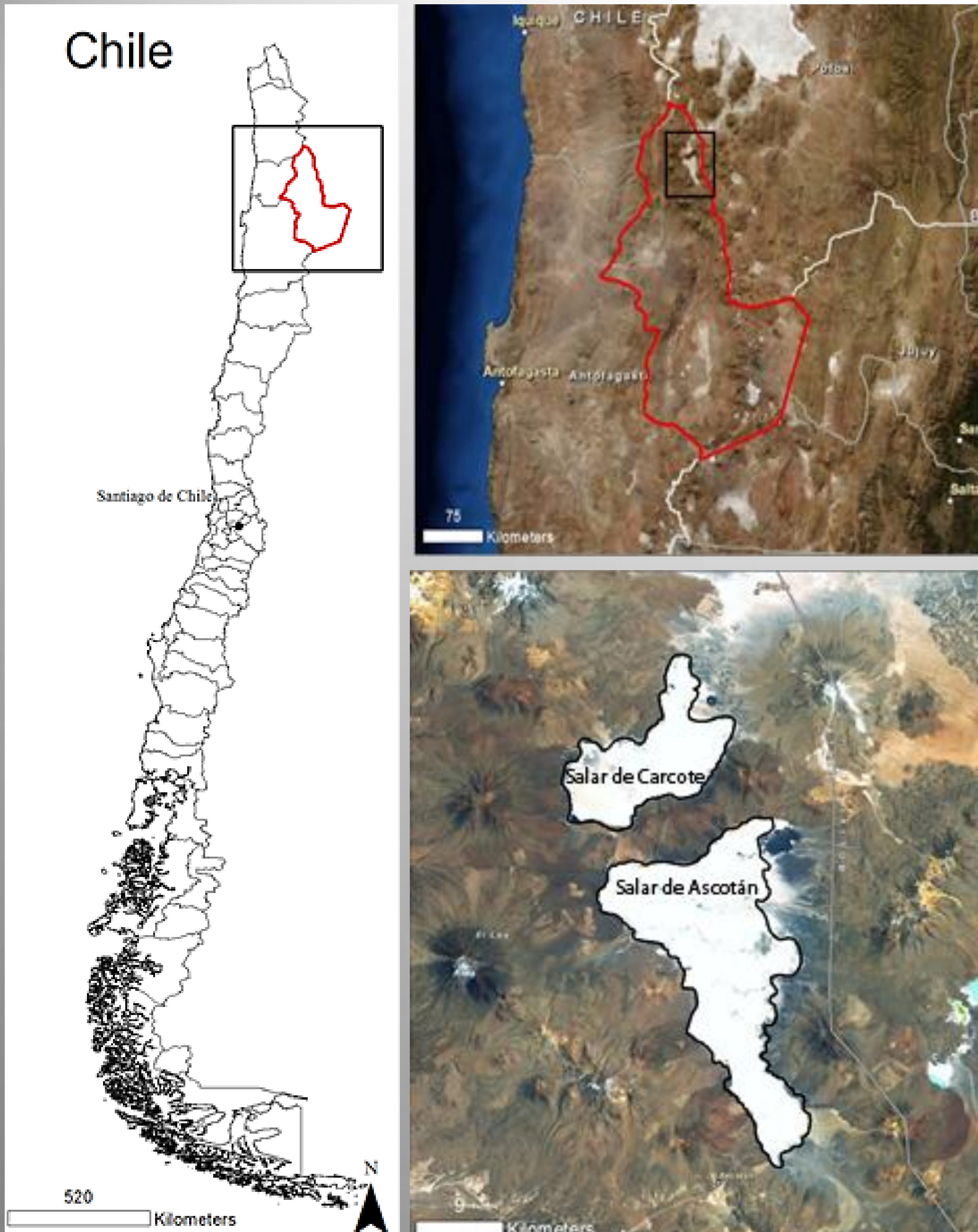
Integrated remote and in situ analysis of a playa lake groundwater system in northern Chile

