The Shrinking Great Salt Lake May Exacerbate Droughts by Reducing Local Precipitation: A Case Study

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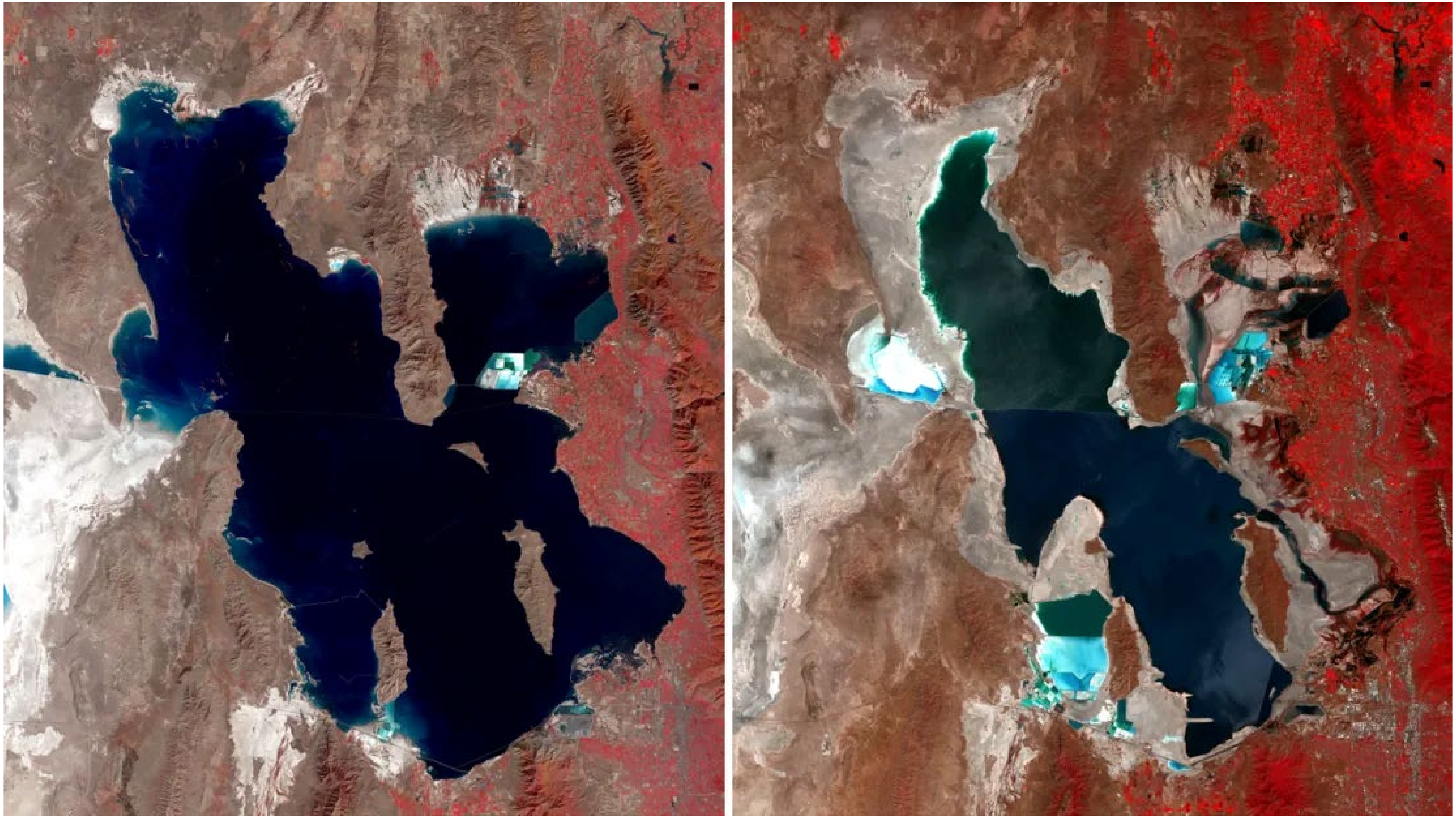
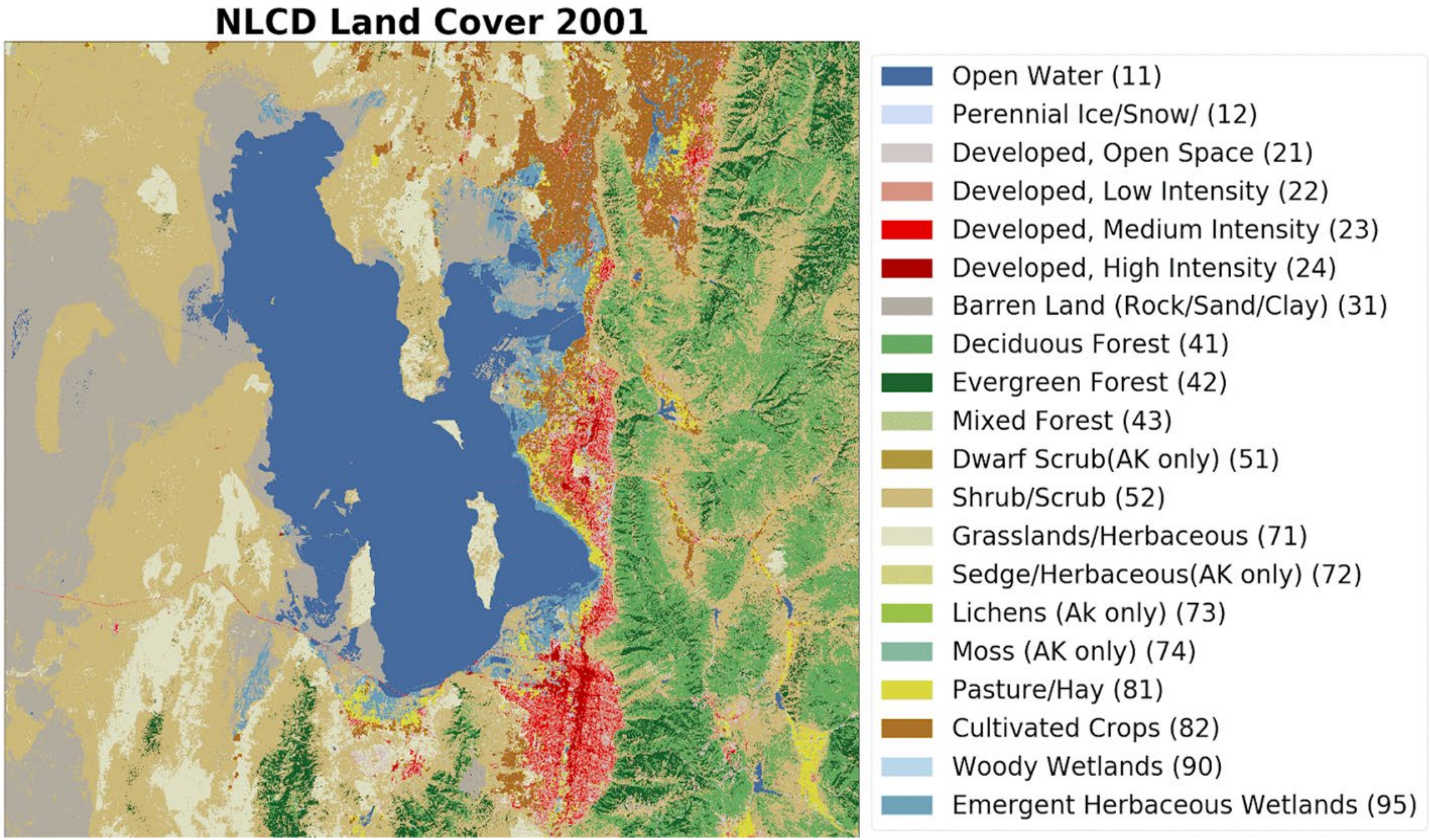
There is a sharp decrease in the areal extent of the Great Salt Lake (1987 vs 2022).



