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Overview of BoM Operational S2S Ensemble Prediction System and Future Plans

The ACCESS-S system

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Assimilation/System Development led by Oscar Alves Team

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ACCESS-S1

- Fast track implementation of the UKMO GC2 model to replace low res POAMA
  - 60km atmos /25km ocean compared to 250km/200km in POAMA
  - S1 similar to GloSea5 but older UM8.6 configured as GA6
- UKMO-FOAM ocean-sea ice initial conditions (NEMOVAR)
- ERA-Interim (hindcasts) or BoM NWP 4dVar (real time)
- (ad hoc) atmosphere ensemble generation (needed for reliable multi-week predictions)
- Became operational mid 2018
- Many big improvements over POAMA but there are some issues:
  - Initialized with climatological soil moisture
  - Ocean initialisation shock (show example)?
  - 23 year hindcasts (not enough ENSOs, IODs) and 11 member ensembles (not sampling tails)
    - Hindcasts not sufficient for many applications (skill, calibration, extremes, etc)
  - Operationally dependent on UKMO ocean-sea ice initial conditions
  - Uncoupled and non-flow dependent ensemble perturbations (POAMA had)

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ACCESS-S1 Hindcast and Real Time Forecasts

Hindcasts

- Initialised: 1st, 9th, 17th, 25th of every month 1990-2012
- Hindcasts to 6-month lead time
- 11 members for every start date; 33-members to 6 weeks for the 1st and 17th starts.
- Calibrated outputs for T, Rain, Humidity, Windspeed, Insolation over Australia

  driven by user demand

  calibrated to 5 km gridded analyses using quantile-quantile matching

  globally, simple bias correction on model 60km/25km grid

Real-time forecasts

- 11-member ensemble generated every day for seasonal timescales (6-month forecasts)
- Additional 22 members are generated every day for multi-week forecasts (6-week forecasts)
- Multiweek and Seasonal Forecast products based on a daily-lagged ensemble of 99-members

  Uses 3 successive days of forecasts to make up the multi-week 99 member ensemble
  Uses 9 successive days of forecasts to make up the seasonal 99 member ensemble

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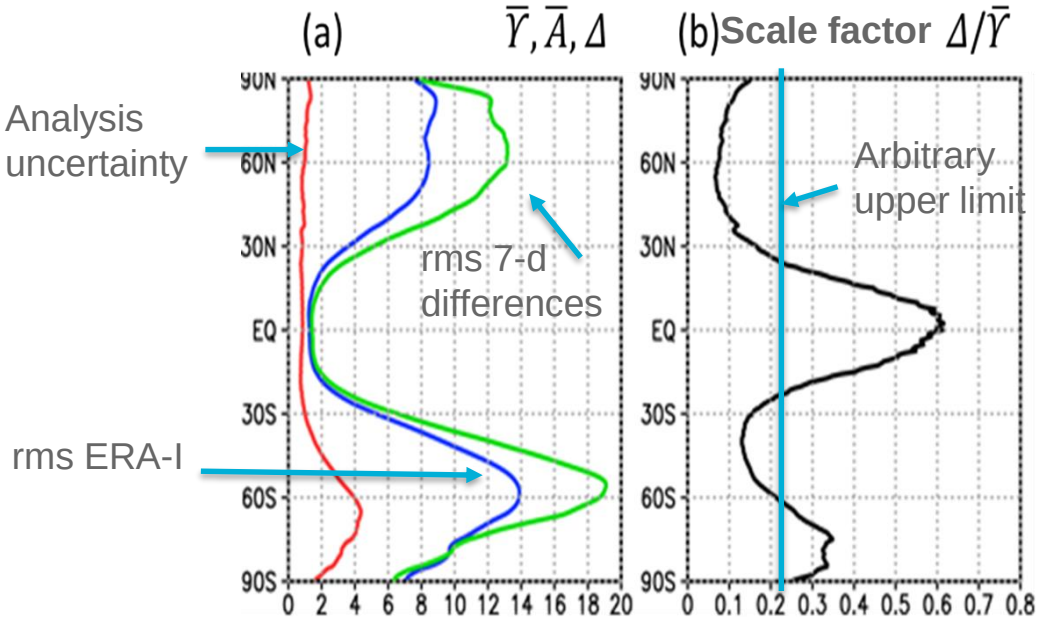
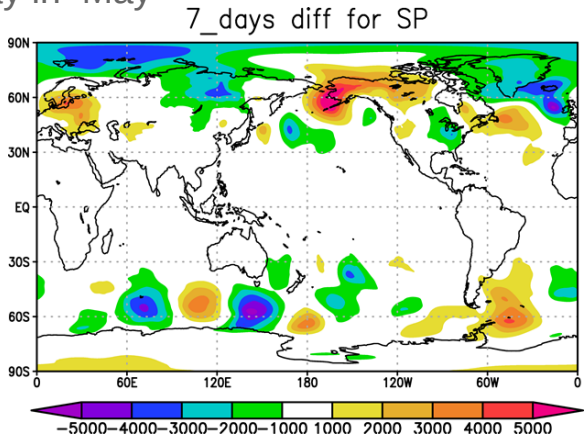
Ad-hoc Method for Generating Atmospheric Perturbations

- Randomly select 7-day differences from ERA-I reanalysis from same start month.
- Scale amplitude using a single scaling (at each latitude) for all fields at all levels to have analysis uncertainty (rms difference of daily ERA-I and NCEP reanalysis of surface pressure)

The perturbation calculation for application to forecasts initialized on 1 May 00Z:



Typical 7-day difference surface pressure analysis from ERA-I for a randomly selected day in May

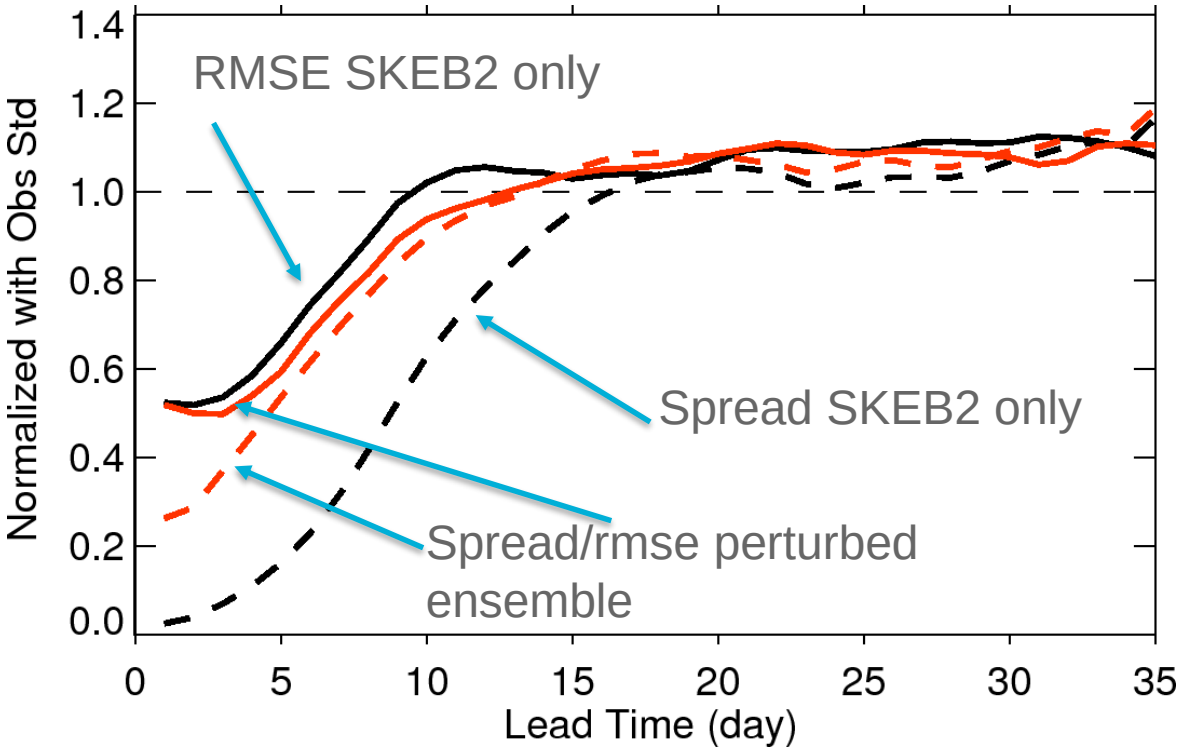


Tried 1d, 5d, 7d and 10d differences > Some indication 7d produced most reliability

