Towards Development of Multiyear Climate Prediction Framework for Australia

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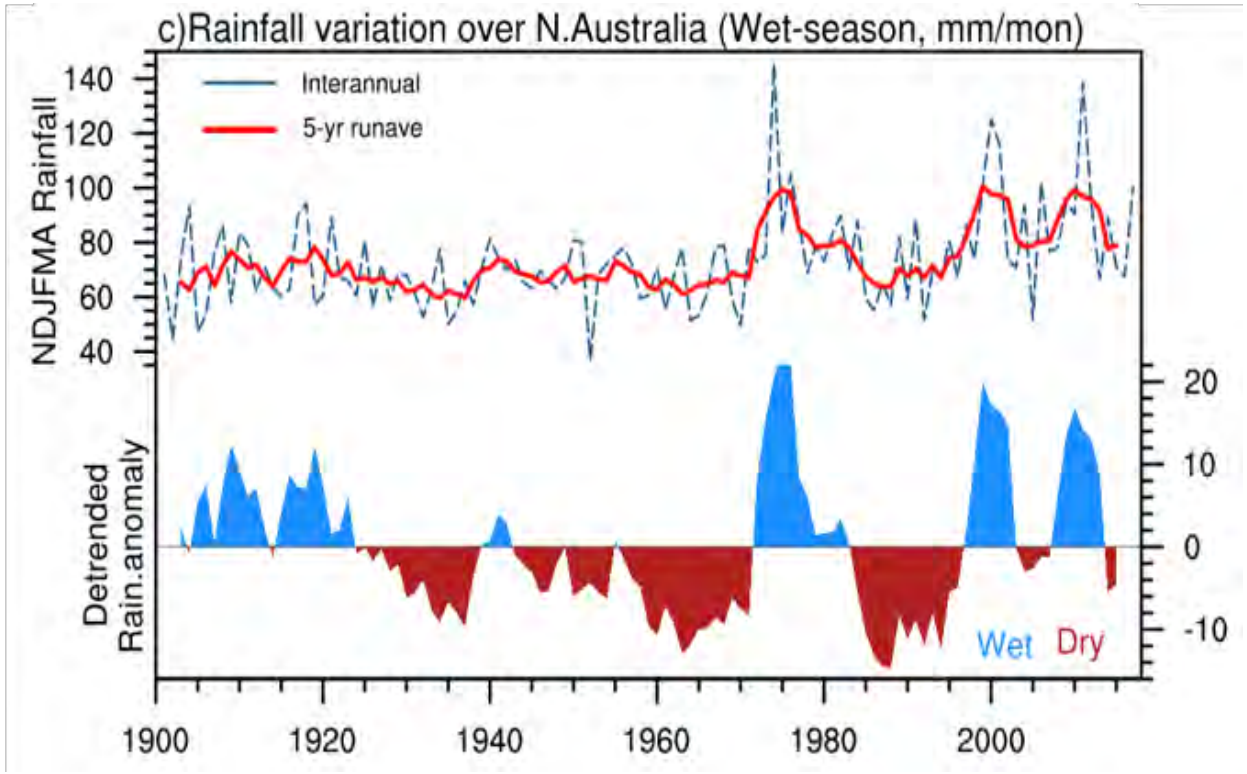
NACP NACP/BOM

Northern Australia Climate Program

Motivation

Northern Australia Climate Program



Australia experiences droughts & pluvials at multiyear timescales that have pronounced impacts on climate-sensitive sectors including agriculture.

NACP aims to improve understanding of multiyear variations and to assess of the feasibility and potential predictability for multiyear climate forecasts – with a focus on Northern Australia

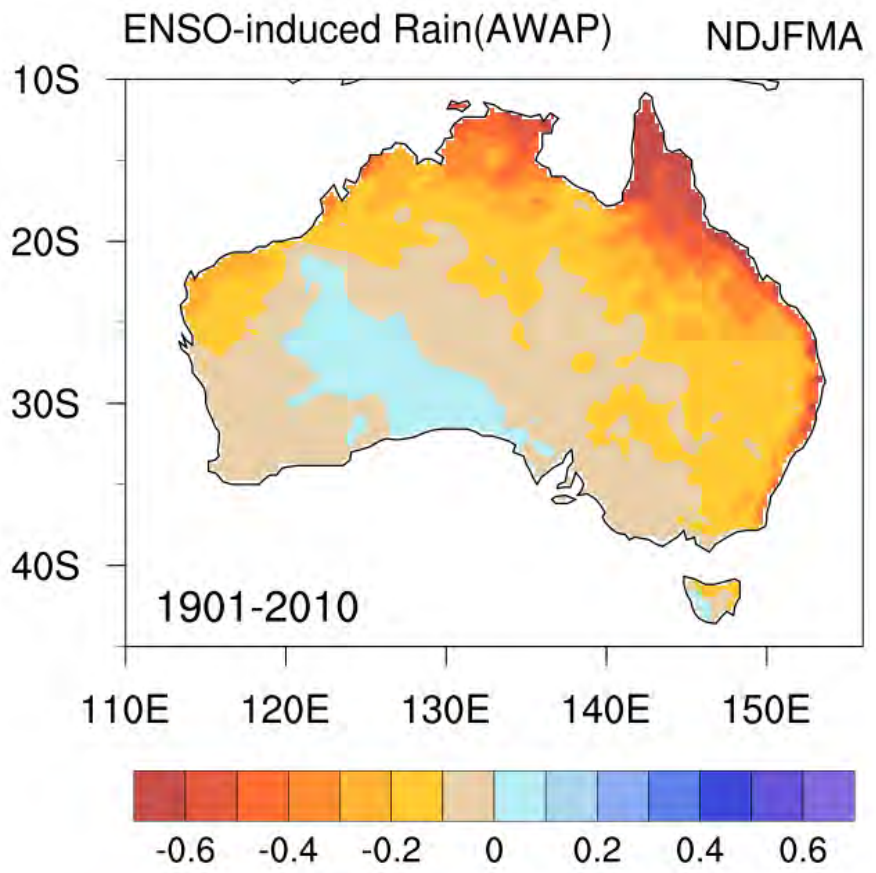
Multiyear Climate Prediction Framework for Australia

Motivation

Long-range ENSO prediction

- ENSO has significant impacts on regional Australia via atmospheric teleconnections - ENSO events lasting for 2 or more years can cause more severe socio-economic distress.
- There is a growing demand for long-range ENSO prediction and multiyear climate information in Australia.

