# Fog Forecasting

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# Heathrow Fog Forecasting

1. Modelling and timescales
2. Why the need at Heathrow?
3. Why climatology is not reliable at Heathrow?
4. Future plans

# 1. Modelling and Timescales

# 2015 NWP Models Seamless Suite

Met Office

## UKV and MOGREPS-UK

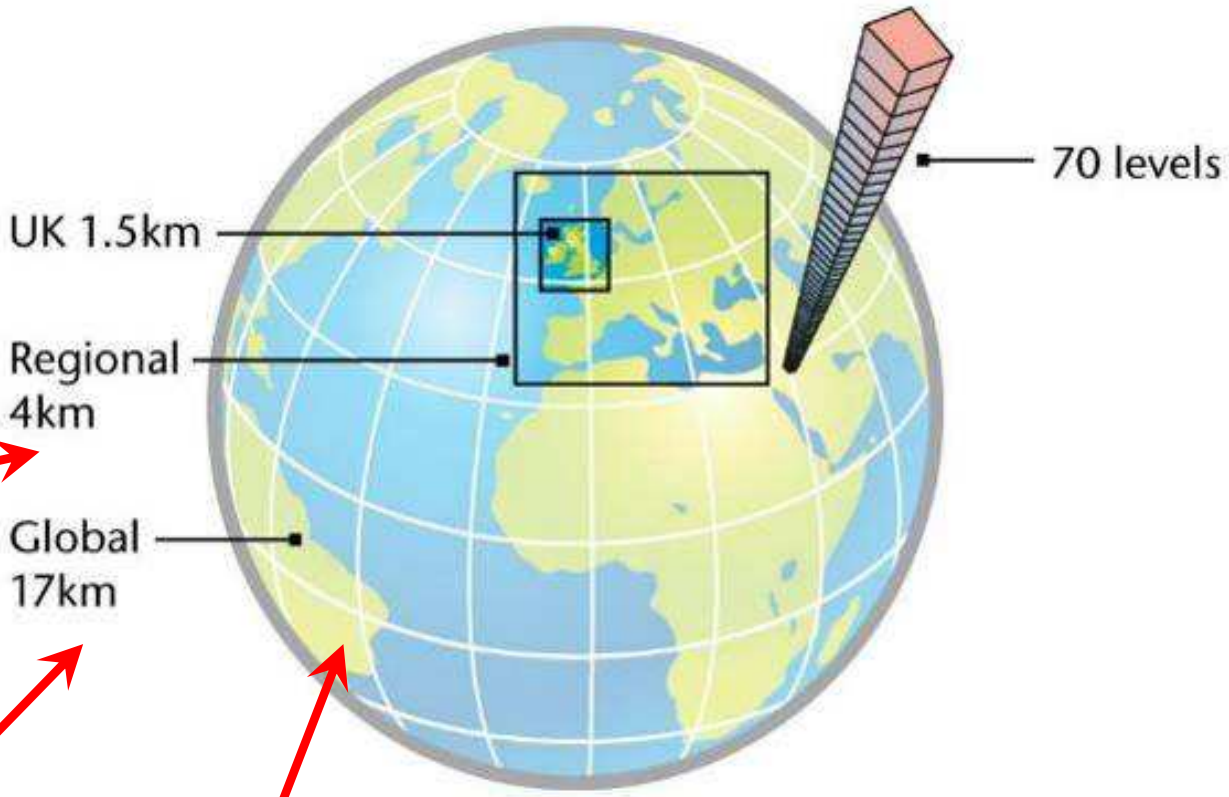
- 1.5km 70L (40km model top)
- 36hr forecast
- 8 times per day
- 12-member Ensemble - 2.2km 4x/day 36h

## Euro4

- 4km 70L (40km model top)
- 66hr forecast twice/day
- 144hr forecast twice/day

## Global and MOGREPS-G

- 17km 70L (80km model top)
- 66hr forecast twice/day
- 144hr forecast twice/day
- 12-member Ensemble - 33km 4x/day 7d
- 24-member Ensemble - 60km 2x/day 15d




## Seasonal: GloSea5

- 60km 85L (80km model top)
- ¼ degree Ocean
- 14-member Ensemble
- 7month forecast once/week

# Long range planning


ECMWF

MOGREPS

DECIDER

Chief Guidance

Customer uses – Strategic planning, including identifying risk areas, periods of prolonged westerlies/easterlies, and seeing trends in the weather (noticeable decreases/increases in temperature, wind speed, etc etc).

Products – 15 Day trend forecast, eILS 15 day outlook (Annex 1 and 2)

# Medium range planning


Chief Guidance

Global Model

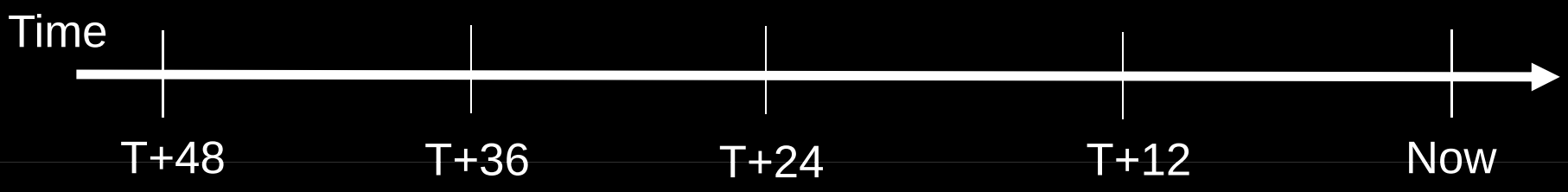
Synoptic Setup

Euro4

Customer uses – Operational planning, looking into weather events that will be potentially disruptive, assessing DvC, need for reduced scheduling.

