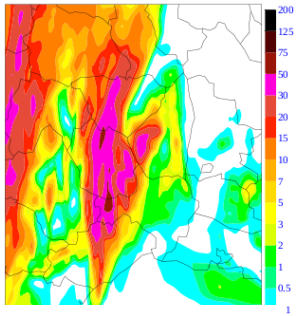


Heavy precipitations cases over south-east of France, 2-8 November 2011

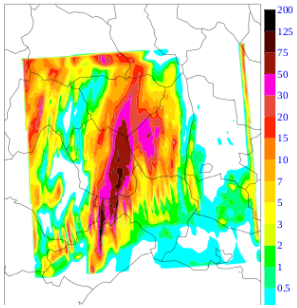




OBS



AROME 2.5km



AROME 500m

3/11/2012 18-21h RR

Modelling the **** weather of ***** Saturday

www.cawcr.gov.au

Robert Fawcett
High Impact Weather Research
28 August 2012

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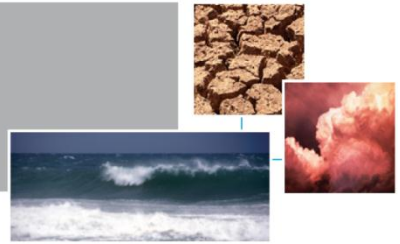
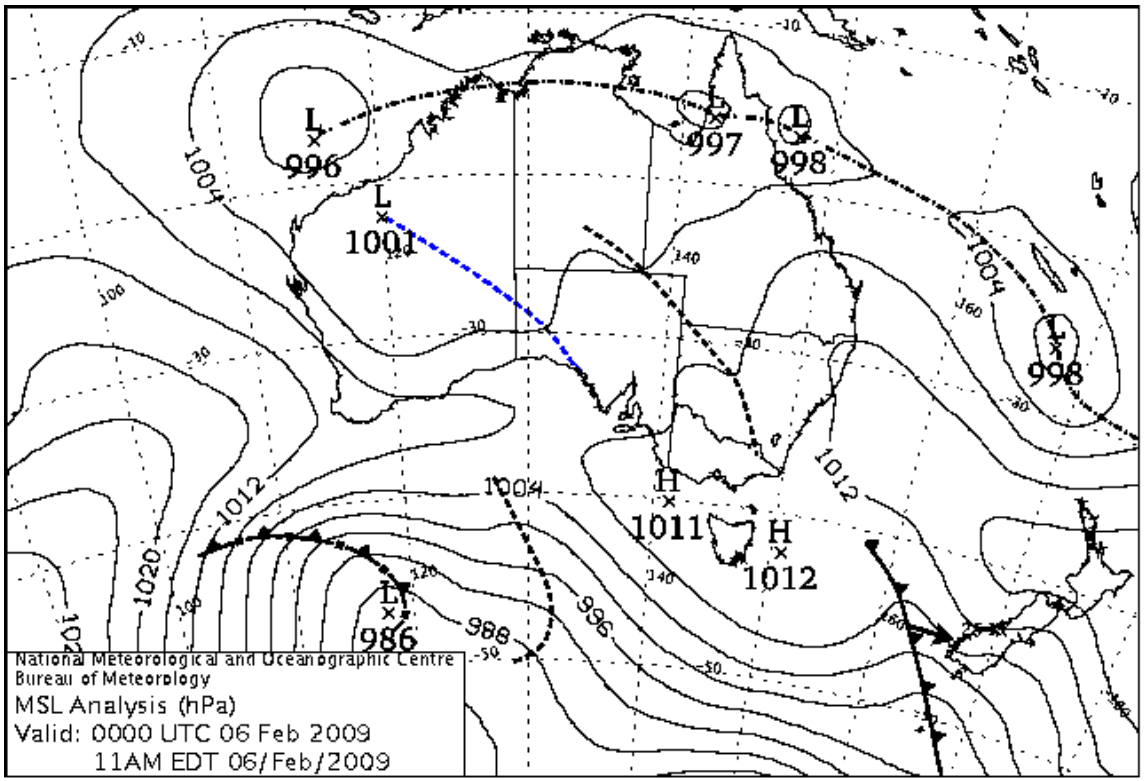
Synoptic meteorology

