PPAI /PSMI Joint session on Decadal Variability

Decadal variability: 5-year-ahead scale for water and other sectors

Robert Burgman: Florida International University
Kevin Reed: Stony Brook University

15:30 – 15:45 “Decadal Climate Prediction Project in CMIP6”: Rob Burgman (FIU)

15:45 – 16:00 "Decadal variability and potential predictability in the Atlantic": Rong Zhang (GFDL)

16:00 – 16:15 “Pacific Decadal Variability” : Emanuel Di Lorenzo (GT)

16:15 – 16:30 "High-resolution climate modeling: A tool to study extreme weather on decadal timescales": Kevin Reed (Stony Brook)

16:30 – 16:45 "The role of ocean eddies in decadal predictability in the North Atlantic": Ben Kirtman (UM/RSMAS)

16:45 – 17:00"Towards the Application of Decadal Climate Predictions in Water Management" : Erin Towler (NCAR)

17:00 – 17:30 Discussion

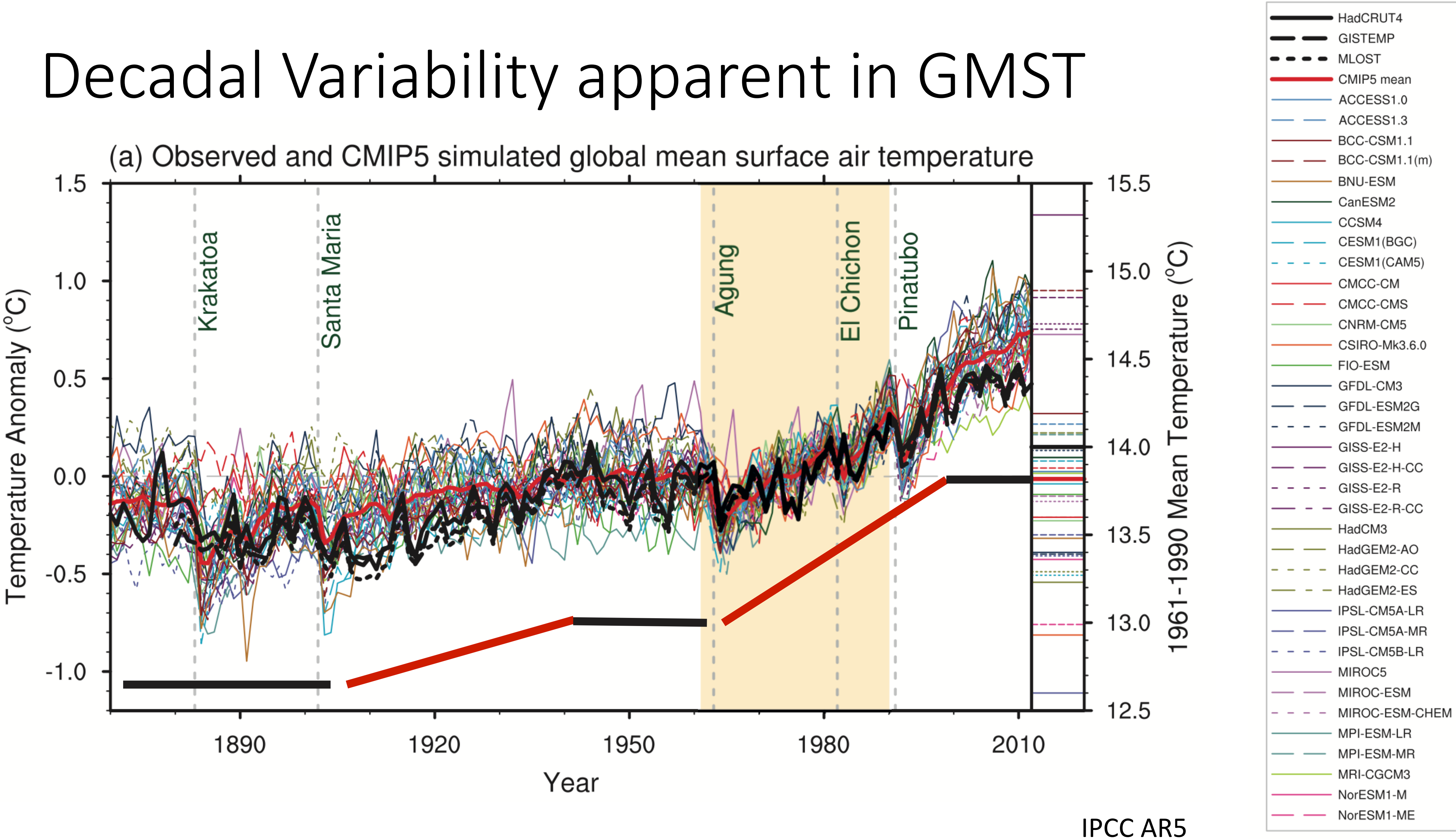
Decadal Climate Prediction Project in CMIP6

