Improving Forecast of Near-Surface Fields Through Noah-MP Coupled in the Unified Forecast System

2024 Noah-MP Workshop, 3-4 June, 2024

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NATIONAL WEATHER SERVICE

United Forecast System (UFS)

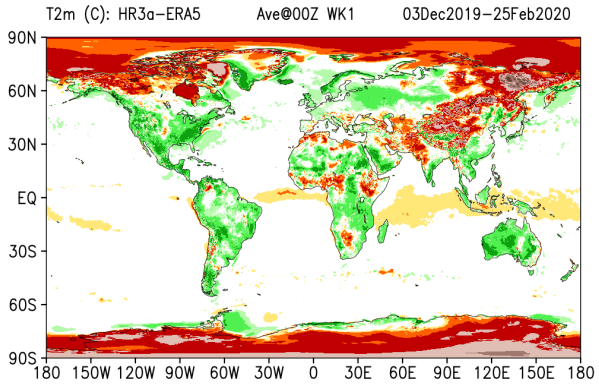
- ***NOAA United Forecast System (UFS)***
  A community-based, coupled, comprehensive earth modeling system.
  It will be the base model for all NOAA forecasts models.
  Noah-MP LSM is being tested and enhanced to replace Noah LSM

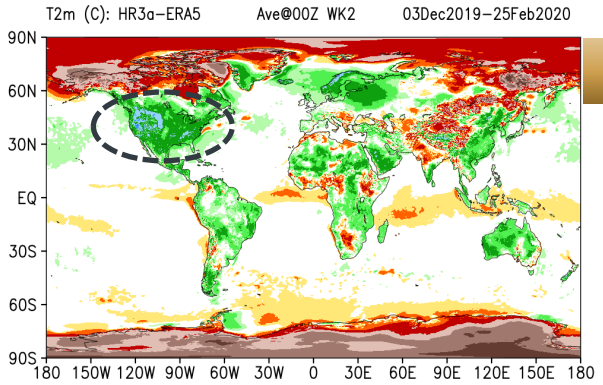
- ***HR1-HR3*: the UFS higher resolution version**
  Coupled Model: Atm (C768) - Ocean (¼ tripolar) - Ice (¼ tripolar) - Wave (⅙ tripolar)

- ***EP5d:* Global Ensemble Forecast System GEFv13 (HR3 tag) (C384)**

- ***SFS:* NOAA Seasonal Forecast System (C96)**

T2m (C): HR3-ERA5 Ave@WK1 & 2 ICs: 03Dec2019-25Feb2020





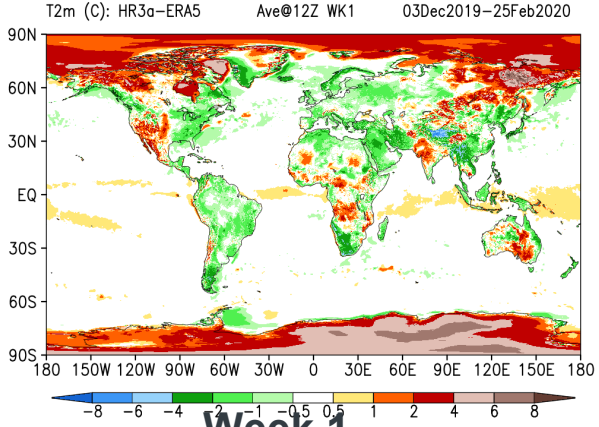
00Z

Winter

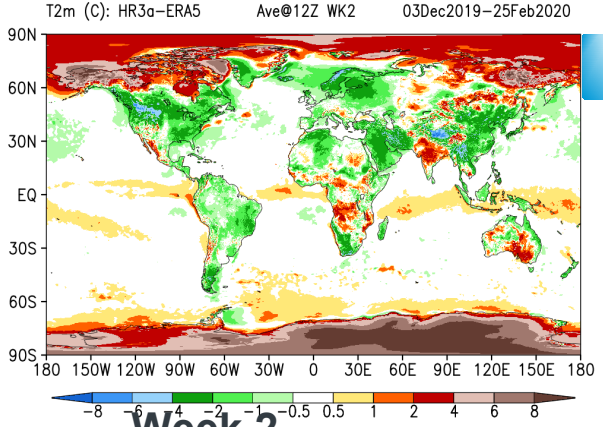
29 cases

Daytime:

- Warm in high latitudes
- Much cold over CONUS in week 2.



Week 1



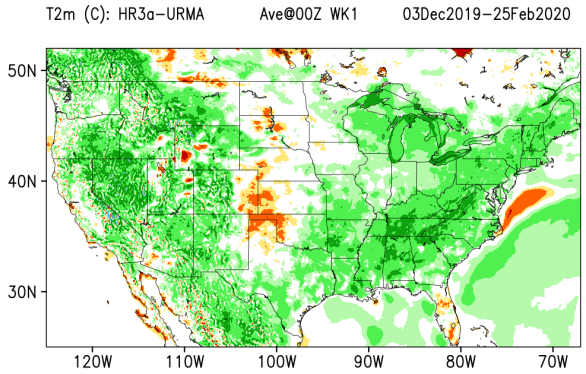
Week 2

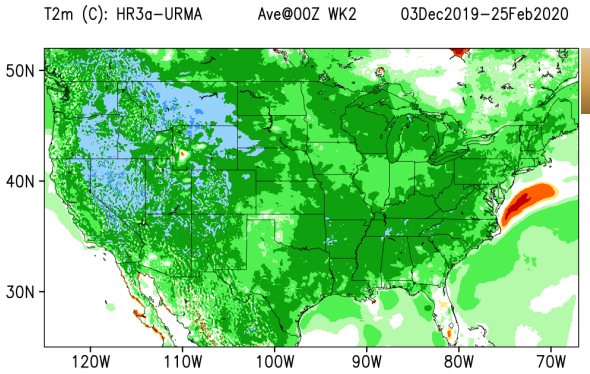
12Z

Nighttime:

- Warm in high latitudes
- Cold in CONUS and east Asia in week 2.

T2m (C): HR3-URMA Ave@WK1 & 2 ICs: 03Dec2019-25Feb2020





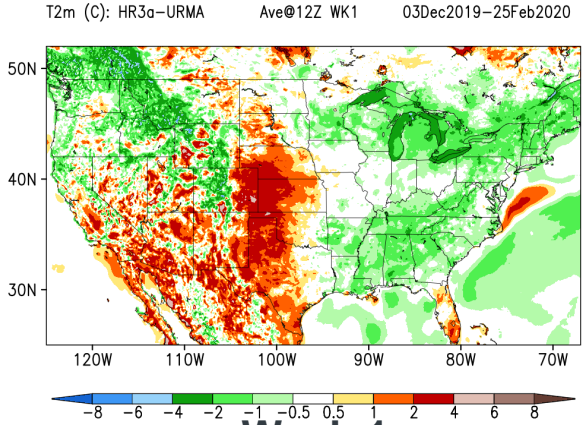
Winter

29 cases

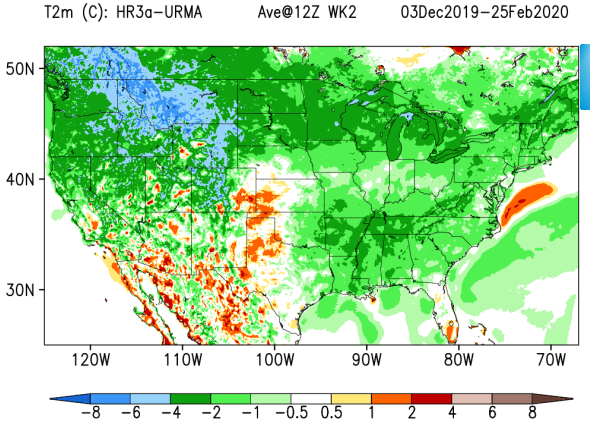
00Z

Daytime:

- **Much cold in week 2.**



Week 1



Week 2

12Z

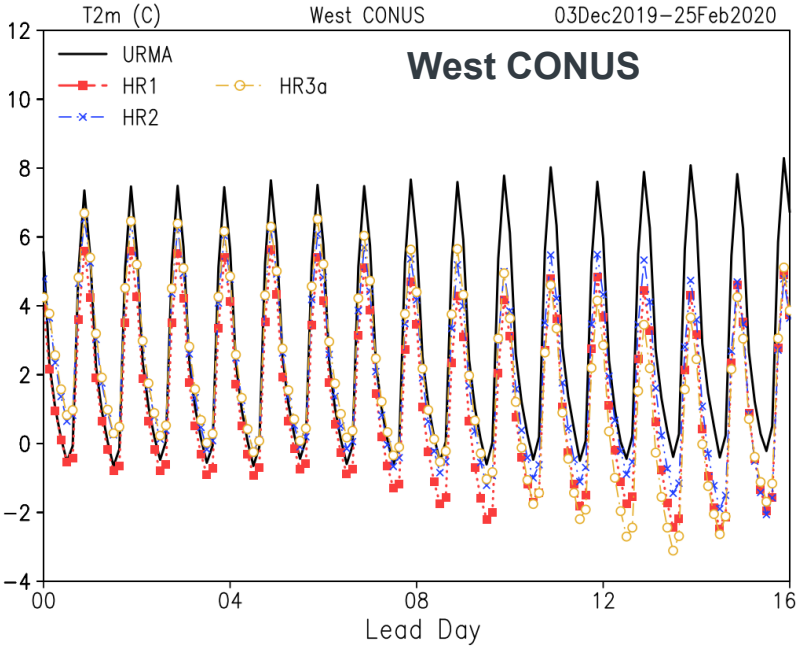
Nighttime:

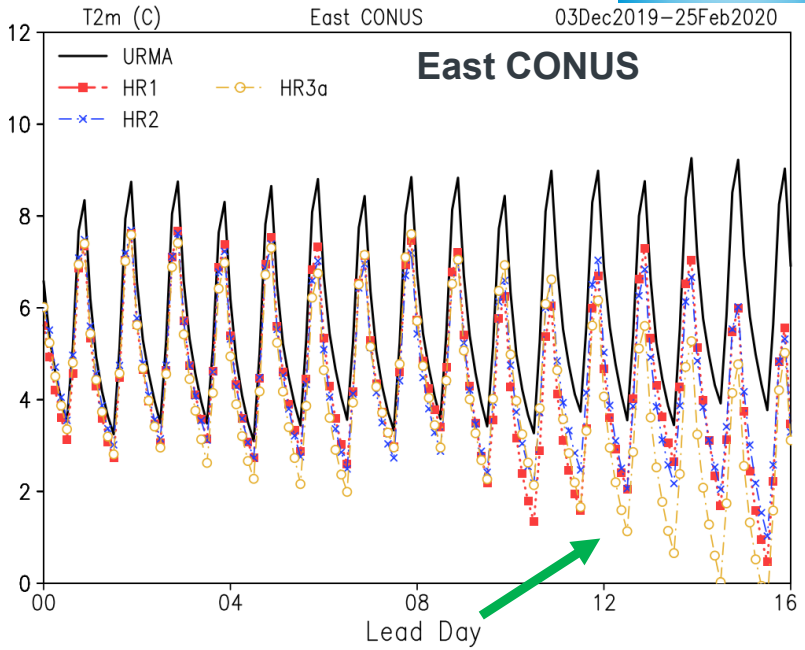
- **Warm on west CONUS in week 1**
- **Much cold in week 2.**

T2m (C): HR vs URMA Ave@W/E CONUS ICs: 03Dec2019-25Feb2020

Day 1 - 16 forecast

Winter



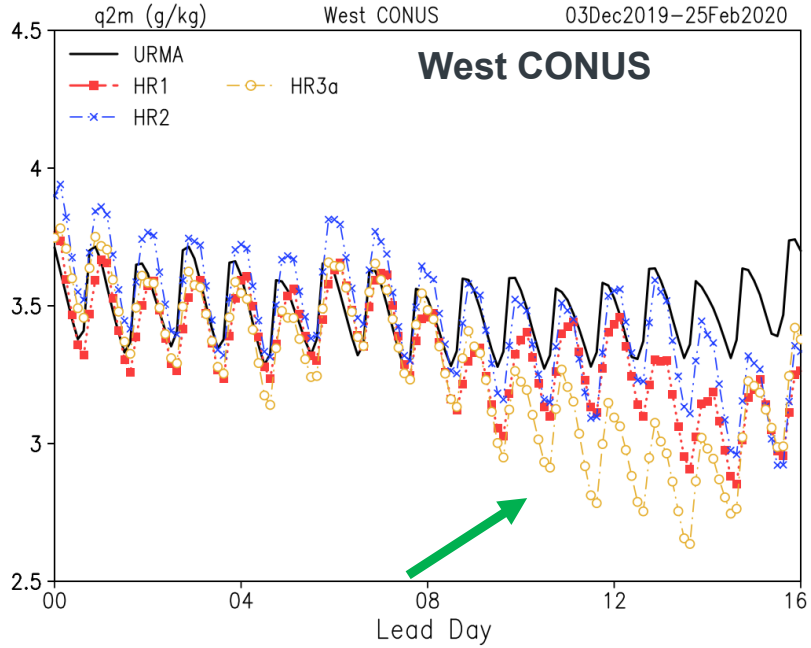


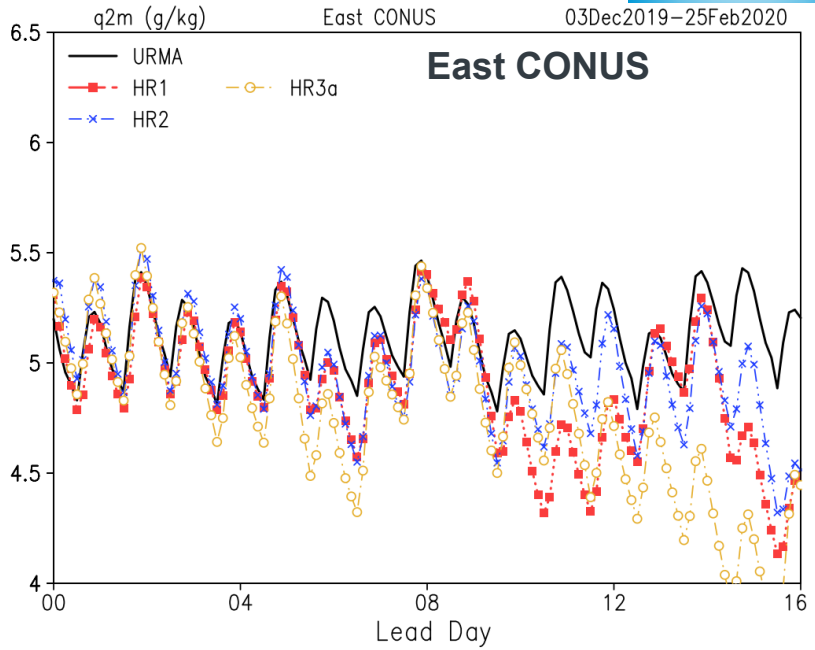
West: Cold daytime bias; HR3a shows night warm bias, and cold bias after one week.
East: HR3a shows much cold after one week.

q2m (g/kg): HR vs URMA Ave@W/E CONUS ICs: 03Dec2019-25Feb2020

Day 1 - 16 forecast

Winter



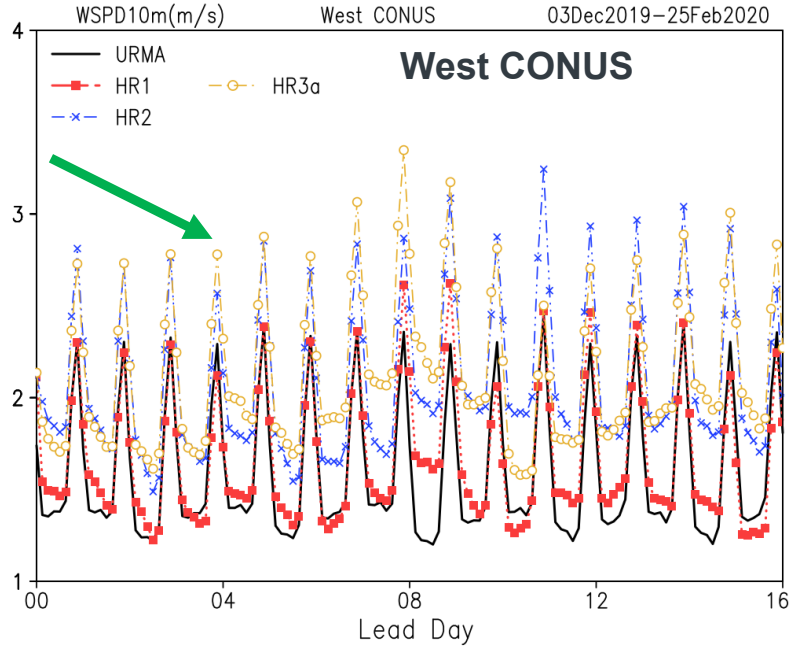


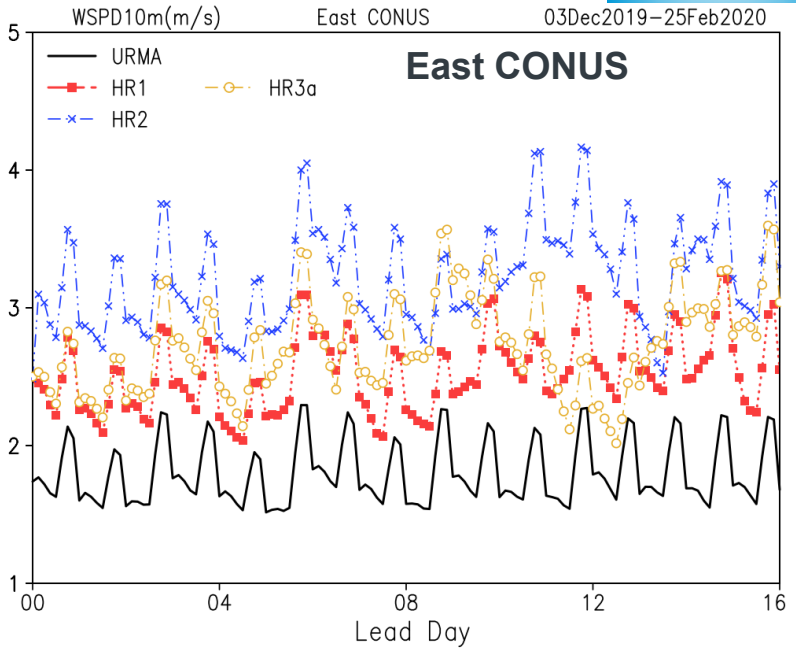
West: HR3a shows dry bias after one week.
East: HR3a shows dry bias after one a few days.

