KIAPS
KOREA INSTITUTE OF ATMOSPHERIC PREDICTION SYSTEMS

A Study on the perturbation effect of the Tibet Plateau and Rocky Mountain Region using the Korean Integrated model

Korea Institute of Atmospheric Prediction Systems (KIAPS), South Korea

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Different from the past

Global/Regional Integrated Model system
(GRIMs; Hong et al. 2013)

KIM(LS4P-II)

non-hydrostatic
spectral element
Runge-Kutta3
cubed sphere grid
6th order diffusion

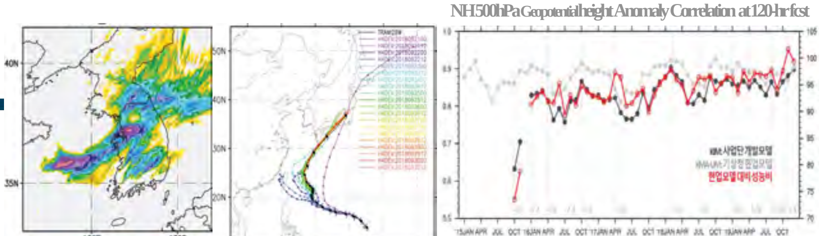
Physics package

GRIMs (LS4P-I)

hydrostatic
spherical harmonics
semi-implicit
Gaussian lat-lon grid
8th order diffusion

seasonal simulation by GRIMs
- cost-effective
- easy to handle pre- and post-process

Korean Integrated Model (KIM)



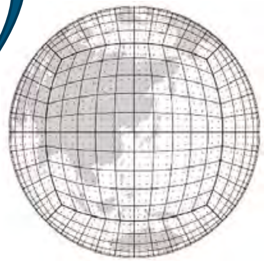
Compared to UM (Met Office)

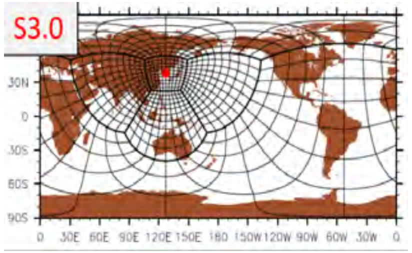
1 KIAPS phase I (2011~2019)

New atmospheric model

- New spectral element dynamical core on cubed-sphere grid
- non-hydrostatic, Runge-Kutta3, 6th order diffusion
- New physics package and data assimilation system
- Deterministic medium-range weather forecast (~10 days)

➔ **KIM has become operational since April 2020**



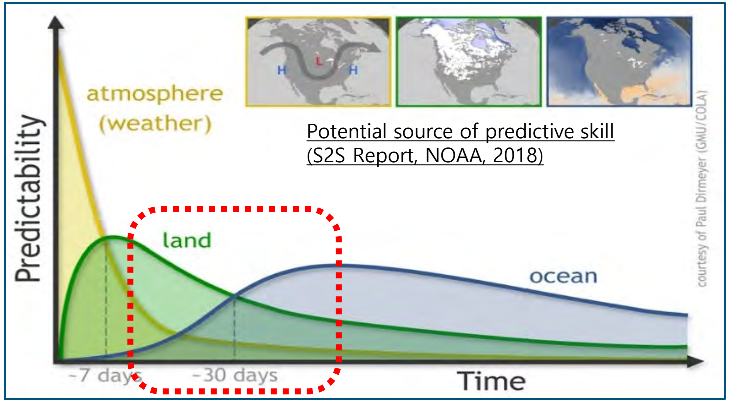


2 KIAPS phase II (2020~2026)

Seamless and coupled model

- Scale-aware physics at variable resolution
- Ensemble forecast at extended-range time scale (~30 days)
- Coupled atmosphere-surface model with chemistry process

➔ **new KIM covering multiple scales in space and time**



KIM (Atmosphere Model) Surface Process

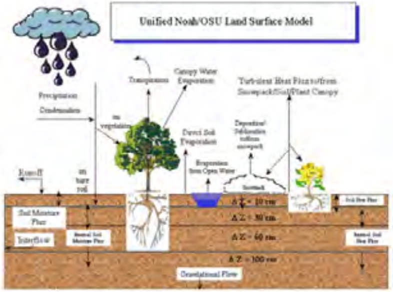
- KIM focuses on ATM so other components are relatively simple
- Noah not having MOST >> Use Surface Layer

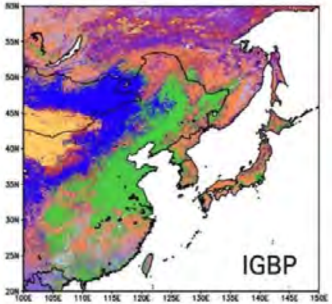
surface layer — **Monin-Obukhov Similarity Theory (based on GFS)**
Long (1984; 1986); Zeng et al. (2012); Wei et al. (2016); Koo et al. (2018)

ocean (0) — **Slab ocean model (mixed layer, diurnal variation)**
Zeng and Beljaars (2005); Kim and Hong (2010); Lee and Hong (2019)

land (1) — **Revised NOAH LSM V3.4.1**
Ek et al. (2003); Mitchell et al. (2005); Koo et al. (2017)

seaice (2) — **3-layer sea-ice model**
Winton (2000); Koo et al. (2017)





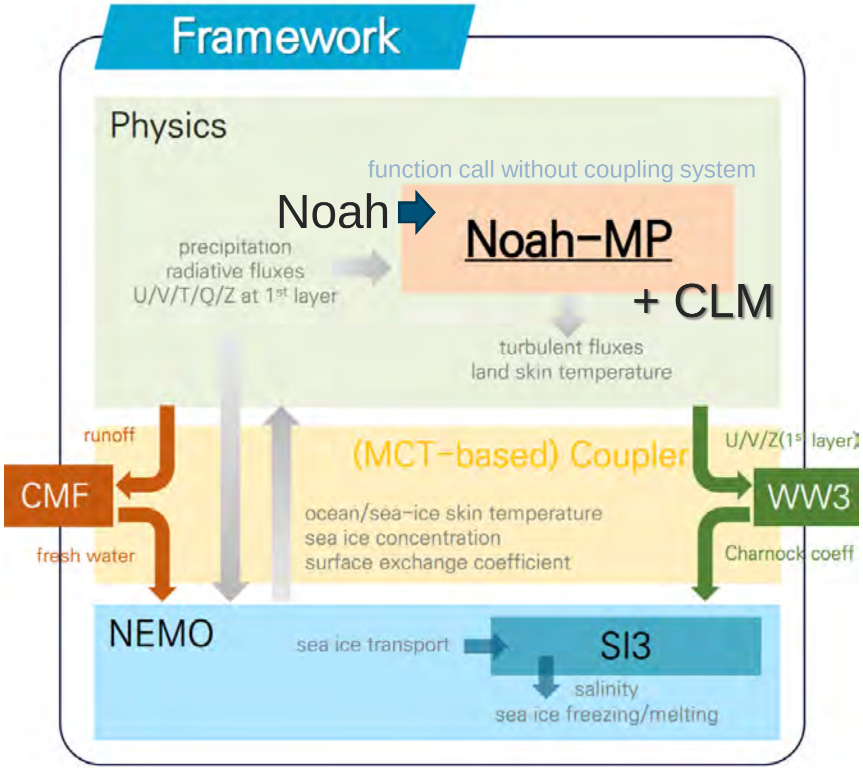
KIM-Noah
- revised Noah V3.4.1
- 1-km land use (IGBP) and soil texture (STATSGO/FAO)
- 1-km vegetation fraction (WRF-based; Noah)
- MODIS-based snow-free albedo (15-daily; radiation)
- maximum snow albedo (radiation)

✓ These all models have been continuously updated to get a better prediction for the KIM atmosphere model