Robert Burgman
Florida International University

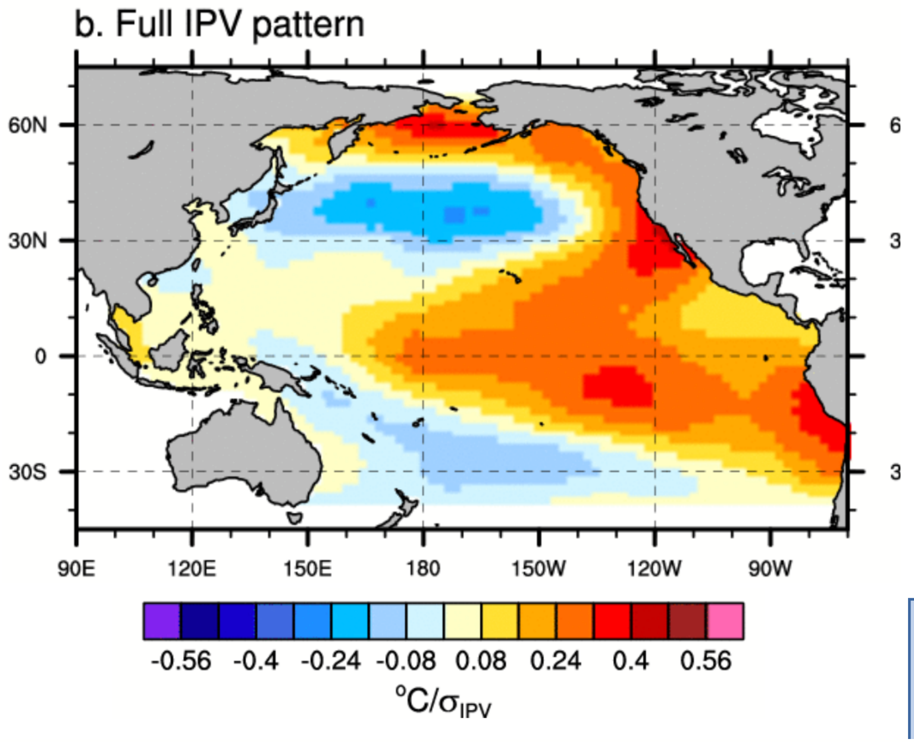
FLORIDA INTERNATIONAL UNIVERSITY

US CLIVAR

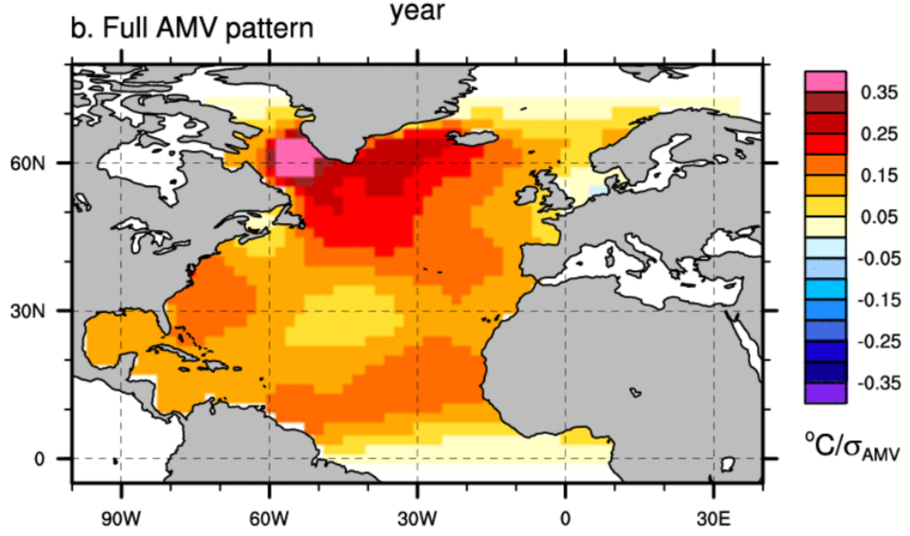
Decadal Variability apparent in GMST



IPCC AR5



Pacific Decadal Variability is associated with potentially important climate impacts, including rainfall over America, Asia, Africa and Australia (Power et al., 1999; Deser et al., 2004; Seager et al., 2008; Burgman et al. 2010; Zhu et al., 2011; Li et al., 2012,).



Atlantic Multidecadal Variability affects

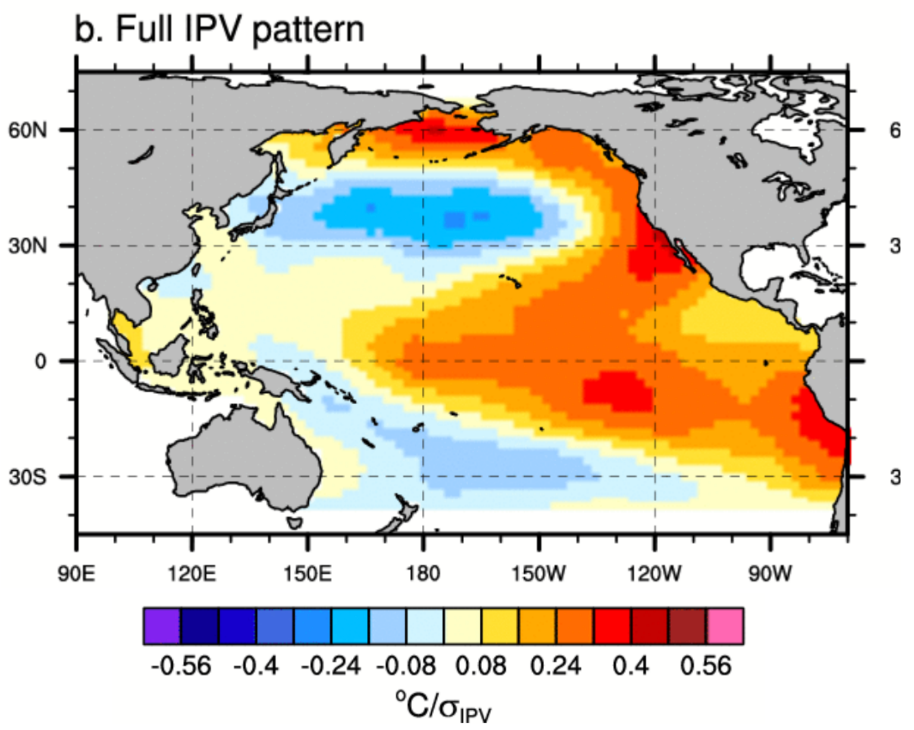
West African monsoon and Sahel rainfall (Sutton and Hodson 2005 ; Mohino et al., 2011)

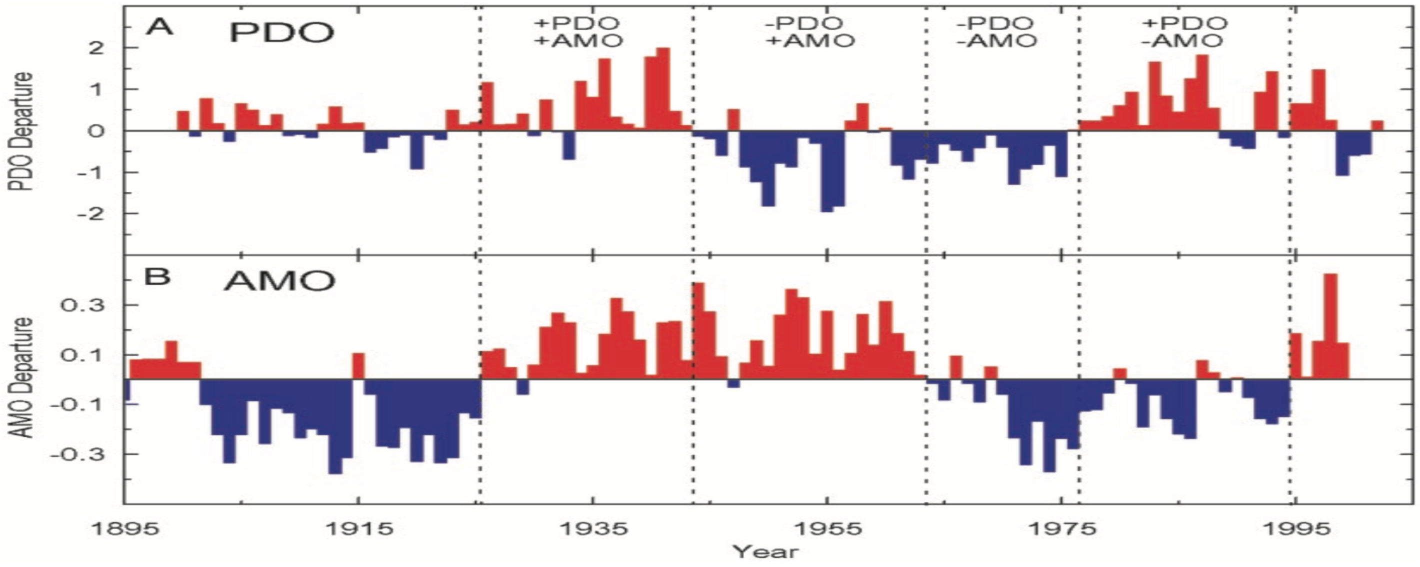
North America and European summer climate (Seager et al., 2008 Feng et al., 2011, Folland et al., 2009; Lonita et al., 2012)

Arctic temperature (Chylek et al., 2009; Mahajan et al., 2011)

