Mining large climate model data sets to make multi-year initialized ENSO forecasts with actionable skill

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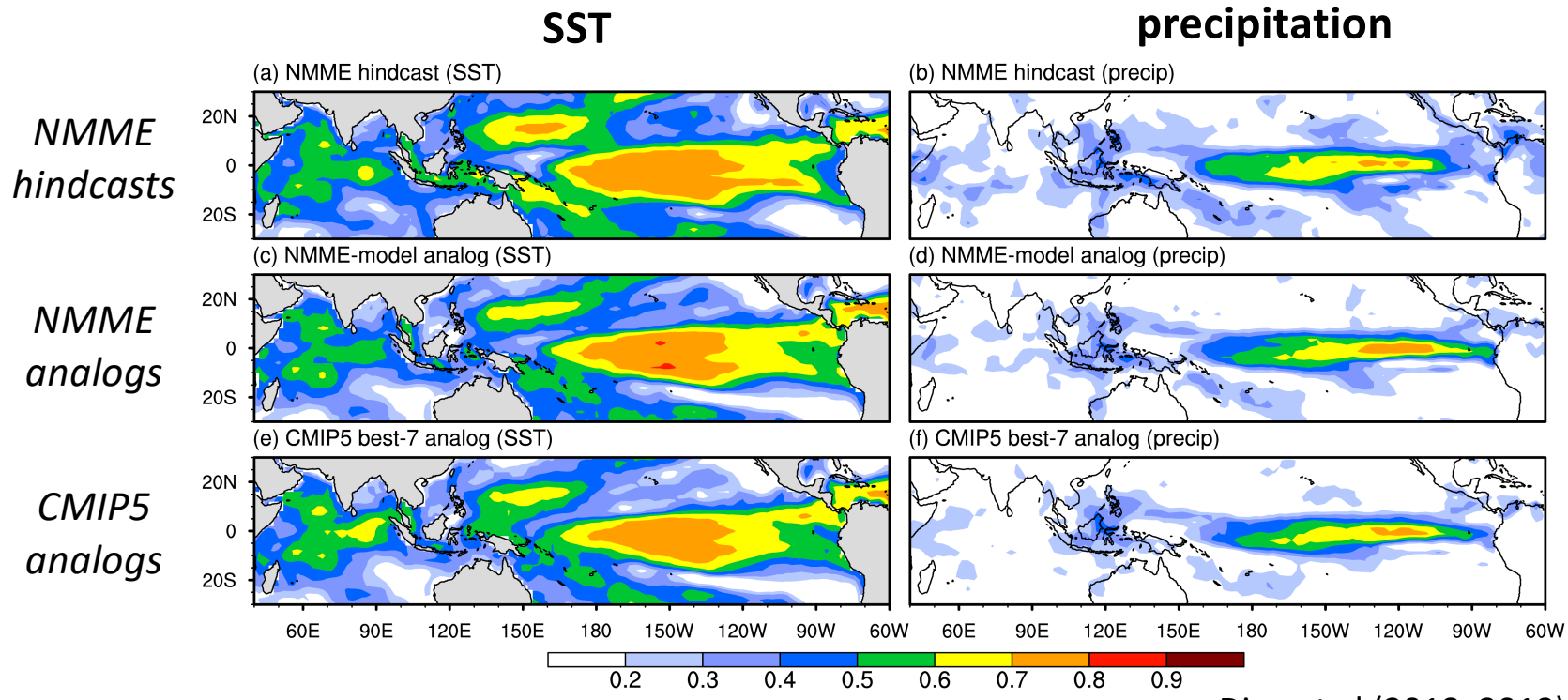
1: University of Colorado/CIRES 2: NOAA/PSL 3: NOAA/GFDL

"Model-analog" technique: Turn every climate model into a forecast model

Find ensemble of closest matches ("analogs") to observed SST/SSH anomaly from the anomalous states of *long climate model simulations*

Evolution of analog ensemble → forecast ensemble, for leads of 1-36 months or more

