Met Office physics developments

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Presented by Mike Bush

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- Seamless turbulence parametrization across model resolutions
- Developments in fog prediction
- Longer term developments in microphysics: CASIM

Seamless turbulence parametrization across model resolutions

Adrian Lock and Ian Boutle

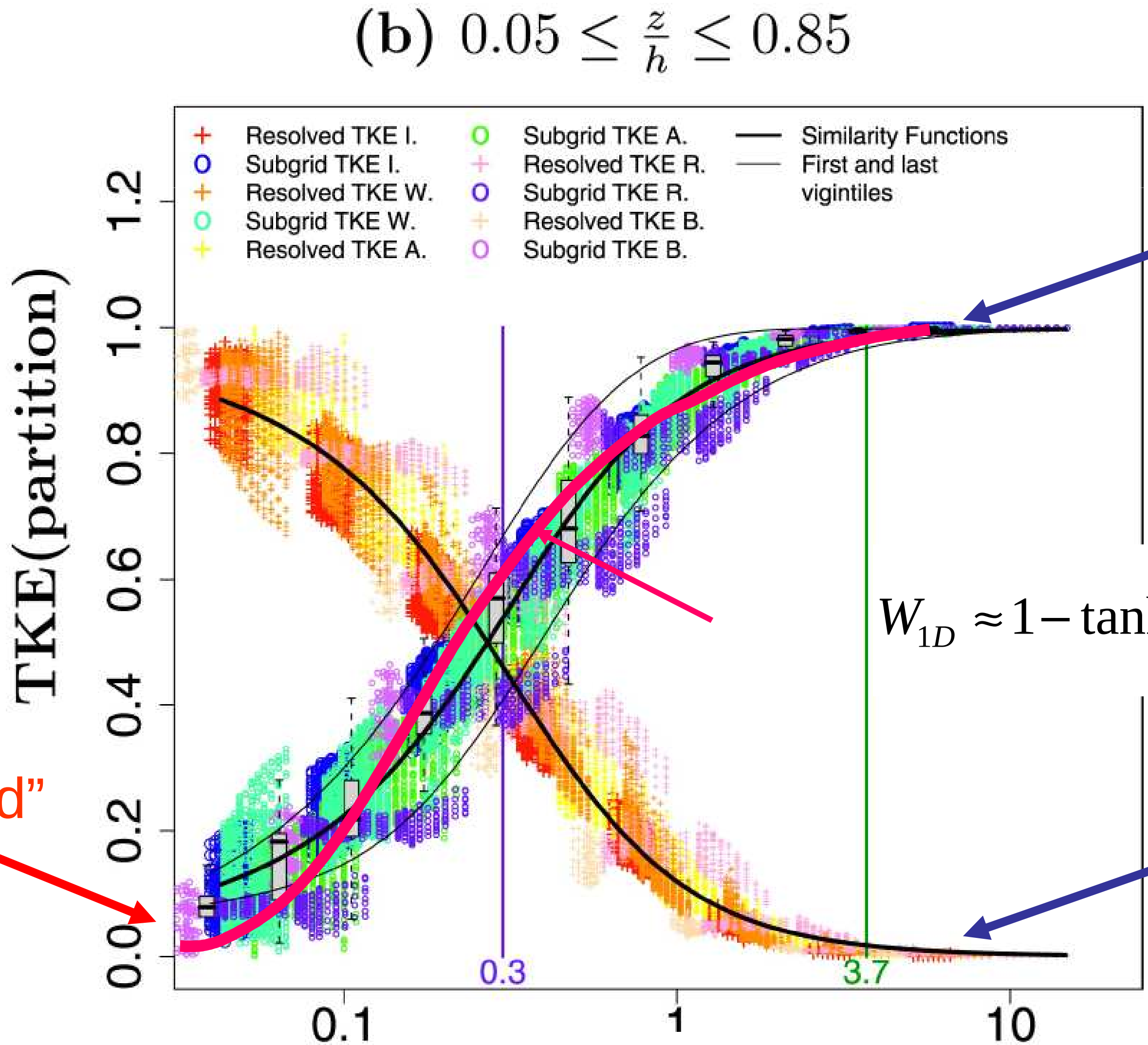
Met UM turbulence parametrization

Met Office

- MetUM has two distinct turbulence parametrizations (both 1st order closure)
  - 1D non-local boundary layer parametrization = standard NWP
  - 3D “Smagorinsky-Lilly” type, as used in the Met Office LEM
- The UKV model uses a split approach:
  - Smagorinsky in the horizontal + 1D BL in the vertical
- **All applications will have a mixture of resolvable and unresolved scales**
- The ultimate aim is a scale-aware turbulence parametrization that can generate a smooth transition from unresolved to resolved scales
- Initial step here is to “blend” between 3D scheme (good at high resolution) and 1D scheme (good at coarse)

Grey zone parametrization

Fit to LES data in Honnert et al (2011)



Subgrid TKE

Length scale of flow is typically the BL depth

$$W_{1D} \approx 1 - \tanh\left(\beta \frac{z_{turb}}{\Delta x}\right)$$

Tends to zero for "well resolved" limit

Resolved TKE

Fine resolution

$$\frac{\Delta x}{z_{turb}}$$

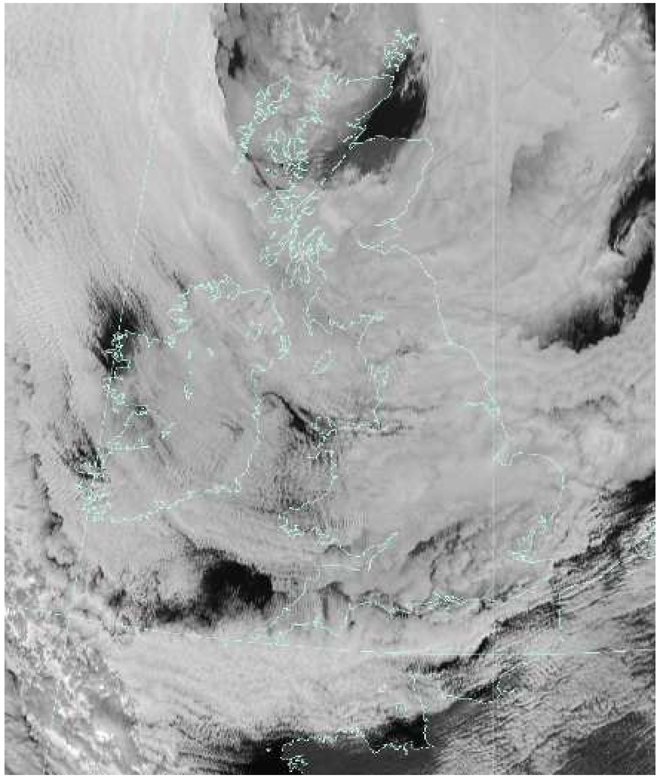
Coarse resolution

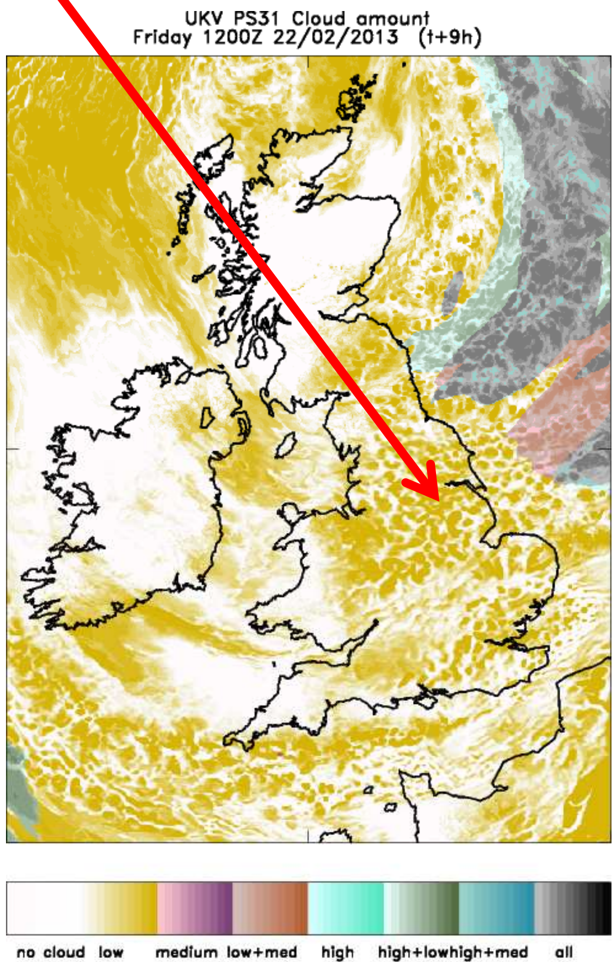
Seamless physics package

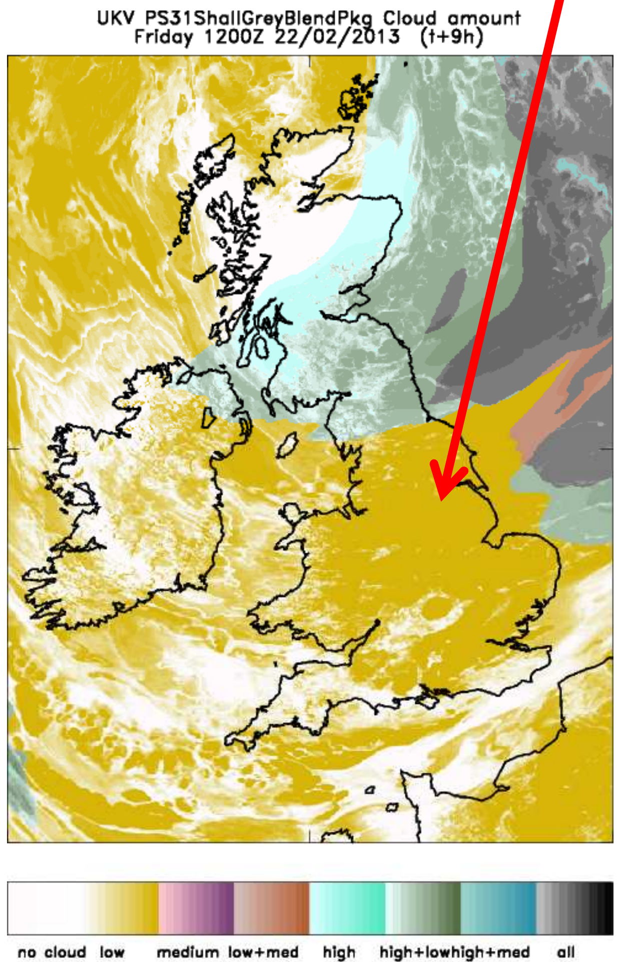
(Scale aware turbulence AND scale aware microphysics)

