Evaluating surface variables simulated by NARCCAP over the Great Lakes Region

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Introduction

- The Great Lakes region, as the largest fresh water body in the world, is regarded as a major resource for water usages and plays an important role in the U.S. economy.
- The Great Lakes region might be susceptible to the effect of global warming, as the changes of climate condition could influence the surface energy partition and water cycle, further affecting Great Lakes water level.
- Regional Climate Models (RCMs), which provides finer spatial resolution than GCMs, provide one possible solution to assess regional impacts of climate change.

Which RCM is good or reliable?

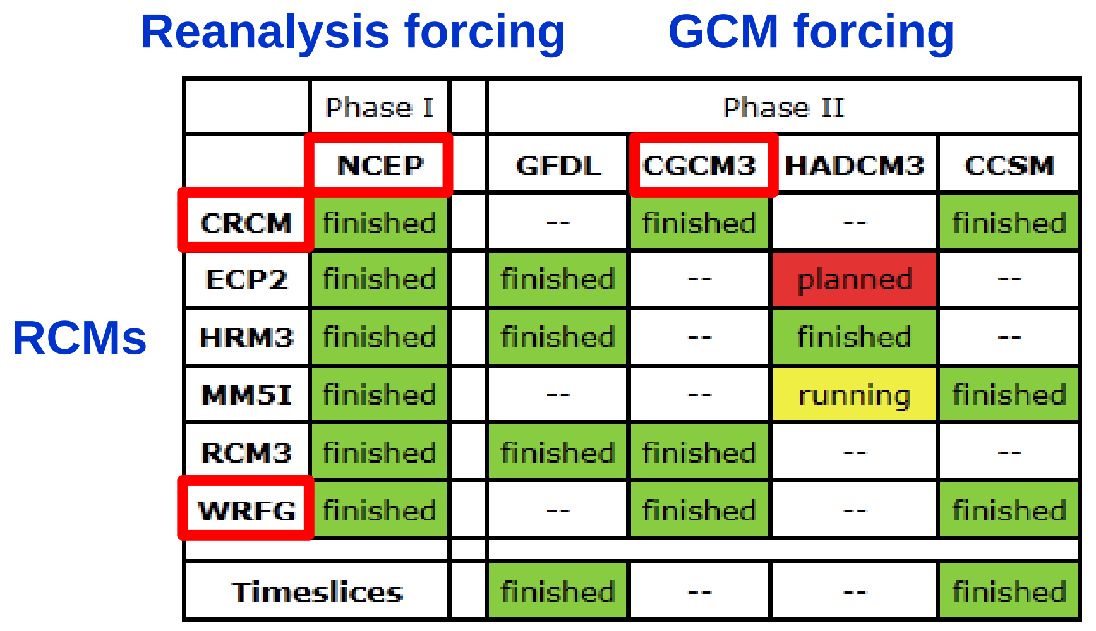
- Although same principles of physics, chemistry, and fluid dynamics are employed in RCMs or GCMs, different formulations, parameterizations, and boundary conditions in models lead to different projections.
- The focus of this study is to evaluate the simulated land surface variables (in energy partition process or in the water cycle) by different RCMs in the NARCCAP archive. The historical runs of the RCMs were compared with the reanalysis dataset from GLDAS over the Great Lakes Region.

Data and methods

NARCCAP

- **N**orth **A**merican **R**egional **C**limate **C**hange **A**ssessment **P**rogram: multiple RCM simulations as an ensemble over the continental U.S. with different GCM hosts providing boundary conditions (REF: Gutowski et al., 2010; Mearns et al., 2009).
- The historical and future runs of RCMs from the NARCCAP program have been used to evaluate effects of climate change on variables such as surface temperature, runoff and snow water equivalent.

Fig. 1. The location of the Great Lakes Region (red area), and the chosen area for analysis (blue box).



