The Great Plains Irrigation Experiment (GRAINEX) - Investigating the Impacts of Irrigation on Regional Weather

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Dec 10, 2018

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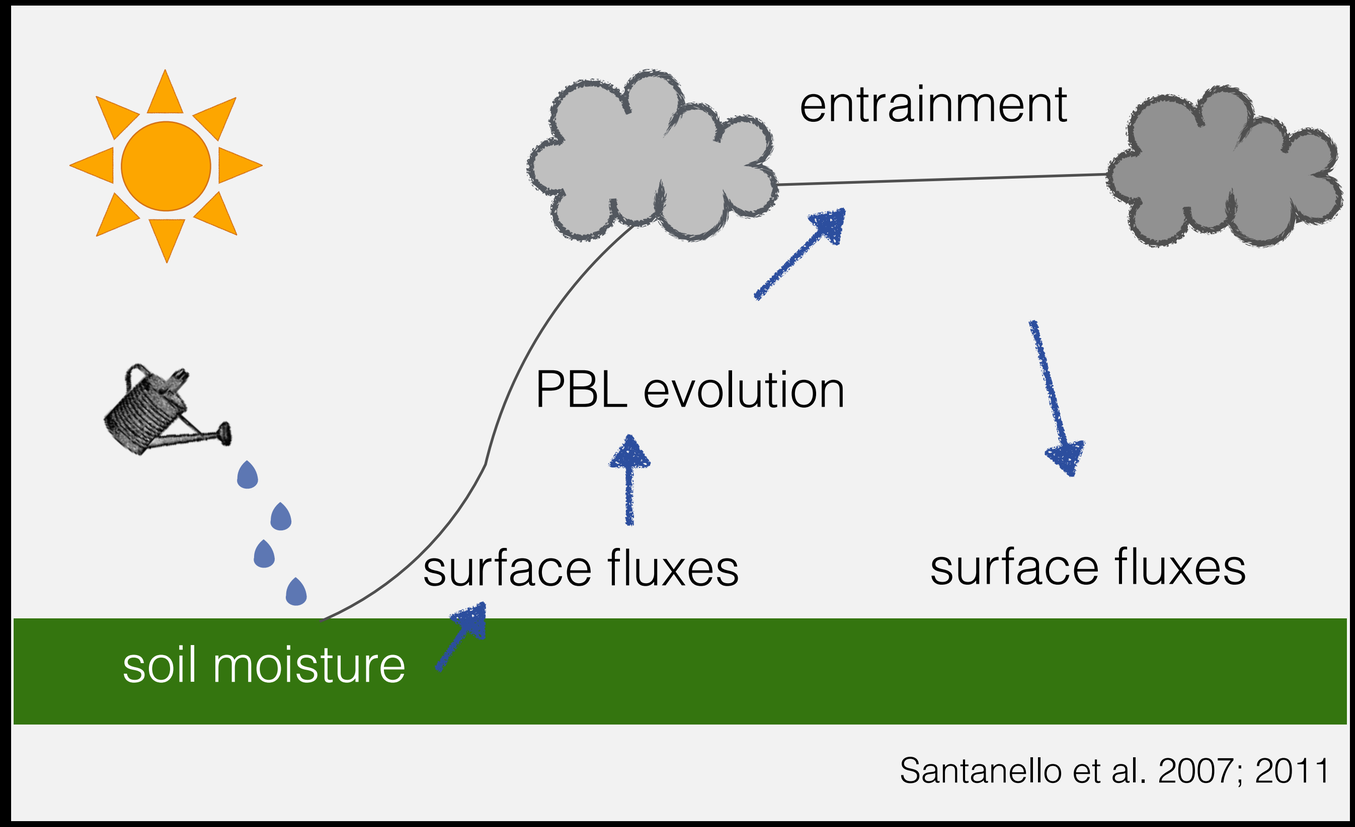
Motivation

- Irrigation impacts soil moisture, but can ultimately influence clouds and precipitation through land-PBL coupling processes
- The Great Plains is a hot spot for land-atmosphere coupling (Koster et al. 2004)
- Nebraska leads the nation in irrigated agriculture production with nearly 8.3 million hectacres of irrigated farm and ranch land.



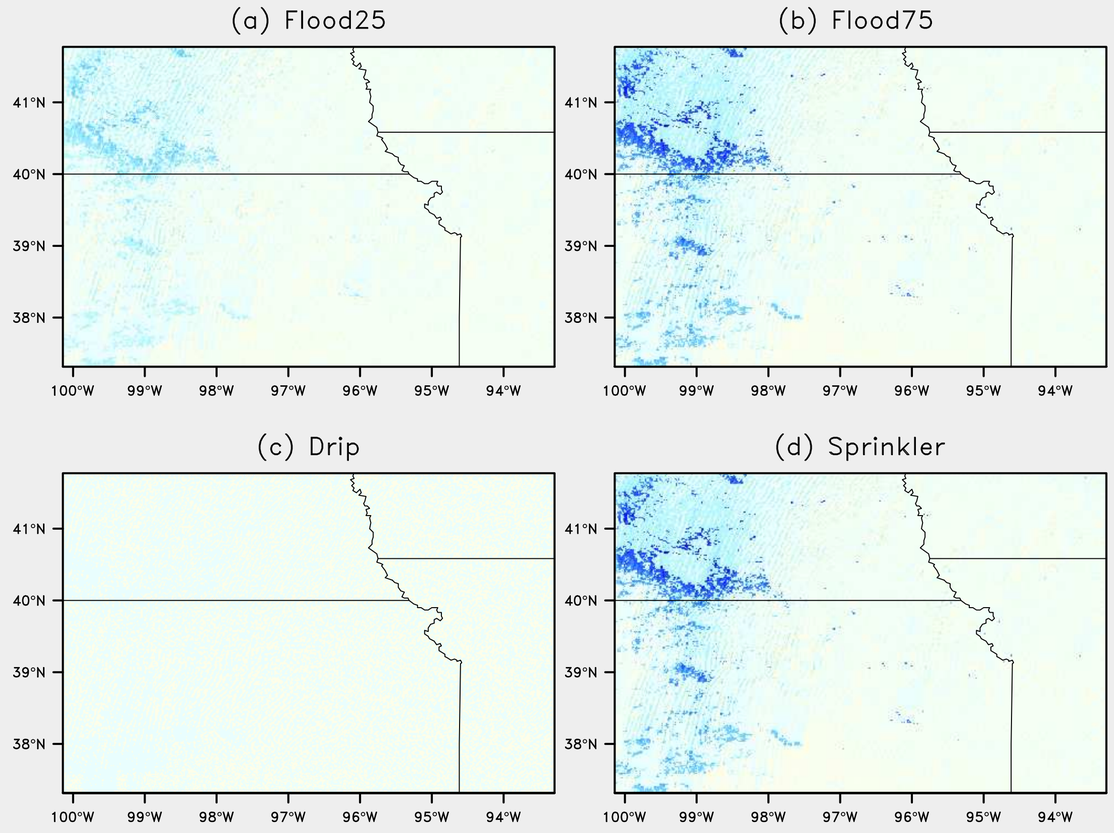
Santanello et al. 2007; 2011

$\triangle$ **SM** → $\triangle T_{2m}, Q_{2m}$ → $\triangle$ **PBL** → $\triangle$ **ENT** → $\triangle T_{2m}, Q_{2m}$ → $\triangle$ **P/Clouds**