- Excessive amplitude mesoscale variability in UKV (control) leading to spurious gaps in cloud.
- Seamless physics weakens resolved scale circulations and increases cloud cover

Satellite image



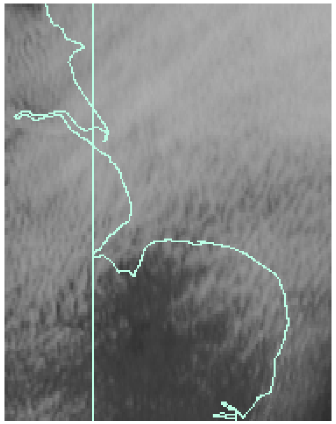




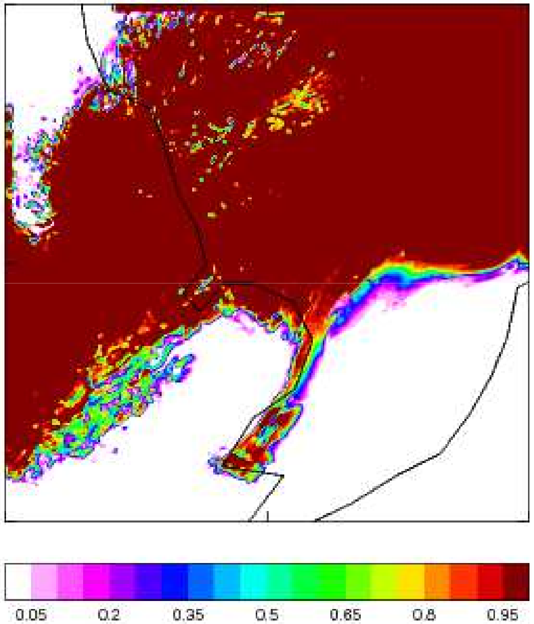
COALESC = UK stratocumulus

Cloud Fraction →

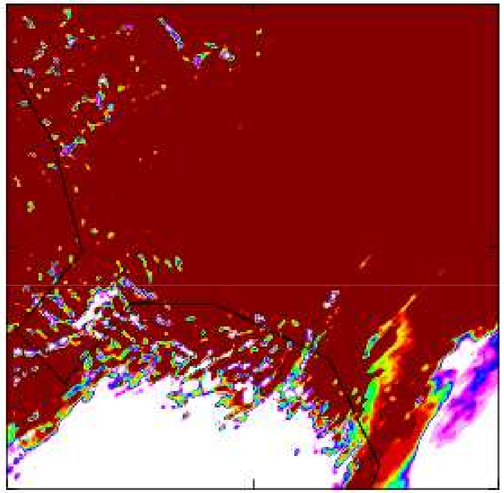
2nd Mar 2011



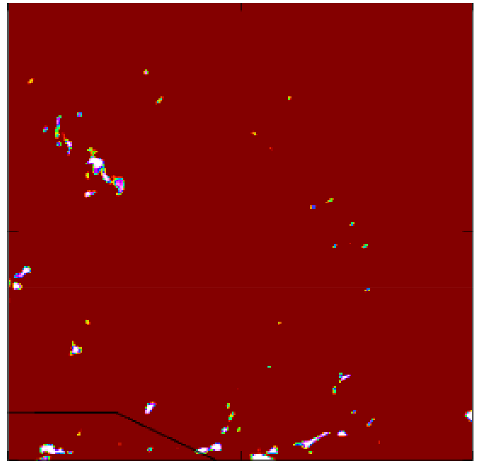
1km: seamless



333m: seamless

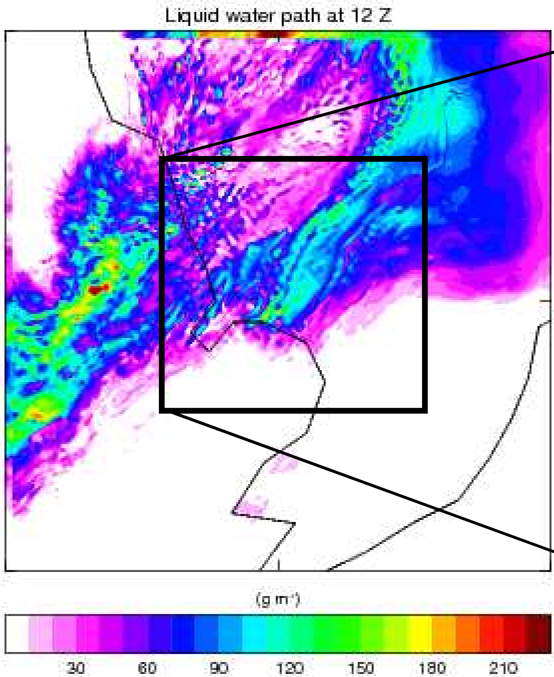


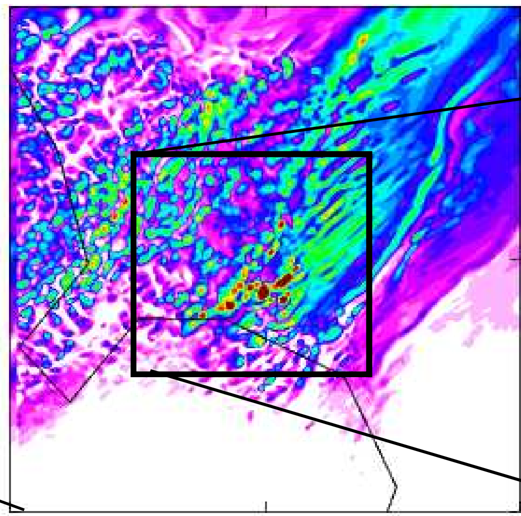
100m: seamless

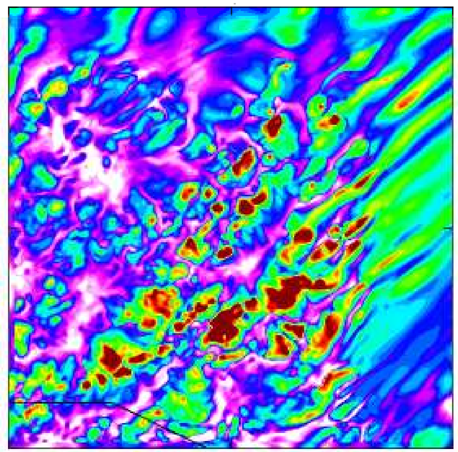


- Combined surface & aircraft measurements
- UM simulations on 1km to 100m grids

Liquid water path (gm^{-2}) →





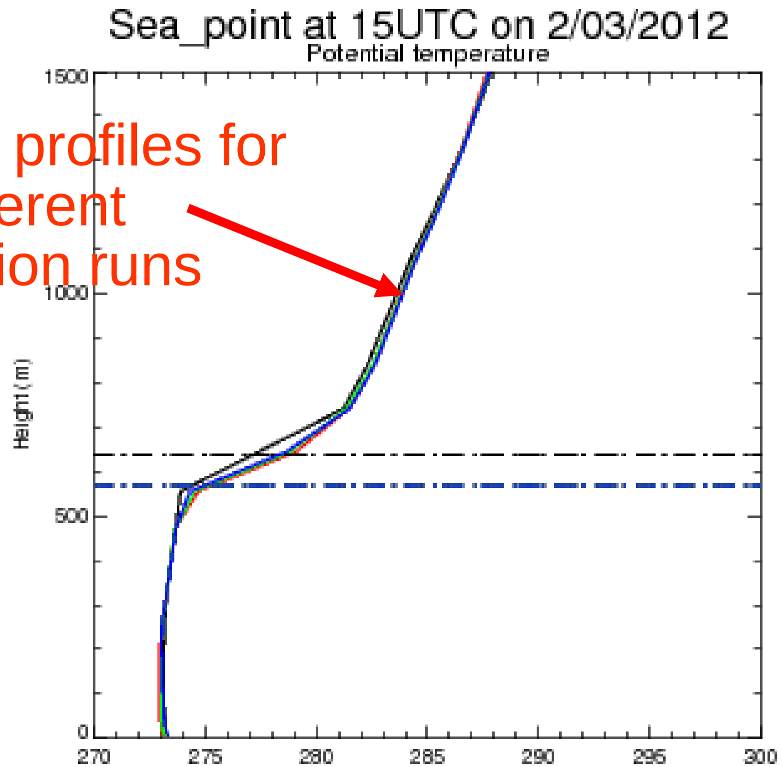


Different scales of motion

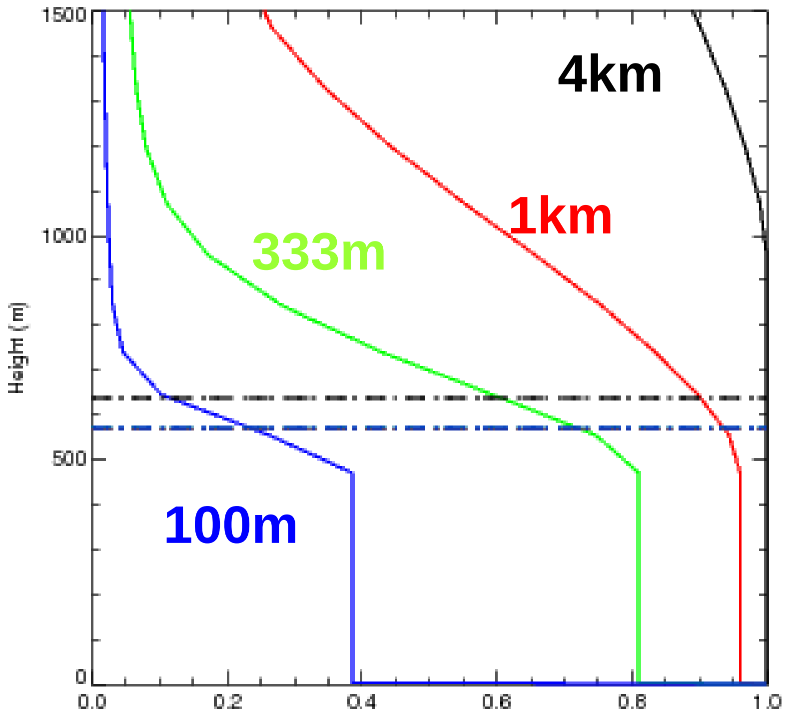
Blending weight profiles

- Plausible looking reduction in W_{1D} in the boundary layer as the grid size decreases (note 100m still not very well resolved)
  - Relaxes to 3D Smagorinsky in the free-troposphere

Similar profiles for the different resolution runs



Potential Temperature (K)



1D Weight

Summary of Initial seamless package

Met Office

- “Blended” 1D BL + 3D Smagorinsky turbulence
