Module 5: ACCESS-S

Model Background and S2 Version Updates

Climate and Oceans Support Program in the Pacific
COSPPac

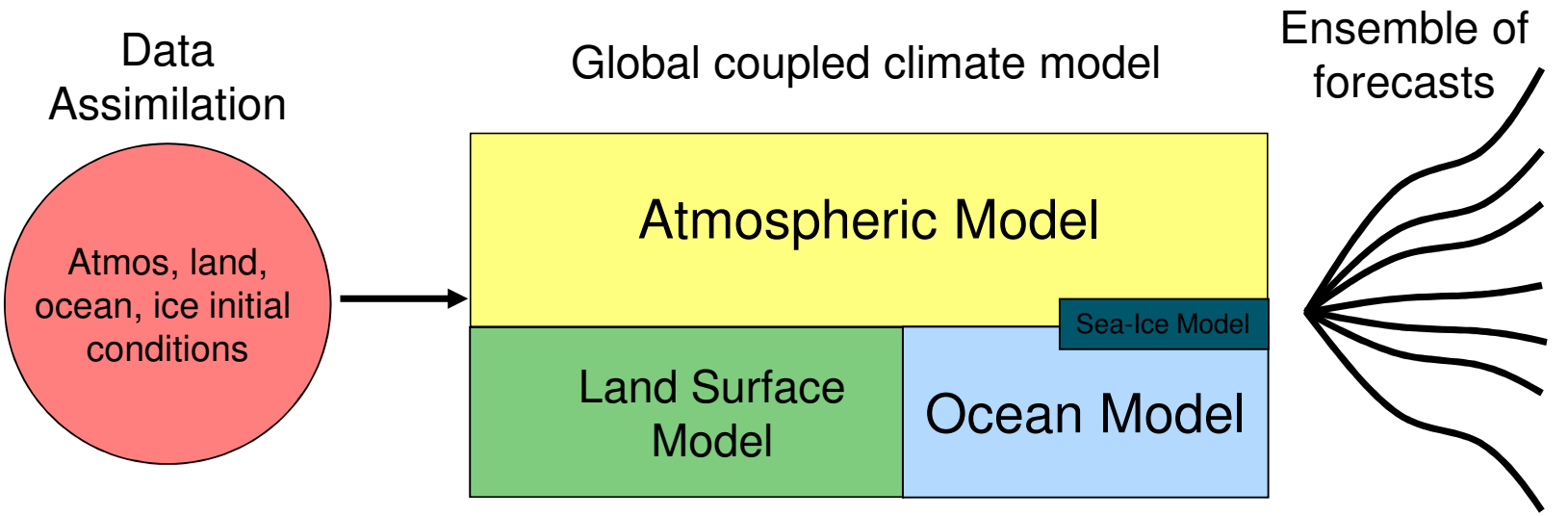
Australian Government
Department of Foreign Affairs and Trade
Bureau of Meteorology

ACCESS-S

- Australian Community Climate Earth-System Simulator – Seasonal (ACCESS-S).
- It is a state-of-the-art dynamical (physics-based) forecast modelling system, which uses ocean, atmosphere, ice and land observations to initiate outlooks.
- Provides climate and ocean outlooks past the weather prediction window for the weeks/fortnights/months/seasons ahead.
- The ACCESS-S climate model is a collaboration between the Bureau of Meteorology and the UK Meteorological Office (UKMO).

ACCESS-S: seasonal forecast system

Not just a model……



Hindcast set design

Real-time design

Reanalysis (provides initial conditions for the hindcasts)

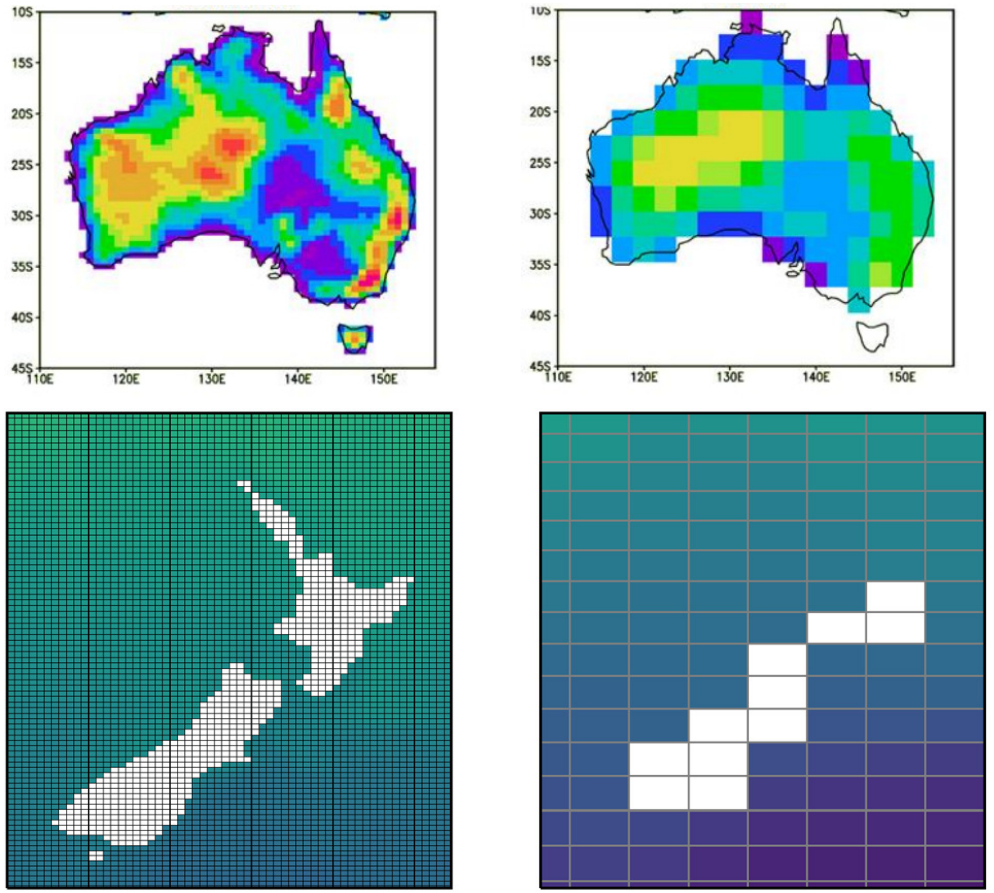
Hindcasts

Post-processing and forecast product generation

ACCESS-S: Seasonal Model Upgrade

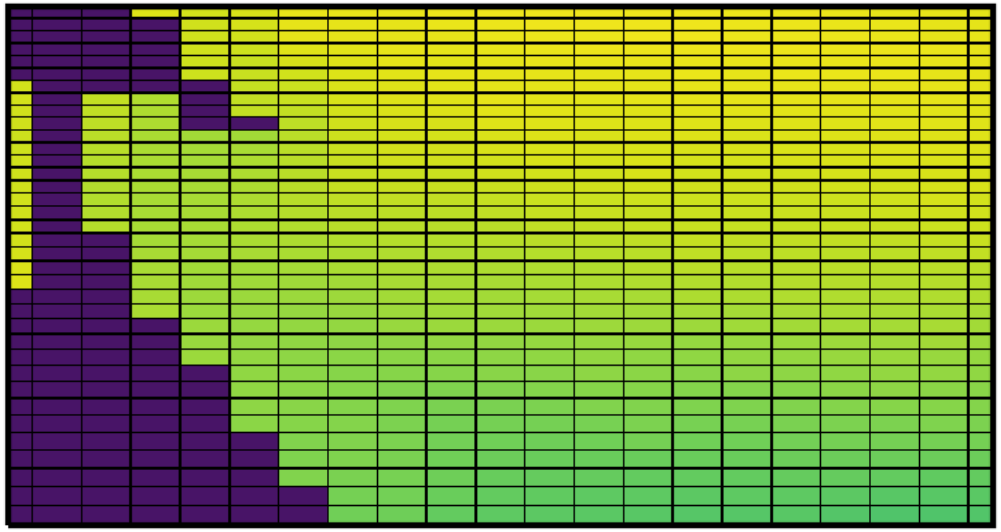
- Higher resolution
- New fortnightly outlooks (filling gap between 7-day weather forecast and monthly and seasonal outlooks)
- Model is run daily
- Project Phases:
  - ACCESS-S1 (decommissioned 2021)
  - ACCESS-S2 (currently operational)

