Modeling the Impact of the Great Salt Lake Salinity on Local Climate

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Motivation

- The Great Salt Lake can increase snowstorms and rainstorms over the Salt Lake City area.

- Better understanding the Great Salt Lake effect on local climate is important.

Regional Climate Model

- The Weather Research and Forecasting (WRF) model version 3.0 is used in this study

- There is no lake scheme in the current version of WRF model

- We have recently coupled a lake model (Hostetler et al,1993;1994) into WRF model.

Salinity of the Great Salt Lake

The Great Salt Lake has high salinity

Gunnison Bay : 25-28%

Gilbert Bay: 8-15%

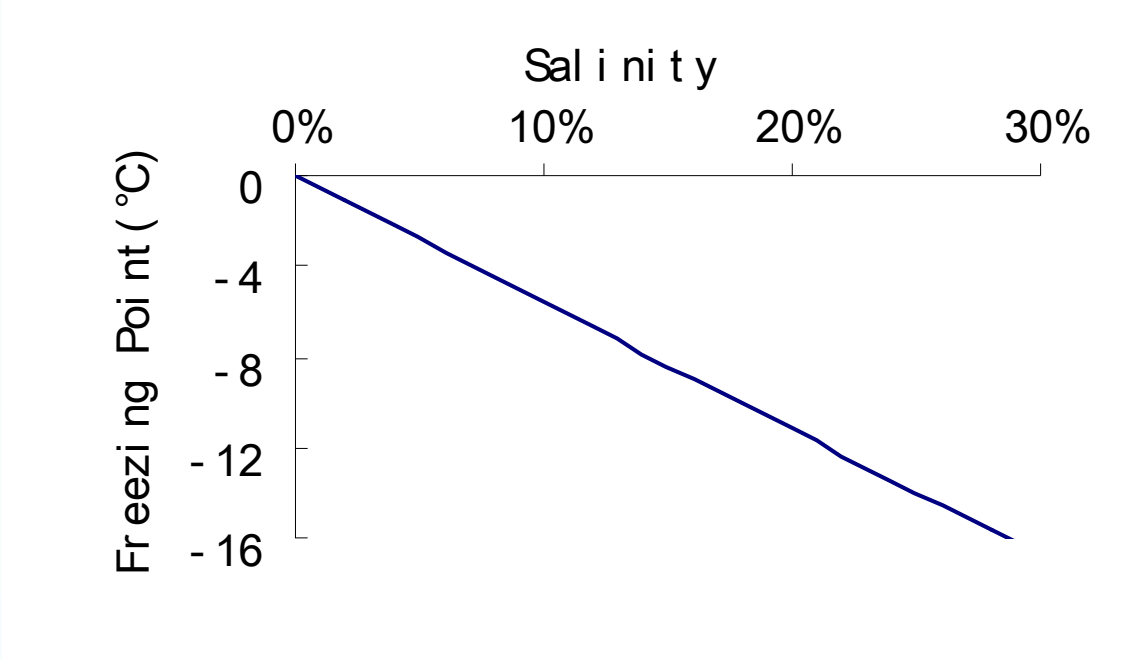
Ocean: 3.5%

However, the lake model does not take salinity into account. We need to add salinity effects into the model.

Salinity Effects on Water Properties

1. Freezing point
2. Water density
3. Water surface saturated vapor pressure
4. Water heat capacity
5. Water thermal conductivity