	Phase I	Phase II			
	NCEP	GFDL	CGCM3	HADCM3	CCSM
CRCM	finished	--	finished	--	finished
ECP2	finished	finished	--	planned	--
HRM3	finished	finished	--	finished	--
MM5I	finished	--	--	running	finished
RCM3	finished	finished	finished	--	--
WRFG	finished	--	finished	--	finished
Timeslices		finished	--	--	finished

Fig. 2. Status of NARCCAP archived RCM/GCM combinations, and the chosen 4 runs: **CRCM-NCEP**, **CRCM-CGCM3**, **WRFG-NCEP**, **WRFG-CGCM3**.

RCMs
- **CRCM**, Canadian Regional Climate Model version 4
- **WRFG**, Weather Research and Forecasting Model

Forcing
- **NCEP**, National Center Environmental Prediction
- **CGCM3**, Coupled Global Climate Model (3rd Generation)

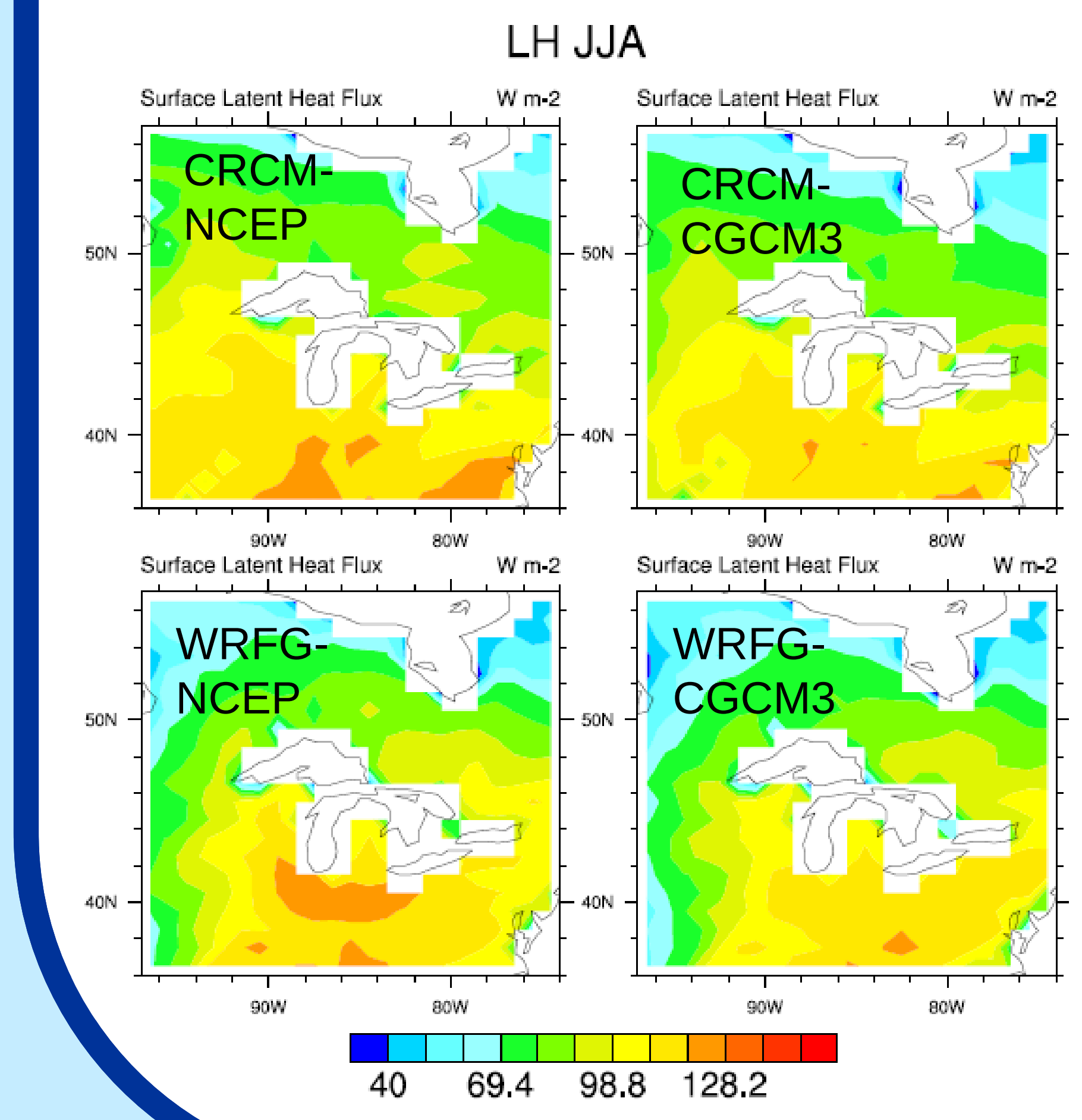
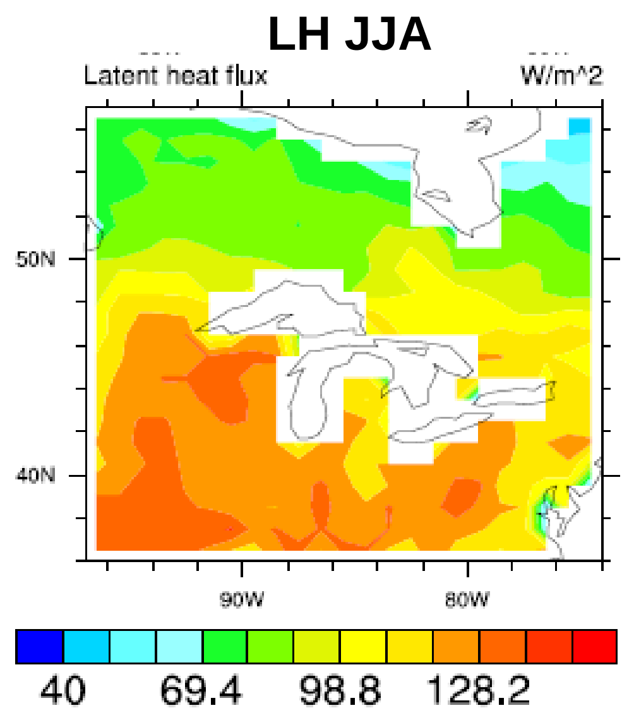


