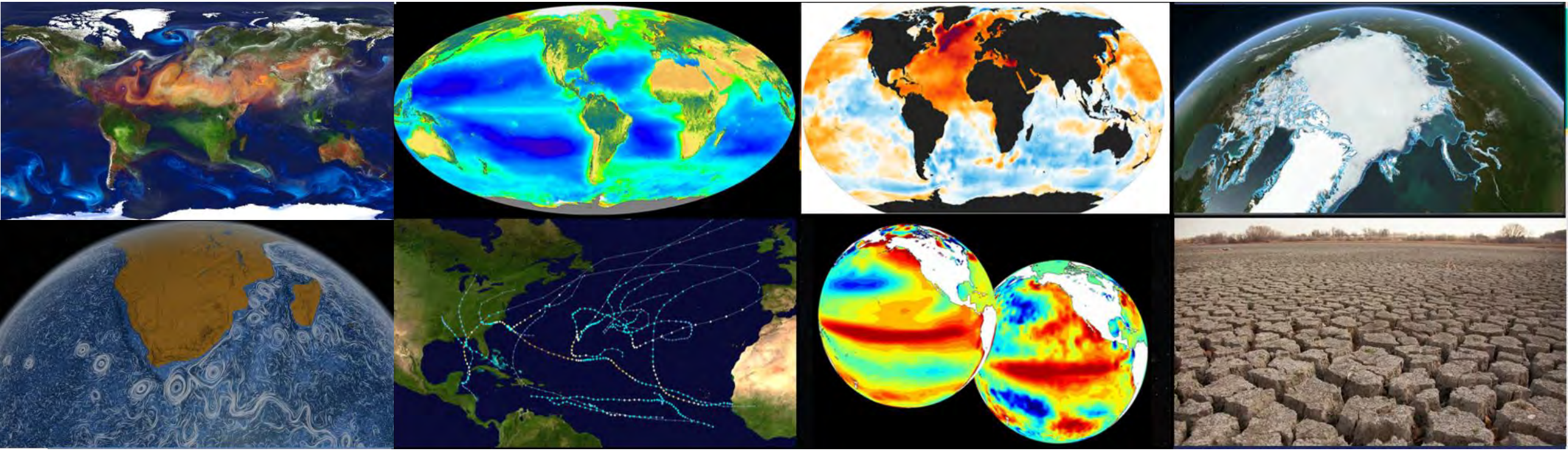


WGSIP activities using multi-model hindcast ensembles in S2D research and prediction

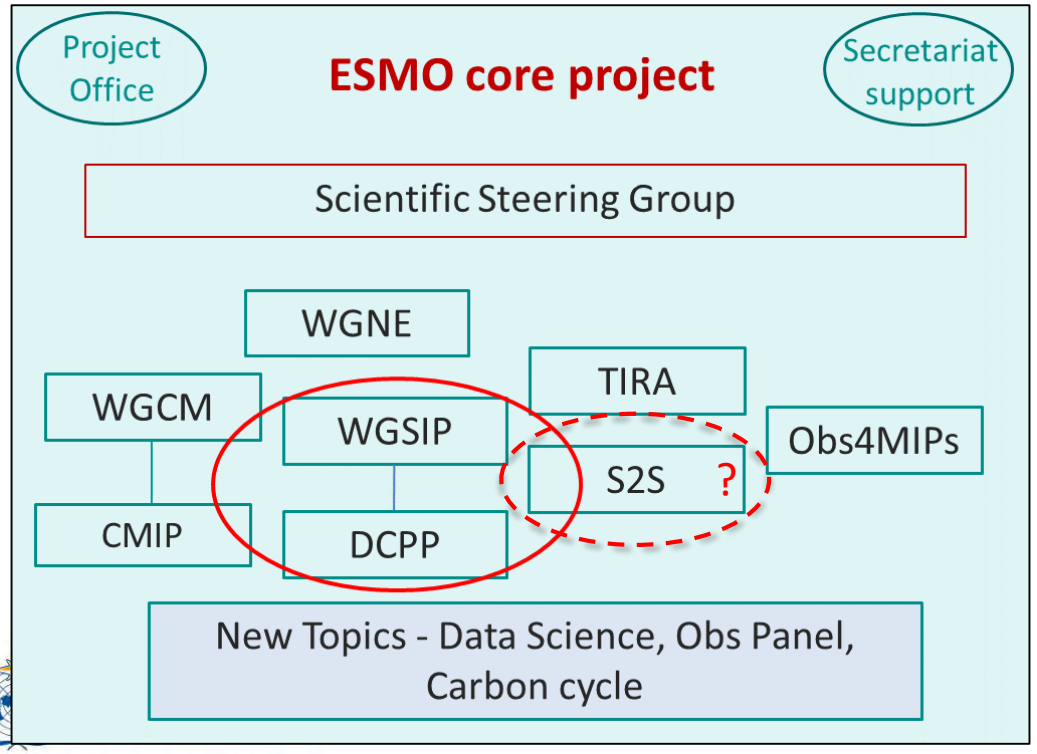
Bill Merryfield, ECCC/CCCma, Victoria, BC

US CLIVAR Summit
1 August 2023

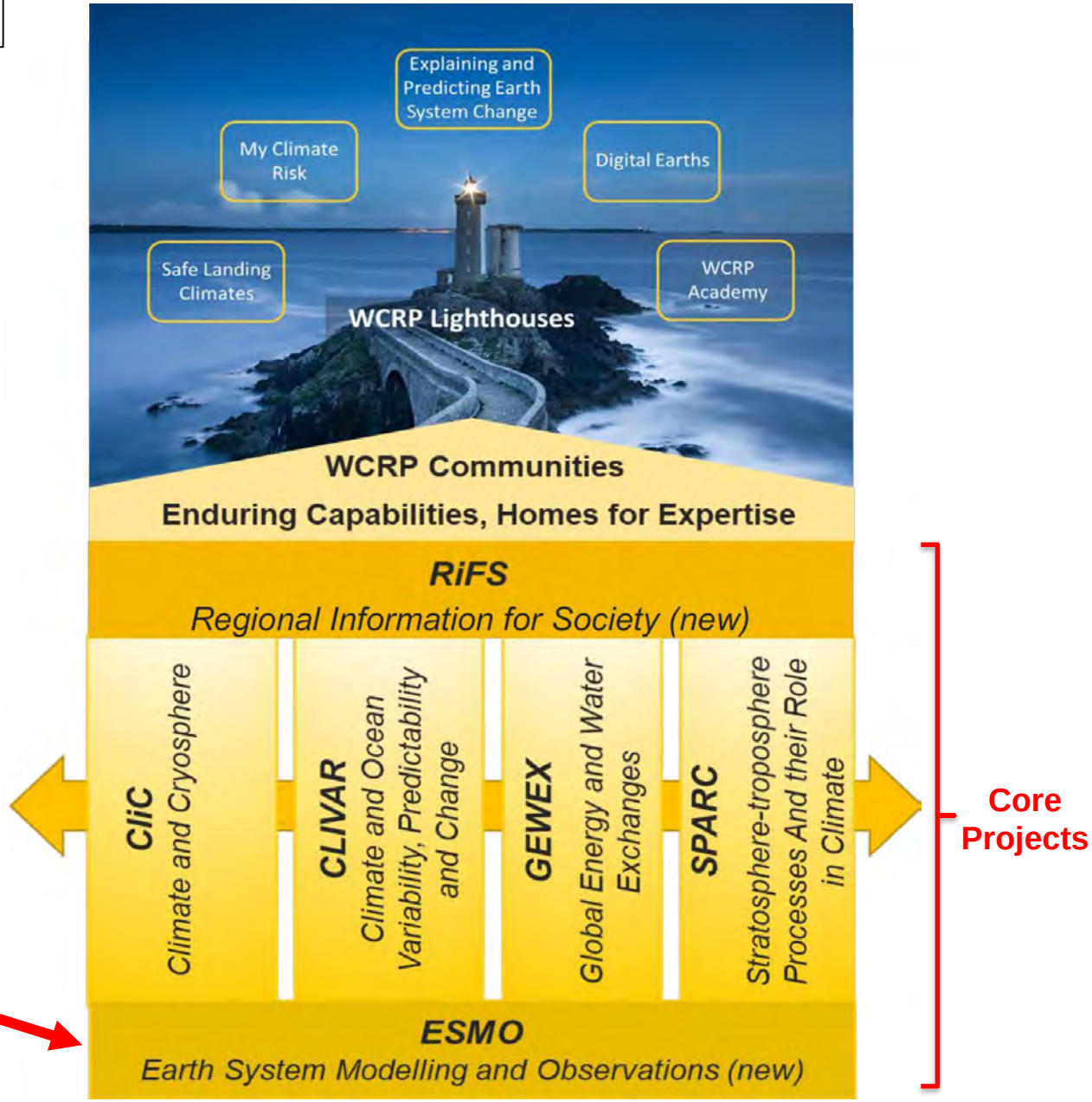
WORLD METEOROLOGICAL ORGANIZATION · United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission · International Science Council · WCRP World Climate Research Programme