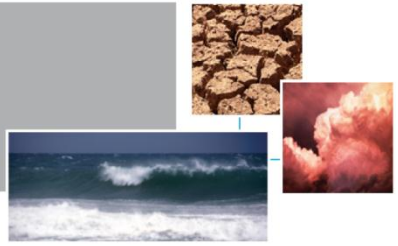


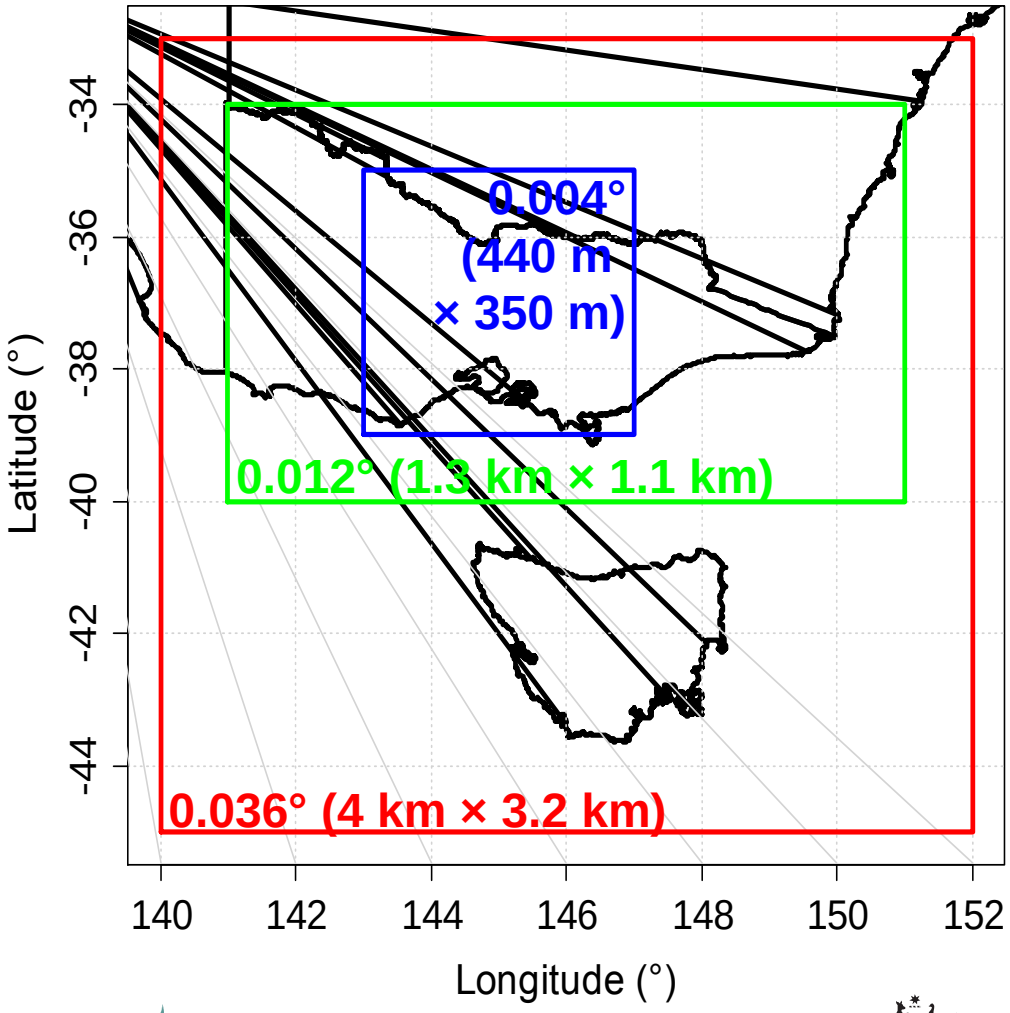


- Primary feature of relevance is the pre-frontal trough (blue line) which crosses Melbourne around 5 pm EDT on 7 Feb 2009.