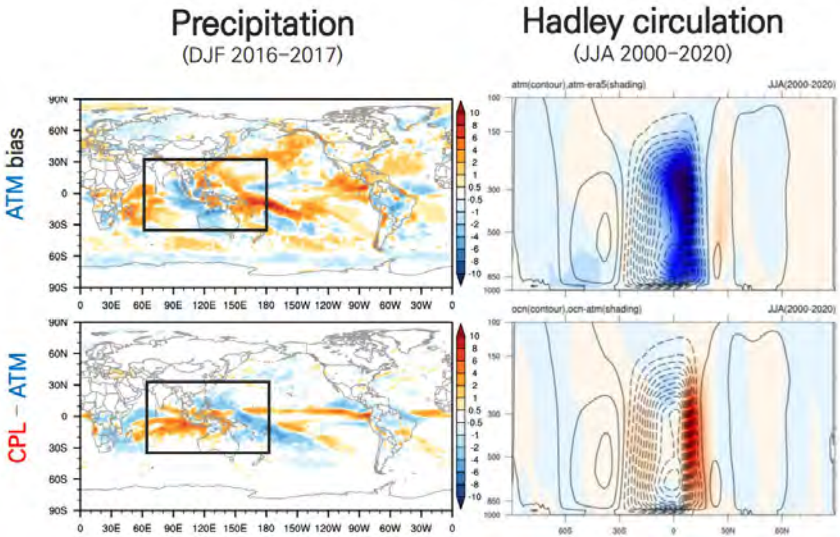
➔ currently operational in KMA with land surface data assimilation (LIS; soil moisture and snow)

Developing KIM Coupled System

- For KIAPS phase II, Coupled system is needed
- 3 years since 2020



Boundary model		OCN	SIC	WAV	RIV
Name		NEMO	SI3	WW3	CMF
Version	current	4.0		7.13 (6.07+α)	4.0
	latest	4.2.0		7.14	4.11
Coupler		MCT			
Initial data		ORAS5	ERA5 GIOMAS	-	-
Exchange freq.		1h (fixed: same with radiation)			24h
Grid system		tripolar		(regular) lat-lon	
Resolution		25km (fixed)			



LSMs in KIM

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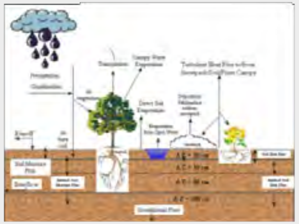
Noah

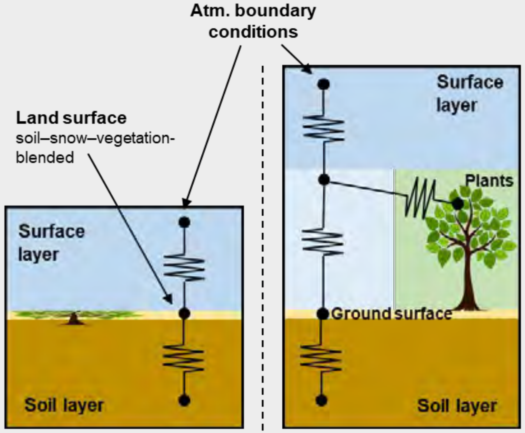
Noah-MP5

CLM5

LSM in KIM of the phase I:



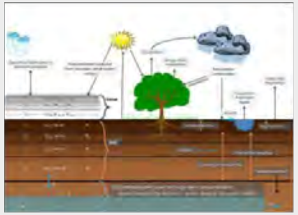
- ✓ Noah v3.4.1 was implemented and revised in KIM (Koo et al. 2018) Revisions including:
  - New land use soil type datasets (IGBP and STATSGO/FAO)
  - 1-km vegetation fraction dataset
  - MODIS-based snow-free albedo



Second generation LSM

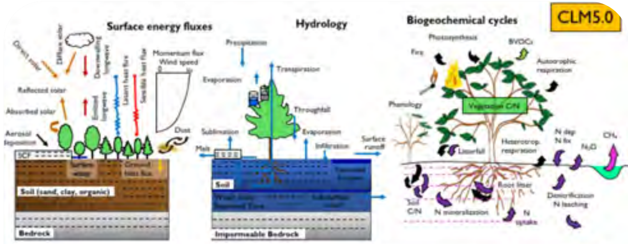
Third generation LSM

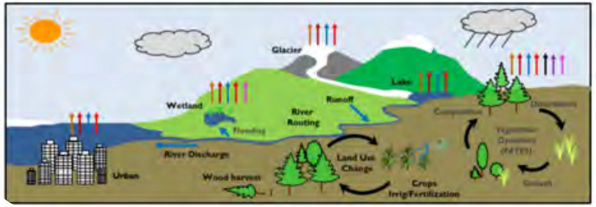
LSM in KIM of the phase II:



- ✓ Noah-MP was coupled with KIM and now it is being revised
- ✓ **More opportunity to become more data-driven LSM:** including global geophysical datasets of plant traits, forest morphology, physiological activity

Jsg.utexas.edu/noah-mp/





CLM5 Doc.

- 1 Snow Layer
- 4 Soil Layer
- Bulk Vegetation Processes
- Computationally efficient

- 1-3 Snow Layer
- 4 Soil Layer
- Big Leaf + M-O + Two stream
- Simple Tile Surface
- Simple Urban & Lake

- 12 Snow Layer
- 25 Soil Layer
- Big Leaf + M-O + Two stream
- Complex Tile Surface
- Adv. Urban & Lake
- More for Climate Model
- Keep updated and complex
- Computationally Expensive

❑ Noah is for operational model so it is well-optimized to KIM

Purpose of this study and Experimental Design

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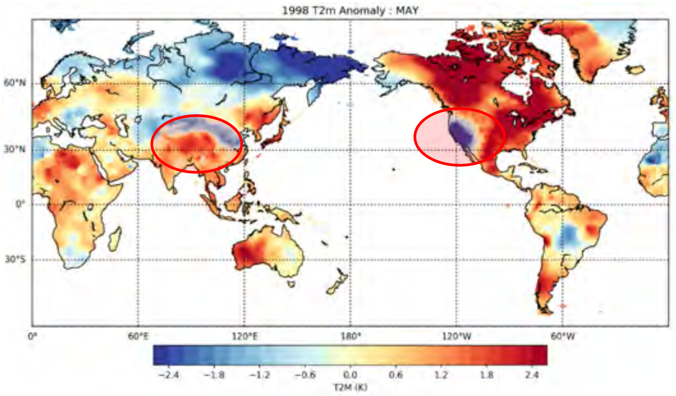
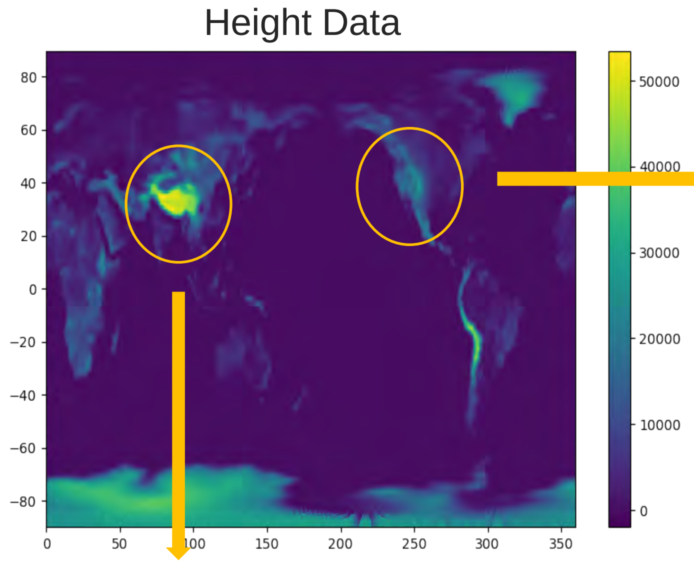
- This study is to test various LSM coupled with KIM and to carry out the LS4P project checking its anomaly and sensitivity
- To find proper perturbation conditions focusing on the Impact of the T2m anomaly of the Tibet (TB) and Rocky Mountain (RM) region : Task2, 3 (Case TB and RM)

