Dynamical Models

- Evolution of Dynamical Prediction on the intraseasonal to interannual (ISI) time scales
- Current Dynamical ISI Forecast Systems
- Why do we need ensemble prediction?

Evolution of Dynamical ISI Prediction

- Some earliest attempts at making climate predictions were performed to essentially extend the range of weather forecasts using AGCMs, which are referred to as dynamical extended range forecasting (DERF).
  - The underlying assumption was that there was enough information in the atmospheric initial conditions to make useful extended range forecasts.
- Seasonal to interannual climate predictions are mainly focused on the prediction of the ENSO.
  - Intermediate model approach: Both the atmospheric and the oceanic models are highly simplified. Such models could successfully predict the ENSO but did not produce useful predictions of atmospheric quantities over land.
  - Two-tier approach: SST was predicted by a simple oceanic model, and it was then used to drive an AGCM.
  - Coupled GCM (CGCM): an AGCM is coupled to an ocean GCM. CGCMs have improved substantially in recent years and are commonly used for operational climate prediction.

Current Dynamical Climate Forecast Systems

- CGCMs are the primary tool for dynamical climate prediction.
- In operational forecasting centers, CGCMs are used in conjunction with sophisticated data assimilation systems and statistical post-processing to produce the final forecasts.
- In addition to the AGCM component, a CGCM often includes a land model, an oceanic model and a sea ice component.
- CGCMs also include physical parameterizations of sub-grid processes.
- Systematic errors exist in the mean state, the seasonal cycle and climate modes of the climate simulations, which can be attributed to both model resolution and physics parameterization.

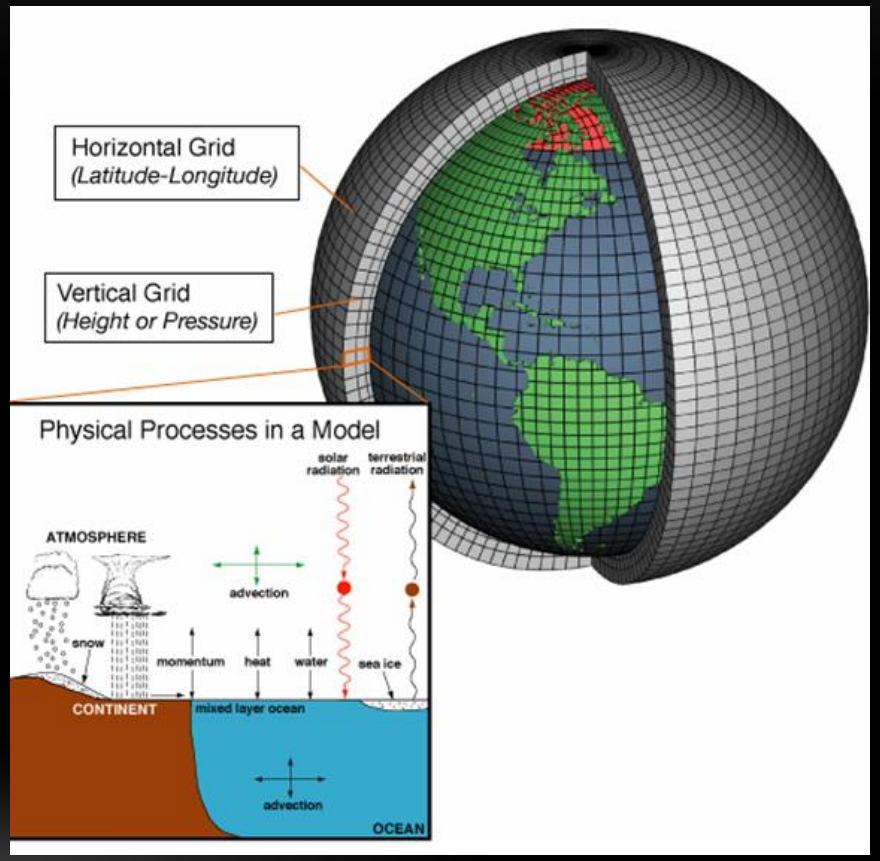
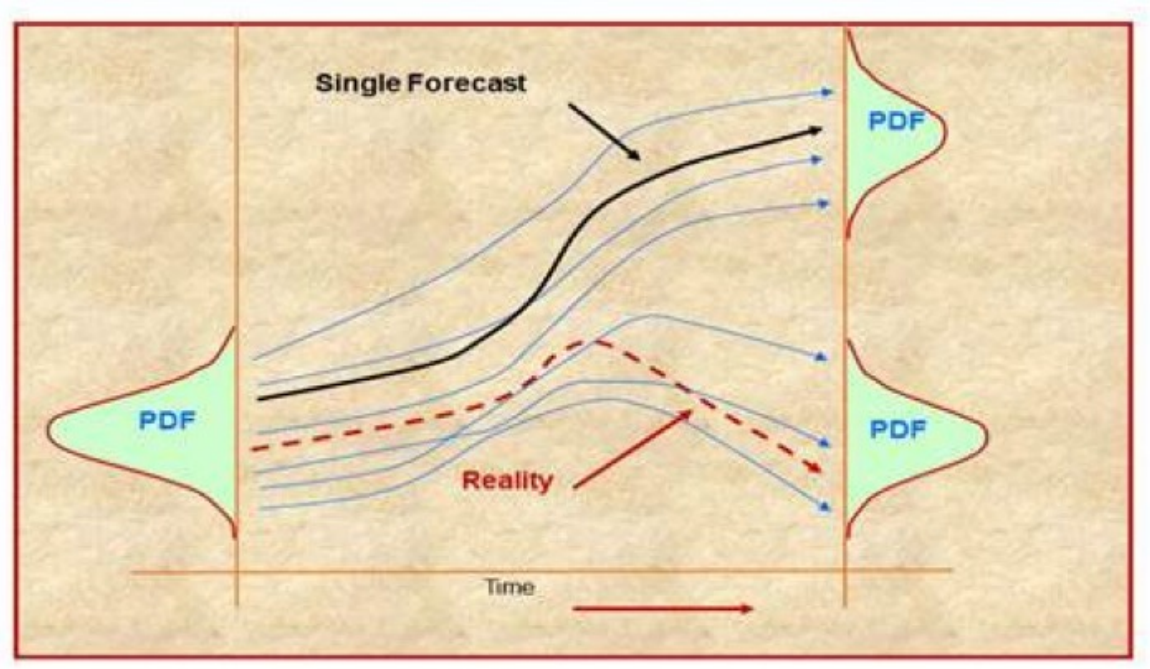


