Sensitivity of Near-Surface Temperature Forecasts to Soil Properties over a Dryland Region in Complex Terrain

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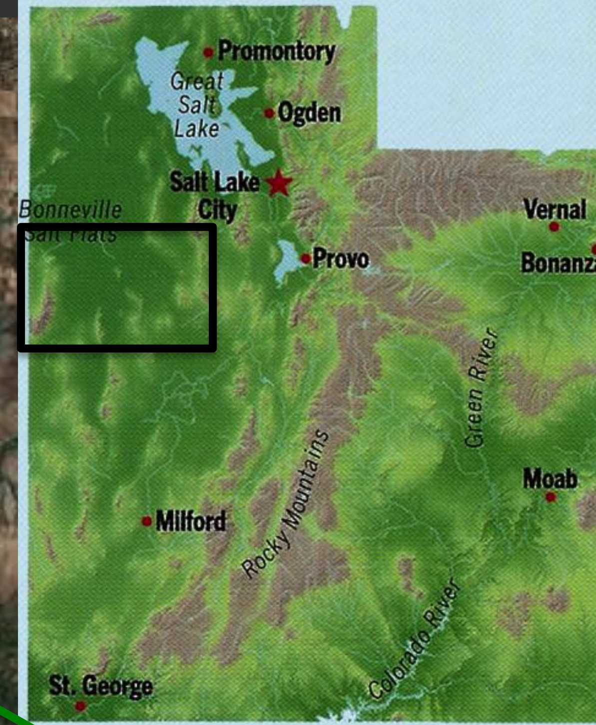
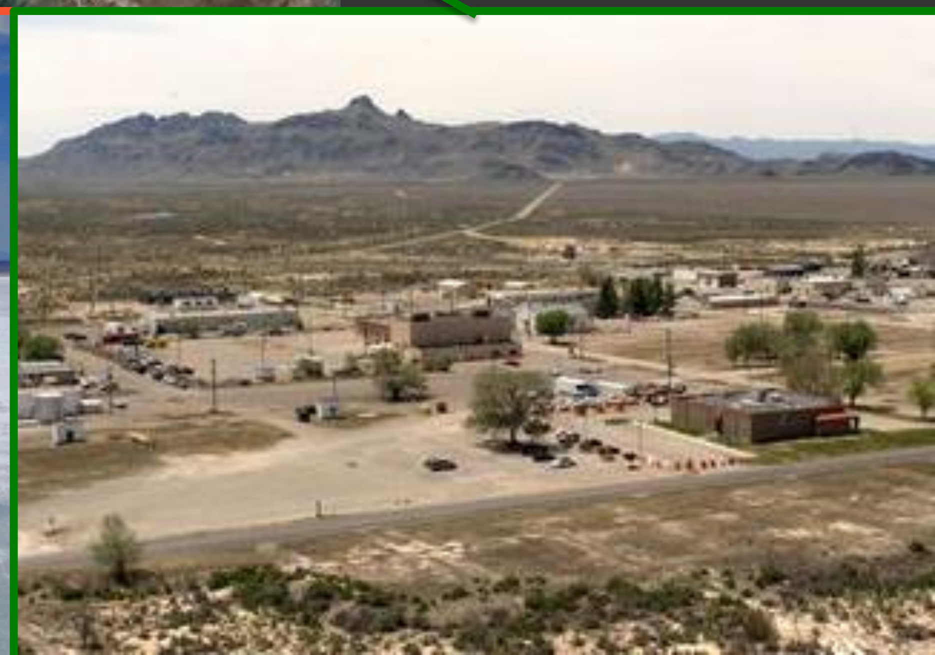
Motivation

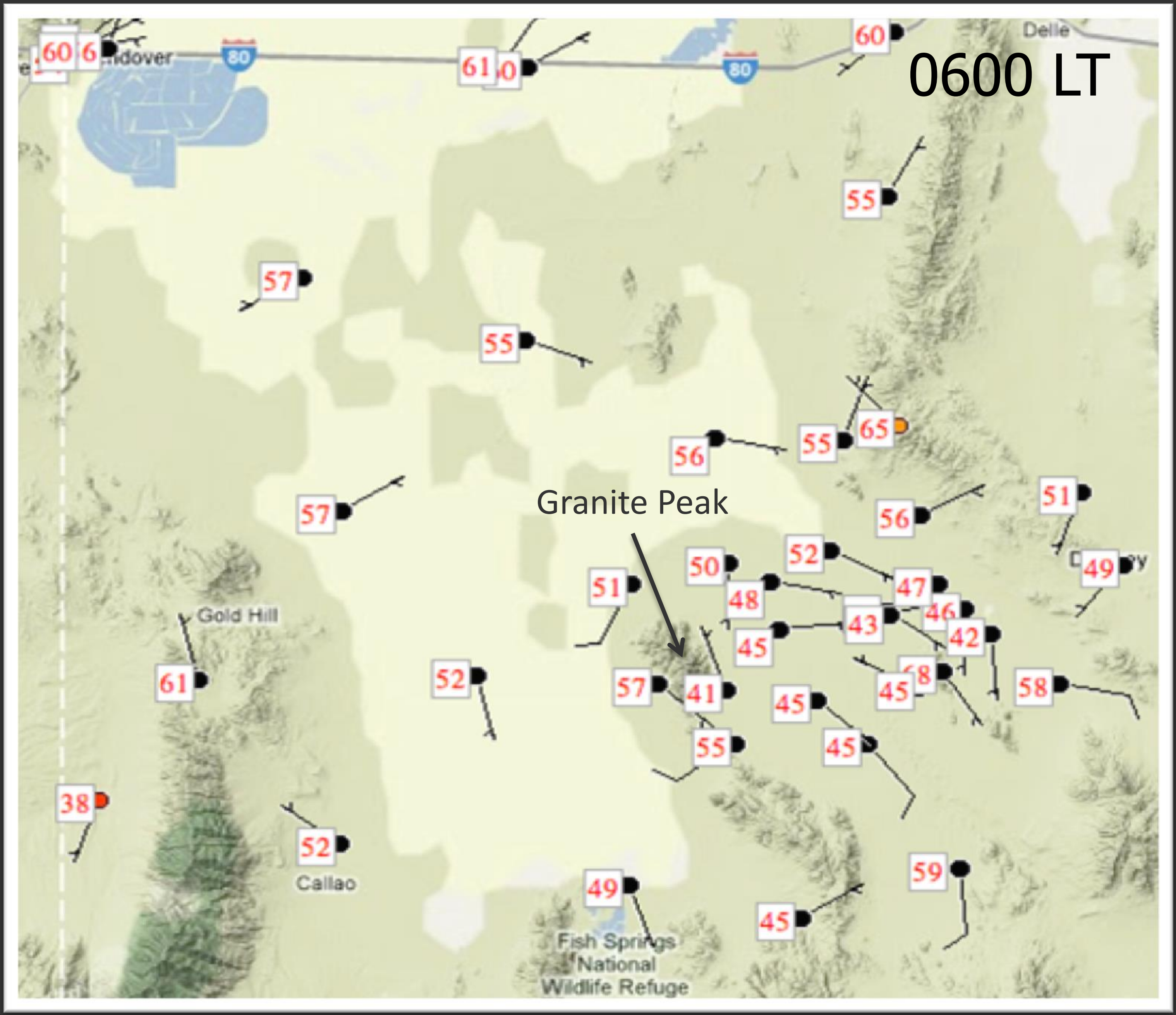
- Many modeling systems have tremendous difficulty accurately forecasting near-surface temperatures.