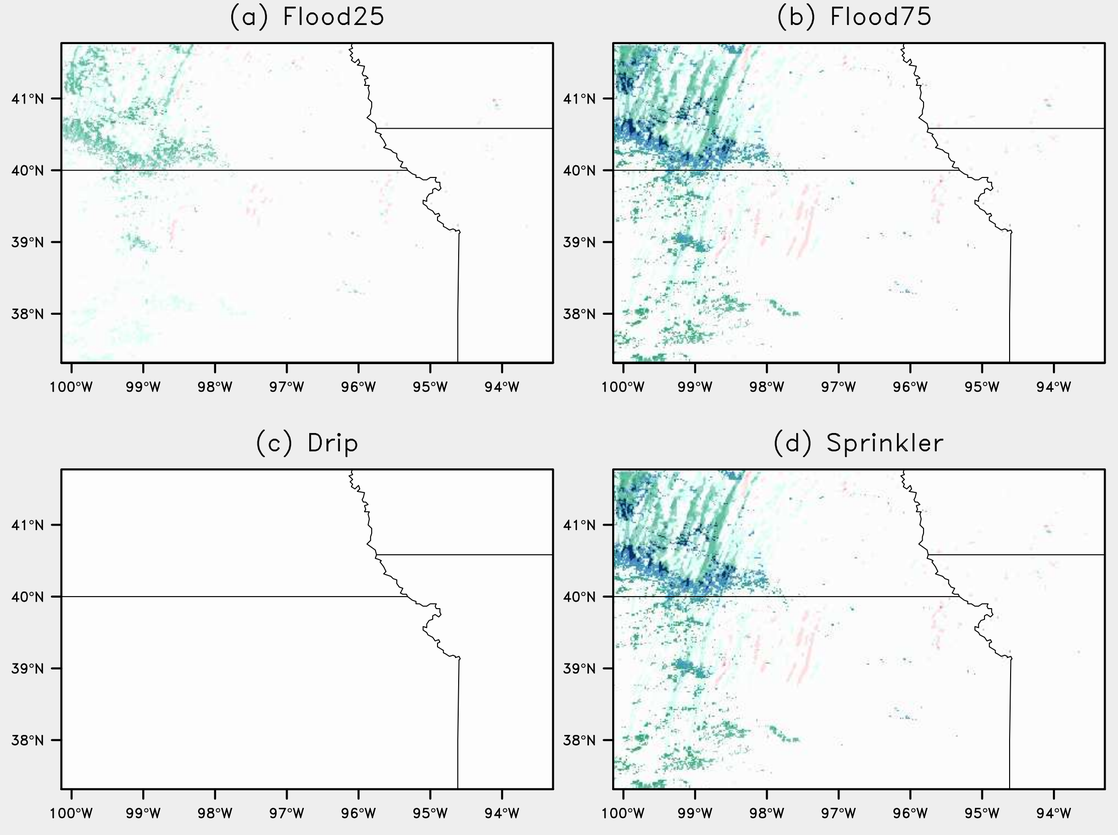
Modeling of Irrigation Impacts in Nebraska

Lawston et al. 2015, JHM

Temperature is reduced



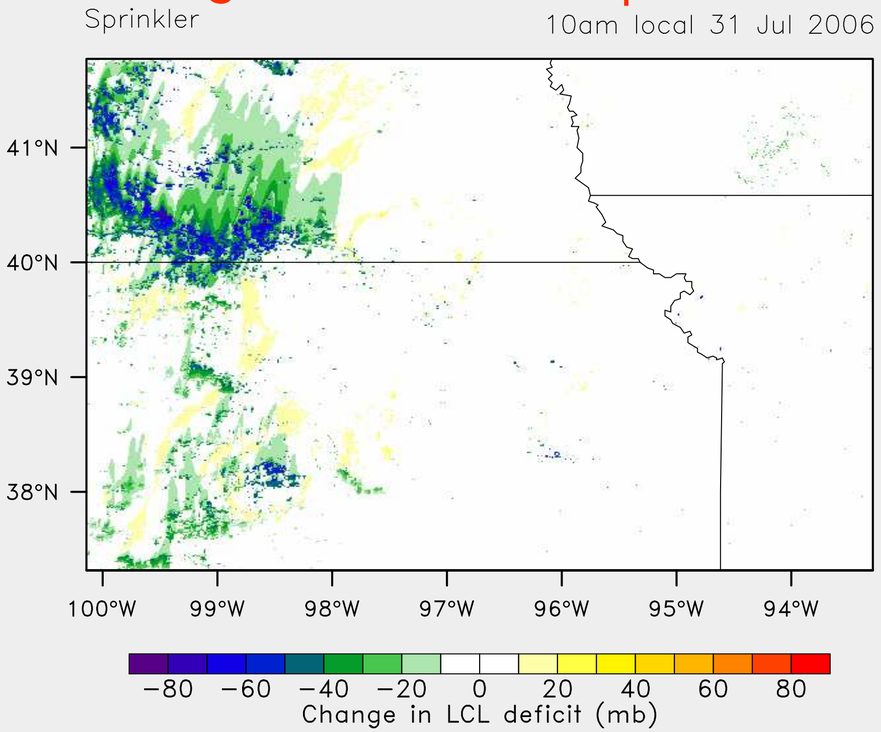
Humidity increases



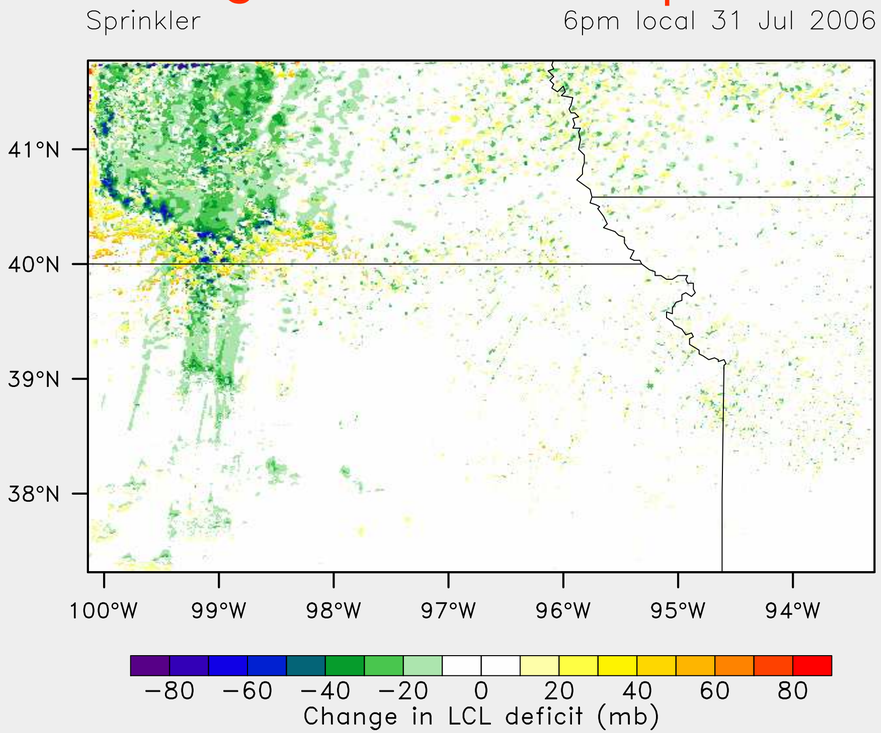
Modeling of Irrigation Impacts in Nebraska