Fig. 3. An exampled of the processed surface variables: spatial distribution of temporally averaged surface latent heat flux of JJA season over the Great Lakes Region. The used NARCAP data: historical time-slice, 3-hourly, 50 km-resolution.

Data processing procedures:
- Select time period: 1980/1-1999/12
- Average/sum 3-hourly to monthly
- Project to regular grids (as in GLDAS)
- Mask out lake area (as in GLDAS)
- Subselect Great Lakes region
- Average spatially over the region

GLDAS

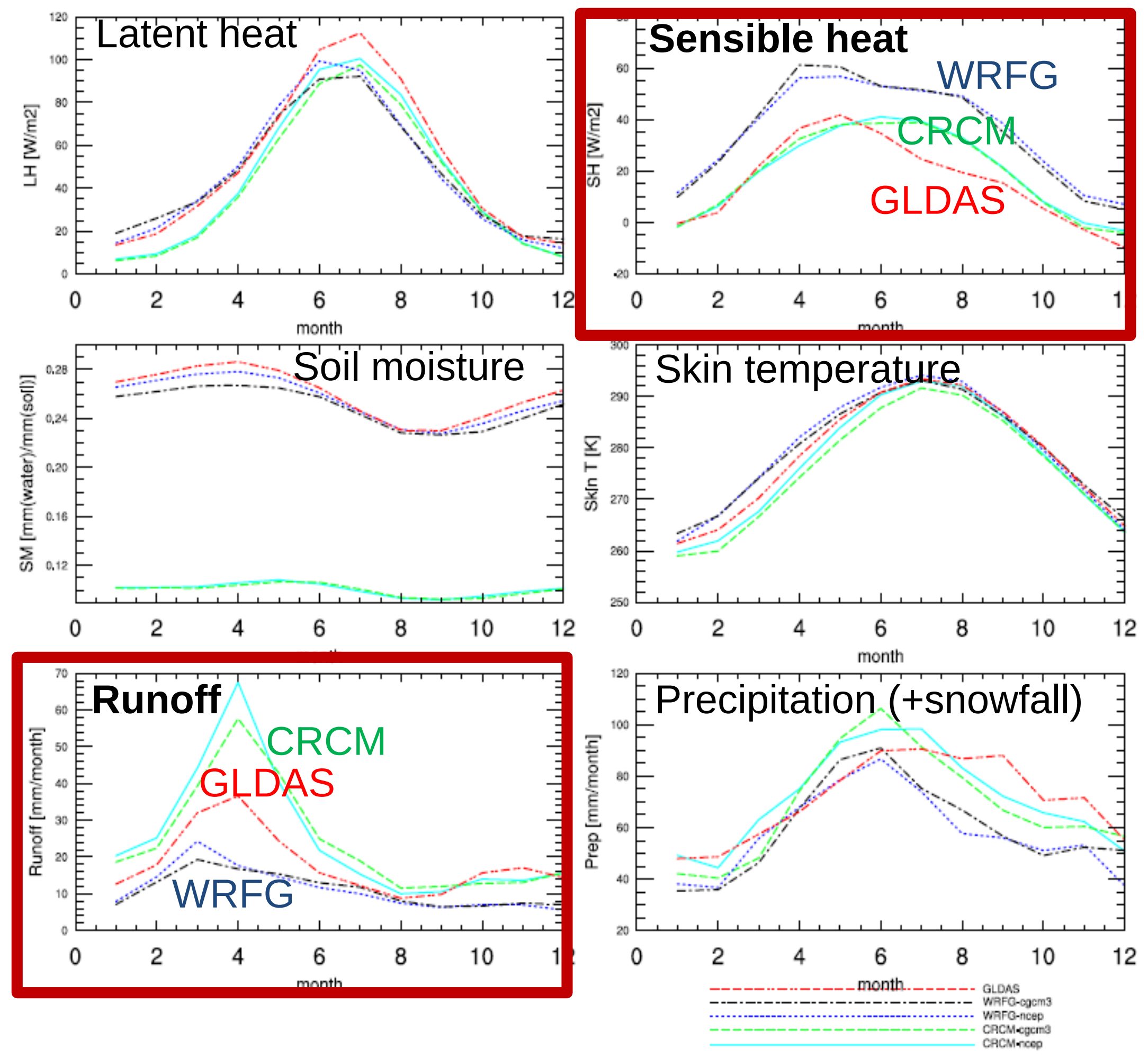


- **G**lobal **L**and **D**ata **A**ssimilation **S**ystem: generated optimal fields of land surface states and fluxes, ingesting satellite- and ground-based observational data products (REF: Rodell et al., 2004).
- GLDAS outputs are not affected by numerical weather prediction biases.
- GLDAS were used as the reanalyzed observation data to evaluate the performance of RCMs from NARCCAP.

Fig. 4. An exampled of the processed surface variables: spatial distribution of temporally averaged surface latent heat flux of JJA season over the Great Lakes Region. The used GLDAS data: monthly, 0.25 degree resolution, driven by **Noah** (**same as in WRFG in NARCCAP**).

Monthly climatology

Significance differences between NARCCAP and GLDAS exist for **sensible heat** and **runoff.**

