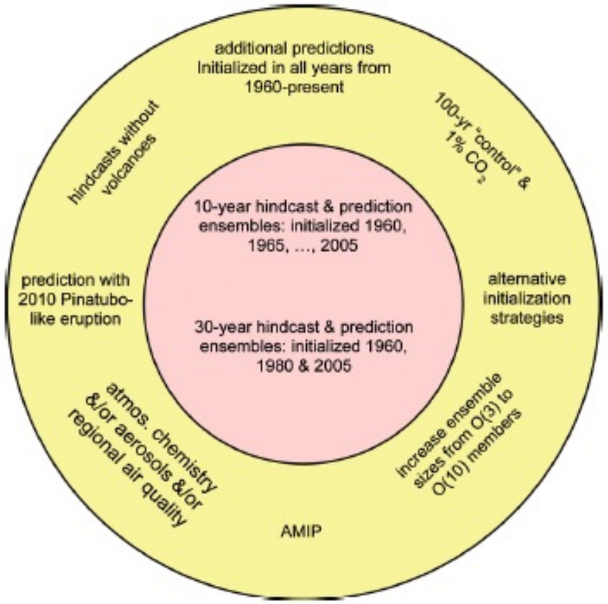
Decadal Climate Prediction Project (DCPP): Progress and Plans

Steve Yeager and Jon Robson (DCPP Co-Chairs)

A Brief History

Disparate uncoordinated DP efforts

CMIP5



Taylor et al. (BAMS, 2012)

DCPP Panel: coordinate the scientific and practical aspects of decadal climate prediction research within WCRP

CMIP6

	Expmt	experiment_id	Tier	Years	Description
Component A: Decadal Hindcasts	A1	dcppA-hindcast	1	3000	Five-year hindcasts every year from 1960. Note that the first forecast year is 1961 from initialization toward the end of 1960.
	A2.1		2	3000	Extend A1 hindcast duration to 10 years
	A2.2	dcppA-historical	2	1700	Ensemble of uninitialized historical/future simulations
	A2.3	dcppA-assim	2	(60-600)	Ensemble of "assimilation" run(s) (if available). These are simulations used to incorporate observation-based data into the model in order to generate initial conditions for hindcasts. They parallel the historical simulations and use the same forcing. The number of years depends on the number of independent assimilation runs.
	A3.1	dcppA-hindcast	3	300m	Increase ensemble size by *m* for A1
	A3.2		3	300m	Increase ensemble size by *m* for A2.1
	A4.1	dcppA-hindcast-niff	4	3000	As A1 but no forcing information from the future (niff) with respect to the hindcast. Forcing from persistence or other estimate.
	A4.2	dcppA-historical-niff	4	3000	As A4.1 but initialized from historical simulations
Component B: Decadal Forecasts	B1	dcppB-forecast	1	50	Ongoing near-real-time forecasts
	B2.1		2	5m	Increase ensemble size by *m* for B1
	B2.2		2	50	Extend forecast duration to 10 years for B1
Component C: Hiatus+	C1.1	dcppC-atl-control	1	250	Idealized Atlantic control
	C1.2	dcppC-amv-pos	1	250	Idealized impact of AMV+
	C1.3	dcppC-amv-neg	1	250	Idealized impact of AMV-
	C1.4	dcppC-pac-control	1	100	Idealized Pacific control
	C1.5	dcppC-ipv-pos	1	100	Idealized impact of IPV+
	C1.6	dcppC-ipv-neg	1	100	Idealized impact of IPV-
	C1.7	dcppC-amv-ExTrop-pos dcppC-amv-ExTtrop-neg	2	500	Idealized impact of extratropical AMV+ and AMV-
	C1.8	dcppC-amv-Trop-pos dcppC-amv-Trop-neg	2	500	Idealized impact of tropical AMV+ and AMV-
	C1.9	dcppC-ipv-NexTrop-pos dcppC-ipv-NexTtrop-neg	2	200	Idealized impact of northern extratropical IPV+ and IPV-
	C1.10	dcppC-pac-pacemaker	3	650	Pacemaker Pacific experiment
	C1.11	dcppC-atl-pacemaker	3	650	Pacemaker Atlantic experiment
Component C: Atlantic gyre	C2.1	dcppC-atl-spg	3	200-400	Predictability of 1990s warming of Atlantic gyre
	C2.2		3	200-400	Additional start dates
Component C: Volcano	C3.1	dcppC-hindcast-noPinatubo	1	50-100	Repeat 1991 hindcast but without Pinatubo forcing
	C3.2	dcppC-hindcast-noElChichon	2	50-100	Repeat 1982 hindcast but without El Chichon forcing
	C3.3	dcppC-hindcast-noAgung	2	50-100	Repeat 1963 hindcast but without Agung forcing
	C3.4	dcppC-forecast-addPinatubo	1	50-100	Repeat 2015 forecast with added Pinatubo forcing
	C3.5	dcppC-forecast-addElChichon	3	50-100	Repeat 2015 forecast with added El Chichon forcing
	C3.6	dcppC-forecast-addElChichon	3	50-100	Repeat 2015 forecast with added Agung forcing