ACCESS-S **POAMA**

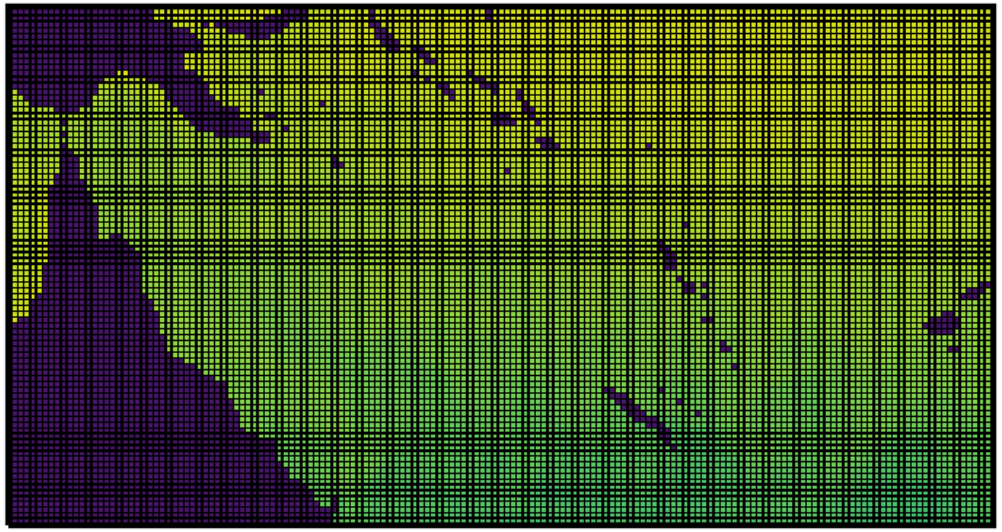


Ocean Resolution in the SW Pacific

POAMA

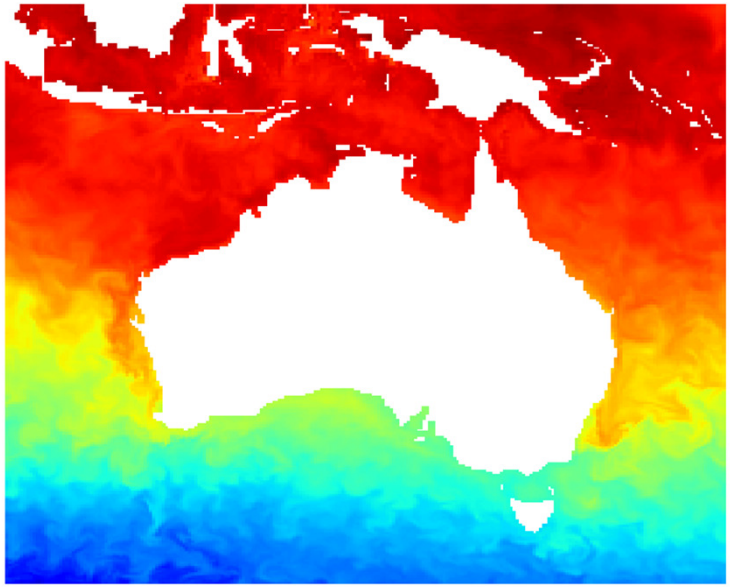


ACCESS-S

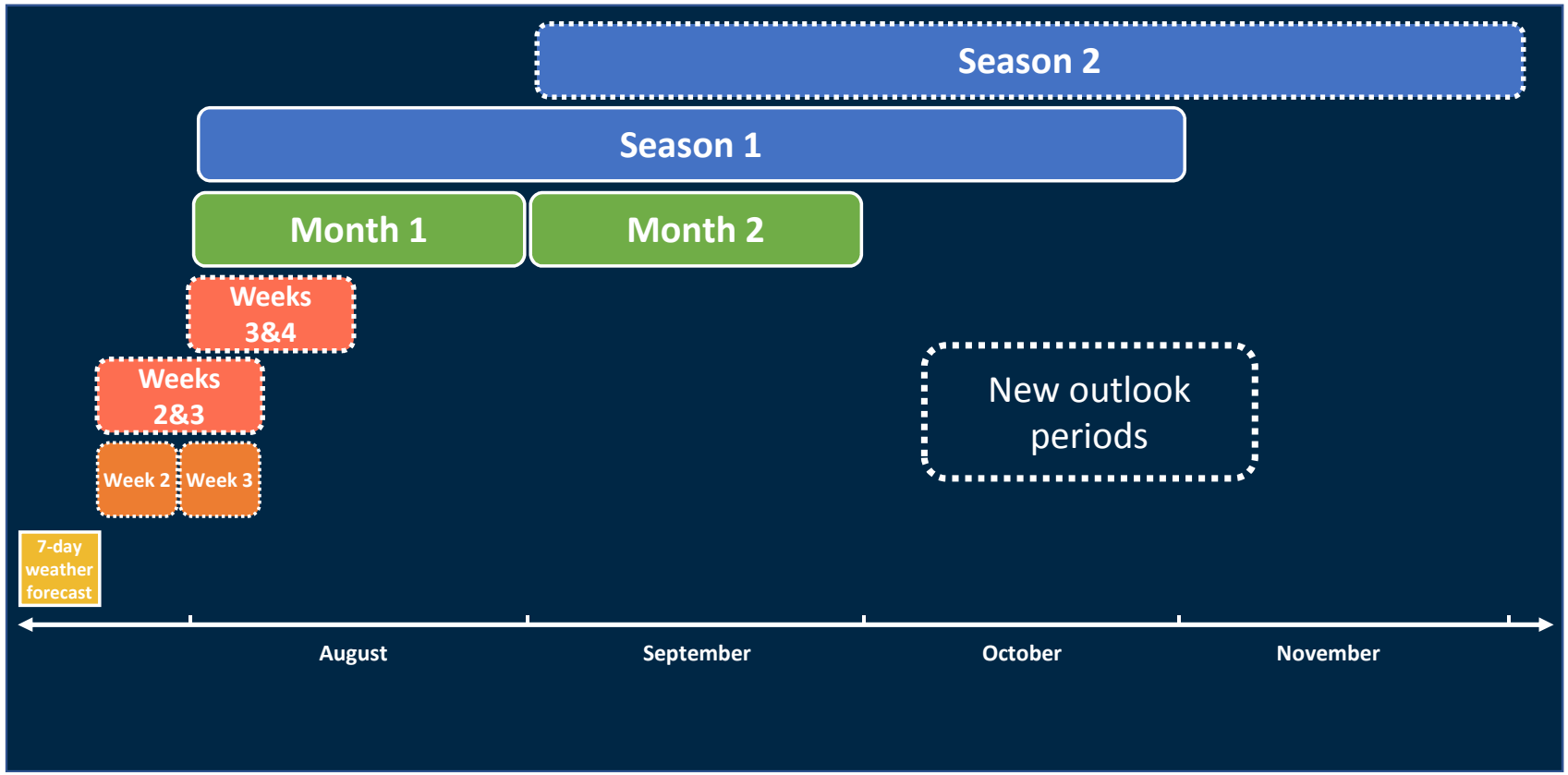


ACCESS-S vs POAMA

	ACCESS-S	POAMA-2
Atmospheric model	Latest UKMO atmospheric model (GC2)	Bureau BAM (~10 years old)
Atmospheric resolution	Horizontal: **60 km** mid latitudes (N216) Vertical: **85 levels**	Horizontal: 250 km (T47) Vertical: 17 levels
Ocean model	Latest European ocean model NEMO	MOM version 2 (~13 years old)
Ocean resolution	Horizontal: **25 km (eddy permitting)** Vertical: **75 levels (1-200 m)**	Horizontal: ~200 km x 100 km Vertical: 25 levels (15-1000m)
Land surface model	State-of-the-art land surface model JULES	Simple bucket model
Realtime system	**99 ensembles** (11 ens x 9 days) **Runs daily** out to 6 months	33 ensembles Runs twice weekly out to 9 months



