KIAPS
KOREA INSTITUTE OF ATMOSPHERIC PREDICTION SYSTEMS

Coupling Noah-MP to the Korean Integrated Model

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

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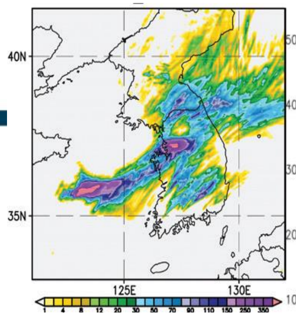
Korean Integrated Model (KIM)

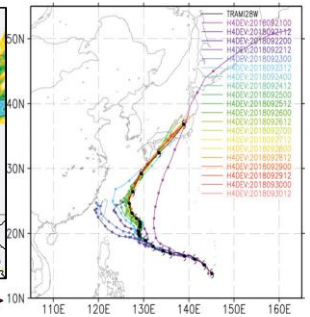
1 KIAPS phase I (2011~2019)

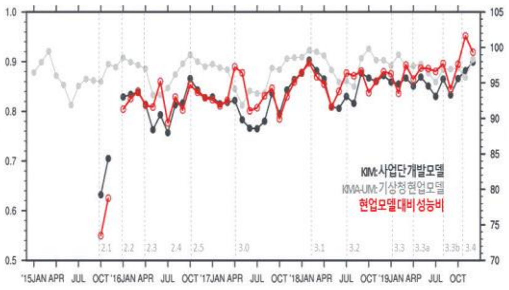
New atmospheric model

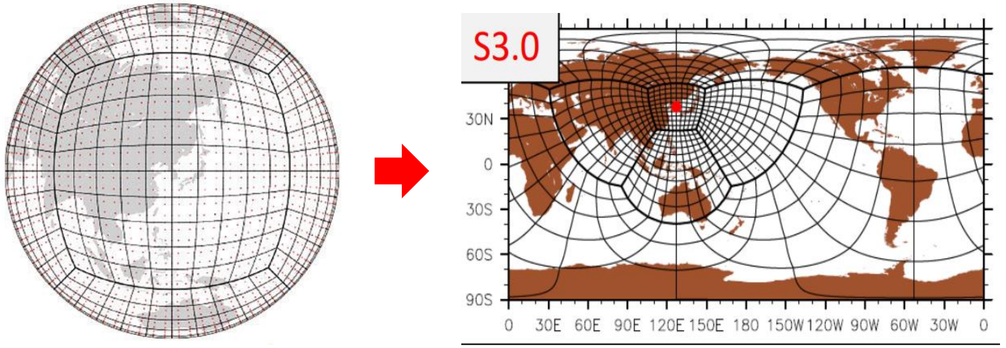
- New spectral element dynamical core on cubed-sphere grid
- New physics package and data assimilation system
- Deterministic medium-range weather forecast (~10 days)

➔ KIM has become operational since April 2020







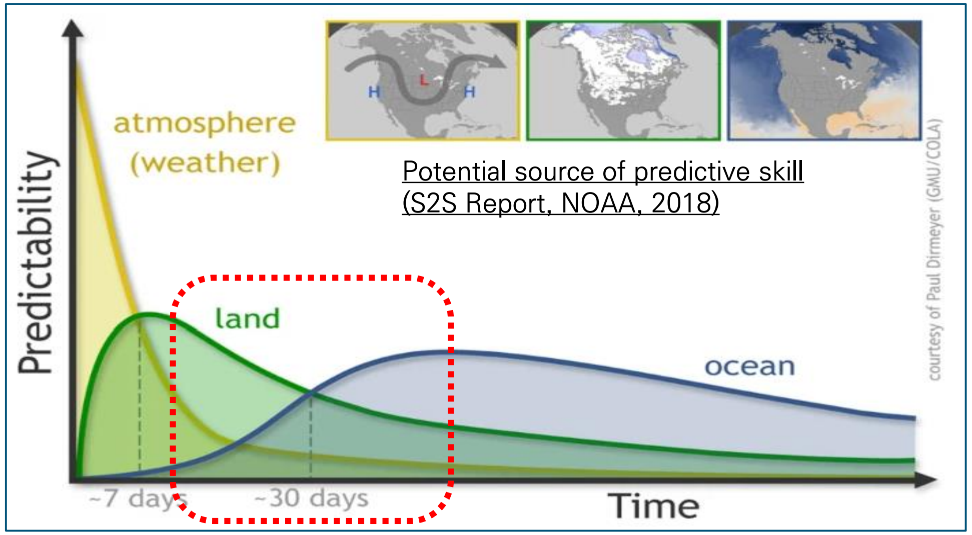


2 KIAPS phase II (2020~2026)

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



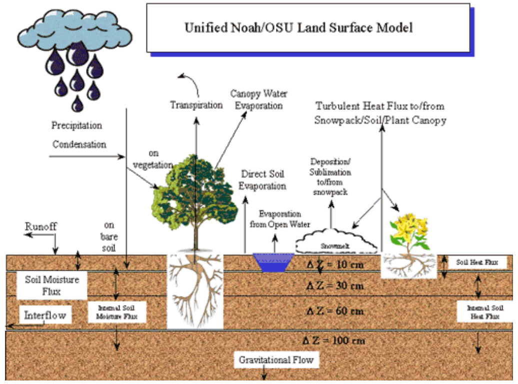
KIM surface process

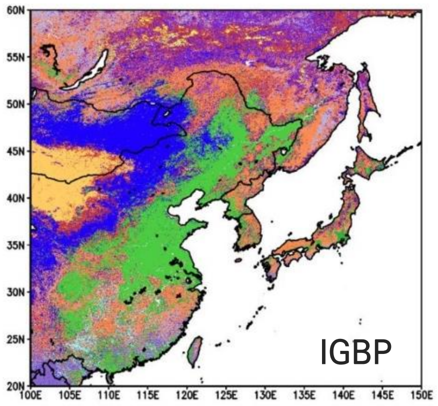
surface layer — **Monin-Obukhov Similarity Theory (based on GFS)**
Long (1984; 1986); Zeng et al. (2012); Wei et al. (2016); Koo et al. (2018)

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)



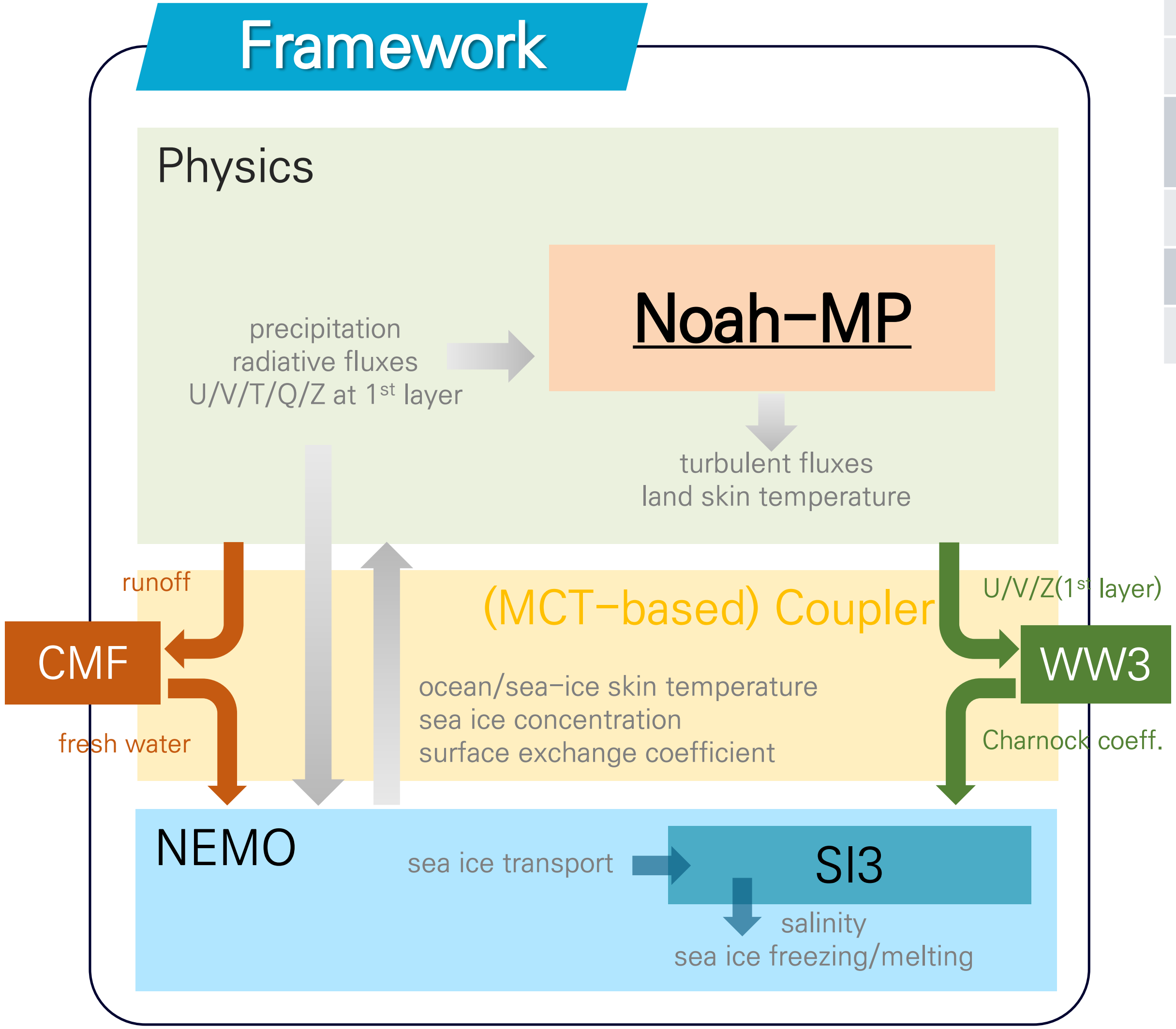


<u>KIM-Noah</u>

- 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)

