The Bureau of Meteorology

Km scale resolution NWP for severe weather

Joint Bureau R&D and 6th Momentum Partnership Convective Scale Workshop

Monday, 9 September 2024

Context

The components that contribute to the thunderstorm and severe weather services meeting our customer needs can be conceptualised as:

Current Situation: What is happening now? Analysis, observations, communication, media, emergency management briefings and intelligence, social media, alerts – including National Analysis System + NWP to understand the current state of the atmosphere.

Forecast: Who, What, When, Where, Why? Time-scales of days to weeks to months – Climate, seasonal, global and high-resolution modelling.

Certainty in the forecast: Confidence in a forecast solution. Range of possibilities for an event including the worst case, most likely scenario, and any outliers. Probabilistic services – NWP ensembles.

Reliability in the forecast: Spatial and temporal consistency in NWP output. How accurate are NWP forecasts? Helps interpret forecasts and communicate the reliability to customers – build trust.

Context of the situation/forecast: What happened previously in similar situation? How severe? How unusual? – Comparison to actual or modelled climatology (e.g., ECMWF EFI/SOT)

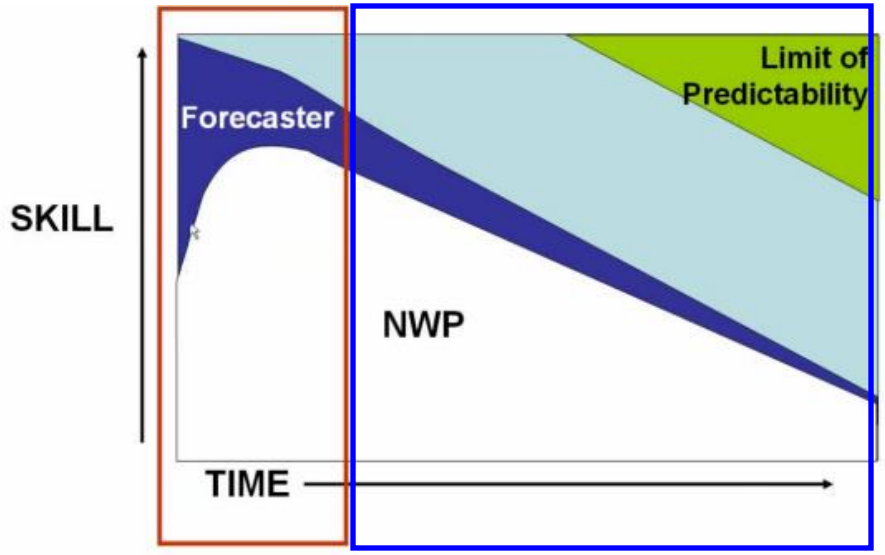
Thunderstorm + Severe Weather Use of High-Resolution Modelling

Forecast Days 0-7, but mostly Days 2-7

- Generalised environmental-based convective analysis
- Largely qualitative based on deterministic + ensemble NWP
- Probabilistic via climatology or explicitly via Ensemble Prediction Systems
- Regional and global models which cannot resolve convection explicitly

Forecast Days 0-2

- Refined and more detailed/precise forecasts
- Combination of regional/global NWP and high-resolution Convection Allowing Models (CAMs)
- Confirm environmental assessment using simulated storms within the CAM including organisation/convective mode, hazards and severity.



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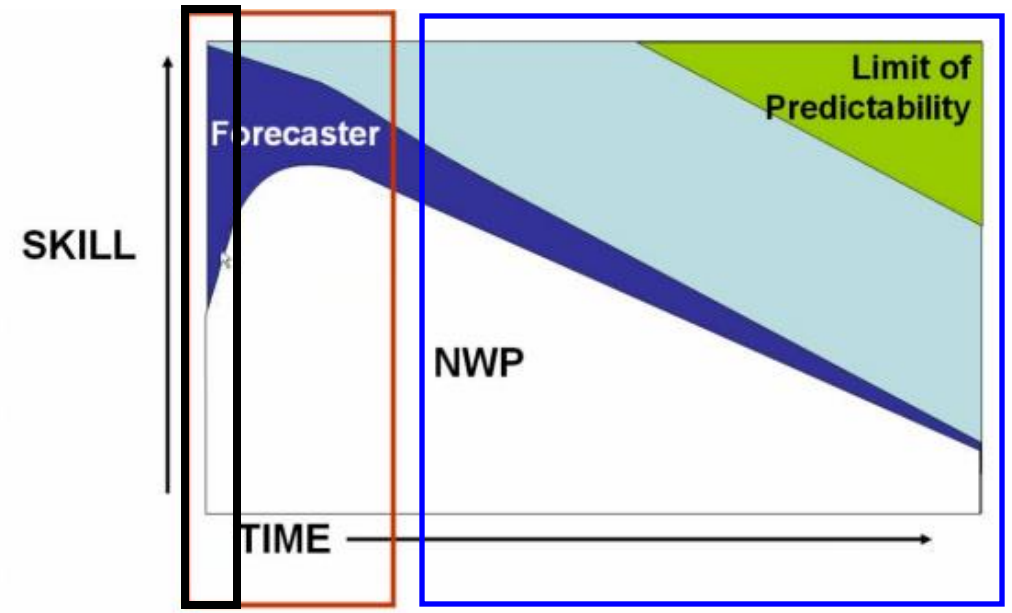
Thunderstorm + Severe Weather Use of High-Resolution Modelling

Forecast Day 0 – 0-3 hrs

- Constant tweaking and nudging of meteorologist's conceptual model
- Combination of multiple inputs including
  - environmental analysis
  - remote sensing (radar/satellite)
  - observations
  - objective radar and satellite analysis and processing tools
  - Mesoanalysis - best guess of what the atmosphere looks like now
  - High-resolution modelling, particularly RUC
- Pattern recognition of radar and satellite signatures
- Projecting forward thunderstorms to determine evolution based on conceptual model and convective environment.