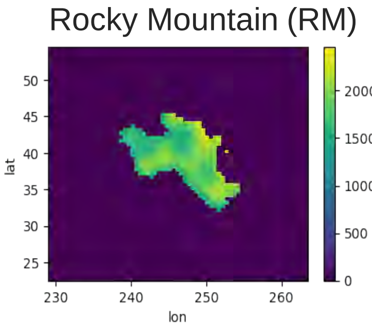
	Description
Model version	KIM V4.0 (+minor revision)
Land surface model	1. Revised Noah (Koo et al. 2017; 2018) 2. NoahMP5.0 w/ the optimization for KIM 3. CLM5
Resolution	50km with 91 vertical Atm. levels
Initial data	ERA5 (0.25˚)
Start time	00Z 21 Apr 1998 (10 members with lagged starting time) ~ 31 AUG 1998 • 1~10 days spin up
Surface cycling	SST every 24 hour

Perturbed Area

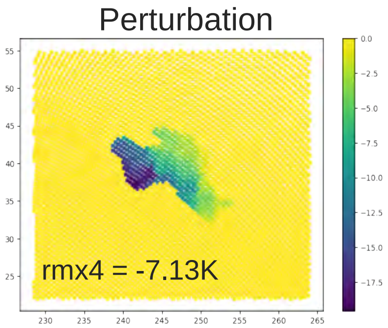
- The experiments were executed for Case CTL, Case RMI(RM), Case TPI(TB)
- If the topographical height is more than 1500m(RM) and 3500m(TP), it was selected as the area of interest
- Not uses any smoothing
- The selected area was perturbed based on given anomaly data (CMA)

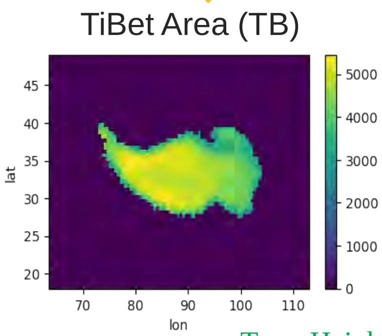


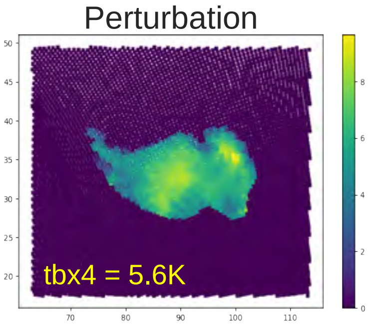




Topo Height > 1500m



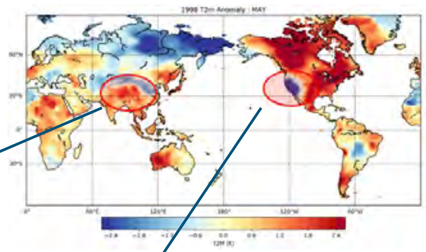


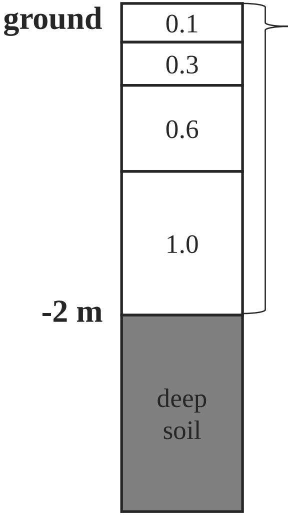


Topo Height > 3500m

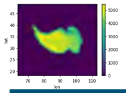
Check Perturbed data

- The anomaly value in the area applied to surface skin temperature(+snow) and soil temperature
- The value added to KIM surface initial data only in the selected area
- The areal average values are listed in the tables: TB + , RM -



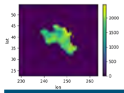


4 layers in Noah(ctl)/NoahMP(mp), 25 layers in CLM(clm)



Modified-Original(TB)

EXP	Area Mean Diff
x1: OBS Anomaly x 1	1.41K
x2: OBS Anomaly x 2	2.81K
x3: OBS Anomaly x 3	4.22K
x4: OBS Anomaly x 4	5.62K
x8: OBS Anomaly x 8	11.25K



Modified-Original(RM)

EXP	Area Mean Diff
x1: OBS Anomaly x 1	-1.78K
x2: OBS Anomaly x 2	-3.56K
x3: OBS Anomaly x 3	-5.35K
x4: OBS Anomaly x 4	-7.13K
x8: OBS Anomaly x 8	-14.26K

Abbreviated word

CLIM : 2001-2020 Climatological Normal (CMA)
OBS : 1998 CMA data (T2M, PR)
CTL(ctl) : KIM-Noah coupled model
MP(mp) : KIM-NoahMP coupled model
CLM(clm) : KIM-CLM coupled Model

RM : Rocky-Mountain
TB : Tibet

Modified-Original(TB)

EXP	Area Mean Diff
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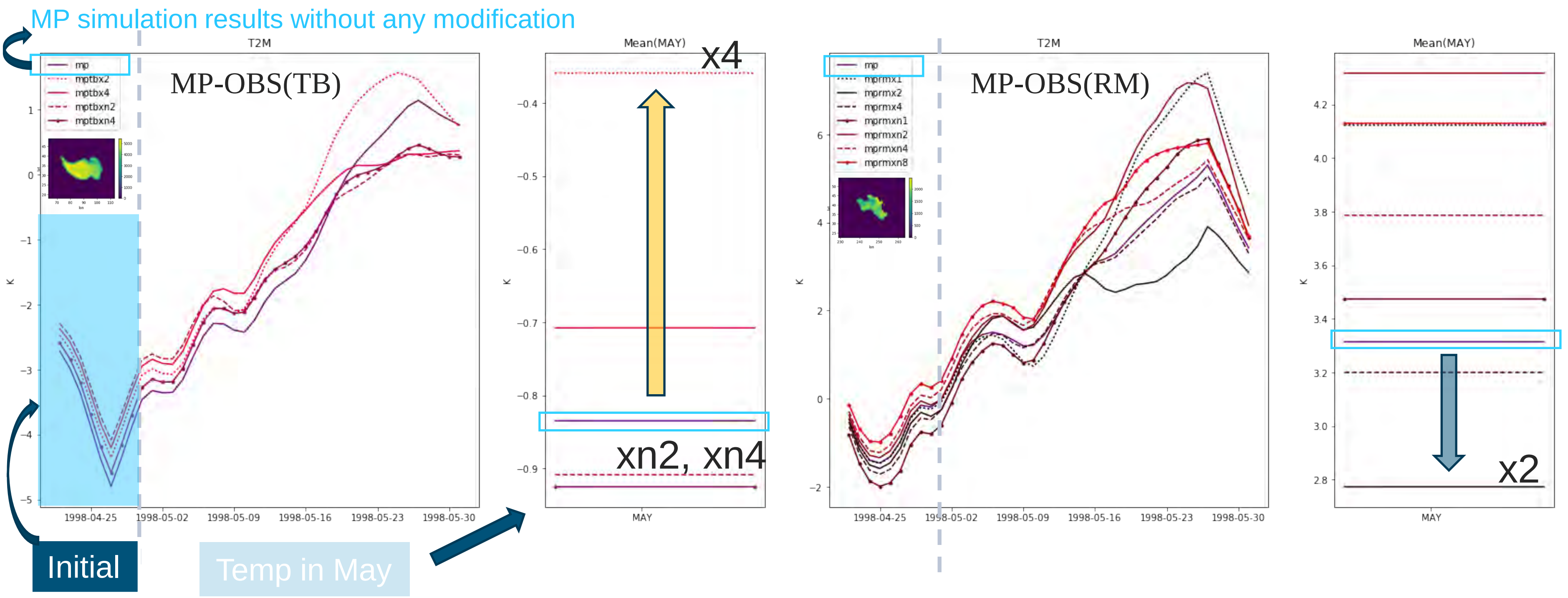
x4: OBS Anomaly x 4	-7.13K
x8: OBS Anomaly x 8	-14.26K

