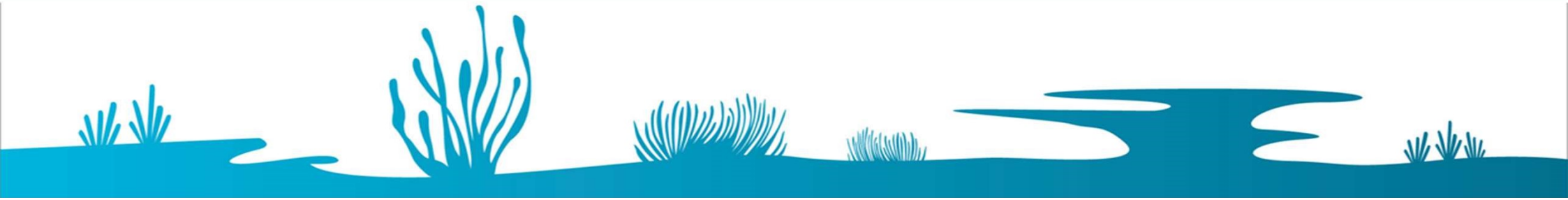
Climate and Oceans Support
Program in the Pacific

ACCESS-S Workshop

MODULE: ACCESS-S Model Design



Topics in this module

- ACCESS-S model implementation
- Dynamical seasonal prediction
- Data assimilation
- Ensemble generation
- Forecasts and hindcasts
- Model skill

Expected learning outcomes

- Basic understanding of how the ACCESS-S model works, including inputs
- Understanding of how forecasts and hindcasts are calculated in ACCESS-S
- Understanding of model skill calculations

These outcomes are important for understanding and interpreting ACCESS-S outputs and products, particularly model skill

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ACCESS-S versions

ACCESSS-S Version 1

- UKMO initial conditions and local ensemble generation
- Model run daily (99 ensembles per day)
- Lead time 6 months
- Hindcast period to 23 years (11 ensembles per start time)

ACCESS–S Version 2 (operational late 2021):

- Bureau data assimilation and ensemble generation
- Increase hindcast period 37 years
- Lead time:
  - Multi-week: 6-weeks
  - Seasonal: 9 months
  - Multi-year: 5-years (investigate potential for forecasts on this timescale)

Comparing ACCESS-S to POAMA-2

	POAMA-2	ACCESS-S
Atmospheric model	Bureau Atmospheric Model (BAM) ~10 years old	Latest UKMO atmospheric model (GC2)
Atmospheric resolution	Horizontal: 250 km (T47) Vertical: 17 levels (does not extend into the stratosphere)	Horizontal: ~60 km in the midlatitudes (N216) Vertical: 85 levels (extending into the stratosphere)
Land surface model	Simple bucket model for soil moisture and 3-layers for soil temperature.	State-of-the-art land surface model (Joint UK Land Environment Simulator; JULES) with 4 soil levels.
Ocean model	Modular Ocean Model (MOM version 2, about 13 years old).	Latest European ocean model (Nucleus for European Modelling of the Ocean; NEMO) which is part of the UKMO coupled model GC2.
Ocean resolution	Horizontal: ~200 km x 100 km Vertical: 25 levels, with thicknesses ranging from 5 m near the surface to almost 1000 m near the bottom	Horizontal: 25 km Vertical: 75 levels, with thicknesses ranging from 1 m near the surface to about 200 m near the bottom (6000 m depth)
Sea ice model	No sea ice model (climatological sea ice is prescribed).	Latest sea ice model developed by the USA and UK (Los Alamos sea ice model; CICE) which is part of the UKMO coupled model GC2.
Model Physics	>10 years old	Latest from UKMO and collaborators

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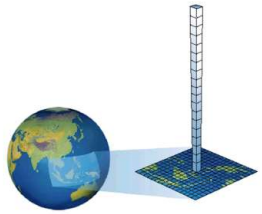
The ACCESS-S1 Coupled Model

A collaboration with the UKMO
(Unified Model Partnership)



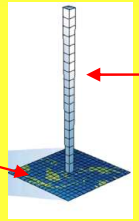
$$d\overline{\mathbf{v}}/dt + fk \times \overline{\mathbf{v}} + \nabla\overline{\phi} = \mathbf{F},$$
$$d\overline{T}/dt - \kappa\overline{T}\omega/p = Q/c_p,$$
$$\nabla \cdot \overline{\mathbf{v}} + \partial\overline{\omega}/\partial p = 0,$$
$$\partial\overline{\phi}/\partial p + R\overline{T}/p = 0,$$
$$d\overline{q}/dt = S_q.$$

ACCESS-S version 1:

- UKMO GC2 (Global coupled model configuration 2)
- Same model used currently by UKMO for seasonal prediction (GloSea5-GC2)

Atmospheric model:

Horizontal resolution:
~60 km in Australian latitudes
(N216: 0.8deg lat X 0.5deg lon)



Vertical resolution: 85 levels

Land Surface Model:

JULES (Joint UK Land Environment Simulator)
Horizontal resolution same as atmosphere
4 soil levels
Land cover heterogeneity

Models are coupled every 3 hours using the Ocean Atmosphere Sea Ice Soil coupler (OASIS)

Sea-Ice Model:

CICE (Los Alamos sea ice model)
Horizontal resolution same as ocean

Ocean model:

NEMO3.4 (Nucleus for European Modelling of the Ocean)
Horizontal resolution: 0.25°
Vertical resolution: 75 levels.
Level thicknesses range from 1 m near the surface to about 200 m near the bottom (6000 m depth).