- Scale-aware warm rain microphysics
  - Explicit representation of sub-grid variability in process rates
- See Boutle, et al 2014, MWR for details
- The impact in the UKV was to smooth out near grid-scale features, meaning less than around 10km (6-8 grid-lengths).
- This was beneficial for reducing Sc break-up but in convective regimes there is a significant amount of precipitation generated from showers on the scale of 10 km or less.
- Initial trials therefore showed a significant detriment to precipitation scores.

Revised seamless package

Met Office

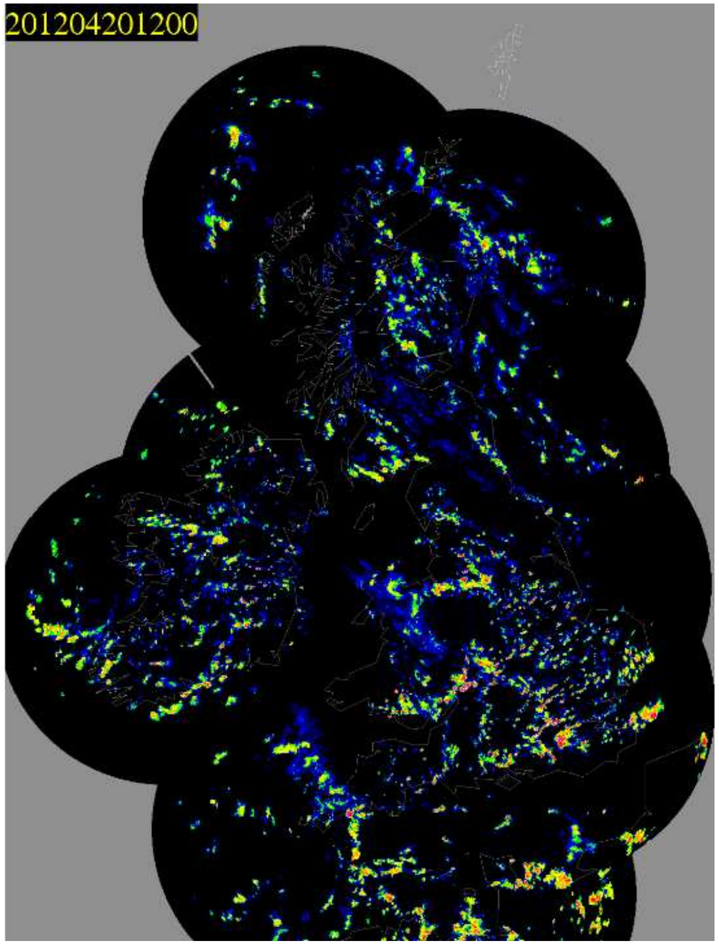
- As a result the shallow convection parametrization was switched on but tests indicated this failed to generate significant precipitation rates and also triggered over far too widespread areas.
- Two further changes were then made to the shallow scheme:
- Adding an additional trigger (that required w > wthres)
- A new closure (that merged linearly with height between the standard shallow massflux closure for cloud tops below 1.5 km and the CAPE-based deep closure for cloud tops higher than 4km).

Grey zone “shallow” cumulus parametrization

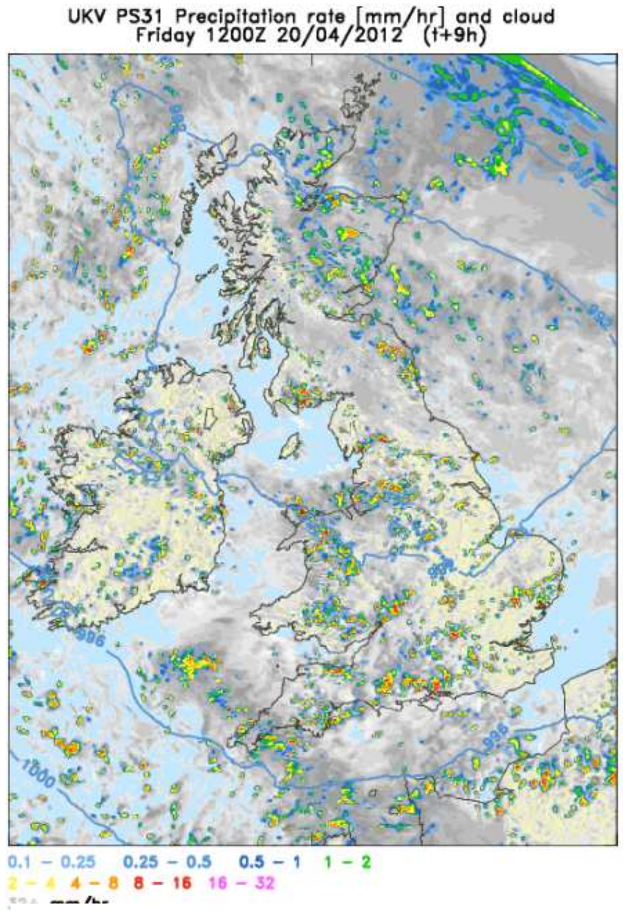
20th April 2012 (DYMECS)

UKV (1.5km grid)