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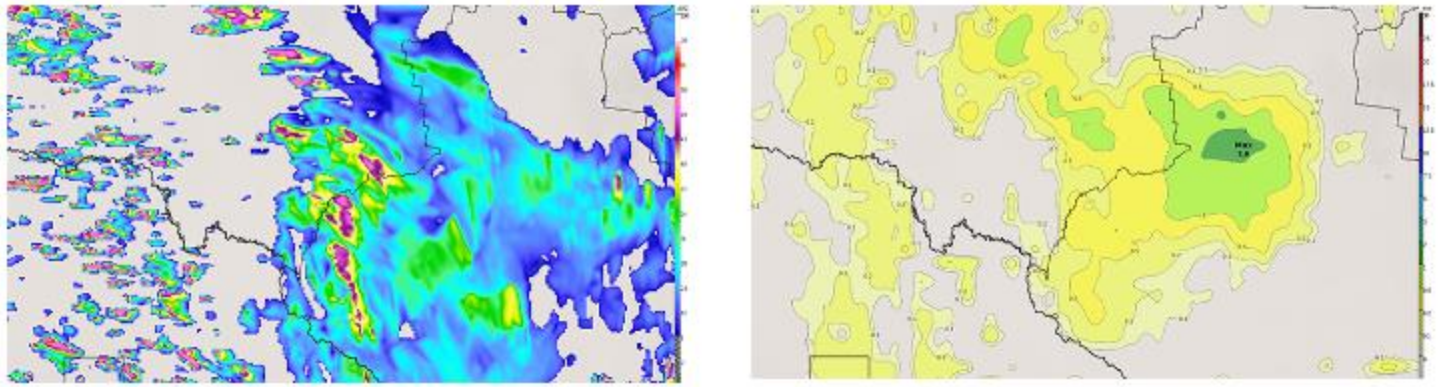
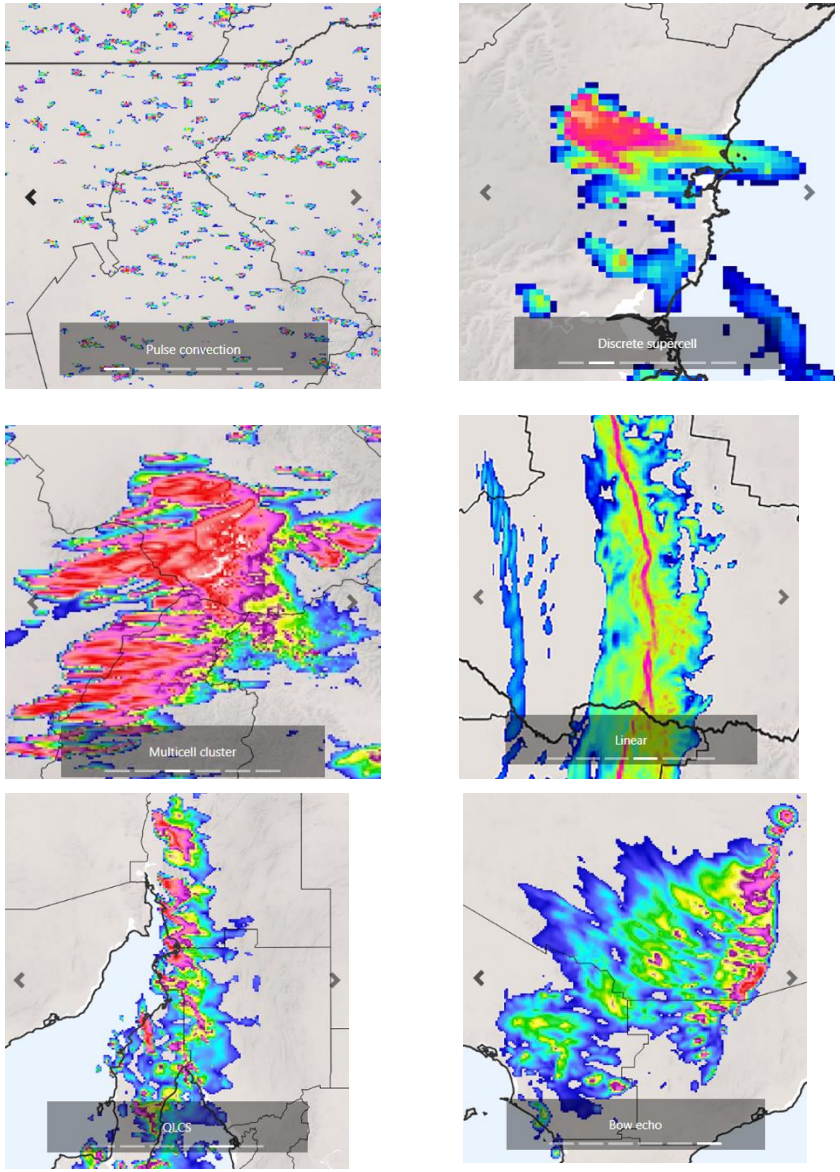
Thunderstorm + Severe Weather Use of High-Resolution Modelling