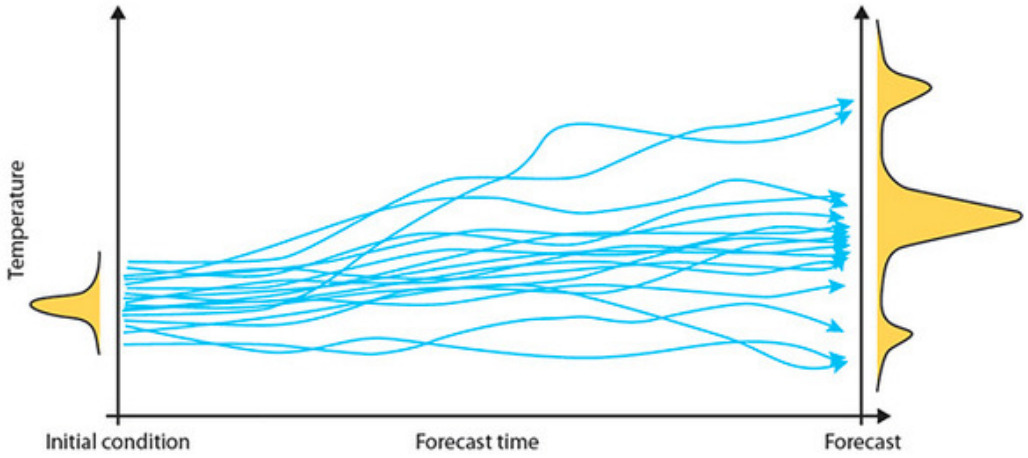
The new Outlook periods



ACCESS-S Forecast design

Larger ensembles than used by UKMO

Forecast design



Every day the following are created:

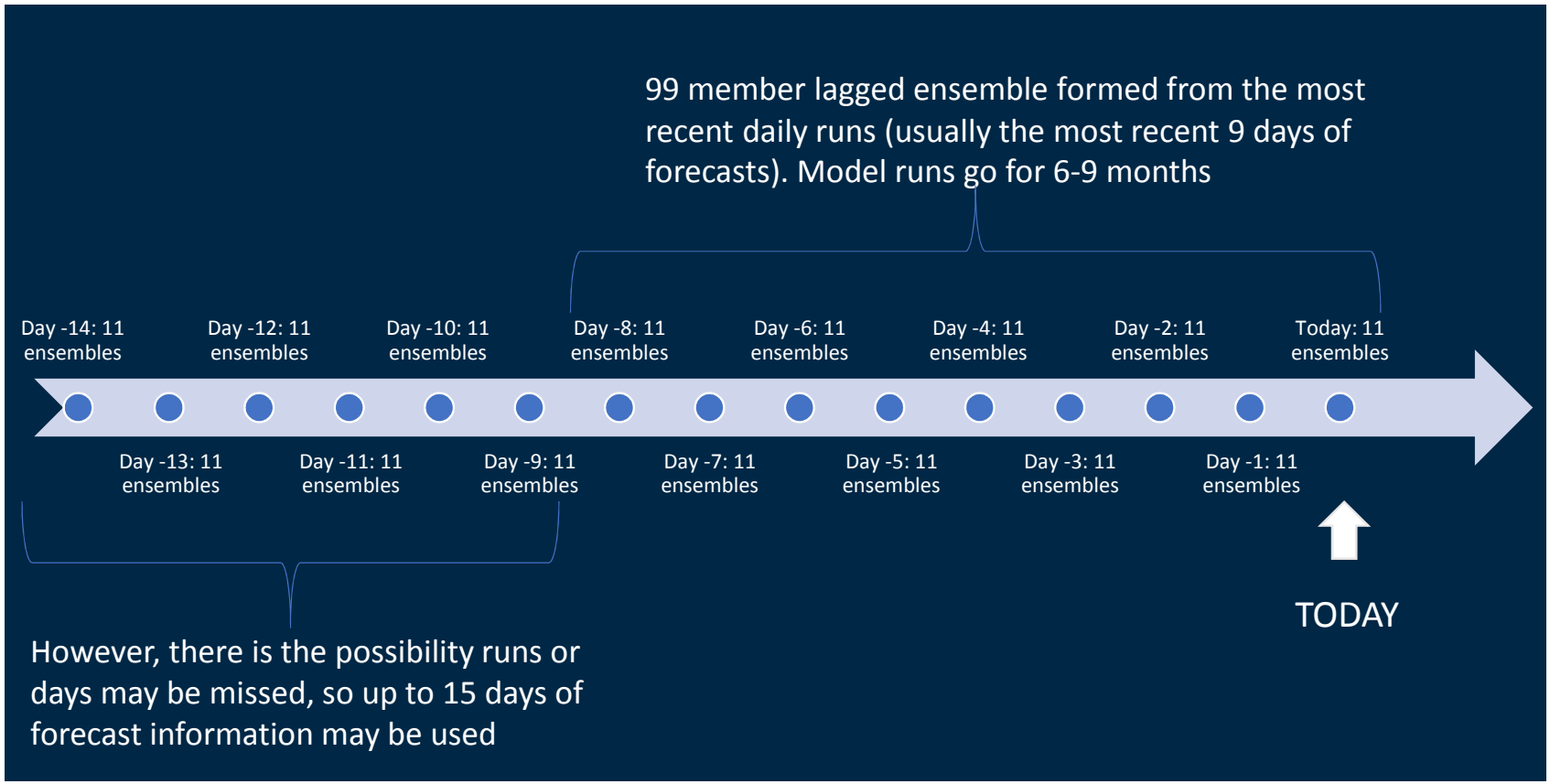
- **11**-members run out for 6 months (210 days)
- **22**-members run out for 6 weeks (*To provide better skill in the subseasonal)*

- Primarily three factors that limit the skill of seasonal forecasts:

- coupled model error
- error in the estimate of the initial state
- the unpredictable nature of atmospheric synoptic variability

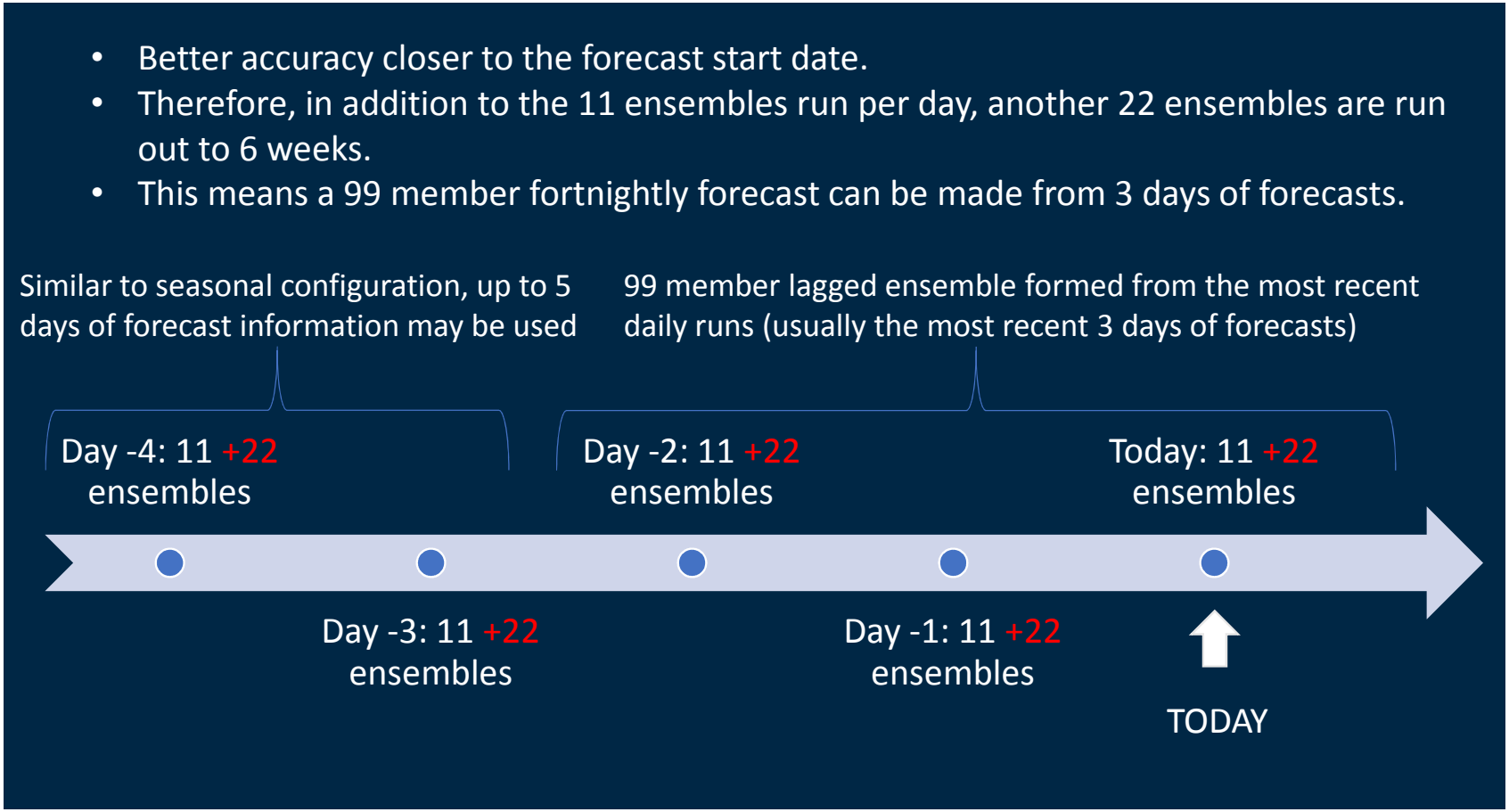
- By running many ensembles we sample the effect of these uncertainties in a seasonal forecast system
- Perturb the initial conditions in agreement with the known statistics of error sources.
- The spread of the ensemble should then provide some measure of the level of uncertainty attached to the forecast.

