Evaluation of land-atmosphere processes of the Polar WRF in the summertime Arctic tundra

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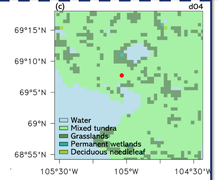
Introduction

- Polar Weather Research and Forecasting (PWRF) is a useful tool for studying the weather and climate in polar regions at a high-resolution.
- It has been developed to simulate the various surfaces of the polar regions, but has been mainly focused on snow and sea-ice surfaces.
- Therefore, its use is limited for studies in snow-free tundra environment in summer, and this period will expand with global warming.
- This study
  1) investigated the performance of PWRF in the summertime Arctic tundra, based on in-situ observations of Korea Polar Research Institute (KOPRI) and Environmental Canada (EC) at Cambridge Bay, Canada.
  2) conducted series of sensitivity experiments to quantify the modeling errors from physical parameters, and improved the model performance.

Materials and methods

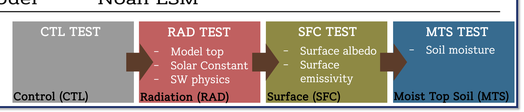
- Site: Cambridge Bay, Nunavut, Canada (69°07′N, 105°03′W)
- Period: 2012.07.01.00 – 10.00 LST (9 days, 48-h spin-up)



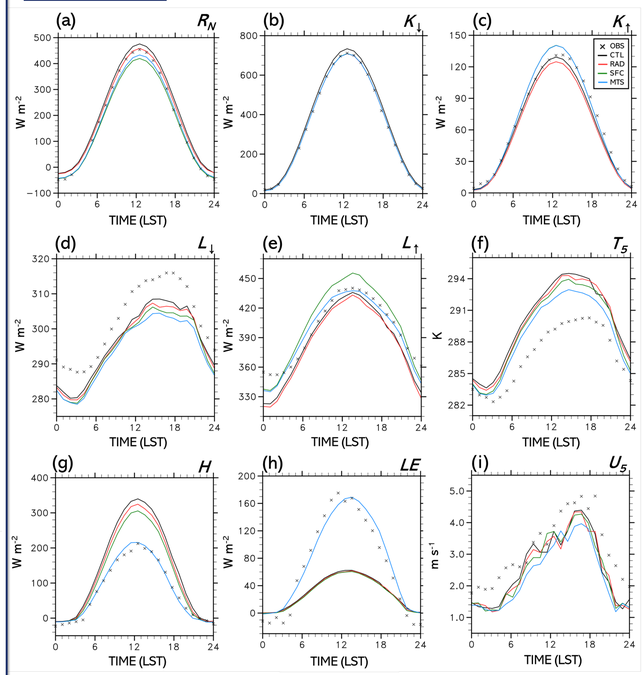
- Evaluation variables: Net radiation (R_N), Shortwave radiation (K), Longwave radiation (L), Sensible heat flux (H), Latent heat flux (LE), 5-m temperature (T_5), 5-m wind speed (U_5), vertical potential temperature (θ)
- Physics package followed Hines et al., 2011

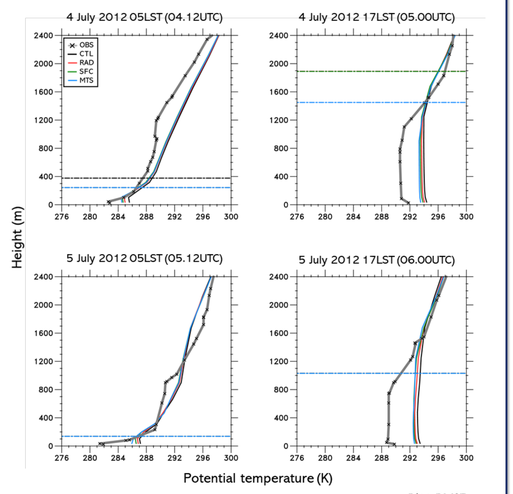
Microphysics	Morrison 2-moment scheme
PBL physics	Mellor-Yamada-Janjic (MYJ) scheme
Surface layer physics	Eta similarity scheme
Radiation physics	Shortwave : Goddard shortwave scheme Longwave : RRTMG longwave scheme
Cumulus physics	Grell – Devenyi ensemble scheme
Land surface model	Noah LSM

- Sensitivity experiments



Results





Bias *RMSE* (Correlation coefficient)