1. Salinity Effect on Freezing Point

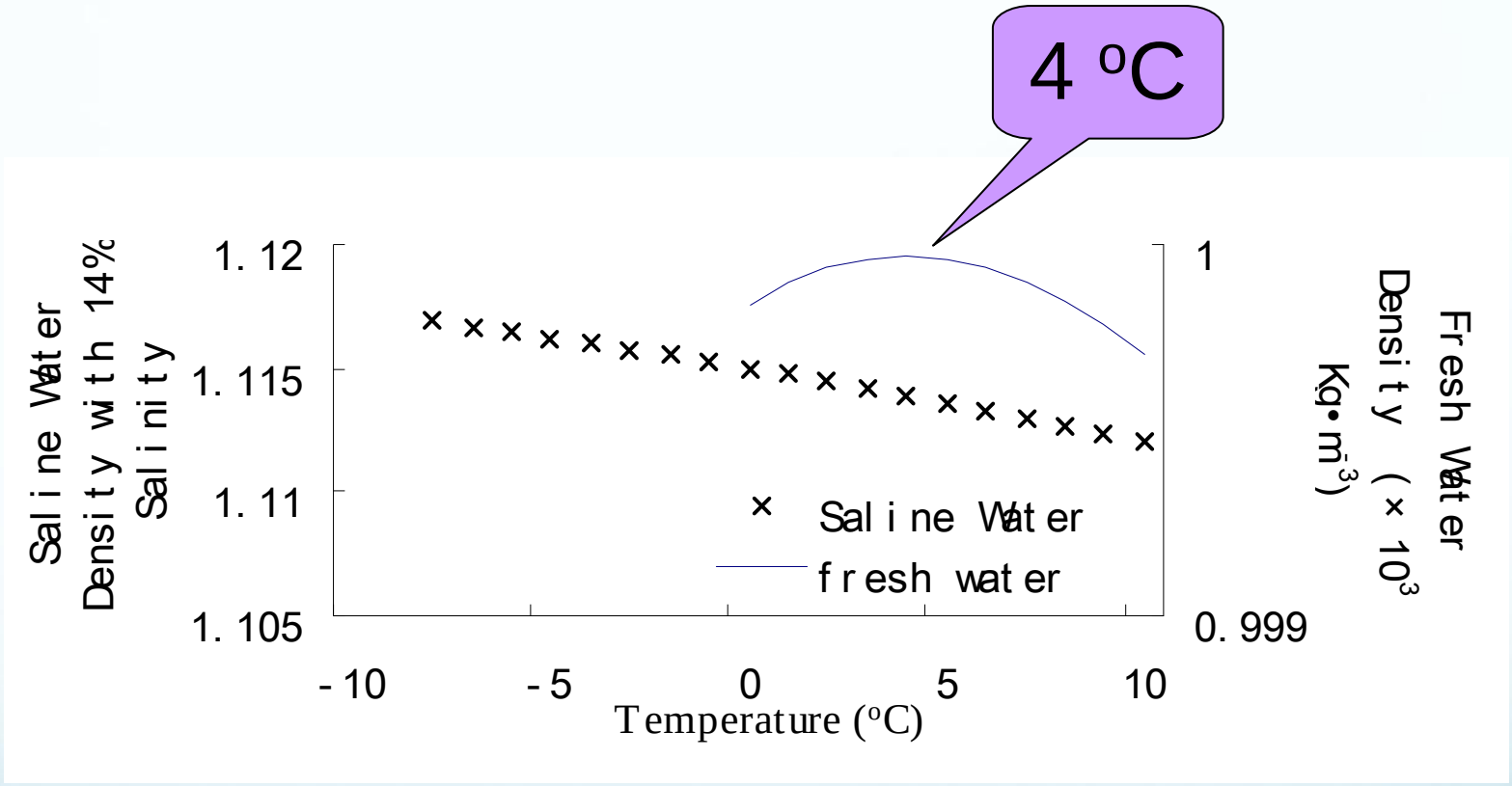


T_f=0 - 0.28s/0.005

T_f: freezing point (℃)
s : salinity

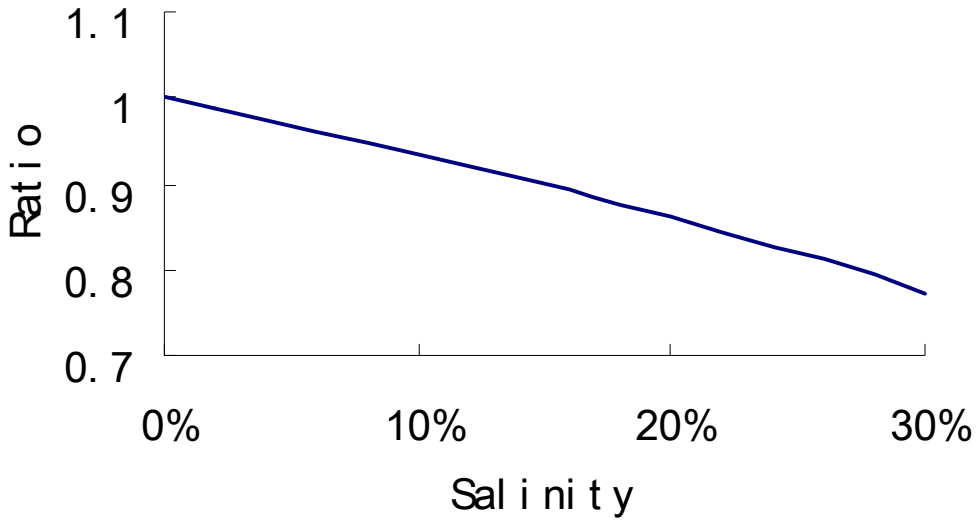
(National Snow and ice Data center)

2.Salinity Effect on Water Density



(Jackett et al,2006)