Benefits of high-resolution modelling (CAMs)

- Improved predictions of the mesoscale environment
- Initiation, evolution and mesoscale characteristics of convection such as convective mode
- Discriminate between convective modes which is strongly associated with the type of severe thunderstorm hazard



Comparison between APS3 ACCESS-VT 1 km AGL simulated radar reflectivity Hour Max Field (refer to Module 2) (left) and corresponding APS3 ACCESS-G total precipitation 1 hour accumulation (right)



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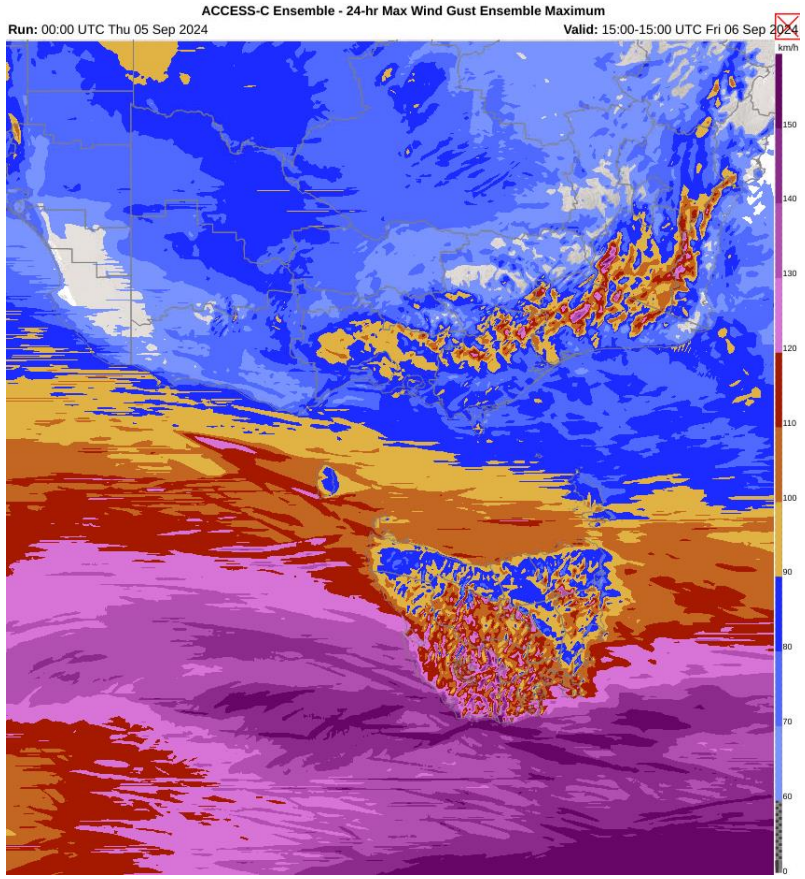
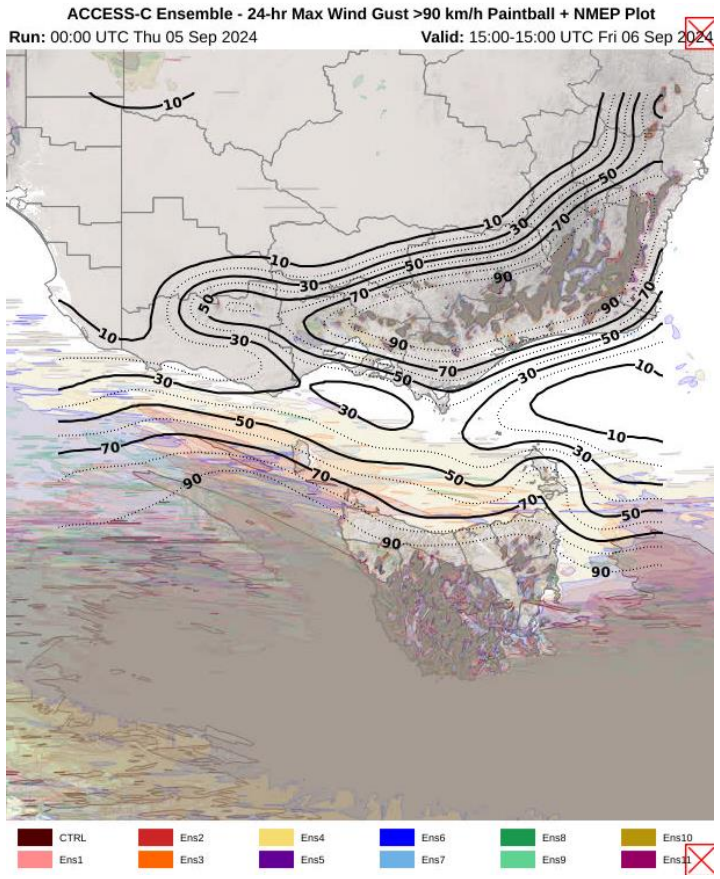
Thunderstorm + Severe Weather Use of High-Resolution Modelling

