MJO Evaluation for UFS High Resolution Prototype

[1]Wei Li

Acknowledgment: [2]Lydia Stefanova, [2]Jiande Wang, [3]Fanglin Yang, [3]Jongil Han

[1]SAIC/EMC/NCEP, [2]Lynker/EMC/NCEP, [3]EMC/NCEP

UFS S2S AT All-hands meeting

October 27 , 2023

Outline

- Overview of the HR1 performance on MJO forecast
  - ACC skill and RMSE
  - Intensity and phase bias

- Case Study: Maritime Continent Barrier
  - Diabatic heating(i.e. apparent heat source or Q1) and its major components
  - Q1 and Q2 profile over Indian Ocean and Maritime Continent

Models and Updates

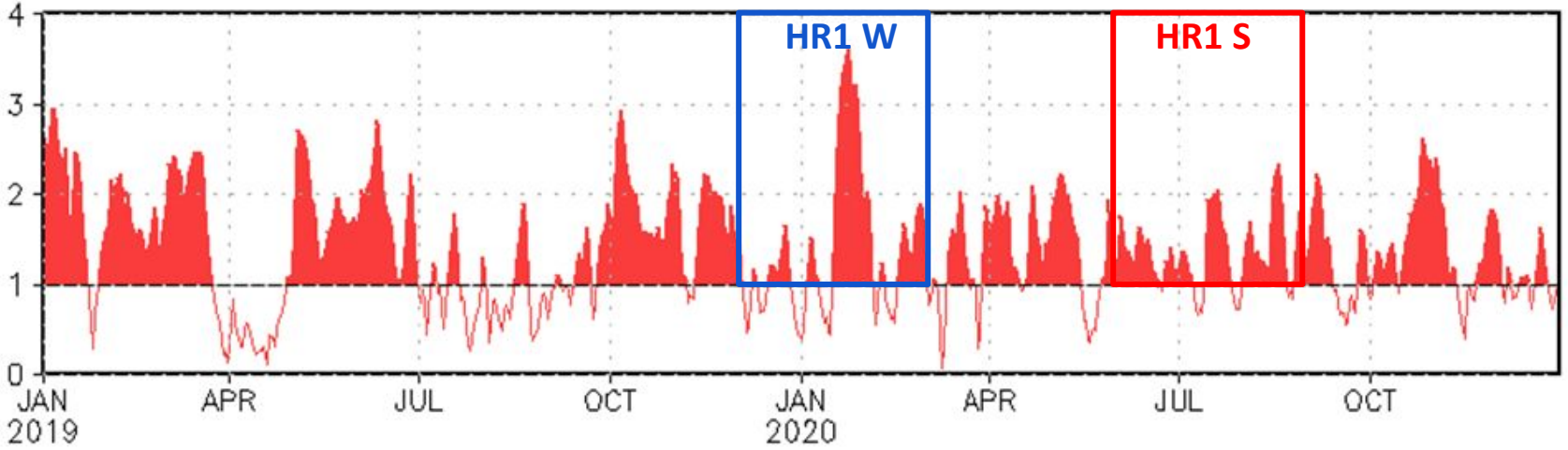
- **Models**
  - **GFSv16**: C768L127, atm+wave, with nsst on
  - **HR1**: C768L127, atm+ocn (MOM6)+ice (CICE6)+wave (WW3)+aerosols (GOCART) with nsst on
- **Major physics update on HR1 compared to GFSv16:**
  - **Land:** Noah-LSM->Noah-MP
  - **Microphysics:** GFDL**->**Thompson microphysics and cloud cover updates
  - **Convection, PBL and surface layer updates**
  - **Cloud and radiation updates**
  - **Gravity wave drag ->** uGWD.v1 and updates
  - **Aerosol:** OPAC -> MERRA2 aerosols
  - **Stochastic->**CA and updates
- **Updates on other coupled components:**
  - **Sea ice**
  - **Lake ice climatology**
  - **Land/lake masks**
  - **Snow and soil ICs**

—Courtesy of Lydia Stefanova and Fanglin Yang for the information

Data

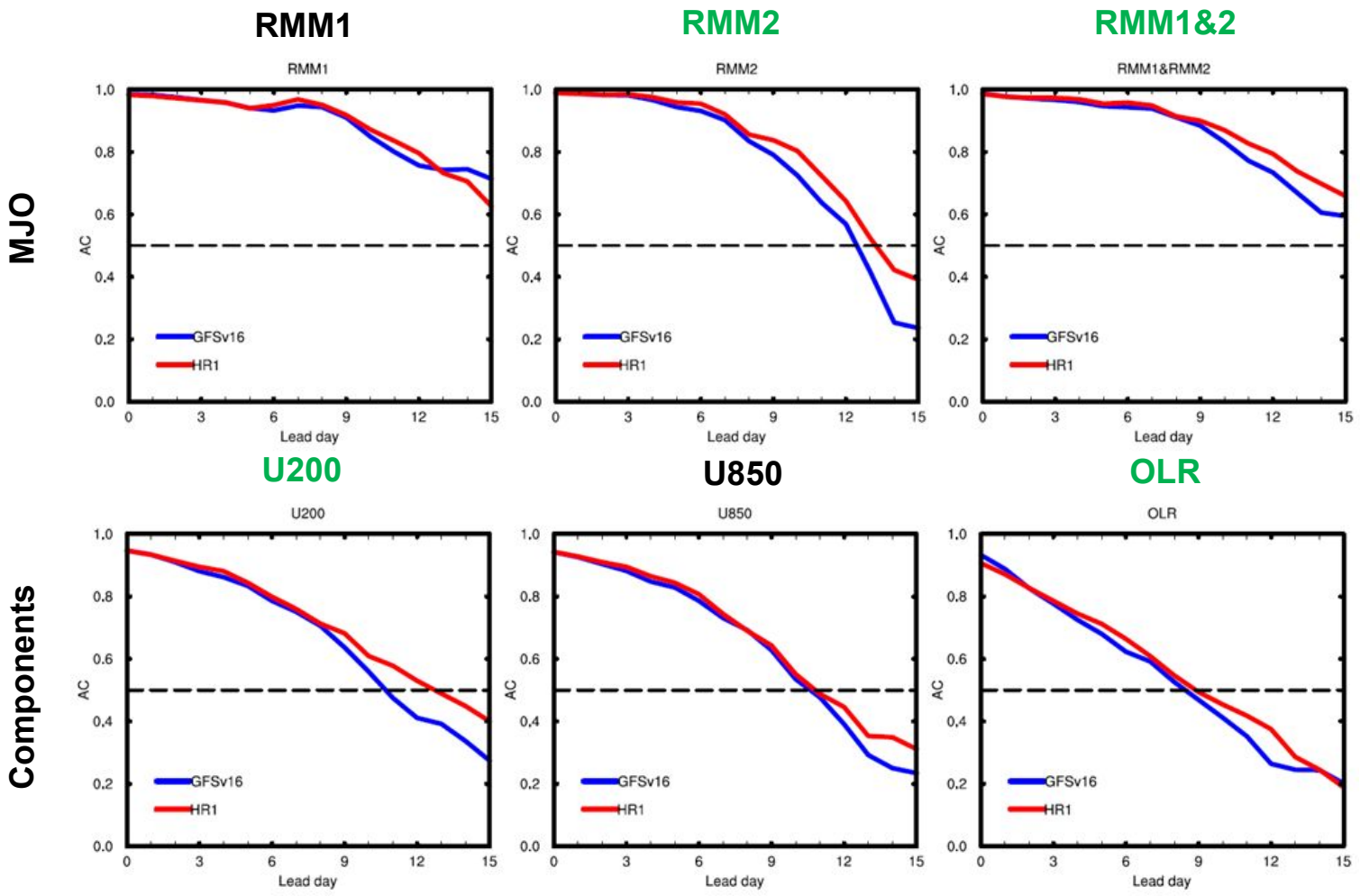
- **Experiment period:**
  - Winter (20191203-20200225, every 3 days, 384 fhr): 29 cases
  - Summer (20200601-20200830, every 3 days, 384 fhr): 31 cases
- **Reference data:** GFSv16 analysis
- **Climatology:** NCEP NCAR reanalysis (1979-2001) -> anomaly without bias correction

