Evaluation on East Asian (EASM) and North American Summer Monsoon (NASM) for UFS High Resolution Prototypes

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UFS S2S AT All-hands meeting

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Outline

- **Overview of the EASM and NASM performance**
  - monsoon indices
  - U850 timeseries over monsoon definition regions
  - Precipitation maps before/after monsoon onset

- **Diabatic heating and its major components**
  - EASM
  - NASM

Models and Updates (link)

- **Models**
  - **GFSv16**: C768L127, atm+wave, with nsst on
  - **HR1, HR2 and HR3a**: C768L127, atm+ocn (MOM6)+ice (CICE6)+wave (WW3)+aerosols (GOCART) with nsst on
- **Major physics and dynamics updates on HRs compared to GFSv16:**
  - **Land:** Noah-LSM->Noah-MP (HR1, HR2 and HR3)
  - **Microphysics:** GFDL**->**Thompson microphysics and cloud updates (HR1, HR2)
  - **Convection, PBL and surface layer updates** (HR1 and HR2)
  - **Cloud and radiation updates** (HR1, HR2 and HR3)
  - **Gravity wave drag ->** uGWD and updates (uGWD.v0 in HR1, HR2 and uGWD.v1 in HR3)
  - **Aerosol:** OPAC -> MERRA2 aerosols (HR1)
  - **Stochastic->**CA and updates (HR1 and HR2)
  - **Dynamics:** (HR2 and HR3)
- **Updates on other coupled components:**
  - **Sea ice**
  - **Lake ice climatology**
  - **Land/lake masks**
  - **Snow and soil ICs**

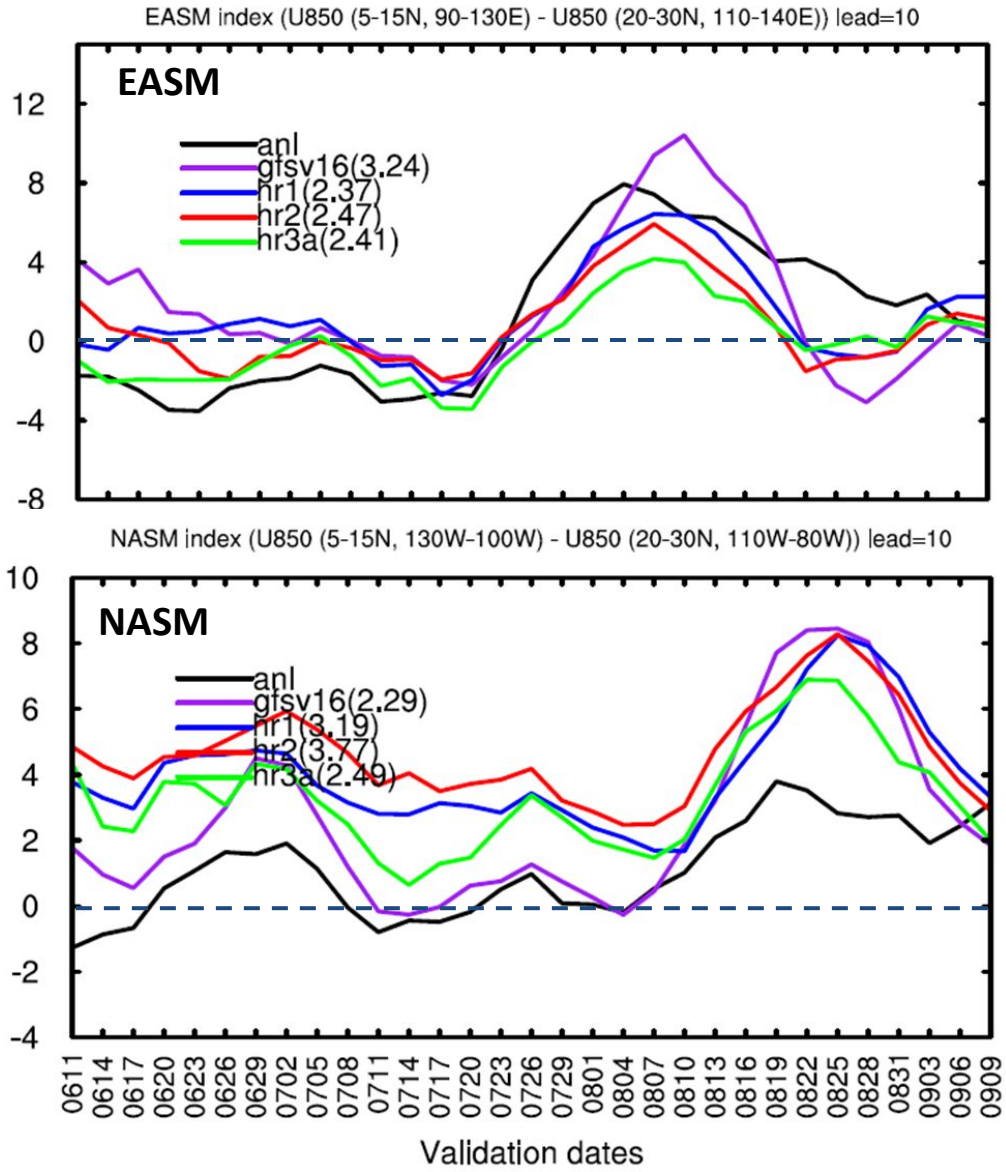
—Courtesy of Lydia Stefanova and Fanglin Yang for the information

Data

- **Experiment period:**
  - 20200601-20200830, every 3 days, 384 fhr, 31 cases

- **Reference**
  - IMERG for precipitation (daily accumulation), 1 deg
  - GFSv16 analysis (4 times/day) for other variables, 2.5 deg

Evolution of monsoon index (lead day=10)