1987 2022

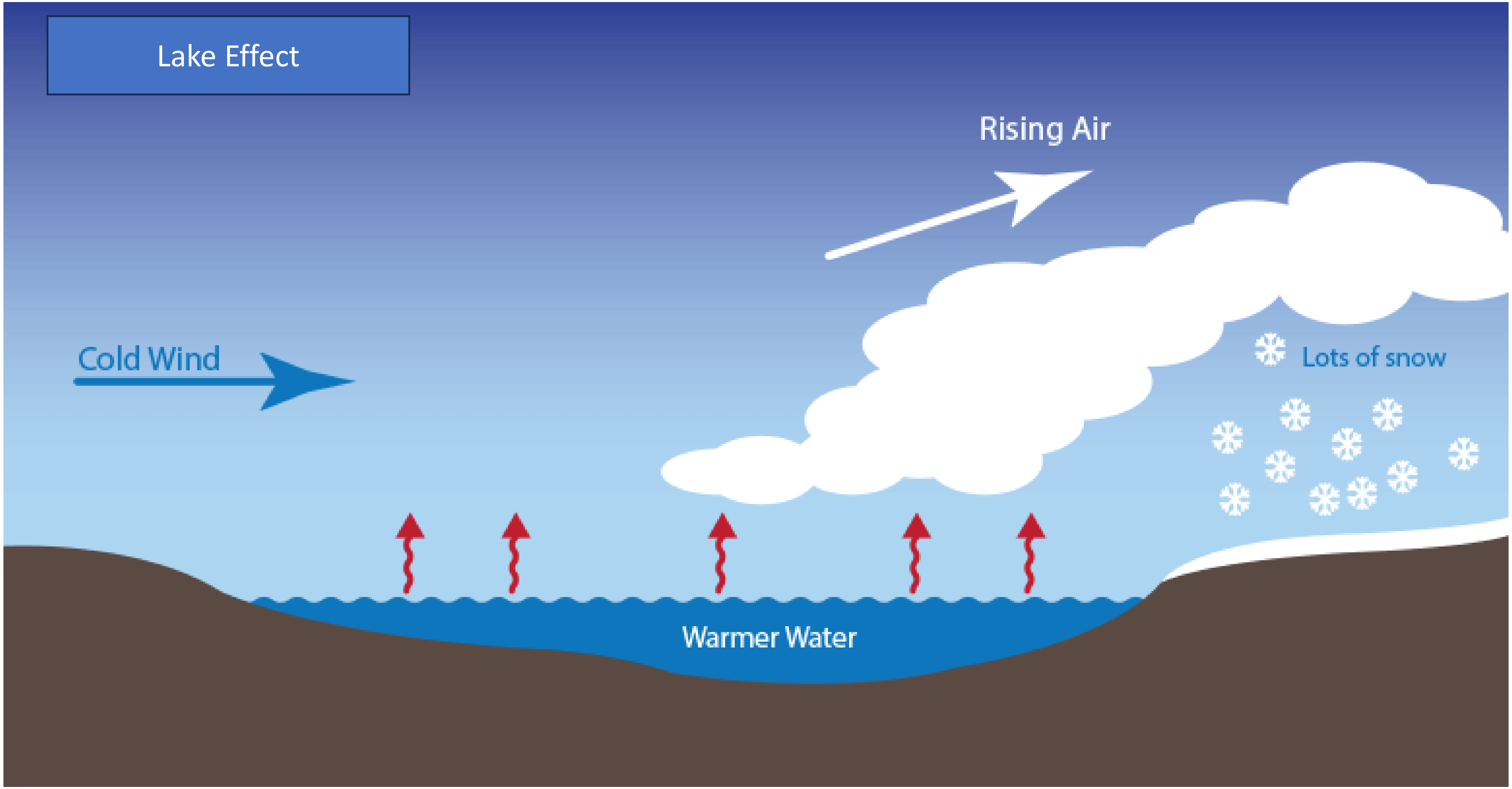
USGS Earth Resources Observation and Science (EROS) Center

The changing land use land cover within and surrounding the Great Salt Lake



From Ratterman etc.

Question: Weather, the extent to which and how the changing water body of the Great Salt Lake would affect local precipitation?



Twenty-eight cases of heavy (greater than 10 cm) GSL lake-effect snowfall were studied to discover parameters that could be used to forecast the occurrence of the lake effect and the location of the heaviest snowfall. It was found that upper-air data taken at the 700-mb level yielded useful information in this regard. A method for predicting the temperature of the GSL was developed. It was found that a difference of at least 17°C between the GSL and 700 mb was common in the heaviest snowstorms. The 700-mb wind direction was also found to be a good predictor of the location of heaviest snowfall.

Carpenter, 1993

During 1998–2009, lake-effect precipitation in the Great Salt Lake accounts for up to 8.4% of the total cool-season precipitation in the Great Salt Lake basin, with the largest contribution to the south and east of the Great Salt Lake.

Yeager et al., 2013

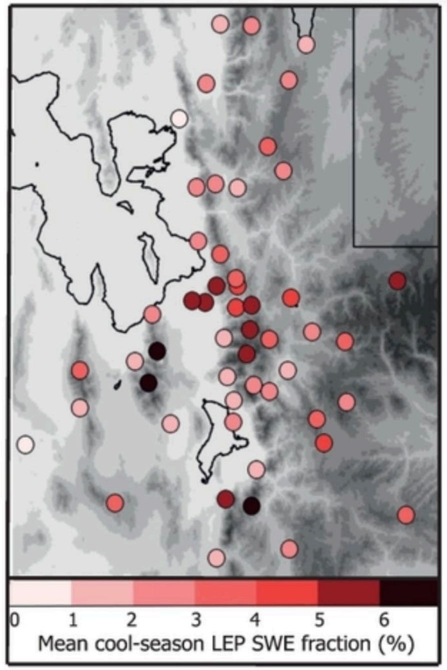


FIG. 8. Mean cool-season LEP fraction (in percent, following the inset scale) at stations in the GSL basin. Maximum is 8.4%.

