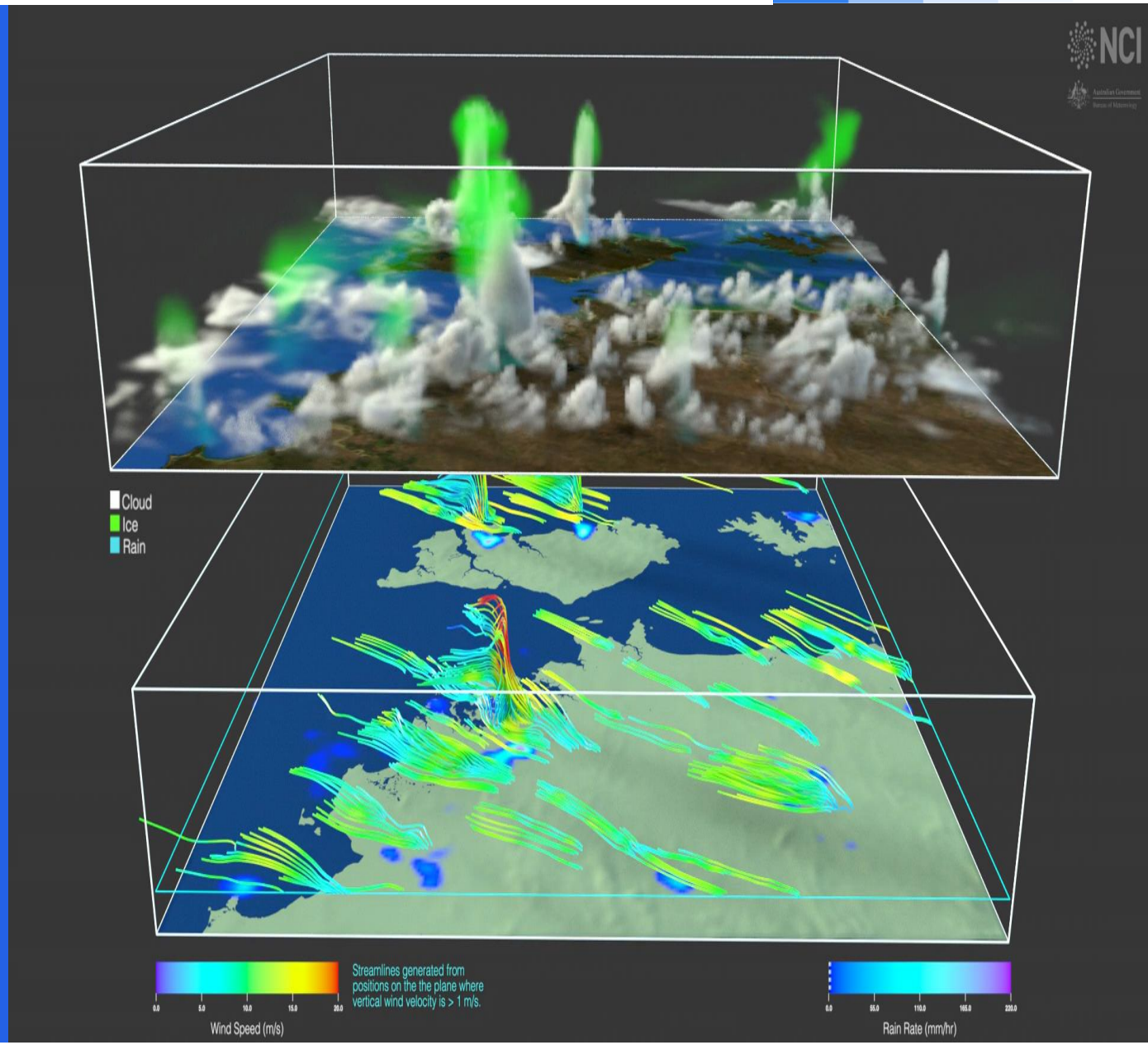
The Bureau of Meteorology

Convective Scale Modelling Opportunities for the Bureau

Charmaine Franklin

Including work from many others in the Bureau's Research Program



Australian weather hazards




Heavy rain and floods

Damaging winds

Hail, lightning and tornadoes

Fog

Bushfires

Heatwaves

Air quality

Escalating demand for improved modelling and prediction of severe weather hazards and extremes, across an increasing range of sectors.