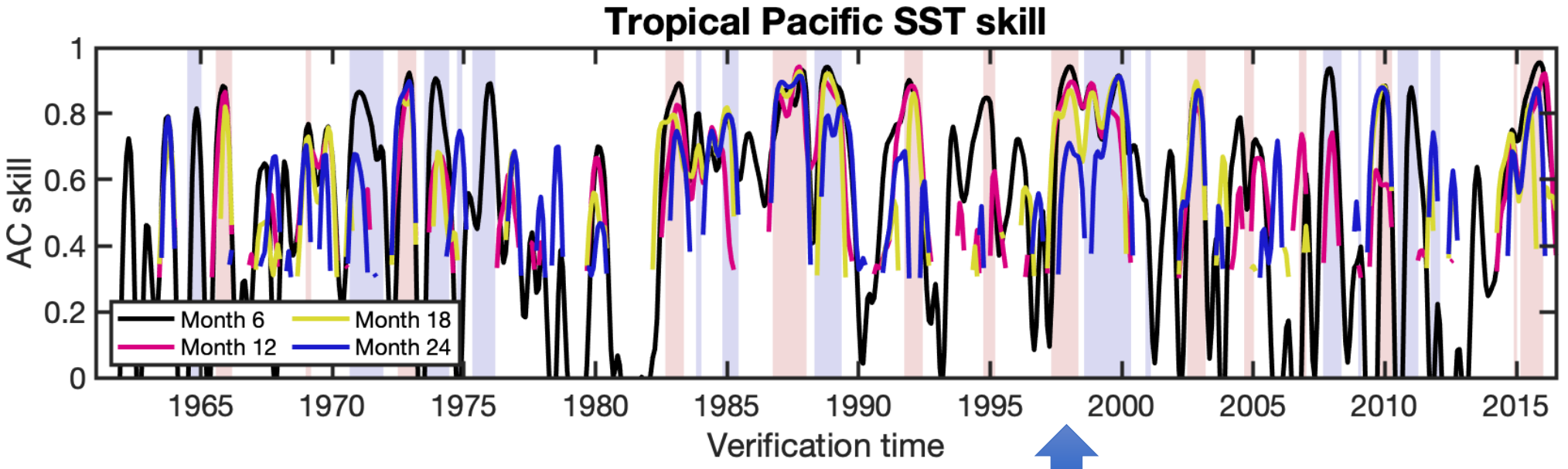
Month 6 hindcast skill, 1982-2009



Ding et al (2018, 2019)

NMME model-analog ensembles for **tropical Indo-Pacific** based on 500 yr+ control runs of the same operational models used for assimilation-initialized hindcasts (NCAR CESM1/CCSM4, GFDL CM2.1/ FLOR)

Some ENSO events are predictable at least 2 years ahead, and with model-analogs this skill can be identified *a priori*



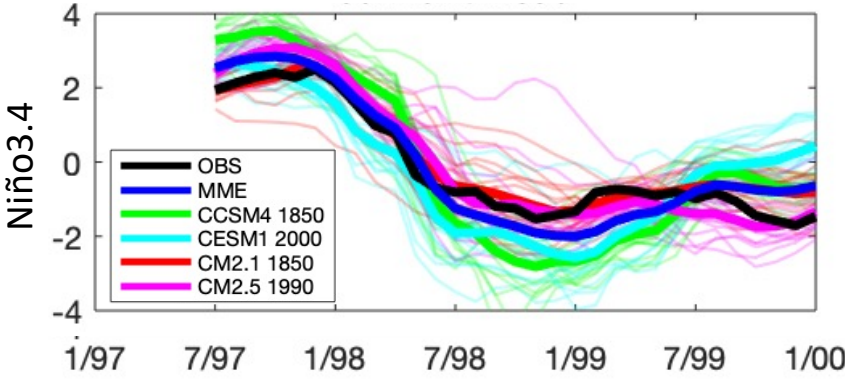
Skill measure: pattern correlation of model-analog SST hindcast ensemble mean to verification within **170E-70W, 20S-20N**

For leads >=12 months, only values above 0.4 are shown.

