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Reducing the cost of disasters: opportunities & challenges for nowcasting

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Met Office, UK

Co-Chair, WWRP/HIWeather

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Outline

- Context
- Recent developments
- Horizon scanning
- Future developments
- HIWeather

Context

- Severe weather forecasting has been transformed in the last 20 years
- Scales that matter are now resolved in local models while synoptic scale guidance is reaching into week 2
- However, in 2012, hydro-meteorological disasters killed 10,000, affected 125,000,000, and cost $150,000,000,000
- The cost of other high impact weather was vast – transport delays, business losses, utility outages, property damage, personal distress – and they are growing as exposure increases
- High impact weather in a resilient community is a disaster in a less resilient one
- Meteorologists have the key to reducing cost & distress, but unlocking the benefits requires partnership

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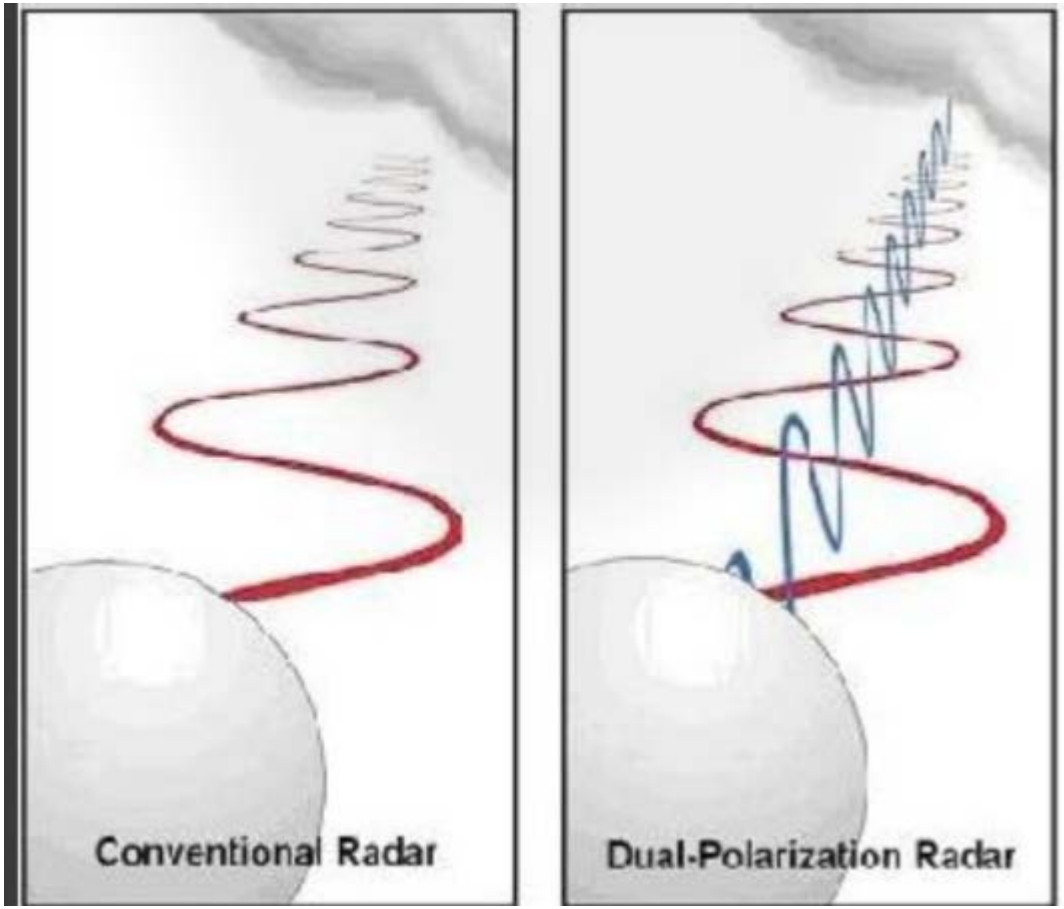
Advances in observing

- Radar, satellite formed the basis of classical extrapolation nowcasting
- Recent developments in dual-polarisation radar are dramatically improving the quantitative precipitation accuracy
- Many nowcast products are now derived from satellite imagery

Use of Doppler & Dual Pol radar

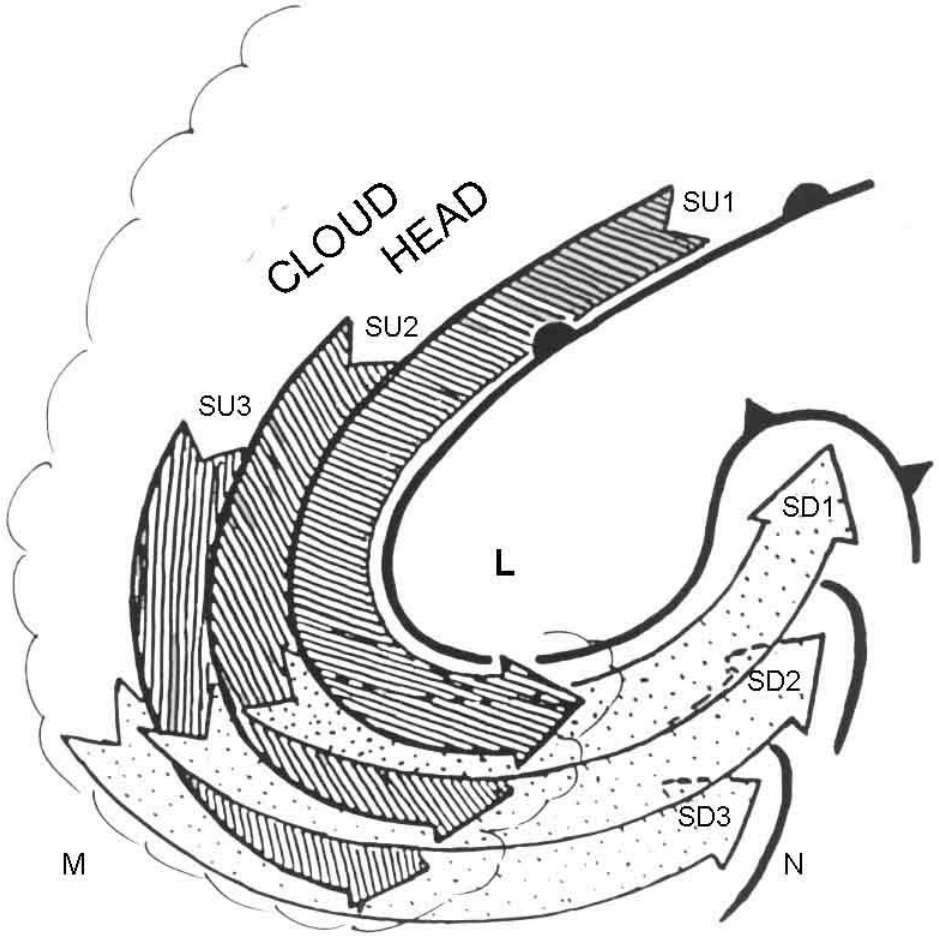
- Doppler radars measure hydrometeor velocity, allowing better quality control
- Dual-polarisation radars measure hydrometeor shape, allowing intensity to be better estimated



Advances in nowcasting tools

- Sting jets help forecasters nowcast extreme winds in extratropical cyclones
- Boundaries help forecasters nowcast severe convection
- Wake vortex behaviour has been characterised for airport nowcasting