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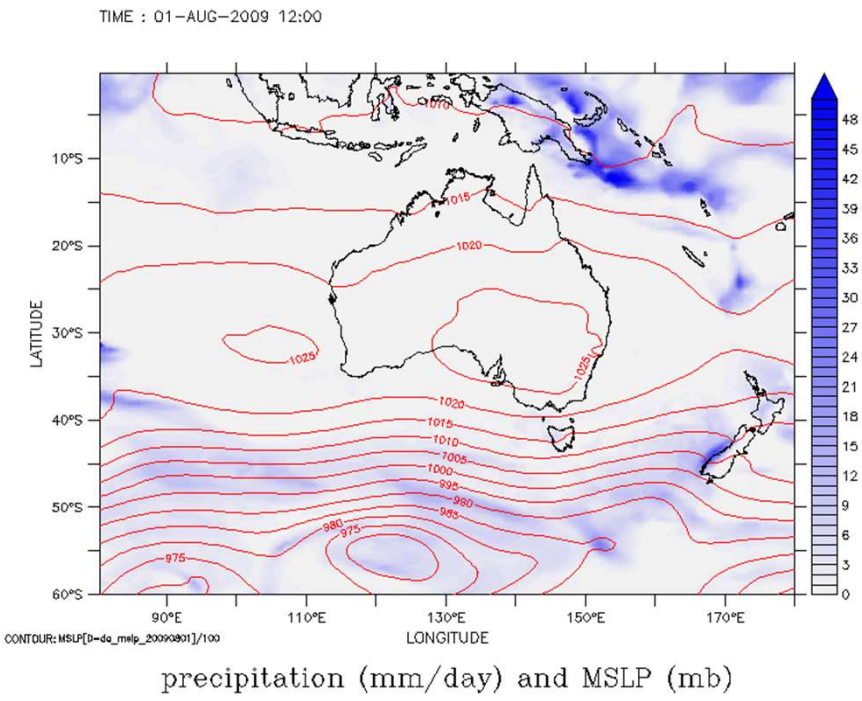
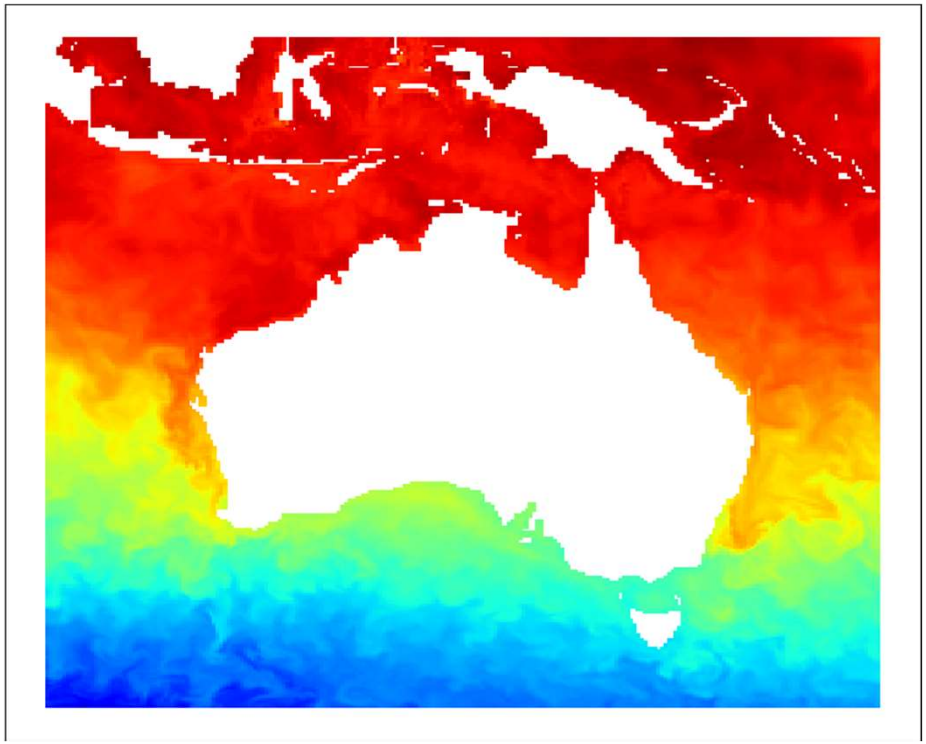
The ACCESS-S1 Coupled Model: Atmosphere and Oceans

Snapshot over the Australian region from a single ACCESS-S forecast (but it is a global model)



precipitation (mm/day) and MSLP (mb)



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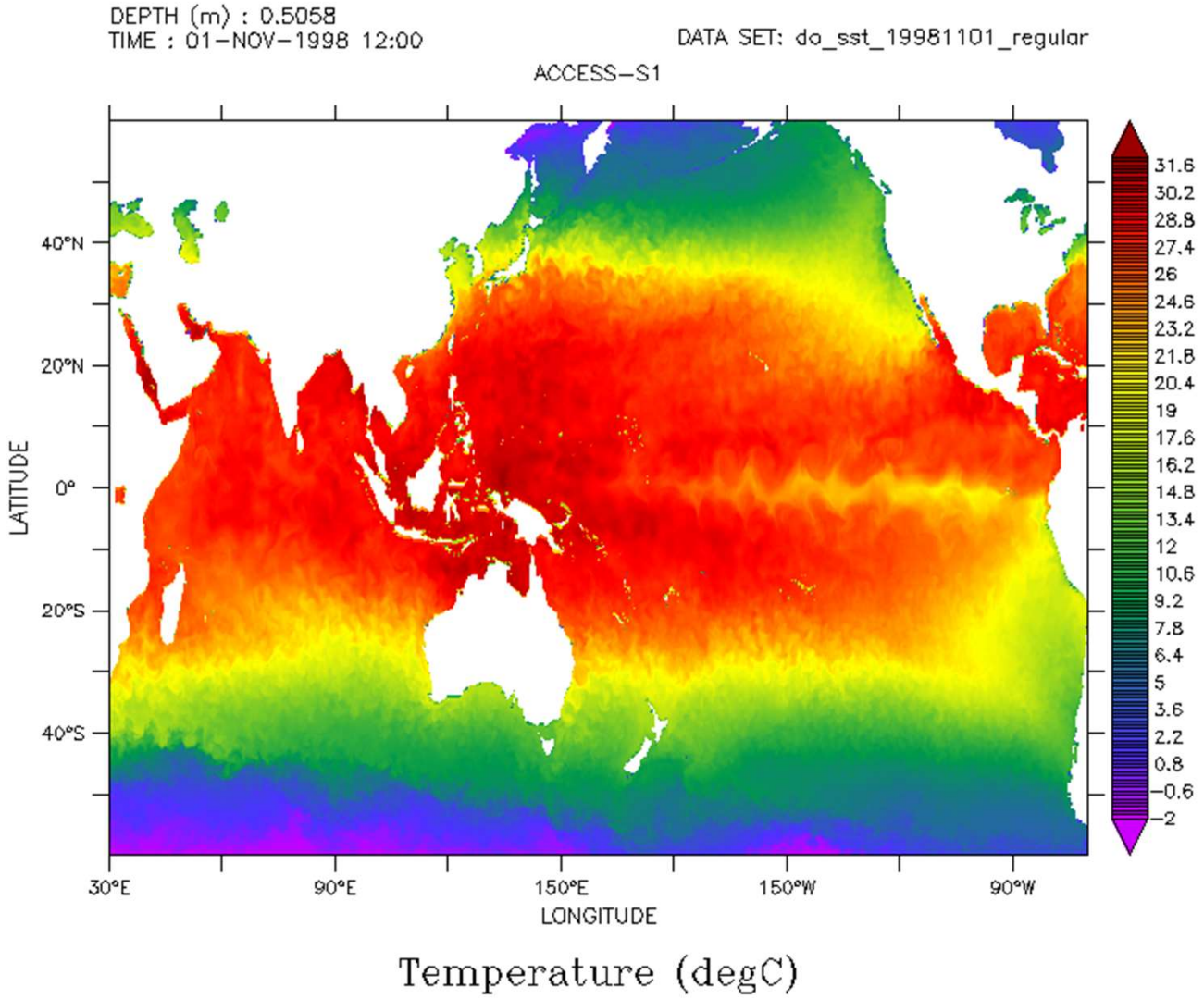

