# Emerging Methods for High Impact Weather Prediction and Observation

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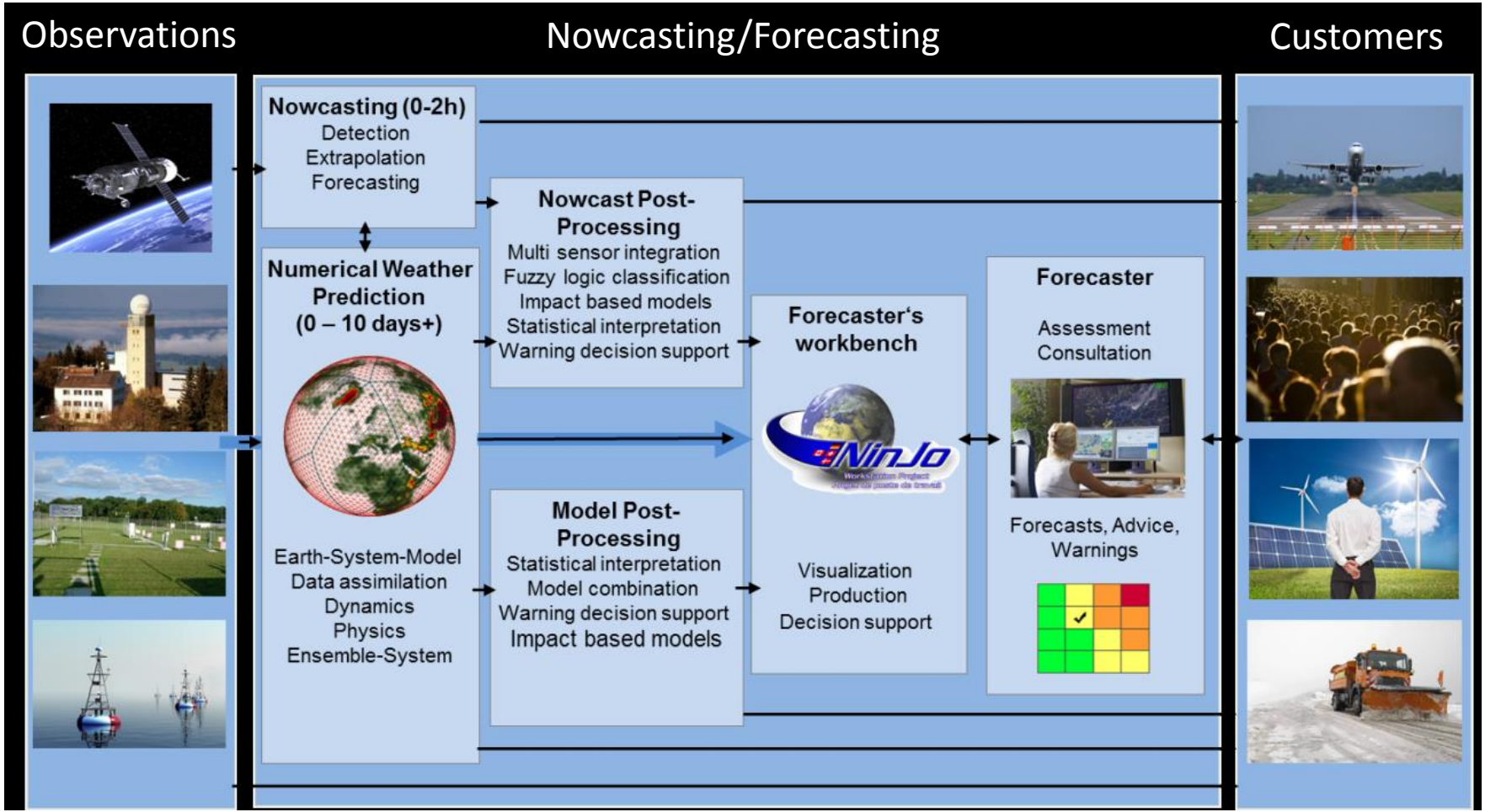
**Bureau of Meteorology**

(with acknowledgments to many colleagues!)

Australian Government
Bureau of Meteorology

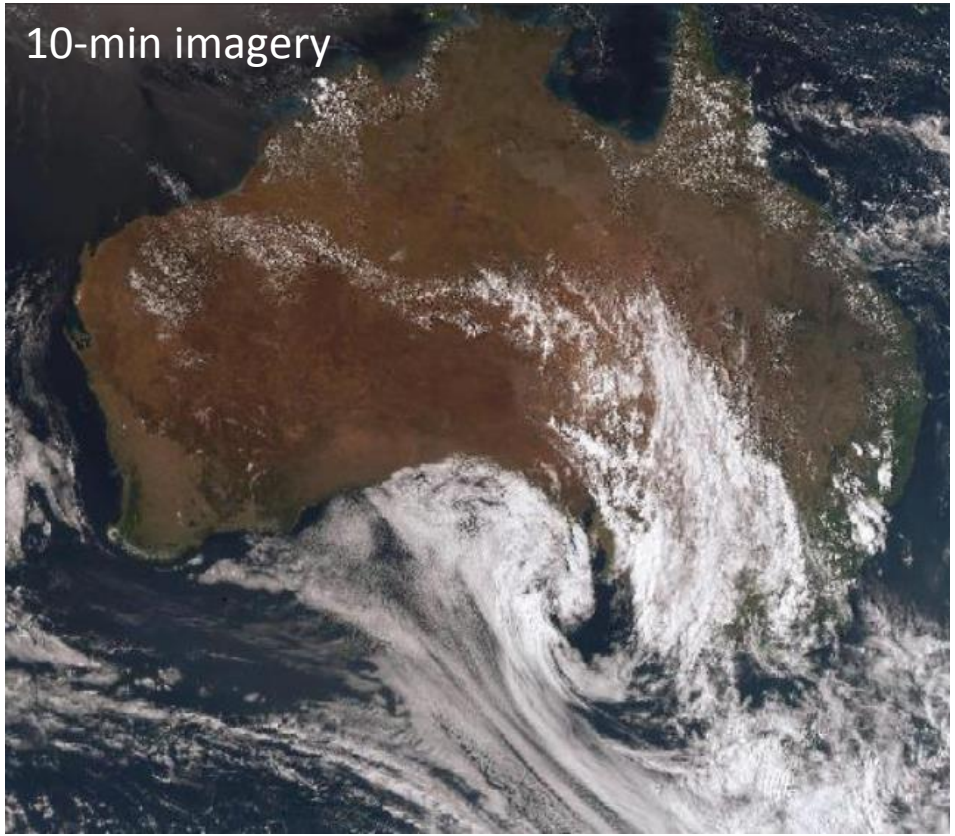
The Collaboration for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO