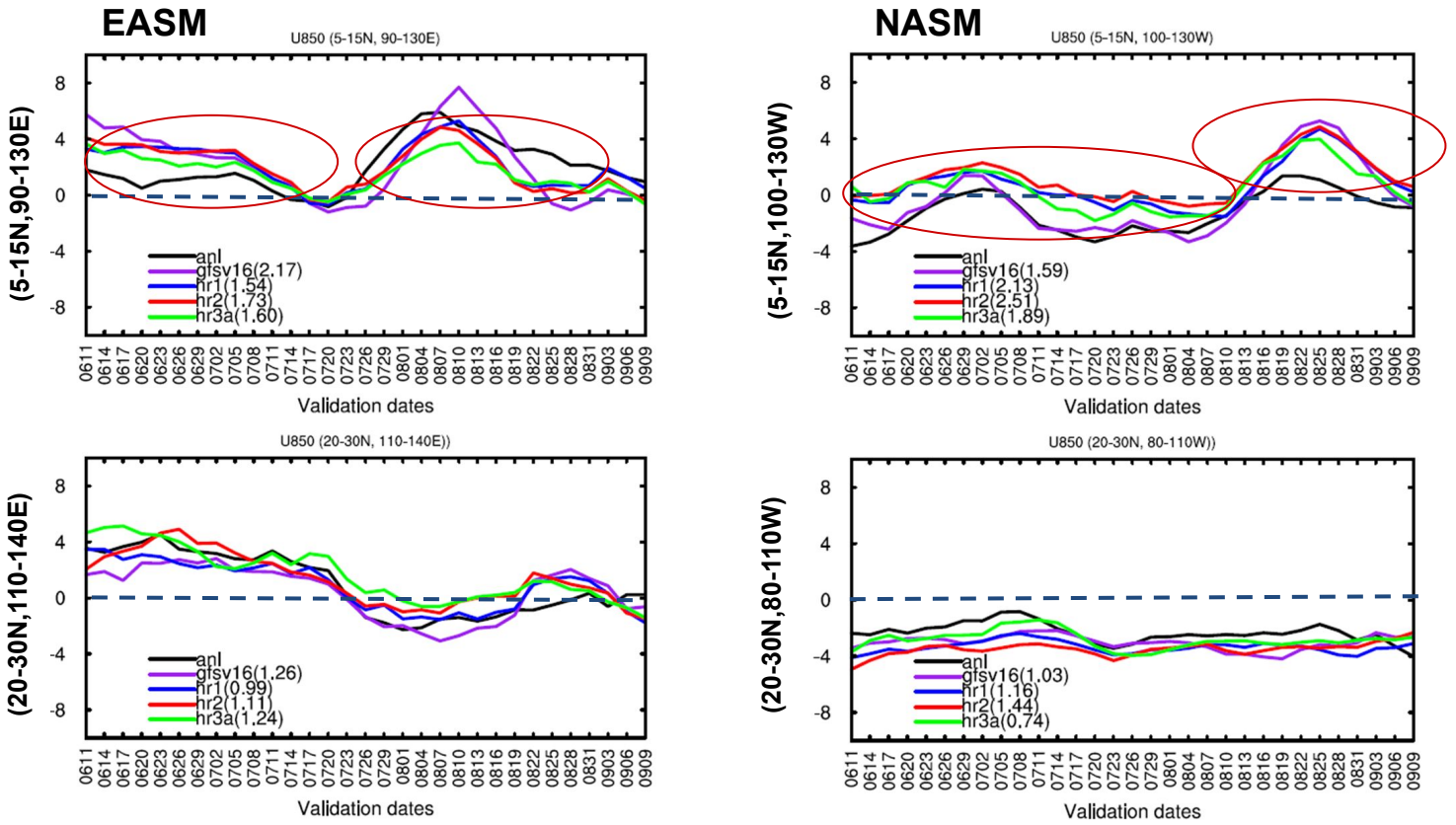


- **EASM:**
  - HR1>HR3a>HR2>GFSv16
  - Strong/weak bias before/after monsoon onset in the model except peak time in GFSv16.
- **NASM:**
  - GFSv16>HR3a>HR1>HR2
  - Strong bias in the model, especially in HRs
- EASM index= U850(5-15N, 90-130E)-U850(20-30N, 110-140E)

  - CPC monsoon indices: *https://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/Figures/Index/*
- NASM index= U850(5-15N, 130-100W)-U850(20-30N, 110-80W)

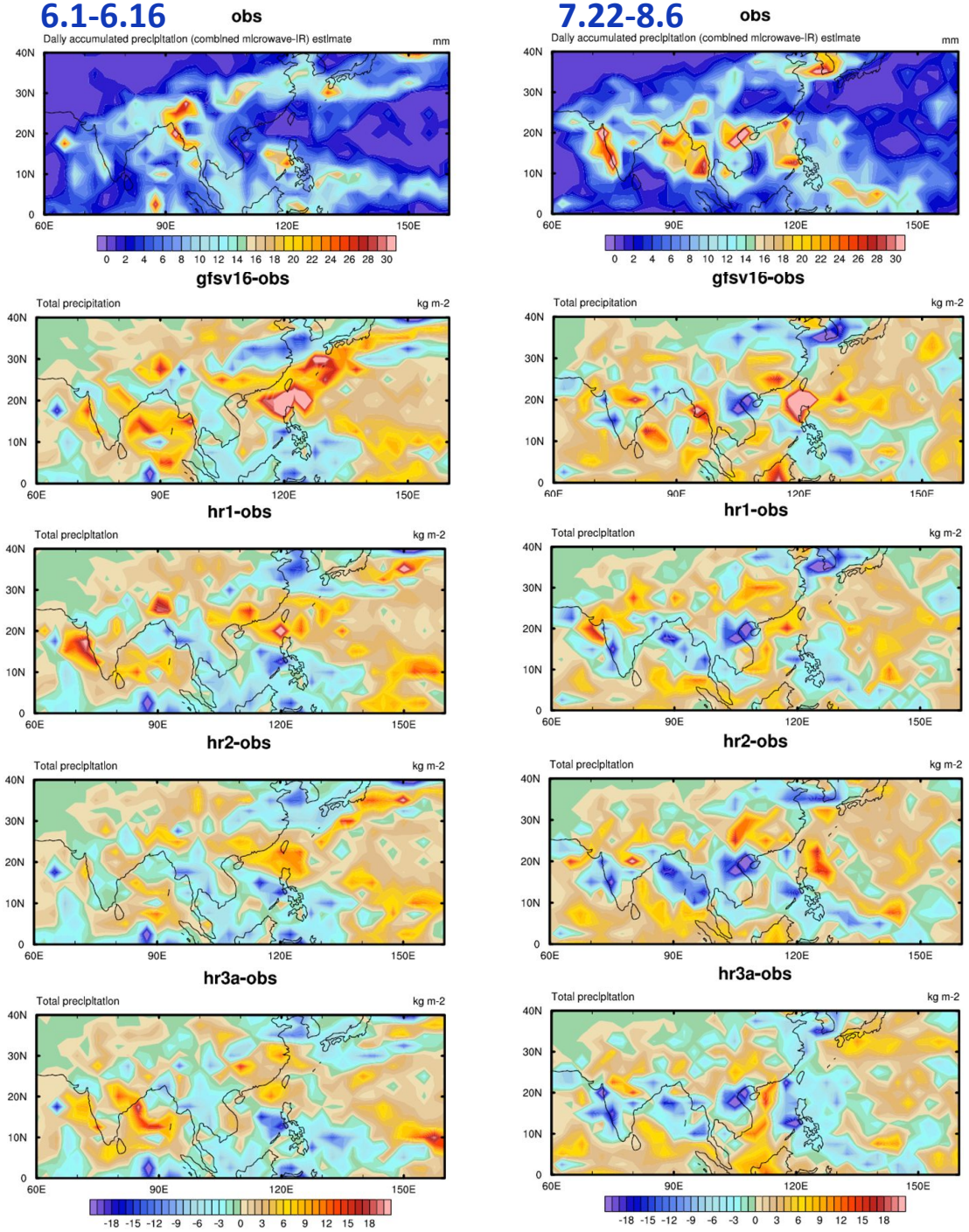
  - Yim. et al.(2014)

U850: (lead day=10)



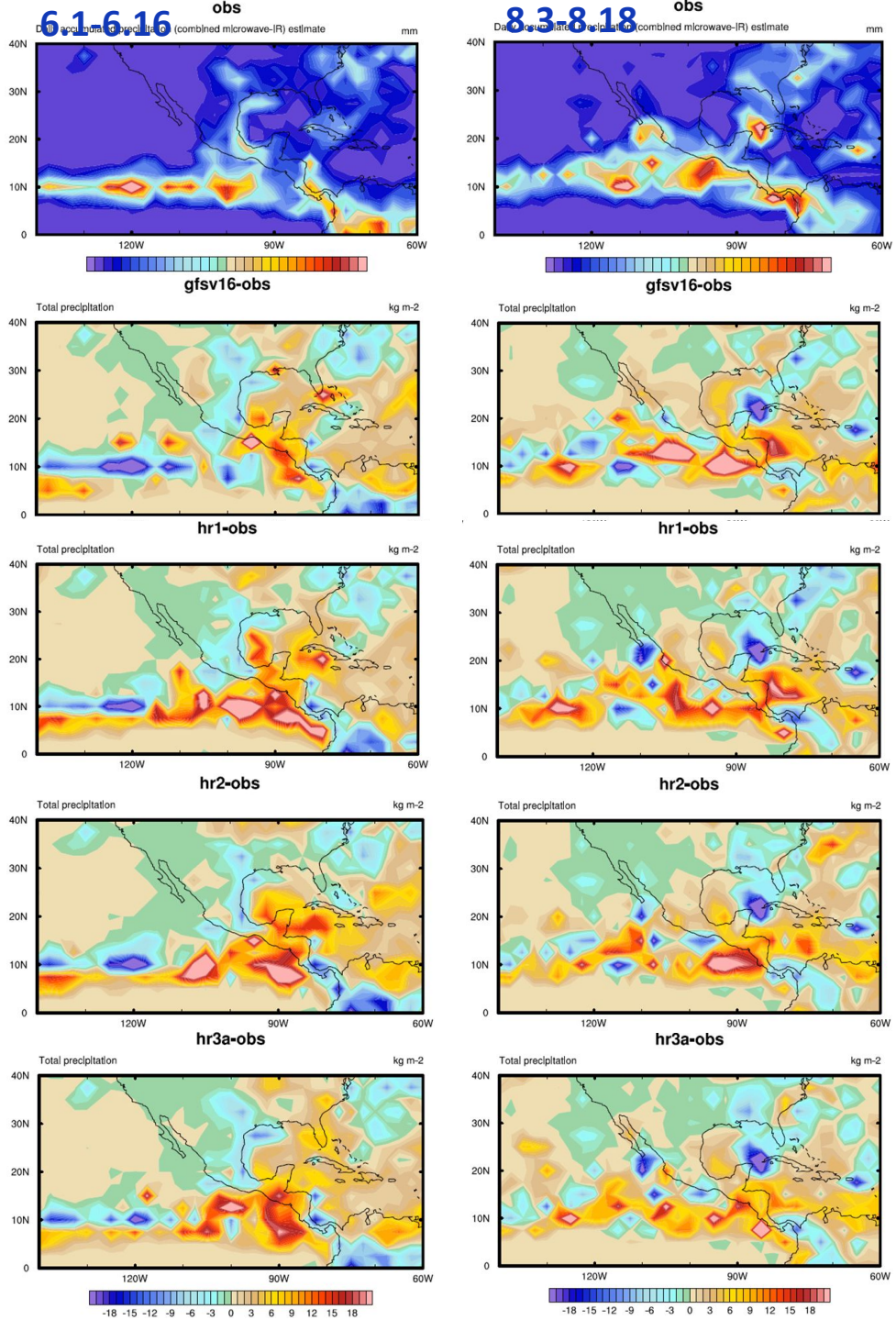
- **EASM:**
  - Strong/weak bias before/after monsoon onset in the model in tropical definition region except peak time in GFSv16; Weak/strong bias before/after monsoon onset in the model in subtropical definition region
  - Performance:HR1>HR3a>HR2>GFSv16
- **NASM:**
  - Weak/strong bias before/after monsoon onset in the model in tropical definition region; Strong bias in the model in subtropical definition region
  - Performance:GFSv16>HR3a>HR1>HR2