16-17 October 1987
The ‘Great Storm’ sting jet



Browning, 2004

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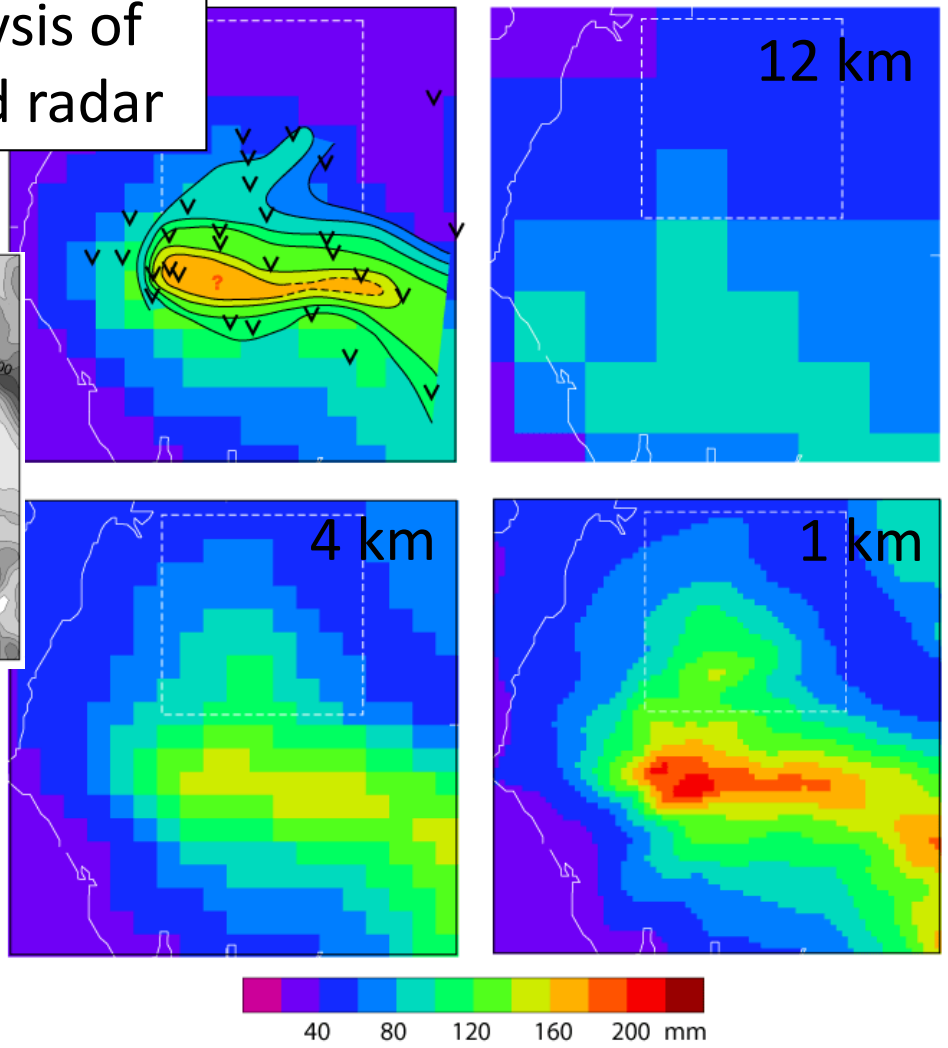
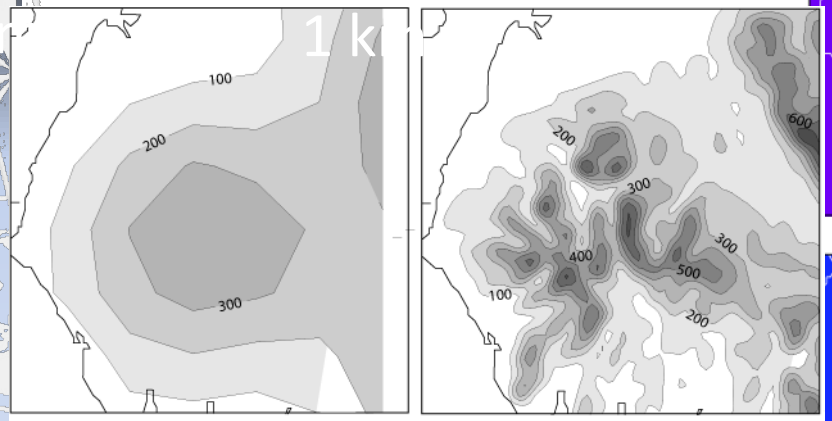
Advances in modelling

- Convection-permitting NWP models have enabled a dramatic improvement in local forecast skill, especially for cloud & precipitation
- Resolution has benefitted forecasts of topographically affected weather, e.g. valley fog, mountain rainfall
- Advances in model physics have improved the representation of clouds and turbulence
- Precipitation forecasts now skilfully distinguish towns 20-30km apart in the UK

Carlisle Flood – Observed & Forecast Accumulations

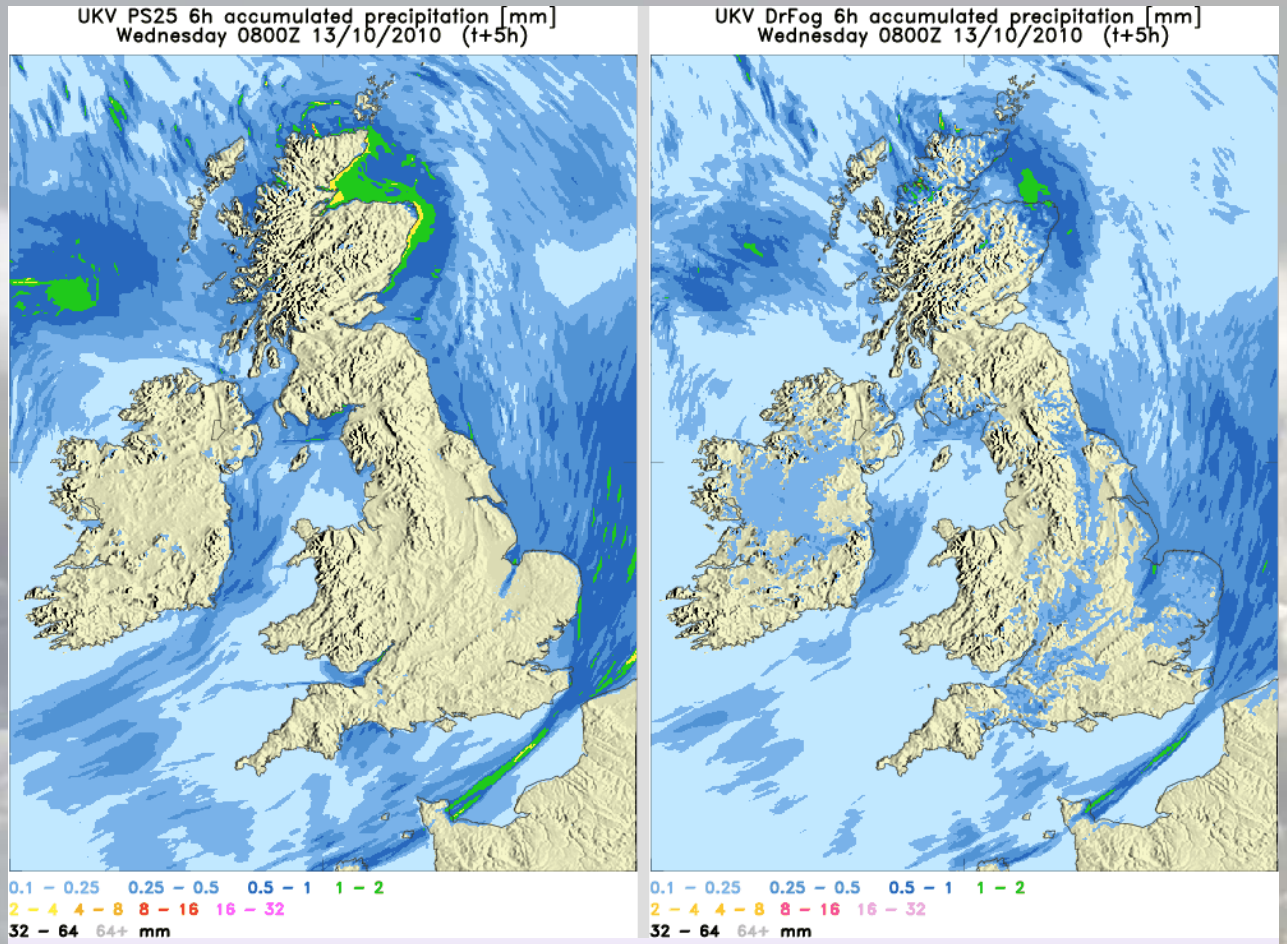
Hand analysis of gauges and radar





Model Orography

Improving forecasts through theory, observations and models



More realistic representation of aerosols leading to improvements in model cloud formation and precipitation, including removal of land-sea split

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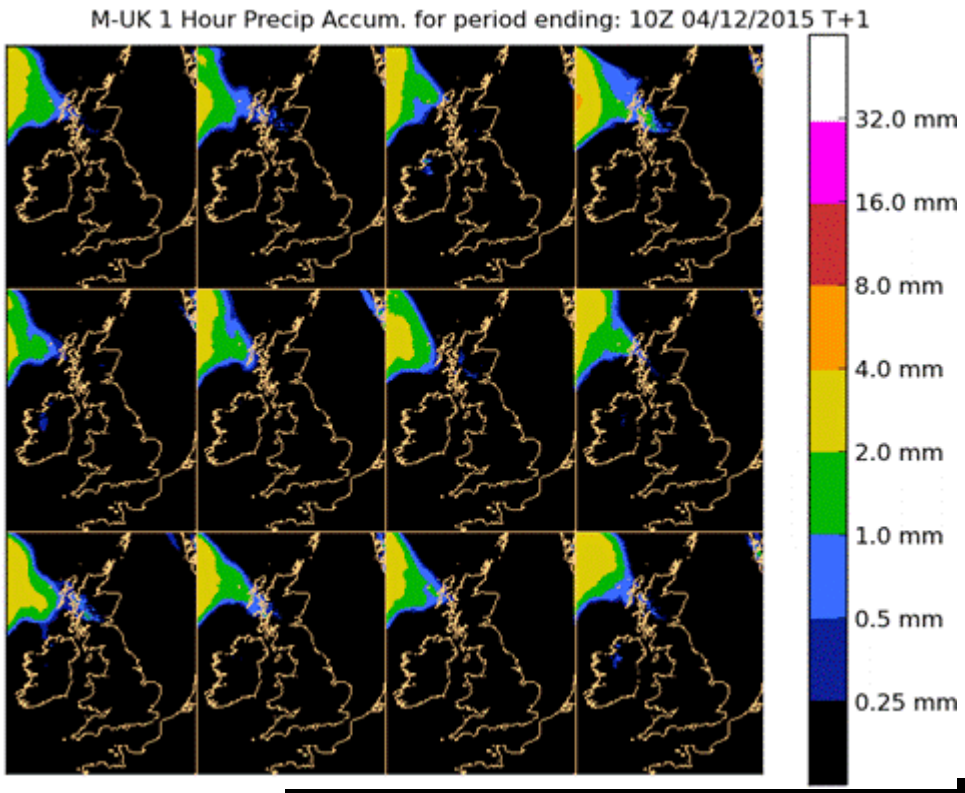
Advances in Forecast Content