Radar



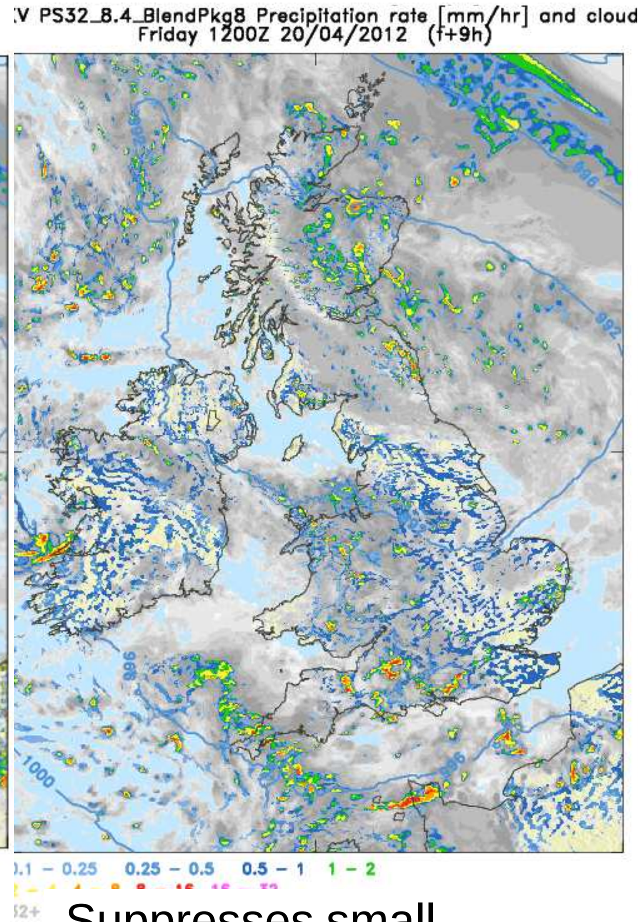
UKV control



Some large, some small showers

Seamless BL only

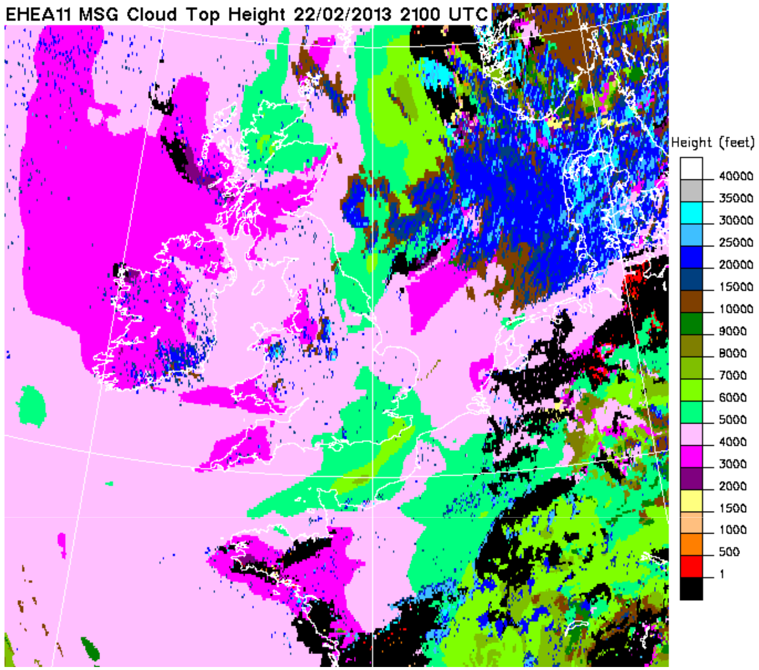
Including grey



Suppresses small showers

The latest blending package

- Is there a way to keep the improved stratocumulus cloud cover without degrading summer showery precipitation?
- Testing a revised blending package that reverts to the standard UKV mixing parametrization in “cumulus” regimes, which means:
  - NO convection parametrization (at all)
  - In “Cumulus” regimes:
    - Use standard UKV turbulence: 1D BL + 2D Smag
    - i.e. no blending

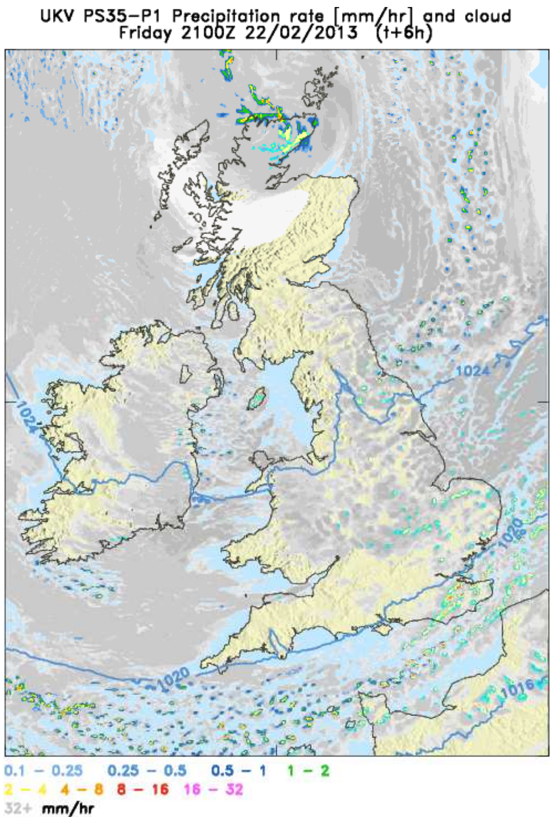


Winter case study

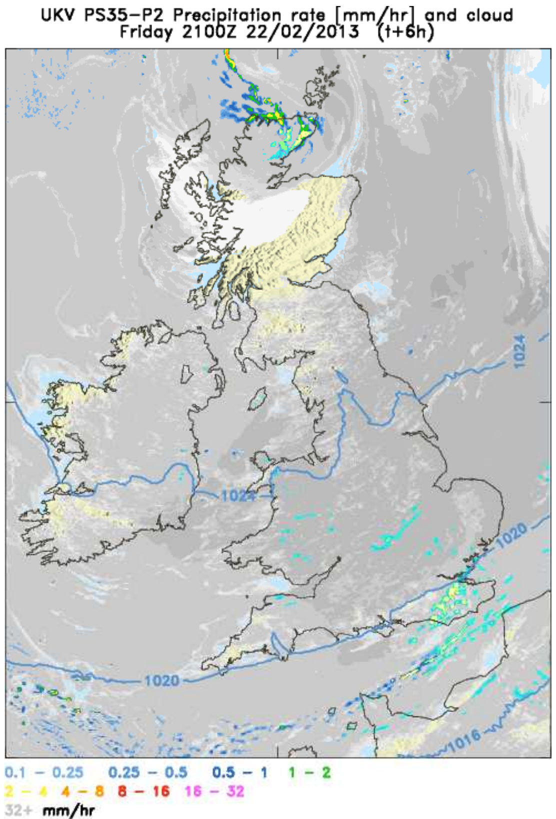
(22 Feb 2013, T+6 from global analysis)

- EG + latest blending much better than Pure EG but still breaks into broken cloud too much

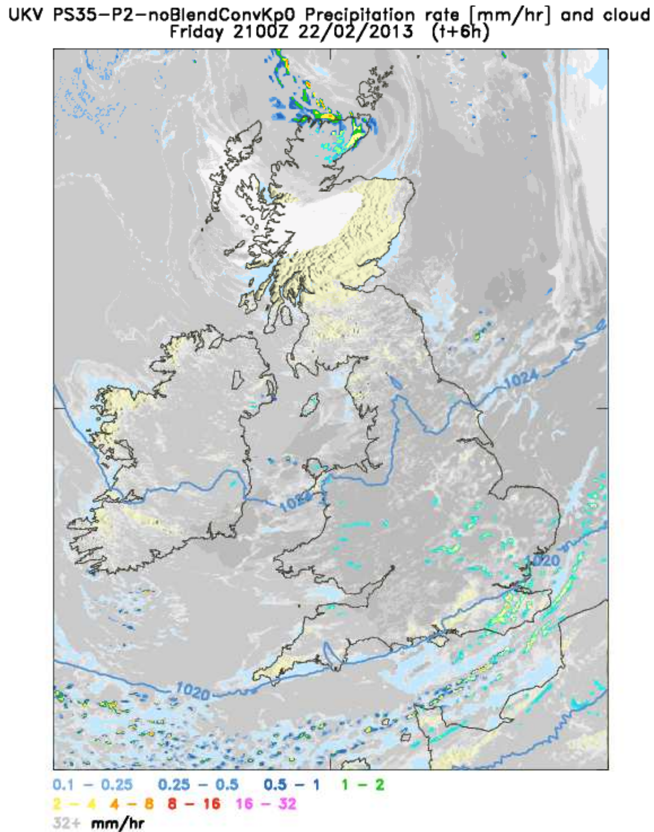
Pure ENDGame (EG)

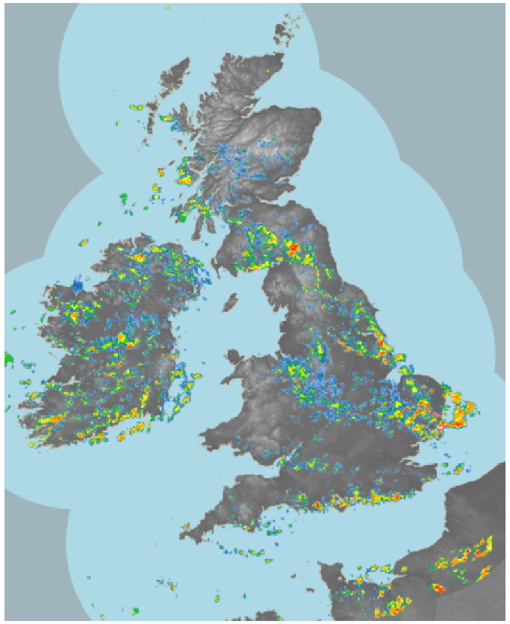


EG + blending



EG + latest blending



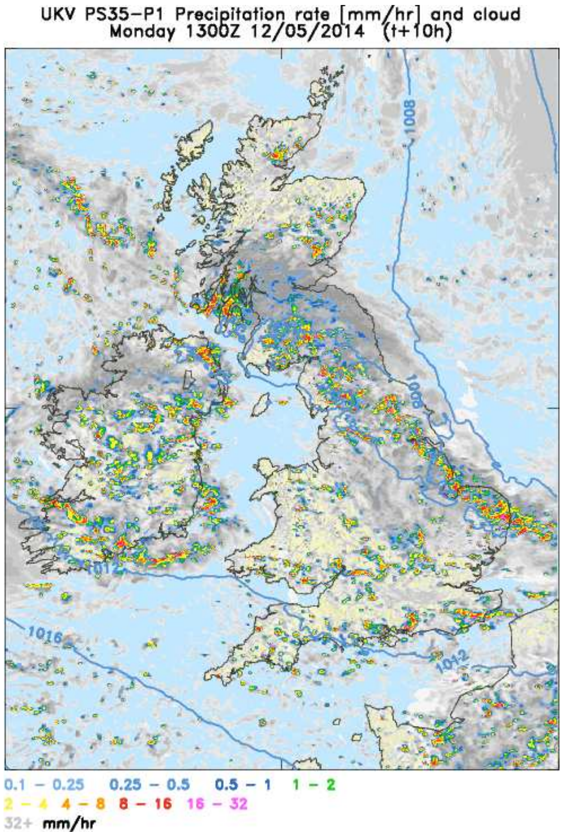


Summer case study

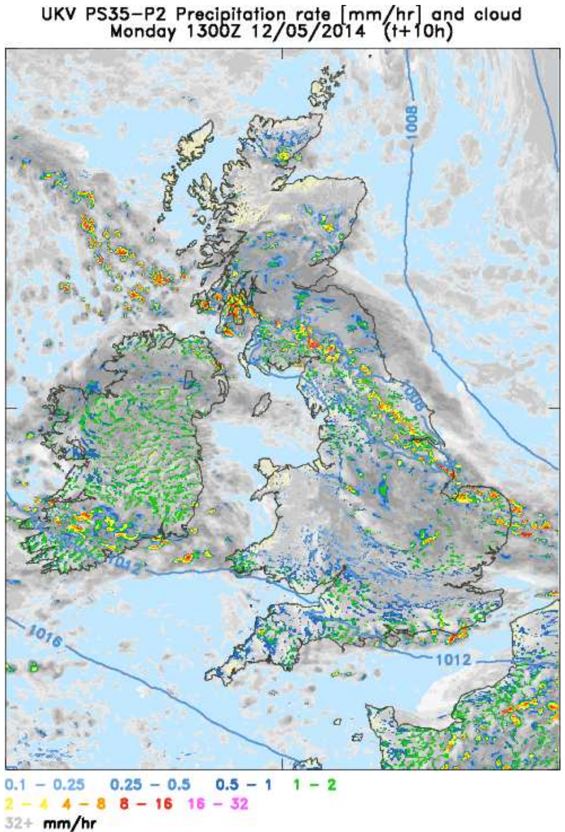
(12 May 2014, T+10 from global analysis)