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

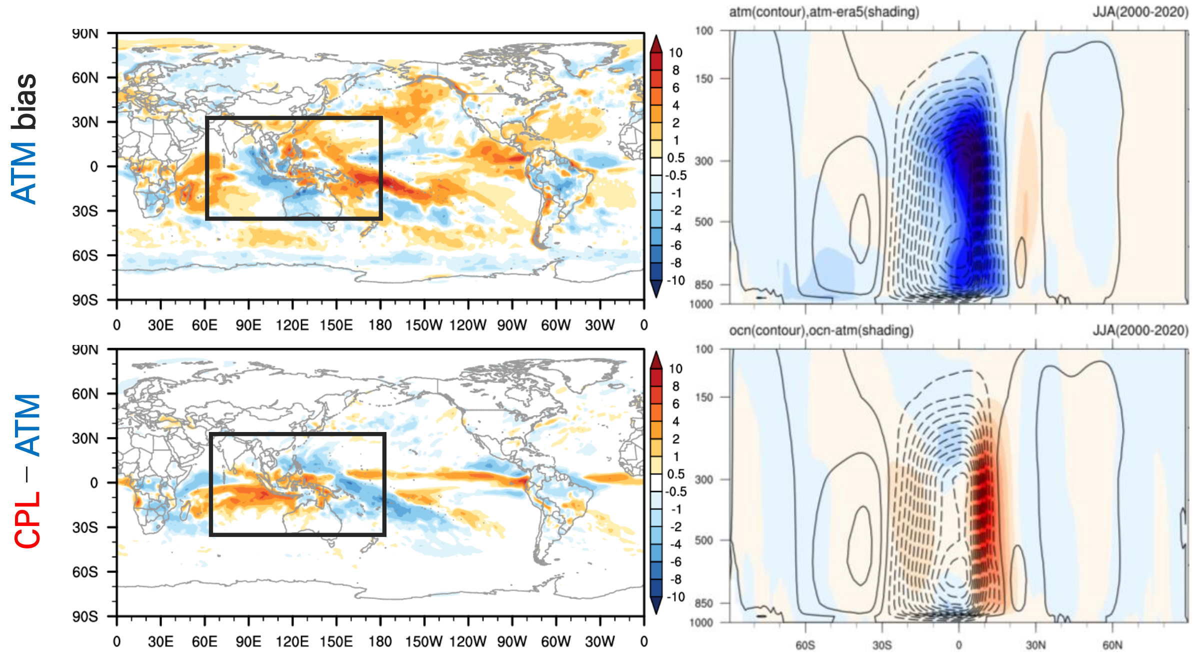
KIM coupled system



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)			

Precipitation
(DJF 2016-2017)

Hadley circulation
(JJA 2000-2020)

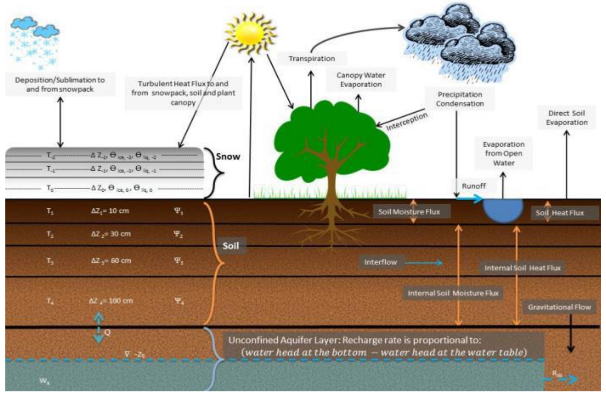


Advanced land surface model for KIM

Noah with multiple parameterization (Noah-MP)

- advanced version of research-based and operational Noah land surface model
- research purpose in WRF and LIS and operational purpose in NCEP-UFS

➔ portable and (still) cost-effective



	Snow layer	Snow density	Canopy flux	Radiative transfer	…
Noah	1 (blended)	fixed	No	No	…
Noah-MP	Up to 3	Variable	M-O	Two stream	…

Option	Description		Namelist
DVEG	Dynamic Vegetation option	4	Off (LAI from table; FVEG = max. vfrac)
CRS	Stomatal Resistance option	1	Ball-Berry
BTR	Soil Moisture Factor for Stomatal Resistance	1	Noah
RUN	Runoff and Groundwater option	1	TOPMODEL with groundwater
SFC	surface layer drag coefficient calculation	1	Monin-Obukhov
FRZ	Supercooled Liquid Water option	1	No iteration
INF	Soil Permeability option	1	Linear effects, more permeable
RAD	Radiative Transfer option	1	Two-stream applied to vegetated
ALB	Ground Surface Albedo option	1	BATS
SNF	Precipitation Partitioning between snow and rain	1	Jordan (1991)
TKSNO	Snow Thermal Conductivity	1	
TBOT	Soil Temperature Lower Boundary Condition	2	TBOT at 8 m from input file
STC	Snow/Soil temperature time scheme	1	semi-implicit
GLA	glacier treatment option	2	slab ice (Noah)
RSF	surface evaporation resistance option	1	Sakaguchi and Zeng, 2009
SOIL	options for defining soil properties	1	use input dominant soil texture

* No crop/urban/irrigation/tile-drain

CPL21.01 (DEC 2021)

Noah-MP V4.0.1 (lsm_flag=2)

- LIS-based code

CPL22.01 (AUG 2022)

Noah-MP V4.2 (lsm_flag=3)

- WRF-based code

CPL22.02 (OCT 2022)

Noah-MP V4.4 (lsm_flag=3)

- Code clean-up
- More parameter in namelist
- Irrigation/tiledrain module
- Revision in CWPVT table value
- New canopy heat storage
- SNOW_EMIS=1.0→0.95

CPL23.01 (JUN 2023)

Noah-MP V5.0 (lsm_flag=4)

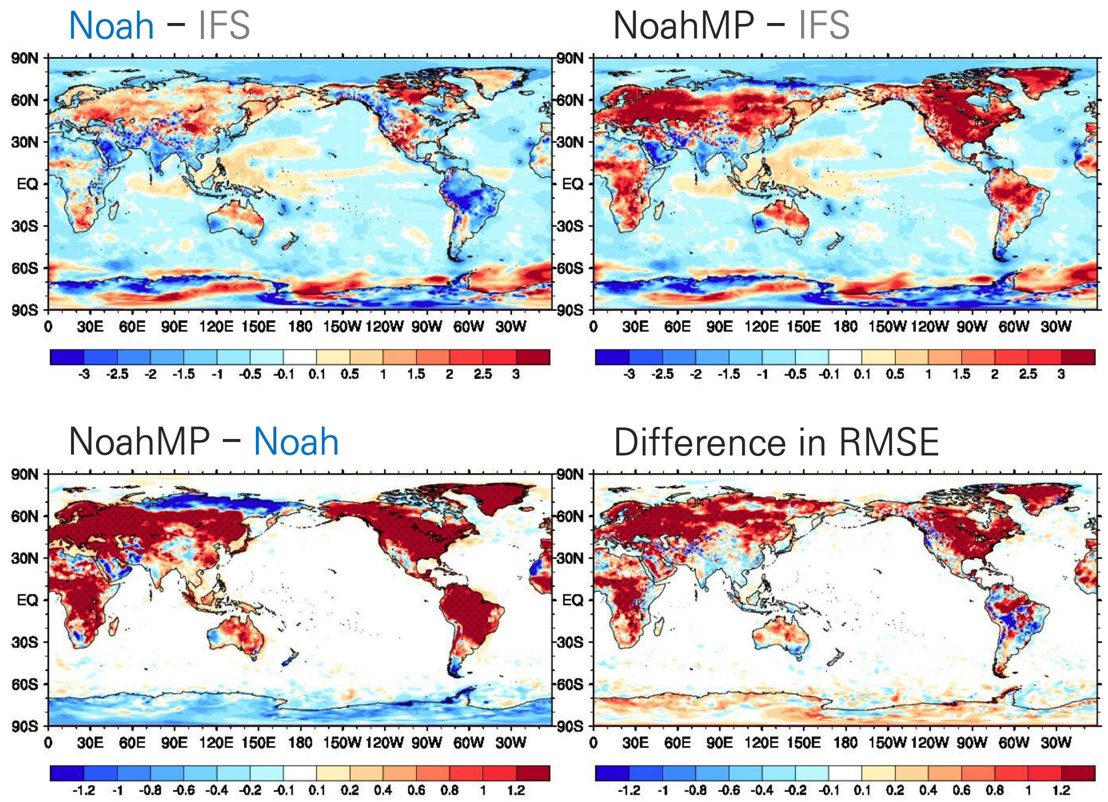
- Modernized/refactored code
- Glacier SNOW_EMIS=0.98→0.95

w/ own updates for KIM-NoahMP

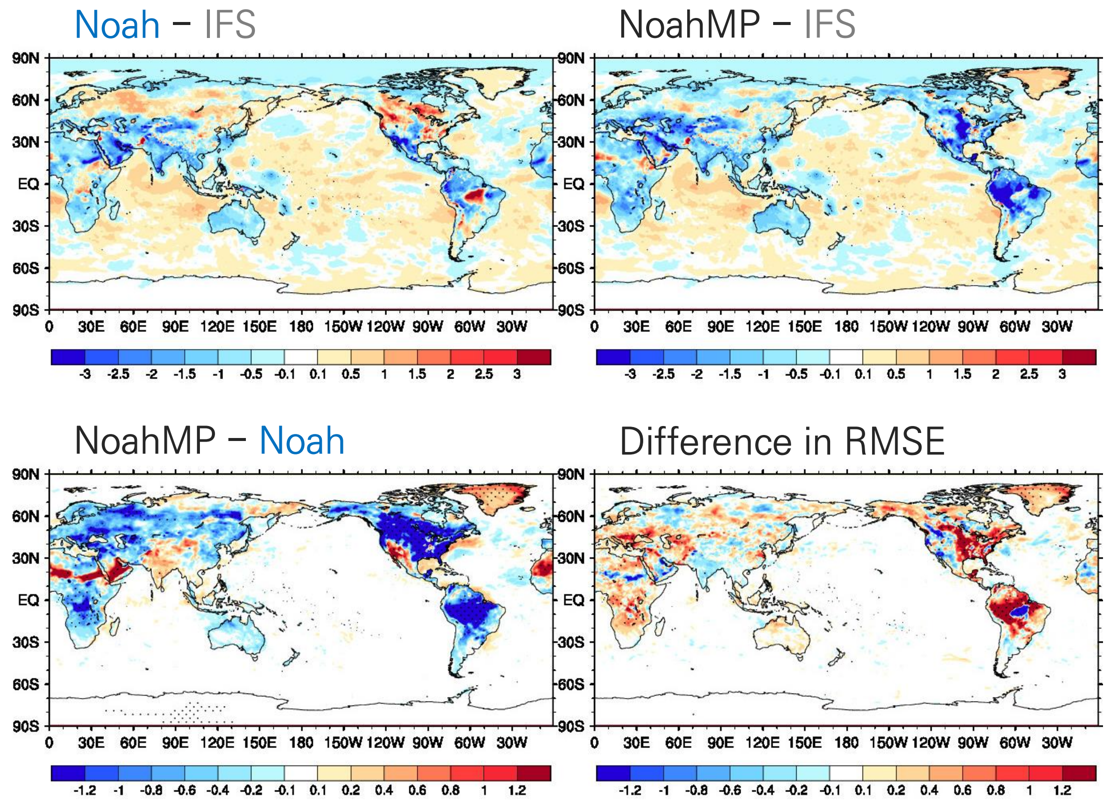
Noah vs. Noah–MP in KIM (forecast day 5, July 2017)