- Merged extrapolation nowcasts with convection-permitting ensembles are now of sufficient quality in the UK to drive rainfall-runoff and hydrodynamic models, and for the results to be used to issue flood warnings.
- Warnings are migrating from weather thresholds to risk thresholds, based on predicted impact and ensemble-based probability.

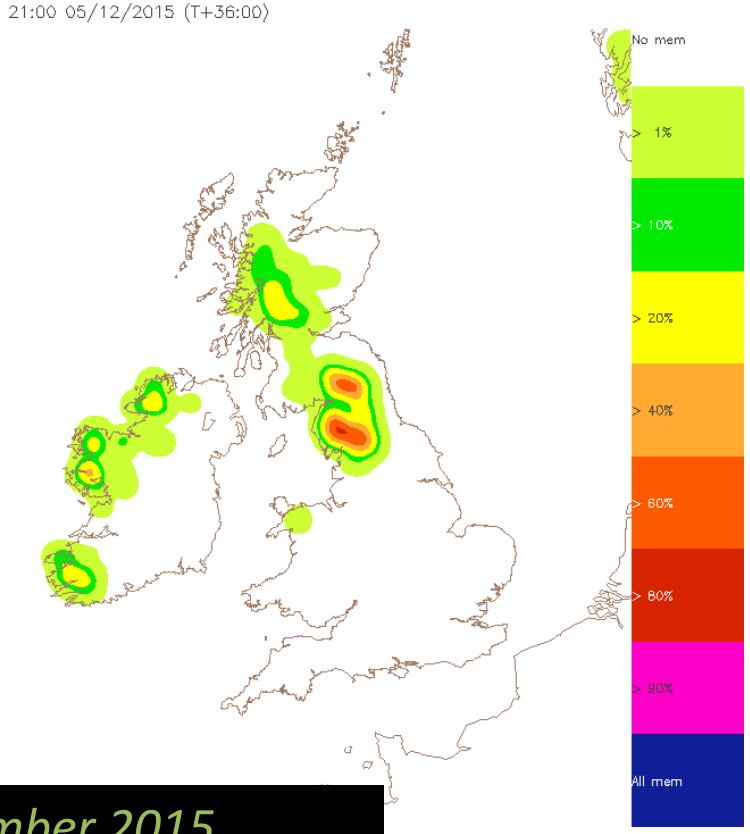
2.2km Convective-Scale Ensemble

Storm Desmond, 4-5 December 2015

12 × 2.2km resolution hourly rainfall accumulation forecasts from MOGREPS-UK



Probability 24 hour rainfall > 100mm. Valid for 2100 4th December to 2100 5th December



09UTC run on 4th December 2015

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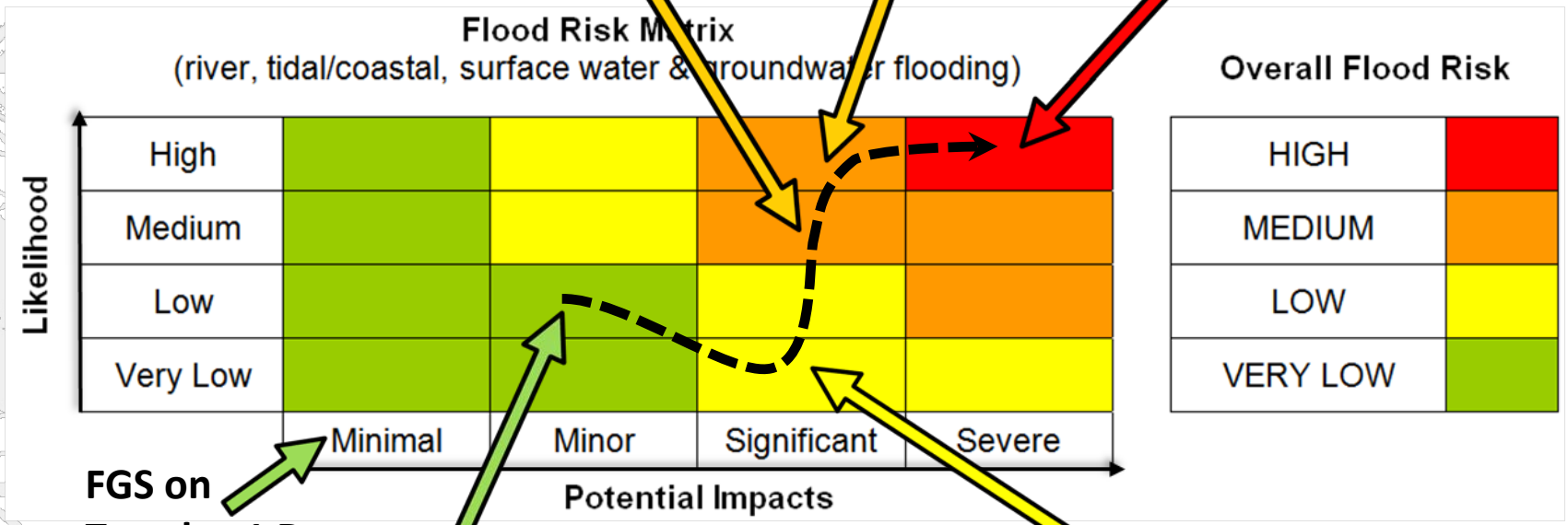
Flood Guidance Statements for Cumbria for 5/6 Dec 15

FLOODFORECASTINGCENTRE

a working partnership between Environment Agency | Met Office



FGS on Friday 4 Dec (10:30)

FGS on Friday 4 Dec (15:30)

FGS on Saturday 5 Dec (10:30; 15:00; 21:30) and Sunday 6 Dec (10:30; 15:30 & 21:30)

FGS on Tuesday 1 Dec (10:30) - for Day 5

FGS on Wednesday 2 Dec (10:30) – focus was on Wales and west Midlands (Significant impacts) for Days 4/5

FGS on Thursday 3 Dec (10:30)

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Advances in communicating

- Mobile phones – Forecasts on the move
- Smart phones – radar images, hourly forecasts, video clips of forecast presentation
- Social media – tweets & blogs reinforce warnings

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Many more channels & formats

Looking forward

- New technologies
- Better forecasts
- A more vulnerable society
- More hazardous weather
- The Sendai Framework for Disaster Reduction

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Sendai Framework for Disaster Reduction:

Growing Safe, Resilient, Sustainable Communities

Climate Change

Population

Wealth

Inequality

Migration

Dependency

Access to early warning systems, risk information & assessments

Understanding

Governance

Investment

Preparedness

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Observations

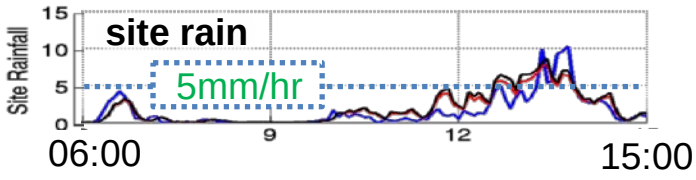
- Need much higher resolution and new variables for monitoring, model initialisation & verification
- More advances in radar & satellite capability
- Unconventional observations – ubiquitous monitoring
  - Other professional networks…
  - New remote sensing capabilities…
  - Wearables…
  - Vehicles…
  - Social media…
  - New variables (AQ?)…
- Quality control & integrate using data assimilation
- Selected data for process-based nowcasts, e.g. vehicle data for smart highway forecasts