Precipitation: EASM (lead day=10)

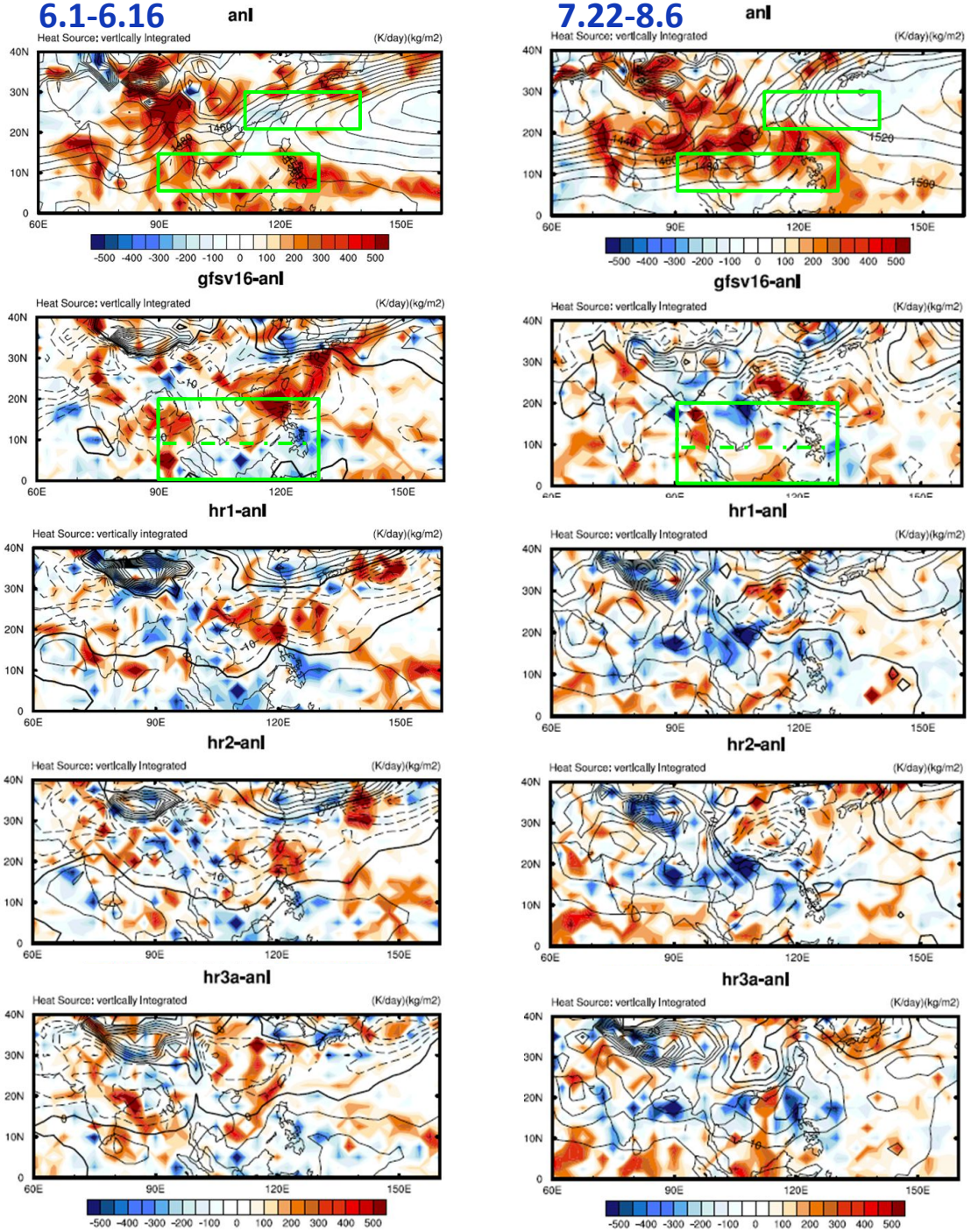


- Larger precipitation and northward propagation of the rain belt after monsoon onset
- Wet biases in Pr. over WNPSH (dry area) except HR3a after onset
- Dry biases over S. EASM regions (wet area)

Precipitation: NASM (lead day=10)



- Larger precipitation and northward propagation of the rain belt after monsoon onset
- Generally wet biases in Pr. over ITCZ except GFSv16 before onset



[Q1]&Z850: EASM (lead day=10)

- [Q1] bias associated with Z850 bias
- [Q1] bias gradient reverse after onset—> different sign in u850 bias over tropical region before/after onset

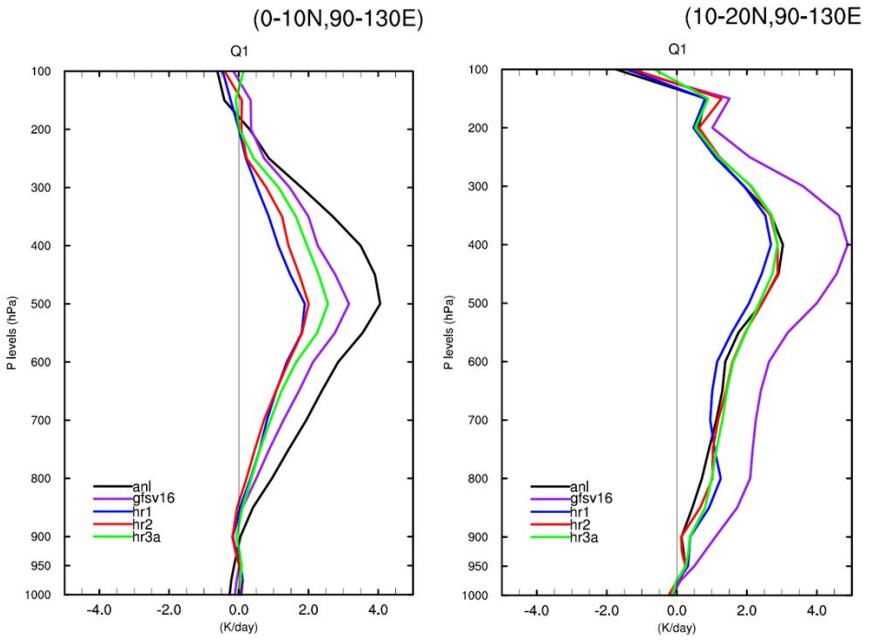
$$Q_1 = c_p \frac{\partial T}{\partial t} - c_p(\omega\sigma - \mathbf{V}\cdot\nabla T),$$