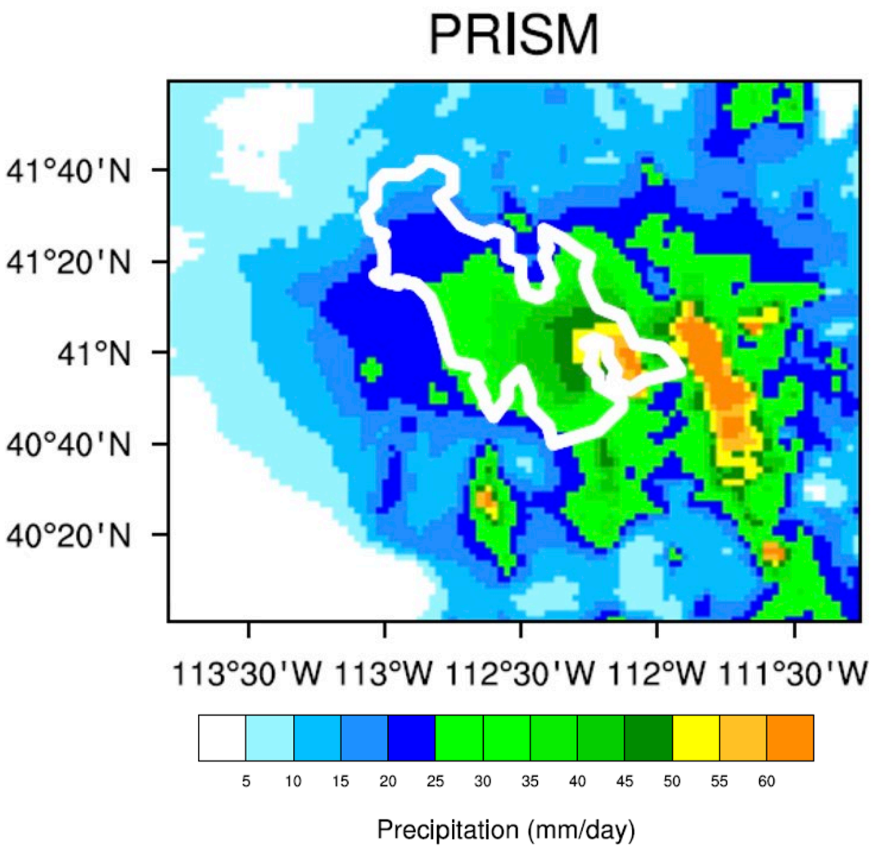
The GSL could increase precipitation averaged over its downwind area from October 2001 to April 2002 by 3.2%.