WGSIP = WCRP Working Group on Subseasonal to Interdecadal Prediction

- Decadal Climate Prediction Project (DCPP) panel aligned with WGSIP
- WGSIP/DCPP sit within WCRP *Earth System Modelling and Observations* (ESMO)
- ESMO newly established as WCRP Core Project (similar to CLIVAR, etc.)



New WCRP research structure (as of 2021)



DCPP for CMIP7

- Planning well underway, to be finalized in early 2024

- Balance sought between reducing “entry card” computational requirements, e.g. by
  - starting hindcasts in 1980
  - initializing every 2 years

  and science objectives involving
  - large ensemble sizes
  - longer hindcast periods (starting 1960 or earlier)
  - longer hindcast range (≥20 years)
  - high resolution

- S2I (multi-year) component involving ~2-year predictions initialized >once/year is likely

- DCPP panel will be circulating survey for community input

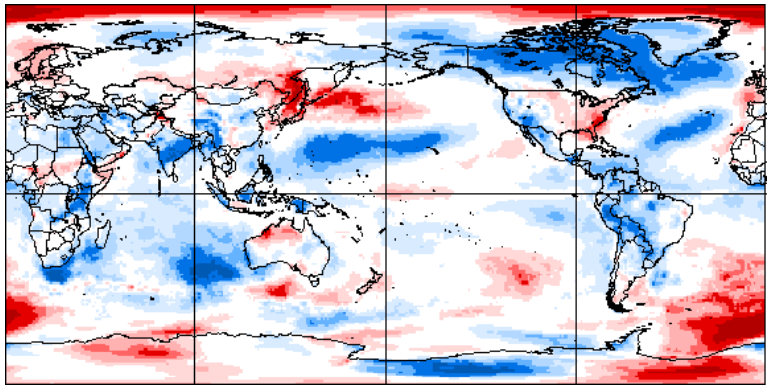
SPARC/DCPP Volcanic Response Readiness Exercise

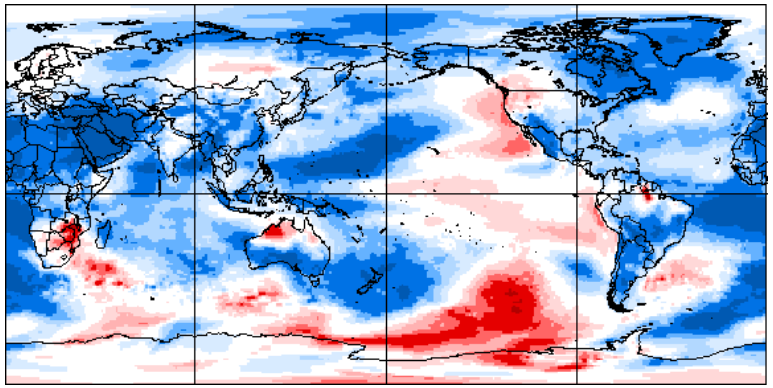
Motivation

- A major volcanic eruption like Pinatubo in 1991 would invalidate WMO's current annual to decadal forecasts
- DCPP has Guidelines for climate forecasts after sudden volcanic eruption describing two potential response protocols
- Responding to a hypothetical volcanic eruption will **increase readiness** of LC-ADCP contributors and support more **durable documentation** via a journal paper

before Pinatubo | **after Pinatubo**

1990 mean temperature*





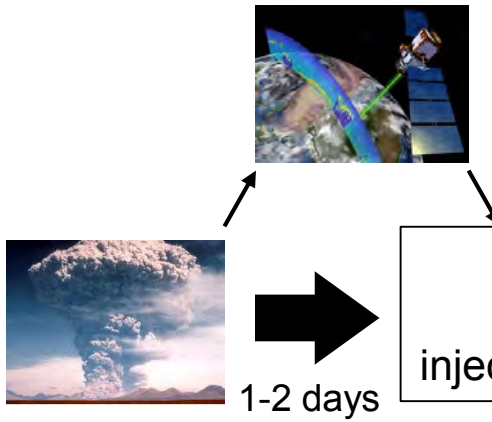
1992 mean temperature*

*1991-2020 percentile, ERA5

SPARC/DCPP Volcanic Response Readiness Exercise

Approach

- Simulate the response to a major volcanic eruption proposed by SPARC & DCPP:



1-2 days

SPARC VolRes
↓
injection amount & height

EVA*
↓
model volcanic aerosol forcings

*Easy Volcanic Aerosol idealized forcing generator

Decadal prediction centres
↓
revised predictions

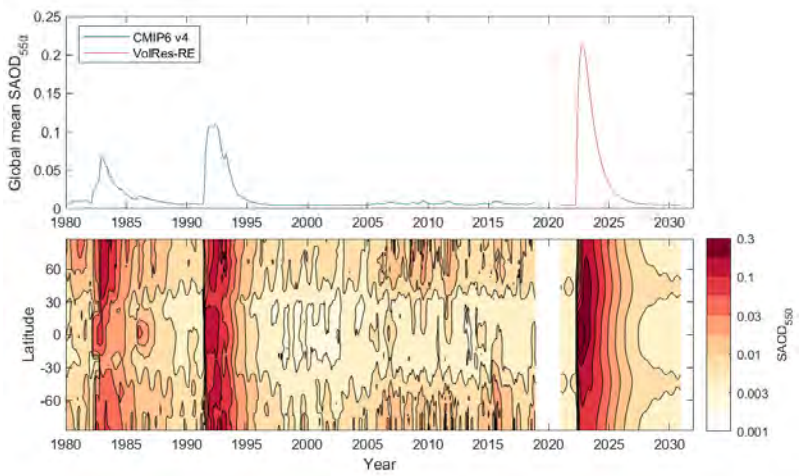
WMO LC-ADCP
↓
dissemination

Readiness Exercise

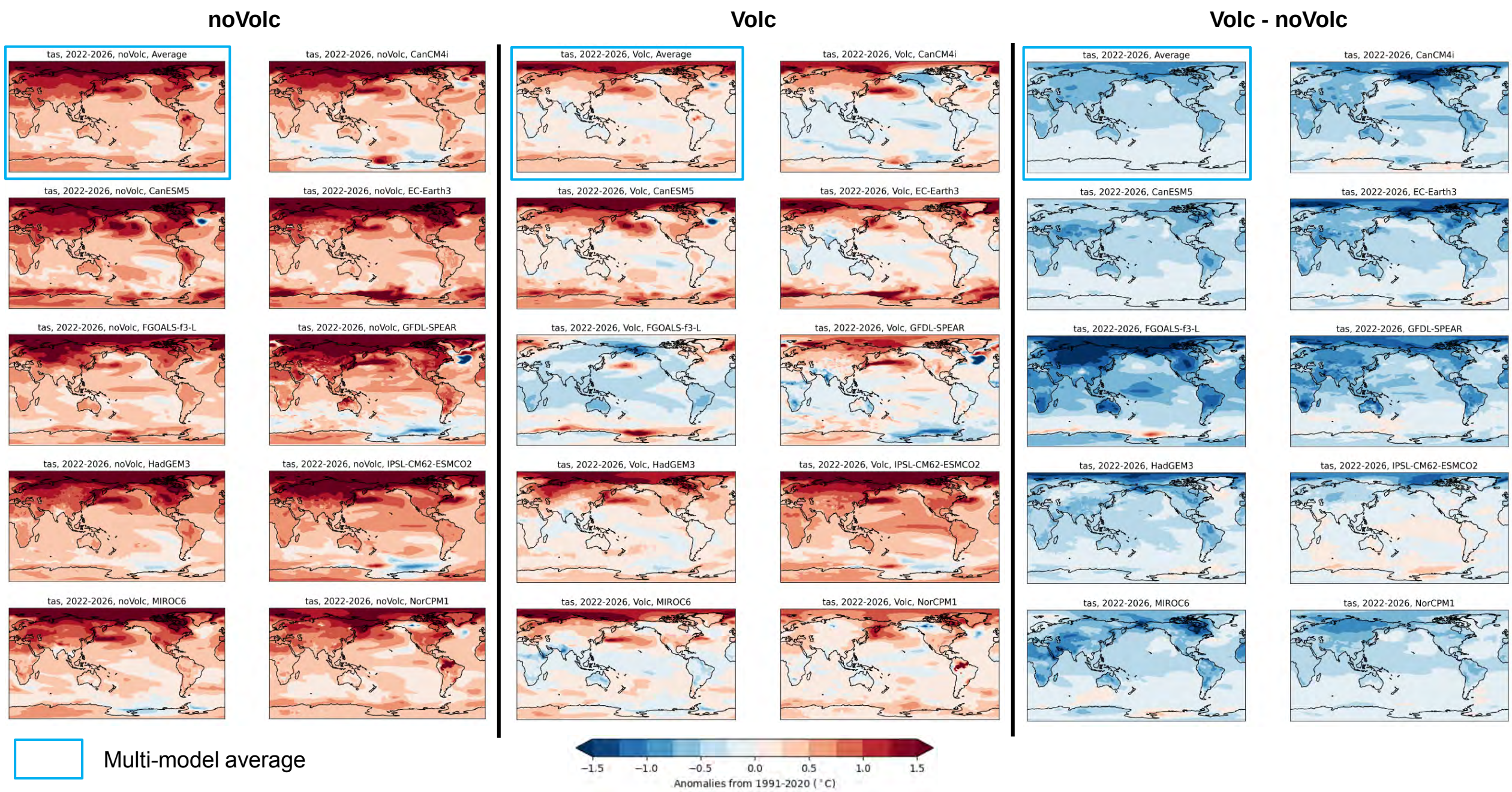
The hypothetical eruption

- **April 2022** in southern Mexico at ~17°N
- ~2 × stratospheric sulfur injection of Pinatubo

Stratospheric Aerosol Optical Depth

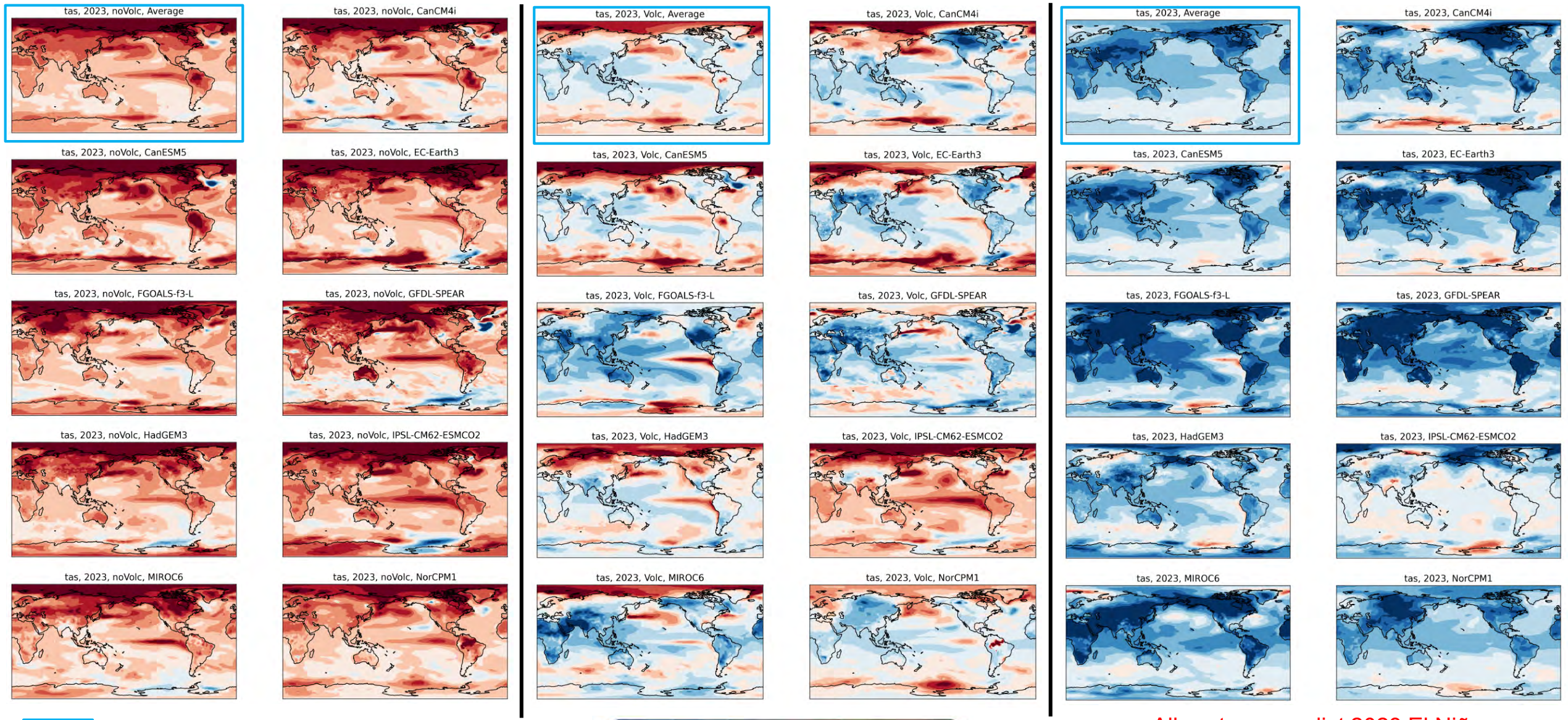


Initial results: 2022-2026 tas



Multi-model average

Initial results: 2023 tas



Multi-model average

All systems predict 2023 El Niño from late 2021!