Z500 RMS and spread 20-60S

1 May start; 1990-2012; 5 members

Verification: NCEP1 reanalysis



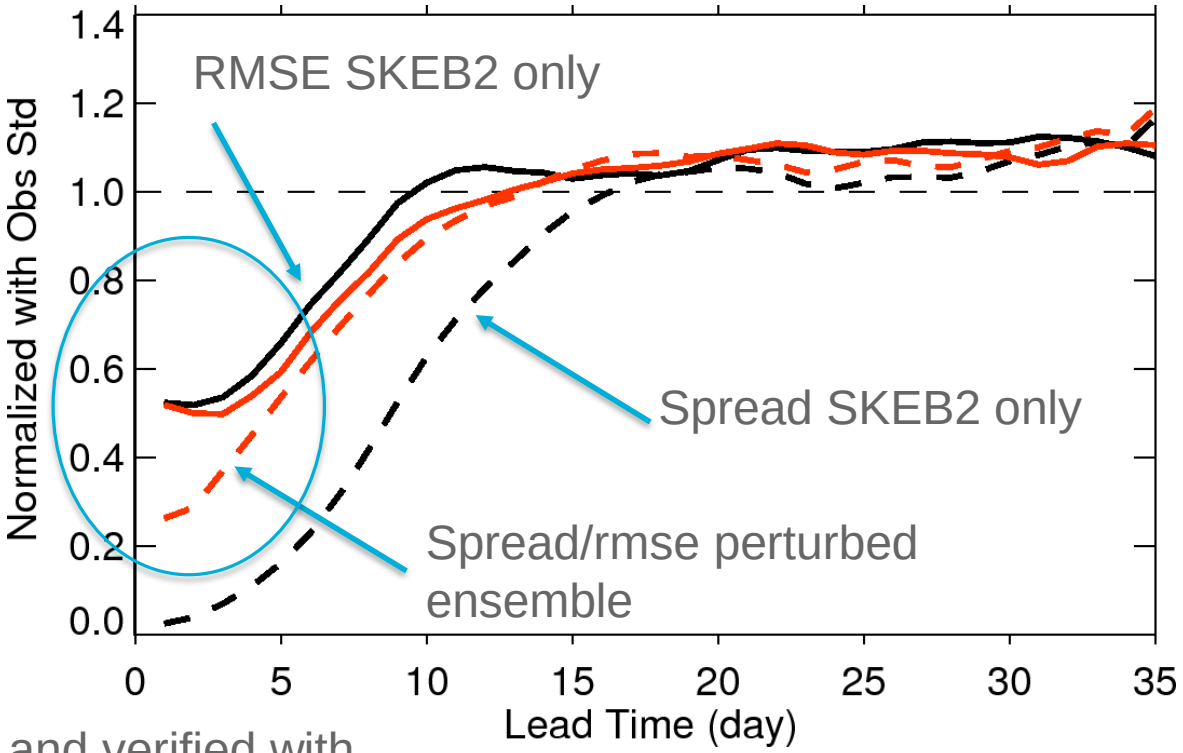
Even at day 1 RMSE lower for perturbed ensemble. But, we didn't compute mean RMSE from each perturbed member to confirm it was higher than unperturbed member (Zoltan)

But, we made a mistake…..

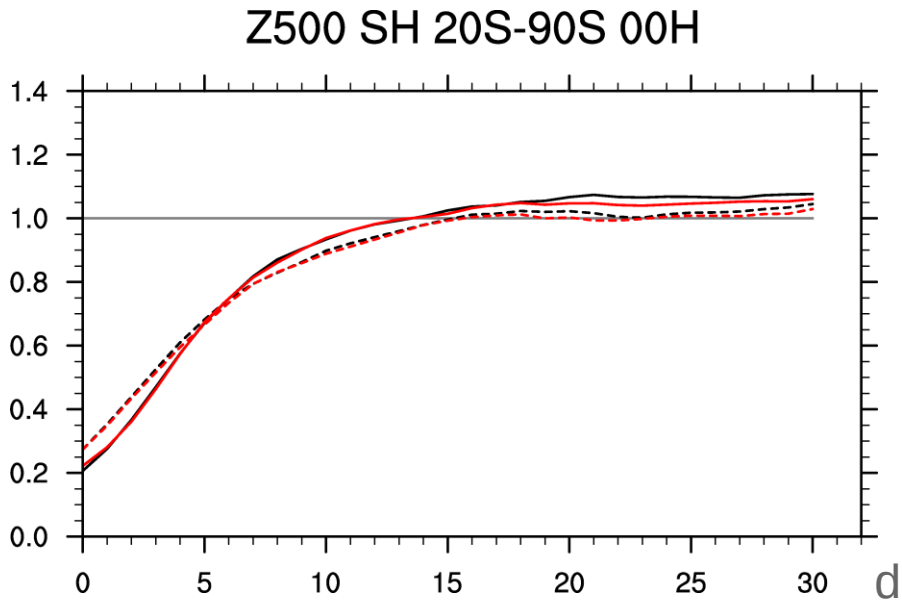
Z500 RMS and spread 20-60S

1 May start; 1990-2012; 5 members

Verification: NCEP1 reanalysis



Made a mistake and verified with daily mean whereas model output is instantaneous: causes initial too large RMSE

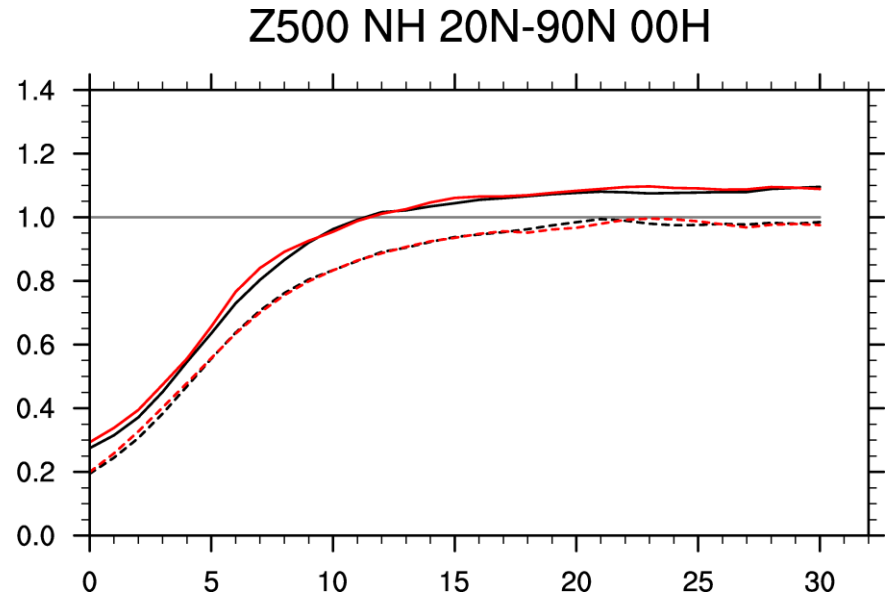


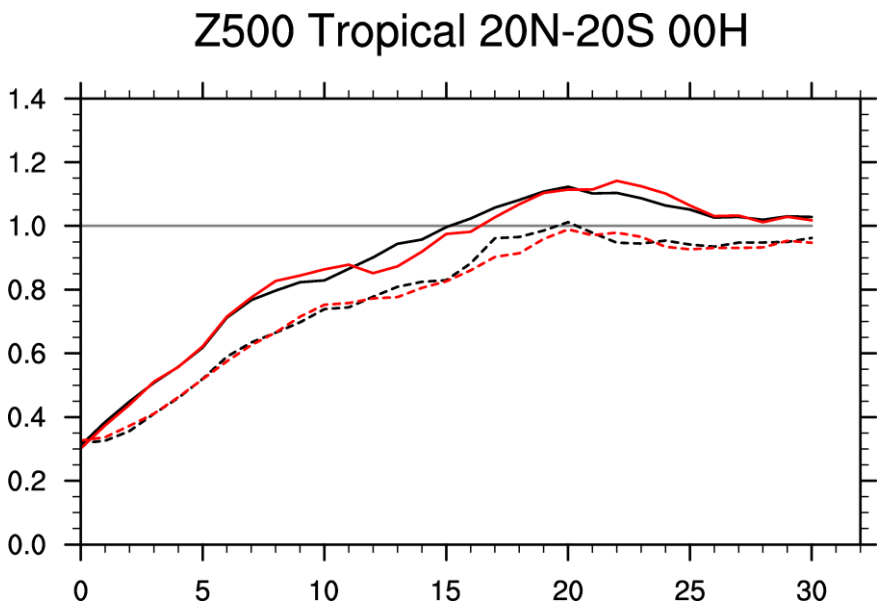
Initialized 1 May and 17 April 1990-2012
Verified with ERA-I 00Z

Normalized

RMSE	SPREAD	
———	- - - - - -	S1
———	- - - - - -	S2

S2 based on new ocean assimilation, described later in talk



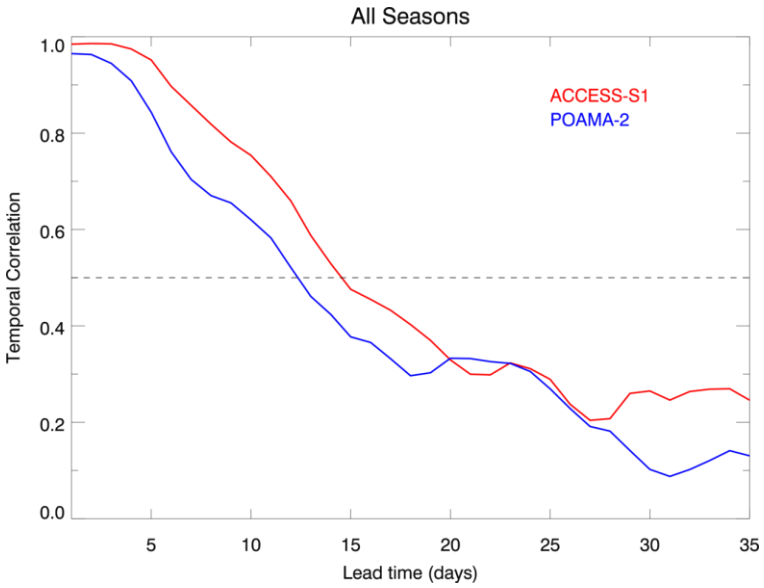


Slightly under-dispersive in Tropics and NH, close to ideal for SH
Don't have comparison for SKEB2 only