- EG + latest blending precipitation characteristics much more like Pure EG
  - not quite as showery as Pure EG though
  - better organisation over France
  - too little rain over Ireland

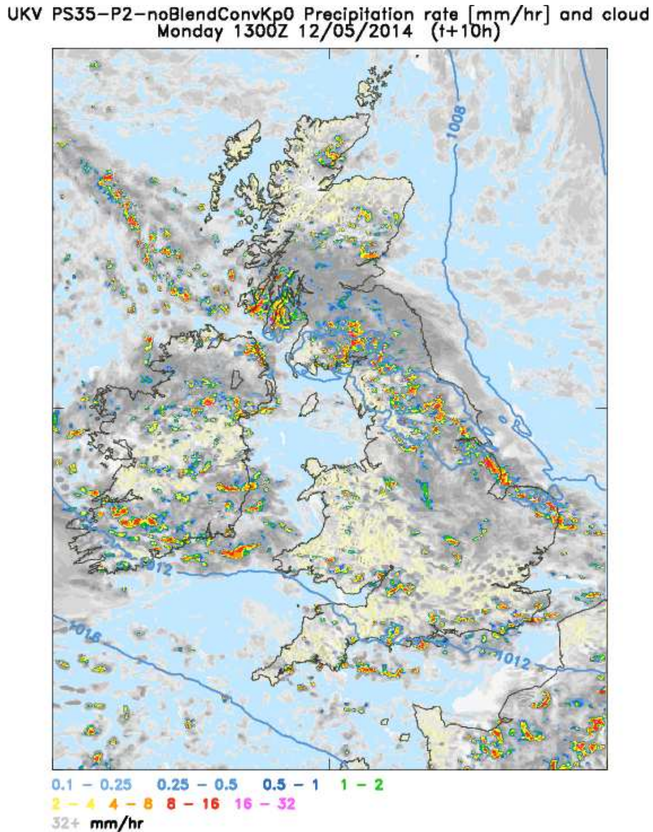
Pure ENDGame (EG)



EG + blending



EG + latest blending



Met Office

Forecasting fog with a very high resolution model

Ian Boutle & Anke Finnenkoetter

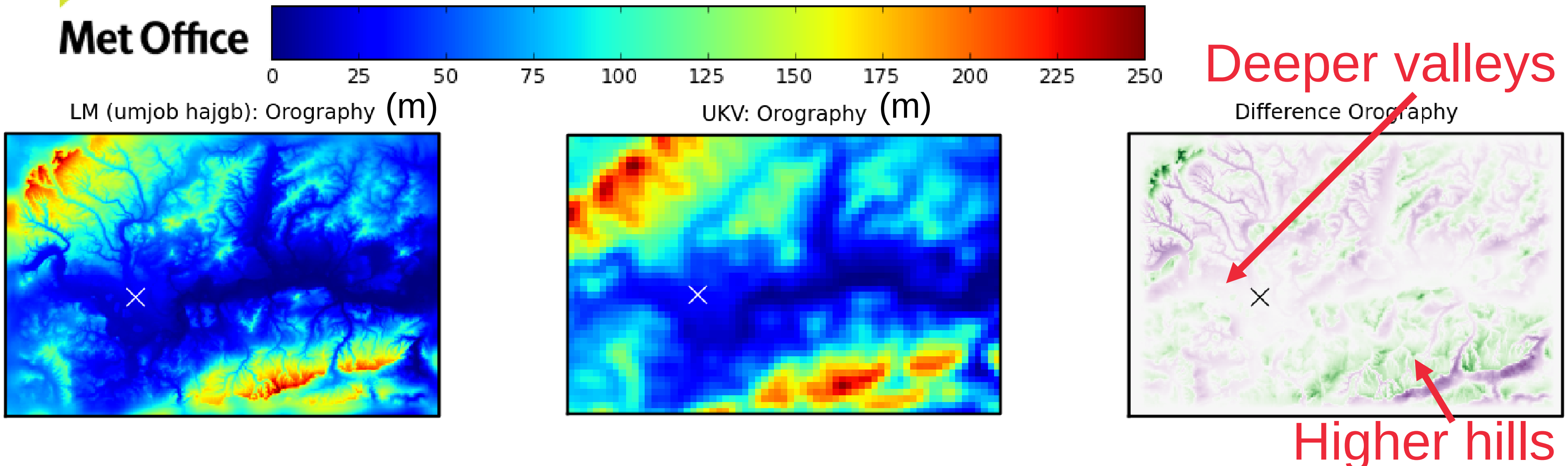
Low visibility and fog forecasting

- Significant high impact weather, particularly for aviation
- Fog at airports reduces take off/landing rates
- At Heathrow, this means cancellations or diversions
  - 3rd busiest airport in the world, running at 95-99% capacity
  - Costs airlines and CAA millions of £/$/€
  - Annoys passengers!!
- Fog is complicated…
  - Interaction of dynamics, radiation, microphysics, turbulence and land surface
- It's also quite rare…
  - If it were more common, we'd probably be better at it!
  - Means significant chance of a forecast bust when it does happen

The London Model (LM)

- Currently, the 1.5km UKV model is used for short-range forecasts over the UK
- Nest a 333m grid-length model inside this
- 300x200 grid-points (100x66km domain)
- Would this be useful?

LM – UKV comparison



- Better representation of orography and surface characteristics in LM
- Use 3D Smagorinsky turbulence scheme in LM rather than 1D BL parametrization
- Use higher critical relative humidity value for cloud parametrization
- All assuming more detail is resolved & less parametrized

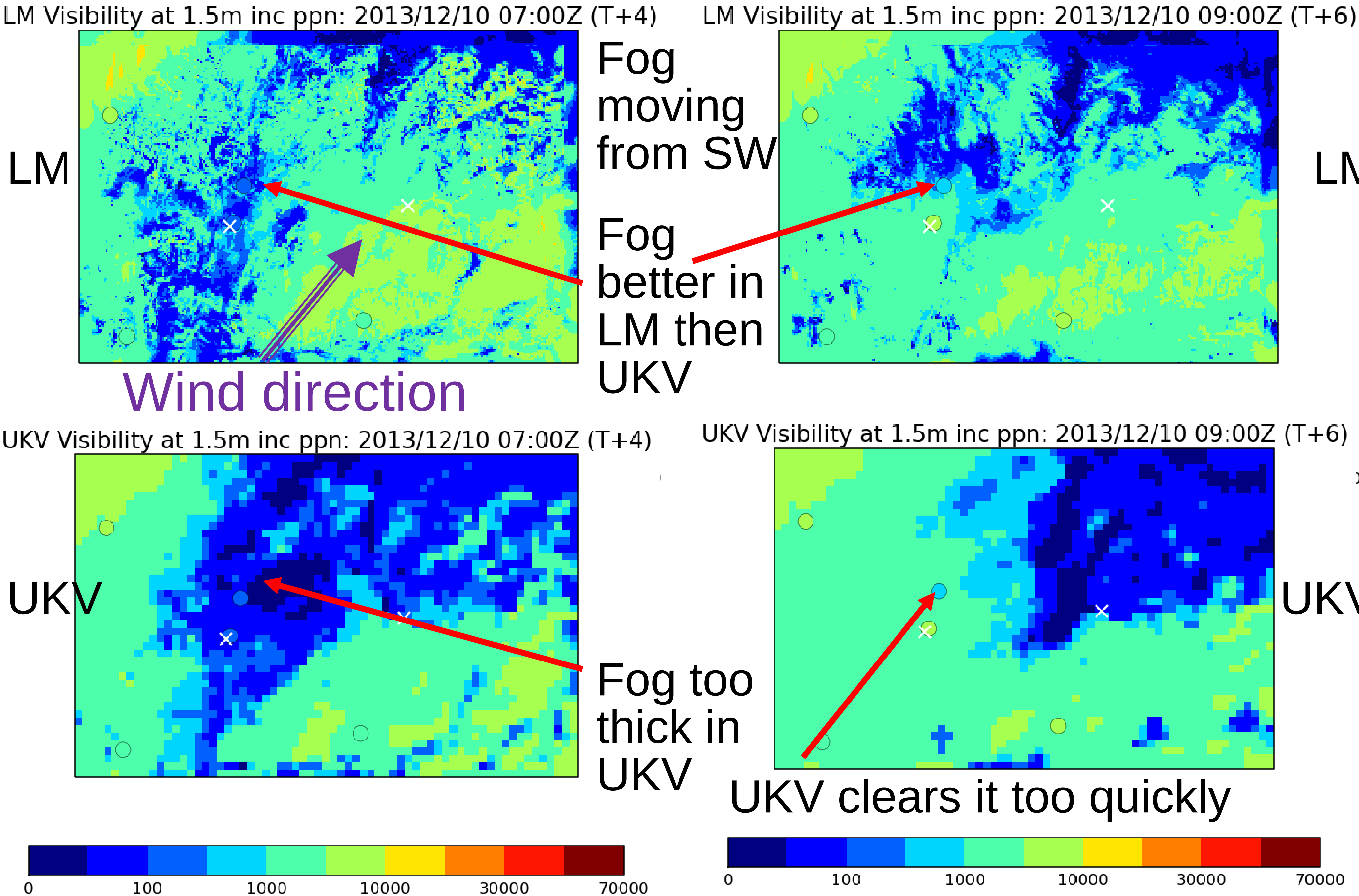
Summary of cases

- 13 cases from Autumn 2013 to Spring 2014 with fog near Heathrow (observed or forecast, not necessarily both)