Monthly and seasonal forecasts: ensemble generation



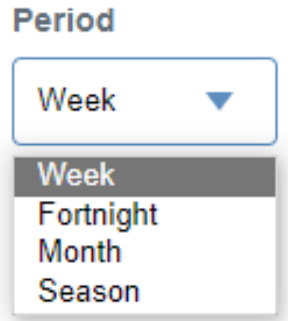
Weekly and fortnightly forecasts: ensemble generation

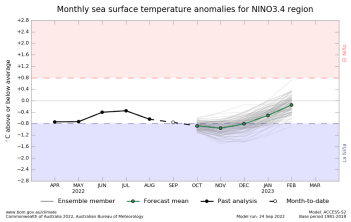
- Better accuracy closer to the forecast start date.
- Therefore, in addition to the 11 ensembles run per day, another 22 ensembles are run out to 6 weeks.
- This means a 99 member fortnightly forecast can be made from 3 days of forecasts.



Post-processing

- As part of the ACCESS-S suite (both S1 and S2) there is a post processing pipeline that post-processes the real-time forecasts. For example, this post processing suite:
  - Creates a standard set of bias corrected global fields (anomalies)
  - Combines the lagged daily forecasts into 99-member ensembles to make it much easier for end users
  - Creates weekly/monthly/seasonal averages from the daily data
  - Creates spatial averages (e.g., for Niño indices)
  - Does the calculations required to support operational products e.g., produces the probabilities of above-median





ACCESS-S1

ACCESS-S1

- Fast track high resolution UKMO GC2 model
- Using UKMO initial conditions (NEMOVAR) + BoM ensemble generation (for multi-week)
- 23-year hindcast period (1990-2012)
- Real-time products based on time-lagged 99-member ensemble
- Went operational mid 2018
- Issues:
  - Improvement not as good as we expected
  - Climatological soil moisture initialisation
  - Ocean initialisation shock?
  - Ozone bug
  - Only 23 year hindcasts, only 11 member ensembles (for hindcast)
  - Operationally dependent on UKMO initial conditions (will break when UKMO upgrade their system)
  - Hindcasts not sufficient for applications (skill, calibration, extremes, etc)

ACCESS-S2 summary

ACCESS-S2

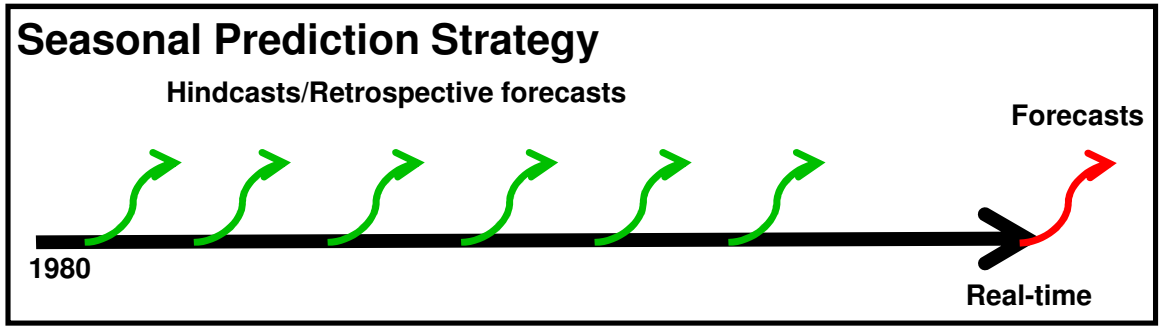
- Operational October 2021
- Break dependency on UKMO Initial conditions by using the Bureau's own
- Same GC2 model (UKMO GC3 showed no improvements) but tweaks/corrections (e.g. inland lakes, ozone error, coupling frequency)
- BoM weakly-coupled assimilation (better ocean and land initialisation)
- More hindcasts: 38 year (1981-2018), 27 member ensemble hindcasts to support applications
- More timely forecasts in real-time (less of a delay) – especially for multi-week
- Same number of real-time forecasts as S1 (i.e., products based on 99-member time lagged ensemble)

Hudson et al. 2017; JSHESS (ACCESS-S1)
Wedd et al.; JSHESS; Submitted (ACCESS-S2)

What is a hindcast and why do we need it

A hindcast is a retrospective forecast or historical re-forecast

- Model skill (run the model lots of times to find how well it performs)
- Model climatology (e.g. calculate anomalies)



How is a hindcast generated

- Choose date in past and only use observations available then to estimate state

- Use model to project forward in time

- Repeat for many dates (e.g. multiple forecasts over a 30-year period). Important for climate so that we have a good sample size of infrequent climate features such as ENSO.

Do ACCESS-S1 and S2 use the same model?

Are the physics packages the same?

Mostly Yes. The coupled model in ACCESS-S1 is the same as in ACCESS-S2. However, minor changes were made to address known issues. These were:

- **Coupling frequency** between the ocean-atmosphere was increased (from 3-hourly to 1-hourly) as research found that this improved shallow layers in the Pacific
- Representation of drainage of rivers into **inland lakes** was changed as the S1 suffered from significant inland bullseyes that led to poor quality products for our customers and were difficult to explain to customers
- The **representation of ozone** was changed following a bug found in the Met Office GC2 core code (Note this bug is present in ACCESS-S1 operational system).

Are the initial conditions different between S1 and S2?

Yes, they are completely different.
In S2, they are generated by our in-house data assimilation system

ACCESS-S1 uses:	ACCESS-S2 uses:
UKMO ocean initial conditions UKMO sea-ice initial conditions ACCESS-G atmosphere and land temperature initial conditions Climatological soil moisture initialisation	The Bureau's weakly coupled ensemble optimum interpolation data assimilation (DA) scheme. This system produces initial conditions for the ocean, atmosphere, sea-ice and land surface (including realistic time-varying soil moisture). The DA system ingests ACCESS-G fields, GAMSSA sea surface temperature and global ocean observations. Climatological sea ice

- Timelier real-time forecasts, especially relevant for multi-week forecasts
- Reduced dependence on UKMO ocean initial conditions
- Linked to improvements in forecast skill

Data assimilation, perturbations & forcing data

- BoM's weakly coupled ensemble optimum interpolation scheme
- This system produces initial conditions for the ocean, atmosphere, land surface, sea ice

- Only the atmosphere is perturbed to generate the ensemble (Hudson et al. 2017).