Climate-system Historical Forecast Project (CHFP)

Current status

http://chfps.cima.fcen.uba.ar/

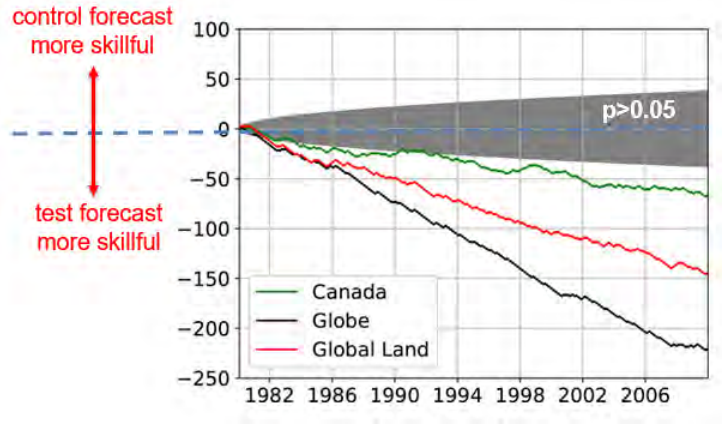
- Database of hindcasts from ~20 seasonal systems
- Has informed ~20 papers
- However, multiple barriers to keeping CHFP relevant:
  - ➢ Difficult to persuade centers to provide tailored data with every system update
  - ➢ Emergence of other hindcast data sources (e.g. NMME, C3S)
  - ➢ Sustainability at CIMA

Possible way forward

- TPOS 2020 final report recommended

  "…*development of a community effort to document model biases and to quantify how [seasonal] prediction systems may be improving with time*"

- WGSIP, APCC and WMO are exploring
  - Quasi-automated archiving of past, present & future generations of hindcasts from WMO Global Producing Centres
  - Migration of CHFP from CIMA
- Methodology for benchmarking performance when hindcast periods differ
  - Compare all systems vs "control" hindcast that spans 1960s-present
  - Employ random walk method of DelSole & Tippett



Lin et al., WAF (2020)

Long Range Forecast Transient Intercomparison Project

- Objective is to facilitate **intercomparisons of shock/drift/bias** following initialization
- Database of **pre-computed hindcast + congruent observed climatologies** (daily, monthly, annual)
- Currently **6 subseasonal**, **20 seasonal**, **16 decadal** systems from S2S, CHFP, DCPP

JAMES | Journal of Advances in Modeling Earth Systems

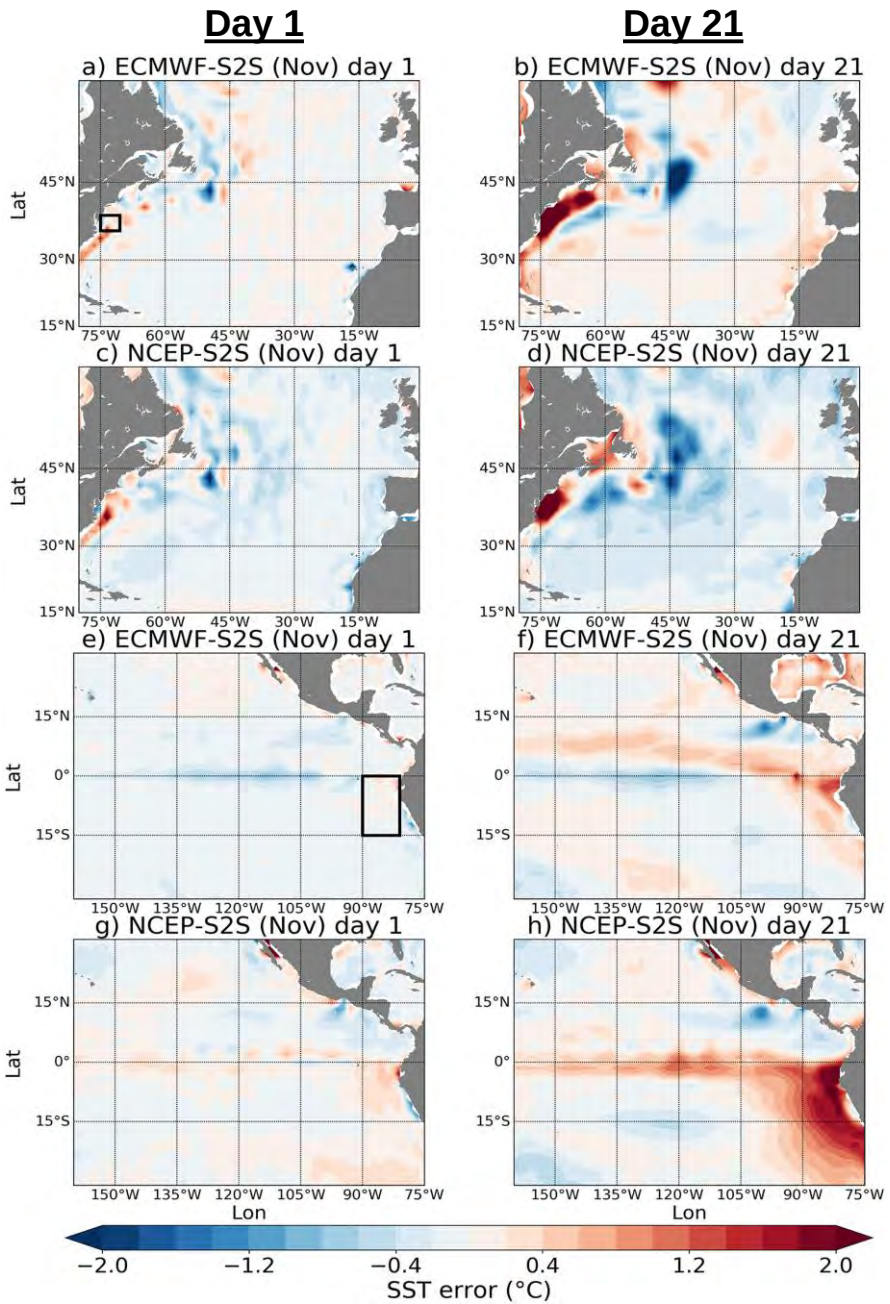
Research Article | Open Access

A Data Set for Intercomparing the Transient Behavior of Dynamical Model-Based Subseasonal to Decadal Climate Predictions

Ramiro I. Saurral, William J. Merryfield, Mikhail A. Tolstykh, Woo-Sung Lee, Francisco J. Doblas-Reyes, Javier García-Serrano, François Massonnet, Gerald A. Meehl, Haiyan Teng,

First published: 25 August 2021 | https://doi.org/10.1029/2021MS002570

Initial development of SST biases in NCEP and ECMWF S2S systems →



WCRP Workshop on Extremes in Climate Prediction Ensembles (ExCPEns)