WSPD (m/s): HR vs URMA Ave@W/E CONUS ICs: 03Dec2019-25Feb2020

Day 1 - 16 forecast

Winter

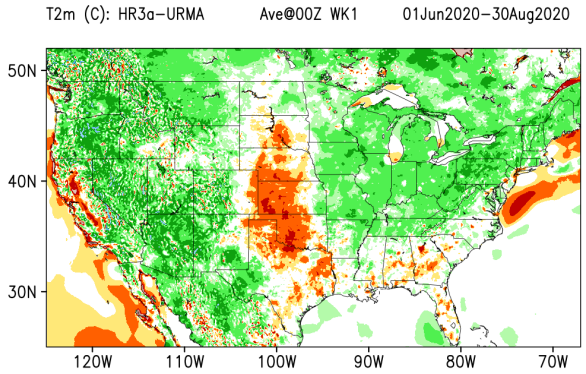


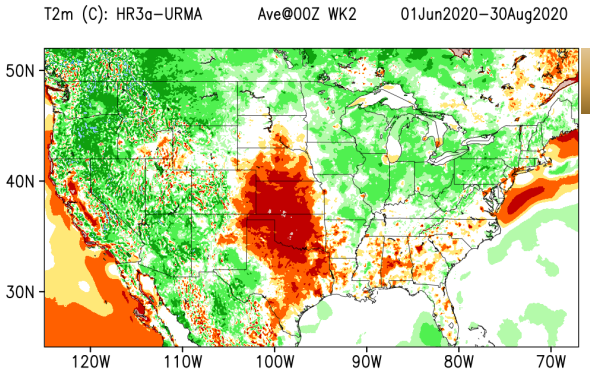


West: Similar or even higher bias than HR2.

East: HR3a shows lower than HR2 but higher than HR1.

T2m (C): HR3-URMA Ave@WK1 & 2 ICs: 01Jun2020-30Aug2020





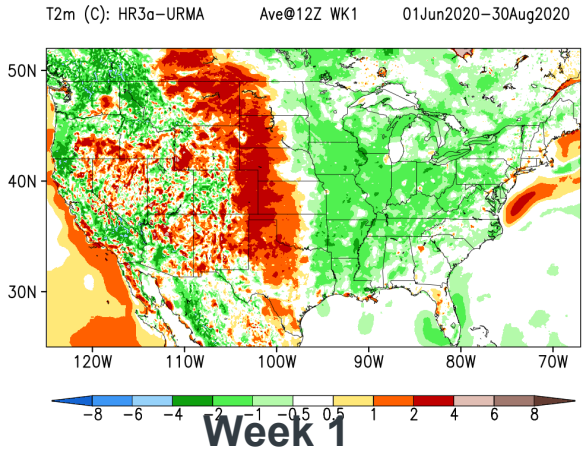
Summer

31 cases

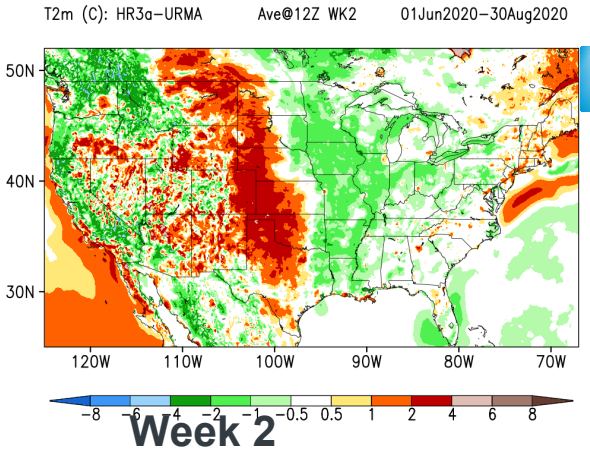
00Z

Daytime:

- **Warm in south GP.**



Week 1



Week 2

12Z

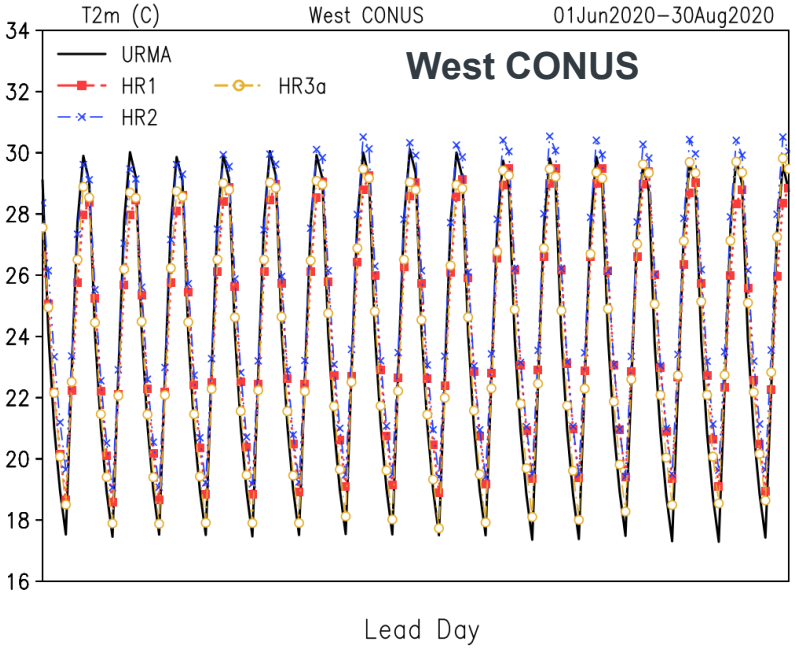
Nighttime:

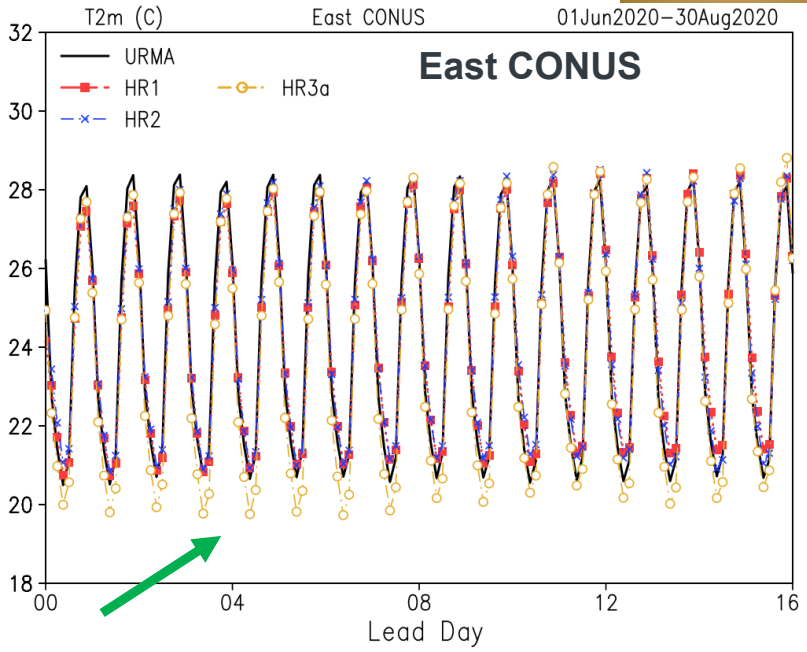
- **Much Warm in the central US.**

T2m (C): HR vs URMA Ave@W/E CONUS ICs: 01June-30Aug2020

Day 1 - 16 forecast

Summer



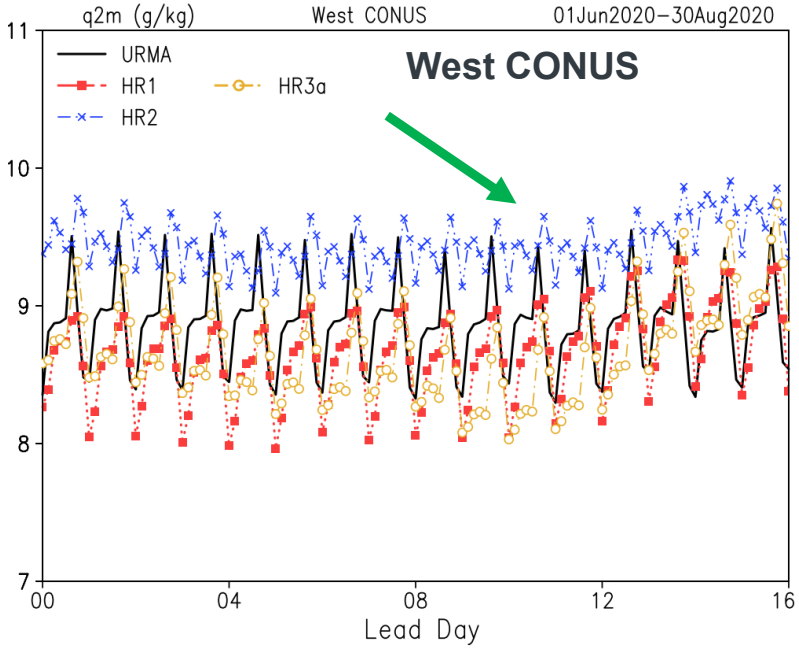


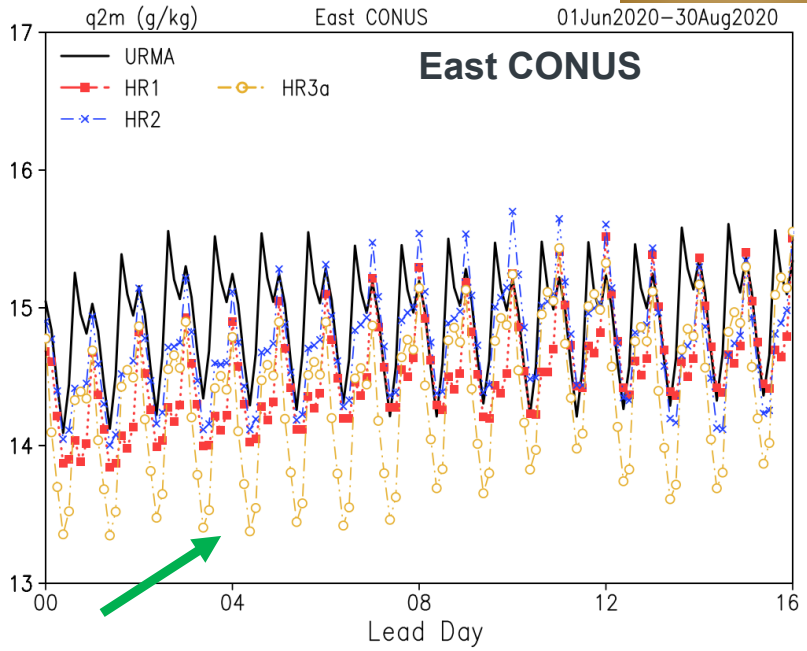
West: HR3a shows cold daytime bias but reduces nighttime warm bias in HR1 or HR2.
East: HR3a shows night cold bias, much colder than HR1 or HR2.

q2m (g/kg): HR vs URMA Ave@W/E CONUS ICs: 01June-30Aug2020

Day 1 - 16 forecast

Summer



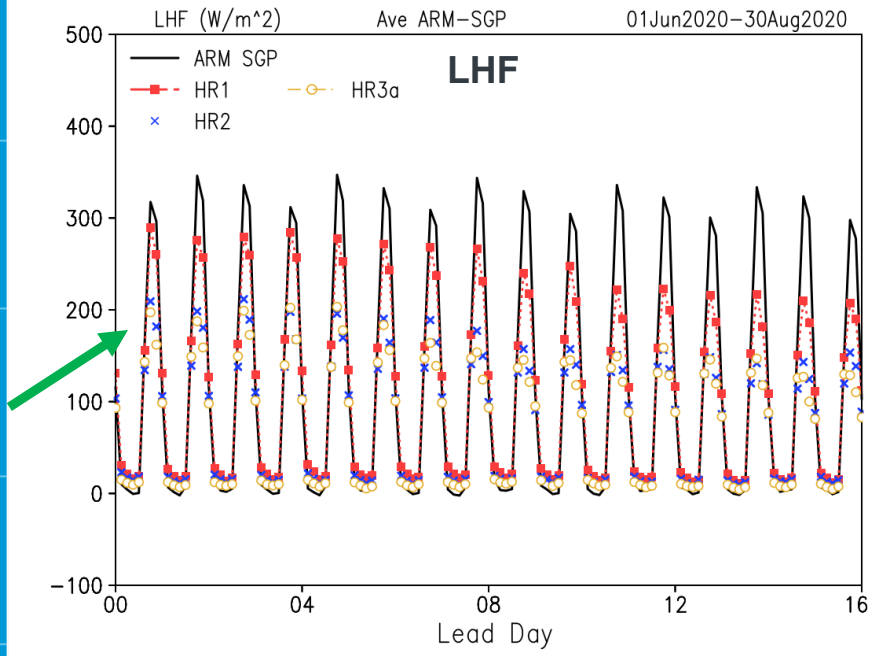


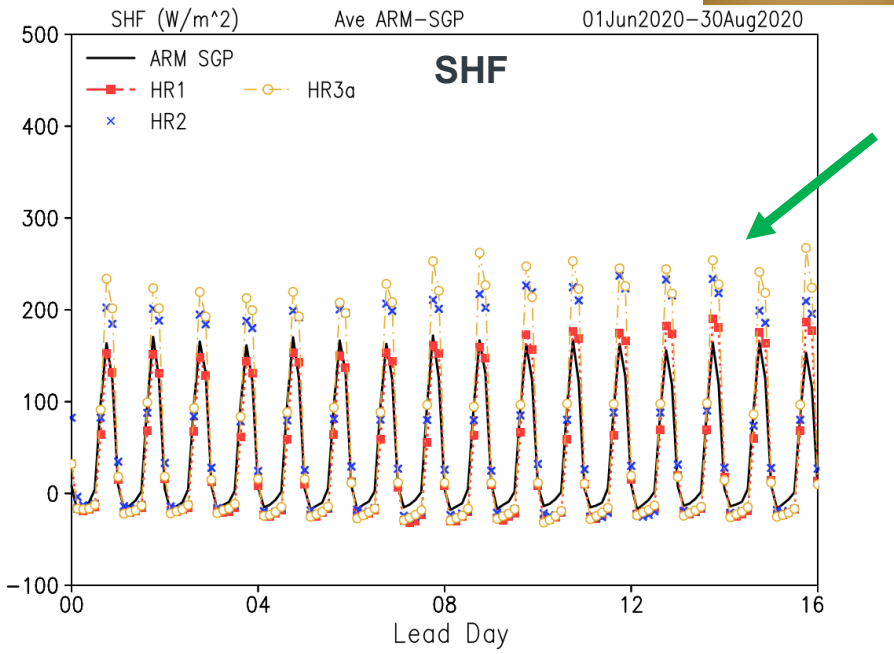
West: HR3a shows similar to HR1; HR2 shows wet bias because of diagnostic issue.

East: HR3a shows much dry bias.