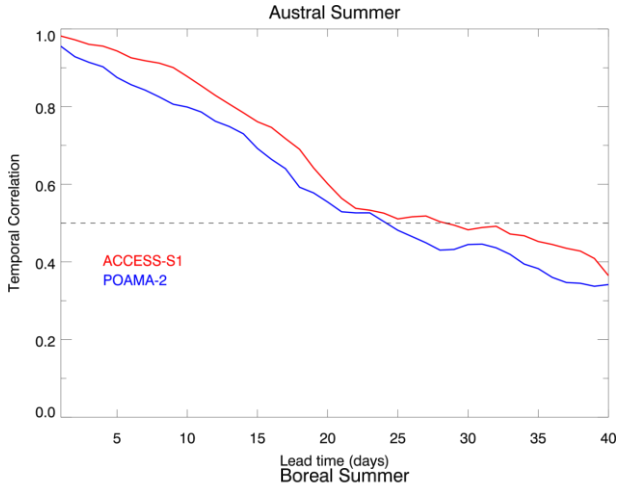
Performance of ACCESS-S1 Compared to POAMA

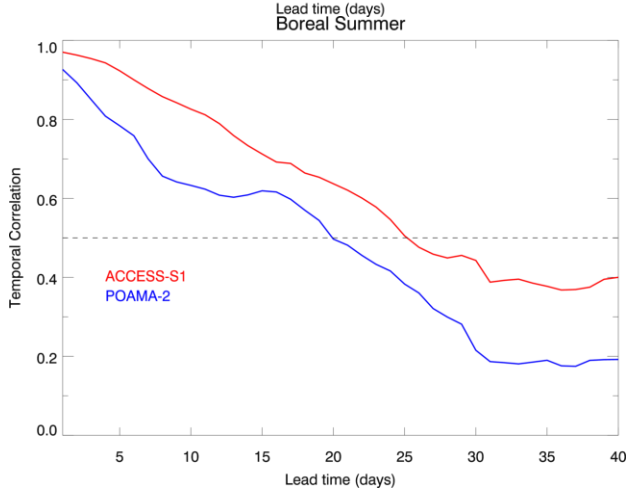
Prediction of the SAM and MJO 1990-2012

Southern Annular Mode



Madden Julian Oscillation



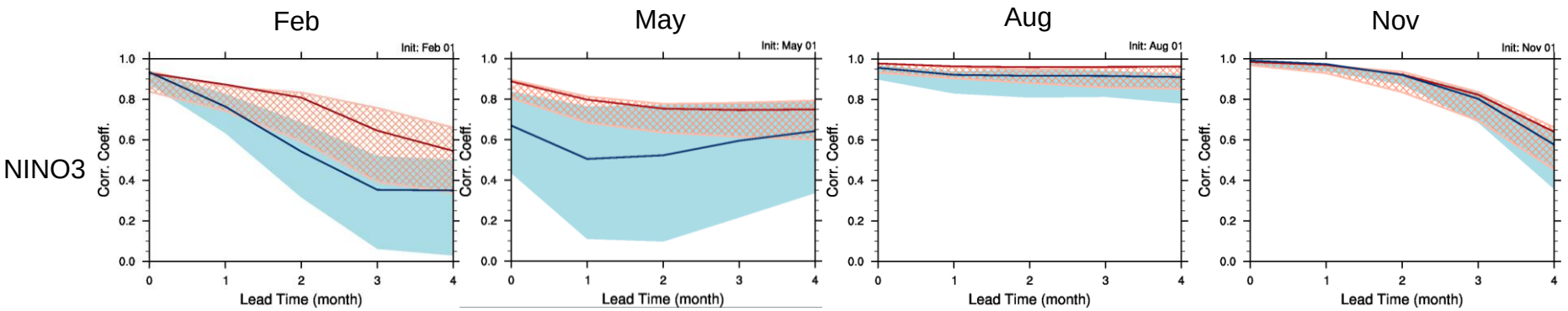


ACCESS-S1 POAMA

Prediction of El Nino

23 Years of Hindcasts

Correlation skill of forecasts of SSTA for NINO3



Pleasing improvement across "spring barrier"
not sure why (yet)

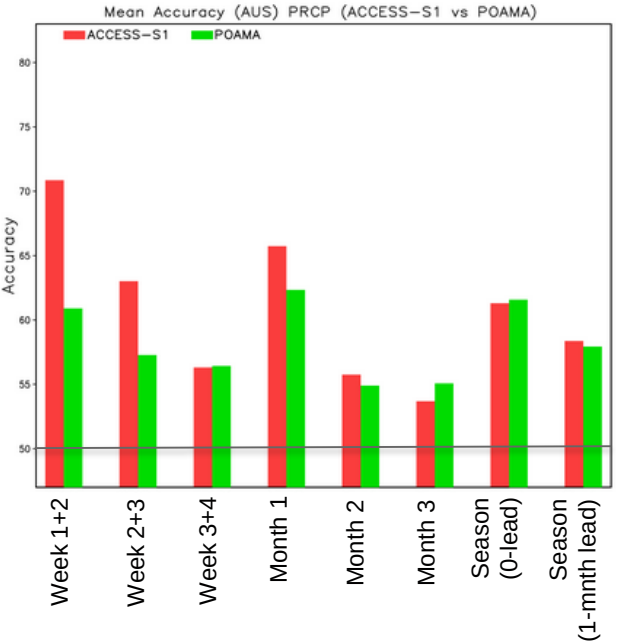
Prediction of Australian Climate

Average accuracy for all points over AUS and all times of year

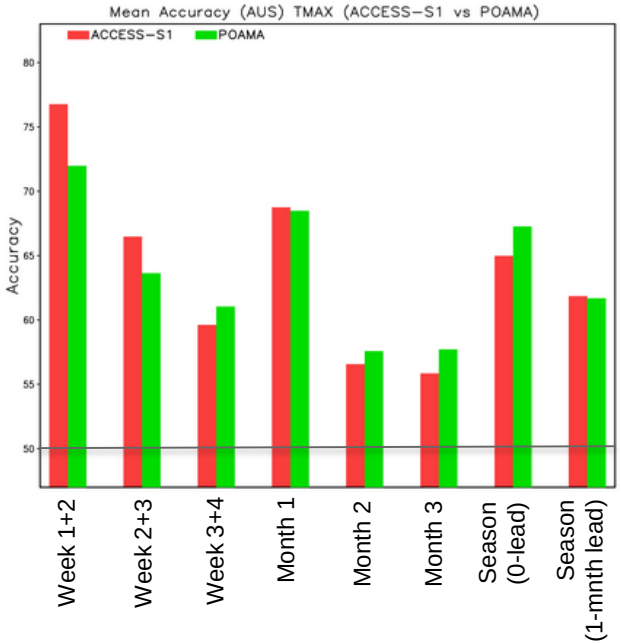
(For forecasts started on the 1st of every month in 1990-2012; n=276 i.e. 12 start dates * 23yrs)

Forecasts of probability of above median

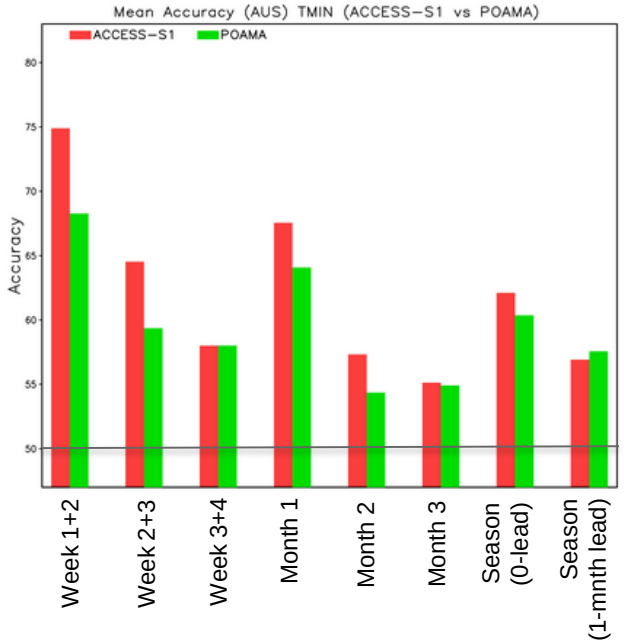
Rainfall



TMAX



TMIN



ACCESS-S1 POAMA

good gains to week 3-4 but challenge to make gains at longer lead times

Forecast Visualisation Tool (FVT)
poama.bom.gov.au (passwd protected)
for prototype products

BoM View
ACCESS-S1

Forecast / Hindcast

Forecast Start Date: < 2018 > < Dec > < 07 >

Feedback

General Products

Climate Drivers
- > Ocean SST indexes
- > Atmos drivers

Atmos Products

Basic Charts
- > 60km
- > 5km bias corrected
- > **5km calibrated**

Regions Stations
- > Pie Charts
- > Daily distributions
- > Quintile bars
- > 30 day Meteogram
- > POE
- > 2D Cumulative POE

Heat Extremes
- > Heat wave map
- > Hot days plume
- > Hot days map
- > Temperature-humidity (THI) daily distributions (stations)
- > Temperature-humidity (THI) maps