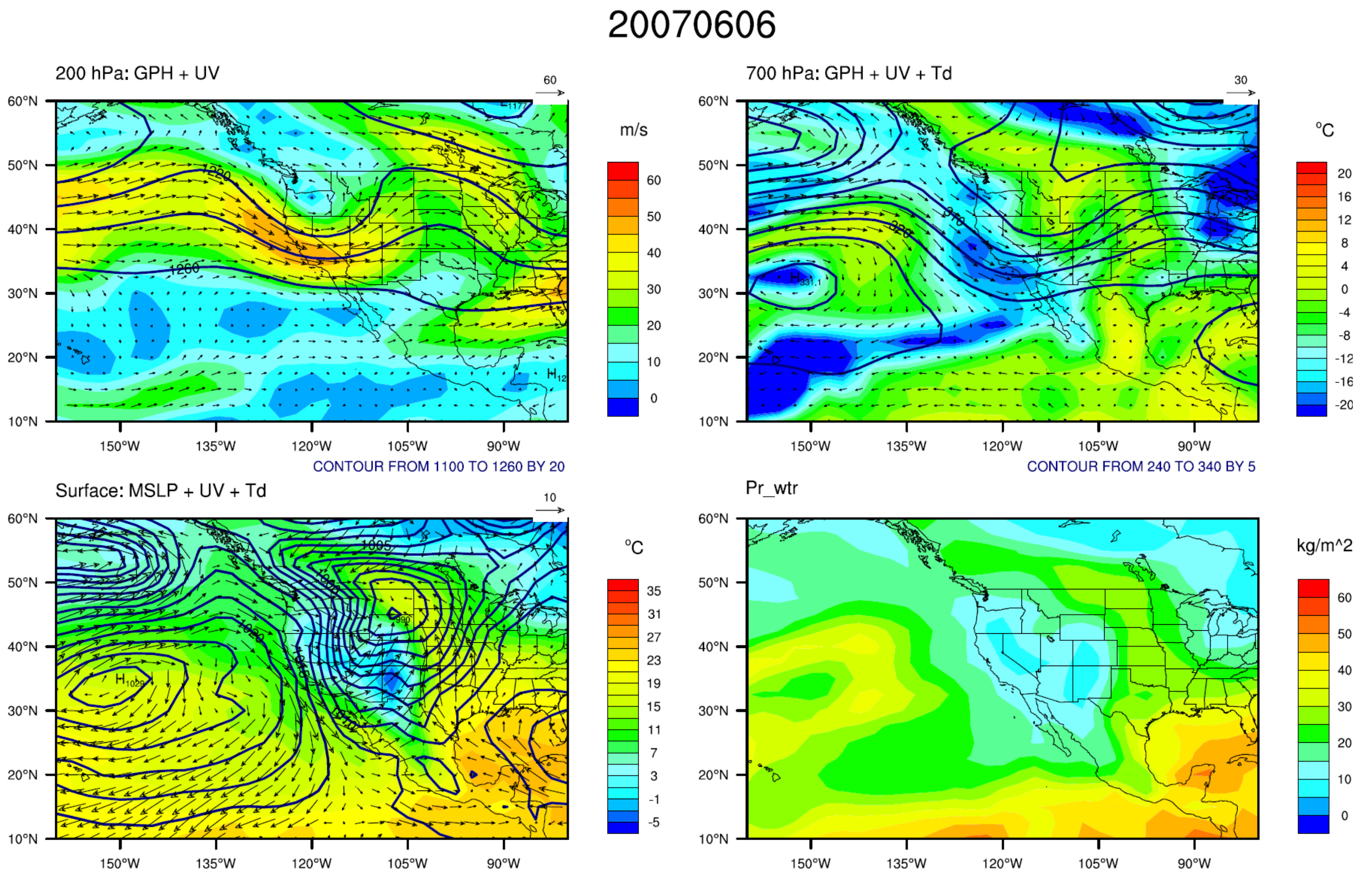
Wen, 2015

Methodology

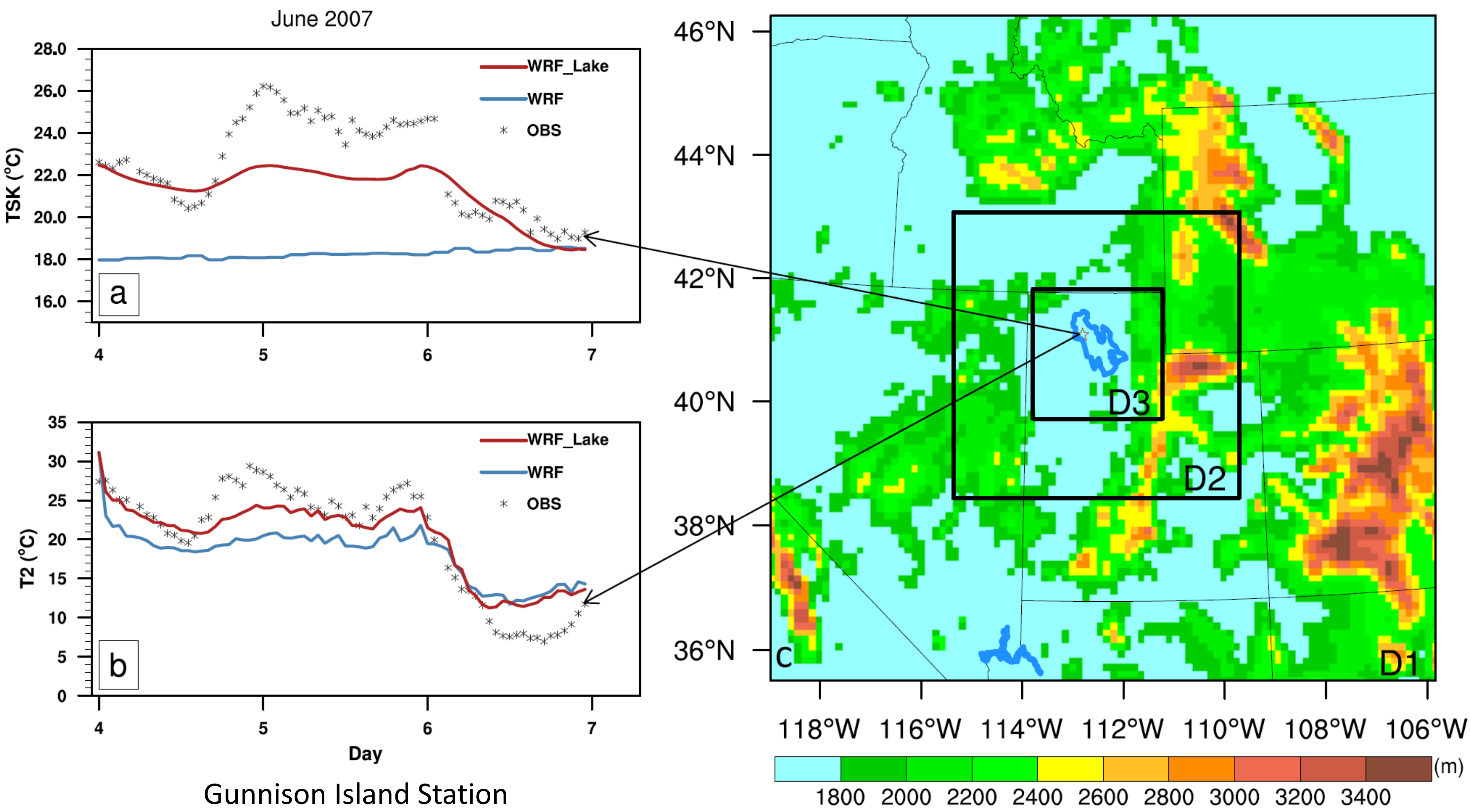
- Weather Research and Forecasting (WRF) Model coupled with the Lake Module (WRF-Lake; Gu et al. 2015)
- Initial and boundary forcing (North American Regional Reanalysis-NARR)