LHF/SHF Ave ARM-SGP 01Jun – 30Aug 2020

Summer



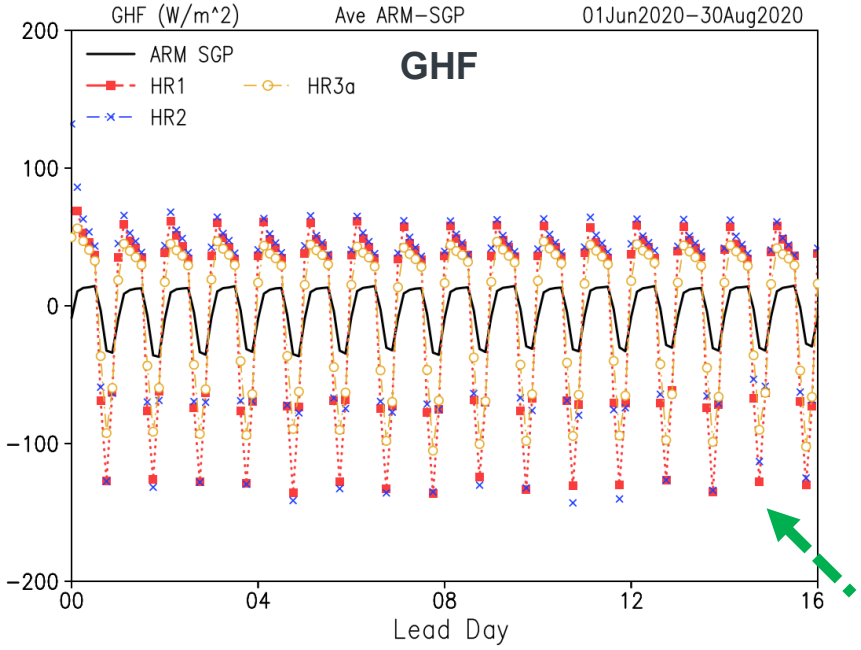


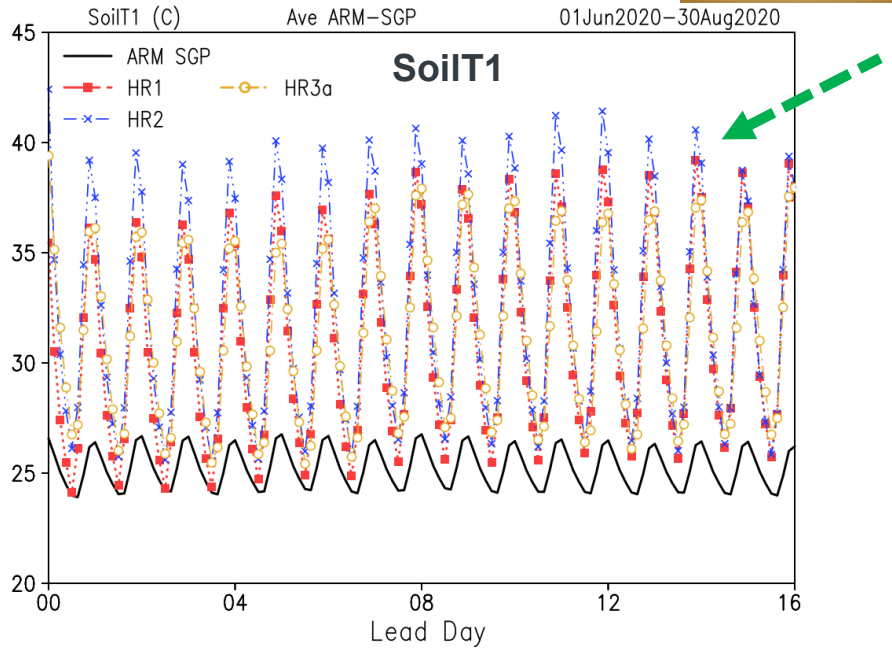
LHF: HR3a is similar to HR2, and shows low daytime bias

SHF: HR3a shows higher daytime bias.

GHF(W/m^2)/SoilT1 (K) Ave ARM-SGP 01Jun – 30Aug 2020

Summer





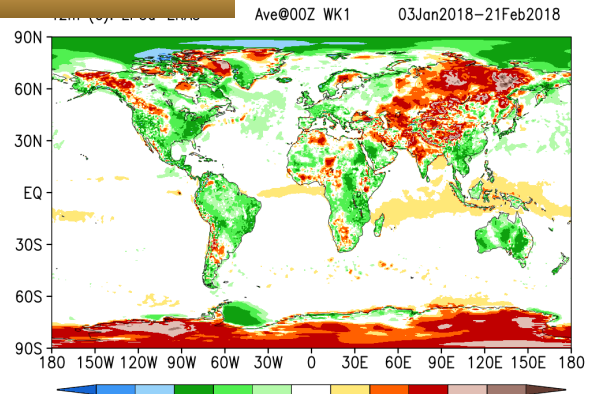
GHF: HR3a is similar to HR1 or HR2, and shows large biases.

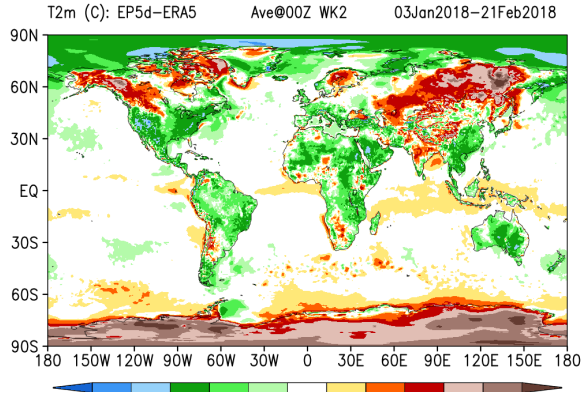
SoilT1: High daytime biases, and much higher in HR2.

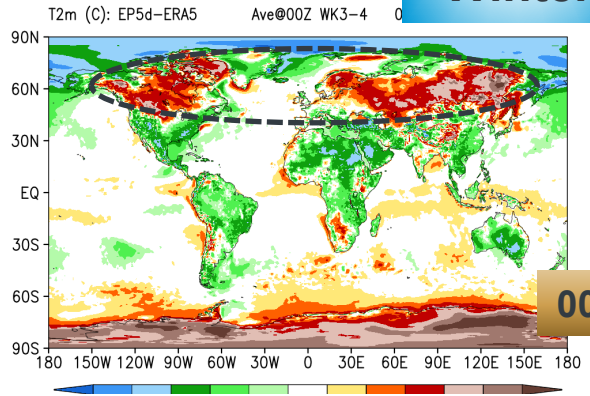
T2m (C): EP5d-ERA5 Ave@00,12Z (8 cases) ICs: 03Jan-21Feb 2018

EP5d fcst

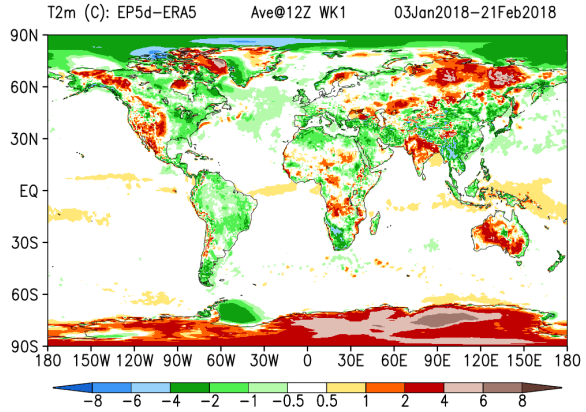
Winter

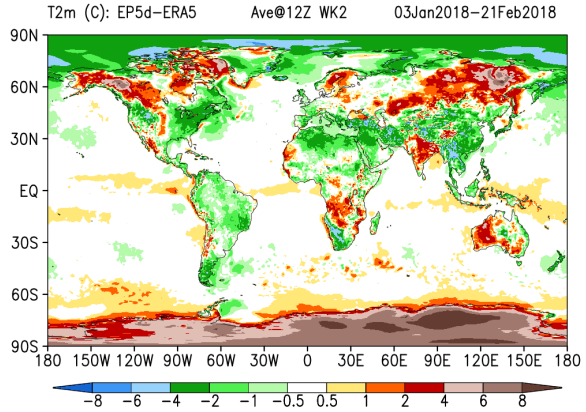


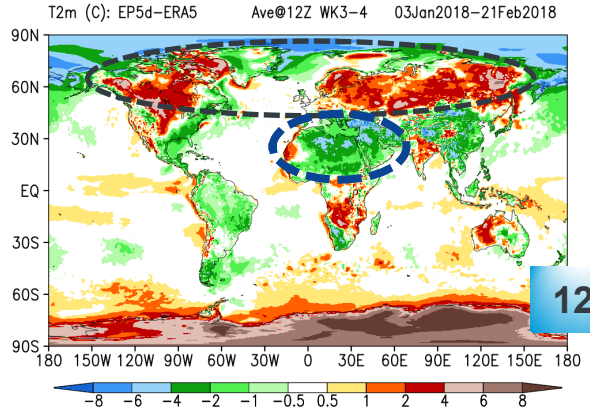




00Z







12Z

Week 1 Week 2 Week 3-4

Sensible/latent heat flux for vegetation

1-Loop test

Vegetated Ground: $SH_{g,v} = \rho\, C_p\, (T_{g,v} - T_{ac})/r_{ah,g}$

Vegetation Canopy: $SH_{can} = 2(L_e+S_e)\rho C_p\, (T_{can} - T_{ac})/r_b$

SHF above Canopy: $SH_{veg} = \rho\, C_p\, (T_{ac} - T_{air})/r_{ah}$

$$SH_{veg} = SH_{g,v} + SH_{can}$$

2-Loop:

loop1: do iter = 1, niterc ! 20

update T_{can}, T_{ac} to calculate SH_{veg}, SH_{can} using old $T_{g,v}$; update T_{ac} once

