KIAPS
KOREA INSTITUTE OF ATMOSPHERIC PREDICTION SYSTEMS

Current Status and Plan of KIM/Noah-MP Coupled Model

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

Coupled Model Team

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Korean Integrated Model (KIM)

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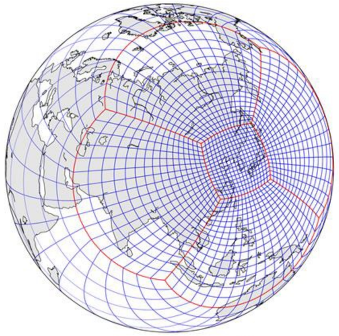
KIAPS phase I (2011~2019)

New atmospheric model

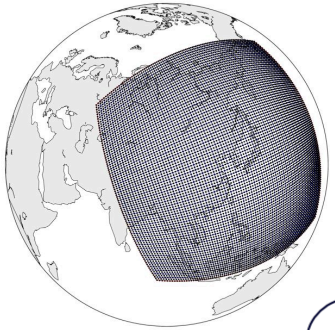
- New spectral element dynamical core on cubed-sphere grid
- New physics package and data assimilation system
- Deterministic medium-range weather forecast (~10 days)

➔ KIM has become operational since April 2020

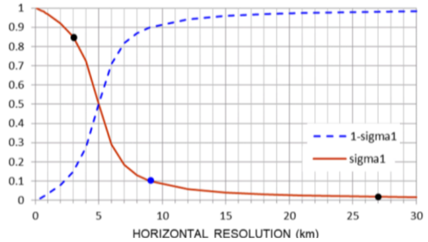
Stretched grid



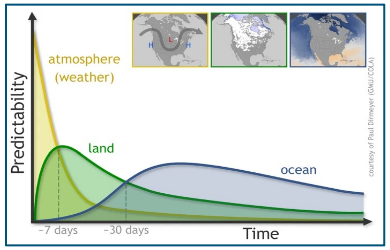
Limited-area model



Scale-aware physics



Extended-range forecast



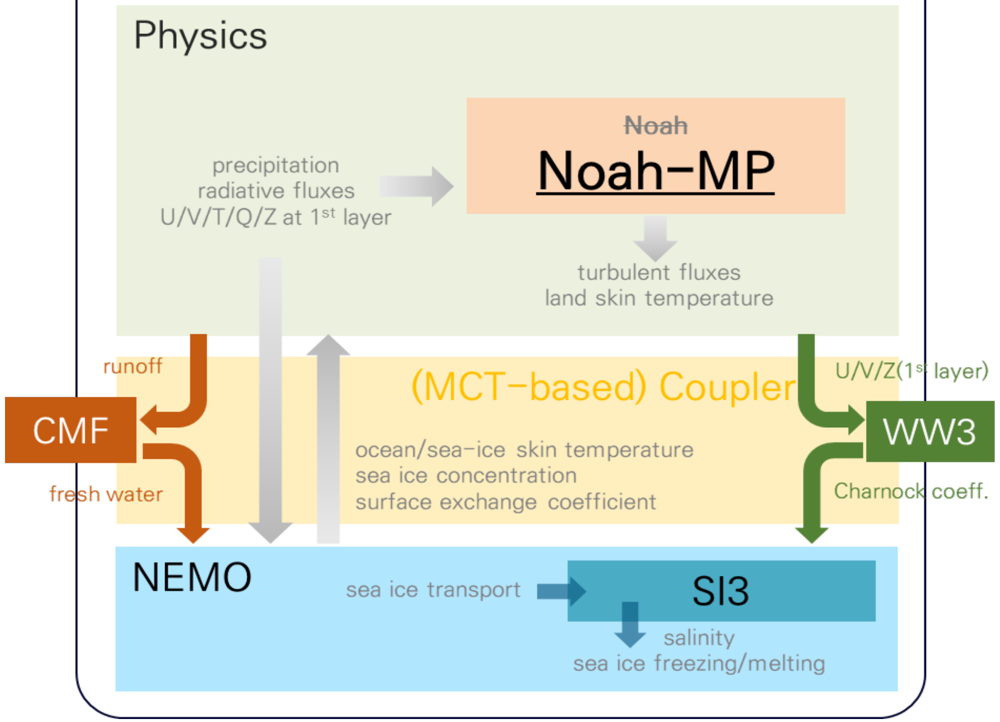
KIAPS phase II (2020~2026)

Seamless and coupled model

- Scale-aware physics for 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 coupled modeling system



Advanced land surface model for KIM

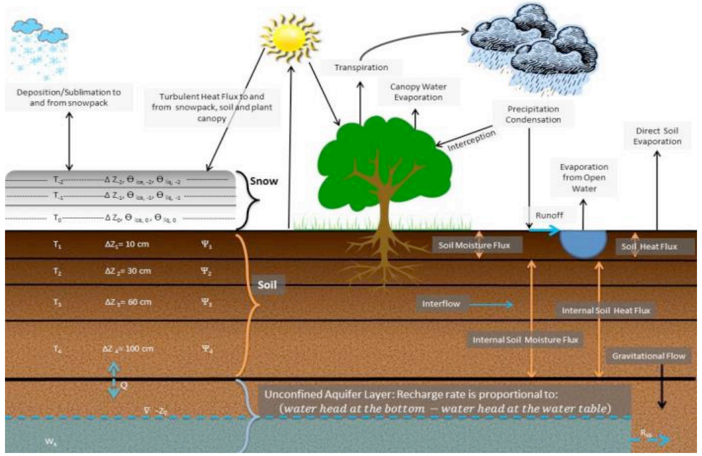
Noah-MP®

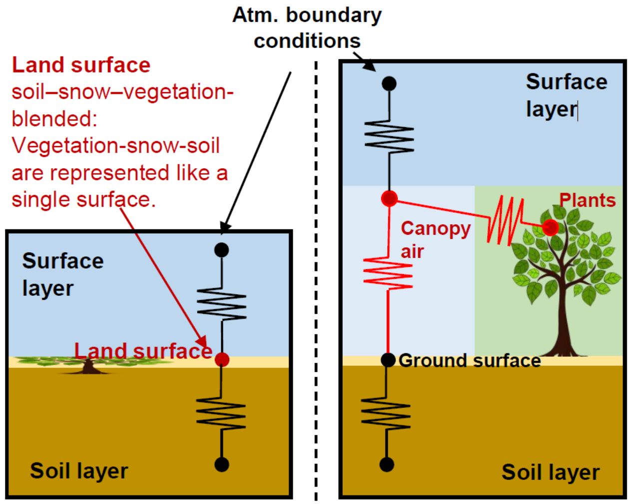
Noah-MP® Open-Source Community Land Surface Model. The 4 colors represents: Soil, Water, Vegetation, and Energy. The 4 big circle "C"s represent: Community, Collaborative, Comprehensive, Cutting-edge

Noah-Multiparameterization (Noah-MP) LSM

- advanced version of research-based (WRF) and operational (UFS) Noah land surface model

➔ portable and (still) cost-effective





Second generation LSM | Third generation LSM

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

* modified for KIM/Noah-MP

2021: Noah-MP V4.0.1

- LIS-based code

2022: Noah-MP V4.2/4.4

- WRF-based code
- No canopy heat storage
- Old CWPVT for evergreen broadleaf forest
- Constant snow albedo for glacier

2023: Noah-MP V5.0

- GitHub-based code
- Thermal roughness parameterization
- Option for snow albedo/conductivity/cover
- CLM-based table value for leaf albedo
- Refinement of soil conductivity
- Nitrogen foliage factor

Performance on medium-range weather forecast: 2021

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July 2017
(boreal summer)

Northern hemisphere

Variable	Level	Metric	1일	2일	3일	4일	5일	6일	7일	8일	9일	10일
MSLP		RMSE	▾	∨	∨	▾	▾	▾	▾	▾	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
Geopotential height	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	▾
	250hPa	RMSE	-	-	▾	-	▾	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	▾	▾
	500hPa	RMSE	▾	▾	▾	▾	▾	▾	▾	-	-	▾
		CCAF	-	-	-	-	-	-	-	-	▾	▾
	850hPa	RMSE	-	▾	▾	▾	▾	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
Temperature	100hPa	RMSE	-	-	-	▾	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	▾	▾
	250hPa	RMSE	-	-	▾	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	▾	▾
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	▾	∨
	850hPa	RMSE	∨	︾	︾	︾	∨	∨	∨	∨	∨	∨
		CCAF	-	-	-	▾	▾	▾	▾	▾	∨	∨
Relative humidity	700hPa	RMSE	▾	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	▴	▴	▾	▾
wind speed	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	▾
	850hPa	RMSE	▾	▾	▾	▾	▾	▾	▾	-	-	-

Southern hemisphere

Variable	Level	Metric	1일	2일	3일	4일	5일	6일	7일	8일	9일	10일
MSLP		RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
Geopotential height	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	850hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
Temperature	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	▾
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	▾
	850hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
Relative humidity	700hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
wind speed	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	850hPa	RMSE	-	-	-	-	-	-	-	-	-	-

Tropics

Variable	Level	Metric	1일	2일	3일	4일	5일	6일	7일	8일	9일	10일
MSLP		RMSE	▾	∨	∨	∨	∨	∨	∨	▾	▾	▾
		CCAF	-	-	-	-	-	-	-	-	-	-
Geopotential height	100hPa	RMSE	-	-	-	▴	▴	▴	▴	▴	▴	▴
		CCAF	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	▴	▴	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	▾	-	-	▴	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	▾
	850hPa	RMSE	-	▾	▾	▾	▾	▾	▾	-	▾	-
		CCAF	-	-	▾	▾	▾	▾	▾	-	-	-
Temperature	100hPa	RMSE	-	-	-	-	-	-	-	-	-	▾
		CCAF	-	-	-	-	-	-	-	-	-	▾
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	-	▾
	850hPa	RMSE	▾	▾	▾	-	-	-	-	-	▾	▾
		CCAF	-	-	-	-	-	-	-	▾	▾	▾
Relative humidity	700hPa	RMSE	-	-	-	-	-	-	-	-	-	-
		CCAF	-	-	-	-	-	-	-	-	▾	-
wind speed	100hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	250hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	500hPa	RMSE	-	-	-	-	-	-	-	-	-	-
	850hPa	RMSE	-	▾	▾	▾	▾	▾	▾	▾	▾	▾

Compared to KIM/Noah, KIM/Noah-MP is worse ← → better

색상 범례 (%) 구간 별 대표 색상 — 범례변경 -100% ~ +100%

-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 +10 +20 +30 +40 +50 +60 +70 +80 +90 +100