Experiment Name

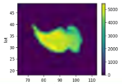
ctlrmx1 : KIM-Noah coupled model with x(+)1 perturbation in RM area
ctlrmxn1 : KIM-Noah coupled model with x(-)1 perturbation in RM area
ctlrmx2 : KIM-Noah coupled model with x2 perturbation in RM area
mprmx2 : KIM-NoahMP coupled model with x2 perturbation in RM area
clmtbx8 : KIM-CLM coupled model with x8 perturbation in TB area
…

Perturbation Example, Change of T2M Temp. [Area Average]

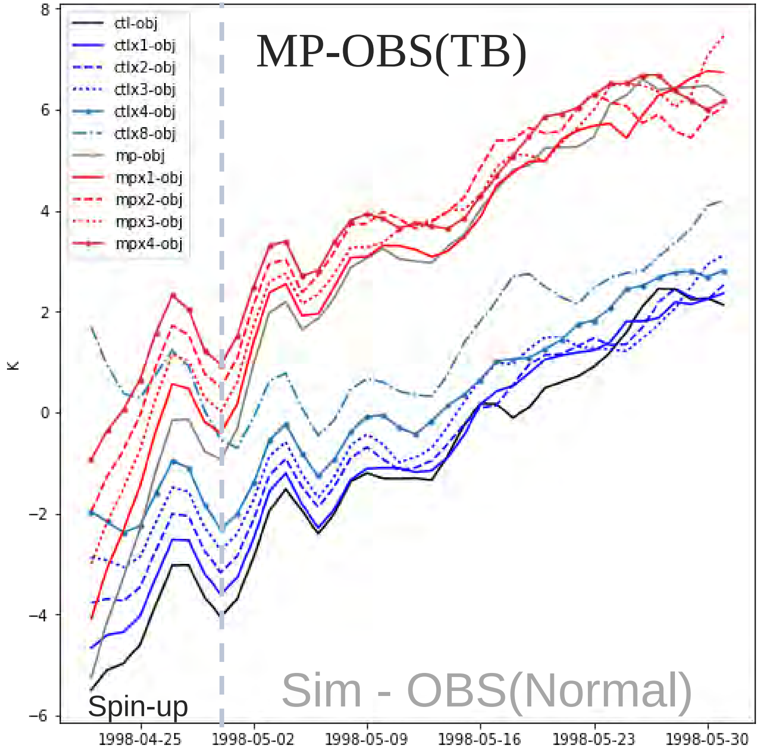


- For MP, TB has cold bias and RM has warm bias compared to CMA data
- Give TB area positive Temp. perturbation (like OBS.)
- Give RM area negative Temp. perturbation (like OBS.)

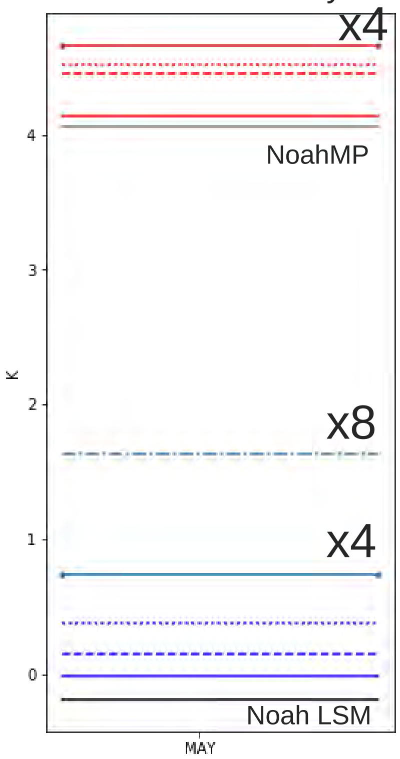
In Asia Meeting, for Tibet, Soil Temperature time-series



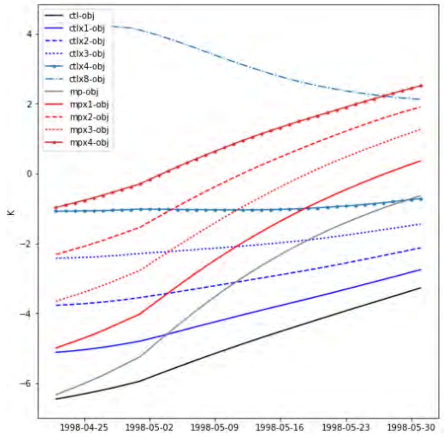
Soil Temperature at the top layer



Area Mean on May



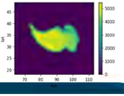
Soil Temperature at the bottom layer



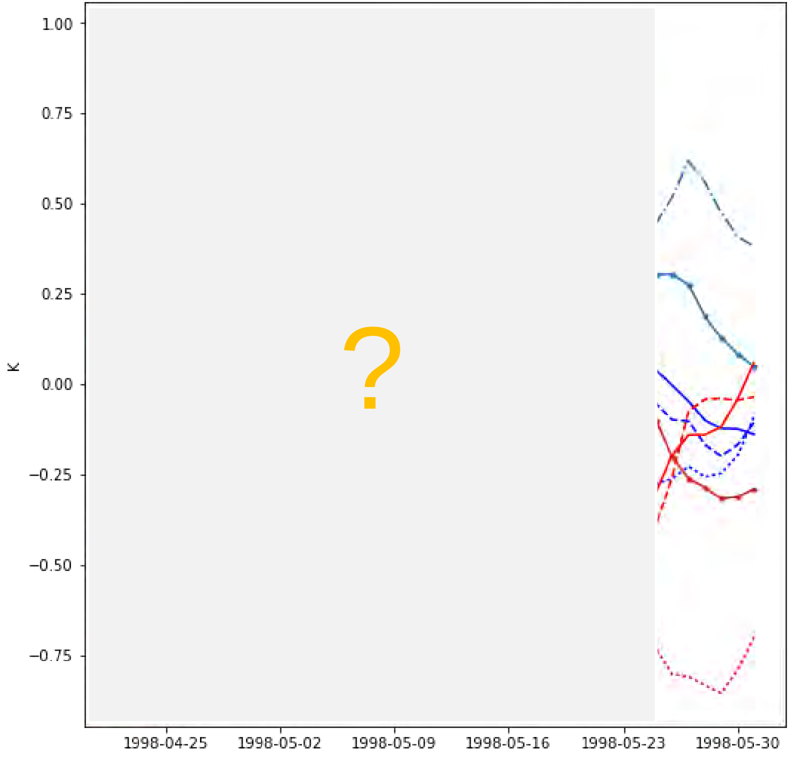
- The perturbation in deep soil is well applied and maintained
- Soil Temp. at the top tend to be easily affected by the atm model

CMA(Climatological Normal)