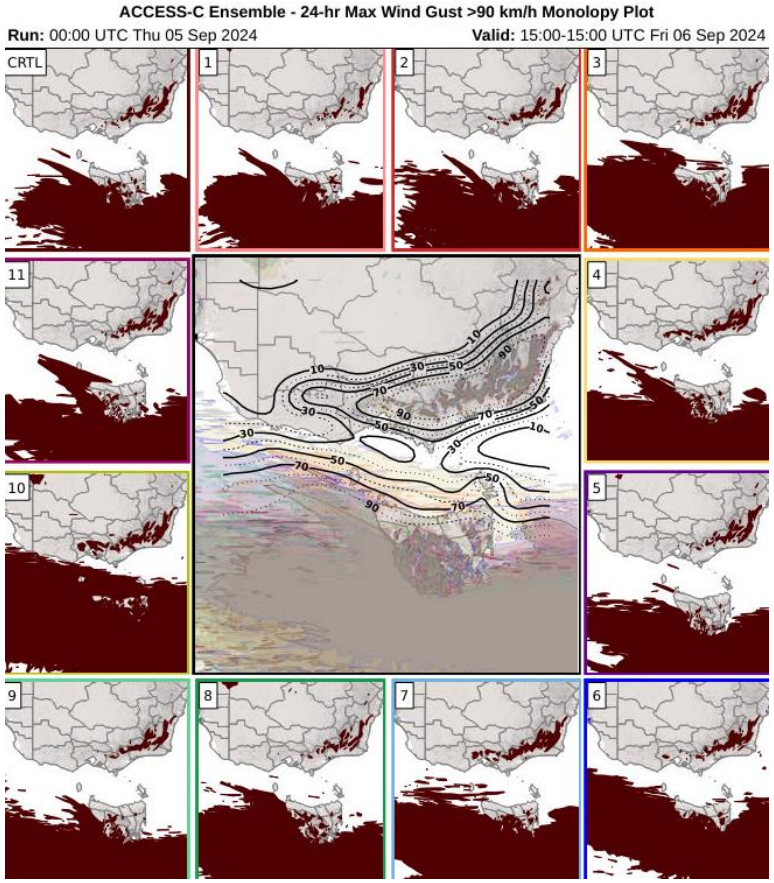
Use of high-resolution ensembles



24-hr Ensemble Max Wind Gust



24-hr Ensemble Wind Gust ≥ 90 km/h Paintball Plot and Neighbourhood Maximum Ensemble Probability (NMEP).



24-hr Ensemble Wind Gust ≥ 90 km/h Monopoly Plot

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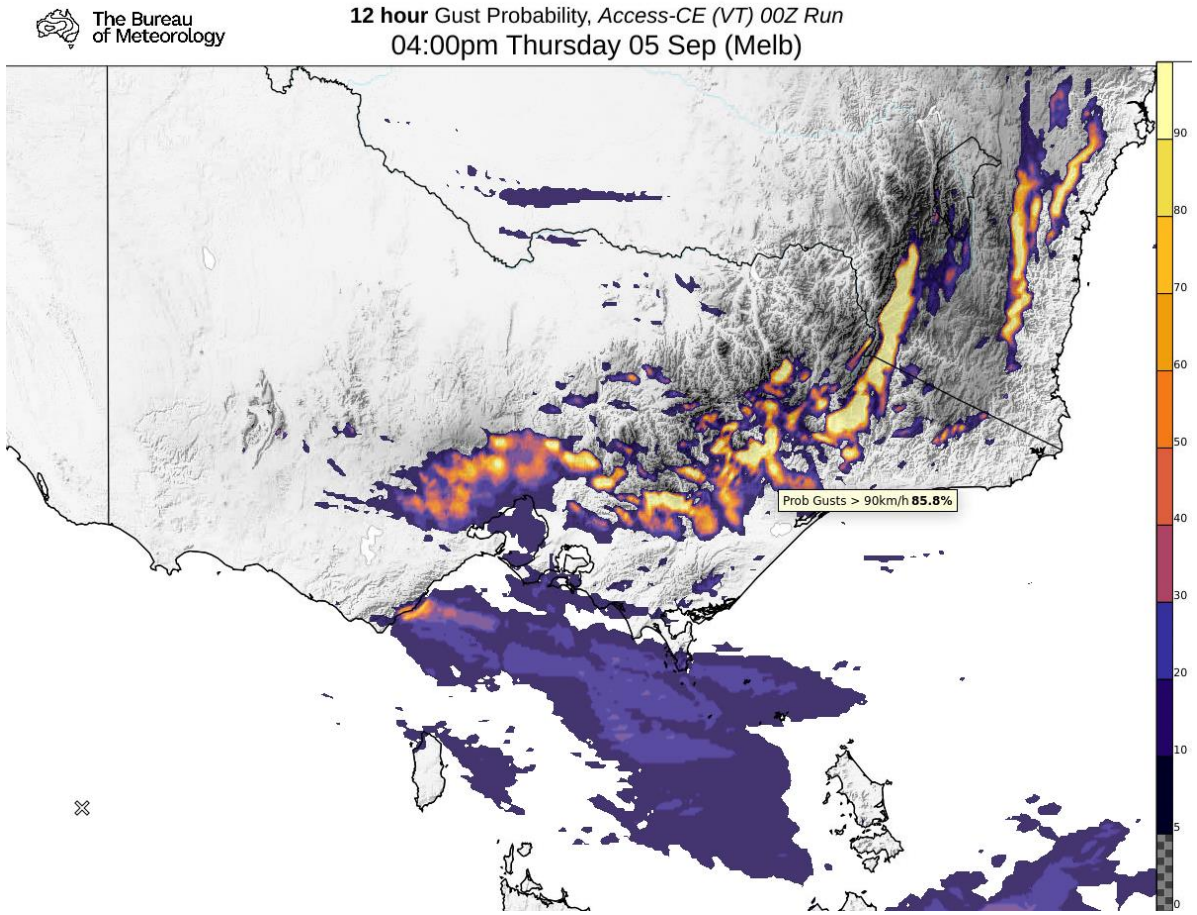
Thunderstorm + Severe Weather Use of High-Resolution Modelling