아이콘 범례 기준의 예측성능이 비교대상보다 좋은 경우 양수(+)값

비교값없음 | ︾ ~ -20% | ∨ ~ -10% | ▾ ~ -3% | - -3% ~ 3% | ▴ 3% ~ | ∧ 10% ~ | ︽ 20% ~

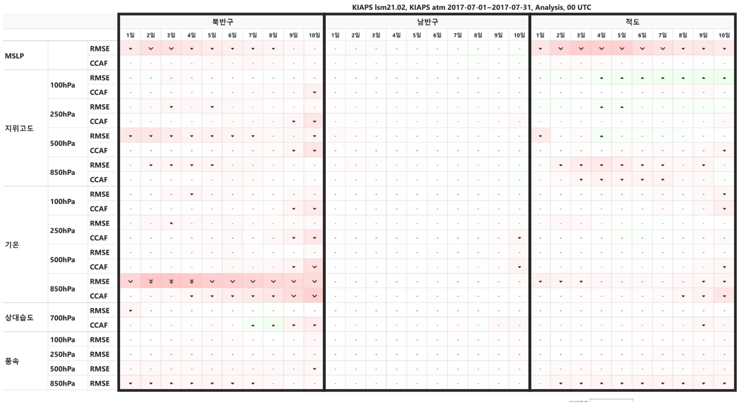
Performance on medium-range weather forecast: 2021 to 2023

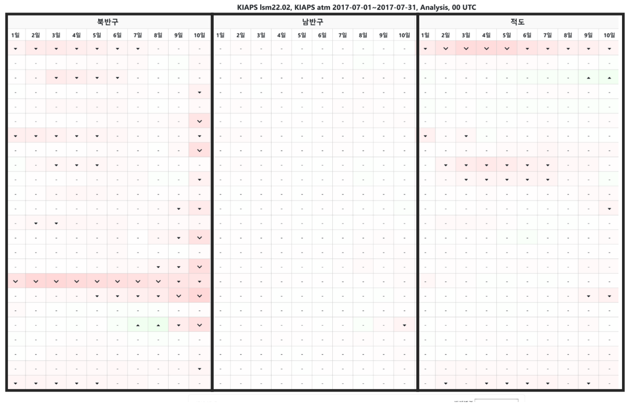
2021

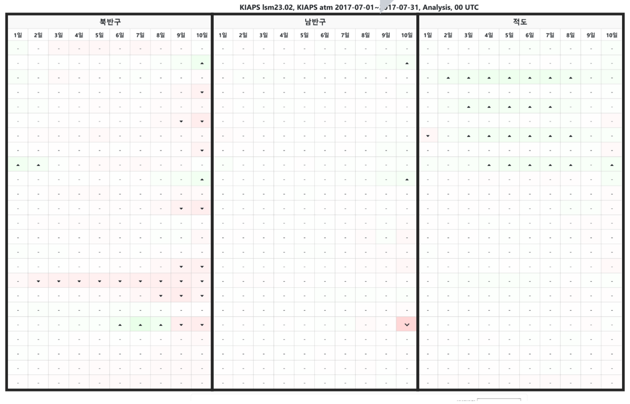
2022

2023

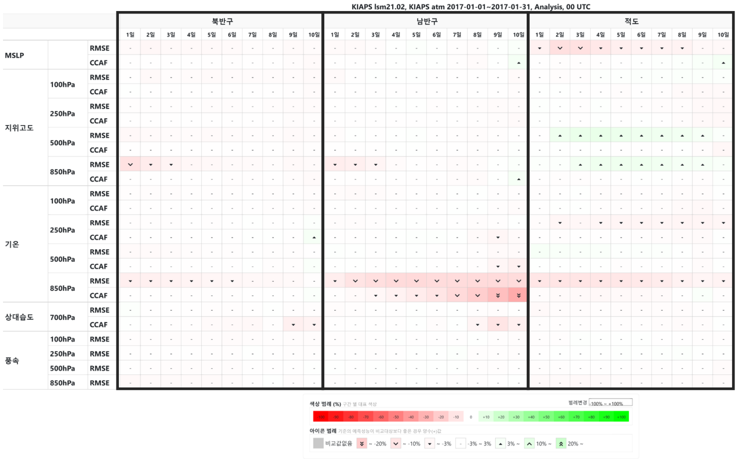
July 2017
(boreal summer)

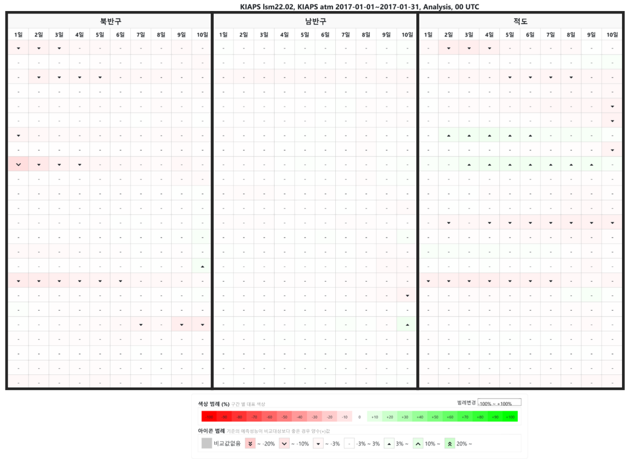






January 2017
(boreal winter)





➔ Continuous improvement but still worse than KIM/Noah

Systematic difference: KIM/Noah-MP (2023) - KIM/Noah

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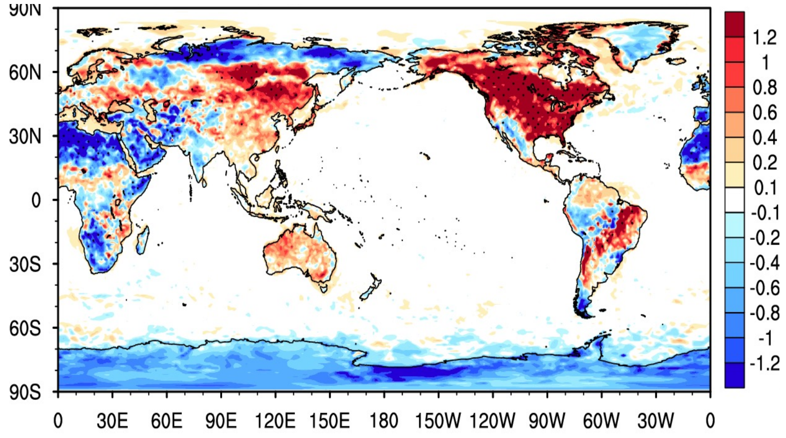
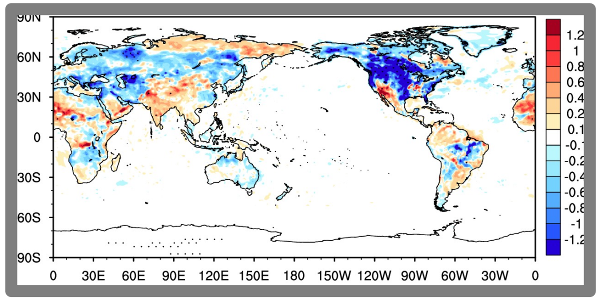
2-m temperature

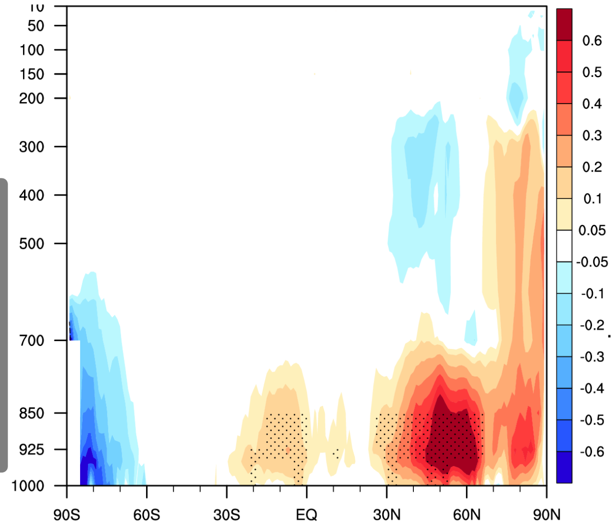
Zonal-mean temperature

July 2017
(boreal summer)

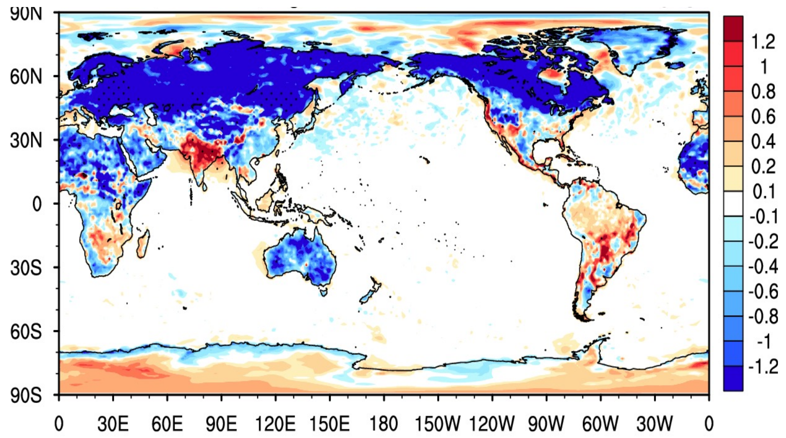


→ warmer over vegetation
(and drier)

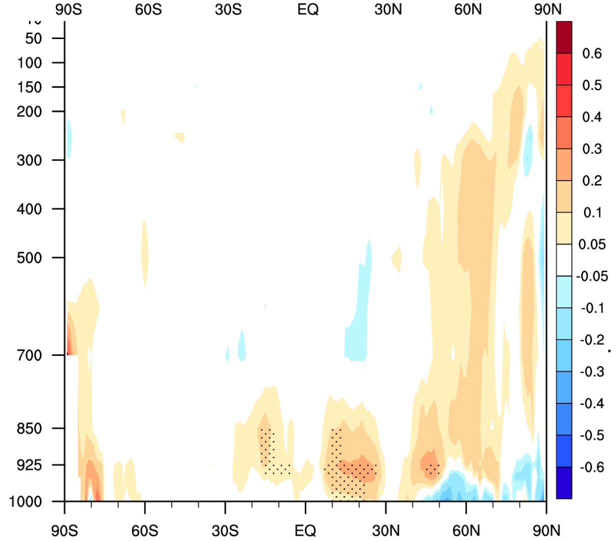




January 2017
(boreal winter)



