# Statistical predictions of multi-annual North Atlantic hurricane activity in a series of CMIP5 decadal hindcasts

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## 1. Introduction

Near term climate prediction is a new and rapidly developing field of climate research made possible by the increasing amount and quality of ocean surface and subsurface observations, by the computing power now available and by the significant improvement in the quality of global climate models (GCMs). Also known as decadal prediction, it aims to fill the gap in available climate information between seasonal predictions (a few months to one year) and climate change projections (>10 years), a timescale over which the influence of internal climate variability is comparable or larger to that associated with changes in radiative forcing. Such forecasts are of particular interest to policy makers, due to their potential use in a range of weather-related economic activities, such as agriculture and energy planning.

Since previous studies have shown that initialized GCMs show some improved skill in predicting the AMO (Garcia-Serrano et al., 2012), and that this same AMO is closely related to North Atlantic cyclones at the decadal timescale, we can expect that initialized GCMs would show some improved skill in predicting North Atlantic cyclone numbers at the multi-annual timescale.

## 2. Data

We use two different multi-model ensembles performed within the context of the CMIP5 project. The first multi-model ensemble is comprised of a series of 10-year long simulations initialized using the November 1st climate state estimated using contemporaneous observations. The number of members varies from model to model, but each GCM has produced multiple decadal forecasts initialized at regular intervals between 1960 and 2005. All of these hindcasts take into account observed changes in external forcings such as greenhouse gases, solar activity, stratospheric aerosols associated with volcanic eruptions and anthropogenic aerosols until 2005, and values from the Representative Concentration Pathway (RCP) 4.5 scenario afterwards.

The second ensemble is constructed using a combination of the historical (1961-2005) and the RCP 4.5 scenario (2006 onward) simulations performed using the same models as the first ensemble. We do not expect the simulated natural variability of this second ensemble to be in phase with the observed variability, allowing for this ensemble to be used as a comparison basis in evaluating the added-value of initialization.

## 3. Statistical emulator

Frequencies of North Atlantic hurricanes are estimated using a statistical emulator formulated as a Poisson regression model with two predictors (Vecchi et al., 2011) : mean ASO tropical SST (limited by 30°N and 30°S) and mean ASO North Atlantic tropical SST (limited by 10°N, 25°N, 80°W and 20°W).

$$\lambda = e^{1.707 + 1.388 SST_{MDR} - 1.521 SST_{TROP}}$$

λ: number of hurricanes
SST: anomalies w.r.t. 1982-2005 mean

High MDR SST leads to more TCs
High tropical SST leads to fewer TCs

The main advantage of this index over tracking storms directly in the model output is that cyclones can be computed easily from many models at low computational cost.

## 4. Measure of forecast skill

To evaluate the skill of the predictions, we use the Mean Square Skill Score (MSSS), which is defined as

$$MSSS = 1 - \frac{MSE_{forecast}}{MSE_{reference}}$$

MSSS=1 -> perfect prediction
MSSS>0 -> improvement over baseline
MSSS <= 0 -> no improvement

where MSE is the Mean Square Error of the forecast or of the baseline (reference; e.g. mean climatology) that we wish to improve upon.

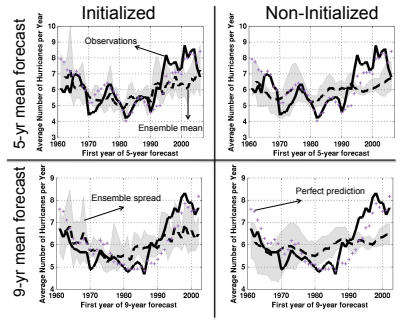
We also compute the Anomaly Correlation Coefficient (ACC) across the start date dimension. A t-test, after a Fisher-Z transformation, is performed to assess the significance level of the ACC. The autocorrelation of the different hindcasts is accounted for through a reduction in the degrees of freedom.

## 10. Reference

Caron, L.-P., C. Jones and F. J. Doblas-Reyes: Multi-year prediction skill of Atlantic hurricane activity in CMIP5 decadal hindcasts. Climate Dynamics, doi:10.1007/s00382-013-1773-1.

For more on the SPECS project: **http://www.specs-fp7.eu**

## 5. Predictions of multi-annual hurricane numbers

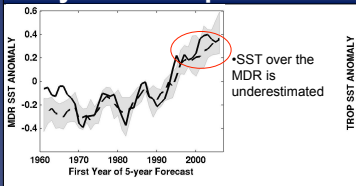



•For both five- and nine-year forecasts, initialized hindcasts capture observed activity better than non-initialized hindcasts, mainly due to increased variance.

•Both types of hindcast severely underestimate recent activity. This does not appear to be caused by the index, since the perfect predictions (purple cross) made with observed SST show heightened activity during that period.

•Five- and nine-year means are used to average out the impact of ENSO.

## 6. 5-year mean predicted SSTs of initialized hindcasts

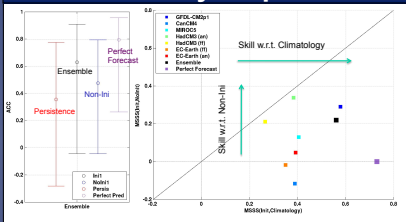



•SST over the MDR is underestimated

•The GCMs fail to capture the recent slowdown in warming: SST over the tropics is overestimated.

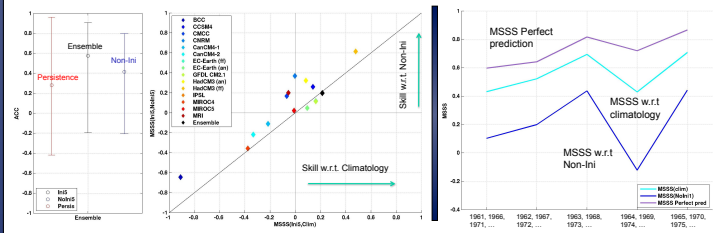
•Both predictors contribute to underestimation in number of hurricanes.

## 7. Skill of 5-year predictions – yearly start dates




•ACC of initialized hindcasts higher than non-initialized and persistence forecasts.
•Large uncertainty due to highly autocorrelated timeseries. Thus, ACC of initialized hindcasts is not significant.
•All systems offer improvements over a climatological forecast, and most over the non-initialized hindcasts.
•All systems offer improvement over persistence forecast (not shown).
•Results are similar for 9-year mean forecasts (not shown).

## 8. Skill of 5-year predictions – 5-yearly start dates




•Make use of a larger number of available systems, but fewer start dates.
•Ensemble mean forecasts shows improvement over climatology and non-initialized hindcasts, but large variability amongst models.

• MSSS relatively dependent on subset of start dates.
•Initialized worst than non-initialized, for 1964, 1969, 1974, …

## 9. Conclusion

•A hurricane index based on two (simple) predictors used in conjunction with initialized hindcasts shows robust skill in predicting multi-annual levels of hurricane activity in the North Atlantic region.

•Both 5-year and 9-year ensemble mean hindcasts offer improvements over climatological, persistence and non-initialized forecasts.

•Recent upswing in hurricane activity severely underestimated due to both underestimation of Atlantic SSTs and overestimation of tropical SSTs. The latter is tied to the failure of most GCMs at capturing the recent slowdown in warming.

•Skill is reduced in a second, larger ensemble using 5-yearly start dates. This second ensemble offers a pessimistic evaluation of the available skill and higher frequency (>1 every 5 years) is necessary to get an accurate picture of the available skill.