Images from: Bureau, Air Environment, EOS, ABC

Images from: Daily Mail, National Museum of Australia, New Scientist, ABC

Benefits of convective scale resolution

Explicitly represented convection

- improved diurnal cycle, more realistic rain rates, coastal convection propagating inland, convective organisation, outflows, back-building, TCs, extreme wind gusts

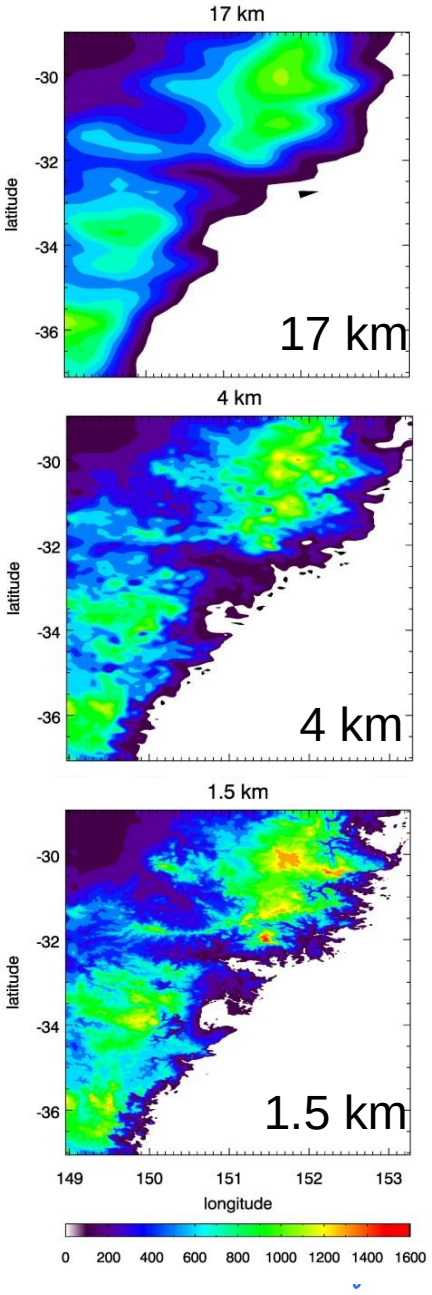
Better local topography and surface characteristics

- orographic precipitation, land-sea breeze circulations, elevated heating, valley cooling, localised fog, air quality

More accurate urban effects

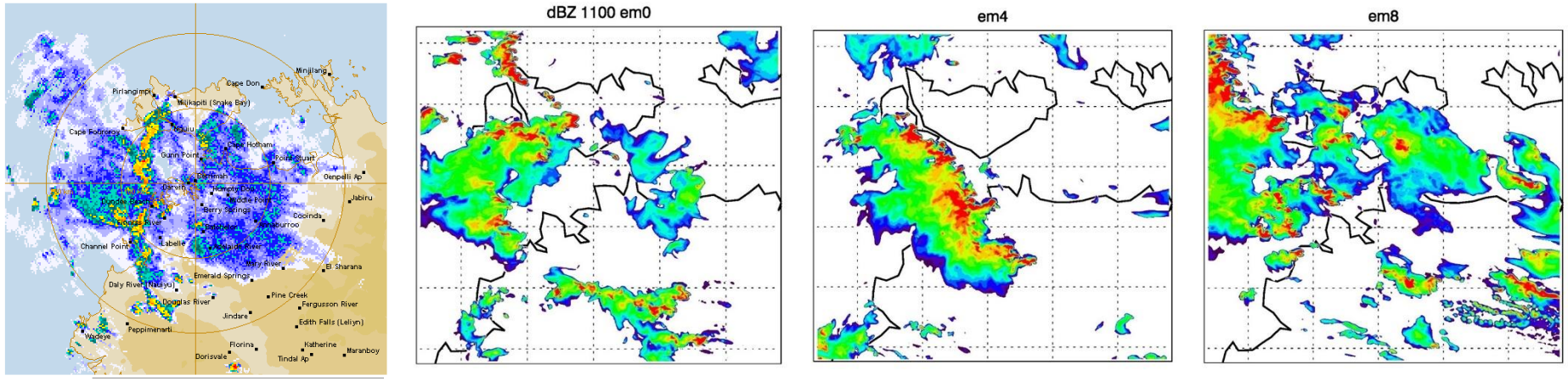
- urban temperature distribution, winds and air quality

The Bureau's convective-scale models deliver improved NWP guidance to better predict local hazards and support downstream models for flooding/streamflow, fire danger, air quality, solar and wind energy, and airport conditions.