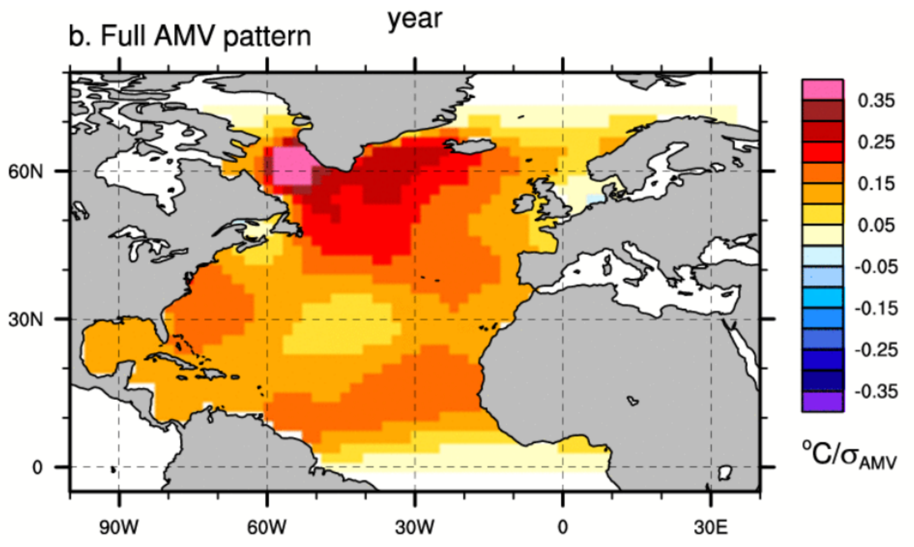
Atlantic major hurricane frequency (Goldenberg et al., 2001; Zhang and Delworth, 2006; Smith et al., 2010; Dunstone et al., 2011 Chylek and Lesins, 2008; Zhang and Delworth, 2009).

https://www.wcrp-climate.org/experimental-protocol





Drought Frequency

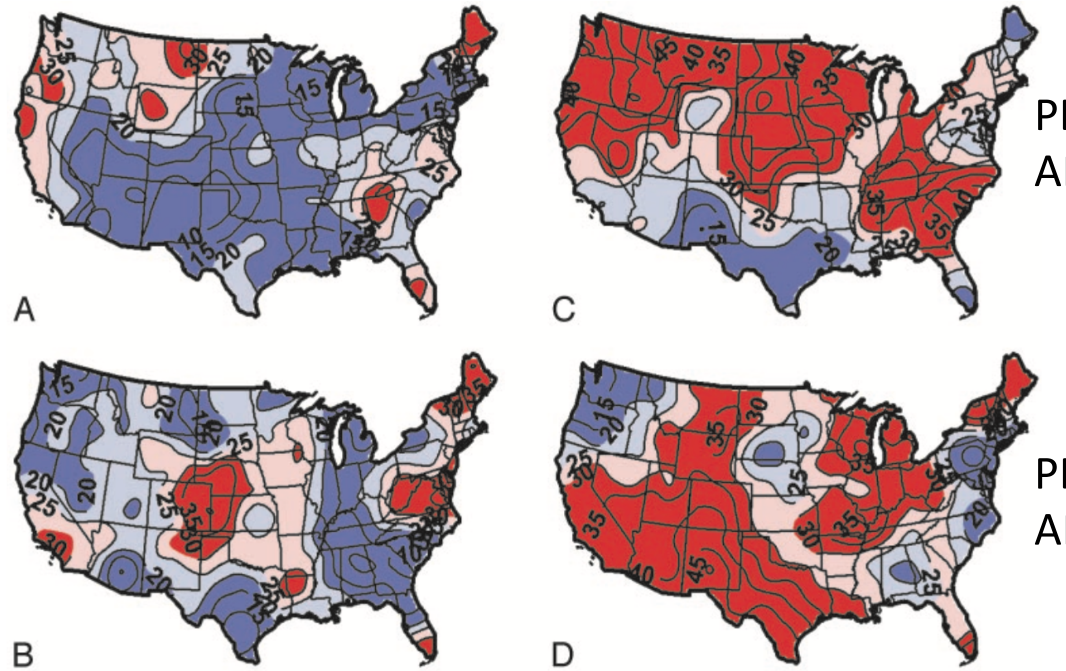


PDO+ AMO-

PDO+ AMO+

PDO- AMO-

PDO- AMO+



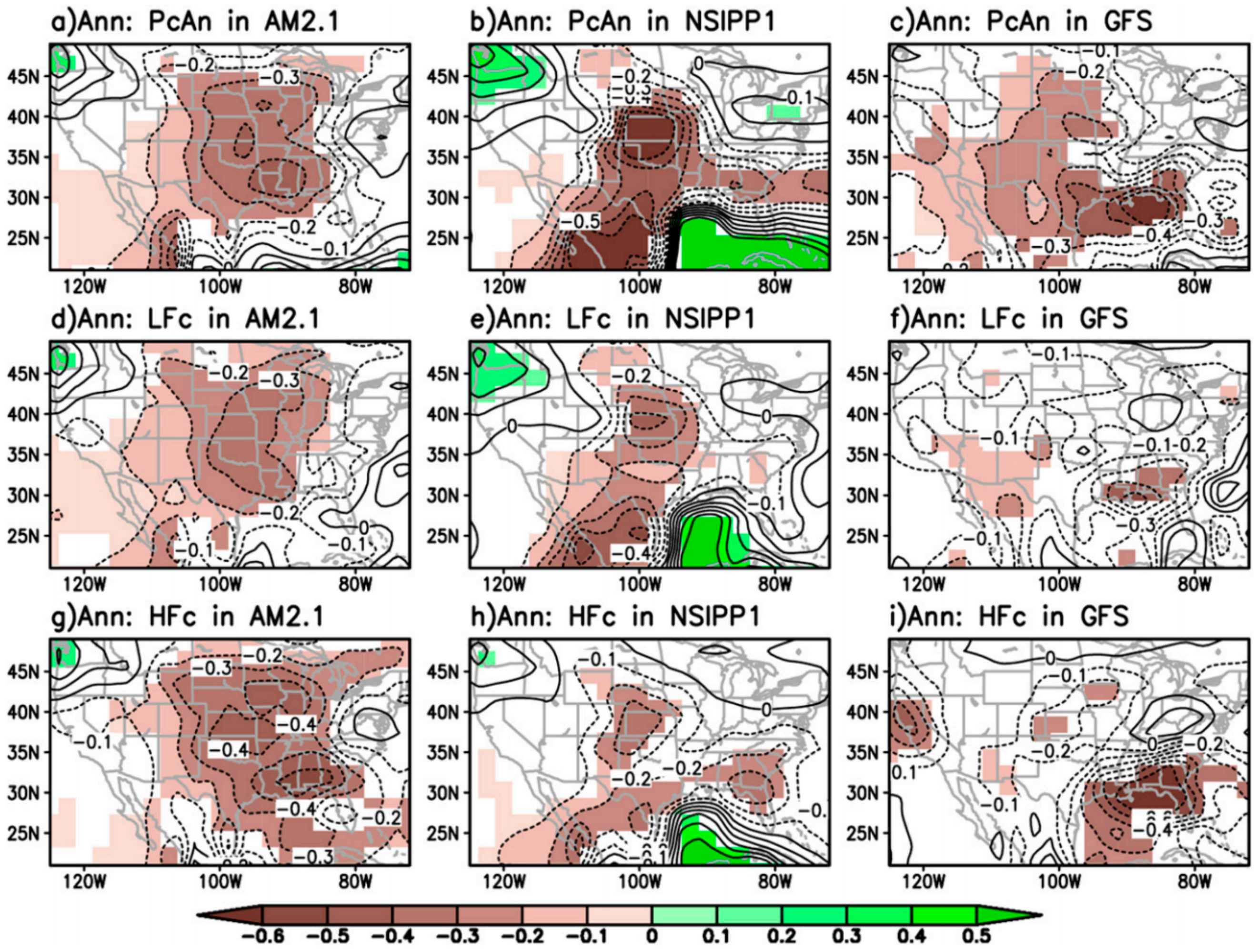
https://www.wcrp-climate.org/experimental-protocol