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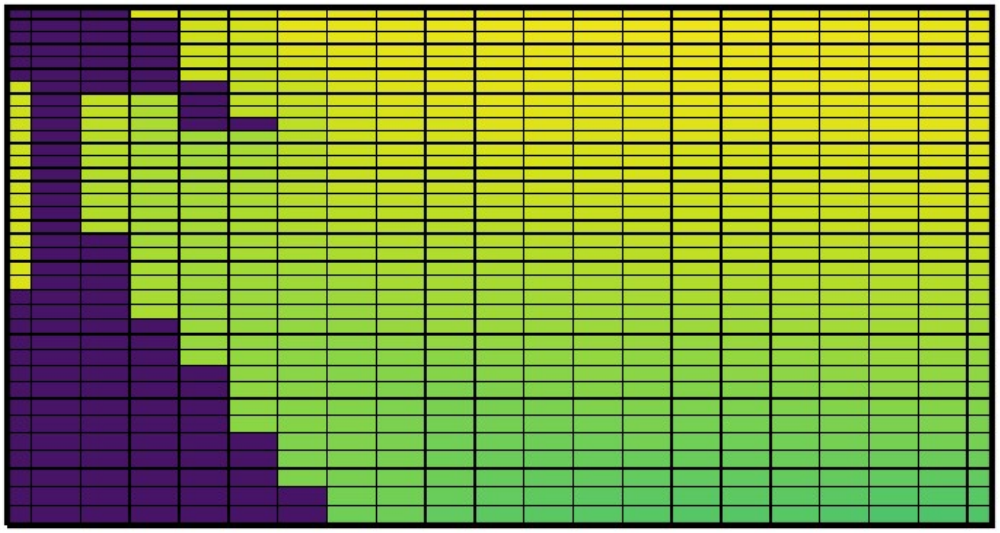
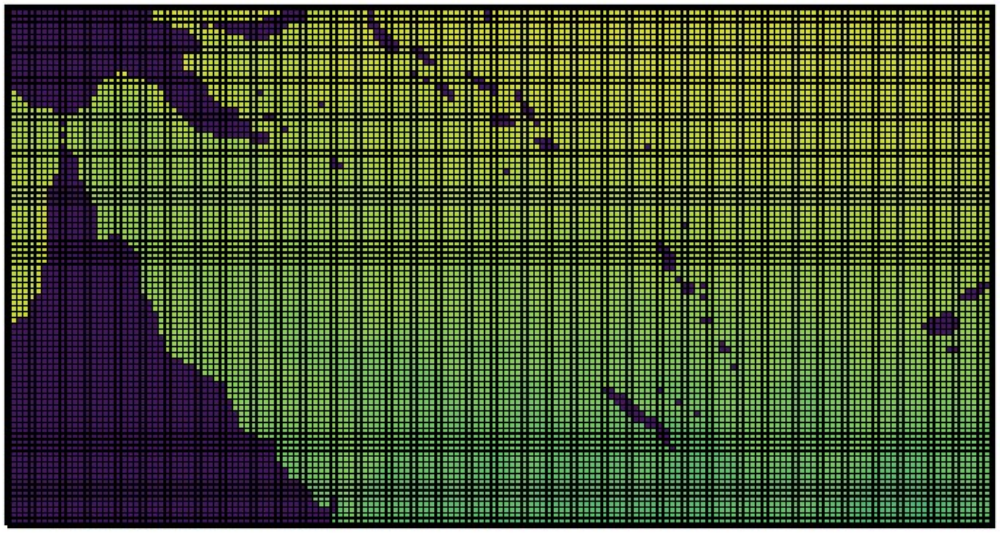
Ocean Resolution in the SW Pacific

ACCESS-S



POAMA



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Phase 1, 2019 – 2022

- Model build, Supercomputer implementation DONE
- Production of hindcasts NOW
- Verification and calibration NOW
- Introduction of ACCESS-S outlooks into service DONE
- Outlooks issued more frequently (twice a month) DONE

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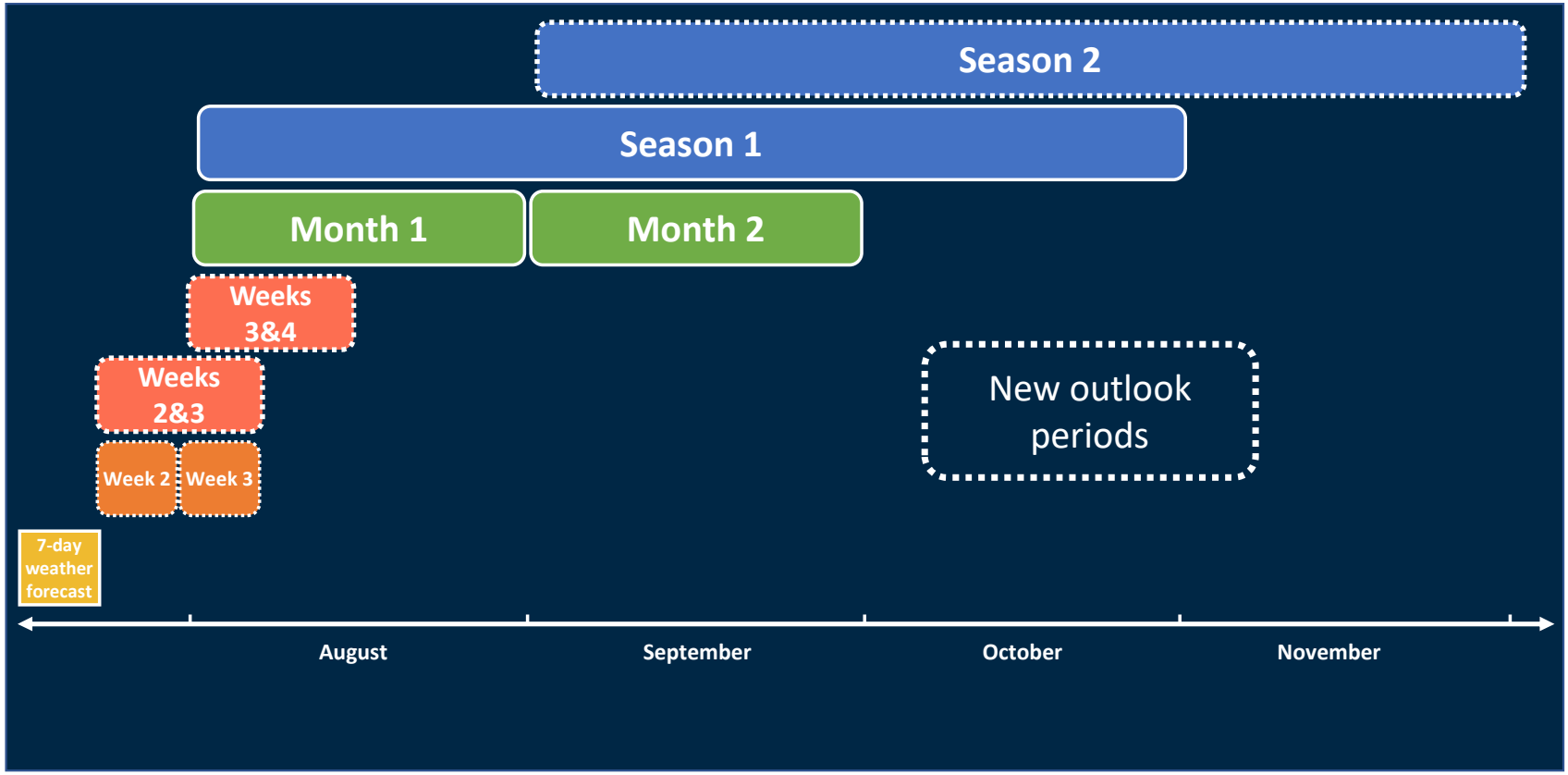
The new Outlook periods