3.Salinity Effect on Water Surface Saturated Vapor Pressure



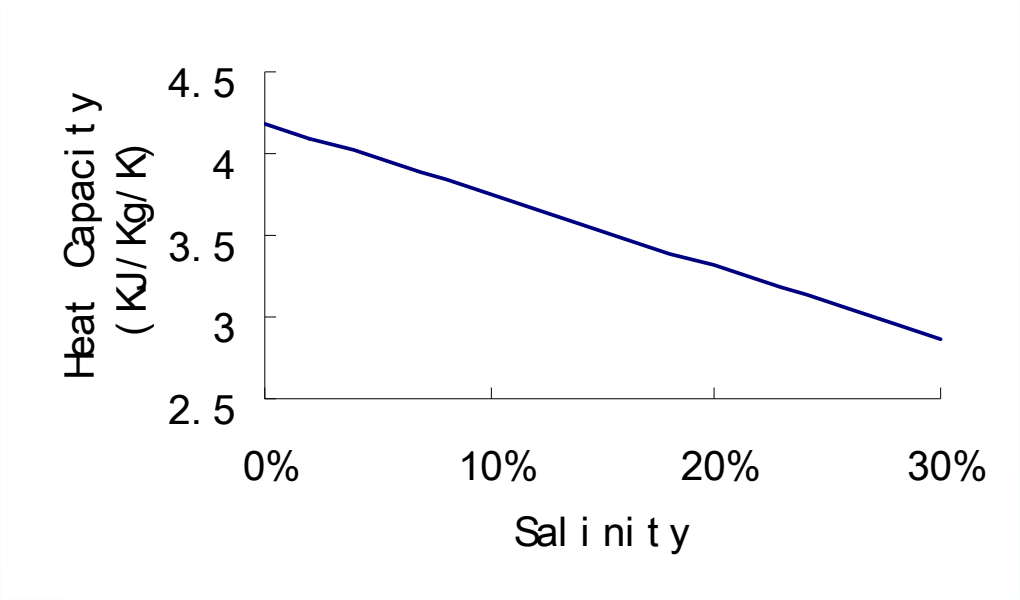
$$\text{Ratio} = e_{SAT\_sw} / e_{SAT\_fw} = \exp\{-2/55.51*[s*1000/(1-s)/58.443+0.77]\}$$

e_{SAT_sw}: saturated vapor pressure over saline water surface

e_{SAT_fw}: saturated vapor pressure over fresh water surface

s:salinity (Low,1969)

4. Salinity Effect on Water Heat Capacity



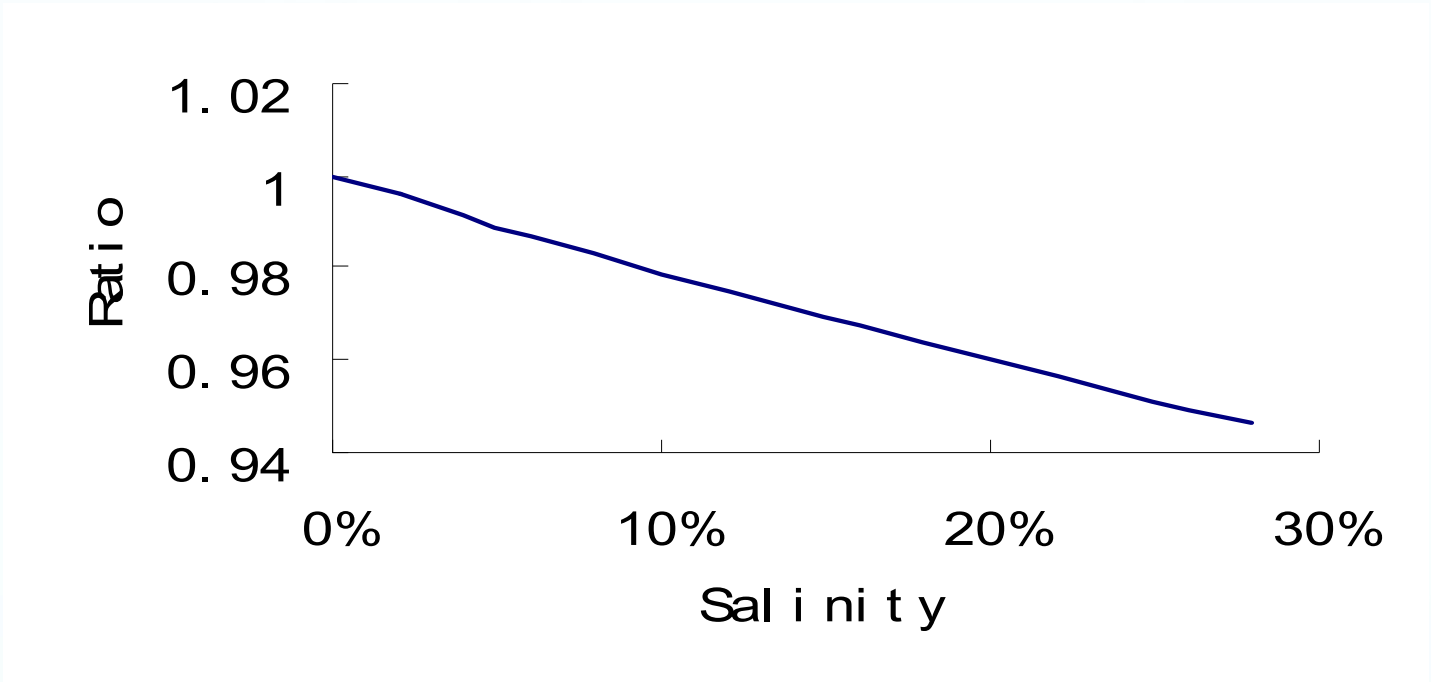
$$c_p = 4.188 - 4.4s$$

C_p: water heat capacity (KJ/Kg/K)

s:salinity

(Sun et al,2008)