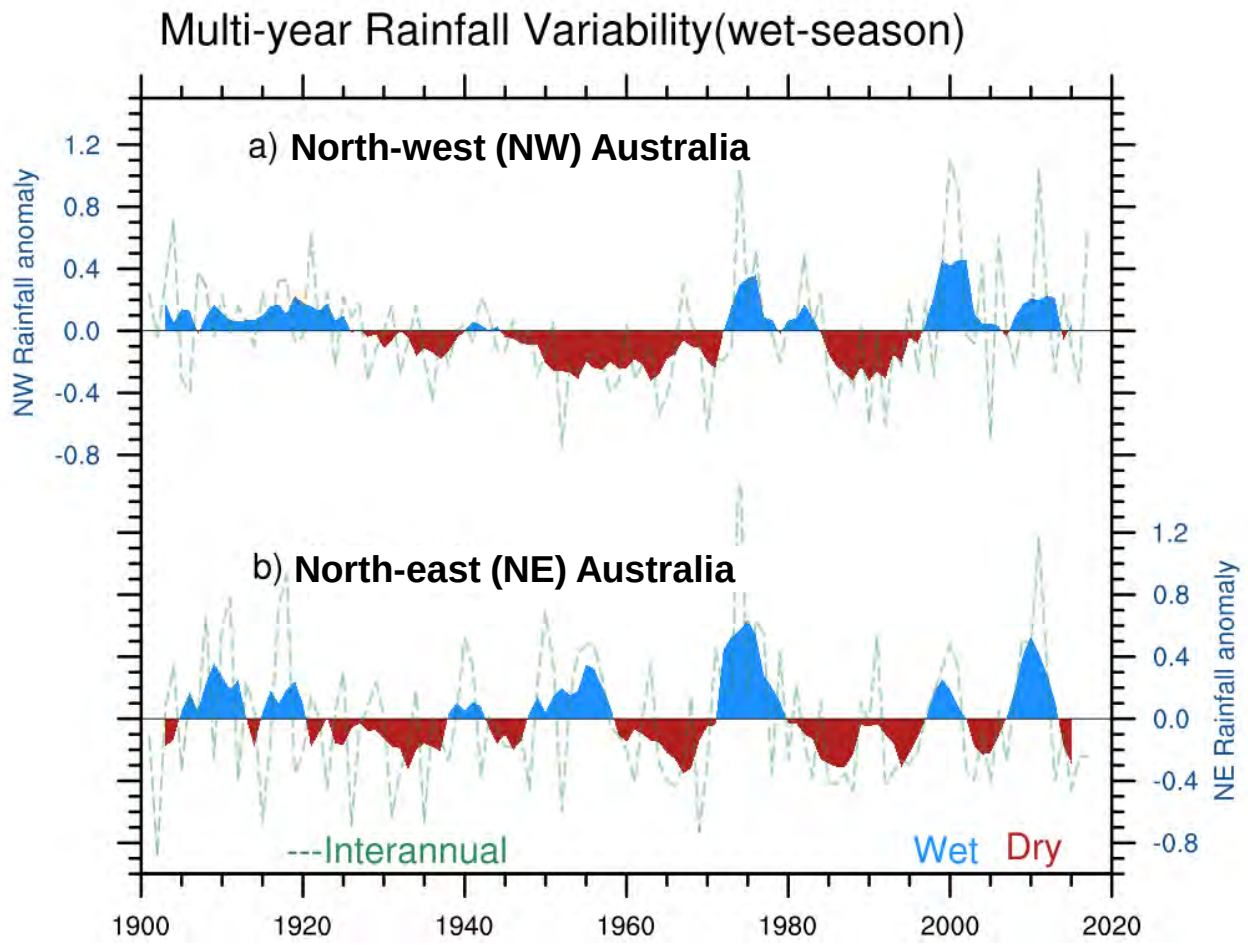
- Skilful prediction of ENSO and its related climate impacts beyond a year is crucial for effective risk management in Australia.
- Previous studies indicate predictive skill of ENSO well beyond the typical 6-9 months lead time used by operational centres.
  e.g. ENSO/climate outlooks from BoM limited to 6-month lead time only.
- Efforts on quantifying ENSO prediction skill beyond a year remain limited, partly due to inadequate long records of seasonal reforecasts.



Wet-season rainfall regressed onto Nino3.4 index

Skilful long-range prediction of ENSO and related impacts beyond a year will be valuable.

What drives multiyear wet/dry conditions over northern Australia?



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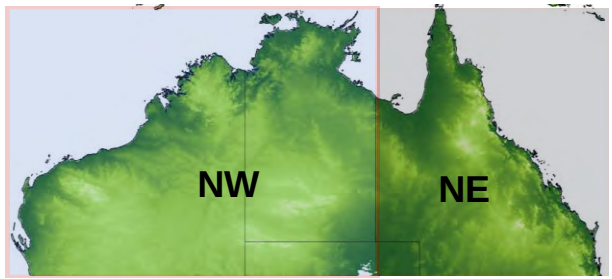
Mechanisms of multiyear variations of Northern Australia wet-season rainfall

S. Sharmila[1,2*] & Harry H. Hendon[2]

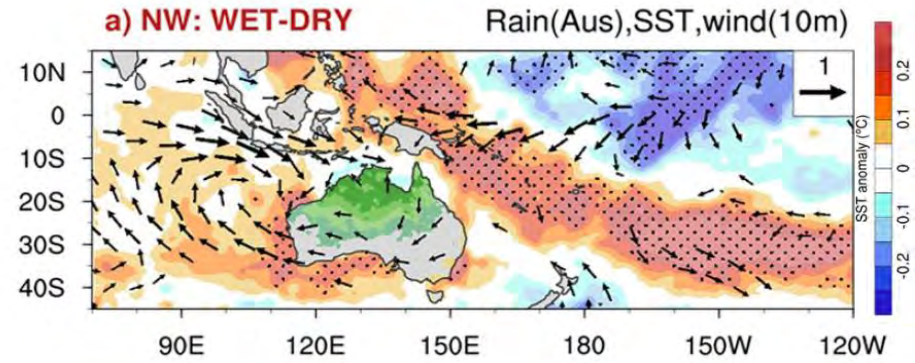
- **Regional asymmetry** in multiyear rainfall variation.



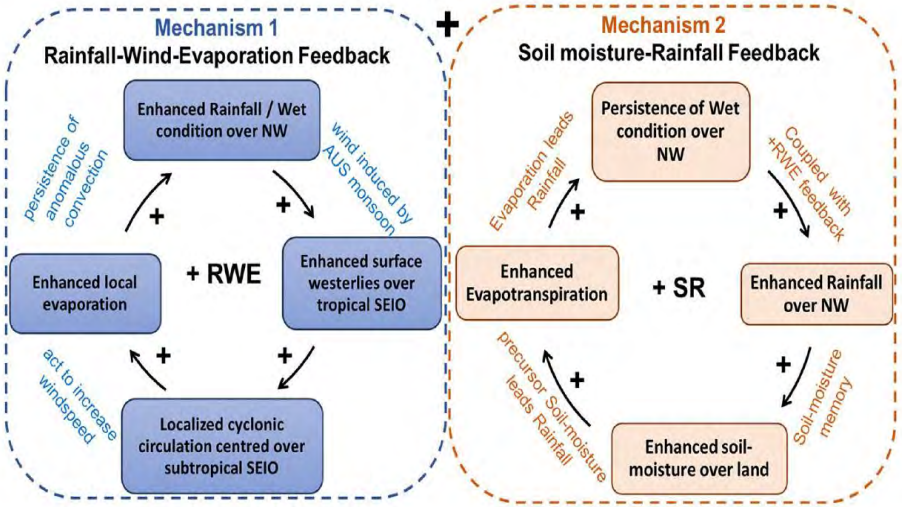
Sharmila and Hendon 2020

What drives multiyear wet/dry conditions over northern Australia?

