The hurricane and sea ice communities have a priori little to do with one another and historically have been distinct from each other. Yet, they have basically arrived to the same questions and run into the same problems: How is skill measured? What information do users need? Is uncertainty communicated adequately?

In conversation, we came to realize that although we had a similar platform aimed at disseminating seasonal forecasts, we were going about it in completely different ways. So we thought it would be interesting to highlight these differences and go back to understand how they came about. Hopefully the readers think so as well.

We also hope to initiate a conversation on how best to bridge the gap that exists between the scientific community and potential users of these seasonal forecasts."

—Louis-Philippe Caron and François Massonnet

Valuable, Not Just Skillful

Enhancing Seasonal Outlooks of Sea Ice and Hurricanes

Adapted from
“Making Seasonal
Outlooks of Arctic
Sea Ice and Atlantic
Hurricanes Valuable—
Not Just Skillful,”
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Recent efforts to make climate forecasts decision oriented have included identifying variables, thresholds, and/or events relevant to users. These elements generally do not coincide with typical forecast variables. To analyze their skill and reliability generally requires sustained dialogue between the involved parties. Here, we discuss two such efforts that attempt to bridge the gap between climate forecasting and application—for hurricanes and Arctic sea ice.

The first seasonal forecast model of tropical cyclone (TC) activity was published in the late 1970s. However, William Gray at Colorado State University (CSU) issued the first publicly available TC outlooks in real time in 1984. The number of groups issuing seasonal predictions for the Atlantic increased dramatically in the mid-to-late 2000s, likely due in part to the extremely active 2004 and 2005 seasons. New technologies as well as easily accessible climate data now make it relatively straightforward for any group (or individual) to develop their own forecasting system. Seasonal predictions of TC activity are produced for each basin where TCs are

observed, and for most TC basins, predictions are issued by multiple groups. For the Atlantic basin alone, 26 groups, ranging from private weather companies to universities to national weather services, are now producing publicly available seasonal outlooks.

Seasonal sea ice forecasts began more than two decades later than seasonal hurricane forecasts. But the record low sea ice extent (SIE) in September 2007, which fell 26% below the previous year, took many scientists by surprise. Afterward, a grassroots project called the Sea Ice Outlook¹ (SIO) led an effort to develop reliable predictions of the minimum SIE a few months in advance. Each year starting in June, the SIO would collect and synthesize sea ice “outlooks” of the pan-Arctic September SIE and share results on its web page. SIOs were requested each month up to the September minimum. In 2014, the effort was formally funded by several U.S. agencies and rolled into the Sea Ice Prediction Network² (SIPN). In 2017, based on the SIPN, the sister project SIPN South³ was initiated to meet the growing demand for sea ice forecasts in the Southern Ocean.

North Atlantic basinwide hurricane number compared to the latest individual hurricane outlooks (and their median) collected since 2015 (one blue dot per group). The climatology forecast (green line) is the average of all hurricane counts from 1969 to the current year minus one, and the 10-yr persistence forecast (purple) is the average of all hurricane counts from the 10 preceding years. The Number of groups that have submitted a forecast for a particular year is shown in parentheses. * ▼

Perhaps surprisingly, despite a 25-yr head start, there is no equivalent organized network in the hurricane community. However, a similar platform has recently been brought online that gathers all freely available Atlantic hurricane outlooks as they are made available by the 26 different groups now issuing them. Each year since 2016, the site has collected and

displayed seasonal hurricane forecasts issued from late March through early August. Spearheaded by the Barcelona Supercomputing Center and CSU and supported by a private sponsor (XL Catlin—now AXA XL) but relying on the volunteer participation of the forecasters, the hurricane collation site⁴ arose from the desire of these three institutions to centralize the various outlooks, which are typically publicly available but scattered across different domains. This stands in contrast with a coordinated community effort that offers its view on the upcoming hurricane season.

While the first hurricane forecasts were based on statistical relationships, increased climate model resolution has allowed the development of dynamical forecasts, wherein hurricane-like vortices are detected and tracked in initialized climate simulations. However, because this requires expensive infrastructure, few groups are issuing dynamical forecasts, and most groups produce so-called hybrid forecasts, which rely on both statistical relationships and initialized climate simulations by dynamical models. The increase in computational power has also fostered the development of innovative technologies, as machine learning techniques have started to be applied to TC forecasting.

