Identifying predictable sea surface temperature patterns by incorporating uncertainty into regression neural networks

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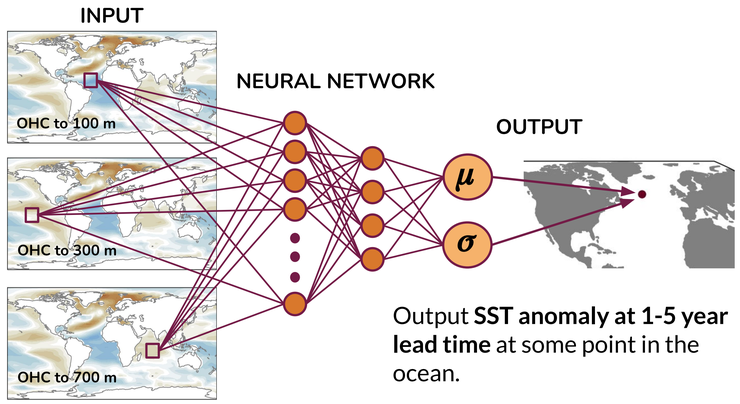
Predicting SST evolution

- **Sea surface temperature (SST) predictability** on decadal (2-10 year) timescales can arise from both **external forcing and internal variability**.
- Recent studies suggest that predictability on decadal timescales can be influenced by the initial state of the system i.e. **some initial states are more predictable than others** (e.g. Mariotti et. al 2020).
- Aim to **identify oceanic patterns that are associated with more predictable SSTs** in the North Pacific and North Atlantic oceans.
- Using output from the CESM2 pre-industrial control simulation for CMIP6 to **examine predictability due to internal variability.**

Using an artificial neural network (ANN) to predict SSTs with uncertainty

We train neural networks to predict SST anomaly 1-5 years in the future



Input **3x maps of ocean heat content (OHC)**

Output **SST anomaly at 1-5 year lead time** at some point in the ocean.

μ = anomaly prediction
σ = uncertainty prediction

This work is available as a preprint:
Gordon, E. M. & E. A. Barnes, *Incorporating Uncertainty into a Regression Neural Network Enables Identification of Decadal State-Dependent Predictability*, submitted to GRL, preprint available at ESSOAr or scan the QR code
Contact me about this work! emgordy@colostate.edu

References:
- Mariotti et. al 2020, *Windows of Opportunity for Skillful Forecasts Subseasonal to Seasonal and Beyond*, BAMS
- Borchert et. al 2018, *Atlantic Ocean Heat Transport Influences Interannual-to-Decadal Surface Temperature Predictability in the North Atlantic Region*, J. Climate

E. M. Gordon is partially funded by Fulbright New Zealand. E. M Gordon and E. A. Barnes are supported in part by NSF CAREER AGS-1749261 under the Climate and Large-scale Dynamics program

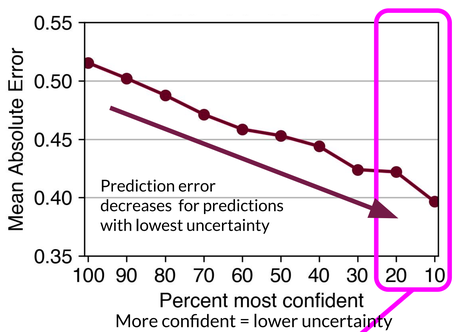
Key Points

- **Artificial neural networks (ANNs) learn to predict SST evolution on decadal timescales**
- **ANNs learn more predictable oceanic states by assigning lower uncertainty to more predictable patterns**
- **More predictable initial states coincide with specific combinations of patterns of decadal variability (e.g. Atlantic Multi-Decadal Variability, AMV, and Interdecadal Pacific Oscillation, IPO)**

