Predictability of the Pacific Decadal Oscillation

Remote and Local Drivers in CESM SMYLE

Evan Meeker[1]

Elizabeth Maroon[1], Daniel Vimont[1], LuAnne Thompson[2], Stephen Yeager[3]

[1]Department of Atmospheric and Oceanic Sciences, University of Wisconsin Madison

[2]School of Oceanography, University of Washington Seattle

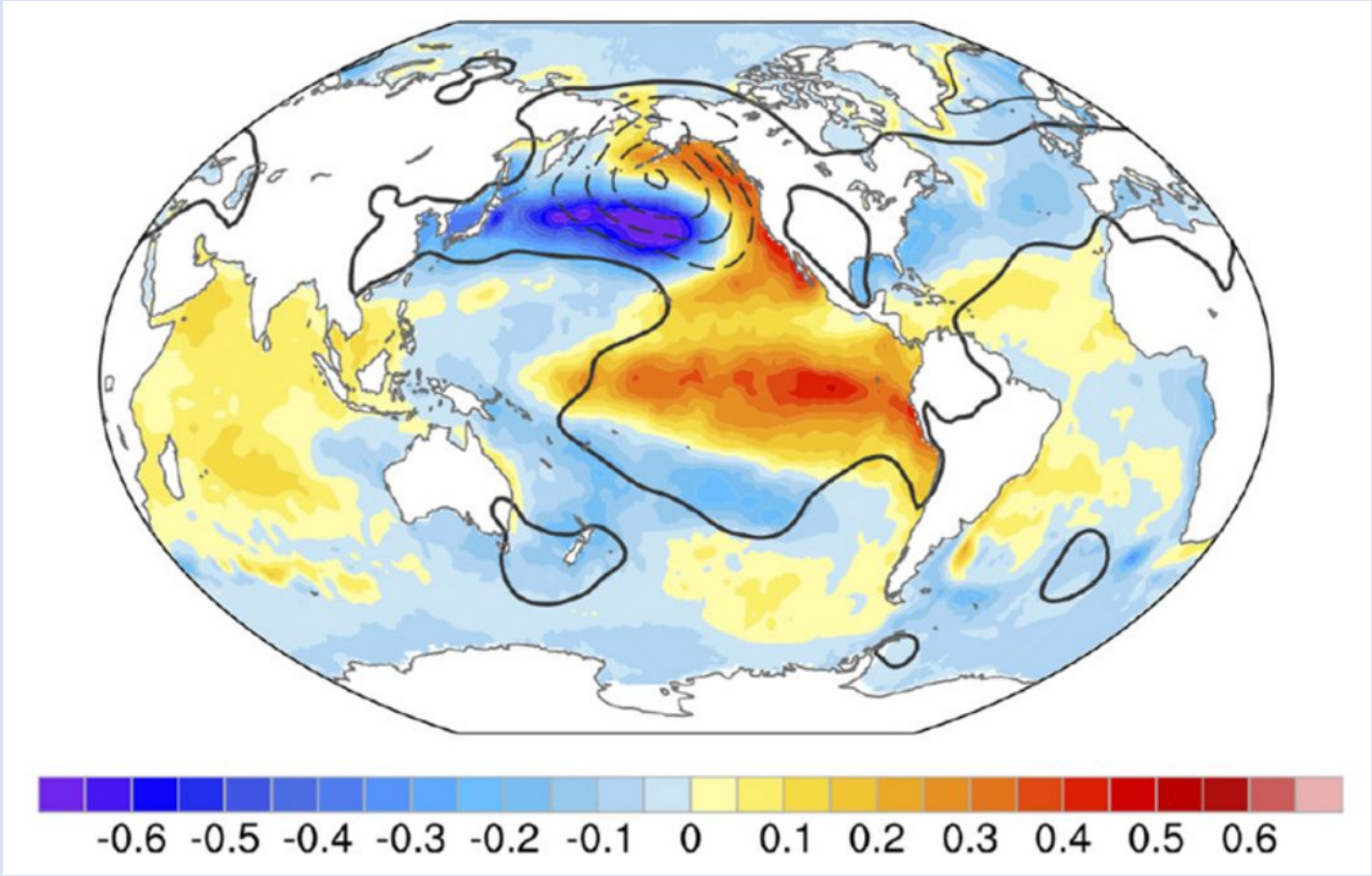
[3]National Center for Atmospheric Research, Boulder, Colorado

Work supported by the National Science Foundation under Grant OCE-2022740

What is the Pacific Decadal Oscillation (PDO)?

"The PDO was first introduced by Mantua et al. (1997) as the leading **empirical orthogonal function (EOF) of North Pacific (20–70N) SST** monthly averaged anomalies."

"Statistical modes may represent physical modes, but there need not be a one-to-one correspondence between them. A body of research exists showing how **different physical processes, including random atmospheric forcing, teleconnections from the tropical Pacific, and ocean Rossby waves/shifts in the basinwide ocean gyre circulation**, contribute to PDO variability on a variety of time scales and regions in the North Pacific Ocean."



Newman et al., 2016

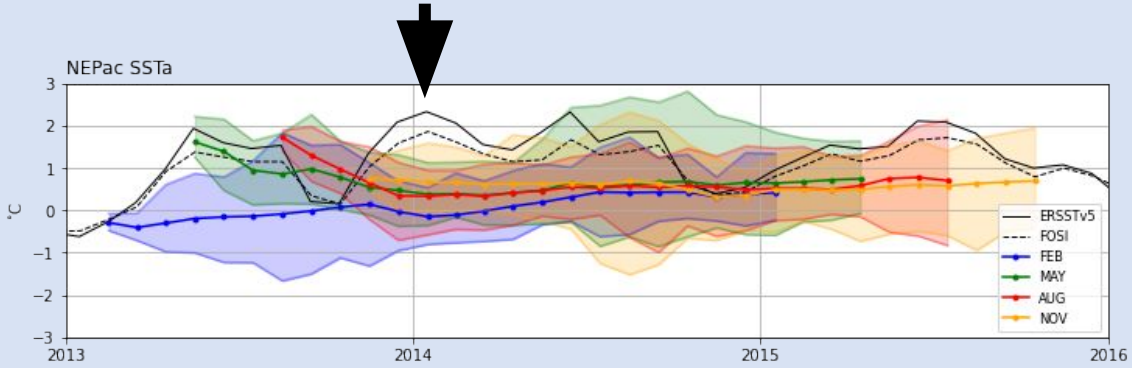
Dataset/Methods

- CESM2 Seasonal-to-MultiYear Large Ensemble (SMYLE) prediction system (Yeager et al., 2022)
  - 24-month hindcast simulations
  - Initialized quarterly (Feb, May, Aug, Nov) from 1970-2019
  - 20-member ensemble
  - Initialized with JRA55 atmospheric forcing and a Forced Ocean–Sea Ice (FOSI) model
- Drift correction using a 30-yr drift climatology [1981-2010]

- Prediction skill assessed using Anomaly Correlation Coefficient (ACC)
- Simplified predictions of the PDO using extended first-order autoregressive (AR1) models (more on this later)

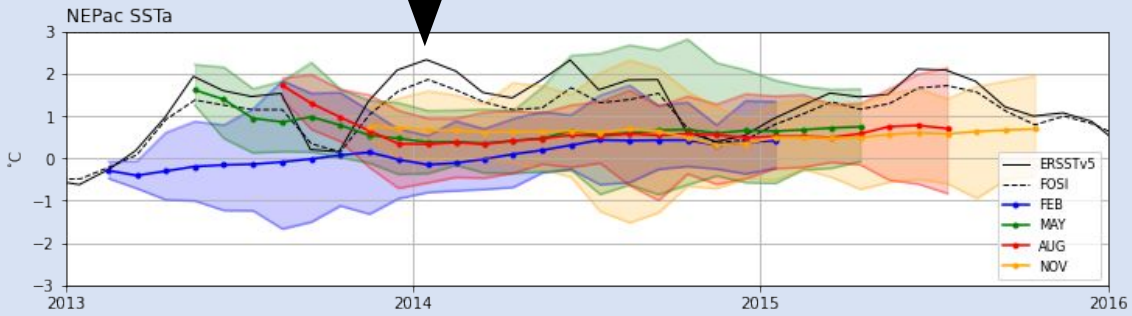
Background – The PDO and the Blob

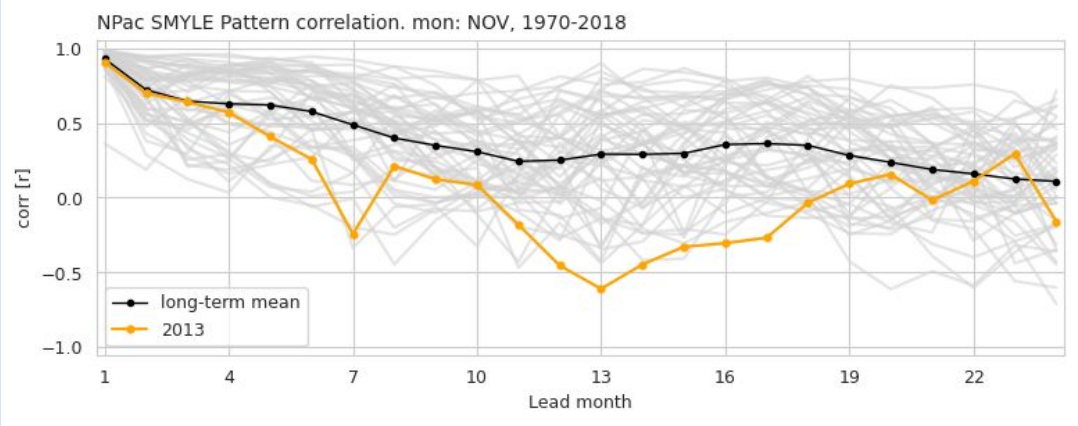
NE Pacific peak magnitude in Jan 2014 not predicted by any SMYLE ensemble member