Ocean Products

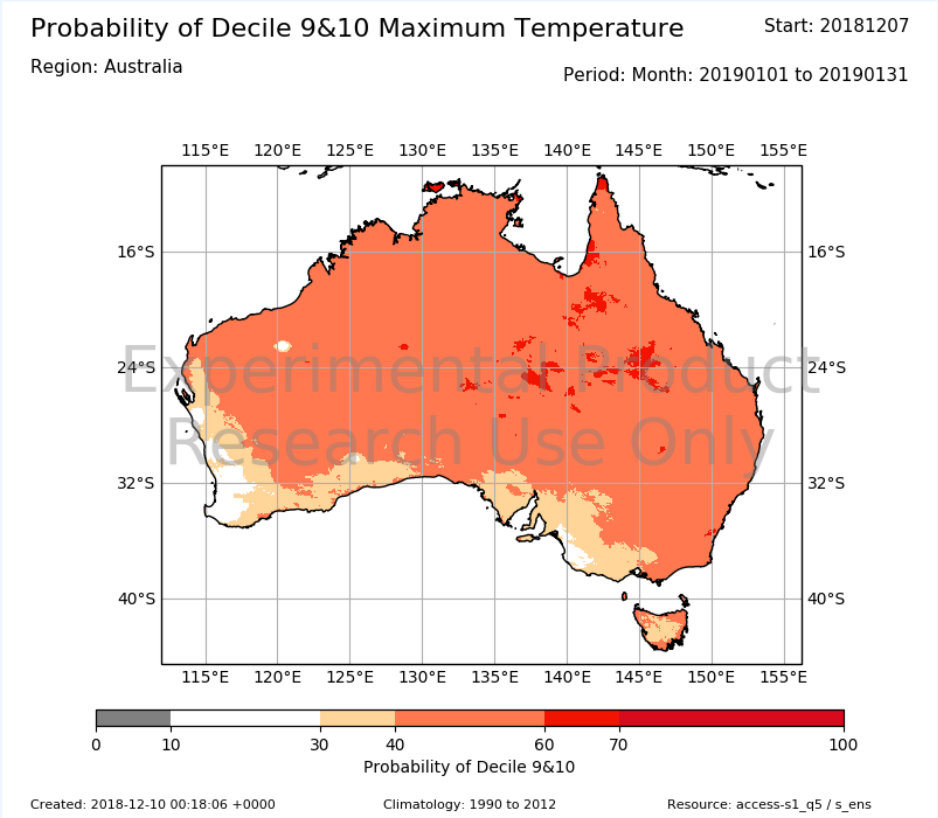
Basic Charts
- > Horizontal Charts

Regions Stations
- > Ocean Plume
- > Ocean Pie Chart
- > Quintile bars
- > 2D Cumulative POE

POE Charts
- > 25km SST

Product Characteristics

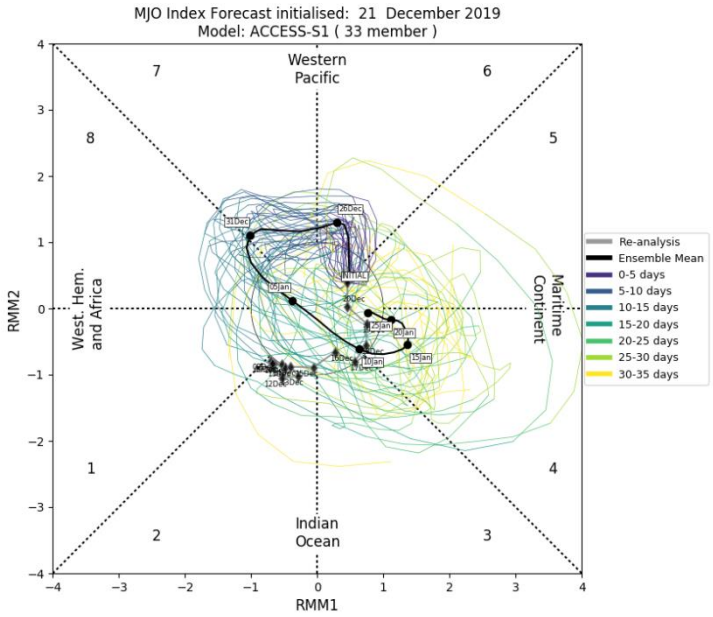
Variable: Maximum Temperature | Domain: Australia | Forecast Period: < Month 1 > | Output options: Probability in Decile 9 & 10



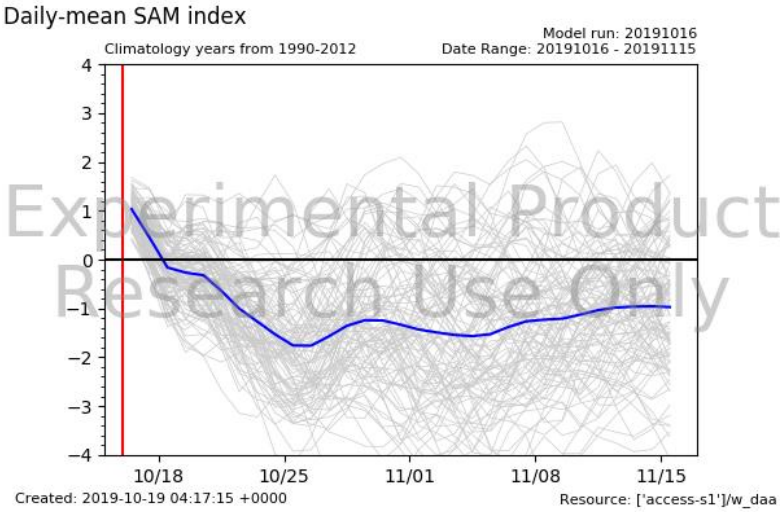
Source Image: plots/atmos_q5/tasmax/australia/atmos_q5_tasmax_australia_m0_ptquintile_20181207_rt.png

Examples of real time products from FVT

MJO plume



Southern Annular Mode plume



Experimental Product
Research Use Only

Onset of negative SAM following SSW in early Sep 2019

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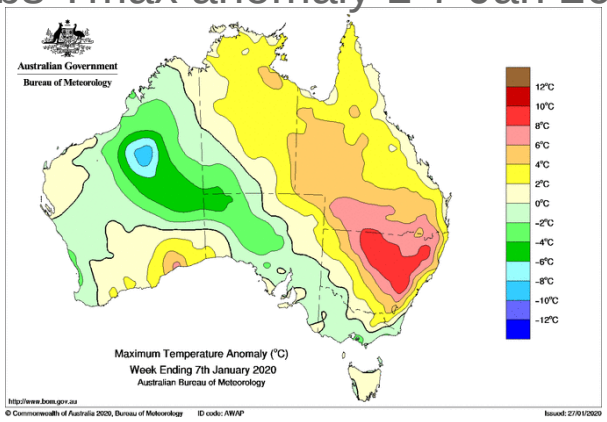
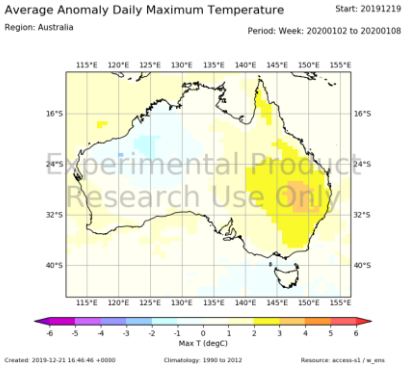
Initialized 19 Dec 2019
Verify 2-8 Jan 2020
Based on calibrated outputs

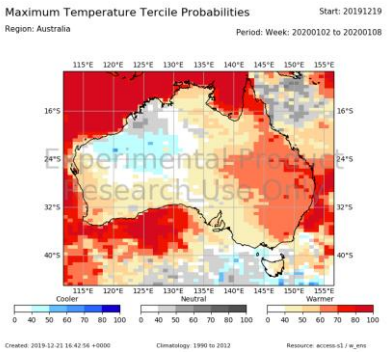
Obs Tmax anomaly 1-7 Jan 2020

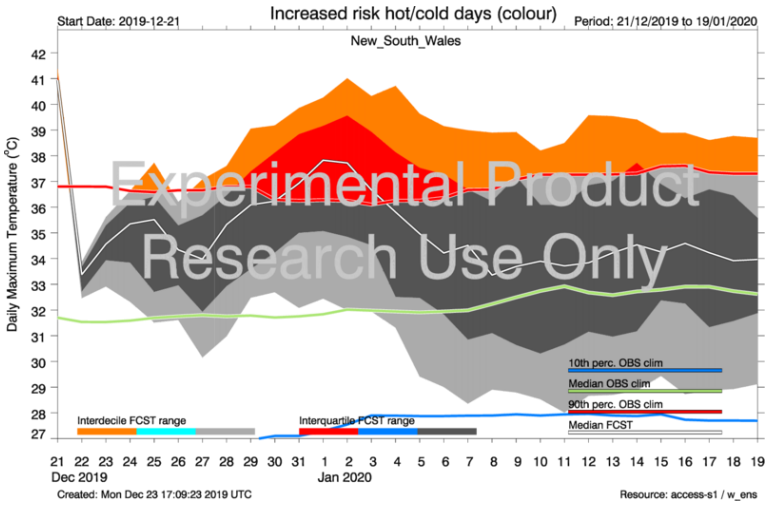


Week 3 Tmax ensemble mean anomaly

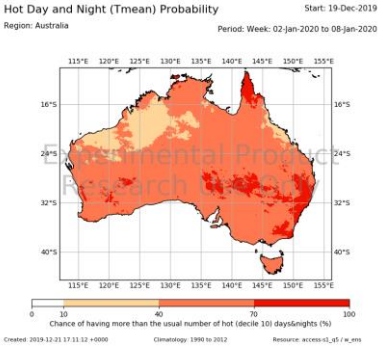


tercile probability





Mean for state of NSW



Week 3 chance of more than usual number of decile 10 days

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Example of product explanation

Hot days/nights forecast for upcoming weeks/fortnights/months/seasons

Hot days definition:
T_{max} > 90th percentile threshold of daily T_{max}

Hot nights definition:
T_{min} > 90th percentile threshold of daily T_{min}

Hot days+nights definition:
T_{mean} > 90th percentile threshold of daily T_{mean}