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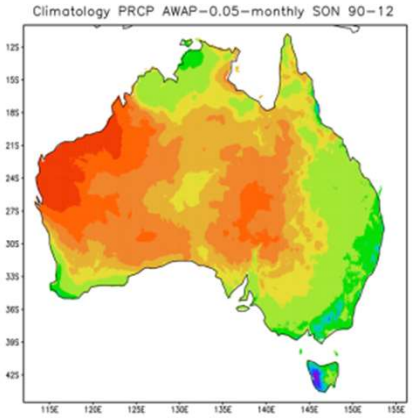
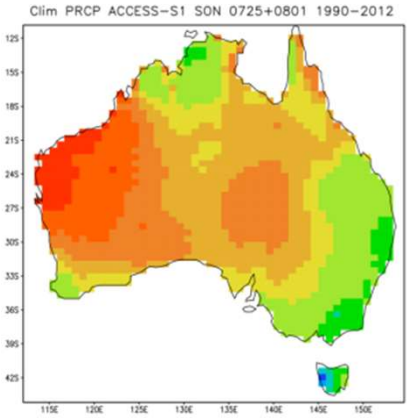
More realistic climate

Example: Mean rainfall (mm/day) for spring (SON)

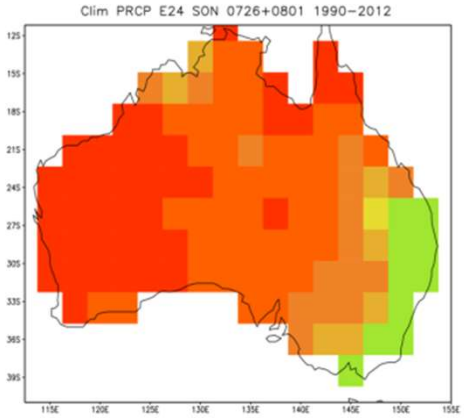
Observations



ACCESS-S1



POAMA



Australian climate better represented

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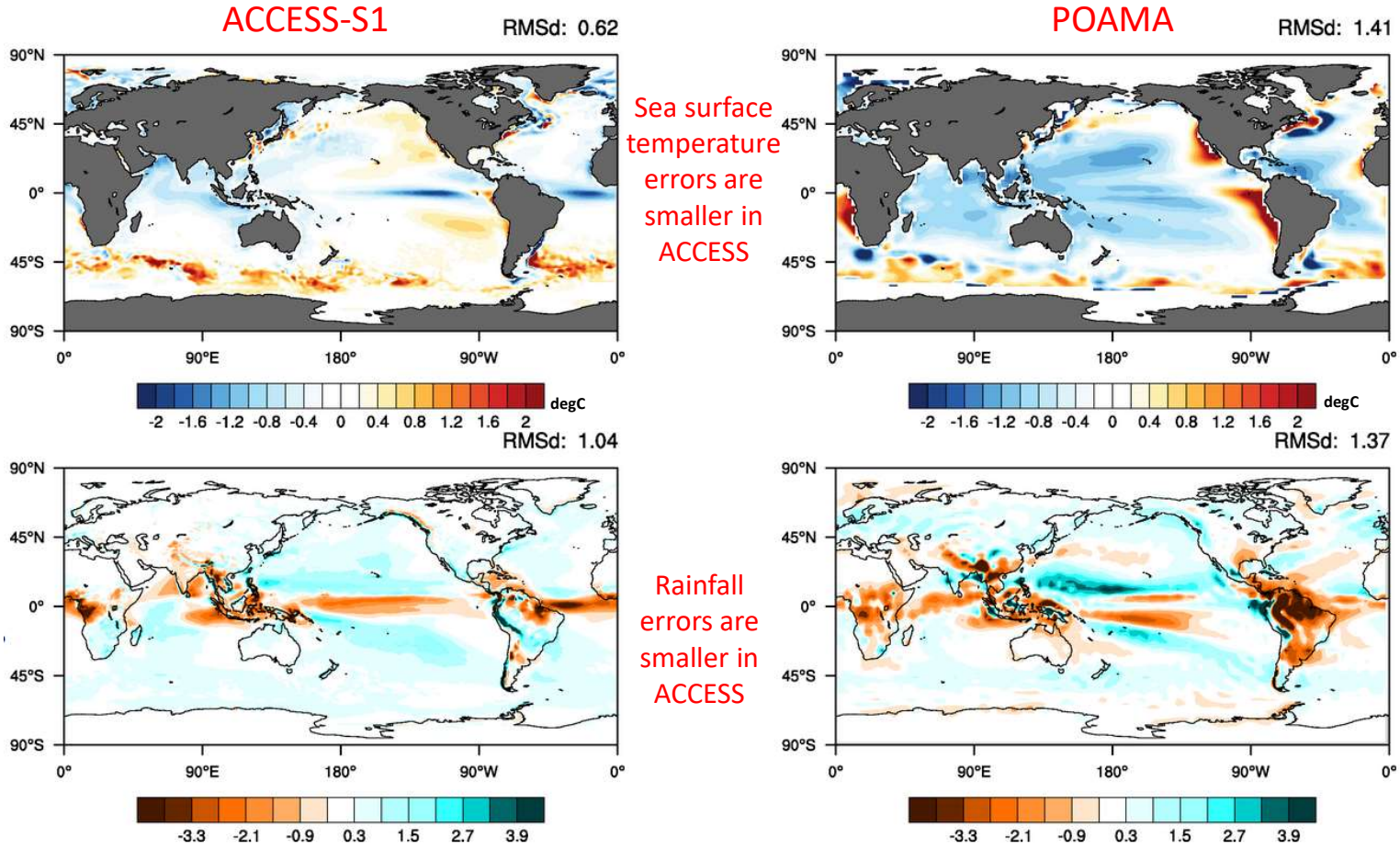
ACCESS-S produces a more realistic climate