> 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)

- Climate forcings of greenhouse gases are set to observed values up to the year 2005 and to follow the IPCC Radiative Concentration Pathway 4.5 scenario post-2005. Other aerosols and ozone are set to the climatological values with a seasonal cycle

More details on ACCESS-S2 weakly-coupled assimilation

Basic fast track version of BoM/CSIRO Coupled EnKF software (Pavel Sakov)

- Weakly coupled daily cycle
- Direct replacement of atmos basic variables (from ERA-interim in hindcasts and ACCESS-G3 in real-time)
- Ensemble OI in ocean – using static ensemble (simpler than POAMA)
- Ocean assimilation uses the background state from the coupled model
- Land surface and sea ice indirect through coupling
- Stronger nudging of SST than UKMO
- SSS is weakly nudged to the climatological data at a two-year restoring time scale (seasonal cycle from World Ocean Atlas 2013). Only implemented where both model and observed SSS are larger than 10 psu
- No Altimeter (only T/S profiles)
- Multi-variate – ocean current increments
- 1981-present re-analyses
- Same adhoc perturbation scheme as in ACCESS-S1 (only the atmosphere is perturbed) for ensemble generation

	Reanalysis 1981-2018	**Real-Time Assimilation 2018-Onward**
Ocean Observations Source	EN4	GTS and GDACS
Atmosphere Initialisation	ERA-Interim	ACCESS-G3
SST nudging	Reynolds OISSTv2.1 (to Dec 2013) GAMSSA (2014-onwards)	GAMSSA
SSS nudging	World Ocean Atlas 2013	World Ocean Atlas 2013

Real-time Strategy

Every day the following are created:

- 11-members run out for 8 months
- 22-members run out for 6 weeks

99-member ensemble for forecast products:

- Seasonal ensemble: create latest 99 ensembles from the last 9 days (go back 15 days if need be) of ensembles 1-11
- Multi-week ensemble: create latest 99 ensembles from the last 3 days (go back 5 days if need be) of ensembles 1-33

NOTE: this is the same as in ACCESS-S1 **EXCEPT**:

- S2 real-time system will be run in a different configuration so that multi-week forecasts are produced much more timely than they were in S1
- more variables to support more users

Rationale for S2 hindcast strategy

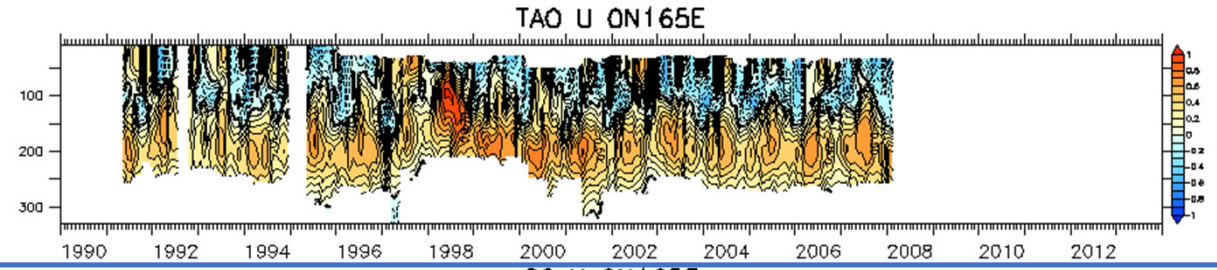
- The format of the hindcast design (not the format of the individual files) is completely different in S2 and S1. S2 hindcast design employs a lagged ensemble rather than a burst ensemble as well as several other changes to reduce cost and improve quality:
  - Reduce cost (fewer hindcasts for the same benefit)
  - Increase ensemble size to enable risk based products to be assessed
  - Have a hindcast lagged ensemble design that matches the real-time system and therefore provides truer estimate of the real-time skill (this was not the case for ACCESS-S1)
  - To improve the calibration and bias correction by having more years
  - To reduce the cost and number of hindcasts required by calibration by increasing the number of years (~x1.8) but decreasing ensemble size (~x1/3)

Data assimilation

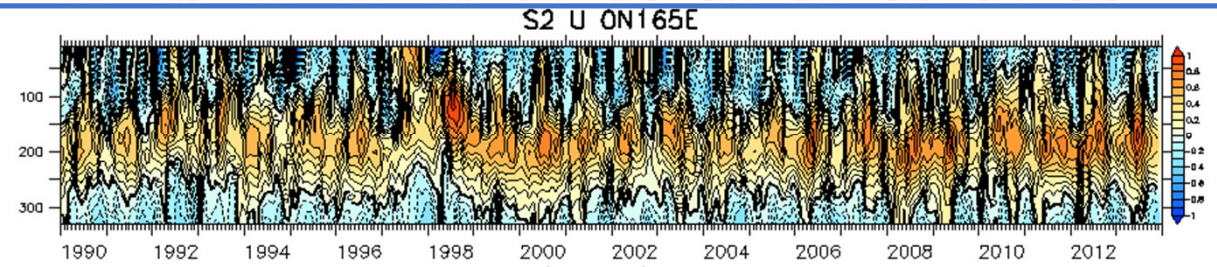
Example: ocean currents better in S2

U (0N,165E) Monthly mean U from ADCP TAO/TRITON, ACCESS-S2, S1(1990-2013)