* NoahMP: V5.0 w/o any physical revision

2–m temperature



2–m specific humidity



- Generally warm and dry, especially over forest
- Cold over tundra region

Noah vs. Noah-MP in KIM (forecast day 5, January 2017)

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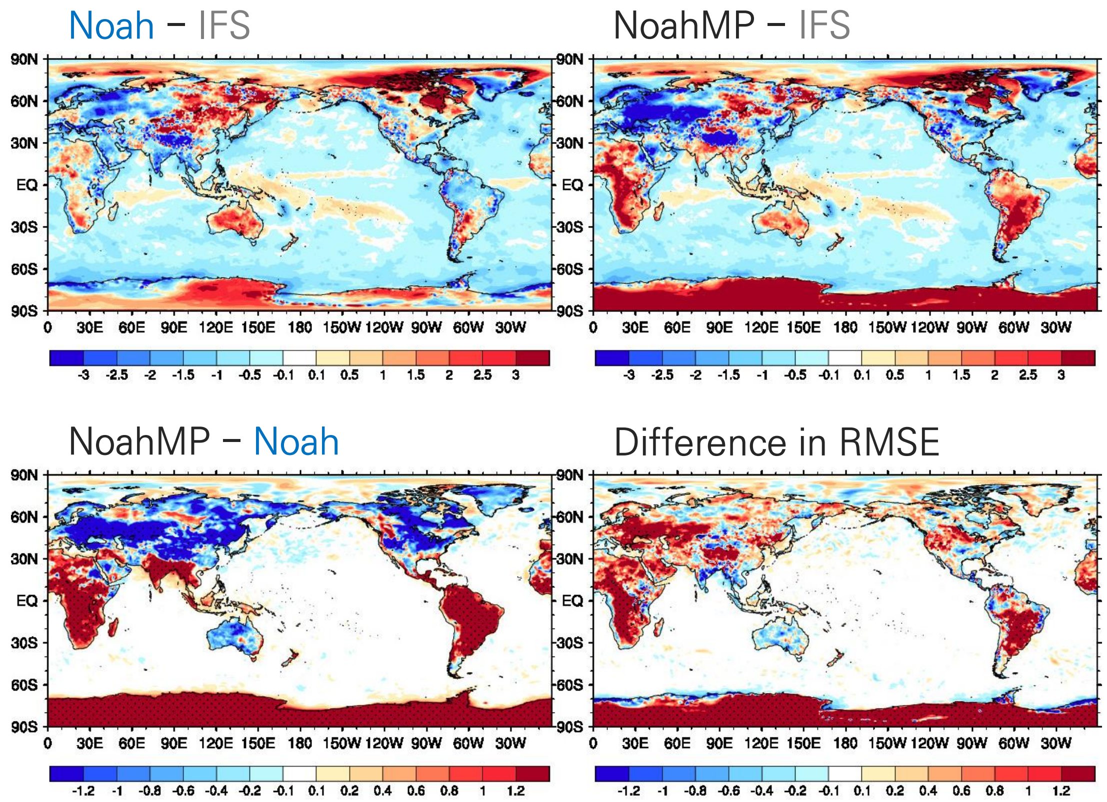
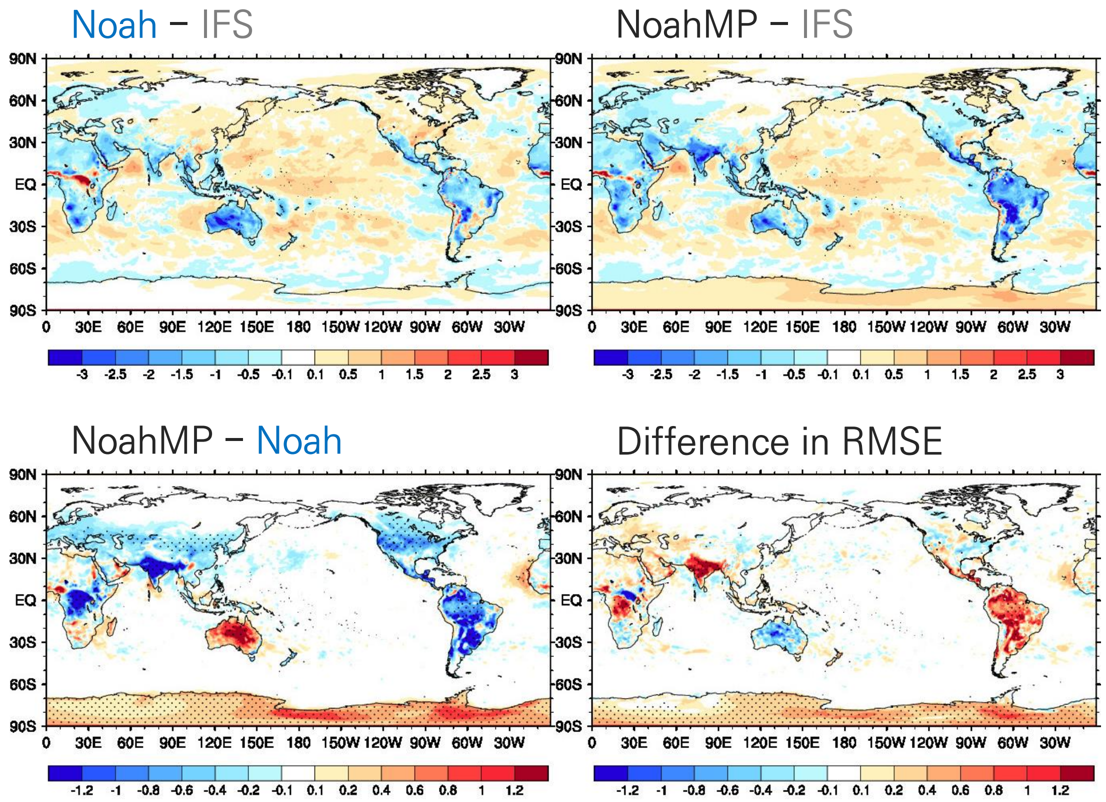
* NoahMP: V5.0 w/o any physical revision

2-m temperature



2-m specific humidity



- Cold over snow region, while warm and dry over forest
- Too warm over the Antarctic

Updates for KIM-NoahMP

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Exp.	Description	Remark	Version
NOAH	Noah	Revised Noah V3.4.1 (Koo et al. 2017/2018)	
MP0	Noah-MP V5.0	Technical implementation w/o any physical revision	
MP1	Fixed snow albedo (0.82) over glacier ice	Same to Noah	22.02 (October 2022)
MP2	No canopy heat storage	Same to Noah-MP V4.2	
MP3	CWPVT=0.67→0.18 for evergreen broadleaf forest	Same to Noah-MP V4.2	
MP4	Use of 2D soil color data	Same to CLM V5.0	23.01 (June 2023)
MP5	Bare soil emissivity 0.97 to 0.90	Same to Noah	
MP6	No nitrogen effect (foliage nitrogen factor=1)		
MP7	New table values for VCMX5	Same to CLM V5.0	

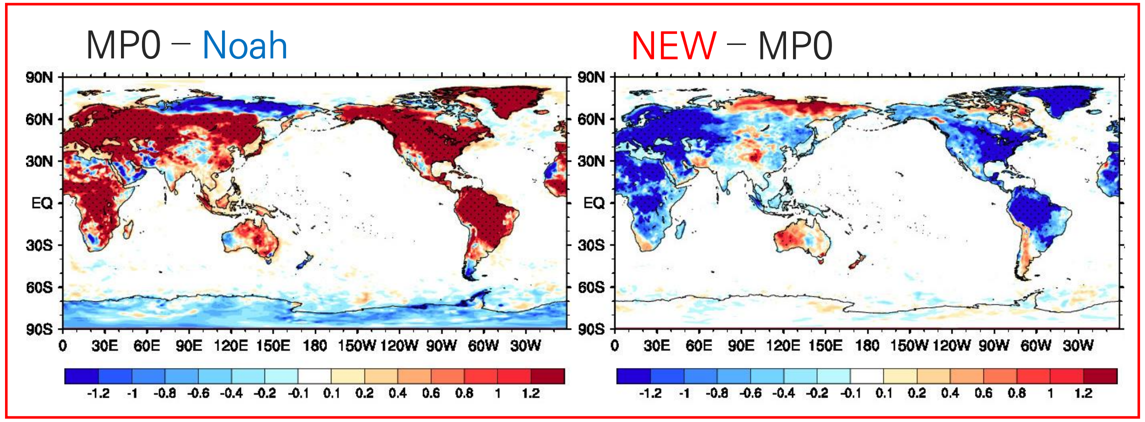
✓ NEW: Noah-MP V5.0 w/ MP1-7

➔ Toward reducing systematic **warm** and **dry** biases

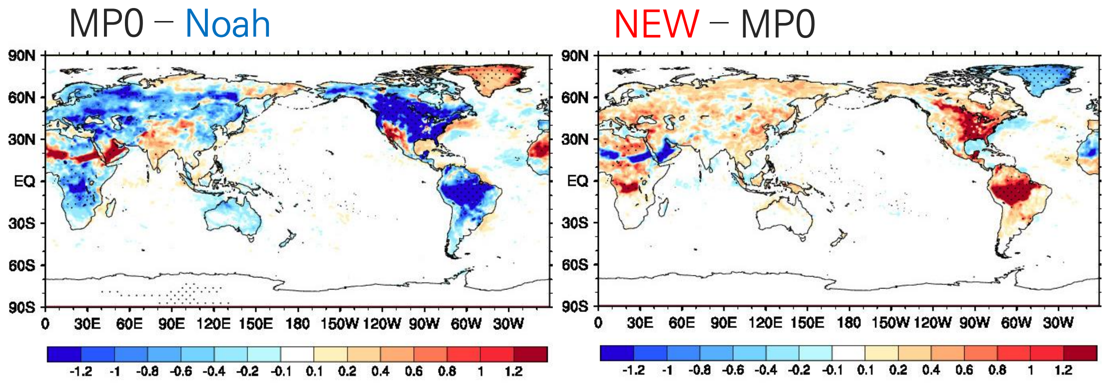
Sensitivity to the updates (JUL 2017)

* NEW : Noah-MP V5.0 w/ MP1-7

2-m temperature



2-m specific humidity



MP1 (snoalb)

MP2 (canhs)