- A nighttime warm bias is one of the more common model errors, especially over the western US.

- Better near-surface temperature forecasts will increase the predictability of near-surface wind/turbulence, air pollution transport, and dust emissions.


Promontory
Great Salt Lake
Ogden
Salt Lake City
Bonneville Salt Flats
Vernal
Bonanza
Provo
Green River
Moab
Milford
Rocky Mountains
Colorado River
St. George

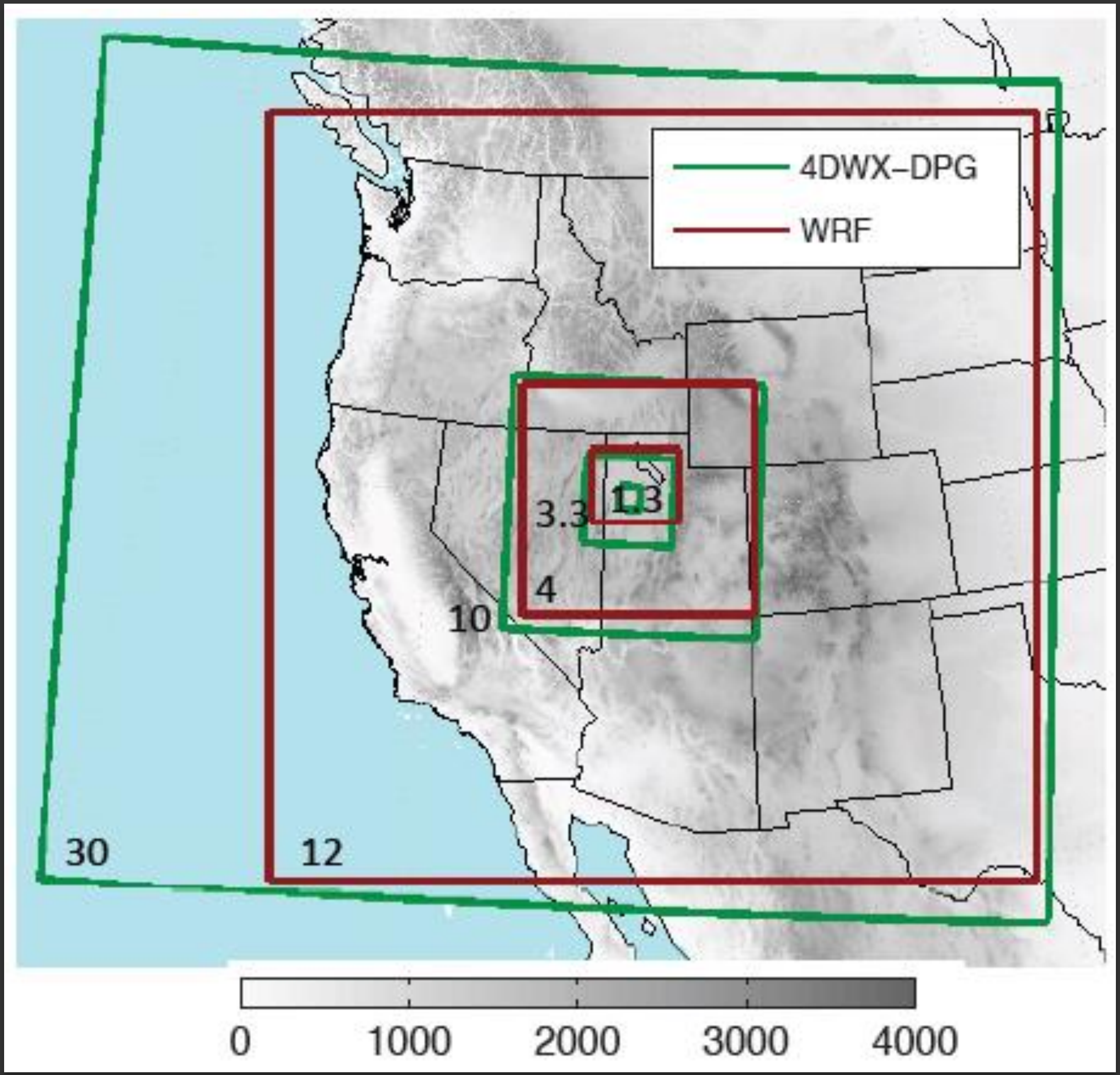




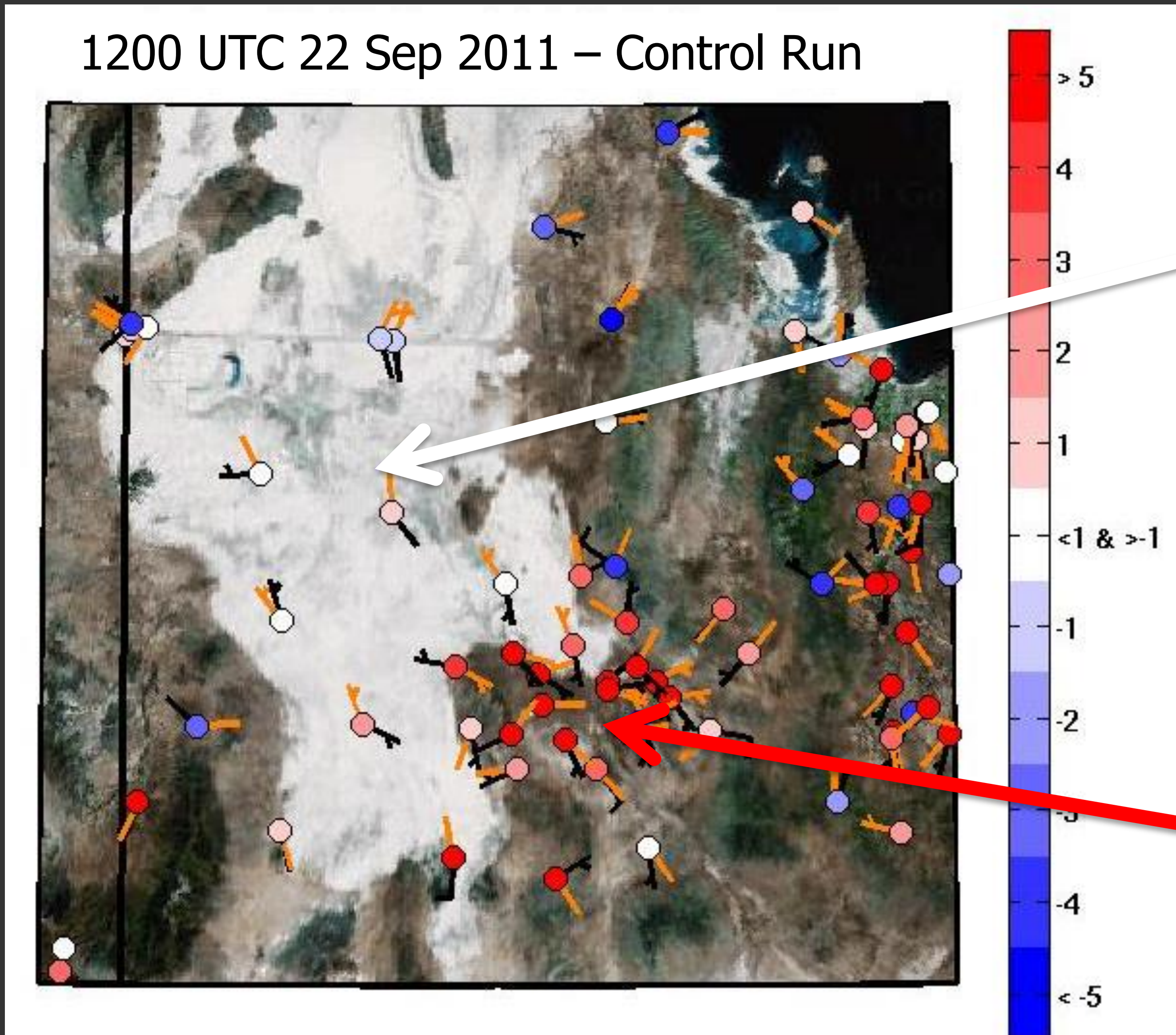
Mesonet observations from 1200 UTC 22 September 2011