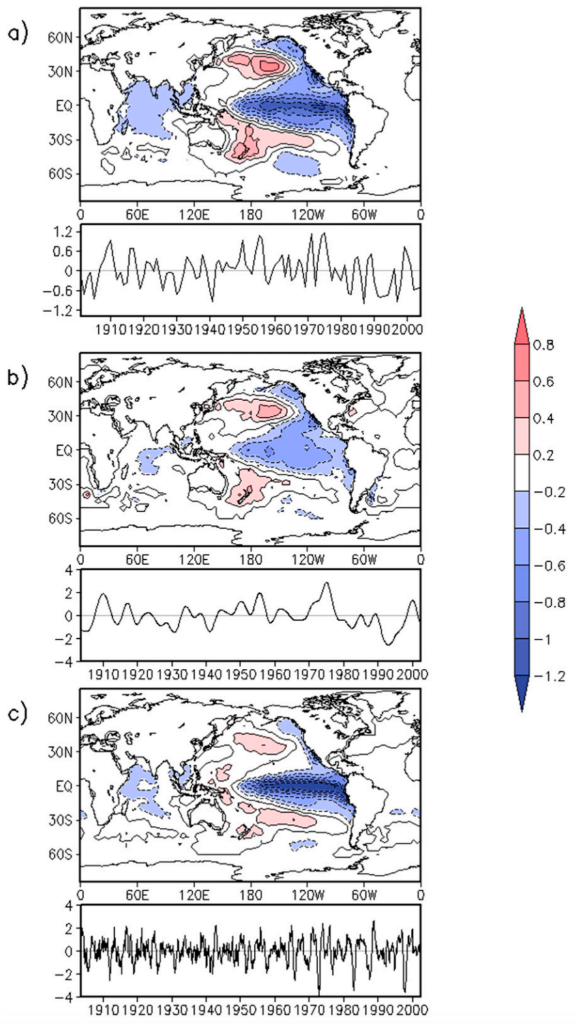
McCabe et al 2004

Broad interests in decadal climate variability and prediction

- **WGSIP -** Sub-seasonal to (inter)annual prediction
- **WGCM** - Forced climate change and natural variability
- **CMIP** - Coordinated experimentation including scenarios, decadal prediction ….
- **CLIVAR** "Focus" on decadal variability and predictability . Ocean aspects, initialization
- **Grand Challenge of Near Term Climate Prediction** -Research and development leading toward operational annual, multi-annual forecasts
- **IPCC** - Near term climate a focus of AR5 and expected to be an important contribution to AR6
- **DCPP** - Decadal climate prediction project currently reports to **WGSIP** and **WGCM, is an endorsed CMIP MIP** and has connections to all groups

USCLIVAR Drought Working Group AMIP





Annual mean precipitation responses (mm day^{-1}) The anomalies are computed with respect to the control simulated (PnAn) annual mean response with prescribed global climatological SSTs only.

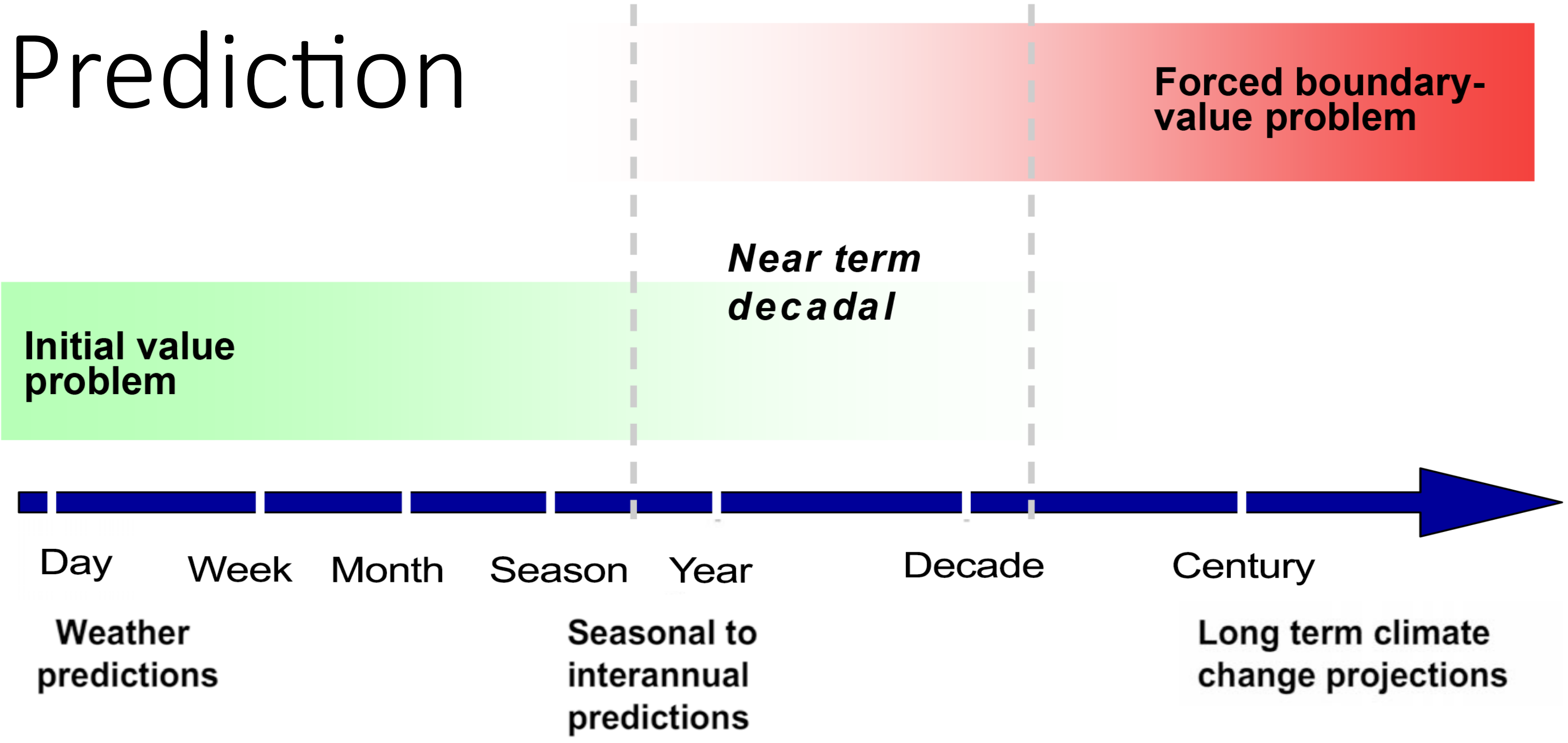
The Decadal Climate Prediction Project (DCPP) contribution to CMIP6

George J. Boer[1], Douglas M. Smith[2], Christophe Cassou[3], Francisco Doblas-Reyes[4], Gokhan Danabasoglu[5], Ben Kirtman[6], Yochanan Kushnir[7], Masahide Kimoto[8], Gerald A. Meehl[5], Rym Msadek[3,12], Wolfgang A. Mueller[9], Karl E. Taylor[10], Francis Zwiers[11], Michel Rixen[13], Yohan Ruprich-Robert[14], and Rosie Eade[2]

[1]Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Victoria BC, Canada
[2]Met Office, Hadley Centre, Exeter, UK
[3]Centre National de la Recherche Scientifique (CNRS)/CERFACS, CECI, UMR 5318 Toulouse, France
[4]Institució Catalana de Recerca i Estudis Avançats (ICREA) and Barcelona Supercomputing Center (BSC-CNS), Barcelona, Spain
[5]National Center for Atmospheric Research (NCAR), Boulder, CO, USA
[6]Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, USA
[7]Lamont Doherty Earth Observatory, Palisades, NY, USA
[8]Atmosphere and Ocean Research Institute, University of Tokyo, Tokyo, Japan
[9]Max-Planck-Institute for Meteorology, Hamburg, Germany
[10]Program for Climate Model Diagnosis and Intercomparison (PCMDI), Lawrence Livermore National Laboratory, Livermore, CA, USA
[11]Pacific Climate Impacts Consortium, Victoria BC, Canada
[12]Geophysical Fluid Dynamics Laboratory/NOAA, Princeton, NJ, USA
[13]World Climate Research Programme, Geneva, Switzerland
[14]Atmosphere and Ocean Sciences, Princeton University, Princeton, NJ, USA