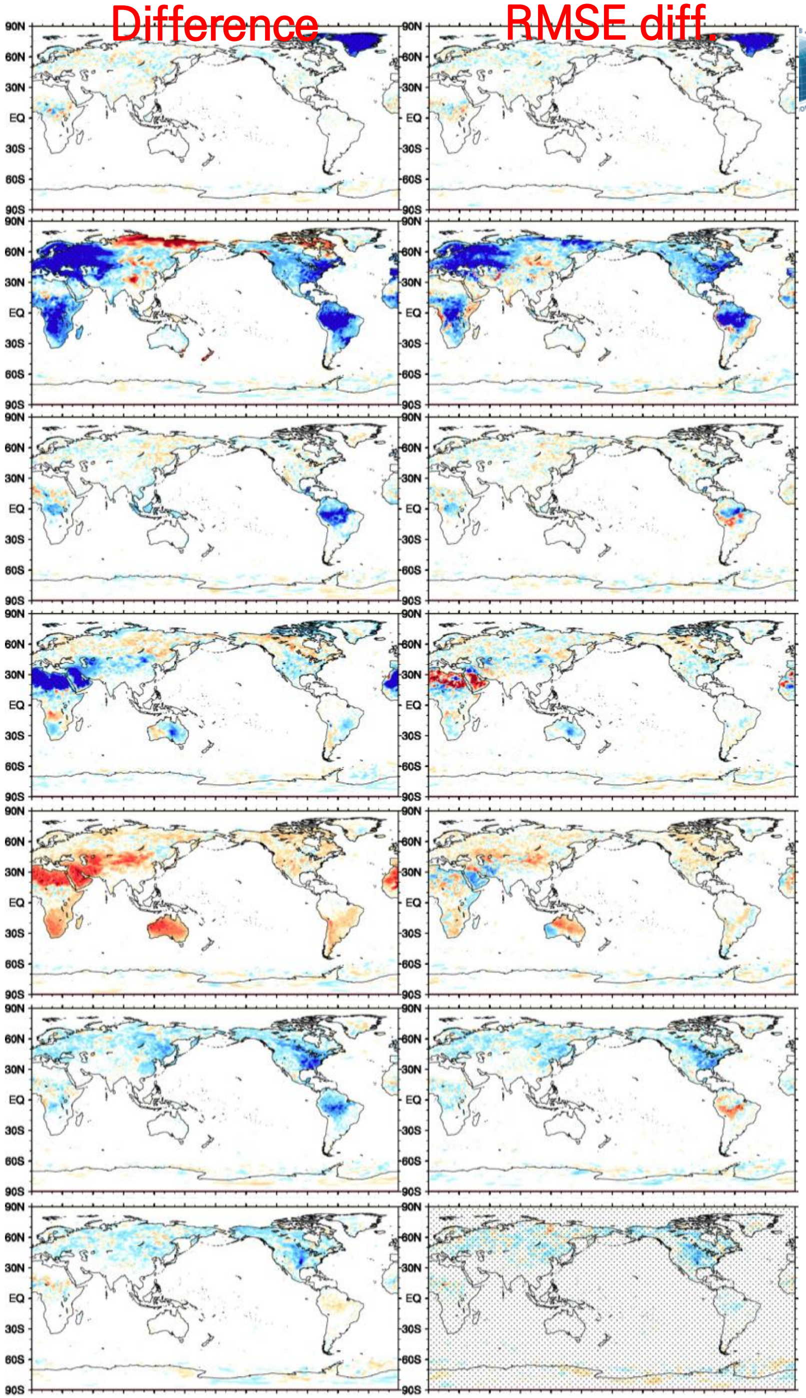
MP3 (cwpvt)

MP4 (scolor)

MP5 (barems)

MP6 (fnf1)

MP7 (vcmx5)



Sensitivity to the updates (JAN 2017)

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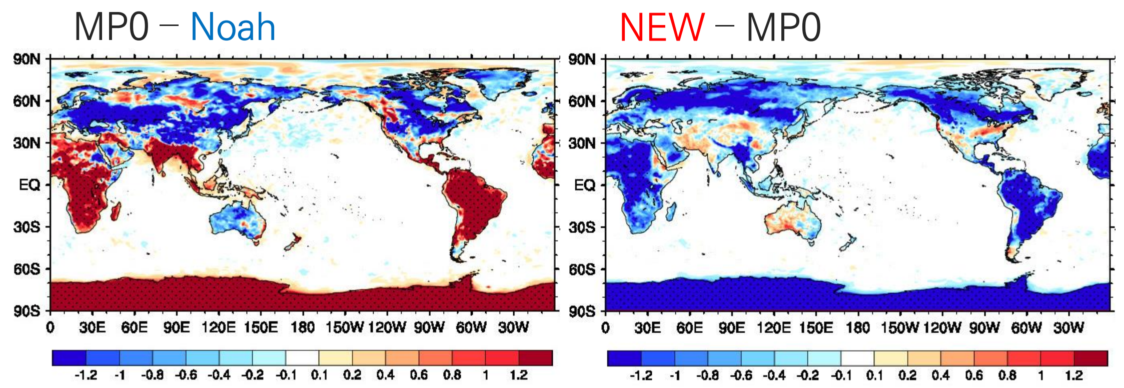
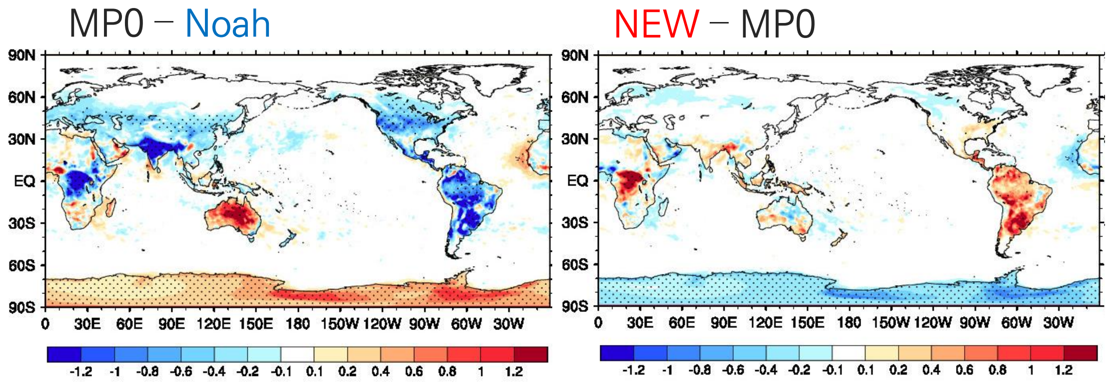
* NEW : Noah-MP V5.0 w/ MP1-7

2-m temperature



2-m specific humidity



MP1 (snoalb)

MP2 (canhs)

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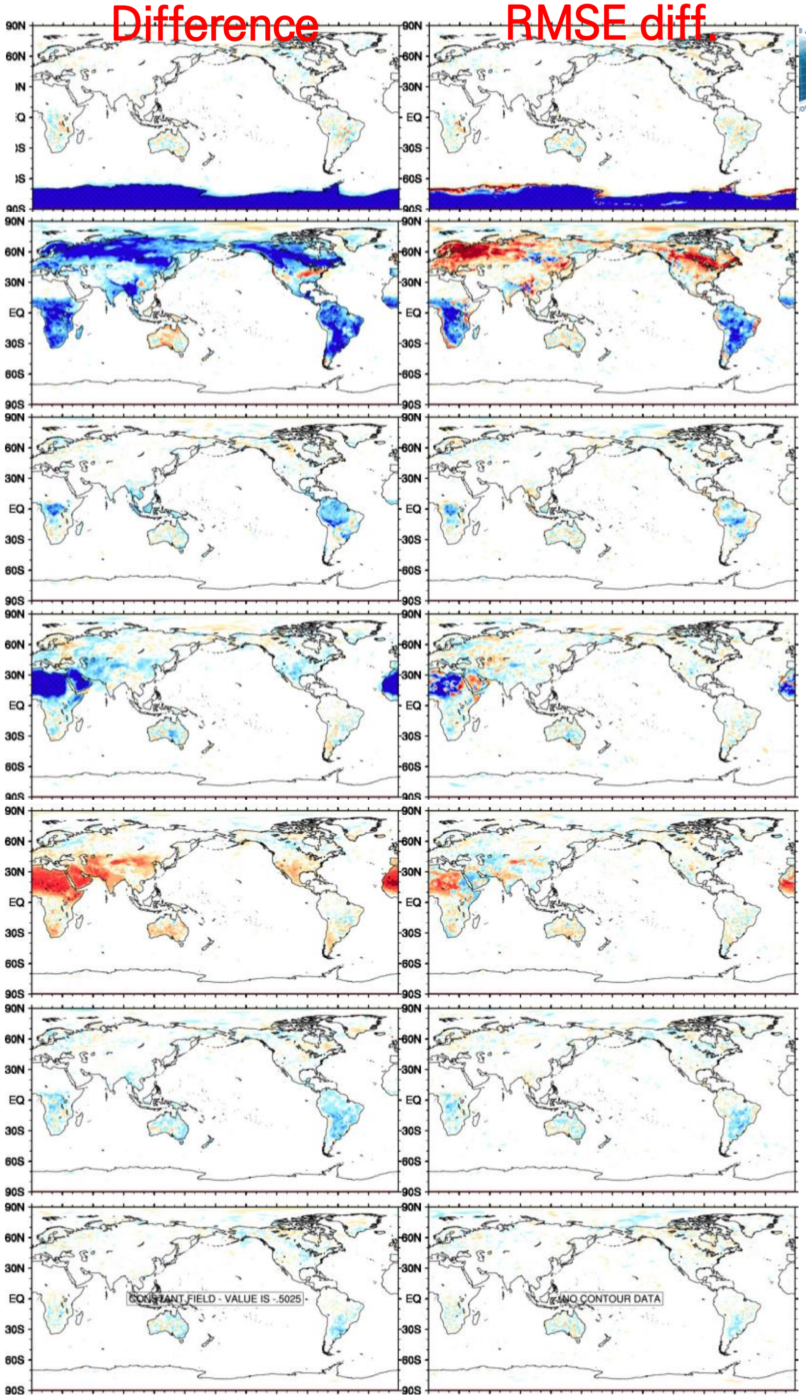

Vertical profile of temperature (against IFS)