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

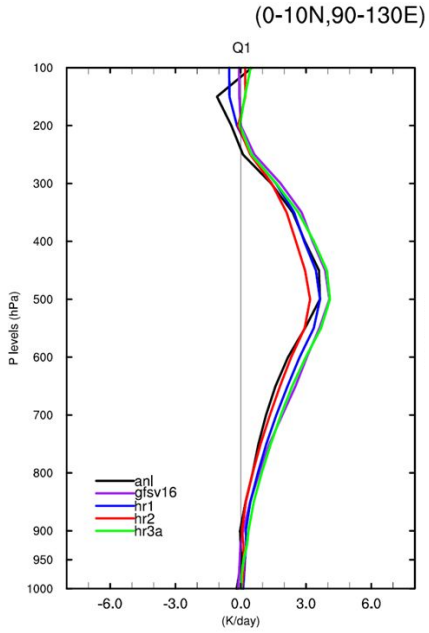
[*Q1*]=[*Qr*]+*LP*+*SH*
[*Q2*]=*L*(*P*-*E*)
-Yanai etal. (1973, 1998)
-https://www.ncl.ucar.edu/Applications/Scripts/Q1Q2_yanai_1.ncl

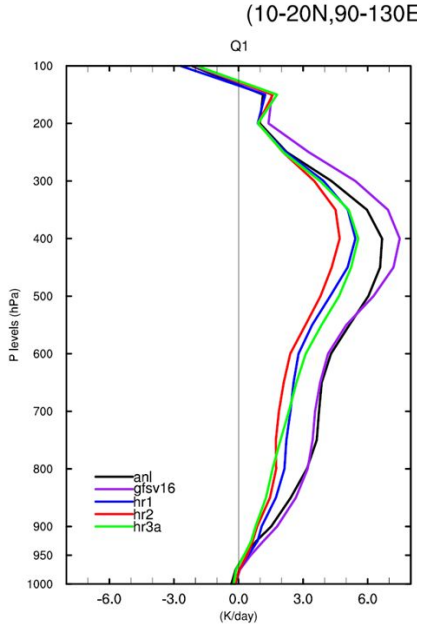
Q1 profiles (lead 8-14)

Before onset (6.1-6.16)



After onset (7.22-8.6)

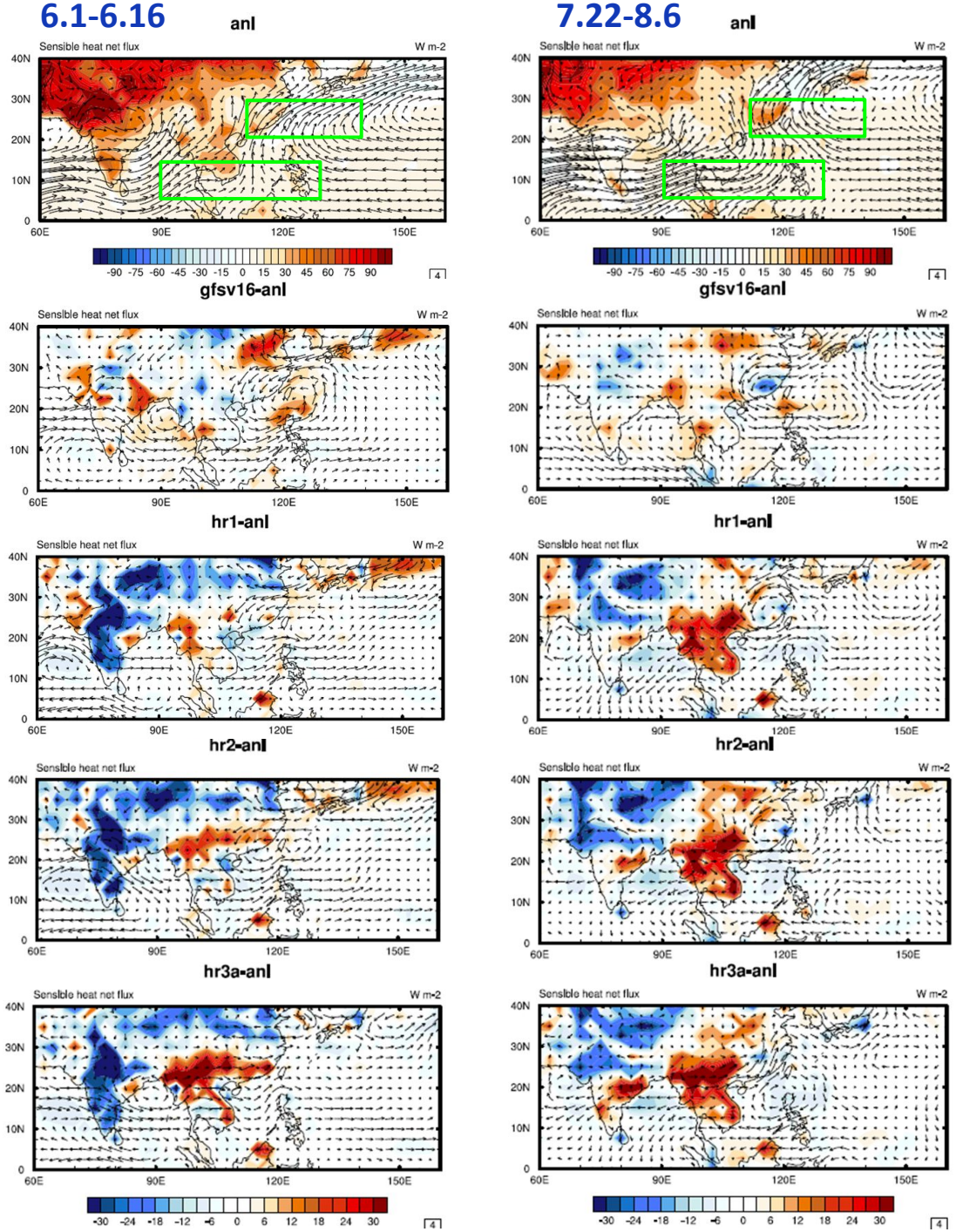




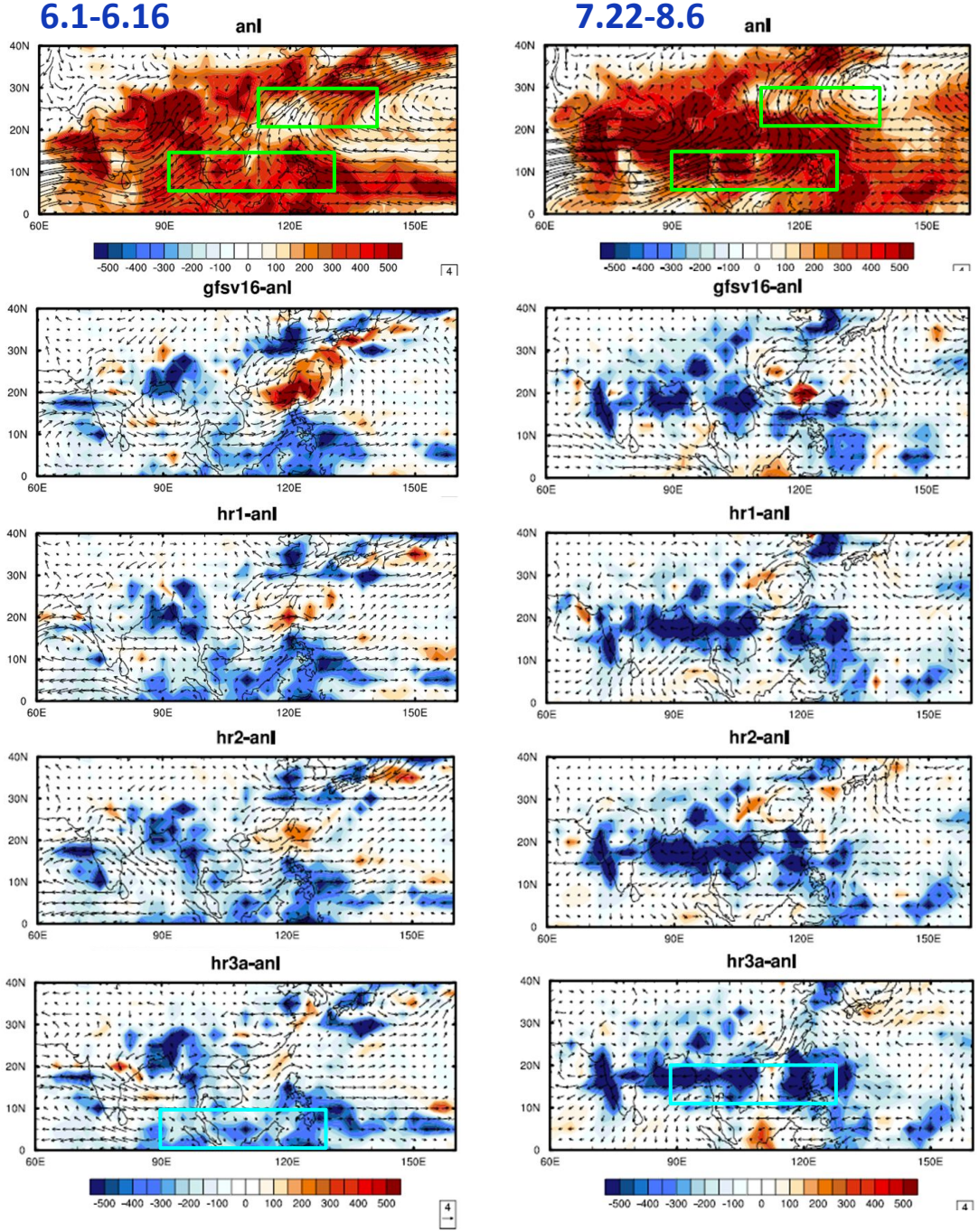
- Cold Q1 biases in all model versions over [0-10N, 90-130E] before onset
- Cold Q1 biases in HRs over [10-20N, 90-130E] after onset