Challenges of km-scale modelling

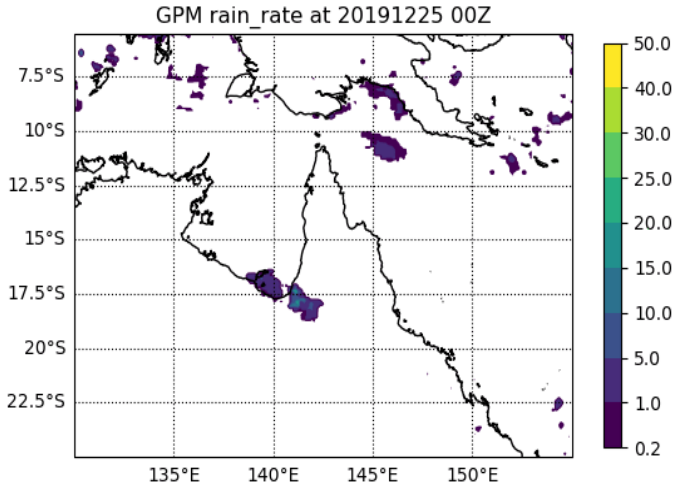
- Partially resolving convection and at sub-km scales partially resolving turbulence
- Finding the balance between domain size and resolution
- Representing uncertainties – initial and boundary conditions, model error
- Developing evaluation tools and appropriate metrics for km and sub-km simulations
- High-resolution observations for initialisation and evaluation

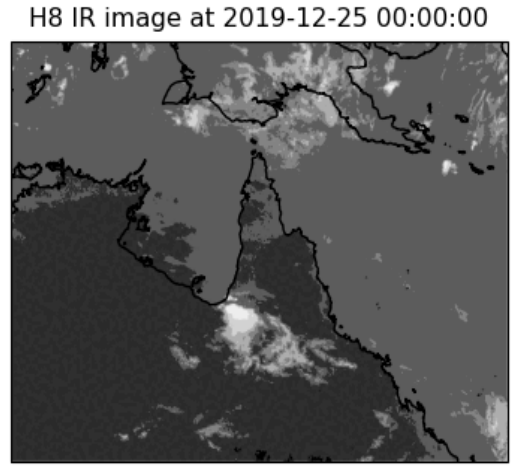


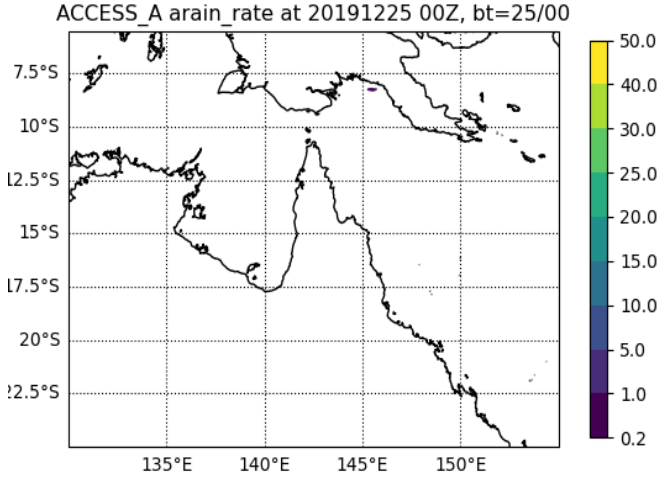
400m ensemble simulation of Darwin tropical squall line

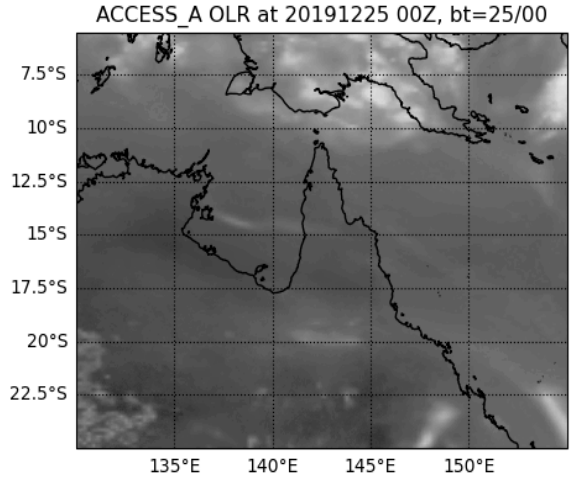
Opportunities for km-scale modelling

- Large domains to better represent scale interactions
- Sub-km urban-scale models for providing more localised information
- Improved representation of atmospheric processes: convection, turbulence, cloud microphysics – aerosol
- Larger ensembles to better represent uncertainty
- km-scale benefits for climate services
- km-scale environmental prediction systems: atmosphere, ocean, waves, sea-ice, aerosols, hydrology
- Flexible km-scale and sub-km systems: on-demand, number of ensemble members, relocatable