- Analyses of mean sea-level pressure
- 11 am EDT 6 Feb to 5 am EDT 8 Feb (6 hours apart)
- High-pressure system in Tasman Sea
- Low-pressure system with embedded cold front in Southern Ocean
- February max. temp. records broken across much of Victoria on 7 Feb, Melbourne's all-months record broken

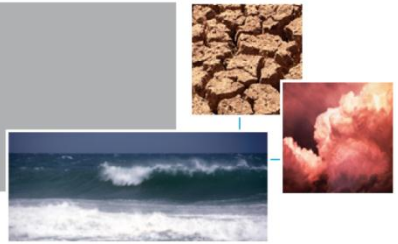
Nesting details





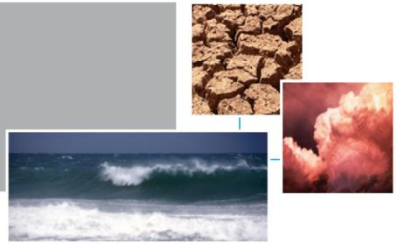
- The modelling begins with a global model run. The second level is at 0.11° resolution covering all of Australia and surrounding waters. Further levels of nesting increasingly focus on the area of interest.
- Boundaries of the third (*red*), fourth (*green*) and fifth (*blue*) nesting levels for the **** Saturday model runs.
- Model boundaries are chosen, as far as is possible, to avoid areas of elevated topography.
- Comparison test runs also done at 0.008° and 0.006° (fifth level).

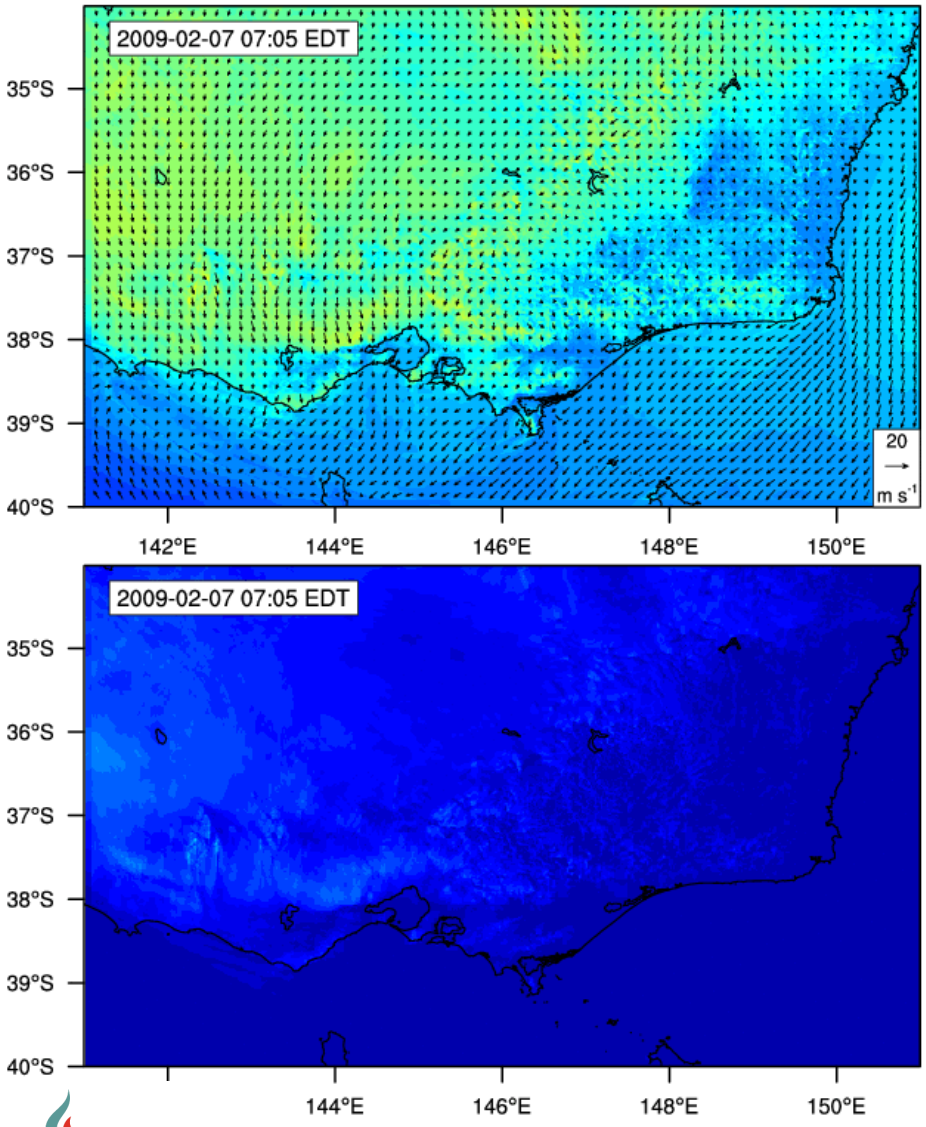
Nesting details (2)