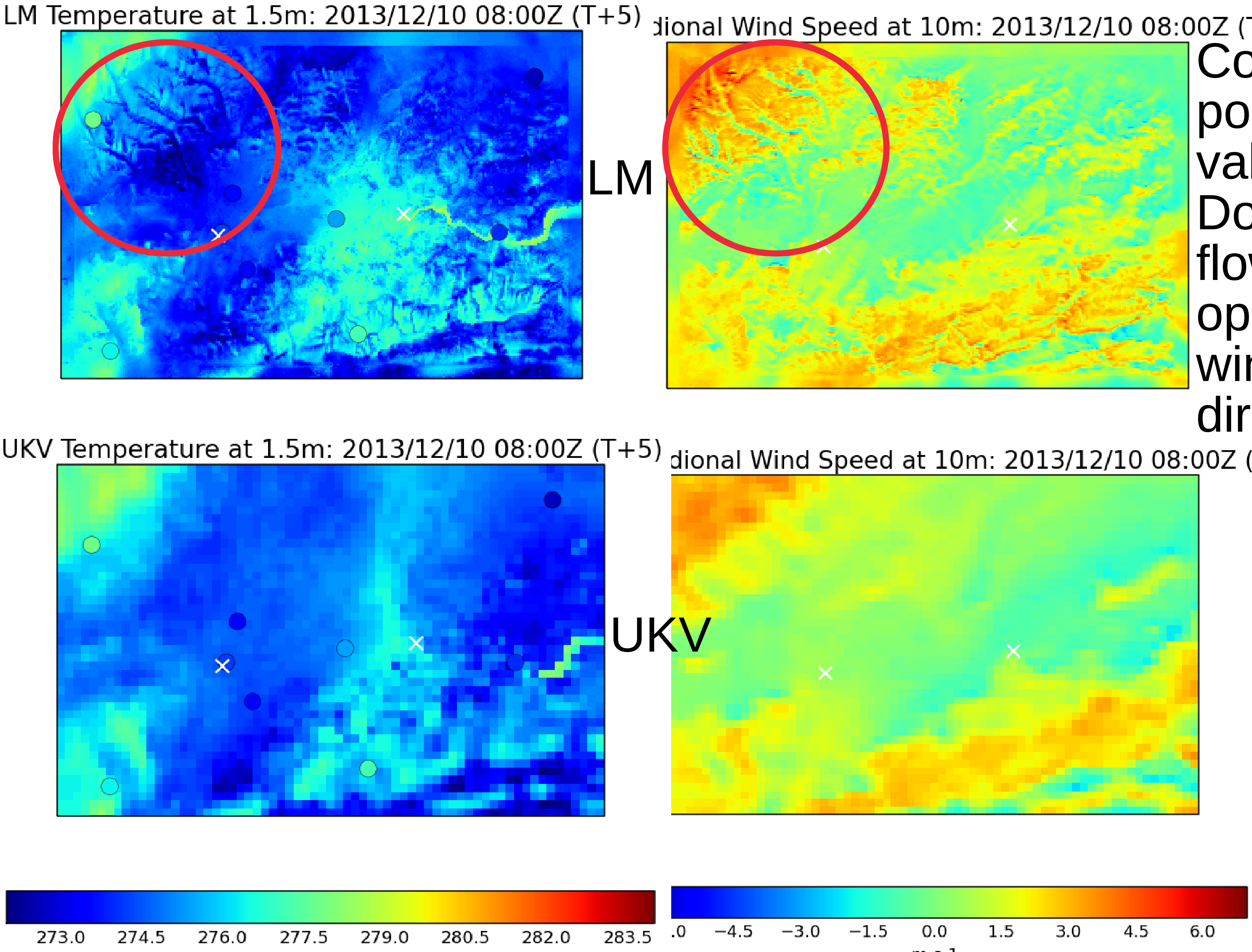
- Group cases according to type/extent of fog:
  - 2 cases of large-scale (radiation) fog covering the entire region
  - 4 cases of hill fog to the north and south of the airport – low cloud base in the valleys, but good visibility beneath the cloud
  - 7 cases of patchy (advection) fog moving across the region – good visibility (possibly clear skies) outside the fog

- 2 poor forecasts - 1 false alarm and 1 miss

10/12/13 Case: Visibility at 7Z & 9Z



10/12/13 Case: T and v-wind at 8Z



Cold air pools in LM valleys. Down-slope flow opposite to wind direction

Conclusions

- LM can produce a forecast which differs from the UKV
- This comes mainly from better representation of surface characteristics (surface heterogeneity, resolved valleys)
  - No evidence (yet) that the higher resolution dynamics is actually improving the stable BL representation
  - This is likely to require much higher resolution (100m or less)
- Bulk temperature and humidity errors are just inherited from driving model, and can be exacerbated in some situations
- Strong sensitivity to RHcrit. Better way needed.
- Plans to try the latest blending package and also increased vertical resolution

The LANFEX field campaign

Jeremy Price, Met Office Research Unit, Cardington, Beds.

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New field campaign: LANFEX

Local And Non-local Fog EXperiment

- 18 month campaign to examine development and evolution of (primarily) radiation fogs (Autumn 2014 - Spring 2016).

- NWP case studies run in parallel

- Based at Met Office Cardington and remote detachment in area of hills

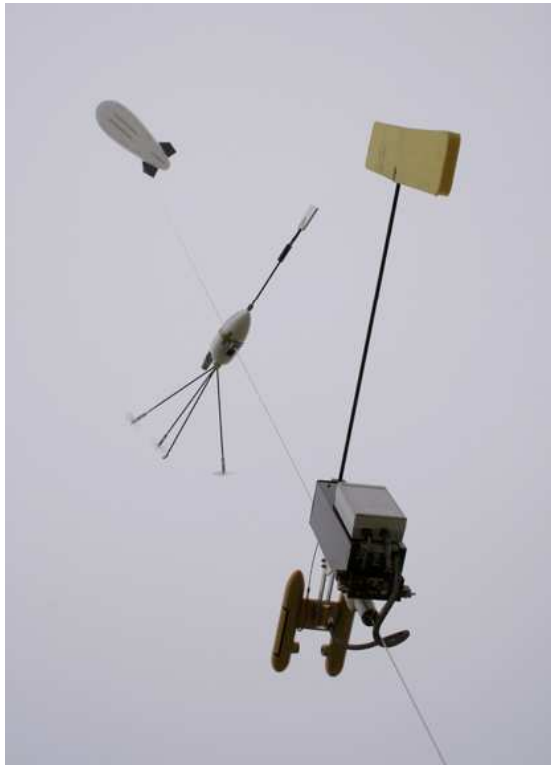
- Networks of instrumentation will examine local and non-local effects on fog formation and evolution.

Surface flux stations and Tethered balloon system

- Flux stations will measure energy balance, T,q, Heat fluxes, radiation, Soil quantities etc. at selected locations, 24/7
- Balloon: Provides profiles of T,q, winds and liquid water parameters in fog. Cardington Turbulence probe. Cloud droplet probe (DMT)

50m tower at Cardington

Tethered balloon system

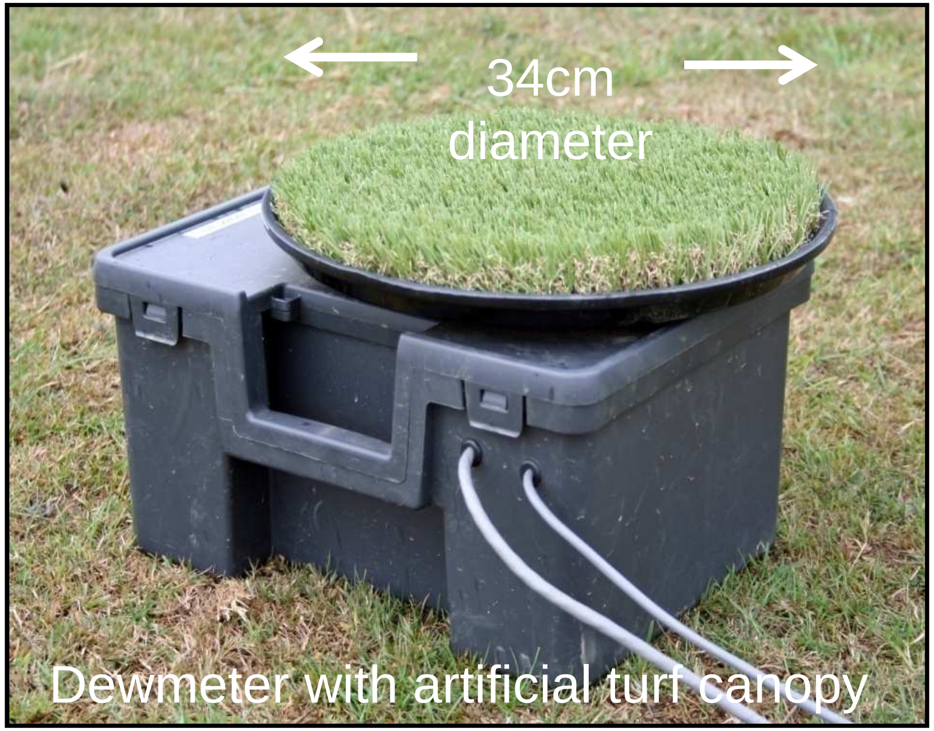


Cardington Instrumented Van – remote observations and recent development of a Light Unmanned Aerial System (LUAS)

- Radiosonde capability, RS92s (20 sondes). Halo Doppler Lidar system
- Provides T,q, wind profiles plus measures aerosol and turbulence before fog onset
- LUAS: Autonomous flight
- Will map regional T,q distributions at low level during evening transition.