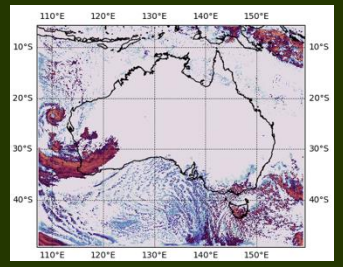


Figures: Belinda Roux

Regional convective-scale modelling activities at the Bureau

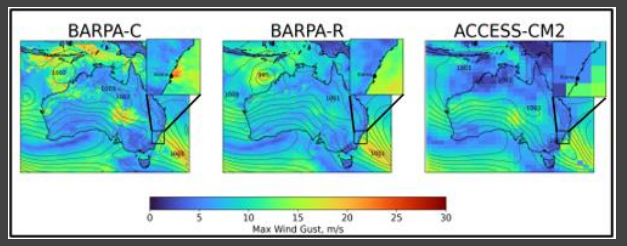
Short-range weather prediction

Advance regional hazard forecasting capability on weather timescales



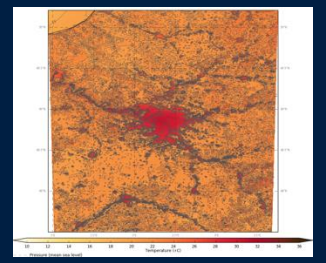
Climate projections & reanalysis

Advance regional hazard forecasting capability on climate timescales



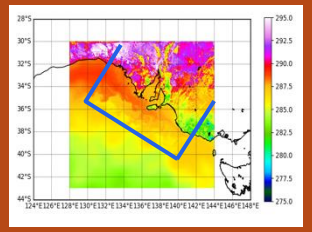
Urban-scale

Support improved weather predictions and warnings on neighbourhood scales



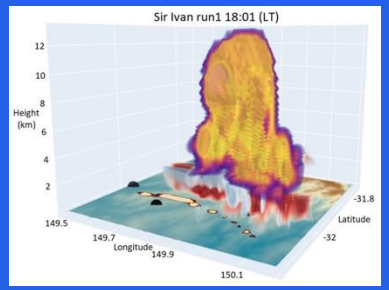
Regional coupled modelling

Developing prediction systems for multi-hazard compound events and future weather and climate systems



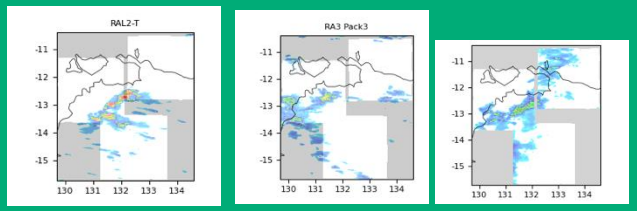
Coupled fire modelling

Research atmosphere-fire interactions to understand fire behaviour



Regional model development

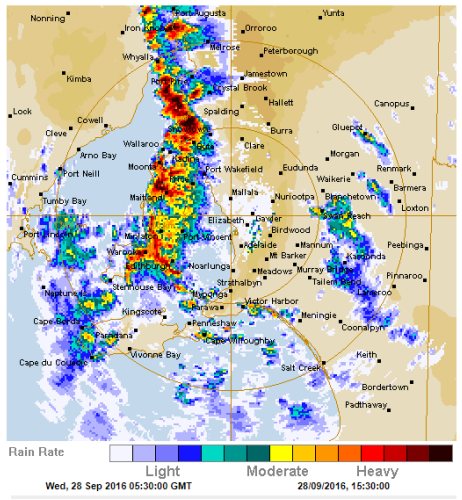
With the Partnership to test improved model configurations that underpin regional NWP and climate