4DWX-DPG and WRF configuration

Domains	30, 10, 3.3, 1.1 km	12, 4, 1.3 km
Shortwave radiation	Dudhia	
Longwave radiation	Rapid radiation transfer model	
Boundary Layer	YSU	
Surface Layer	Monin-Obukhov	
Land Surface	Noah Model	
Cumulus convection	Kain-Fritsch on domains 1 & 2	
Microphysics	Lin	
Vertical Levels	37	
Initial/ Boundary Conditions	GFS	



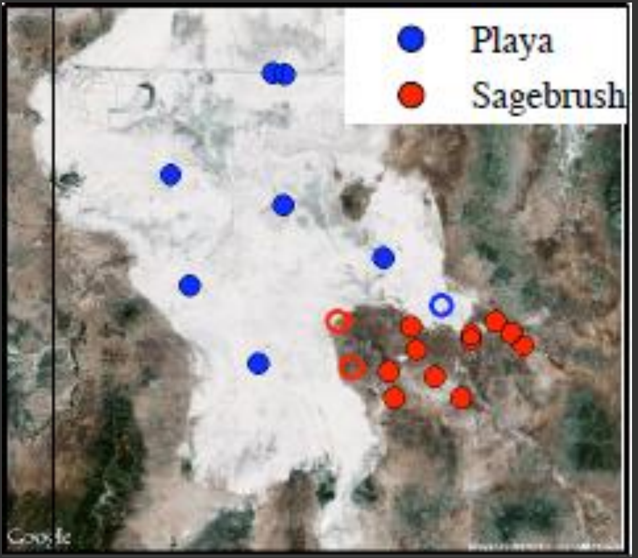
WRF 2-m Temperature Bias Errors



Little if any bias over the playa

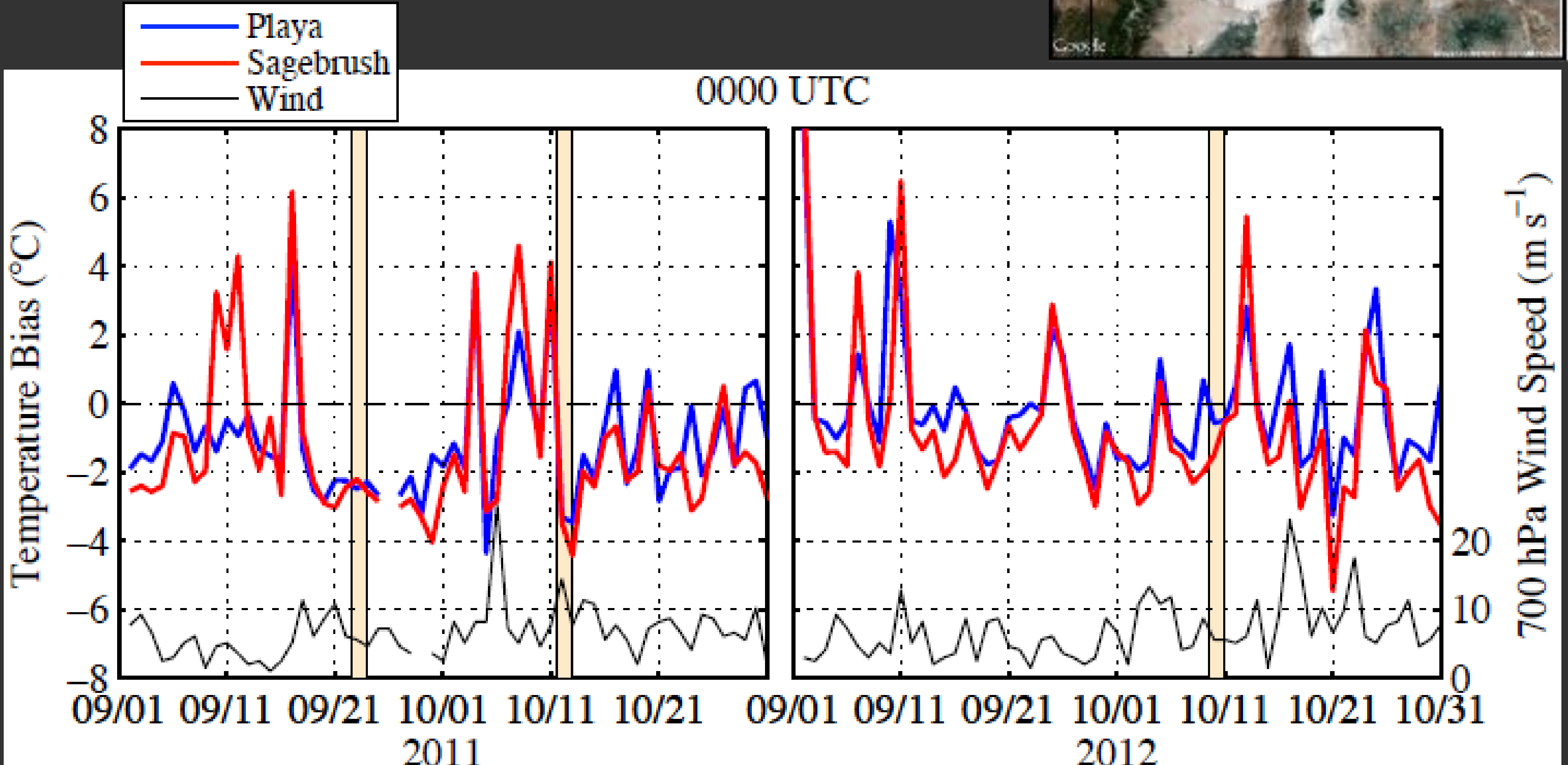
Large (> 5°C) warm bias over sagebrush stations and other lowland sites