Geoscientific Model Development
Open Access

Decadal Prediction



Early efforts by Smith et al. (2007), Keenlyside et al. (2008), and Pohlmann et al. (2009) showed less warming than uninitialized simulations. Further analysis of CMIP5 models showed similar results for the period 2016-2035 (AR5, Kirtman et al 2013). Attributed to the negative phase of the IPO

Boer et al. (2016)

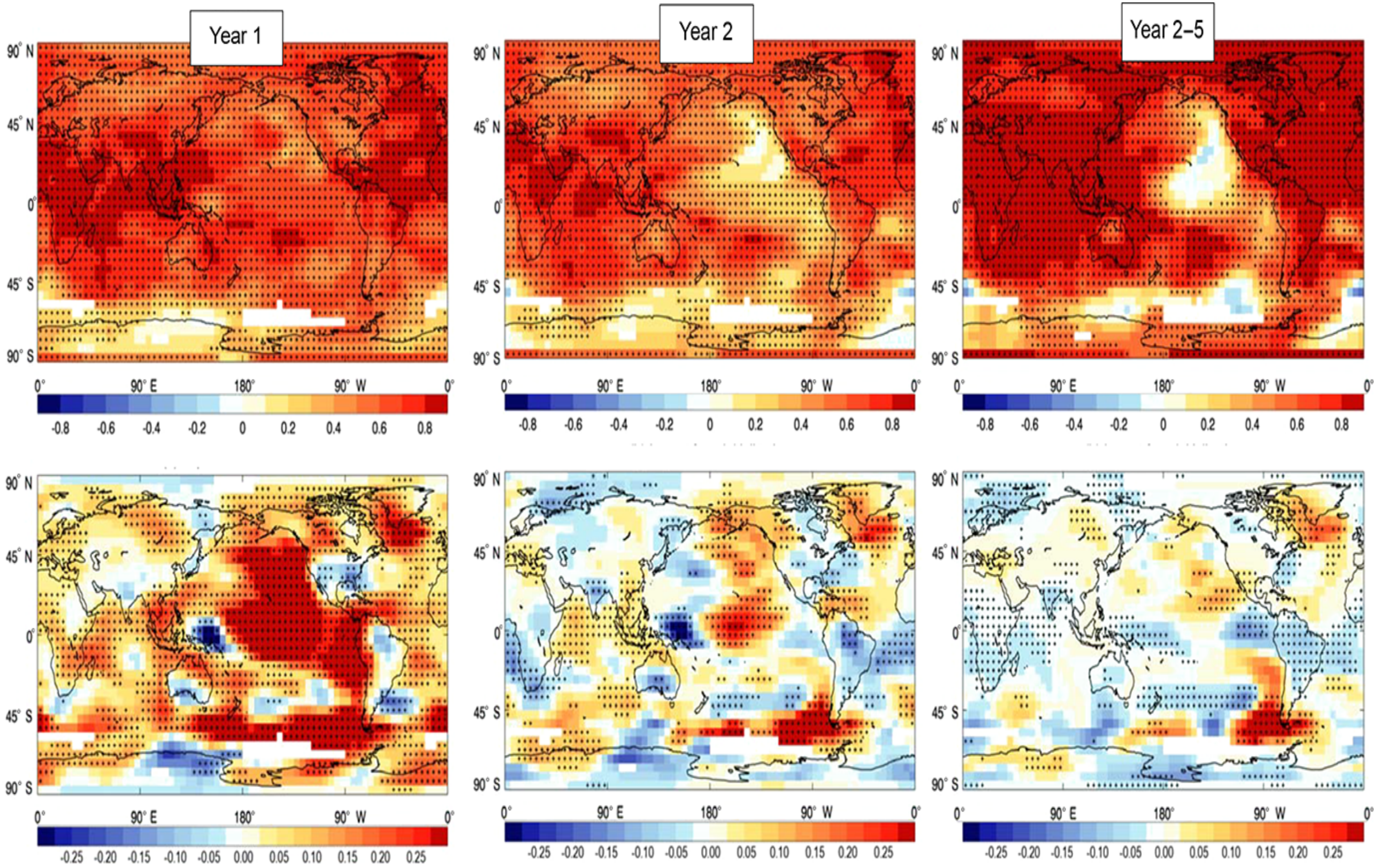
Initialized Hindcasts

Enhanced skill due to initialization in the first few years

At longer leads forecast skill is due to the external forcing

Impact of initialization= Initialized - Uninitialized

Correlation skill for forecasts of surface air temperature



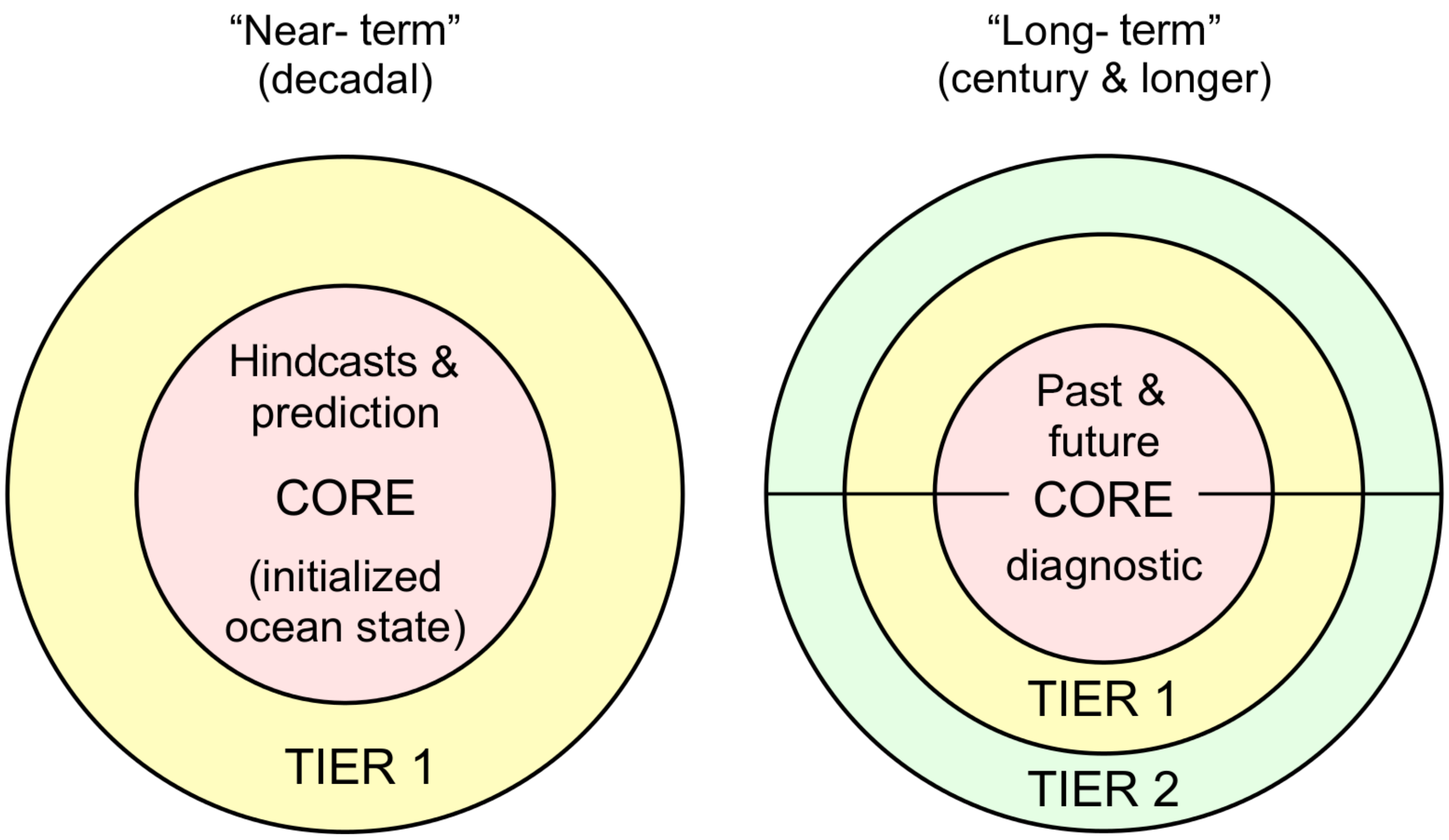
Boer et al. (2016)