Katherine H. Markovich
The University of Texas at Austin

Hydrogeology of Arid Environments

March 15th, 2012



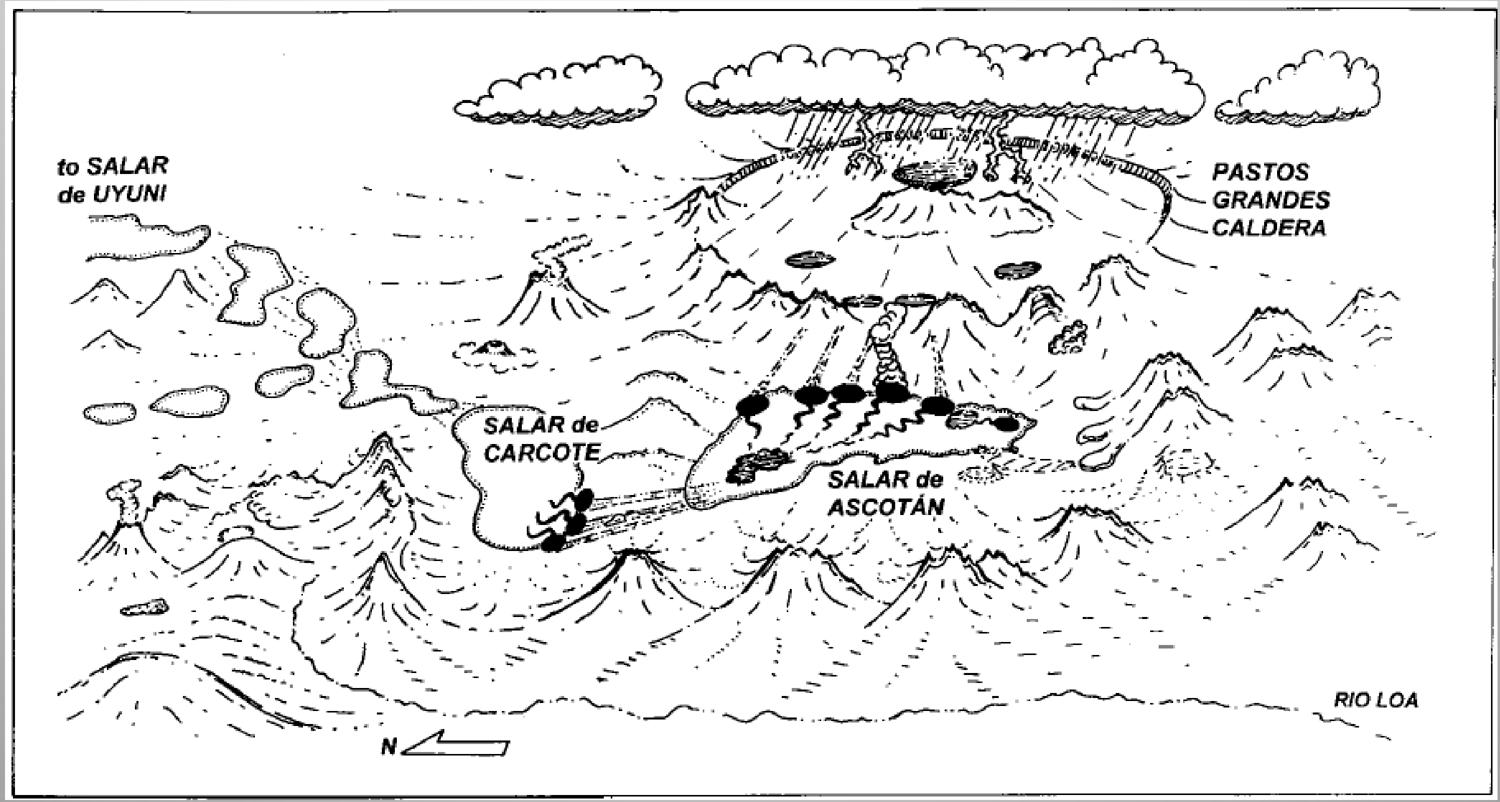
- Precipitation: 78.8 mm/yr

  (88% occurring during summer)

- Evapotranspiration: 1630 mm/yr
- Mean Temperature: 5.8 °C
- Elevation: 3700 masl
- Salar Size:
  - Ascotán: 243 km^2
  - Carcote: 108 km^2

Why do we care?

Image courtesy of Wikimedia Commons



Keller and Soto, 1998

What has been the extent of the climatic and anthropogenic influence on this groundwater system over time?