Products – 5 Day Forecast, LVP Matrix

# Short range planning




Chief Guidance

Global Model
Synoptic Setup

Euro4

UKV

Best Data

**Forecaster Input**

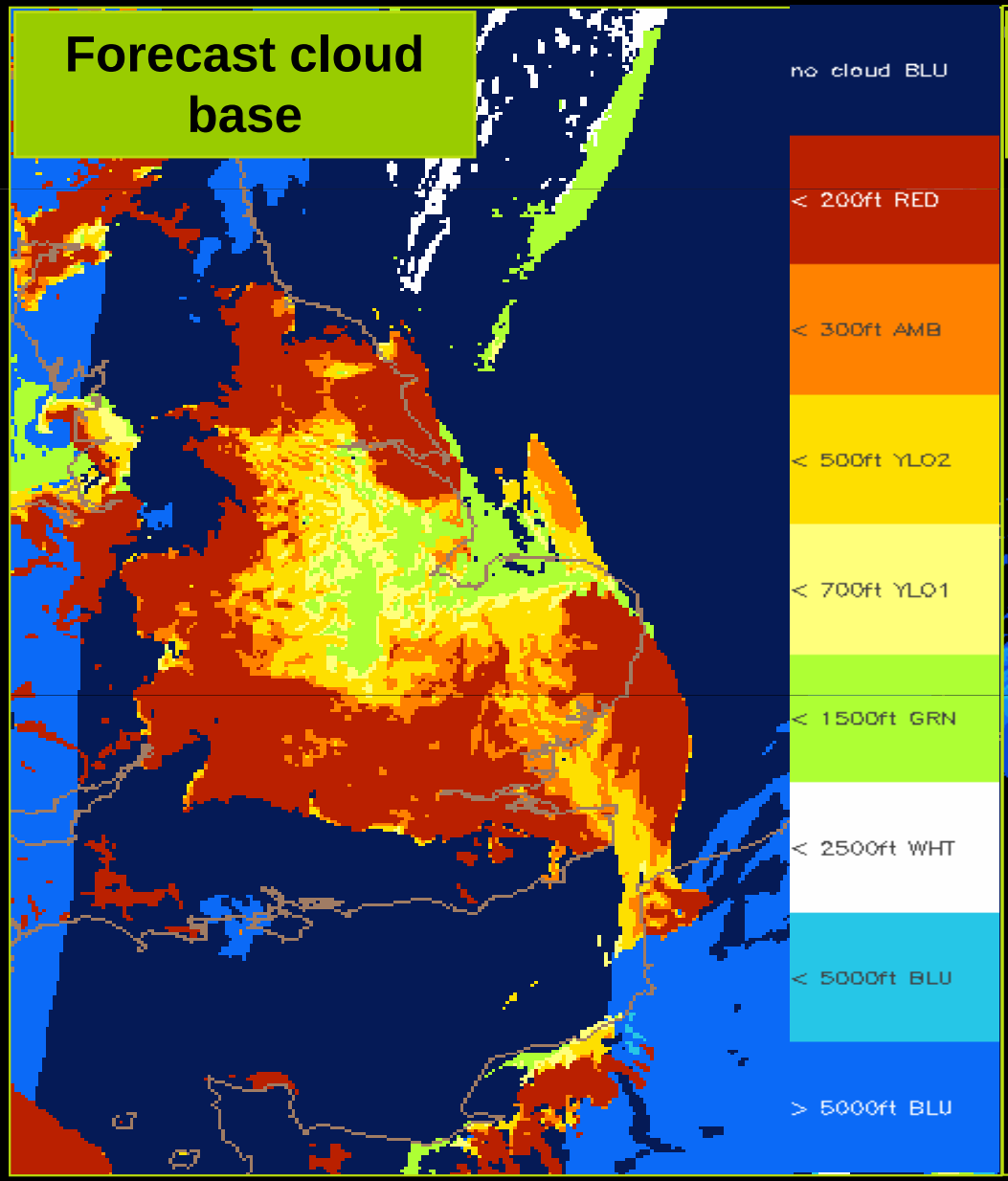
Customer uses – Operational planning, looking into weather events that will be potentially disruptive, helping to conduct DvC meetings – impact of wx on operations, and best way to deal with the impact. HOCC calls

Products – 5 Day Forecast, LVP Matrix, TAF's, Trends, Aerodrome Warnings,

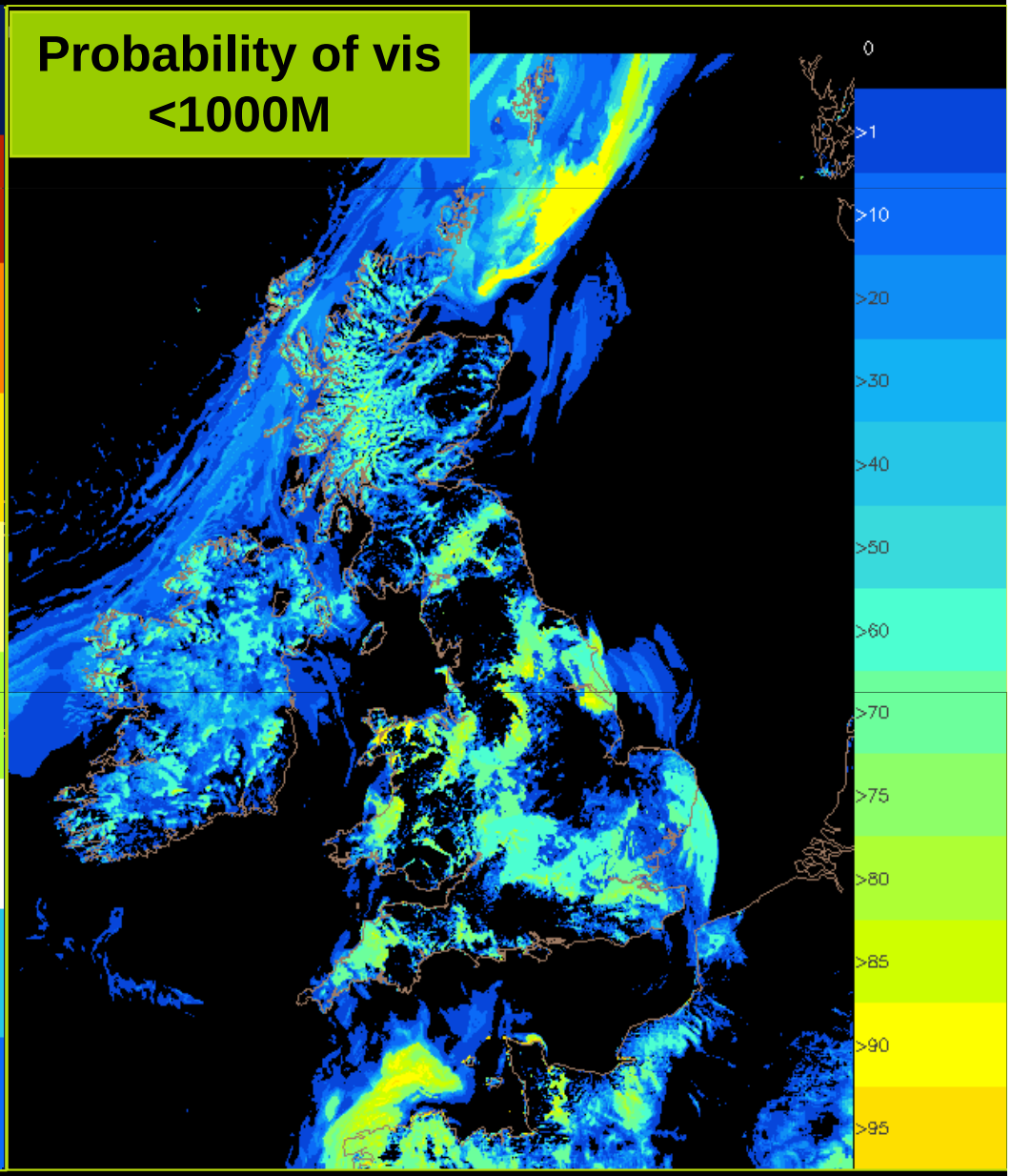
# Model Data- examples both from UKMO Hi-res 1.5KM model (WSI use our 4KM model)

Met Office

## Forecast cloud base




## Probability of vis <1000M



# Forecaster input

- Assesses model for strengths and weaknesses
- Reviews current verification
- Seeks review from Aviation Team Leader, Chief Forecaster
- Speaks to local forecasters
- Climatology of the area / historical knowledge of weather types
- Topography of the area
- Uses empirical techniques to potentially improve/verify on model
    - McKenzies minimum temperature, Barthram Curve, Saunders fog point, Middle Wallop method etc etc

- FORECASTER IS RELIANT ON MODELLING FROM T+24 ONWARDS
- FORECASTER CAN ONLY REALLY ADD VALUE T+0 - T+24 by the use of local knowledge, current observations and empirical methodology

Met Office

## Other Forecaster Tools:

Imagery- various forms of satellite imagery are available, but they have their limitations