5. Salinity Effect on Water Thermal Conductivity



$$\text{Ratio} = \lambda_{sw} / \lambda_{fw} = 1.0 - 0.22s + 0.1s^2$$

λ_{sw}: thermal conductivity of saline water

λ_{fw}: thermal conductivity of fresh water

s:salinity

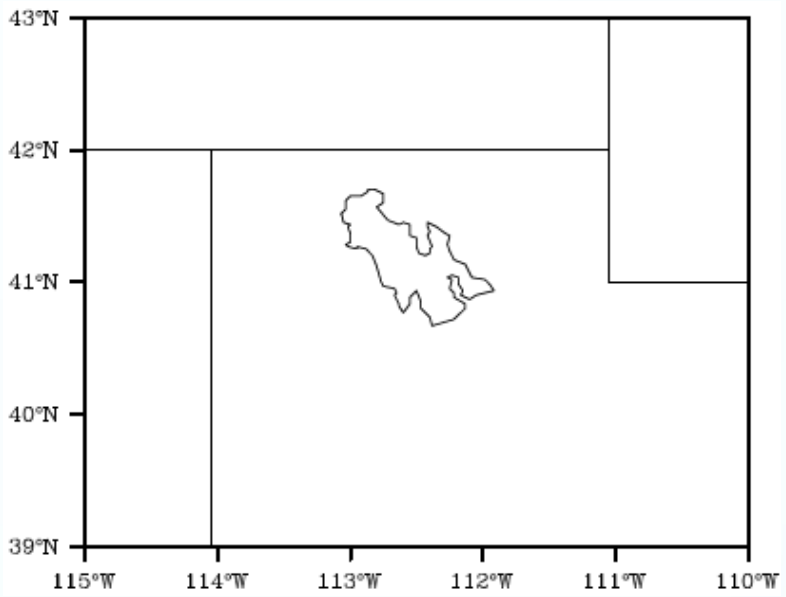
based on the Nacl solution (Ozbek and Phillips,1980; Diguilio and Teja,1992)

Model settings

✓Horizontal grid spacing :10 km

✓Grid point: 100×100

✓Lake depth : 5 m



✓Salinity: 14% for the south part of the Great Salt Lake

27% for the north part of the Great Salt Lake

✓Forcing data: 32 km North American Regional Reanalysis (NARR) data

✓Simulated period: from September 3 2001 to September 30 2002

Parameterization schemes used in the simulation

Physics Options	Parameterization Schemes
Microphysics	Morrison double-moment scheme (Morrision et al,2005)
Cumulus parameterization	Kain-Fritsch scheme (Kain, 2004)
Shortwave radiation	Dudhia scheme (Dudhia, 1989)
Longwave radiation	Rapid Radiative Transfer Model (RRTM) scheme (Mlawer et al.,1997)
Land surface	Community Land Model version 3.5 (CLM3.5) which includes a lake scheme (Oleson et al,2008)
Planetary boundary layer	Yonsei University(YSU) scheme (Noh et al., 2003)

Study Cases

✓Case excluding salinity

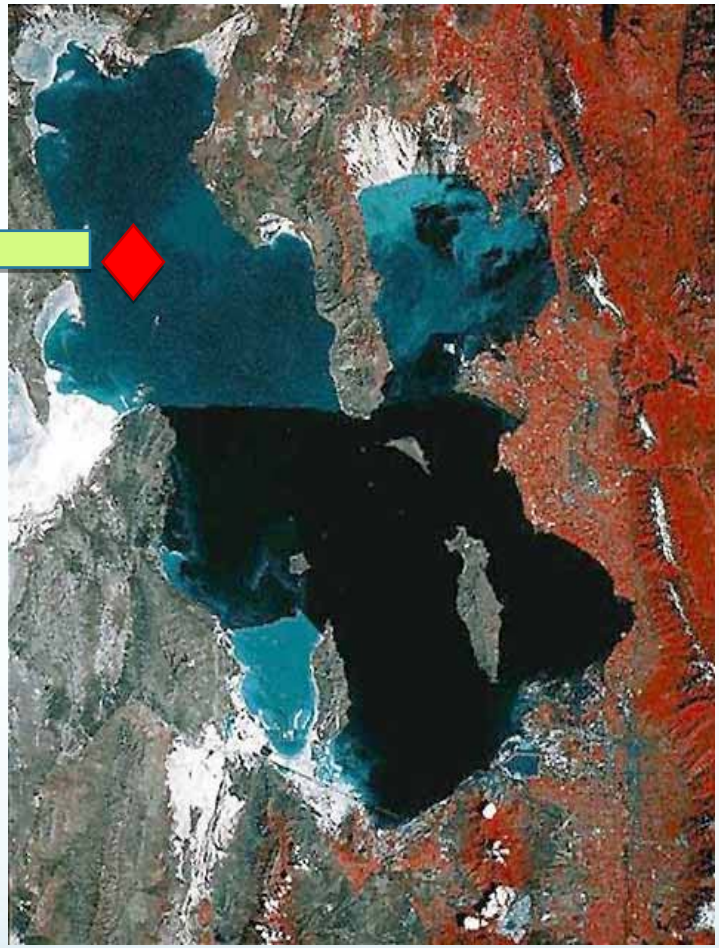
does not consider salinity effects in the lake model