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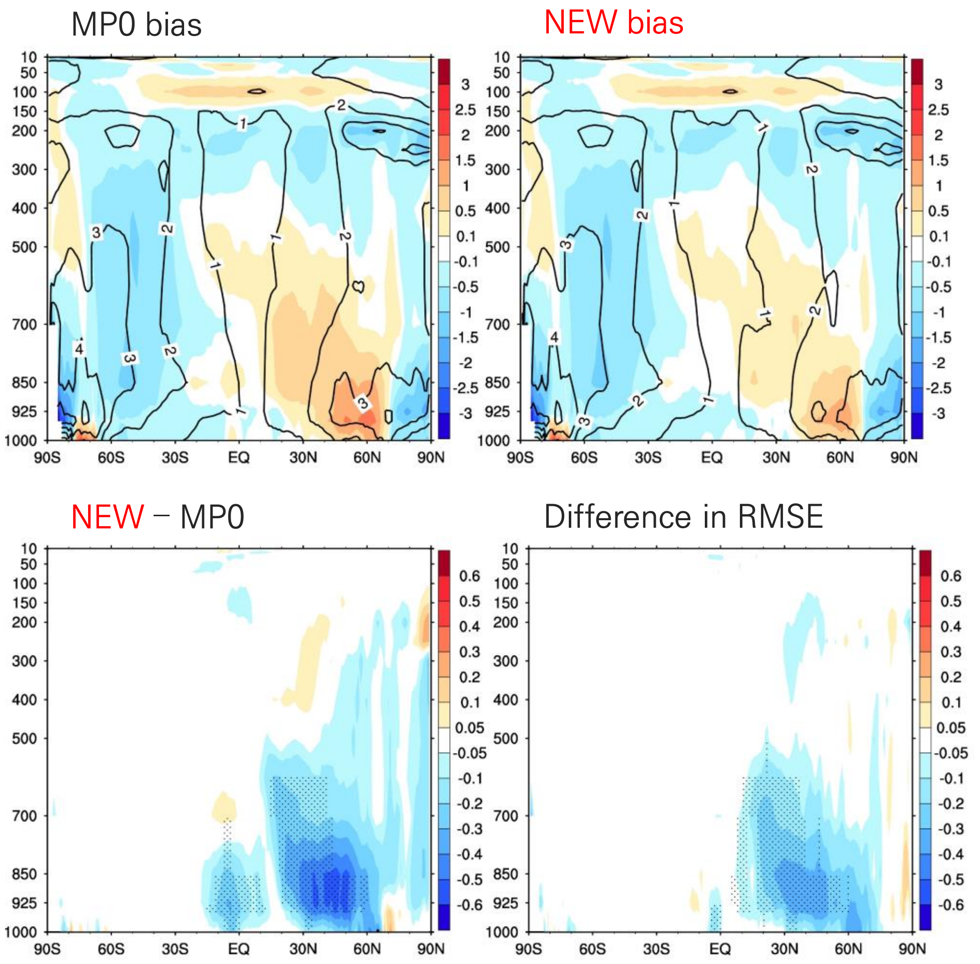
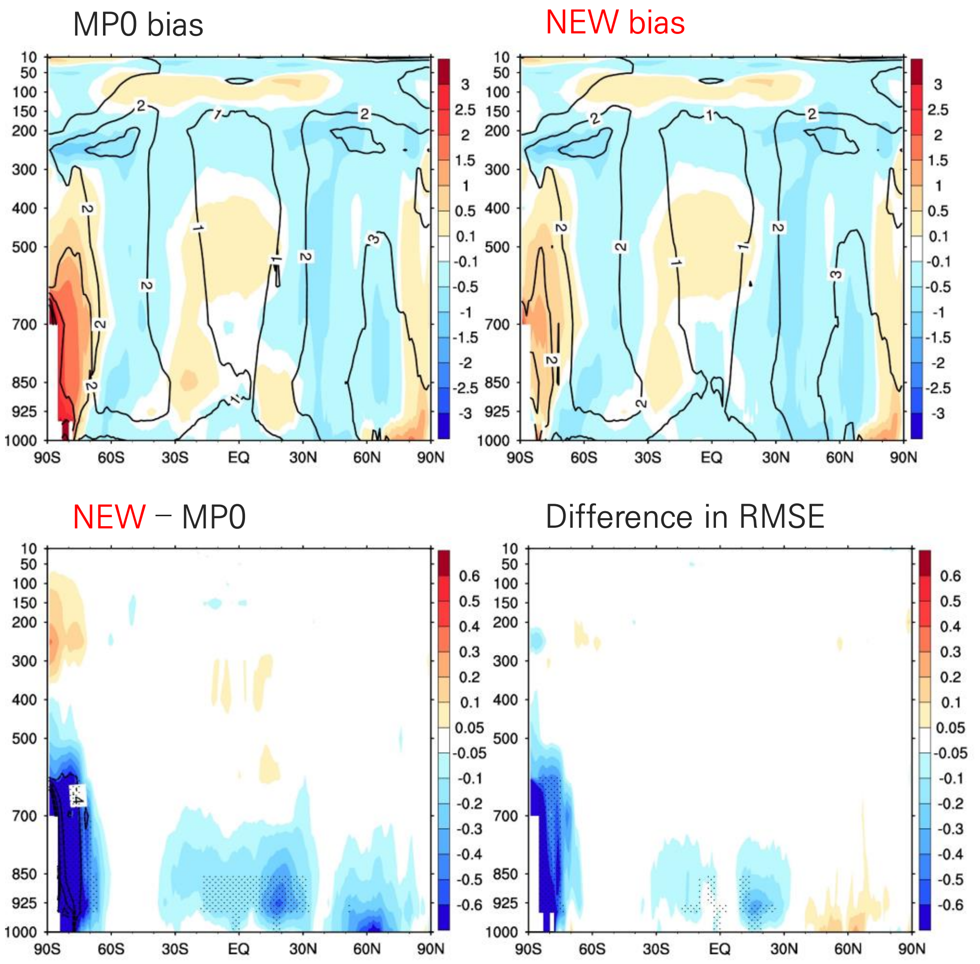
* NEW : Noah-MP V5.0 w/ MP1-7

July 2017



January 2017

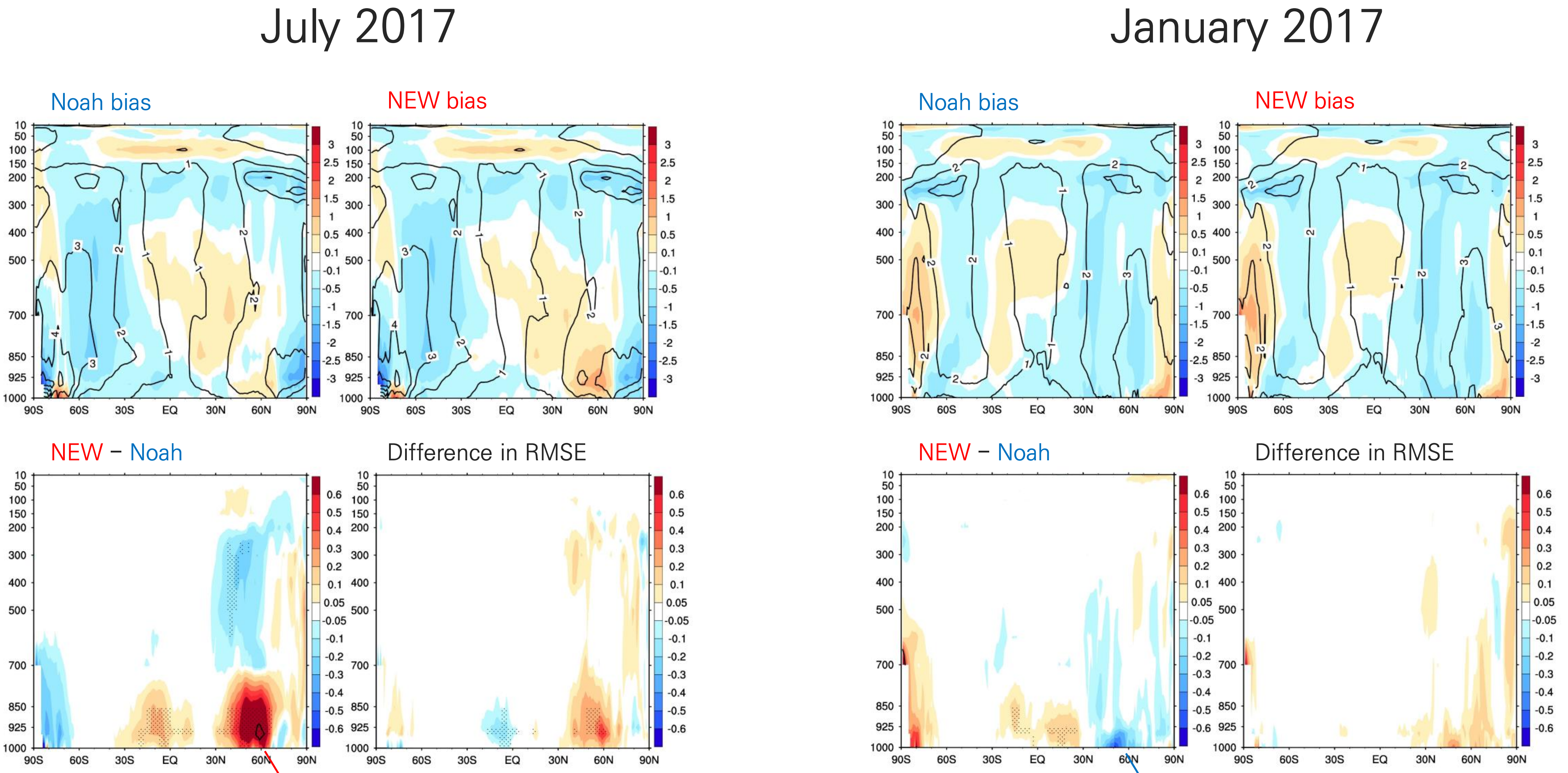


➔ highly improved in temperature

Vertical profile of temperature (against IFS)