Lawston et al. 2015, JHM

Morning: Increased cloud potential



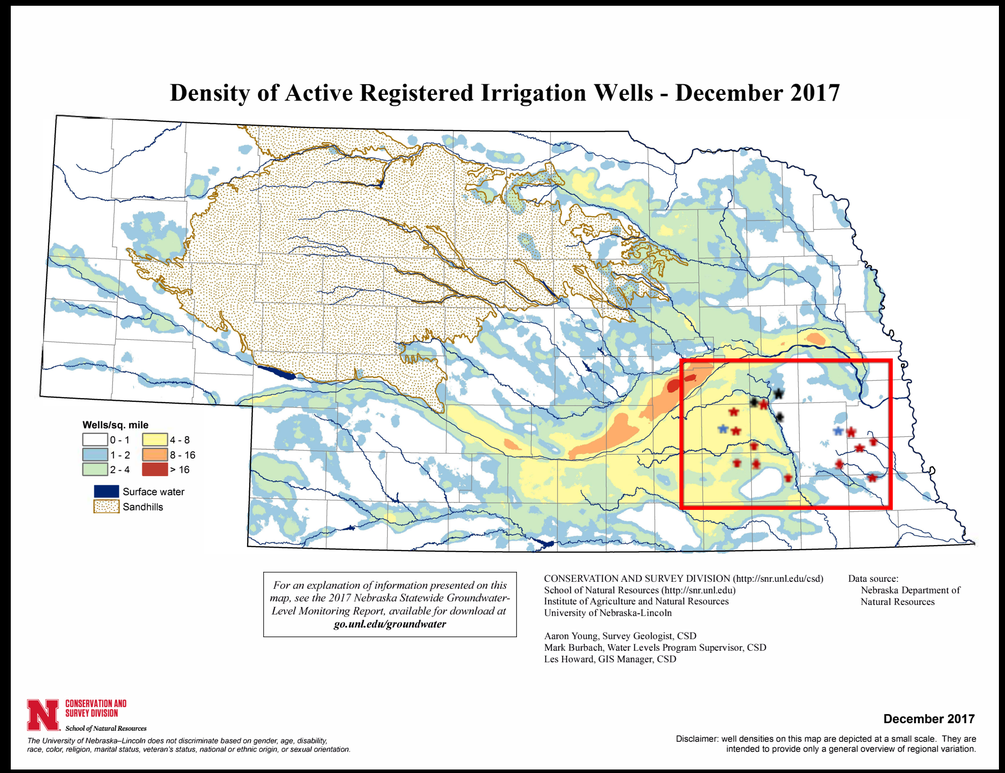
Evening: Decreased cloud potential



Potential for cloud development increases in the morning over irrigated areas, is reduced in the evening

GRAINEX Science Questions

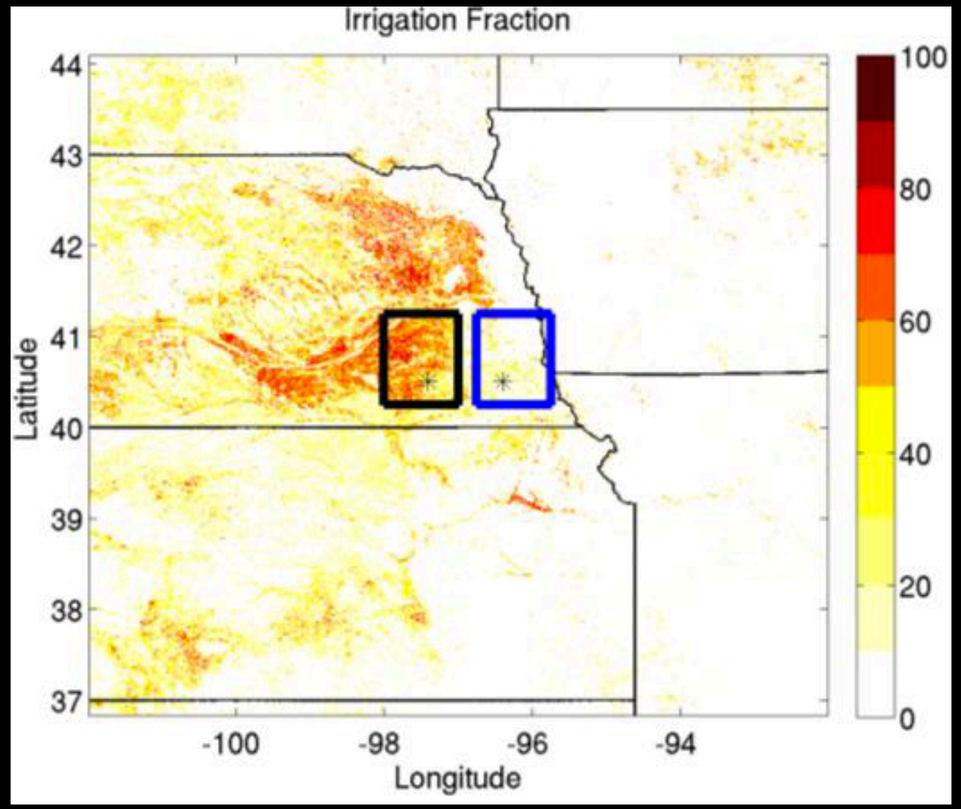
1. How does boundary layer development differ between irrigated and non-irrigated regions?
2. Is irrigation the dominant contributor for observed differences?
3. Do these differences impact isolated convection?
4. Does baroclinicity caused by irrigation induce mesoscale circulations and enhance convective development?
5. What proportion of irrigation is recycled as local rainfall?



Experimental Plan

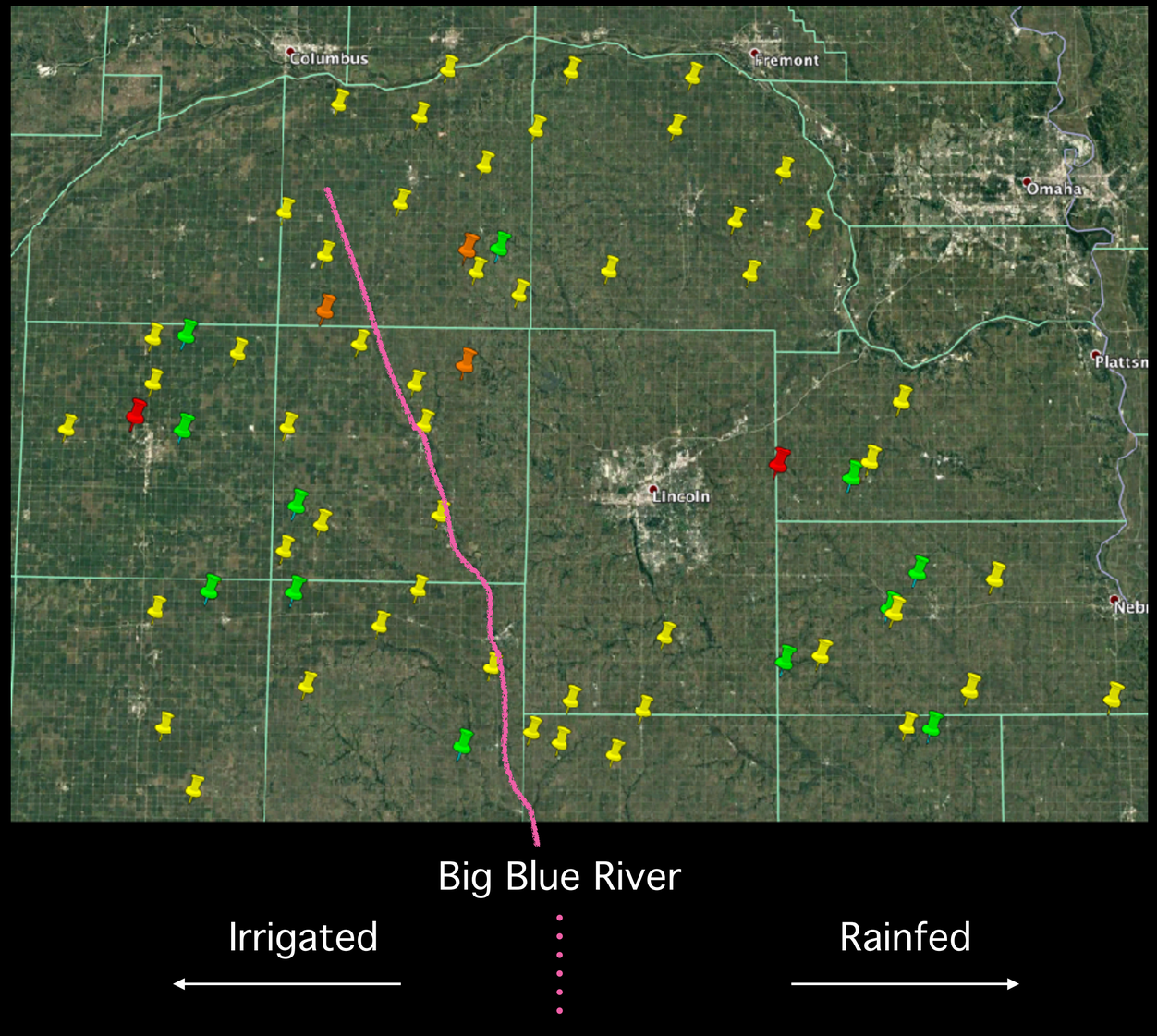
- Hypothesis:
  - *Temporally rapid and spatially widespread* commencement of irrigation at the beginning of the growing season in the Great Plains significantly alters the planetary boundary layer (PBL), weather events, and land-atmosphere coupling.