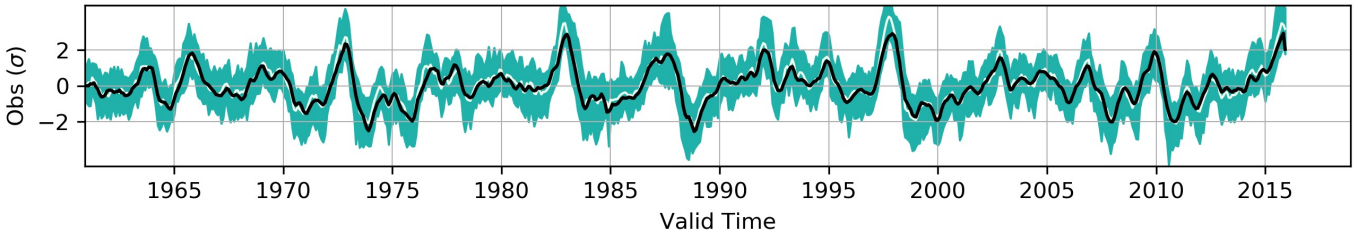
Evolution through DJF '99-'00 would have been predicted in *July 1997*

But could we have known that at the time and with sufficient confidence to use the forecast?

30 mo forecast initialized 7/97



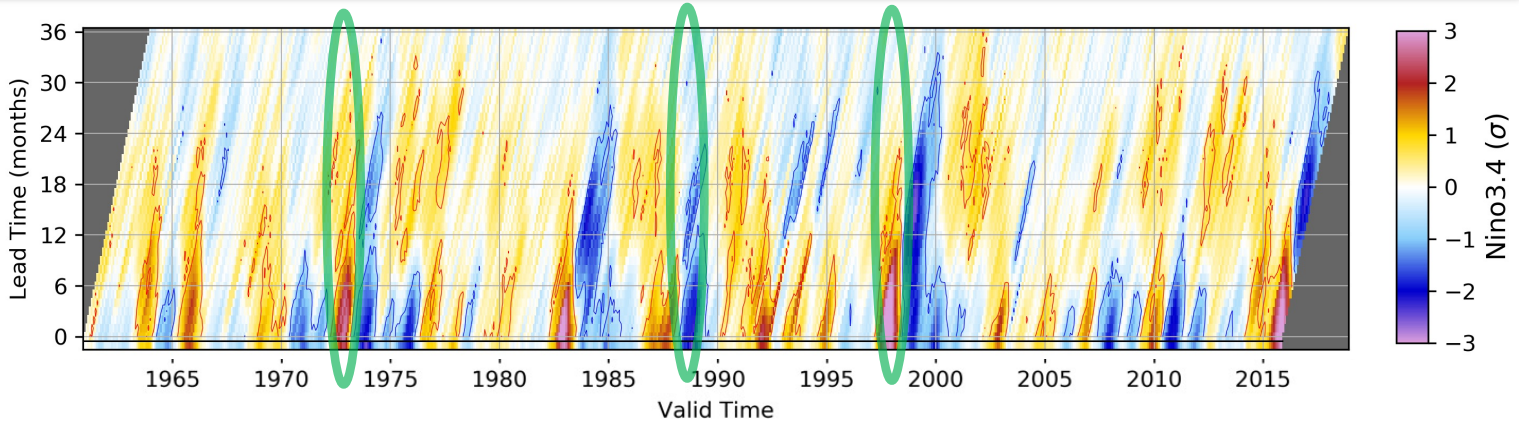
Actionable long-lead ENSO forecasts of opportunity