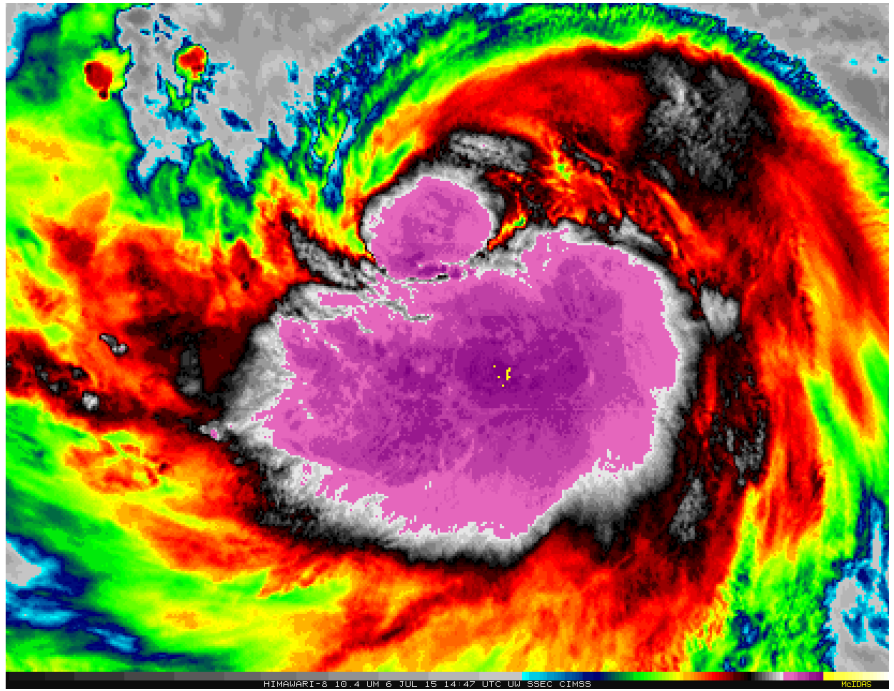

(Heizenreder *et al.* 2015, in WWRP, 2015: *Seamless Prediction of the Earth System: from Minutes to Months*)

# Himawari-8 geostationary satellite




| Channel | Wavelength (μm) | Spatial Resolution | Senses |
|---|---|---|---|
| 1 | 0.43 -0.48 | 1 km | RGB *true colour* image |
| 2 | 0.50 -0.52 | 1 km | |
| 3 | 0.63 -0.66 | 0.5 km | |
| 4 | 0.85 -0.87 | 1 km | Vegetation, cloud |
| 5 | 1.60 -1.62 | 2 km | |
| 6 | 2.25 -2.27 | 2 km | |
| 7 | 3.74 -3.96 | 2 km | Cloud |
| 8 | 6.06 -6.43 | 2 km | Water vapour |
| 9 | 6.89 -7.01 | 2 km | |
| 10 | 7.26 -7.43 | 2 km | |
| 11 | 8.44 -8.76 | 2 km | $SO_2$ |
| 12 | 9.54 -9.72 | 2 km | $O_3$ |
| 13 | 10.3 -10.6 | 2 km | Surface, SST, volcanic ash |
| 14 | 11.1-11.3 | 2 km | |
| 15 | 12.2 -12.5 | 2 km | |
| 16 | 13.2 -13.4 | 2 km | $CO_2$ |

# Himawari-8 geostationary satellite



TC Chan-Hom, 1447-2002 UTC on 6 July 2015

"Target Sector"
2.5-min resolution

Enhanced 10.4 µm imagery

(http://cimss.ssec.wisc.edu/goes/blog/archives/category/himawari-8)

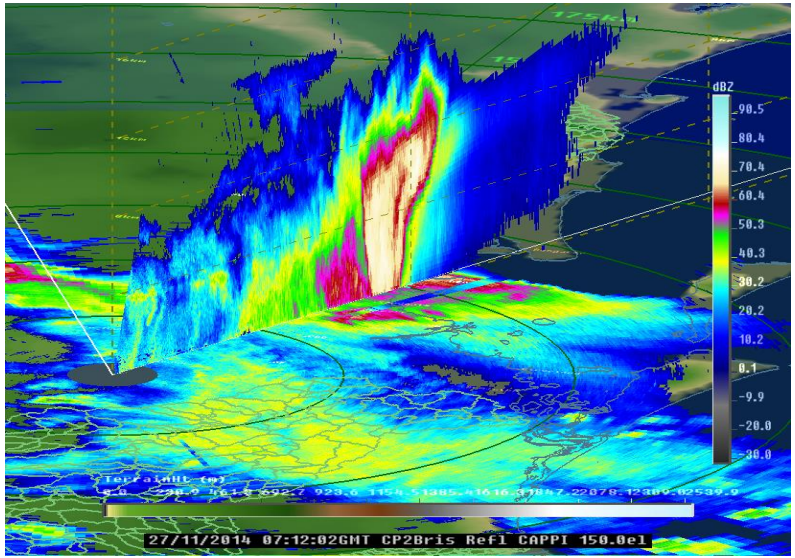
# Himawari-8 geostationary satellite

**Highest priority products**

| | |
|---|---|
| Cloud and moisture imagery | Cloud top temperature |
| Cloud top pressure and height | Derived motion winds |
| Low cloud and fog | Volcanic ash |
| Sea surface temperature | Image enhancements |
| Downward solar insolation at surface | Radiances / clear radiances |
| Convective initiation | Clear sky mask |
| Rainfall rate | Total precipitable water |
| Tropical cyclone intensity | Enhanced V / overshooting top |
| Fire / hotspot characterisation | Thunderstorm nowcasts |

# Dual-polarimetric radar

- Better quality control, improved precipitation rates and severe weather classification
- Research and operational tool
  - CPOL (Darwin), CP2 (Brisbane) research radars
- USA, European dual-pol radar networks
- Plans for Australia
  - CP2 being decommissioned
  - Upgrade capital city radars to dual-pol in next two years



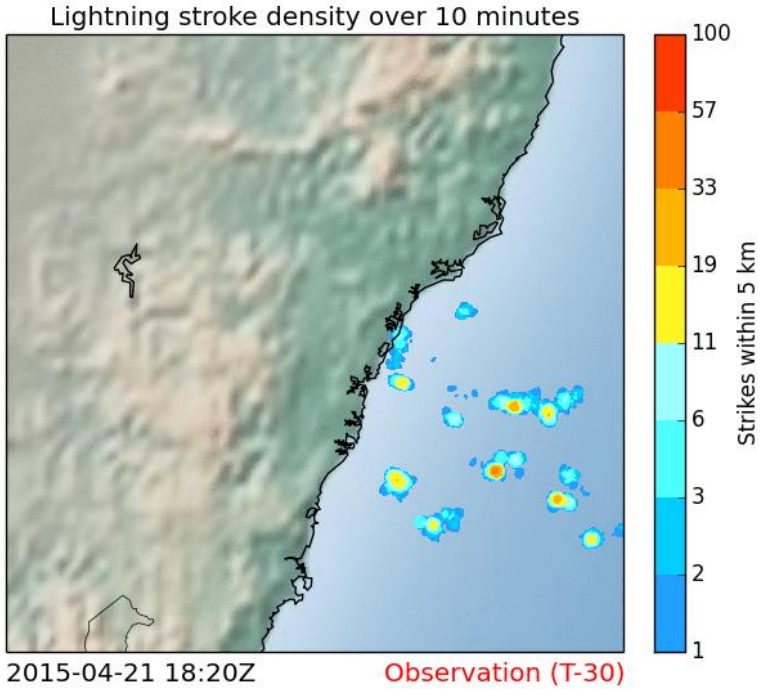

Brisbane supercell storm 27 Nov 2014

Courtesy Phil Purdam

# Lightning detection and applications

New lightning detection service for the Bureau of Meteorology

1. Long-range cloud-to-ground lightning coverage over the Melbourne and Brisbane Flight Information Regions (FIRs), mainly for aviation
2. High-resolution national lightning service with improved in-cloud detection efficiency