3-month mean bias in climatology (all seasons, 1-month lead)



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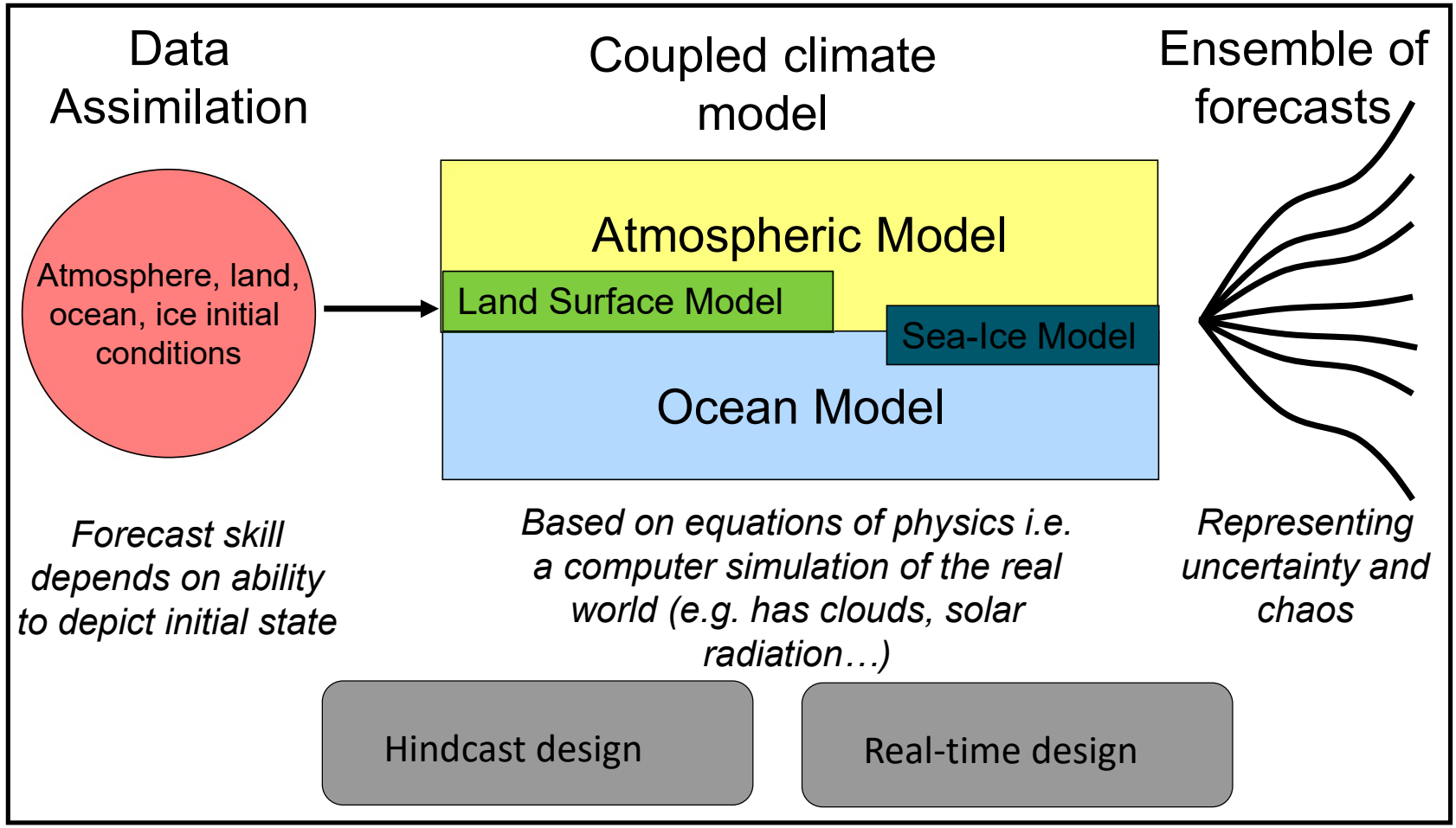
Dynamical Seasonal Prediction System



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ACCESS-S compared to POAMA summary

- ACCESS-S is higher resolution and more accurate compared to previous models
- Currently running ACCESS-S1 but will eventually move to ACCESS-S2
- New outlook periods include:
  - Weeks 2, 3, 2-3, 3-4, season 2
- ACCESS-S features an atmospheric model, a land surface model, an ocean model and a sea ice model

Discussion question

- How would you use the new outlook periods available in ACCESS-S?