CMIP5

Two core experiments,

1 A set of 10 year hindcasts or predictions initialized from climate states in the years **1960, 1965, 1970, and every five years to 2005,** with this last simulation representing the sole actual prediction beyond the present (i.e., beyond 2009).

2. **Extends the 10 year simulations initialized in 1960, 1980, and 2005 by an additional 20 years.**
- at least three ensemble members extend up to
- 10 members as a tier 1 experiment.



Boer et al. (2016)

DCPP - CMIP6

*The DCPP represents a **"multi-system" approach** to climate variation and prediction in which the basic experiments are specified **but the details of the implementation are not**.*

Three Focus areas, with tiered structure for groups who have resources / interest

– *Component A, **Hindcasts***: the design and organization of a coordinated decadal prediction (hindcast) component of CMIP6 in conjunction with the seasonal prediction and climate modelling communities and the production of a comprehensive archive of results for research and applications

– *Component B, **Forecasts***: the ongoing production of experimental quasi-operational decadal climate predictions in support of multi-model annual to decadal forecasting and the application of the forecasts to societal needs

– *Component C, **Predictability, mechanisms, and case studies***: the organization and coordination of decadal climate predictability studies and of case studies of particular climate shifts and variations, including the study of the mechanisms that determine these behaviors

Boer et al 2016

Component A: Hindcasts

Hindcasts are **initialized every year** instead of every 5 years. Improved statistics, skill assessment, better treatment of model drift

Initial hindcasts are run **out to 5 years** ,not 10 , extension to 10 years, not 30 years

Comparison with **uninitialized simulations** allow estimates of skill due to initialization

Assimilation runs estimate the benefits of assimilation vs full field or anomaly initialization

Addition of ensembles give better estimate of spread / uncertainty

Tier 4 ..unlikely. **Reduce artificial skill** in hindcasts due to prescribed forcing (ie volcanoes)

	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

Boer et al. (2016)

Component B: Forecasts

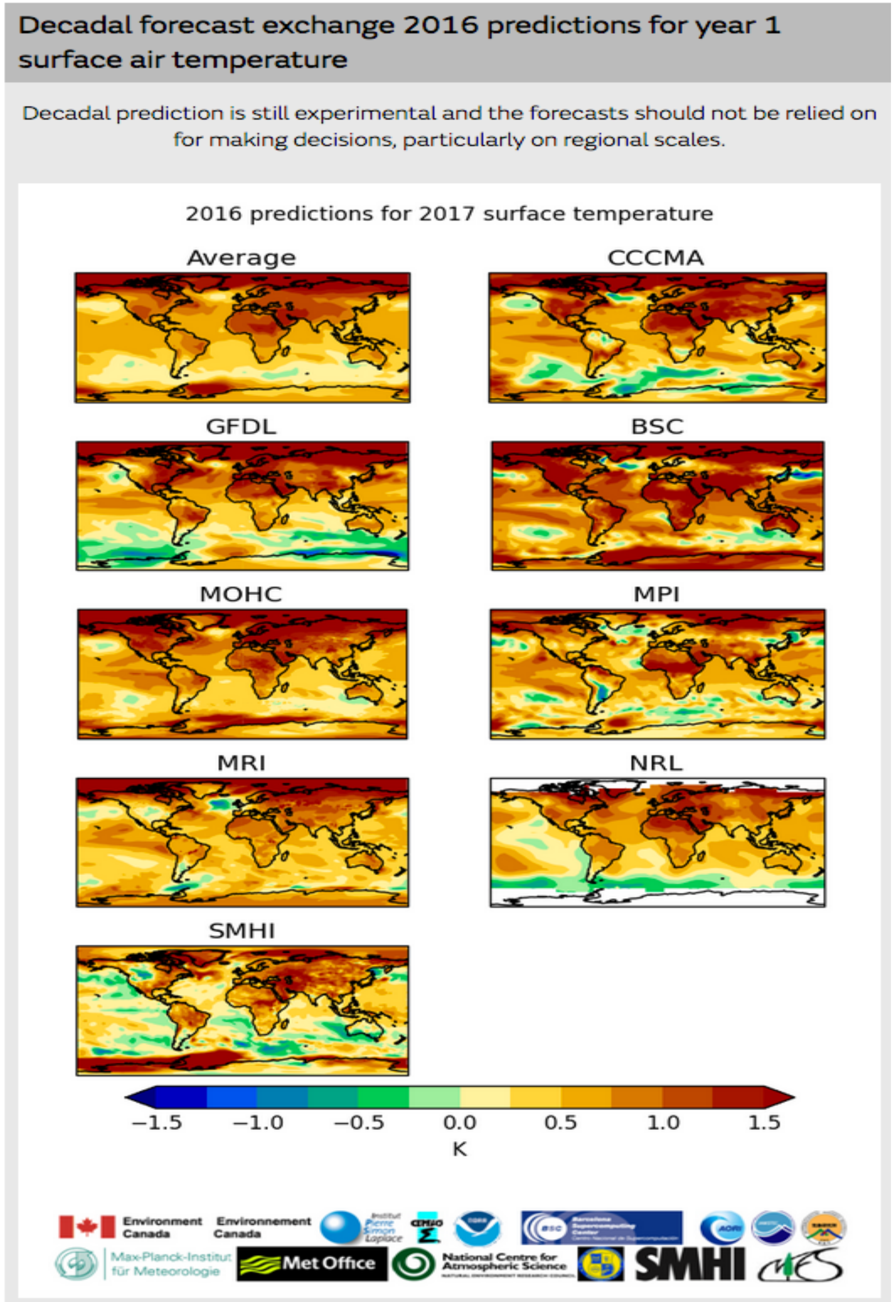
Multi-model decadal forecast exchange at UK Met office

The Met Office coordinates an informal exchange of near-real time decadal predictions. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic.

The contributing prediction systems are a **mixture of dynamical and statistical methods**. Current elements include *surface air temperature, precipitation, sea level pressure, and AMOC*.