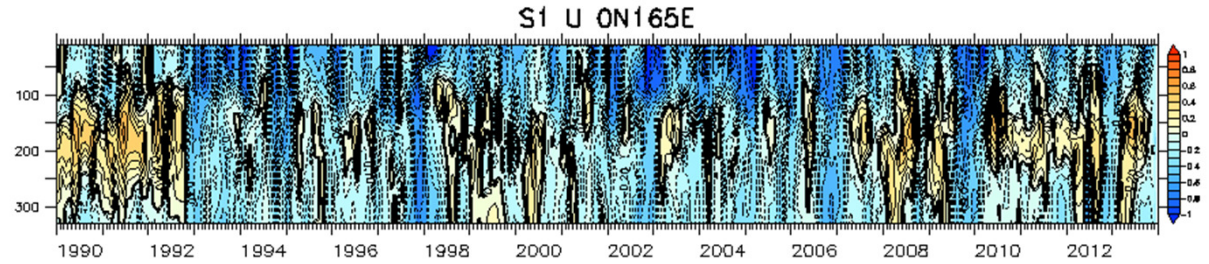
OBSERVED



S2



S1



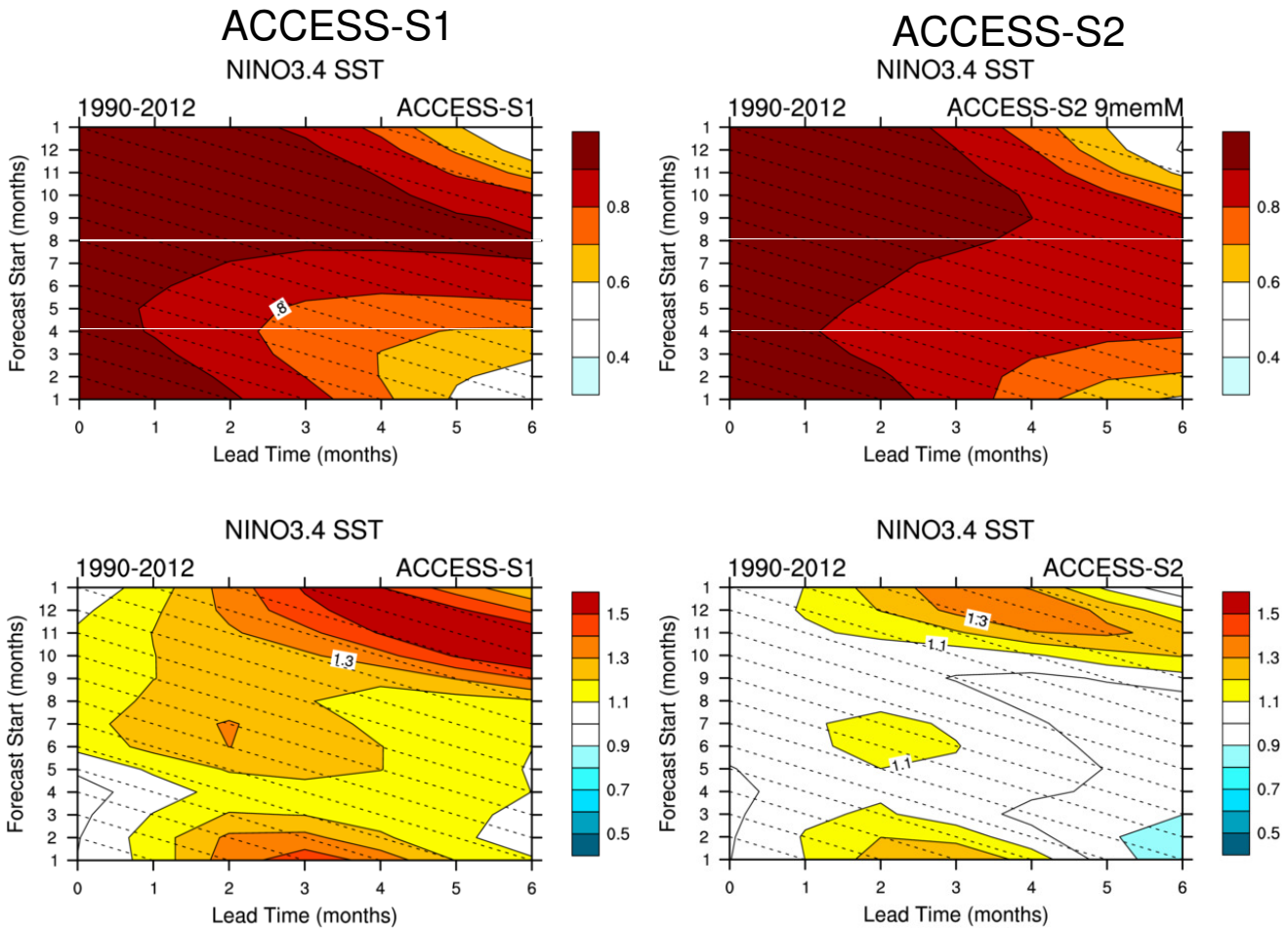
Improved ocean skill

Some indications of improved forecasts of ENSO, particularly for forecasts started in Autumn

Correlation skill
Redder is better

"Strength" of ENSO
White is good

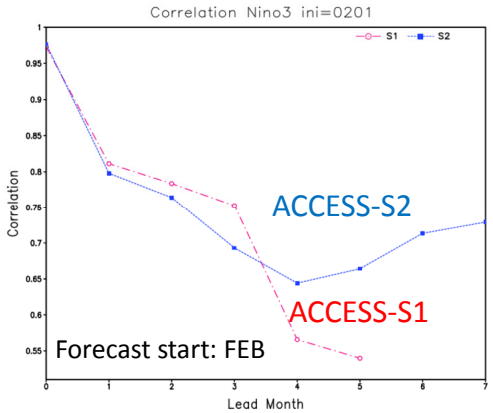
Ratio of
model stddev/obs stddev

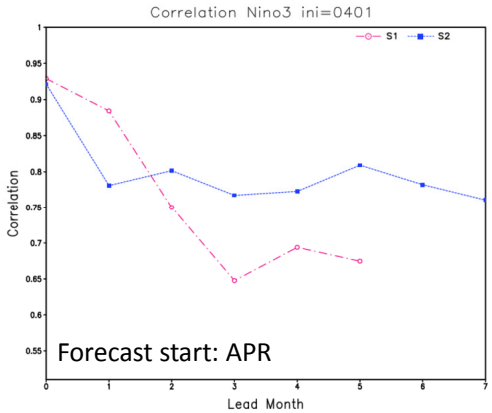


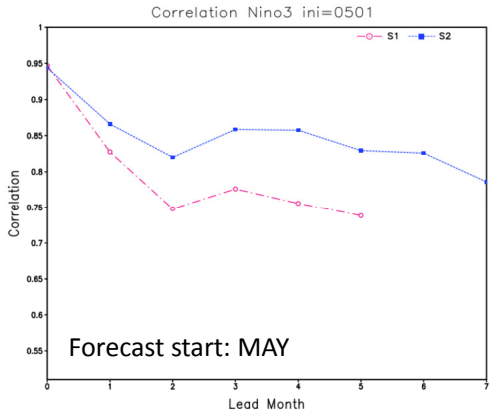
From: Eun-Pa Lim

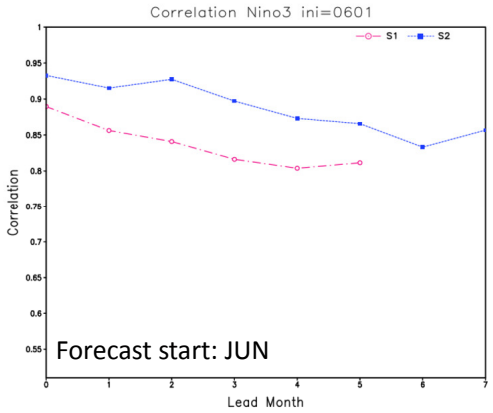
Caution: Only 23 years in the comparison