Background – The PDO and the Blob

NE Pacific peak magnitude in Jan 2014 not predicted by any SMYLE ensemble member

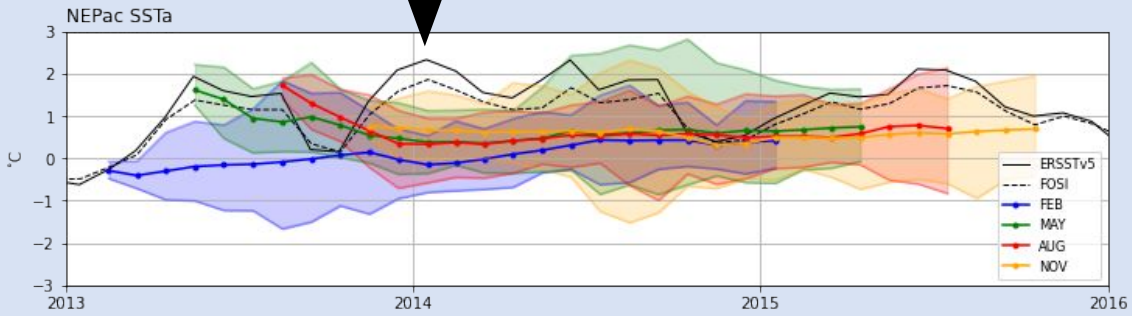


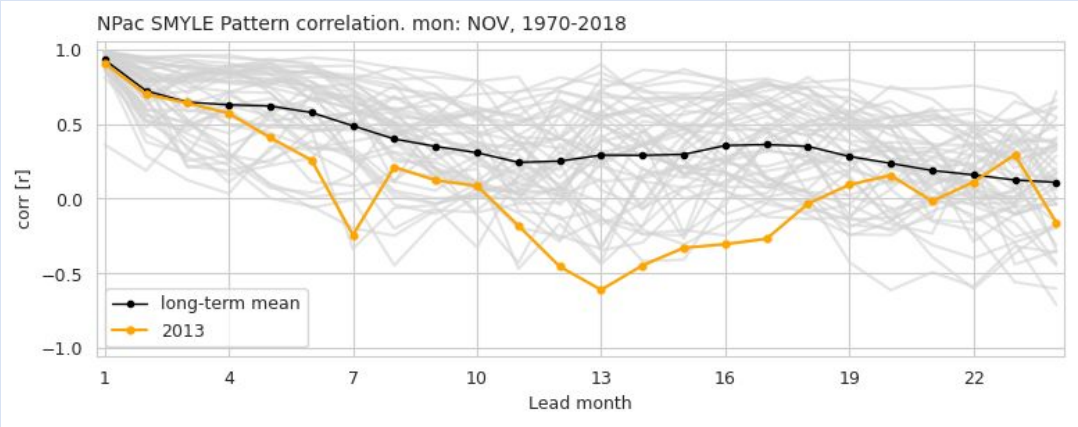


North Pacific SST anomaly *pattern* performs poorly, with negative correlation from 11-18 month leads

Background – The PDO and the Blob

NE Pacific peak magnitude in Jan 2014 not predicted by any SMYLE ensemble member

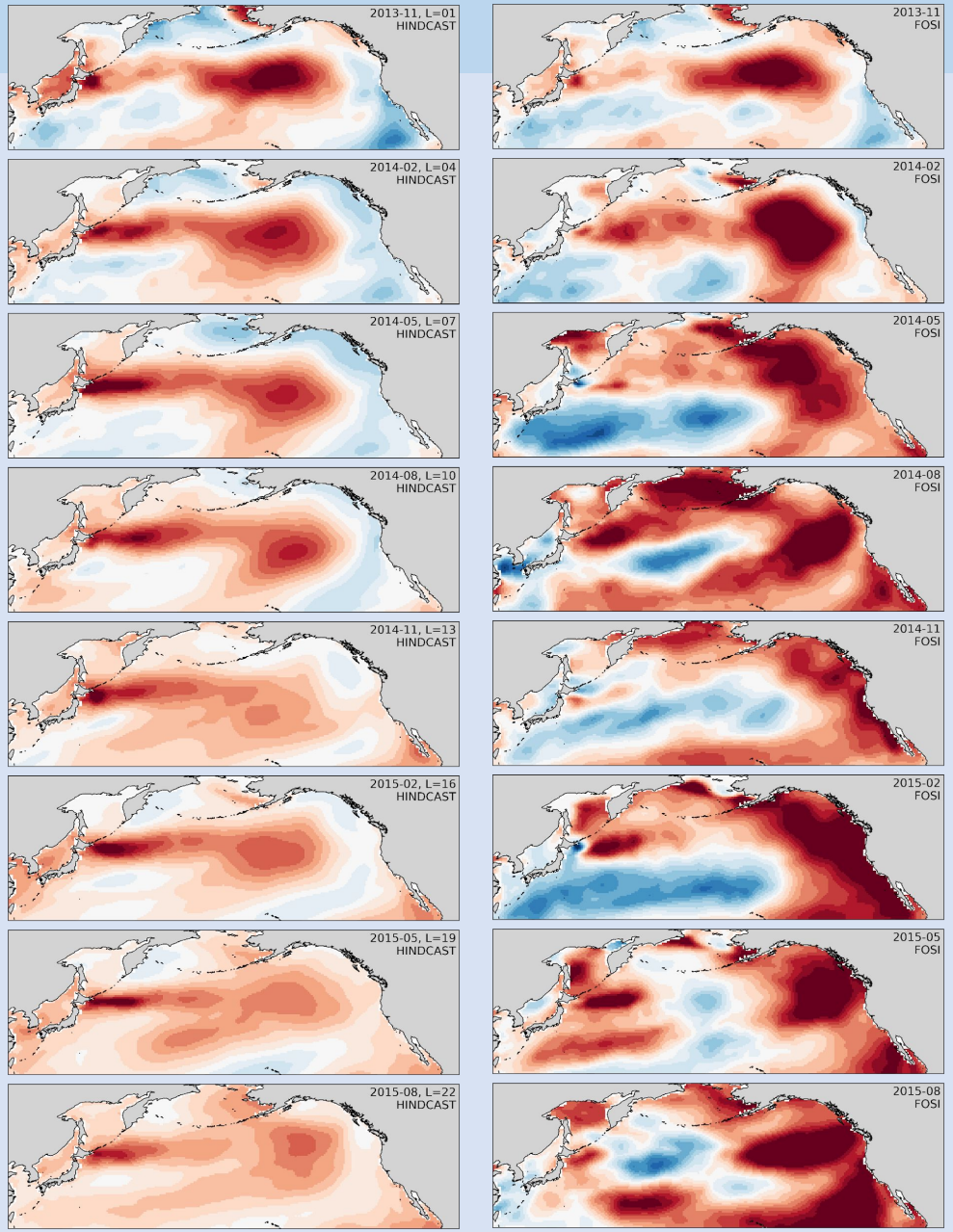




North Pacific SST anomaly *pattern* performs poorly, with negative correlation from 11-18 month leads

(left) **SMYLE** November 2013 initialization ensemble mean SST anomaly prediction.

(right) **Observed** SST anomalies ERSSTv5 (Huang et al., 2017)



Research Questions

- Why doesn't SMYLE predict the spatial evolution of the Blob? → Why doesn't SMYLE predict a change in the sign of the PDO?

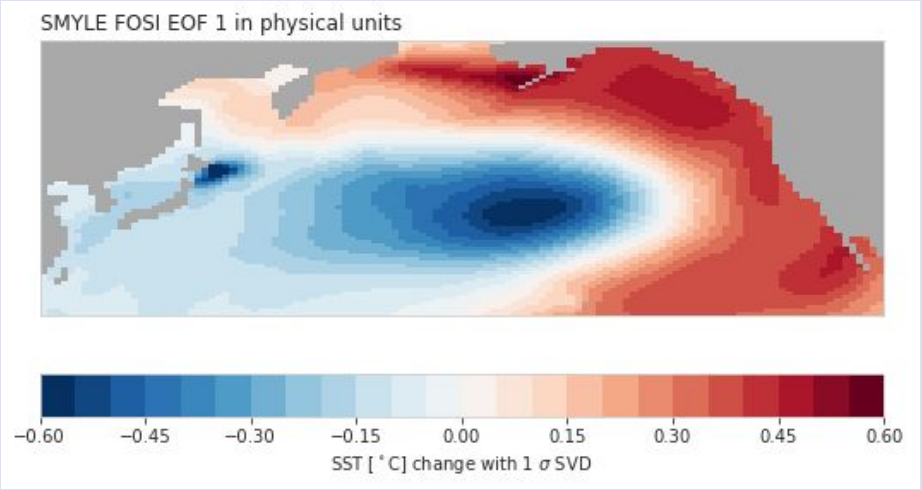
1. How skillful is the predictability of the PDO in SMYLE?
2. How do SMYLE predictions perform compared to simpler models?
3. What are the sources and limitations of PDO predictability?

Research Questions

- Why doesn't SMYLE predict the spatial evolution of the Blob? → Why doesn't SMYLE predict a change in the sign of the PDO?