MJO index from CPC



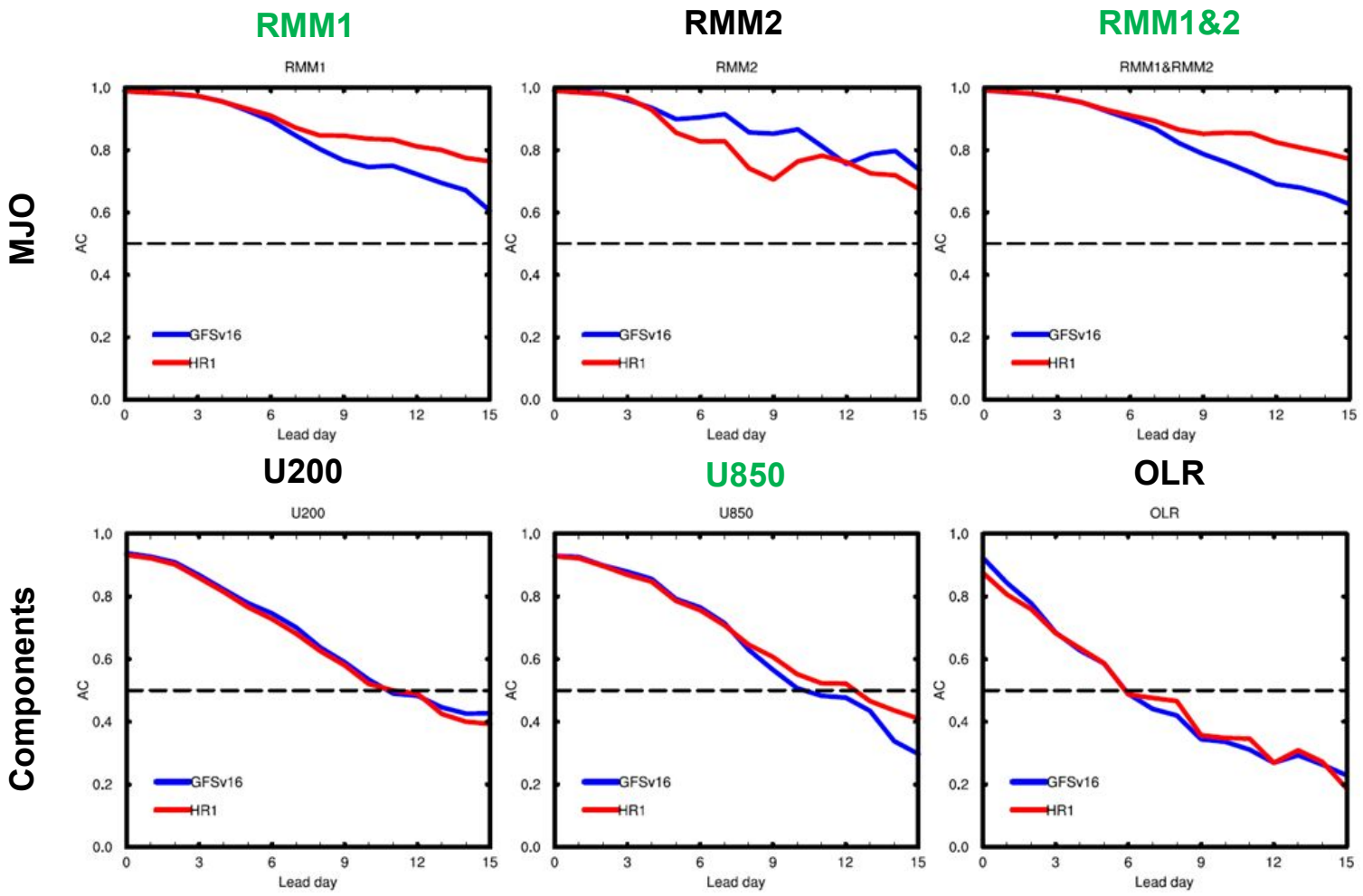
https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/whindex.shtml

AC (winter)



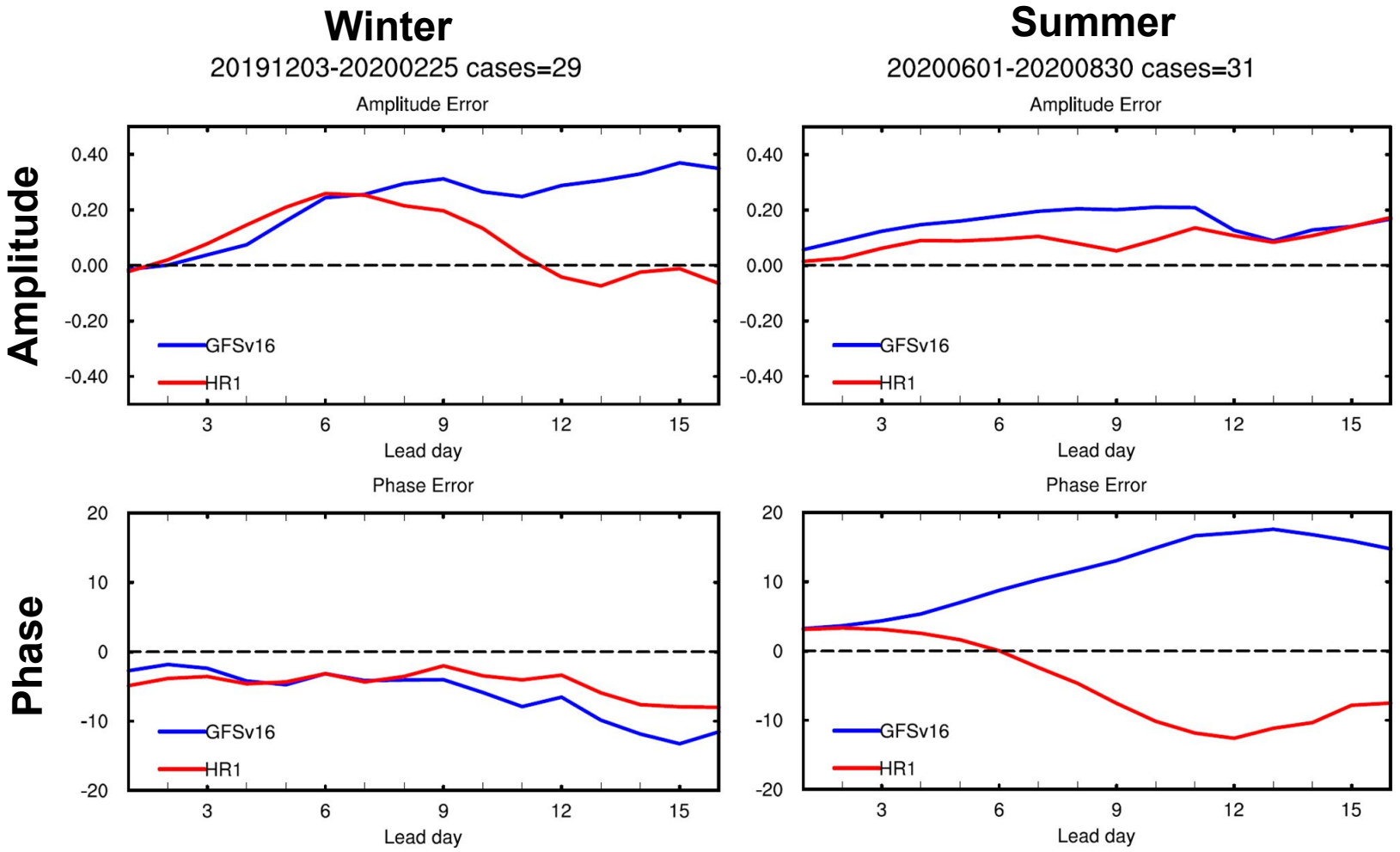
- MJO AC skill in HR1 is higher than GFSv16 due to higher AC in RMM2
- Higher AC in U200, U850 and OLR over tropics

AC (summer)