4DWX-DPG Late Afternoon Mean 2-m Temperature Bias Errors



Mean sagebrush bias: -1.0°C

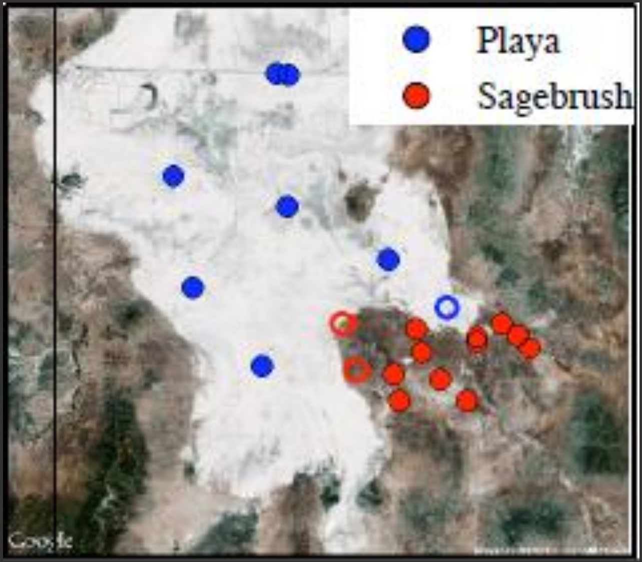
Mean playa bias: -0.6°C

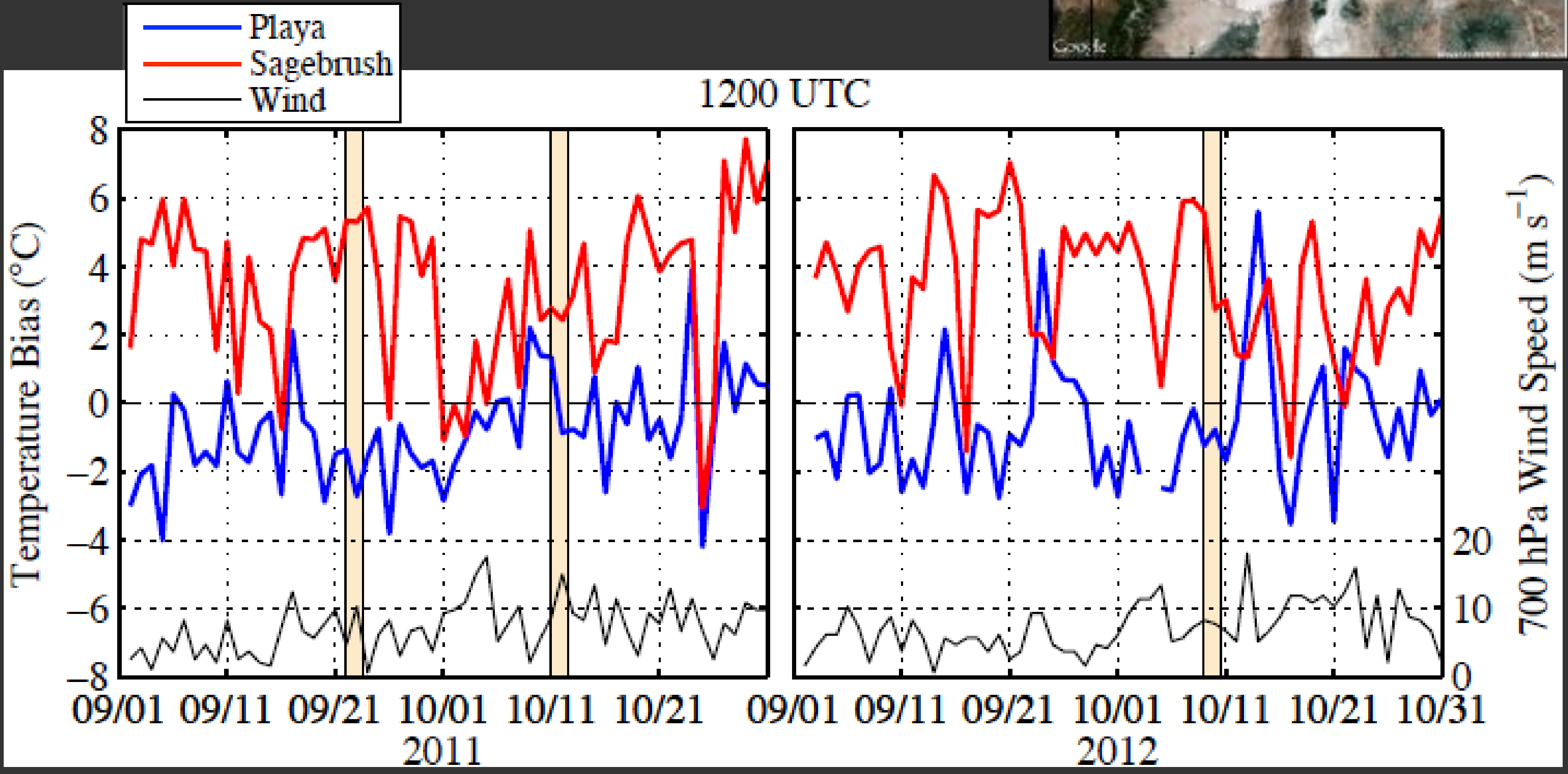


4DWX-DPG Early Morning Mean 2-m Temperature Bias Errors

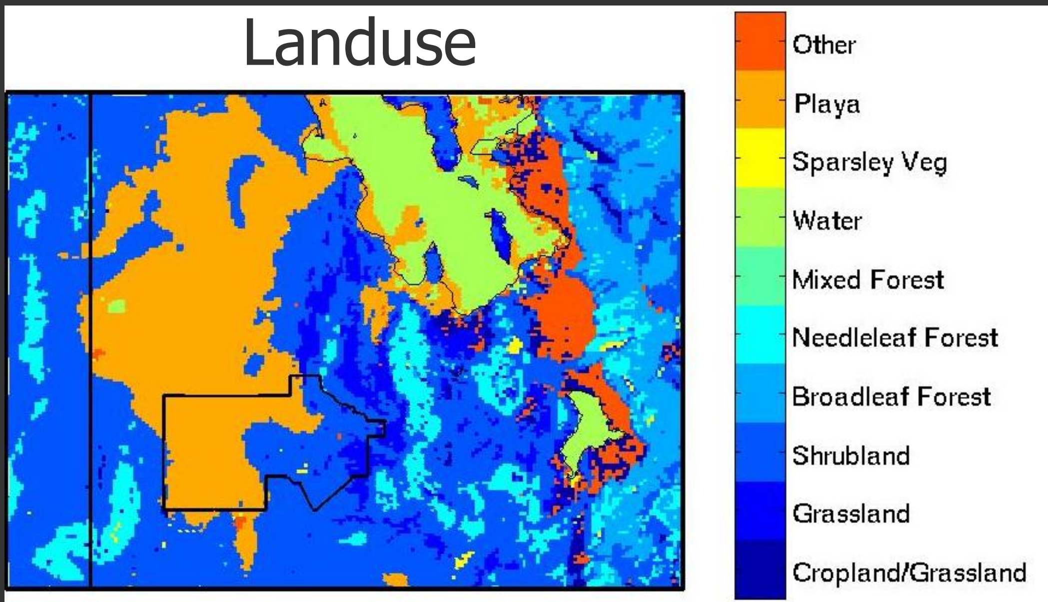
Mean sagebrush bias: 3.4°C

Mean playa bias: -0.7°C

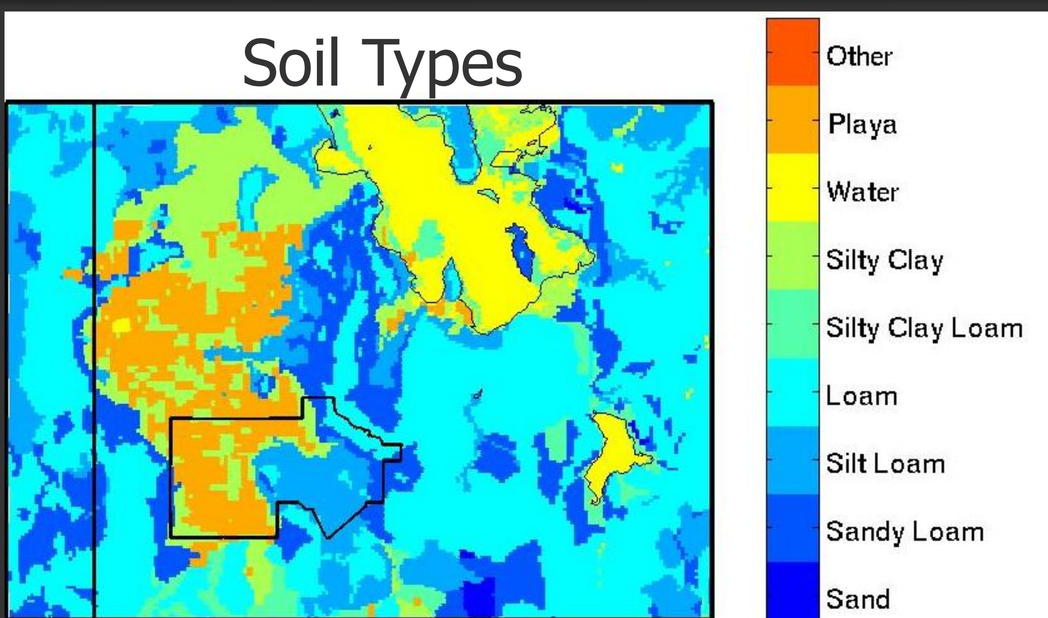




WRF Landuse and Soil Types



Shrubland surrounds the playa



Loamy soils surround the playa. Specifically:

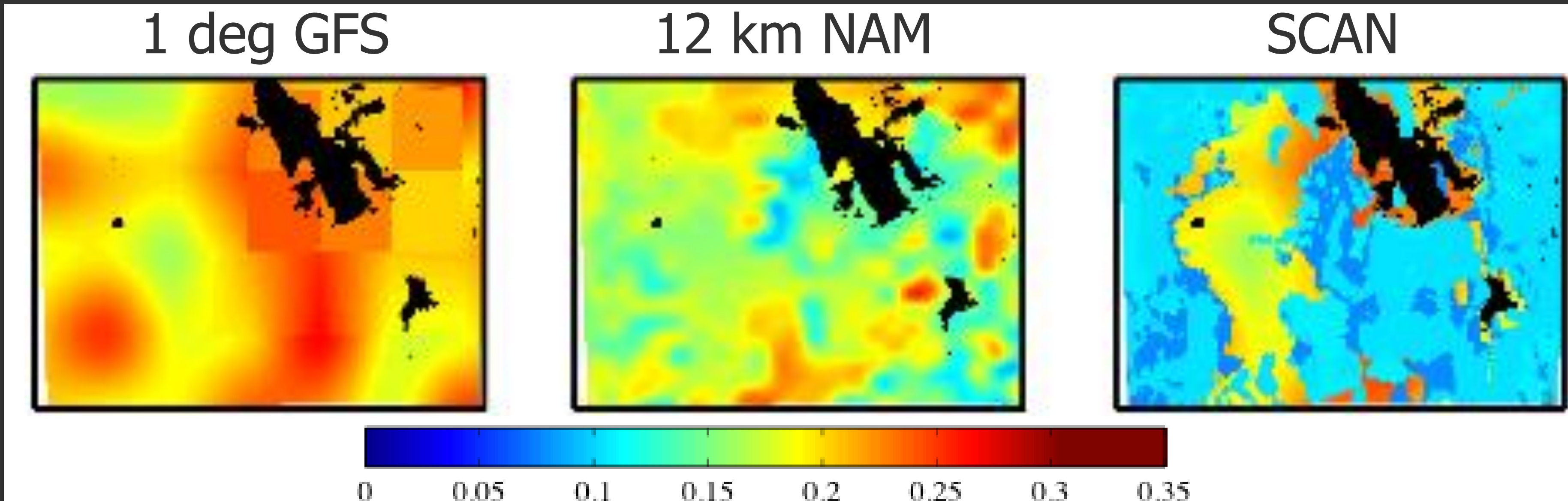
1. Loam
2. Silt Loam
3. Sandy Loam
4. Silty Clay Loam

Playa vs. Surrounding Desert

Differences between the playa and surrounding desert (Rife et al. 2002):

1. **Albedo** – Playa has a higher albedo than the surrounding desert.
2. **Vegetation** – Playa has less vegetation than surrounding desert.
3. **Latent heat flux** – Playa has higher soil moisture so it has a higher latent heat flux.
4. **Soil thermal conductivity** – Playa has a higher soil thermal conductivity compared to surrounding desert.