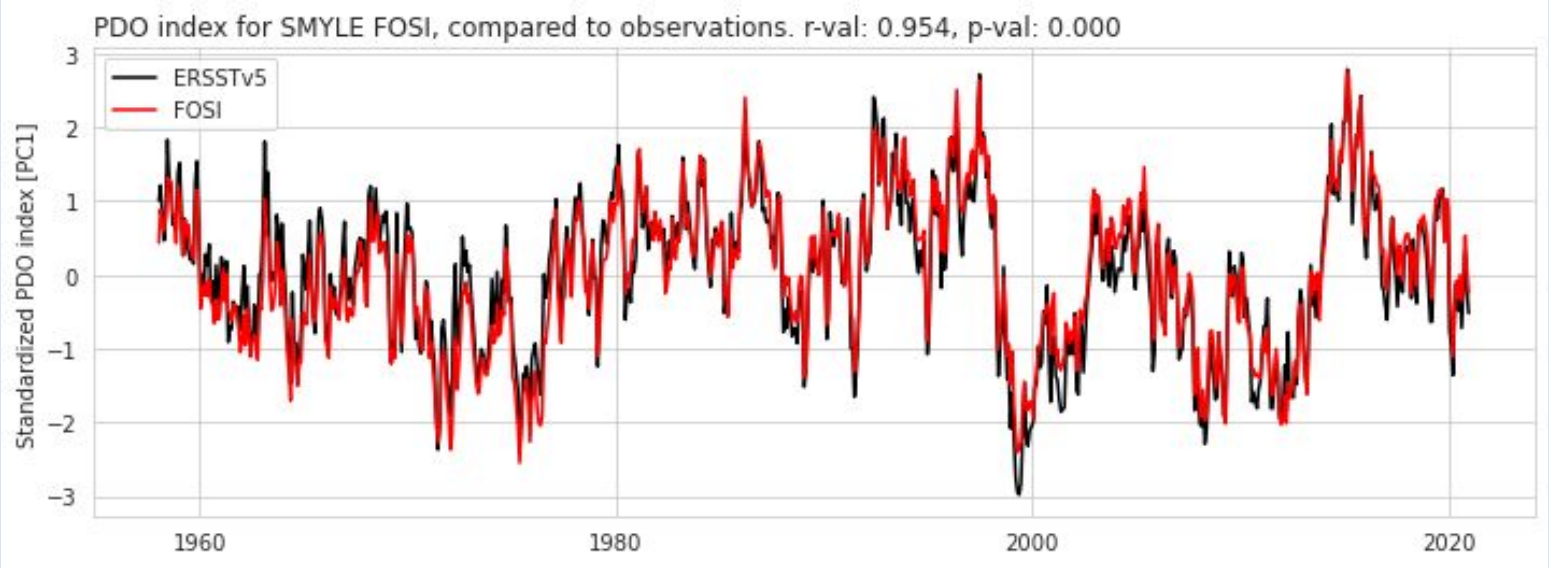
1. **How skillful is the predictability of the PDO in SMYLE?**
2. How do SMYLE predictions perform compared to simpler models?
3. What are the sources and limitations of PDO predictability?

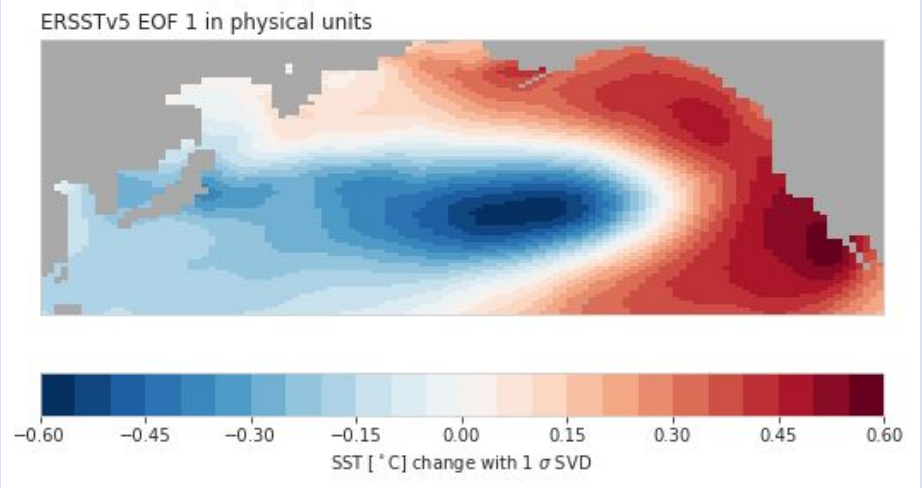
Calculating the PDO in SMYLE – CESM FOSI



(top) FOSI PDO

Correlation: 0.954





(bottom) ERSSTv5 PDO

Calculating the PDO in SMYLE

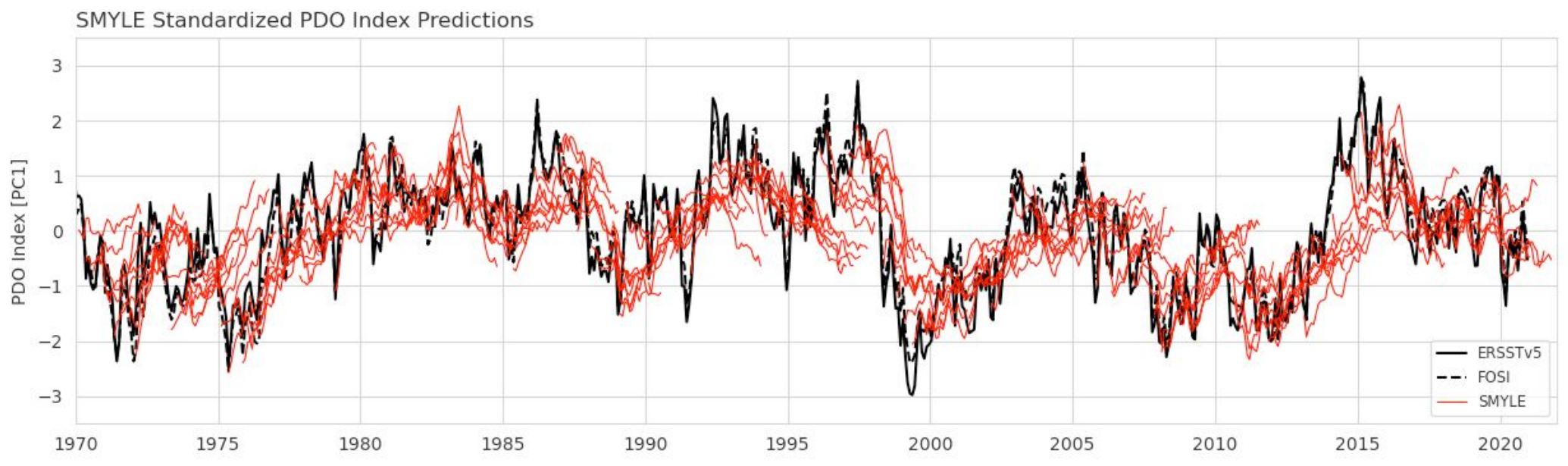
- SMYLE hindcasts are only 24 months long – too short to calculate EOF
- Solution: Project FOSI EOF onto hindcast anomalies

$$e_M \cdot {}_M X_N = z_N$$

Calculating the PDO in SMYLE

- SMYLE hindcasts are only 24 months long – too short to calculate EOF
- Solution: Project FOSI EOF onto hindcast anomalies