Noah vs. Noah–MP

* NEW : Noah–MP V5.0 w/ MP1–7

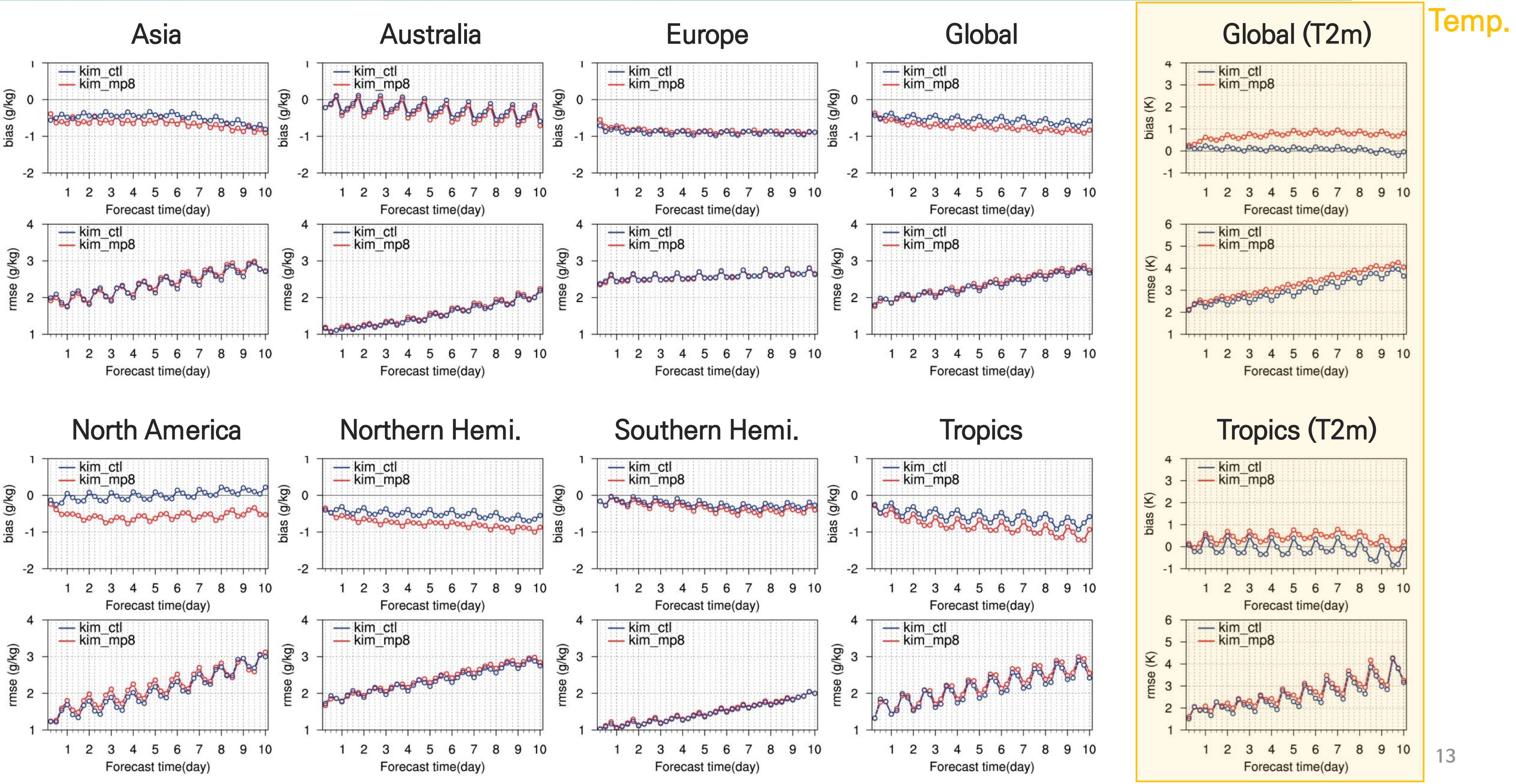


still warmer over forest (and dry)

still colder over snow (and dry)

Q2m against surface observation (July 2017)

Noah vs. Noah-MP

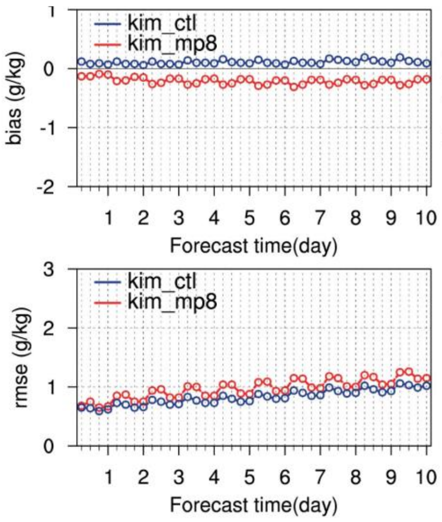


Q2m against surface observation (January 2017)

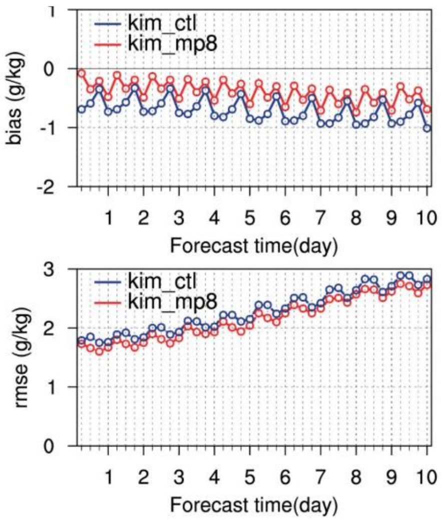
Noah vs. Noah-MP

Temp.

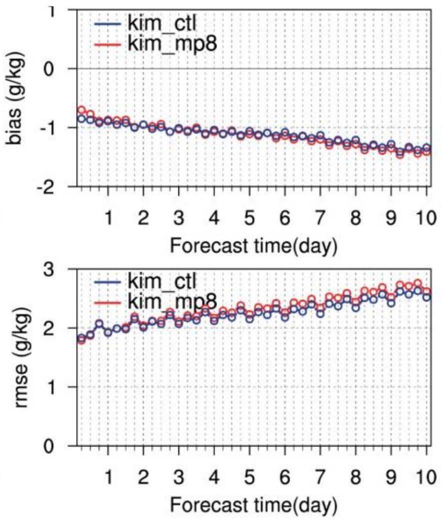
Asia



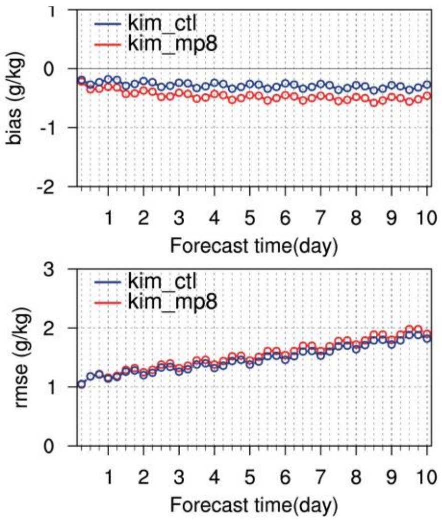
Australia



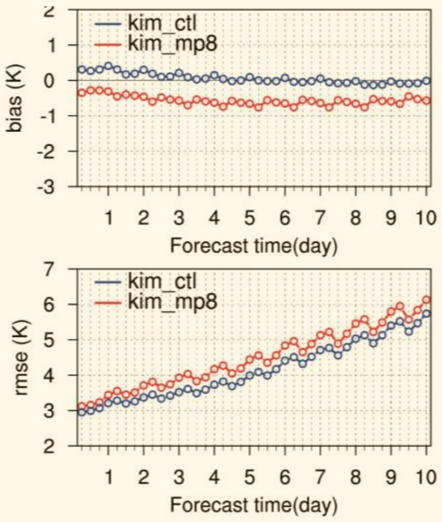
Europe



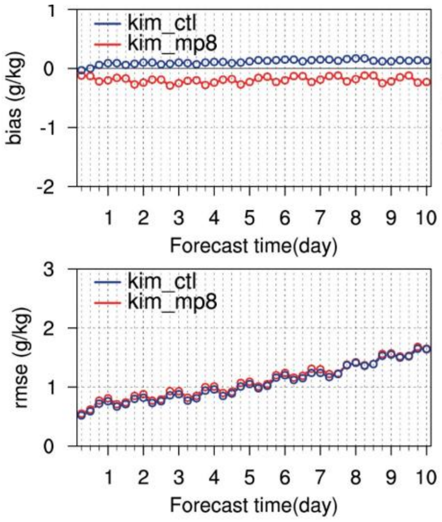
Global



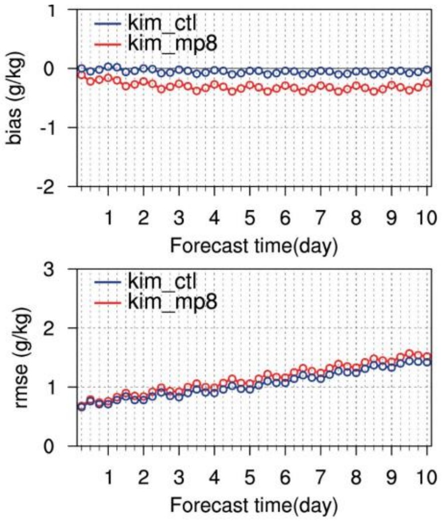
Global (T2m)



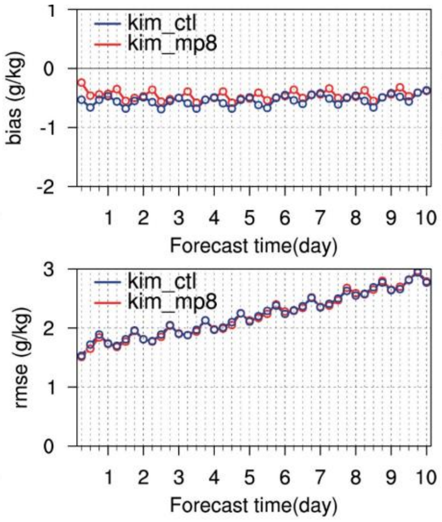
North America



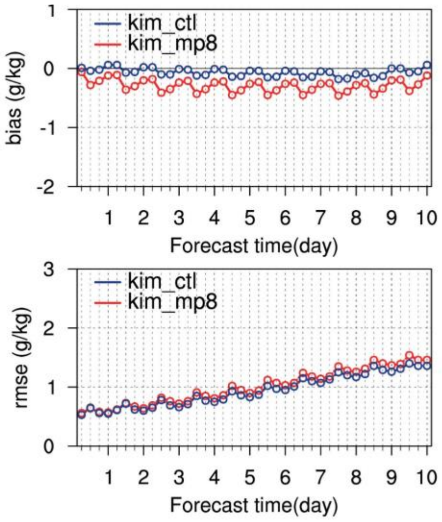
Northern Hemi.



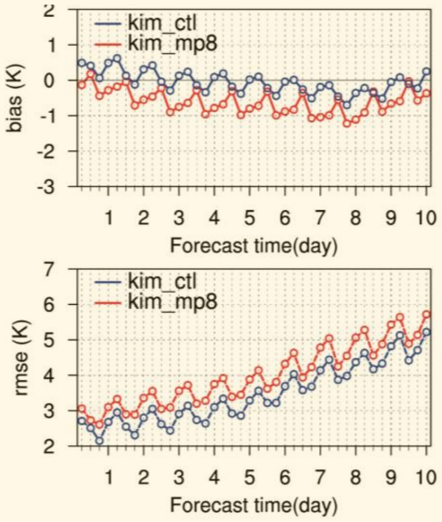
Southern Hemi.