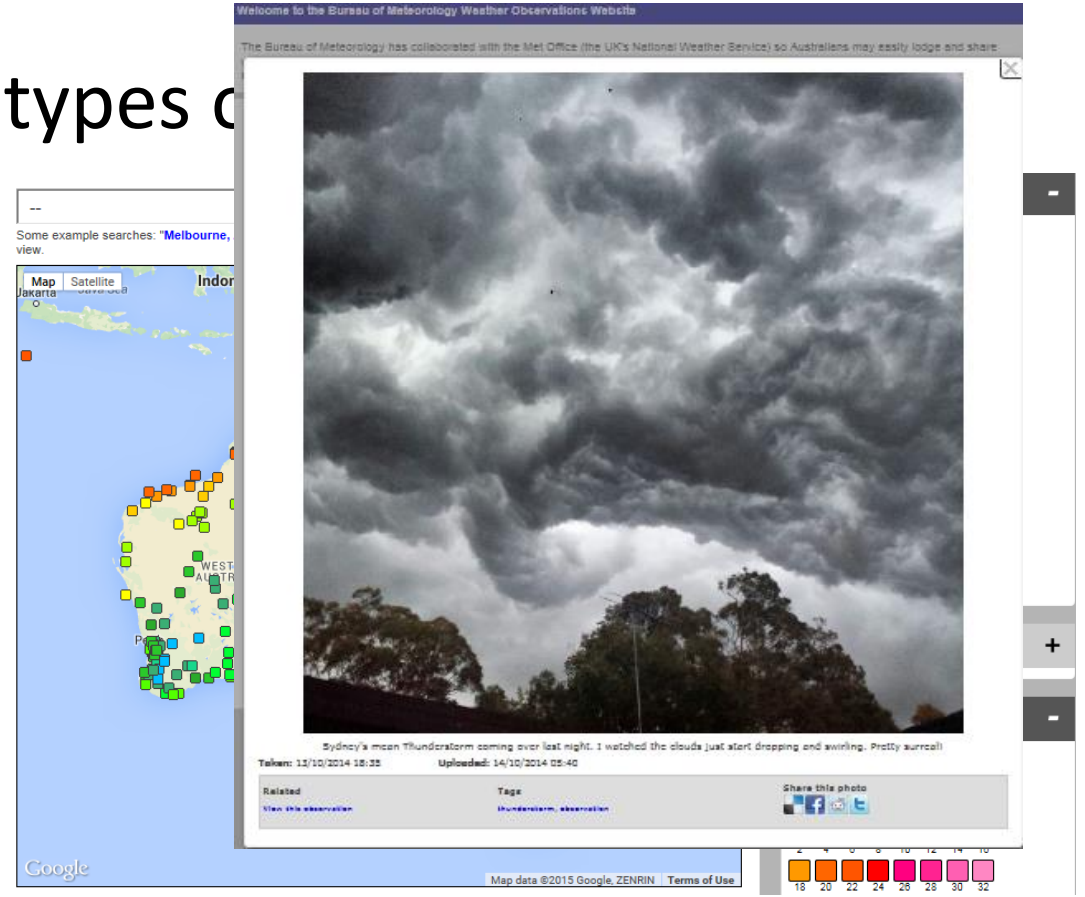



Lighting nowcasting/tracking (early stage prototype)

Courtesy Alan Seed

# New types o

- Third party networks
- Social media (e.g., Twitter)
  - CSIRO Emergency Situation Awareness (ESA)
- Crowd-sourcing of weather and impact data
  - mPING (*Meteorological Phenomena Identification Near the Ground*) app for winter weather
  - WOW (*Weather on the Web*)




WOW – Weather on the Web

http://bom-wow.metoffice.gov.uk/

# ACCESS NWP model plans

| Configuration | APS-2 (Op: 2015) | APS-3 (Op: Mid-2018) | APS-4 (Op: End 2020) |
|---|---|---|---|
| ACCESS-G global | 25 km {4dV} | 12 km {4dVH} | 12 km {4dVH/En} |
| ACCESS-R regional | 12 km {4dV} | 8 km {4dVH} | 4.5 km {4dVH/En} |
| ACCESS-TC tropical cyclone | 12 km {4dV} | 4.5 km {4dVH} | 4.5 km {4dVH} |
| ACCESS-GE ensemble | 60 km (lim) | 30 km | 30 km |
| ACCESS-C city | 1.5 km {FC} | 1.5 km RUC {4dVH} | 1.5 km RUC {4dVH/En} |
| ACCESS-CE city ensemble | - | 2.2 km (lim) | 1.5 km |
| ACCESS-X relocatable | - | 1.5 km {4dVH} | 1.5 km {4dVH/En} |
| ACCESS-XE reloc. ensemble | - | - | 1.5 km |

# Ensemble/probabilistic forecasting

- Internal and external users can make better decisions when quantitative uncertainty information is provided (e.g., probabilistic forecasts, scenarios)
- Future service requirements for probabilities of exceeding:

High fire danger conditions

Conditions favourable for severe weather

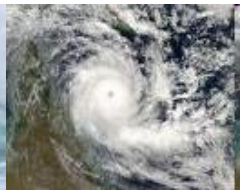
Critical heat stress index

Critical rain accumulation thresholds

Critical wind speeds, e.g., gales

Critical flood heights

Critical wave heights



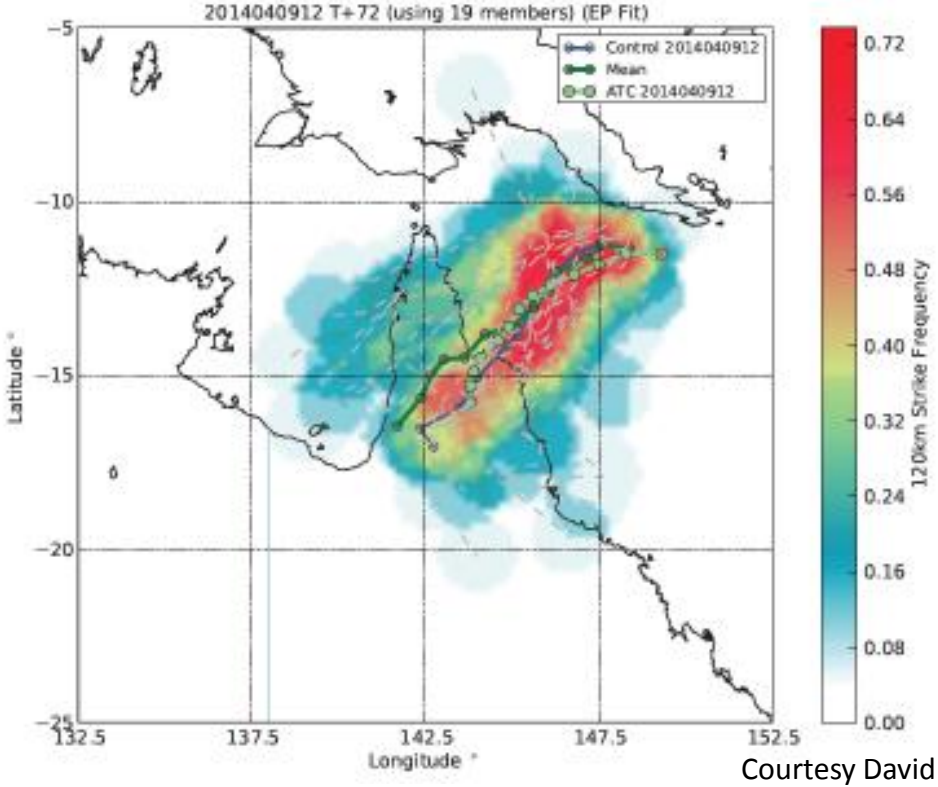
TC strike probability

# Ensemble applications in development at BoM

## Tropical cyclone track

- TC tracks for individual ensemble members and ensemble mean
- Strike probability (within 120 km)

TC Ita , April 2014

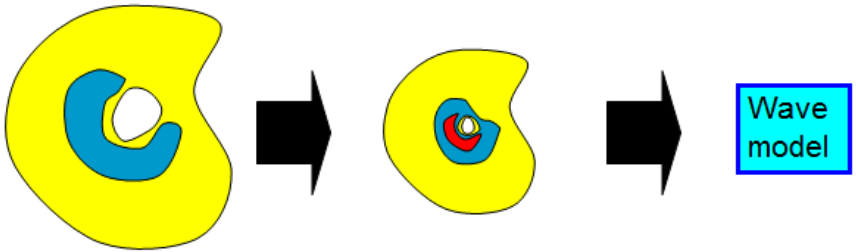



Courtesy David Smith

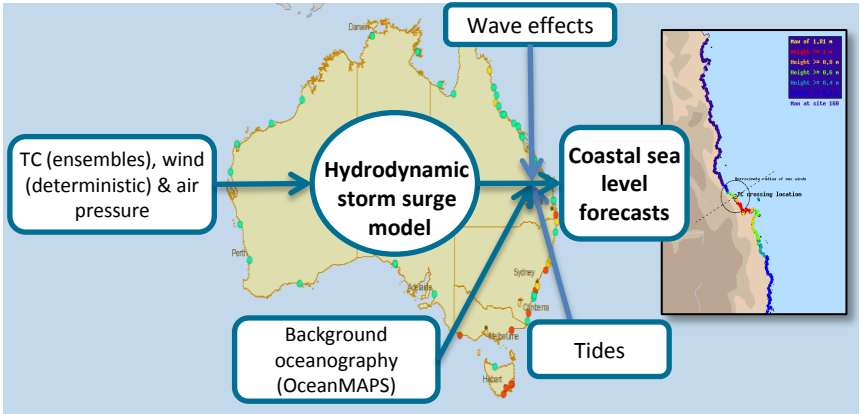
# Ensemble applications in development at BoM