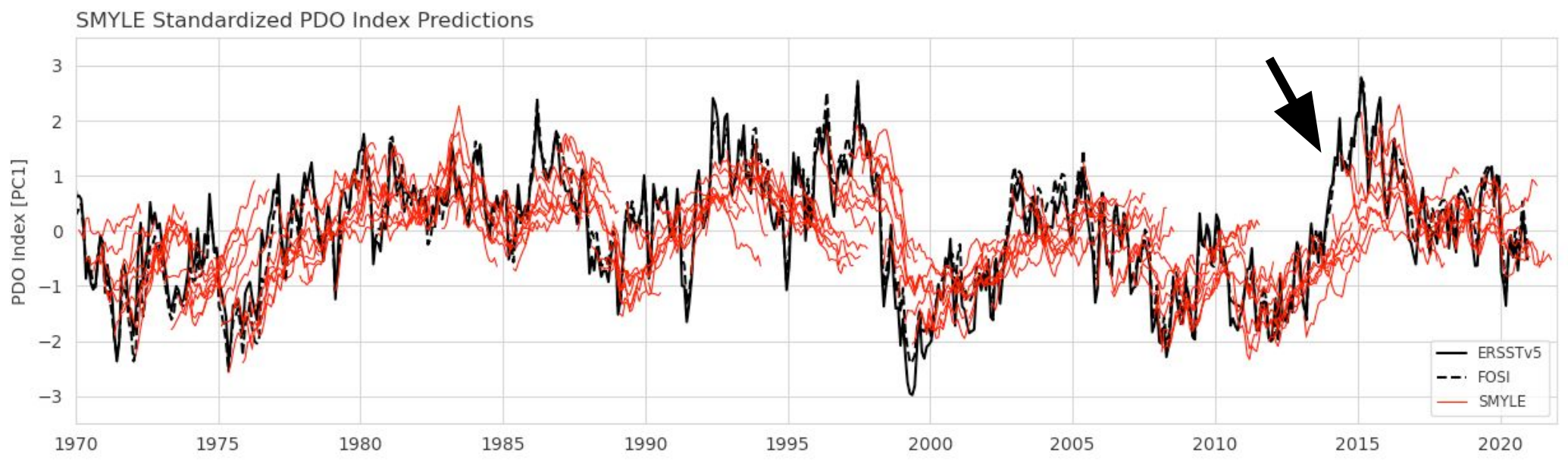
$$e_M \cdot {}_M X_N = z_N$$



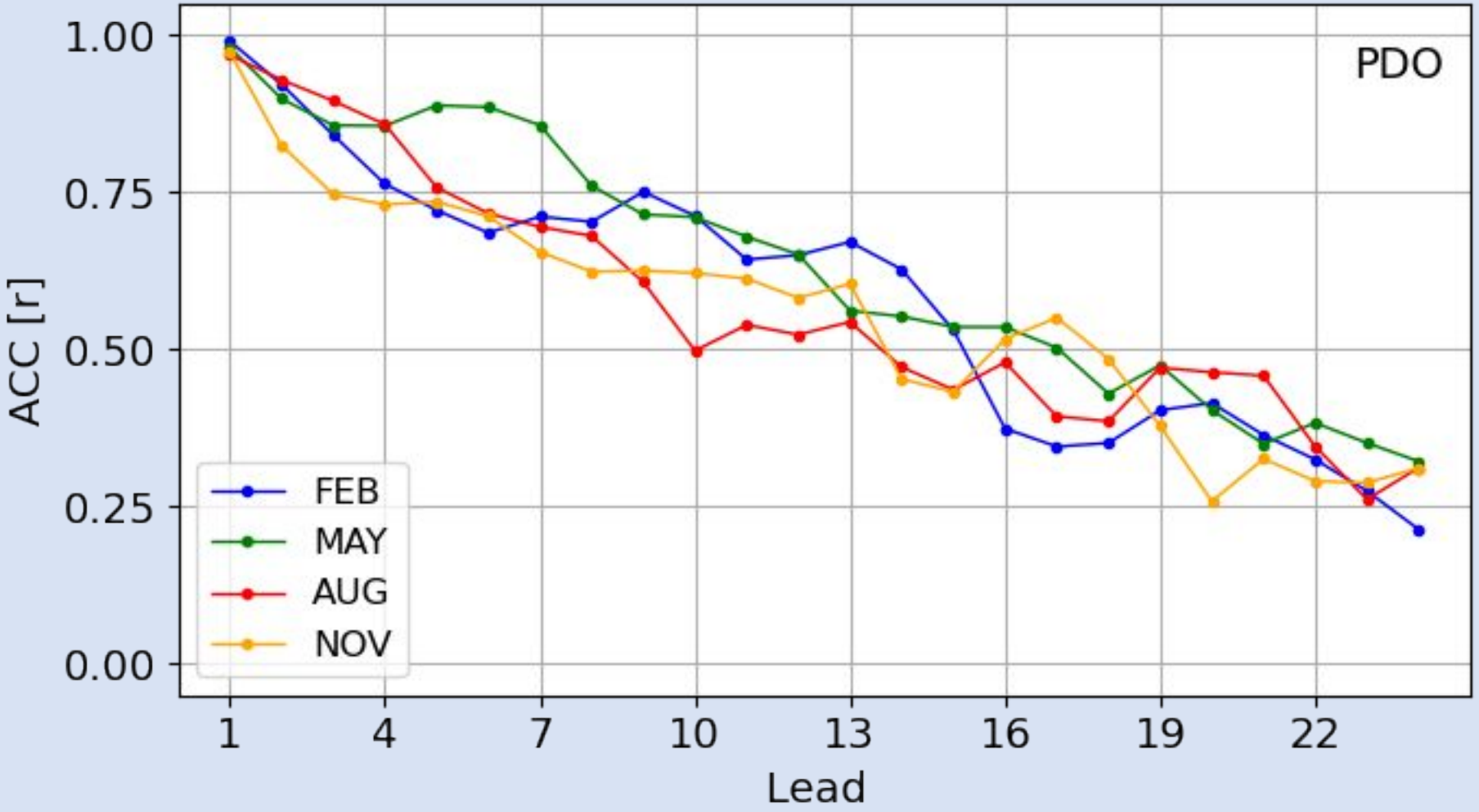
Calculating the PDO in SMYLE

- SMYLE hindcasts are only 24 months long – too short to calculate EOF
- Solution: Project FOSI EOF onto hindcast anomalies