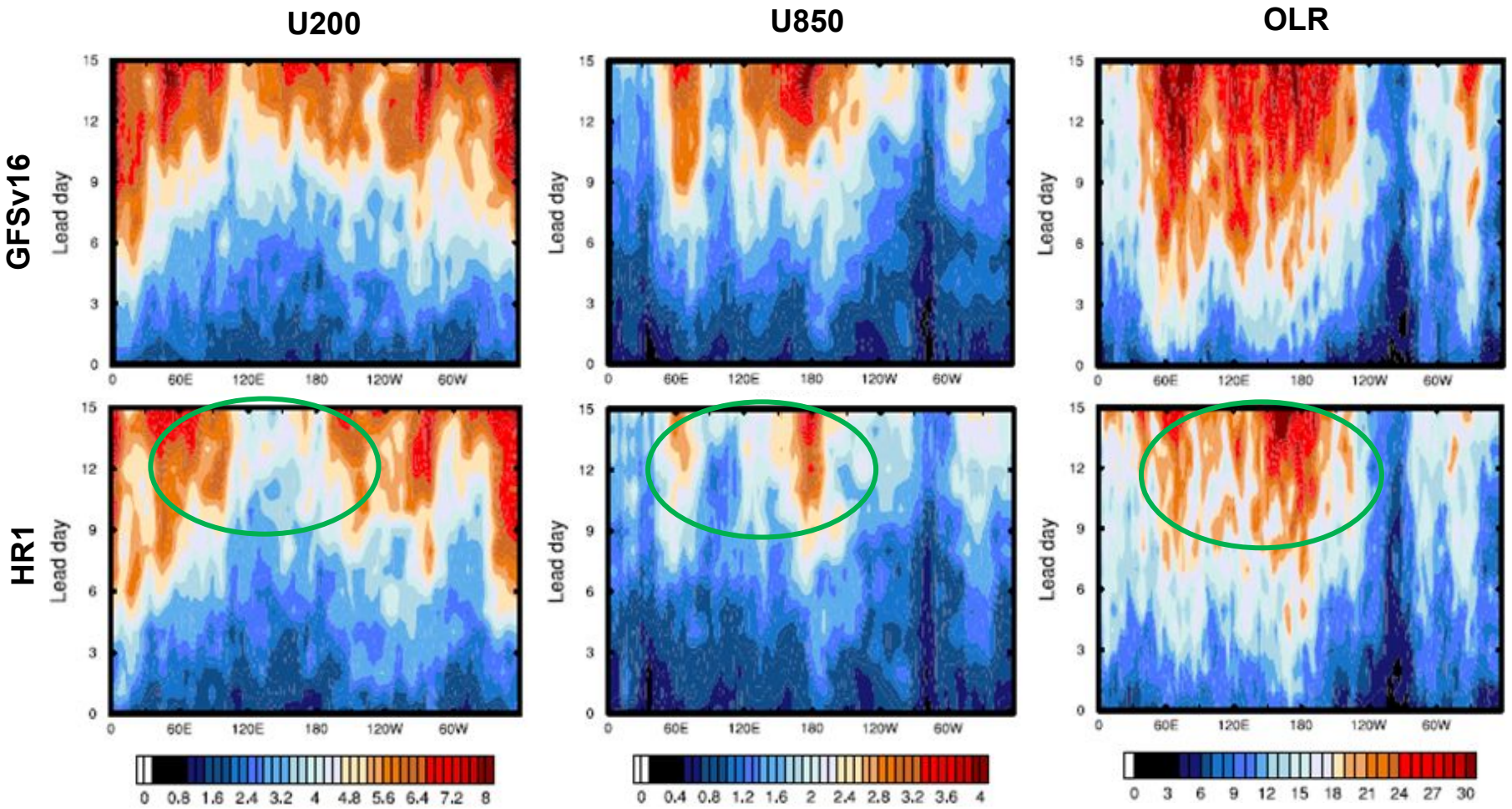
- MJO AC skill in HR1 is greater than GFSv16 due to higher AC in RMM1
- Higher AC in U850 over tropics

Bias



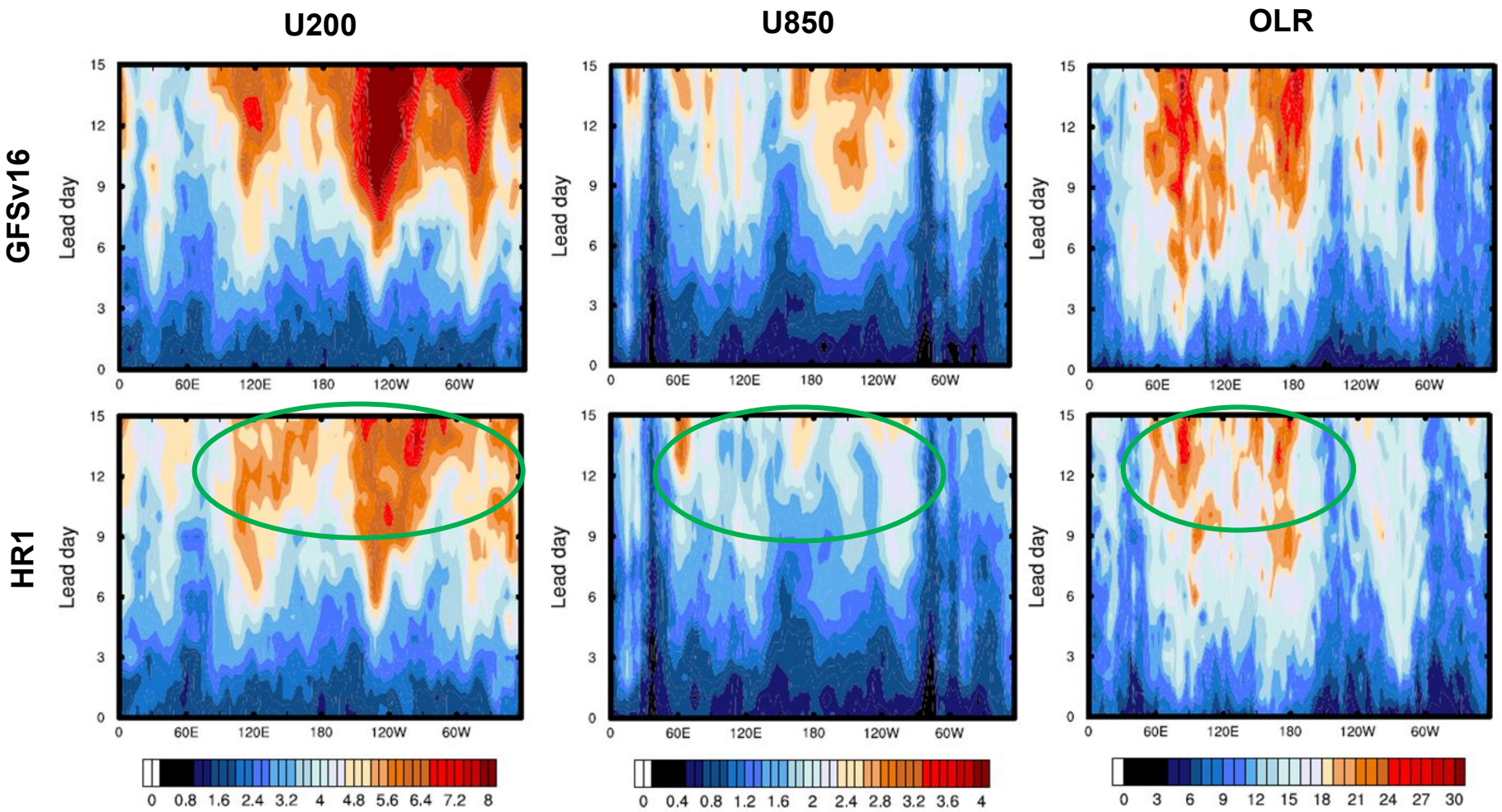
- MJO amplitude bias in HR1 is smaller than GFSv16 for both seasons.
- HR1 MJO propagates less slow than GFSv16 in winter season; HR1 MJO propagates too slow in summer season.
- For both GFSv16 and HR1, larger amplitude bias in strong MJOs; larger propagation bias in weak MJOs.

Component RMSE (Lead-longitude): Winter



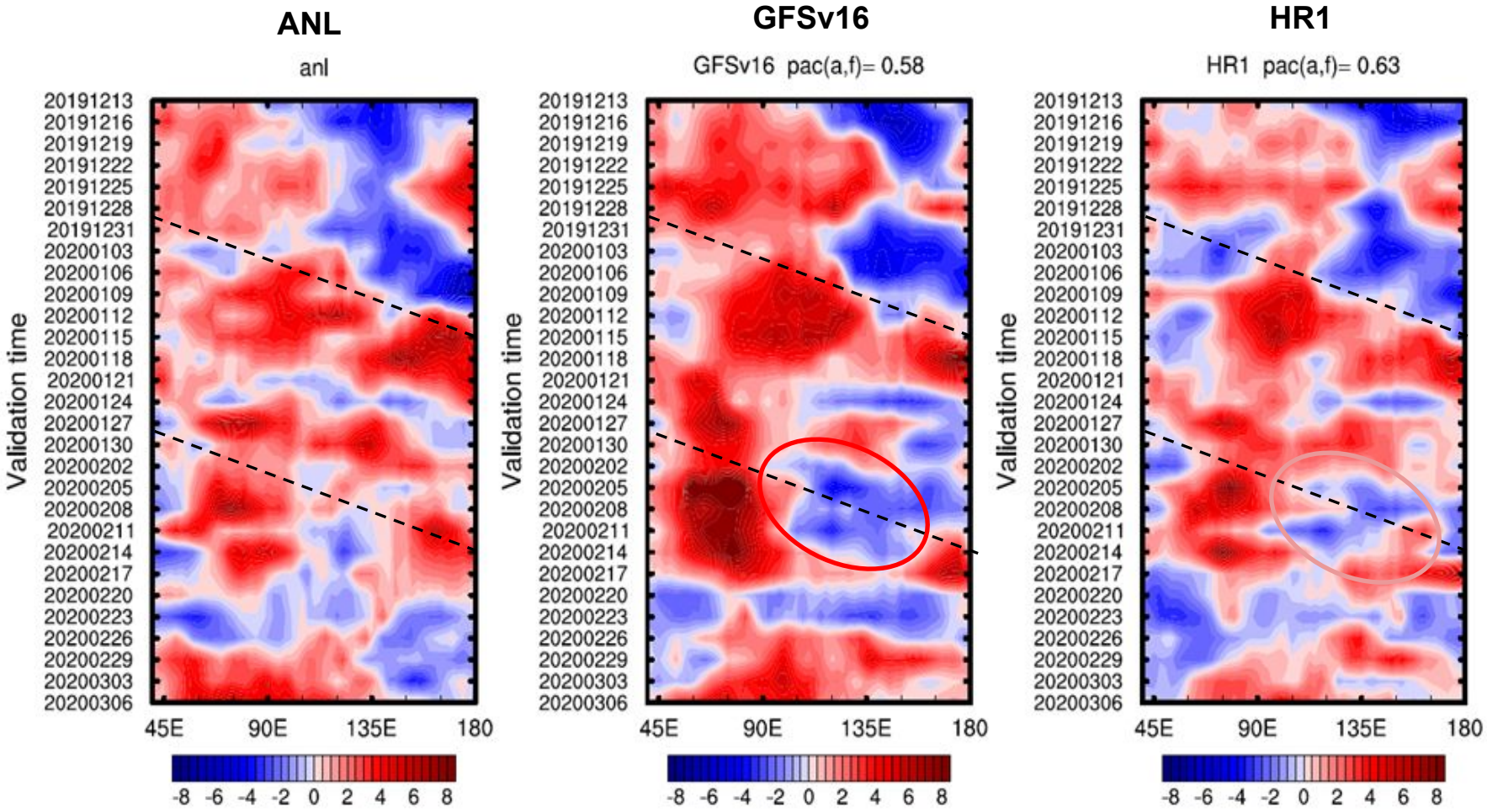
- Overall smaller RMSE in HR1 for U200, U850 and OLR over tropics, especially IO-WP