- Approach:
  - Measure meteorology, surface fluxes, soil moisture/ temperature at ~100 stations distributed across a 100 x 100 km domain where there is a sharp transition between irrigated and non-irrigated fields.
  - Collect observations of the PBL structure and evolution at 2 sites using ground-based remote sensing and radiosondes.
  - Use Doppler radar to characterize potential irrigation-induced mesoscale circulations and behavior of convective systems in the vicinity of the study area.



Experimental Design

- May 2018 - August 2018:
  - 80 temporary meteorological stations
    - ~50% in irrigated area
  - 12 Flux towers
    - 6 irrigated, 6 non-irrigated
  - 2 Mobile Integrated Sounding System (MISS) sites:
    - Vertical wind profiler
    - Radiosondes
- Two Intensive Observation Periods:
  - MAY 30 - June 13 & July 16-30
    - 3 Doppler on Wheels (DOWs) from NCAR
    - Weather balloon launches every 2 daytime hours



Flux Sites

Irrigated Flux Site

Non-Irrigated Flux Site

Doppler on Wheels

Nebraska

Media Coverage

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News Release 18-048

Scientists study connection between Great Plains precipitation and agricultural irrigation

GRAINEX field campaign underway to determine link among agriculture, irrigation and cloud formation

The Doppler On Wheels 7 mobile radar deployed at a GRAINEX site near Dwight, Nebraska.
Credit and Larger Version

July 11, 2018

Can crop irrigation affect the clouds that form high above farm fields? Indeed it can, say atmospheric scientists.

Agricultural irrigation to meet a growing demand for food is adding significant amounts of water to the land surface and altering regional land use and land cover. These changes affect lower atmosphere circulation, potentially influencing cloud development and precipitation.

To further understand how irrigation may be affecting precipitation, scientists from several institutions have teamed up for a National Science Foundation (NSF)-funded project known as the Great Plains Irrigation Experiment, or GRAINEX.

"Prior studies have found that the Great Plains is a hotspot where soil moisture plays an important role in cloud formation and precipitation," said Nick Anderson, a program director in

GRAINEX scientists Udaysankar Nair and Eric Rappin install a weather station.
Credit and Larger Version

The Doppler On Wheels 8 mobile radar as a thunderstorm passes through the GRAINEX domain.
Credit and Larger Version

GRAINEX researchers get ready to launch a weather balloon.
Credit and Larger Version

NSF grant to examine irrigation's role in precipitation

A national team led by the University of Nebraska-Lincoln is studying potential links between irrigation, cloud formation and rainfall.

Funded by the National Science Foundation, the Great Plains Irrigation Experiment — or GRAINEX — is gathering weather observations in June and July from a 3,600-square-mile region in southeastern Nebraska. The timing allows the team to better understand how irrigation may affect climate conditions at the start of irrigatio when it peaks.

"The study area includes transition from e or non-irrigated areas," said Rezaul Mahn Nebraska's High Plains Regional Climate Resources. "In other words, the experime opportunity to investigate the influence o surface and land cover side-by-side."

Inside the School of Natural Resources

FRI. JULY 13, 2018

NSF grant to examine irrigation's role in precipitation

Five Nebraska faculty named Fulbright scholars

Husker-Led Research Team Studying The Effect Of Irrigation On Weather Patterns

by Alex Fernando, NET News

July 19, 2018 - 10:11am

A national team of researchers led by the University of Nebraska-Lincoln is conducting research to determine the effects of irrigation on climate conditions. The Great Plains Irrigation Experiment, or GRAIN-EX, is funded by the National Science Foundation.

The team has been gathering data from weather observations from a 36-Hundred square mile region in southeastern Nebraska throughout June and July. Some of their research includes testing on heat and water vapor flux, temperature changes, soil moisture and temperature levels.

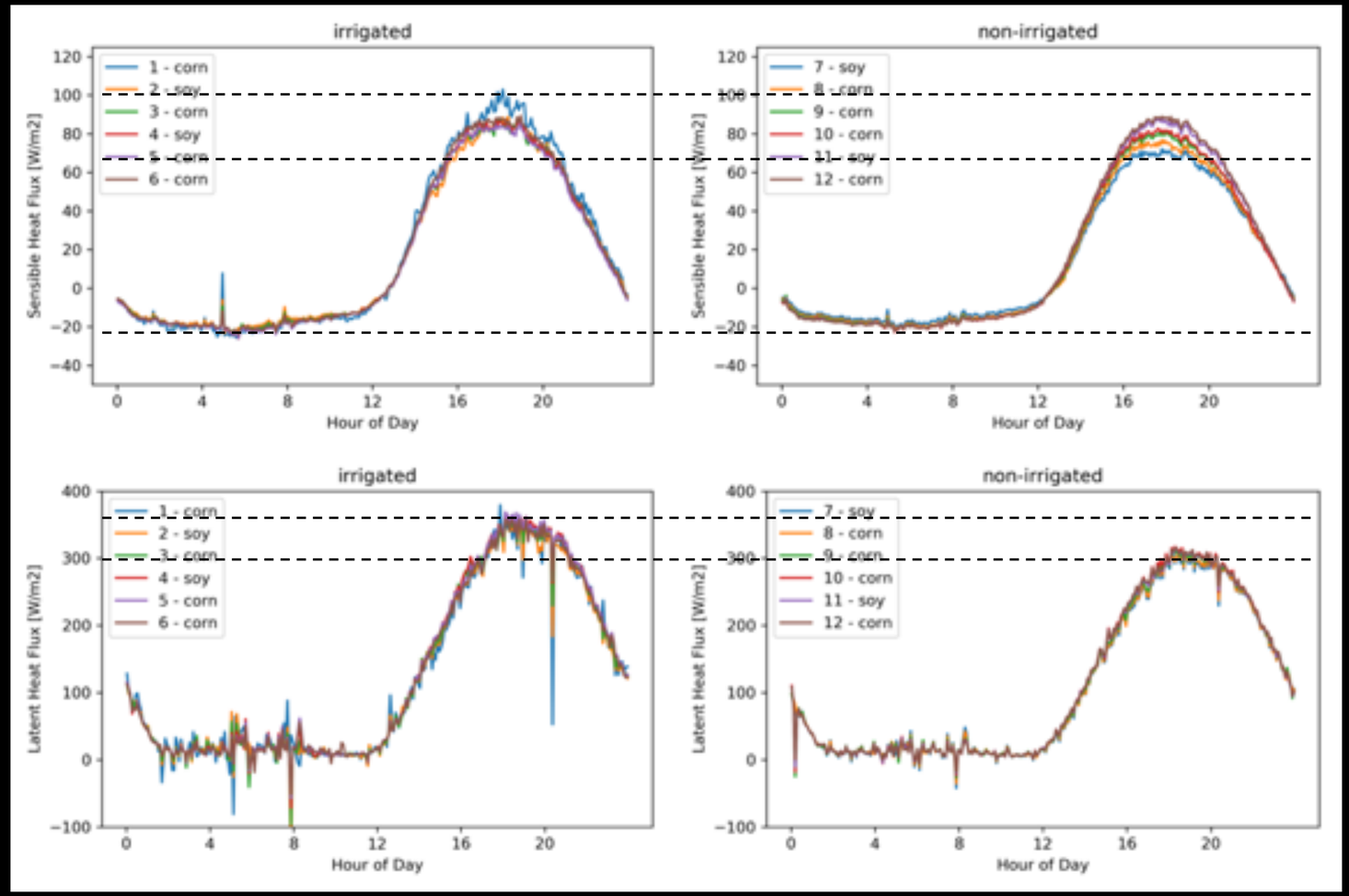
Lead researcher and director of Nebraska's High Plains Regional Climate Center, Rezaul Mahmood , says Nebraska is the perfect location for this type of research.