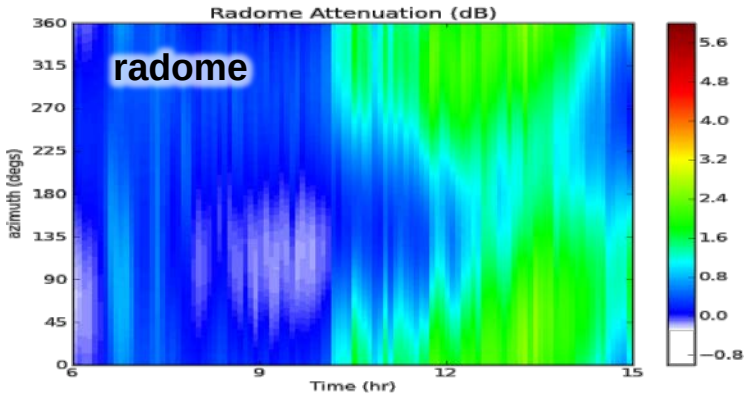
Correcting radar attenuation with emissions measurements

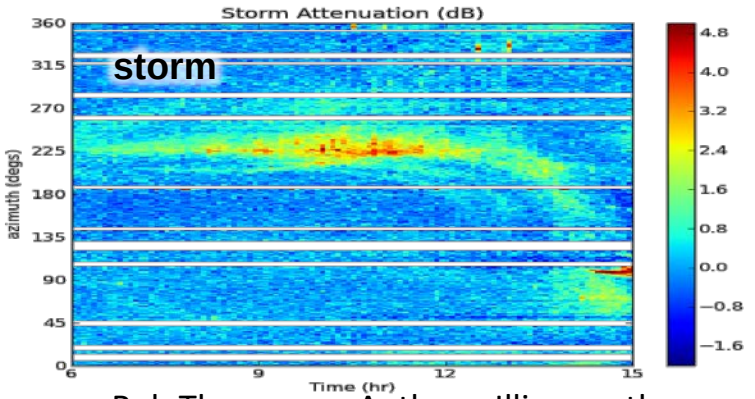
- Attenuation is a major problem for C-band radars in intense rainfall – 60% losses were seen during the London floods of 2007
- Attenuation is seen as increase in background noise from attenuators

  "all absorbers are emitters"
- Total attenuation can be calculated and split into radome and storms.
- Radome corrections affect the whole radar scan – more effect seen into the wind
- Storm attenuation affects only some rays.
- Use dual polarisation to correct attenuation constrained by the emission derived total

Now implemented in UK network







Rob Thompson, Anthony Illingworth

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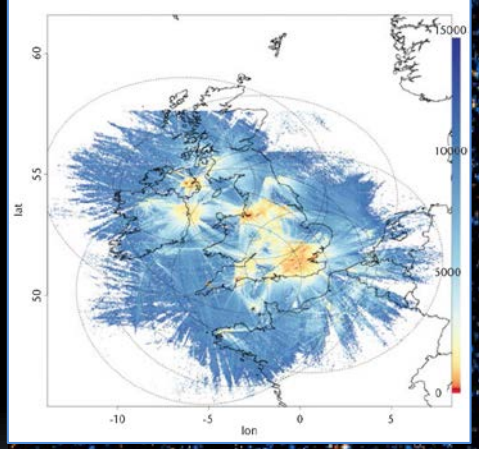

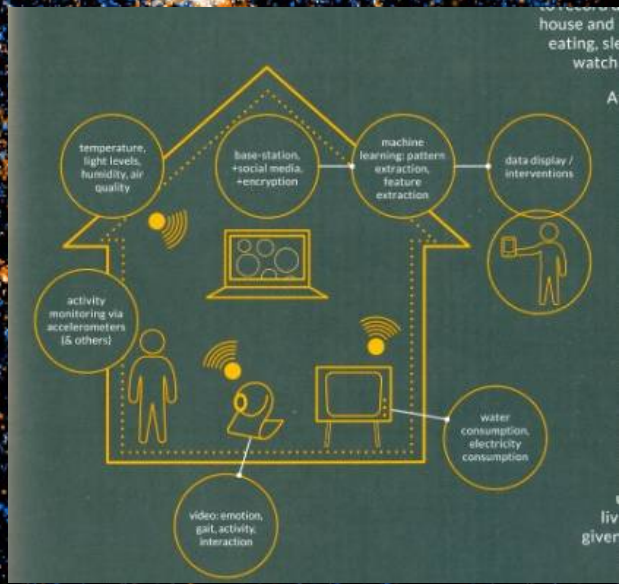

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Models will dominate >1hr
Focus on process-based <1hr nowcasts

- Fire: are there advance indicators of the sudden changes of wind that cause fire casualties?
- Surface flood: are there advance indicators of the "cloud burst" that overwhelms the drains?
- Tornado: are there advance indicators of formation, track deviation at km-scale?
- Wind: are there advance indicators of the gust that knocks down trees, buildings, turns over vehicles
- Frozen precipitation: are there advance indicators of rain turning to ice/snow on a road?
- Fog: are there indicators of patches of very thick fog?

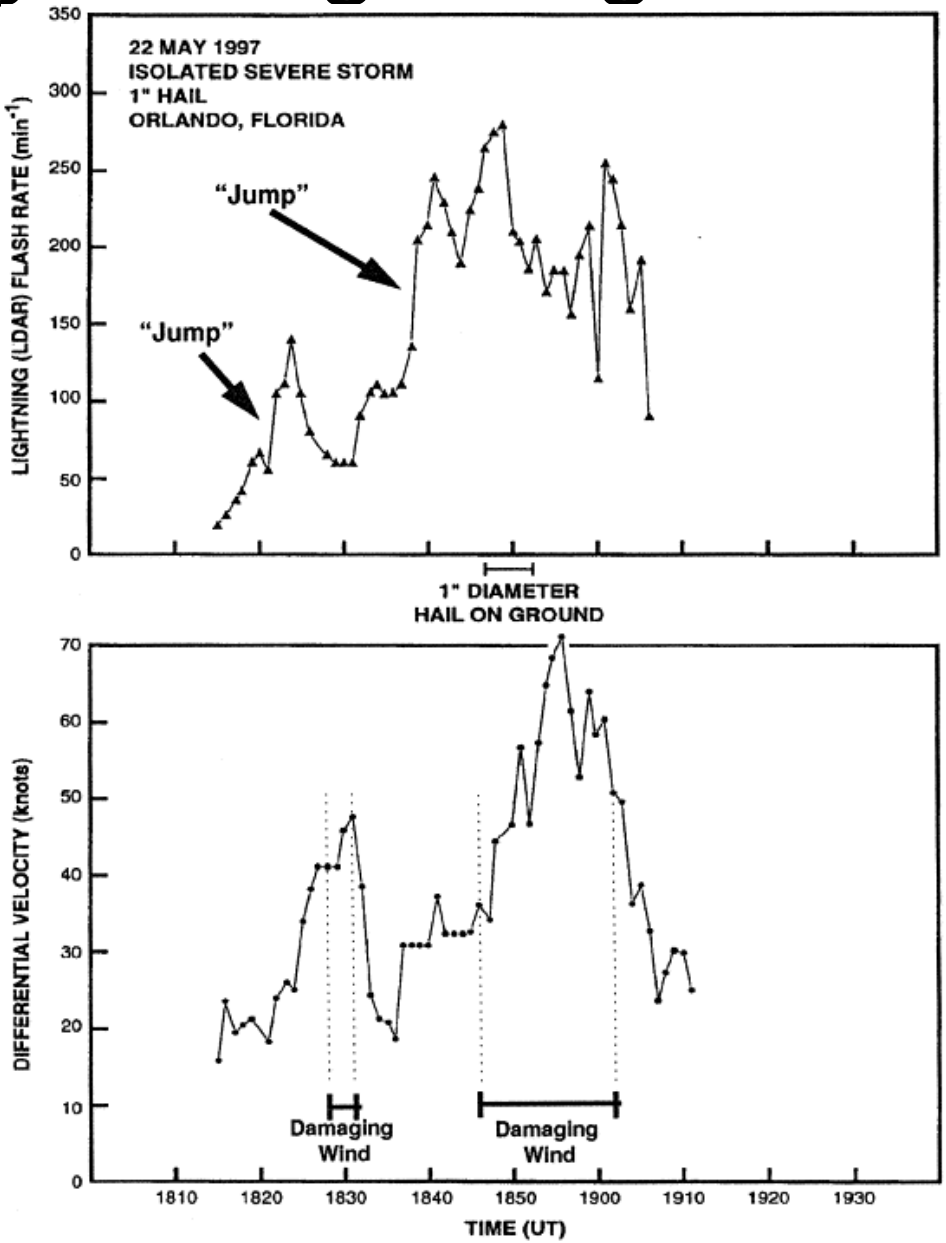
Prediction of severe convective weather using total lightning

The behavior of total lightning activity in severe Florida thunderstorms

Earle Williams et al,

Atmospheric Research

1999, **51**, 245–265



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Modelling

- Moore's Law will likely continue for the next decade, for efficient codes, giving x100
- This gives the possibility of ~3km global, ~400m local & ~80m city forecast models
- Other uses of this power might be in data assimilation, model physics, ensemble size, vertical resolution
- Coupled hazard models: convergence of land surface models with flood models; ocean models with surge & wave models; inclusion of chemistry in NWP models.
- Coupled impact models – infrastructure, buildings, transport, behaviour?