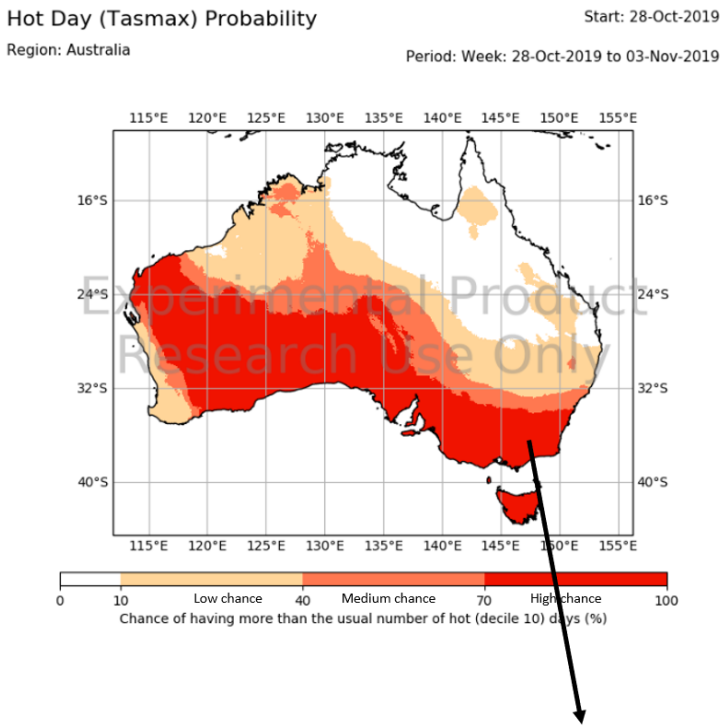
"Hot" is defined as being in decile 10. The 90th percentile threshold is calculated by looking back over the historical period for the particular time of year of interest. 10% of days are hotter than this threshold. The index will capture "warm" days in the winter half of the year and "warm" days in cold regions (i.e., unusually warm days) because the threshold is determined relative to the given time of year and region.

In this definition, the hot events do not have to be consecutive.

What does "usual number of hot days" mean?

The 'usual number' of hot days is 10% of the forecast period. For example, for an upcoming month of 30 days, the usual number of hot days will be 3. For an upcoming season of 90 days, the usual number of hot days will be 9. Therefore, for the latter, if 80 of the 99 members of the forecast ensemble are forecasting >9 hot days, then there is an 80% chance of having more hot days than usual for the given location.

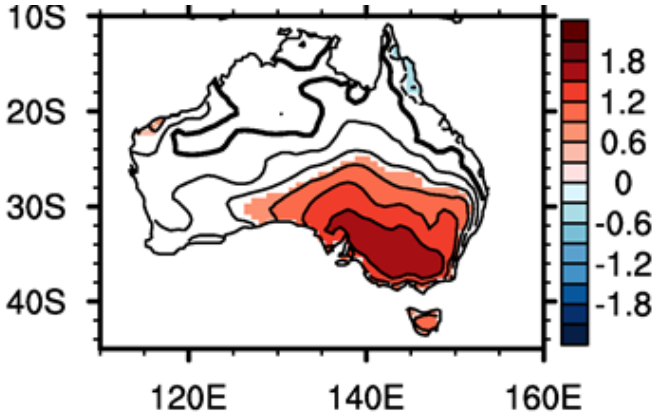
Example: hot days



Dark Red: More than 70% of the forecast ensemble (plausible outcomes) are forecasting more hot days *than usual*

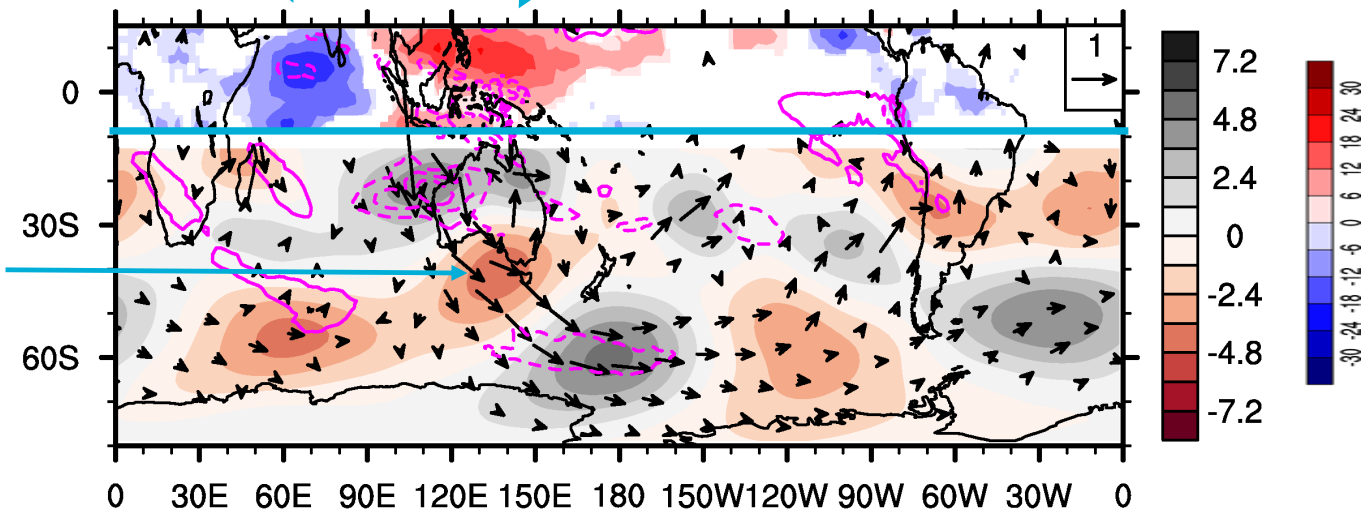
Examples of systematic errors: MJO teleconnection

Observed composite for MJO Phase 2 S-O-N Tmax weekly anom



MJO enhanced rainfall and suppressed rainfall

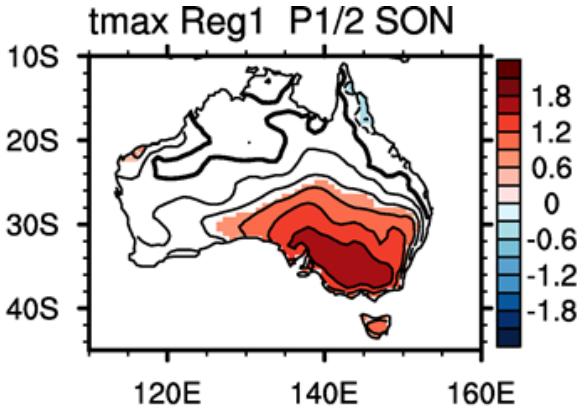
Hot because MJO forces an anticyclone centred just west of Tasmania (makes hot northerlies in SE)



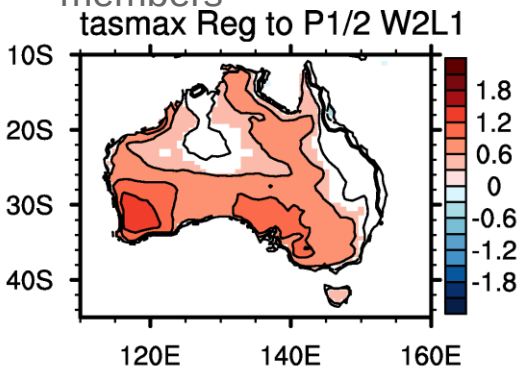
Shaded: streamfunction 200hPa
Wave activity flux: direction of group velocity

How well does ACCESS-S1 simulate SON MJO teleconnection?

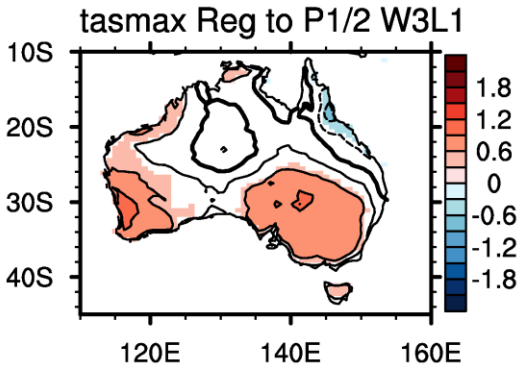
Observed Tmax anomaly Ph1/2



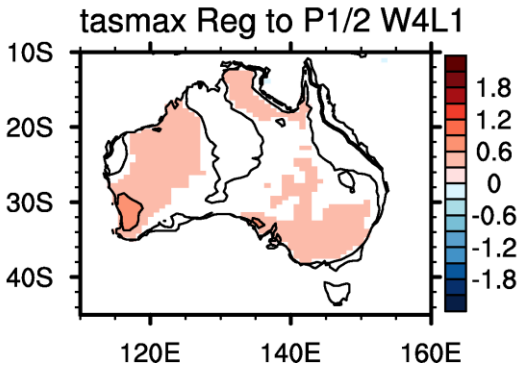
Model MJO composite Ph1/2 using individual members