"Well first, Nebraska irrigates more acreage than any other state in the country. Eastern Nebraska in particular, there are areas where it nicely transitions from heavily, very intense irrigated areas to dry land agriculture, non-irrigated agriculture. So that also provides us a nice set of our ideal testing ground where we can see irrigation versus non-irrigation," Mahmood said.

Mahmood and his team believe this research can be used to improve agricultural planning and weather forecasting both in the United States and around the world.

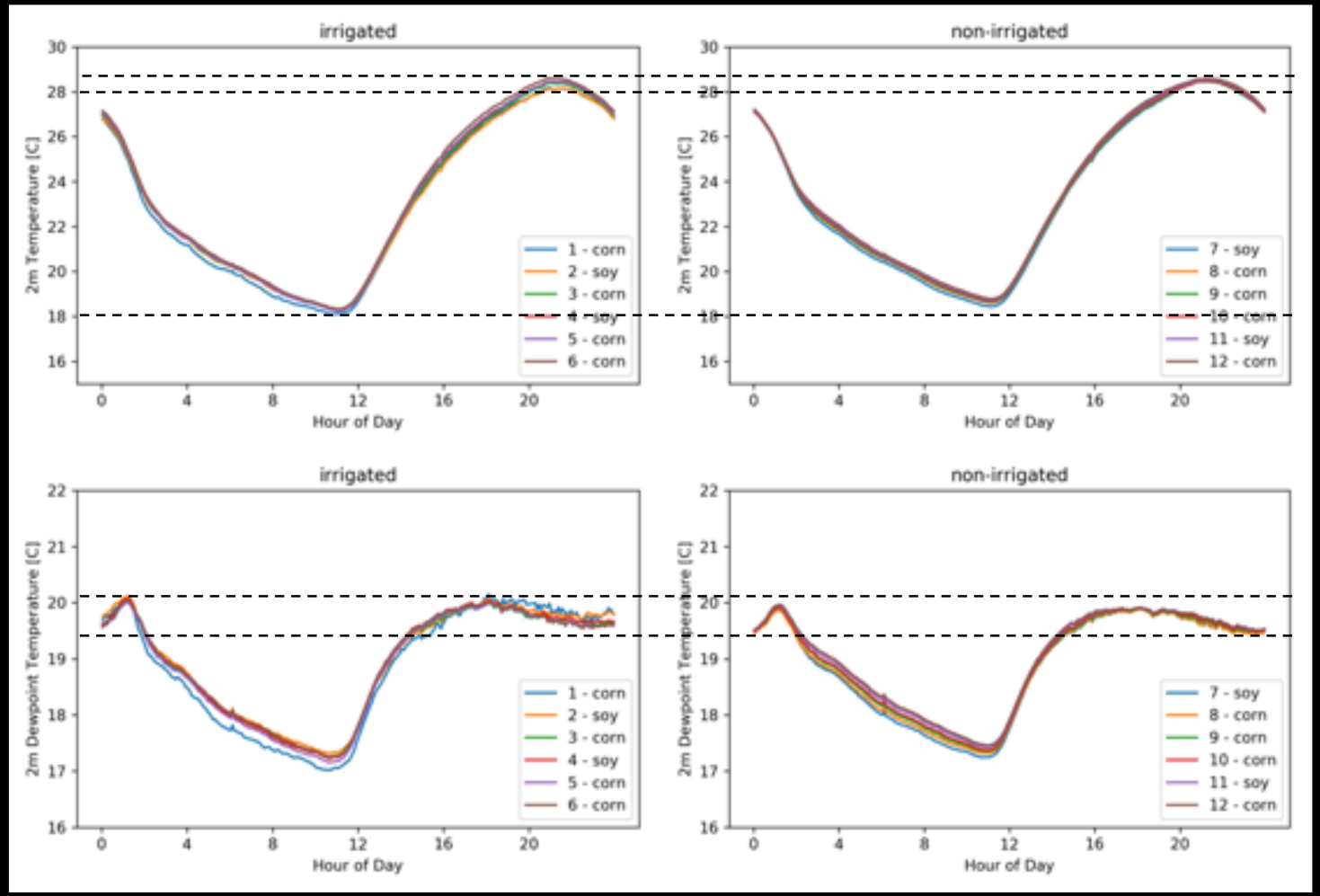
Preliminary Analysis

Average diurnal variation of sensible and latent heat fluxes at different sites

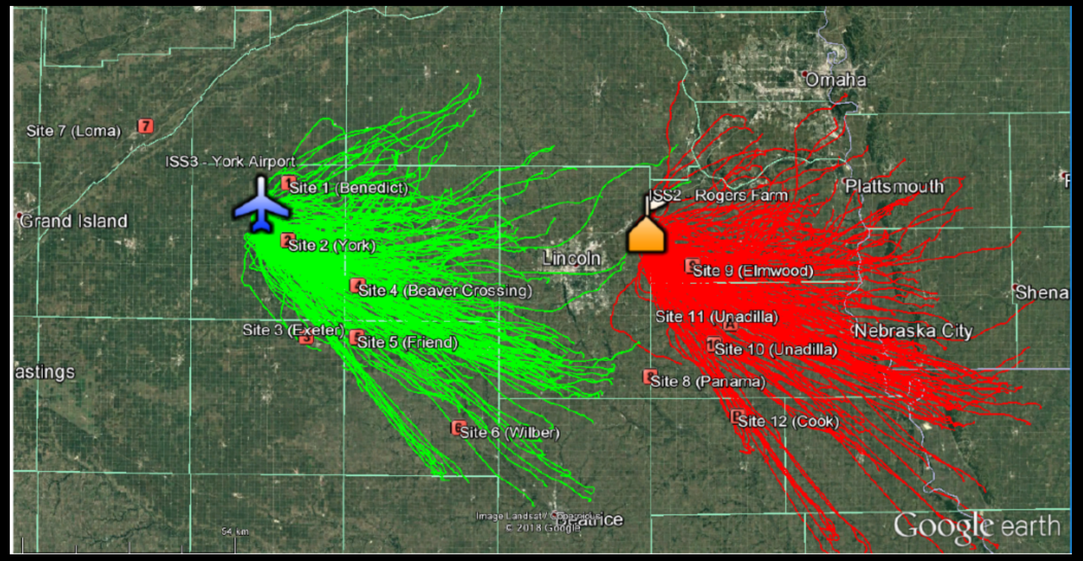


Preliminary Analysis

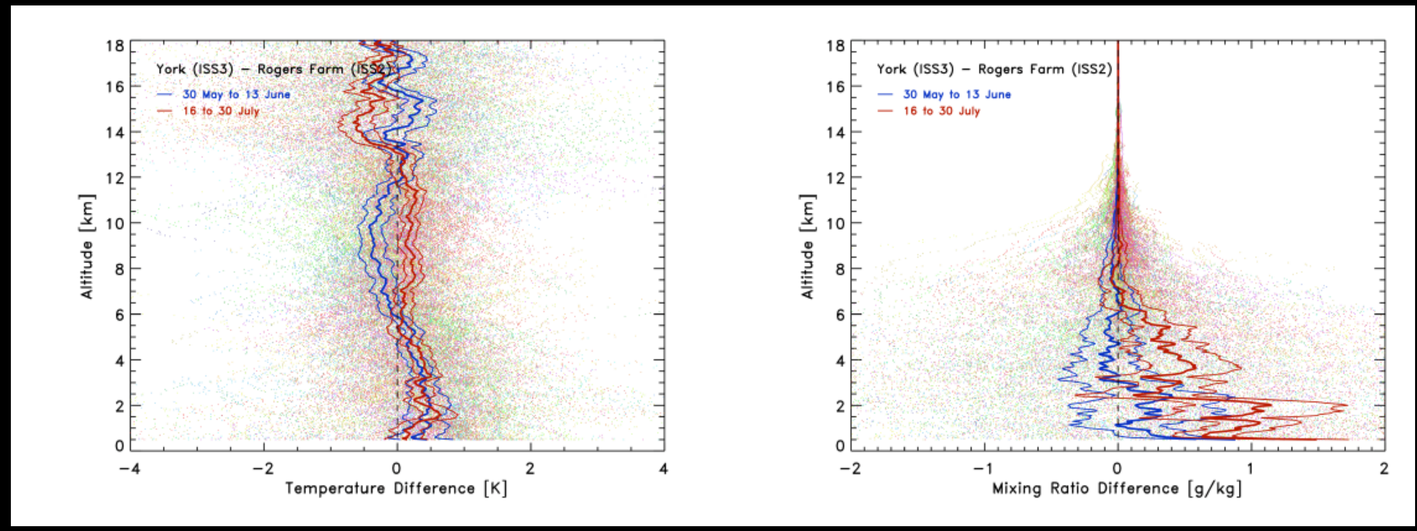
Average diurnal variation of temperature and dew point at different sites



Preliminary Analysis



Mean temperature and moisture difference in the boundary layer between irrigated and non-irrigated sites substantially increases during growing season

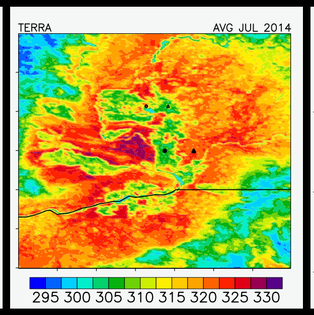


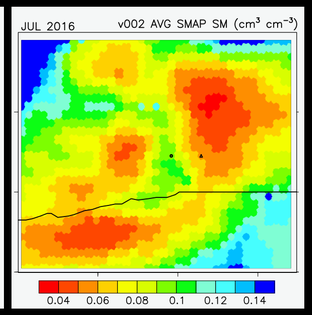
Irrigation Detection from SMAP

MODIS LST

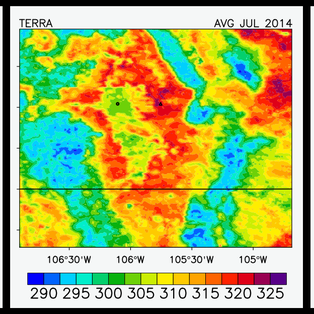
SMAP SM

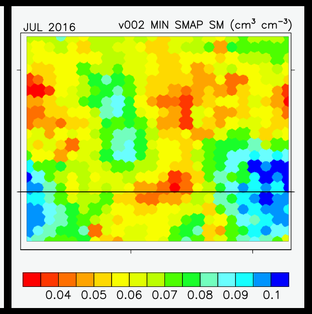