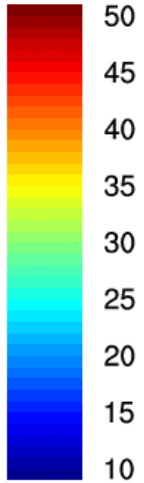


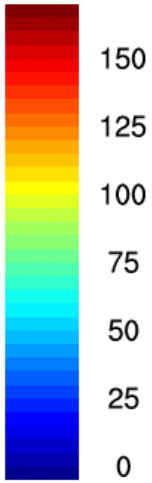
- 50 vertical levels
  - 30 + 20
  - 60 km modelling depth
- APS1 (UKMO Unified Model version 7.5)
- UK Met Office Initial Condition
  - 2009-02-06 0300 UTC (2009-02-06 1400 EDT)
- 0.012° resolution and finer
  - no convective parameterisation
  - 1D planetary boundary layer scheme replaced with full 3D Smagorinsky turbulence closure
- archiving
  - 5-minute surface outputs
  - 15-minute model-level outputs

What do the simulations show?









7:05 am to 4:00 am (EDT), 0.012° simulation

Screen-level air temp. (°C)
10-metre wind vectors

FFDI

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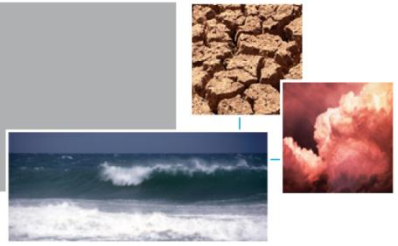
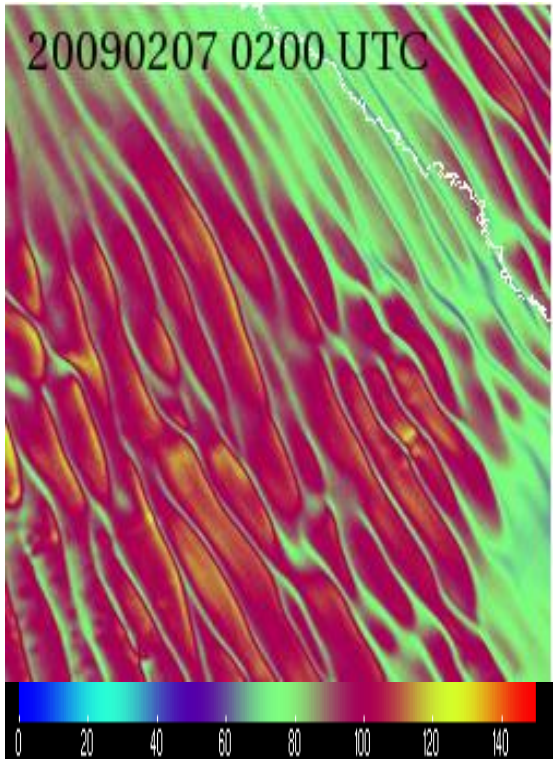
What do the simulations show?