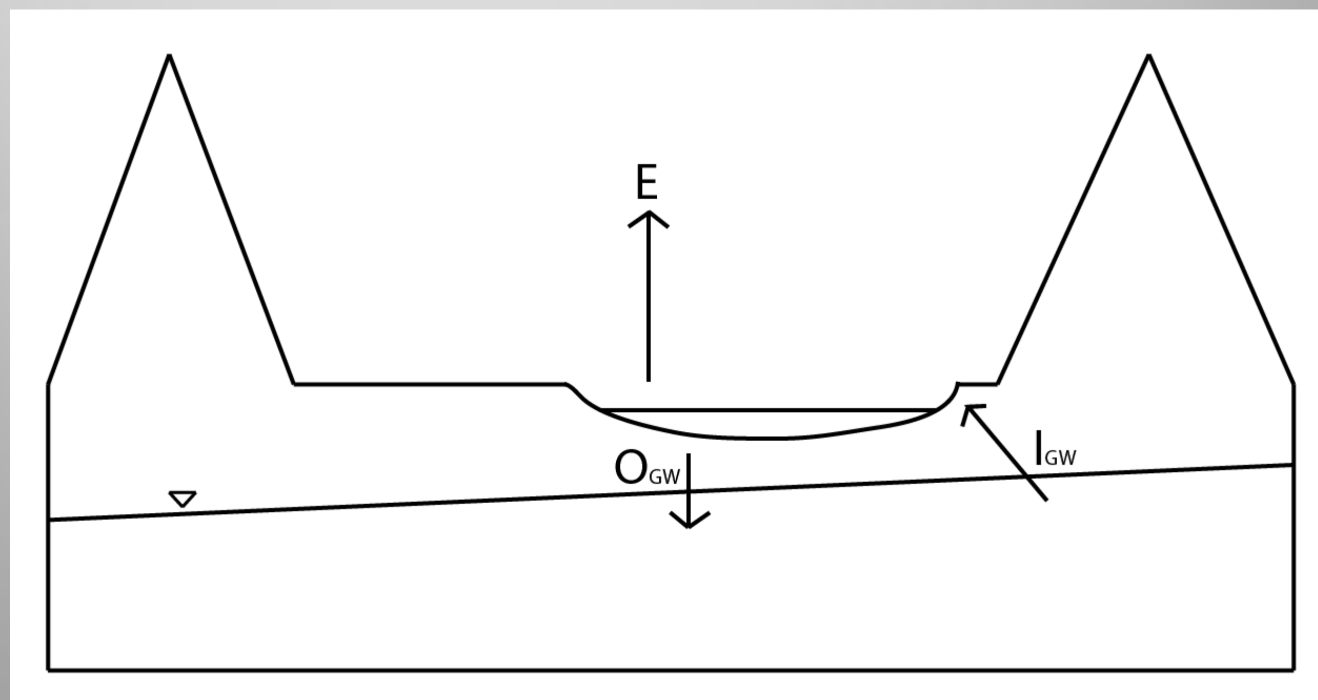
1) Characterize regional and local behavior using **remote sensing**.
2) Relate the spatiotemporal variation to **climate** and/or **anthropogenic** forcings.
3) Supplement with **in situ** and **hydrochemistry** data.
4) Assess implications for **future water resource management**.

Salar Water Budget

$\Delta V = (\cancel{P} + I_{GW} + \cancel{I_{SW}}) - (ET + O_{GW} + \cancel{O_{SW}})$ **ET >> P**

Simple water budget for salars: $\Delta V = (I_{GW}) - (ET + O_{GW})$

ΔV=change in volume
P=precipitation (rain/snow)
I_{SW}=surface water inputs
I_{GW}=groundwater inputs
ET=evapotranspiration
O_{SW}=surface water outputs
O_{SW}=groundwater outputs

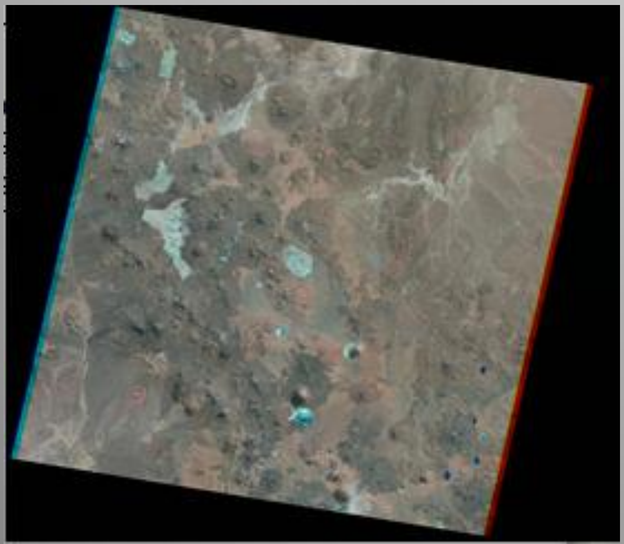


Remote sensing gives us ΔA, which can be related to the groundwater system!