Boer et al. (GMD, 2016)

CMIP6 DCPP Protocol

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Component A

- 5/10 year hindcasts every year from 1960
- 10+ member ensembles
- CMIP6 historical forcings + SSP2-4.5
- 10+ member set of uninitialized hist+ssp

Component B

- Real-time forecasts

Component C

Predictability, mechanisms, & Case Studies

- Idealized AMV and PDV experiments
- Atlantic & Pacific pacemaker experiments
- Perturbed initialization experiments
- Experiments with/without volcanic forcing
- Allows participation from groups not doing initialized prediction

Boer et al. (GMD, 2016)

Select CMIP6 DCPP Results

npj Climate and Atmospheric Science 2019 www.nature.com/npjclimatsci

ARTICLE OPEN

Robust skill of decadal climate predictions

D. M. Smith[1], R. Eade[1], A. A. Scaife[1,2], L.-P. Caron[3], G. Danabasoglu[4], T. M. DelSole[5], T. Delworth[6], F. J. Doblas-Reyes[3,7], N. J. Dunstone[1], L. Hermanson[1], V. Kharin[8], M. Kimoto[9], W. J. Merryfield[8], T. Mochizuki[10], W. A. Müller[11], H. Pohlmann[11], S. Yeager[4] and X. Yang[6]

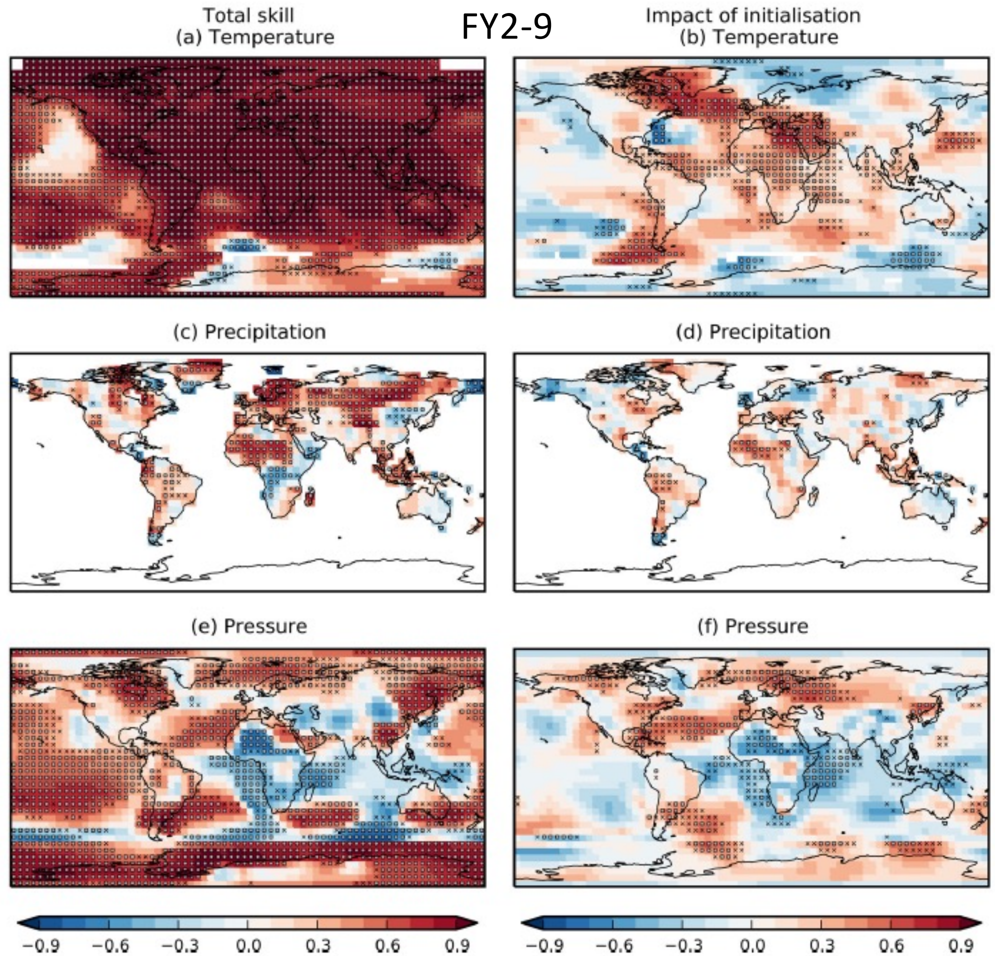
Table 1. Forecast systems and ensemble sizes