North-west (NW) Australia



a) Mechanisms for NW multiyear rainfall



Multiyear NW rainfall modulated by local rainfall-wind evaporation feedback & rainfall-soil moisture feedback.

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OPEN **Mechanisms of multiyear variations of Northern Australia wet-season rainfall**

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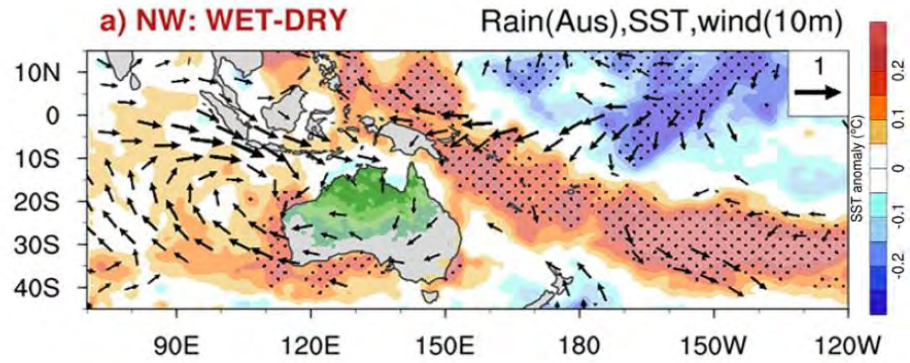
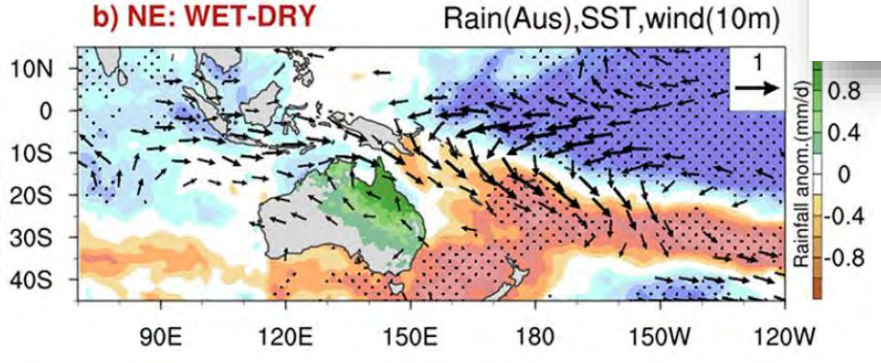
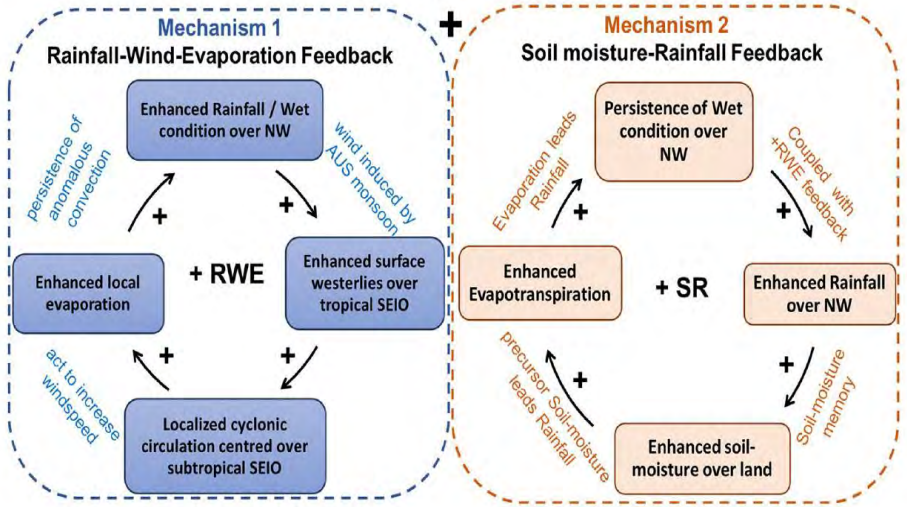
North-west (NW) Australia



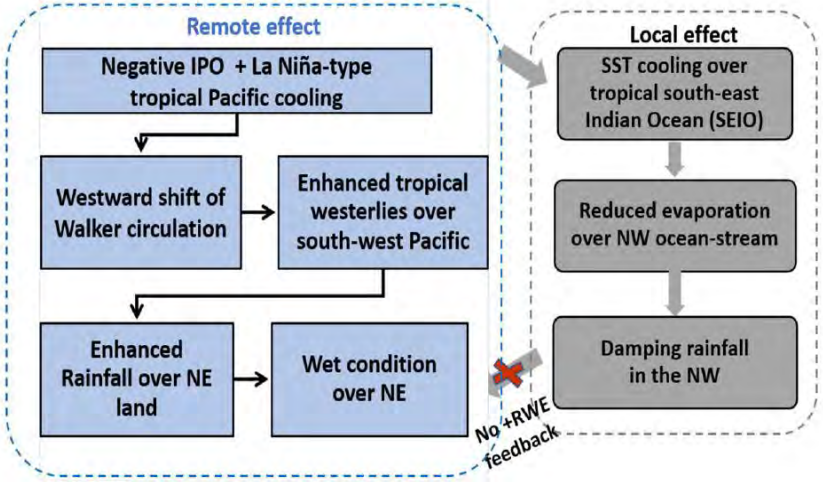
North-east (NE) Australia



a) Mechanisms for NW multiyear rainfall



b) Mechanism for NE multiyear rainfall



Multiyear NW rainfall modulated by local rainfall-wind evaporation feedback & rainfall-soil moisture feedback.

Multiyear NE rainfall modulated by remote low-frequency ENSO induced tropical Pacific SST

- **Regional asymmetry** in multiyear rainfall variation.
- Role of **local vs remote** drivers on observed multiyear rainfall variability over northern Australia.

Sharmila and Hendon 2020

Assessment of ENSO predictability beyond a year

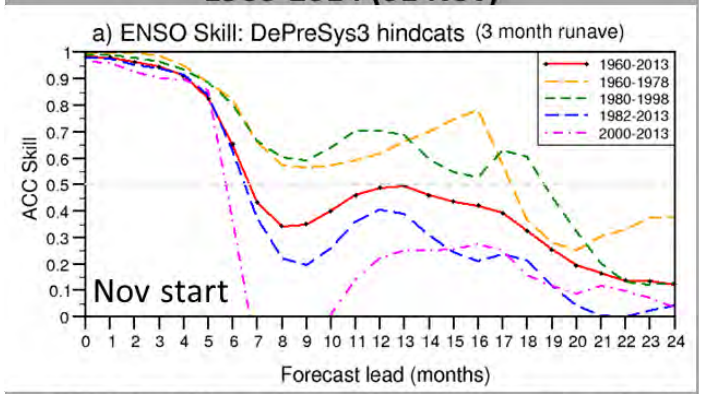
from experimental multiyear hindcasts

Northern Australia Climate Program

Previous assessment with limited ensembles

DePreSys3 (Met Office)

10 member 66-month hindcasts
1960-2014 (01 Nov)



ENSO skill varies with hindcast period

Based on 25 start dates only

Data accessed from Nick Dunstone (UKMO)

Complete set of multiyear hindcasts (1981-) using ACCESS-S2 in currently underway

ACCESS-S2 (BOM)

6 member 60-month hindcasts
1981-2014 (01 May)

skilful ENSO prediction of 1-year lead time with May start

Limited ensemble

Short hindcast period

Running multiyear hindcasts - computationally very expensive!