For sea ice forecasts, various methods were used initially, including heuristic estimates, simple linear regression models, and dynamical coupled ice–ocean models. However, with time, the use of dynamical models for sea ice forecasts has grown, including both coupled ice–ocean models forced by atmospheric re-analysis data or fully coupled climate models, with and without initialization by data assimilation. And while early forecasts simply provided estimates of the pan-Arctic sea ice extent, today’s forecasts also include sea ice thickness, spatial maps of sea ice probability (presence of ice or not), and timing of sea ice breakup and ice advance. These metrics are arguably of more use to various stakeholders than sea ice extent, whether it is local communities planning for the seasonal hunt or shipping companies trying to avoid the ice. This effort has been extended recently to include a year-round portal for subseasonal-to-seasonal forecasts. By comparison, the hurricane website includes an outlook for four different basinwide statistics (named storms,

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¹ <https://www.arcus.org/sipn/sea-ice-outlook>
² <https://www.arcus.org/sipn>
³ <http://acerc.org.au/sipn-south>
⁴ www.seasonalhurricanepredictions.org

hurricanes, major hurricanes, and accumulated cyclone energy—an integrated measure of frequency, intensity, and duration), thus only providing information on the expected overall level of hurricane activity.

Moderate hurricane seasonal forecast skill emerges in June, and August forecasts show the greatest skill. By contrast, pan-Arctic September SIE forecasts generally fail to capture large deviations from the long-term trend, and the forecast skill does not necessarily improve with shorter lead times as one would expect. Perhaps even more interestingly, the median outlooks are highly correlated (0.89) with the verification data from the previous year.⁵

The total hurricane count—one of the most commonly forecasted variables—is of relatively little use to many stakeholders. Although not included on the platform itself, many groups are also forecasting the number of landfalling storms in different parts of the basin, generally including U.S. coastline areas with the largest potential for financial impacts. However, even these landfall forecasts are of limited use because they are not explicitly tailored to a stakeholder's decision process. In reality, this lack of tailoring is likely due to

- 1) the sheer scope and complexity of stakeholders, who range from emergency planners and aid agencies to financial risk managers such as reinsurance companies;
- 2) the stakeholders' desire for predictions of a tightly defined risk (which has not yet been attempted very explicitly) rather than the scientific hazard itself.

Risk is a function of hazard, vulnerability, and exposure; this way of thinking is deeply ingrained in the catastrophe modeling industry, which attempts to quantify societal impacts of perils. Even if proven skillful, seasonal tropical cyclone landfall forecasts will likely remain of limited use because they remain disconnected from any particular decision-maker's fully coherent picture of vulnerability and exposure. On the other hand, these attempts at landfall forecasts are facilitating a conversation between the academic communities focused on the hazard and the applied communities focused on the risk. In tailoring future predictions to decision-making, the hurricane seasonal

forecasting community should consider emulating the SIPN.

Hurricane and sea ice forecasting have more in common than it might initially appear. With global climate change, both hurricane and sea ice forecasting are chasing a moving target. Identifying, through fundamental research, new physical mechanisms that offer predictability at seasonal time scales would indeed improve sea ice or hurricane forecast skill and also drive our understanding beyond simple predictor–predictand empirical relationships that might break down as mean states change.

Another point of convergence between the two fields of research is the notion that at the time scales considered, forecasts can only be expressed in probabilistic terms. Indeed, while climatic preconditioning drives seasonal sea ice retreat and hurricane activity, weather—unpredictable beyond two weeks—modulates both sea ice evolution and the timing and location of hurricane formation. Probabilistic forecasts, even if well calibrated, are prone to misinterpretation by audiences outside the forecasting community itself, underlining the need to provide expert guidance when these forecasts are communicated to the public and stakeholders.

Finally, a third common aspect is the awareness that forecast skill and value are different concepts. A forecast can be correct (i.e., correspond with observations), but unexploitable for stakeholders. Region-wide quantities such as total sea ice extent or basin-wide hurricane count can readily be a key to moving beyond the academic framework and making forecasts operationally useful. ••

▲ * September Arctic sea ice extent from the National Snow and Ice Data Center sea ice index (version 3) compared to individual June sea ice outlooks (and their median) collected since the inception of the project in 2008 (one blue dot per group). A linear trend forecast based on September extents from previous years is shown in green and an anomaly persistence forecast is shown in purple. To produce the anomaly persistence forecast, May anomalies were added to the September climatology. The number of groups that have submitted a forecast for a particular year is shown in parentheses.

⁵ The sea ice and hurricane outlook data can be obtained from, <https://github.com/fmassonn/paper-hurricanes-seaice.git>.

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