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

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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.)
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
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

![Maps showing mean temperature before and after Pinatubo volcano eruption](image)

*1991-2020 percentile, ERA5
SPARC/DCPP Volcanic Response Readiness Exercise

**Approach**

- Simulate the response to a major volcanic eruption proposed by SPARC & DCPP:
  - SPARC VolRes ↓ injection amount & height
  - 1-2 days

**EVA***

- model volcanic aerosol forcings

**Decadal prediction centres**

- revised predictions

**WMO LC-ADCP**

- dissemination

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**The hypothetical eruption**

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

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*Easy Volcanic Aerosol idealized forcing generator*
Initial results: 2022-2026 tas

Multi-model average

Anomalies from 1991-2020 (°C)
Initial results: 2023 tas

All systems predict 2023 El Niño from late 2021!
Climate-system Historical Forecast Project (CHFP)

Current status

• 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
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

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 [APN APCC RCGS WCRP]

See [https://www.apcc21.org/act/workView.do?lang=en&bbsId=BBSMSTR_000000000024&nttId=7395](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

Extreme ENSO events in Copernicus seasonal hindcasts

Example
- Raw & rescaled ECMWF plumes from July 2015:

Results
- Based on these many realizations, occurrence 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

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

WCRP hybrid symposium on Frontiers in Subseasonal to Decadal Prediction

28 March 2023, ECMWF Reading, UK and online

Agenda and presentations

- 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. Duenb
- 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. Prassoni
- 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. Alessandr
- Application of subseasonal to decadal predictions to marine ecosystem management - M. Jacon
- Improving seasonal forecasts using probabilistic deep learning - D. Lucas
- Current and future directions for development of subseasonal to multisessional climate services - J-H. Yoo

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

(search WGSIP meetings)
Extra slides
VolRes-RE Participation

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

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*Contributed to LC-ADCP 2022-2026 forecast  **All systems initialized on 1st day of indicated month
What does this imply about ENSO extremes?

- Maximum observed*: 4.3% of hindcast values
- Minimum observed*: 7.4% of hindcast values

*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
• 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 ↓

Standard assessments of climate forecast skill can be misleading

2021

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

Results & community activity
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