Satellite Data ↔ Hydrochemistry

Satellite Data

- 14 scenes during 1985-2011
- Landsat 4-5 TM and 7 ETM+ from the USGS Archive.
- Supervised Classification in ERDAS Imagine 2011
- Monthly precipitation data during 1984-2011
  (Lat: 23- 20.5 S, Lon: 68-66 W)
- NASA Tropical Rainfall Measuring Mission (TRMM) archive.



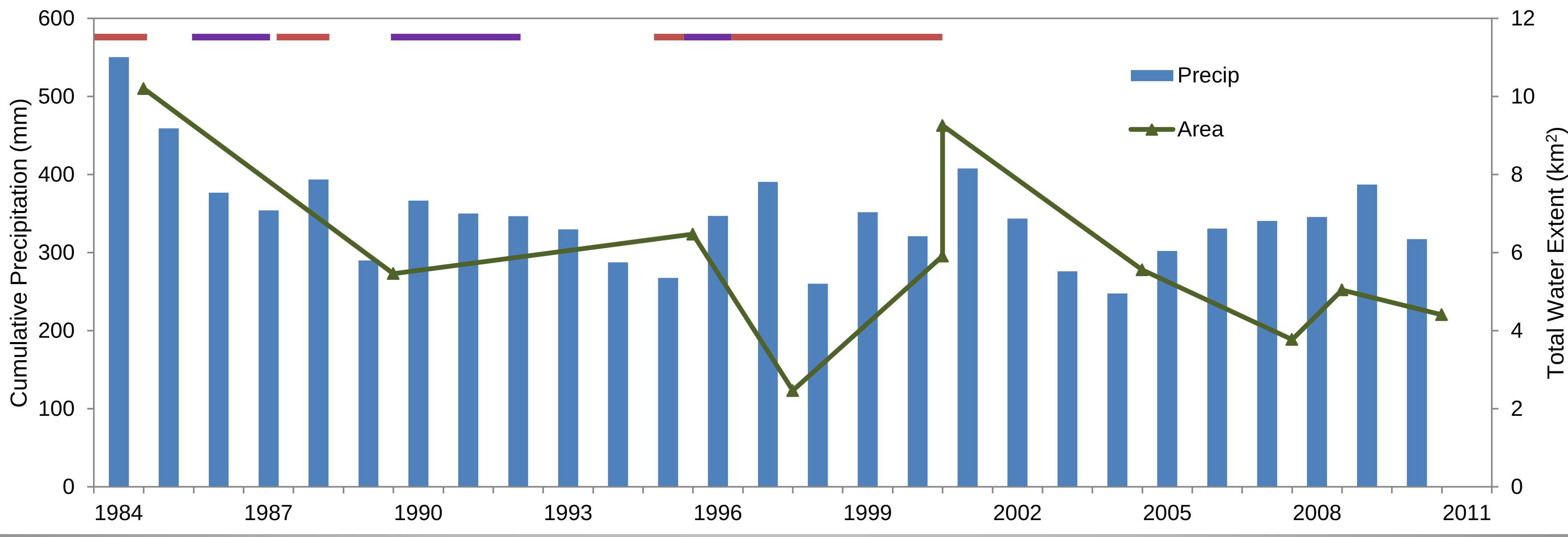
Hydrochemistry

- pH
- Conductivity (µS/cm)
- Temperature (°C)
- Water depth (m)
- Cl/Br (mg/l)

-(Risacher et al., 2003)