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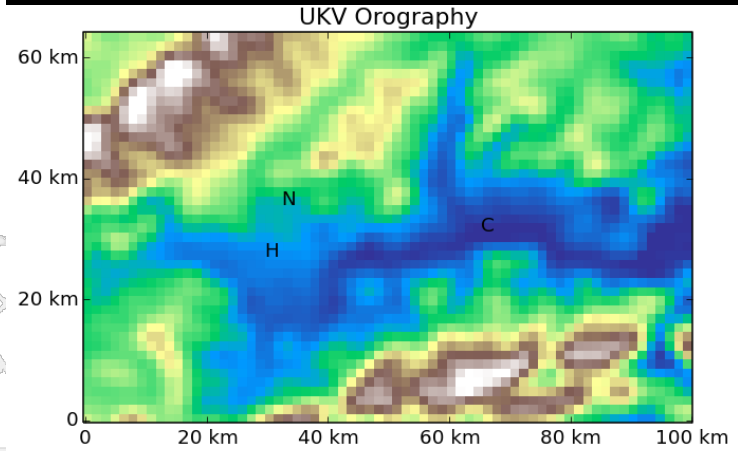
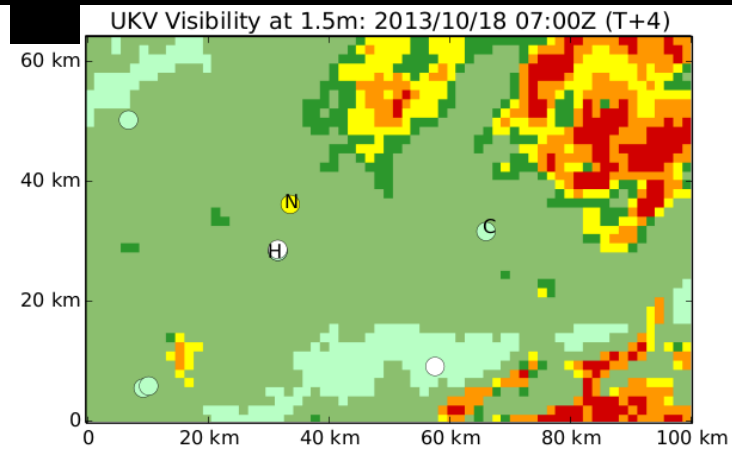
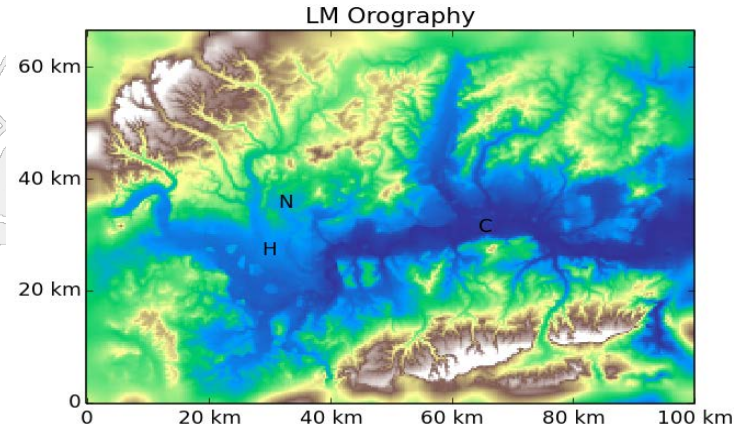
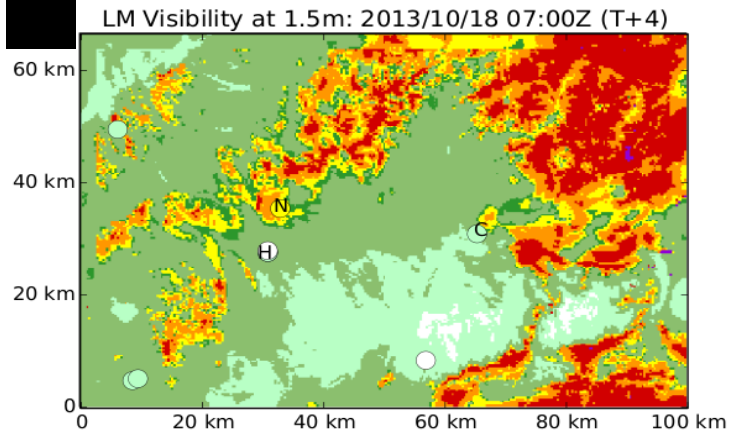
Local impacts and the benefits of very high resolution modelling

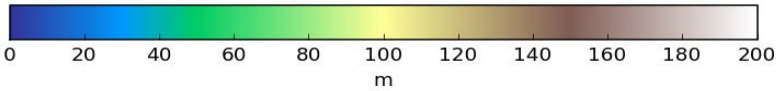
Using a 300m model to deliver better fog forecasts

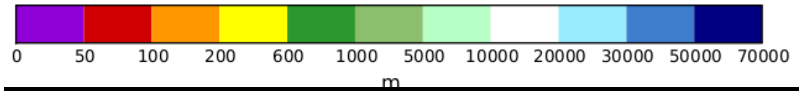












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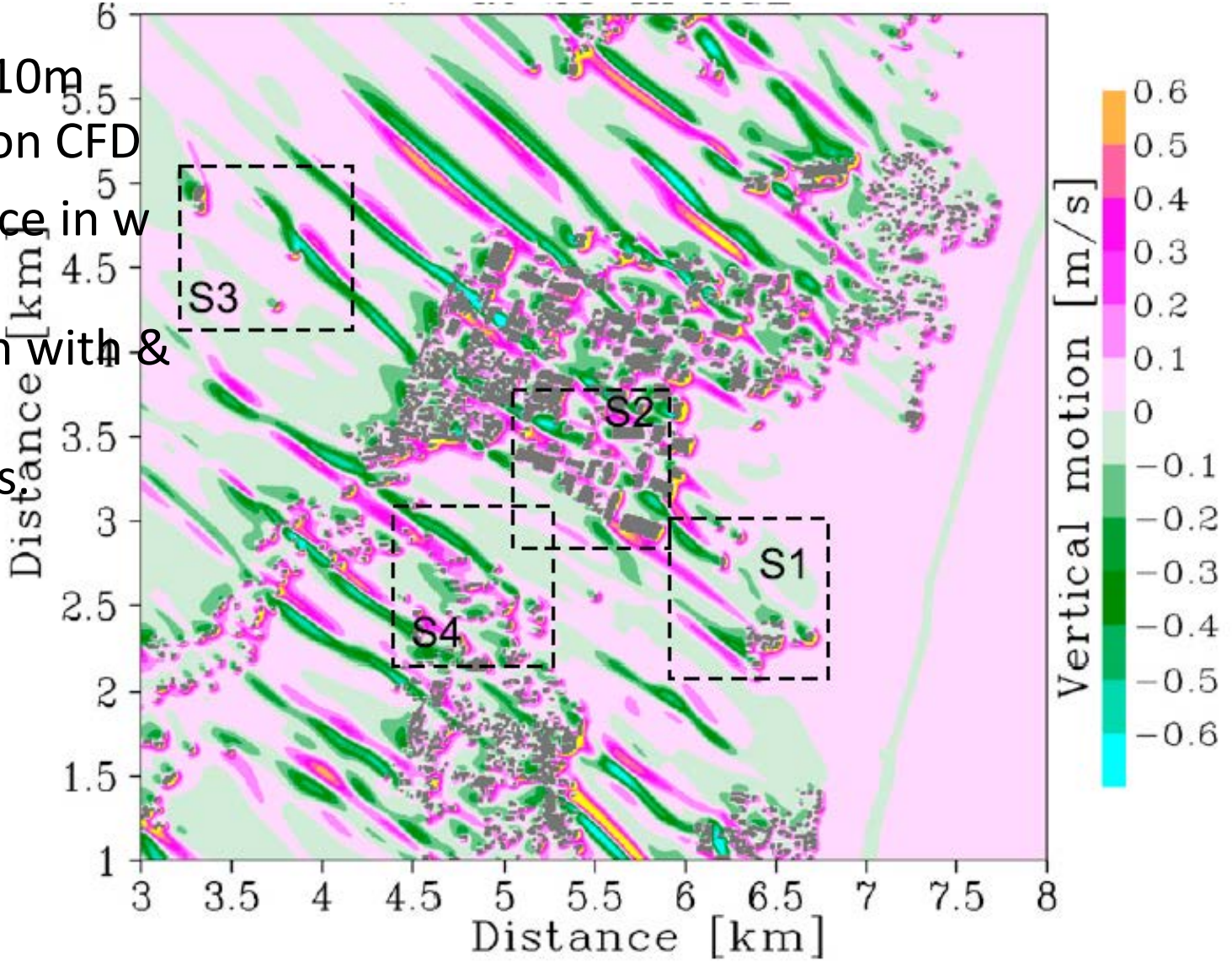
Chen et al, 2015, Towards Improved forecasts of sea breeze horizontal convective rolls at super high resolutions, MWR, 143, 1873-1894

