Seamless Approach of Subseasonal-to-Seasonal Climate Forecasting

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Outline

1. Different kinds of predictability
2. Seamless prediction
3. Seamless verification and diagnostics
4. Examples of seamless approach at S2S timescales
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Predictability of the First Kind

CLIMATIC PREDICTABILITY

by Edward N. Lorenz
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Weather is often identified with the complete state of the atmosphere at a particular instant. As such the weather is continually changing. Weather prediction is then identified with the process of determining how the weather will change as time advances, and the problem of weather predictability becomes that of ascertaining whether such prediction is possible.

Climate may be identified with the set of statistics of an ensemble of many different states of the atmosphere. Particularly when the real atmosphere is replaced by an idealized mathematical system, the ensemble is often taken to consist of all states during an infinite time span. In this event the climate, by definition, does not change, and climatic prediction and predictability become meaningless concepts.

Our interest in what we call climatic change has arisen because atmospheric statistics taken over a rather long

We shall refer to the climatic prediction (and predictability) which we have just introduced as climatic prediction (and predictability) of the first kind, because there is another kind of climatic prediction, with its associated predictability, which is of very real concern to us, and which incidentally possesses meaning even when the ensemble defining the climate covers an infinite time span. We may inquire, for example, what would be the effect upon the climate of doubling the concentration of CO₂ in the atmosphere — an event which could conceivably result some years hence from human activity. An answer would not constitute a prediction of the first kind, unless accompanied by a prediction that the CO₂ concentration will indeed double. We shall refer to such predictions, which are not directly concerned with the chronological order in which atmospheric states occur, as climatic predictions of the second kind.
Different kinds of predictability

\[
\begin{align*}
\dot{x} &= -\alpha x + \sigma y \\
\dot{y} &= -xz + rx - y \\
\dot{z} &= xy - bz,
\end{align*}
\]
Predictability of the First Kind

High predictability

Medium predictability

Low predictability

Adapted from M. Liniger & T. Palmer
Predictability of the First Kind
Predictability of the Second Kind

Even though individual weather events are not predictable beyond 10 days, the *average weather behavior* (=climate) may be influenced by predictable boundary conditions for several months and longer.

Experiment 1: coincidence

Experiment 2: With boundary cond.

(Palmer, 1998)
Predictability in the Midst of Chaos: A Scientific Basis for Climate Forecasting

J. Shukla

The Earth’s atmosphere is generally considered to be an example of a chaotic system that is sensitively dependent on initial conditions. It is shown here that certain regions of the atmosphere are an exception. Wind patterns and rainfall in certain regions of the tropics are so strongly determined by the temperature of the underlying sea surface that they do not show sensitive dependence on the initial conditions of the atmosphere. Therefore, it should be possible to predict the large-scale tropical circulation and rainfall for as long as the ocean temperature can be predicted. If changes in tropical Pacific sea-surface temperature are quite large, even the extratropical circulation over some regions, especially over the Pacific–North American sector, is predictable.

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Fig. 1. Average rainfall anomaly (mm day⁻¹) for JFM for two sets of five-model integrations with observed SST in 1982–1983 starting from atmospheric initial conditions in mid-December 1988 (A) and 1982 (B) and observed (C).
Predictability of the Second Kind

Á.G. Muñoz: IRI’s Data Library for S2S

Munoz et al 2010 (BAMS)
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Seamless Prediction of Weather and Climate: A New Paradigm for Modeling and Prediction Research

J. Shukla

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Abstract

This paper describes the concept of seamless prediction and its evolution during the establishment of the COPES (Coordinated Observation and Prediction of the Earth System) framework of the World Climate Research Program (WCRP), where the concept was first presented in 2005.
Seamless Prediction
Seamless Prediction

Supporting decision making

Analysis of past weather observations to manage climate risks
- Eg. Agriculture: this informs crop choice and planting date to optimise yields and minimise crop failure risk.

Predicting routine and hazardous weather conditions and disseminating tailored and timely warnings.
- Public, emergency response, international disaster risk reduction

Monthly to decadal predictions informs probability of drought, cold, heat.

Contingency planners, national and international humanitarian response, government and private infrastructure investment

Global and regional climate predictions.
- Informs mitigation policy and adaptation choices. Impacts on water resources, heat stress, crops, infrastructure.

Forecast lead-time
Seamless Prediction

NOAA Seamless Suite of Forecast Products Spanning Climate and Weather

Service Center Perspective

- Forecast Lead Time
  - Years
  - Seasons
  - Months
  - 2 weeks
  - 1 week
  - Days
  - Hours
  - Minutes

Impact-Based Decision Support

- Recovery
- Response
- Preparation

Climate Outlooks
Climate Predictions
Weather Forecasts
Warnings

MDO & SDO
HPC
OPC
TPC
SPC
AWC
SWPC

Collaborative Forecasts
Climate/Weather Linkage

Forecast Uncertainty

10th ITWCVP – July 16-20, 2018, Ecuador
A.G. Muñoz: IRI’s Data Library for S2S

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Seamless Verification

FIG. 1. Schematic of the time window and lead time definitions used in this analysis. The horizontal axis represents forecast time from the initial condition. The expression “1d1d” refers to an averaging window of 1 day at a lead time of 1 day. Similarly, “2d2d” represents an averaging window of 2 days at a lead time of 2 days, and so on. Note that 1d1d is what is usually called “day 2” in other papers, and 1w1w is what is usually called “week 2.”

Zhu et al 2014
(MWR)
Seamless Verification

Fig. 2. Maps of COR for model forecasts at (top) 1d1d, (middle) 1w1w, and (bottom) 4w4w, for (left) DJF and (right) JJA.