- **Online from APEC Climate Center**
  25-27 October 2021

- **Early Career Scientist training and discussion forum**
  27-28 October 2021

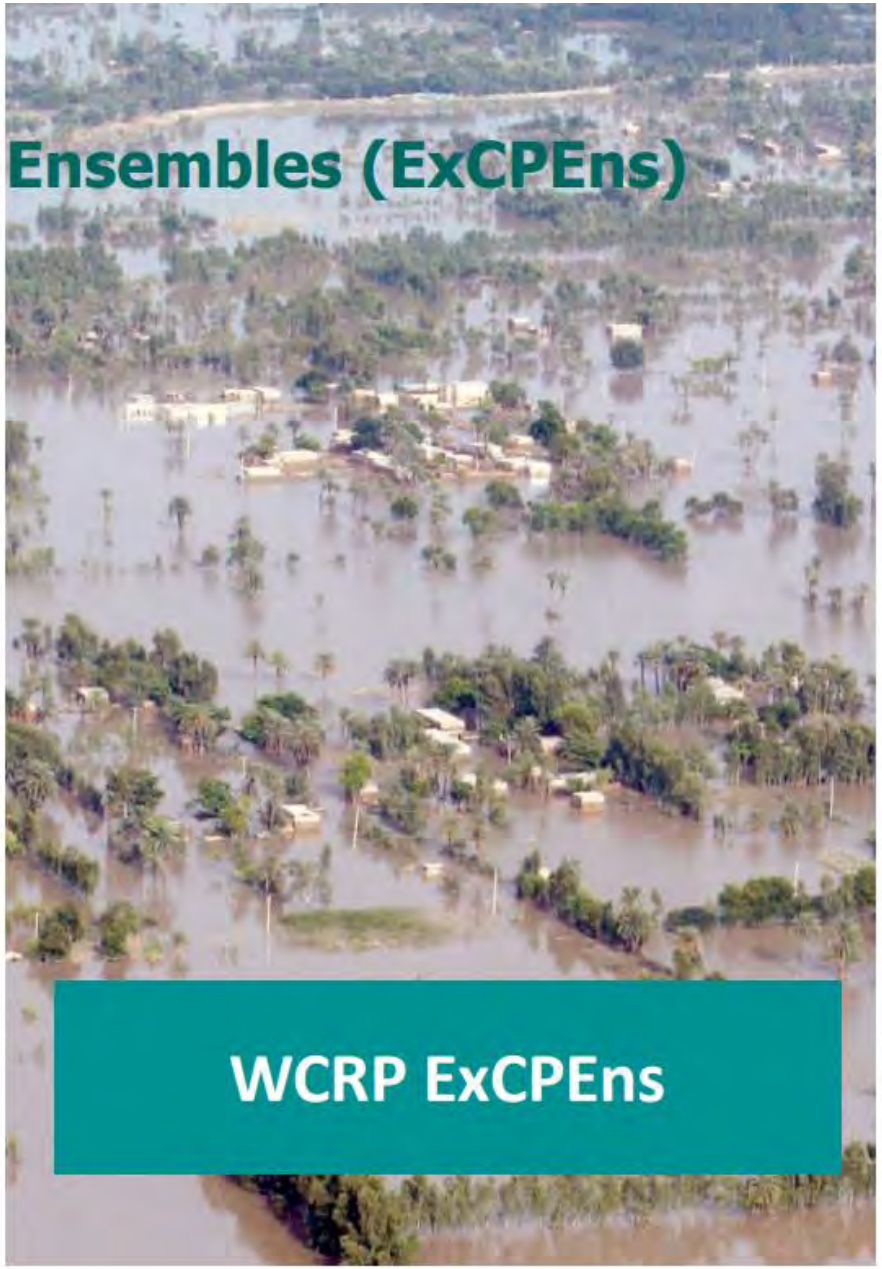
The focus of this workshop is exploiting subseasonal, seasonal, annual to decadal and longer-term prediction ensembles to improve the prediction and understanding of extreme weather and climate events.

Sessions:

1. Identification of extremes in observations and climate prediction ensembles
2. Physical mechanisms of extremes in observations and climate prediction ensembles
3. Regional climate extreme information relevant to impacts, vulnerability and adaptation
4. Prediction and predictability of large-scale climate variability relevant to extreme events
5. Prediction and predictability of specific extreme events (>10 days)
6. Quantifying current and future risks of climate extremes

Sponsored by

RCCS · APN ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH · PUSAN NATIONAL UNIVERSITY · ICCP · WCRP World Climate Research Programme · APCC APEC CLIMATE CENTER



See https://www.apcc21.org/act/workView.do?lang=en&bbsId=BBSMSTR_000000000024&nttId=7395 *(search ExCPEns APCC WGSIP)*
for links to program, presentation files, recorded talks

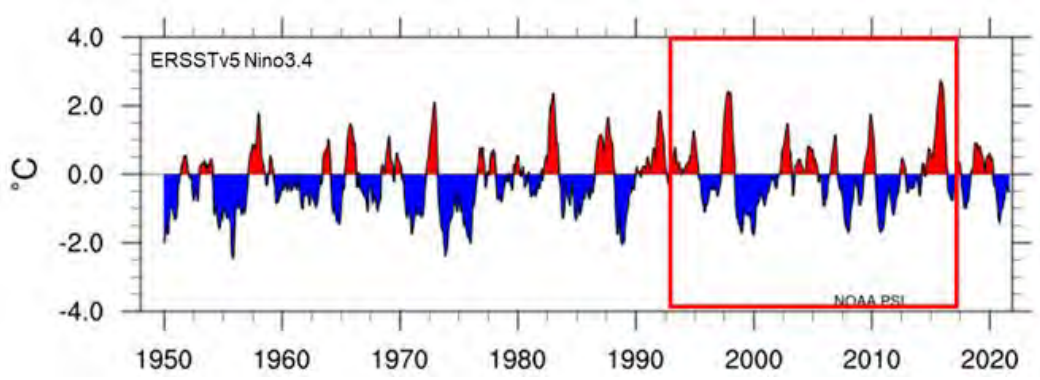
Extreme ENSO events in Copernicus seasonal hindcasts

Motivation

- Knowledge about potential ENSO extremes is limited by having only **one observed realization** + limited modern observational record
- Climate prediction ensembles can **greatly multiply** the number of realizations (assuming sufficiently realistic)

Approach

- Examine ENSO extremes in **C3S seasonal hindcasts**
  - 8 models, 184 ensemble members
  - 6-month hindcasts, 1993-2016
  - 4416 realizations!
- Focus on **December Niño3.4 initialized in July** (least constrained by initial conditions)
- Remove amplitude biases by rescaling to observed Niño3.4 variance

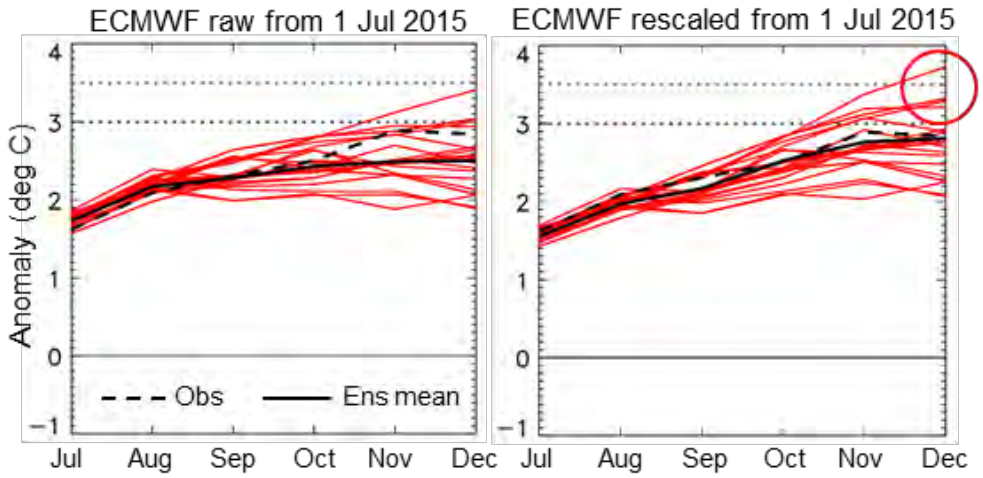


Merryfield & Lee, *Asia-Pacific Journal of Atmospheric Sciences* 2023, https://doi.org/10.1007/s13143-023-00328-2