- many interesting things
  - primary and secondary wind change
  - pre-frontal boundary-layer rolls over a wide area
  - numerous small-scale vortices along the primary wind change (trailing wakes behind the wind change)
  - an undular bore

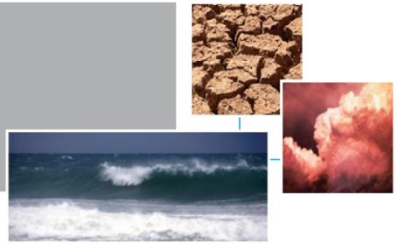


Notional instantaneous FFDI for NW Vic.
36.5 - 35.5°S,
143.5 - 144.5°E
(0.004° resolution)

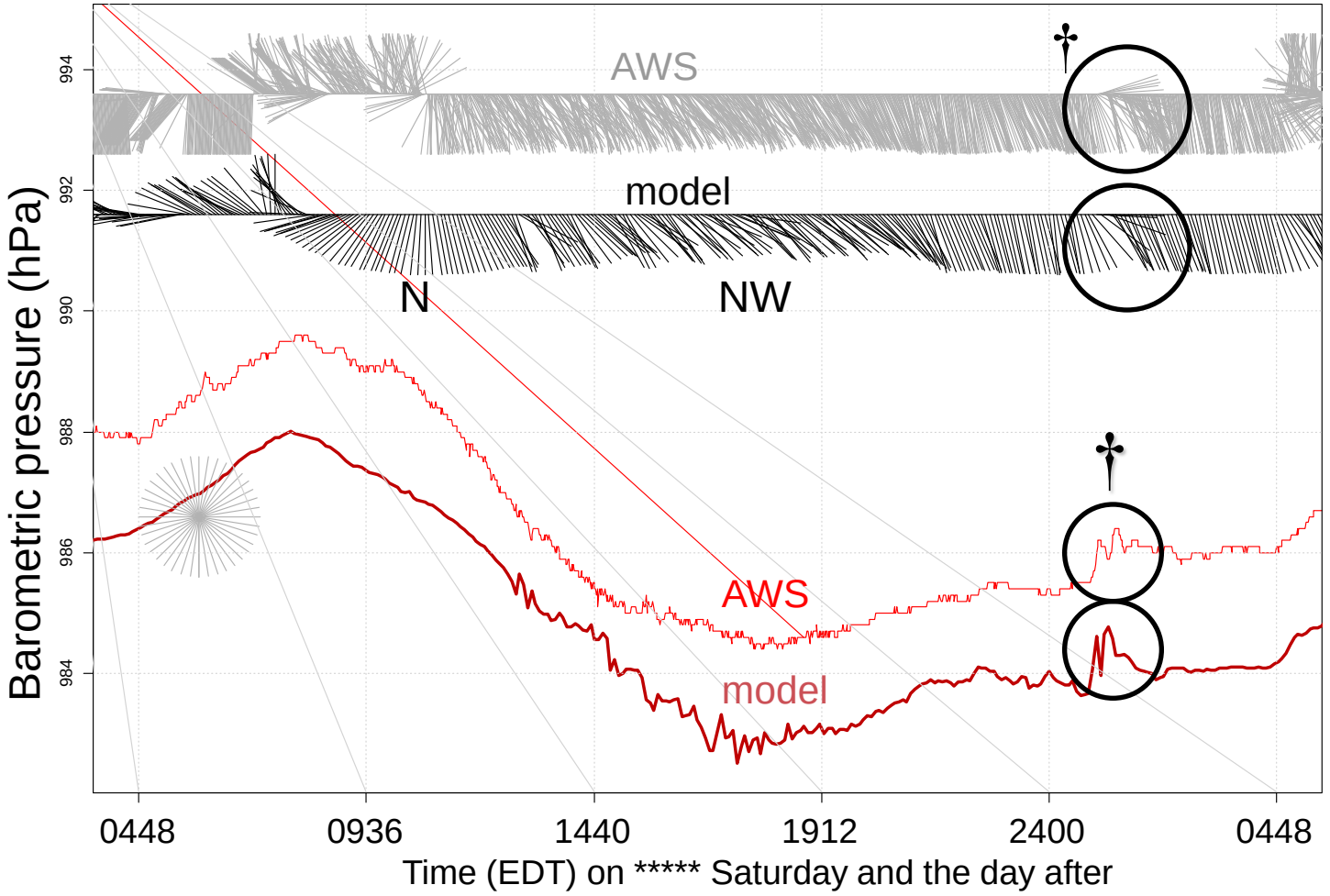
0200 UTC / 1300 EDT
to
1055 UTC / 2155 EDT