## Improved TC hazard predictions

Downscale global ensemble winds to drive wave model

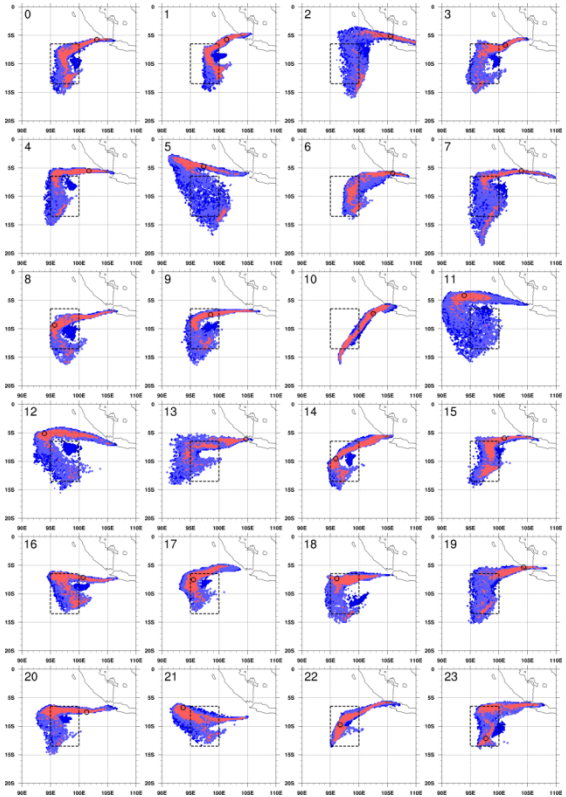



Storm surge



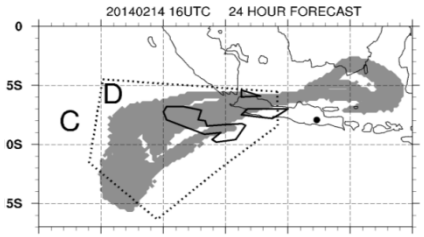

Courtesy Jeff Kepert and Eric Schulz

# Ensemble applications in development at BoM

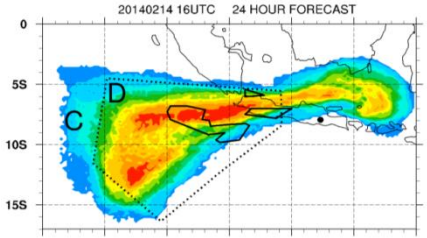



## Volcanic ash dispersion

- HYSPLIT dispersion model run from 24 ACCESS-GE ensemble members




Single control member

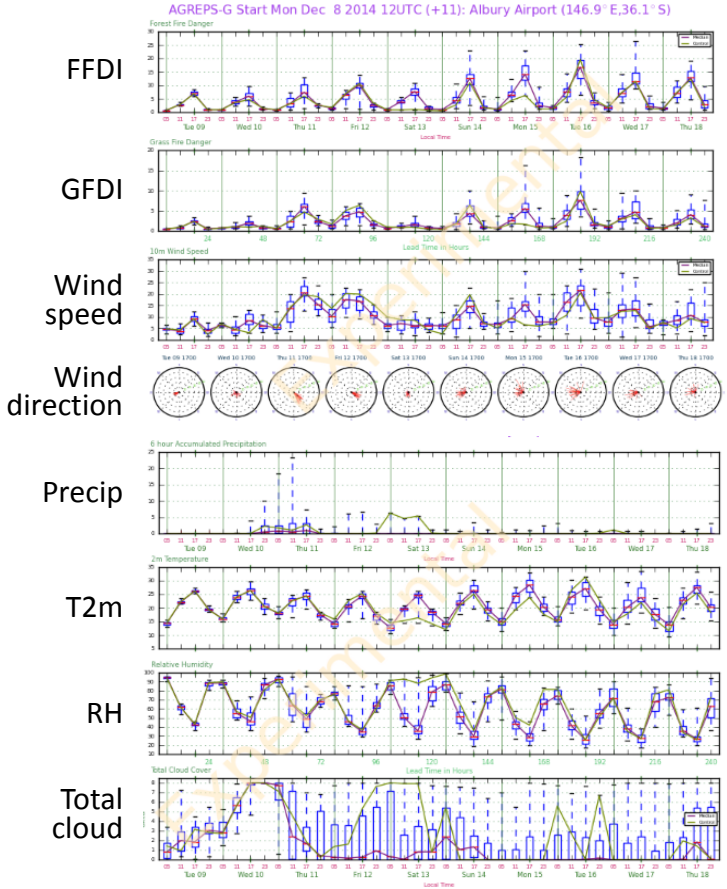



Ensemble probability

Individual member 24-hour forecasts of ash concentration in the 10-15 km layer.

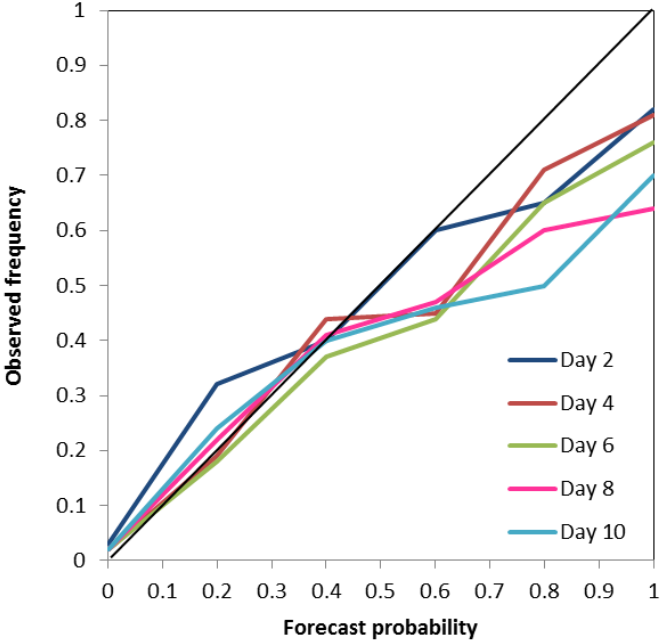
Courtesy Richard Dare

# Ensemble applications in development at BoM




## Fire weather

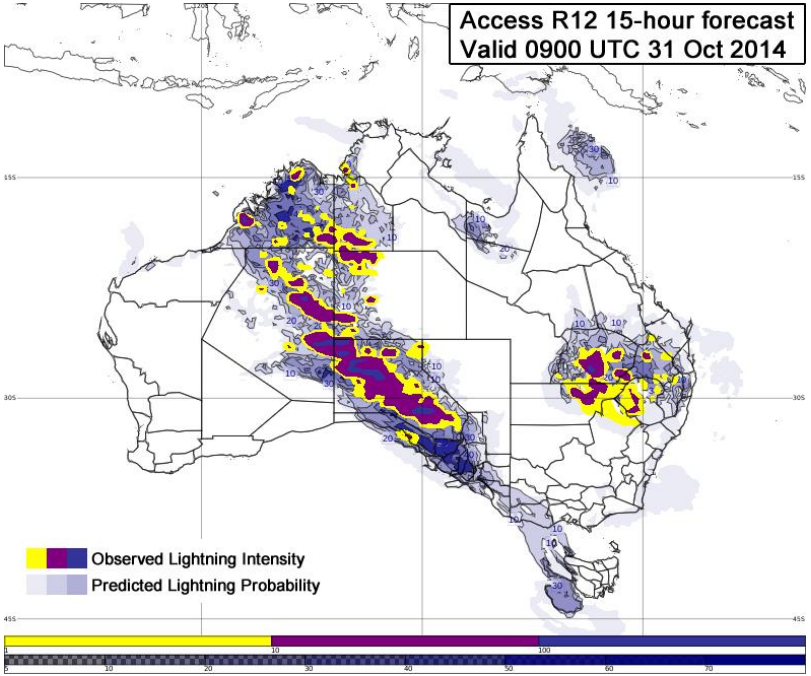
P(FFDI ≥ 25), 43 NSW stations, Dec14-Feb15



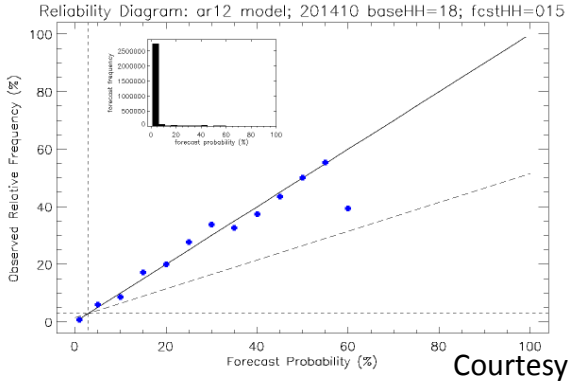

Courtesy David Smith

# Ensemble applications in development at BoM

## Thunderstorm probability




- "Calibrated thunder"
- Combine (lagged) ensemble NWP Prob(CPTP>1) and Prob($rain_{3h}$≥ 0.25 mm), calibrate against observed lightning frequency over past 30 days




Courtesy Harald Richter

# Ensemble applications in development at BoM

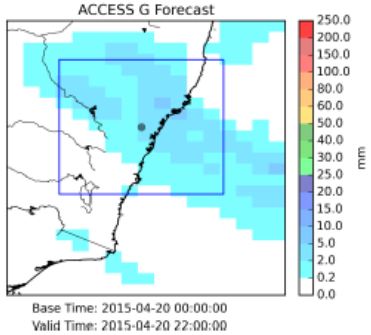
## Seamless rainfall ensemble

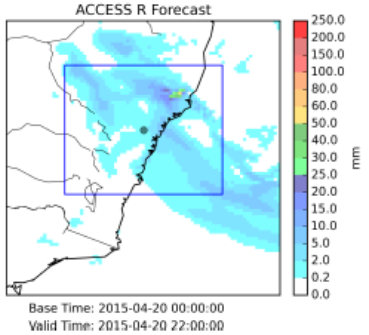
- Blend NWP models, weighting by *spatial scale* at each lead time
- Downscale using stochastic model based on radar rainfall