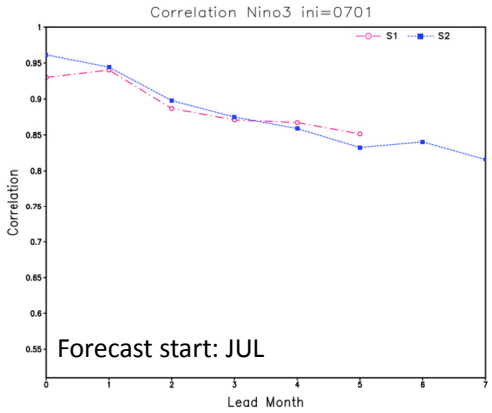
Forecasts
Nino3

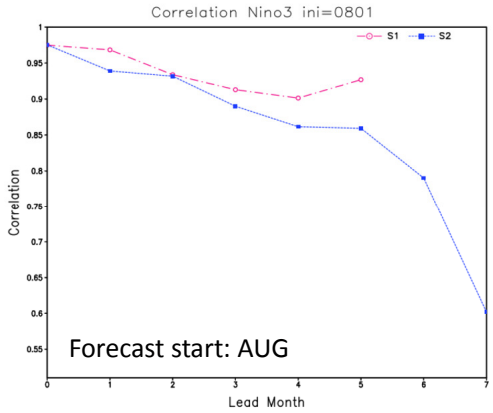










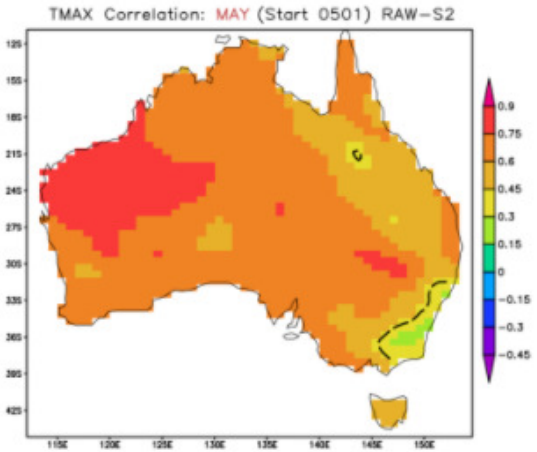


From: Li Shi

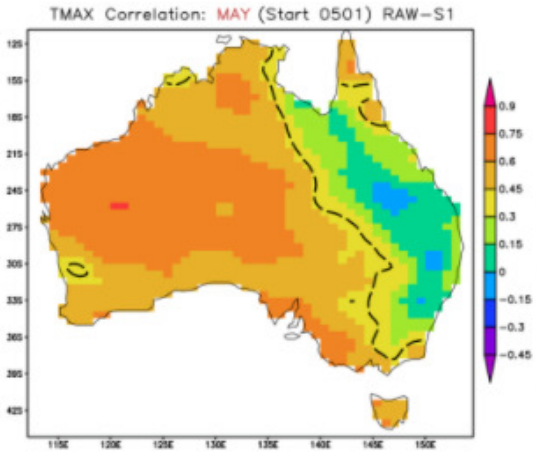
Forecasts
Example: Tmax

Tmax: benefits of realistic soil moisture initialisation

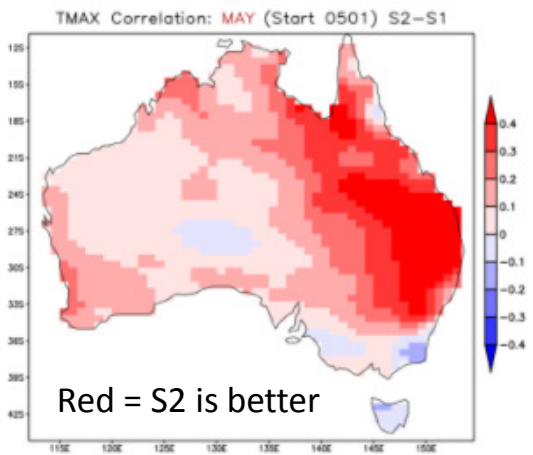
ACCESS-S2



ACCESS-S1



Difference (S2 minusS1)

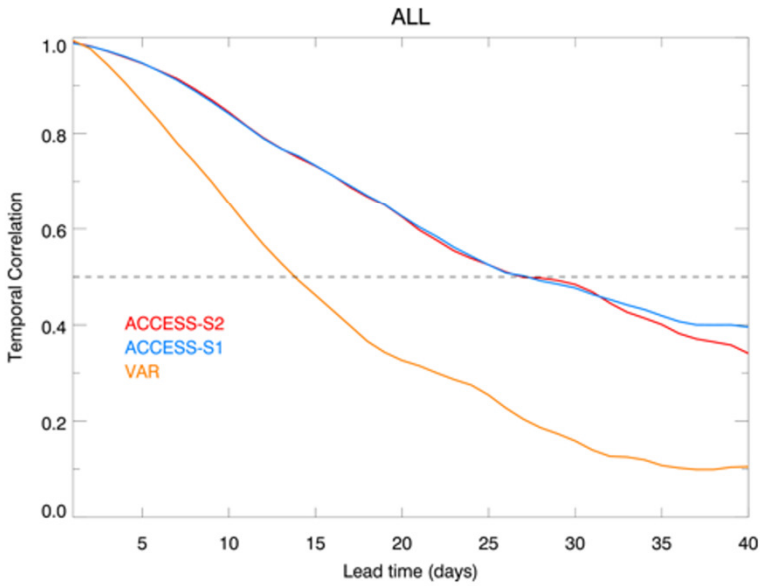


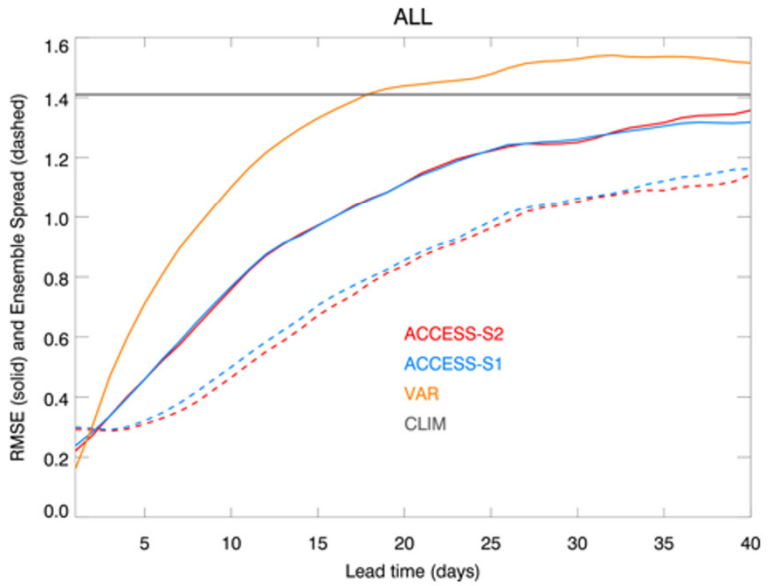
Correlation skill for May (from 1st May Starts)

From: Li Shi

Forecasts
MJO

ACCESS-S2 vs ACCESS-S1 MJO (RMM bivariate) skill comparison
Hindcasts initialised on 1st and 16th/17th (S2/S1) of month, 1990-2012
9 members for S2, 11 members for S1, ***verified against ERA-Interim***