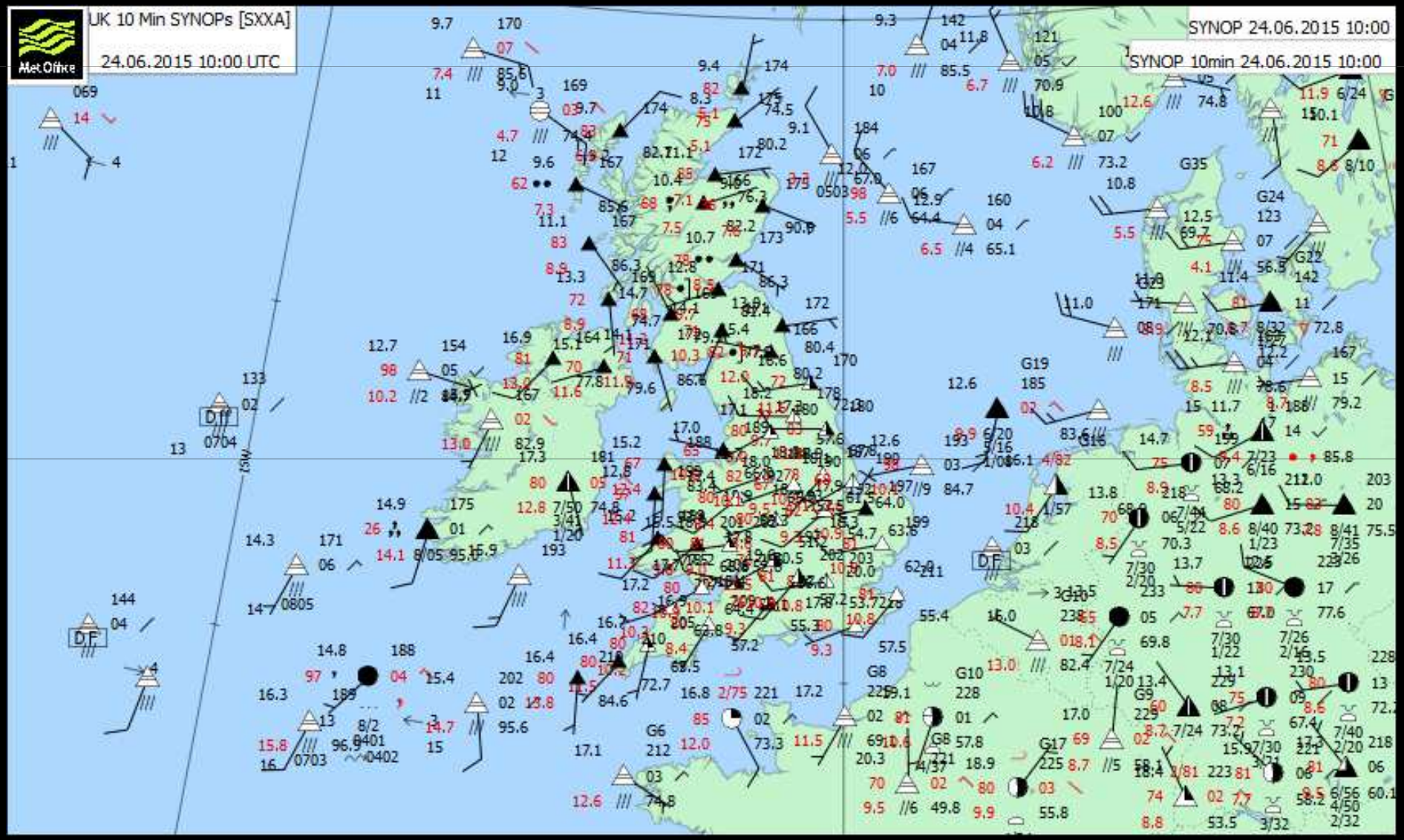
Tephigrams- may not have a representative tephi from which to calculate fog points

Experience- forecasters are highly trained, and also have an experienced team to call upon

Continuity- was it foggy yesterday?