SEAS5-20C (ECMWF)

10 member 24-month hindcasts
1901-2010 (1 May, 1Nov)

Weisheimer et al. 2022

Initial Conditions: CERA-20C

- To address various aspects of ENSO predictability.
- To assess prospects for 2-year climate prediction.

Multiyear Climate Prediction for Northern Australia

Skillful long-lead ENSO prediction will provide a new foundation for predicting multiyear climate over Australia !

Model

ECMWF model (SEAS5-20C)

Weisheimer et al. 2021

1901-2010, 10-member, 24-month hindcasts

a state-of-the-art coupled model and data assimilation system

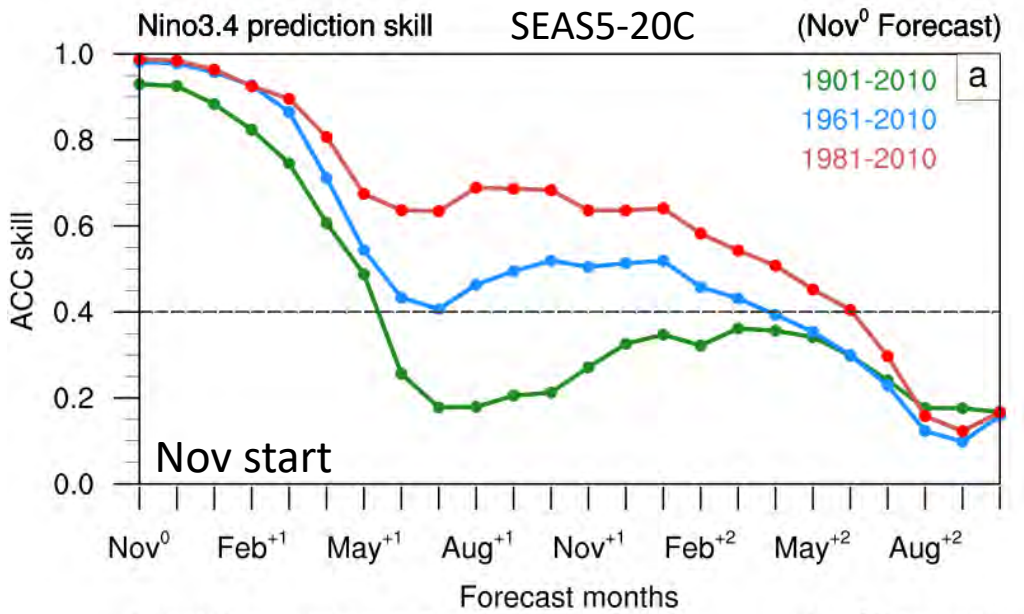
- ECMWF's Integrated Forecasting System (IFS) coupled model – similar to SEAS5
- SEAS5 low-resolution configuration
- Initial conditions : ECMWF Reanalyses of the 20th Century (CERA-20C)
- Coupled data assimilation
- Start date: 1 November and 1 May
- 24-month hindcasts with 10 ensemble members
- Hindcast period: 1901-2010, 110 years

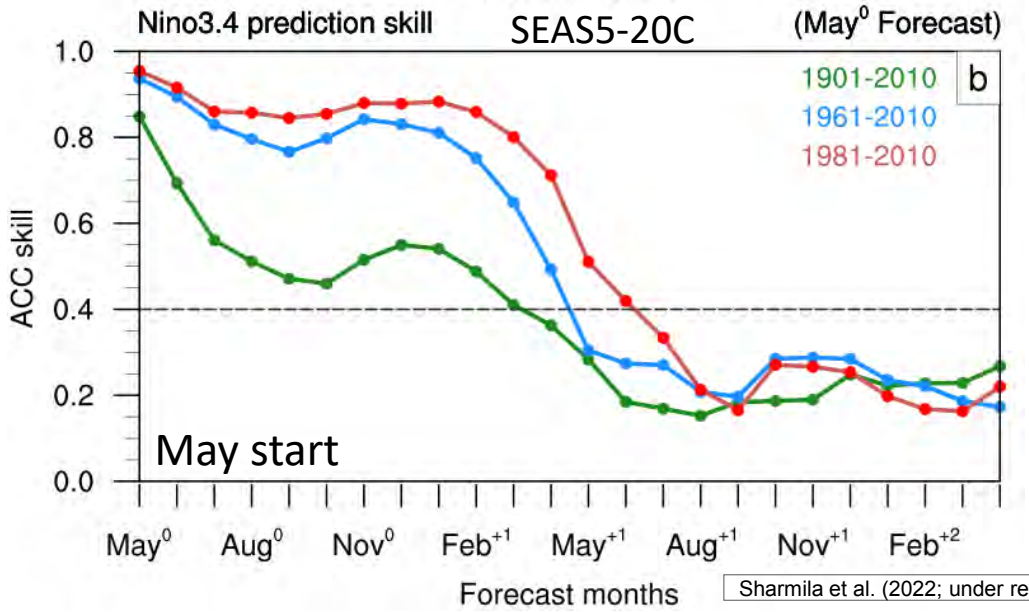
Data for verification: ERSST.v5 (SST), AWAP (rainfall) etc.

This assessment aims to provide crucial insights on some fundamental questions related to ENSO predictability & prospects for 2-year climate prediction!

Long-lead ENSO prediction skill

ENSO Predictability beyond a year





Sharmila et al. (2022; under review)

How far ahead can we predict ENSO?

- ENSO can be skillfully predicted up to 18 months in advance (1 Nov start).
- Skill largely depends on the hindcast period
  – best forecasts achieved in the recent period.