✓Case including salinity

considers salinity effects in the lake model

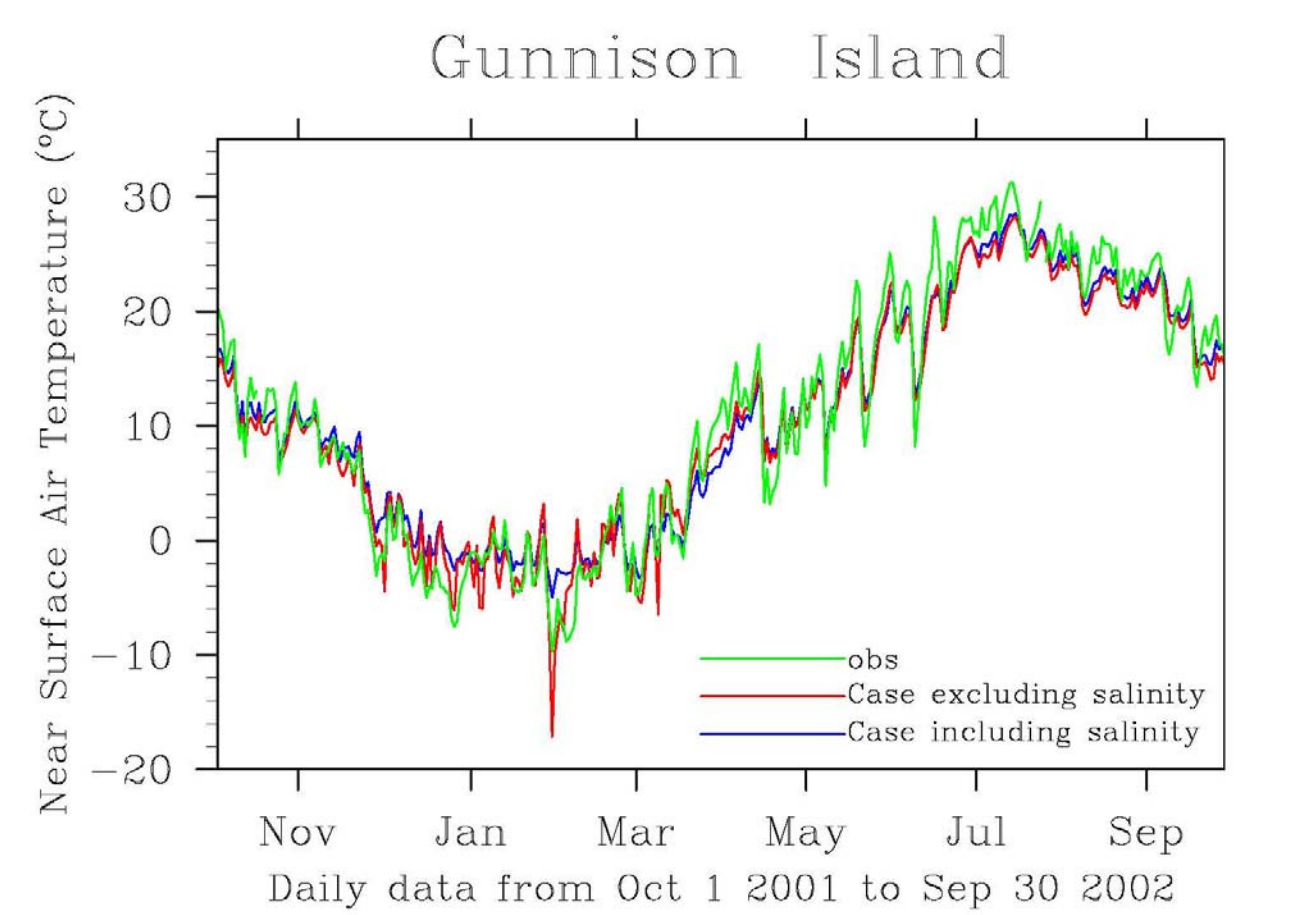
the Great Salt Lake and the Lake Station