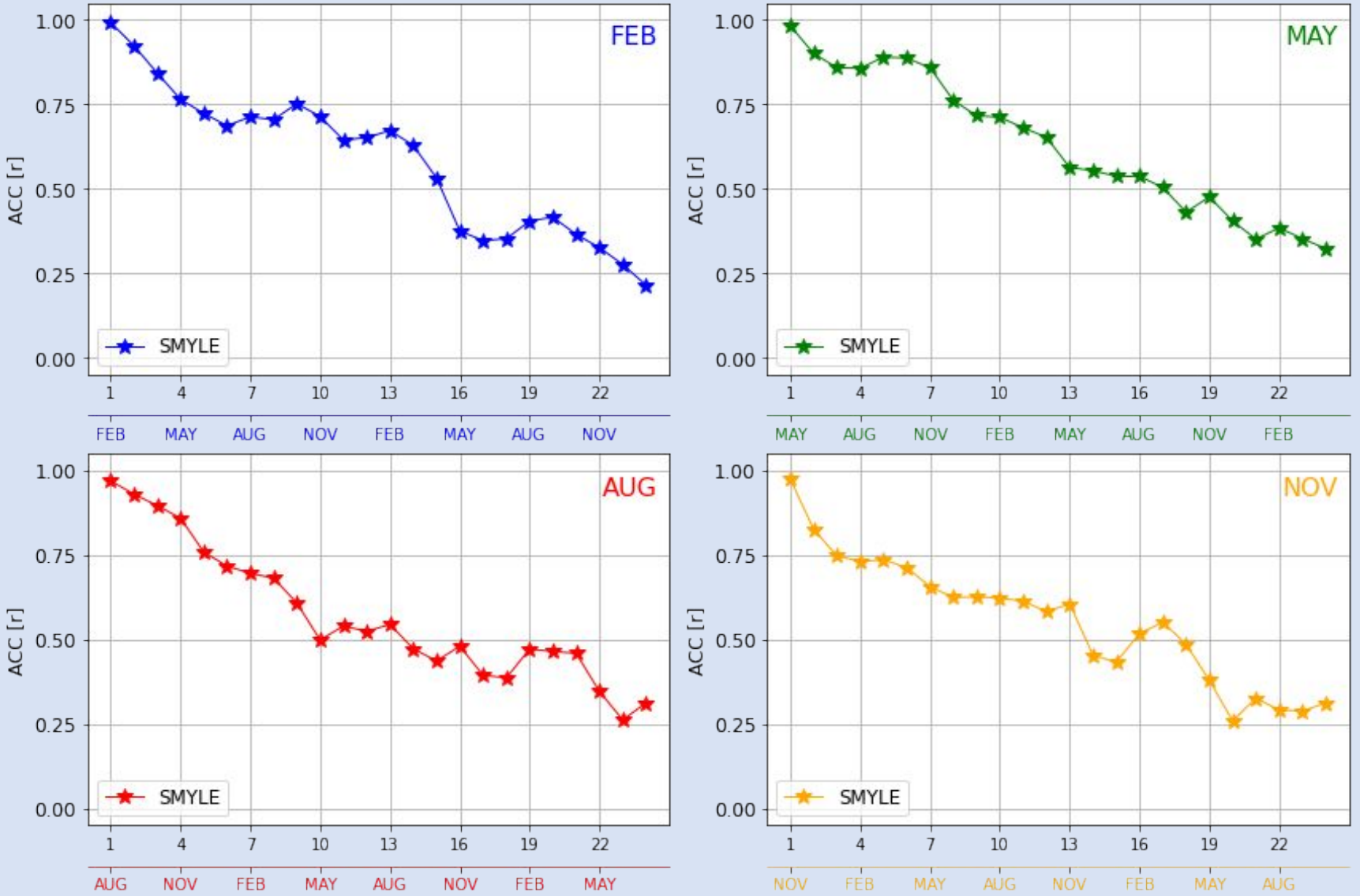
$$e_M \cdot {}_M X_N = z_N$$



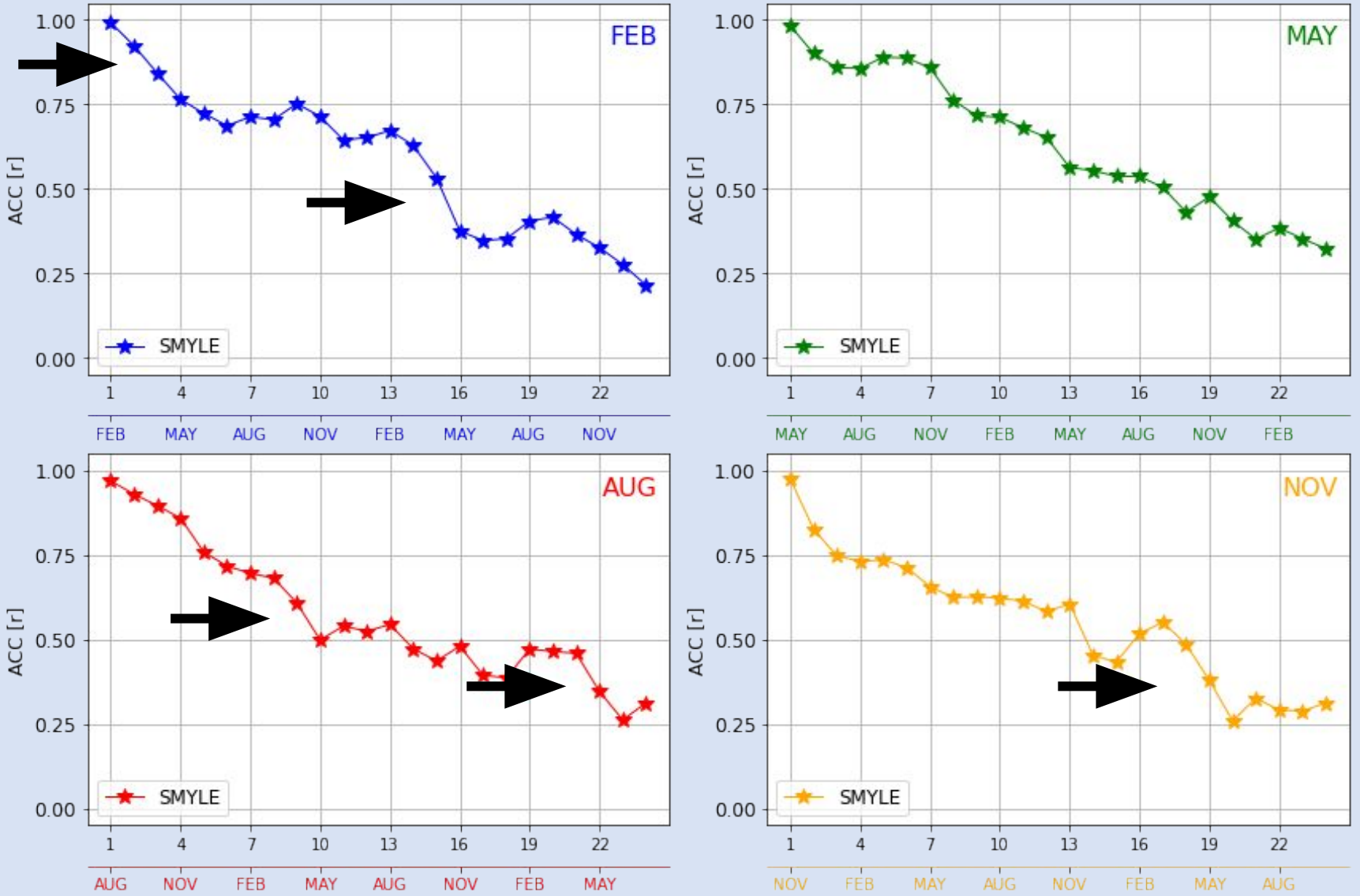
Results – PDO Prediction Skill in SMYLE



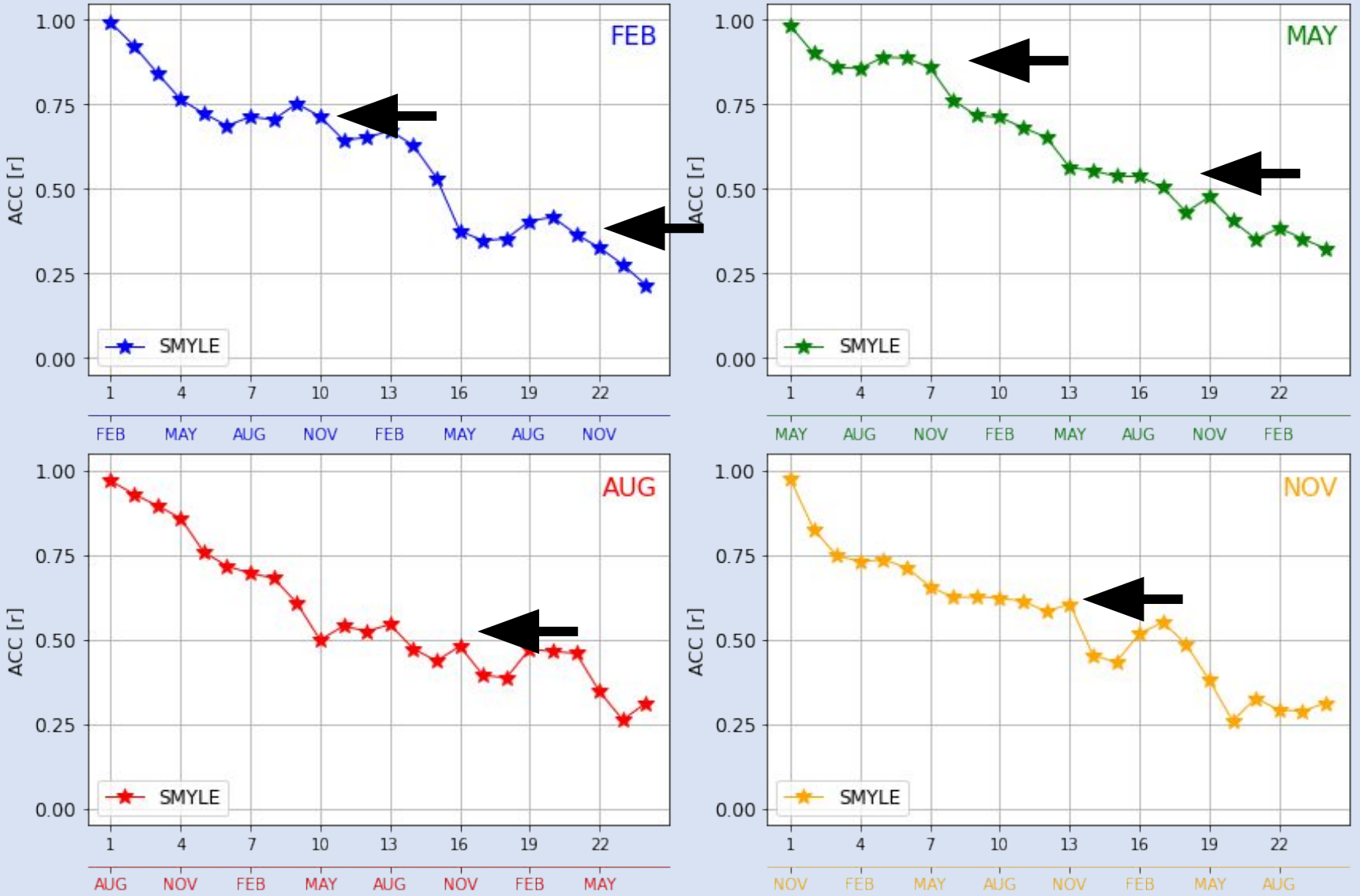
Results – PDO Prediction Skill in SMYLE



Results – PDO Prediction Skill in SMYLE



Results – PDO Prediction Skill in SMYLE



Research Questions

1. **How skillful is the predictability of the PDO in SMYLE?**
   - **Generally skillful, with ACC>0.5 for leads up to 13 months and significant to 24 months**
   - **Seasonal dependence in decorrelation rate: Faster in Feb-May, slower in May-Nov**

2. How do SMYLE predictions perform compared to simpler models?

3. What are the sources and limitations of PDO predictability?

Research Questions

1. How skillful is the predictability of the PDO in SMYLE?
   - Generally skillful, with ACC>0.5 for leads up to 13 months and significant to 24 months
   - Seasonal dependence in decorrelation rate: Faster in Feb-May, slower in May-Nov

2. **How do SMYLE predictions perform compared to simpler models?**

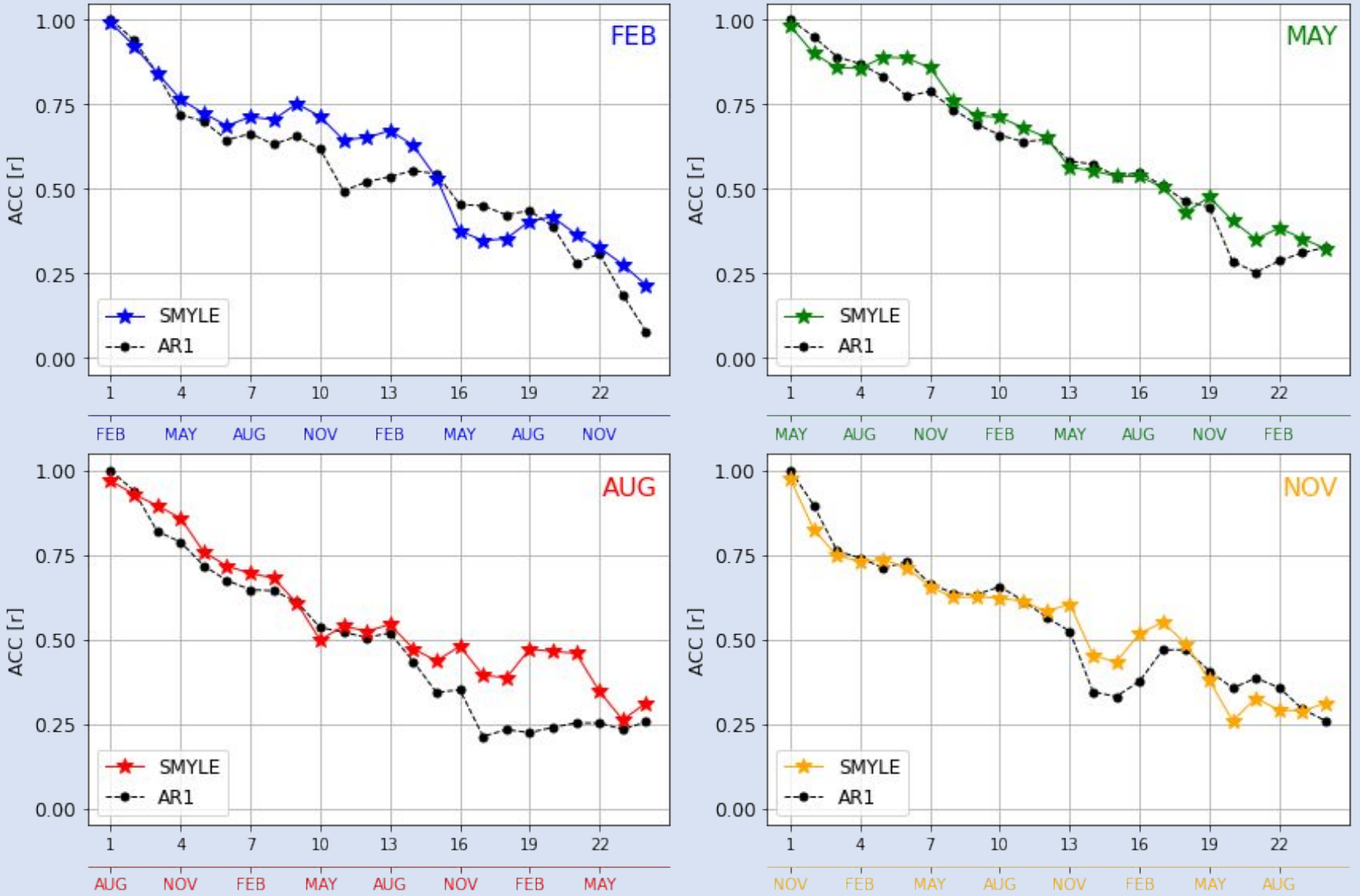
3. **What are the sources and limitations of PDO predictability?**

