Assimilation of freeze-thaw observations into the NASA Catchment land surface model

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INTRODUCTION

The land surface freeze-thaw (F/T) state is considered a critical threshold that controls hydrological and carbon cycling and thus affects water and energy exchanges at land surface.

In this study, we have developed an algorithm for diagnosis of landscape's F/T state [1]. This model is compatible with the information contained in the remotely sensed F/T state of land surface at different frequency and wavelengths. We then updated the Global Modeling and Assimilation Office (GMAO)'s land data assimilation system in offline mode with a new designed F/T assimilation module. A rule-based approach that incorporates model and observational errors is developed and used for assimilating the categorical F/T measurements into the land surface model (F/T analysis). In order to test the methodology, an observing system simulation experiment is conducted using synthetically generated F/T measurements.

OBJECTIVE

To update the GEOS-5 land data assimilation system with a newly designed F/T assimilation module. The ultimate goal of this project is to provide a framework for the assimilation of SMAP (Soil Moisture Active Passive) F/T observations into the NASA Catchment land surface model

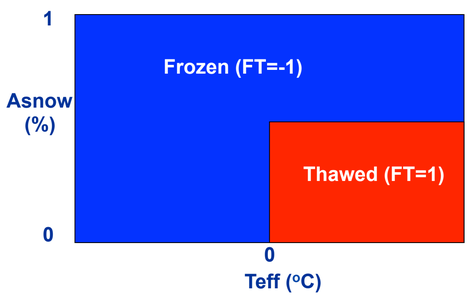
F/T DETECTION AND ANALYSIS ALGORITHM

➢**F/T =f (Tsurf, Tsoil)**

- Tsurf=f(Tsurf_nosnow , Tsnow)
- Tsurf_nosnow=f(surface temperature prognostics)
- Tsnow= f(snow prognostics)
- Tsoil=f(prognostic variable; soil heat content)

Tsurf	Surface temperature
Tsnow	Snow temperature
Tsoil	Soil temperature
SWE	Snow water equivalent
HTSN	Snow heat content
SNDZ	Snow depth

Snow Prognostics



➢Teff=(1-α)Tsoil+ α Tsurf_nosnow

➢ Asnow : snow cover fraction(%)

➢ Asnow_threshold: depends on the frequency of backscatter/Tb. [Higher frequency-> lower threshold and vice versa];

➢The Threshold on Teff and Asnow are relaxed [indirect weigth to model results

➢Red region: Completely thawed

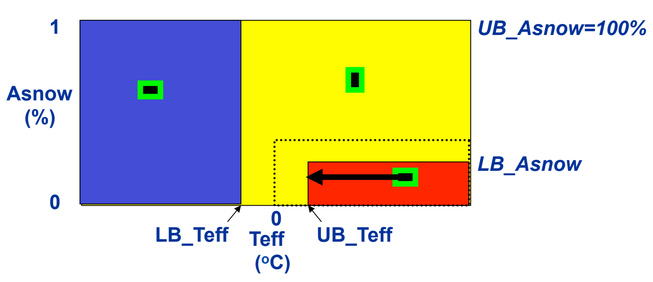
➢Blue region: Completely frozen

➢Yellow region: Undetermined

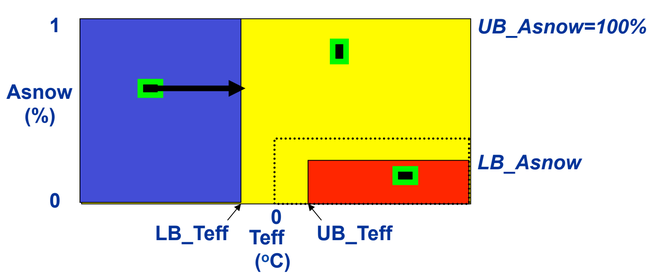
➢Model results (Teff, Asnow)

➢Performing Analysis ←

Observed FT=-1

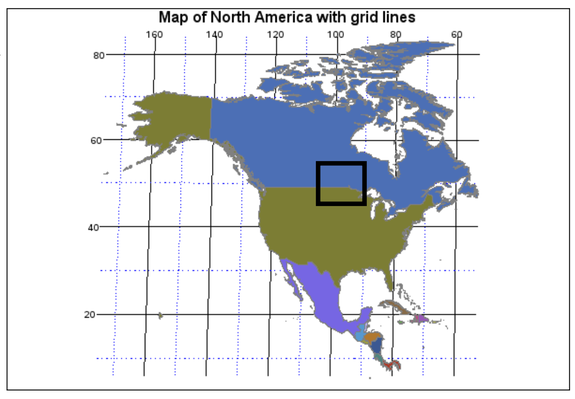


Observed FT=1



EXPERIMENTAL SETUP

➢Area Under investigation →



➢Time period :
8 year (2002-2010))

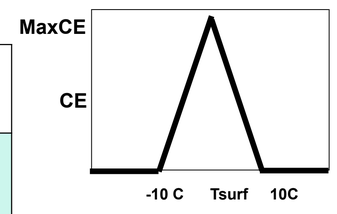
➢Design settings:
α=0.5

➢Threshold and boundary values

Asnow_threshold=10%	Teff_threshold=0°C
UB_asnow=100%	UB_Teff=1°C
LB_asnow=5%	LB_Teff=-1°C