—> [Q1] bias gradient reverse after onset

SH&wnd850: EASM (lead day=10)

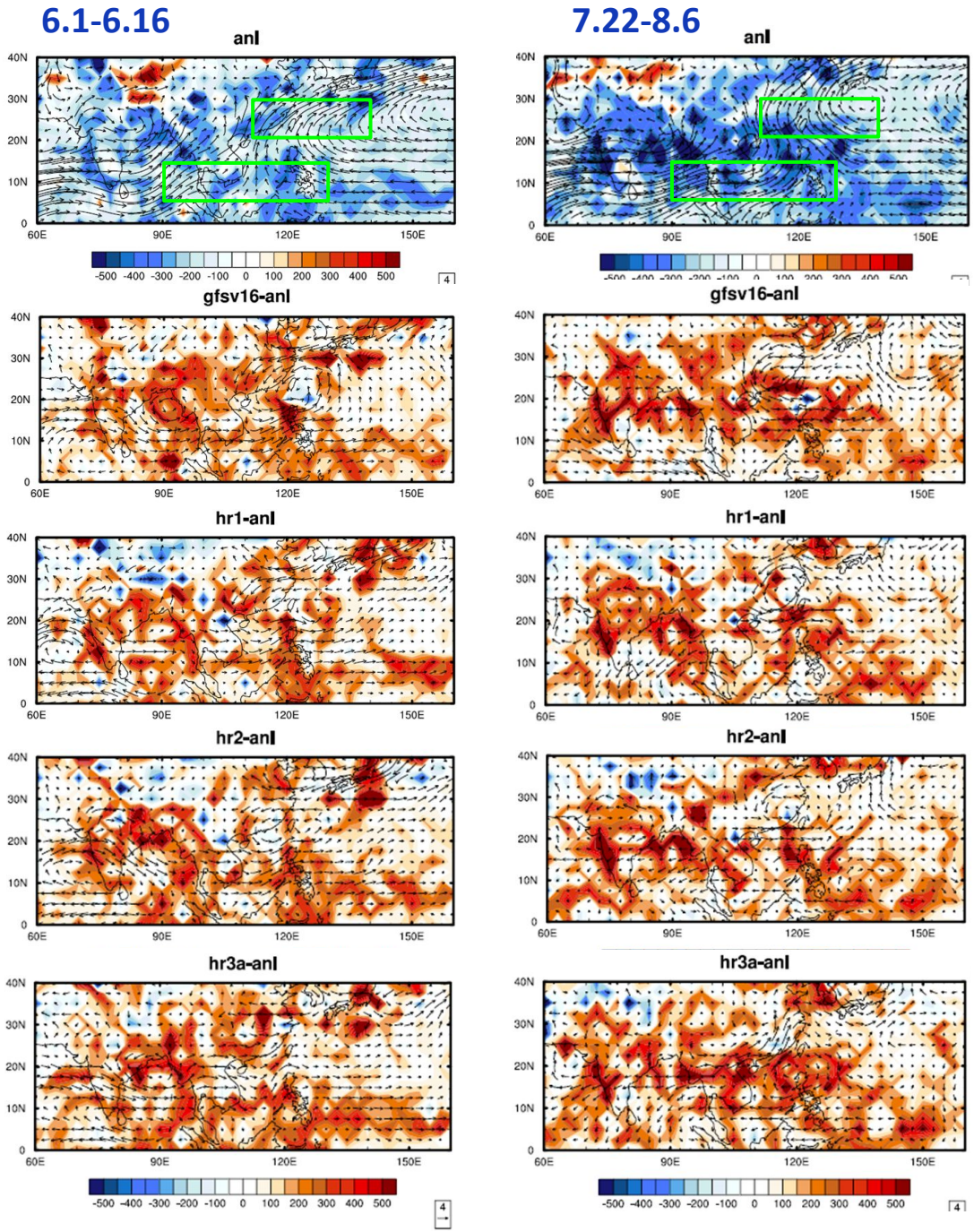


- Larger SH bias over land in HRs



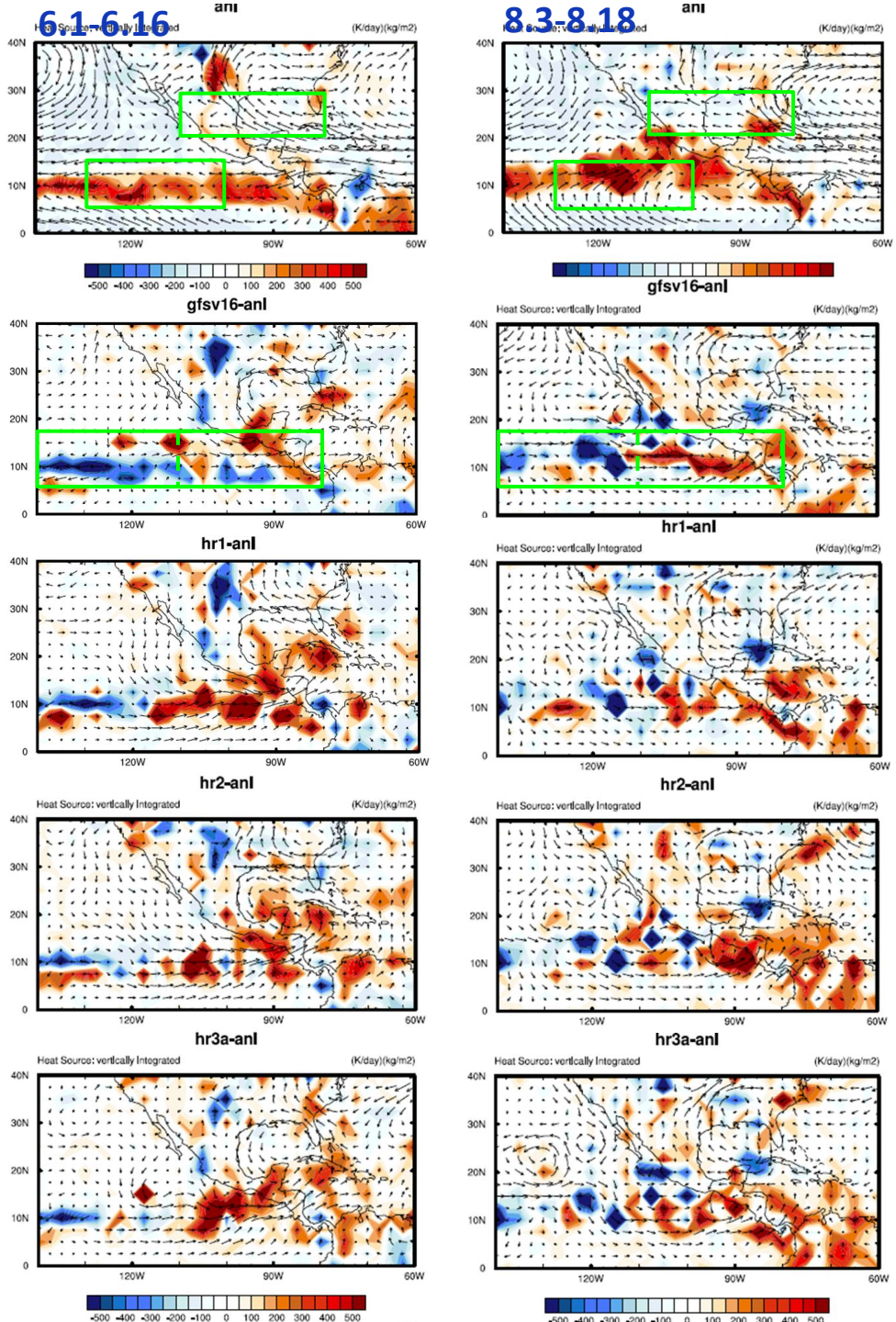
LP&wnd850: EASM (lead day=10)