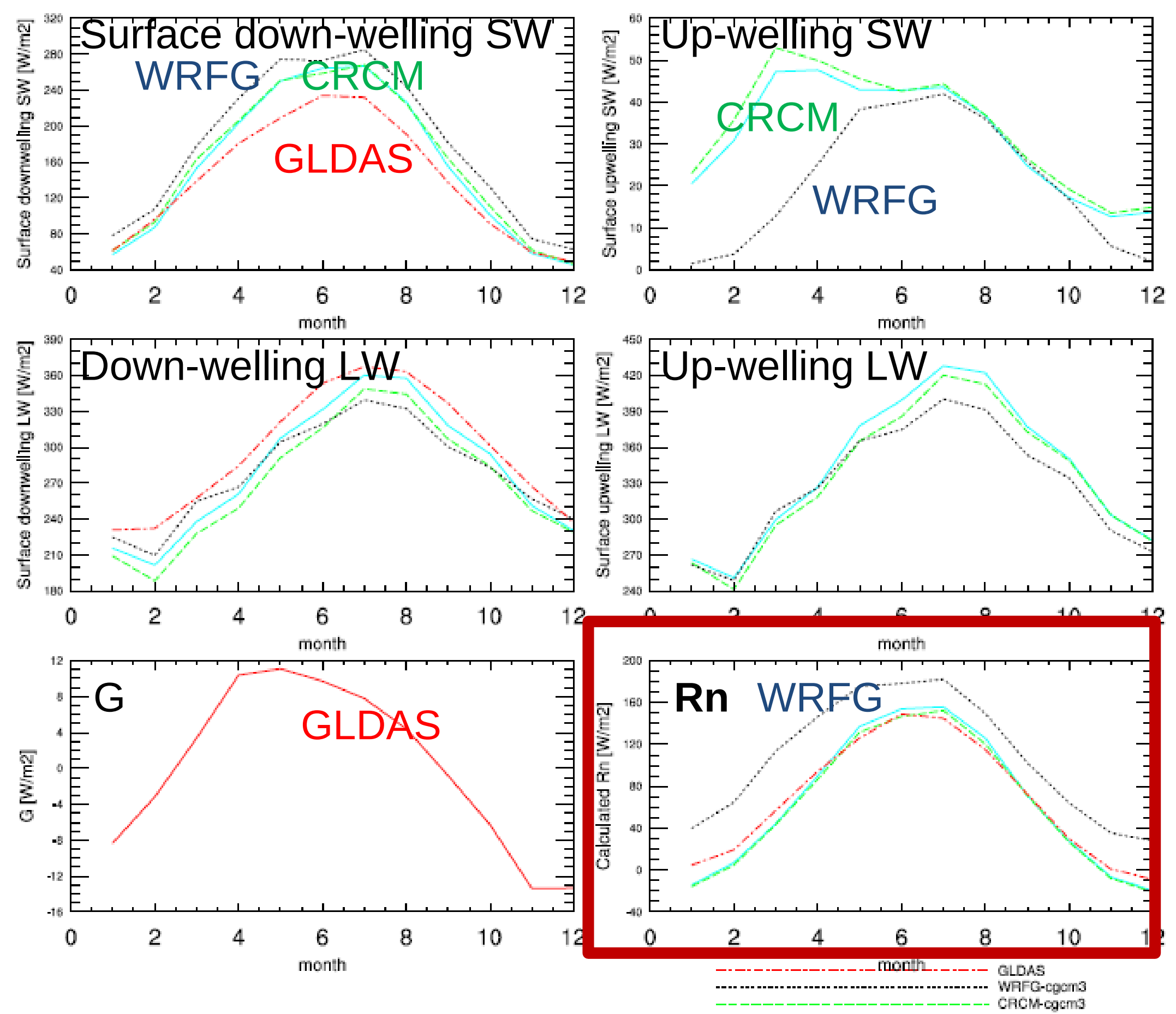


Variability is mainly caused by model schemes, rather than forcing, i.e., same RCMs give similar results:
- WRFG-NCEP VS. WRFG-CGCM3
- CRCM-NCEP VS. CRCM-CGCM3

Soil moisture differences
- Averaging depths
- Initial value
- Soil properties
- Precipitation

Consistent latent heat, skin air temperature, seasonality of precipitation.

Rn



Down-welling SW differences
- Different atmospheric schemes

Up-welling SW differences
- CRCM has more snow

Calculation of Rn
- WRFG, CRCM:

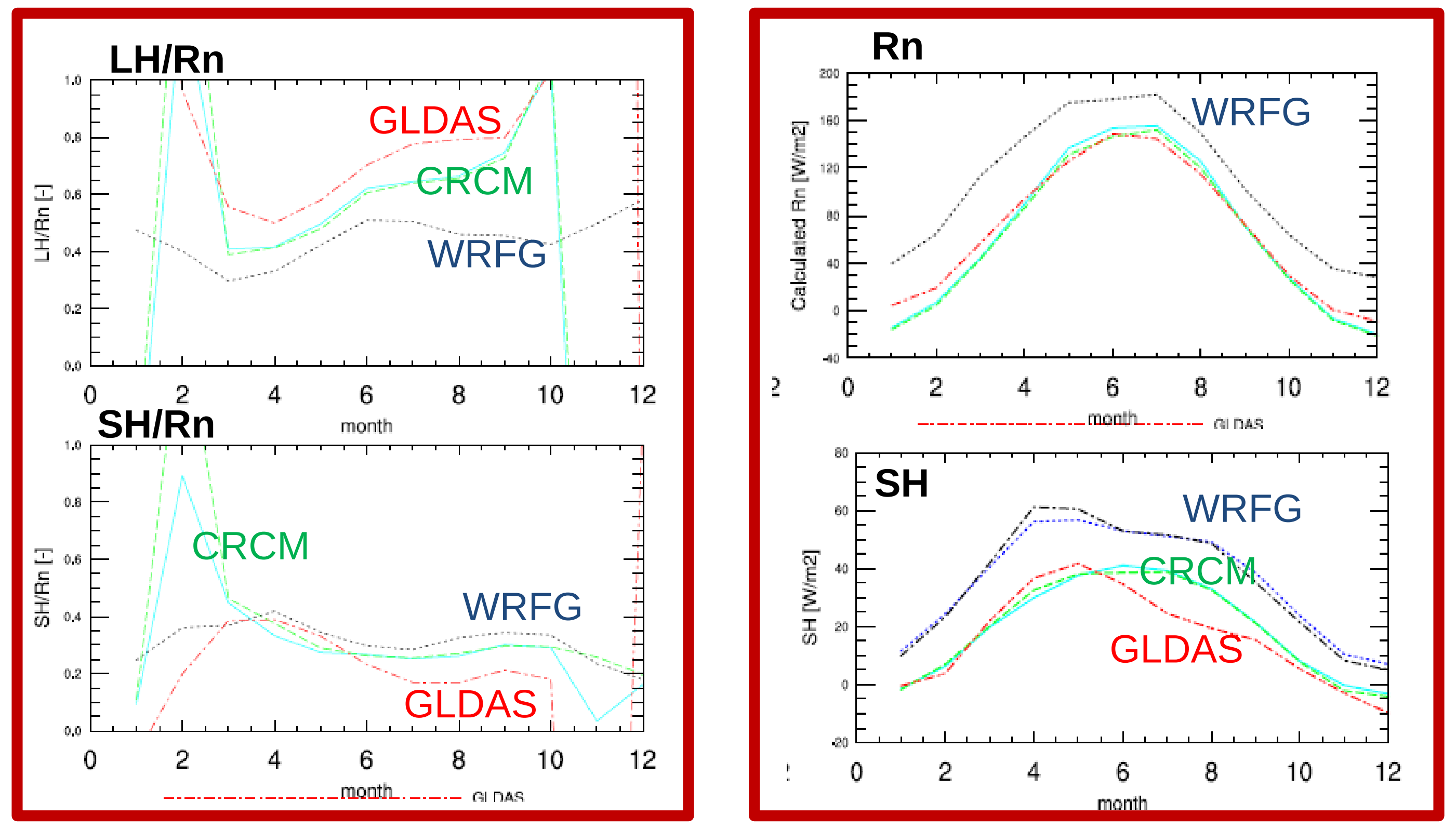
$$R_n = (SW_{down} - SW_{up}) + (LW_{down} - LW_{up})$$

- GLDAS:

$$R_n = LH + SH + G$$

WRFG has a warmer bias
- **Overestimated Rn**
- **Larger down-welling SW, smaller reflected SW**
- Positive biases in SH, LH, and surface temperature