  → 50 stochastic ensemble members, 2km, hourly to 10 days

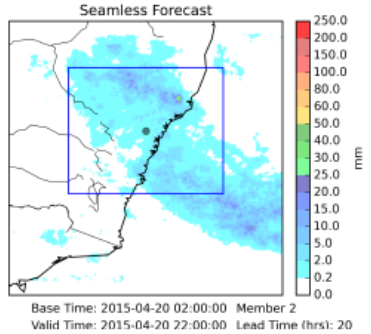
- Next: Apply to dynamical ensemble

- - - - - - - - Input - - - - - - - -

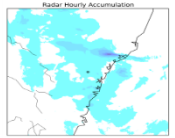



Output – ens. mem. 2




Radar (verification)

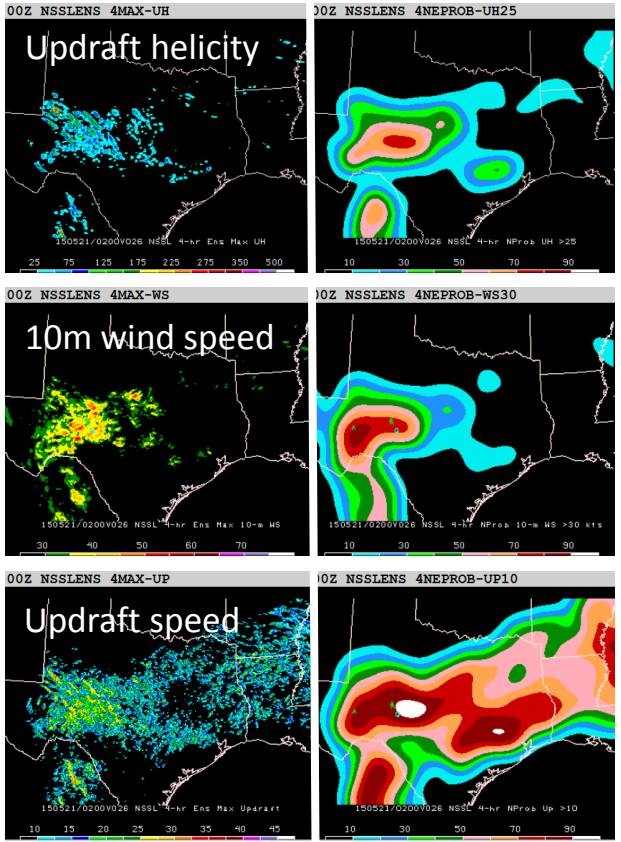



20 hr fcst, 20 April 2015

Courtesy Alan Seed

# High resolution ensembles

- Designed to aid short range forecasting of high impact weather
- Modelling challenges
  - Domain size and lateral boundary conditions
  - Data assimilation and ensemble initial conditions
  - Partially resolved convection ("grey zone")
  - Number of ensemble members




NSSL WRF ensemble 4-hourly maximum storm attribute fields (left) and corresponding 4-hourly neighbourhood probabilities (right)

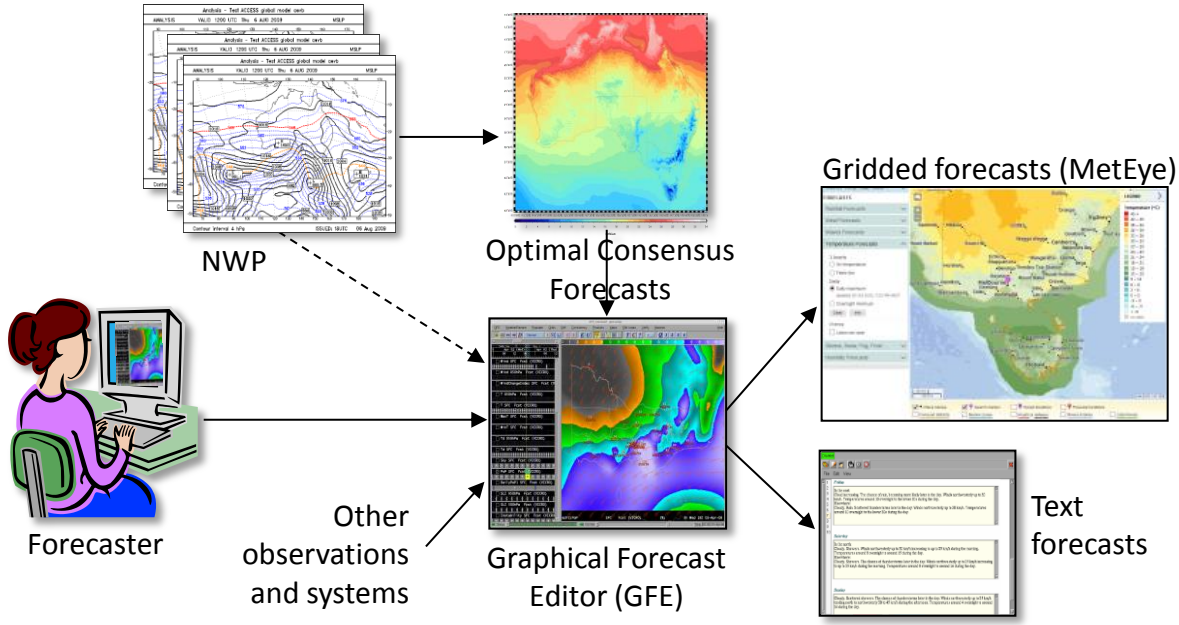
# Statistical post-processing

- Adds value to raw model output and nowcasts
  - Blends output from multiple NWP inputs
  - Calibration increases accuracy by removing bias in predicted variables, probabilities, ensemble spread
  - Smooths out unrealistic detail and "spreads" probabilities in space
  - Downscales to higher spatial resolution, e.g., to account for topography
- Transforms large amounts of data into more usable information
  - Alerts for forecasters based on critical thresholds
  - Derived products (e.g., thunderstorm probability)

# Direct use of (post-processed) numerical guidance in forecast generation

## Next Generation Forecast & Warning System

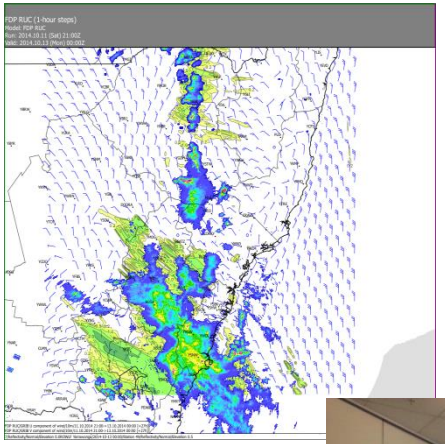
- Optimal use of NWP
- Grid editing tools
- Automated text generation
- Systematic forecast process



