GRACE and Human Impacts on the Water Cycle

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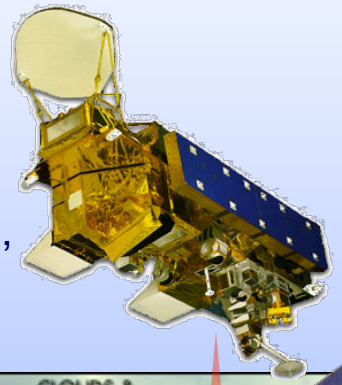
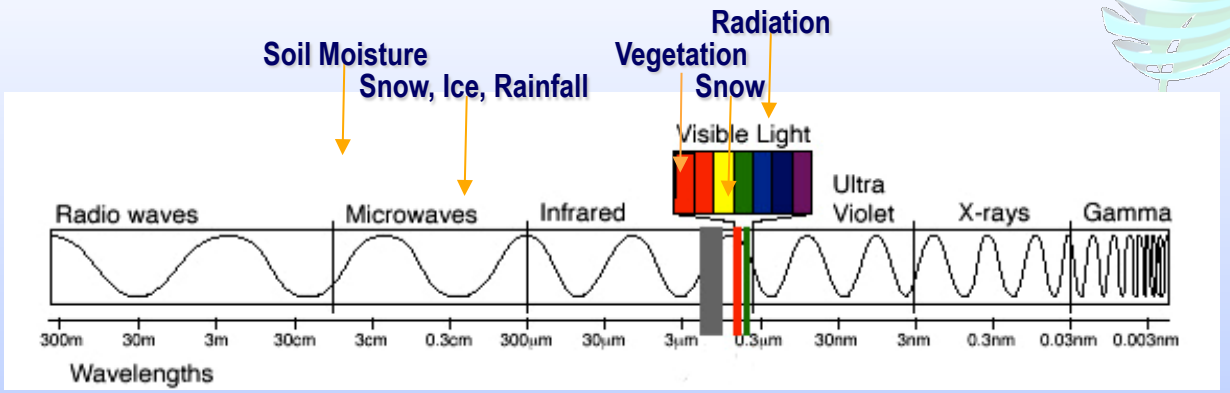
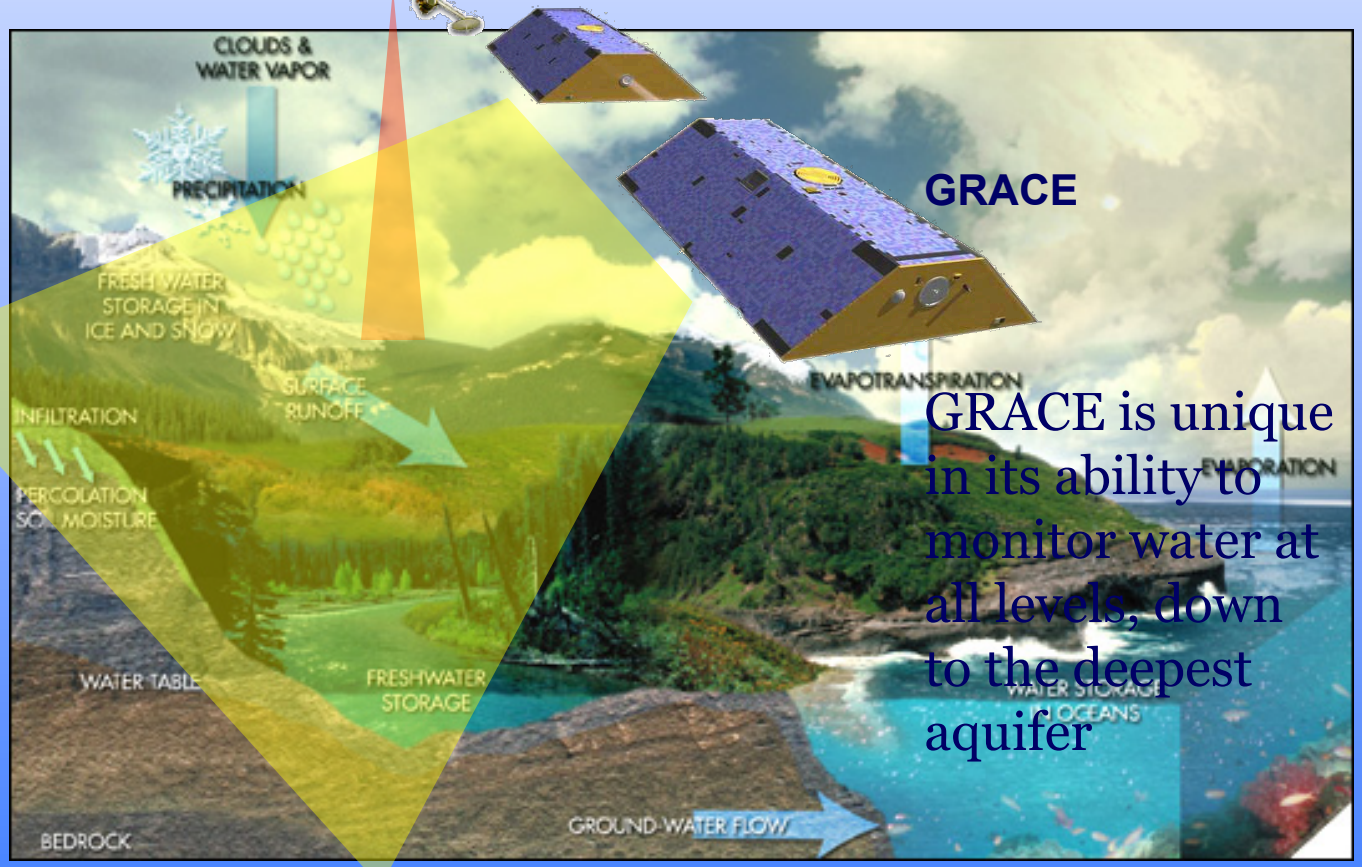
Gravity Recovery and Climate Experiment (GRACE)

Aqua:
MODIS,
AMSR-E,
etc.







