Decadal Predictions: State of the Science

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EaSM Meeting, NCAR
Jan 20, 2015
Why the emphasis on decadal predictions?

- **Societal need** for near term/decadal predictions of climate for decision support (Vera et al. 2010)
  - Actual time evolving predictions rather than uninitialized projections\(^1\).

- Research shows **potential (and some evidence) for prediction skill** on decadal timescales

- **Less sensitive to emissions scenario**

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\(^1\) IPCC definition is predictions are initialized, projections are uninitialized

Kirtman et al. 2013, IPCC
Emissions scenario less important on decadal timescales

- CMIP5 decadal predictions used the **RCP4.5** scenario. (Meehl et al. 2014)

Hawkins and Sutton 2009
Bridge gap between ENSO forecasting and future climate change projections
Bridge gap between ENSO forecasting and future climate change projections

- **Synoptic weather**: 2 weeks (Lorenz 1963)
- **ENSO evolves more slowly**: 6-12 months
- **What’s the “sweet spot”?** (out 10-30 years defined as “decadal”)
- **Long-term trends based on GHG forcing**

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Figure 2 Meehl et al. 2009 BAMS
What are the CMIP5 decadal predictions?

- Two core sets of near-term experiments
  - 10-year hindcasts
  - 30-year hindcasts (out to 2035)
- Specialized simulation options

Fig. 3. Schematic summary of CMIP5 decadal prediction integrations.

Taylor et al. 2012 BAMS
Aim is to understand predictability, merits of data assimilation approaches, and limitations of current observations.

<table>
<thead>
<tr>
<th>Experiment description</th>
<th>CMIP5 label</th>
<th>AOGCM</th>
<th>ESM or EMIC</th>
<th>High resolution</th>
<th>Major purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Holocene conditions (as called for by PMIP)</td>
<td>midHolocene</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Last Glacial Maximum conditions (as called for by PMIP)</td>
<td>lgm</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Natural forcing for 850–1850 (as called for by PMIP)</td>
<td>past1000</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Evaluation, natural variability</td>
</tr>
<tr>
<td>Decadal hindcasts/predictions, some extended to 30 yr</td>
<td>decadalXXXX(^d)</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Predictability, prediction, evaluation</td>
</tr>
<tr>
<td>Hindcasts but without volcanoes</td>
<td>noVolcXXXX(^d)</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Predictability</td>
</tr>
<tr>
<td>Decadal forecast with Pinatubo-like eruption in year 2010</td>
<td>volcIn2010</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Predictability, prediction</td>
</tr>
<tr>
<td>SST and some other conditions for 2026–35 specified from a coupled model experiment</td>
<td>sst2030</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Projection</td>
</tr>
</tbody>
</table>

\(^d\) The “XXXX” is a generic representation of the year in which the decadal prediction was initiated. As an example, a simulation focusing on the 10-yr period from Jan 1966 to Dec 1975 will typically be initiated sometime between 1 Sep 1965 and 1 Jan 1966 and would be labeled “decadal1965.”

Taylor et al. 2012 BAMS
Decadal predictions and projections have built-in skill\(^1\) from:

1. Climate change commitment

2. The forcing from increasing greenhouse gases

CMIP3 models can already simulate the magnitude of observed decadal surface temperature variability over land (IPCC 2007 WGI Fig 9.8)

\(^1\)Barring volcanic eruption

Meehl et al. 2009; Lee et al 2006
Skill from **initialization** versus radiative forcing depends on time horizon, variable, & region

- **Initialization** contributes most skill in
  - **first few years**: annual mean temperature
  - **a few years to a decade**: global mean surface temperature and temperature over the North Atlantic, regions of the South Pacific and the tropical Indian Ocean

- **Radiative forcing** contributes most skill
  - **Beyond first few years**: for annual and multi-annual averages of temperature and precipitation

Kirtman et al. 2013, IPCC
Some general findings

• For initialized decadal hindcasts, **multimodel ensemble outperforms most single model results** (Chikamoto et al. 2012a, Kim et al. 2012, and Smith et al. 2012b.) (From Meehl et al. 2014 BAMS)

• **Potential predictability:**
  • Greater for ocean heat content than atmospheric or land variables (Hermanson and Sutton 2010) (From Kirtman et al. 2013 IPCC)
  • Ocean skill increases with latitude and depth (Power and Colman 2006) (From Kirtman et al. 2013 IPCC)
  • Greater at higher latitudes (extratropical oceans) than over land (Figure 11.1, Kirtman et al 2013, IPCC)
  • Lower for tropics and over land, where skill mostly from external forcing (Figure 11.1, Kirtman et al. 2013, IPCC)
Decadal phenomena that could contribute to skill

- **Pacific**
  - 11-year solar cycle with tropical Pacific SSTs
  - Pacific Decadal Oscillation (PDO), North Pacific Index (NPI), Interdecadal Pacific Oscillation (IPO)

- **Atlantic**
  - Atlantic meridional overturning circulations (AMOCs)
    - Strong ties with North Atlantic Oscillation
  - Atlantic Multidecadal Oscillation (AMO), Atlantic multidecadal variability (AMV)

Meehl et al. 2009
Technical challenges remain

• **Model initialization/data assimilation**
  - Many different methods by different modeling groups (Table 1, Meehl et al. 2014 BAMS)
  - For drift: Full-field initialization vs anomaly initialization (Meehl et al. 2014 BAMS)

• **Limited availability of observations** (Goddard et al. 2012 BAMS)

• **Dynamical model limitations** (Goddard et al. 2012 BAMS)

Kirtman et al. 2013, IPCC
Technical challenges remain

- Predictions require bias adjustment\(^1\)
  - Models drift from the observed initial state to its own preferred state, sometimes rapidly.
  - Mean bias adjustment does not address issues such as potential trends (time dependence) in the drift/bias.
  - i.e., correction is more complicated than for centennial runs.