- Three nested domains (~1km for the inner domain)
- Ensemble runs (initial dates and parameterization schemes)

We selected an extreme precipitation event on 6 June 2007.

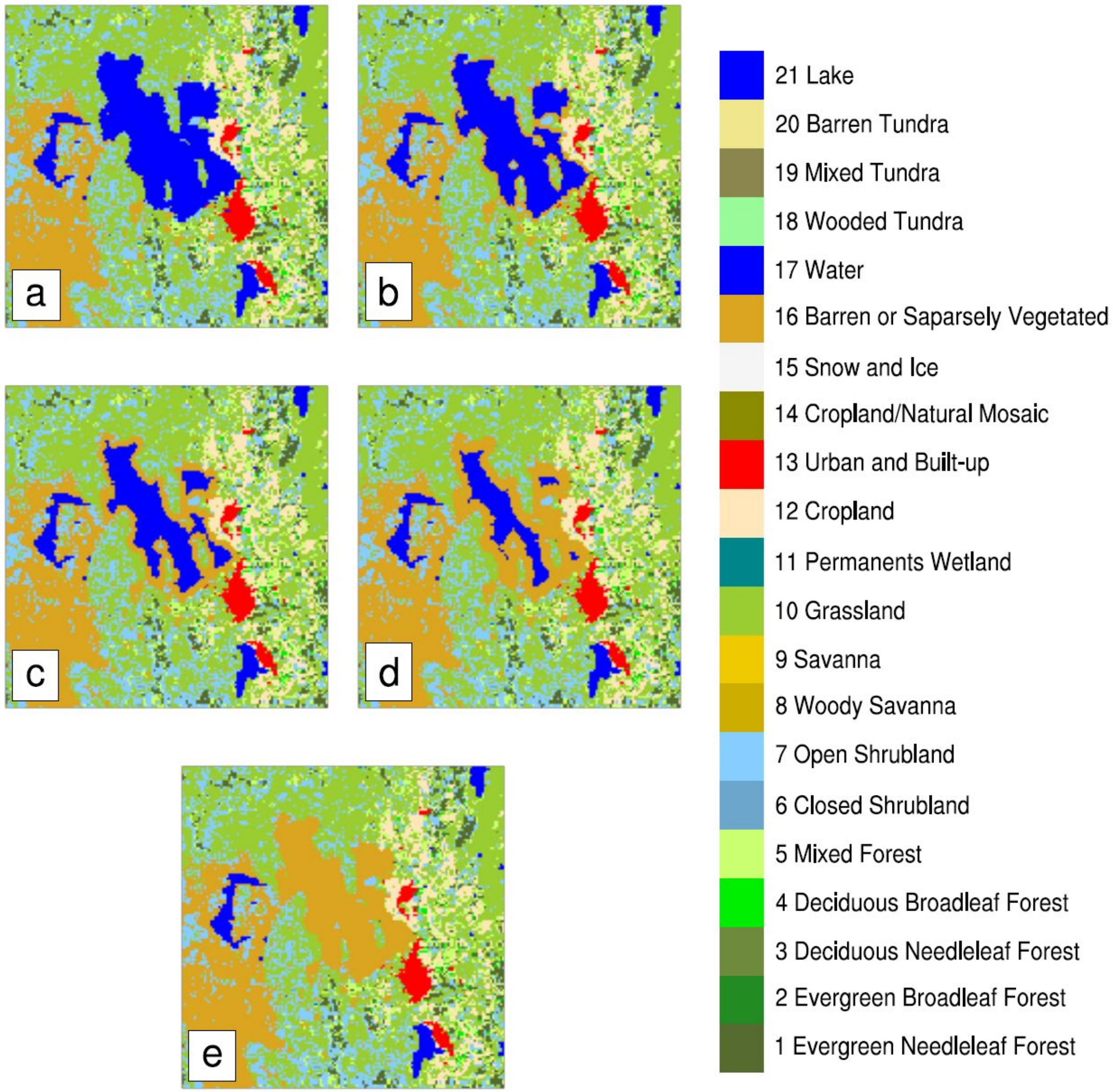




WRF-Lake outperforms WRF in reproducing observed temperature in the Great Salt Lake.