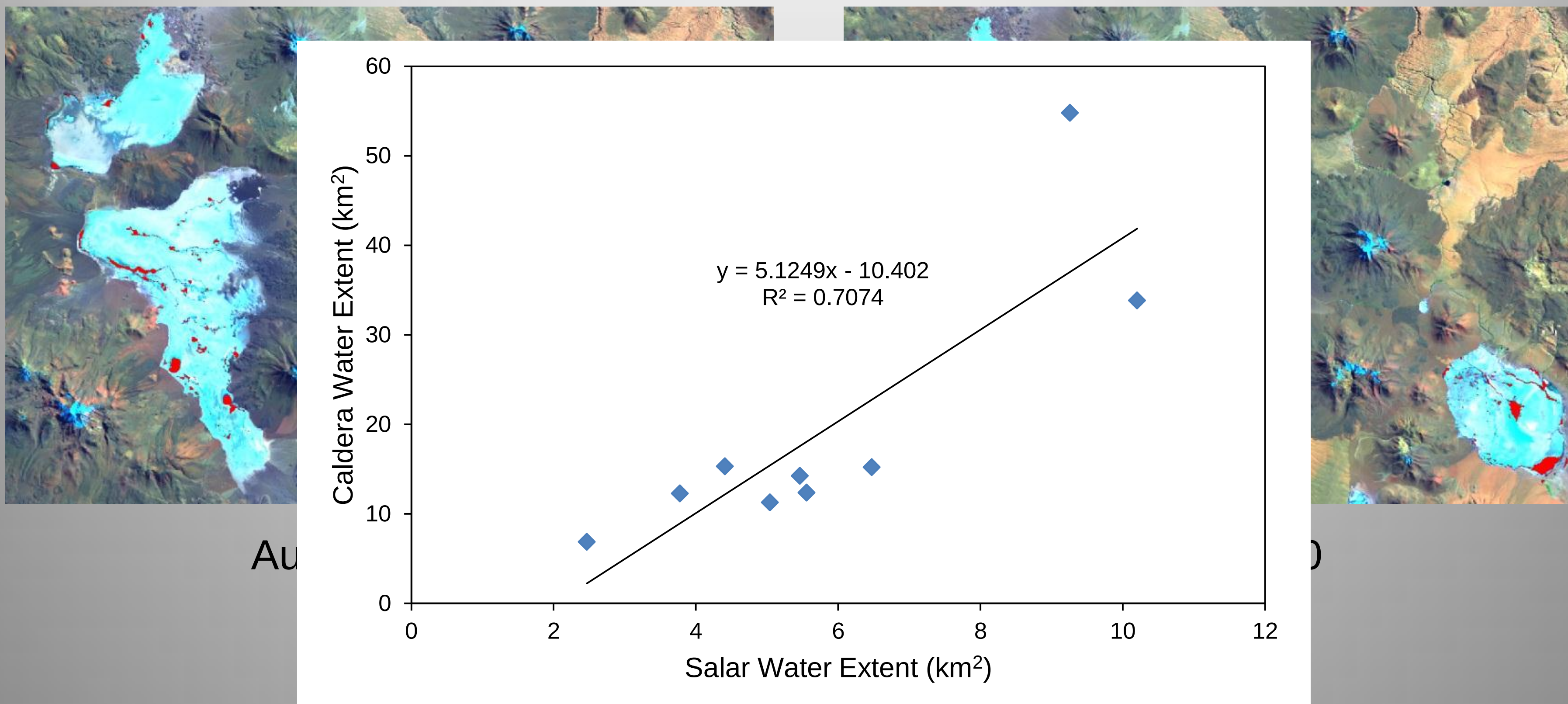
Significance of Climate

Red= La Niña **Purple**= El Niño

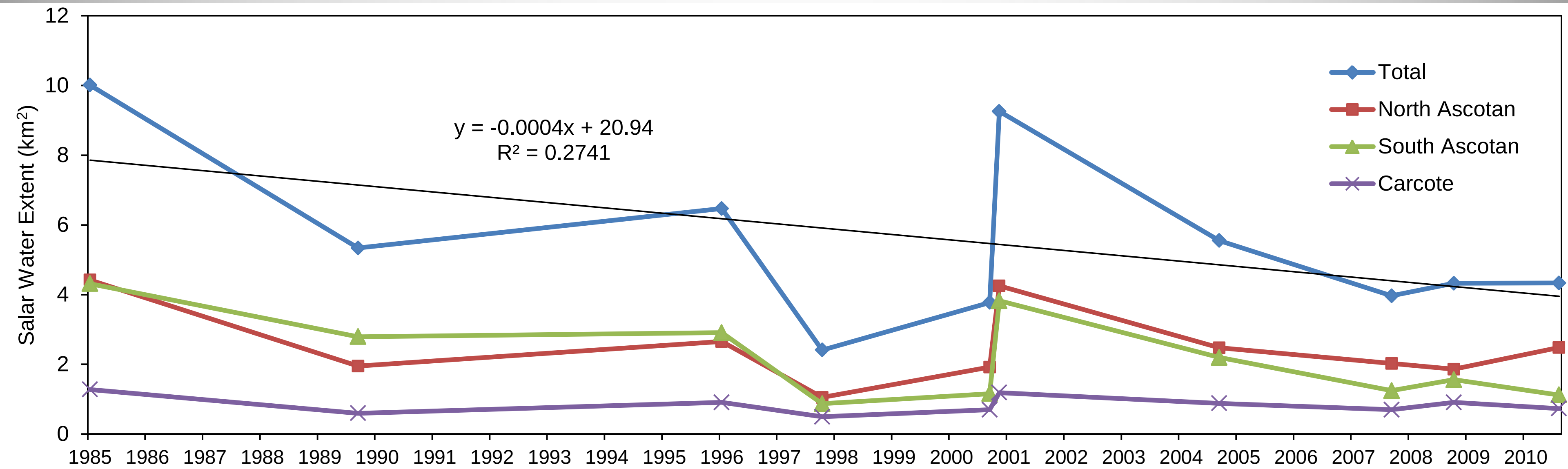


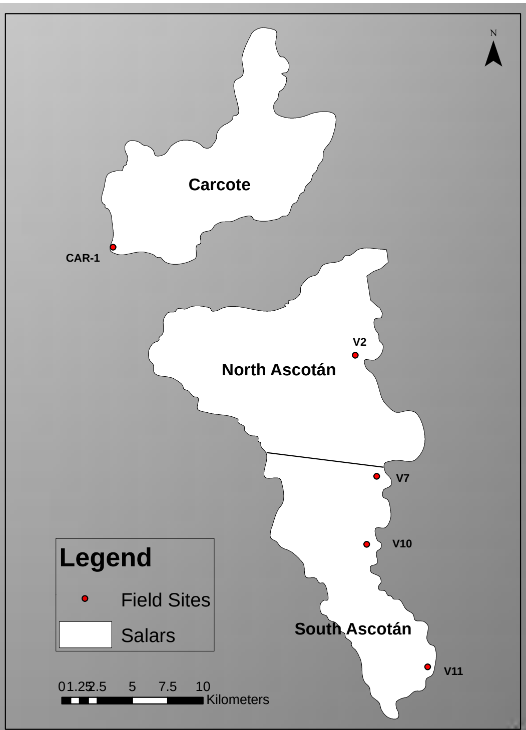
- Houston (2006) study linked precipitation in the region to ENSO cycles
- Link between increased GW contributions to the salars, precipitation, and La Niña

Regional application: **Pastos Grandes** as a **recharge** zone for Ascotán?

