Comparison of Land Surface Temperature From a Land Model, Remote Sensing, and In-situ Measurements

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RESEARCH APPLICATIONS LABORATORY

Study goals

- Develop a testing and evaluation system for analyzing land surface temperature (T_s) from a land surface model, MODIS satellite-observed T_s, and in-situ measurements;
- Focus on consistent comparisons among the three sources;
- Investigate the sensitivity of a land surface model to turbulent exchange parameterization.

Modeling Tools and Data

Land Surface Model

- Community Land Model (CLM) v4.0 (Oleson et al. 2010)
- Offline 1.9°x2.5° simulation driven by obs-based atmospheric forcing data (Qian et al. 2006).

CEOP Observations

- Coordinated Energy and Water Cycle Observation Project T_s observations for evaluation in 2003
- 4 semi-arid sites: Desert Rock, Colorado, Tongyu, Gaize

MODIS T_s Observations

- 4x daily LST monthly-averaged product (MOD/MYD11C3) plus quality control; global 0.05° product

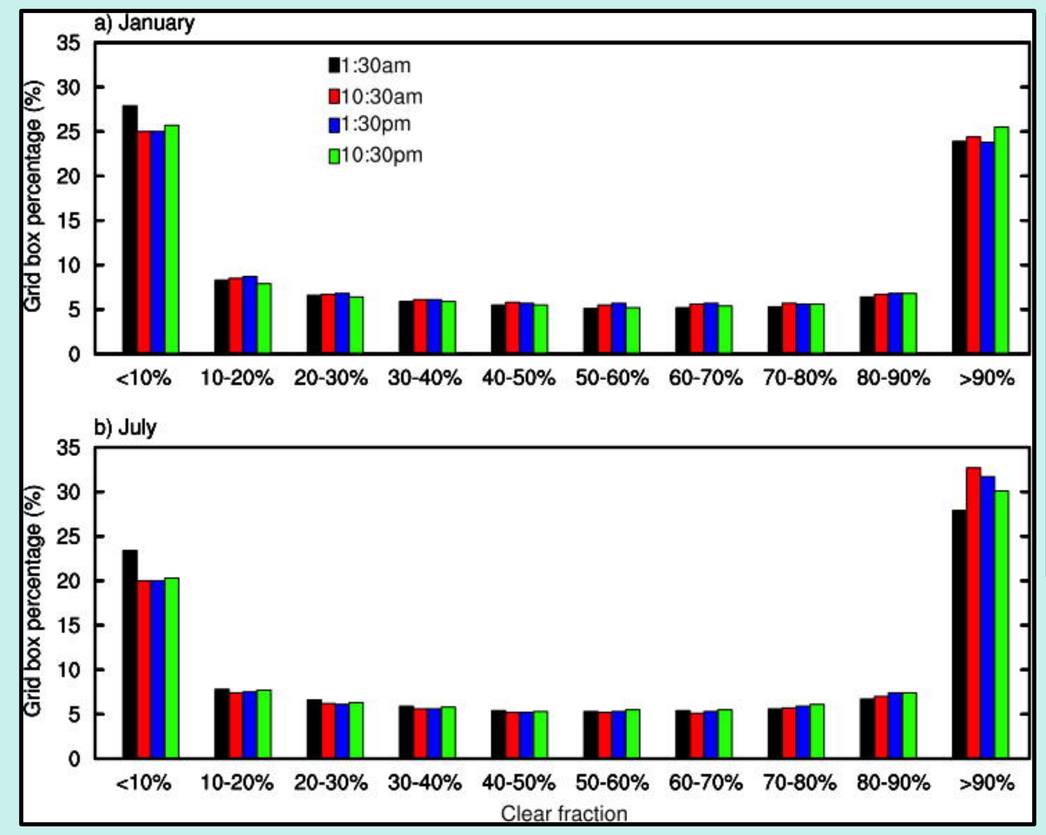
MODIS and Model T_s Bias Relative to CEOP

- Significant cold bias exists between in-situ measurements and both MODIS and CLM;
- Bias magnitude is generally larger at night

Table 1. Monthly mean T_s differences between MODIS, CLM-C and CLM-N versus in situ observations over four stations at four satellite overpass times in July 2003. Only the values under clear-sky conditions as indicated by the MODIS Ts data are used. The corresponding biases between T_{air} and downward shortwave radiation (SW_{dn}) between CLM forcing and in-situ measurements (i.e., forcing minus observation) are also shown in the last two columns. Biases that are statistically significant at the 1% level based on the Student's t-test are indicated in bold.