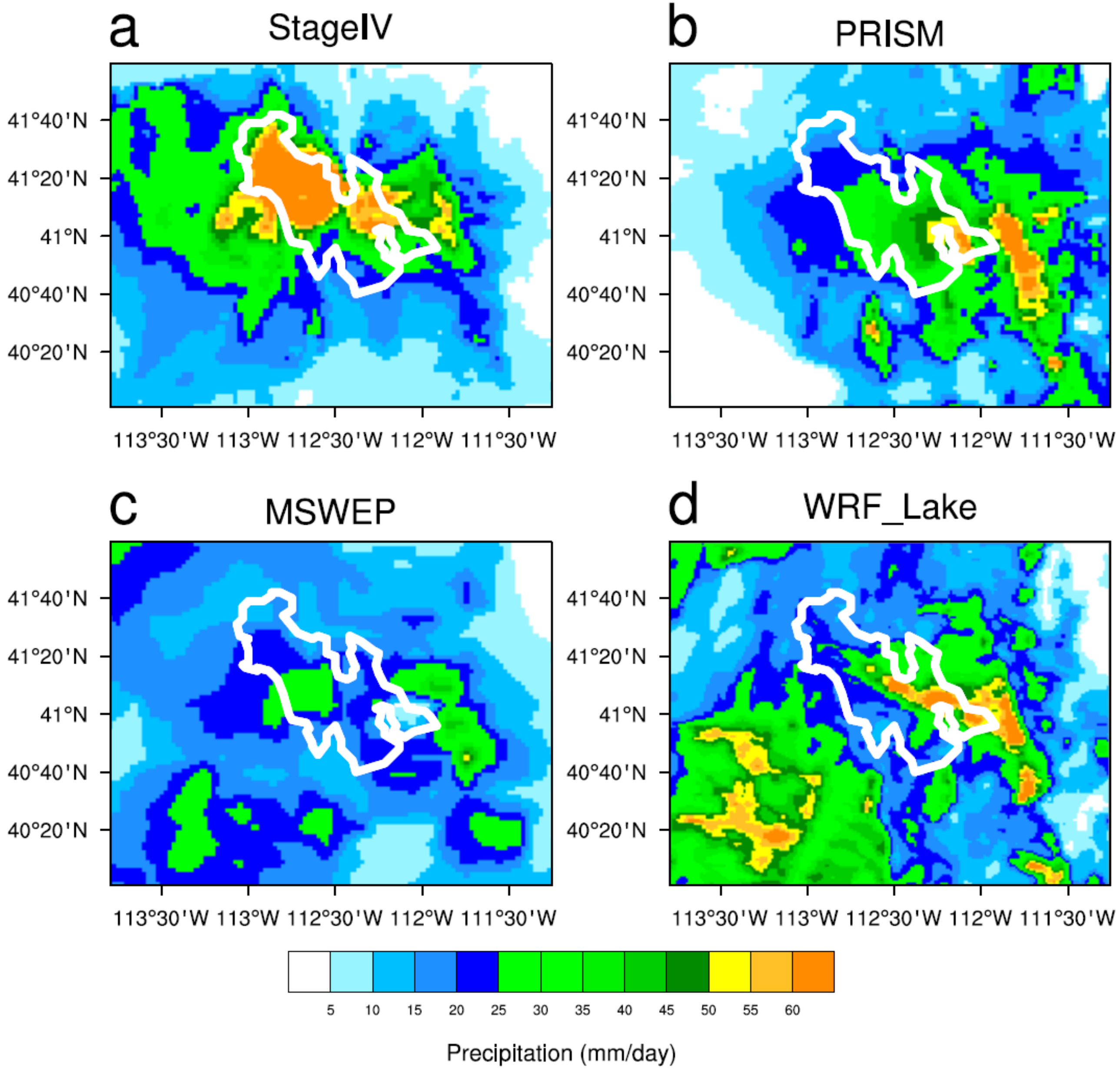


Gunnison Island Station

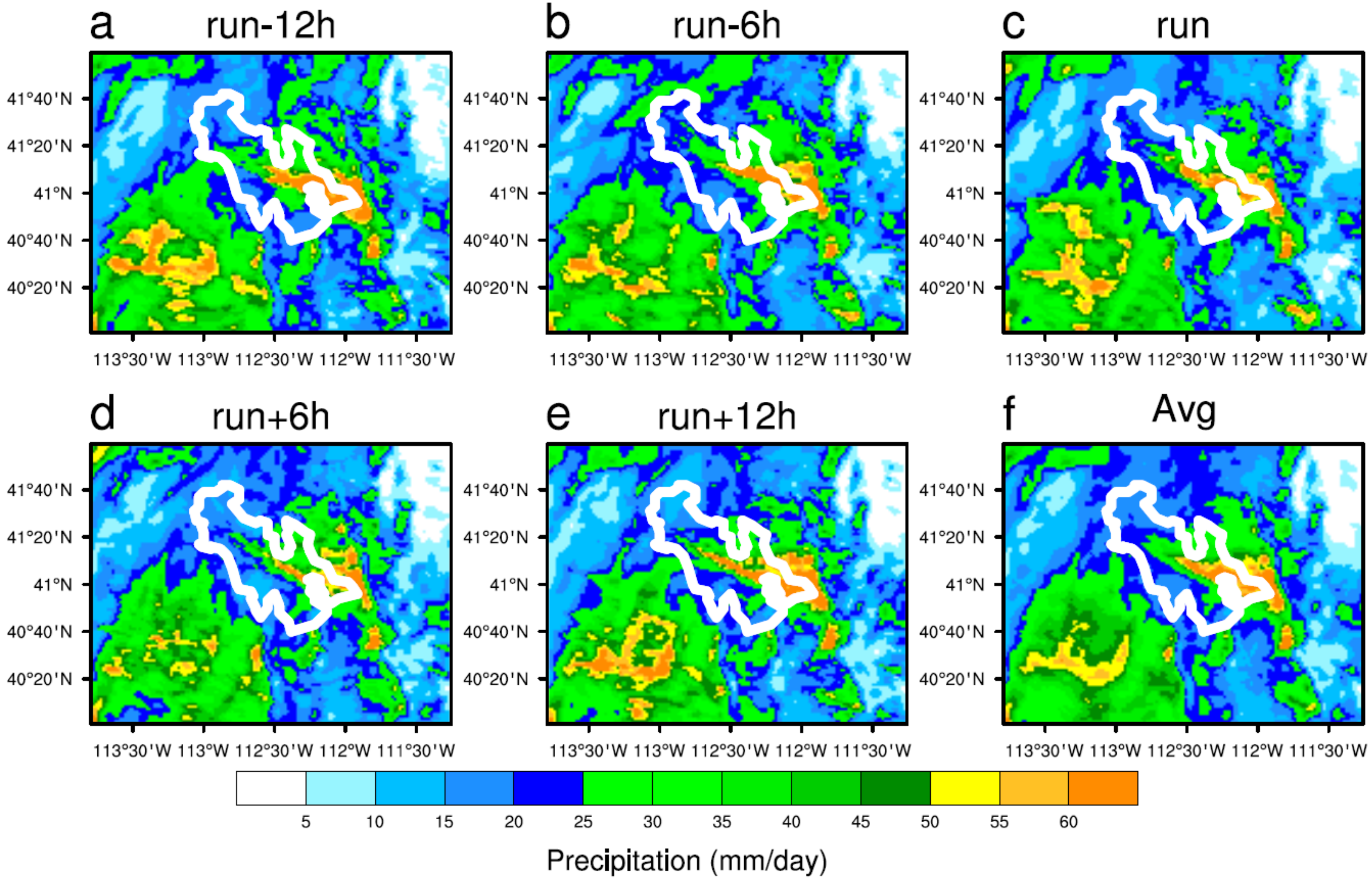


Five scenarios were designed :
100% (a; as of 2004 in USGS data)
75% (b)
50% (c)
25% (d)
0% (e; completely dry)

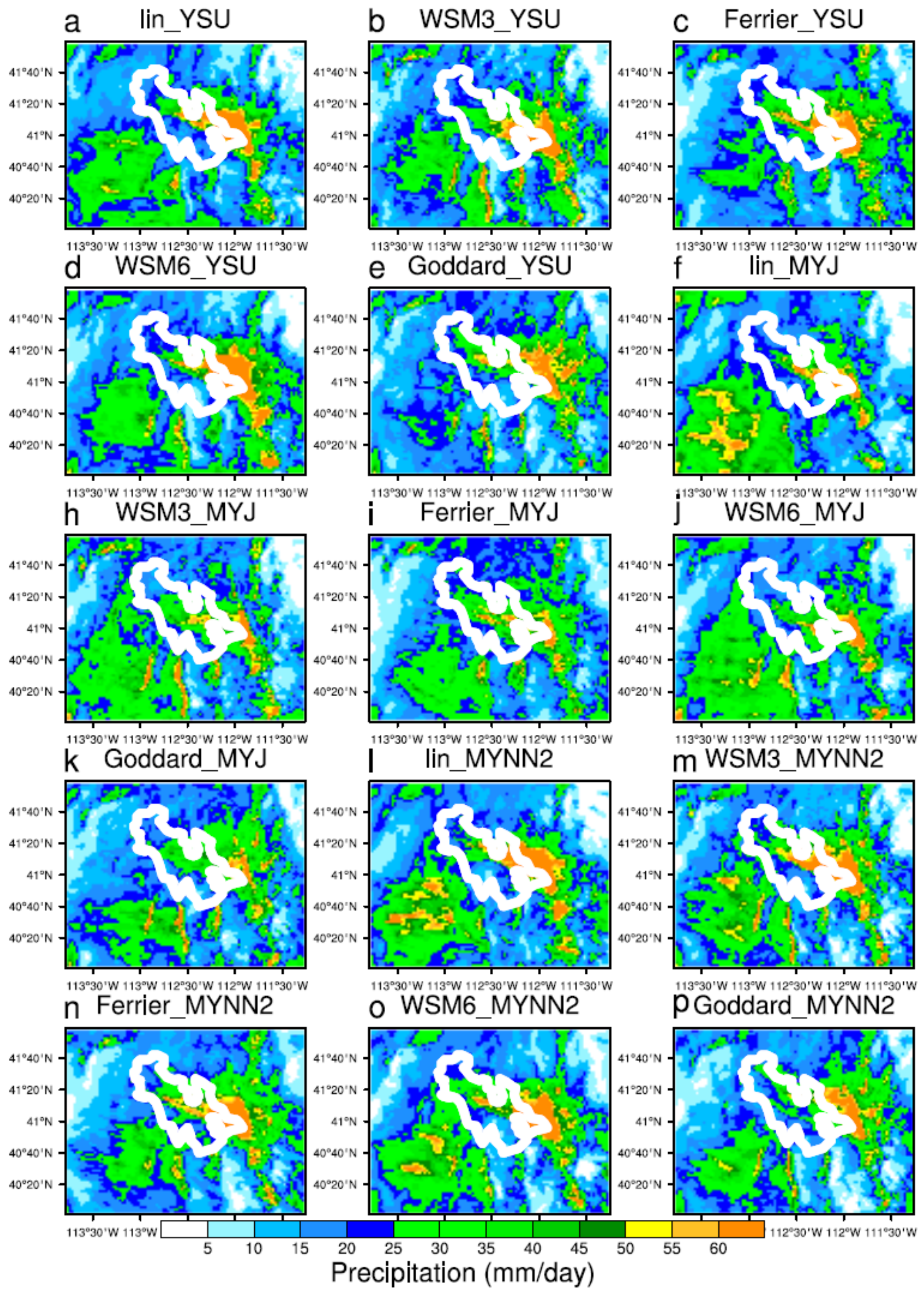
WRF_Lake can reasonably reproduce observed precipitation for the selected case.