Forecast Centre	Model	Initialised ensemble size	Uninitialized ensemble size	References
Barcelona Supercomputing Center, Spain	EC-EARTH	5	10	89,90
Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada	CANCM4	10	10	91
Geophysical Fluid Dynamics Laboratory, USA	CM2	10	10	92
Met Office Hadley Centre, UK	HADCM3 (ANOMALY INITIALISATION)	10		93
Met Office Hadley Centre, UK	HADCM3 (FULL FIELD INITIALISATION)	10	10	93
University of Tokyo, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	MIROC5	6	3 (1 for precipitation and MSLP)	94,95
Max Planck Institute for Meteorology, Germany	MPI-ESM-LR	10	3	96
National Center for Atmospheric Research, USA	CESM1.1	10	10	35
	Total	71	56 (54 for precipitation and MSLP)	

71-members

- Signal-to-noise paradox widespread in decadal prediction
  ➔ need for very large ensembles
- Significant benefits from initialization for decadal climate outlooks
- Hints of decadal NAO prediction skill (ACC ~ 0.5)

FY2-9



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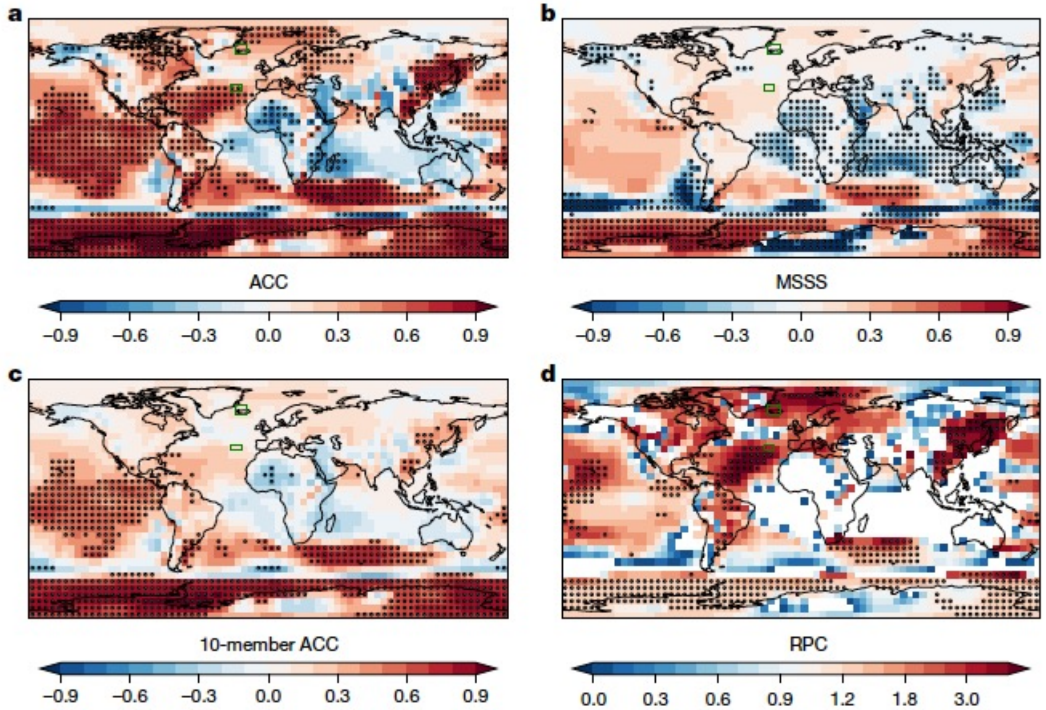
North Atlantic climate far more predictable than models imply