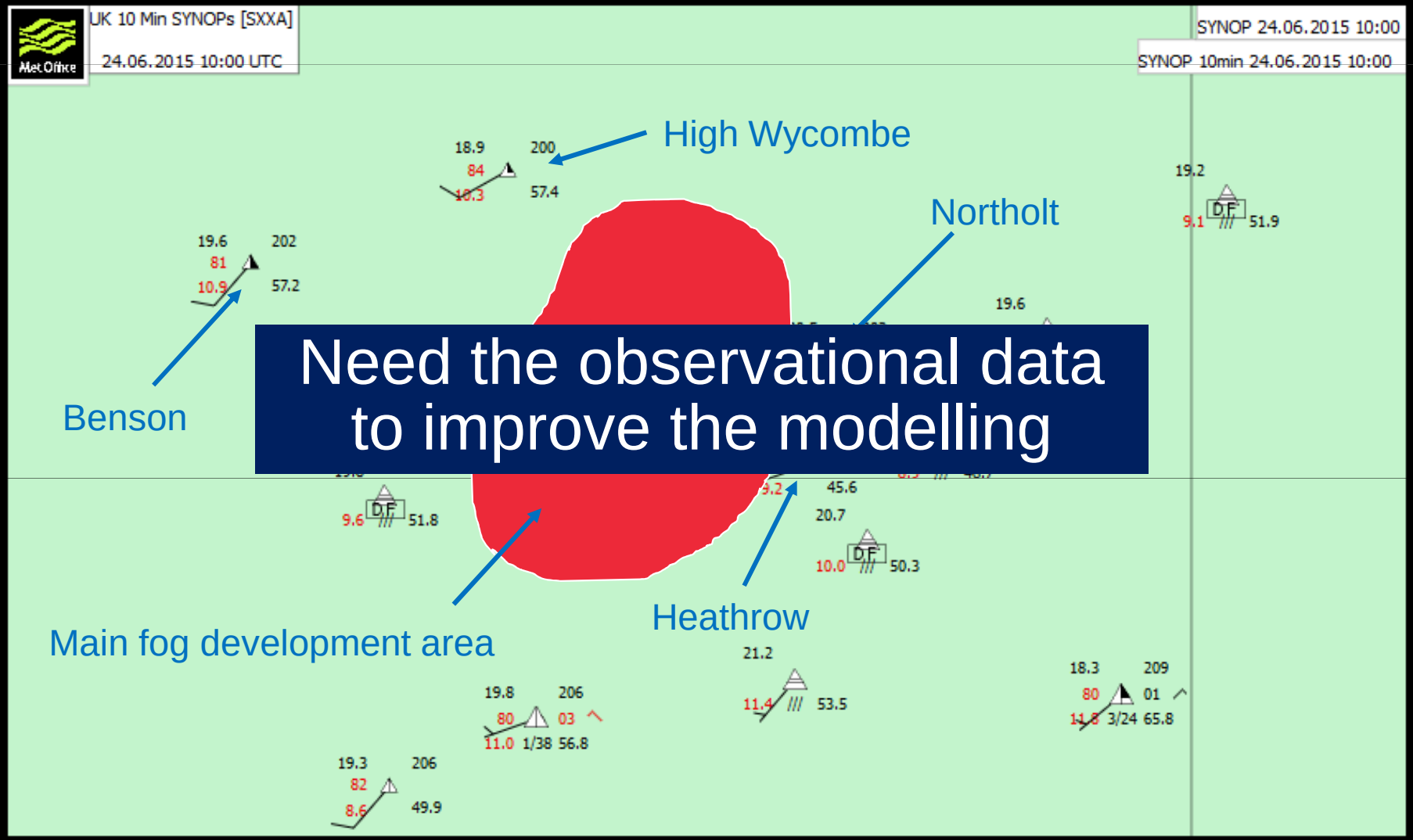
# Weather Forecasting

## Observational Data – current capability is good for broad forecast data



# Weather Forecasting

## Observational Data – but relatively sparse for high resolution spot forecasts



Met Office

## Fog- why is it difficult to forecast?

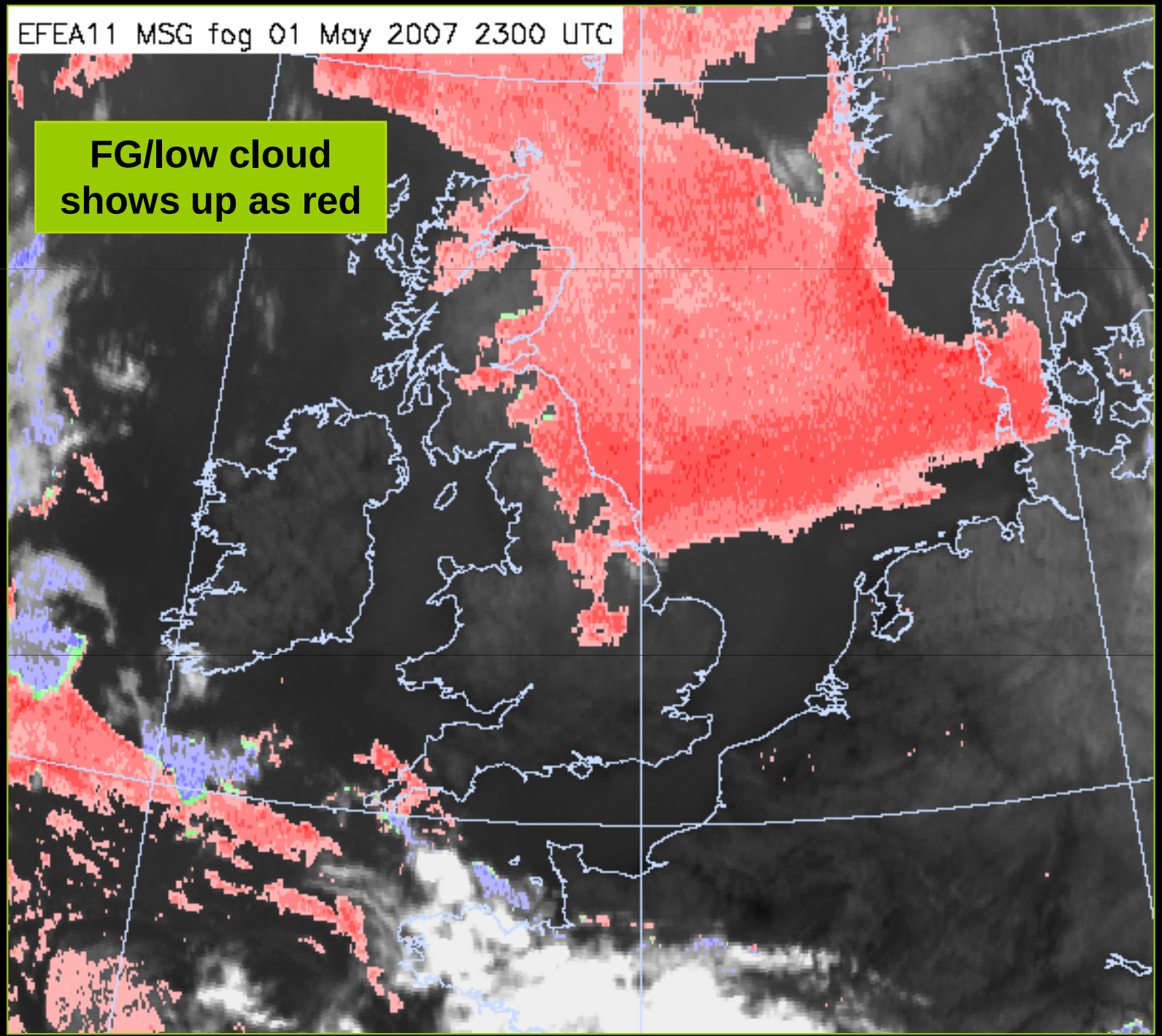
Fog forms when the temperature of the air cools to the dew point of the air- “cloud” forms at the surface (radiation fog)

or

Fog forms when low cloud which has already developed advects across the airfield (advection fog)

Slight changes in- wind speed (a matter of KTs), humidity (1-3%), cloud cover, surface heat flux, dew/frost deposition *will* impact the likelihood of future FG, or longevity of current FG