end do loop1

loop2: do iter = 1, niterg ! 5

update $T_{g,v}$ and $SH_{g,v}$l using new T_{ac}

end do loop2

1-Loop:

loop1: do iter = 1, niterc ! 20

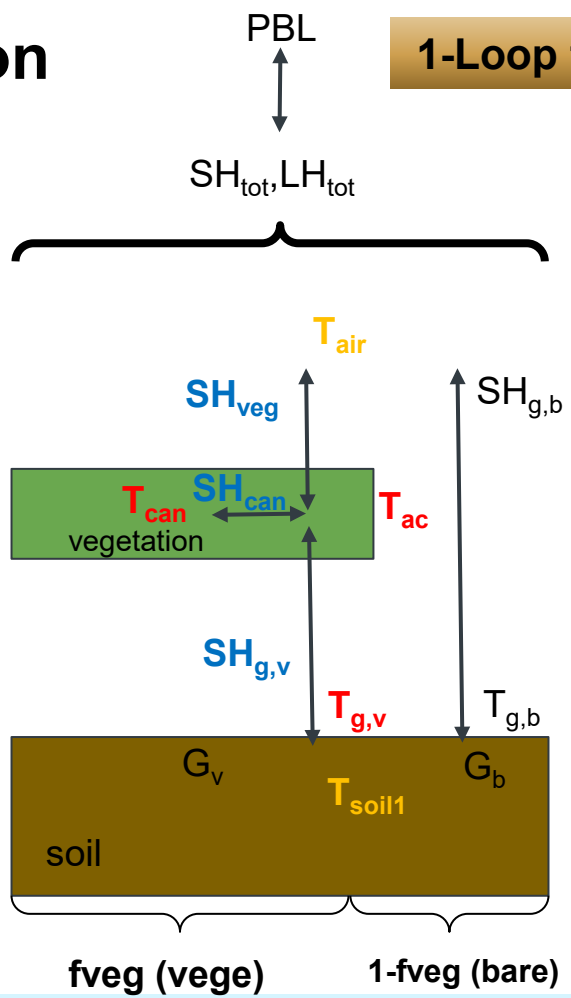
update T_{can}, T_{ac} to calculate SH_{veg}, SH_{can} using old $T_{g,v}$; update T_{ac}

update $T_{g,v}$ and $SH_{g,v}$l using new T_{ac}

end do loop1

T_{air} and T_{soil1} are prognostic variables, and others are diagnostic variables.

(Note: iteration until $SH_{veg} = SH_{can} + SH_{g,v}$, and similar to LH_{veg})

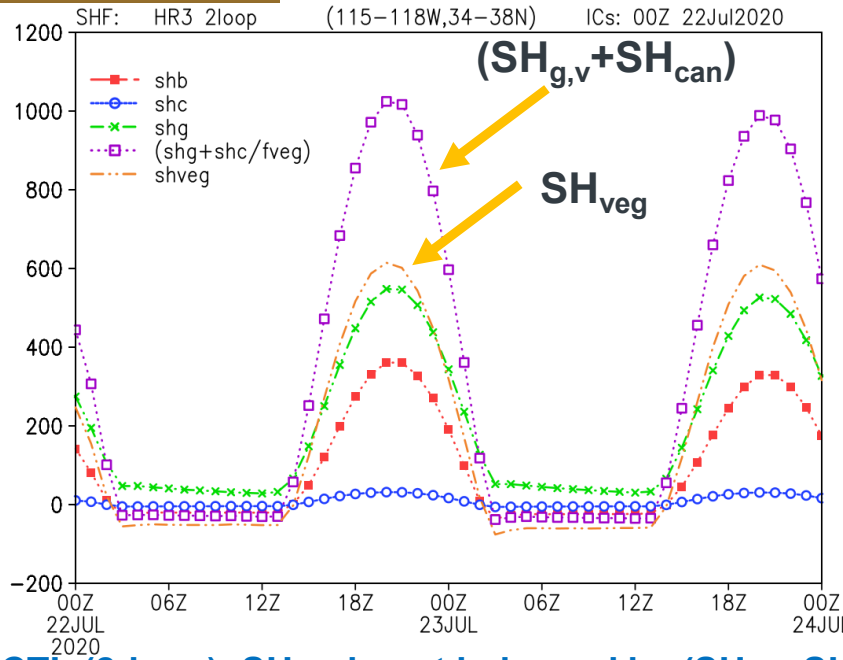


SHF_vege_bare Ave (115-118W, 34-38N) IC: 00Z 22July2020

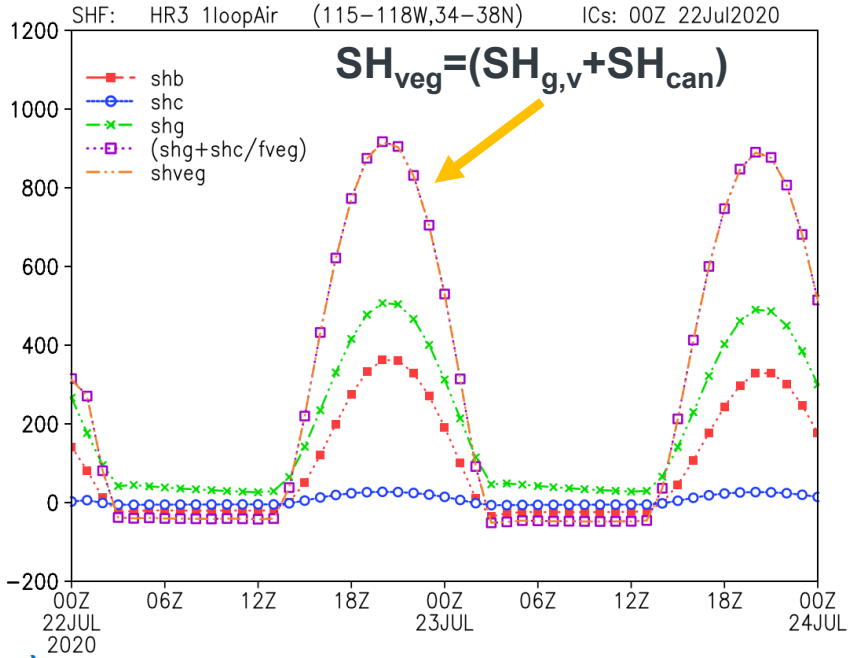
Day 1-2 fcst

1-Loop test

CTL (2-Loop)



1-Loop



Δ CTL (2-loop): SH_{veg} is not balanced by $(SH_{g,v}+SH_{can})$.

Δ EXP (1-loop): SH_{veg} would be balanced by $(SH_{g,v}+SH_{can})$.

Note: Flux calculation over vegetated tiles uses the Newton-Raphson iteration until $SH_{veg} = SH_{can} + SH_{g,v}$

Though the fluxes are not balanced, the surface energy is balanced, so no energy would lost here.

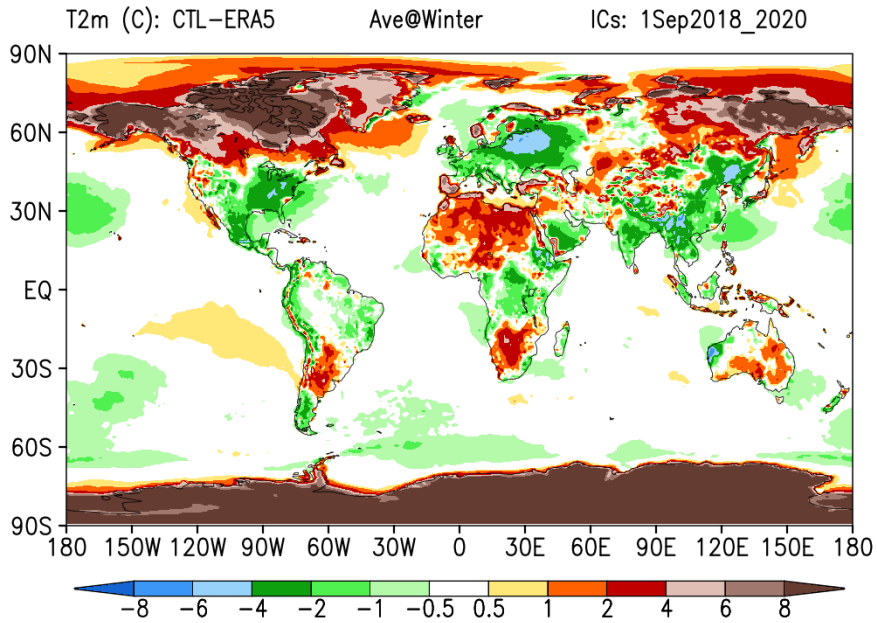
Diff T2m: 1Loop-CTL Ave@Winter ICs: 01Sep2018_2020