[Available online at www.wcrp-climate.org /decadal/references/DCPP_Bias_Correction.pdf.]
Recommendation for bias correction:

• “Most users will find it difficult to bias correct the decadal prediction runs; it is therefore recommended that analysis of the near-term simulations be limited to the four variables that the modeling groups themselves plan to bias correct: near-surface air temperature, surface temperature, precipitation rate, and sea level pressure.”*

*I’m not sure if CMIP5 archive includes bias-corrected fields – need to check.
Bias correction option for 30-year hindcast:

• One method is to use the year 10 bias adjustment for years 11–30, assuming most of the drift occurs by year 10 (Meehl and Teng 2012, 2014).

(Towler et al., 2012 AGU poster)
Prediction quality needs to be assessed using a common verification framework

http://clivar-dpwg.iri.columbia.edu/
Temp: Widespread predictive skill of predictions vs. observations.

Fig. 4. Surface air temperature predictive skill (correlation with observations), predictions for years 6–9 averages based on CMIP5 multimodel ensemble mean hindcasts (see Table 1 for details). Results are from initialized hindcasts with 5-yr intervals between start dates from 1960 to 2005. Correlations are calcu-
Temp: Less skill added from initialization, varies spatially

Meehl et al. 2014 BAMS
Oceans show highest skill, but skill source and regions vary

• **Indian Ocean**
  • Shows highest surface temp skill – due to external forcing from GHGs (so projections are also skillful)

• **Atlantic Ocean**
  • Many studies find that initialization improves the predictive skill of temperature in the North Atlantic – partially due to skillful AMOC prediction.
  • Some encouraging results for tropical Atlantic

• **Pacific Ocean**
  • Less skill than Indian and Atlantic Ocean
    • Interannual variability from ENSO, but debate on relationship between ENSO and decadal oscillations like PDO.
    • Some studies do show some improved skill from initialization, esp. in Western & South Pacific

Meehl et al. 2014 BAMS
Precipitation is less skillful than temp

Precipitation skill can be attributed mostly to radiative forcing (high confidence), initialization improves the skill very little (Goddard et al., 2013). “
Some skill in predicting extreme temperatures and precipitation

- 10% likelihood of occurrence (moderate extremes)
- Met Office Decadal Prediction System (DePreSys)
- Skill in extremes is similar but slightly lower than for mean
  - Some exceptions where there are trends in extremes (e.g., USA cold nights).
- Over multiyears, skill is from external forcing

Eade et al. 2012

- Skill in summer extreme indices, mostly from external forcing; DePreSys (Hanlon et al. 2013)
Decadal ocean skill could lead to skillful predictions over land

• Skillful North Atlantic Ocean SSTs could improve (i) rainfall over African Sahel, India, and Brazil, (ii) Atlantic hurricanes, and (iii) summer climate over Europe and America.

• Skillful Pacific SSTs could improve rainfall over North and South America, Asia, Africa, and Australia.

• Skillful Pacific and Atlantic SSTs could improve drought prediction over US.

Meehl et al. 2014 BAMS
Initialized predictions show less warming than projections.

Figure 11.9b

Kirtman et al. 2013, IPCC
Decadal predictions are not considered “operational”

• “decadal predictions... are in an exploratory stage”  (Taylor et al. 2012 BAMS)

• “... very much an experimental and nascent activity.” (Goddard et al. 2010 Clim Dyn)

• “Due to the limitations, the estimates obtained from the hindcasts may provide a poor, and even misleading, guide to the future performance of the decadal prediction systems.” (Goddard et al. 2010 Clim Dyn)
Decadal predictions have many features in common with seasonal forecasts

Goddard et al. 2012 BAMS;
Seasonal forecasts can provide a testbed for decadal predictions.

- **Build trust:** Seasonal forecasts offer opportunity to demonstrate performance over the recent past and over the next few seasons/years.

- **Increase uptake:** Using seasonal climate information will indirectly strengthen capacity for using climate info on longer time scales.
Additional/Upcoming decadal prediction experiments

• Seasonal-to-Decadal Climate Prediction for the Improvement of European Climate Services (SPECS)

• “Mittelfristige Klimaprognose” Germany (meaning decadal climate prediction) (MiKlip)

• New set of decadal climate predictions experiments into CMIP6.
The way forward

• Increase understanding of climate and social influences on impacts
• Leverage predictions in places where initialization improves skill (e.g., North Atlantic)
• Leverage projections in places where skill is due to external forcing (e.g., Indian Ocean) (*This is mostly what IPCC 2013 does; also can compare predictions and projections-extremes?).
• Leverage NCAR medium/large ensemble where internal variability is important (e.g., local impacts)
• Develop generalized framework that will be ready when decadal predictions improve
  – Use seasonal forecasting as a “testbed”
  – Investigate how to “best” incorporate decadal predictions in decisions
  – Investigate “best” communication of decadal predictions