Washington

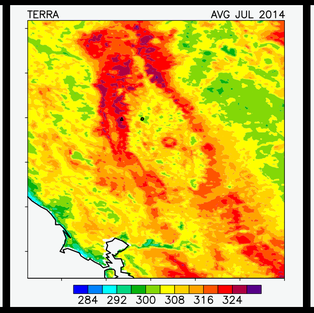


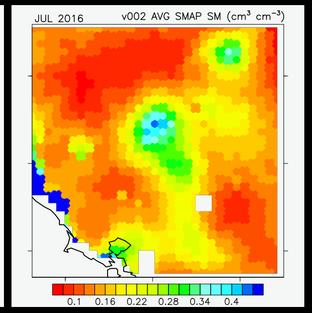
Colorado

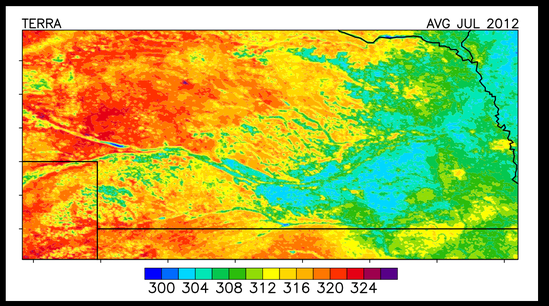



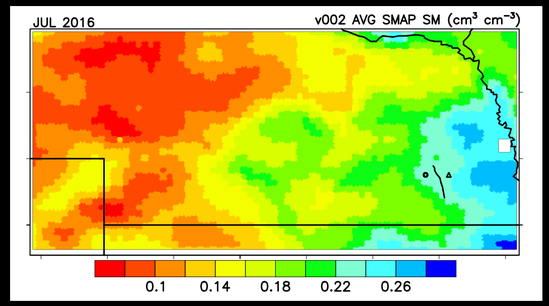


California





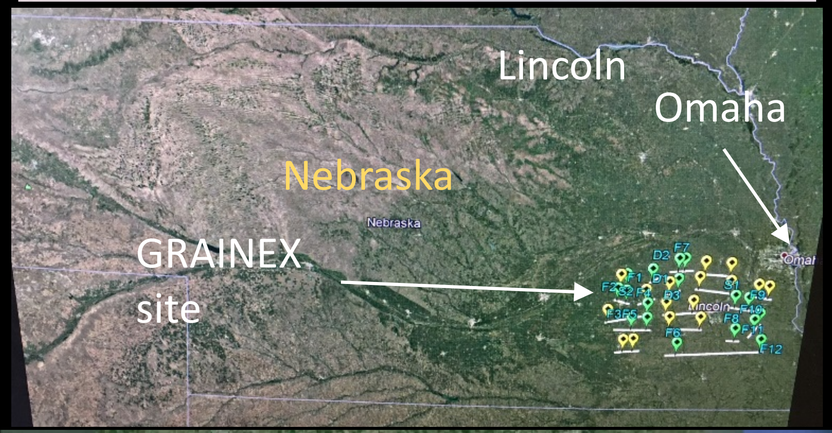


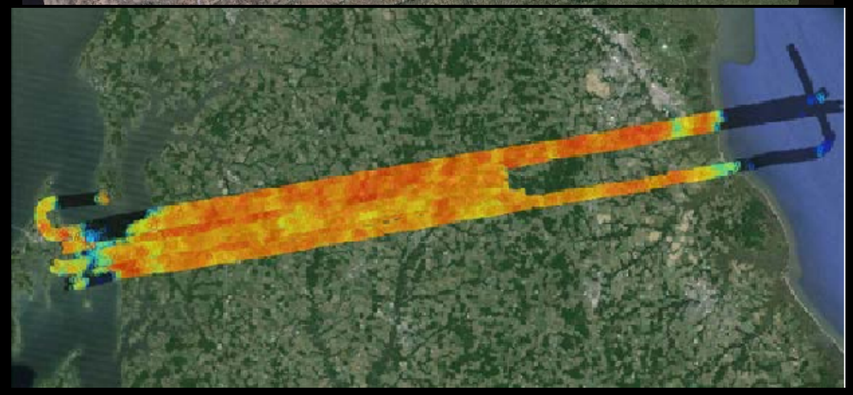
SMAP is able to detect an irrigation signal in three semi-arid regions

Lawston, P. M., Santanello, J. A., Jr, & Kumar, S. V. (2017). Irrigation signals detected from SMAP soil moisture retrievals. Geophysical Research Letters, 44. https://doi.org/10.1002/2017GL075733

Goddard RF Explorer (GREX) deploys for GRAINEX

- Goddard's GREX instrument flew on NASA Glenn's Twin Otter to provide high-resolution wide-area soil moisture transects across the transition zone
  - Cannot be obtained any other way
  - Complemented NSF's ground measurements with remote sensing
- GREX observes V-polarized L-band brightness temperature - the same as SMAP.
  - These will be converted to soil moisture using the SMAP algorithm.
- Operations were based out of Lincoln, NE July 16-27, 2018. GSFC personnel Ed Kim, Albert Wu, Eugenia De Marco deployed with GREX.
  - Completed science flights on 7 days over GRAINEX 100x100 km domain around Lincoln.