- Nested 10m resolution CFD
- Difference in w at 25m between with & without buildings



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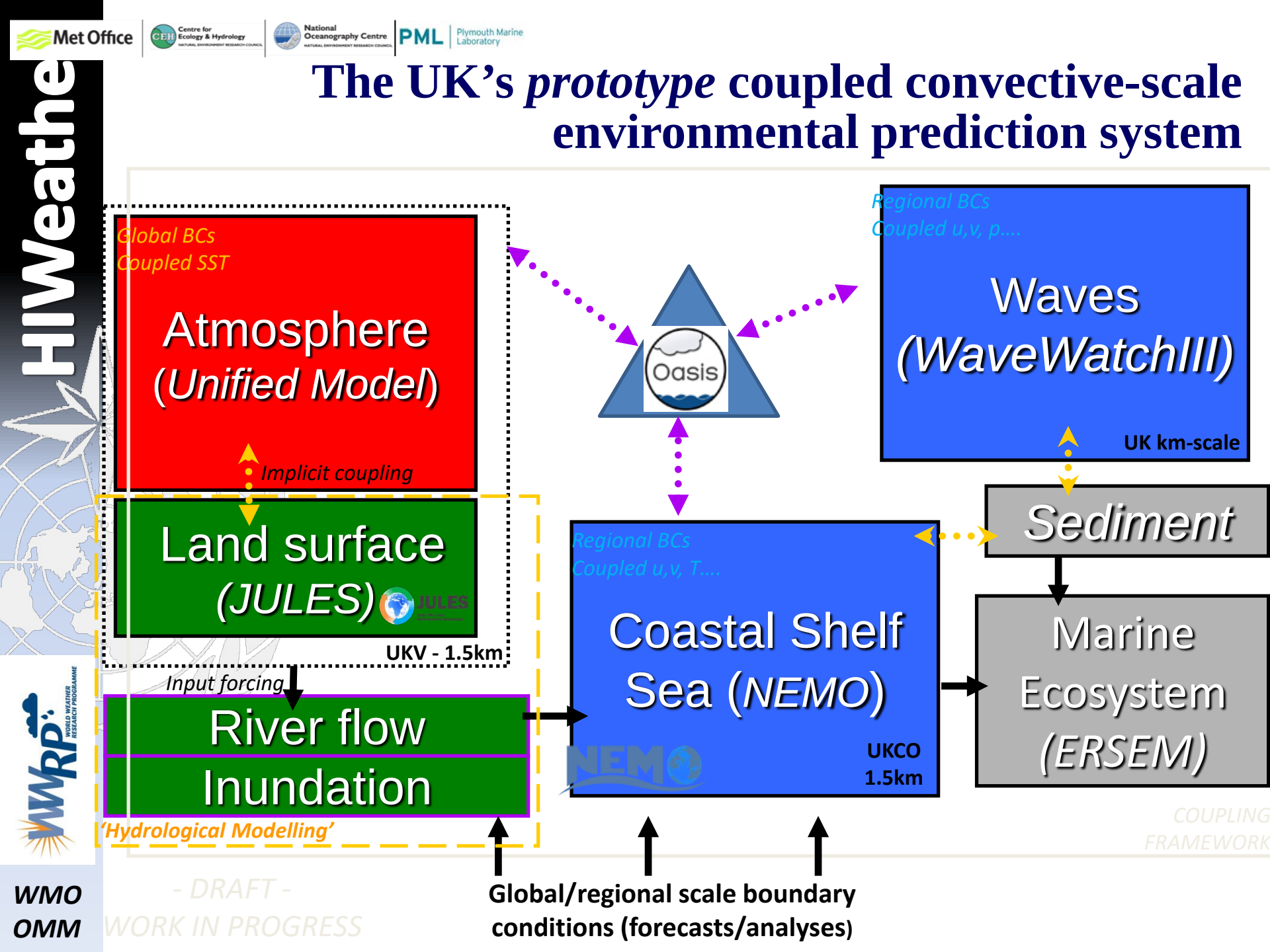
Content

- Smart highways: coupled sensing & warning displays of hazards – feeding directly into control of autonomous vehicles
- Social media-based nowcasts: analysis of tweets used to feedback areas of hazard impacts to users
- NextGen ATM: complete aircraft trajectory fixed and cleared before take-off.
- Preferred communication format - video clip?
- Professionals will continue to move towards open format GIS layers

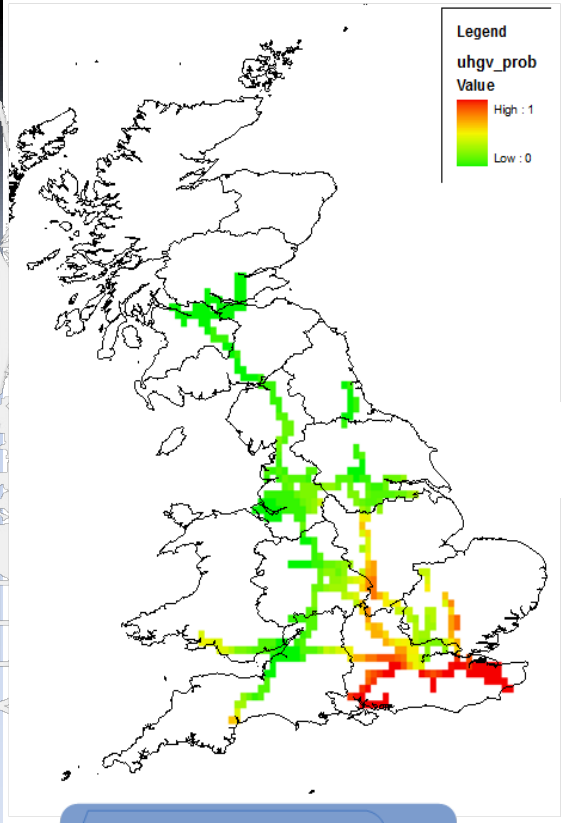
The UK's *prototype* coupled convective-scale environmental prediction system



Hazards Risk Mapping

Example: road vehicle overturning in strong winds

NHP:HIM



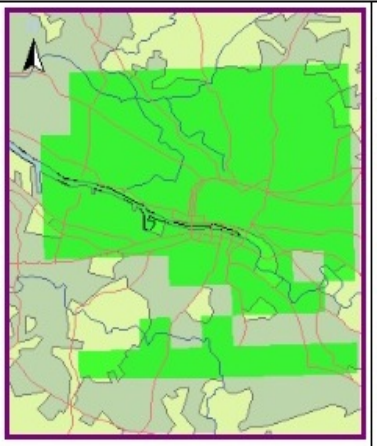
UHGV T027 Probability

11/5/2008

Raster map – Probability of gust speeds exceeding the pre-defined UHGV overturning gust speed threshold

Impact prediction during the July 2014 Commonwealth Games in Glasgow

People & Property (Overall) - Forecast T3 - T27 10:15 : 10:00

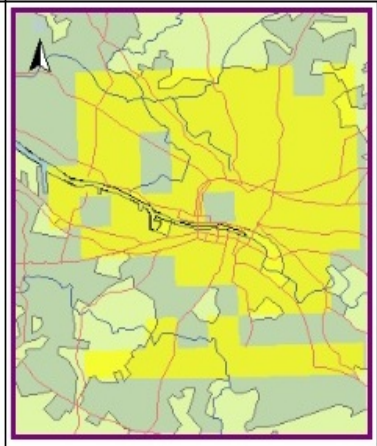


Overall Surface Water Flood Risk to People and Property during the forecast period

Very Low
Low
Medium
High

Forecast name : Blended Ensemble
Forecast time (T0): 10/08/2014 07:00 GMT

Transport (Overall)- Forecast T3 - T27 10:15 : 10:00

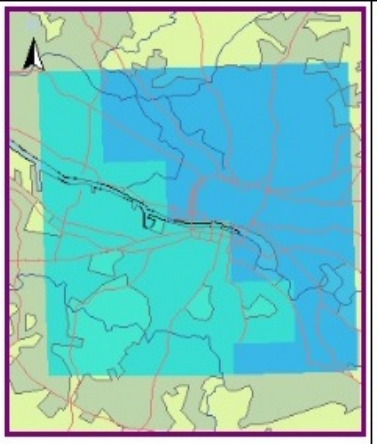


Overall Surface Water Flood Risk to Transport during the forecast period

Low
Medium

Forecast name : Blended Ensemble
Forecast time (T0): 10/08/2014 07:00 GMT

Rainfall (minor) - Forecast T3 - T27 10:15 : 10:00



Probability of exceeding 20mm rainfall within 3 hours during the forecast period

5% - 19% (2-5 members)
20% - 39% (5-9 members)
40% - 59% (10-14 members)
60% - 79% (15-19 members)
80% - 100% (>=20 members)

Forecast name : Blended Ensemble
Forecast time (T0): 10/08/2014 07:00 GMT

Estimated probabilities of overall surface water flood impact, some time in 24 hours

Aggregation of individual risks specified by emergency managers: length of flooded street or railway; number of properties flooded; at different thresholds

Communication: the last mile!