Google terrain map

On the ground …



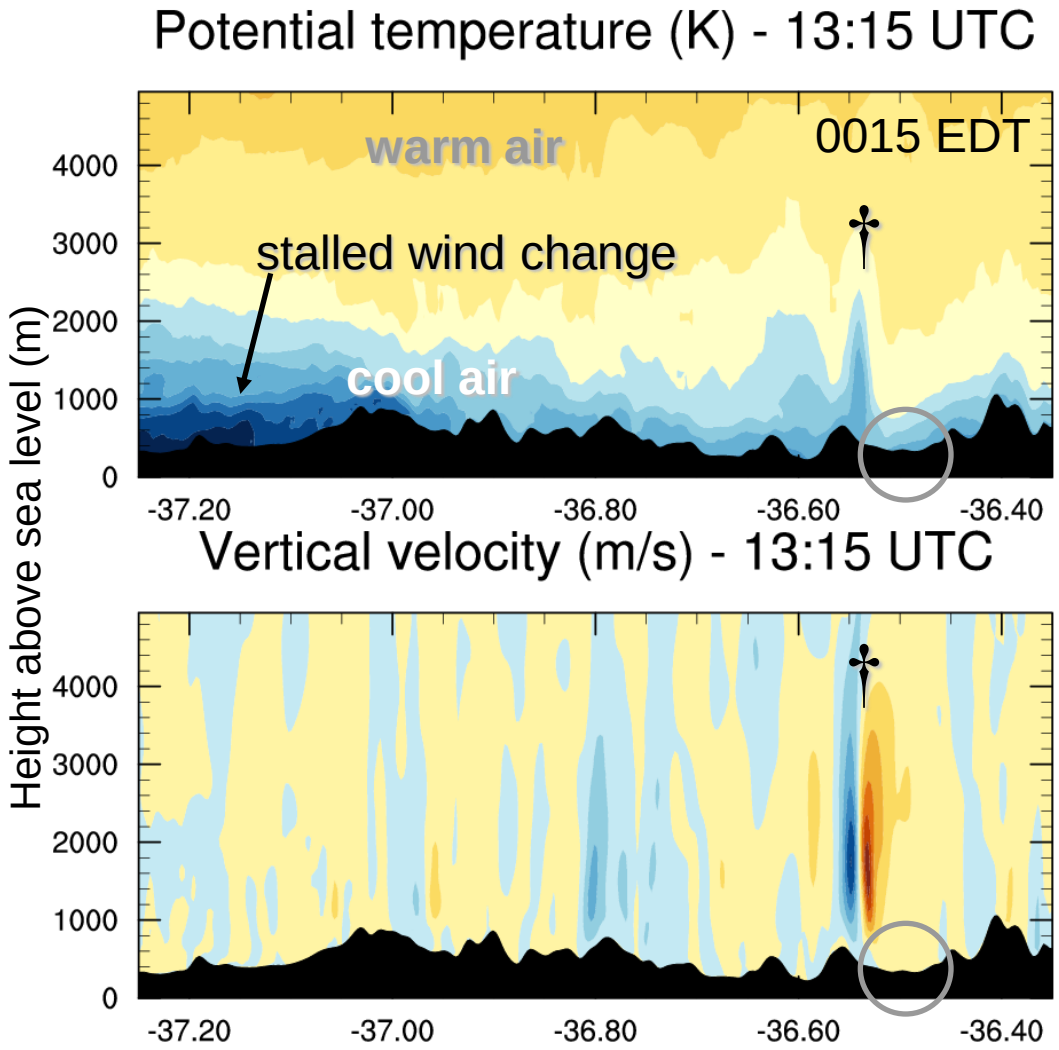
AWS and 0.004° model data for 072160 Albury Airport AWS