Use of high-resolution ensembles



3-hr Ensemble Wind Gust ≥ 90 km/h grid point probabilities.

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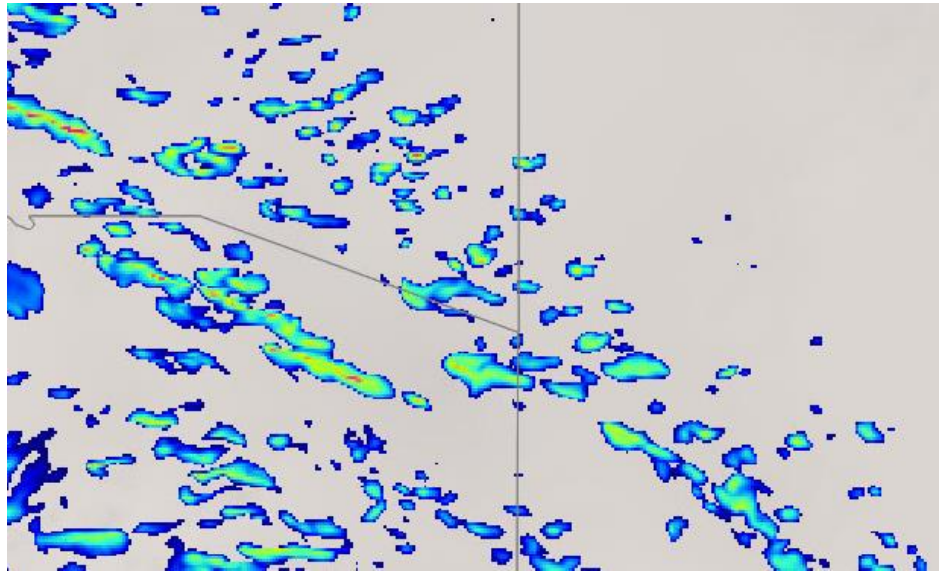
Thunderstorm + Severe Weather Use of High-Resolution Modelling

Limitations + opportunities to improve

- 1.5 km (deterministic)/2.2 km (ensemble) convection too "blobby" and circular with too intense rainfall rates and excessive simulated radar reflectivity values.
- Stochastic PBL perturbations leading to "measles"-like convective initiation.
- ACCESS-C domains are a pain to use in operations and do not cover all threat areas with notable population centres.
- Wind gust fields typically too strong
- Strongly coupled to ACCESS-G boundary and initial conditions limiting ensemble spread – failure to identify severe thunderstorms or heavy rainfall.
- Under-dispersive ensemble solutions lacking sufficient spread in forecast scenarios to appropriate encapsulate the observations that result.
    - Too high confidence in ensemble probabilities
    - False sense of confidence in forecast solutions.



Example of too many large and circular "measles" convective initiation.