Nature 2020

https://doi.org/10.1038/s41586-020-2525-0
Received: 23 December 2019
Accepted: 1 May 2020
Published online: 29 July 2020
Check for updates

D. M. Smith[1]✉, A. A. Scaife[1,2], R. Eade[1], P. Athanasiadis[3], A. Bellucci[3], I. Bethke[4], R. Bilbao[5], L. F. Borchert[6], L.-P. Caron[5], F. Counillon[4,7], G. Danabasoglu[8], T. Delworth[9], F. J. Doblas-Reyes[5,10], N. J. Dunstone[1], V. Estella-Perez[6], S. Flavoni[6], L. Hermanson[1], N. Keenlyside[4,7], V. Kharin[11], M. Kimoto[12], W. J. Merryfield[11], J. Mignot[6], T. Mochizuki[13,14], K. Modali[15,19], P.-A. Monerie[16], W. A. Müller[15], D. Nicolì[3], P. Ortega[5], K. Pankatz[17], H. Pohlmann[15,17], J. Robson[16], P. Ruggieri[3], R. Sospedra-Alfonso[11], D. Swingedouw[18], Y. Wang[7], S. Wild[5], S. Yeager[8], X. Yang[9] & L. Zhang[9]

FY2-9 DJFM SLP



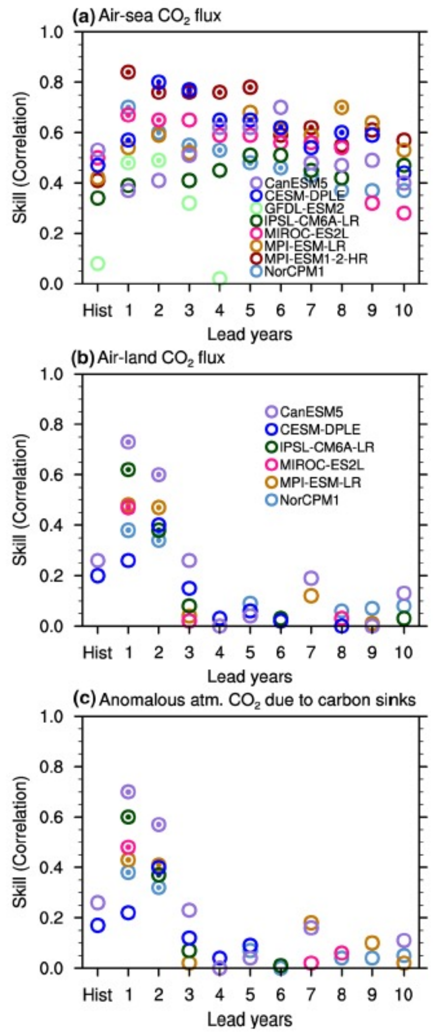
- 169-member ensemble
- Unrealistically low signal-to-noise (RPC>1) where ACC shows skill
- Lagged ensemble (676-member) yields high skill for decadal NAO (ACC ~ 0.8) & related impacts over Europe, N. America after calibration
- High decadal NAO skill also seen in some individual systems (e.g., CESM1-DPLE; Athanasiadis et al. 2020)

Select CMIP6 DCPP Results

Predictable Variations of the Carbon Sinks and Atmospheric CO_2 Growth in a Multi-Model Framework

T. Ilyina[1], H. Li[1], A. Spring[1,2], W. A. Müller[1], L. Bopp[3], M. O. Chikamoto[4], G. Danabasoglu[5], M. Dobrynin[6], J. Dunne[7], F. Fransner[8], P. Friedlingstein[9], W. Lee[10], N. S. Lovenduski[11], W.J. Merryfield[10], J. Mignot[12], J.Y. Park[13], R. Séférian[14], R. Sospedra-Alfonso[10], M. Watanabe[15], and S. Yeager[5]

GRL 2021



Skill due to initialization:

← Up to 6 years

← Up to 2 years

← Up to 2 years

- Advent of Earth system model contributions to DCPP permits assessment of carbon cycle predictability
- Essential for carbon monitoring programs in the presence of internal variability
- Multi-year skill also found for ocean acidification (Brady et al., 2020) & ocean net primary productivity (Krumhardt et al., 2020)