DPCC Component B forecasts will augment these forecasts when available. **Initialized every year prior to 31 Dec**, (15 Nov allows for DJF seasonal forecast). **10 ensemble members**

Component B:	B1	dcppB-forecast	1	50	Ongoing near-real-time forecasts
Decadal Forecasts	B2.1		2	5m	Increase ensemble size by *m* for B1
	B2.2		2	50	Extend forecast duration to 10 years for B1



http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel

*Atmospheric composition and/or emissions (and other conditions including volcanic aerosols) to follow a prescribed forcing scenario as in A1. (Boer et al. 2016)

Component C: Predictability, Mechanisms, and Case Studies

Targeted simulations / predictions intended to

1. Investigate the origins, mechanisms and predictability of long timescale variations in climate and their regional imprints

2. Investigate the influence and consequences of volcanic eruptions on decadal prediction and predictability.

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. (2016)

Component C: Predictability, Mechanisms, and Case Studies

Reseach Area 1; The Hiatus

this is used as a shorthand to indicate investigations into the origins, mechanisms and predictability of long timescale variations in both global mean surface temperature (and other variables) and regional imprints, including periods of both enhanced global warming and cooling with a focus on the most recent slowdown that began in the late 1990s.

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

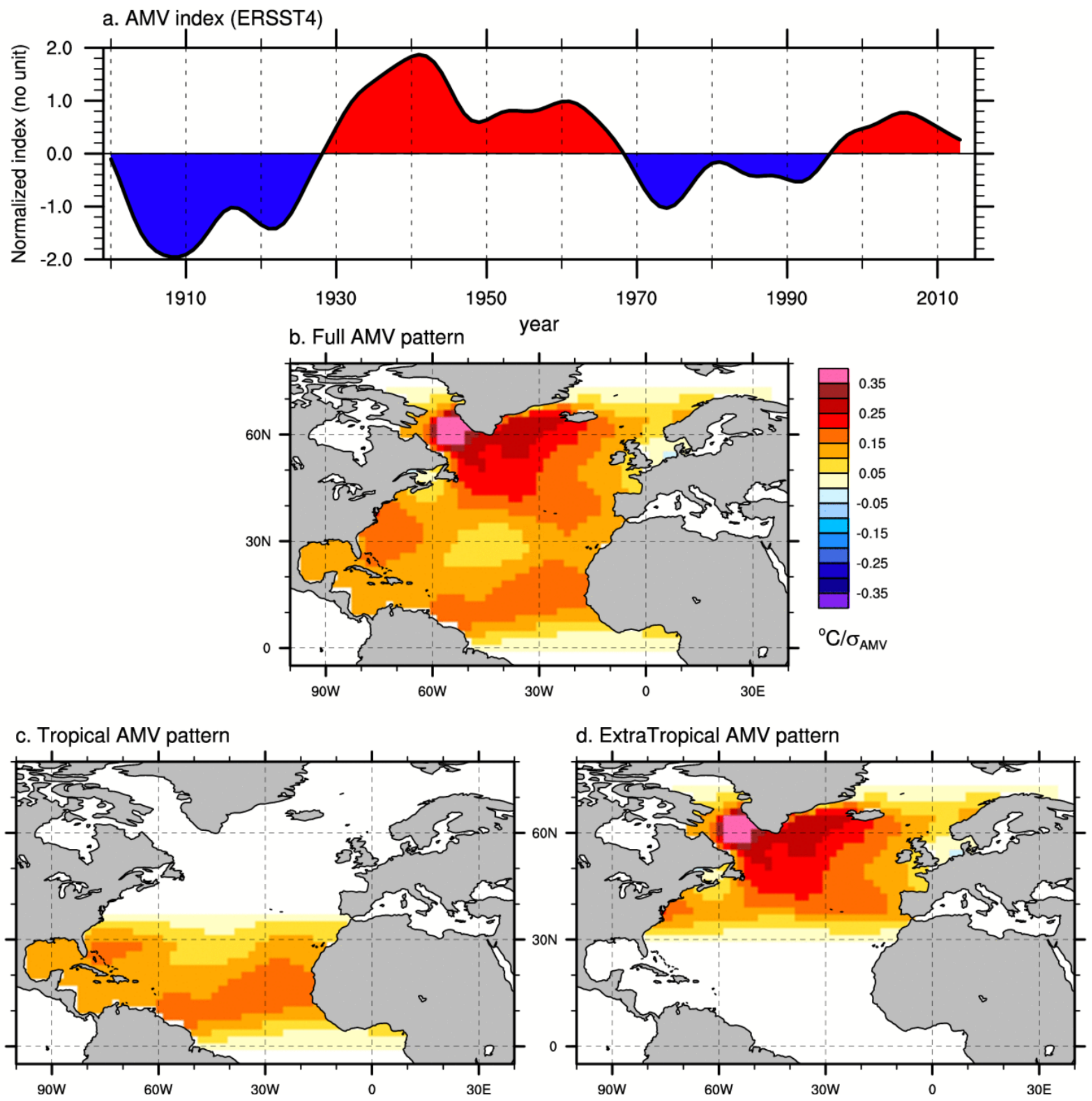
Boer et al. (2016)

Component C: Predictability, Mechanisms, and Case Studies

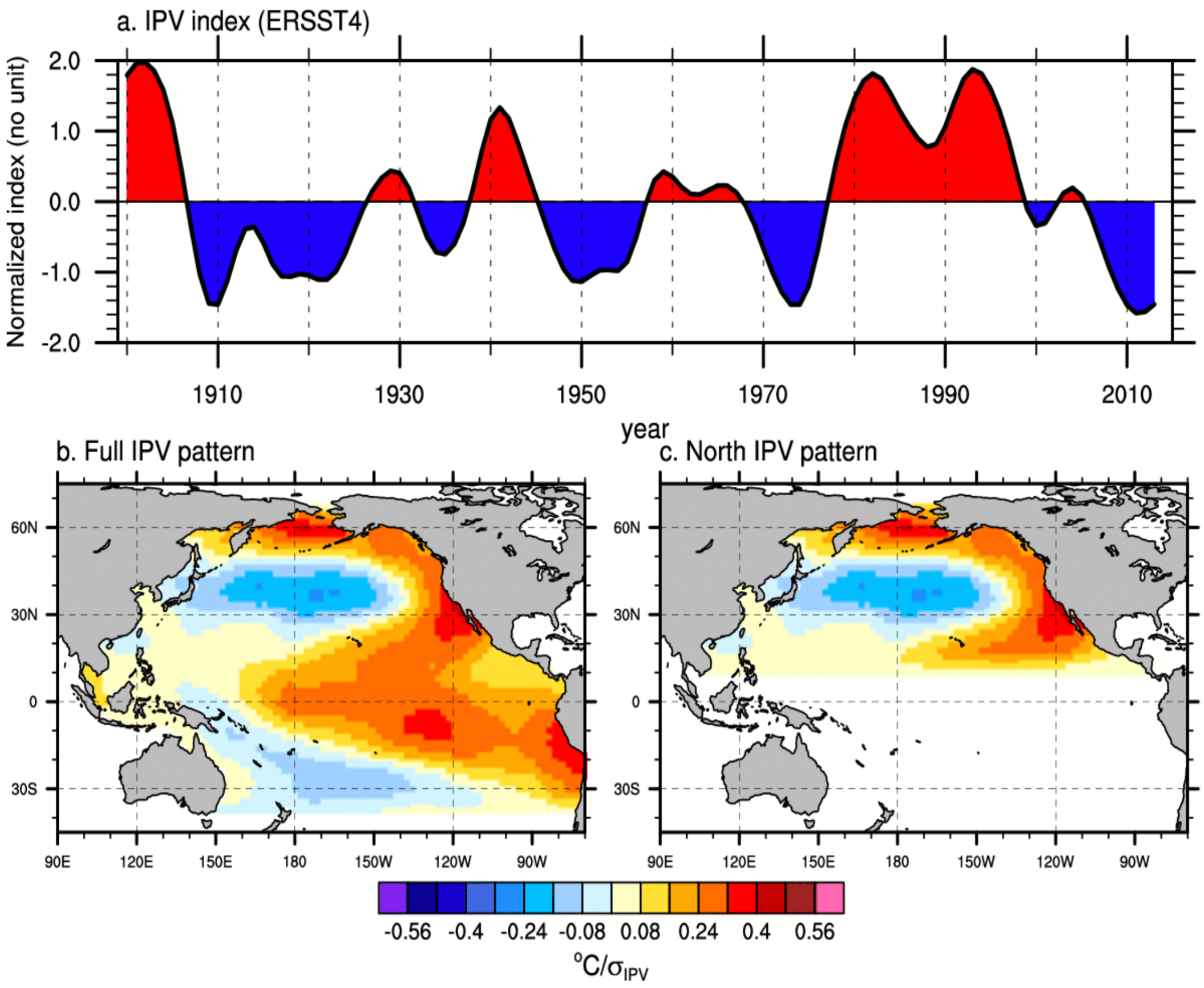
to what extent we can attribute decadal climate anomalies at regional scales (particularly over land) to the patterns of Atlantic Multidecadal Variability (AMV) and Pacific Decadal Variability (PDV) sea surface temperature