Gunnison Island Station



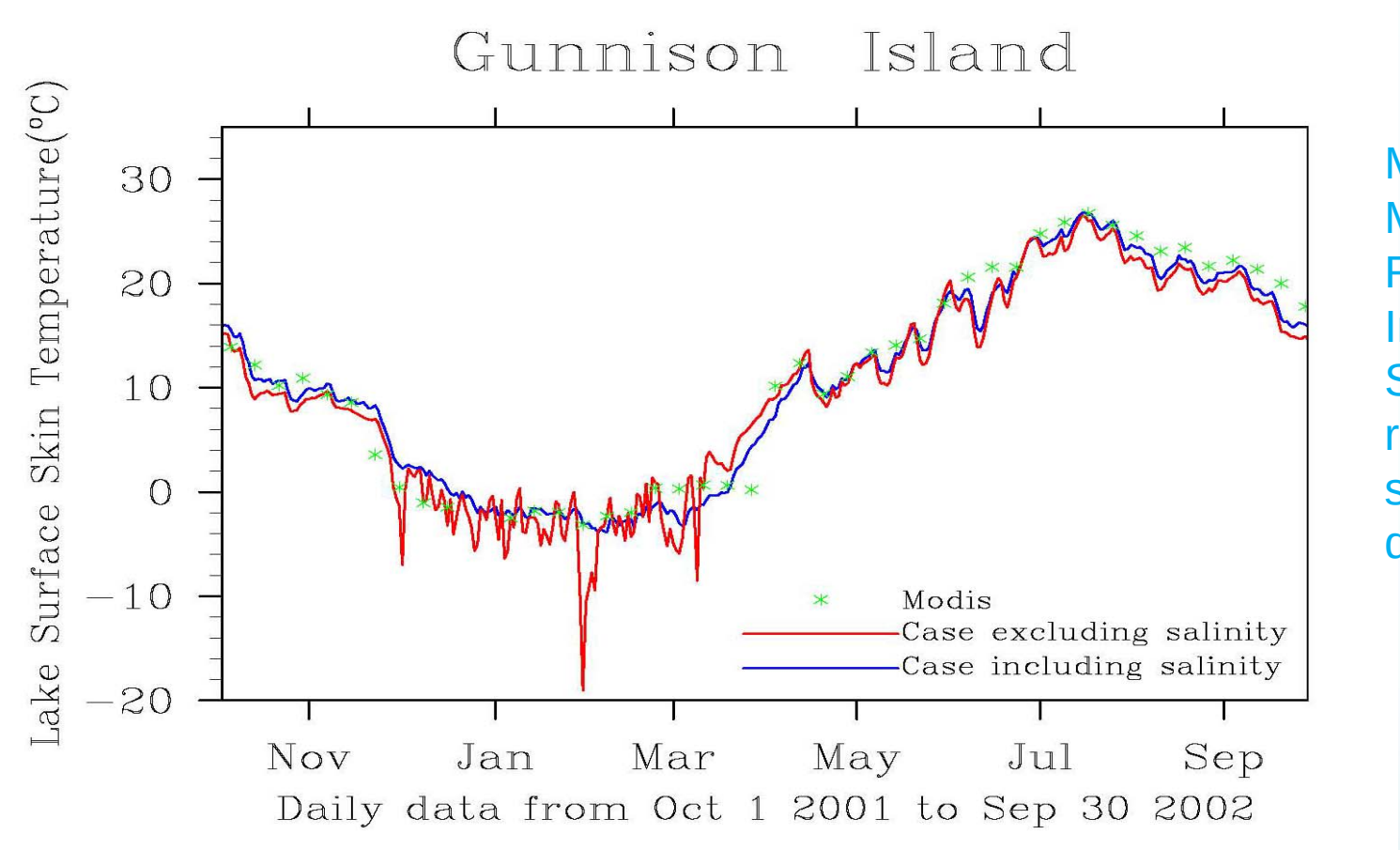
Using observed data from this station to evaluate the simulation over lake

Near surface air temperature over Lake



Case	RMSE (°C)	Bias (°C)
simulation **excluding** salinity	2.3	-0.7
simulation **including** salinity	2.3	-0.2