→ colder over snow



➔ **insufficient turbulent surface fluxes and vertical mixing**

Namelist for KIM/Noah-MP: 2024 update

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Noah-MP Physics	Default (Noah-MP version 5.0)	KIM/Noah-MP	Date
OptDynamicVeg	4: Off (use table LeafAreaIndex; use maximum vegetation fraction)	42: Off (use table LeafAreaIndex; use land use)	2024.06
OptRainSnowPartition	1: Jordan (1991) scheme		
OptSoilWaterTranspiration	1: Noah (soil moisture) (Ek et al., 2003)		
OptGroundResistanceEvap	1: Sakaguchi and Zeng (2009) scheme		
OptSurfaceDrag	1: Monin-Obukhov (M-O) similarity theory (Brutsaert, 1982)		
OptStomataResistance	1: Ball-Berry scheme (Ball et al., 1987; Bonan, 1996)		
OptSnowAlbedo	1: BATS snow albedo (Dickinson et al., 1993)	2: CLASS snow albedo (Verseghy, 1991)	2023.11
OptCanopyRadiationTransfer	3: Two-stream applied to vegetated fraction (gap=1-VegFrac) Dickinson, 1983; Sellers, 1985)		
OptSnowSoilTempTime	1: Semi-implicit; flux top boundary condition (Niu et al., 2011)		
OptSnowThermConduct	1: Stieglitz scheme (Yen, 1965)	4. Verseghy (1991) scheme 3. Constant	2023.11 2024.06
OptSoilTemperatureBottom	2: TemperatureSoilBottom at DepthSoilTempBottom (8m) (original Noah; Ek et al., 2003)		
OptSoilSupercoolWater	1: No iteration (Niu and Yang, 2006)		
OptRunoff(Sub)Surface	3: Schaake scheme (original Noah) (Schaake et al., 1996)		
OptSoilPermeabilityFrozen	1: Linear effects, more permeable (Niu and Yang, 2006)		
OptDynVicInfiltration	1: Philip scheme (Liang and Xie, 2003)		
OptTileDrainage	0: No tile drainage		
OptIrrigation	0: No irrigation		
OptIrrigationMethod	0: Method based on geo_em fractions		
OptCropModel	0: No crop model		
OptSoilProperty	1: Use input dominant soil texture		
OptPedotransfer	1: Saxton and Rawls (2006) scheme		
OptGlacierTreatment	1: Include phase change of glacier ice	2: Glacier ice treatment more like original Noah	2022.11
OptCanopyHeatCapacity	1: On	0: Off (HeatCapacCan = 0.0)	2022.11
OptCWPVT_EBF	0.67 for evergreen broadleaf forest	0.18 for evergreen broadleaf forecast	2022.11
OptSnowAlbedoGlacier	=OptSnowAlbedo	0.82	2022.11
OptEmissivityBare	0.97	0.90	
OptSoilColor	constant(=4)	CLM-based data	2023.07
OptNitrogenFoliage	1: On (NitrogenFoliageFac = 1/1.5)	0: Off (NitrogenFoliageFac =1.0)	2023.07
OptVCMX25	default table value	CLM-based table value	2023.07
OptZ0T	z0t=z0m	z0t=z0m	2023.11
OptSnowFraction	1: Niu07	0: Noah (Ek et al., 2003)	2023.11
OptSoilCond	default scheme	Refinement for coarse soil	2023.11
OptLeafReflectance	default table value	CLM-based table value	2023.11
OptRoughness	default table value	Trigo et al. (2015)-based table value	2024.06
OptGreenVegFrac	=VegFrac	CLM-based parameterization	2024.06

➔ **newly made for KIM/Noah-MP**

[2024 update] Consistency with atmospheric physics

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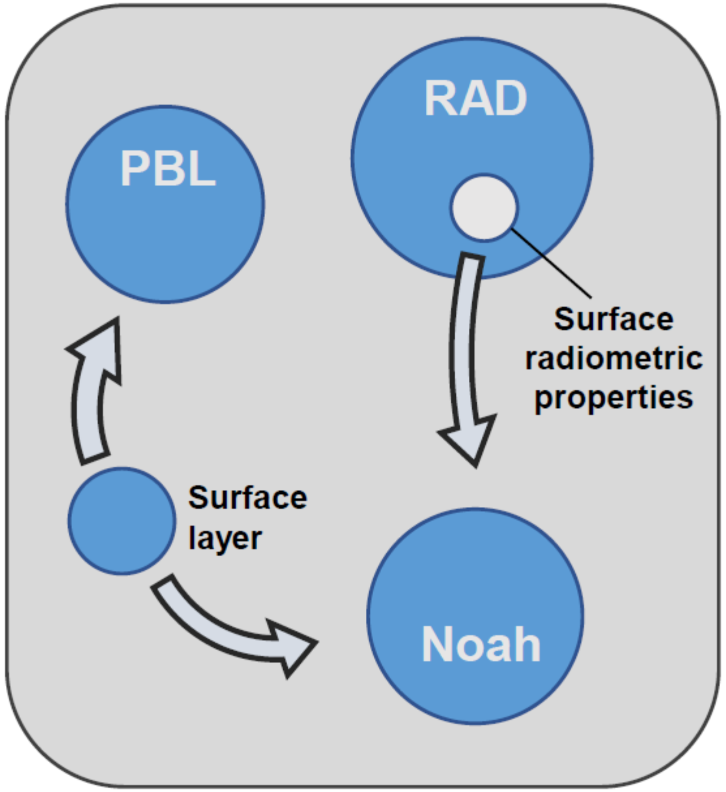
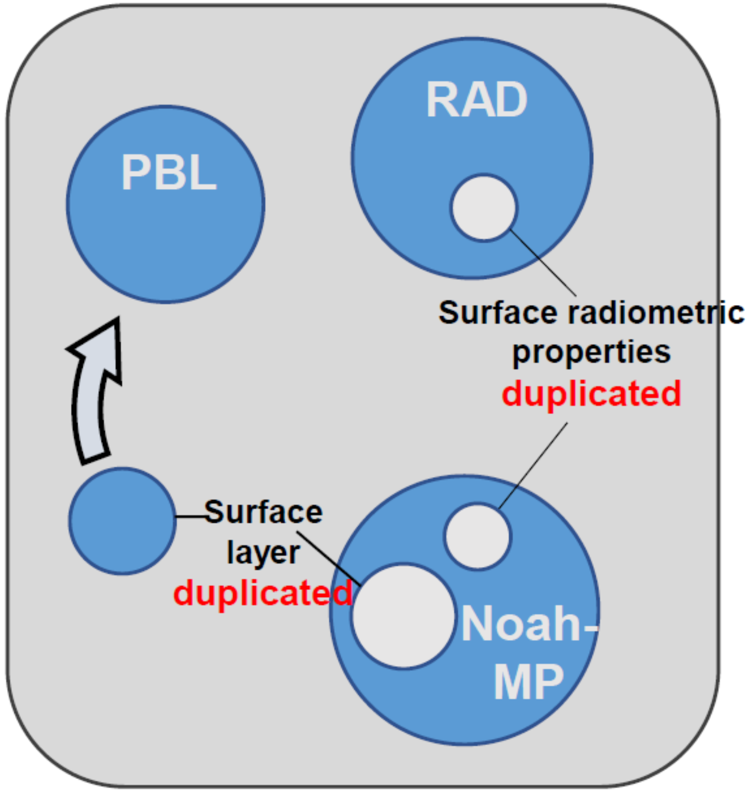
KIM/Noah

- **Atmosphere model** calculates **surface layer** and **surface radiometric properties**, and conveyed them **to Noah**



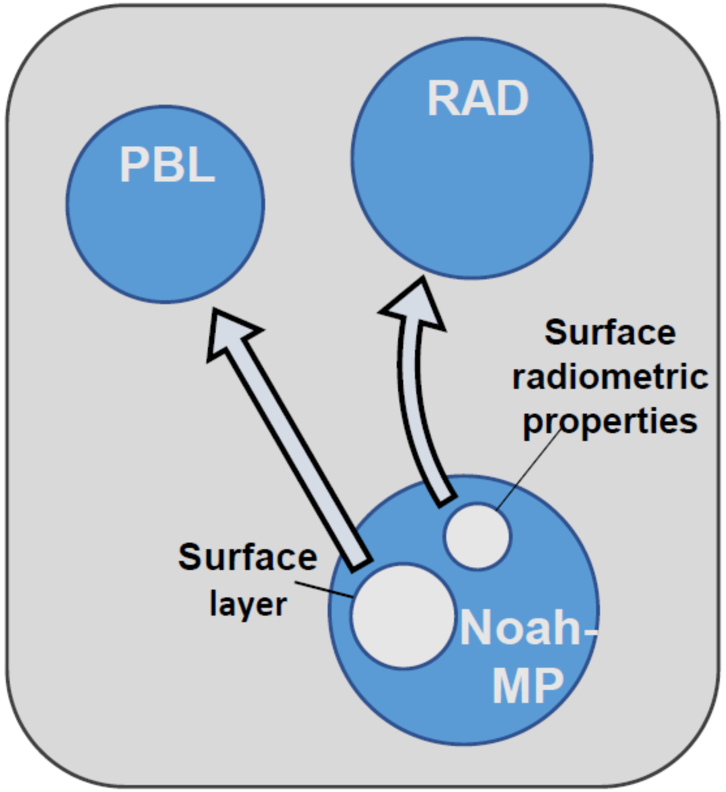
KIM/Noah-MP (old)

- Atmosphere model and Noah-MP **both calculate surface layer and surface radiometric properties**, so they are **duplicated** with different values



KIM/Noah-MP (new)

- **Noah-MP** is the only model **calculating surface layer and surface radiometric properties**, and **it convey to** Atmosphere model.



[2024 update] Roughness length for momentum

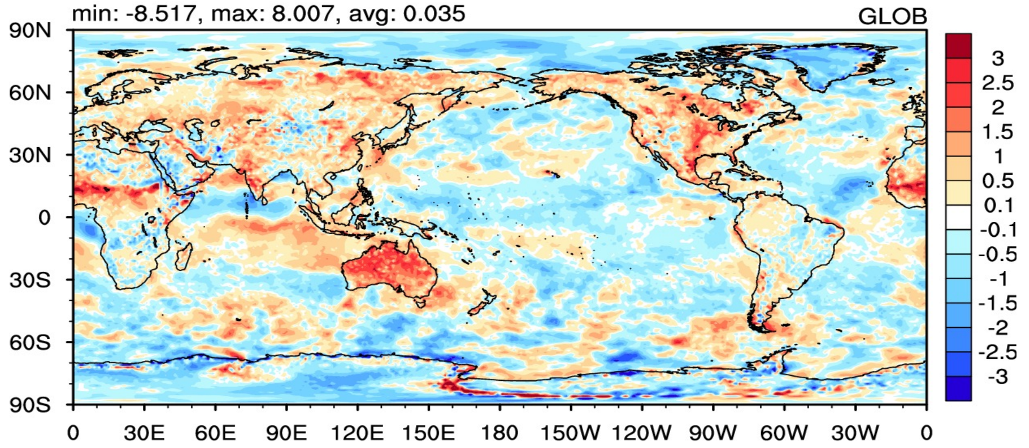
✓ IFS

	Land use (Modified IGBP-MODIS)	Noah	Noah-MP	Trigo et al. (2015)
1	evergreen needleleaf forest	0.50	1.09	2.00
2	evergreen broadleaf forest	0.50	1.10	2.00
3	deciduous needleleaf forest	0.50	0.85	2.00
4	deciduous broadleaf forest	0.50	0.80	2.00
5	mixed Forests	0.20 ~ 0.50	0.80	2.00
6	closed Shrublands	0.01 ~ 0.05	0.20	0.37
7	open Shrublands	0.01 ~ 0.06	0.06	
8	woody Savannas	0.01 ~ 0.05	0.60	
9	savannas	0.15	0.50	
10	grasslands	0.10 ~ 0.12	0.12	0.20
11	permanent wetlands	0.30		0.83
12	croplands	0.05 ~ 0.15	0.15	0.50
13	urban and built-up	0.50	1.00	
14	cropland/natural vegetation mosaic	0.05 ~ 0.14	0.14	
15	snow and ice	0.001		0.0013
16	barren or sparsely vegetated	0.01		0.013
17	water	0.0001		
18	wooded tundra	0.30		0.10
19	mixed tundra	0.15	0.20	0.034
20	barren tundra	0.05 ~ 0.10	0.03 (0.10)	0.034