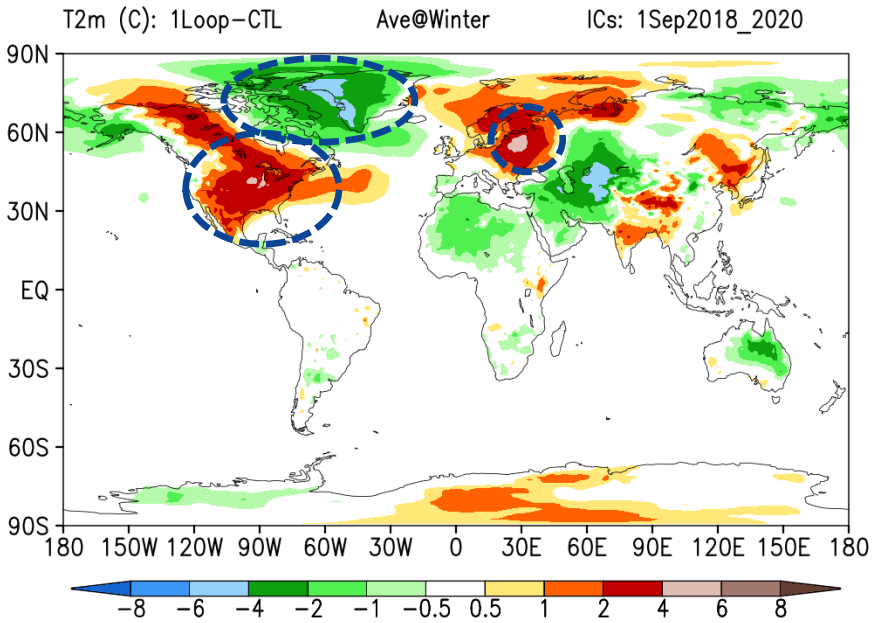
SFS fcst

CTL-ERA5

1Loop-CTL

1-Loop test

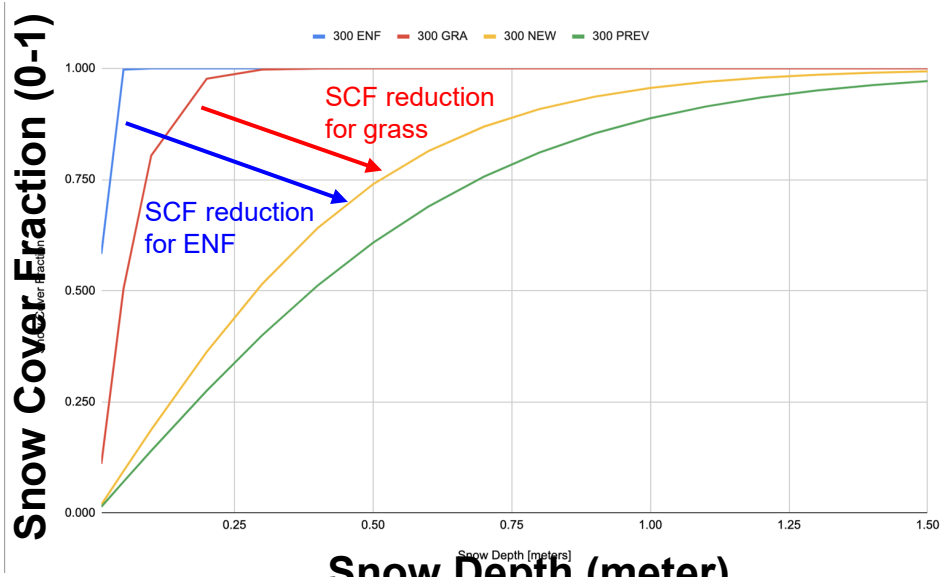


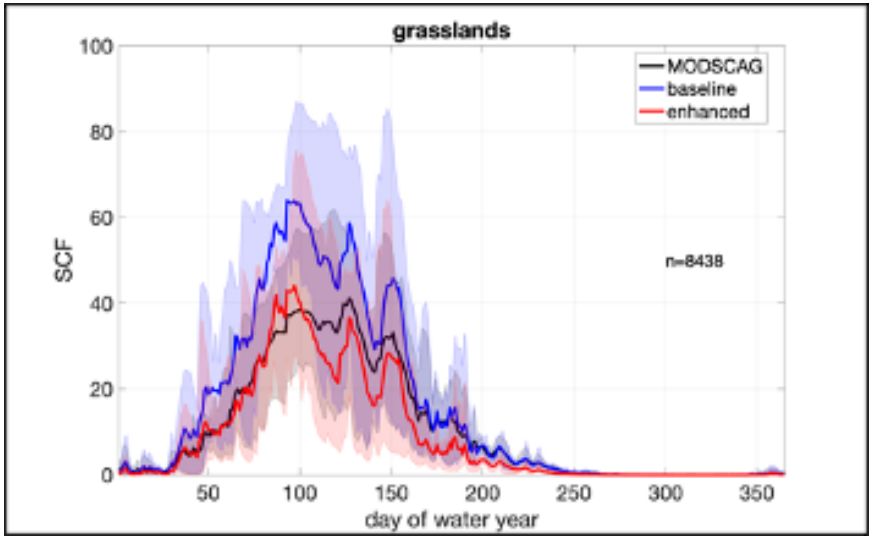


CTL: **Much warm in northern America & east Russia; Cold in CONUS, Central Europe & south Asia.**
1Loop: **Reduction of warm bias in northern America, and cold biases in CONUS & central Europe.**

Enhanced Snow Cover Fraction Parameterization

Courtesy Mike Barlage





Courtesy Ronnie A-R

SCF formulation (Niu and Yang, 2007):

SnowDensBulk = SnowWaterEquiv / SnowDepth

MeltFac = (SnowDensBulk / 100.0) SnowMeltFac**

SnowCoverFrac = tanh(SnowDepth /(SnowCoverFac * MeltFac))

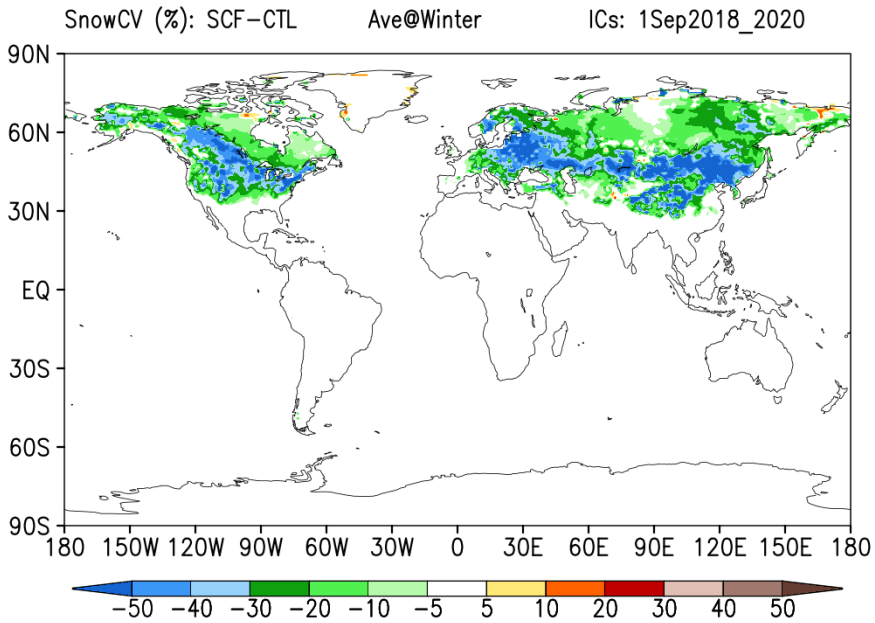
SCF: depends on snow depth, density, grid-size, veg_type.

- Working with NCAR group funded through WPO S2S/CTB to work on drought/snow in the western US; update snow parameters are being tested and should benefit winter cold bias.