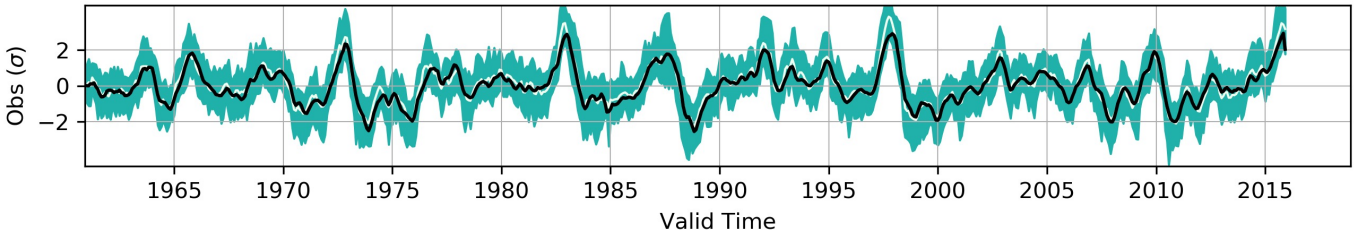


Bottom: Niño3.4 time series (black) compared with model-analog reconstruction (white); green indicates model-analog initial spread

Actionable long-lead ENSO forecasts of opportunity

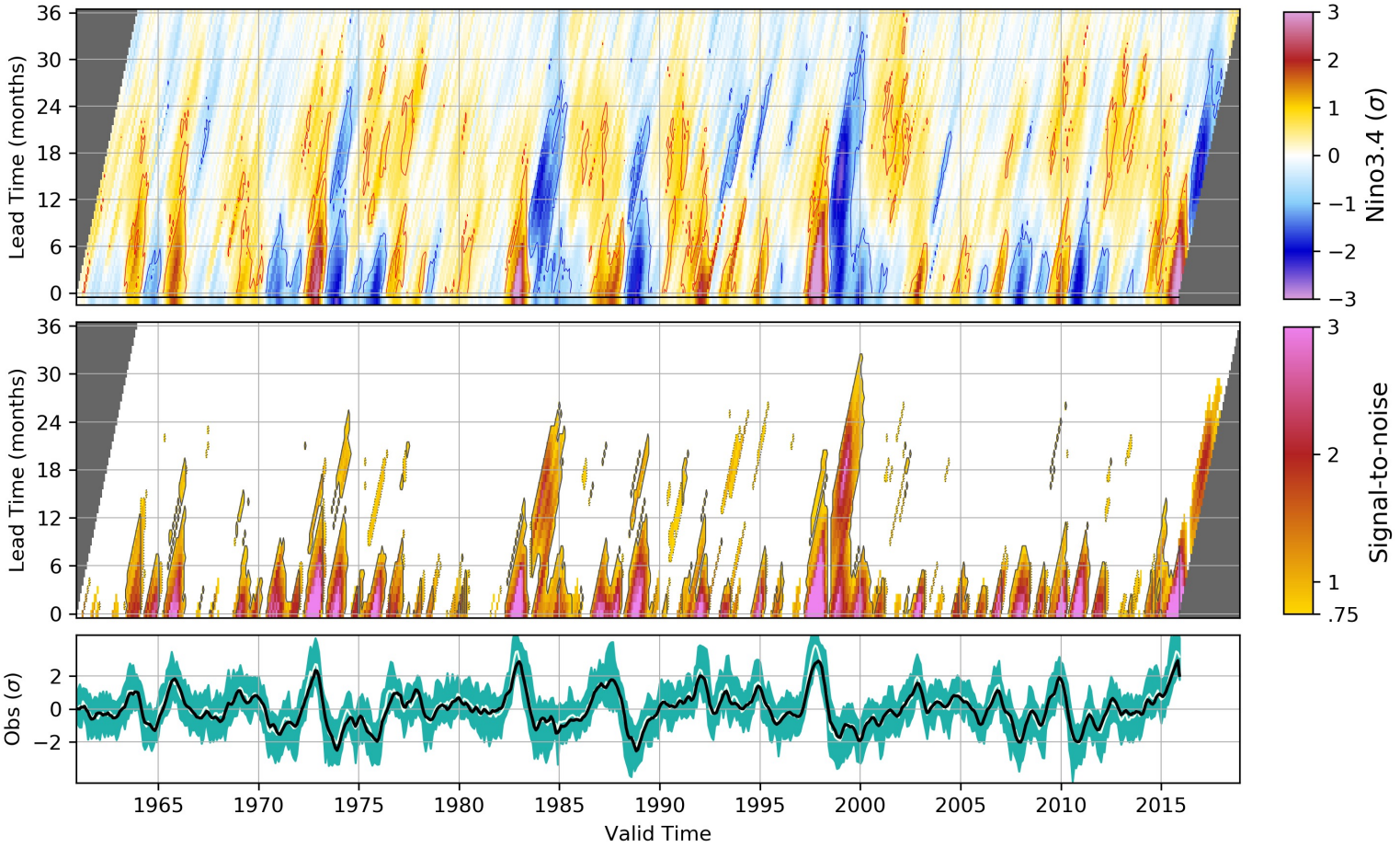
Top: Each column shows hindcasts (leads 0-36 months) that *all verify at the same time*