Component RMSE (Lead-longitude): Summer



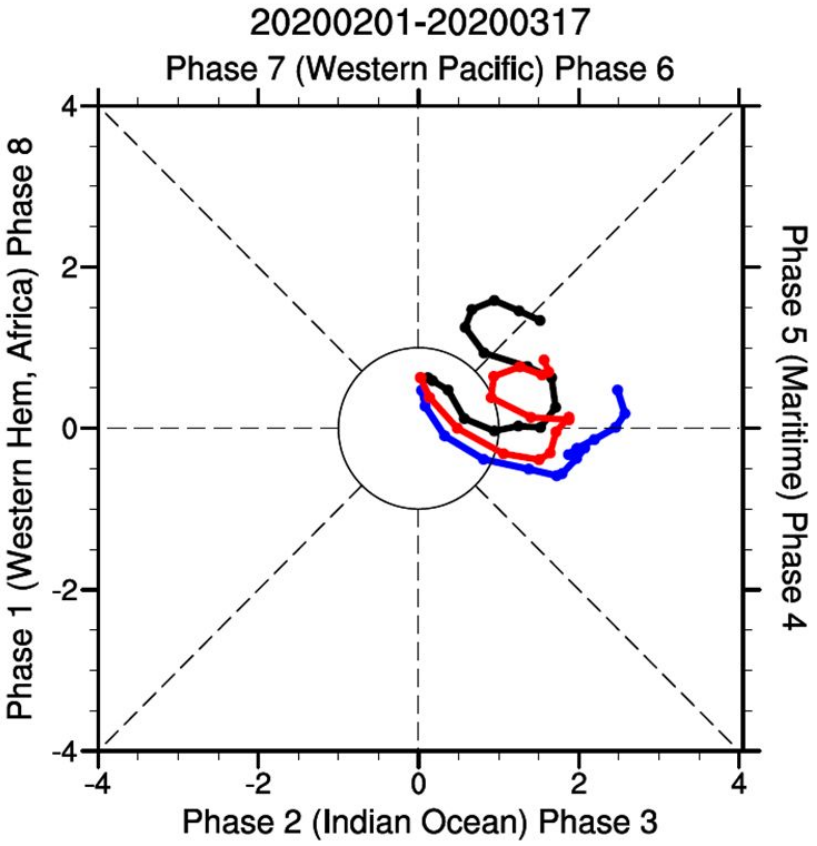
- Overall smaller RMSE in HR1 for U200, U850 and OLR over tropics

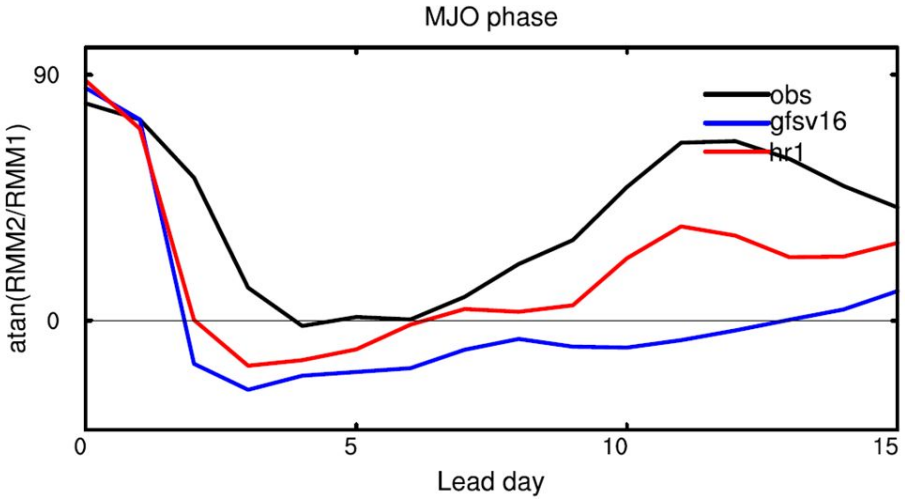
MJO propagation (U850 anomaly: winter, lead=11)



- Less break of MJO propagation near Maritime Continent in HR1

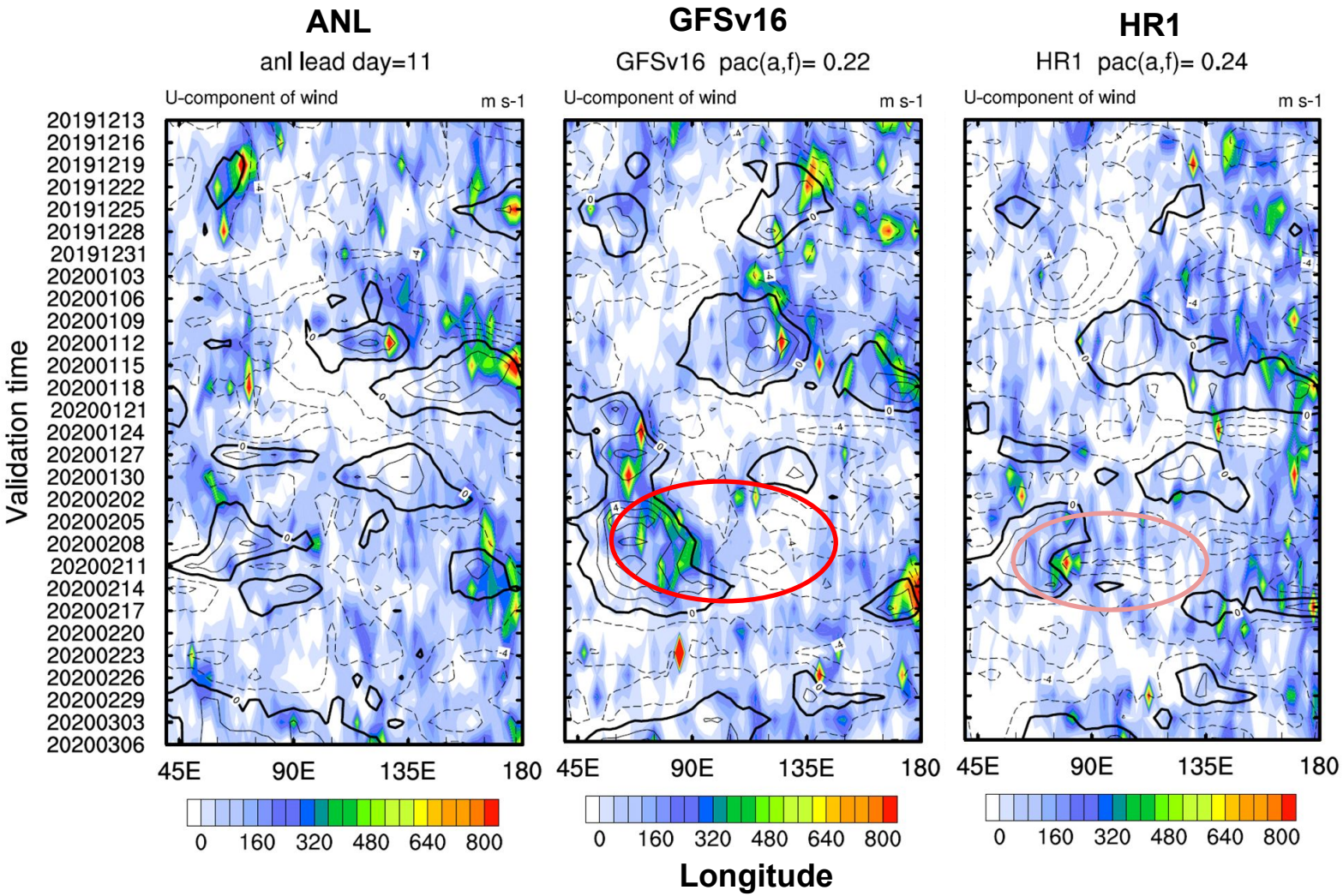
MJO case (20200201)