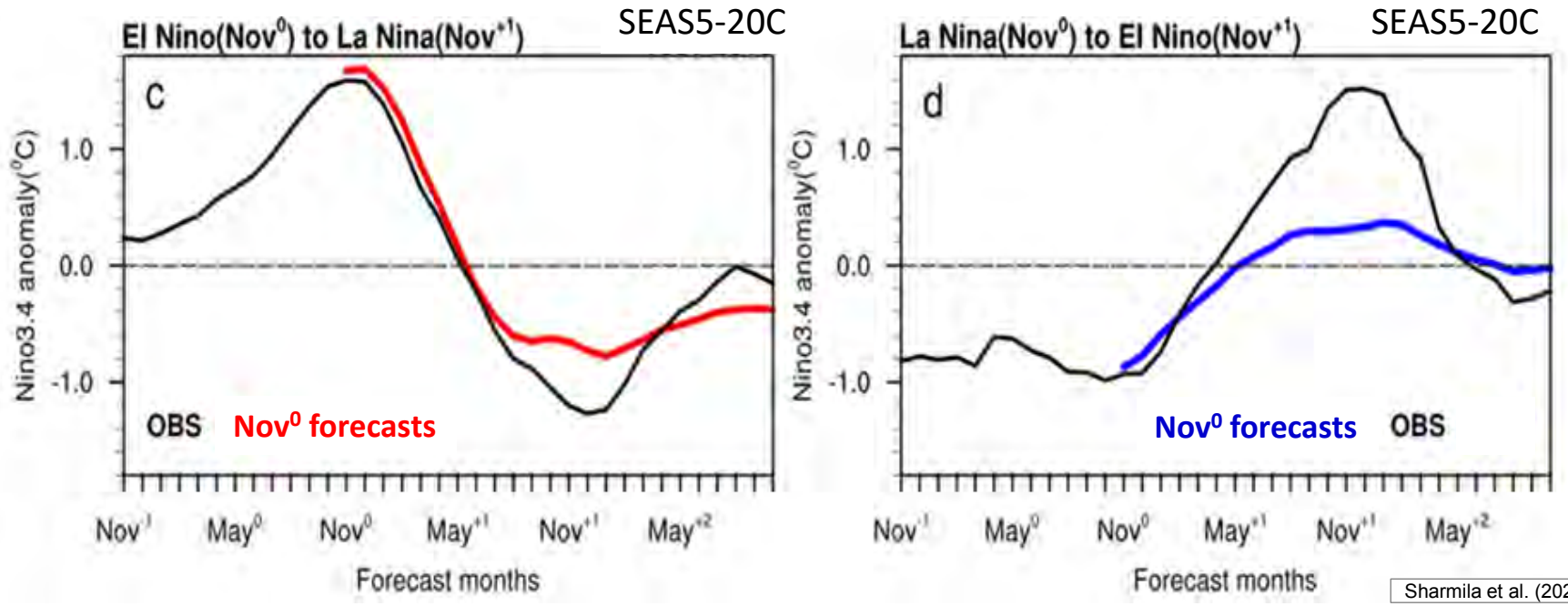
- ENSO may be predictable 1 year in advance when initialized on 1st May.

- Strong decadal variation in ENSO prediction skill is also noted (Weisheimer et al. 2022).

Long-lead prediction of El Nino and La Nina

Which ENSO phase is more predictable?

Ensemble mean forecast
(Subset of El Nino/La Nina events)



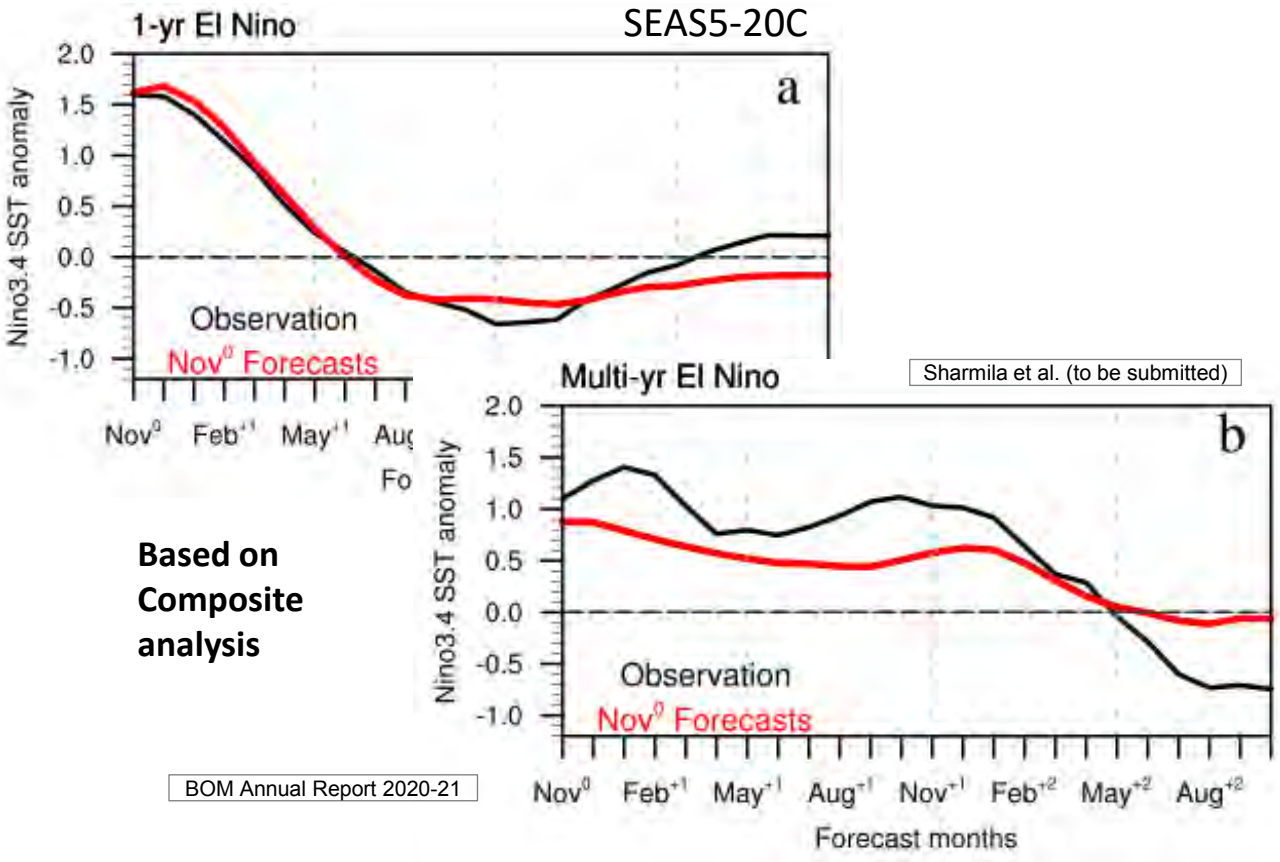
Sharmila et al. (2022; under review)

Composite temporal evolution of Nino3.4 SST anomaly

El Nino to La Nina transition is more predictable.

- Development of La Nina in year 2 is more predictable.