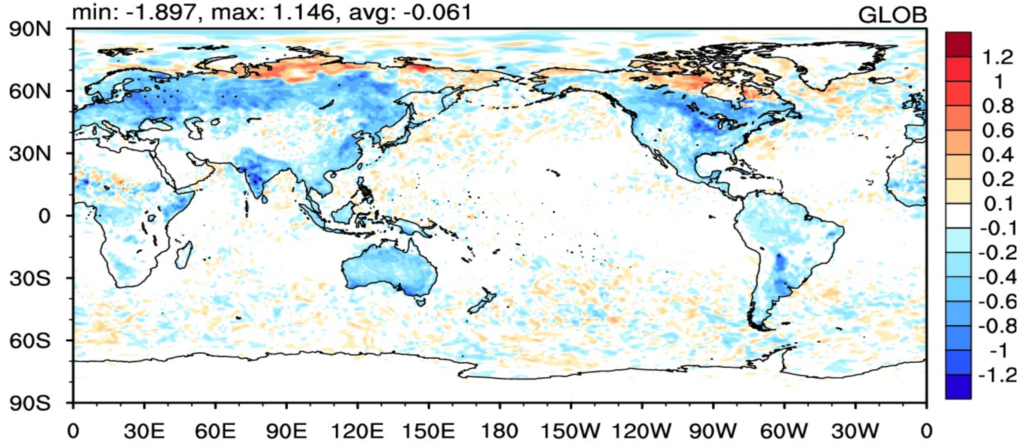
* This modification has been done in response to the recent update in subgrid-scale orography (SSO) parameterization.

10m Wind speed Bias

OLD - ERA5



NEW - OLD



➔ Reduction in the overestimated wind speed

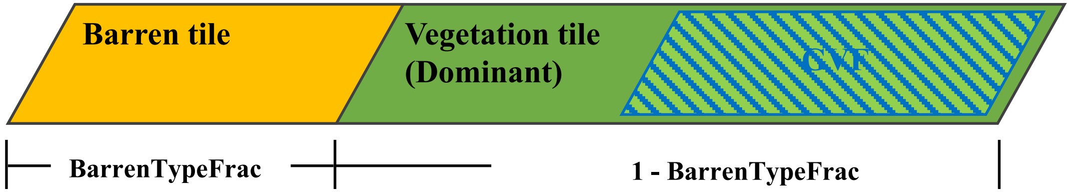
[2024 update] New option for dynamic vegetation (and greenness)

OptDynamicVeg = 4 → 32

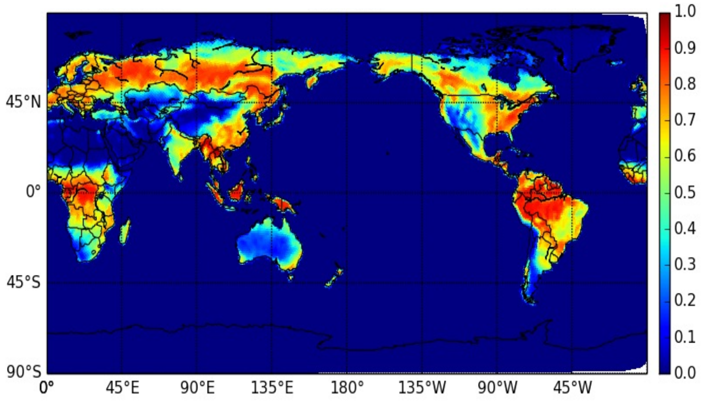
	Leaf Area Index (LAI)	Green Vegetation Fraction (GVF)	Vegetation Tile Fraction (VegFrac)
1	Table	Input data	
2	Prognostic	Calculated with LAI	
3	Table	Calculated with LAI	
32	Table	Calculated with LAI	1 - BarrenTypeFrac
4*	Table	Input data (annual maximum; GVF_{max})	
5	Prognostic	Input data	
…			

Original Noah-MP version 5 (OptDynamicVeg=4; recommended)

New option for KIM/Noah-MP (OptDynamicVeg=31)

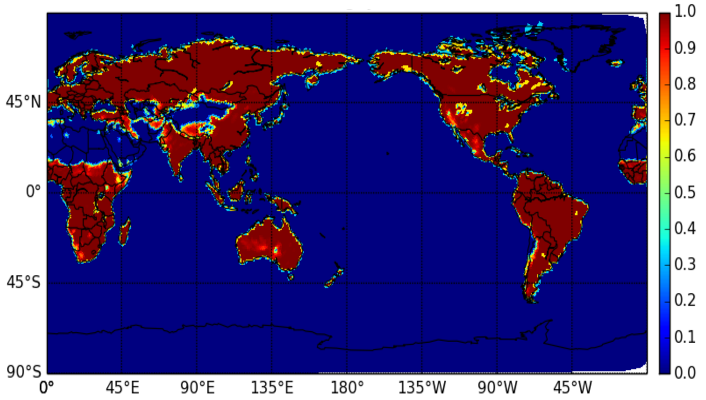


OLD



- VegFrac = GVF = GVF_{max} (fixed)

NEW



- VegFrac = 1 - BarrenTypeFrac (fixed)
- GVF $= GVF_{CLM} = \frac{1-e^{-\min(LAI+SAI,2)}}{1-e^{-2}}$ (variable)

Temperature at forecast day 5 (July 2017; 25 km)

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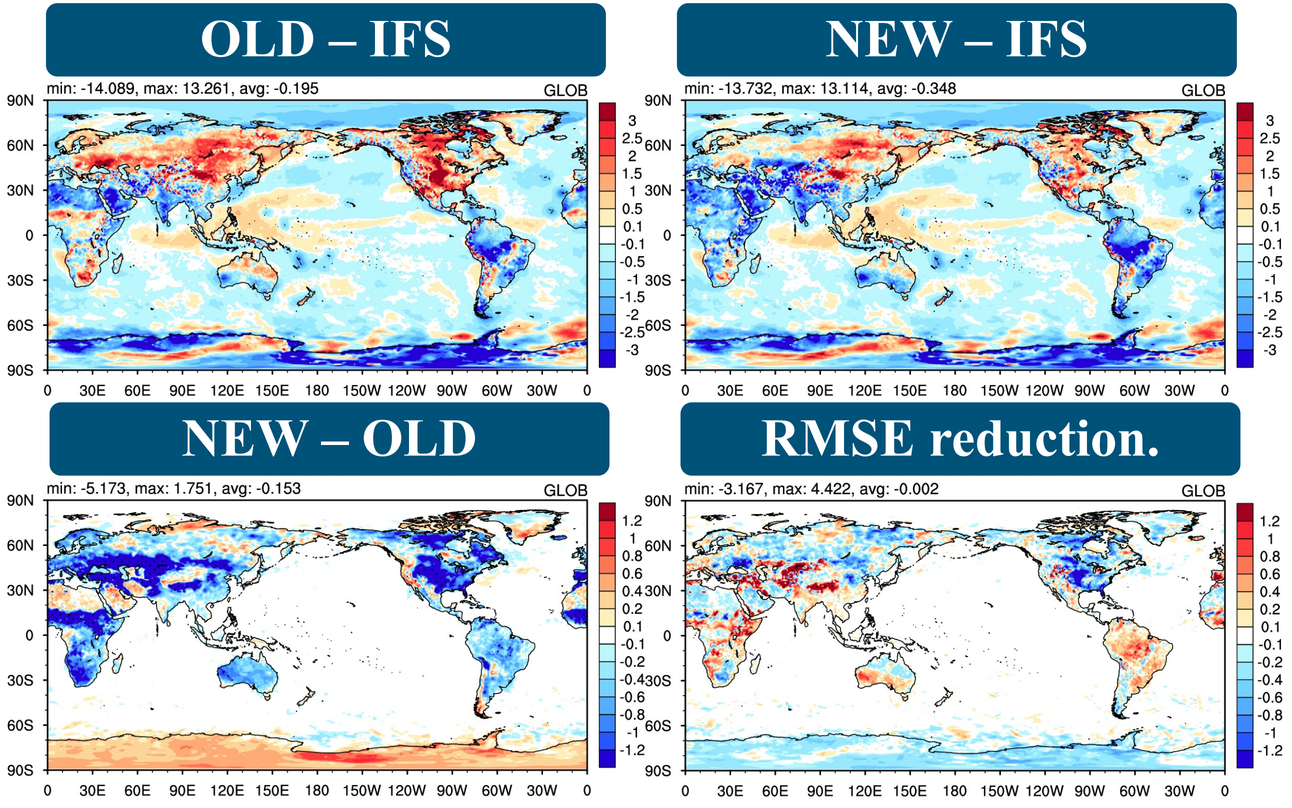
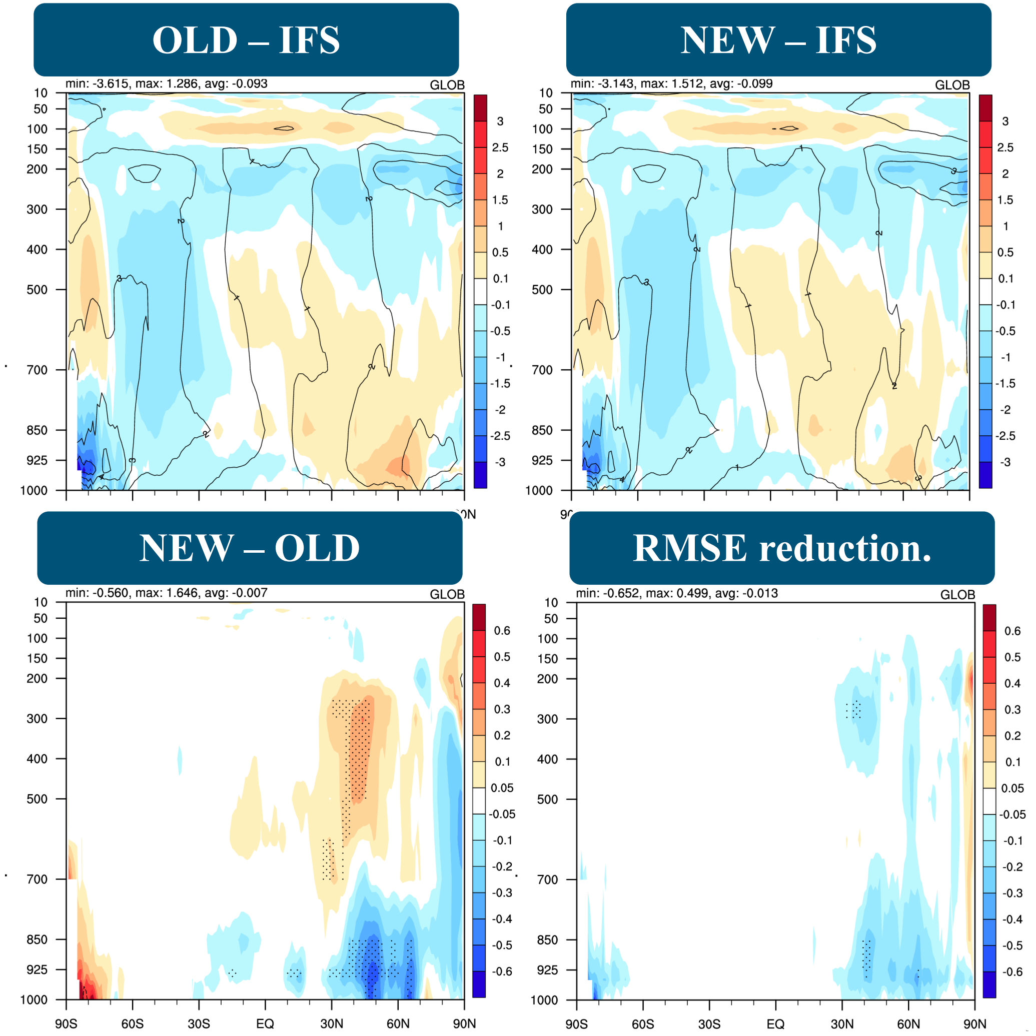
2-m temperature