		T_s diff [K]				
		MODIS	CLM-C	CLM-N	T_{air} diff	SW diff
Desert Rock	1:30a	-4.1	-6.5	-5.7	-10.3	0
	10:30a	2.2	-3.8	-1.9	-3.0	-142
	1:30p	-1.3	-4.4	-1.6	-1.8	-154
	10:30p	-4.2	-5.7	-4.9	-8.5	0
Colorado	1:30a	-4.1	-5.2	-4.8	-9.9	0
	10:30a	2.3	-7.0	-6.8	-4.3	-207
	1:30p	-1.3	-5.9	-5.5	-3.7	-78
	10:30p	-4.3	-5.1	-4.6	-8.0	0
Tongyu	1:30a	-2.6	-0.4	-0.2	-0.9	0
	10:30a	-2.3	-5.3	-4.9	-4.2	-216
	1:30p	-1.2	-2.4	-2.0	-1.9	-79
	10:30p	-1.9	0.2	0.4	0.7	0
Gaize	1:30a	-3.5	-2.3	-1.2	-3.8	0
	10:30a	10.6	-8.8	-7.1	-9.3	-216
	1:30p	1.9	-11.4	-8.9	-7.8	-186
	10:30p	-5.2	-2.8	-1.6	-4.0	0

Global Clear-sky Fraction



- Globally, 25% of land model grid show >90% clear fraction in the MODIS product
- Clear fraction is nearly independent of MODIS overpass time

Figure 1. CLM4.0 grid box number percentages over land globally versus clear-sky percentages using results from each overpass for the entire month in January (top) and July (bottom) 2003.