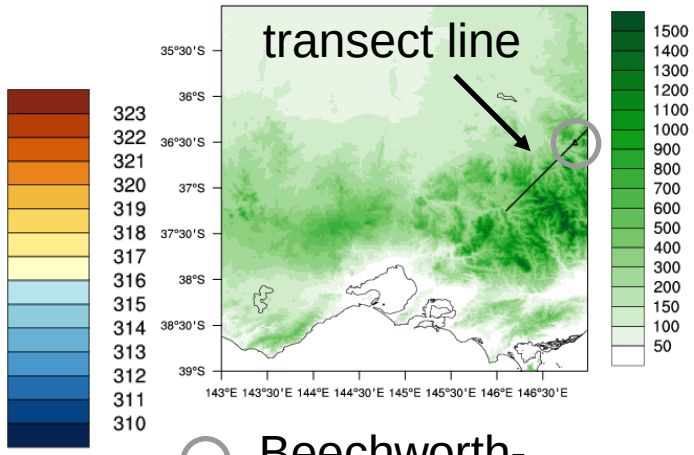


10-metre wind direction

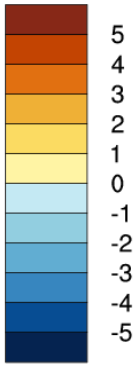
- The disturbance (†) is visible in the wind direction and the barometric pressure data.
- AWS wdir < 280° from 0101 EDT to 0108 EDT.
- Disturbance also seen in the Yarrawonga AWS.

Implications for the ***** …





○ Beechworth-Mudgegonga ****



- The modelling suggests the undular bore (†) generates updrafts strong enough to further loft pieces of bark raised to about 1000 metres by the ****.