➢**Data sets**

Synthetic true FT	**Produced by running the Catchment model [1] using MERRA forcing**
Synthetic observed FT data set	**Produced by applying classification error (CE)* to synthetic true data set**
Open Loop (No assimilation)	**Produced by running the Catchment model with GLDAS forcing.**
FT Analysis	**Produced by performing FT analysis, using synthetic observation and running the Catchment model with GLDAS forcing**



* We assume classification error as a function of Tsurf

➢ **Assimilation time step**

Synthetic observed FT Data are assimilated at 6am, 6pm local time (Compatible with planned overpass time of SMAP)

RESULTS

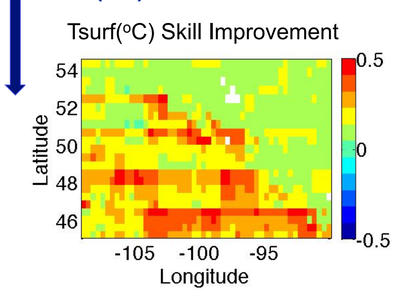
Variable	RMSE* (OL)
Tsurf (°C)	3.08
Tsoil (°C)	1.97

Skill Improvement (RMSE* (OL)-RMSE* (FT/Analysis)

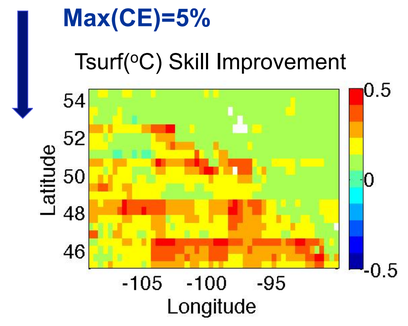
Var \ Max(CE)	0%	5%	10%	20%	30%
Tsurf (°C)	0.206	0.192	0.178	0.149	0.118
Tsoil (°C)	0.061	0.049	0.036	0.006	-0.0305

*Excluding times/locations with Tair>7°C or Tair<-7°C

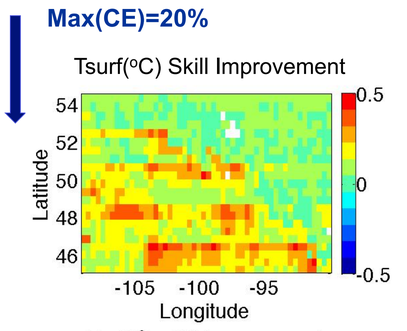
Max(CE)=0%



Max(CE)=5%

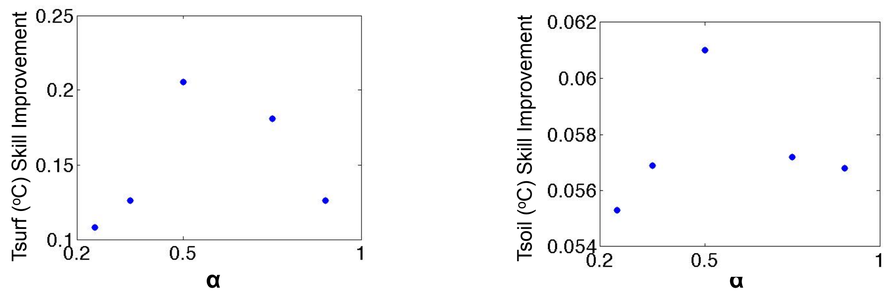


Max(CE)=20%



Sensitivity of assimilation results to α

No Classification Error



CONCLUSION

An algorithm for diagnosis of F/T state of soil in the NASA Catchment land surface model was developed which is compatible with the information contained in remotely sensed F/T state of land surface at different frequency and wavelengths. The Global Modeling and Assimilation Office (GMAO)'s land data assimilation system in offline mode was updated with the new designed F/T assimilation module.

The performance of the method for a synthetic experiment showed encouraging improvements in skill of soil temperature and surface temperature. Results demonstrate the dependency of the average skill improvement of temperature values to the classification error of F/T index. For a maximum classification error of 20%, skill improvement in temperature is no longer evident. The results also show sensitivity of Data Assimilation (DA) performance to the α parameter. maximum skill improvement for temperature variables happen when this parameter is 0.5 (value used for producing synthetic F/T measurements). Thus, a realistic value for this parameter which is compatible with the effect of Tsurf and Tsoil in determining remotely sensed soil F/T state, can improve the performance of DA method.

This Freeze/Thaw assimilation module will be tested with satellite retrievals of F/T from AMSR-E to test its performance at large scale.

REFERENCE

[1] Koster, Randal D., et al. "A catchment-based approach to modeling land surface processes in a general circulation model. I- Model structure." Journal of geophysical research 105.24 (2000): 809-24.

[2] Algorithm Theoretical Basis Document (ATBD)SMAP Level 3 Radar Freeze/Thaw Data Product (L3_FT_A)