- Future social media?
- Sensors on smartphones?
- Wearables?
- Intelligent materials?
- Internet of Things?
- Full integration of online and phone ?
- Continuous streaming while mobile?
- How to communicate risk?
- Maintaining communication in a disaster

medium & format

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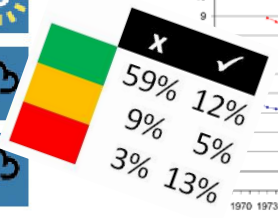
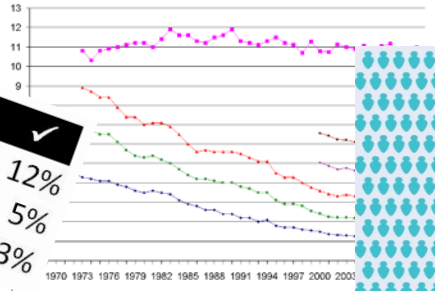
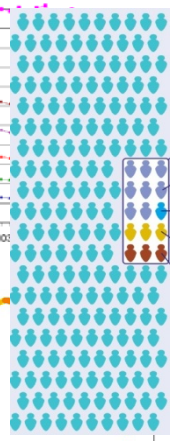
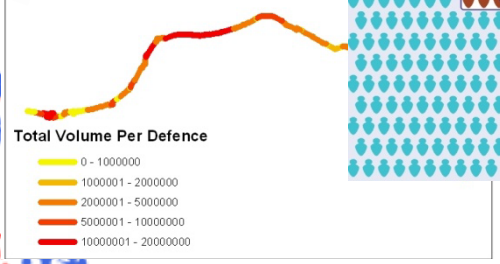
P_{msl}
H_{500}





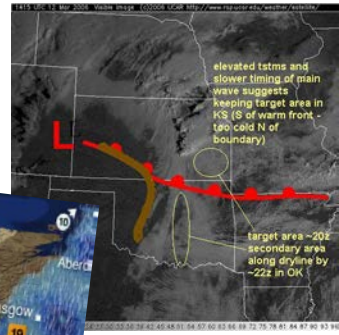


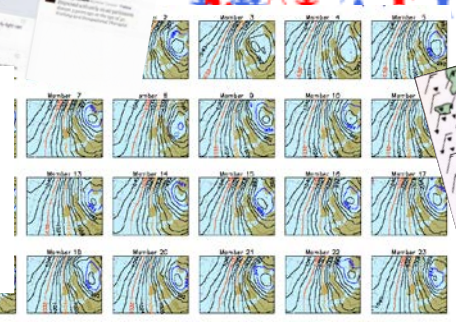


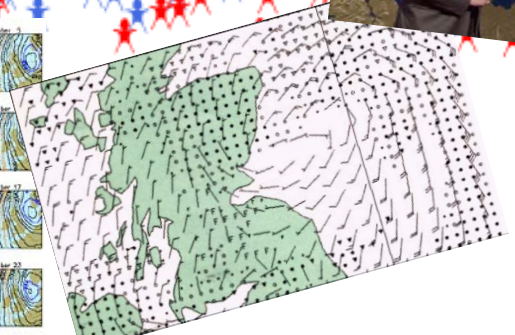
The Gulf coast of Florida

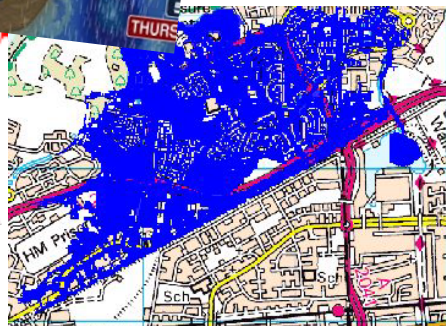
Outlook for days 3-5

A 10% chance of a shower









20% prob of intense rain within 30km between 1-2pm tomorrow

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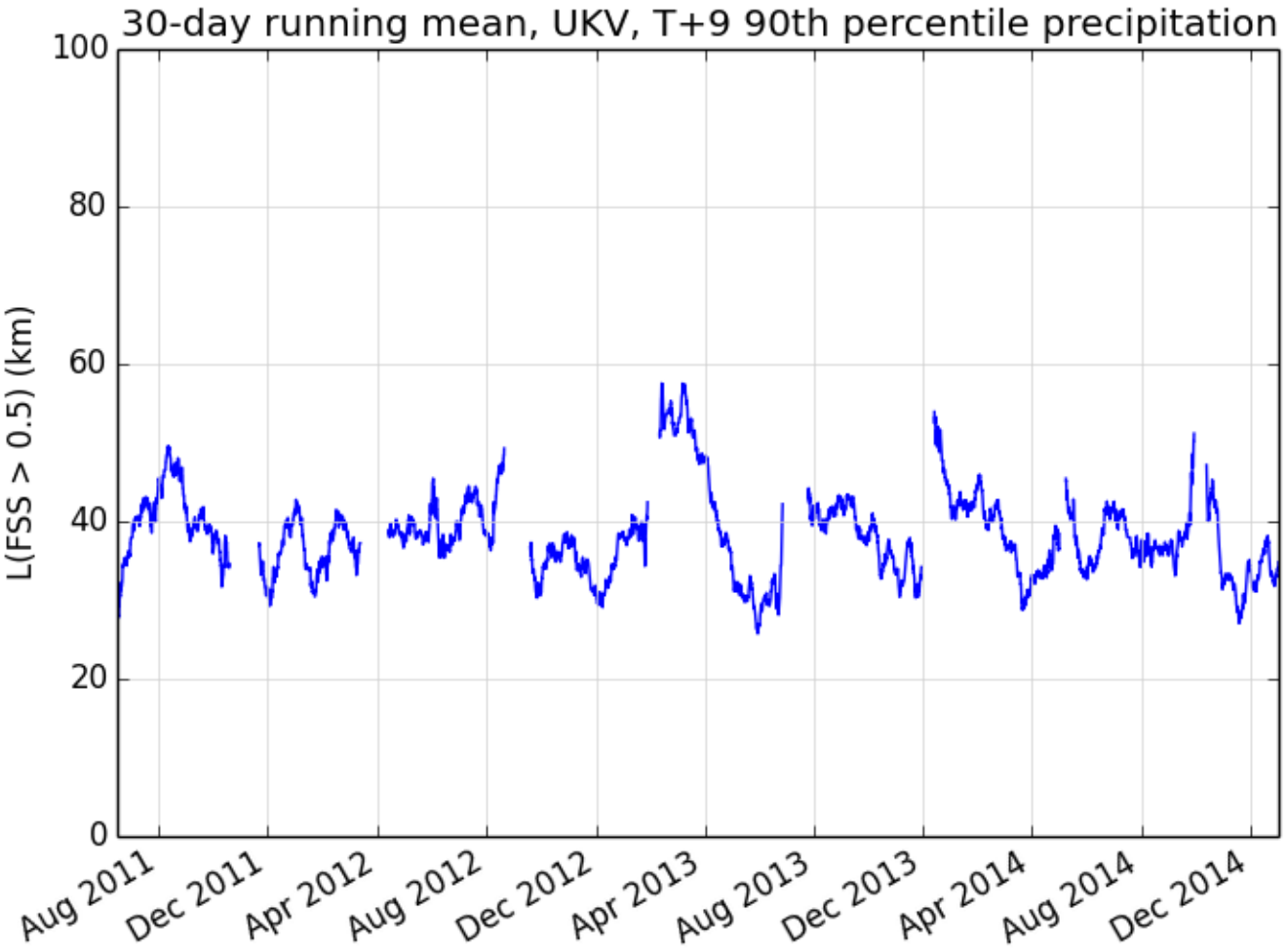
Metrics

- Need justify investment by measuring benefit in better decisions
- Evidence may come from conventional surveys &/or analysis of social media data
- Need to track value through the production chain – & focus effort where value is lost

Measure of minimum skilful scale



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Multi-hazard warning systems

- Integration & standards
- Possible models:
  - EM hosted – multiple input streams integrated using GIS overlays
  - NHMS hosted – works with partners to generate consistent hazard advice for EM & others
  - Integrator hosted – contractor builds integration service with feeds from science institutes and consistent advice to EM