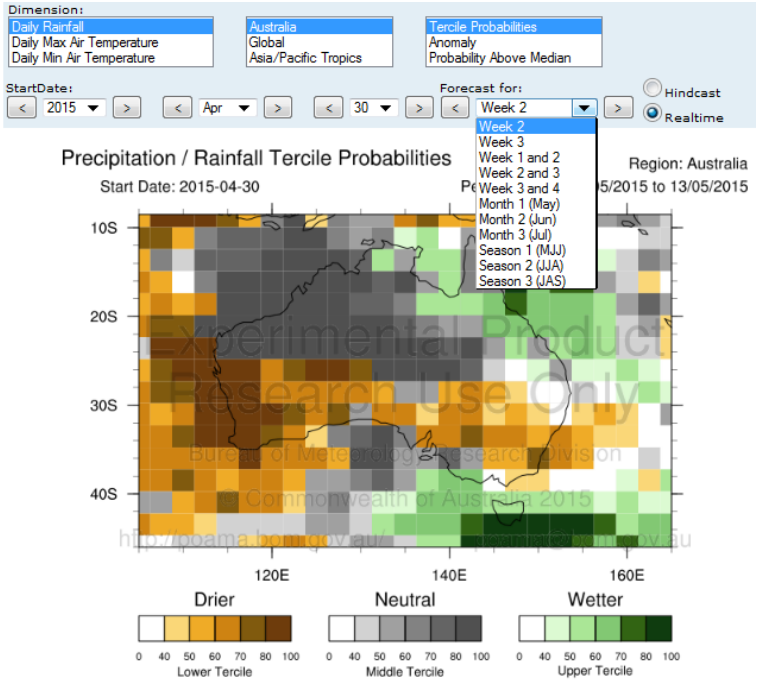
# Forecast Demonstration Projects

## Sydney 2014 FDP

- How to use 1.5km, hourly rapid update model (RUC) in forecasting?
- Researchers and forecasters worked side by side for 10 weeks
- Tests of new tools and applications
- High-res RUC preferred to existing models
- Improved forecaster conceptual understanding of the meteorological situation on the mesoscale



# Bridging time scales




Weather → multi-week → seasonal

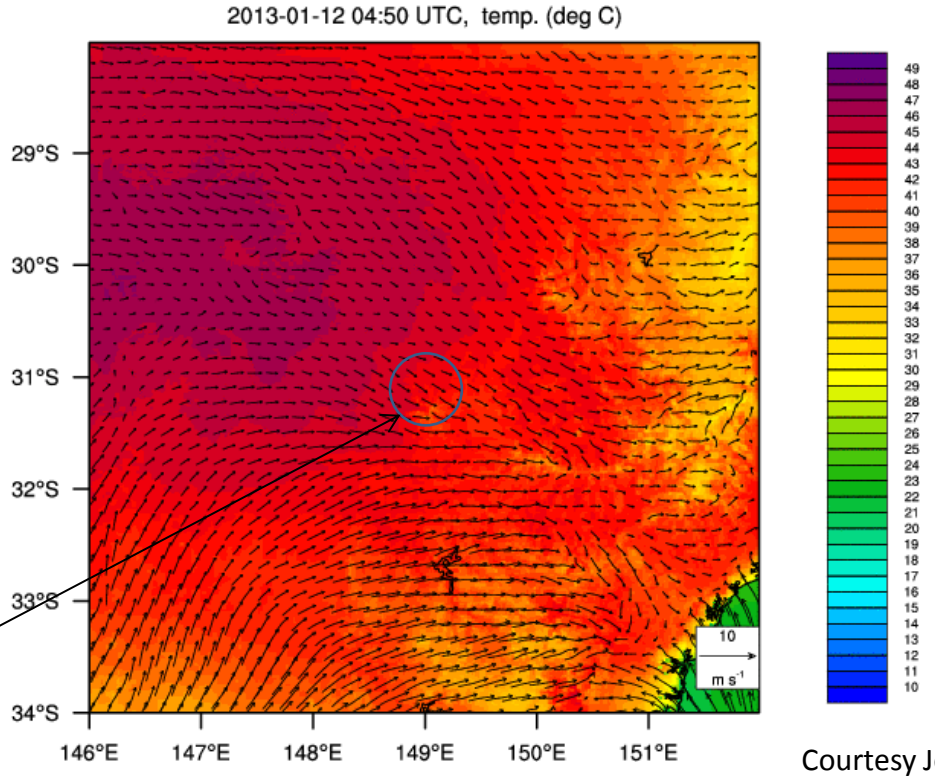
- Sources of predictability – land surface, tropical convective regime (MJO)
  - Heat waves and cold snaps
  - Dry and wet spells
  - TC genesis
- Improved coupled seasonal and multi-week prediction capability in ACCESS-S

Courtesy Oscar Alves

# Simulating high impact weather

- Screen temperature + wind
- 0.012° ACCESS model
- Notable features
  - Wind curvature around trough line
  - Convective outflows
  - Incursions of maritime air
  - Colliding change lines
  - Main change with cold-front characteristics
  - Pooling of cold air in valleys