VAR. / Units	R_N (W m^{-2})	$K_\downarrow$ (W m^{-2})	$K_\uparrow$ (W m^{-2})	$L_\downarrow$ (W m^{-2})	$L_\uparrow$ (W m^{-2})	H (W m^{-2})	LE (W m^{-2})	T_5 (K)	U_5 (m s^{-1})
CTL	26.5 *27.7* (0.99)	17.5 *20.2* (0.99)	−3.9 *6.3* (0.99)	−7.7 *10.2* (0.86)	−12.4 *16.2* (0.97)	66.9 *83.9* (0.99)	−43.3 *64.9* (0.94)	3.0 *3.4* (0.93)	−0.5 *1.1* (0.79)
RAD	14.6 *17.3* (0.99)	0.5 *6.3* (0.99)	−6.8 *8.6* (0.99)	−8.4 *10.4* (0.87)	−15.3 *18.5* (0.97)	56.6 *72.1* (0.99)	−44.3 *65.7* (0.94)	2.7 *3.1* (0.94)	−0.6 *1.1* (0.81)
SFC	−15.7 *21.6* (0.99)	0.8 *6.4* (0.99)	1.1 *6.0* (0.99)	−9.0 *10.4* (0.87)	6.2 *14.0* (0.97)	45.7 *59.0* (0.99)	−45.1 *66.1* (0.95)	2.4 *2.9* (0.93)	−0.7 *1.2* (0.79)
MTS	−7.5 *14.0* (0.99)	0.6 *6.5* (0.99)	1.1 *6.0* (0.99)	−9.5 *10.4* (0.86)	−2.3 *10.0* (0.97)	3.3 *15.2* (0.98)	6.0 *19.4* (0.97)	1.9 *2.4* (0.93)	−0.8 *1.3* (0.80)

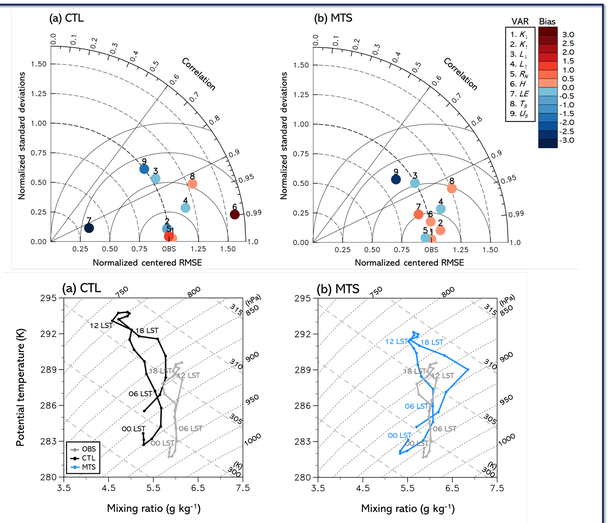
1) CTL (black line)

- Except for $L_\downarrow$, all radiative fluxes contributed to overestimate R_N (Overestimated $K_\downarrow$, Underestimated $K_\uparrow$ and $L_\uparrow$).
- The model allocated more available energy to H than LE (Large Bowen ratio > 5).
- This surface energy imbalance is caused by solar radiation parameterization, surface radiative properties, and dry simulated land.
- It leads to warm and dry PBL.

We conducted RAD, SFC, MTS tests to improve the model's performance.

2) RAD (red line)

- Sensitivity tests are conducted for
  (1) Model top (50 to 1 hPa)
  (2) Solar constant (1370 to 1361 W m^{-2})
  (3) Shortwave scheme (Goddard to RRTMG)
  to reduce the overestimated $K_\downarrow$.
- It shows best simulation performance when the RRTMG scheme is used instead of Goddard.
- We decided it as the RAD test.
- Bias and RMSE of $K_\downarrow$ decrease drastically, and it makes R_N better (Table above).



3) SFC (green line)

- Surface albedo is changed to 0.20 from 0.18, and surface emissivity is changed to 0.98 from 0.92 based on observation.
- The performance of $K_\uparrow$ and $L_\uparrow$ is improved.

4) MTS (blue line)

- Fixed top soil layer's water content to 0.28 m^3 m^{-3} based on observation.
- As surface temperature decreases, the $L_\uparrow$ is improved and the R_N is also improved.
- H and LE are also simulated to the level similar to the observations.
- Surface energy balance is improved and other simulated variables also show improved results.
- When simulating a tundra region with PWRF, it is necessary to select and prescribe appropriate physical parameterizations.

Acknowledgement

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