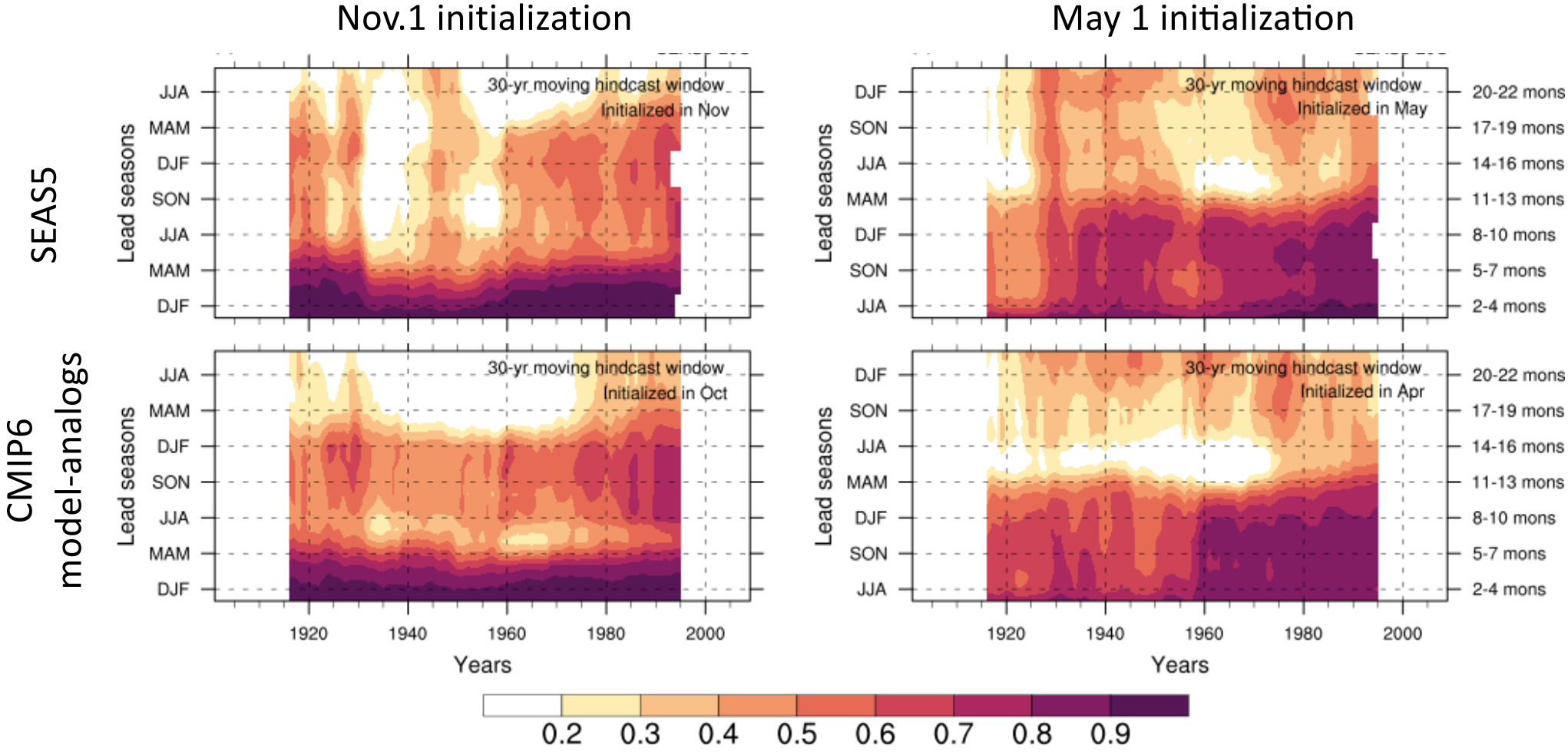
Actionable long-lead ENSO forecasts of opportunity