Week 2



Week 3

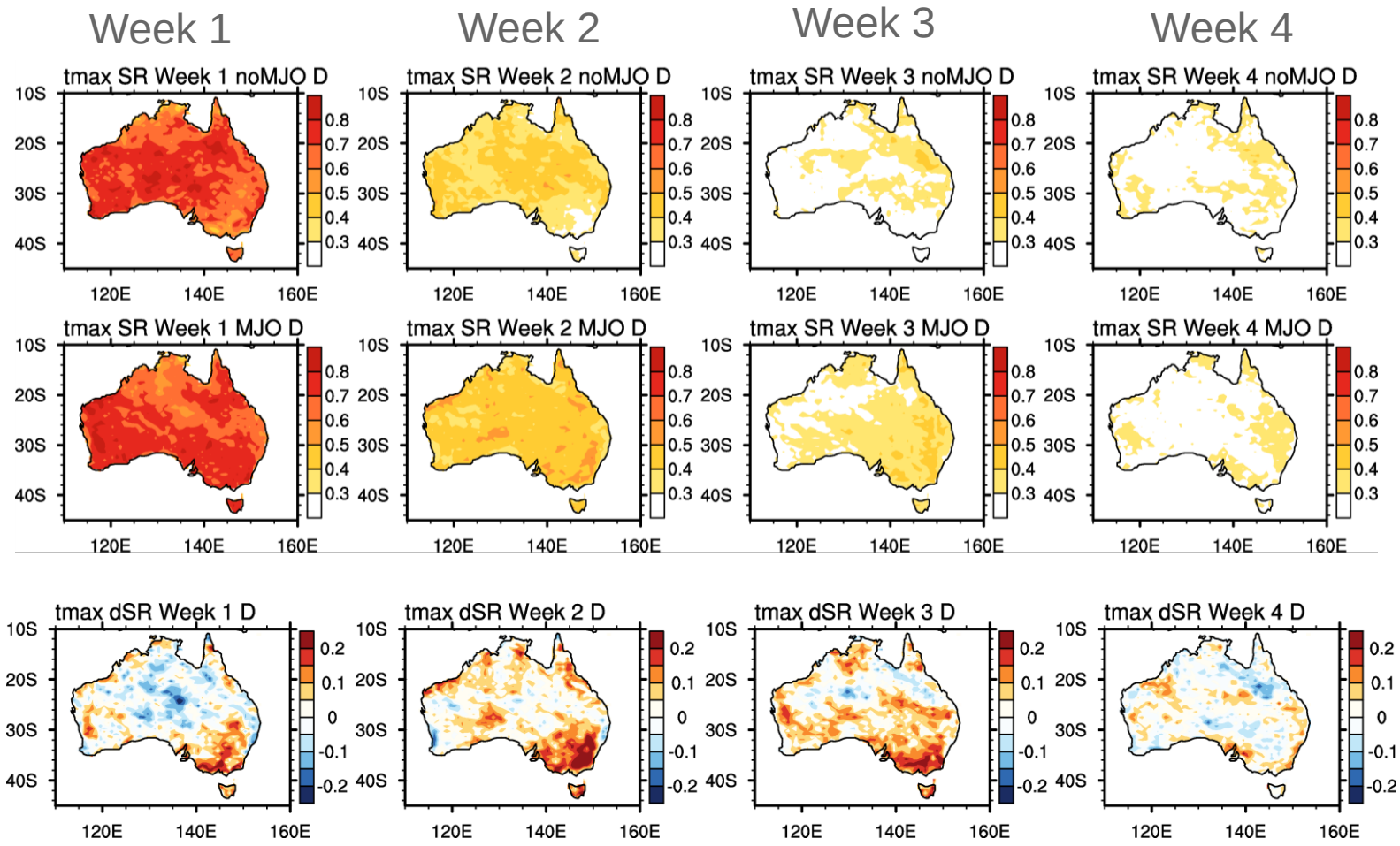


Week 4

Model signal too far west and weakens with lead time

MJO Impact on Tmax extreme forecast skill

Success Ratio =hits/(hits+false alarms) for Tmax in upper quintile SON 1990-2012



Weak obs MJO at start of each week

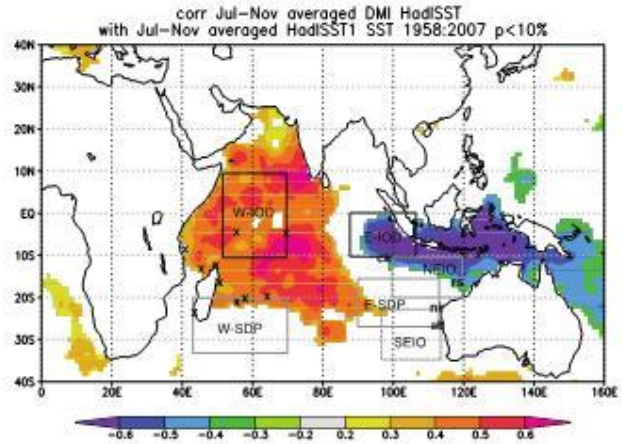
Strong obs MJO at start of each week

Difference

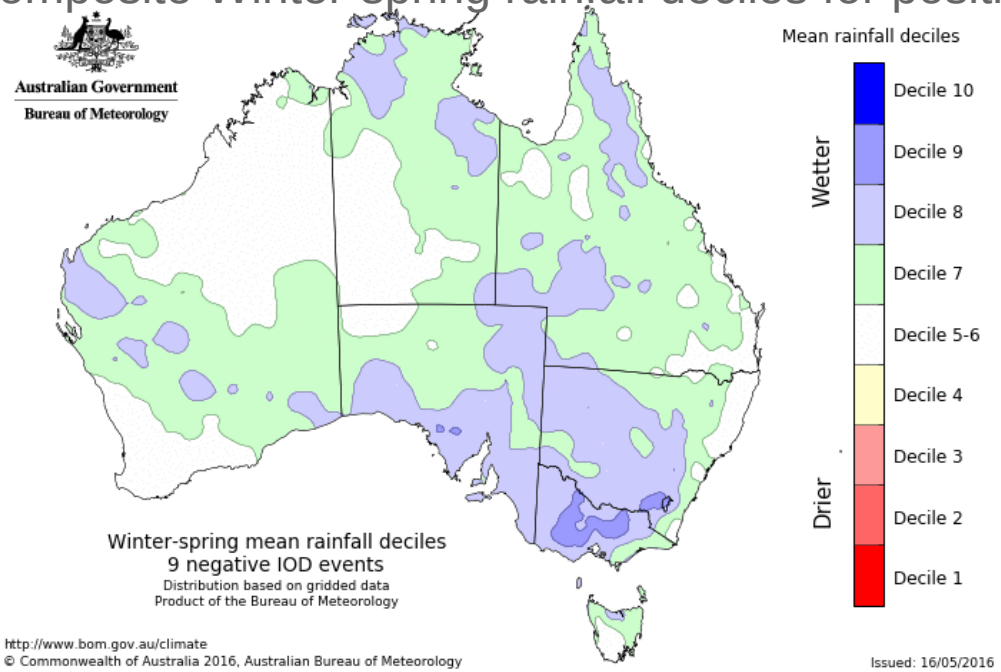
MJO is source of predictability but systematic errors are limiting skill at longer leads

Indian Ocean Dipole

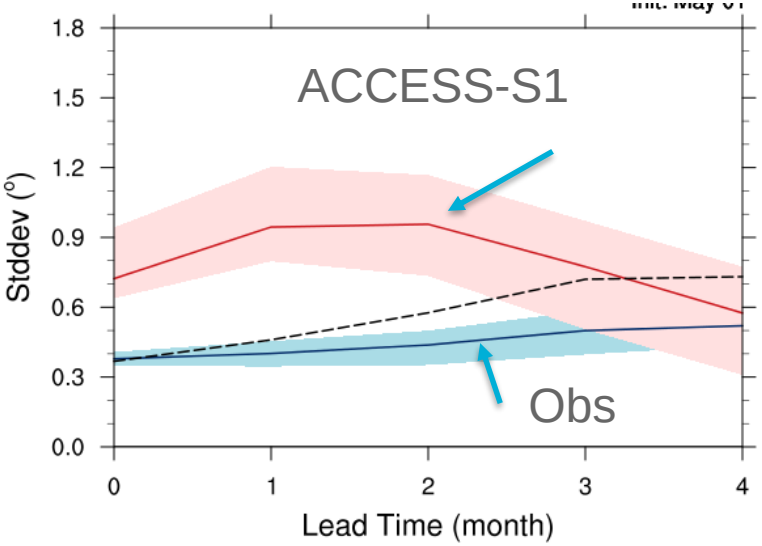
Obs SST



IOD matters to Australia:
Composite Winter-spring rainfall deciles for positive IOD