Global Model T_s Bias Relative to MODIS

- Arid regions are dominated by daytime low T_s bias

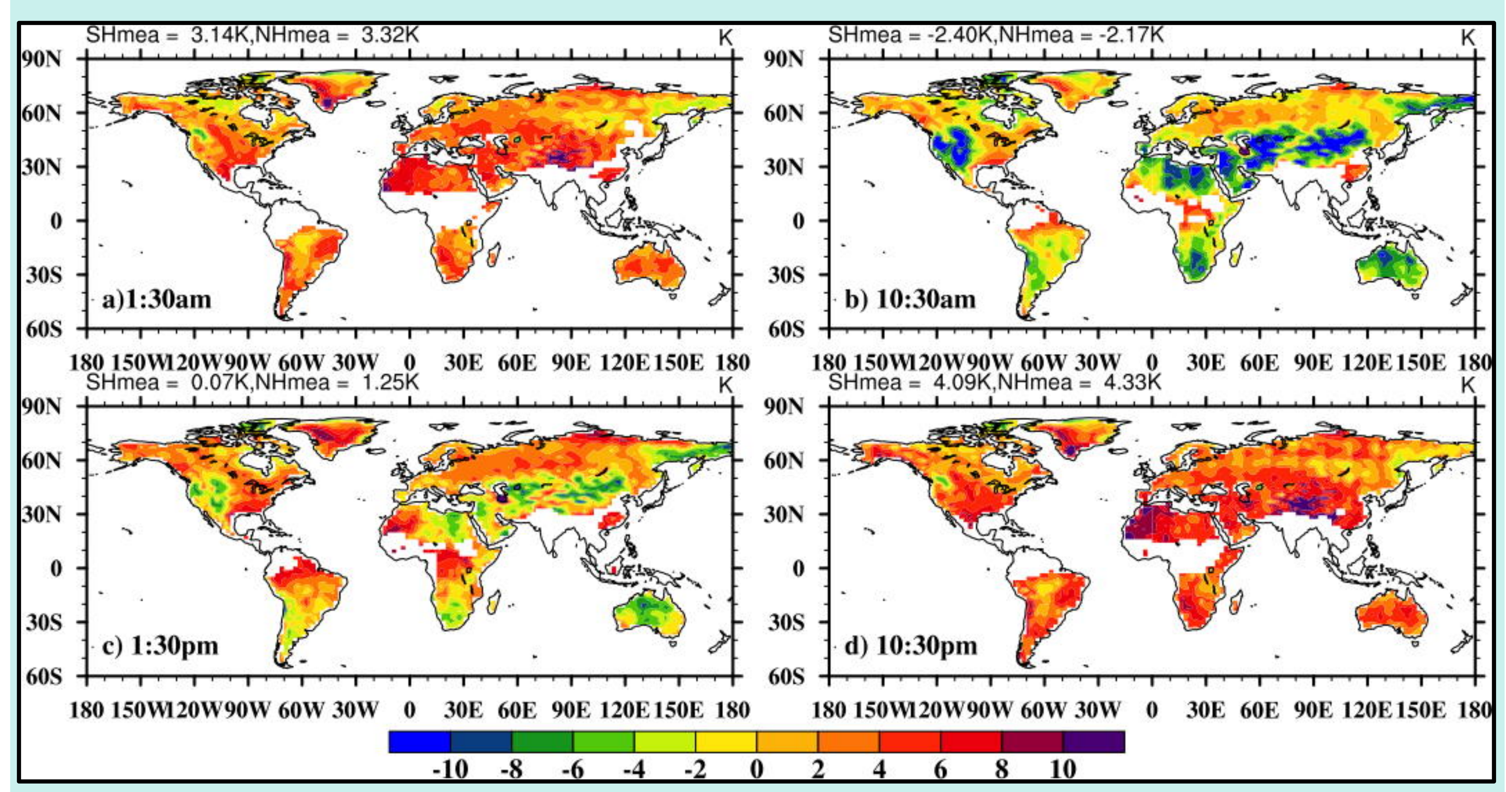


Figure 2. Monthly T_s differences between CLM-C and MODIS at four overpass times in July 2003. At each overpass time, CLM-C monthly T_s values are computed only for grid boxes with MODIS clear-sky fraction > 50% for at least 10 days in the month.

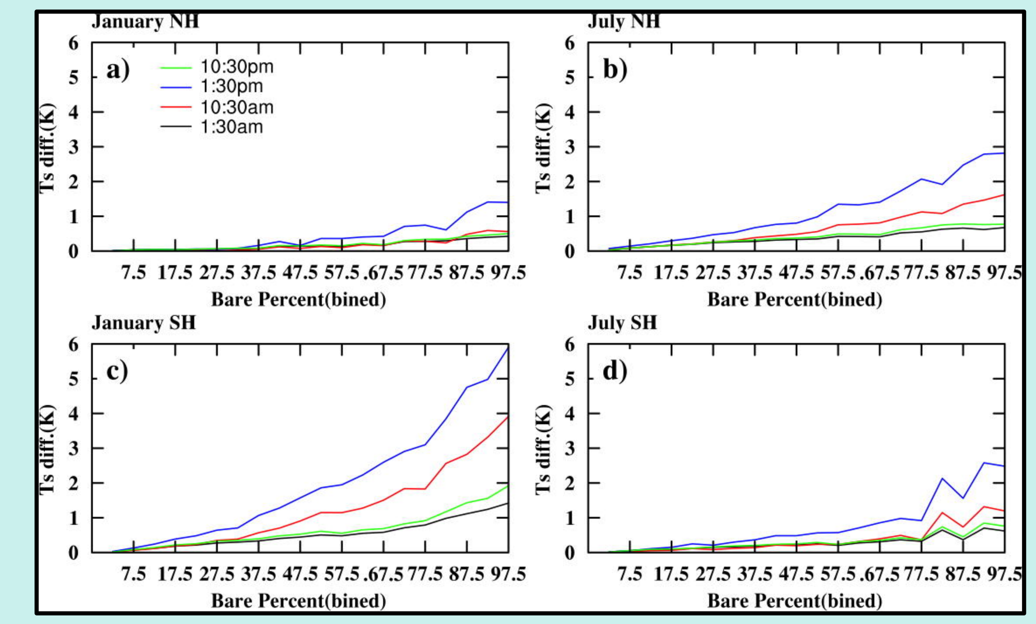
Model Modifications to Improve Performance in Arid Regions

- To improve model T_s performance in arid regions, new formulations are added that modify turbulent exchange for heat (Zeng et al. 2012):
- $\ln (z_{0m}/z_{0h}) = 0.36 (u_* z_{0m} / \nu)^{0.5}$
- $u_{*,min} = 0.07\, \rho_0 / \rho\, (z_{0m}/z_{0g})^{0.18}$

where z_{0m}, z_{0h}, z_{0g} are the roughness length for momentum, heat and bare soil; u_* is the friction velocity; ν is the molecular viscosity of air; and ρ_0 / ρ is the reference air density divided by the actual air density

- The first modification effectively reduces the coupling of the atmosphere with respect to heat
- The second modification increases the atmospheric coupling during stable boundary layers (typically at night)
- These simulations are denoted by CLM-N. Control as CLM-C.

Model T_s Bias Changes Due to Modifications



- Direct relationship between grid box bare ground fraction and model bias changes
- Also a relationship between magnitude of bias and time of day

Figure 3. Hemisphere mean T_s differences between CLM-N and CLM-C versus bare soil fraction in 5% intervals at four satellite overpass times averaged in January and July 2003. NH and SH denote Northern and Southern Hemispheres, respectively.