Middle: Forecast signal-to-noise ratio (SNR); *there are no tercile category forecast misses almost everywhere SNR is shaded*



Variations in ensemble spread from year-to-year are ~10-20% and forecast PDFs mostly not significantly different from Gaussian: *probabilistic skill mostly due to predicted mean PDF shift.*

Model-analog skill is comparable to skill from initialized model (ECMWF SEAS5) since 1900



Skill measure: anomaly correlation of hindcast ensemble mean to observed Niño3.4, relative to running 30-yr mean

ECMWF SEAS5: 10-member ensemble initialized with CERA20C
Weisheimer et al. 2022, GRL

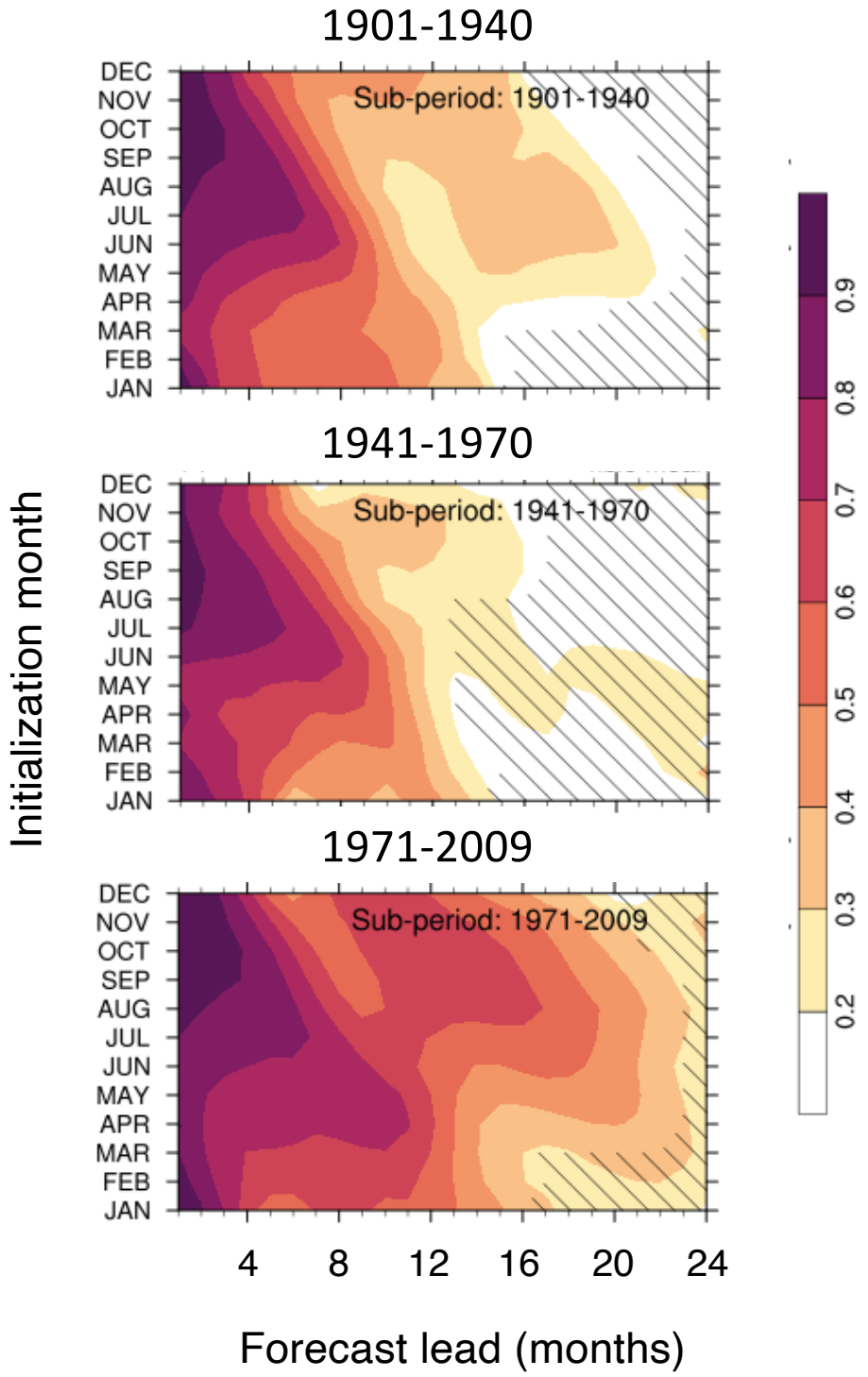
CMIP6 model-analogs: 9 models, each with 5 member-ensemble, using CERA20 SST/SSH
From Lou et al. 2022, in preparation