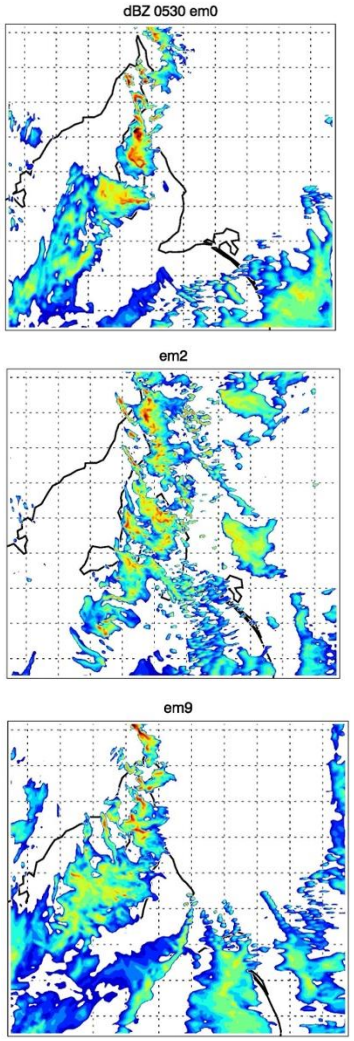
On-demand, relocatable 300m ensemble for extreme weather

- Sub-km scale models better represent convection and high impact weather, but small errors grow quickly due to moist convection.
- **Develop an on-demand, relocatable 300m ensemble system to support day ahead severe weather forecasting.**
- Explore ML techniques to reduce costs, e.g. increase ensemble members.

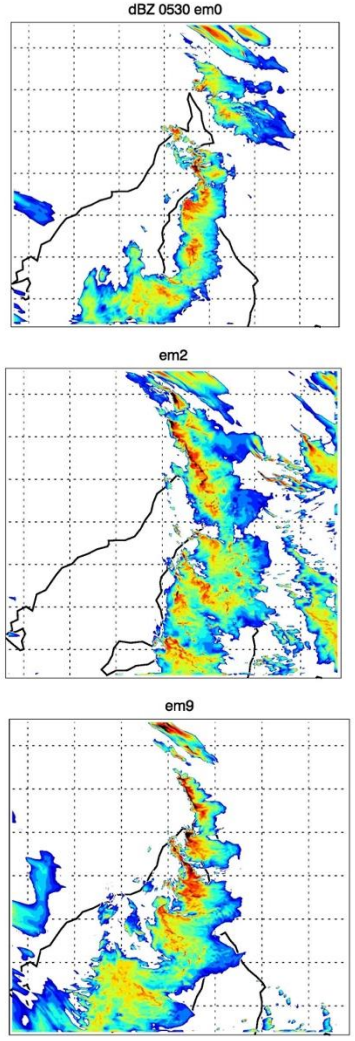
Observed and simulated radar reflectivity



1.5 km

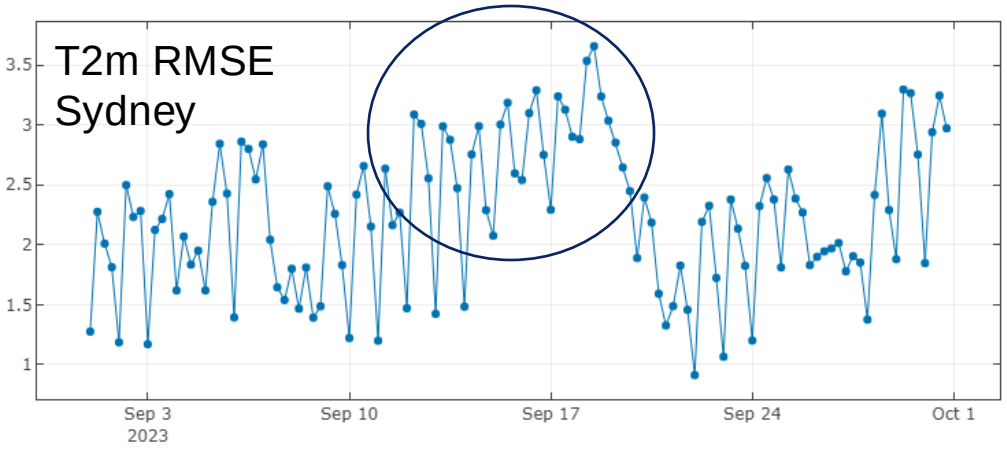


400 m



Interactive aerosols

- ACCESS NWP models use prescribed aerosol climatology, missing smoke and dust events.
- Leads to incorrect surface temperatures, atmospheric stability, cloud properties.
- Aerosol-cloud interactions are not represented, impacting cloud lifetime, brightness and precipitation.
- **Adding interactive aerosols to ACCESS models could improve accuracy and lead to a wider range of services.**