Figure from https://celebrating200years.noaa.gov/breakthroughs/climate_model/AtmosphericModelSchematic.png

Ensemble Prediction System



Du et al. 2018

Ensemble prediction refers to a set of different forecasts all valid at the same forecast time(s). The differences between the forecasts can provide information on the probability distribution of the predicted variables. (AMS Glossary).

Climate predictions are predictions of distributions because of the chaotic nature of the climate system and some uncertainty sources.

Some methods to address uncertainty in initial conditions

- Random Perturbation
- Scaled Time-Lagged Perturbation .
- Bred Growing Mode
- Singular Vector
- Ensemble Kalman Filter

Some methods to address uncertainty in model

- Multi-model and multi-physics
- Stochastically Perturbed Parameterization Tendency scheme
- Stochastic Kinetic Energy Backscatter scheme

Multi-Model Ensembles

- A multi-model ensemble (MME) often performs better than the best model in the group.
  - A major source of uncertainties resides in the model physics parameterization.
  - Averaging across different models may thus reduce such ”random” errors.
- Different MME approaches:
  - A standard approach: a simple average across all models, each with the same weight.
  - Ensemble approaches in which models are weighted based on the past performance: However, hindcasts are often too short to establish robust statistics on model performance.

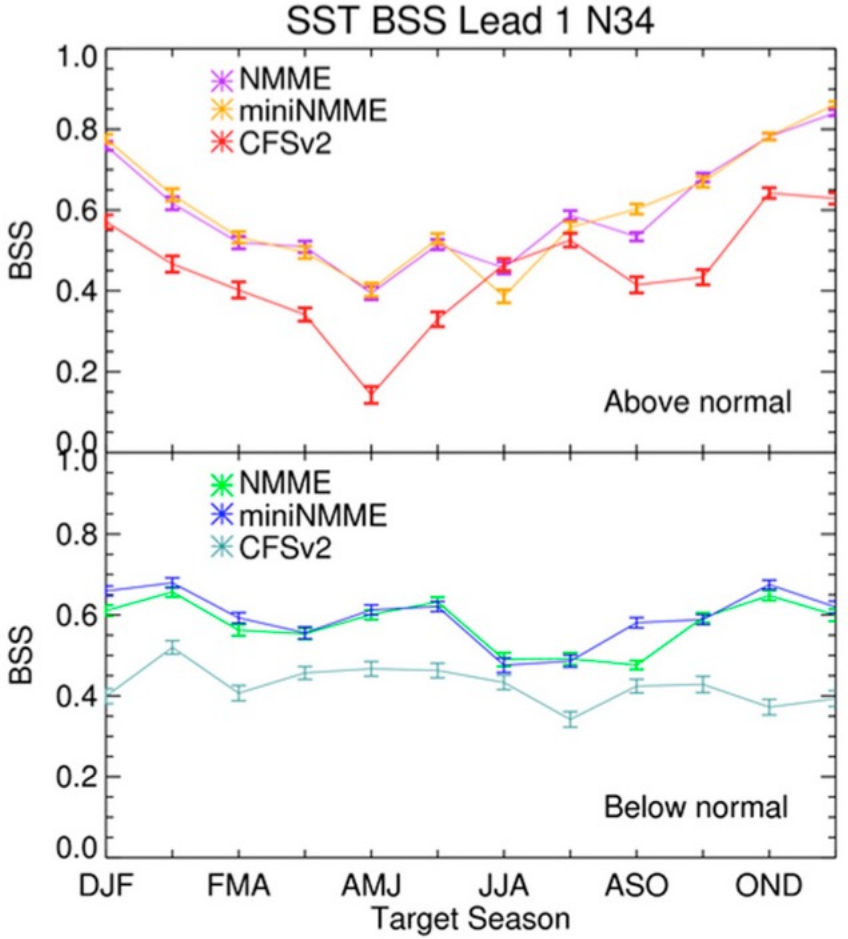
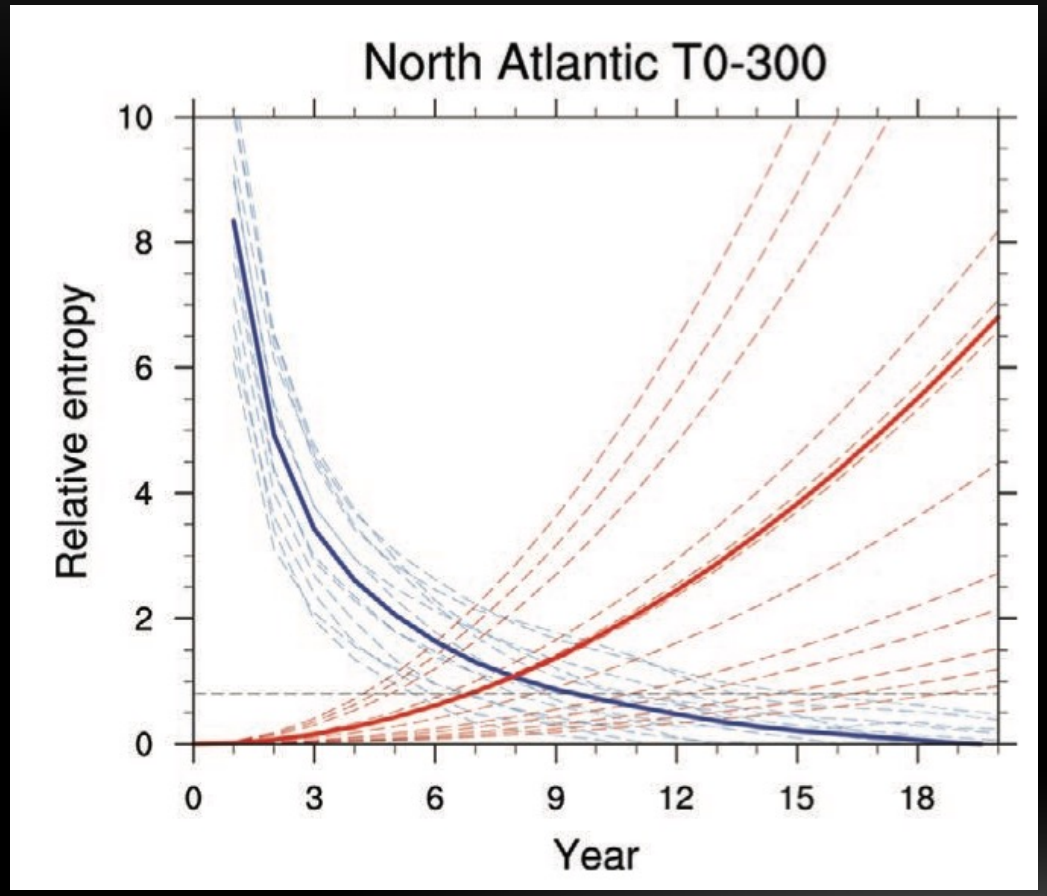


