Arctic System Reanalysis: Land Surface Parameter Assimilation and Model Updates

Poster LA – 1

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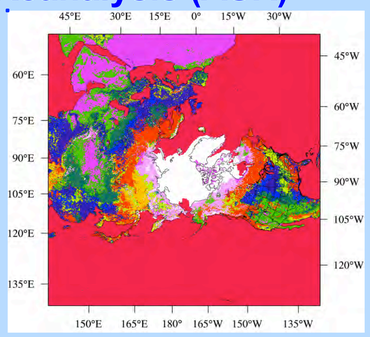
The Arctic System Reanalysis (ASR)

- What is the Arctic System Reanalysis?
  - Modeling effort primarily led by Ohio State University and NCAR with contributions from University of Illinois and University of Colorado
  - Funded by NSF to conduct a 10-year, 10km WRF-3DVar simulation over the Arctic extending to ~20N (2000 – 2010)
  - The 30km intermediate ASR runs are available through NCAR DSS



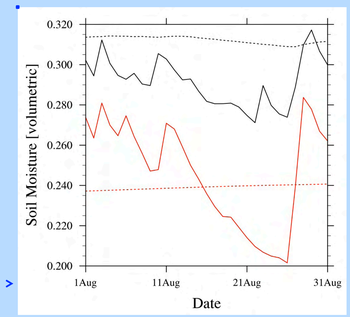
ASR domain with land cover

WRF Land Surface Enhancements/Additions

- Land surface state spin-up: more consistent initialization, less time for soil states within coupled system to equilibrate
- Changes to model structure: add more and deeper soil layers, zero-flux lower boundary condition
- Land surface parameter and state assimilation: snow cover and snow depth, albedo, and green vegetation fraction inserted into model daily/weekly

Land Surface State Spin-up

- Why is this necessary?
  - Land surface models have their own climatology
  - Soil layers depths between models may be inconsistent
  - Vegetation types, soil types, terrain, etc. are likely different between models



August 2008 volumetric soil moisture in top and bottom layer for ERA-I initialization (black) and HRLDAS multi-year simulation (red) for a region average near 64N, 158E (NE Siberia).

- Use High Resolution Land Data Assimilation System (HRLDAS) with atmospheric forcing from reanalysis
- HRLDAS: uses WRF model grid and static fields (land cover, soil type, parameter tables) to run an offline version of the Noah LSM
- Use 6-hourly reanalysis output (precipitation, wind, temperature, pressure, humidity, SW and LW radiation) from ERA-40 (1980 – 1999) and JRA-25 (2000 – 2009)
- Advantages are that initial fields (especially soil ice/moisture/temperature):
  - are already on the WRF grid
  - are consistent with terrain, land cover and soil types/levels
  - are consistent with WRF land model

Land Parameter/State Assimilation

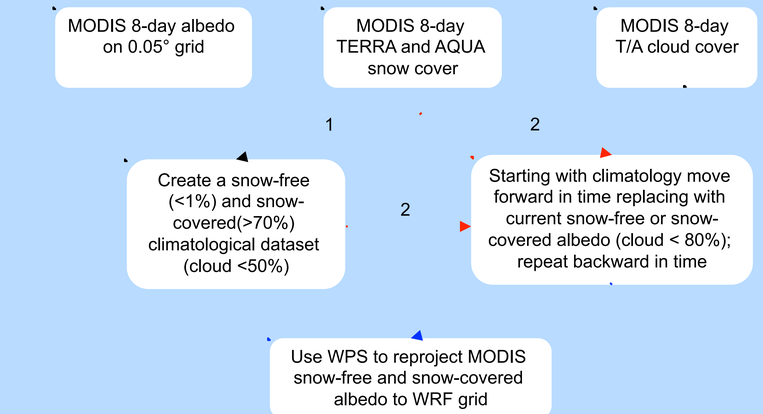
Data assimilation - infrastructure added to HRLDAS/WRF(+WRF-Var) to include:

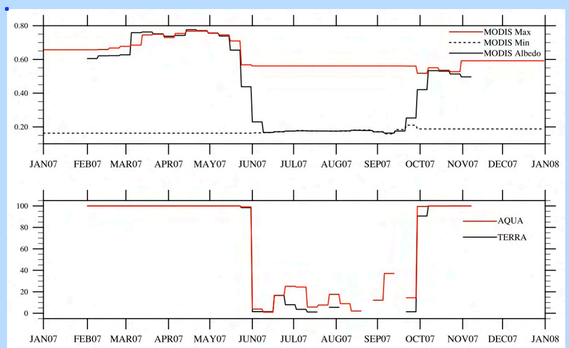
- IMS snow cover: daily, 2004 to current at 4km; pre-2004 at 24km; this product is used operationally at NCEP
- SNODEP snow depth: daily, obs/model product; on GFS T382 (~30km) grid; used as guidance to put snow where IMS says snow exists
- MODIS albedo: 8-day 0.05º global; available from Feb 2000; also use MODIS snow cover and cloud cover
- NESDIS vegetation fraction: weekly, 0.144º global; transitioning to use in NCEP operations
- MODIS daily albedo over Greenland: ~1km, available over MODIS period

Products are assimilated into the wrfinput file at 00Z of each cycle

MODIS Albedo Products

- Challenge: Use MODIS albedo products in a way consistent with Noah LSM structure
- Solution: Create two new time-varying datasets of snow-covered and snow-free albedo



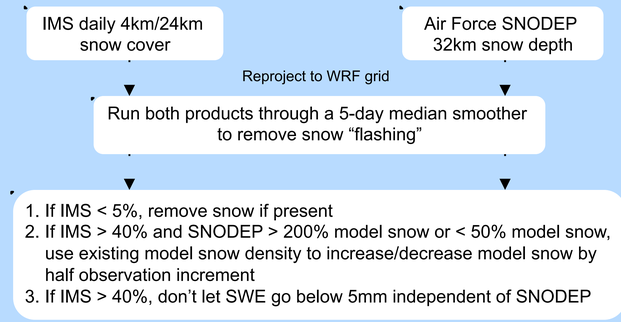


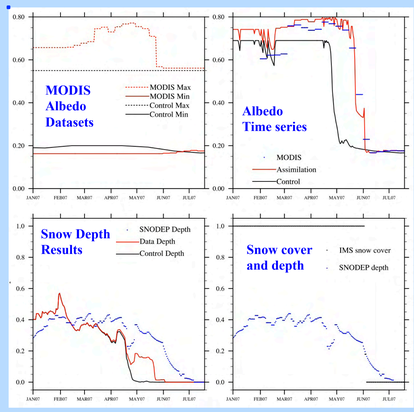
Top: Time-varying snow-free and snow-covered albedo along with MODIS observed albedo at a grid point in northern Alaska

Bottom: Observed snow cover from the Terra and Aqua MODIS sensors

Snow Cover/Depth Products

Use IMS daily snow cover to determine snow coverage and SNODEP daily snow depth as guidance for quantity





- Seven-month simulation with land data assimilation
- Region near 69N, 155W (North Slope)
- Model albedo agrees better with MODIS albedo
- SNODEP snow is inconsistent with IMS snow cover in June
- Report snow increments so users can recreate model snow

ASR with/without Land Data Assimilation

ASR without HRLDAS: average statistics compared to observations (2007)

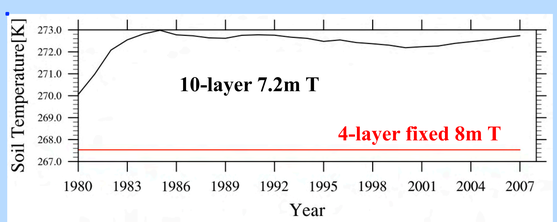
Month	Wind Speed bias	Wind Speed RMSE	Wind Speed corr	2m - Temperature bias	2m - Temperature RMSE	2m - Temperature corr	2m - Dew Point bias	2m - Dew Point RMSE	2m - Dew Point corr
Jan	0.44	2.29	0.69	0.28	2.05	0.92	1.11	2.48	0.92
Feb	0.35	2.18	0.69	0.25	1.99	0.93	1.25	2.59	0.91
Mar	0.26	2.17	0.69	-0.06	1.99	0.93	0.87	2.35	0.89
Apr	0.16	2.01	0.68	-0.10	1.92	0.94	0.82	2.31	0.87
May	0.12	2.02	0.65	-0.03	1.97	0.93	0.57	2.21	0.87
Jun	0.07	1.85	0.65	0.00	2.02	0.91	0.25	2.06	0.84
Jul	0.12	1.82	0.64	0.05	2.02	0.90	0.07	2.02	0.82
Aug	0.14	1.91	0.64	0.02	1.94	0.91	-0.06	1.94	0.84
Sep	0.29	1.96	0.66	0.00	1.82	0.92	0.05	1.93	0.89
Oct	0.29	1.99	0.67	0.04	1.77	0.93	0.24	1.87	0.91
Nov	0.42	2.22	0.68	0.20	1.89	0.92	0.67	2.14	0.92
Dec	0.40	2.22	0.69	0.31	1.99	0.92	0.89	2.37	0.91
AVG	0.26	2.05	0.67	0.08	1.95	0.92	0.56	2.19	0.88