- Model performance is improved over arid regions globally

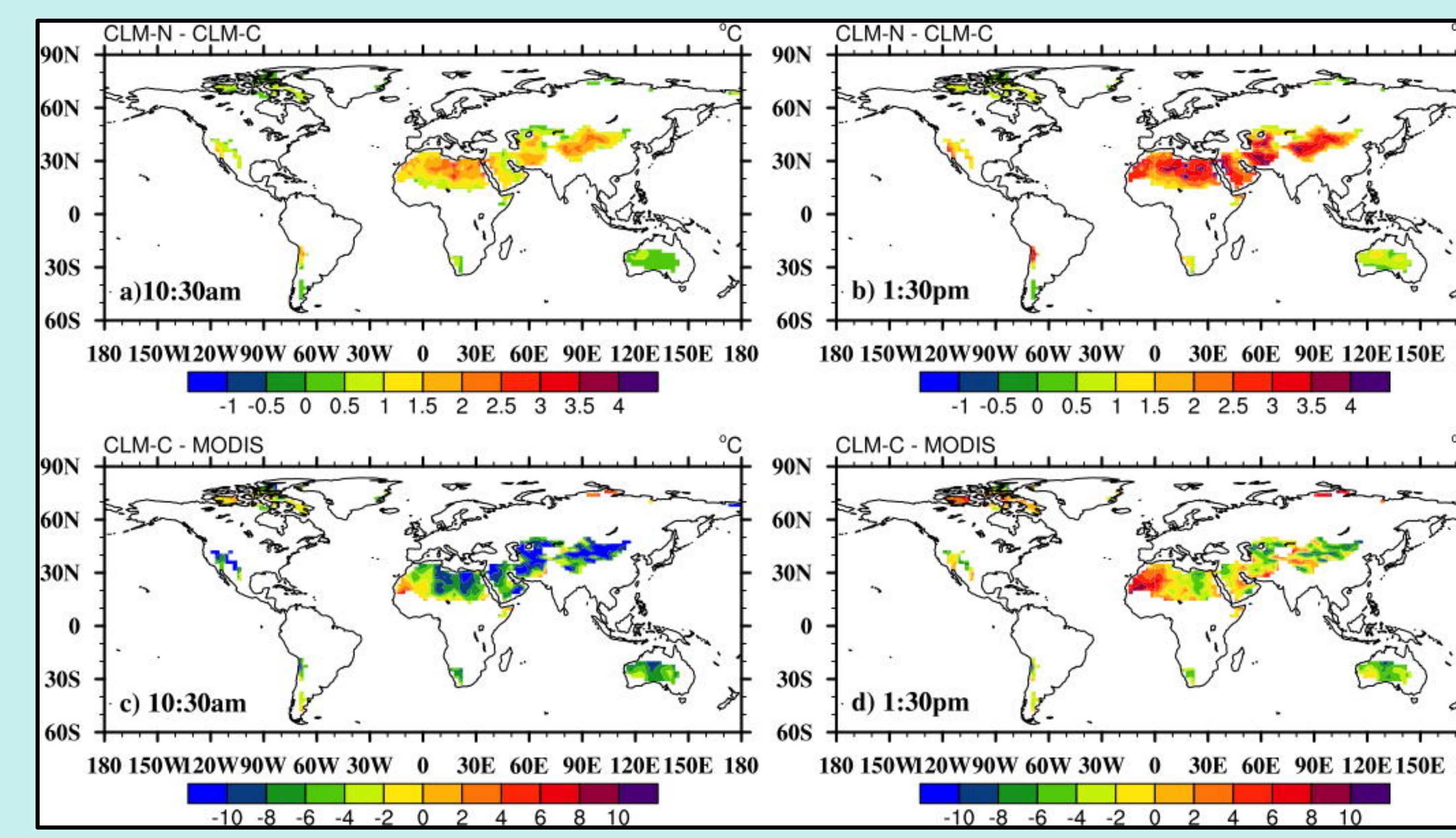


Figure 4. Global distribution of Ts differences between CLM-N and CLM-C at a) 10:30am; b) 1:30pm, and between CLM-C and MODIS at c) 10:30am; d) 1:30pm in July 2003. At each satellite overpass time, monthly Ts is computed over grid boxes with bare soil fraction greater than 30% and MODIS clear-sky fraction greater than 50% for at least 10 days in the month.

Summary

- Five factors contributing to T_s differences among model simulations:

1. Difficulty in properly accounting for cloud cover information at appropriate spatial and temporal resolutions,
2. Model uncertainties in surface energy budget computations,
3. Quality of atmospheric forcing data,
4. Representation of surface emissivity among data sources,
5. MODIS T_s uncertainty;

- This work is a first step toward evaluating LSM outputs using remotely sensed T_s products over global land areas.

References

Oleson, K., et al. (2010), Technical description of version 4.0 of the Community Land Model, NCAR Tech. Note NCAR/TN-4781STR, 257 pp.

Qian, T., A. Dai, K. E. Trenberth, and K. W. Oleson (2006), Simulation of global land surface conditions from 1948 to 2002: Part I: Forcing data and evaluations, J. Hydrometeorol.,7, 953–975.

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