- Cold LP bias except over the north western Pacific subtropical high (NWPSH)
- Cold LP bias over tropical [90-130E)] move northward after monsoon onset→[Q1] bias gradient reverse



[Qr]&wnd850: EASM (lead day=10)

- Warm [Qr] bias in all model versions

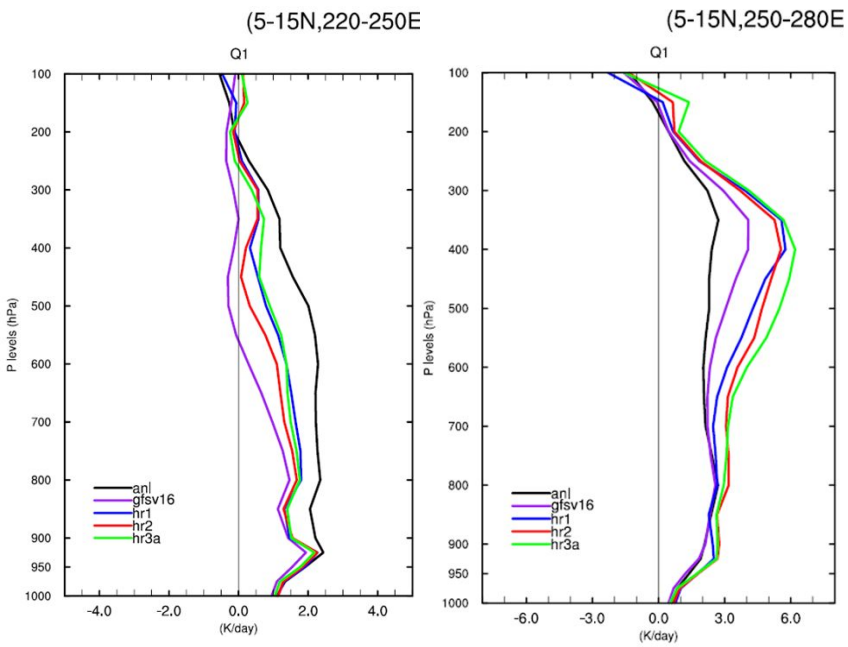


[Q1]&wnd850: NASM (lead day=10)

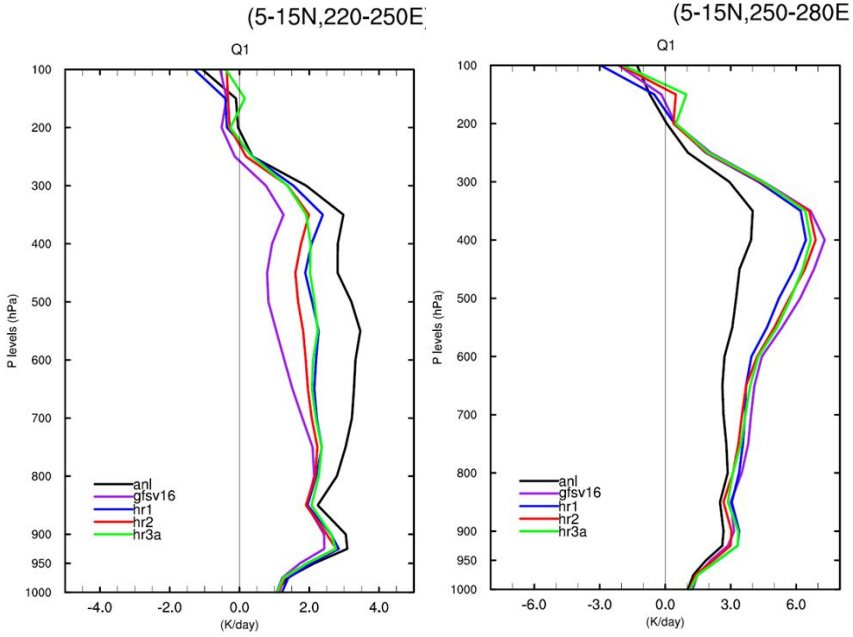
- Too warm [Q1] over ITCZ in HRs before onset
- Westerly biases in all model versions

Q1 profiles (lead 8-14)