Zonal-mean temperature



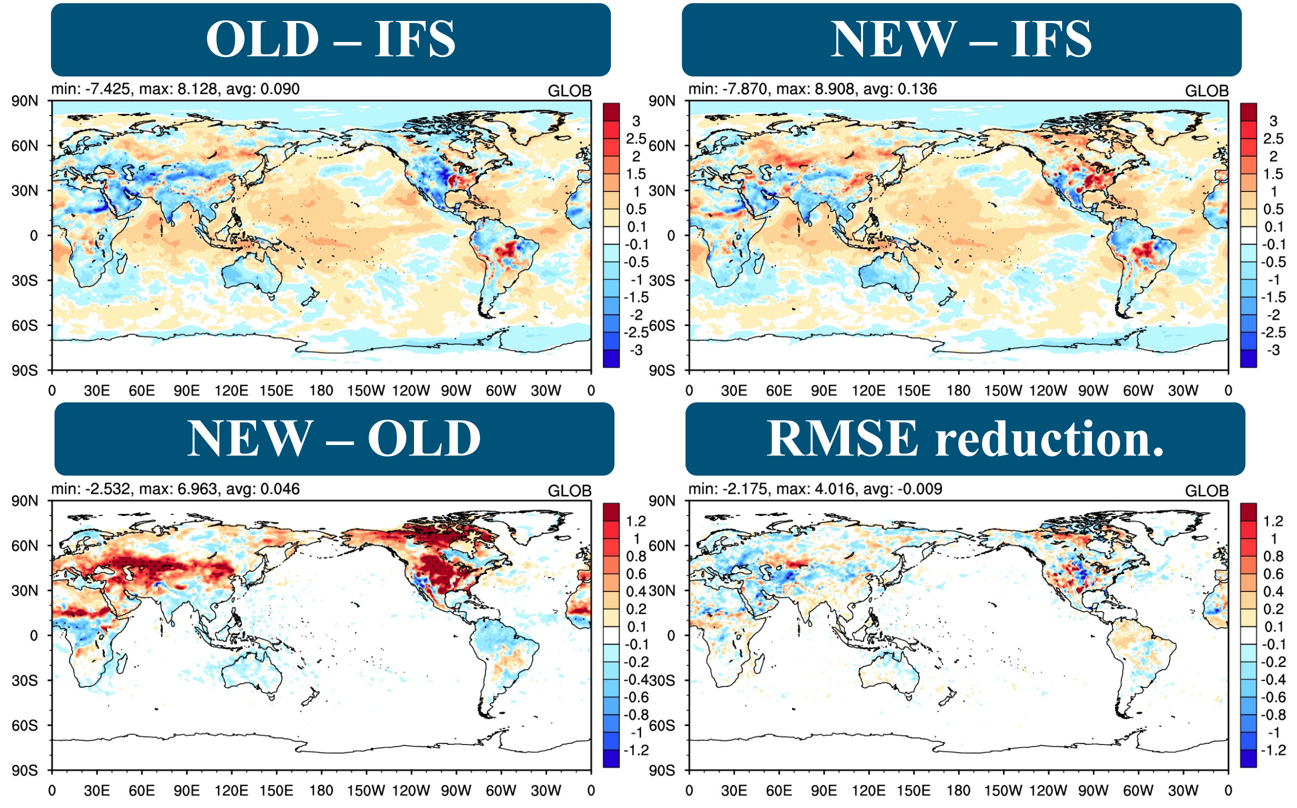
- cooling over vegetation w/ the enhanced vertical mixing

→ highly attributed to the new vegetation tile

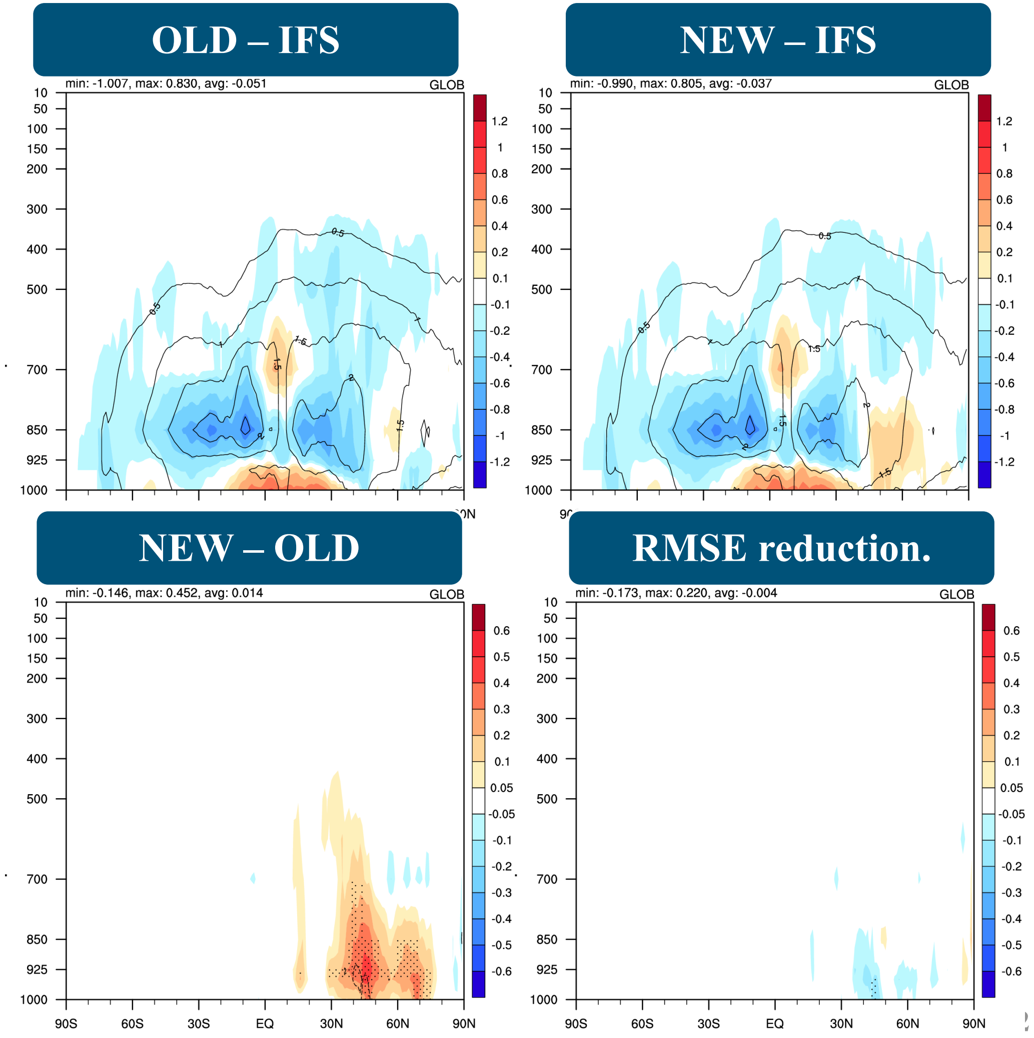
Specific humidity at forecast day 5 (July 2017; 25 km)

KIAPS

2-m specific humidity



Zonal-mean specific humidity



- more humid over vegetation

➔ attributed to the vegetation tile

Wind speed at forecast day 5 (July 2017; 25 km)

KIAPS

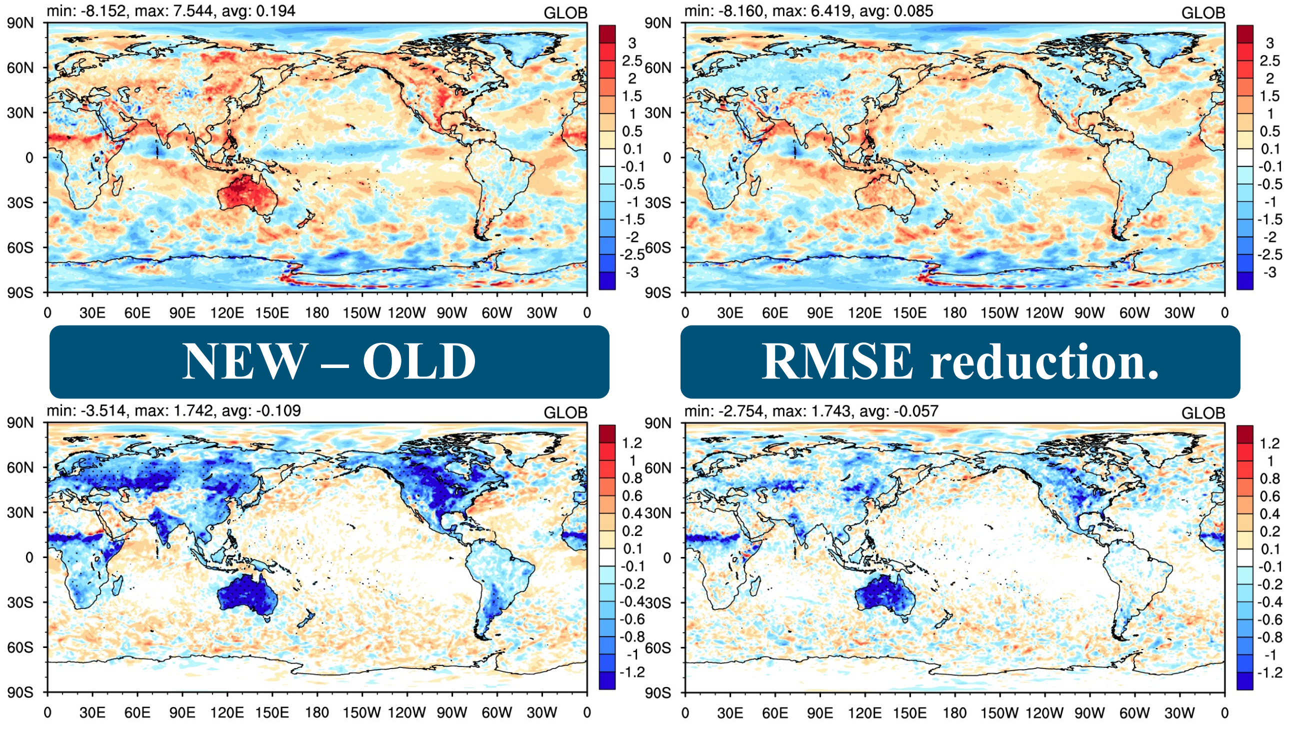
10-m wind speed

OLD – IFS

NEW – IFS

NEW – OLD

RMSE reduction.