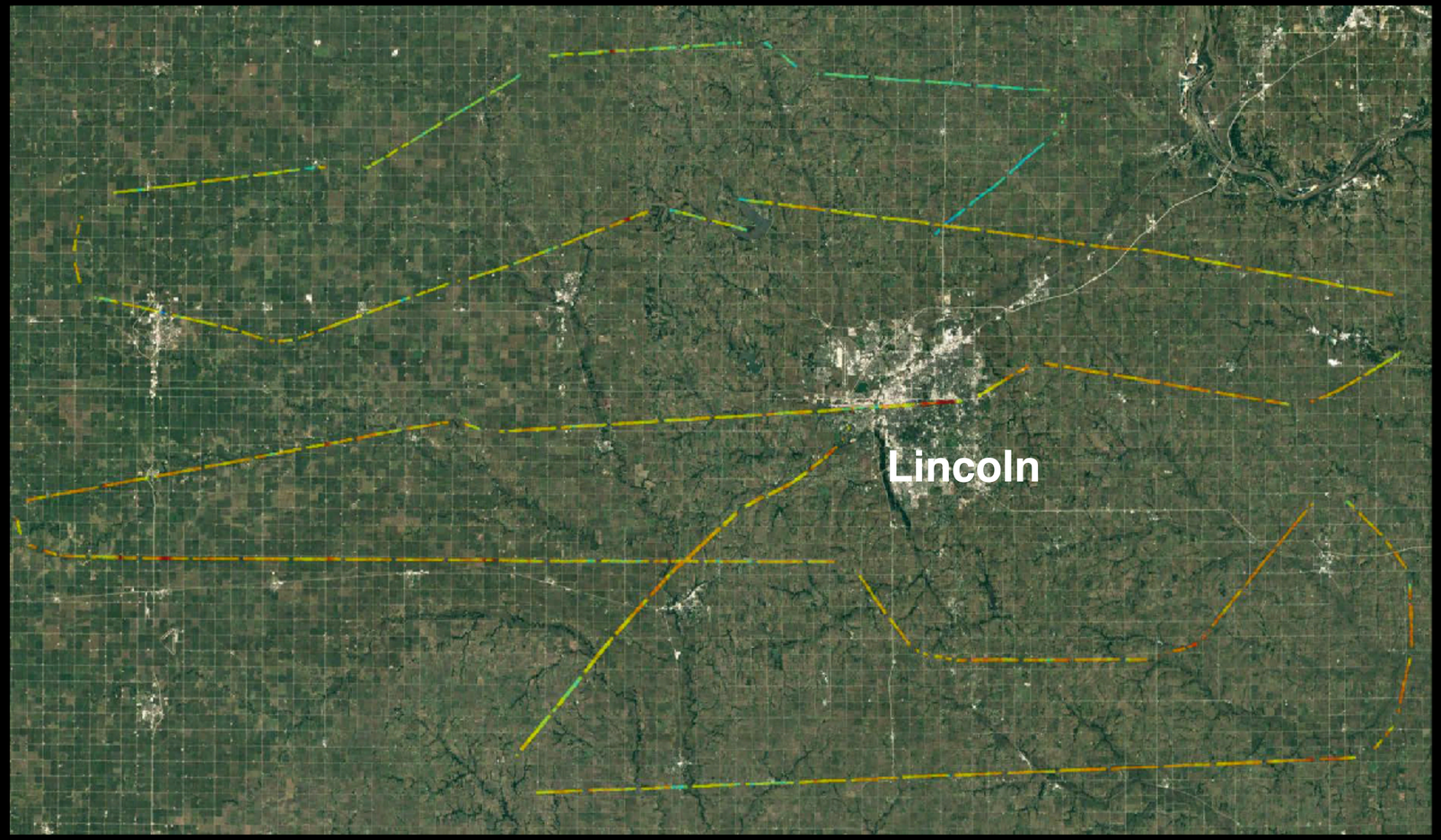


Goddard RF Explorer (GREX) deploys for GRAINEX

26 July 2018 Quick Look

Orange/Red: warmer
and/or drier soil

Green/Blue: cooler
and/or wetter soil



Conclusions

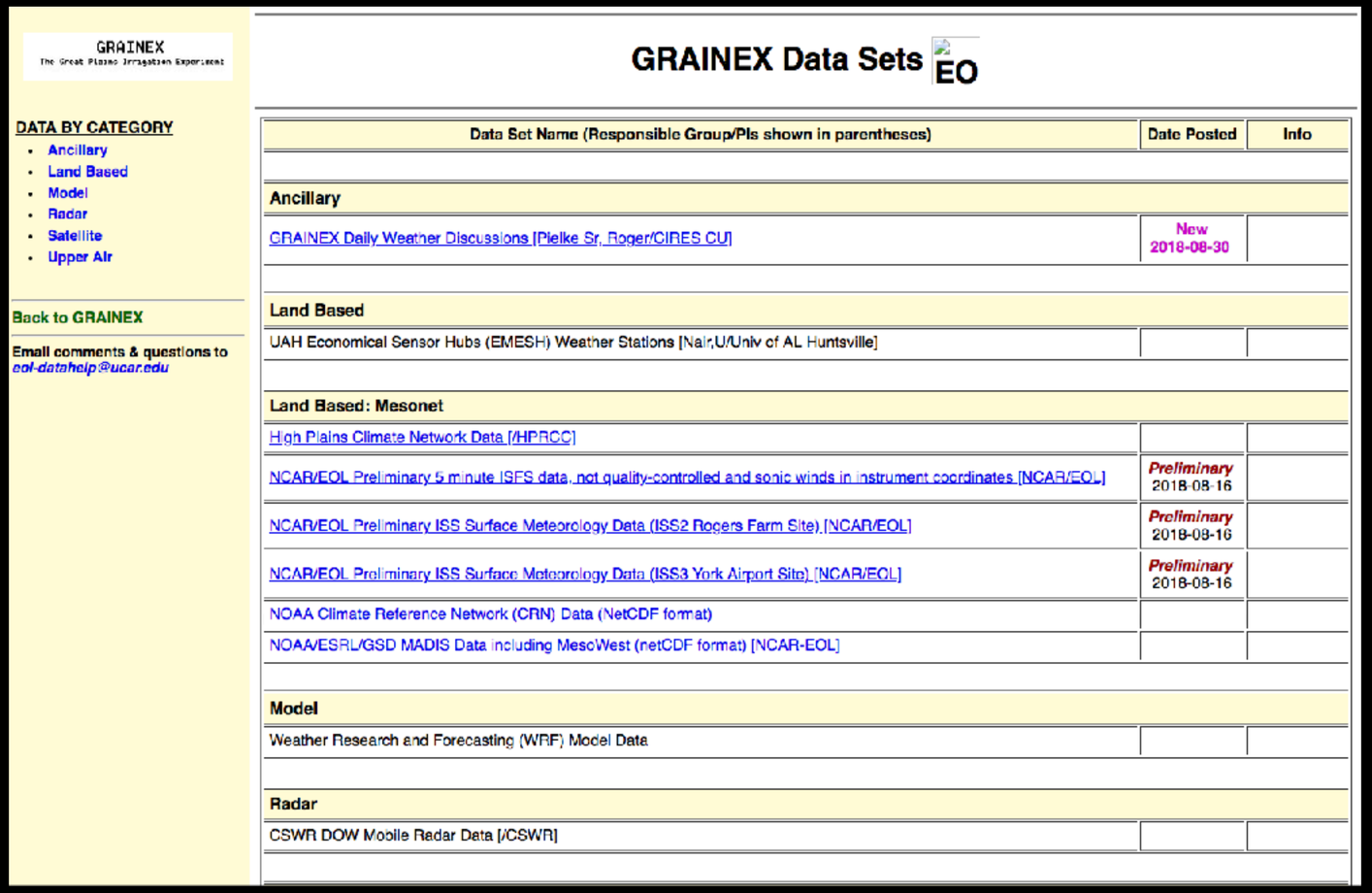
- A comprehensive dataset for analyzing LULC-atmosphere coupling has been compiled during the GRAINEX field campaign.