Coonabarabran fire, January 2012



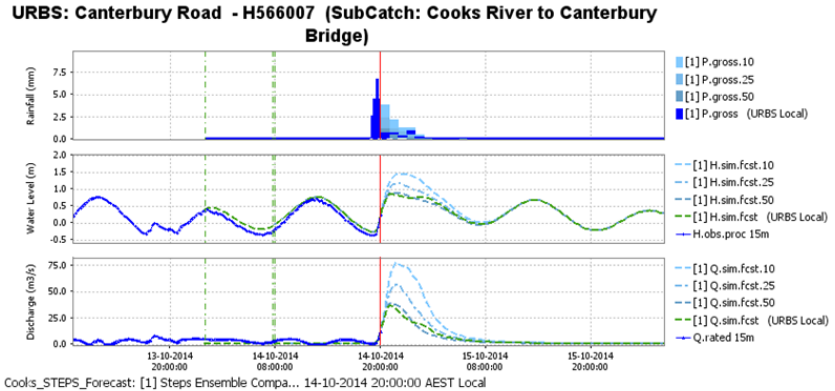

Warrambungle NP

Courtesy Jeff Kepert

# Bridging domains

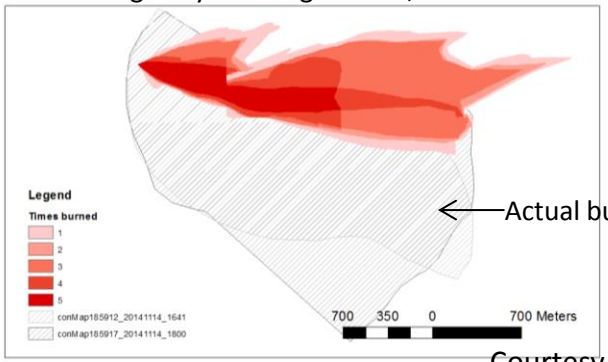
Weather → hazards

- Precipitation forecasts input to hydrological model for flood prediction




- High-res weather input to bushfire spread model

Hume Highway Coolac grass fire, 14 Nov 2014

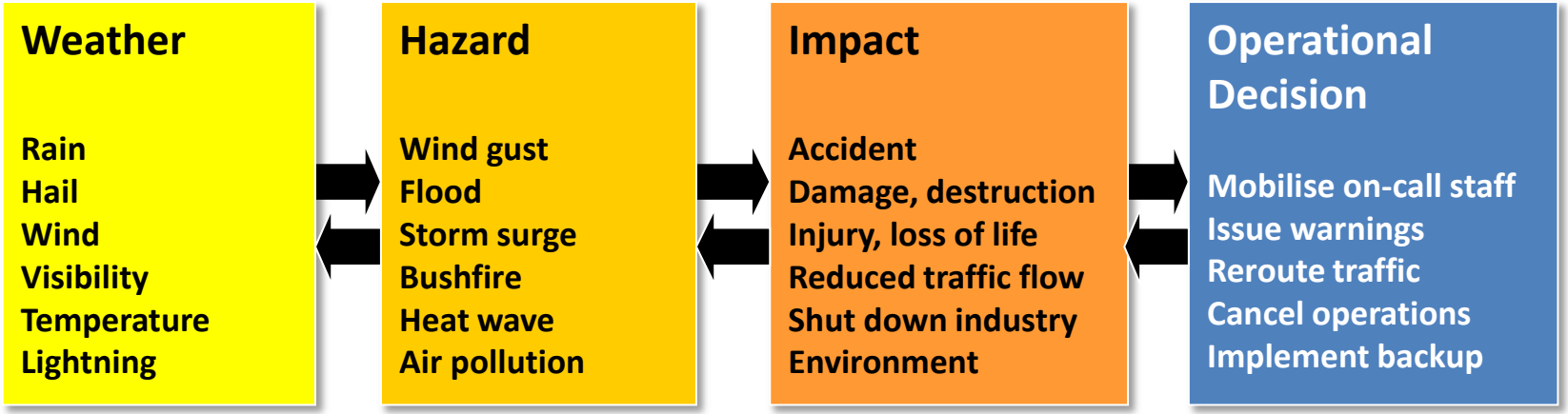



Number of model runs predicting burning

Actual burnt area

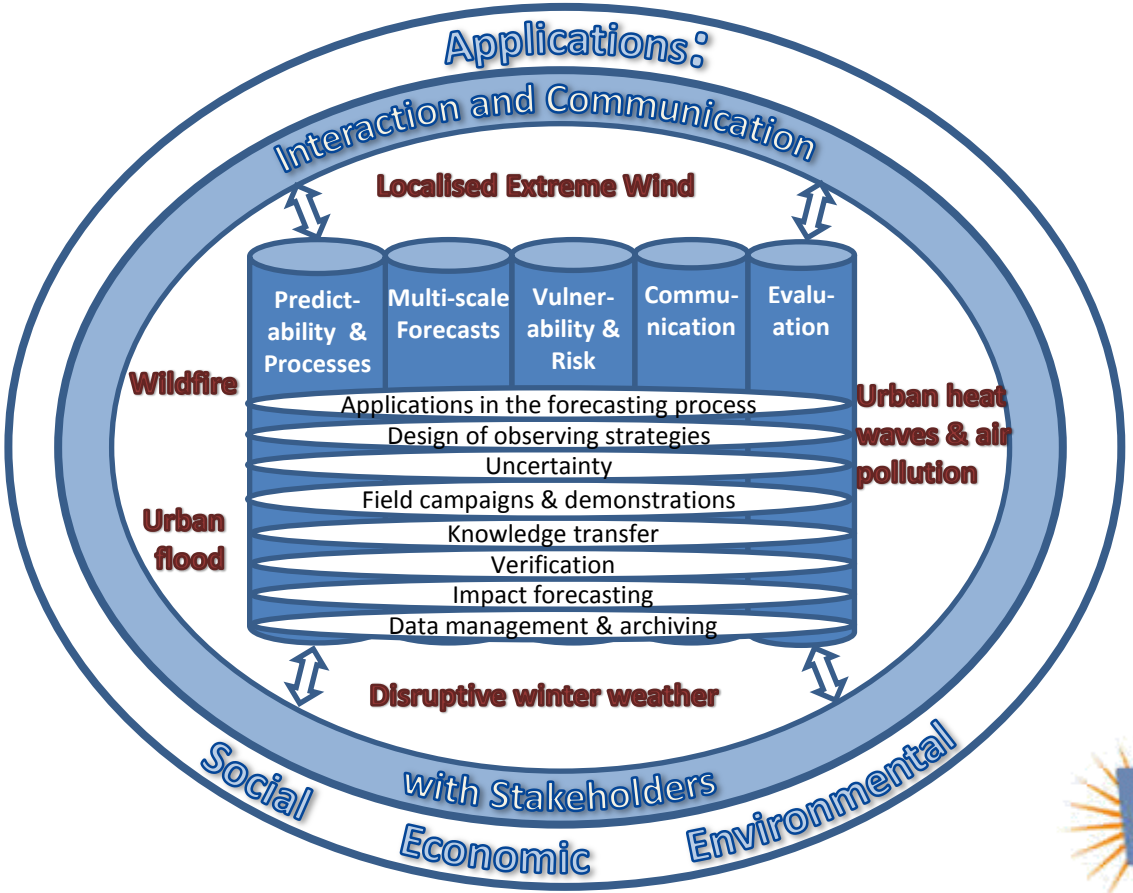
Courtesy Simon Louis

# Hazard impact prediction




- Explicit use of weather forecasts to predict hazard impacts
- Opportunities to partner with the emergency management, health, infrastructure, resource, and other sectors to provide new targeted products to help meet their needs

# WMO High Impact Weather (HIWeather) project




WWRP WORLD WEATHER RESEARCH PROGRAMME

# WMO High Impact Weather (HIWeather) project

## Research questions

- How far in advance can we predict high impact weather and associated hazards?
- How can new data sources be exploited to observe weather hazards and impacts and initialise models?
- What are improved approaches to assessing weather-related vulnerability and risk?
- Many more!

## Application development

- Weather, hazard and impact forecasts based on dynamic modelling, expressed as scenarios and probabilities
- Decision support tools that link hazards with risk and vulnerability
- Tools for communication and evaluation of hazards

## Activities

- Forecast & Research Demonstration Projects
- Workshops on specific hazards & applications
- Develop applications for/with specific users
- Inter-comparisons of techniques
- Reviews of better practice
- Engagement with practitioners in risk, economics, social science
- Case study evaluation

http://www.wmo.int/pages/prog/arep/wwrp/new/high_impact_weather_project.html

# The road ahead

- More and better observations, especially from remote sensing
- Improvements in numerical weather prediction
- Post-processing of model output
- Quantification of forecast uncertainty
- Seamless prediction across timescales and domains
- Increasing focus on users and applications
- Prediction of hazard impacts
- Underpinned by increasing scientific understanding!

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# Thank you

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