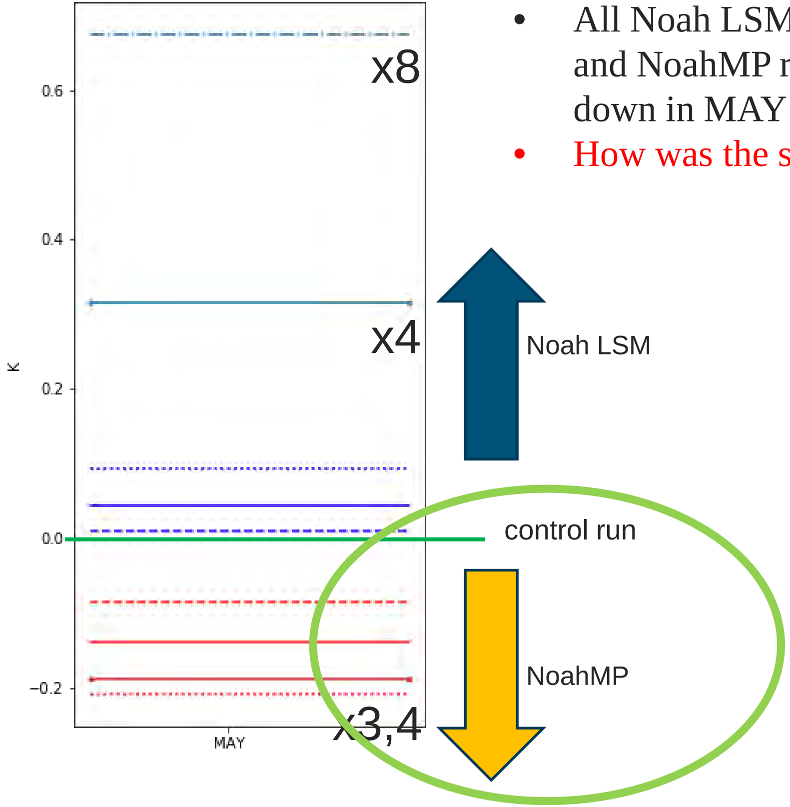
In Asia Meeting, for Tibet, Time series of 2-m temperature (T2M)



Pert. MP-MP(TB)



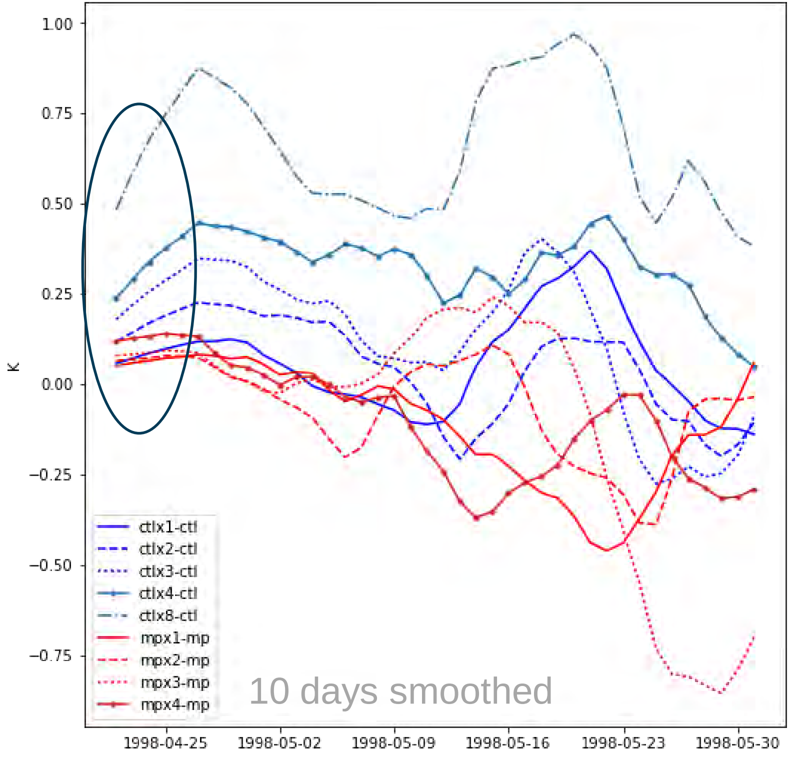
Area Mean on May

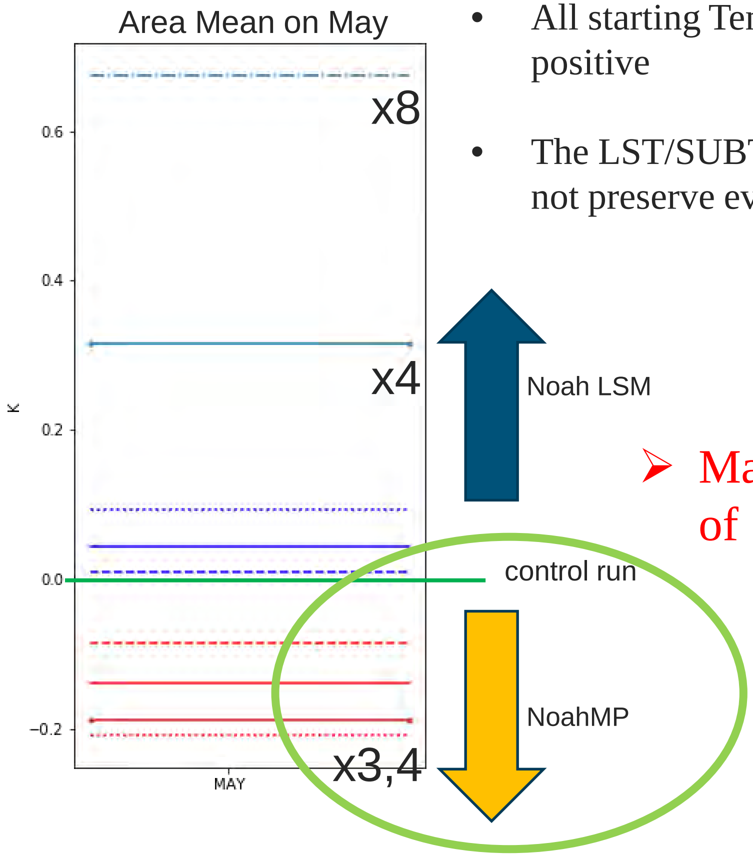


- All Noah LSM results went up and NoahMP results went down in MAY
- How was the starting Temp?

In Asia Meeting, for Tibet, Time series of 2-m temperature (T2M)

Pert. MP-MP(TB)





- All starting Temp. anomaly was positive
- The LST/SUBT perturbation did not preserve even in a short time

➢ May be because of Snow

Update NoahMP

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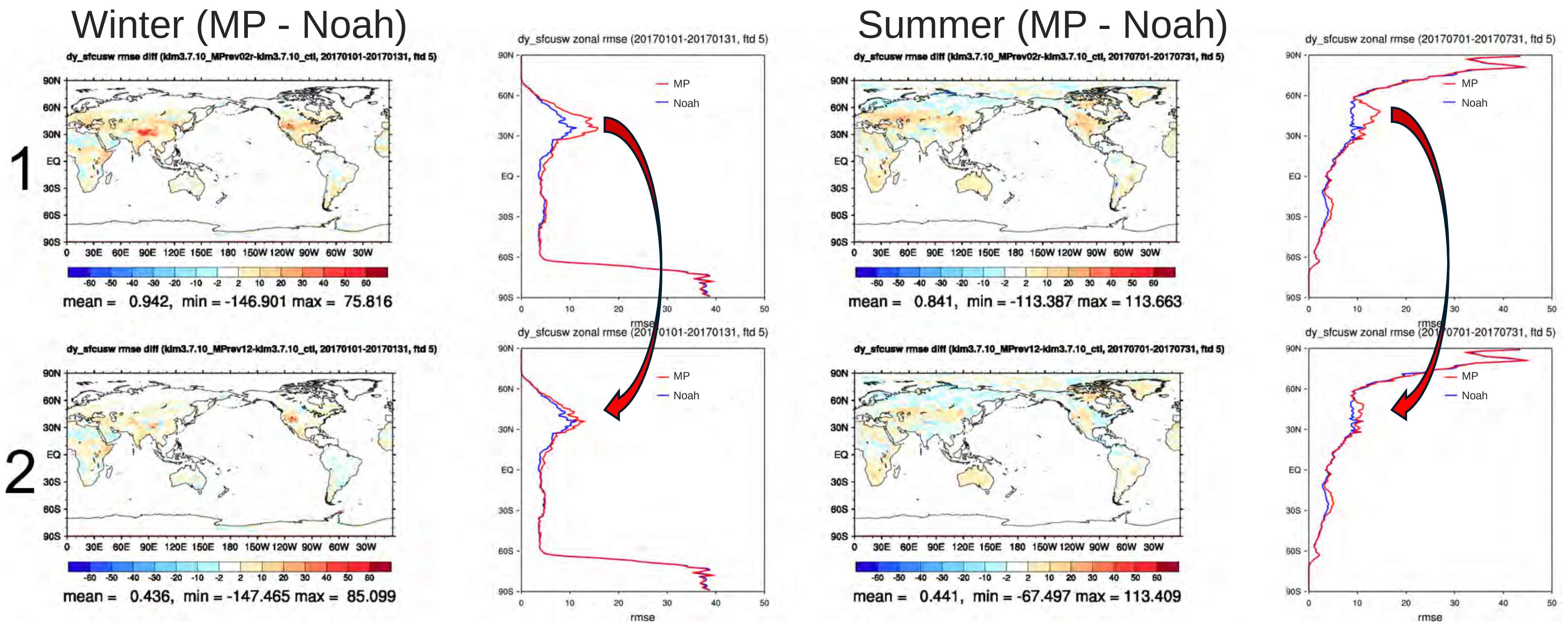
Winter (MP - Noah) / Summer (MP - Noah)