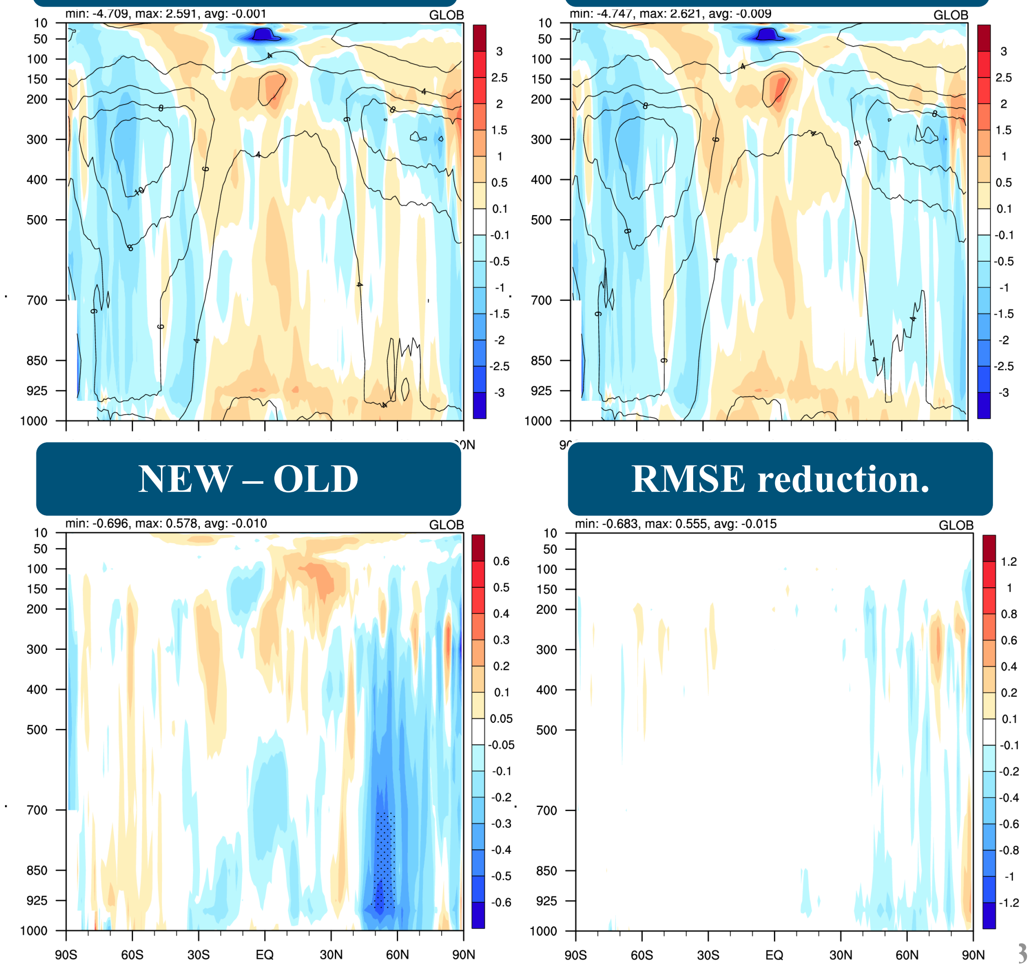
Zonal-mean wind speed

OLD – IFS

NEW – IFS

NEW – OLD

RMSE reduction.



- reduction of the overestimated wind speed

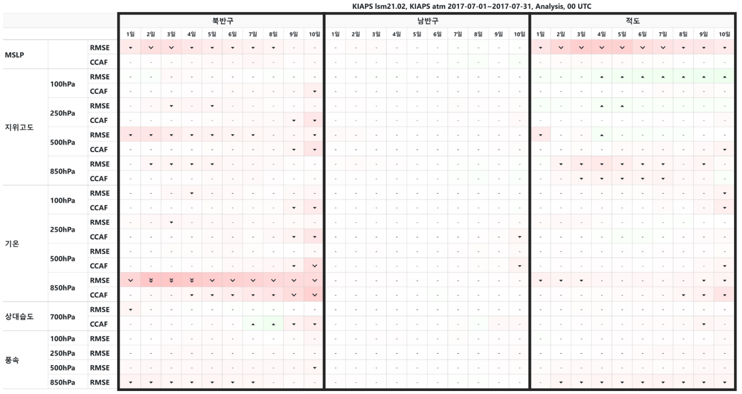
➔ attributed to the vegetation tile and roughness length

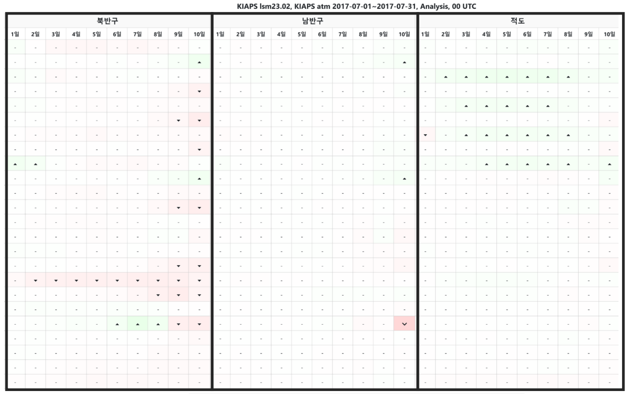
Performance on medium-range weather forecast: Atmosphere (25km)

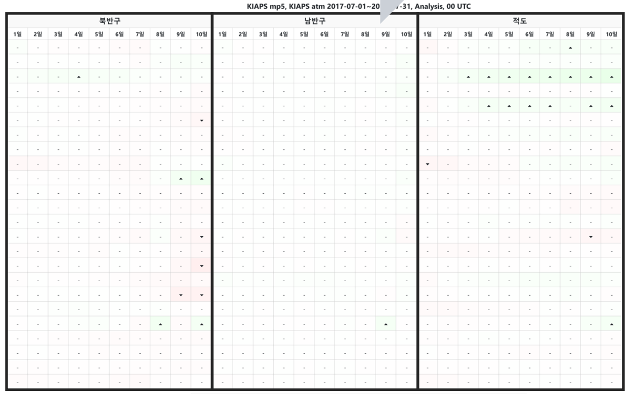
KIAPS

2021 (initial) | 2023 (last year) | 2024 (NEW)

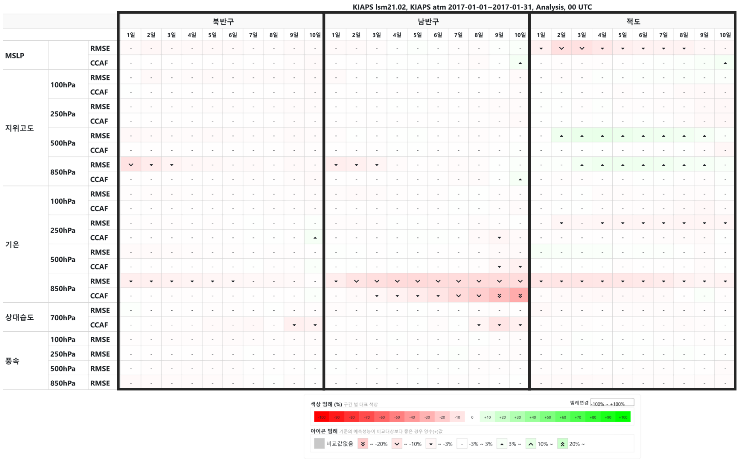
July 2017
(boreal summer)

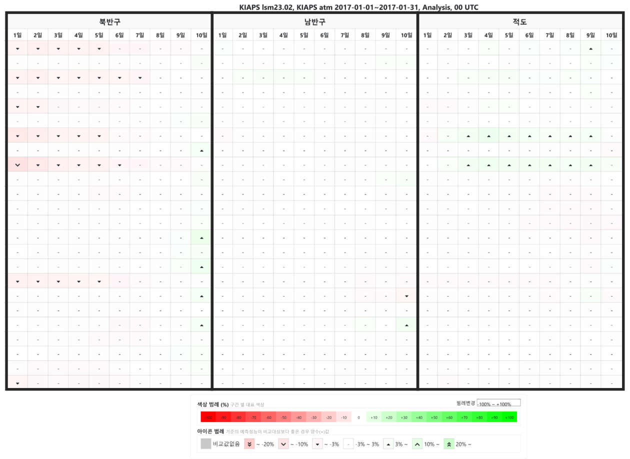


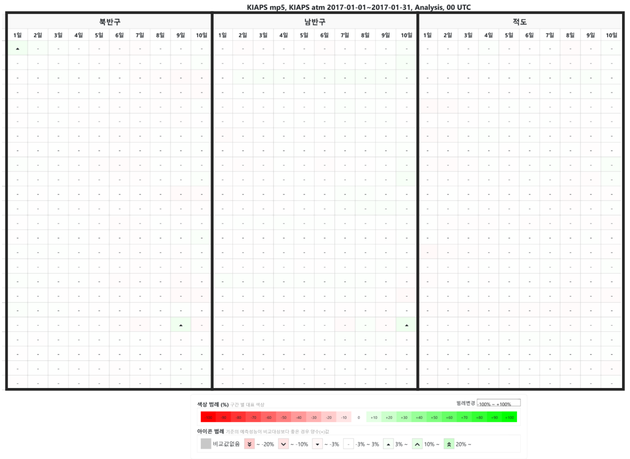




January 2017
(boreal winter)





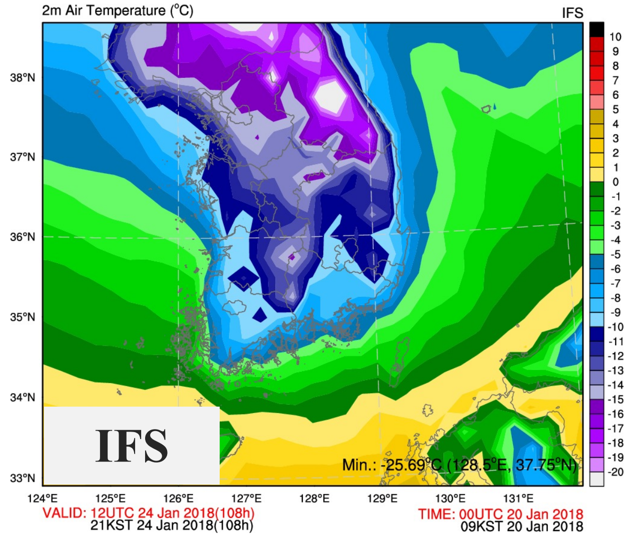


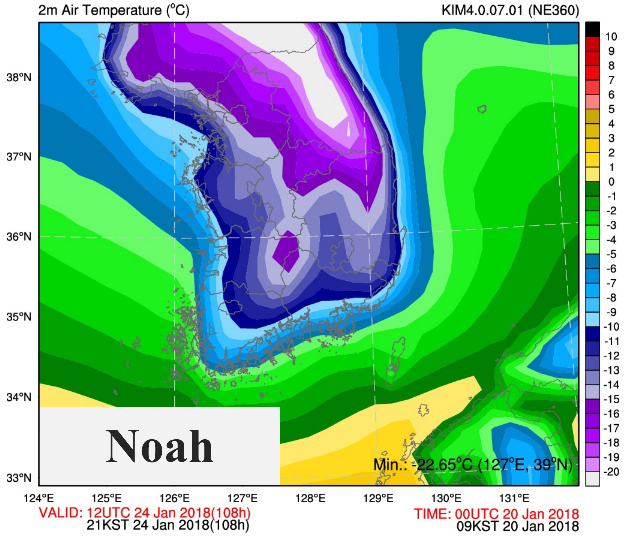
➔ In general, skill scores are now neutral or better than KIM/Noah