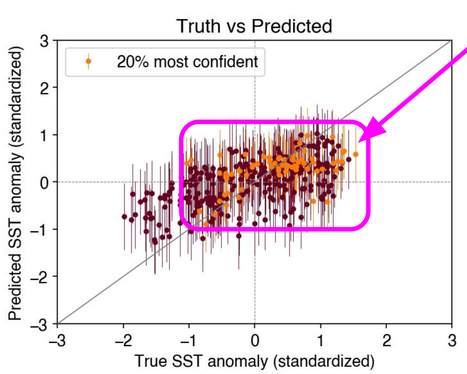
Leveraging uncertainty predictions to identify predictable SST patterns

The neural network identifies more predictability by assigning **lower uncertainty values to more predictable samples**

Prediction error (difference between predicted and true anomaly) **decreases for predictions with lower uncertainty**



What predictions lead to lower predicted uncertainty?



Examine only the **20% most confident** (lowest uncertainty) **predictions**

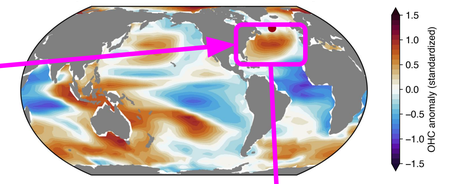
Look for commonalities between confident predictions

E.g. in the North Atlantic (53N, 325E), low uncertainty predictions (orange) are mostly positive

Predictable North Atlantic Variability

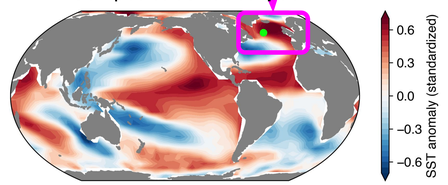
- **Predict SST anomaly** at 1-5 year lead time at a point in the North Atlantic Ocean **(53N, 35W)**
- Examine **20% most confident predictions of positive anomaly**

Composite OHC to 300 m at **input**



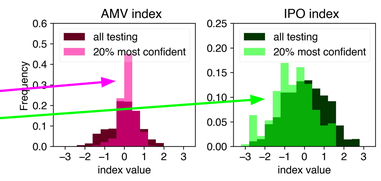
- Composite of OHC input for **confident predictions** shows **anomalously positive heat in the subtropical Atlantic**
- Composite SST 1-5 years later shows **heat transport into North Atlantic Sub-polar Gyre**
- **Anomalously northward heat transport leads to increased predictability** in North Atlantic Sub-polar Gyre → agrees with e.g. Borchert et. al 2018

Composite SST at **output**



What about modes of decadal-multidecadal variability?

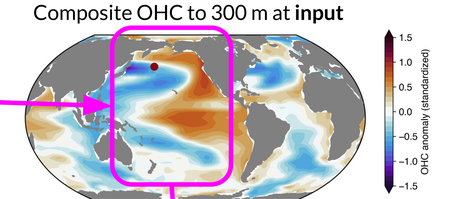
Predictable initial states (i.e. 20% most confident predictions) are most likely to occur with the combination of
- Positive AMV
- Negative IPO



Predictable North Pacific Variability

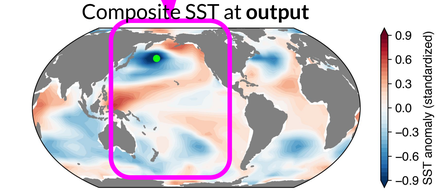
- **Predict SST anomaly** at 1-5 year lead time at a point in the North Pacific Ocean **(43N, 175E)**
- Examine **20% most confident predictions of negative anomaly**

Composite OHC to 300 m at **input**



- Composite of OHC input for **confident predictions** shows **strongly positive IPO/PDV pattern**
- Composite SST 1-5 years later shows **IPO/PDV pattern persists**
- **Positive phase IPO/PDV leads to predictable SST in the North Pacific**
- Suggests positive-to-positive persistence is more predictable?

Composite SST at **output**



Predictable initial states (i.e. 20% most confident predictions) are most likely to occur with
- Positive IPO
- No significant AMV