# Imagery- coloured fog image



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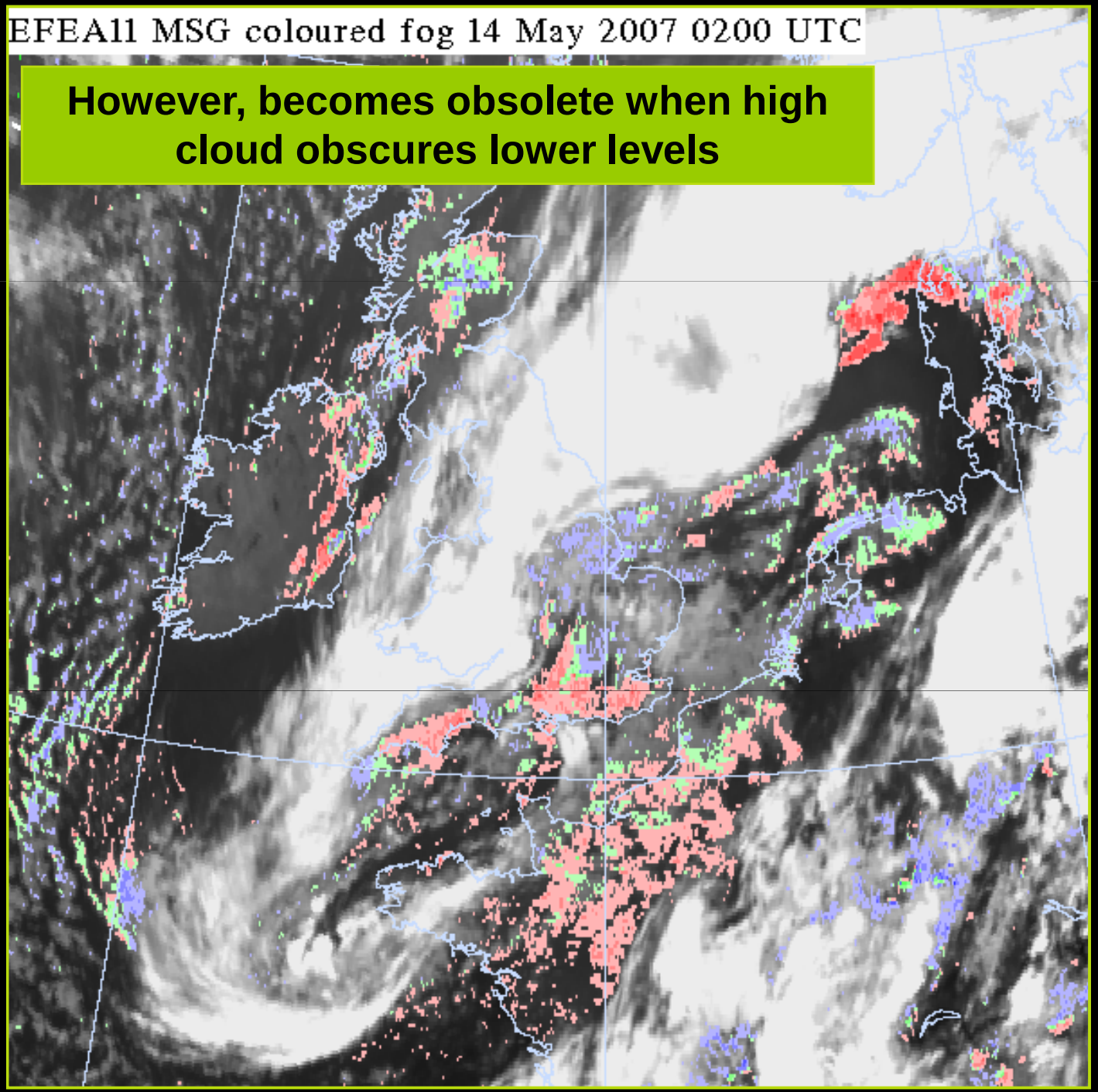
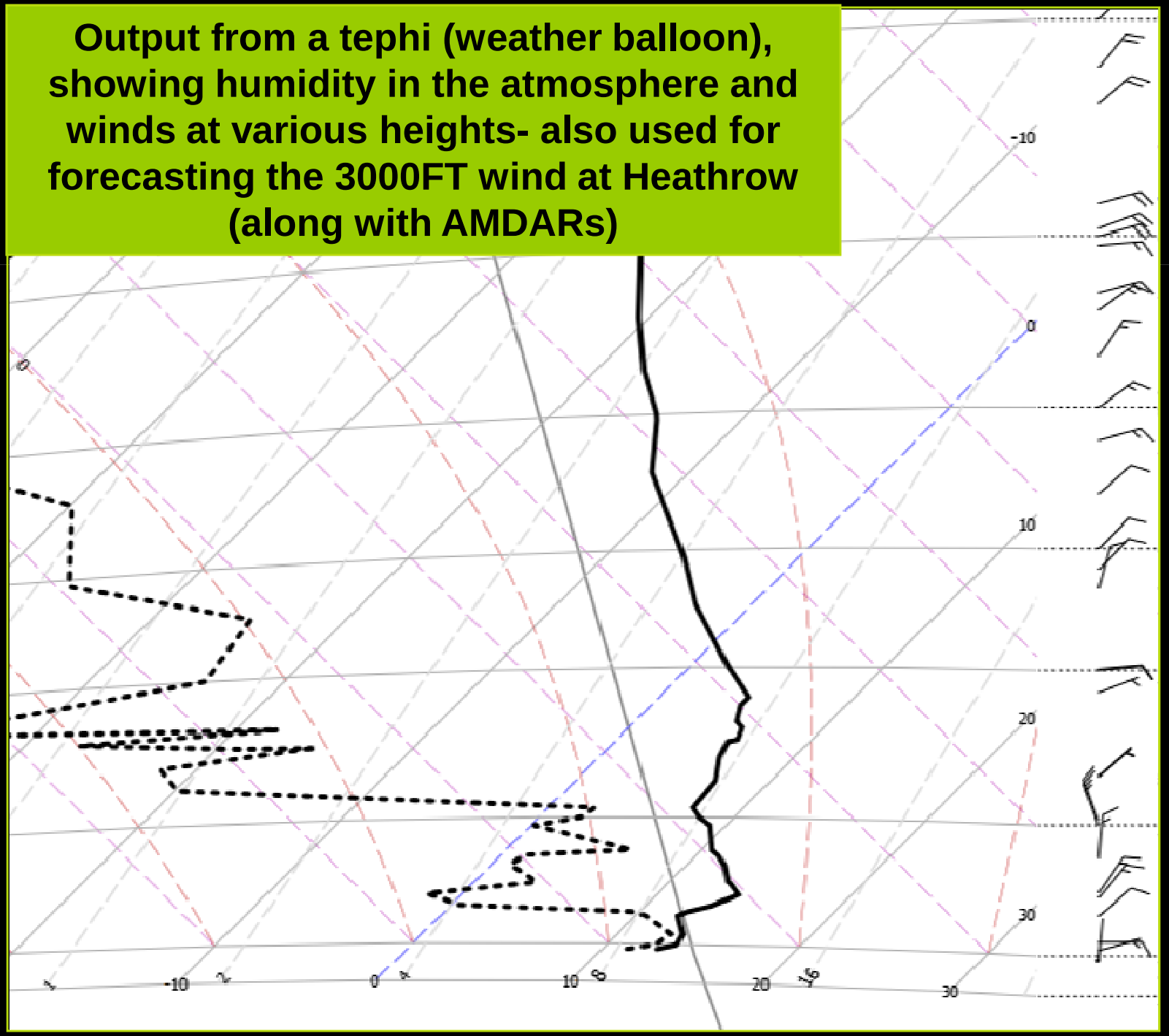


# Tephigrams

**Output from a tephi (weather balloon), showing humidity in the atmosphere and winds at various heights- also used for forecasting the 3000FT wind at Heathrow (along with AMDARs)**



# 2. Why the need at Heathrow?

# Heathrow Airport

- Average about 1290 movements per day
- 73.4 million passengers during 2014
- 1.5 million tonnes of cargo during 2014
- 3rd busiest airport in the world for passengers in 2014
- 2 RUNWAYS!!!
- Heathrow runs between 95-98% capacity
- Hub airport and home airport for British Airways
- Part of National Infrastructure – 2009 £32.4 billion of freight through Heathrow to non-EU countries alone!

# Customers

- Heathrow Airport – Service Provider
  - ~ £800,000 per year contract over 5 years with Met Office
- NATS – Service Provider
  - Strong collaboration work between Met Office and NATS
- Airlines – End User
  - British Airways hub based at Heathrow
- Passengers – End User
  - £6 Billion spent in the UK per year from tourists travelling through Heathrow – *'Making every journey better'*

# Impacts of the Weather

- Fog – Visibility on the ground.
- Snow – Snow clearance / runway friction
- Thunderstorms – Airspace management
- Strong winds – arrival rates
- En-route Weather
- Destination / departure Weather

**90% of all departure or arrival delays are caused by the weather!**

# Deadlines for Decision Making - Airport

- Can be up to 5 days ahead.
- Primarily for snow, 48 hours for staffing and resources
- For schedule assessment intervention, DvC meetings held at 1100 L the day before a weather (or non-weather) event.
    - Leads to increase in time for arrivals
    - Possible cancellations of flights
- Flow rates for Swanwick (NATS control centre) normally applied pre-tactically at  0400 L on the morning of the weather.

# Deadlines for Decision Making - Airlines

- DvC meeting set at 1100 L to allow decision on any schedule interventions.
- If cancellation of flights, this timing allows for:
  - Informing passengers
  - Rebooking passengers
  - Adjustment of aircraft, crews and resources across network
- TAF requirements for flight planning - important to understand flight planning as this is a main purpose of TAF’s.

# Decision Making – N.B

- Weather is a good parameter to blame delays on.
- Airlines and airports have their own agendas, so although weather may be a factor, it may not be the trigger for alterations to schedules.
- DvC gives a recommendation to airlines, airlines do not have to co-operate.
- HIGH PRESSURE ON THE ON-SITE METEOROLOGIST.