- Strong and slow bias in GFSv16 and HR1
- Better intensity and propagation in HR1

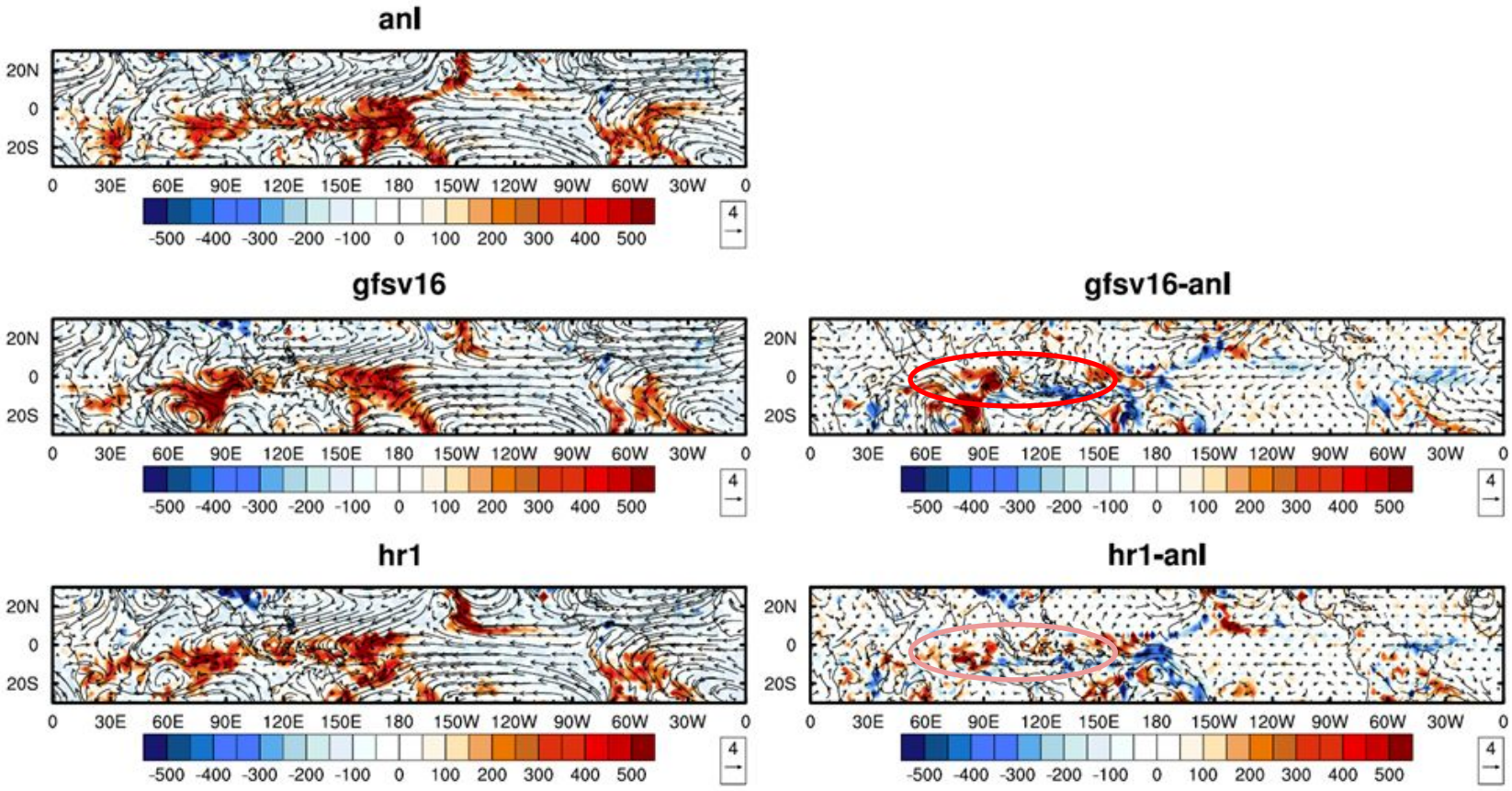
Time-longitude of [Q1]&U850 (20191203-20200225, lead=11)



- Too strong [Q1] over Indian ocean in the models but less strong in HR1
- Strong zonal convergence associated with the [Q1]

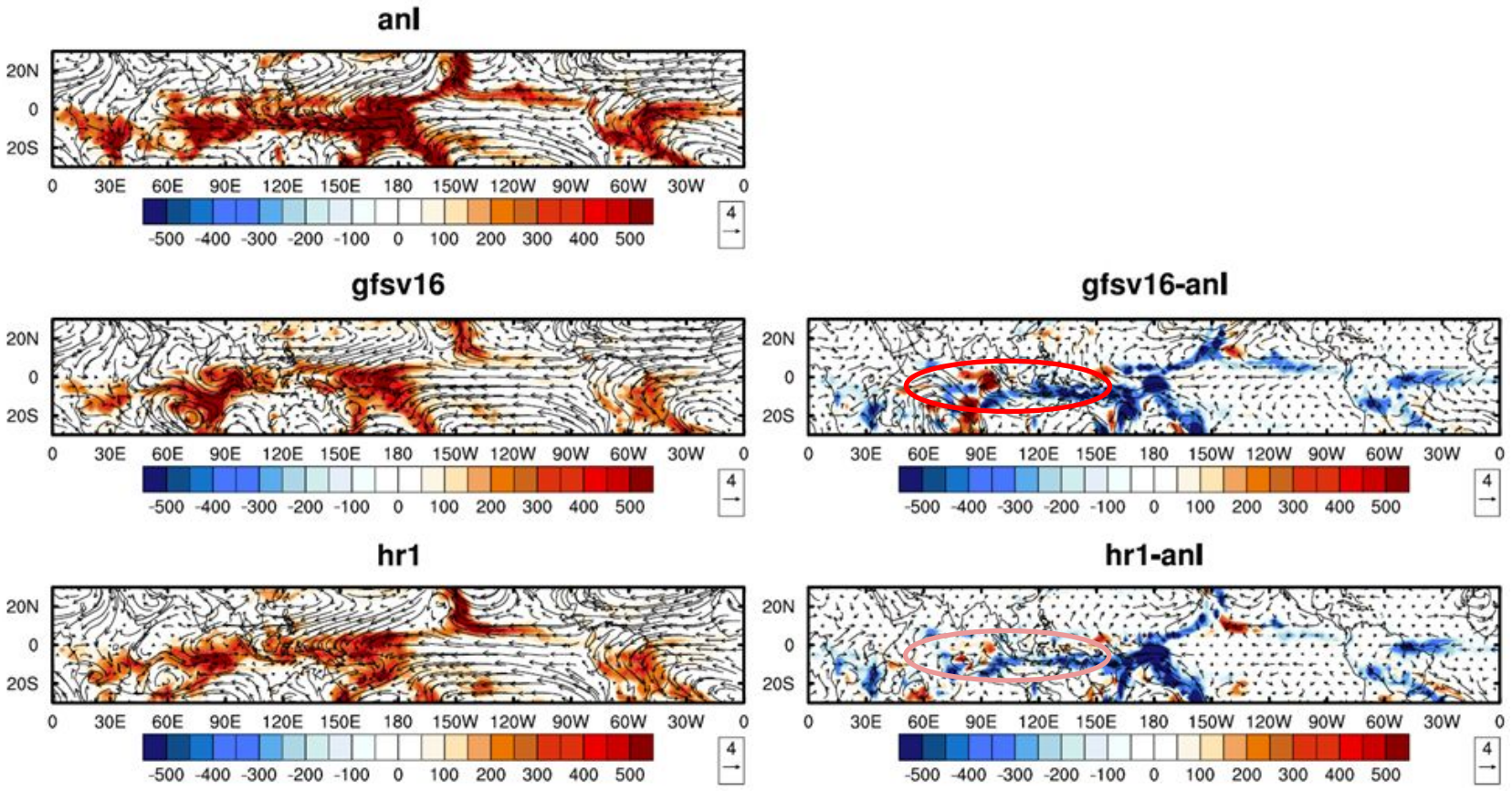
$[Q1]=[Qr]+LP+SH$
$[Q2]=L(P-E)$
-Yanai etal. (1973, 1998)
-https://www.ncl.ucar.edu/Applications/Scripts/Q1Q2_yanai_1.ncl

[Q1] and UV850 (wk2)