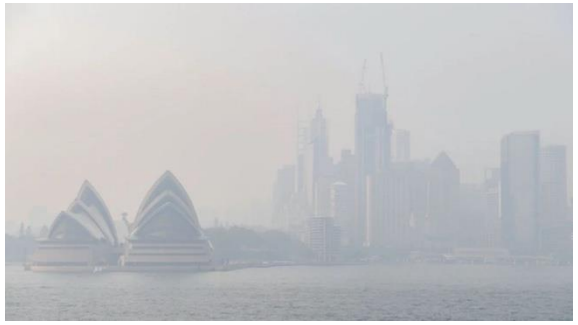
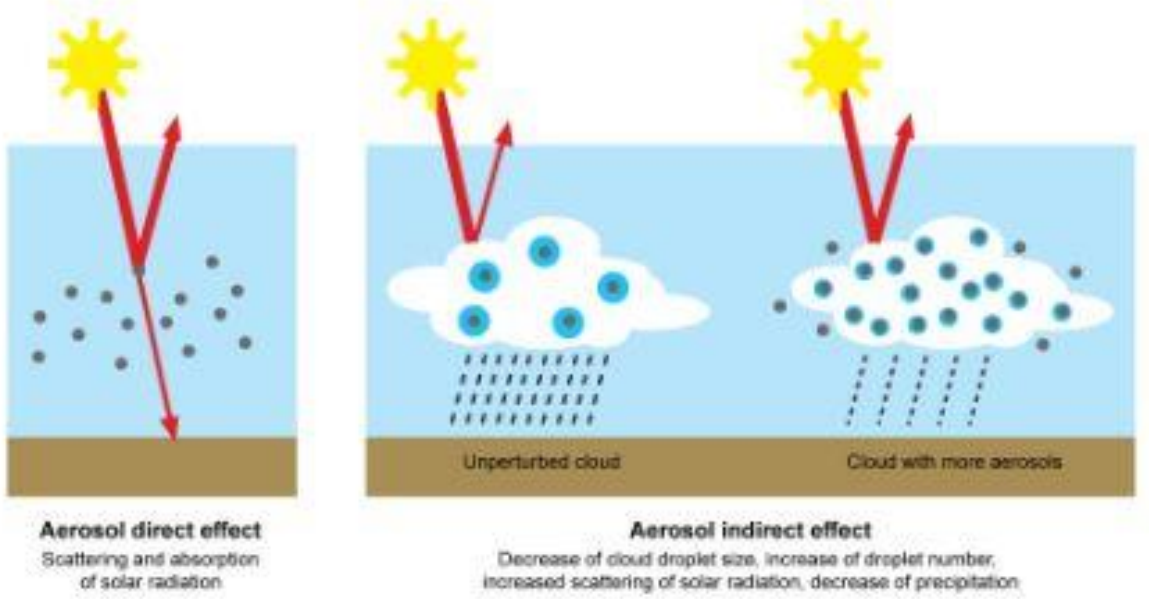