Cardington Dew Deposition Meter

- Measures deposition of dew and fog droplets
- Aids study of fog formation and quantification of water budget within established fog



Dewmeter with artificial turf canopy


Two Dewmeters deployed at Cardington airfield

IR imaging will map surface temperature characteristics

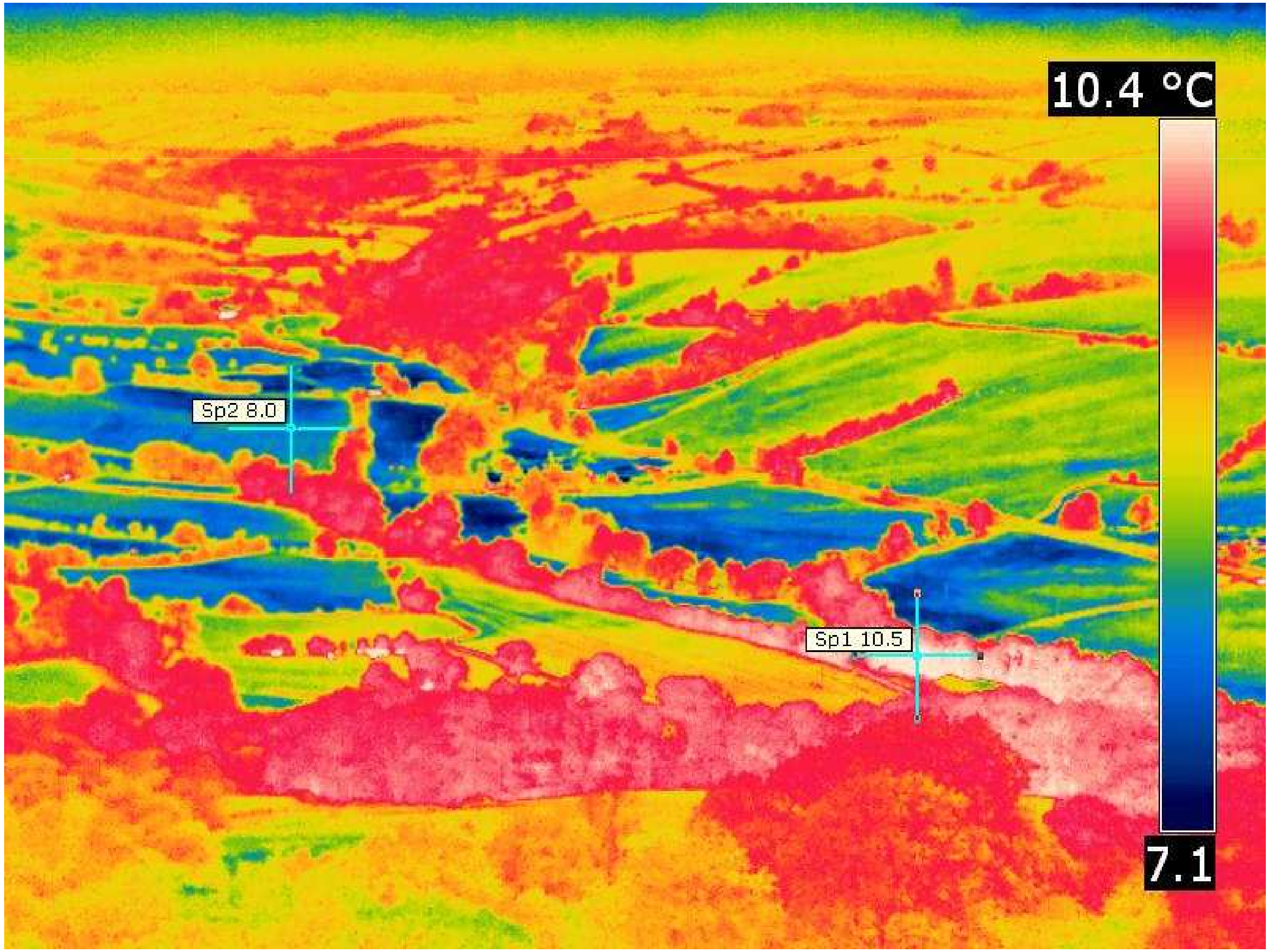


Image from recent COLPEX field campaign (Clun Valley)

Some expected outputs:

- Processes affecting the initial formation of fog and its prediction will be better understood.
- The evolution of persistent fogs from thin radiation fogs will be better predicted.
- Improved forecast products will lead to better planning of aviation and other activities during episodes of fog outbreak over the UK

Met Office

CASIM

Adrian Hill and Ben Shipway

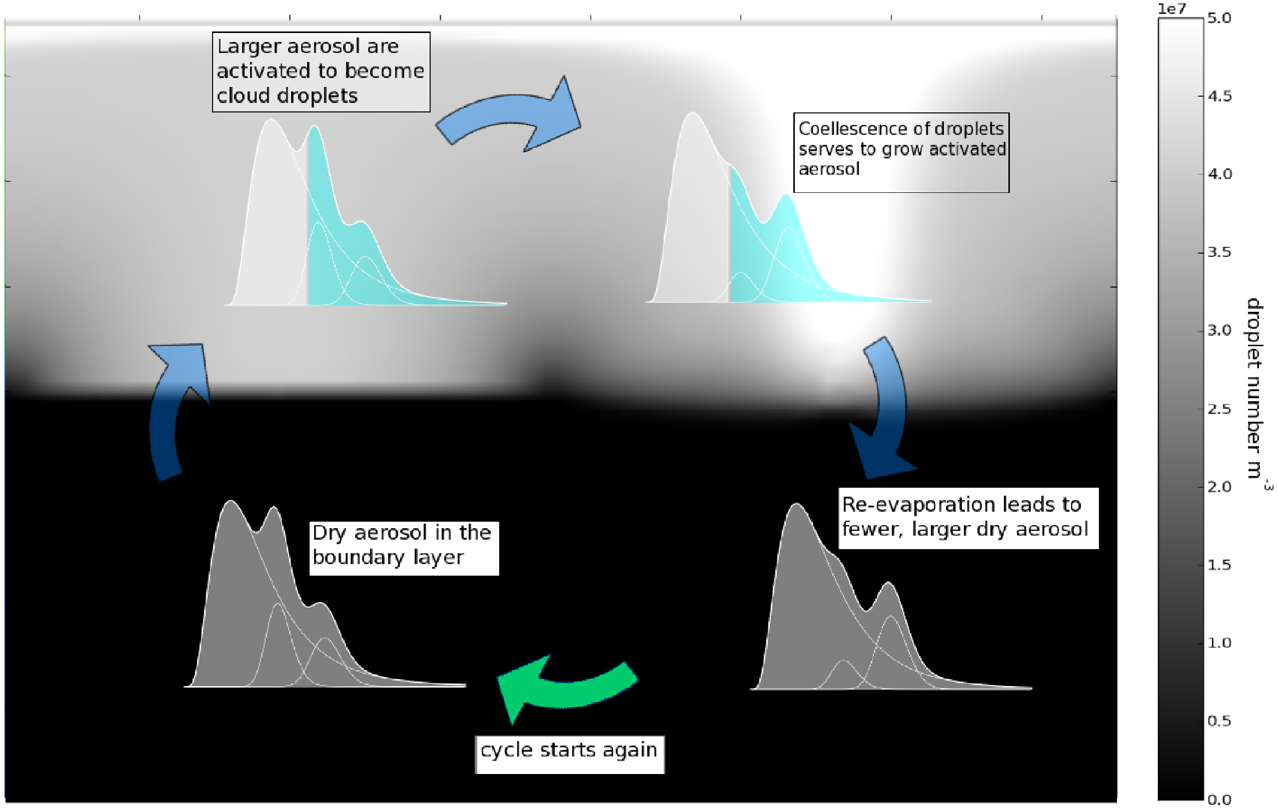
Overview of Cloud AeroSol Interacting Microphysics scheme (CASIM)

Met Office

- CASIM developed to incorporate aerosol effects incl. in-cloud processing of aerosol
- Long term replacement for MetUM and LEM microphysics
- User definable
    - number of cloud species (e.g. cloud, rain, ice, snow, graupel)
    - number of moments to describe each species (1,2 or 3)
- Coupled to aerosol (both user defined and chemistry aerosol scheme, UKCA)
- Extensively tested in kinematic framework (Shipway and Hill 2012; Hill et al, 2014) and Large Eddy simulation
- CASIM installed in the MetUM to test with high resolution NWP