Year 2 ENSO skill has increased in recent decades

However, it was also higher in late 1800's/early 1900's

This result is robust to different verification datasets and variables

Note: model-analogs use **CMIP6 preindustrial control runs** for data libraries



Skill measure: Niño3.4 AC skill between hindcast ensemble mean and observed Niño3.4 index, relative to running 30-yr mean. Hatched values not 95% significant
From Lou et al. 2022, in preparation

Conclusion

- **Model-analogs provide a cheap and easy way of making multiyear ocean predictions (initialized every month), with hindcast datasets potentially extending back before 1900**
- **Some ENSO events are predictable two or more years ahead, particularly over the last few decades and in the late 1800's/early 1900's period (all using fixed 1850 climate model runs!)**
- **Actionable forecasts of opportunity may be identified beforehand from their *ensemble-mean forecast signal-to-noise ratio***

Ding, Hui, Matthew Newman, Michael A. Alexander, and Andrew T. Wittenberg, 2018: Skillful climate forecasts of the tropical Indo-Pacific ocean using model-analogs. *J. Climate*, **31**, 5437-5459, doi: 10.1175/JCLI-D-17-0661.1.

Ding, Hui, Matthew Newman, Michael A. Alexander, and Andrew T. Wittenberg, 2019: Diagnosing secular variations in retrospective ENSO seasonal forecast skill using CMIP5 model-analogs. *Geophys. Res. Lett.*, **46**, 1721-1730, doi: 10.1029/2018GRL080598.

Ding, Hui, Matthew Newman, Michael A. Alexander, and Andrew T. Wittenberg, 2020: Relating CMIP5 model biases to seasonal forecast skill in the tropical Pacific. *Geophys. Res. Lett.*, **47**, e2019GL086765, doi: l10.1029/2019GL086765.

Matthew Newman, Hui Ding, Michael A. Alexander, and Andrew T. Wittenberg, 2022: Mining large climate model datasets to make multi-year Initialized ENSO Forecasts with actionable skill., in preparation.

Lou, Jiale, Matthew Newman, and Andrew Hoell, 2022: Multi-year variation of seasonal ENSO skill since the late 1800's. To be submitted to *J. Climate*