Select CMIP6 DCPP Results

npj | Climate and Atmospheric Science

2021

www.nature.com/npjclimatsci

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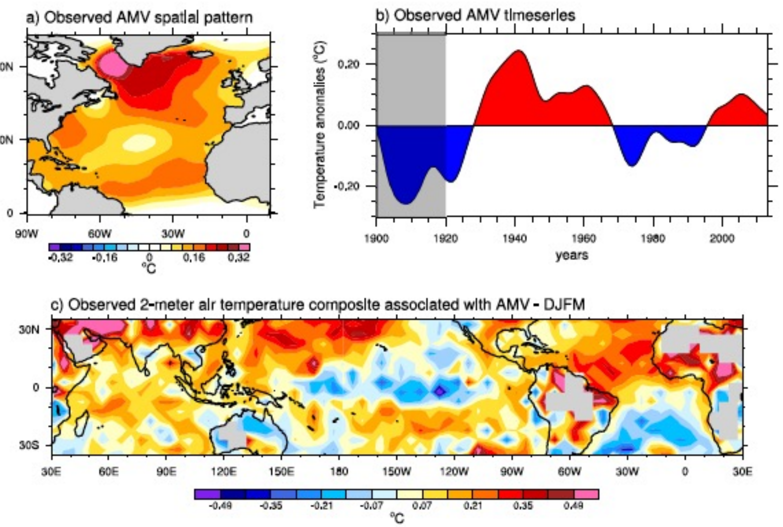
Check for updates

Impacts of Atlantic multidecadal variability on the tropical Pacific: a multi-model study

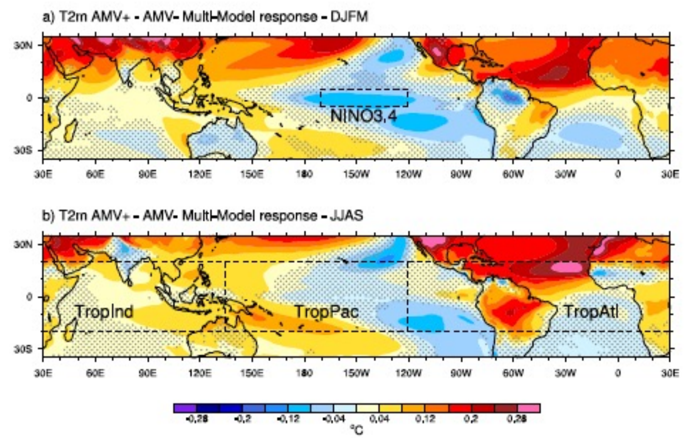
Yohan Ruprich-Robert[1], Eduardo Moreno-Chamarro[1], Xavier Levine[1], Alessio Bellucci[2,3], Christophe Cassou[4], Frederic Castruccio[5], Paolo Davini[6], Rosie Eade[7], Guillaume Gastineau[8], Leon Hermanson[7], Dan Hodson[9], Katja Lohmann[10], Jorge Lopez-Parages[4], Paul-Arthur Monerie[9], Dario Nicolì[2], Said Qasmi[4,11], Christopher D. Roberts[12], Emilia Sanchez-Gomez[4], Gokhan Danabasoglu[5], Nick Dunstone[7], Marta Martin-Rey[13], Rym Msadek[4], Jon Robson[9], Doug Smith[7] and Etienne Tourigny[1]

DCPP-C Imposed SST →



- AMV warming linked to tropical Pacific cooling
- Other recent DCPP-C AMV studies:
  - Global monsoons (Monerie et al. 2019)
  - N. Atlantic storm track (Ruggieri et al. 2020)
  - Arctic sea ice (Castruccio et al. 2019)
- Ongoing debate regarding validity of experimental design (e.g., Kim et al. 2020; O'Reilly et al. 2022)

Multi-model response →



WMO Annual to Decadal Climate Update

WMO Lead Centre for Annual-to-Decadal Climate Prediction

The Lead Centre for Annual-to-Decadal Climate Prediction collects and provides hindcasts, forecasts and verification data from a number of contributing centres worldwide.