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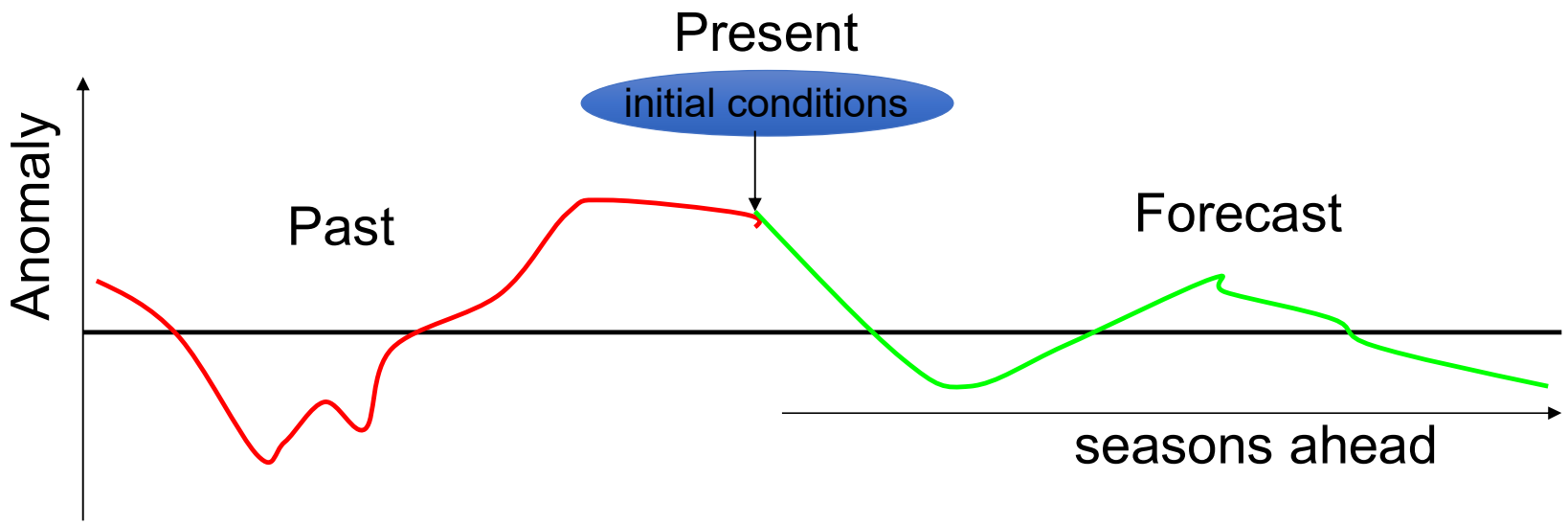
Data Assimilation - introduction



- Initial state is complete 3D description of atmosphere/land/ocean/ice on model grid
- Coupled model evolves initial state forward in time
- Forecast depends on **initial state** - e.g. why this year different from next
- Forecast depends on ability of present state to influence the future
- Forecast skill depends on ability to depict initial state

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Data Assimilation

- Estimating the 3D state of the system is critical at the start of the forecast. These include:
  - Ocean (most important for seasonal)
  - Land surface
  - Ice
  - Atmosphere (we rely on NWP)

- **Observations** are critical for data assimilation

- There are several data **assimilation techniques** that combine sparse data and models (e.g. Ensemble Kalman Filter)

- Data assimilation is becoming more complex than coupled models

- Need data assimilation for the hindcasts (as well as real-time forecasts)

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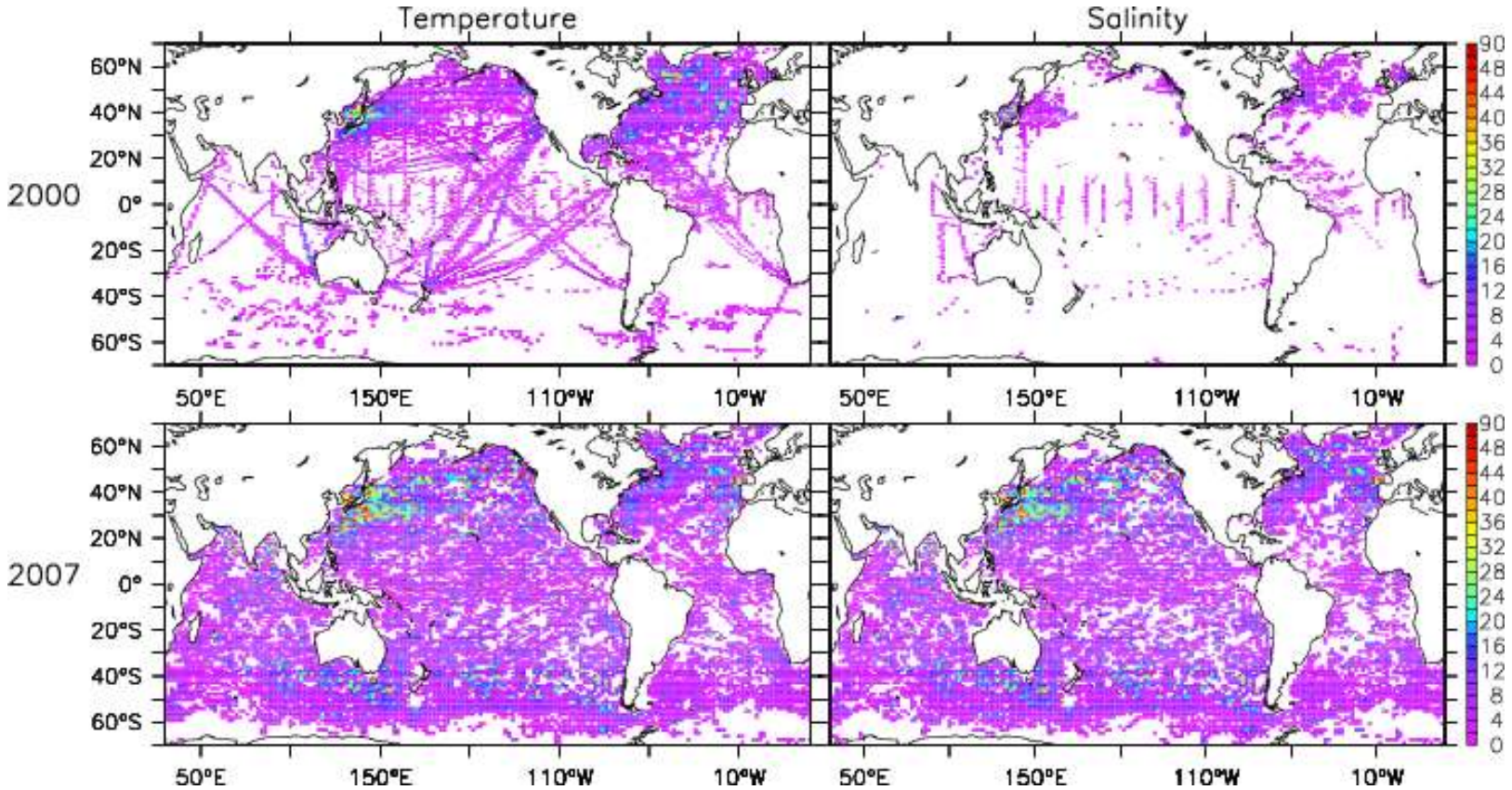
Increase in ocean observations



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Data assimilation in ACCESS-S1

Data Assimilation

Atmosphere, land, ocean, ice initial conditions

Forecast skill depends on ability to depict initial state

	Hindcast (1991-2012)	Real-time
Atmosphere	ERA-Interim	ACCESS-G analysis
Ocean	Met Office Forecast Ocean Assimilation Model (FOAM) which uses the NEMO 3-dimensional variational ocean data assimilation (NEMOVAR)	Met Office Forecast Ocean Assimilation Model (FOAM) which uses the NEMO 3-dimensional variational ocean data assimilation (NEMOVAR)
Land	Climatological soil moisture Time varying soil temperature	Climatological soil moisture Time varying soil temperature
Sea-ice	UKMO sea-ice assimilation	UKMO sea-ice assimilation