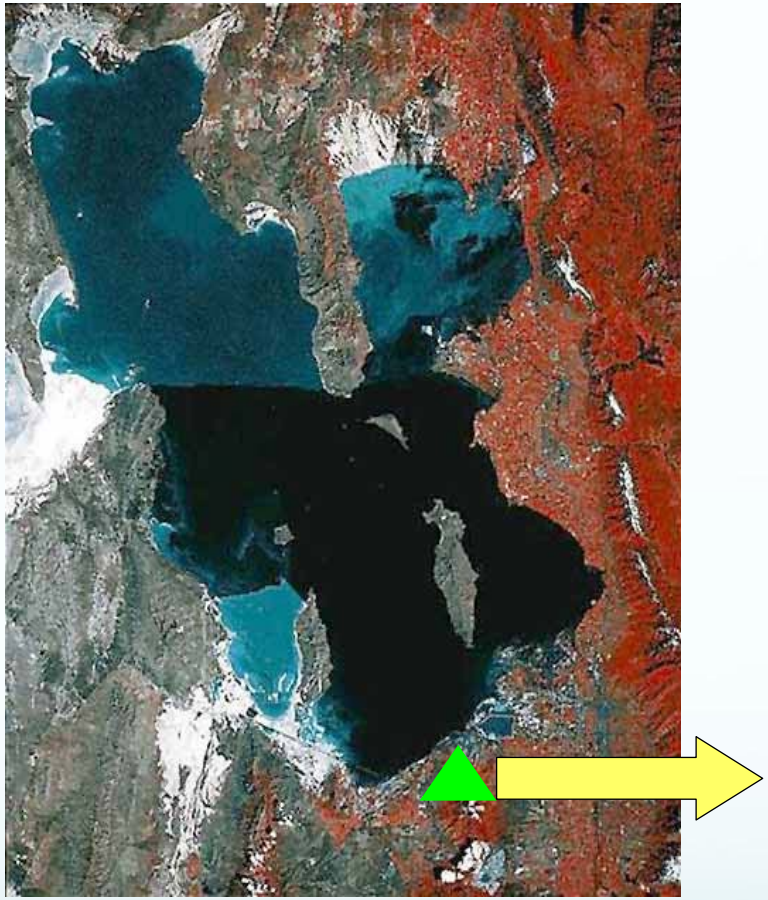
Lake surface skin temperature over Lake



MODIS: Moderate Resolution Imaging Spectro-radiometer satellite data

In winter, the simulation including salinity has much better result than that excluding salinity.

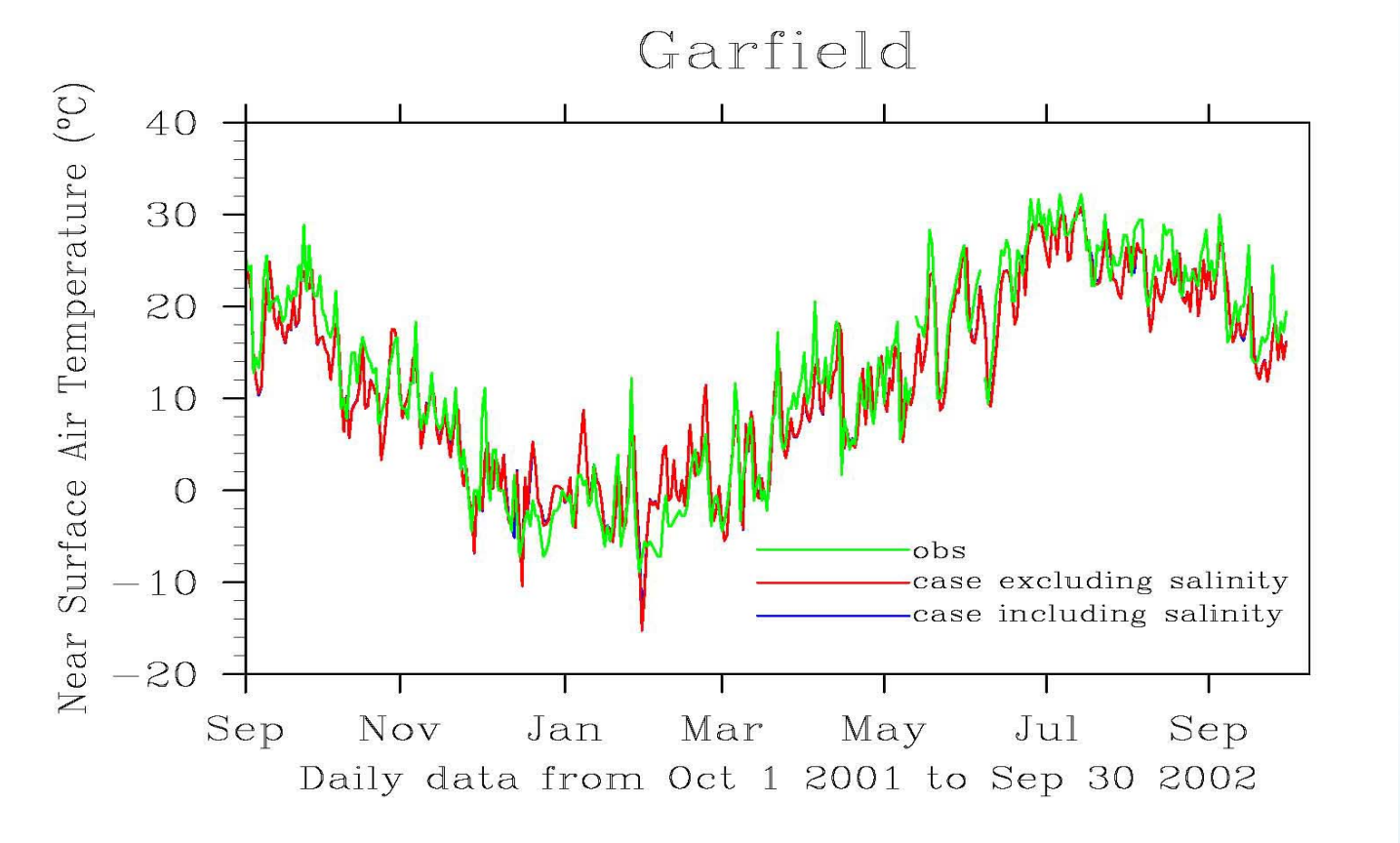
the Great Salt Lake and the Land Station