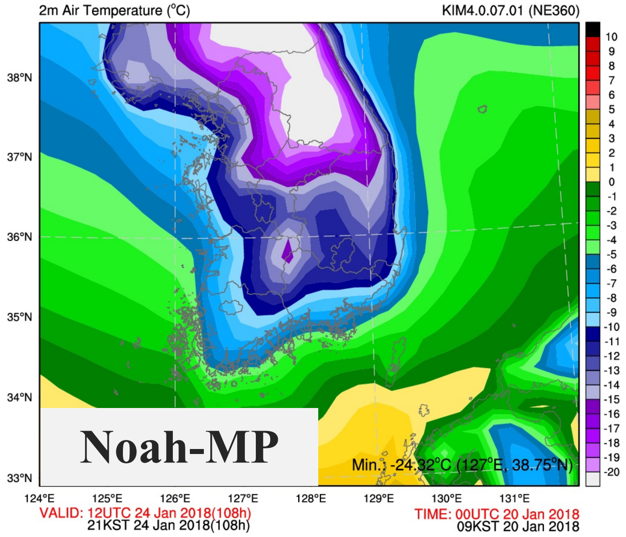
Performance on extreme weather: 2-m temperature (12 km)

KIAPS

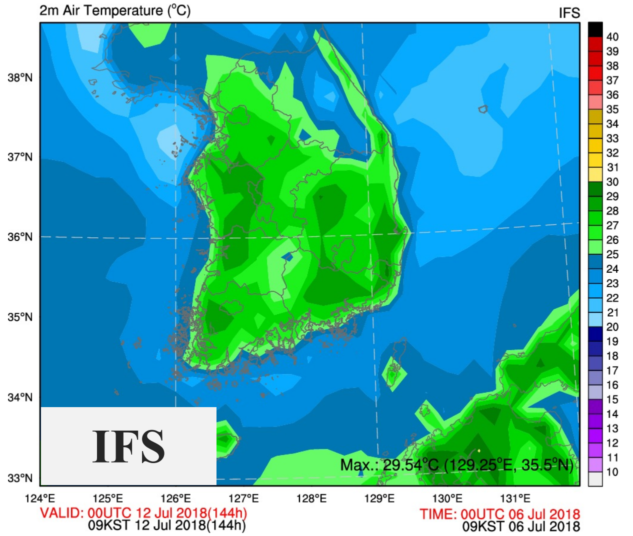
Cold wave
(2018.01.24)

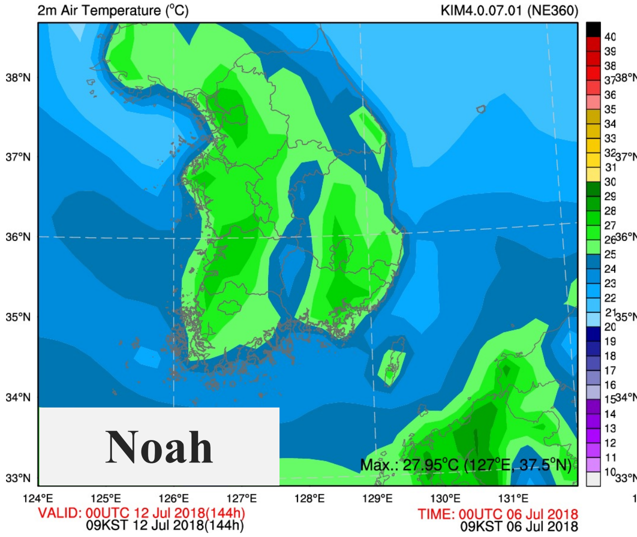


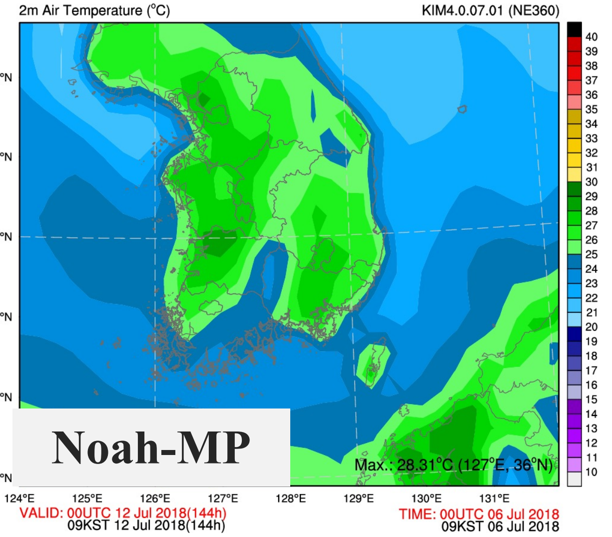




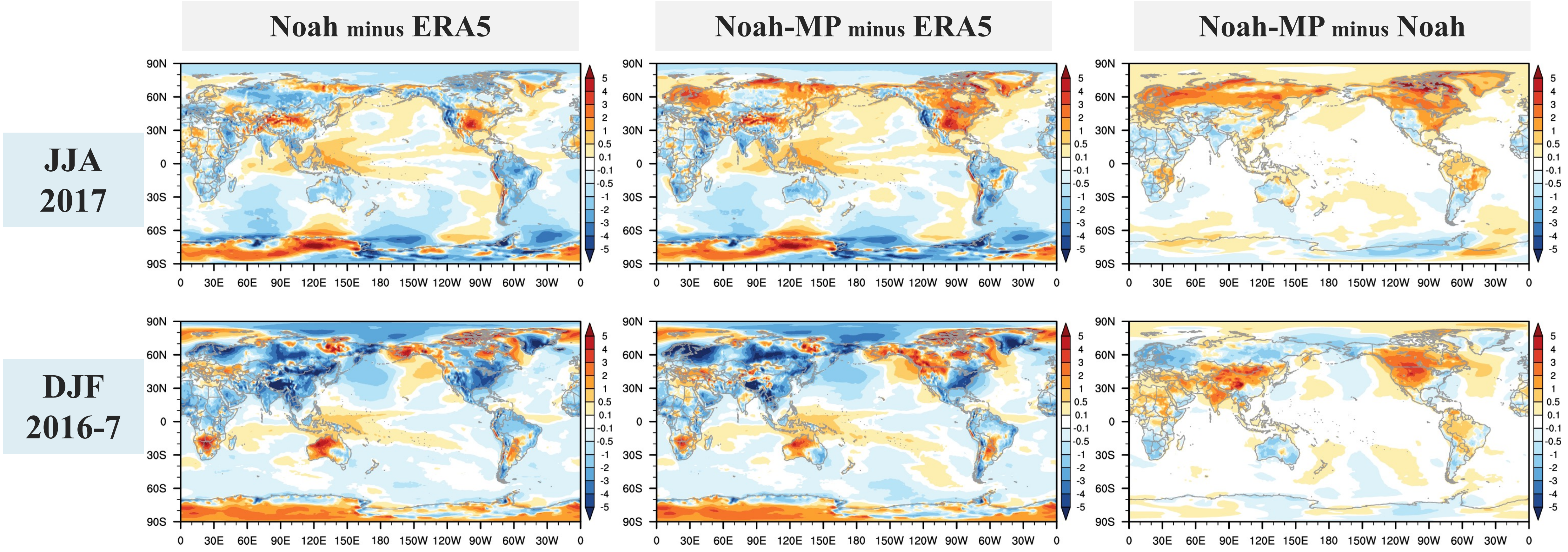
Heat wave
(2018.07.12)







Performance on seasonal simulation: 2-m temperature (50 km)

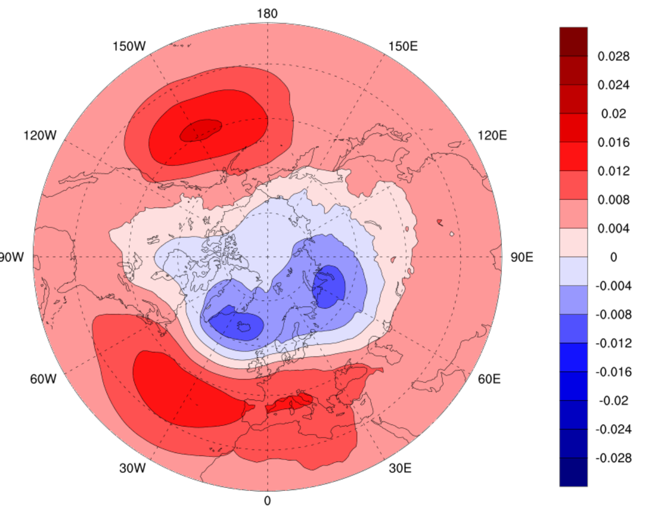


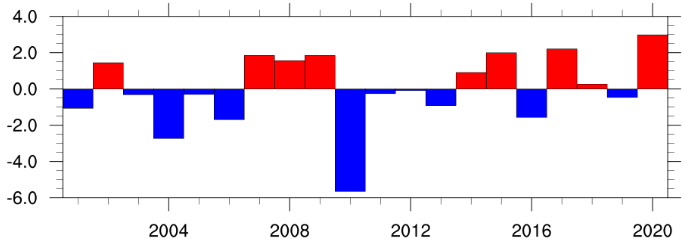
- similar spatial pattern **but still warmer (colder) over forest (snow) ?**

20-year simulation (2001-2020): Arctic Oscillation (100 km)