- NoahMP’s RMSE for USW was high in both summer and winter, compared to operational model
- NoahMP has been updated about snow fraction (for winter) and vegetation albedo (for summer)
- The two updates reduce USW RMSE (with CERES), 10 days, 10 ensemble members

[TB] With Updated NoahMP (Positive perturbation)

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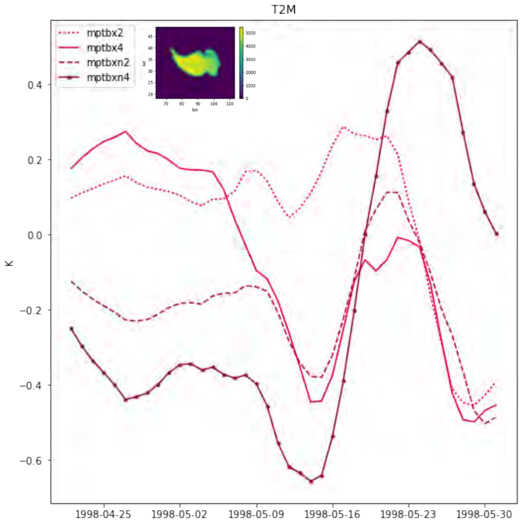
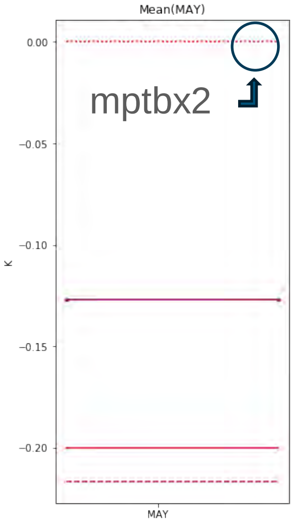


Time-series(T2M)

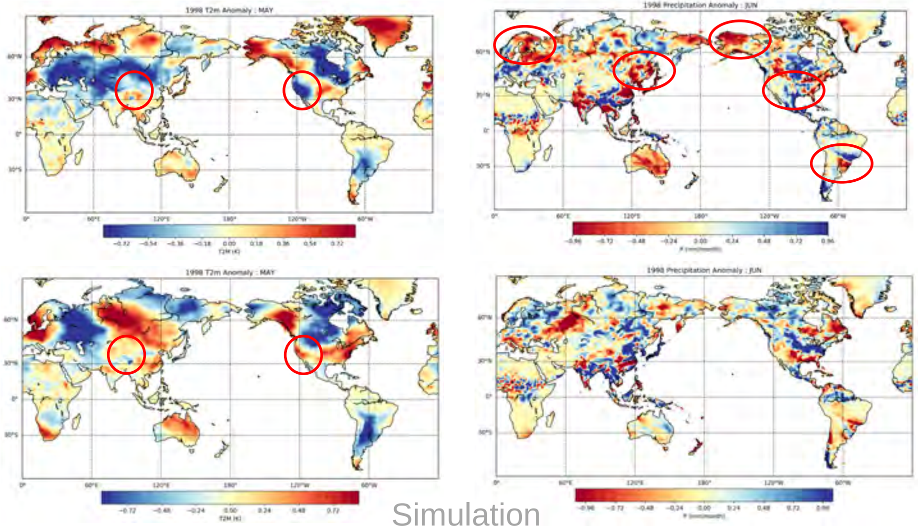


T2M MAY(mptbx2-mp)

PR JUN (mptbx2-mp)

New

Ori.

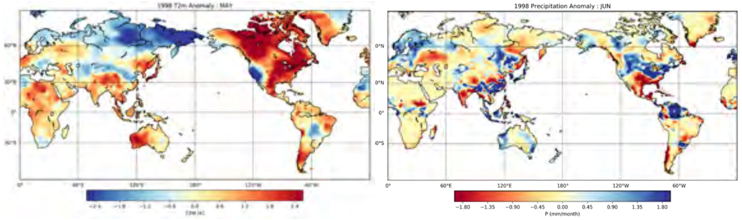


Simulation

OBS-CLIM

T2M MAY

PR JUN



Observation

- The previous version of Noah-MP did not produce warm perturbation
- Current Version (snow fixed version) can produce some warm perturbation on TB, but it still has up and down
- It results in a cold anomaly on RM and an opposite pattern for JUN precipitation in some regions compared to the old version
- LSM parameterization is very important

[TB] With CLM

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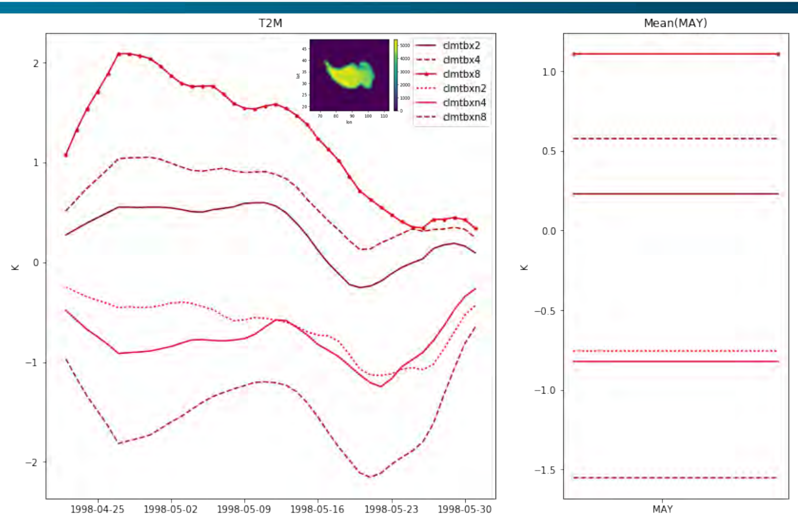