UK Natural Hazards Partnership

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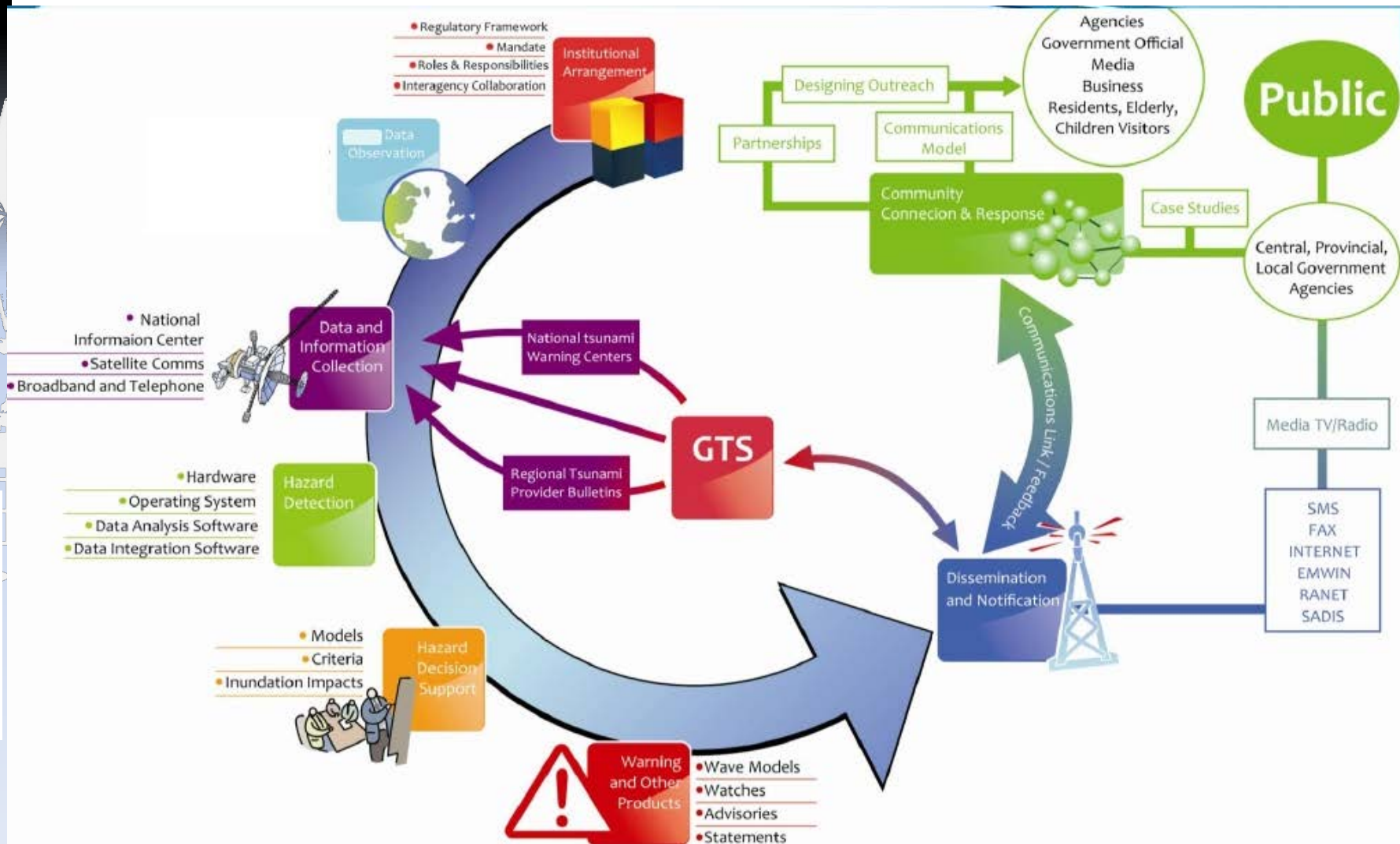
International Program Civil Engineering for Risk Management
An end to end Early Warning System- Lessons Learned from Recent Floods

S.H.M. Fakhruddin, fakhruddin@rimes.int 08 March 2012. Politecnico di Milano,



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Promote Co-Operative International Research

to achieve a Dramatic Increase in Resilience to High Impact Weather, worldwide,

through Improving Forecasts for timescales of minutes to two weeks,

and Enhancing their Communication & Utility,

in Social, Economic & Environmental Applications

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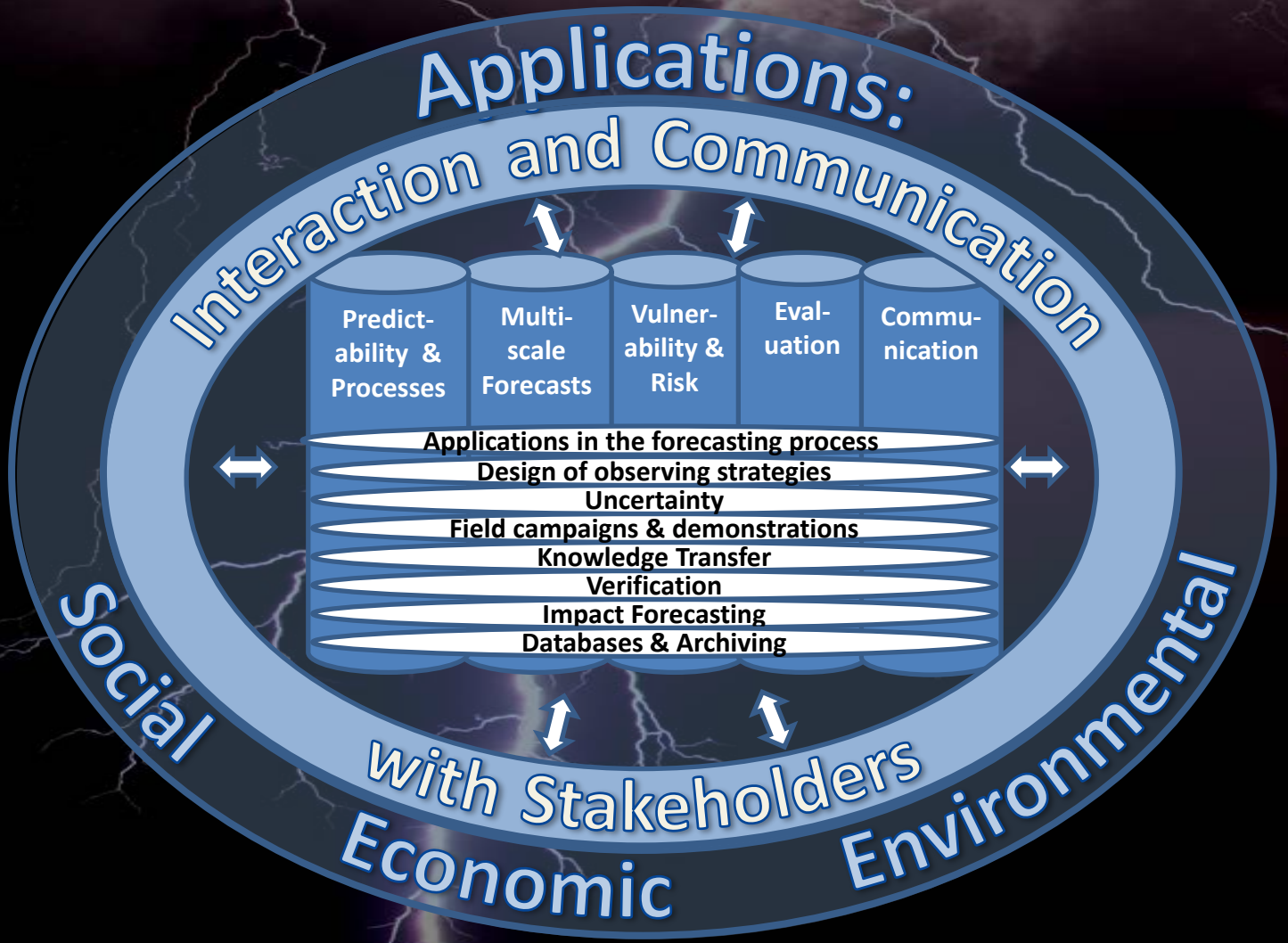
…addressed by research in…



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Questions?
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Reducing the cost of disasters: opportunities & challenges for nowcasting

- The Sendai framework is a year old. It commits the world to reducing the cost of disasters, whether human, economic or environmental, including through better knowledge of weather-related hazards and its application in warning systems. Our science is ready. Recent advances in numerical weather prediction enable us to predict the weather at the scale of the hazard beyond the very short period for which feature extrapolation is useful. Nevertheless, many challenges remain, not least in observing the hazards themselves. In my talk, I will identify some of the key technologies that offer pathways to delivering the Sendai goal. It is the aim of the WMO HIWeather project to direct research towards accelerating progress in these and other areas so as to develop operational capabilities of benefit to all countries.
- 20+10 minutes

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