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

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

Weizhong Zheng\textsuperscript{1,2}, Michael Barlage\textsuperscript{2}, Helin Wei\textsuperscript{1,2} and Fanglin Yang\textsuperscript{2}

\textsuperscript{1} Lynker @ NOAA/NWS/NCEP/Environmental Modeling Center
\textsuperscript{2} NOAA/NWS/NCEP/Environmental Modeling Center
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)
### Winter

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

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

---

29 cases
**Winter**

**Daytime:**
- Much cold in week 2.

**Nighttime:**
- Warm on west CONUS in week 1
- Much cold in week 2.
West: Cold daytime bias; HR3a shows night warm bias, and cold bias after one week.

East: HR3a shows much cold after one week.
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

West: Similar or even higher bias than HR2.
East: HR3a shows lower than HR2 but higher than HR1.
**Daytime:**
- Warm in south GP.

**Nighttime:**
- Much Warm in the central US.
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.
West: HR3a shows similar to HR1; HR2 shows wet bias because of diagnostic issue.
East: HR3a shows much dry bias.
LHF: HR3a is similar to HR2, and shows low daytime bias.

SHF: HR3a shows higher daytime bias.
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

Week 1

Week 2

Week 3-4

Building a Weather-Ready Nation // 13
Sensible/latent heat flux for vegetation

**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 \( SH_{g,v} \) 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 \( SH_{g,v} \) 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 \( LH_{veg} \))
\( \Delta \ \text{CTL (2-loop): } SH_{veg} \text{ is not balanced by } (SH_{g,v} + SH_{can}). \)

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

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 be lost here.
Diff T2m: 1Loop-CTL

Ave@Winter

ICs: 01Sep2018_2020

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**

SCF formulation (Niu and Yang, 2007):

\[
\text{SnowDensBulk} = \frac{\text{SnowWaterEquiv}}{\text{SnowDepth}}
\]

\[
\text{MeltFac} = (\frac{\text{SnowDensBulk}}{100.0})^{\text{SnowMeltFac}}
\]

\[
\text{SnowCoverFrac} = \tanh\left(\frac{\text{SnowDepth}}{(\text{SnowCoverFac} \times \text{MeltFac})}\right)
\]

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**

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

### CTL-ERA5

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

### SCF-CTL

- 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?

Email: Weizhong.Zheng@noaa.gov