Prediction of multiyear ENSO events



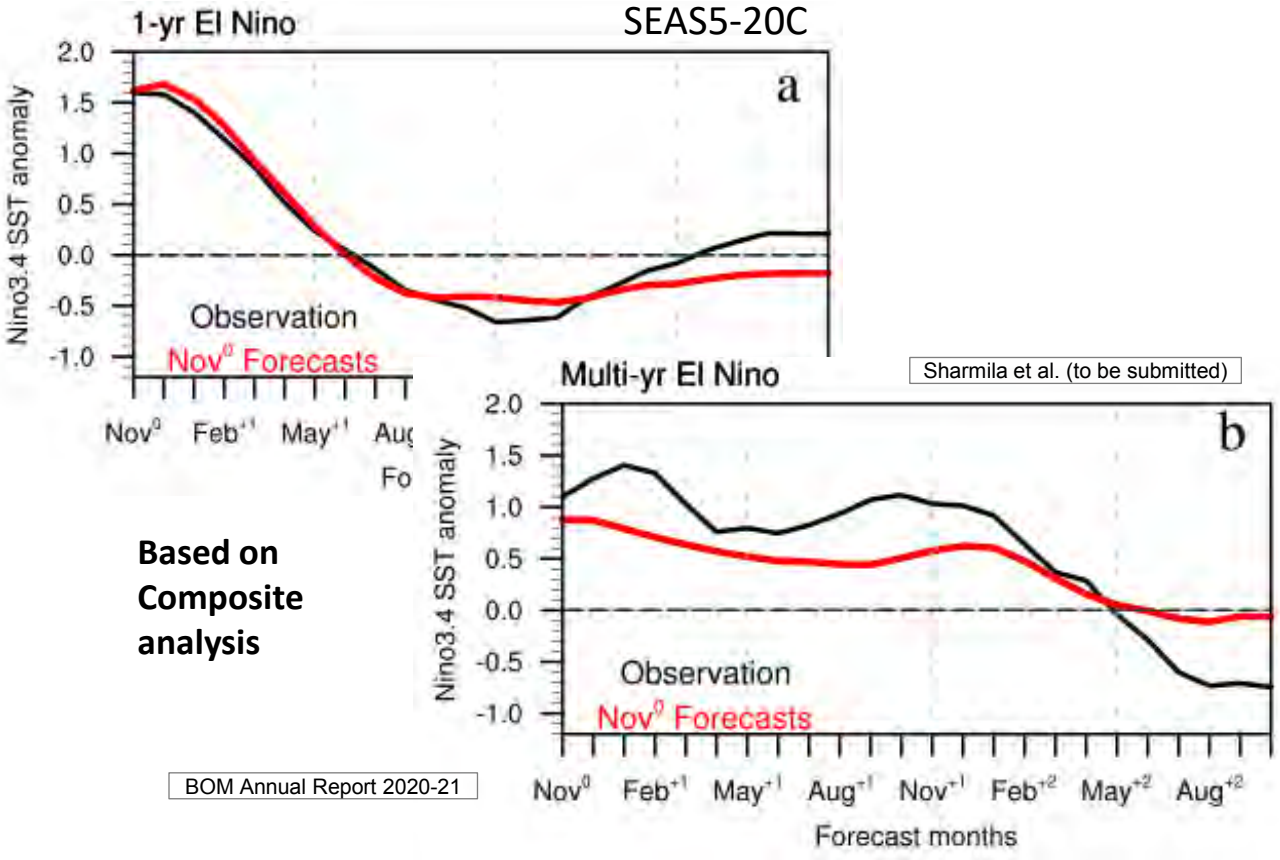
Sharmila et al. (to be submitted)

Based on Composite analysis

BOM Annual Report 2020-21

- Model forecasts can predict if a current El Niño will terminate in the following year or continue – but underestimate the magnitude.

Prediction of multiyear ENSO events



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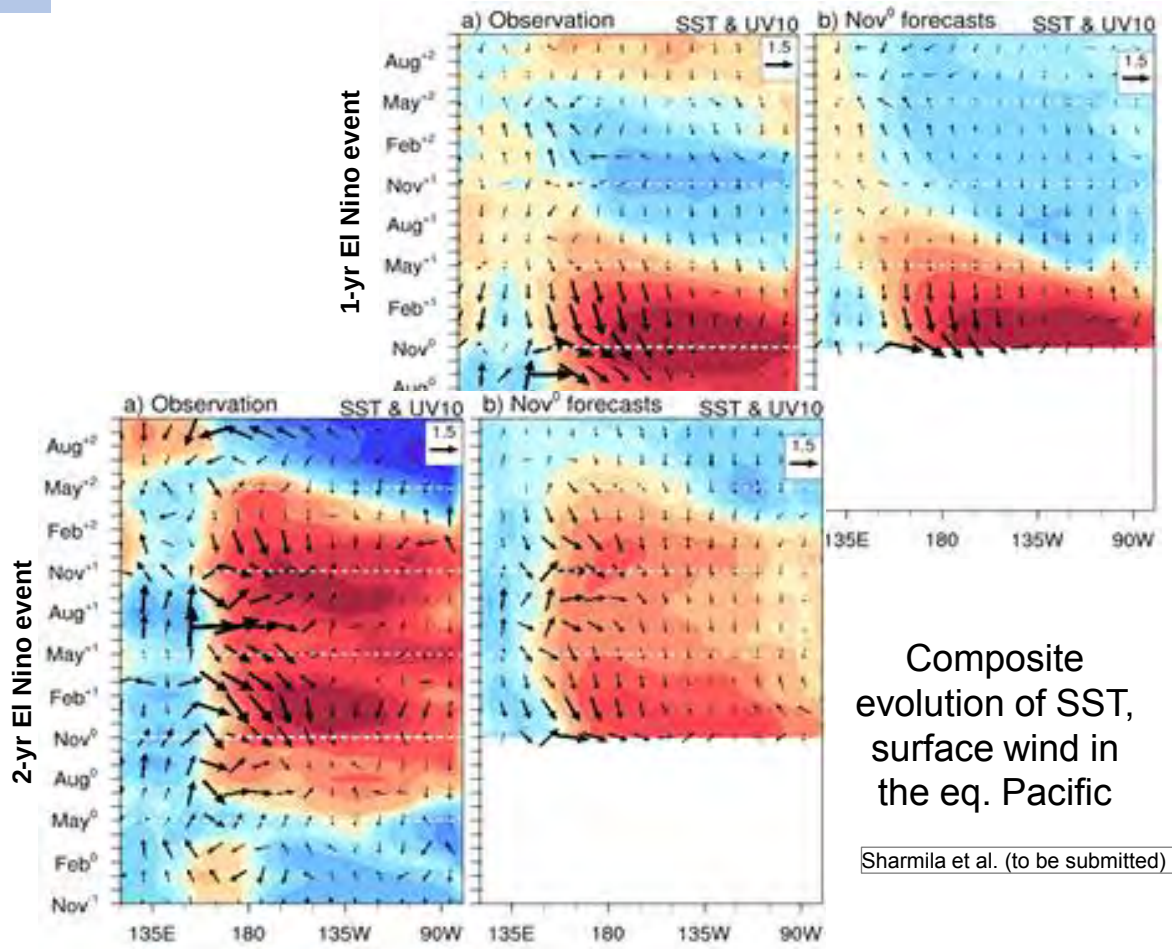
Based on Composite analysis

BOM Annual Report 2020-21

- Model forecasts can predict if a current El Niño will terminate in the following year or continue – but underestimate the magnitude.

Recommends to extend ENSO outlooks at least 2 years into the future – currently BoM provides up to 6 months only.