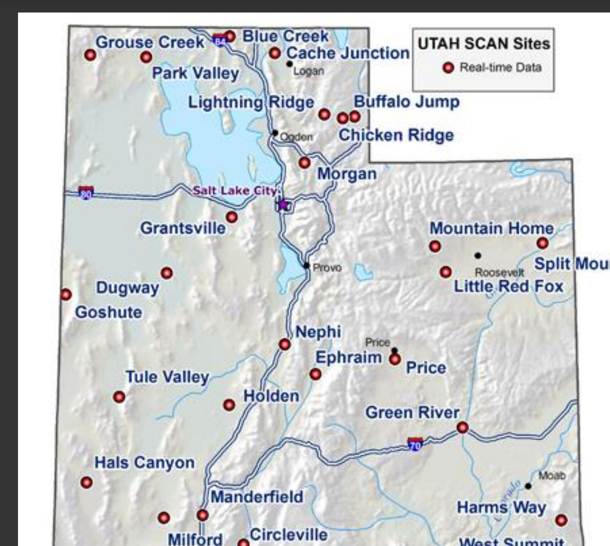
5-cm Soil Moisture



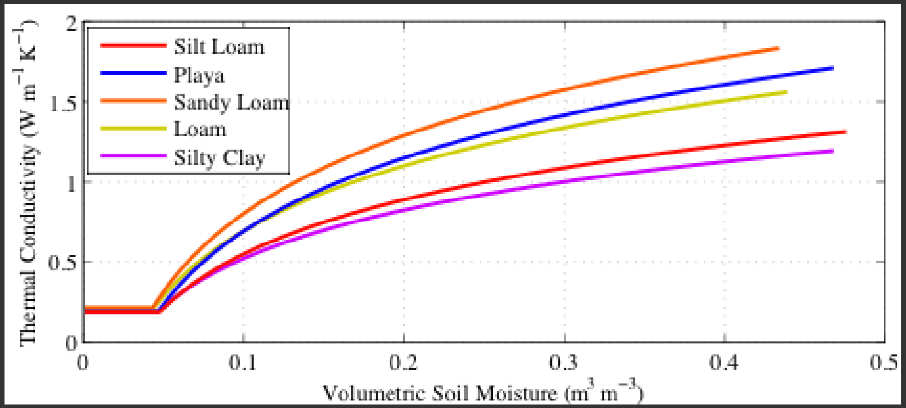
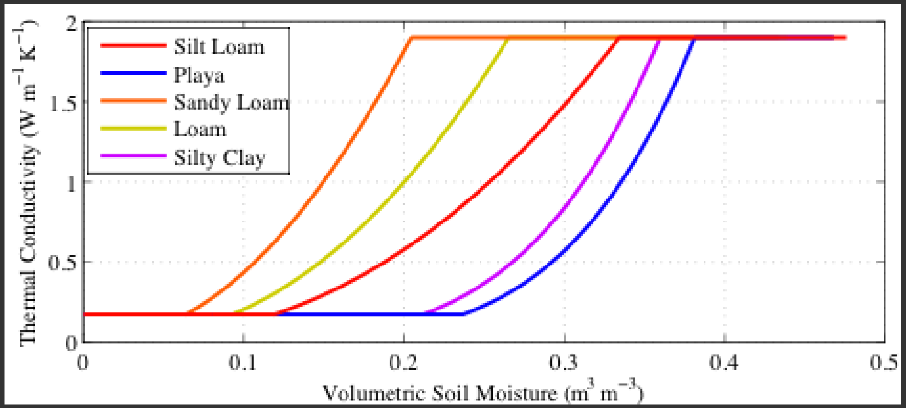
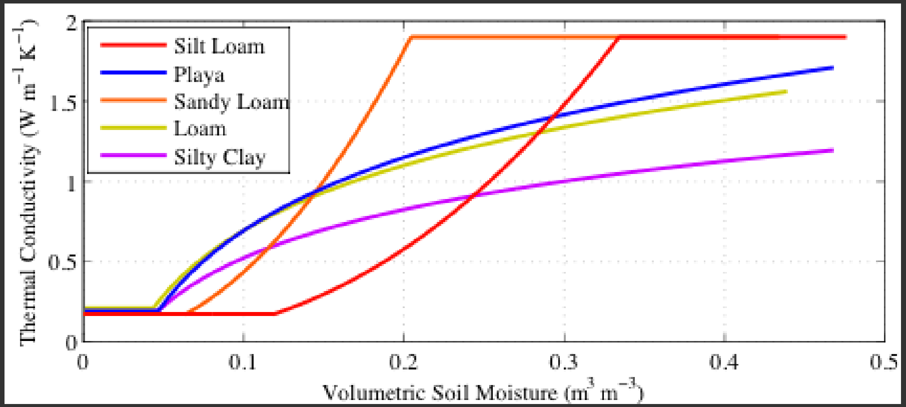
Initialized 5-cm soil moisture at 1200 UTC 22 September 2011

Soil Climate Analysis Network (SCAN)

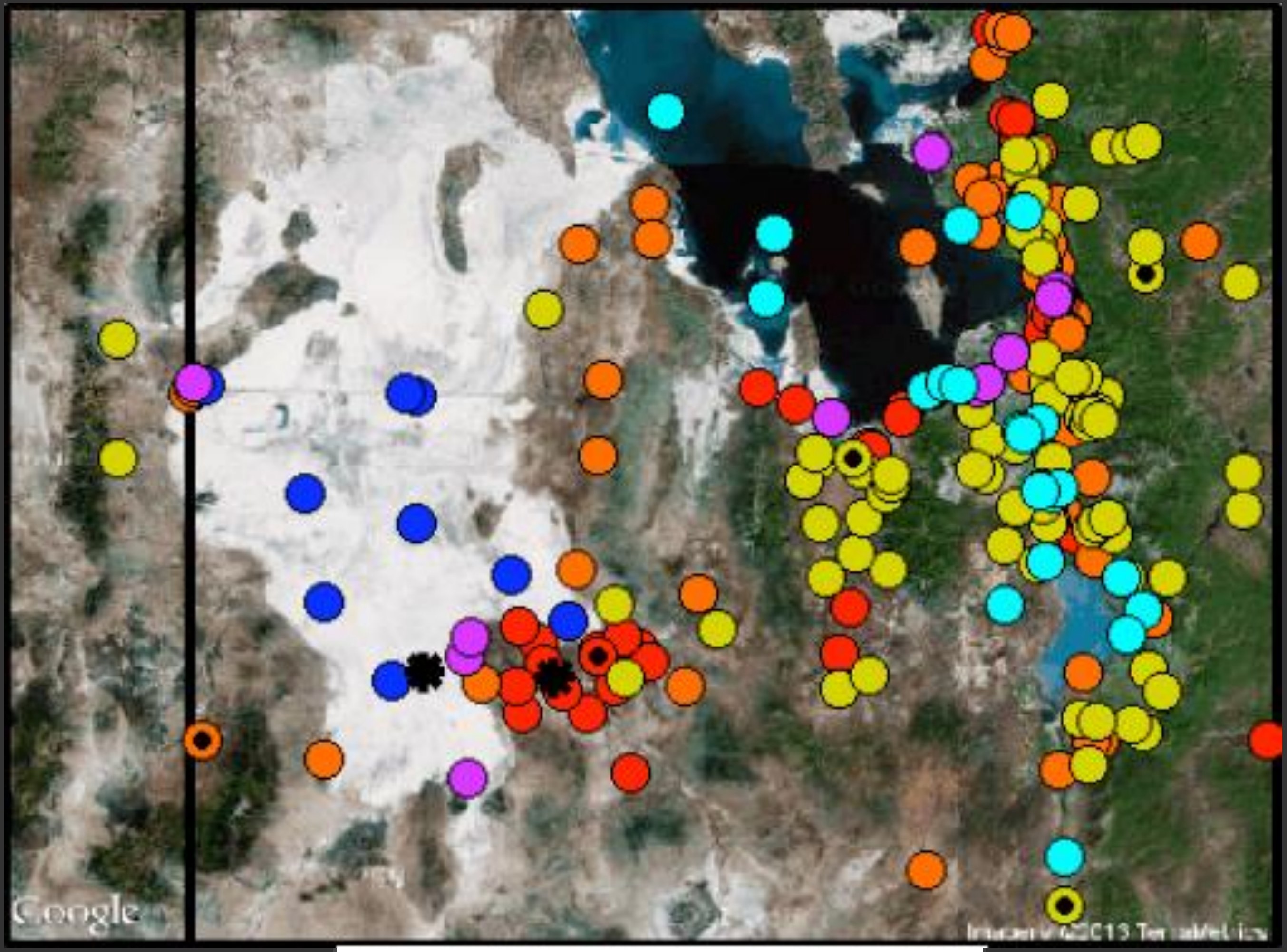
- Relatively dense network over Northern Utah
- Stations cover wide variety of soil types
- Station located in Sagebrush area

