Towards Advancing the MJO Forecasting in the NGGPS

(A R2O Project Contributing to NGGPS)

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Objective and Approaches

The proposed study aims to better understand the impacts of cumulus parameters and underlying SST conditions and to improve the MJO and 1-30-day weather forecasting in the prototype NGGPS system (and GFS/GEFS).

Three steps are planned to achieve the proposed goal:

- **Understand the impacts of cumulus parameters and SST conditions** on the MJO and 1-30-day weather forecasting;

- **Document the systematic SST errors in the NGGPS**: mean state, interannual variability, *intra-seasonal variability* and diurnal cycle;

- **Understand the causes of systematic SST errors and assess their impacts on the MJO and 1-30-day weather forecasting**.
UH Sub-seasonal Forecasting System

Global Model Physics
- Shallow convection (Fu et al. 2008)
- Stratiform rainfall (Fu and Wang 2009)

Sub-seasonal Prediction
- Multi-Model Ensemble (MME) (Fu et al. 2013)

Sea Surface Conditions
- Air-sea Coupling (Fu et al. 2003; Fu and Wang 2004; Fu et al. 2007; 2013)
- Forecasted Daily SST (Fu et al. 2008; Fu et al. 2015)

Initial Conditions
- Nudging strategy and signal-recovering method (Fu et al. 2009, 2010)

http://iprc.soest.hawaii.edu/users/xfu

NOAA/NCEP, Aug. 02, 2017
How will Cumulus Parameterizations and SST Conditions Influence MJO Forecasting in the GFS?
1. Model
   • Atmosphere-only GFS (May 2011 version)
   • T126/L64

2. SSTs
   • Clim (no intra-seasonal SST anomalies)
   • NCDC OI analysis (weak intra-seasonal SST anomalies)
   • TMI (TRMM Microwave Imager) (strong intra-seasonal SST anomalies)

3. Convection parameterizations
   • SAS (Simplified Arakawa Schubert (Pan&Wu 1995)): Operational CFSv2
   • SAS2 (Revised Simplified A-S (Han&Pan 2011)): Operational GFS
   • RAS (Relaxed A-S (Moorthi and Suarez (1999)))

4. Forecast runs
   • Initial conditions: CFSR
   • Integrate 31 days

Wang et al. (2015)
Sensitivity of Nov-MJO to Cumulus Parameterizations and SST Forcing

Wang et al. (2015)

NOAA/NCEP, Aug. 02, 2017
Ocean coupling has stronger influences on some MJOs than on other MJOs

Fu et al. (2015, 2017a)
Forecasting Oct- & Nov-MJO Events During DYNAMO IOP

Clim-SST Forcing

TMI-SST Forcing

OLRA (shading)
SSTA (contours, CI: 0.2°C)
MJO Diversity

During Entire DYNAMO Period (Oct. 01, 2011-Mar. 31, 2012)

Five MJO events are observed in which only two of them have robust SST anomalies associated.

- **The October-MJO** is largely controlled by atmospheric internal dynamics.
- **The November-MJO** is strongly coupled to underlying ocean.

Year-around:
- Primary vs. Successive (Matthews 2008)
- Propagating vs. Non-propagating (Kim et al. 2014)
- Coupled vs. Uncoupled (Fu et al. 2015)

Boreal-Winter:
- Three MJO types (Hirata et al. 2013)
Different Air-Sea Coupling Regimes from Long-term Observations
Why are the impacts of SST-feedback on Nov-MJO so different in the RAS and SAS2?

Fu et al. (2017b)
OLR and Surface Convergence in Response to Same SST Anomalies

Day-5

Day-10

 --------- Positive SSTA

---------- Negative SSTA

OLR (shading)

---------- Convergence

NOAA/NCEP, Aug. 02, 2017
Q1 and Q2 in Response to Same SST Anomalies

Day-5

Day-10

Day-15

Day-20

NOAA/NCEP, Aug. 02, 2017
Schematics of SST-Feedback Processes

- Positive SSTA
  - Convergence
  - Evaporation
  - Convective Instability
  - Weak upward-downward feedback

- GFS-SAS2

- Positive SSTA
  - Convergence
  - Evaporation
  - Convective Instability
  - Strong upward-downward feedback

- RAS

NOAA/NCEP, Aug. 02, 2017
Three-type Boreal-summer MJOs

Another example of MJO diversity

Fu et al. (2017c)
Three Different MJO Types

Type-I  Type-II  Type-III

OLR

TRMM

NOAA/NCEP, Aug. 02, 2017
Different Downstream Impacts

Type-I

Type-II

Type-III

200hPa-VP (contours)
Recent Progresses Made on MJO Forecasting with GFS/GEFS at NCEP/EMC

Courtesy of Yuejian Zhu’s group
Intra-seasonal SST forcing (RTG) improves MJO Forecasting of the GFS
Updated Stochastic Physics Further Improves MJO Forecasting of the GFS

MJO skill: RMM1+RMM2
20140501-20160526 for STTP&SPs
20140909-20160830 for GEFS_v10

OLR

U850

U200

NOAA/NCEP, Aug. 02, 2017
• Major Accomplishment in FY17:

✓ A suite of hindcasts with the GFS under three different cumulus schemes and SST conditions during DYNAMO IOP is used in this study.
✓ Reveal MJO diversity in ocean coupling: The Oct-MJO is largely controlled by atmospheric internal dynamics while the Nov-MJO is strongly coupled to underlying ocean.
✓ Cumulus parameterization plays an essential role in capturing the impacts of ocean coupling on the MJO.
✓ There are three different boreal-summer MJO types: Type-I&III have robust downstream impacts in Pacific and Atlantic sectors while Type -II is limited in Indian sector.

• Priority Focus for FY18

➢ Continue to collaborate with NCEP/EMC team to better understand the impacts of cumulus schemes and SST and explore the ways to improve MJO and 1-30-day weather forecasting in the GFS/GEFS and NGGPS.

• Key Issue

➢ Availability of NGGPS model and outputs.
➢ NOAA computing resources for research.
Thank You Very Much!
Extra Slides
MJO Skills in Three GCMs during DYNAMO Period

(Wheeler-Hendon Index) (Sep 2011- Mar 2012)

GFS/GEFS: 14 days
(Hamill and Kiladis 2014)

CFSv2&UH: 25/25 days

CFSv2&UH MME: 37 days

Fu et al. (2013)
Forecasts of GFS, CFSv2 and UH with IC on Nov. 11

November-MJO & Thanks-giving TC

Observed and forecasted U850 and OLR averaged for days-13-15

Fu et al. (2013)
Air-sea Coupling **Doubles** the MJO/ISO Intensity

- **Fu et al., 2003** ; **Fu and Wang 2004**

**ECHAM-4 AGCM + UH IOM**
Air-sea Coupling Extends the **Predictability of the MJO/ISO** by at least One Week

We first discovered that **forcing the atmosphere-only model with the forecasted daily SST** from the coupled model can reach the same sub-seasonal forecasting skill as the fully coupled model.

Fu et al. (2015); Wang et al. (2015)

Fu et al. (2007, 2008) along with Vitart et al. (2007) and Woolnough et al. (2007)
Schematics of MJO Vertical Structure

Kiladis et al. (2009)

Grid-scale Representation??

Moistening

40-60%

Classic Cumulus Parameterization

Model Physics
Enhanced Shallow-Convection Moistening Speeds up Model MJO Propagation

Fu et al. (2008)
Stratiform Rainfall Fraction is an Essential Factor for MJO Simulation

Fu and Wang (2009)
The MJO has broad wavenumber-frequency bands

Paul Roundy (2004)