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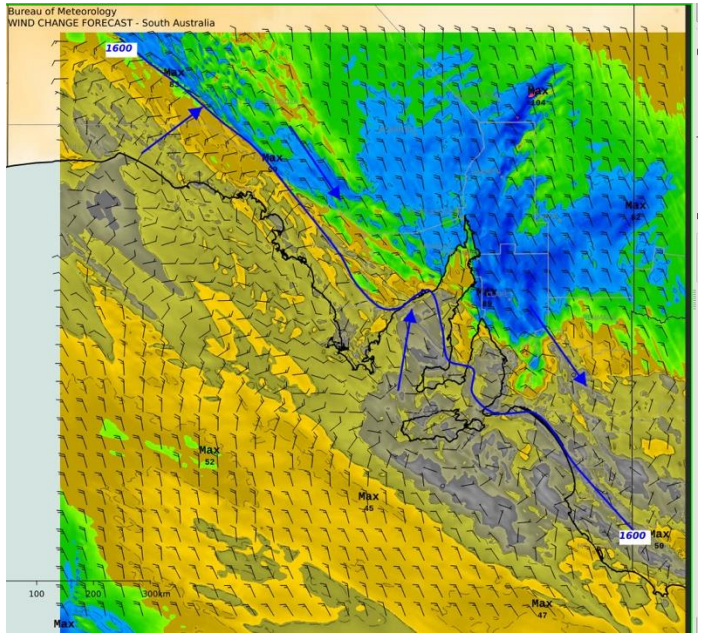
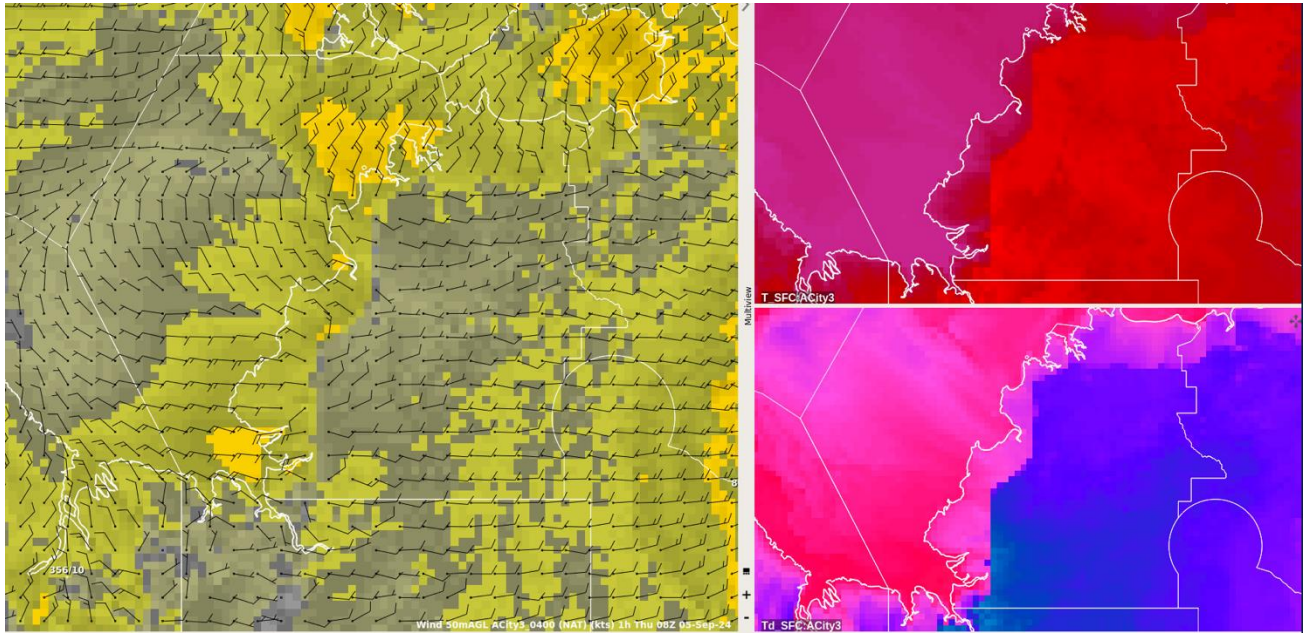
Fire Weather Use of High-Resolution Modelling

- Preparation of Incident Weather Forecasts (IWFs)
  - Vertical and horizontal resolution is incredibly important to adequately capture topographic effects
- Preparation of Wind Change Charts
  - Wind direction probability using ensembles for wind change timing and uncertainty
  - Wind direction and speed, temperature and dewpoint temperature around wind changes.
- Inform wind gust magnitudes for fire weather forecasts and IWFs



Wind Change Chart preparation using high-resolution wind modelling.



50 m AGL wind (left), 2 m temperature (top right), and 2 m dewpoint temperature (bottom right).