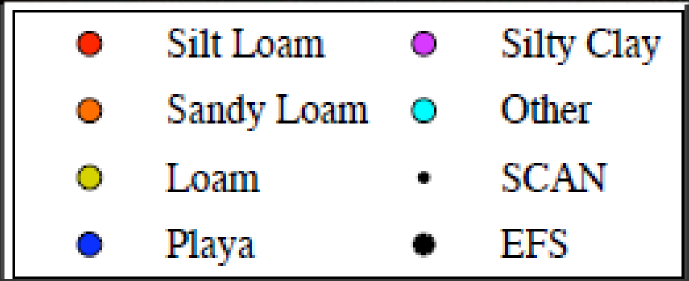


Soil Thermal Conductivity

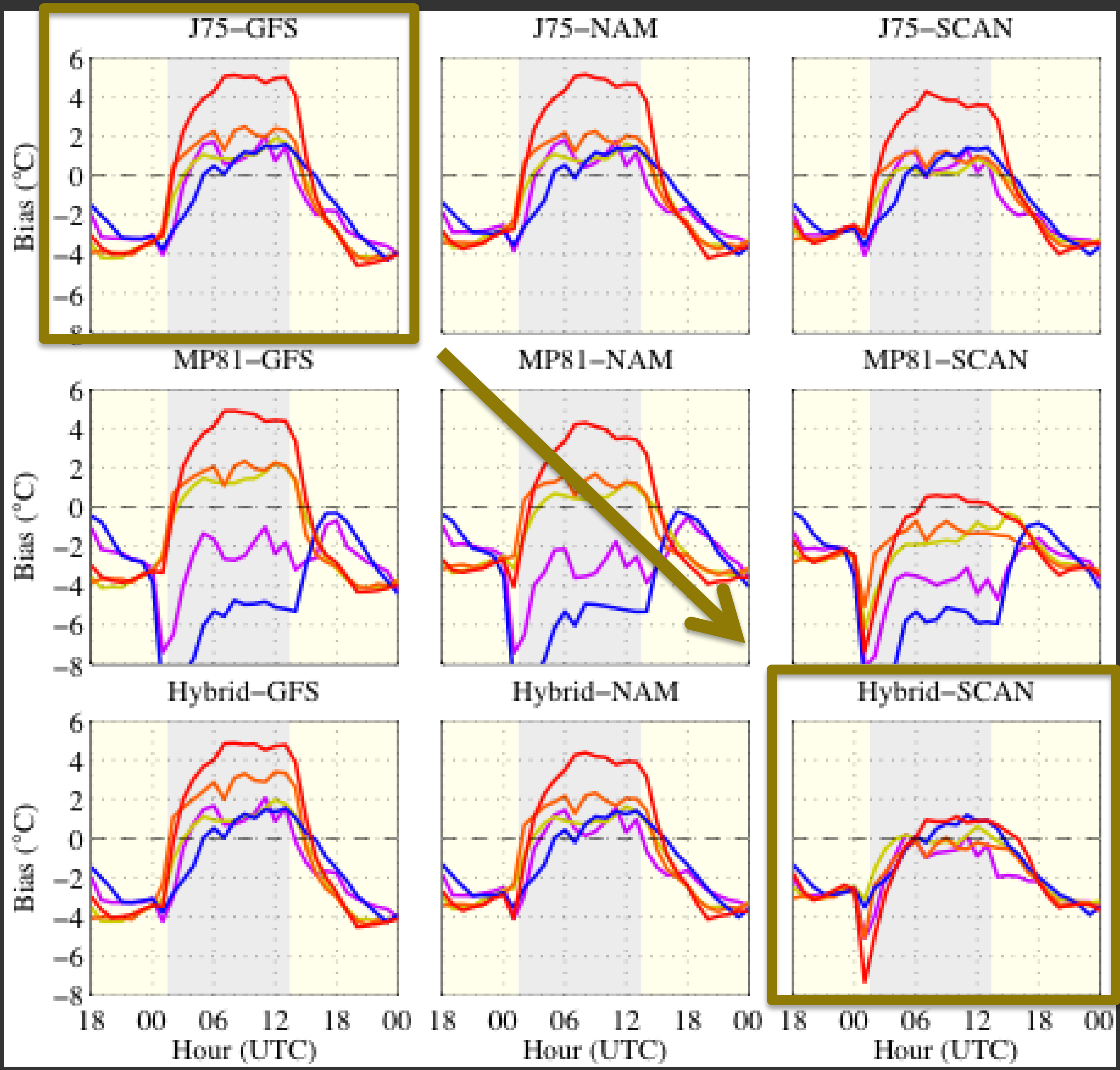
Johansen 1975 (J75) – less spread among soils and less sensitivity to soil moisture.	J75	
McCumber and Pielke 1981 (MP81) – greater spread among soil types and greater sensitivity to soil moisture.	MP81	
Hybrid – Uses MP81 for silt loam and sandy loam, and J75 for all other soil types.	Hybrid	