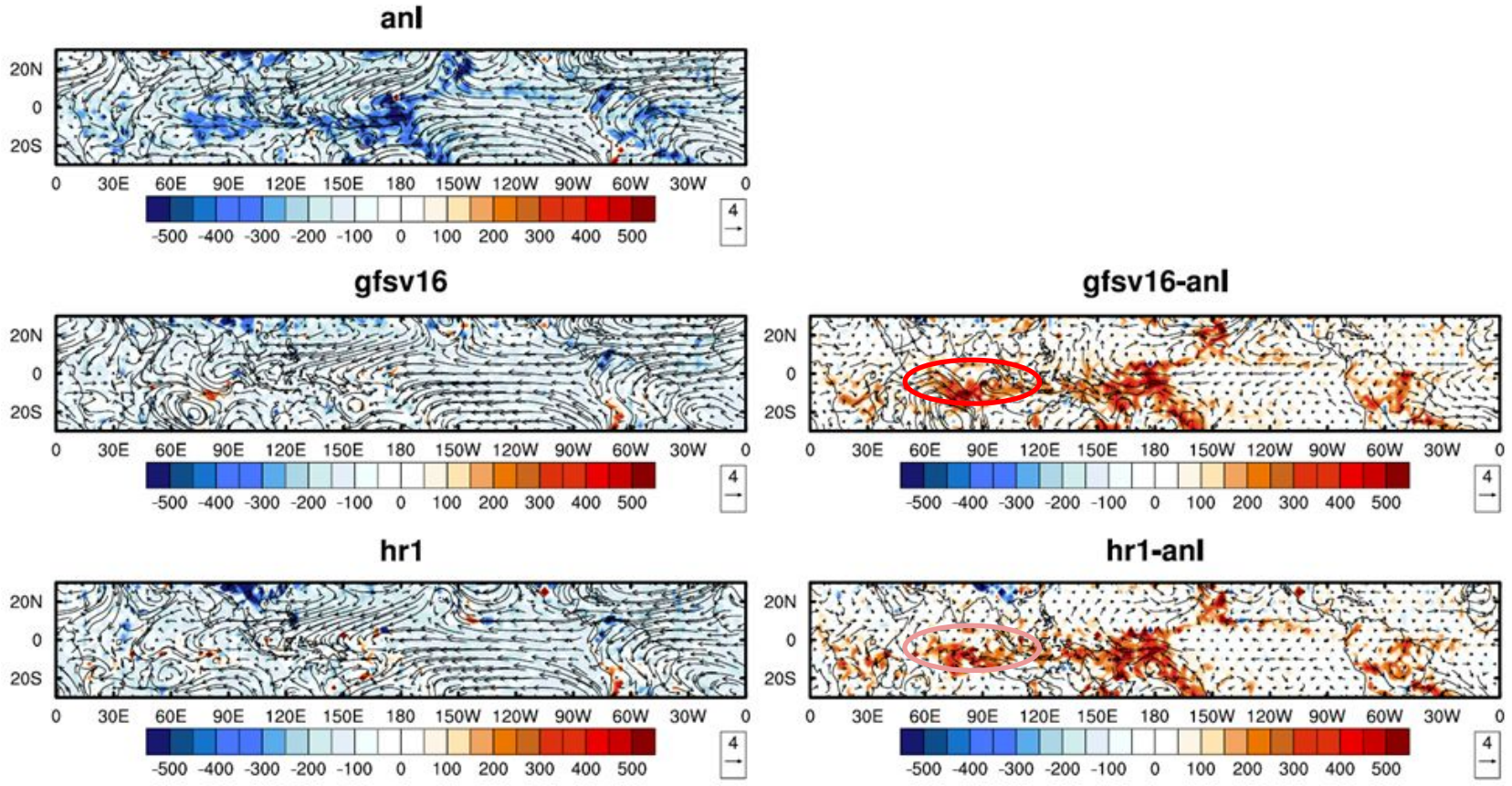
- Convergence of the flow towards the heating
- Strong [Q1] bias over Indian ocean (IO) and weak [Q1] bias over Maritime Continent (MC) in the models
- East wind bias over IO-MC in the models, with less bias in HR1

LP and UV850 (wk2)



- LP is the largest contributor to [Q1] in tropics
- Weak LP bias over most tropical regions in the models (except strong LP bias over IO in GFSv16), with less bias in HR1

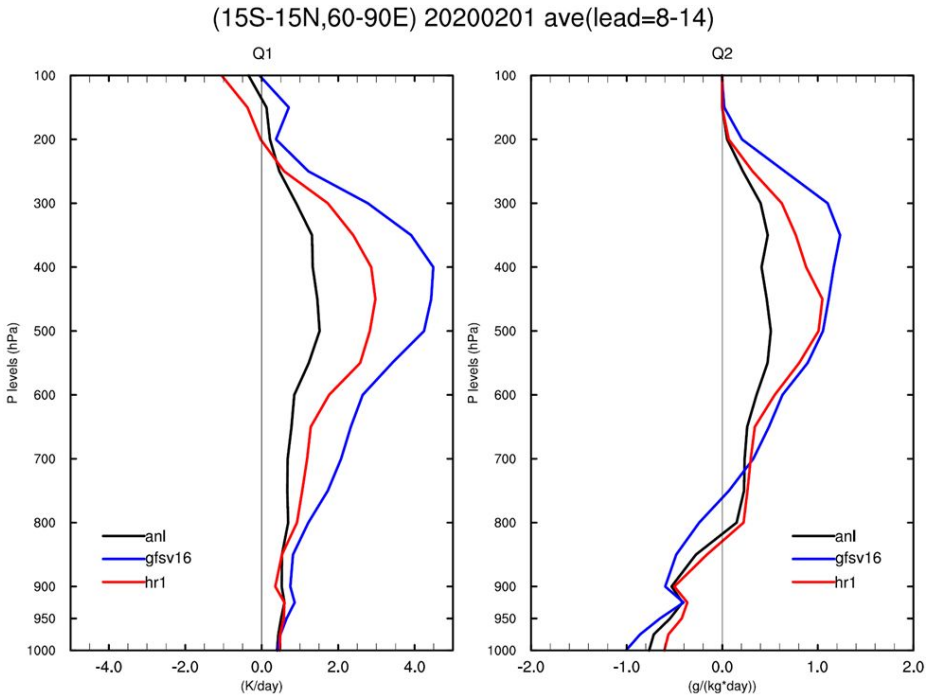
[Qr] and UV850 (wk2)



- [Qr] is the second largest contributor to [Q1] in tropics
- Less radiative cooling in the models, with less [Qr] bias over Indian ocean (IO) in HR1

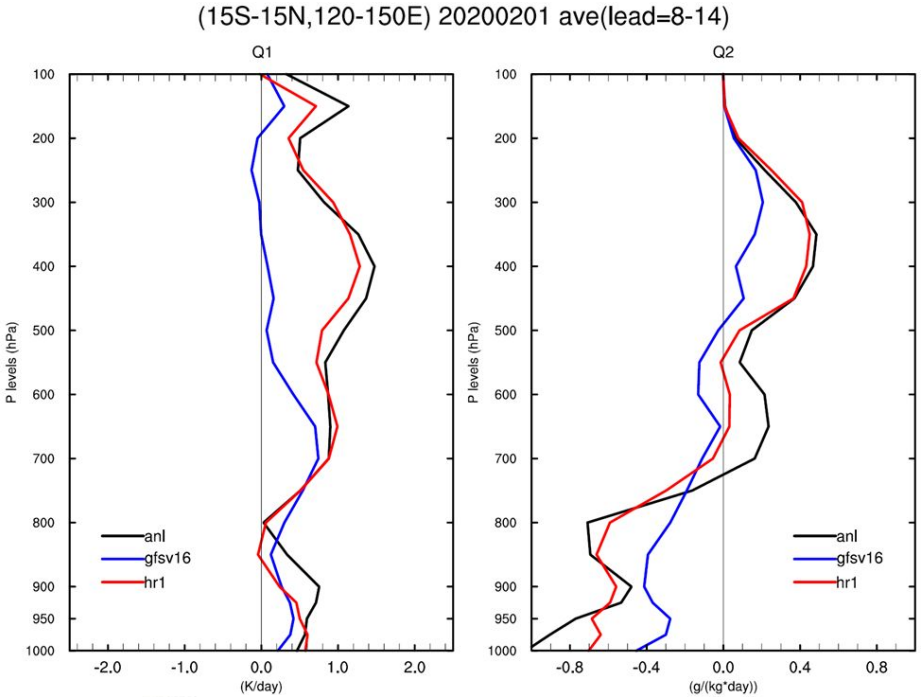
Q1 and Q2 profiles (wk2)

Indian Ocean



- Strong Q1 and Q2 biases over IO in the models, with less bias in HR1
- Much less Q1 and Q2 biases in HR1 over MC