Extreme ENSO events in Copernicus seasonal hindcasts

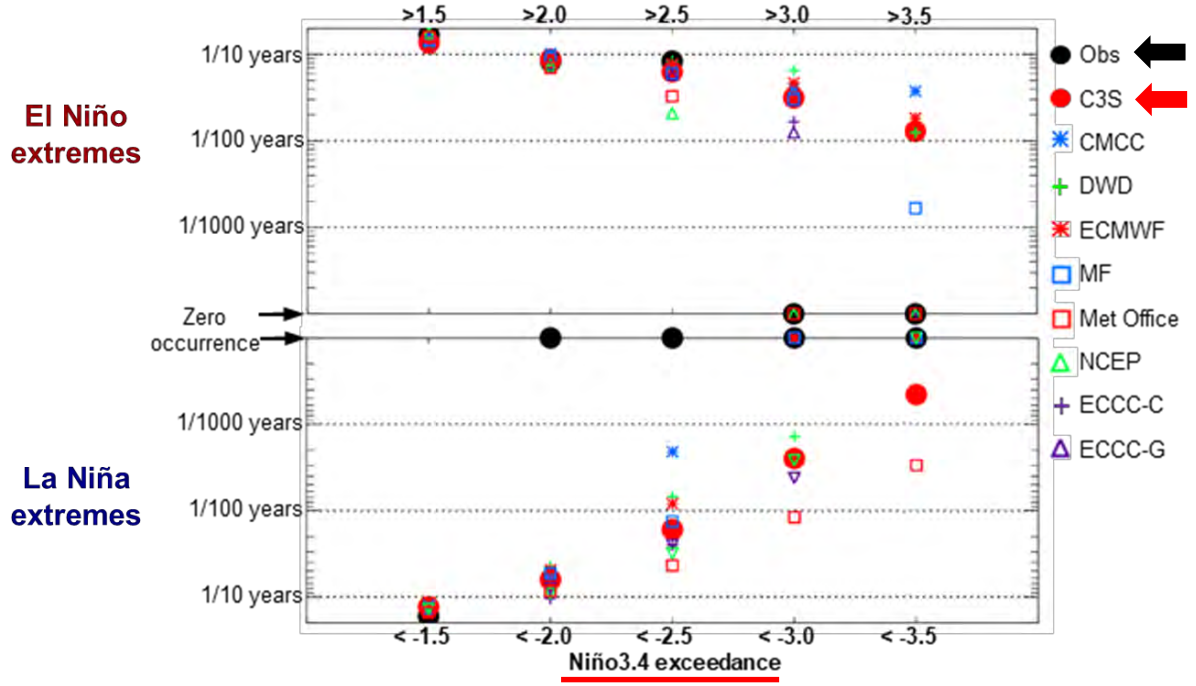
Example

- Raw & rescaled ECMWF plumes from July 2015:



Results

- Based on these many realizations, occurence frequencies for Dec Niño3.4 correspond to
  - **> 3.0 once in ≈30 years**
  - **> 3.5 once in ≈80 years**
  - **< -2.5 once in ≈60 years**
  - **< -3.0 once in ≈400 years**
- Caveats
  - model biases besides mean & amplitude not accounted for
  - occurrence frequencies somewhat model dependent
  - results are specific to 5-month lead realizations of 1993-2016 period



Merryfield & Lee, *Asia-Pacific Journal of Atmospheric Sciences* 2023, https://doi.org/10.1007/s13143-023-00328-2

Additional WGSIP activities involving MME

- Influences of temperature trends
- Seasonal prediction of ocean MLD, SSH and associated verification issues
- Seasonal to multi-year monsoon prediction
- Symposium on Frontiers in Subseasonal to Decadal Prediction →

https://www.wcrp-climate.org/decadal-prediction-link/symposium-frontiers-sdp

(search WGSIP meetings)

WCRP hybrid symposium on Frontiers in Subseasonal to Decadal Prediction

28 March 2023, ECMWF Reading, UK and online

Agenda and presentations

Agenda (.pdf version)

- The bone and the marrow: some suggestions for the future of climate prediction - ***F. Doblas-Reyes***
- Destination Earth and the future of climate information - ***P. Dueben***
- Prospects for Earth system reanalysis at ECMWF: ERA6 and beyond - ***H. Hersbach***
- Multi-year prediction of the global carbon cycle and potential policy implications - ***T. Ilyna***
- The role of aerosols in climate predictability and prediction - ***A. Frassoni***
- Toward resolving the ocean mesoscale: challenges and potential benefits - ***C. Roberts***
- Explainable AI for Climate Science: Detection, Prediction and Discovery - ***E. Barnes***
- Use of assimilation increments for bias correction and predictability studies – ***A. Molod***
- The role of vegetation in climate predictability and prediction - ***A. Alessandri***
- Application of subseasonal to decadal predictions to marine ecosystem management - ***M. Jacox***
- Improving seasonal forecasts using probabilistic deep learning - ***D. Lucas***
- Current and future directions for development of subseasonal to multiseasonal climate services - ***J-H. Yoo***

Extra slides

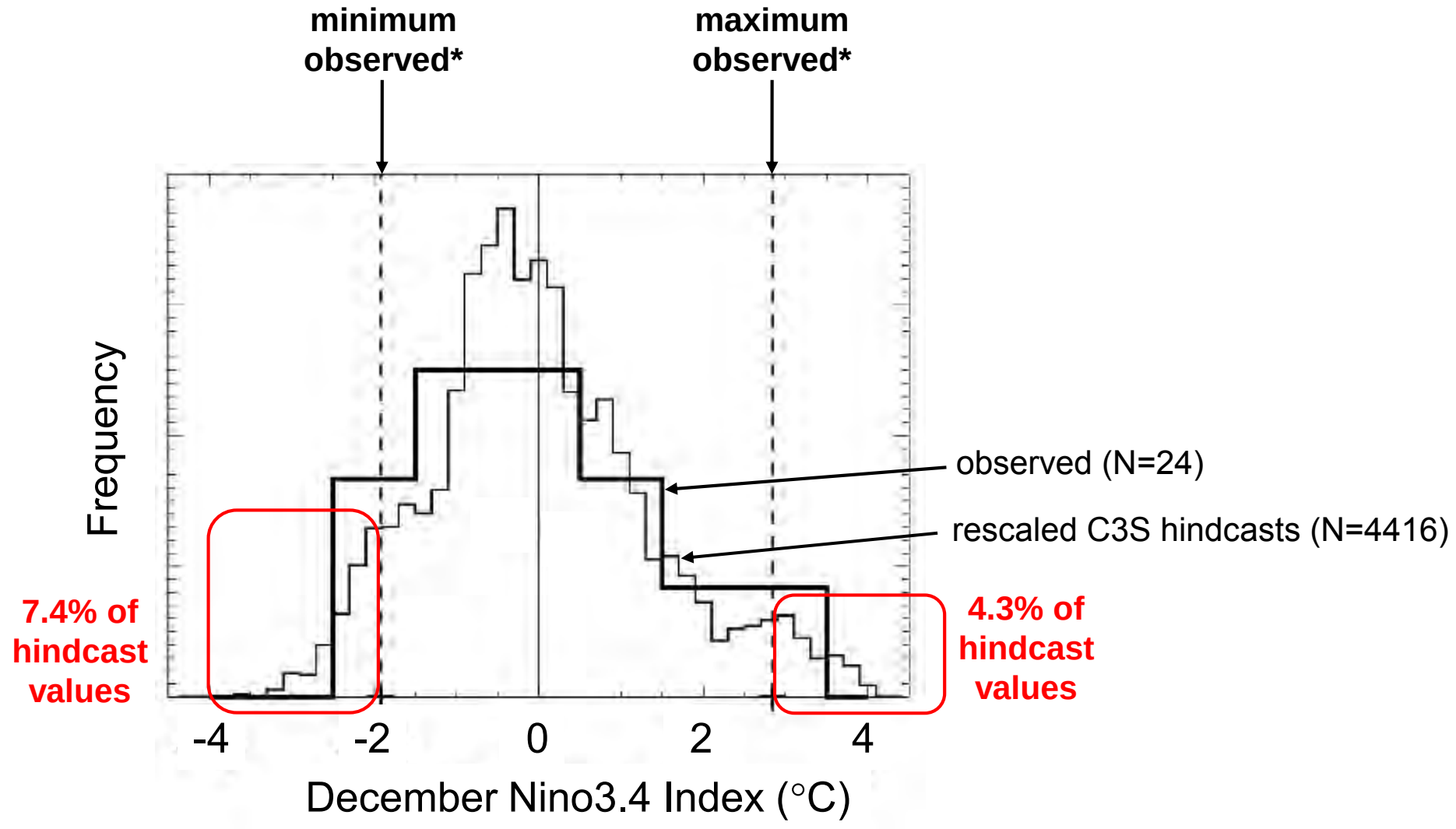
VolRes-RE Participation

- Currently, 9 models have contributed Protocol 1 forecasts, 7 have contributed Protocol 2 forecasts:

Centre	Model	Init time** P1(P2)	Range (y)	Ens size (H/F)	Fcst type
CCCma*	CanCM4i	2022-01(2022-04)	10(10)	10/10	Full
CCCma	CanESM5	2022-01(2022-04)	10(10)	20/40	Full
BSC*	EC-Earth3	2021-01(2022-04)	10(10)	10/10	Full
LASG*	FGOALS-f3-L	2021-01(2022-04)	9(5)	9/9	Full
GFDL*	SPEAR	2022-01(2022-04)	10(10)	-/10	Anom
MOHC*	HadGEM3	2021-11(—)	10(—)	10/10	Full
IPSL	CM62-ESMCO2	2022-01(—)	5(—)	5/10	Full
MIROC*	MIROC6	2021-01(2022-04)	10(10)	10/10	Full
BCCR*	NorCPM1	2021-01(2022-04)	10(10)	10/30	Full
MRI*	(in progress)				

*Contributed to LC-ADCP 2022-2026 forecast **All systems initialized on 1st day of indicated month

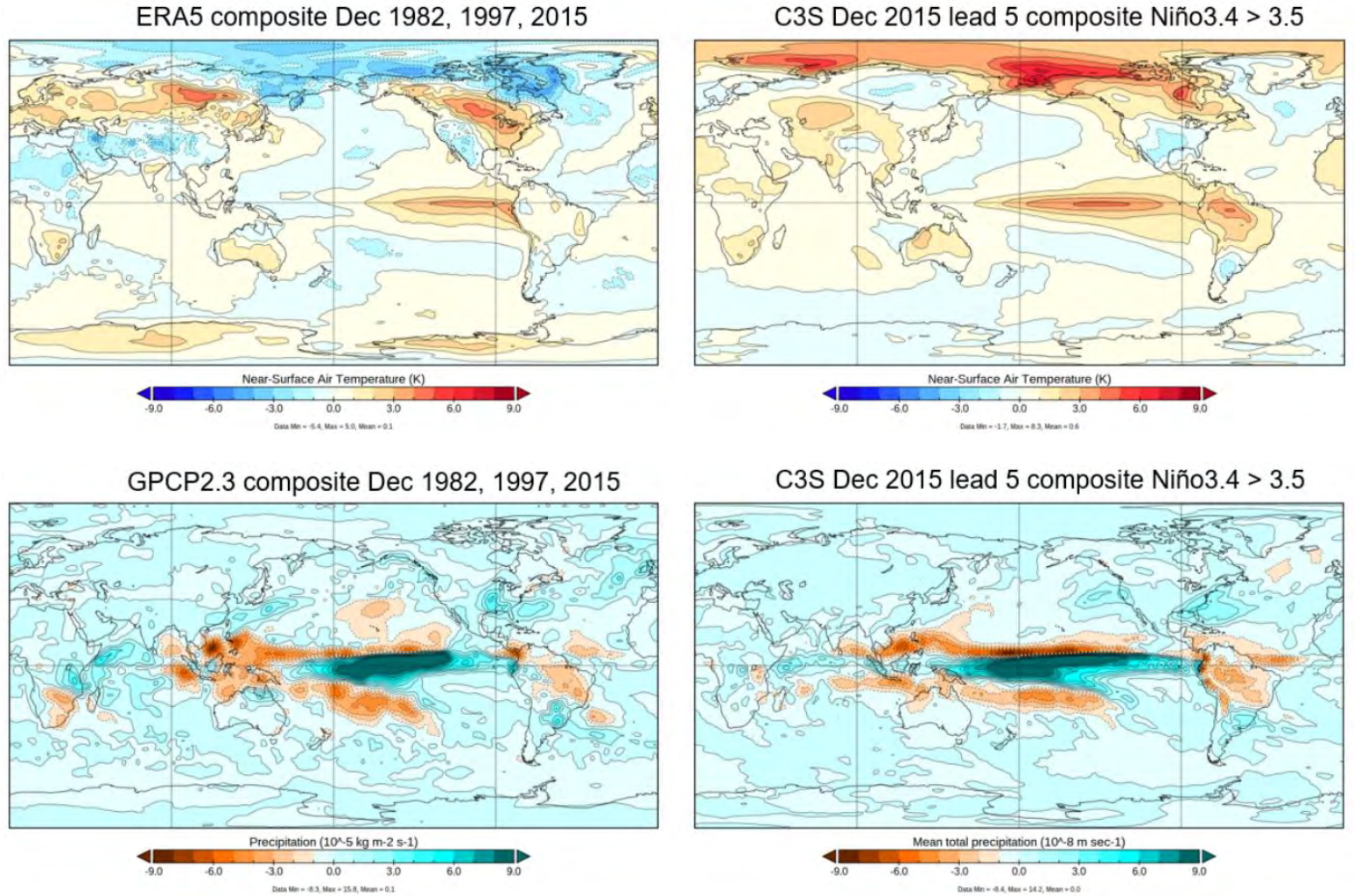
What does this imply about ENSO extremes?



*during 1993-2016

Conclusions

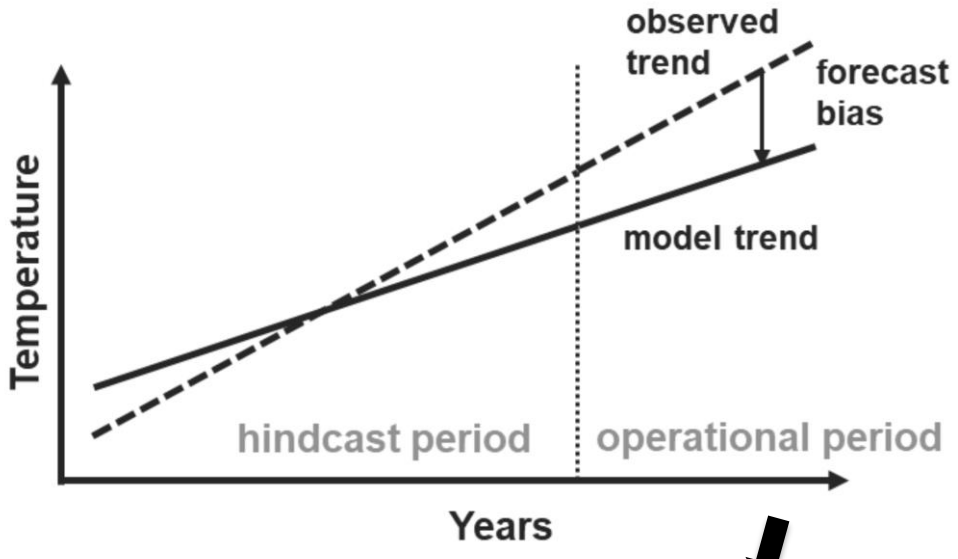
- Results suggest ENSO extremes exceeding those in observed record are realizable, leading to unprecedented impacts