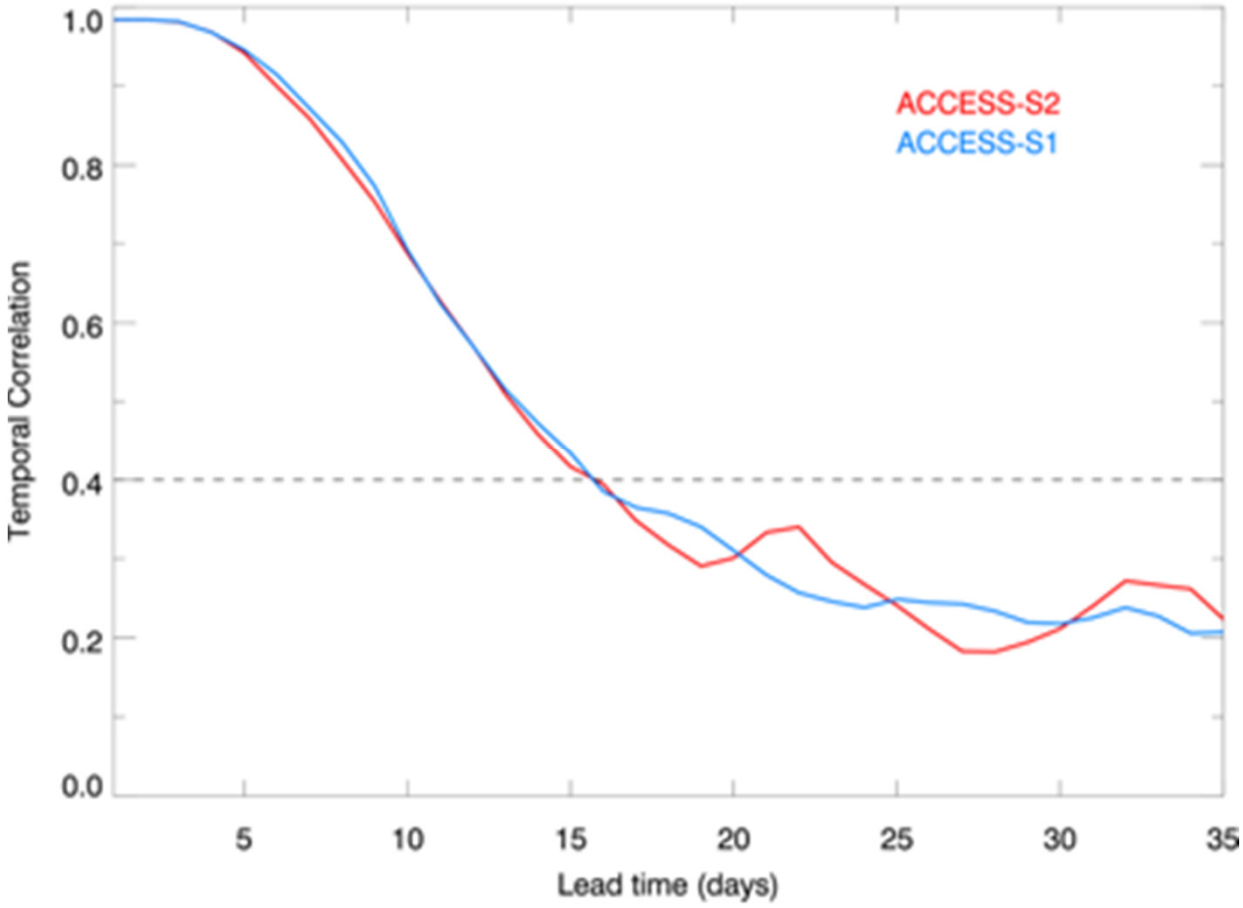




From: Andrew Marshall

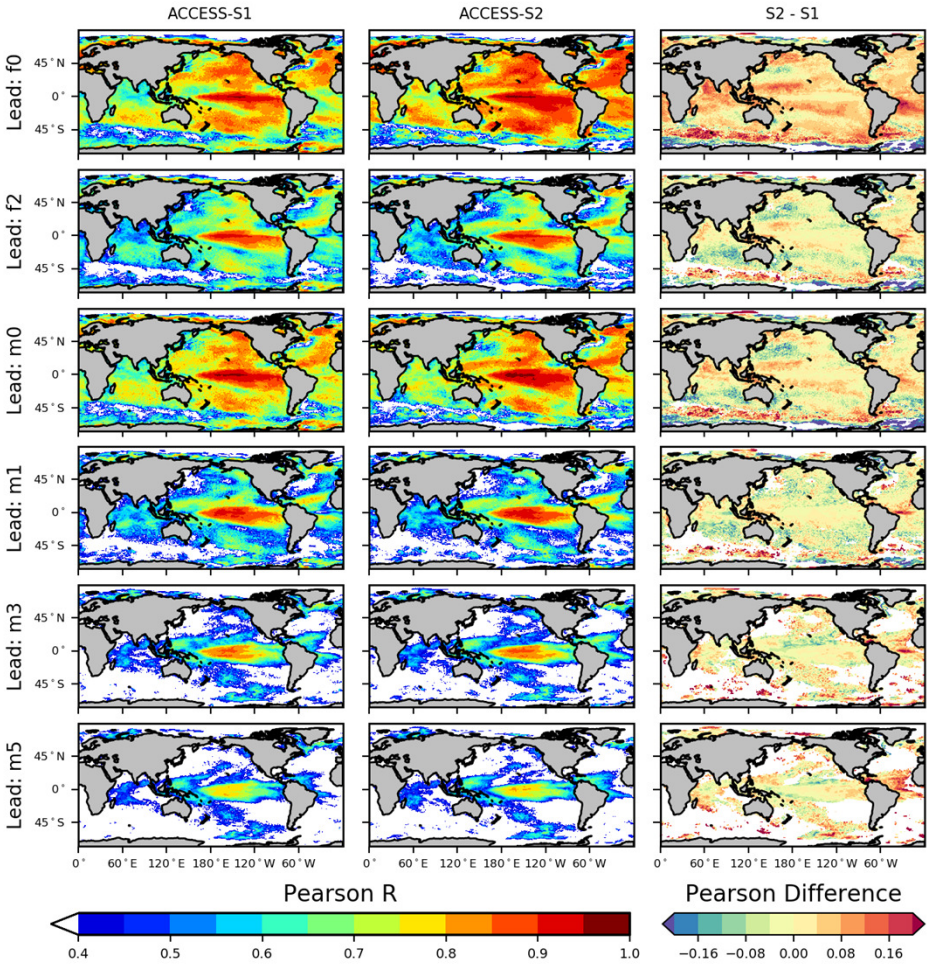
Forecasts

SAM



Hindcast Skill: SST

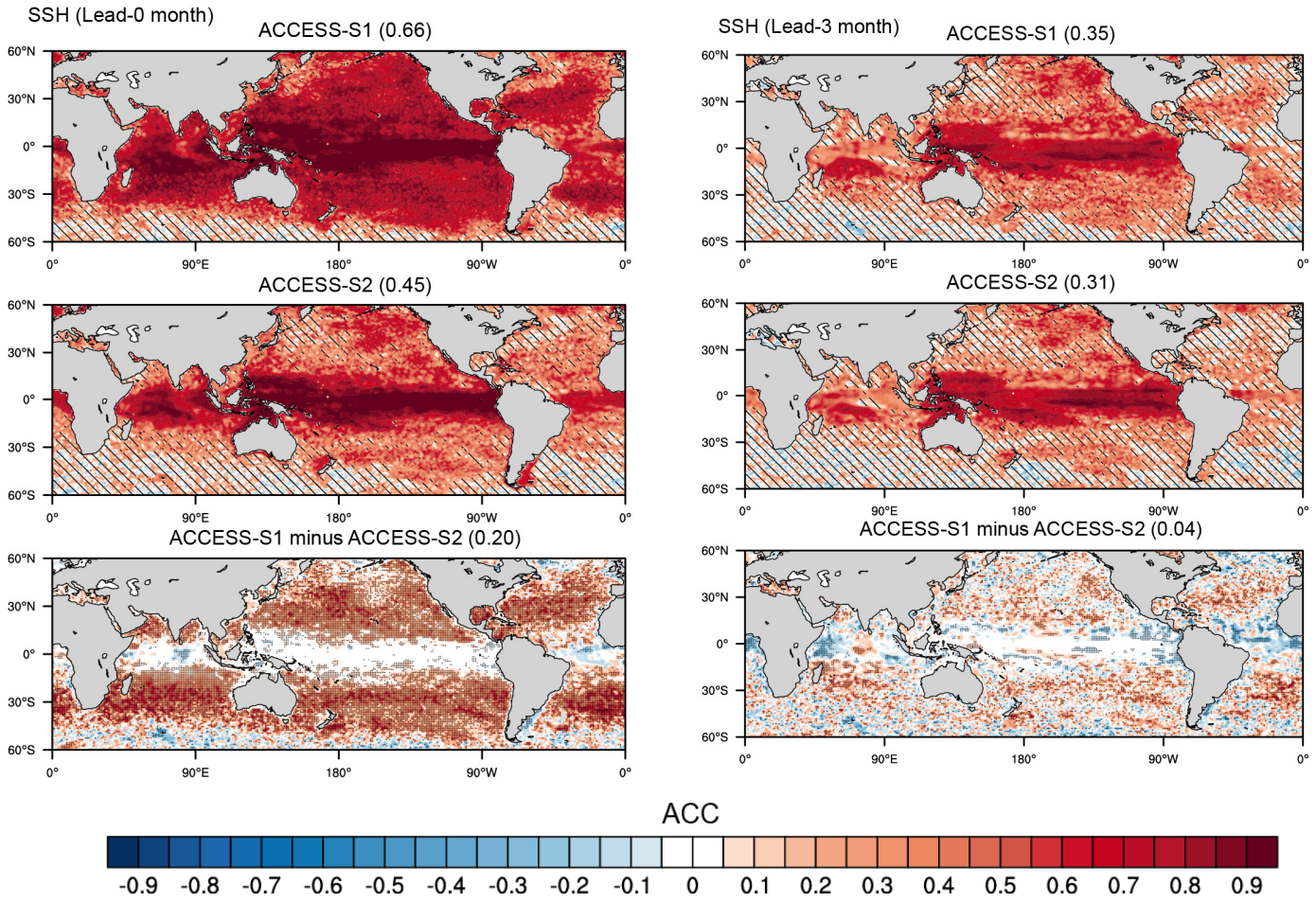
- Comparison between ACCESS-S1 and ACCESS-S2 correlation coefficients
- Biggest improvement in the tropical Pacific is in the subseasonal timescale
- Exception is the Southern Ocean due to changes in sea ice initialisation
- Monthly correlation similar between the two models



Forecasts

Sea Level

- Comparison between ACCESS-S1 and ACCESS-S2 correlation coefficients
- First column: lead 0
- Second column: lead 3
- Bottom row: Red means ACCESS-S1 is better
- Only an issue at shorter lead times



Summary

- ACCESS-S1 and ACCESS-S2 both provide 99-member daily ensembles for subseasonal and seasonal forecasting
- ACCESS-S2 hindcast is longer (38-years) and better matches the operational ensemble system
- Model skill improvement demonstrated for ENSO SST indicators at autumn start dates
- Subseasonal forecast improvements mainly from more timely data assimilation system
- Sea level outlooks have less skill in the subtropics at shorter lead times in ACCESS-S2