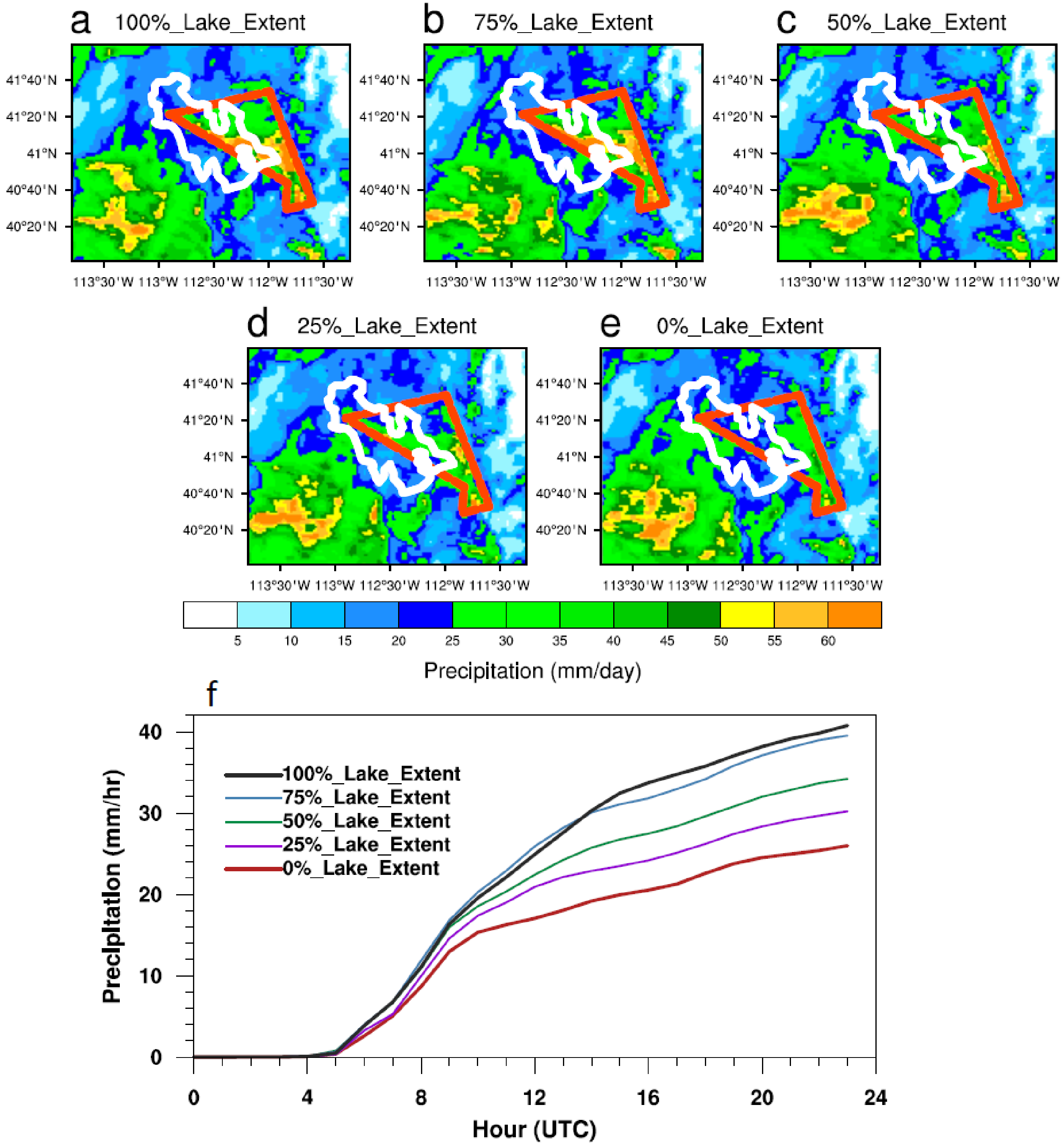
The simulate results are consistent across different initial time.



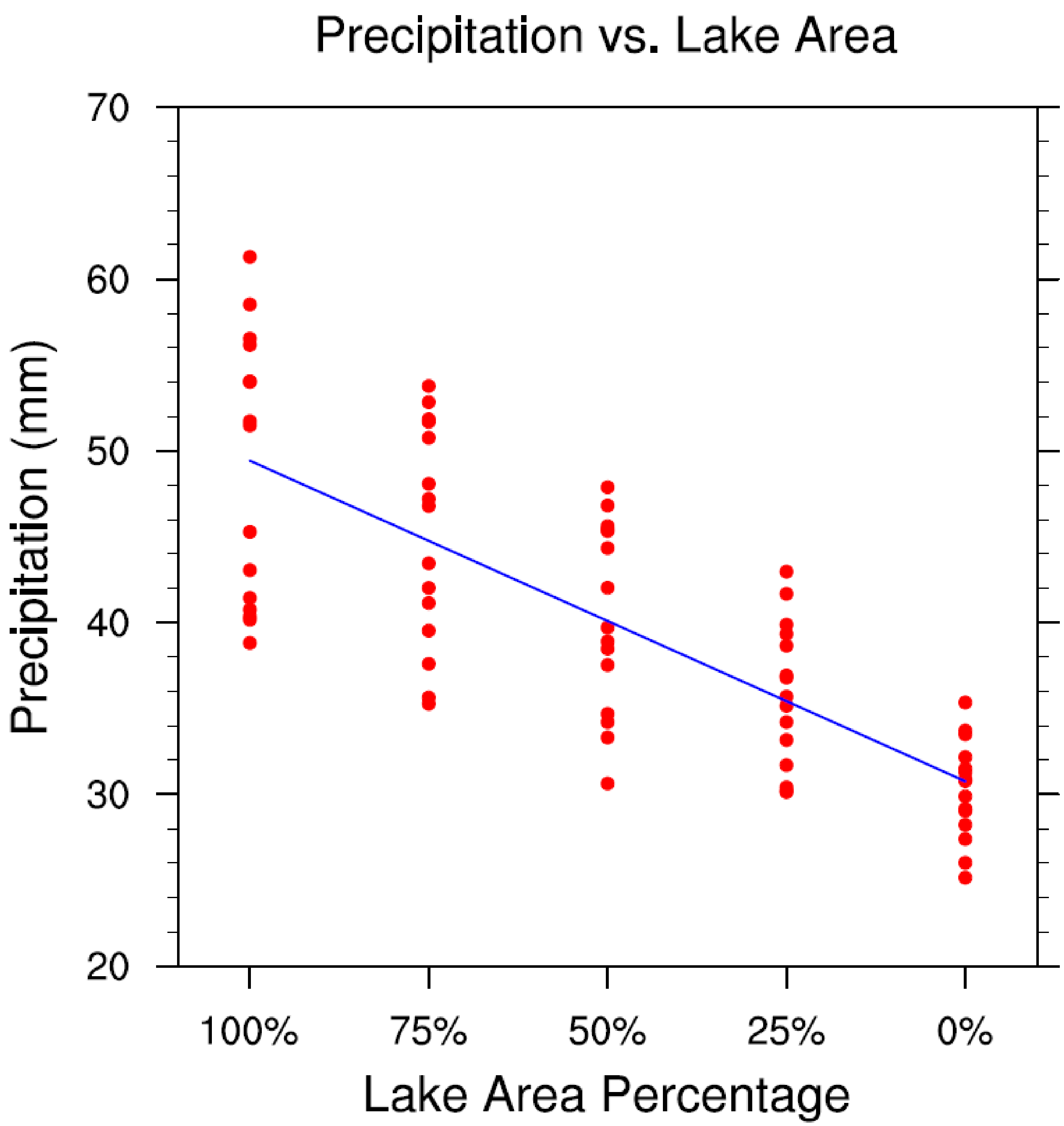
Overall, the results are consistent across different parameterization schemes, such as microphysics, boundary layer physics, and radiation.