Physical processes controlling predictability of ENSO duration

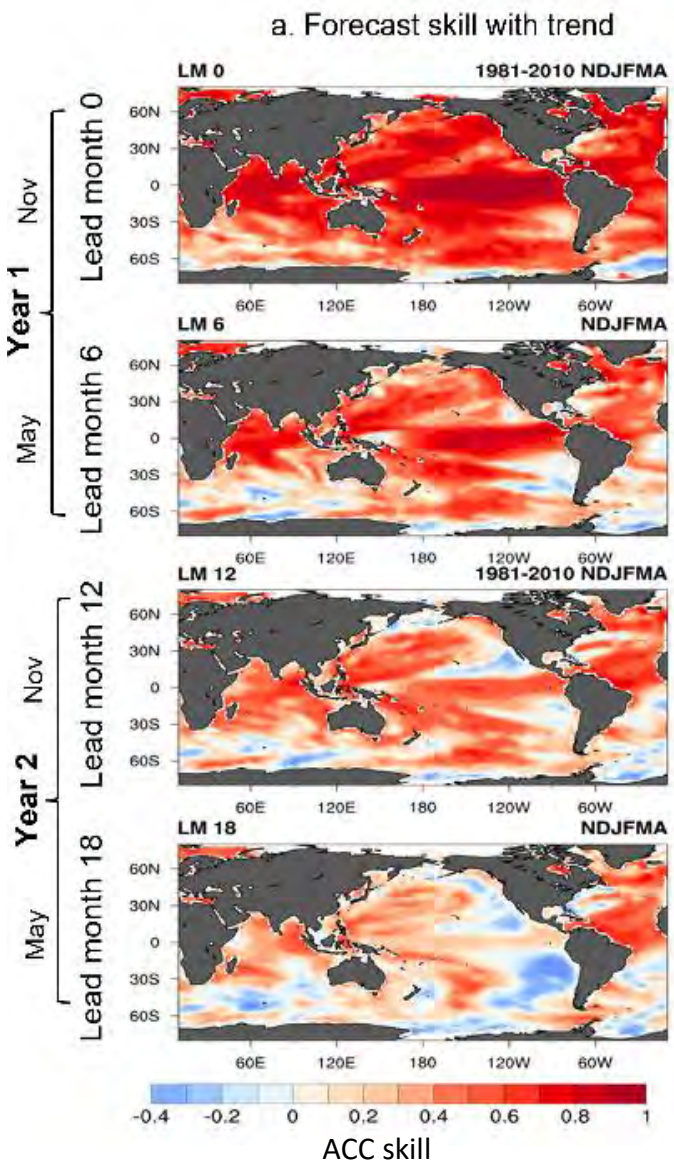


Composite evolution of SST, surface wind in the eq. Pacific

Sharmila et al. (to be submitted)

Model can predict distinct evolution of SST and surface wind for 2-yr El Nino events though underestimates the magnitude.

2-year climate prediction: Global SST (NDJFMA)

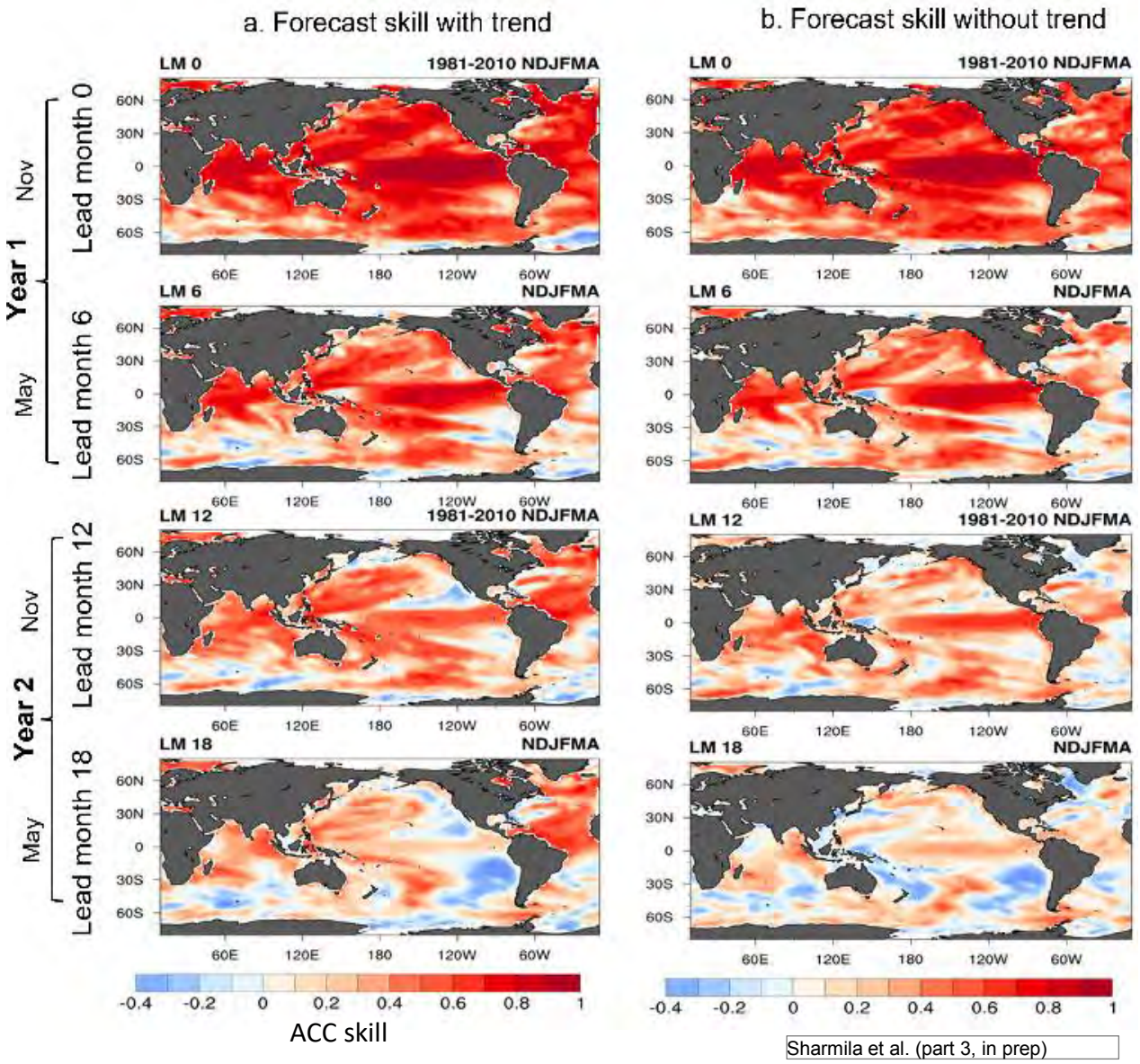


- 2-year prediction of wet-season global SST anomalies is skilful over most of the oceans especially in the equatorial Pacific region.