consistency of models' responses to these SSTs and the pathways through which the responses are expressed throughout the ocean and atmosphere.

These experiments also address the inter relationships between the AMV and PDV shifts and the mechanisms at play.



Boer et al. (2016)



Boer et al. (2016)

Component C: Predictability, Mechanisms, and Case Studies

Reseach Area 2; Volcanoes

Volcanoes in a prediction context: an investigation of the influence and consequences of volcanic eruptions on decadal prediction and predictability

Remove the Pinatubo from 1991 Hindcast
Remove the El Chicon from 1982 Hindcast
Remove the Agung from 1963 Hindcast

Repeat 2015 forecast with Pinatubo forcing
Repeat 2015 forecast with El Chicon forcing
Repeat 2015 forecast with Agung forcing

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
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	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. (2016)

Summary

- The Decadal Climate Prediction Project (DCPP) is a coordinated multi-model investigation into decadal climate prediction, predictability, and variability.
- It builds on recent improvements in models, in the re-analysis of climate data, in methods of initialization and ensemble generation, and in data treatment and analysis to propose an extended comprehensive decadal prediction investigation as a contribution to CMIP6 (Eyring et al., 2016) and to the WCRP Grand Challenge on Near Term Climate Prediction (Kushnir et al., 2016).
- Differences in the CMIP6 experimental protocol compared to that of CMIP5 include **more frequent hindcast start dates** and **larger ensembles of hindcasts** for each start date intended to provide robust estimates of skill (e.g. Sienz et al., 2016), the addition of **ongoing quasi-operational experimental decadal forecasts** (Smith et al., 2013a), and the addition of **targeted experiments to provide insight into the physical processes affecting decadal variability and forecast skill** (e.g. Ruprich-Robert et al., 2016).

Extra slides

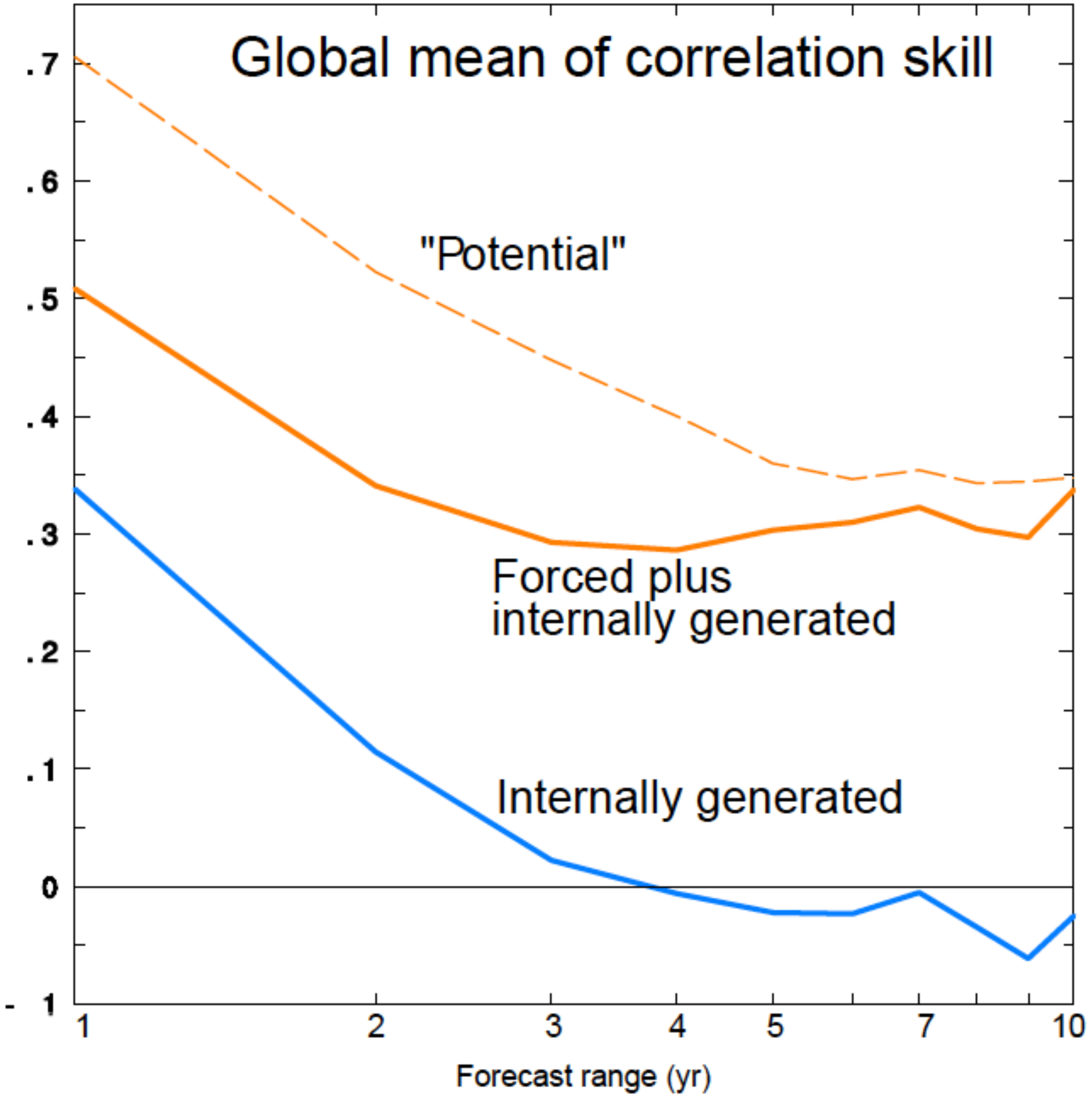
CMIP1

CMIP2

CMIP3

CMIP5

CMIP6


Global mean of correlation skill
"Potential"
Forced plus
internally generated
Internally generated
.7
.6
.5
.4
.3
.2
.1
0
-.1
1
2
3
4
5
7
10
Forecast range (yr)

Additional Slides

- Predictability studies, used with care, can give an indication as to where, under what circumstances, and the level of confidence with which it may be possible to predict various climate parameters on timescales from seasons to decades.

- Forecast skill, on the other hand, is measured by comparing initialized forecasts with observations and indicates the “ability to predict” the actual evolution of the climate system. A forecast is essentially useless unless there is some indication of its expected skill.

COMPONENT C
removal of the forced response