Linear Prediction of the PDO – AR1 Model

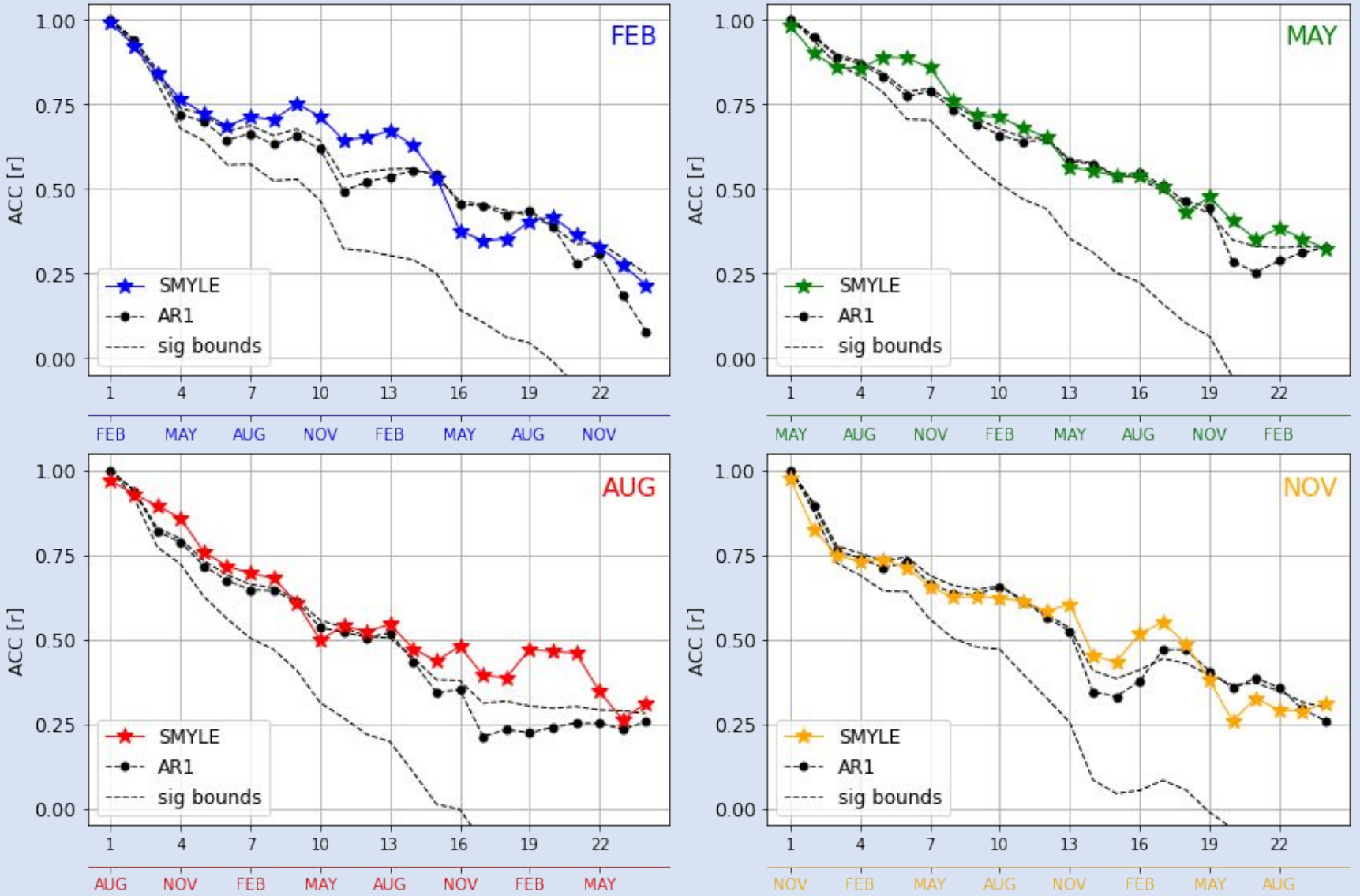
- PDO as a first order autoregressive (AR1) model (Newman et al., 2016; Hasselmann, 1976)

$$PDO(n) = \phi_1 PDO(n-1) + F$$

Results – PDO as an AR1 Process



Results – PDO as an AR1 Process



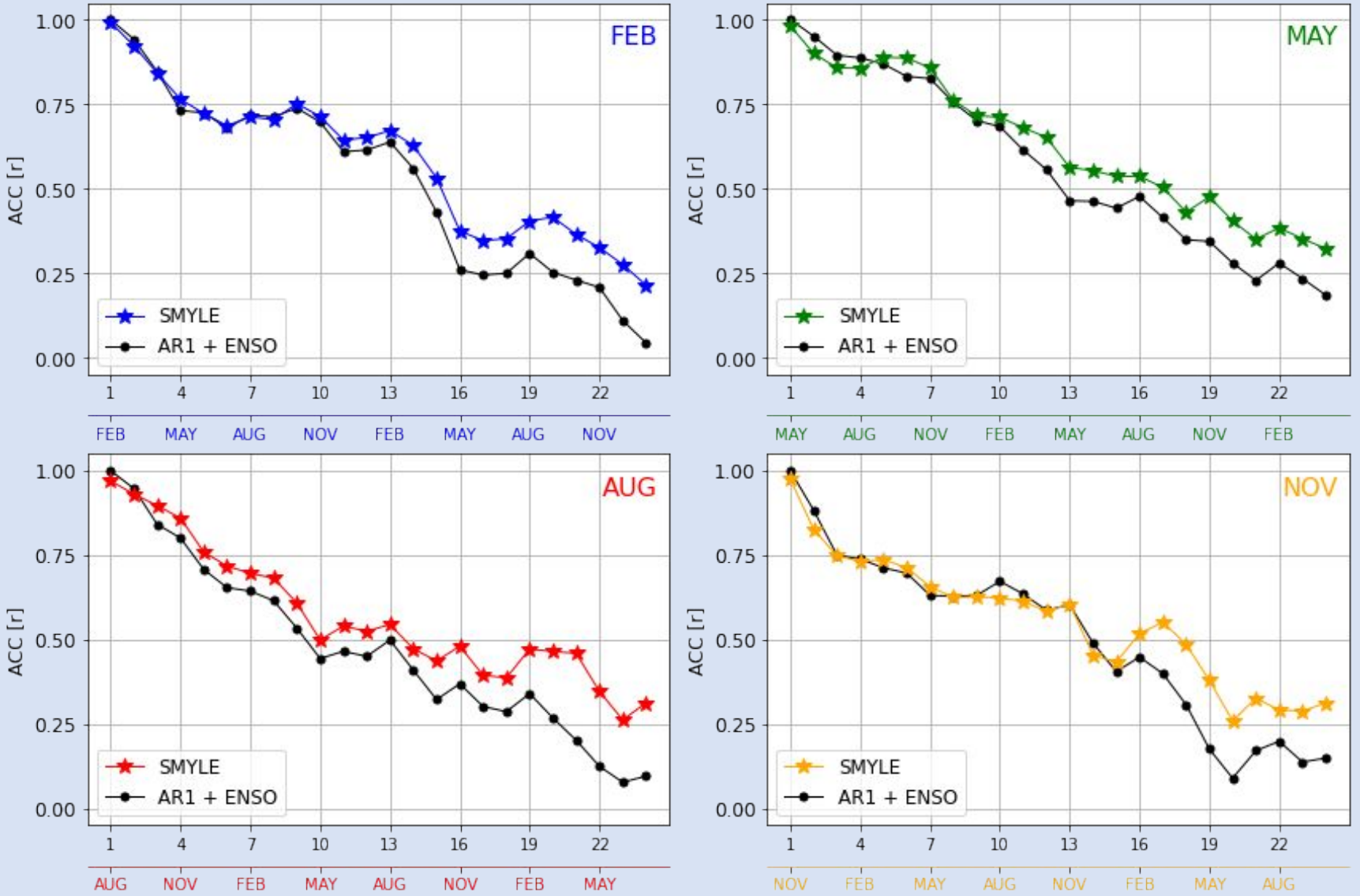
Linear Prediction of the PDO – Extended Linear Model

- We will consider the influence of ENSO (Niño3.4) using:

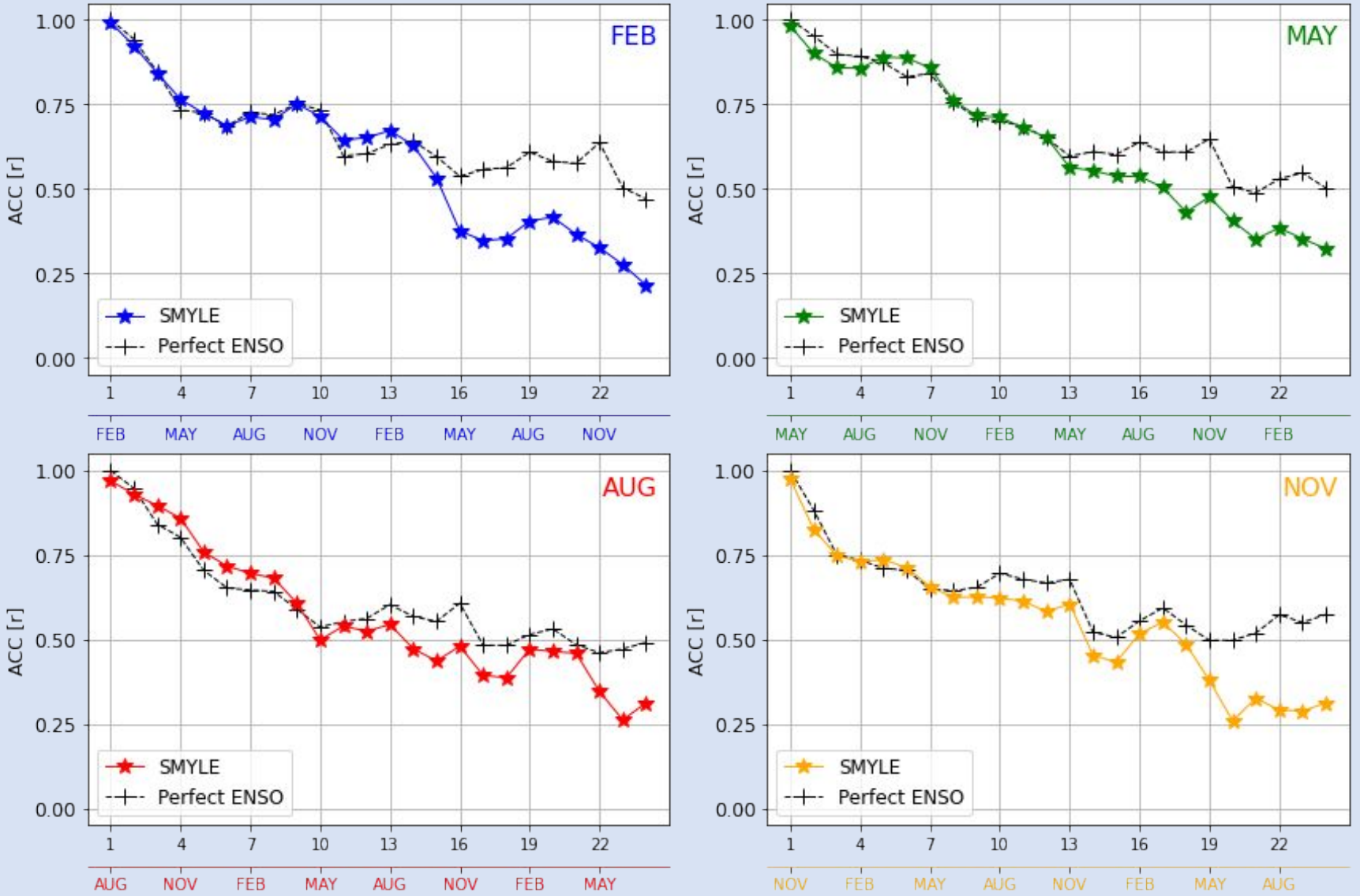
$$PDO(n) = \phi_1 PDO(n-1) + \phi_2 ENSO(n)$$

- Two experiments:
  - Using Niño3.4 values predicted by SMYLE
  - Using observed Niño3.4 values
- In both cases, the **only** information for the PDO comes from the initial time step

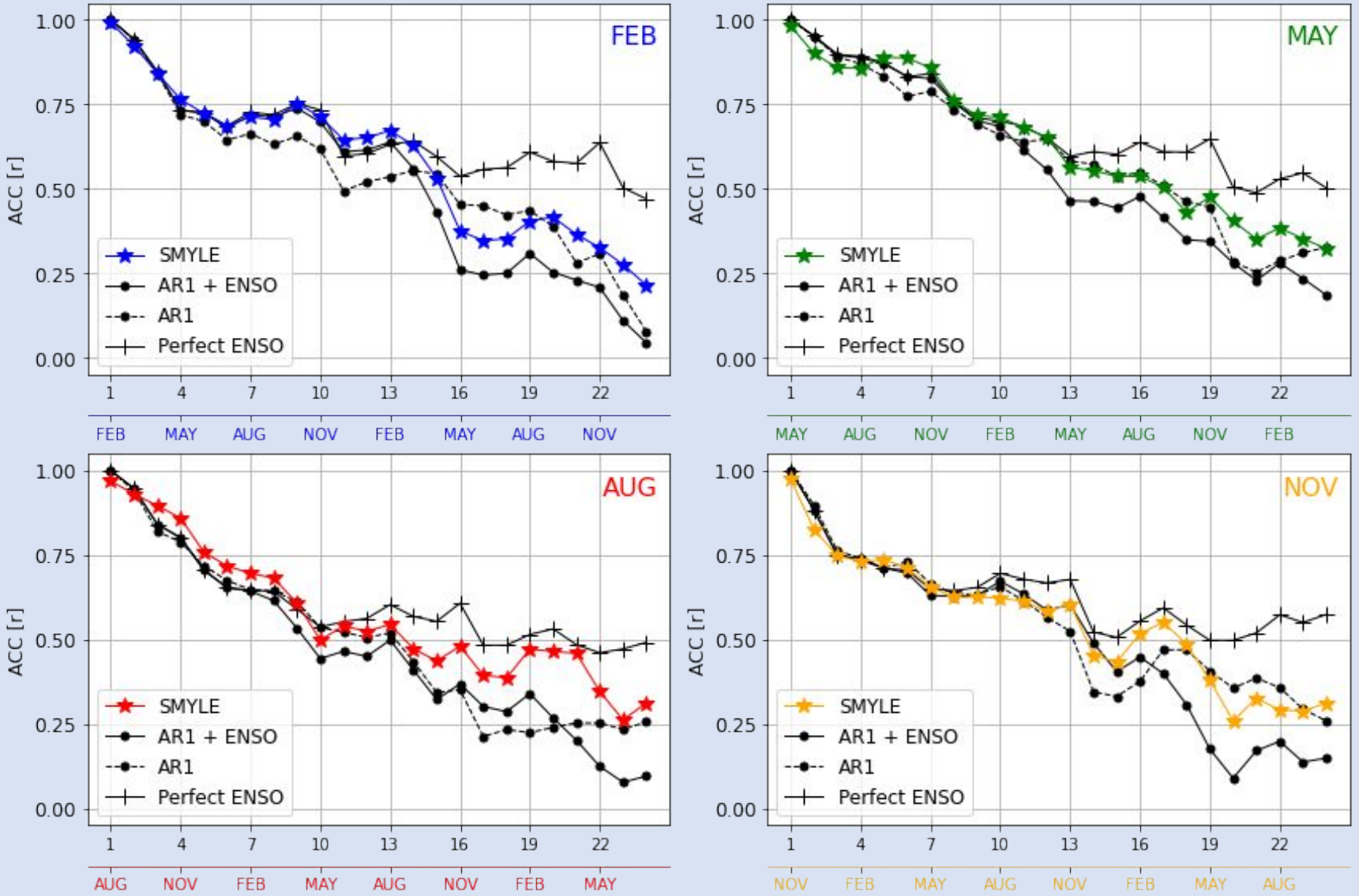
PDO as an Extended AR1 Process – SMYLE ENSO