Surface Stations used for Verification





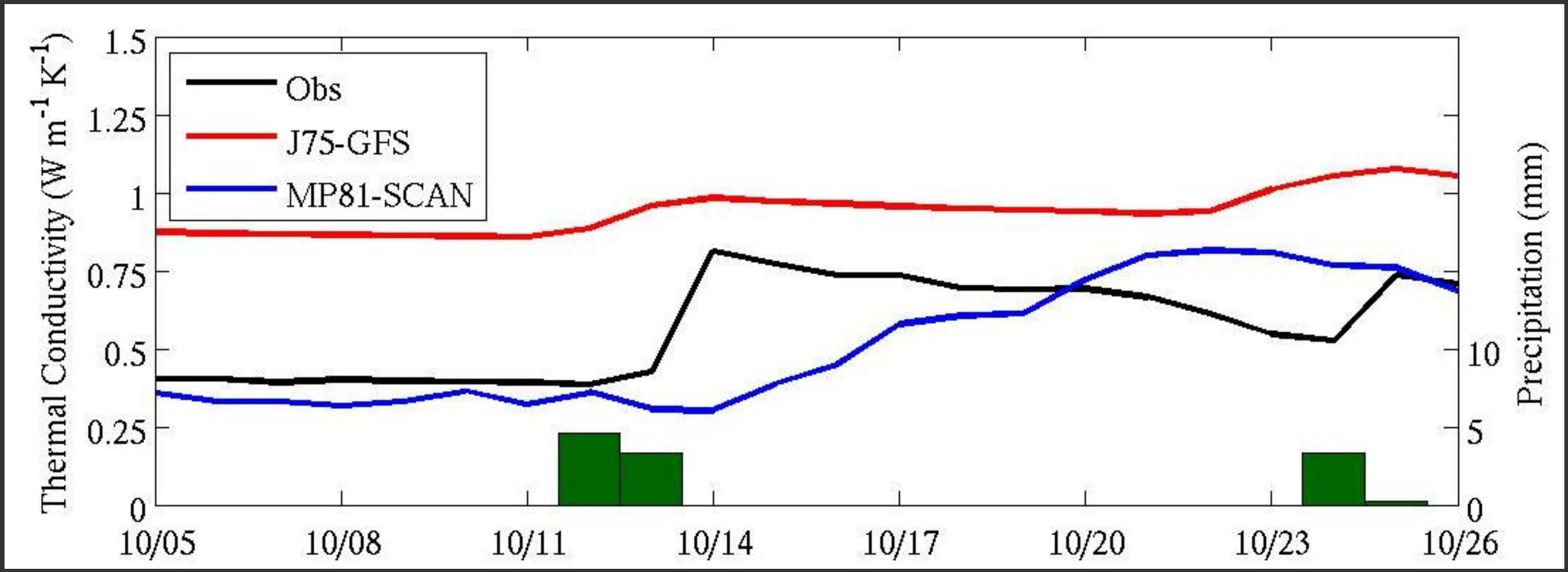
Near-Surface Temperature Bias Errors



Improved soil moisture initialization and the hybrid parameterization reduce nighttime bias errors and reduce the variance of bias errors over different soil types.

MATERHORN Sagebrush Observations

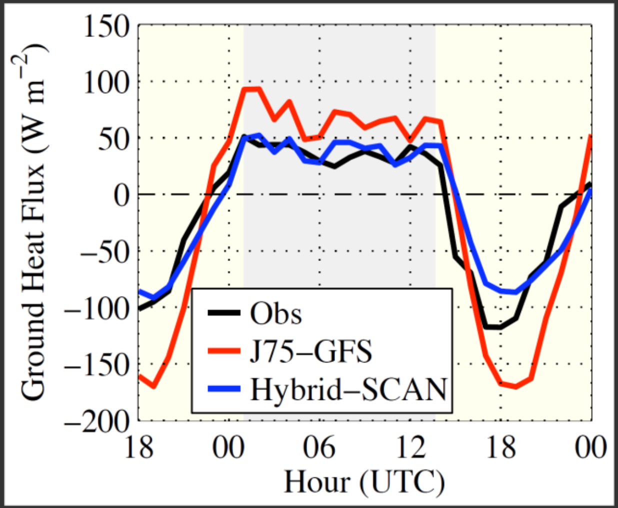
Soil Thermal Conductivity



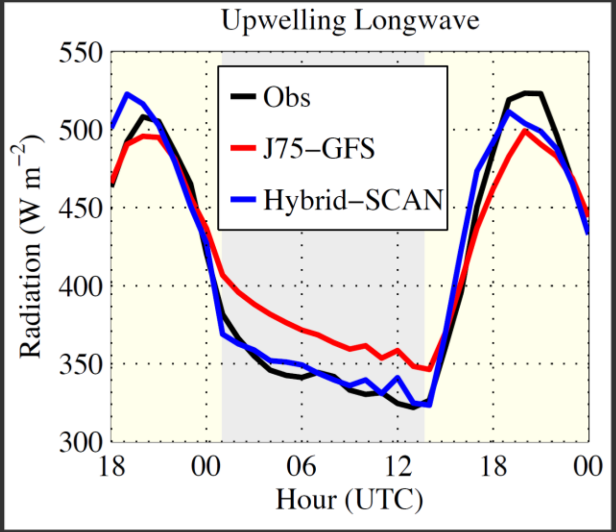
Soil thermal conductivity calculated using MP81-SCAN more closely matches observations relative to the soil thermal conductivity calculated using J75-GFS

MATERHORN Sagebrush Observations

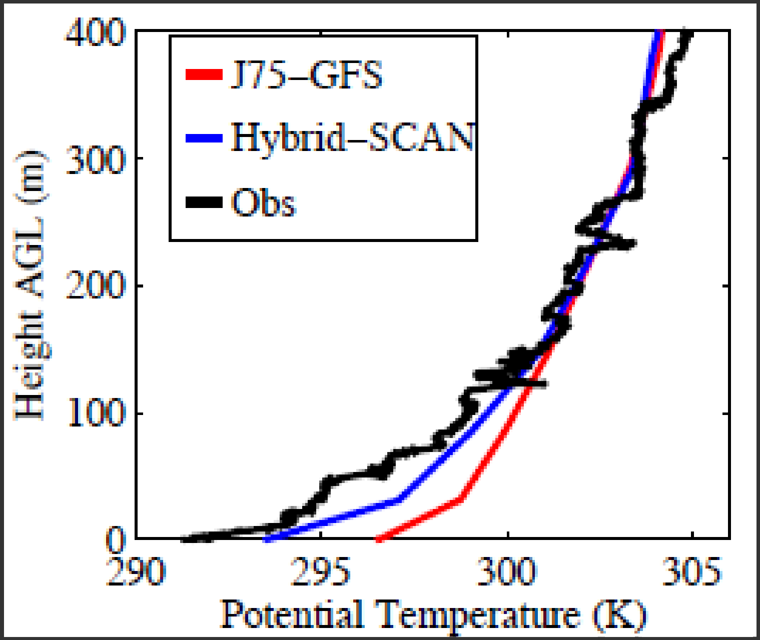
Ground Heat Flux



Upwelling Longwave Radiation



1200 UTC Vertical Potential Temperature Profile



Hybrid-SCAN also more closely matches observed surface energy budget components and vertical temperature profiles

Conclusions

- Initializing 5-cm soil moisture with observed values and using the MP81 soil thermal conductivity parameterization reduces the nighttime warm bias over silt loam and sandy loam soils.

- These results were consistent in several other cases we tested over DPG and we anticipate similar results in other dryland regions with silt loam and sandy loam soils.

- MATERHORN observations provide additional support for these changes since all forecasted surface and subsurface variables improved.