Image from BBC

Image from The Guardian

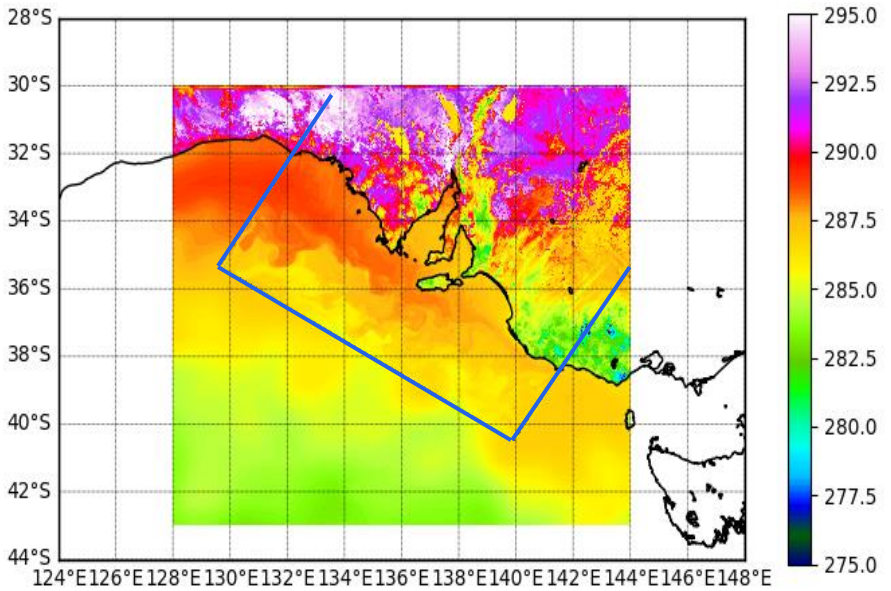


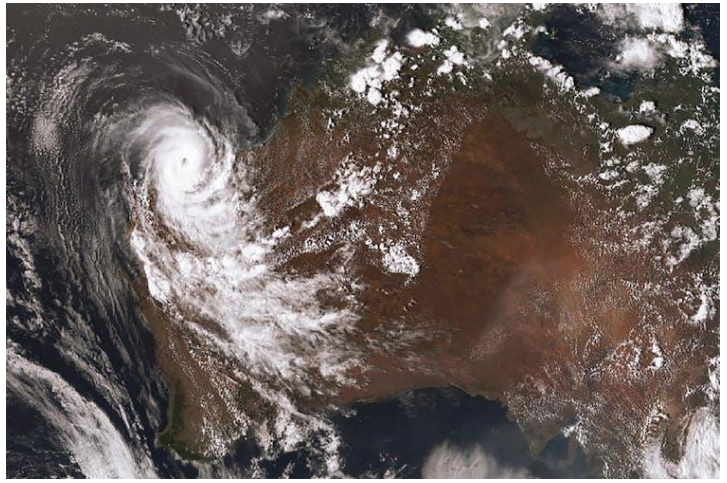
https://www.meteoswiss.admin.ch/climate/climate-change/monitoring-the-atmosphere/aerosols-and-climate.html

Coupling to ocean and waves

Towards a regional environmental prediction system

- Bureau has developed the capability to develop a regional atmosphere and land – ocean coupled model.
- Coastal zones are important as this is where feedbacks between atmosphere, land, ocean and waves occur, and where 80% of Australia's population lives.
- Coastal hazards mainly occur through meteorological events that drive multiple hazards, such as strong winds, heavy rain, storm surge, high waves.
- Tropical cyclones have been shown to be better modelled with coupled atmosphere – ocean – wave systems.
- **Coupled convective-scale modelling systems could enhance the range and consistency of guidance and warnings.**



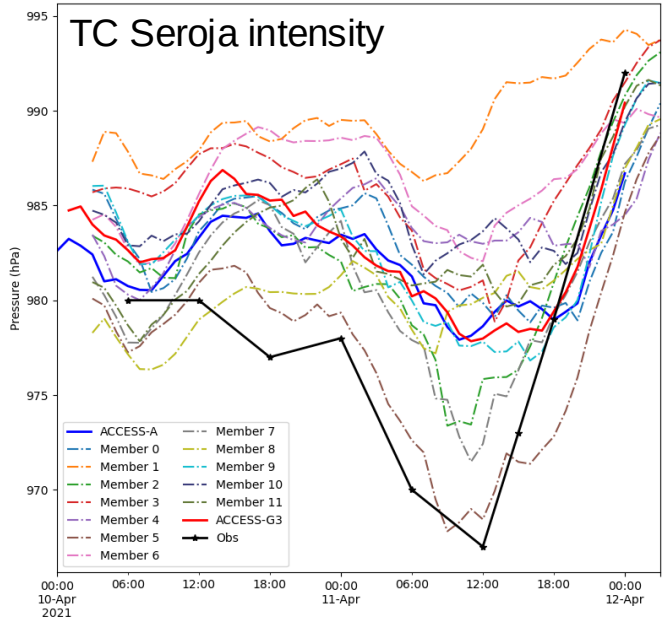


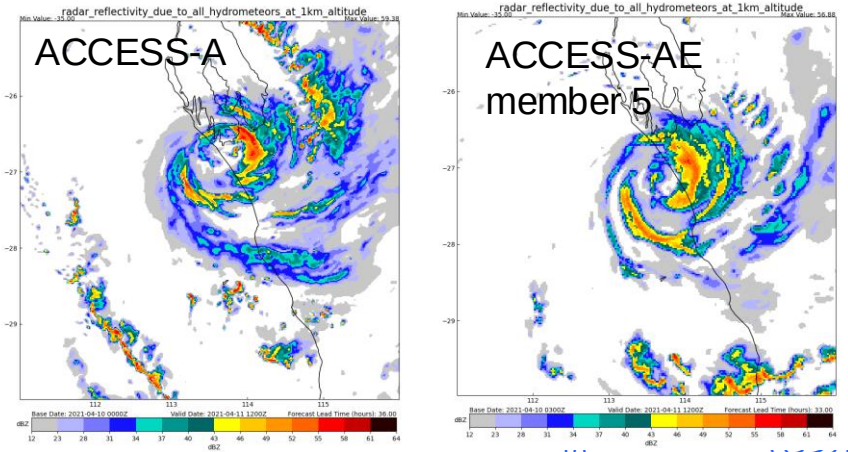
Figures: Frank Colberg, Bureau

Physical processes – convection, microphysics, turbulence

Pan-Australia models provide an ideal laboratory for testing convective-scale model developments