ASR with HRLDAS: average statistics compared to observations (2007)

Month	Wind Speed bias	Wind Speed RMSE	Wind Speed corr	2m - Temperature bias	2m - Temperature RMSE	2m - Temperature corr	2m - Dew Point bias	2m - Dew Point RMSE	2m - Dew Point corr
Jan	0.20	2.21	0.70	0.26	2.06	0.93	1.19	2.51	0.92
Feb	0.15	2.12	0.69	0.16	2.02	0.92	1.27	2.61	0.91
Mar	0.04	2.10	0.69	-0.16	2.01	0.93	0.86	2.36	0.89
Apr	-0.07	1.96	0.68	-0.22	1.92	0.94	0.79	2.32	0.87
May	-0.11	1.96	0.65	-0.12	1.92	0.92	0.51	2.17	0.87
Jun	-0.14	1.79	0.65	-0.08	1.97	0.92	0.18	2.02	0.85
Jul	-0.09	1.75	0.65	-0.12	1.85	0.91	0.20	1.98	0.83
Aug	-0.05	1.74	0.65	-0.01	1.81	0.92	0.02	1.86	0.85
Sep	0.11	1.89	0.67	0.05	1.73	0.93	0.10	1.87	0.90
Oct	0.12	1.91	0.68	0.12	1.73	0.93	0.30	1.85	0.91
Nov	0.22	2.13	0.68	0.30	1.93	0.92	0.78	2.19	0.92
Dec	0.20	2.15	0.69	0.26	2.06	0.92	1.04	2.45	0.91
AVG	0.05	1.98	0.68	0.05	1.92	0.93	0.60	2.18	0.89

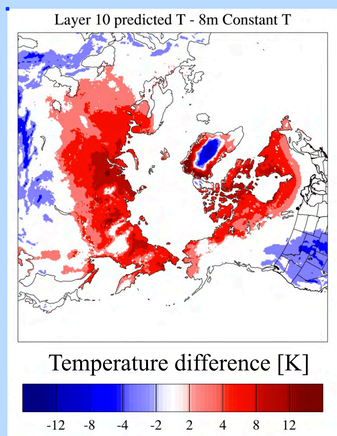
Noah Land Model Structural Modifications

- The default WRF model uses the Noah land surface model with four soil layers that have nodes at 0.05m, 0.25m, 0.7m, and 1.5m and a fixed deep soil (8m/25m) temperature
- It has been suggested that the fixed deep soil temperature is likely too low over much of the Arctic because it is based on annual mean air temperature
- Within the ASR WRF model, the Noah LSM is modified to have 10 soil layers and a free, zero-flux lower boundary condition



Average soil temperature in the lowest layer of the 10-layer model compared to the 4-layer model 8-meter fixed lower boundary condition for 60-70N.

- The 10 soil layers have interfaces at 0.05m, 0.15m, 0.25m, 0.4m, 0.65m, 1.05m, 1.7m, 2.75m, 4.45m and 7.2m
- Most of the Arctic region is much warmer in the 10-layer zero-flux model
- Implications for soil temperature/moisture related processes, e.g., permafrost prediction



Difference between lowest layer (7.2m) temperature [K] after a 28-year simulation and the prescribed 8m deep soil temperature in standard WRF

Preliminary ASR 30km Results Compared to ERA-Interim

Month	Case	Wind Speed bias	Wind Speed RMSE	Wind Speed corr	2m - Temperature bias	2m - Temperature RMSE	2m - Temperature corr	2m - Dew Point bias	2m - Dew Point RMSE	2m - Dew Point corr
2007	ERA-Int	0.42	2.14	0.64	0.28	1.98	0.92	0.37	2.08	0.89
	ASR	-0.05	1.95	0.68	-0.11	1.67	0.94	-0.05	1.95	0.90
2008	ERA-Int	0.42	2.13	0.64	0.27	1.97	0.92	0.34	2.04	0.89
	ASR	-0.02	1.96	0.67	-0.09	1.69	0.94	-0.07	1.97	0.90

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