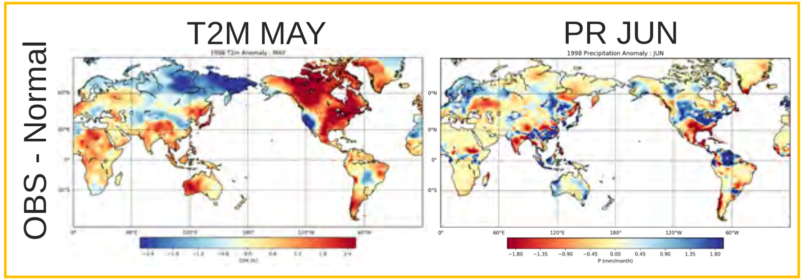

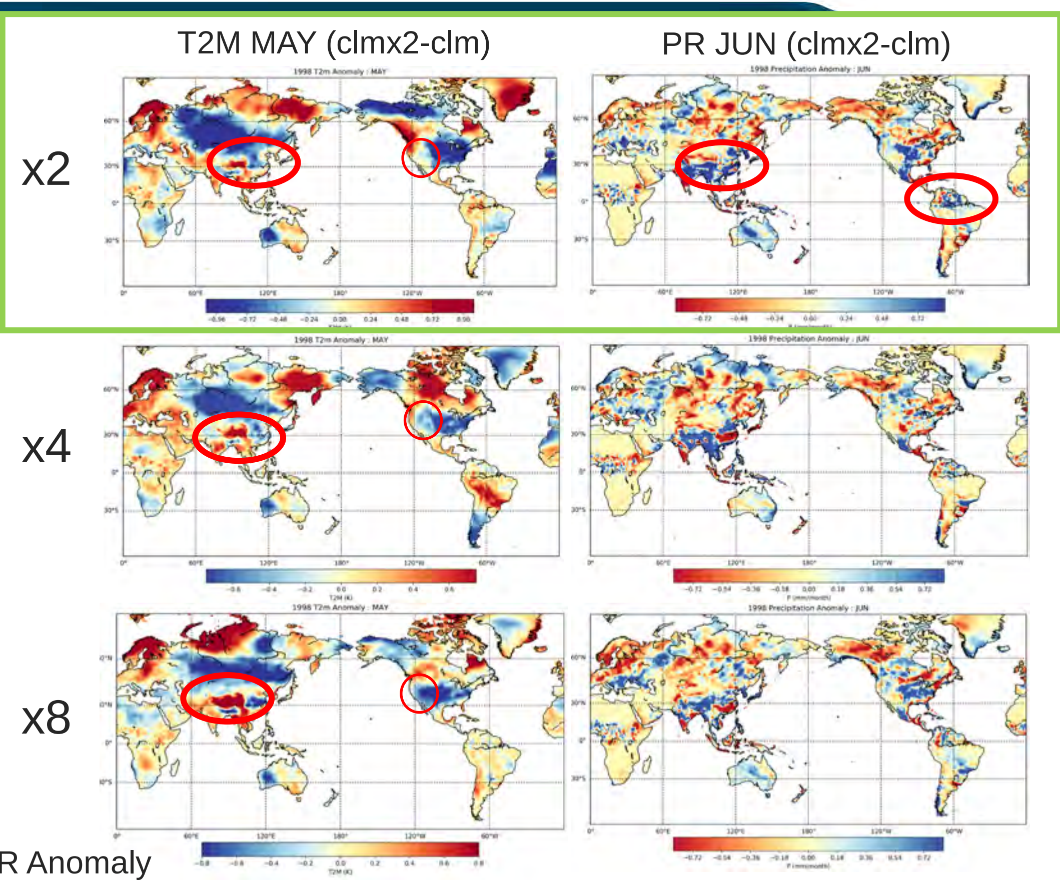

- CLM tends to preserve initial Temp.
- 3 CLM's results have consistency in both Temp and PR Anomaly
- Elevated Temp. on TB area result in lower Temp. in RM -> some dry conditions appear around TX
- Strong wet conditions in the Yangtze River basin occurred only in x2 Exp. [Too high Temp. produces different results]

[RM] With CTL(Noah)

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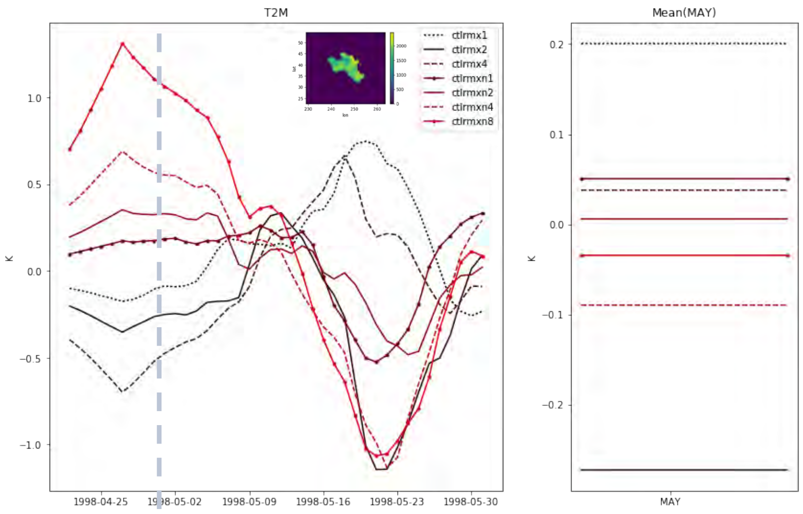
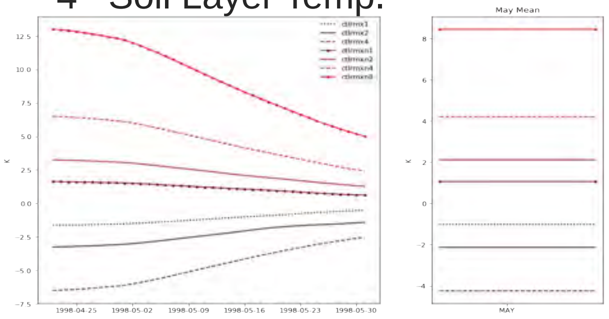
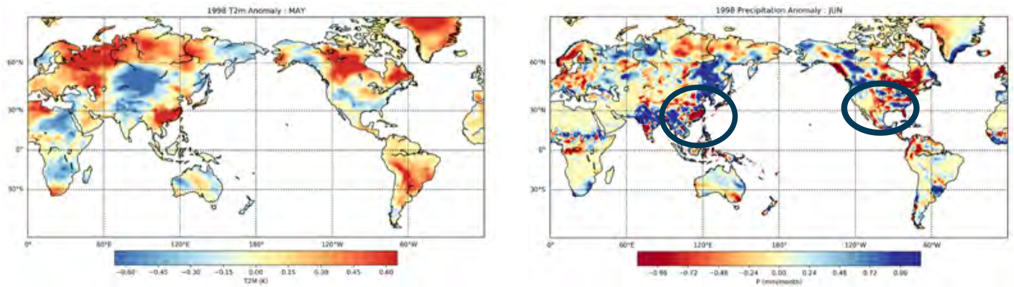


x2

4th Soil Layer Temp.