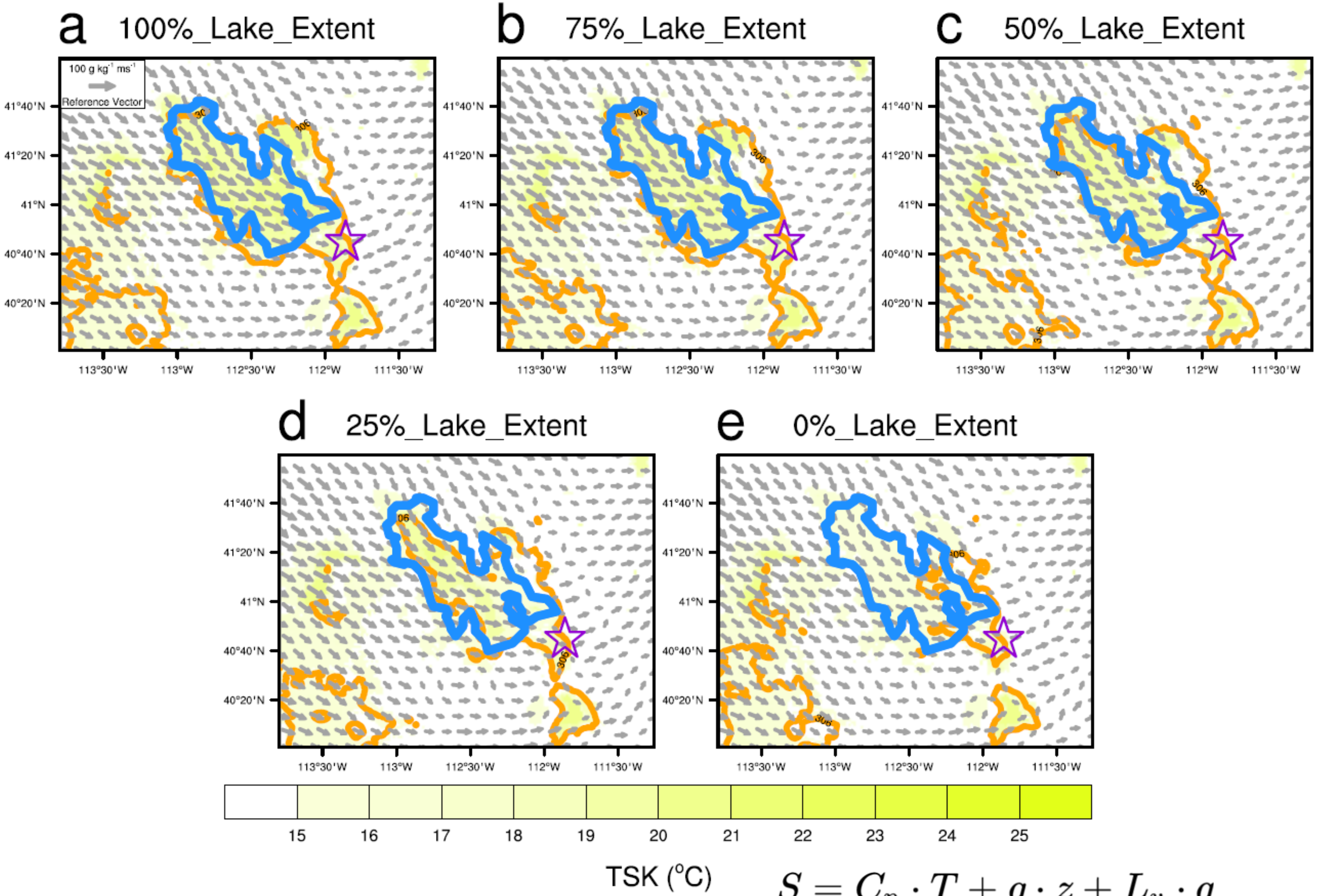
A reduced lake extent would dramatically reduce downwind precipitation.



The results strongly supported a linear decrease in precipitation associated with this precipitation event corresponding to a reduced lake water extent, with an average decrease of 4.7 mm for every 25% reduction in the lake extent.



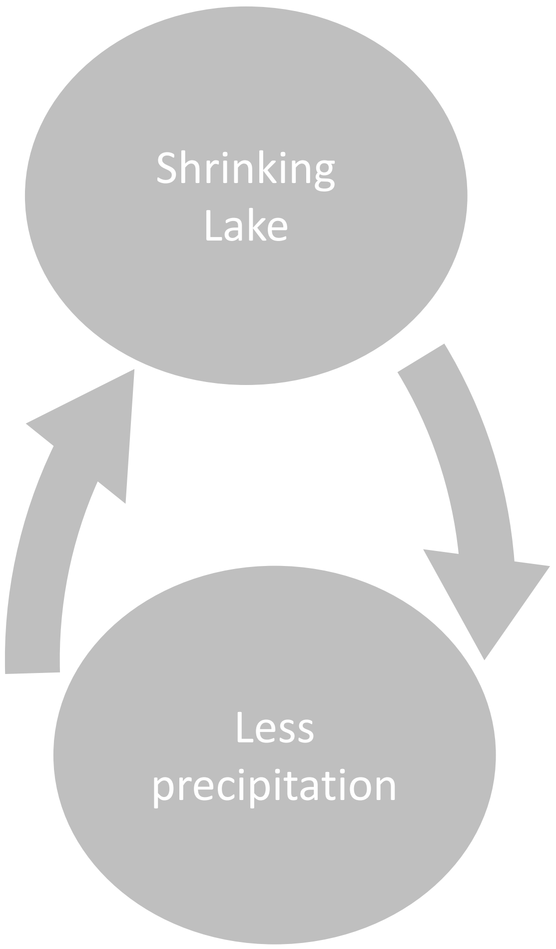
This decrease in precipitation is principally attributed to a diminished water vapor flux and moist static energy (MSE) above the lake.



$$S = C_p \cdot T + g \cdot z + L_v \cdot q$$

Conclusions

- We utilized the Weather Research and Forecasting model version 4.2 coupled with a lake model to simulate a series of high-resolution numerical experiments; these experiments aimed to assess the effect of varying lake areal extents on a storm event that occurred on June 6, 2007.
- The results revealed a systematic decline in the quantity of precipitation over the GSL and downwind regions with declining areal coverage. In the event of complete disappearance, the regional average precipitation would experience an approximate 50% reduction relative to its 2004 base lake extent.
- The research underscores the consequences of a shrinking GSL, not just for precipitation delivery downstream but that of a negative feedback loop within the hydroclimatic system of the GSL basin, i.e., water flow reductions into the basin.



Questions?

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Thanks for your attention!

Gu, H., W. Zhang and R. Gillies, The Shrinking Great Salt Lake May Exacerbate Droughts by Reducing Local Precipitation: A Case Study, Journal of Hydrometeorology, under review after revision.

Table 1. Key lake physical parameters and their values used in the WRF-Lake experiments.

Parameters	Units	Values
Density of liquid water	Kg m^{-3}	1.0×10^{3}
Emissivity of the water surface	-	0.97
Specific heat of water	J kg^{-1} K^{-1}	4.188×10^{3}
Latent heat of evaporation for water	J kg^{-1}	2.501×10^{6}
Thermal conductivity of water	W m^{-1} K^{-1}	0.6
Molecular diffusion coefficient for water	m^{2} s^{-1}	4.188×10^{6}
Stefan-Boltzmann constant	W m^{-2} K^{-4}	5.67×10^{-8}
Water layers		10