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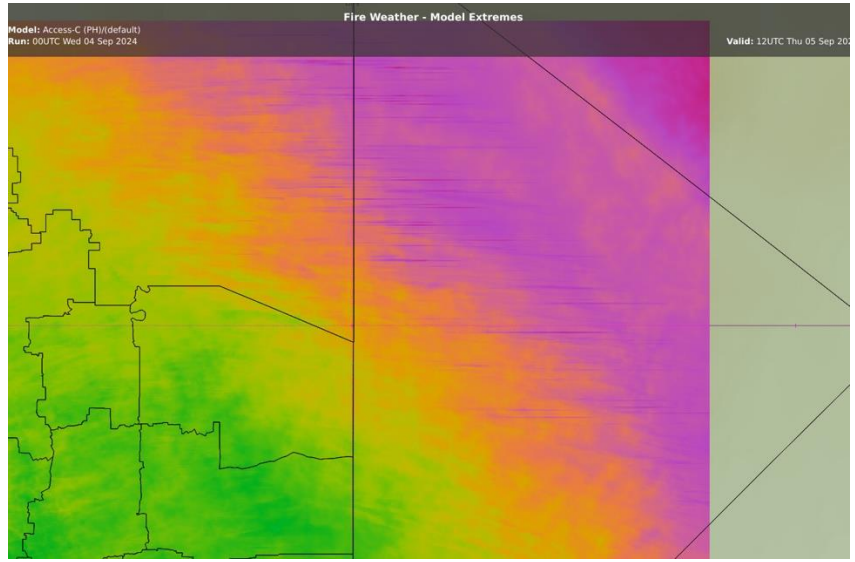
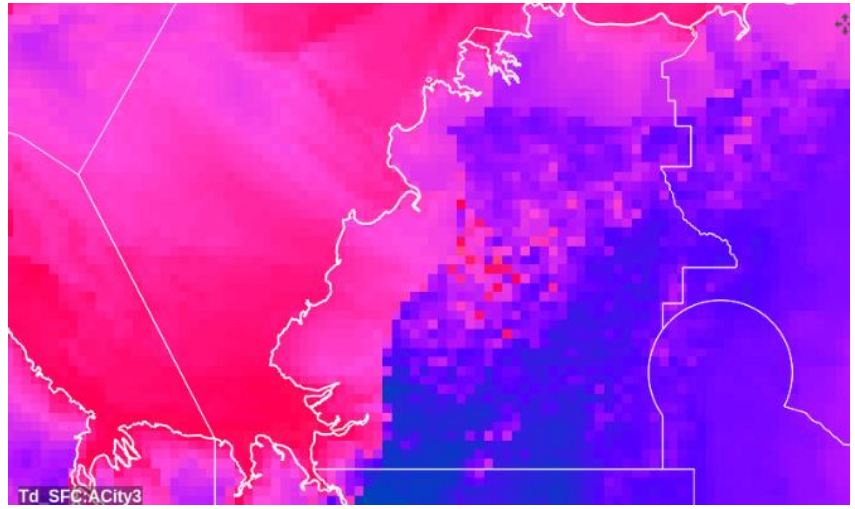
Fire Weather Use of High-Resolution Modelling

Limitations + opportunities to improve

- Zonal "streakiness" in numerous output fields
- 09 UTC (PBL decoupling) dewpoint temperature jump
- 10 m AGL wind speed too light – typically use 50 m AGL (hybrid level 3)
- MaxT over urban heat islands over-represented (too high)
- Ensemble solutions can be more "extreme" (too high) which is useful for probabilistic fire weather forecasts to enable future services
    - Global NWP solutions are typically too low and require time consuming manual intervention to correct.



2 m AGL temperature "streakiness"



2 m AGL dewpoint temperature 09 UTC issue.

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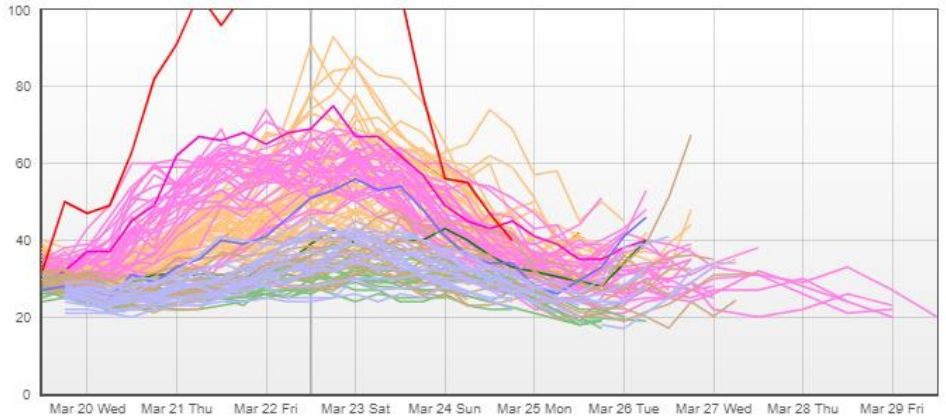
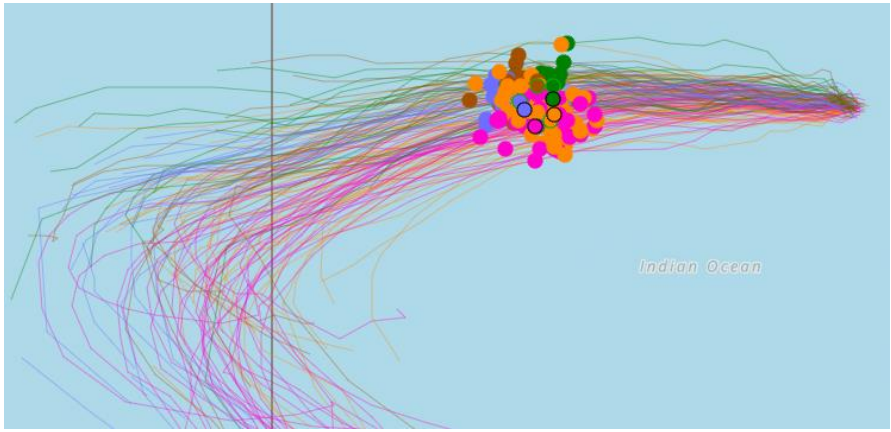
Tropical Cyclone Use of High-Resolution Modelling

Limitations + opportunities to improve

- Don't actively use high-resolution modelling
  - ACCESS-TC with roaming domain of limited use, particularly given 72-hour forecast.
  - ACCESS-C not useful as tropical systems typically don't reside in the limited city domains long enough and have too small oceanic coverage.
  - Reliability: intensity of systems often too high, or intensify too quickly
- TC track forecasting doesn't require ultra fine detail that a high-resolution model may provide, although this information could be useful in the future if sufficiently reliable.
- Typically use super ensembles to combat the under-dispersed and too weak peak intensities of individual NWP ensembles
  - Employ calibration to reduce "over-spread" of super ensemble and adjust peak intensities.