Before onset

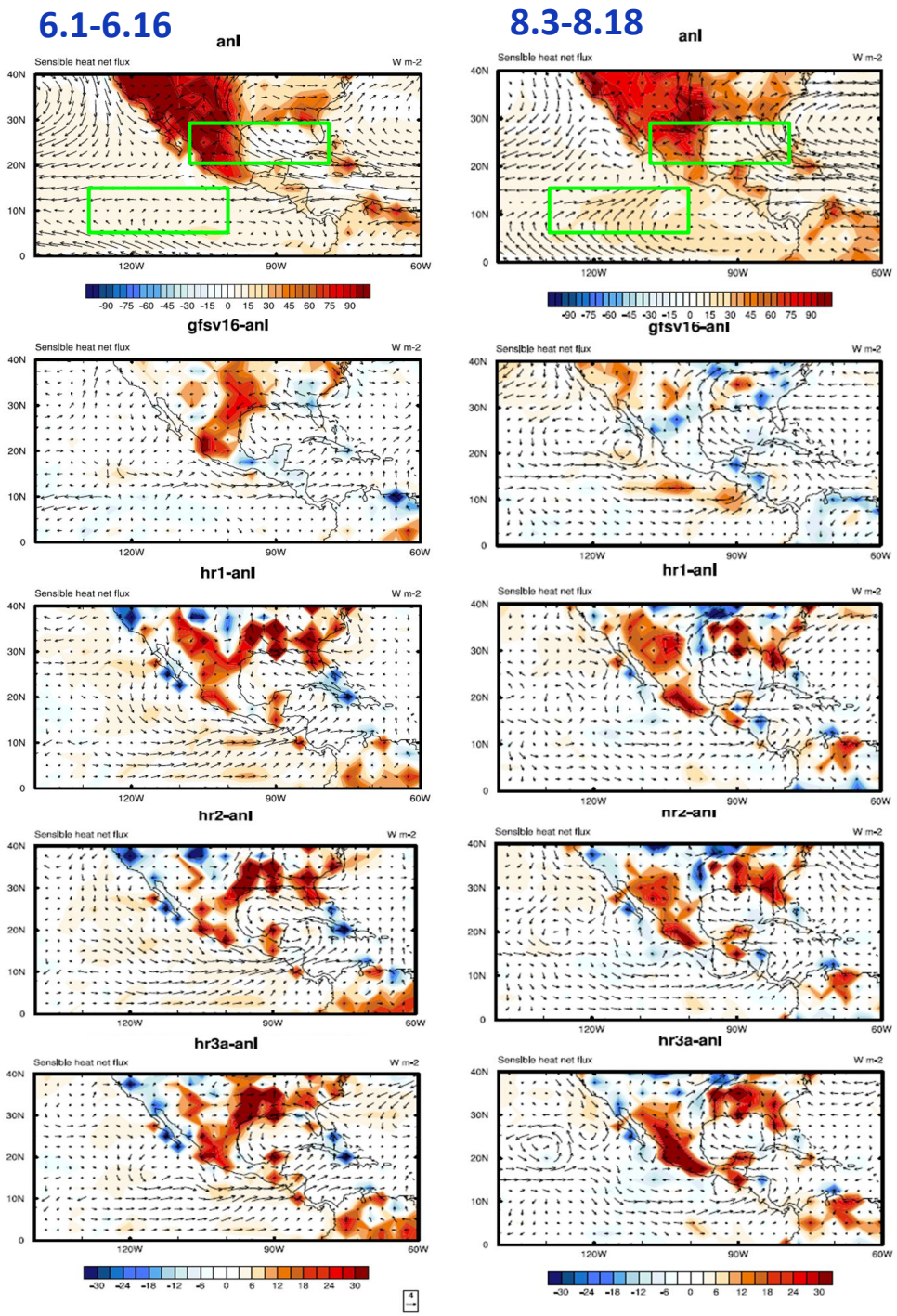


After onset



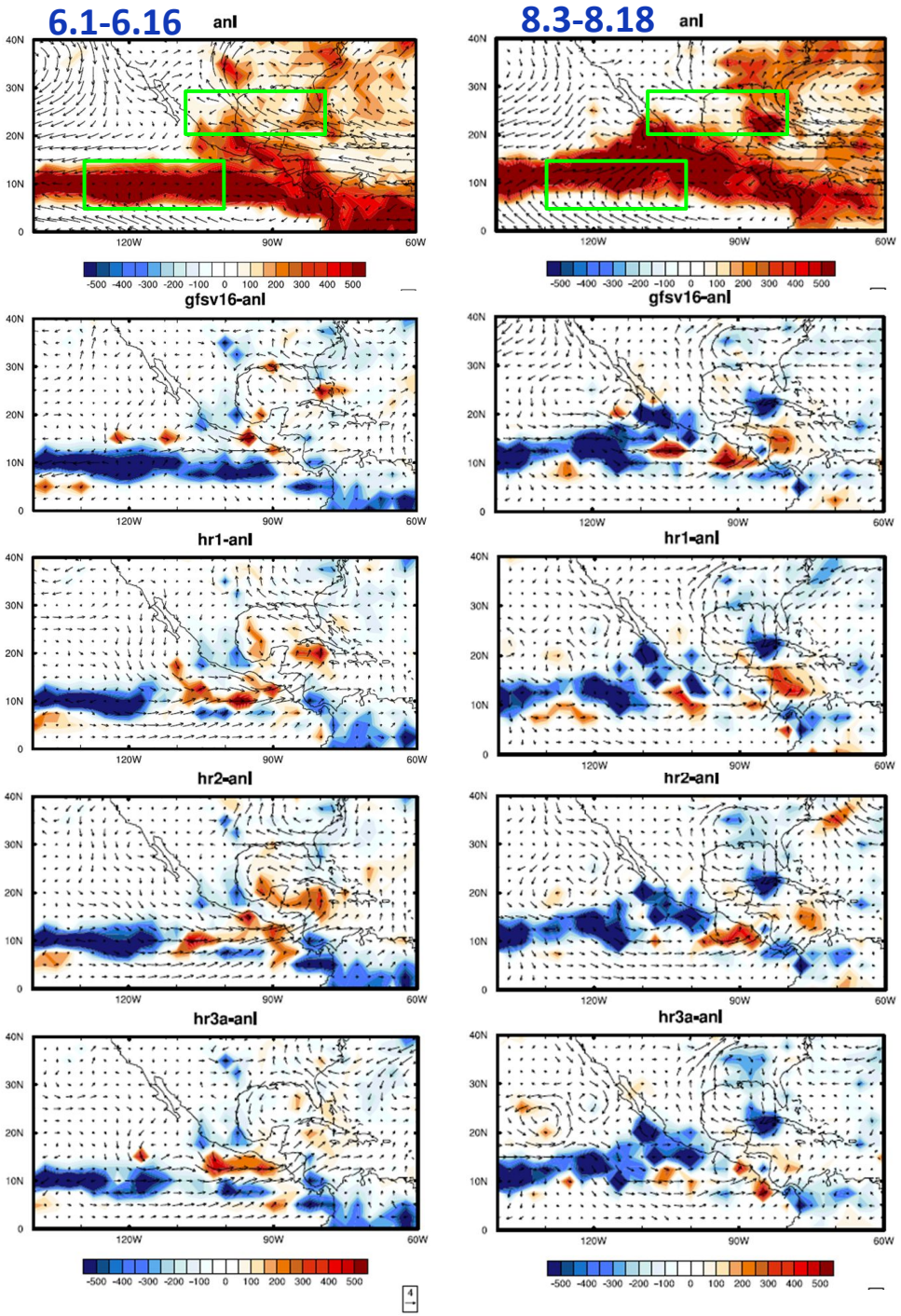
- Cold/warm Q1 biases over [110-140W]/[80-110W] in all model versions → westerly bias in tropical definition region

—> Weak/strong bias in u850 before/after monsoon onset in tropical definition regoin



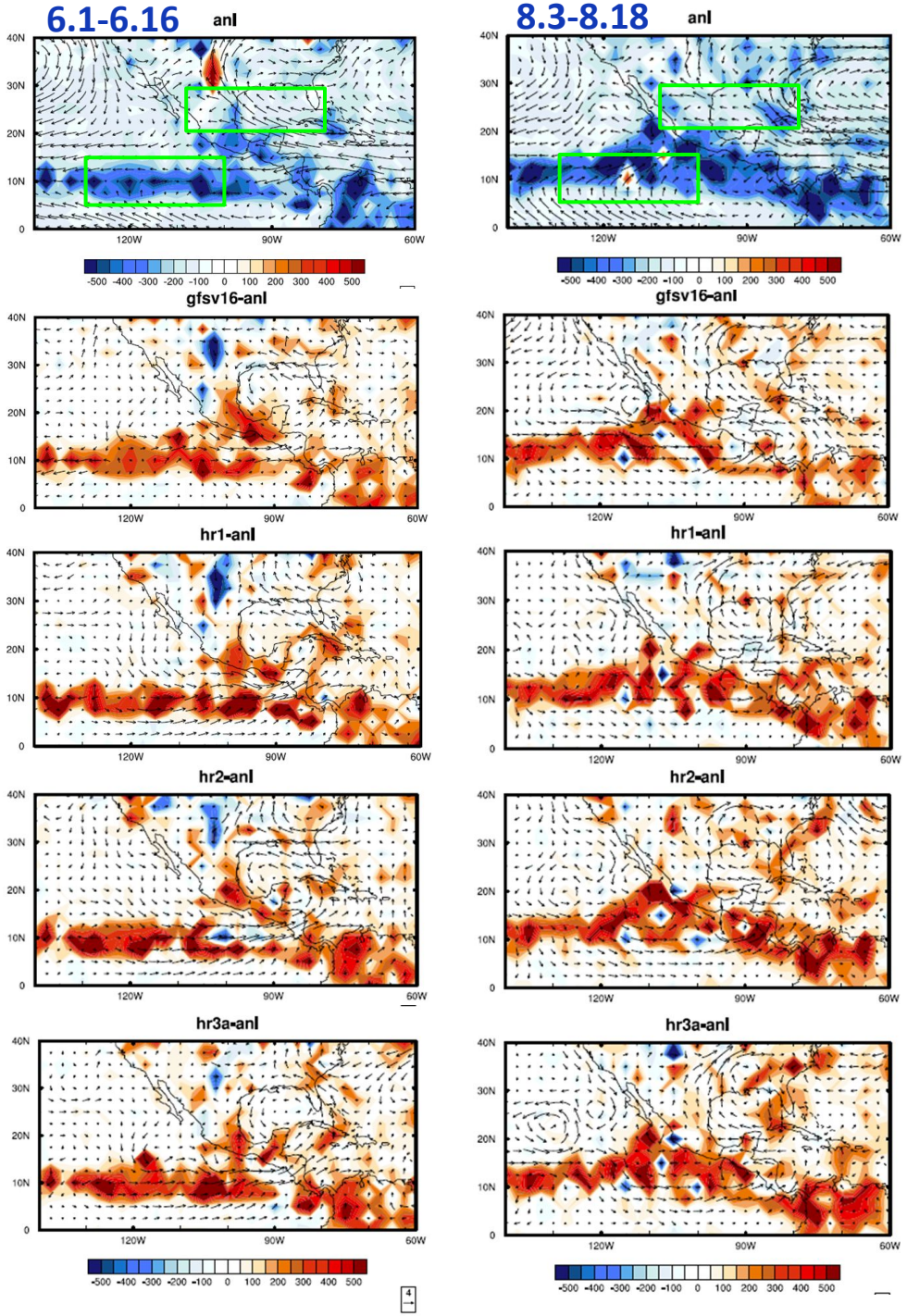
SH&wnd850: NASM (lead day=10)

- Larger warm SH biases in HRs



LP&wnd850: NASM (lead day=10)

- Warm and cold LP biases over ITCZ in HRs esp. before onset→ larger weak u850 biases in HRs than GFSv16 before onset over the tropical definition region



[Qr]&wnd850: NASM (lead day=10)