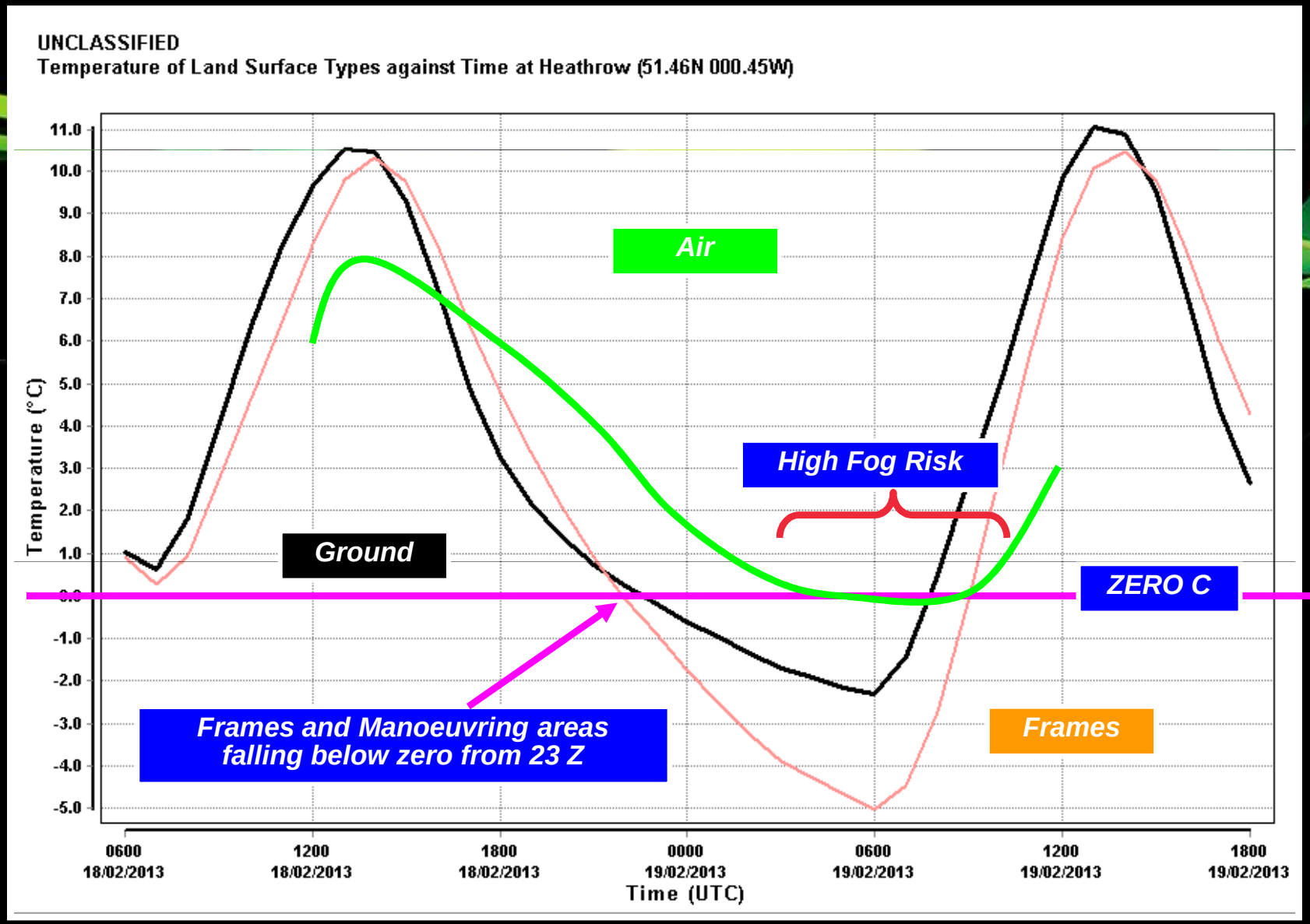
# Impacts of fog for Heathrow

- Aircraft can land in fog if they are equipped for this but taxiing to the stand is more problematic
- Air traffic controllers cannot see the aircraft in the air or on the ground – safety
- Generally halves the number of arrivals and departures – aircraft held in stacks above London or delayed on the ground
- When schedules slip, there is not enough flex in the capacity to catch up – flights get cancelled
- Large financial implications of fog to affect the airport, airlines and national economy

# Impacts of fog on airlines

- Airlines generally plan off the Terminal Aerodrome Forecast (TAF)
- Warning of fog need to be as long as possible (Heathrow TAF is 36 hours long)
- If cancellations are required, need lead in time for instructing passengers and crew.
- Diversions possible if the airline is not carrying enough fuel for holding pattern

# Temperature fall



# Reservoir Steam Fog Case study 05th October

- Events over last autumn could be formed by evaporation of moisture in the reservoirs.

Picture taken at 0626Z on 5th of October

# Reservoir Steam Fog
# Case study 05th October

Picture taken at 0626Z on 5th of October

With light NW surface wind, this posed no threat to operations.

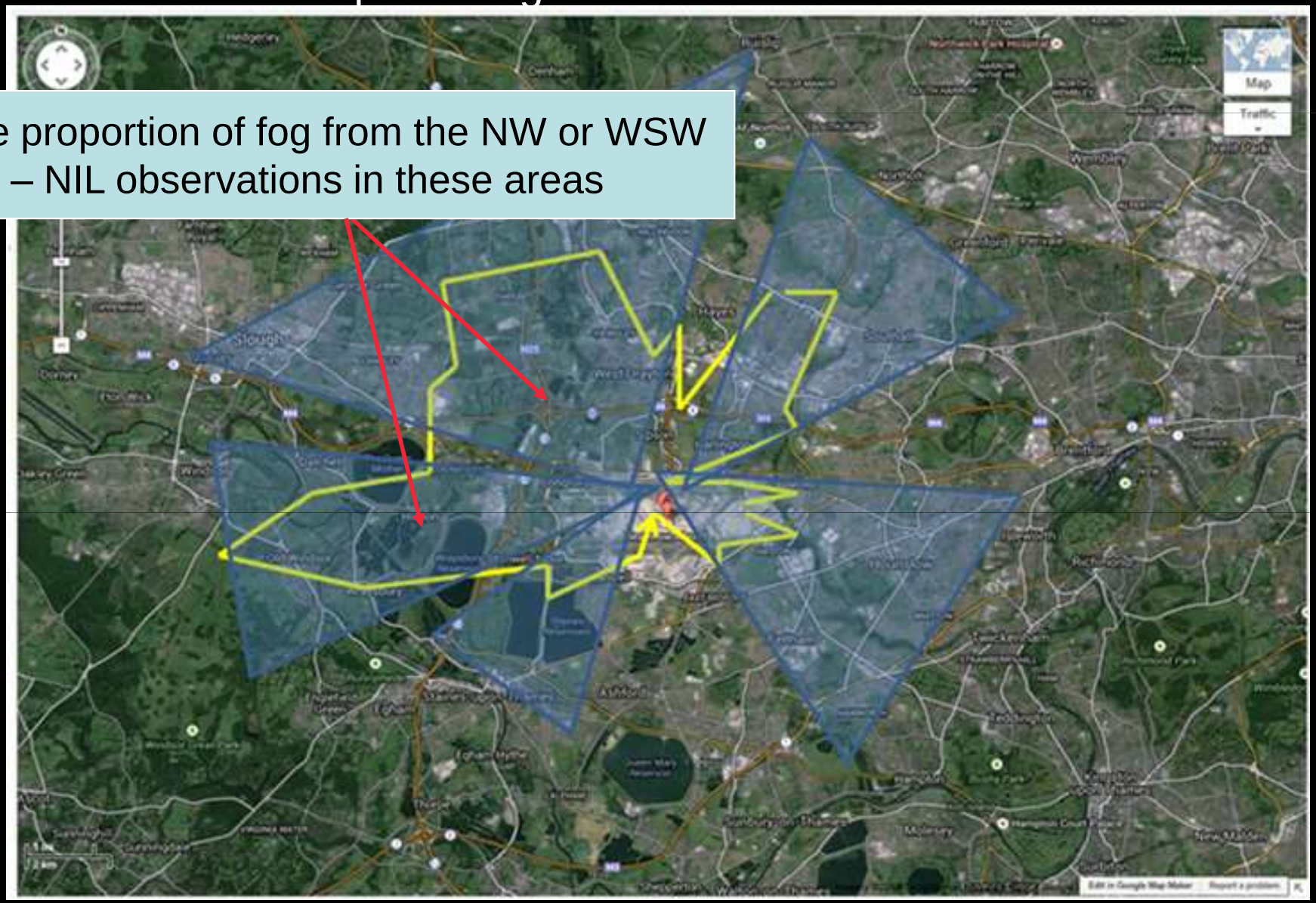
# Reservoir Steam Fog
# Case study 05th October

Picture taken at 0741Z on 5th of October

However a light S'rly developed, and started to spread across Terminal 5.