- Development required to improve model biases and accuracy in convection, clouds, and turbulence.
- Models generate training data for ML applications.
- Pan-Australia models provide an ideal testbed for model developments, such as ML-based parameterisations.
  - Diverse climate zones (tropics – midlatitudes, arid)
  - Frequent and varied convective events (TCs, severe thunderstorms, monsoonal systems, cold air outbreaks, extratropical cyclones)
  - Wide range of weather hazards
  - Observational data
- Exploit national convective scale ensembles to better understand cause of model errors.





Figures: Shaun Cooper

Towards a Weather Extremes Regional Digital Earth

Convective-scale modelling for the past, present and future conditions, including 1-2 day forecasts to support decision making and rapid response

- New national convective scale ACCESS models for reanalysis, weather and climate prediction.
- Development is needed to improve model biases for more accurate and reliable forecasts.
- Demonstrate impact of adding ocean-wave coupling to ACCESS weather model.
- Potential on-demand 300m ensemble system for sub-km scale extreme weather impact assessments.
- Adapting the NextGen model to run efficiently, need for better observation integration and uncertainty quantification using machine learning.

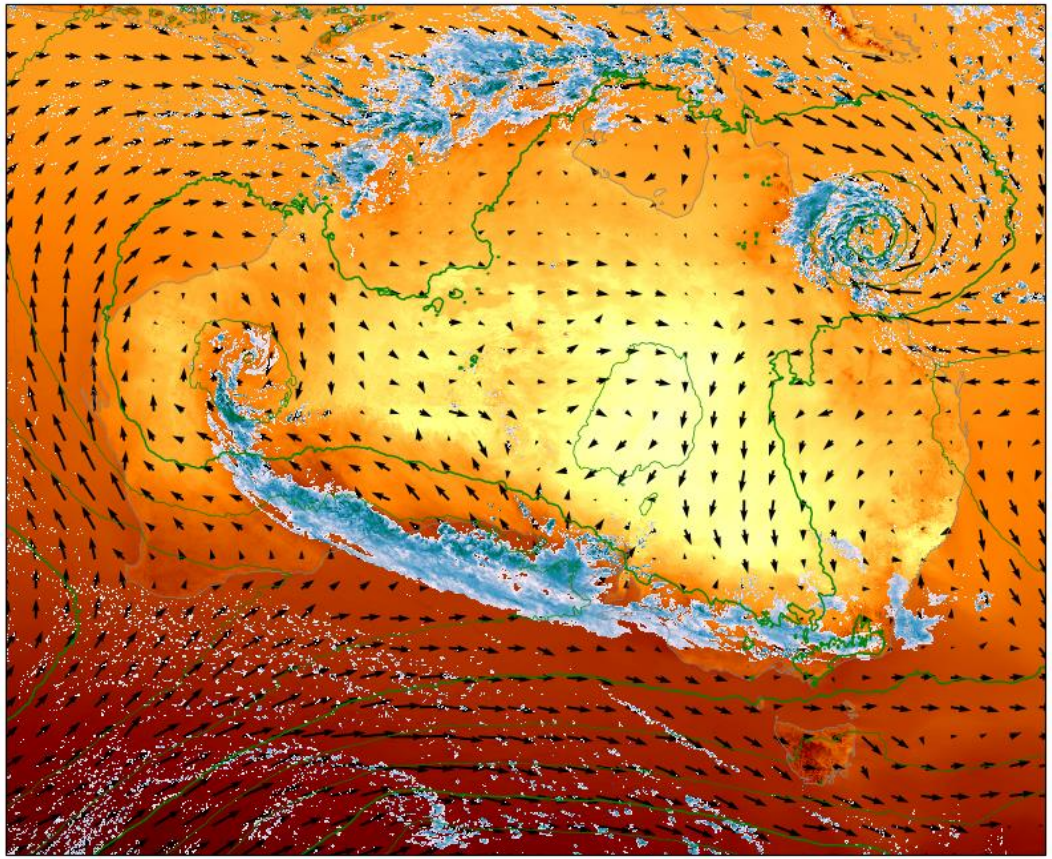


Figure: Susan Rennie

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Thank you

Charmaine Franklin