Zhu et al 2014

(MWR)
FIG. 4. As in Fig. 3, but for most of North America.
Fig. 10. Ensemble-mean subseasonal frequency of occurrence for each weather type, smoothed with an 11-day moving average. Periods in the black boxes were selected for further analysis (see section 5c).

Fig. 11. (a) Observed and (b)–(d) ensemble-mean interannual frequency of occurrence for each weather type (see label bar), for all MAM seasons.

Muñoz et al 2017 (JCLI)
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Examples: Seamless Approach at S2S

- Improve forecast skill and understanding on the sub-seasonal to seasonal timescale (2 weeks to 2 months) with special emphasis on high-impact weather events.
- Promote the initiative’s uptake by operational centres and exploitation by the applications community.
- Capitalize on the expertise of the weather and climate research communities to address issues of importance to the Global Framework for Climate Services.

The S2S Database, hosted by ECMWF and CMA, went online in May 2016. International Coordination Office hosted by KMA.

Sub-seasonal to Seasonal (S2S) Prediction Project

- Teleconnections (C. Stan and H. Lin)
- Madden-Julian Oscillation (D. Waliser and S. Woolnough)
- Monsoons (H. Hendon)
- Africa (A. Robertson and R. Graham)
- Extremes (F. Vitart)

Verification and Products (C. Coelho)

Research Issues
- Predictability
- Teleconnection
- O-A Coupling
- Scale interactions
- Physical processes

Modelling Issues
- Initialisation
- Ensemble generation
- Resolution
- O-A Coupling
- Systematic errors
- Multi-model combination

Needs & Applications
- Liaison with SERA (Working Group on Societal and Economic Research Applications)

S2S Database

Ready - Seasonal forecasts
Set - Mid-Range forecasts
Go! - Short-Range forecasts

- Begin monitoring mid-range and short-range forecasts
- Update contingency plans
- Train volunteers
- Sensitize community
- Enable early-warning system
- Continue monitoring short-term-scale forecasts
- Mobilize assessment team
- Alert volunteers
- Warn community
- Local preparation activities
- Deploy assessment team
- Activate volunteers
- Distribute instructions to community, evacuate if needed

Vitart et al. 2017 (BAMS)
Goddard et al. 2015 (Ea. Persp.)
International Research Institute for Climate and Society
Earth Institute | Columbia University

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Examples: Seamless Approach @ S2S

FIG. 7. Time series of area-averaged rainfall in the LPRB (see Fig. 1) for each day of NDJF 2015/16. Lines indicate the rainfall value (mm day$^{-1}$). The WT corresponding to each day is indicated by the adjacent text label. The horizontal dashed blue lines indicate, from bottom to top, the climatological 50th, 90th, and 99th percentiles, respectively, of NDJF area-averaged rain over the LPRB.

FIG. 8. Seasonal model forecast for probability of exceedance of 90th percentile of DJF rainfall, as issued in November 2015. Color indicates the forecast probability of exceeding the 90th percentile of climatological rainfall during DJF 2015/16—this is presented as odds, defined in Eq. (3). A value greater than 1 indicates that the model forecast greater-than-average odds of rainfall exceeding the 90th percentile. Grid cells that observed an exceedance of the 90th percentile of DJF rainfall are outlined in black.
Examples: Seamless Approach & S2S

Fig. 10. Raw and MOS-adjusted S2S model forecasts and skill scores for the methods indicated in Table 1. (a)–(e) The heavy rainfall forecast for 1–7 Dec 2015 as odds, defined in Eq. (3) over the target domain. A value greater than 1 indicates that the model forecast greater-than-average odds of rainfall exceeding the 90th percentile. (f)–(j) The IGN defined in Eq. (4), with zero indicating a perfect forecast. (k)–(o) The 2AFC skill score for each grid cell; a value greater than 50 indicates that the model outperforms climatology. Different MOS models except for Raw in (a), (f), (k), which indicates the uncorrected S2S model output. In (top)–(bottom), the grid cells that observed a 90th percentile exceedance for 1–7 Dec 2015 are outlined in black.

Doss-Gollin et al 2018 (JCLI)
Examples: Seamless Approach

FIG. 9. (top) Chiclet diagram (see Carbin et al. 2016) of ensemble-mean precipitation anomaly forecasts over the LPRB (see Fig. 1) from uncorrected ECMWF S2S model forecast data, as a function of the forecast target date (horizontal axis) and lead time (vertical axis). (bottom) Time series of CPC daily mean precipitation over the same area is plotted with y axis inverted; horizontal black line denotes NDJF climatology.
Un entrenamiento práctico de una semana sobre características y predicción de la canícula

Los institutos hidrometeorológicos de todo el mundo están buscando formas de mejorar su capacidad para producir y entregar predicciones confiables de eventos extremos de alto impacto a una escala de tiempo subestacional (20-90 días) a estacional (~3-9 meses). Mejorar las predicciones sub-estacionales y estacionales, evaluar sus habilidades e incertidumbres, y explorar formas de comunicar sus beneficios a los tomadores de decisiones son desafíos significativos. El proyecto WWRP / WCRP de predicción subestacional-a-estacional (S2S) (http://s2sprediction.net) está adoptando todos estos desafíos y, para promover esta investigación, ha creado una nueva base de datos con un conjunto de pronósticos S2S multi-modelos, libremente disponibles para la comunidad.

La disponibilidad de los servicios climáticos S2S es clave para muchas decisiones administrativas en África, Asia, América Latina y algunos países europeos.
Summary

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