# Weather Forecasting

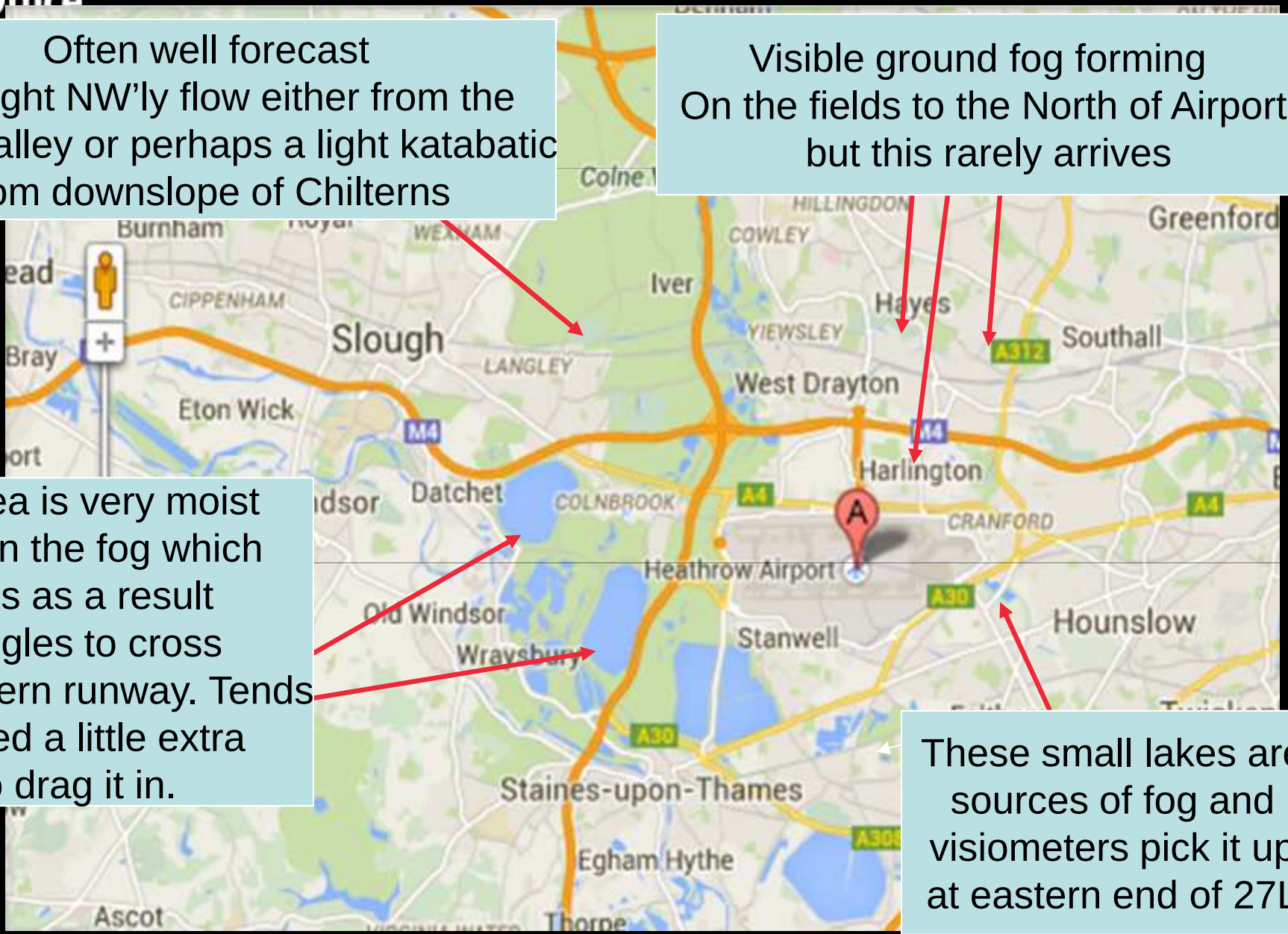
MSc Dissertation and local knowledge of when fog occurs and what the prevailing wind direction is at the time



Where does our fog come from? It almost never forms on site but always drifts in from somewhere else.

Often well forecast
On a light NW'ly flow either from the Colne Valley or perhaps a light katabatic from downslope of Chilterns

Visible ground fog forming
On the fields to the North of Airport but this rarely arrives

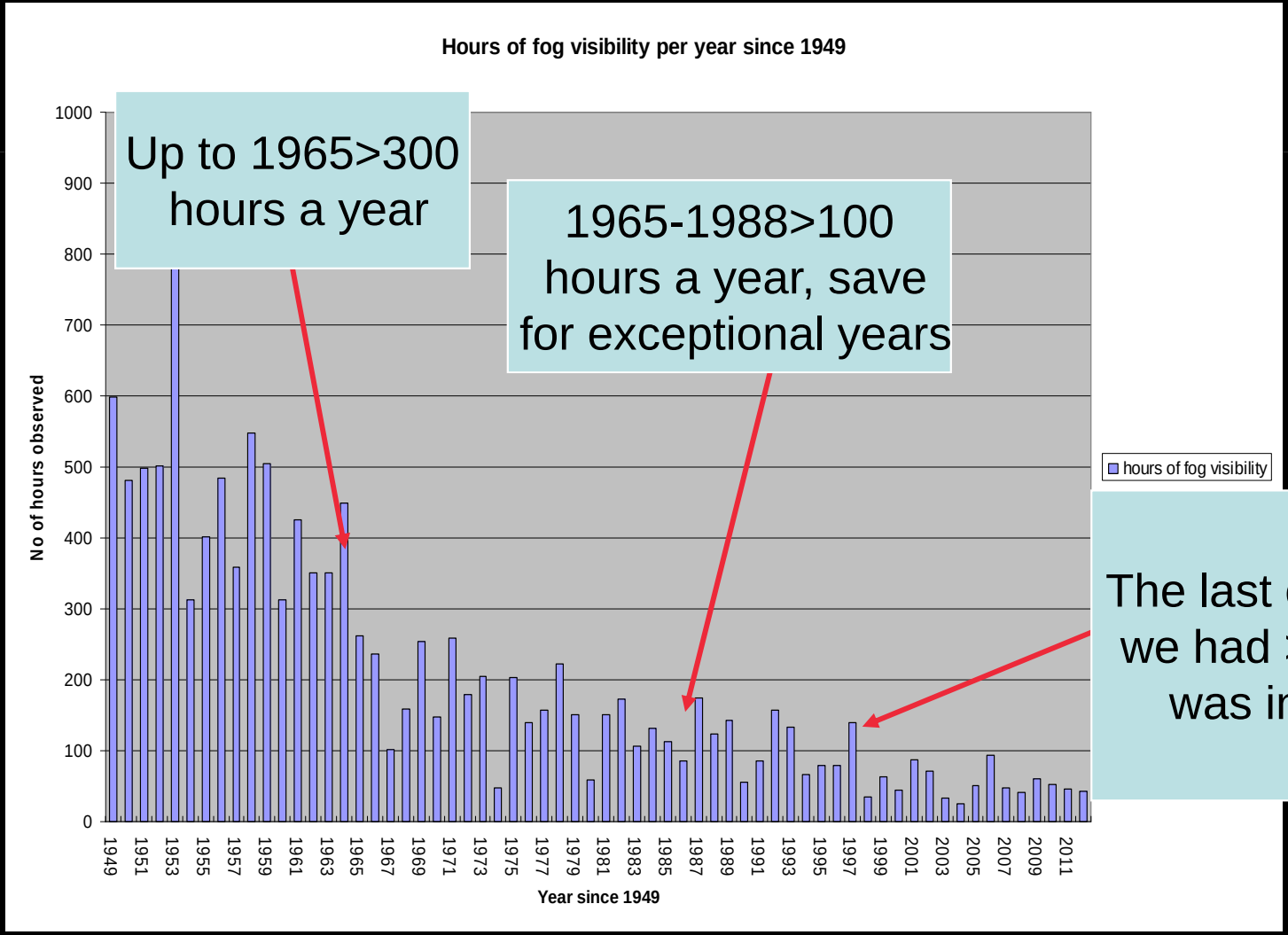



This area is very moist
But often the fog which forms as a result struggles to cross the southern runway. Tends to need a little extra to drag it in.