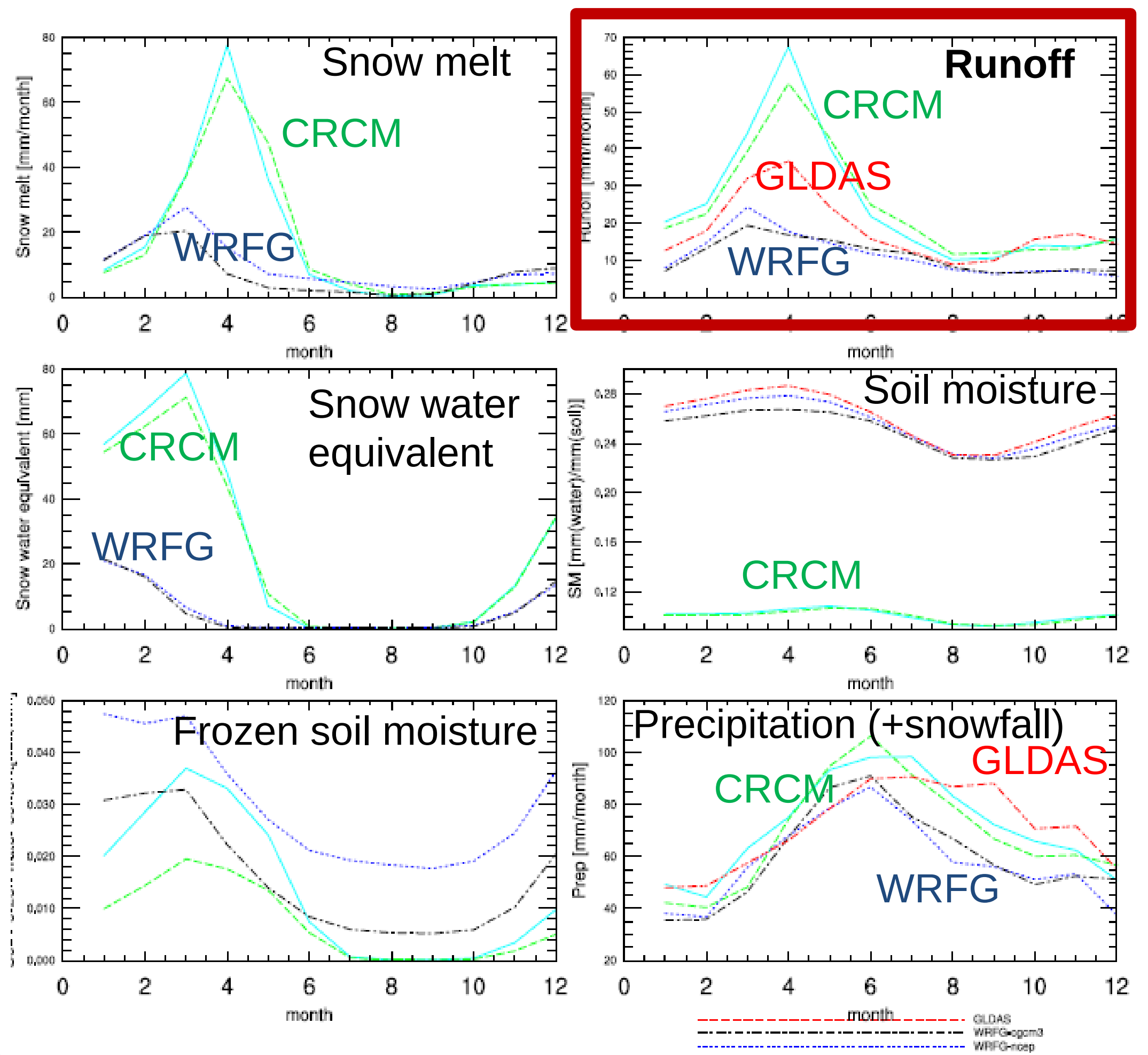
Energy partition of Rn



WRFG has less energy partitioned to LH, more energy partitioned to SH.

WRFG has larger Rn and larger SH.

Runoff



CRCM, larger runoff at winter/spring than truth data
- More snow in winter and more snow melt in spring

CRCM, lower soil water content than truth data

CRCM, more snow in winter time
- More surface upwelling surface SW is due to the high albedo values of snow

Summary

- **RCMs (NARCCAP) VS. GLDAS**: consistent latent heat, skin air temperature; different sensible heat, runoff.
  - WRFG and GLDAS (same Noah land surface scheme): different simulated SW, Rn, and SH values are due to different atmospheric schemes.
  - CRCM and GLDAS: CRCM results show more snow, snowmelt, runoff in winter/spring time.
- Variability among RCMs is mainly from land surface schemes (i.e., CRCM, WRFG) rather than boundary forcing (i.e., NCEP, CGCM3).

References

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