PDO as an Extended AR1 Process – “Perfect” ENSO



PDO Prediction Comparison



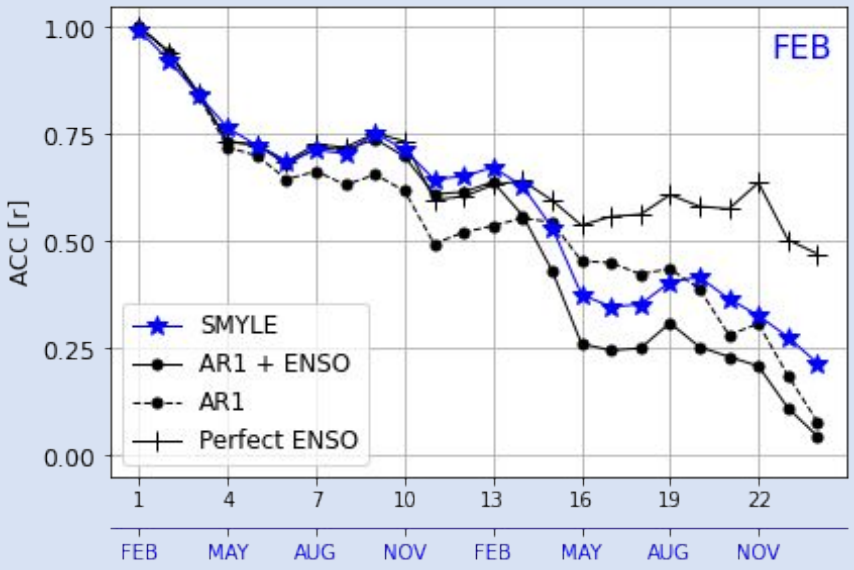
Conclusions

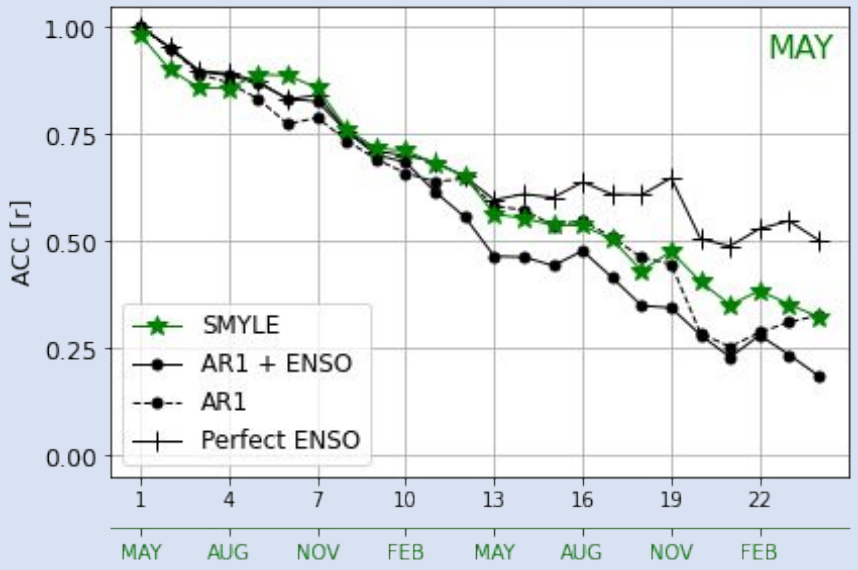
1. How skillful is the predictability of the PDO in SMYLE?
   - Generally skillful, with ACC>0.5 for leads up to 13 months and significant to 24 months
   - Seasonal dependence in decorrelation rate: Faster in Feb-May, slower in May-Nov

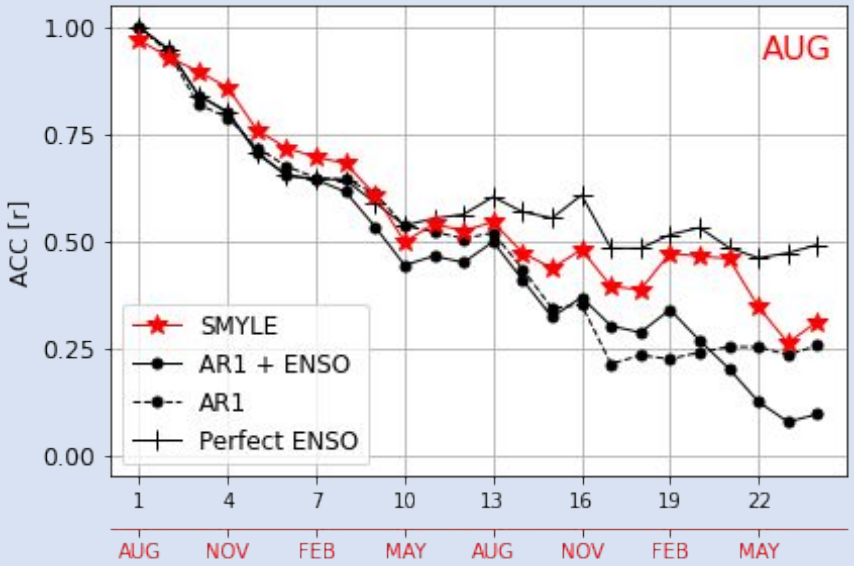
2. **How do SMYLE predictions perform compared to simpler models?**
   - **SMYLE skill is equal to or greater than AR1 prediction skill**
   - **AR1+ENSO model performs as well as and captures the seasonality of the SMYLE prediction in the first year.**
   - **SMYLE PDO predictions underperform a hypothetical "perfect ENSO" prediction**

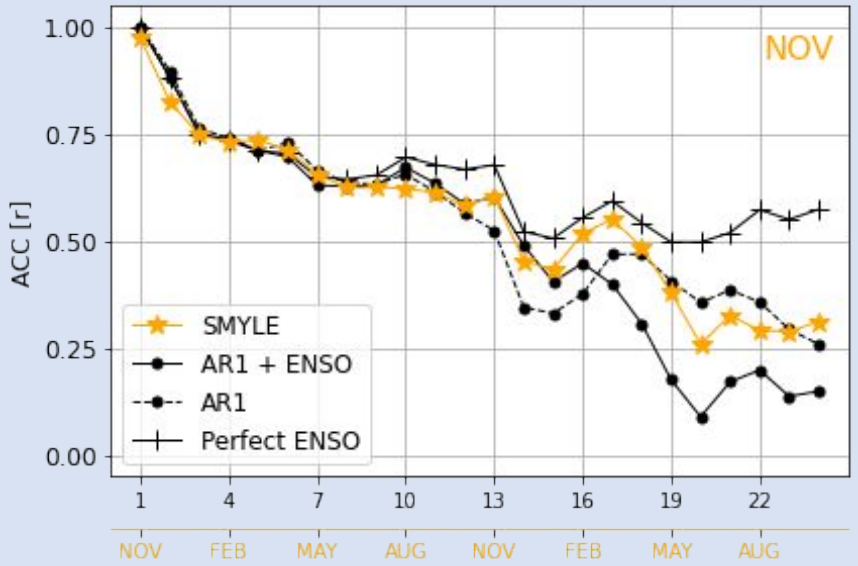
3. **What are the sources and limitations of PDO predictability?**
   - **SMYLE PDO prediction skill dominated by memory + ENSO forcing in first year.**
   - **Improvements in ENSO prediction skill and/or condition-dependent predictability could improve SMYLE PDO prediction skill in 2nd year**

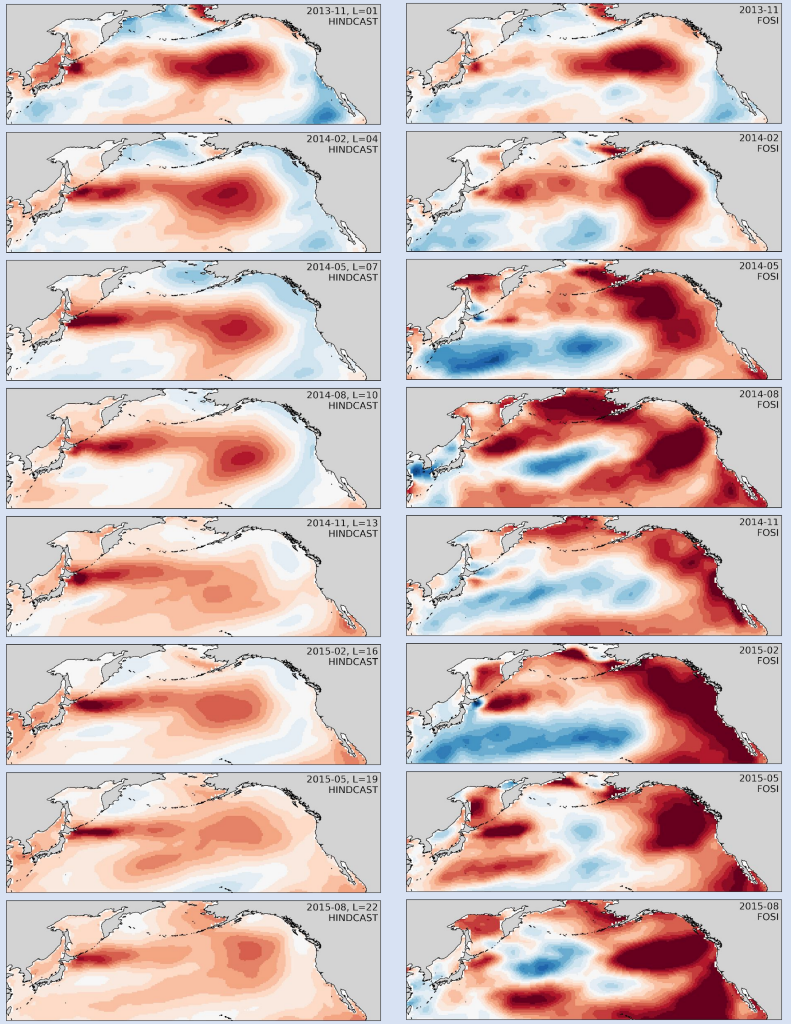
Questions?


FEB
ACC [r]
1.00
0.75
0.50
0.25
0.00
SMYLE
AR1 + ENSO
AR1
Perfect ENSO
1 4 7 10 13 16 19 22
FEB MAY AUG NOV FEB MAY AUG NOV


MAY
ACC [r]
1.00
0.75
0.50
0.25
0.00
SMYLE
AR1 + ENSO
AR1
Perfect ENSO
1 4 7 10 13 16 19 22
MAY AUG NOV FEB MAY AUG NOV FEB


AUG
ACC [r]
1.00
0.75
0.50
0.25
0.00
SMYLE
AR1 + ENSO
AR1
Perfect ENSO
1 4 7 10 13 16 19 22
AUG NOV FEB MAY AUG NOV FEB MAY


NOV
ACC [r]
1.00
0.75
0.50
0.25
0.00
SMYLE
AR1 + ENSO
AR1
Perfect ENSO
1 4 7 10 13 16 19 22
NOV FEB MAY AUG NOV FEB MAY AUG


2013-11, L=01 HINDCAST
2013-11 FOSI
2014-02, L=04 HINDCAST
2014-02 FOSI
2014-05, L=07 HINDCAST
2014-05 FOSI
2014-08, L=10 HINDCAST
2014-08 FOSI
2014-11, L=13 HINDCAST
2014-11 FOSI
2015-02, L=16 HINDCAST
2015-02 FOSI
2015-05, L=19 HINDCAST
2015-05 FOSI
2015-08, L=22 HINDCAST
2015-08 FOSI