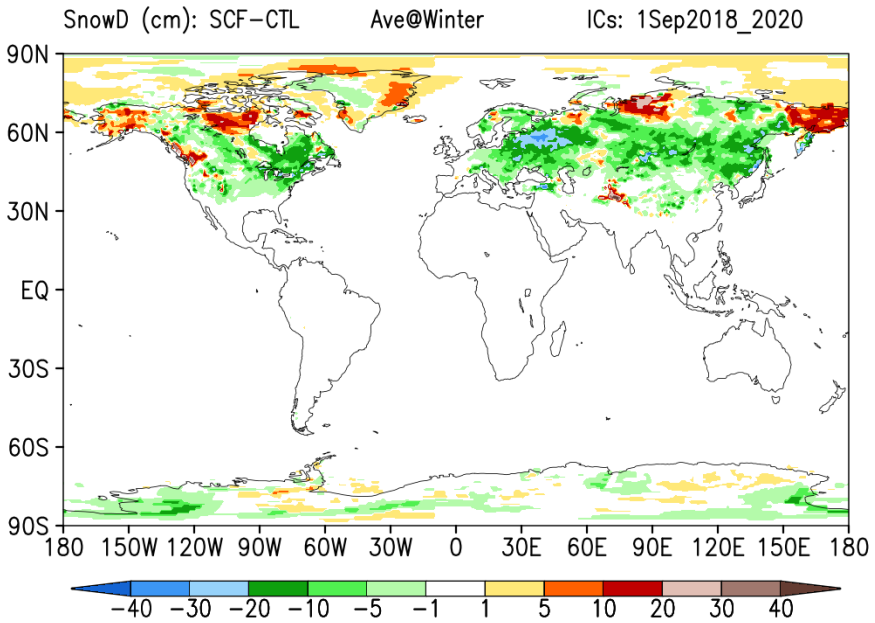
Diff Snow: SCF-CTL Ave@Winter ICs: 01Sep2018_2020

SFS fcst

Snow Cover (%)



Snow Depth (cm)

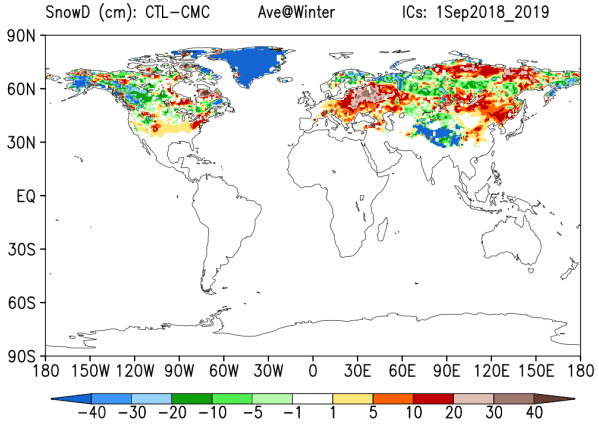


- ▲ ***Snow Cover***: **Reduction over the southern regions of NH;**
- ▲ ***Snow Depth***: **Reduction over northeast CONUS, from Europe to Asia.**

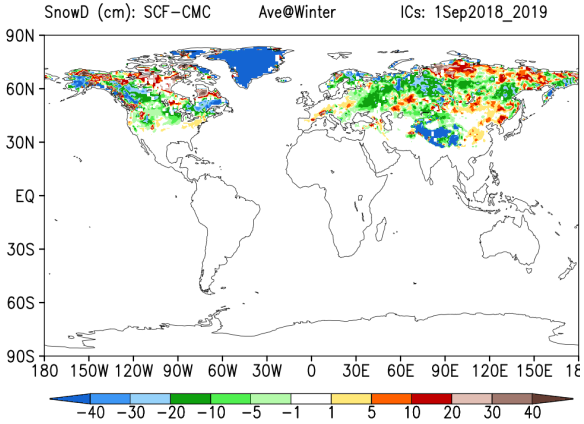
SnowD (cm): CMC Ave@Winter ICs: 01Sep2018_2019

SFS fcst

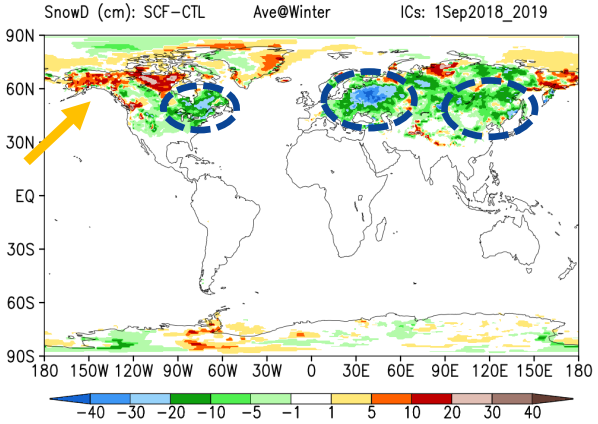
CTL-CMC



SCF-CMC



SCF-CTL



SCF sensitivity: against the CMC daily snow depth analysis data (Winter):

- ▲ *CTL*: high bias over northeast CONUS, Europe and east Asia;
- ▲ *SCF*: Reduction over these three regions in CTL; Increase in Alaska.

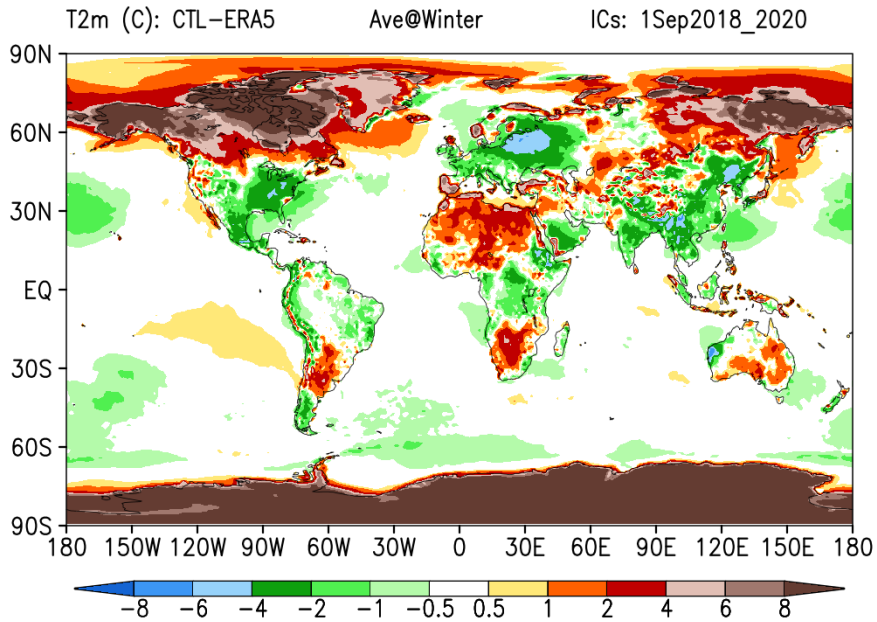
Diff T2m: SCF-CTL Ave@Winter ICs: 01Sep2018_2020

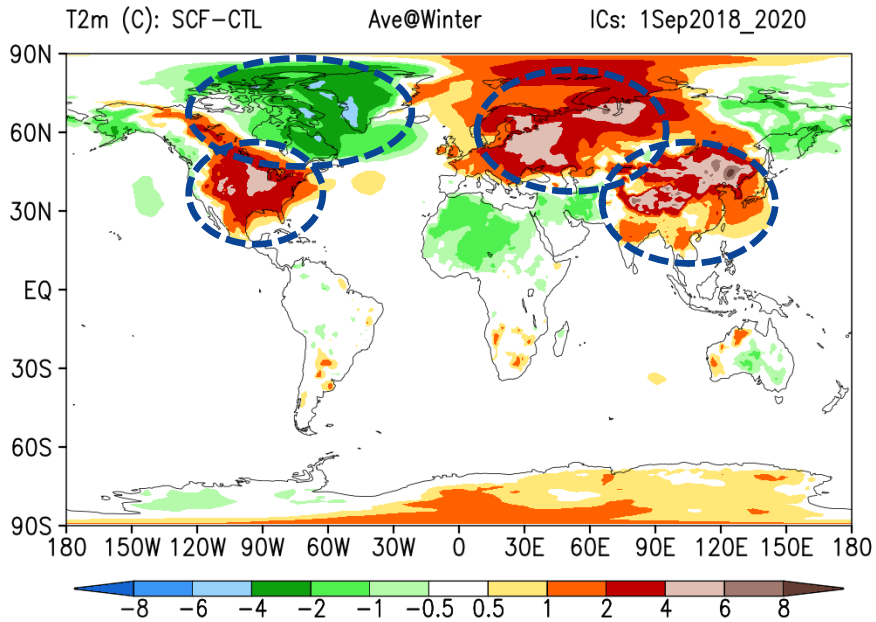
SFS fcst

CTL-ERA5

SCF-CTL

SCF test





CTL: **Much warm in northern America & east Russia; Cold in CONUS, Central Europe & southeast Asia.**

SCF: **Reduction of warm bias in northern America, and cold biases in other three regions.**

Need to understand these patterns via further analyses with multi-year runs.

Summary and Discussion

- There are noticeable improvements and biases in the model performance from UFS (HR3), EP5d and SFS which are coupled with Noah-MP LSM.

- Some biases such as the ground heat flux or soil temperatures need further investigation and improvement.

- The single loop approach for vegetation calculation in Noah-MP produced balanced sensible heat flux and showed improvement of 2-m temperature simulation.

- The enhanced snow cover fraction parameterization produced lower snow cover fraction, mostly over the southern regions of snowpack in the Northern Hemisphere. Consequently, it reduced biases in 2-m temperatures in the middle and high latitudes.

- Future: Validation against more observed measurements, parameter optimization and improvement of the land surface physics.

Thank you!

Any questions/comments?

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