Tropics



Tropics (T2m)



Seasonal simulation: 2-m temperature (against ERA5)

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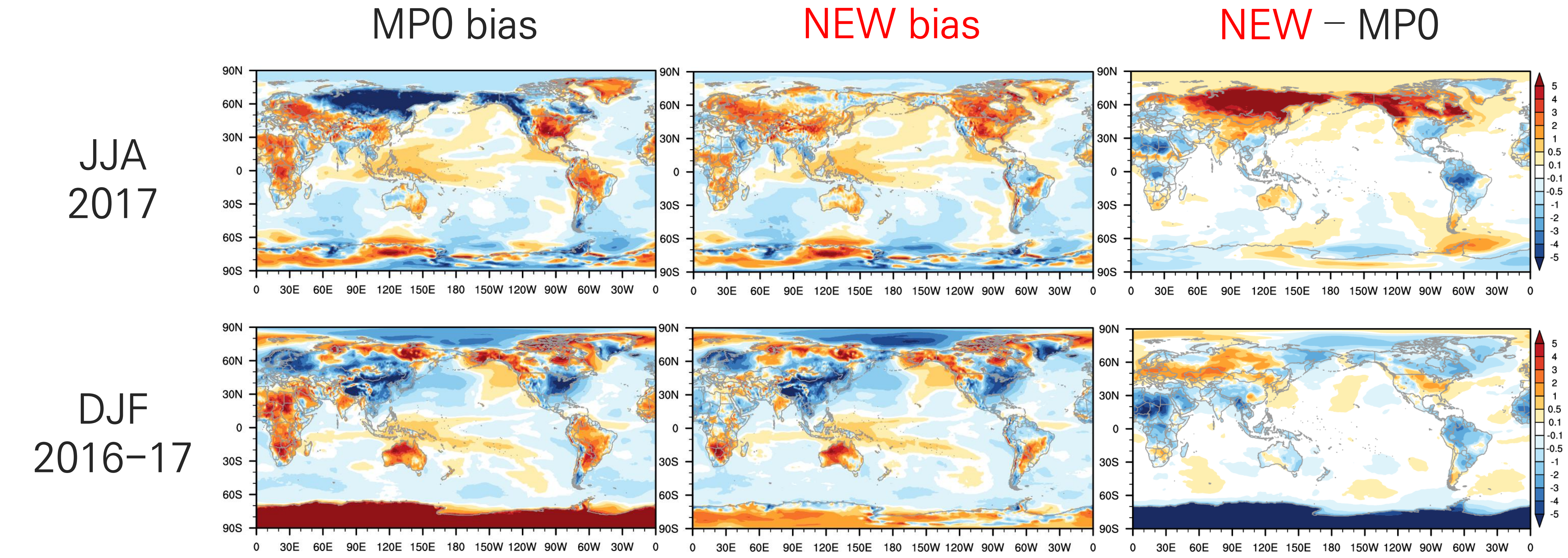
* NEW : Noah-MP V5.0 w/ MP1-7

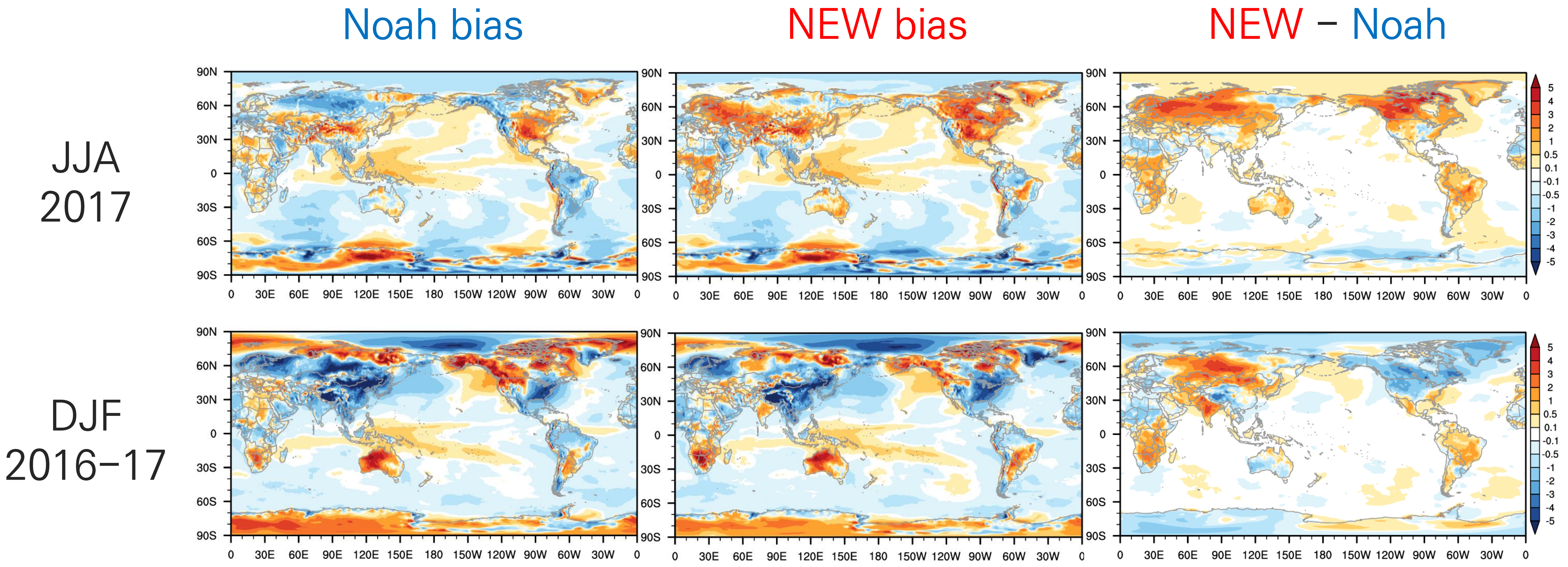


- The improvement in temperature is preserved in terms of seasonal mean.
  - mainly due to canopy heat storage, soil color/emissivity, glacier snow albedo
  - also improved in wind, moisture, … (not shown here)

Seasonal simulation: 2-m temperature (against ERA5)

Noah vs. Noah-MP

* NEW : Noah-MP V5.0 w/ MP1-7



- generally warmer over forest similar to medium-range forecast
- rather warmer over snow ? why?

KIM-Single column model (SCM)

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RESEARCH ARTICLE

Long-term single-column model intercomparison of diurnal cycle of precipitation over midlatitude and tropical land

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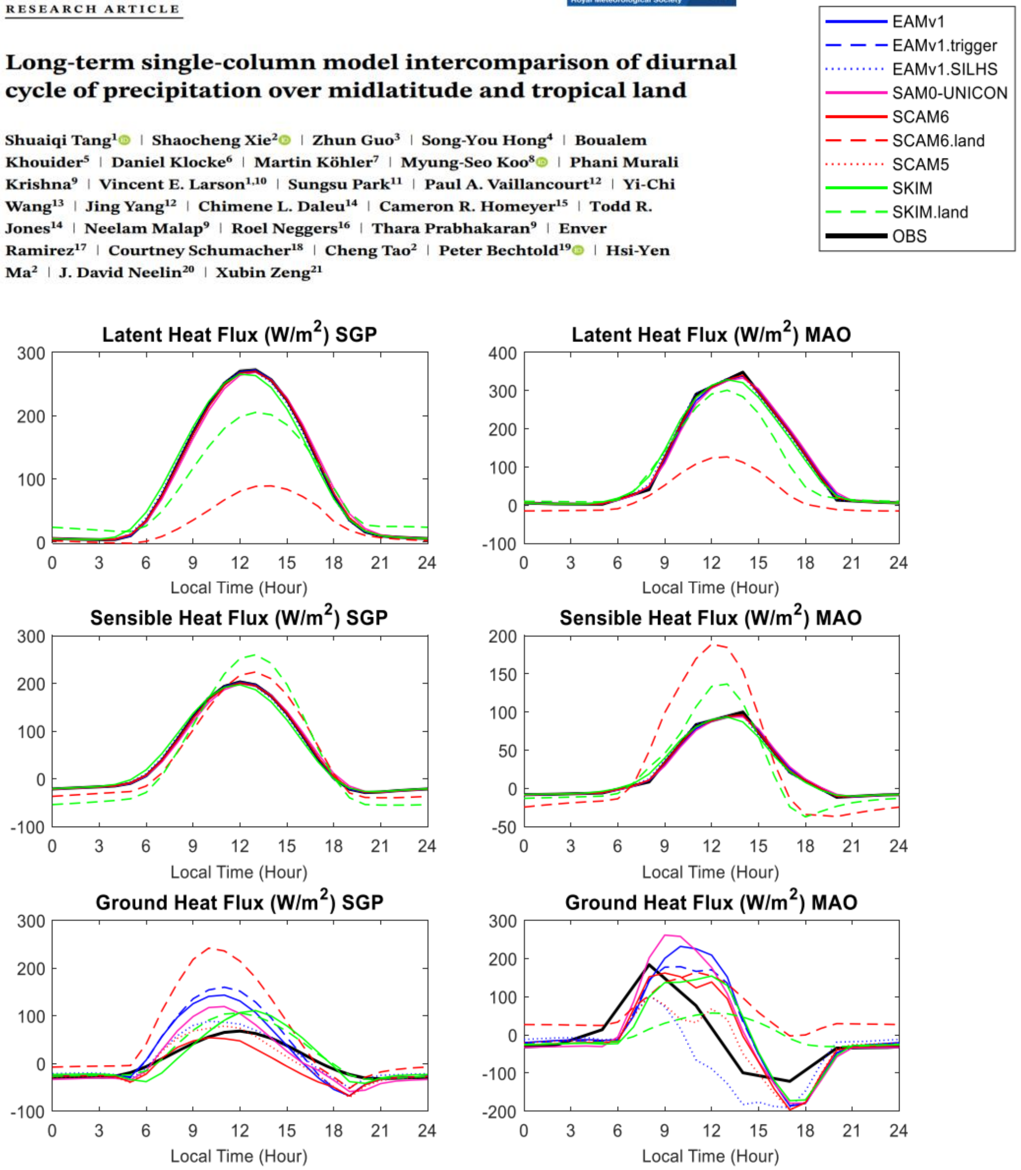
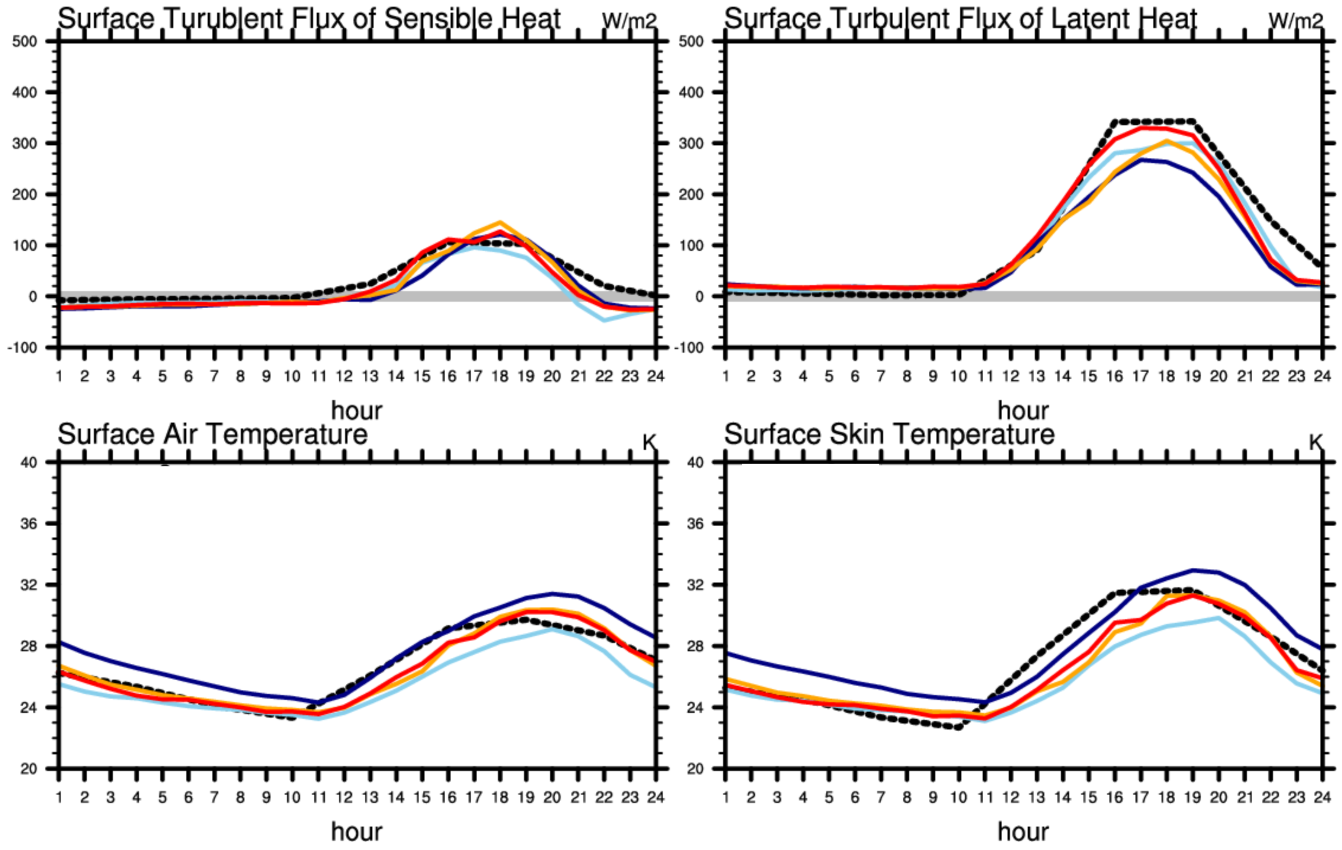