TC Neville intensity super ensemble timeseries.



TC Neville system center and track super ensemble.

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Operational Priorities + Wish List

General

- National high-resolution model (ACCESS-A) with:
  - Rapid Update Cycle (RUC)
  - Increased ensemble members/ensemble spread
  - National Analysis System
- Improving global model to
  - remove zonal streaking
  - low bias of intensity (wind gust, rainfall, TC intensity etc.)
  - Increase ensemble members/ensemble spread
- Limiting increasing resolutions for global models to maintain synoptic "bearing"

Thunderstorm + Severe Weather

- Additional NWP core-derived storm attributes (e.g., 0-3 km updraft helicity)
- Climatological comparison to provide context (how significant; e.g. PW anomalies, precipitation AEPs)
- Improved microphysical diagnostics to inform:
  - Improved lightning prediction particularly elevated dynamically forced convection
  - Hail occurrence and hail size estimates.

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Operational Priorities + Wish List

Fire Weather

- High-resolution model without convective contamination of fields as cannot be used to inform fire weather forecasts (outflow boundaries in wind field, increased dewpoint temperatures etc.)
- An "open" 10 m AGL wind (to compensate for too low wind magnitudes).
- Ensemble 50 m AGL wind
- Probabilistic location and time of arrival of wind changes
- Fire-Atmosphere coupled modelling (ACCESS-Fire) to better resolve hazards associated with plume/PyroCb, fire fronts, near fire winds etc.

Tropical Cyclone

- Errors in ensemble solutions independent of the other NWP centre solutions to capture the probabilistic distribution.
- Improve the predictability of cyclogenesis at longer lead times
- Improved post-processing / statistical methods to reduce the manually intensive process of TC structure forecasting (radius of gales, storm force, max winds etc.) that are typically "jumpy" and inconsistent.

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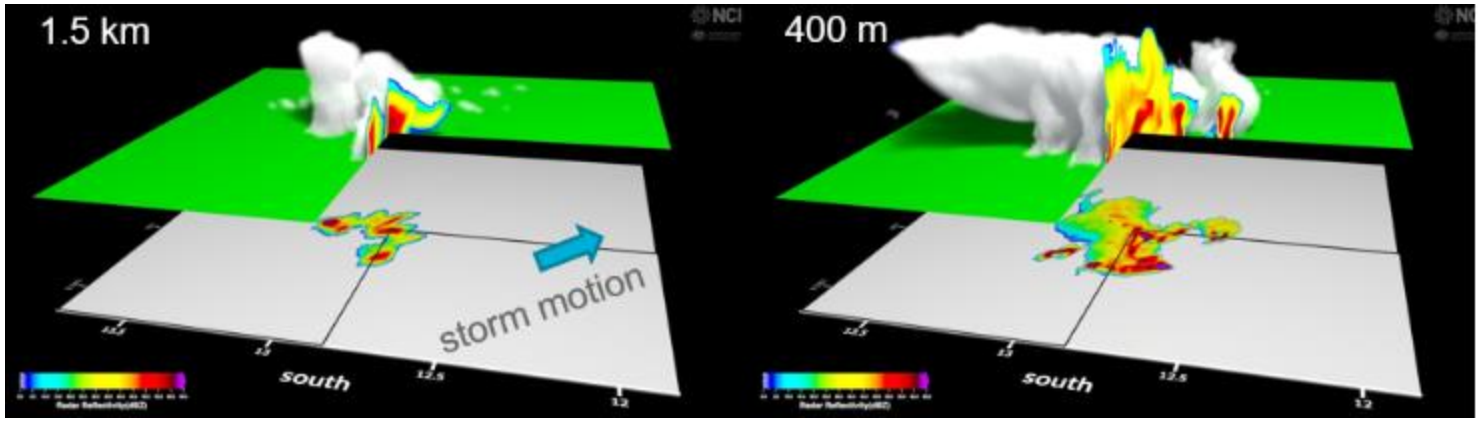
300 m modelling systems

"We have the ability to produce extremely detailed forecasts that can be extremely wrong." – Paul Janish, SPC 1996

- Suggest prioritisation of ACCESS-A/NAS before 300 m resolution systems
  - 300 m resolution systems as city domains
  - Change in operations to 300 m systems ~ order of change from global model to 1.5 km CAM (science questions, how would we use it, interpretation, typical values etc.)
- Better resolve internal convective processes resulting in more realistic storm structure, reducing "blobbiness", more realistic precipitation/simulated reflectivity/convective mode
  - more likely to be "wrong"?
- Greatly assist IWFs, particularly for improved resolving of sharp topographic effects.
- Little to no foreseeable usefulness for TC forecasting.



Comparison of a modelled thunderstorm at 1.5 km resolution (left) and 400 m resolution (right)

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Questions?

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