- Larger warm [Qr] bias (less radiative cooling) over ITCZ in HRs

Summary

- ***EASM:***
  - HR1>HR3a>HR2>GFSv16
  - Strong/weak monsoon bias before/after monsoon onset in the models
  - Overall, less [Q1] bias in HRs than GFSv16
  - LP and [Qr] biases contributed to the [Q1] bias; cold LP bias over tropical [90-130E)] move northward after monsoon onset→[Q1] bias gradient reverse

- ***NASM:***
  - GFSv16>HR3a>HR1>HR2
  - Strong monsoon bias in the models
  - Too warm [Q1] (mostly contributed by warm [Qr] bias) over E. ITCZ in HRs than GFSv16 before onset (due to joint contribution from LP and [Qr])

References

1. Yim, et al. 2014: A comparison of regional monsoon variability using monsoon indices, Clim. Dyn.43: 1423-1437
2. Varuolo-Clarke et al. 2019:Characterizing the North American Monsoon in the Community Atmosphere Model: Sensitivity to Resolution and Topography, JCLI, 32, 8355-8372

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

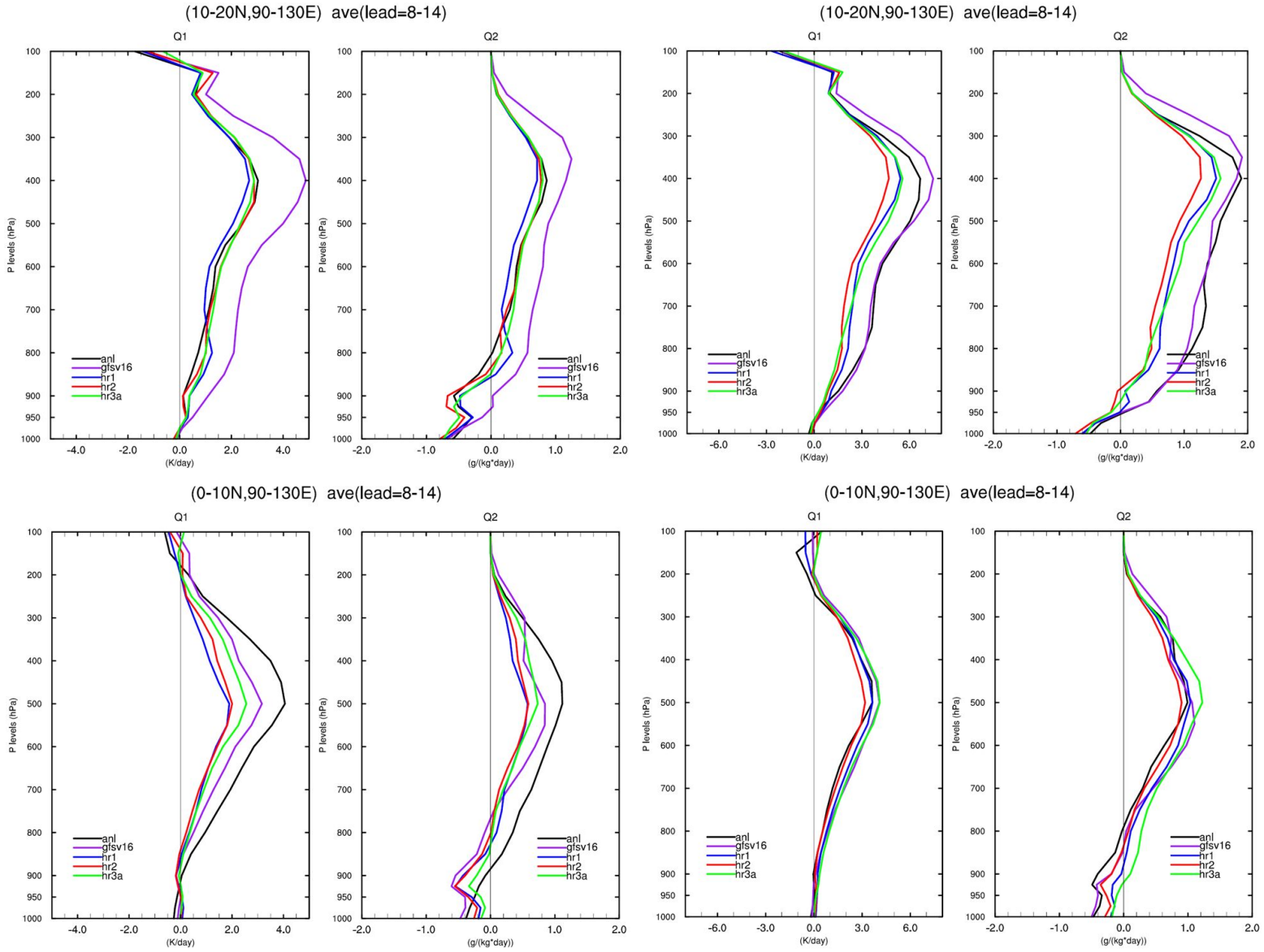
$$Q_2 = -L\frac{\partial q}{\partial t} - L\mathbf{V}\cdot\nabla q - L\omega\frac{\partial q}{\partial p},$$

[Q1]=[Qr]+LP+SH=[Qrs]+[Qrl]=Qswt↓(1-At)-Qsw0↓(1-A0)+Qlw0-Qlwt
*SH=ro*CH*|V|*cp*(Ts-Ta)*
[Q2]=L(P-E)
-Yanai etal. (1973, 1998)

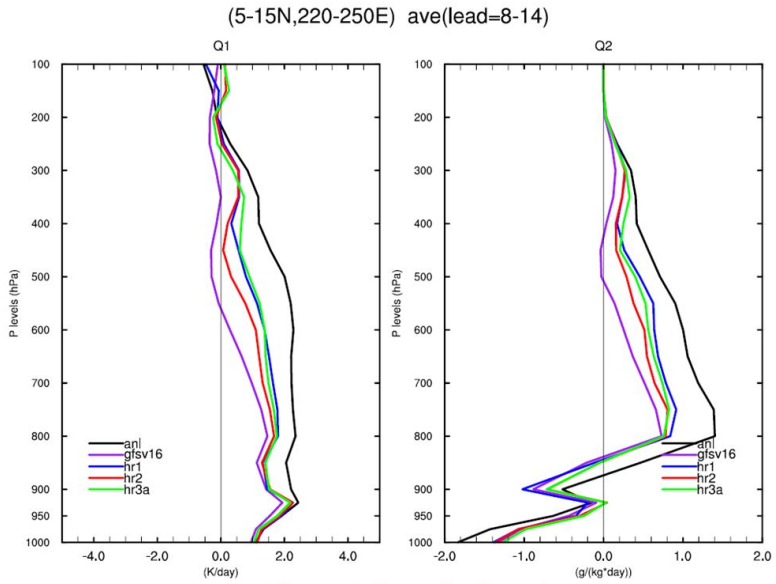
Supplementary Slides

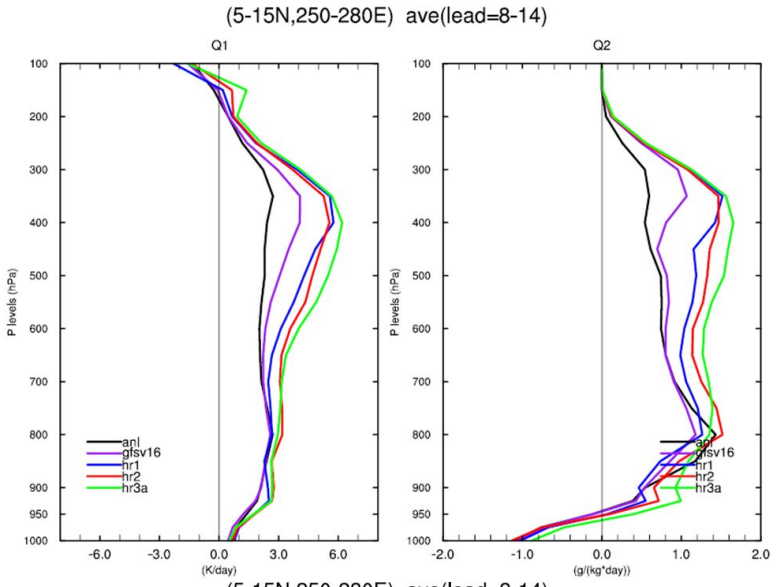
before onset

after onset



before onset





after onset