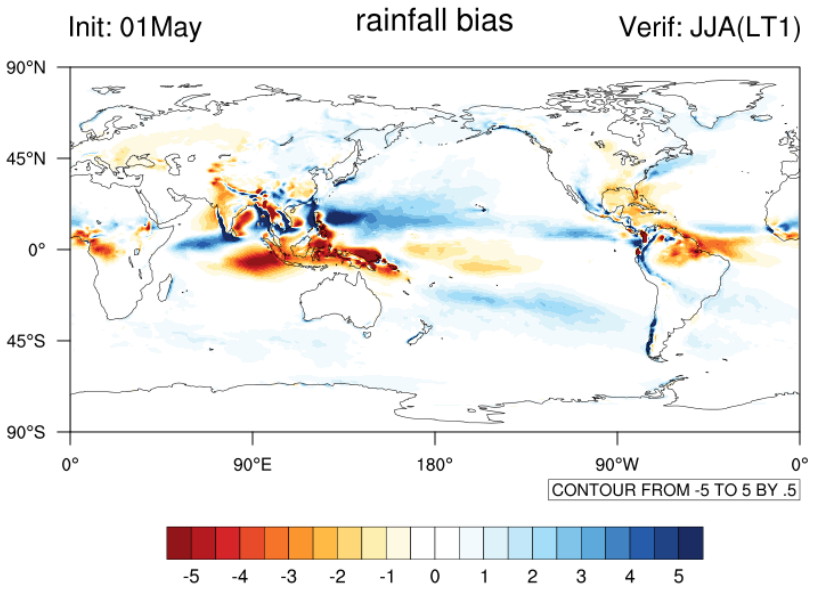
DMI Stand Dev

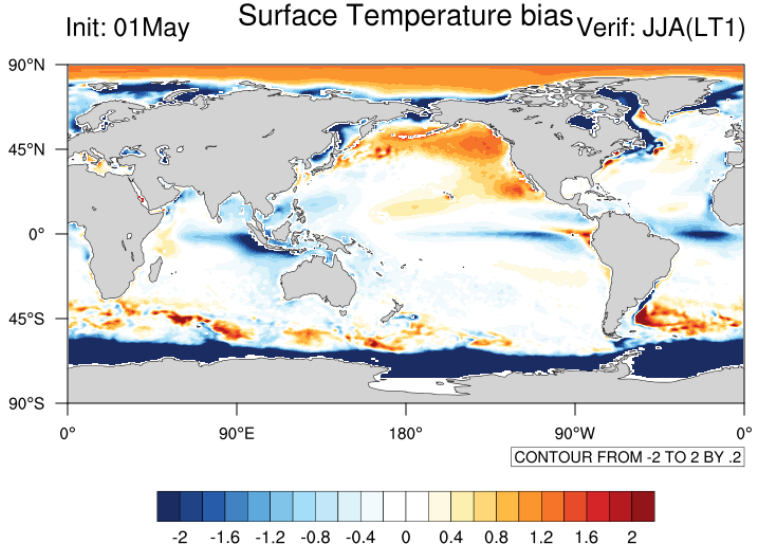


Bias in amplitude of IOD

LT 1 mnth ACCESS-S1 rainfall /SST bias

JJA from 1 May 1990-2012





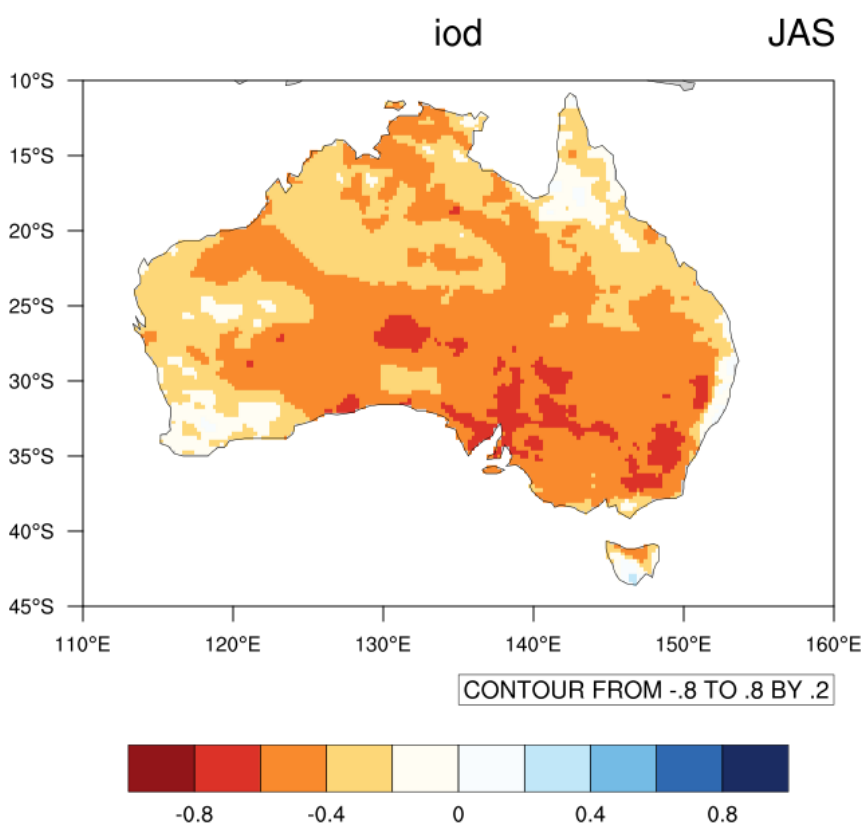
Indian Ocean rainfall bias drives easterly wind bias, drives thermocline up in the east, SST cools and coupled variability increases

Rainfall bias similar in other seasons

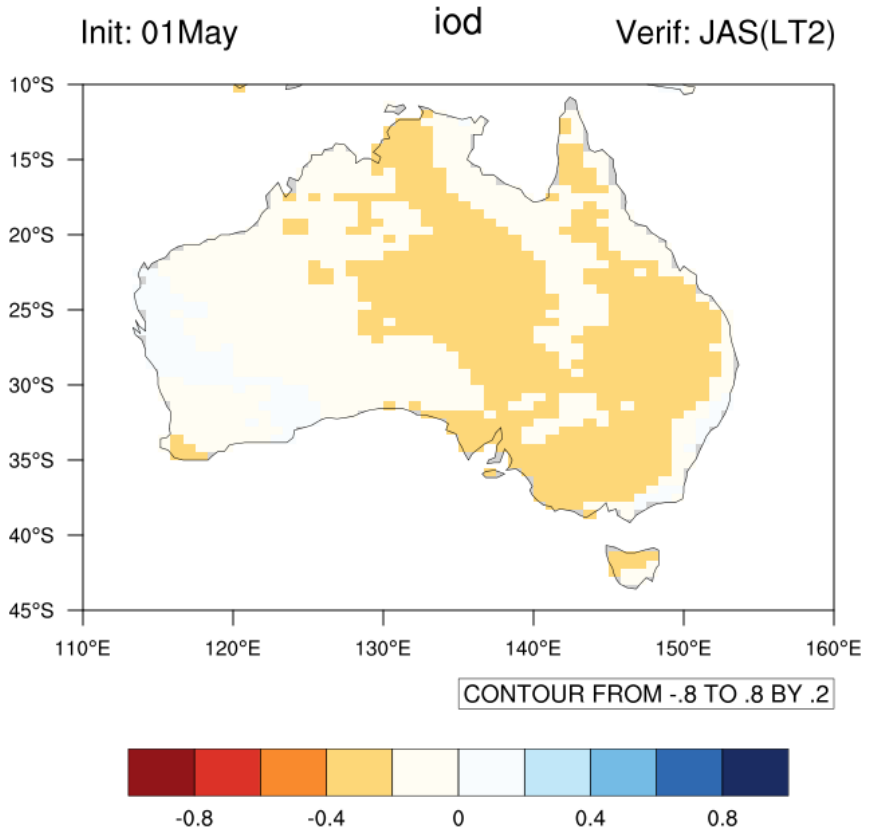
But cold SST/too strong IOD bias emerges primarily JJA-SON (upwelling season)

IOD Teleconnections to Australia Rainfall

Obs DMI-rainfall correlation



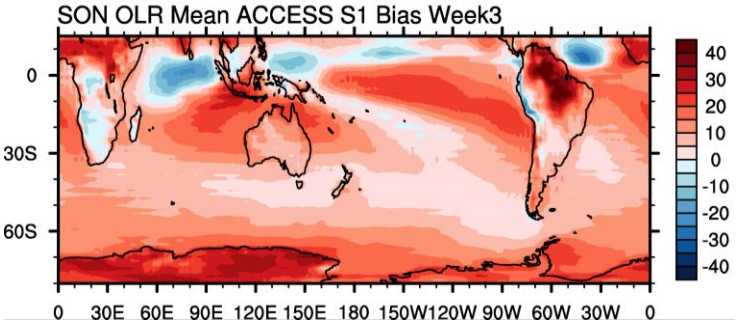
Model correlation



Besides bias in IOD amplitude, biases in IOD teleconnections acting to limit predictive skill of SE Australia winter-spring climate

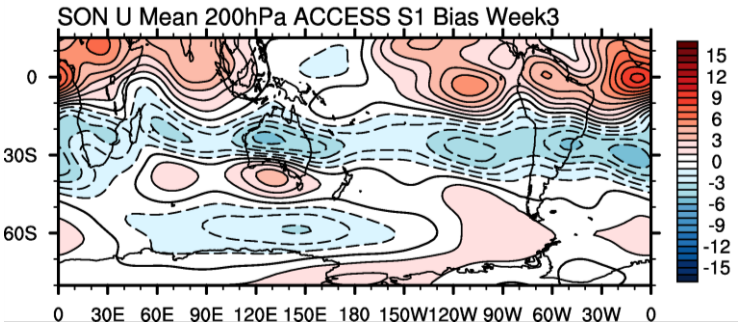
Biases in mean state week 3 (also indicative of longer leads) of the ACCESS-S1 forecasts

OLR bias



Too much rain in western Indian Ocean and too little to NW of Australia

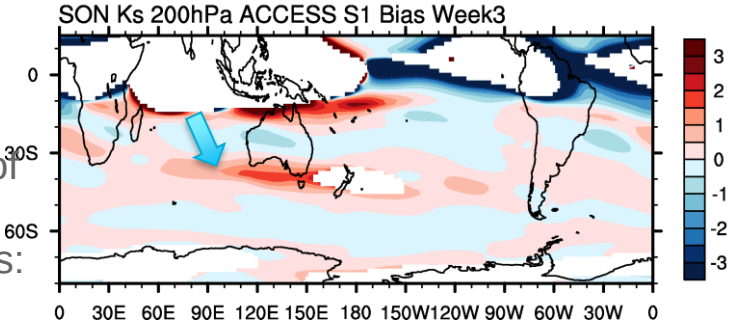
U 200 hPa bias



Separation of Subtropical jet and high latitude jet reduced

K_s 200 hPa bias

Ks is an index of refraction for planetary waves: waves will propagate toward higher values