Garfield Station

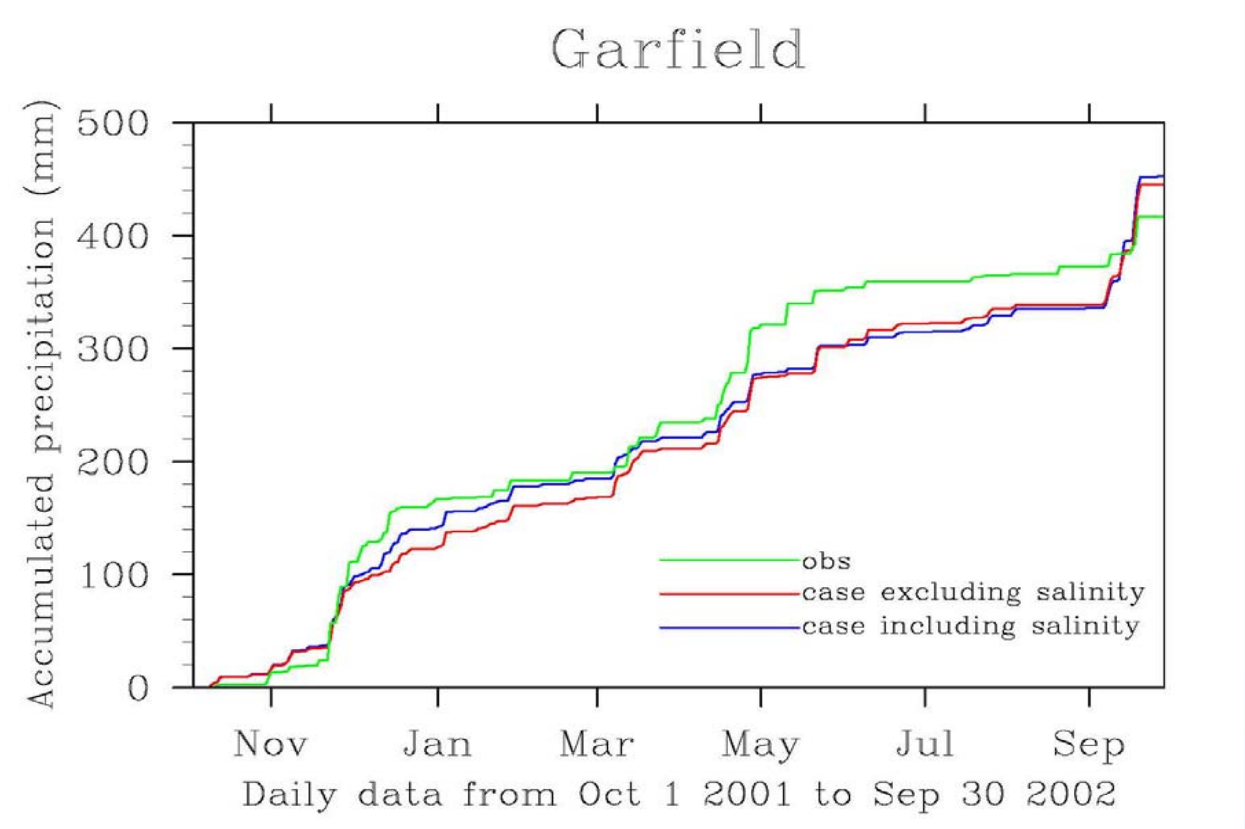
Using observed data from this station (outside of the lake) to evaluate the simulation over land and show the salinity effect on local climate

Near Surface Air Temperature over Land



Case	RMSE (°C)	Bias (°C)
simulation **excluding** salinity	3.51	-0.64
simulation **including** salinity	3.49	-0.59

Accumulated Precipitation over Land



The simulation including salinity has more precipitation than that excluding salinity in winter

Conclusions

❖ We have explicitly included the effects of salinity on freezing point, water density, water surface saturated vapor pressure, water heat capacity, and water thermal conductivity in the WRF-Lake model.

❖ These effects result in more accurate simulations of surface and near-surface temperatures over the Great Salt Lake.

Conclusions

❖ When compared to fresh water, the saline water increases winter lake-effect precipitation that results from stronger atmospheric convection due to higher simulated surface skin temperature.

Thanks for your attention!!!