Maritime Continent

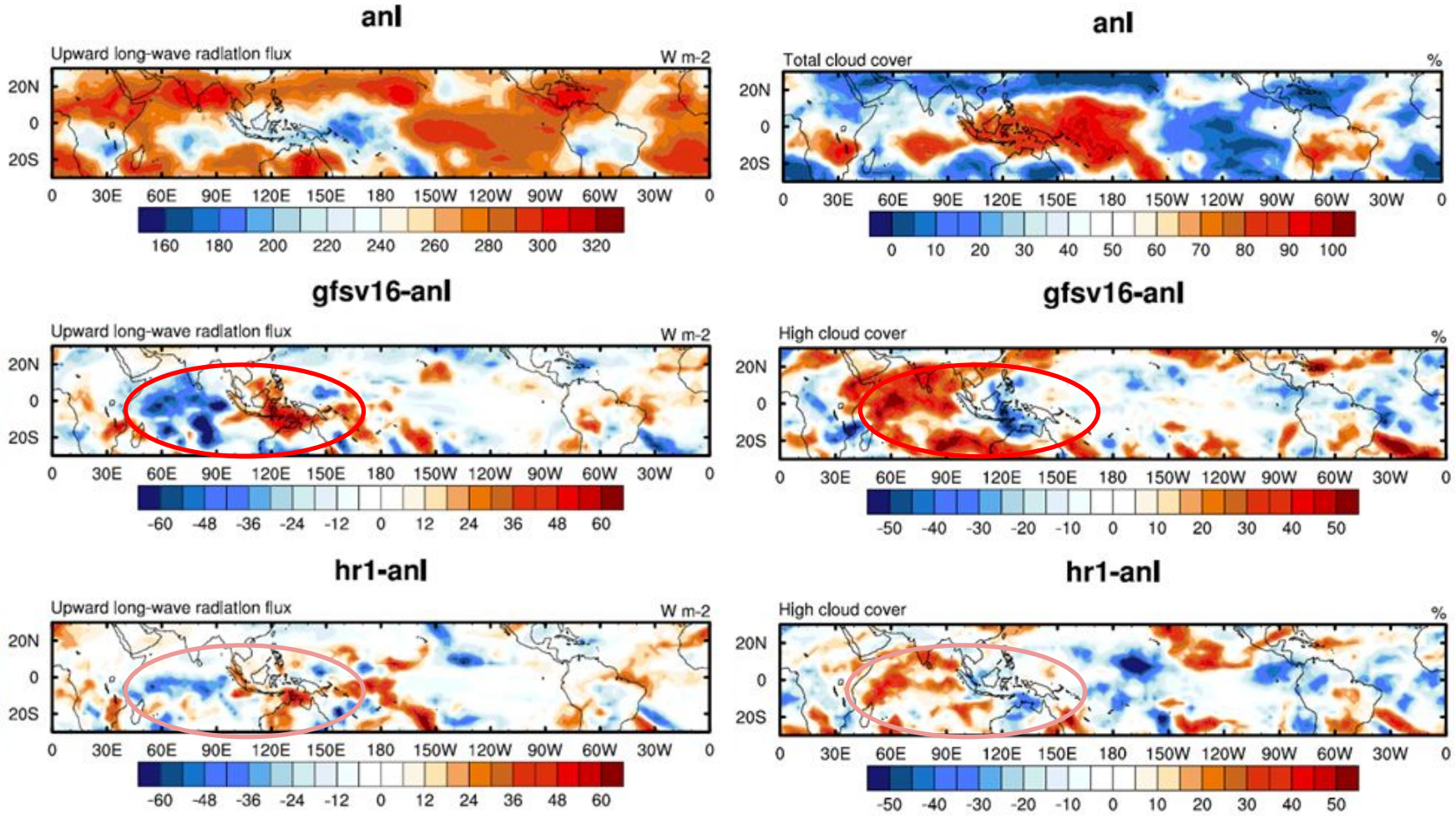


$$Q_1 = c_p \frac{\partial T}{\partial t} - c_p(\omega\sigma - \mathbf{V}\cdot\nabla T),$$

$$Q_2 = -L\frac{\partial q}{\partial t} - L\mathbf{V}\cdot\nabla q - L\omega\frac{\partial q}{\partial p},$$

-Yanai etal. (1973, 1998)
-https://www.ncl.ucar.edu/Applications/Scripts/Q1Q2_yanai_1.ncl

OLR and high cloud cover (wk2)



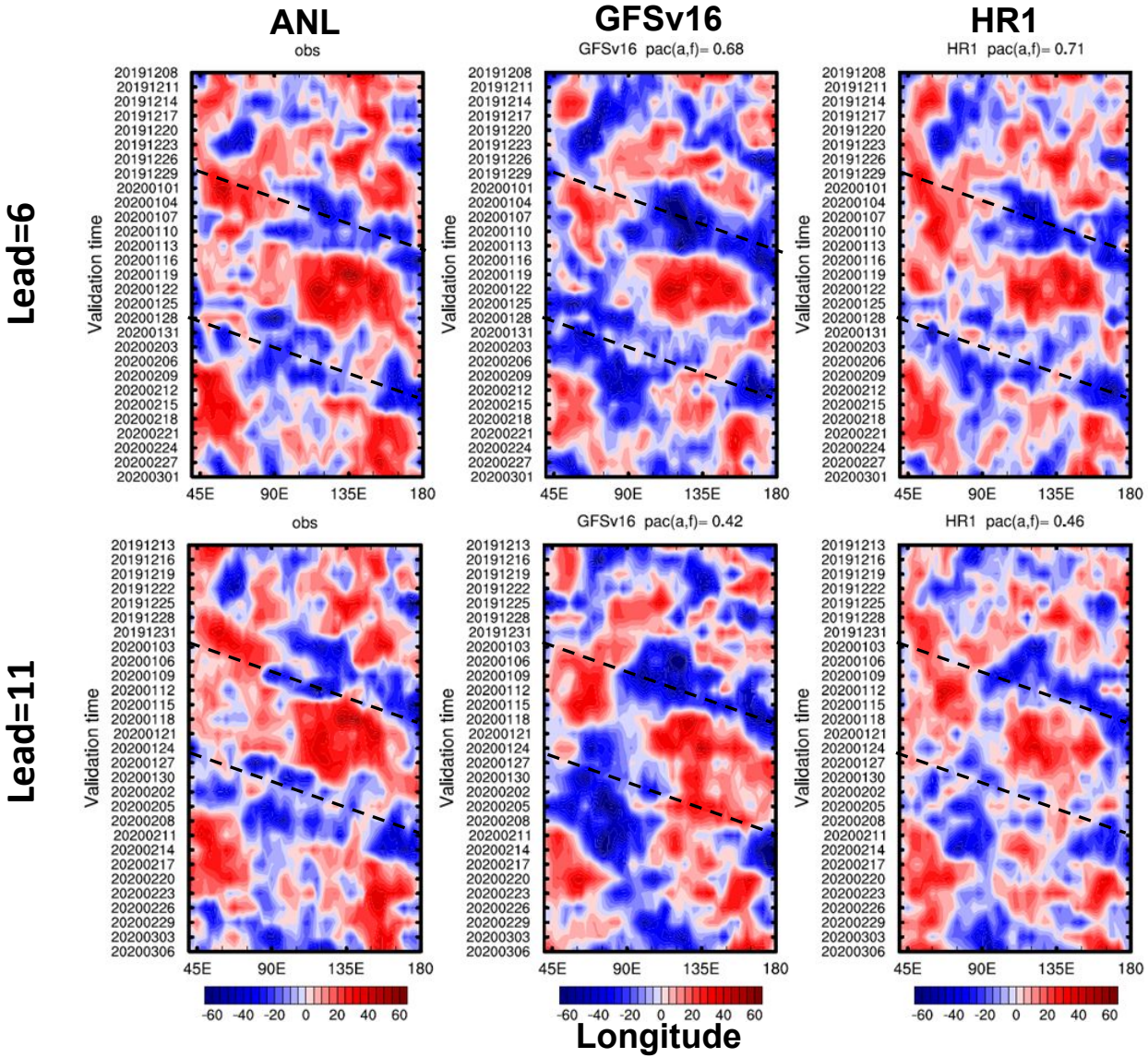
- OLR and high clouds cover biases over IO/MC in the models
- Less bias in OLR and high cloud cover over IO/MC in HR1

Summary

- HR1 data is limited for MJO evaluation
- Overall
  - Improved MJO forecast in HR1 in both winter and summer ← greater AC on tropical U200 , OLR (winter) and U850 (summer).
  - Less strong MJO intensity bias in HR1 in both seasons; Less slow MJO in HR1 in winter season
- MC barrier (case study)
  - Smaller break over MC in HR1
  - Less bias in [Q1] (mostly due to combined LP and [Qr]) over IO-MC in HR1
  - **Less bias in Q1 and Q2 profiles over the IO and MC in HR1**
  - Less bias in OLR and high cloud cover over IO and MC in HR1
- Weakness in HR1
  - Strong MJO bias in winter and slow MJO bias in summer
  - Strong bias in Q1, Q2 profiles over IO (convection, cloud [type] and radiation)