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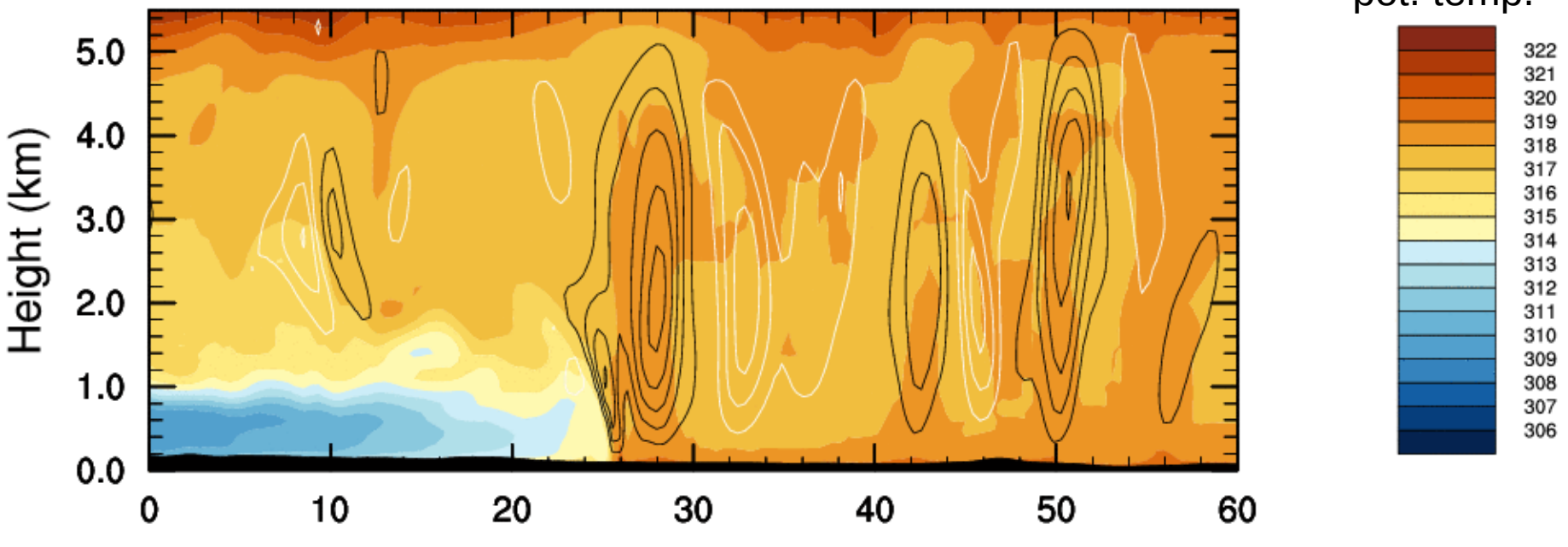
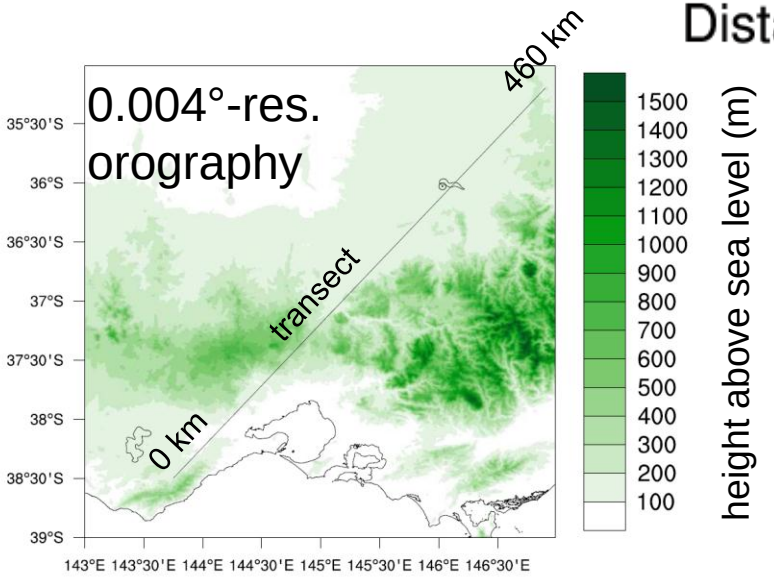
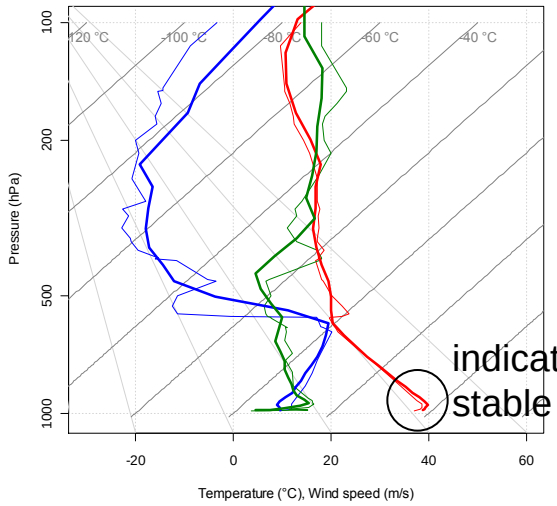
θ (K) and w (ms^{-1}) - 04:15 UTC / 15:15 EDT







Wagga
1100 UTC
2200 EDT
(0.012°)

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