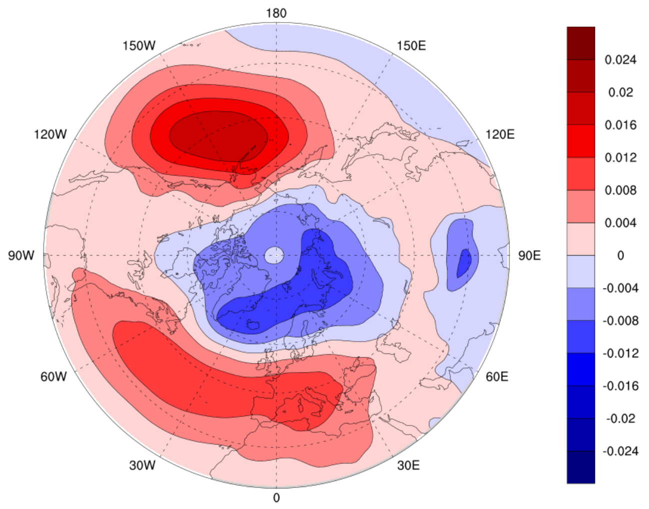
KIAPS

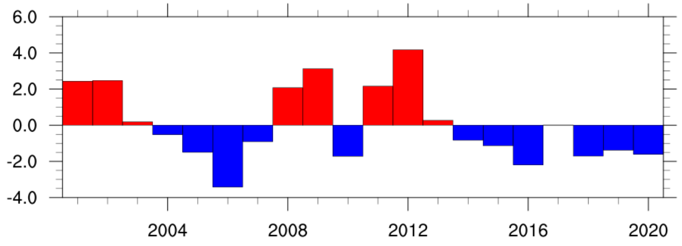
ERA5



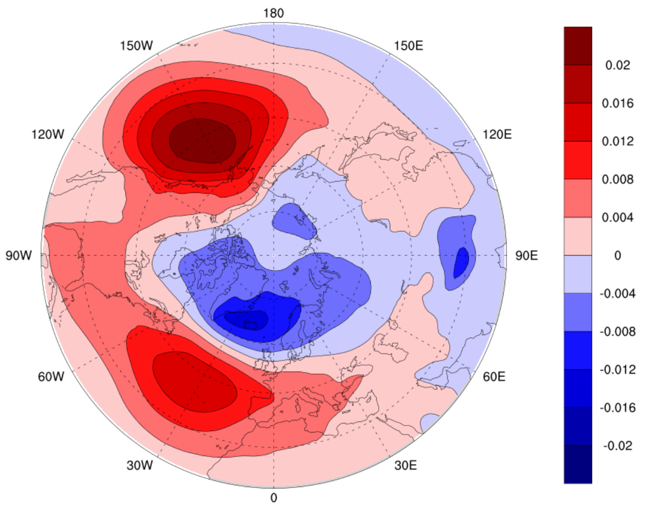


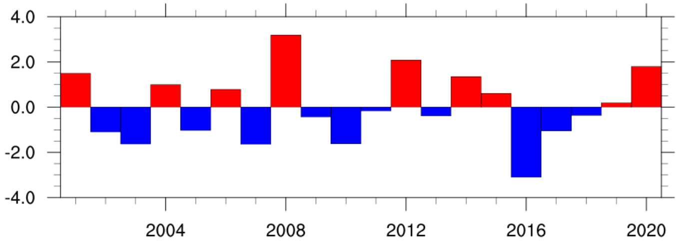
Noah





Noah-MP

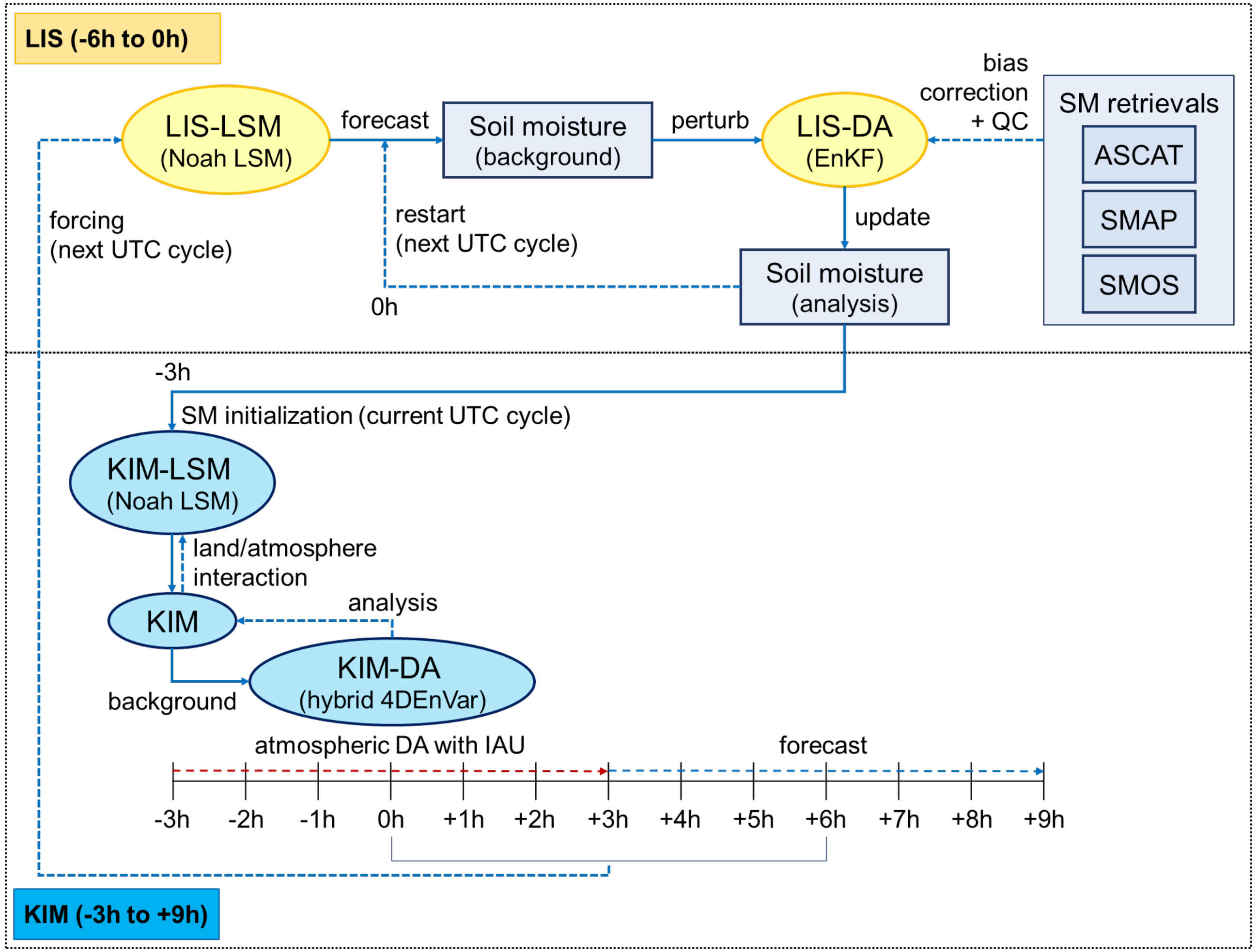




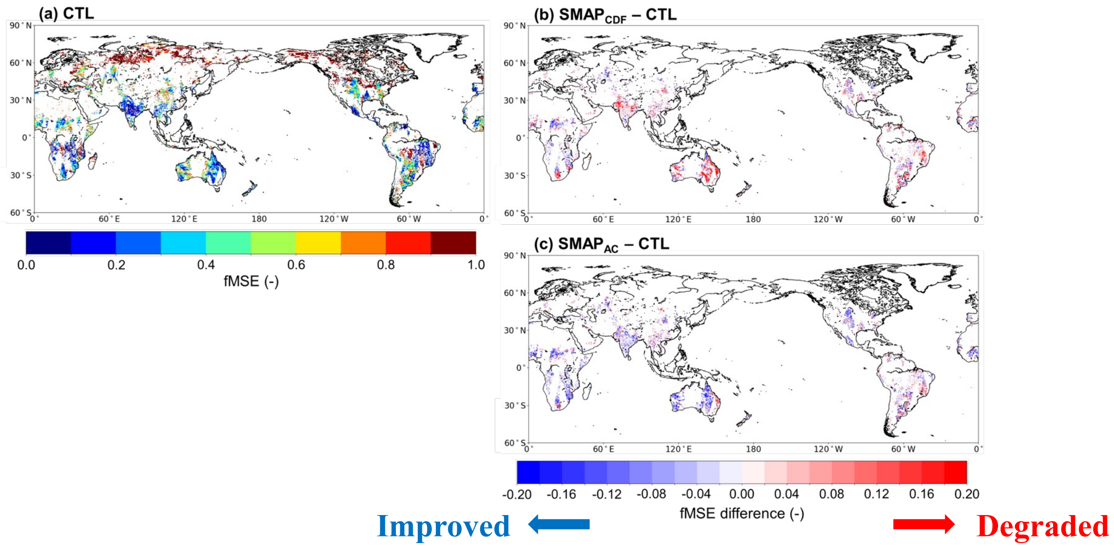
- Stable integration for long-term period
- Similar pattern correlation **but larger amplitude and variability ?**

Weekly coupled data assimilation

Land data assimilation with LIS/Noah



Improvement of soil moisture DA



LIS/Noah-MP DA system

Concluding remark

KIAPS

- ✓ KIM/Noah-MP has been updated with respect to
  - physical consistency with radiation (albedo, emissivity) and boundary layer (surface layer)
  - roughness length for momentum (enhanced to be comparable with IFS)
  - vegetation fraction (vegetation tile versus greenness)
  - snow physics (will be presented tomorrow)

- ✓ In comparison to KIM/Noah, the performance of the recent KIM/Noah-MP became neutral or slightly better on medium-range forecast skill as well as long-term simulation:
  - the systematic warm (cold) bias over vegetation (snow) was highly reduced.
  - the major improvement was attributed to the separation of vegetation tile and greenness, which needs to be considered in the community Noah-MP.

- ✓ In the future, KIM/Noah-MP will replace KIM/Noah, along with
  - LIS/Noah-MP land data assimilation system
  - more sophisticated physics (multi-layer canopy, irrigation, …) and realistic data (LAI/SAI, canopy height, …)

Thank you for listening

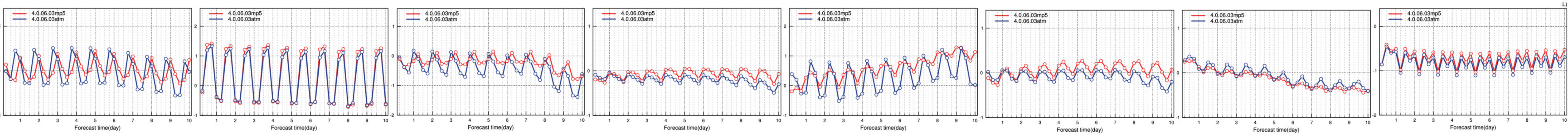
Performance on medium-range weather forecast: Surface (25 km)

KIAPS

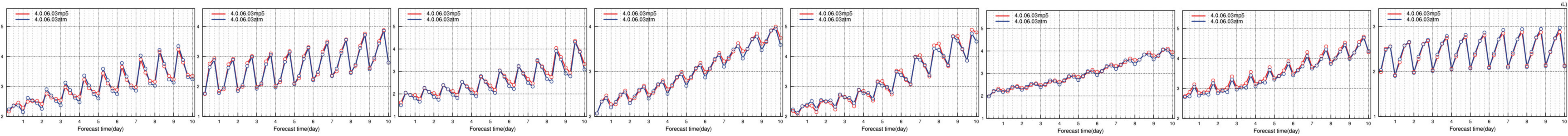
2-m temperature against SYNOP (July 2017)

Asia	Australia	Europe	Global	North America	Northern Hemisphere	Southern Hemisphere	Tropics

Bias



RMSE



Noah
Noah-MP

- Similar magnitude in bias and root-mean-squared error
- Slightly different in diurnal variation