Aerosol Processing in CASIM

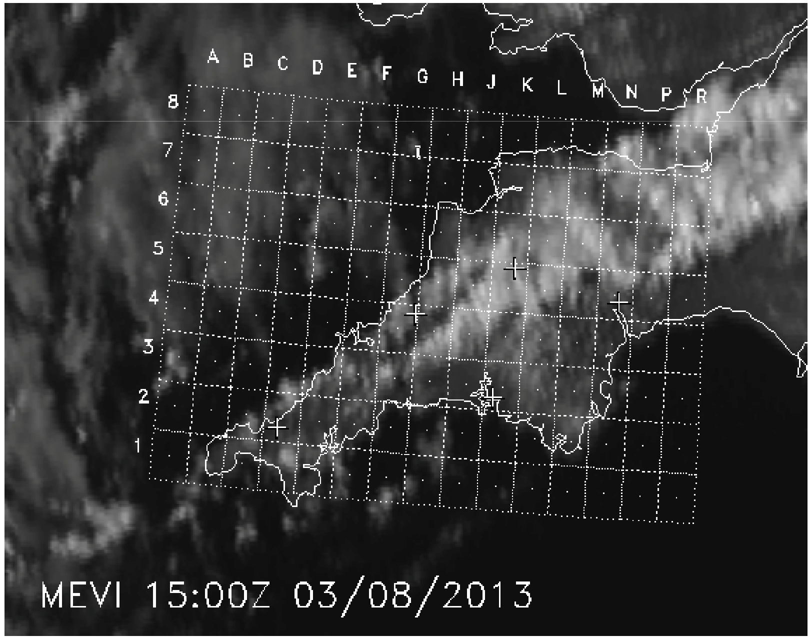
- The aim of the aerosol processing is to capture
  - the growth of aerosol that results from physical processing, e.g. collision-coalescence of droplets,
  - Removal by nucleation scavenging
  - Replenishment of processed aerosol by evaporation



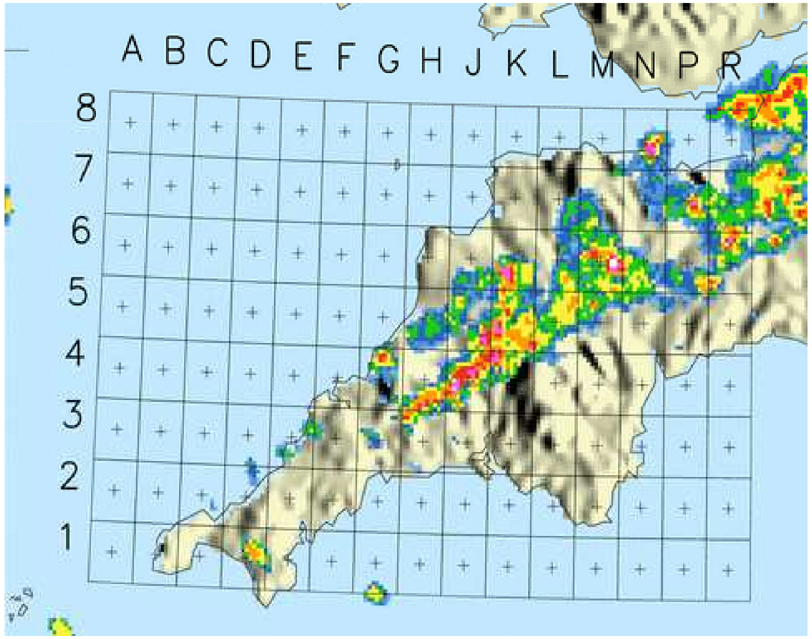
COPE case study: August 3rd 2013

Met Office

Visible satellite image



Radar

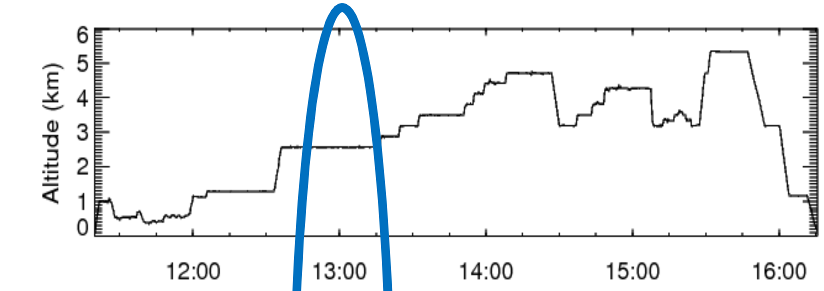


- Persistent line of organised, orographically initiated convection throughout the afternoon
- Multiple convective cells, intense rain both warm and ice, high cloud drop number concentrations.
- Not a case where you might think aerosol is important (clean air + orographic initiation)

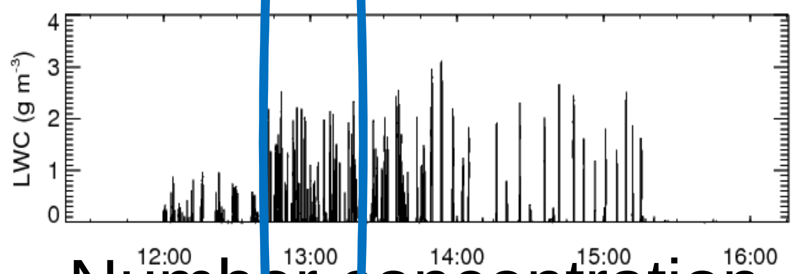
Highly idealised tests and comparison to FAAM obs

Met Office

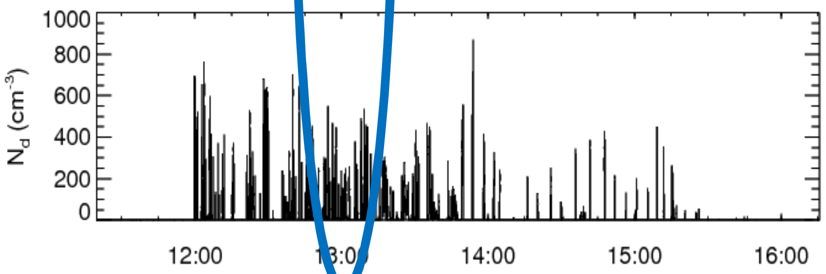
Aircraft altitude with time



LWC

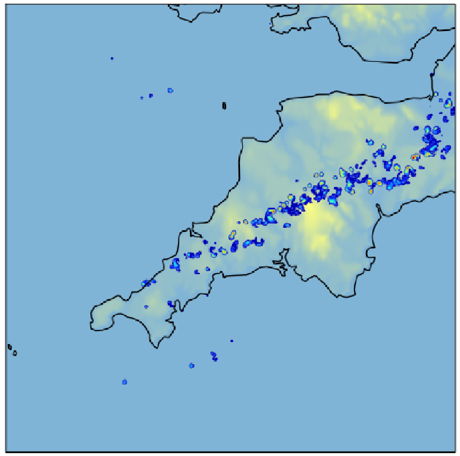


Number concentration

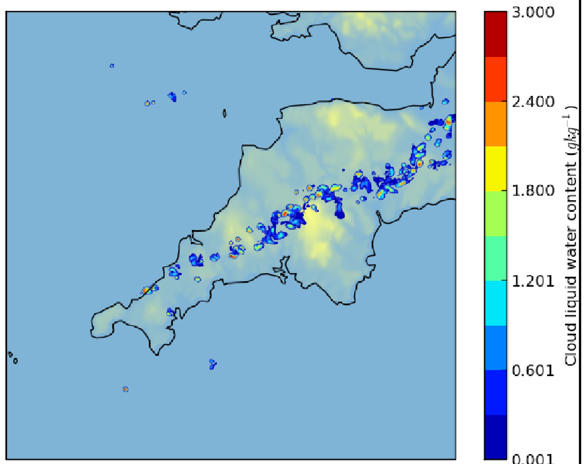


Clean	Polluted

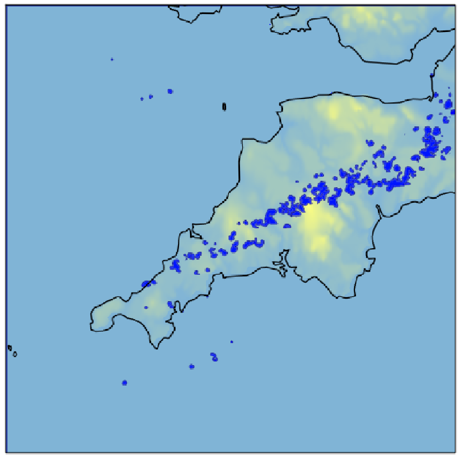
LWC @ 1300, z=2400



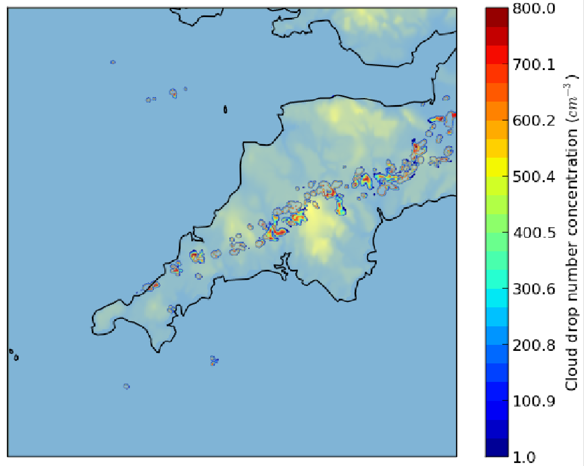
LWC @ 1300, z=2400



Nd @ 1300, z=2400



Nd @ 1300, z=2400



Values of aerosol at initialisation time: 100 cm -3 1000cm -3

Future work and questions to be answered

- How complicated do we need to make an aerosol aware microphysics scheme?
- How many moments will we be able to afford when running operationally in the UKV?
- Aerosol processing within cloud: how many species can we get way with?
- Interactions of CASIM with the PC2 cloud scheme and convection (needed if CASIM is to run in the Global model)
- MURK replacement


Questions?