These small lakes are sources of fog and visiometers pick it up at eastern end of 27L

# 3. Why climatology is not reliable at Heathrow!

Previous graphs have been only for long-lived fogs i.e those lasting until 0900Z this is the total each year for total hours of fog.



Aerial view in 1998.

Central complex of terminals 1,2 and 3 with terminal 4 to south, BA Cargo west of that, Beeline base to East.

# 4. Future plans

# Weather Forecasting

## Observational Data

- Increase local observations
- Increase AMDAR data (including RH)
- Find alternative to radiosonde for EGLL
- Wind profilers
- LIDAR
- Other sources – WOW, webcams, Highways Agency obs

# Fog forecasting- the future

**Future developments:**

Further research into aerosol modelling- essential in formation of fog

Increased resolution both horizontally and vertically of existing and future models

Increase in automated weather observation sites- gives better input into model

Increased use of ensembles

**Better stratocumulus modelling- this is the main problem we have when forecasting fog formation**

# See the Poster if you haven't already!

## The London Model: forecasting fog at 333m resolution

Ian Boutle, Anke Finnenkoetter, Adrian Lock, Helen Wells

Q. J. R. Meteorol. Soc., doi:10.1002/qj.2656

**Abstract**

A very high resolution numerical weather prediction model is nested inside the Met Office's main United Kingdom forecast model to investigate whether further enhancements to resolution provide any benefit for fog forecasting. The London Model (LM) shows similar performance to its lower resolution equivalent at short lead times, but improved performance at longer lead times and an improved frequency bias of forecast fog events. Differences in the model cloud parametrization are the key reason for the differing behaviour, leading to systematically less cloud, colder night time minimum temperatures and therefore more fog in the London Model. Benefit of the enhanced resolution is also found, via an improved representation of how orographic variability enhances turbulence in the stable boundary layer.

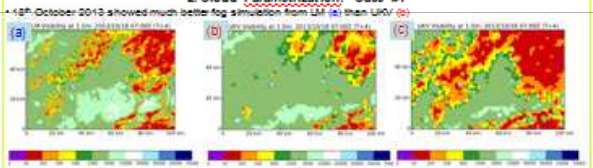
**1. Model Setup**

- 333m horizontal grid-length, 70 vertical levels, 10s timestep
- 1 way nested inside 1.5km UKV model
- 100 x 86 km domain covering the Greater London area
- Running twice per day

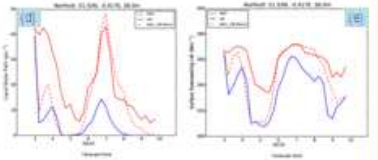
- Better representation of surface characteristics – orography, land usage
- Modified cloud parametrization – increased critical relative humidity (RHcrit) for onset of cloud - less parametrizing is required as more variability should be resolved

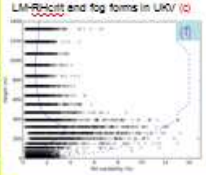
**2. Cloud Parametrization: Case #1**

- 18th October 2013 showed much better fog simulation from LM (a) than UKV (b)



- Widespread patchy fog in west of LM domain (a) absent from UKV (b)
- Fog formation in LM due to absence of low-level stratocumulus between 4.30 and 5.30 UTC (d), giving less downwelling long-wave radiation (e) and colder surface temperatures
- Difference due to different cloud parametrization used in UKV and LM
- Remove this difference, run UKV with LM-RHcrit and fog forms in UKV (c)

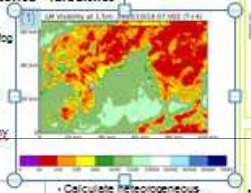


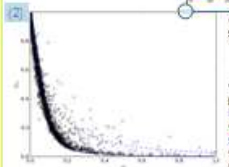


- Suggests there should be less of a difference between RHcrit values used in LM and UKV
- Difference in parametrized values is up to 14% (f, dashed curve)
- Investigate resolved variability in LM at grid-scale of UKV (5 x 5grid-points)
- Actual resolved variability in RH from LM at grid-scale of UKV is often much less (f, black crosses)
- This is the additional variability the UKV parametrization needs to produce
- Lots of scatter in resolved variability, showing that one single value of RHcrit does not exist – need more sophisticated parametrization!

**3. Unresolved Turbulence**

- Case #1 showed much thicker fog in the UKV with LM-RHcrit simulation (c)
- A real effect of resolution
- Caused by rougher orography enhancing turbulence in the stable boundary layer
- Running LM with UKV-orography (i) leads to much thicker fog



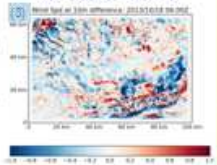


- Calculate heterogeneous stability function:

$$f_m(Ri_b) = \frac{\overline{w\theta_{sgs}}}{\overline{w\theta_{sgs}}} f(Ri_b)$$

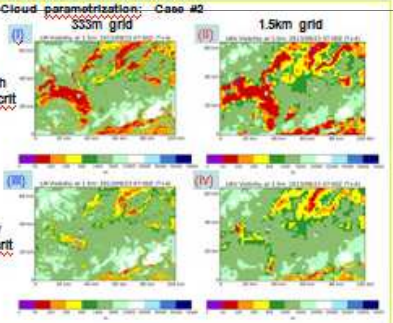
- Shows resolved mixing at UKV grid-length from LM simulation (2, black crosses)
- Parametrized mixing in UKV (2, ) is always less
- Lots of scatter, difficult to just use a function to give more mixing (e.g. 2, dashed blue curve)

- Variability arises through variation in low level windshear
- Shown by difference in wind-speed between runs with smooth and rough orography (3)
- This variability is often linked to variability in terrain, but not always
- Difficult to parametrize, hence motivating use of high-resolution model



**4. Cloud parametrization: Case #2**

- 23rd September 2013 showed similar differences between LM (i) and UKV (iv) to Case #1
- This time, LM (i) was too foggy
- UKV (iv) was correct in maintaining cloud and preventing the onset of fog
- Again, difference is entirely due to the cloud parametrization and values of RHcrit used
- Running LM with UKV-RHcrit (iii) strongly suppresses fog formation
- Running UKV with LM-RHcrit (ii) allows fog formation
- Shows that cloud scheme needs to adapt from case to case




**Key Findings**

- Cloud parametrization is important in sub-kilometre scale models
- Orographic roughness enhances turbulence in the stable boundary layer
- There are clear benefits of sub-kilometre scale NWP (for fog forecasting)

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# Barthram curve

(d) *A nomogram for forecasting clearance of fog by insolation*

**Fig. 3.6** is a nomogram, due to Barthram, for predicting the time of fog clearance due to insolation, where:

$T_1$ = surface temperature at dawn

$T_2$ = fog-clearance temperature

d = depth of fog at dawn in hectopascals.