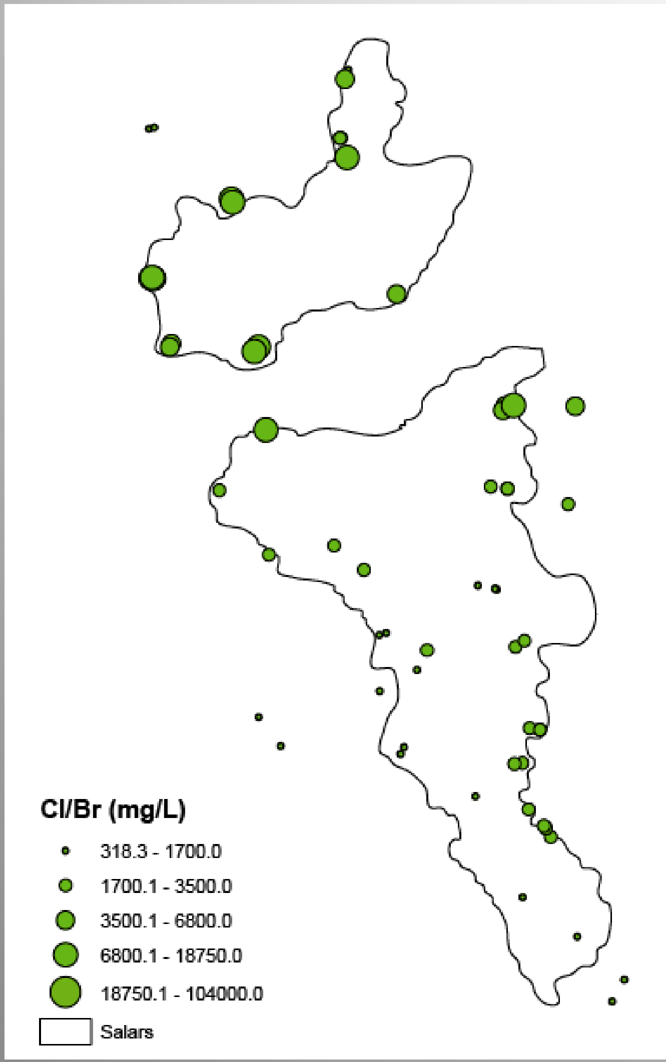


Current groundwater abstraction is located in the southern portion of Ascotan. Has this affected springs to the north?





Integrate remote sensing observations with hydrochemistry analysis.



- Water temperature, conductivity, and pH gave no clear indication of regional versus local flow
- Cl/Br ratios provide the best indication for spatial relationships
- Possible inverse Ghyben-Herzberg flow in the north, causing the recycling of brines

Conclusions

1) Remote sensing allowed for antecedent analysis and large scale observation of regional recharge behavior.
2) Total surface water extent has fluctuated with a clear response to pumping initiation, but also appears to be dominated by precipitation.
3) Integration of hydrochemistry data, namely Cl/Br ratios, provided evidence for disconnect between north and south Ascotán

Future water resource management to take into account:

- Ocean circulation cycles
- Climate change
- New mine projects
- Cost-benefit analysis of water importation

Next steps:

1) Build systems dynamics models.
2) Compare across multiple salar sites in Chile
3) Incorporate into cyberinfrastructure to support cross-disciplinary and longitudinal studies.

Thank you for listening!

THE UNIVERSITY OF TEXAS AT AUSTIN JACKSON SCHOOL OF GEOSCIENCES

CIEEP

encompass Science for Society

Thanks to:

- Suzanne Pierce, Kelley Crews, Wendy Robertson, Reed Malin, Sandra Guzman, and Jack Sharp for help on the field work and the project
- François Risacher (U. Strasbourg), Martin Reich (CEGA, U. Chile), Boris (SCM El Abra), and Eugenio Figueroa (U. Chile) for data
- University of Texas Co-op and Jackson School of Geosciences for funding


Questions?

References

Casteñeda, C., Herrero, J., and Casterad, M.A., 2005. Landsat monitoring of playa-lakes in the Spanish Monegros desert. Journal of Arid Environments, v. 63, pp. 497-516.

Hartley, A., May, G., Chong, G., Turner, P., Kape, S.J., and Jolley, E.J., 2000. Development of a continental forearc: A Cenozoic example from the Central Andes, northern Chile. Geology, v. 28, pp. 331-334.

Houston, J., 2006. Variability of precipitation in the Atacama desert: It's causes and hydrological impact. International Journal of Climatology, v. 26, pp. 2181-2196.

Keller, B. and Soto, D., 1998. Hydrogeologic influences on the preservation of *Orestias ascotanensis* (Teleostei: Cyprinodontidae) in Salar de Ascotán, northern Chile. Revista Chilena de Historia Natural, v. 71, pp. 147-156.

Risacher, F., Alonso, H., and Salazar, C., 2003. The origin of brines and salts in Chilean salars: a hydrochemical review. Earth-Science Reviews, v. 63, pp. 249-293.

Rodriguez-Rodriguez, M., Benavente, J., Cruz-San Julian, J.J., & Moral Martos, F., 2006: Estimation of ground-water exchange with semi-arid playa lakes (Antequera region, southern Spain --Journal of Arid Environments. **66**: 272-289.

Xu, H., 2006. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing, v. 27 (14), pp. 3025-3033.

Zhou, Y., 2009: A critical review of the groundwater budget myth, safe yield, and sustainability --Journal of Hydrology, v. 370, pp. 207-213.