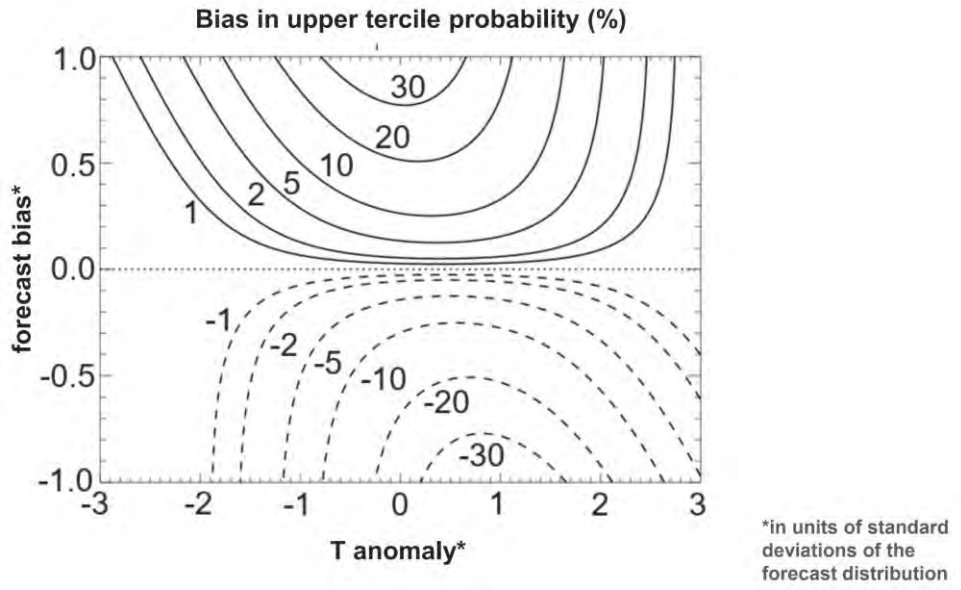


WGSIP Temperature Trends project

Objectives

- Assess long-term global and regional **temperature trend errors** as a function of lead time across many seasonal prediction systems
- Assess extent to which temperature trend errors **impact temperature prediction skill**
- Relate trend errors to radiative forcings and initialization methodologies
- Develop a **synthesis** of previous & new results for the community





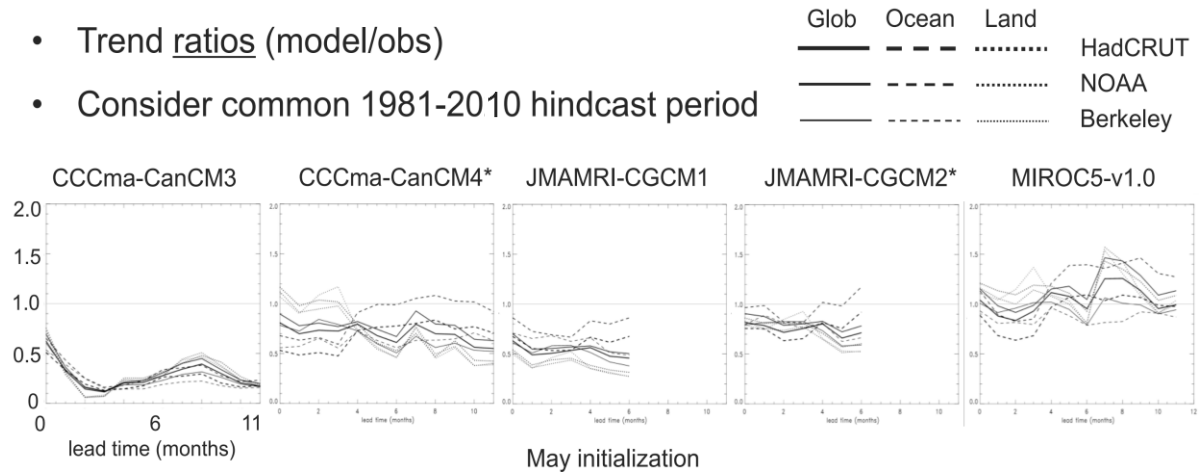
*in units of standard deviations of the forecast distribution

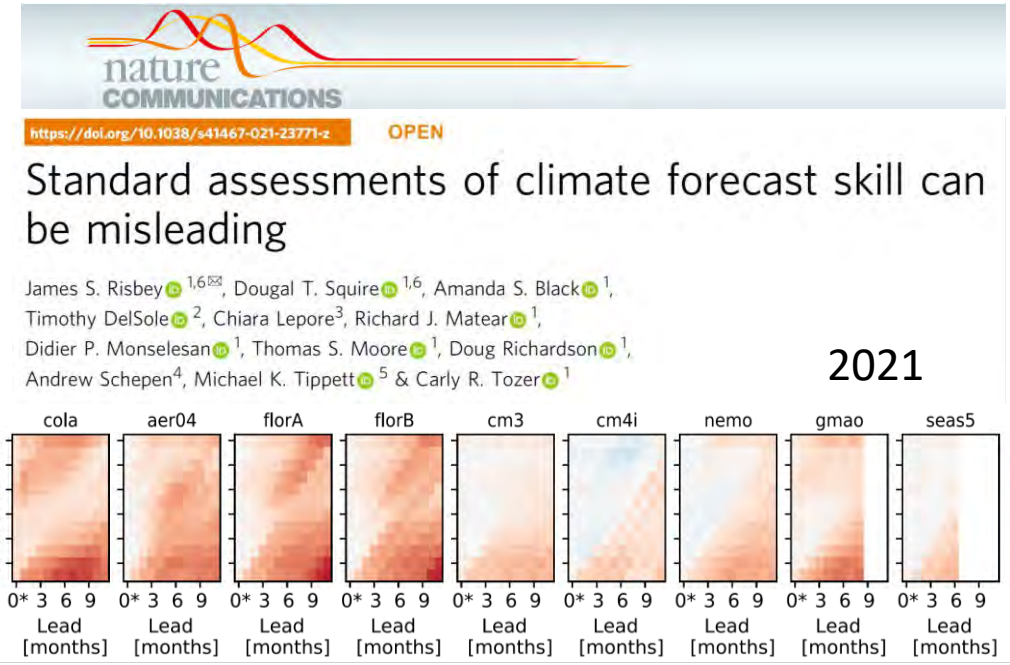
Results & community activity

- Temperature trend errors ~20 models have been assessed →

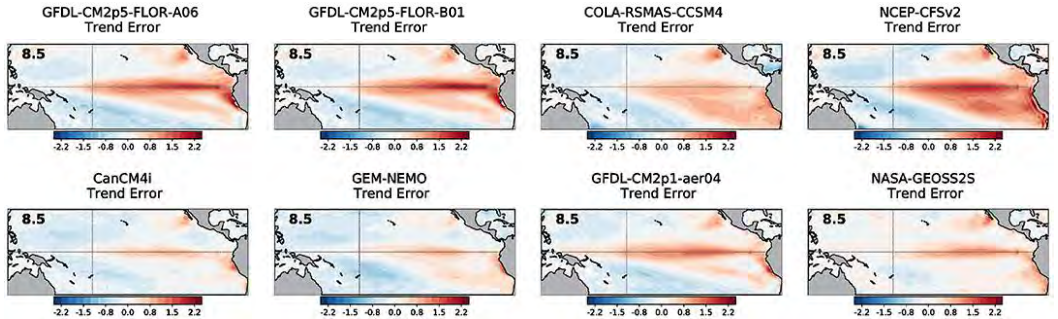
- The issue of how such errors can bias forecasts & skill measures is gaining traction in the community, though not in a coordinated manner ↓

- Trend ratios (model/obs)
- Consider common 1981-2010 hindcast period





Δ(Eq Nino3.4 ST bias), (1999-2016)-(1982-1998)



SST trend error at 8.5 month lead, 1982-2014

MLD prediction results & plans

- MLD is important for ecosystems, atmosphere-ocean interactions
- Intercompare multiple verification products (done) →
- Assess skill of 5 CHFP models & combinations thereof
- Assess utility of **multi-product verification**, as for SSH →
- Paper discussing skills, efficacy of verification datasets, potential utility of seasonal MLD predictions