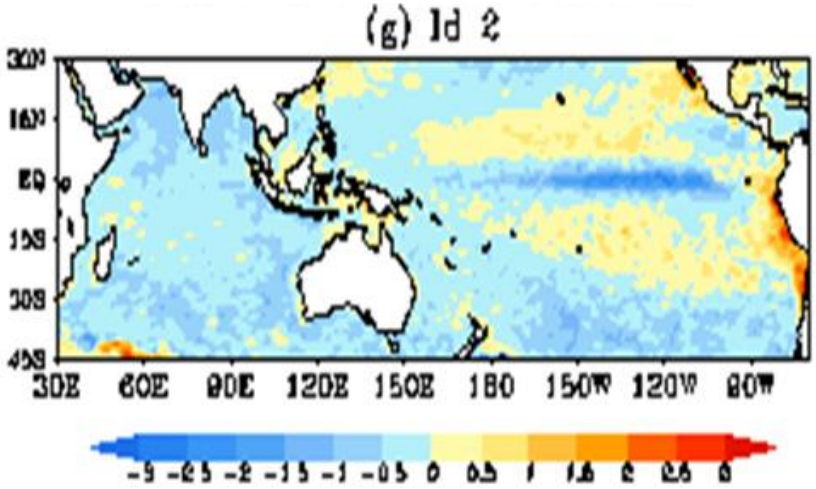
Positive K_s bias to south and west of Australia allows too much wave propagation west of Australia: ***MJO/IOD teleconnection gets smeared out***

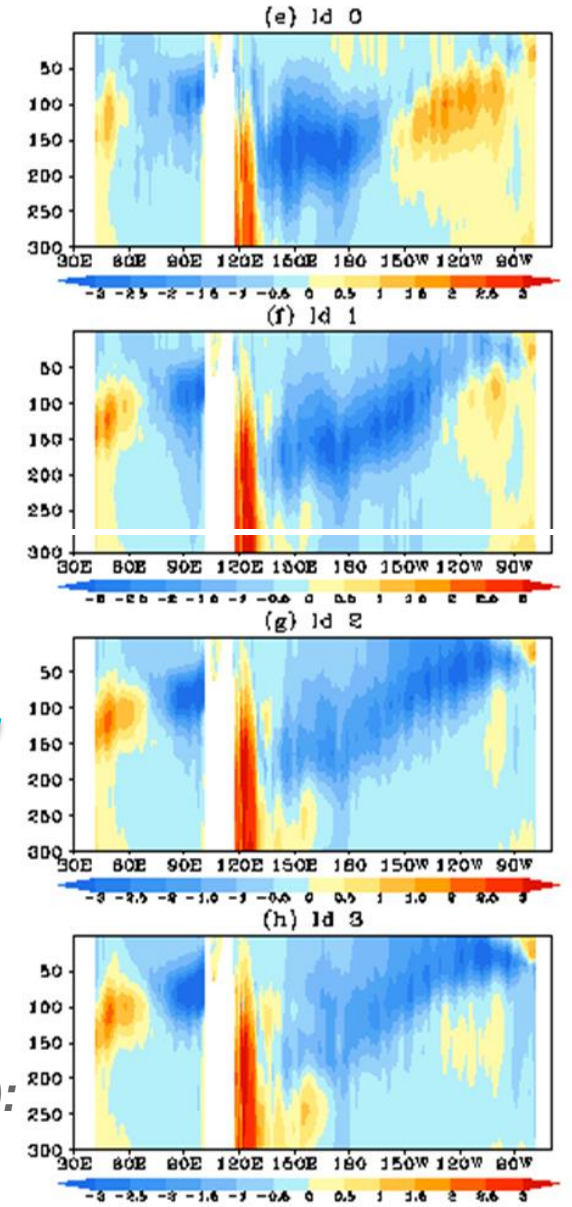
Evolution of biases in ocean

Temperature Bias section along equator

Model – obs mean (PEODAS analysis)

SST Month 3





Month 1

Month 2

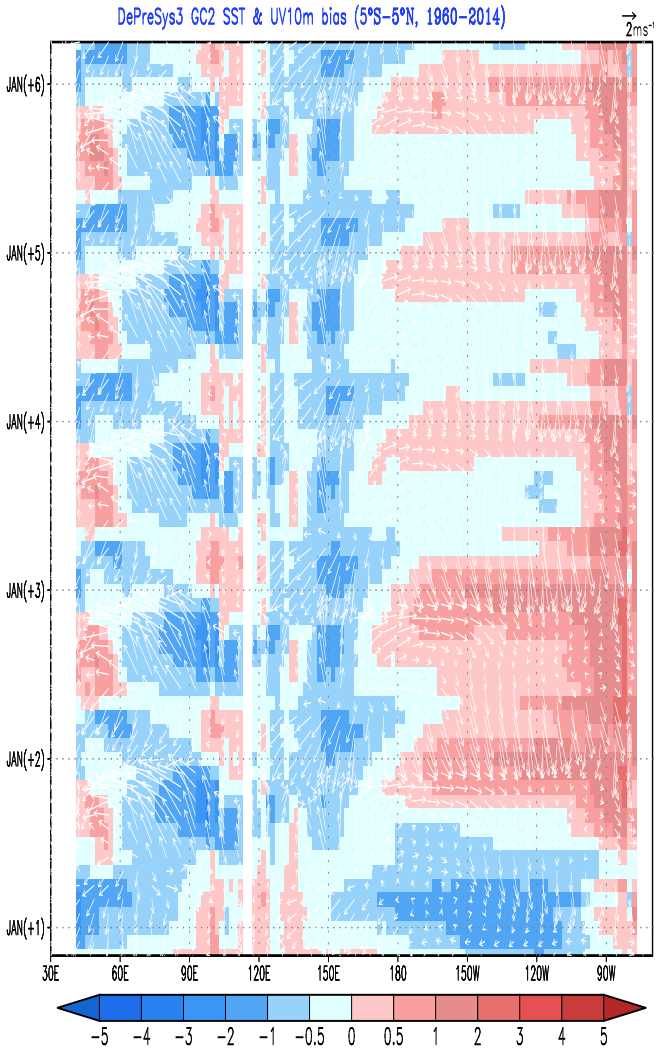
Month 3

Month 4

Bias emerges from systematic bias in initial state of western Pacific thermocline (too cold): Problem with NEMOVAR assimilating altimetry?

Climatology bias 5N-5S (1960-2014):

DecPreSys 66 months



Evolution of Ocean bias

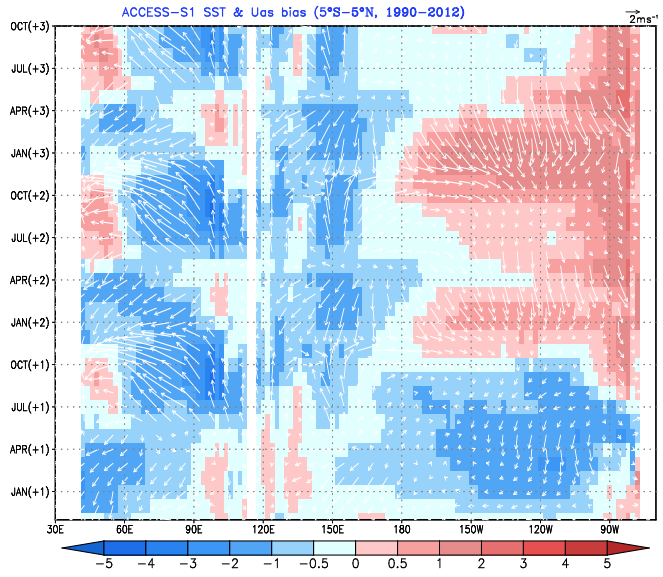
ACCESS-S1 36 months 1990-2012
Bias SST 5N-5S

Jul +3

Jul +2

Jul +1

Nov 0



Takes >1 yr for SST bias to equilibrate: refer to as coupled shock. Problematic because causes evolving impact on amplitude of ENSO during seasonal forecast

Australian Government
Bureau of Meteorology

ACCESS-S2

- Short term motivation: Break dependency on UKMO ocean/ice initial conditions
- Same GC2 model (UKMO seasonal showed limited improvements with GC3) > have to live with same biases
- Simplified version of BoM/CSIRO Weakly Coupled ocean assimilation (static ensemble)
- Expanded hindcasts: 37 years, 33 member ensemble hindcasts to support applications
- Was due in operations Feb 2020 (revised target end of 2020)

Australian Government
Bureau of Meteorology

ACCESS-S2 Coupled Assimilation

- Basic fast track version of BoM/CSIRO Coupled EnKF software (Pavel Sakov)
- Weakly coupled daily cycle (ie ocean assimilation in coupled model)
- Direct replacement of atmos basic variables (from ERA-interim)
- Ensemble OI in ocean – using static ensemble (simpler than POAMA)
- Land and sea ice initialized indirectly through coupling: seems ok for now
- Stronger nudging of SST than UKMO FOAM
- No Altimeter (only T/S profiles)
- Multi-variate co-variances– ocean current increments
- 1981-present ocean/land/sea ice re-analyses
- Same ad hoc atmosphere ensemble scheme as in ACCESS-S1 (perturb atmos only);
- Same ensemble size in real time but more hindcast members for multiweek

So far so good: a bit better performance than S1 and less ocean shock
On track now to go operational end of 2020

ACCESS-S3: Target 2025

First time to upgrade model: GC5 (or 6?)

- Model improvements from partnership between BoM/USQ/UKMO targeting key tropical biases (IOD/MJO)
- We are not targeting increased resolution (yet)

Assimilation: weakly coupled EnKf (joint BoM/CSIRO development)

- Still use atmospheric analyses as "observations"
- Include altimetry for ocean
- Assimilate SST and sea ice
- Land initialization continue to be indirect
- Basic coupled perturbations directly from assimilation
- More advanced stochastic parameterizations available possibly in NEMO ocean model as well, but need to convince ourselves of their utility (e.g., we found SKEB to be useless)