Dry season (GoAmazon)

OBS
Noah
MP1 (ORG)
MP4 (22.02)
MP8 (NEW)



- Distinct improvement with updates
- Being tested for other cases (wet, clear, ..)

Summary

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✓ The recent version of Noah-MP (V5.0) LSM has been successfully coupled to the Korean Integrated Model (KIM).

✓ From KIM's point of view, the systematic biases were found in Noah-MP LSM as below:

- warm and dry bias over forest and arid region
- cold and (weakly) dry bias over snow region
- warm and wet bias over glacier region

✓ The systematic warm and dry biases could be rectified by

- removing canopy heat storage over forest region
- using a fixed snow albedo over glacier region
- employing soil color map over arid region
- (temporarily) not considering foliage nitrogen effect
- refining a reference table values (CWPVT, VCMX5)

✓ In the next version of coupled KIM with the aforementioned updates, Noah-MP LSM will offer a comparable performance to Noah LSM in terms of medium-range forecast and seasonal prediction.

Ongoing and future work: physical consistency

Surface layer parameterization

Physics module		Friction velocity	Exch. coeff. for momentum	Exch. coeff. for heat/moisture	wind speed (z=1)
SFC (based on GFS)		u*	$C_m \sim f(F_m)$	$C_h \sim f(F_h)$	w/ SGS effect
LSM	Noah			C_h	w/ SGS effect
	Noah-MP	u*	$C_m = C_h \sim f(F_m = F_h)$		lower limit=1
PBL		u*	F_m	F_h	w/ SGS effect

Surface albedo and emissivity

Physics module		Albedo (4-class: diffused/direct for VIS/NIR)	Emissivity
RAD		MODIS-based clim.	Noah Table
LSM	Noah	SW_{net} from RAD	Noah Table
	Noah-MP	parameterized	parameterized

Ongoing and future work: advancement in physics and input data

New method development:

Determination of vegetation layer emissivity, reflectivity, and transmittivity with simplified method

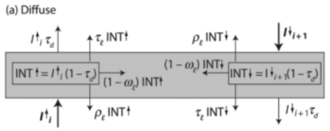
New model is designed by fusing

Analytic solution based on Beer-Lambert law

$$\varepsilon_v = 1 - \exp(-LAI)$$

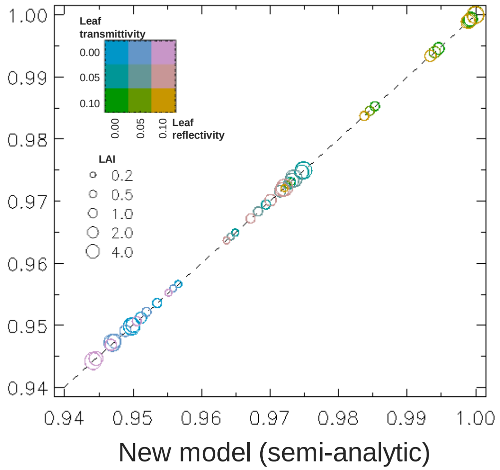
and

Numerical model of multi-vegetation layer [Norman 1979]

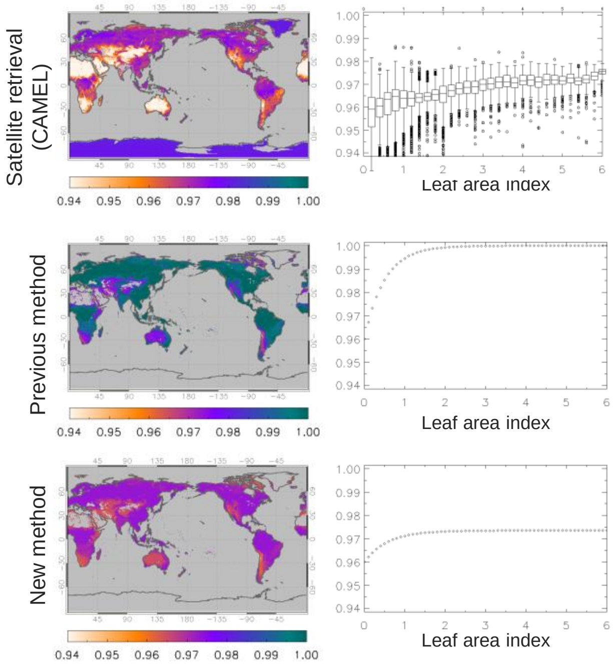


[Image from Bonan, 2019]

Land surface emissivity with different conditions



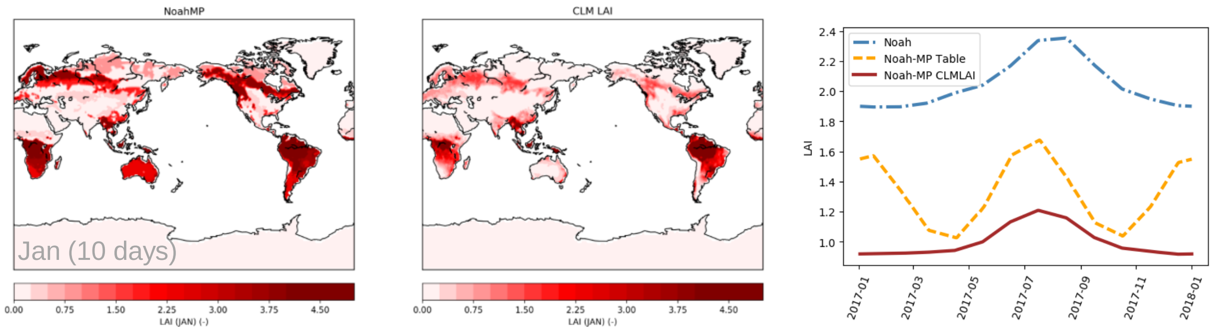
Land surface emissivity in July, 2016



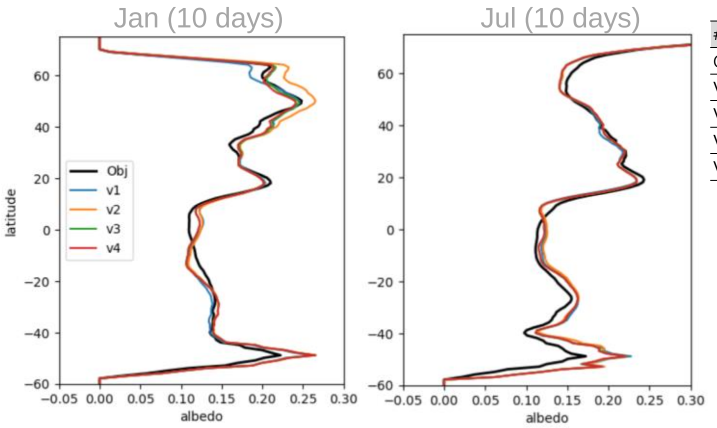
Update Vegetation Parameters:

Applying leaf/stem area index (LSAI) and canopy top height (HTOP) to the NoahMP

- Noah, NoahMP, and CLM use significantly different LAI/SAI: (1) Noah LAI has an unrealistically high value, (2) Noah-MP has an abnormal seasonal cycle
- CLM LAI climatological data was made based on MODIS but Noah and Noah-MP take a table value that variates depending on the surface type



- Applying only correct LAI generally increases model error including T, RH, etc.
- Correct LAI can improve surface albedo in the summer: snow may mainly affect the winter albedo
- SAI and HTOP play an important role in albedo estimation
- Applying the data consistency gives better results than applying individual data



#	LSM	Vegetation	RMSE (JAN)	RMSE (JUL)
Obj	Noah	Obj	-	-
V1	NoahMP	Table	0.0358	0.0326
V2	NoahMP	CLM LAI	0.0384	0.0325
V3	NoahMP	CLM LAI+SAI	0.0368	0.0322
V4	NoahMP	CLM LAI+SAI+HTOP	0.0365	0.0320

Thank you for listening