- Preliminary analysis shows consistent differences in energy fluxes between irrigated and non-irrigated regions, leading to substantial differences in temperature and moisture throughout the depth of the boundary layer.

- High spatial and temporal resolution surface and boundary layer observations, in combination with numerical modeling, will allow for isolating the irrigation effect from other confounding factors.

Data Availability

- https://data.eol.ucar.edu/master_list/?project=GRAINEX



GRAINEX
The Great Plains Irrigation Experiment

DATA BY CATEGORY

- Ancillary
- Land Based
- Model
- Radar
- Satellite
- Upper Air

Back to GRAINEX

Email comments & questions to
eol-datahelp@ucar.edu

GRAINEX Data Sets

Data Set Name (Responsible Group/PIs shown in parentheses)	Date Posted	Info
Ancillary		
GRAINEX Daily Weather Discussions [Pielke Sr, Roger/CIRES CU]	New 2018-08-30	
Land Based		
UAH Economical Sensor Hubs (EMESH) Weather Stations [Nair,U/Univ of AL Huntsville]		
Land Based: Mesonet		
High Plains Climate Network Data [/HPRCC]		
NCAR/EOL Preliminary 5 minute ISFS data, not quality-controlled and sonic winds in instrument coordinates [NCAR/EOL]	*Preliminary* 2018-08-16	
NCAR/EOL Preliminary ISS Surface Meteorology Data (ISS2 Rogers Farm Site) [NCAR/EOL]	*Preliminary* 2018-08-16	
NCAR/EOL Preliminary ISS Surface Meteorology Data (ISS3 York Airport Site) [NCAR/EOL]	*Preliminary* 2018-08-16	
NOAA Climate Reference Network (CRN) Data (NetCDF format)		
NOAA/ESRL/GSD MADIS Data including MesoWest (netCDF format) [NCAR-EOL]		
Model		
Weather Research and Forecasting (WRF) Model Data		
Radar		
CSWR DOW Mobile Radar Data [/CSWR]		

Poster Today: H11J-1594

Impact of Irrigation on Summertime Temperatures in the Pacific Northwest

Patricia M. Lawston[1,2], Joseph A. Santanello, Jr.[2], Brian Hanson[3]

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PAPER # H11J-1594

1) MOTIVATION:

- Large scale irrigation projects developed in the early-to-mid 1900s drastically increased the area of irrigated land in the Columbia River Valley CRV).
- Irrigation increases soil moisture, thereby altering water and energy fluxes into the planetary boundary layer (PBL).
- This study uses local observations, satellite remote sensing, and numerical modeling to:
  1. Explore whether irrigation has historically impacted summer maximum temperatures (Tmax) in the CRV,
  2. Characterize the current extent of irrigation impacts to soil moisture (SM) and land surface temperature (LST),
  3. Better understand the regional influence of irrigation using numerical modeling.

Figure 1. Google Earth image of study area in Washington and Oregon, U.S.A.

2) DATA & METHODS:

- The following **observational datasets** are analyzed in the CRV:
  - Global Historical Climate Network Tmax
  - Soil Moisture Active Passive (SMAP) satellite soil moisture retrievals
  - MODIS Aqua and Terra LST
  - US Dept of Ag Census of Agriculture reports
  - U.S. Bureau of Reclamation Agrimet meteorological data (15-min temperature, humidity, winds)
- We completed a series of **regional modeling simulations** with the following configuration:
  - **NASA's Land Information System (LIS)** coupled to the **NASA-Unified WRF (NU-WRF)** atmospheric model
  - 3 nested domains: 9km, 3km, 1km resolution
  - 3 case studies of 60-hour simulation length: 1-3 July, 16-18 July, 23-25 July 2015.
  - Control (no irrigation) and irrigated runs for each case

3) RESULTS: Historical Climate Analysis

- Some stations downwind of irrigation, such as Odessa, show a statistically significant decrease in average JJA Tmax in the decades following irrigation expansion.

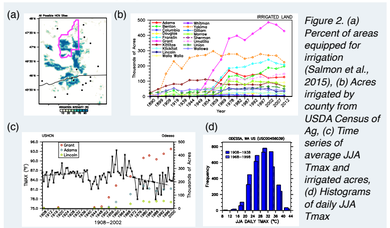


Figure 2. (a) Percent of areas equipped for irrigation (Salmon et al., 2015). (b) Acres irrigated by county from USDA Census of Ag, (c) Time series of average JJA Tmax and irrigated acres, (d) Histograms of daily JJA Tmax

4) RESULTS: Satellite Remote Sensing

- Both MODIS LST and SMAP SM show the spatial and temporal signatures of irrigation, indicating that the scale and impact on temperature and soil moisture is robust enough to be detected via satellite.

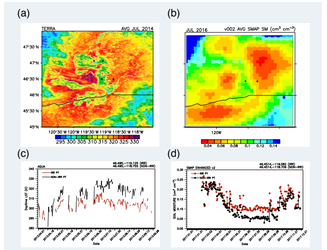
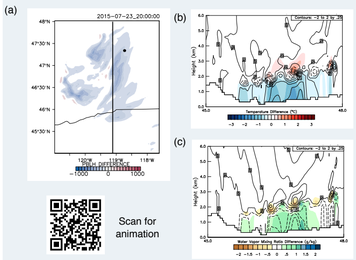


Figure 3. (a) MODIS Terra LST, (b) SMAP SM. Time series of (c) MODIS Aqua LST, (d) SMAP SM.

5) RESULTS: Regional Modeling

- Irrigation decreases temperature, increases humidity and reduces PBL height. The cooler, more humid air is advected downwind.



Scan for animation

Figure 4. (a) Change in midday PBL height due to irrigation. Vertical cross sections showing (b) change in temperature and, (c) change in humidity due to irrigation.

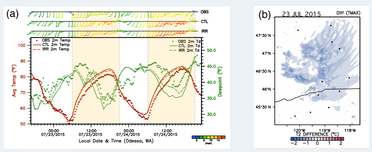


Figure 5. (a) Temperature, humidity, and winds from WRF runs and observations, (b) difference in maximum temperature due to irrigation

6) PRELIMINARY CONCLUSIONS:

- Irrigation expansion may have contributed to a reduction in summertime maximum temperatures and heat extremes downwind of the Columbia Basin Project.
- Local observations, satellite remote sensing, and numerical modeling all suggest that there is a regional (i.e., beyond local) impact of irrigation in the study area.

7) ACKNOWLEDGEMENTS & REFERENCES:

- This study was supported by NASA grant NNH15ZDA001N-SUSMAP.

- Lawston et al., 2017: Irrigation signals detected from SMAP soil moisture retrievals, *Geophys. Res. Lett.* **44** (23).
- Lawston et al., 2015: Impact of irrigation methods on LSM spinups and initialization of WRF Forecasts, *JHM.***16**, *1135-1154.*
- Salmon et al. 2015: Global rain-fed, irrigated, and paddy croplands: A new high resolution map derived from remote sensing, crop inventories and climate data. *Int. J. Appl. Earth Obs. Geoinf.* **38**, 321-334.

Questions?

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