This will all change for ACCESS-S2: will be generated by BoM using assimilation techniques developed with POAMA

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Ensemble generation in ACCESS-S1

Creating an ensemble using initial condition uncertainty

BoM perturbation scheme: perturb the initial conditions of the atmosphere for a given forecast start – burst ensemble

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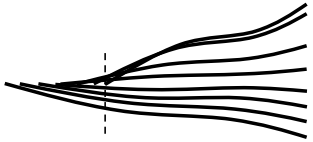
Lagged initial conditions (use past days of the burst ensemble to make an even bigger ensemble)



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Perturbations to u, v, T, q, p

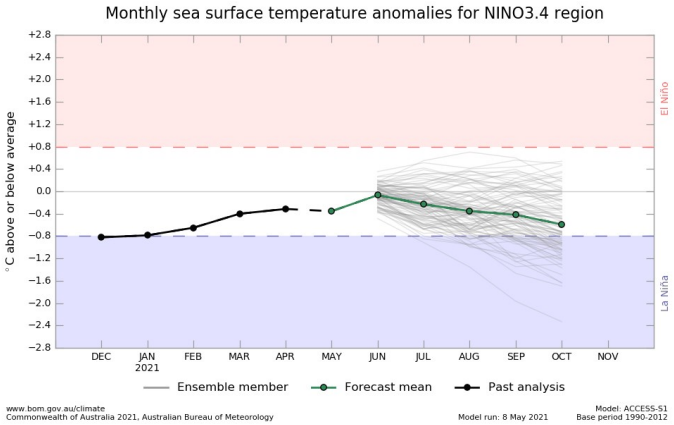
Patterns of the perturbations come from 7-day difference patterns

Perturbations are scaled to have a magnitude equal to analysis uncertainty (ERA-Interim vs NCEP-NCAR reanalyses)