FIG. 1. Brier skill score (BSS) area-aggregated for all lead-1 seasonal probabilistic forecasts of SST in the Niño-3.4 region (5°S–5°N, 190°–240°E). Forecasts for the (top) above-normal and (bottom) below-normal terciles are shown for three forecasting systems: all members of the 6-model NMME (75 members), a mini-NMME comprising 4 members from each of the 6 models (24 members), and the CFSv2 alone (24 members). The lead-1 forecast for December–February (DJF) is made using November initial conditions, etc. Bars show the 95% confidence interval from 1000 bootstrap samples.

Becker and van Den Dool 2016 (© American Meteorological Society. Used with permission)

Role of Initialization for Climate Prediction



- The initial states of the slowly varying components of the global climate system, such as the ocean and land, serve as an important source of predictability.
- The initial value predictability generally decreases with the increasing forecast lead time.

Predictability of upper 300-m temperature of the North Atlantic for 12 CMIP5 models resulting from initialization (dashed blue lines) and the response to RCP4.5 forcing (dashed red lines). From Branstator and Teng 2012

References

- Becker, E., & van den Dool, H. (2016). Probabilistic Seasonal Forecasts in the North American Multimodel Ensemble: A Baseline Skill Assessment, Journal of Climate, 29(8), 3015-3026.
- Branstator, G., and H. Y. Teng, 2012: Potential impact of initialization on decadal predictions as assessed for CMIP5 models. *Geophys. Res. Lett.,* **39,** L12703, doi:10.1029/2012GL051974.
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