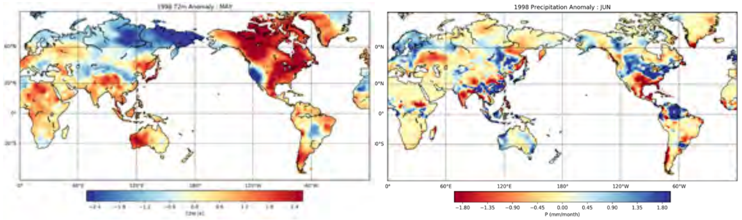
Perturbation is well applied



OBS - Normal

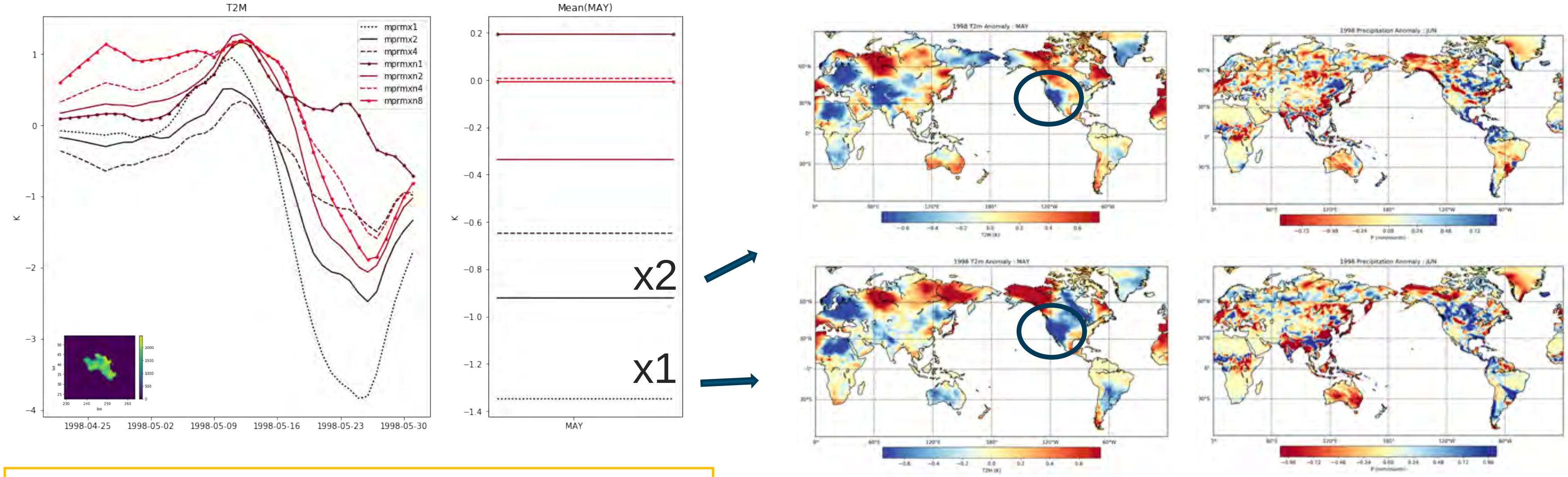
T2M MAY

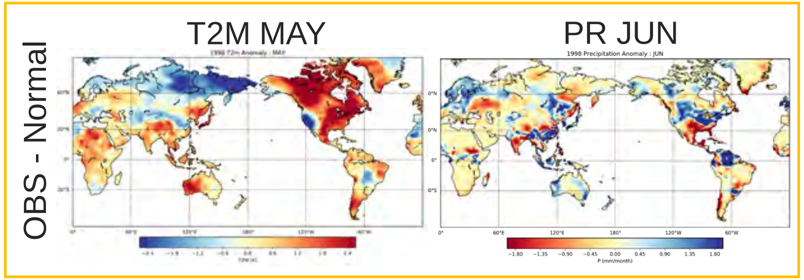
PR JUN



- Perturbation effect is very weak (<1K)
- Only rmx2 Exp. was well perturbed in RM
- TB Temp. decrease
- Produce drought in N. America (CA ~ TX) and Yangtze river

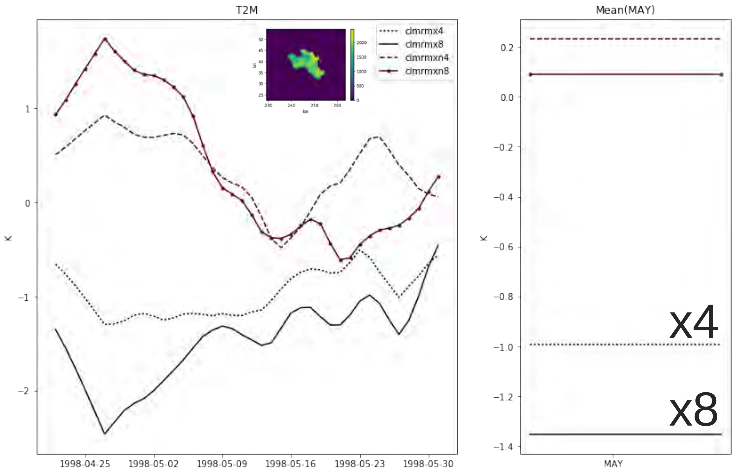
[RM] With NoahMP

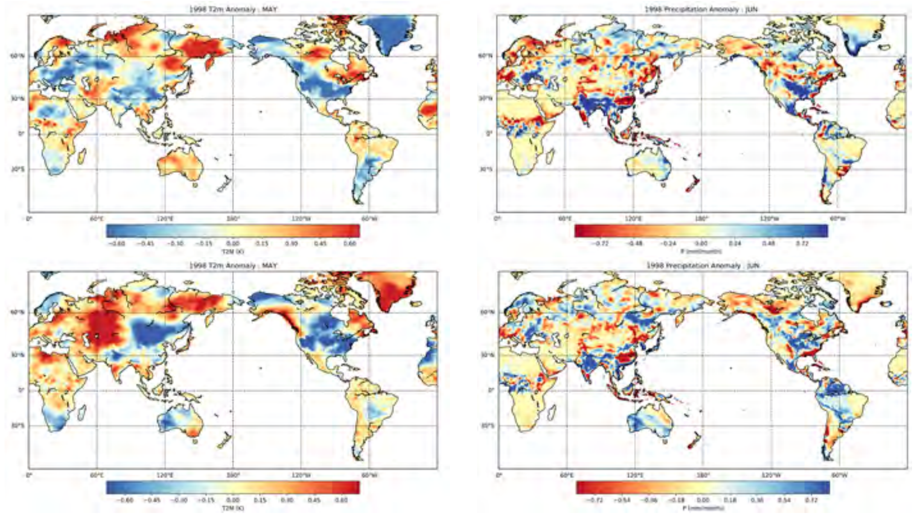


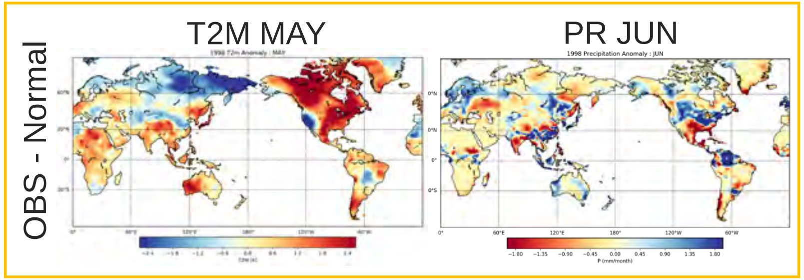


- The RM T2M was eventually lowered well in late MAY but not in early MAY
- The NoahMP's T2M tends to decrease compared to all initial cases. Such fluctuation may cause having uncertainty for this Exp., because T2M was not fully perturbed in MAY
- This cold perturbation produces drought in the Yangtze River/India/TX but is not strong in TX

[RM] With CLM







- Well perturbed (initial condition and target perturbation are the same)
- Cooling RM can trigger to a cold anomaly in TB?
- Produce drought in Yangtze River/India and the southwestern part of the US

Summary and Conclusion

KIAPS

- The snow model was corrected in NoahMP, and after that, its surface temperature tends to keep the initial condition but is not greatly improved clearly for the LS4P experiment

- In many cases, Noah and NoahMP cannot keep their initial temperature condition. However, CLM's result showed very stable conditions around all experiments. This can be because the number of soil layer

- For RM, all LSM-coupled models showed they have the ability to make the intended condition (Temperature in MAY) but not all of them had a strong signal for JUN PR

- The case studies showed that lowered Temperature in RM results in dry conditions in TX. Also, Lowered RM Temp. seems to be related to cooling TB and this can be linked to dry in South China. However, its linkage to JUN PR may need more experiments and analysis

- We found that clmtbx2 and ctlrmx2 experiments showed proper results for the LS4P project

- We need to analyze the mechanisms in the atmosphere, and we will additionally conduct SST-related experiments. Also, giving perturbation in both TB and RM areas can be an interesting experience