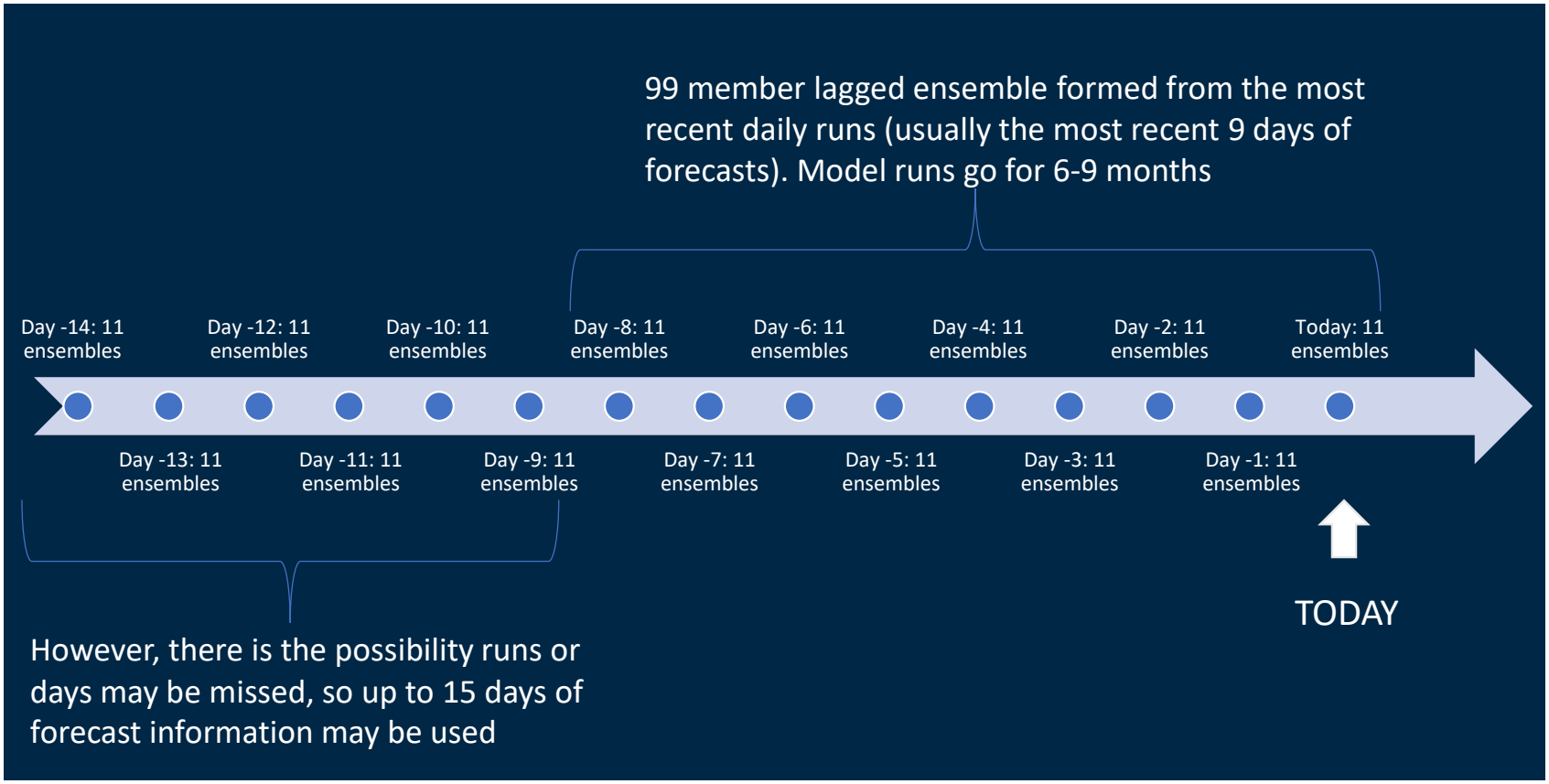
Ensemble of forecasts

Representing uncertainty and chaos

Example ensemble forecast

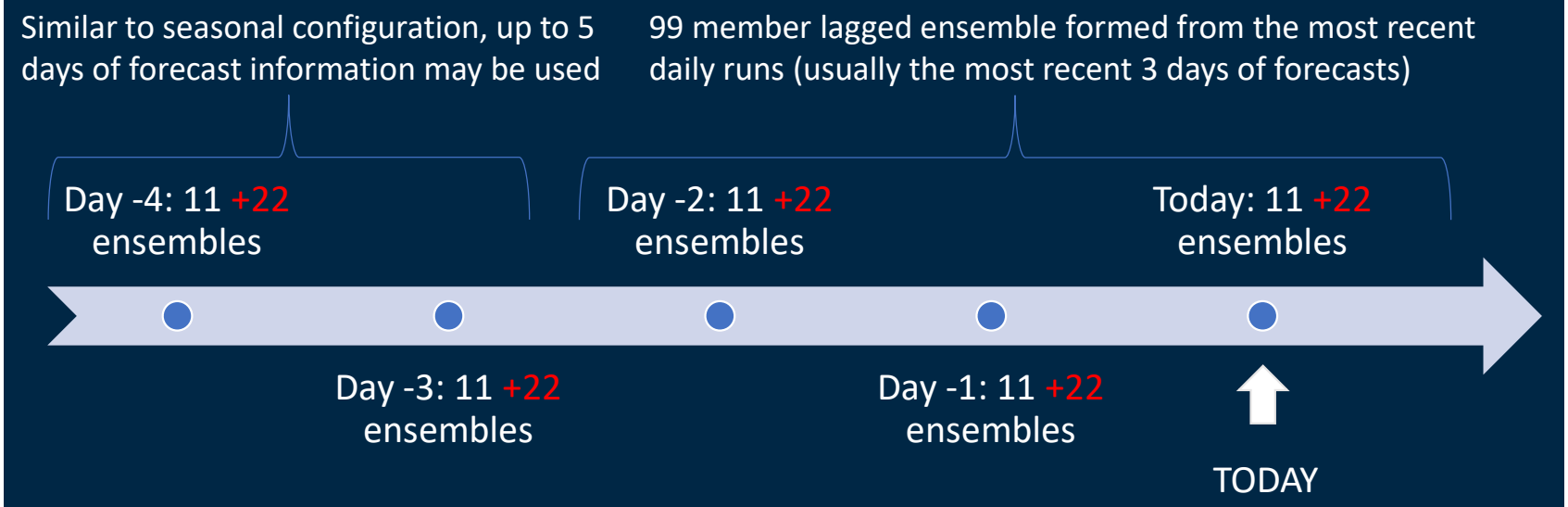


Monthly and seasonal forecasts: ensemble generation



Weekly and fortnightly forecasts: ensemble generation

- Better accuracy closer to the forecast start date.
- Therefore, in addition to the 11 ensembles run per day, another 22 ensembles are run out to 6 weeks.
- This means a 99 member fortnightly forecast can be made from 3 days of forecasts.



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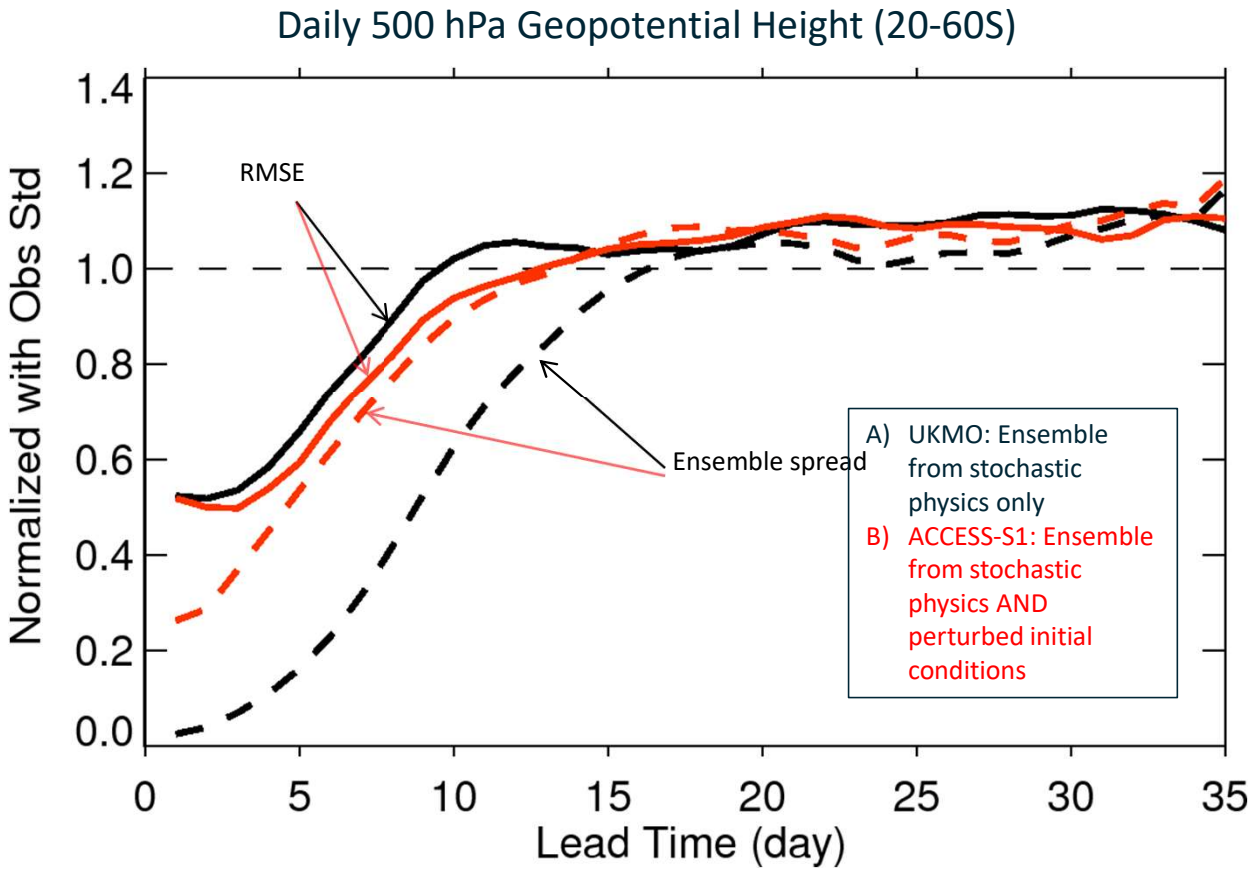
Ensemble generation in ACCESS-S1



1 May start, 5-member ensemble

Underdispersed (overconfident)

$Spread_{ens}$ < RMSE

Consistent/reliable

$Spread_{ens}$ ≈ RMSE

Data assimilation and ensemble generation summary

- Models are sensitive to the initial conditions, and require a complete model grid of observations at the beginning of each model run.
- The model grid of observations is created using Data assimilation, a process that can be as complex as climate models themselves.
- ACCESS-S runs 11 slightly different model runs each day, creating an ensemble
- Each ACCESS-S outlook has a 99 member ensemble
- The accuracy of models improves closer to the model start date

Discussion questions

- Name an example of an observation that would be used for data assimilation