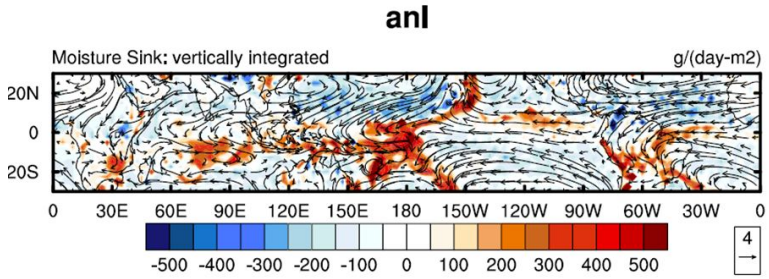
Supplementary Materials

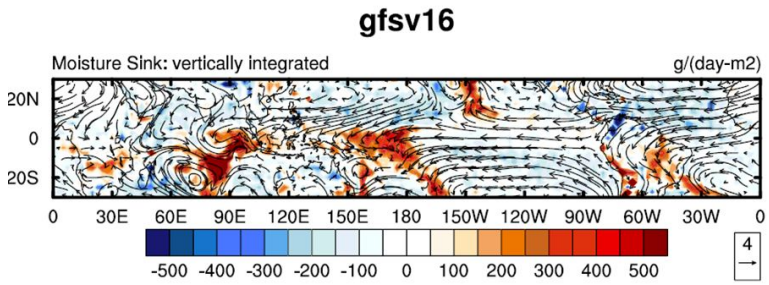
MJO propagation (OLR anomaly: 20191203-20200225)

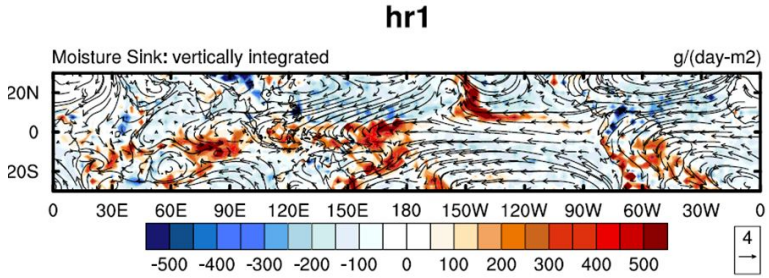


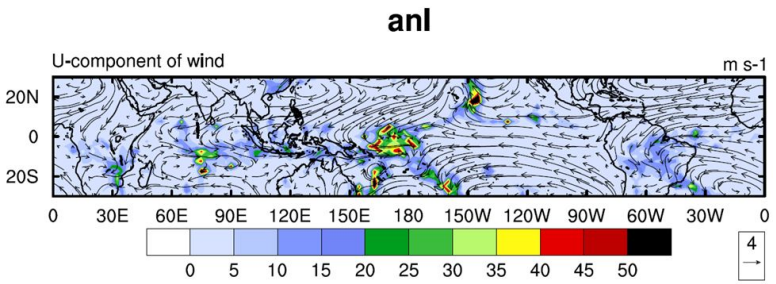
- Less break of MJO propagation near Maritime Continent in HR1

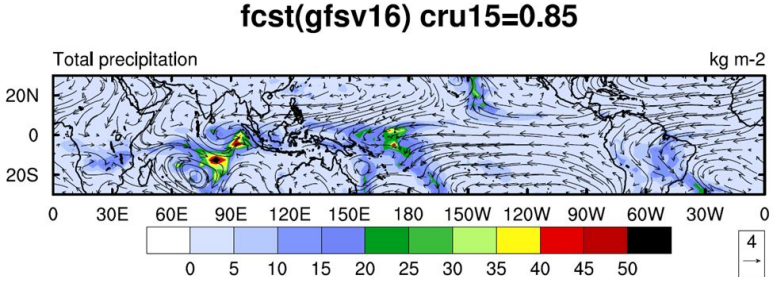
Q2, Pr and UV850 (wk2)

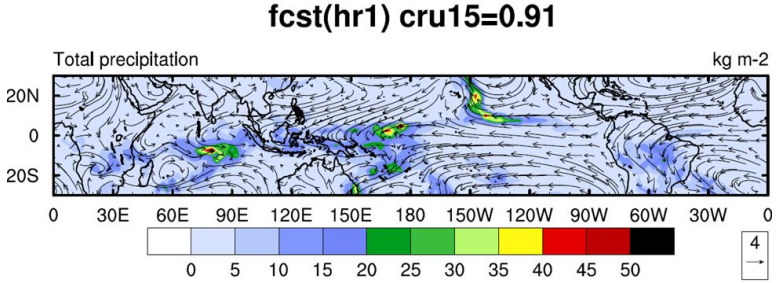




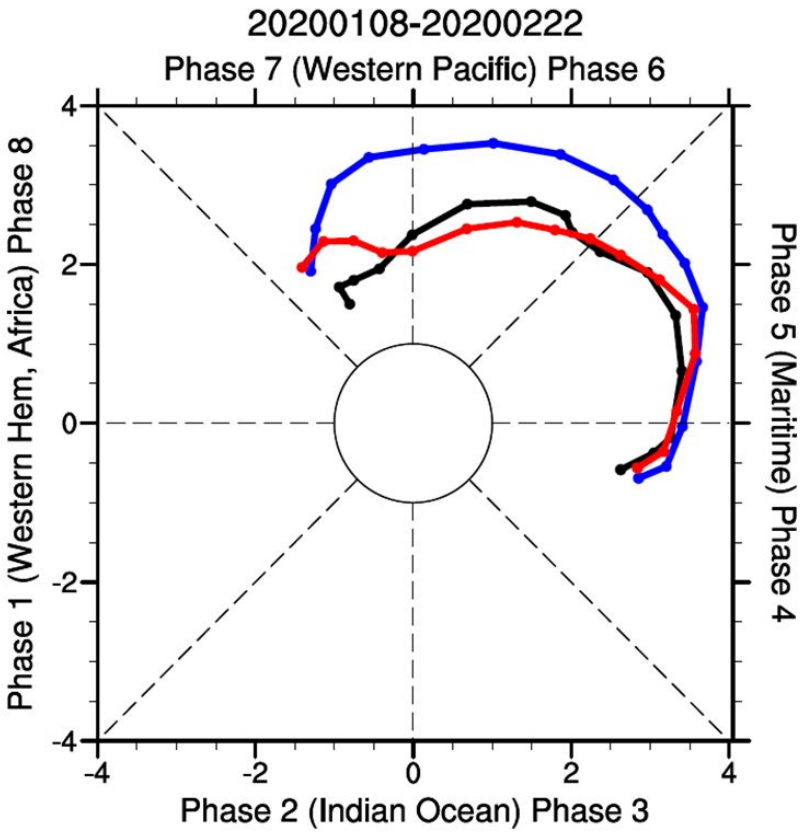


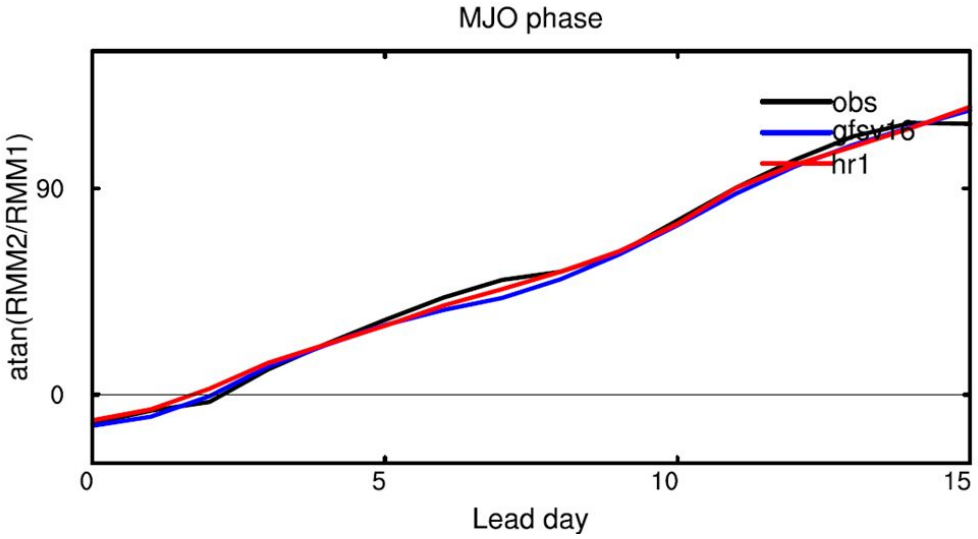






MJO


20200108-20200222
Phase 7 (Western Pacific) Phase 6
Phase 1 (Western Hem, Africa) Phase 8
Phase 5 (Maritime) Phase 4
Phase 2 (Indian Ocean) Phase 3
4
2
0
-2
-4
-4
-2
0
2
4


MJO phase
atan(RMM2/RMM1)
90
0
0
5
10
15
Lead day
obs
gfsv16
hr1