Seasonal Predictability of Tropical Atlantic Variability

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Outline

- Background and Motivations
- Experiment design
- Results
  - Predictability of Northern Tropical Atlantic (NTA) pattern;
  - Predictability of Southern Tropical Atlantic (STA) pattern
- Summary
TAV is characterized by:

- Northern tropical Atlantic (NTA) pattern centered in the Open ocean of the northern tropical Atlantic;
- Southern tropical Atlantic (STA) pattern centered near the Angola coast, which extends toward the central equatorial ocean and the Gulf of Guinea;
Why is TAV important?
TAV Modes have strong seasonality

- **NTA** (Meridional mode, Dipole mode);
- **STA** (Zonal mode, Atlantic Nino);
- El Nino-Southern Oscillation (ENSO);
- North Atlantic Oscillation (NAO)

Strong seasonality of Tropical Atlantic Variability makes understanding and prediction of tropical Atlantic variability a challenge.

(Sutton et al, 2007)
Motivation: theoretically, the mechanisms of both NTA and STA modes are well known and they have high potential predictability (Kushnir et al 2006)

NTA: wind-evaporation-SST positive (WES) feedback

STA: Bjerknes feedback

(Chang et al, 2006)
In reality, the skill of STA prediction is low

- **S4** is a newer version of **S3** of ECMWF
- Persistence (black dash);
- In Month 6, ENSO: 0.8; STA: <0.5
- STA: S3 close to persistence; S4 improved but still low.

Why is Atlantic Nino harder to predict?
Hypothesis 1: Model bias;

Predictions from realistic ICs will generate strong initial shock and climate drift

(Richter et al, 2012)

Hypothesis 2: Uncertainty of Initial conditions is large

Heat Content Uncertainty in Ocean Analyses (1979-2007)

Signal/Noise Ratio

\[ \text{Signal/Noise Ratio} = \frac{\text{Var(Ensemble Mean)}}{\text{Var(Intra_Ensemble Deviation)}} \]

DATA SOURCE

ECMWF: ORA-S3, COMBINE-NV
NCEP: GODAS, CFSR
UM/TAMU: SODA
GFDL: ECDA

Zhu et al. (Clim. Dyn., 2012)
Hypothesis 3: Intrinsic limits of TAV predictability

Scientific Questions:

• What is the potential predictability of the TAV modes?
• What are the factors determining the potential predictability?
Predictability experiments of TAV events

– **Control run using the state-of-the-art fully coupled model:**
  • Model description: (Community Earth System Model, CESM1.1.2)
    – Atmosphere: CAM 5, 1° latitude/longitude, 30 vertical levels;
    – Ocean: POP2, 1° latitude × 1.25° longitude, 60 vertical levels;
  • Total 86 years in the control (“truth”).

– **Seasonal predictions of the selected TAV events:**
  • Perfect model scenario;
  • Perfect oceanic initial state;
  • Small atmospheric random perturbation.

**Advantage:**
Eliminating the model climate drift and initial shock in real predictions.

**Potential Issue:**
Model biases (different from observed and model climate) still exist;
Results are model dependent.

*Quality of the TAV simulation is critical to this study!*
• Averaging between 10N-20N
• SST anomalies generated by the surface latent heat flux anomalies 2 months ahead;
• Model is able to predict this NTA event skillfully with long leads

• All cases predict warm events;
• Uncertainty does not increase with lead time.
Prediction skill evaluation

- **Deterministic metrics:**
  - Correlation: 0.75-0.99 (0.95);
  - RMSE: 0.05-0.2 (0.2);

- **Probabilistic metrics:**
  - Spread: similar with RMSE;
  - Reliability: spread/RMSE~1, reliable.

- Predictability limit up to 9 months and even longer.

\[
\text{Spread} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_{ens,i} - \bar{x})^2}
\]

\[
\text{Reliability} = \frac{\text{Spread}}{\text{RMSE}}
\]

Where is the high predictability from?
STA predictability

Case Study of SSTA and TAUXA

- Ensemble mean depends on lead time;
- Uncertainty increases with lead-time (Spread largest in January case and smallest in May case)

- Sensitive to lead time IC;
- With JAN IC, sign is predicted but magnitude is much lower;
- Whether Bjerknes feedback can be triggered in late spring is crucial.