Sharmila et al. (part 3, in prep)

2-year climate prediction: Global SST (NDJFMA)

SEAS5-20C



Sharmila et al. (part 3, in prep)

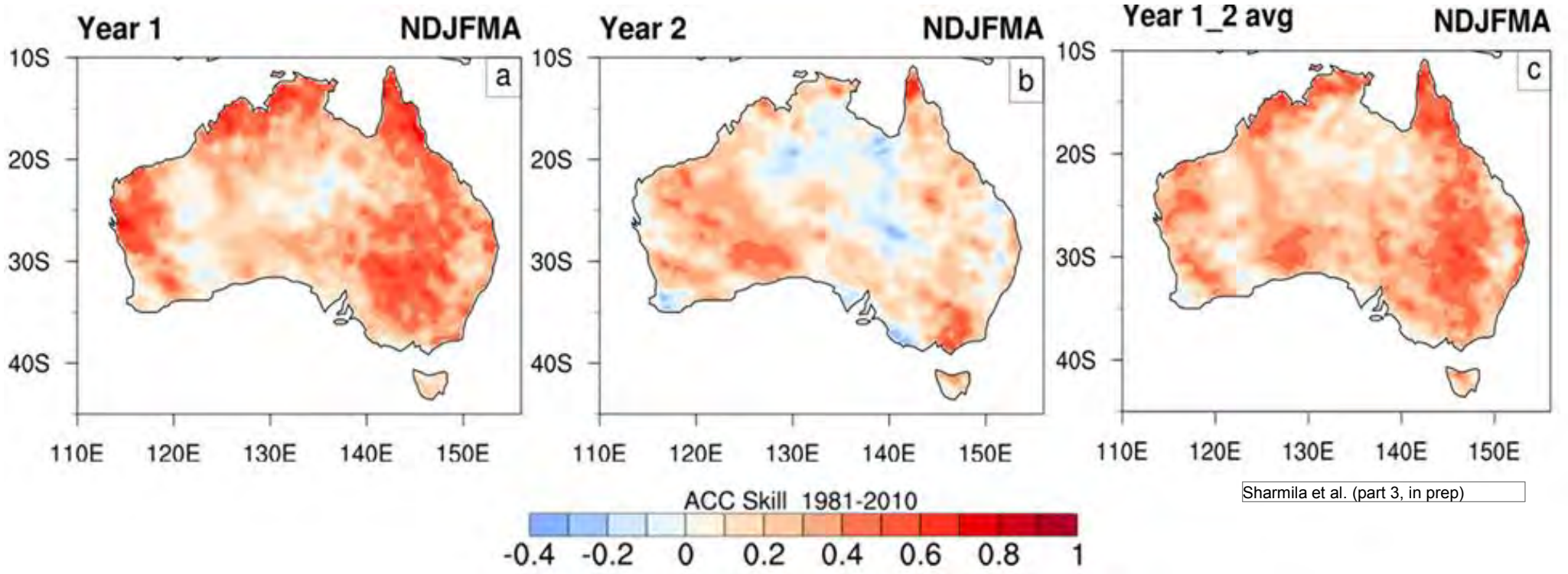
- 2-year prediction of wet-season global SST anomalies is skilful over most of the oceans especially in the equatorial Pacific region.

- The warming trends in the tropical Indian Ocean and north Atlantic also contributed to the overall skill, signifying the role of forecasted trends on multiyear climate prediction.

Prospects for 2-year Prediction: Regional Rainfall (NDJFMA)

SEAS5-20C

Prediction Skill of northern wet-season Rainfall



Sharmila et al. (part 3, in prep)

- Skilful prediction of wet-season rainfall for year 1 & year 1_2 avg, especially in the eastern Australia.
- Many challenges remain, e.g., limited skill in predicting year 2 rainfall.
- More investigation required on model biases and process-oriented understanding of climate predictability to achieve greater confidence in future real-time operational forecasts.

Sharmila, Hendon, Alves, Weisheimer, Balmaseda: Prospects for 2-year prediction of regional climate. Part 3, (in prep.)

Summary

- **Improved basic science of multiyear droughts:** Improved industry and community knowledge on the drivers of multiyear climate variability and droughts over northern Australia.

- **Advanced knowledge on ENSO predictability:** Skilful long-lead ENSO prediction in ECMWF SEAS5-20C & predictability of multiyear ENSO events signify the prospects for extending seasonal operational forecasts beyond a year.
  - Key driver of BoM's future strategy for extending operational ENSO outlooks up to 2 years into the future.
  - 2-year experimental hindcasts from ACCESS-S2 are currently underway for further assessment.

- **Development of a multiyear climate prediction framework for Australia:** Skilful 2-year prediction of global and regional climate - will be highly useful for managing droughts, climate risk and decision making across Australia.

Skilful prediction of ENSO beyond a year provides a new foundation for forecasting prolonged droughts & widespread flooding at multiyear timescales.

- Sharmila S., and H. Hendon (2020) Mechanisms of multiyear variations of Northern Australia wet-season rainfall. *Scientific Reports*, 10, 5086.
- Weisheimer, A, Balmaseda M, Stockdale T, Mayer M, de Boisseson E, Senan R, Johnson S (2021) Retrospective two-year ENSO predictions during the 20th century. ECMWF Newsletter, 169, 7-8. https://www.ecmwf.int/sites/default/files/elibrary/2021/20225-newsletter-no-169-autumn-2021.pdf
- Sharmila S, Hendon H, Alves O, Weisheimer A, Balmaseda M (2022a): Contrasting El Niño and La Niña forecast skill in SEAS5-20C coupled model 2-year reforecasts 1901-2010 (under review)
- Weisheimer A, Balmaseda MA, Stockdale TN, Mayer M, Sharmila S, Hendon H & Alves O (2022): Variability of ENSO forecast skill in 2-year global reforecasts over the 20th Century (under revision).
- Sharmila S, Hendon H, Alves O, Weisheimer A, Balmaseda M: Long-lead prediction skill of multiyear ENSO events in ECMWF 2-year long 20th Century reforecasts (to be submitted).
- Sharmila S, Hendon H, Alves O, Weisheimer A, Balmaseda M: Prospects for 2-year regional climate prediction (in prep.)

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Data & Method

- We explored observational and reanalysis datasets (1901-2017) to identify key drivers of multiyear rainfall variation across northern Australia. More details on various methods used are available in Sharmila and Hendon (2020).

- To explore multiyear ENSO predictability and to develop a more general framework for multiyear climate prediction, we assessed large ensembles of multiyear coupled model experimental hindcasts from DePreSys3 (UKMO; 1960-2014, limited Nov start dates) and ACCESS-S2 (BoM; 1981-2014, May start) with forecast lead time over 60 months and 110 years of hindcasts from SEAS5-20C (ECMWF, 1901-2010, Weisheimer et al. 2021, Nov & May start) with forecast lead time of 24 months.

- We used standard metrices and statistical methods to evaluate the model biases, and prediction skill.

- We removed the model drift by subtracting the model's climatology from each ensemble forecast at each lead time before assessing the prediction skill.

- More details on the model, hindcasts and verification methods are available in the submitted papers (e.g., Sharmila et al. 2022a; Weisheimer et al. 2022).