https://hadleyserver.metoffice.gov.uk/wmolc/

Global Producing Centres

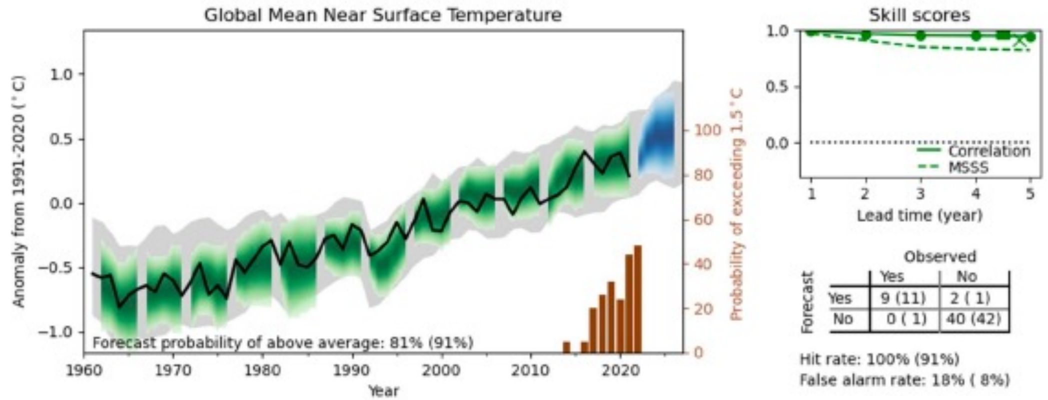
BSC	CCCMA	CSIRO	DWD	MOHC

Contributing Centres

BCCR	DMI	LASG	MRI	Reading
CERFACS	GFDL	MIROC	NCAR	SMHI
CMCC	IPSL	MPI	NRL	

- Decadal climate predictions are now operational, with annual updates (outgrowth of DCPP-B)

From update for 2022-2026:



"The chance of global near-surface temperature exceeding 1.5°C above preindustrial levels at least one year between 2022 and 2026 is about as likely as not (48%). There is only a small chance (10%) of the five-year mean exceeding this threshold."

DCPP Recent Activities

- 9 virtual meetings since 2019
- Data submissions to CMIP6
- Contributions to WGI Chapter 4 of AR6 Report (Merryfield + others)
- 2019 WCRP-DCPP AGU Townhall
- Coordinated analysis (e.g., DCPP-C volc/novolc experiments; Hermanson et al. 2020; Bilbao et al. 2022)
- New coordinated experiments:
  - DCPP-D (with/without COVID emissions reductions)
  - Volcanic Response Readiness Exercise (VolRes RE), a joint SPARC/DCPP effort
- Gaps in existing DCPP experimental protocol:
  - Seasonal-to-interannual (S2I) timescales
  - High-resolution DP
- Upcoming in-person meeting (WCRP EPESC/DCPP in Exeter, UK, March 2023)

DCPP in CMIP7

- Ideas for updates to Boer et al. (2016) protocol:
  - DCPP-A to include seasonal-to-interannual hindcasts in addition to decadal (e.g., CESM2-SMYLE; Yeager et al., *GMD*, 2022)
  - DCPP-A to include explicit protocol for high-resolution (0.1° ocean, 0.25° atmosphere) hindcasts to facilitate multi-model comparison/analysis
  - DCPP-C pacemaker experiments to utilize emerging techniques that circumvent SST restoring
  - DCPP-C no-volcano experiments to call for full hindcast set
  - Increased emphasis (higher tier) for ”niff” (no information from the future) & single-forcing hindcasts sets to better understand predictability mechanisms
  - Initialized forecasts with geoengineering? (in coordination with GeoMIP)
  - Multidecadal (30-year hindcasts) protocol?

- Overlaps & collaborations with WCRP Lighthouse activities need scoping out
  - Explaining and Predicting Earth System Change
  - My Climate Risk

- **Should uninitialized mechanisms experiments continue to be a DCPP activity?**
- **How should DCPP in CMIP7 synergize with ongoing WMO operational prediction activities?**

DCPP Panel Membership

- Jon Robson (Co-Chair), U. Reading
- Steve Yeager (Co-Chair), NCAR
- Tatiana Ilyina, MPI
- Jerry Meehl, NCAR
- Bill Merryfield, ECCC
- Juliette Mignot, IPSL
- ~~Rym Msadek, CERFACS~~
- Wolfgang Müller, MPI
- Terence O'Kane, CSIRO
- Pablo Ortega, BSC
- Doug Smith, UKMO
- ~~Christophe Cassou, CERFACS~~
- ~~Takashi Mochizuki, JAMSTEC~~
- ~~Louis-Philippe Caron, BSC~~

→ Need broader representation from active DP-producing institutions moving forward