An example
Prediction skill evaluation

- Deterministic metrics:
  - Correlation: 0.7-0.99 (0.8);
  - RMSE: 0.1-1.2 (0.8);
- Probabilistic metrics:
  - Spread: lower than RMSE;
  - Reliability: spread/RMSE<1, overconfident;
- Predictability limit up to 4 months.
Summary

“Perfect” model approach is used to evaluate the predictability of two patterns of the leading modes in the tropical Atlantic;

- The **NTA** is predictable up to 9 months, and the source of the predictability comes from:
  - Positive WES feedback
  - ENSO predictability and tele-connection

- The **STA** has intrinsic prediction limit up to 4 months
  - Predictable with late-spring ICs;
  - Strength of **Bjerknes Feedback** is seasonal;
  - ENSO teleconnection is not critical.
Publications


- Fang G. and B. Huang, 2018: Seasonal Predictability of the Tropical Atlantic Variability: Southern Tropical Atlantic Pattern, ready for submission.
Future Work

- Limitations of the experiment design:
  - Model dependence (what is the effect of model bias?);
  - Pre-selected events (can we predict the neutral states with skill?)

- Examining the TAV prediction skill in re-forecasts and operational prediction of the North American Multi-Model Ensemble (NMME):
  - Effect of model bias and drift;
  - Analyzing all situations of TAV;
  - Extra-tropical effects like NAO.

- Southern hemisphere influence: the southern subtropical Atlantic (SSA) mode.
Currently looking for a job!
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Thank you!
😊

SCAN ME

SCAN ME
Recap of NTA

- Predictability of NTA is high (long lead);
- Sources of predictability:
  - Air-sea WES feedback;
  - ENSO forcing.
- Source of high NTA predictability (up to 9 months) comes from high ENSO predictability;
Recap of STA

- Predictability of STA is limited by the initial condition in late spring (April and May);

- Source of predictability:
  - Bjerknes feedback;
    - The pre-condition of deepening of the thermocline in African coast is necessary but not sufficient;
    - Effective Bjerknes feedback in late spring or early summer is critical;
  - The role of ENSO teleconnection is secondary.
Model evaluation

- Main feature of ITCZ-cold tongue complex is realistic;
- Shortcomings:
  - Overestimated Precipitation;
  - Double ITCZ.
Simulated leading modes of TAV are realistic and adequate for conducting the predictability experiment.
TAV prediction is to predict the occurrence of anomalous events.

Experiment design:

Anomalous events in observations
• 13 anomalous event chosen: 6 positive and 7 negative.

• 18 anomalous event chosen: 9 positive and 9 negative.
• NTA and STA events have strong seasonal phase-lock;
• NTA peaks in April and STA peaks in July;
• Different starting dates for each forecast due to its seasonality.
Source of Predictability: WES feedback

- Not very sensitive to lead time of IC;
- The key feature is the cyclonic anomaly in sub-tropic.

Why predicted well? Wind > Latent heat flux > SST anomalies

Where does the cyclone come from?
Source of Predictability:  

- Remote forcing from winter to spring;
- Cyclone comes from ENSO response by Pacific/North American (PNA) pattern;
- Successful prediction of El Nino > cyclonic SLPA > warming in NTA region.

Averaging 500 mb height anomaly (m) for JFM 1998 and 1983 from NCEP (Shukla, 1998)
Source of Predictability: Regional feedback

Composite SSH & TAU of Positive STA

Composite SST & SLP of Positive STA

Bjerknes feedback: North wind anomalies increasing > easterly trade winds depressing > deepening thermocline > upwelling suppressing > SST increasing > wind converging to warm water > westerly anomalies increasing

- Low pressure center > warm anomalies;
- For January case: no low pressure center.
Source of Predictability

Composite SSH & TAU of Positive STA

- SSH & TAU decaying in model;
- No air-sea feedback in January forecast

Composite SST & SLP of Positive STA

- SST & SLP decaying in model;
- Ocean memory existing but not persistent;
- No air-sea feedback in prediction
Does ENSO teleconnection play a role?

STA occurring in ENSO transition period, but not related to the strength of ENSO;
In January case, no STA developing although ENSO is stronger than other cases;

Pr & SLP not predicted in the January case;
Warm low SLP anomaly center is the key!
Annual cycle is the dominant variability in the tropical Atlantic domain.

Associated with the covariation of the intertropical convergence zone (ITCZ)-cold tongue complex; Seasonal cycle has significant climate influence.