GRACE is unique in its ability to monitor water at all levels, down to the deepest aquifer

Conventional radiation-based remote sensing technologies cannot sense water below the first few centimeters of the snow-canopy-soil column

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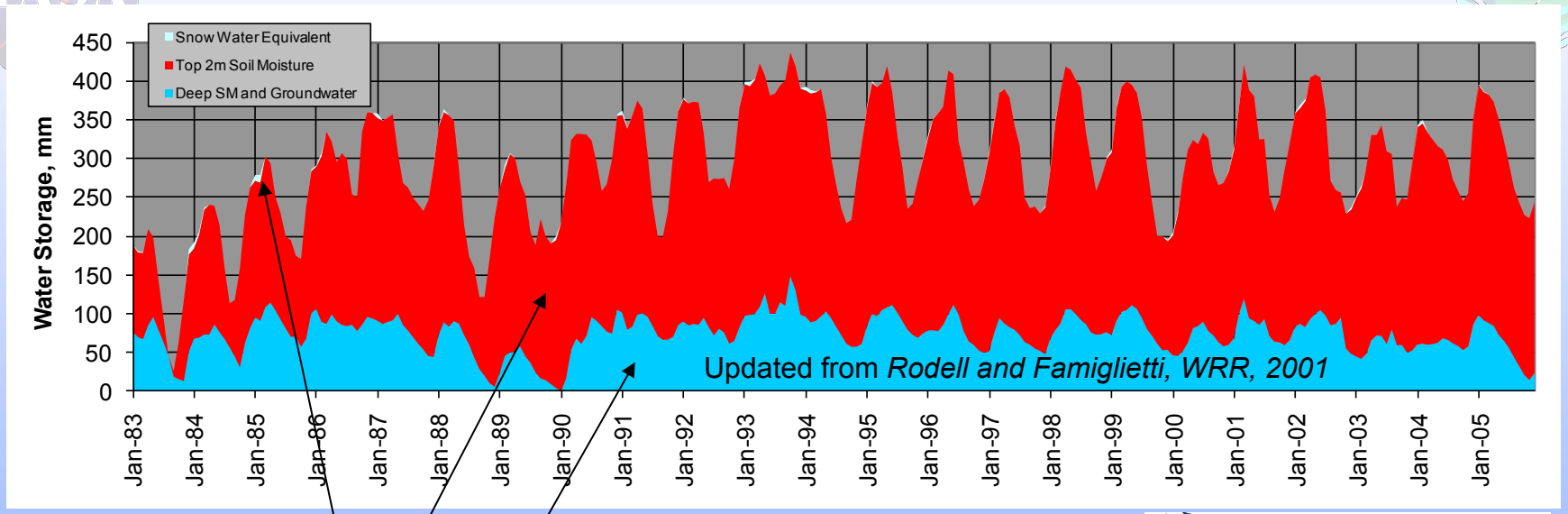
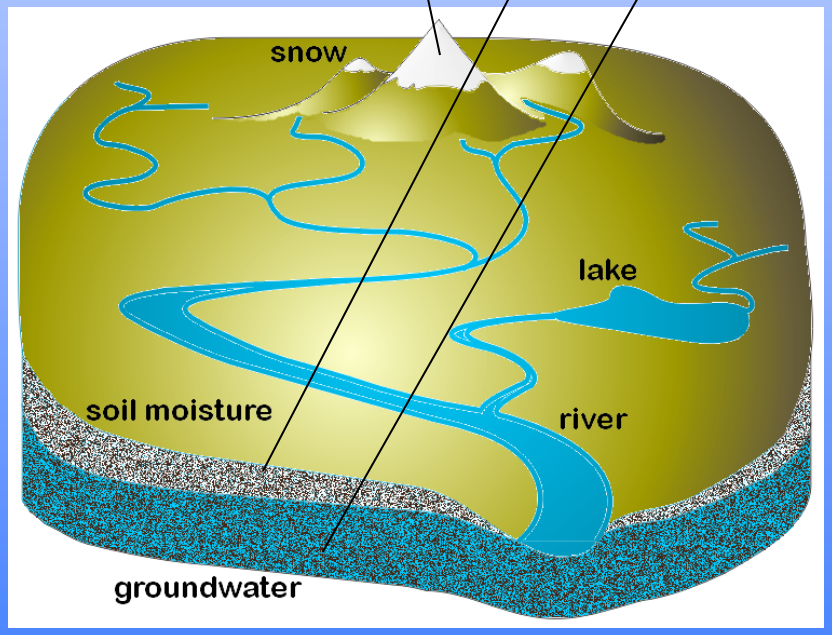
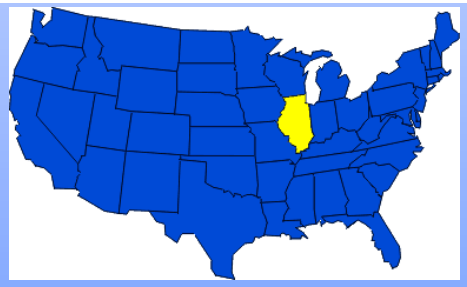
Terrestrial Water Storage Variations





Top: 23 year time series of snow, soil moisture, and groundwater storage in Illinois, USA (right)



TWS variations are dominated by:

- **Soil moisture in temperate regions;**
- **Snow in polar and alpine regions;**
- **Surface water in the wet tropics.**

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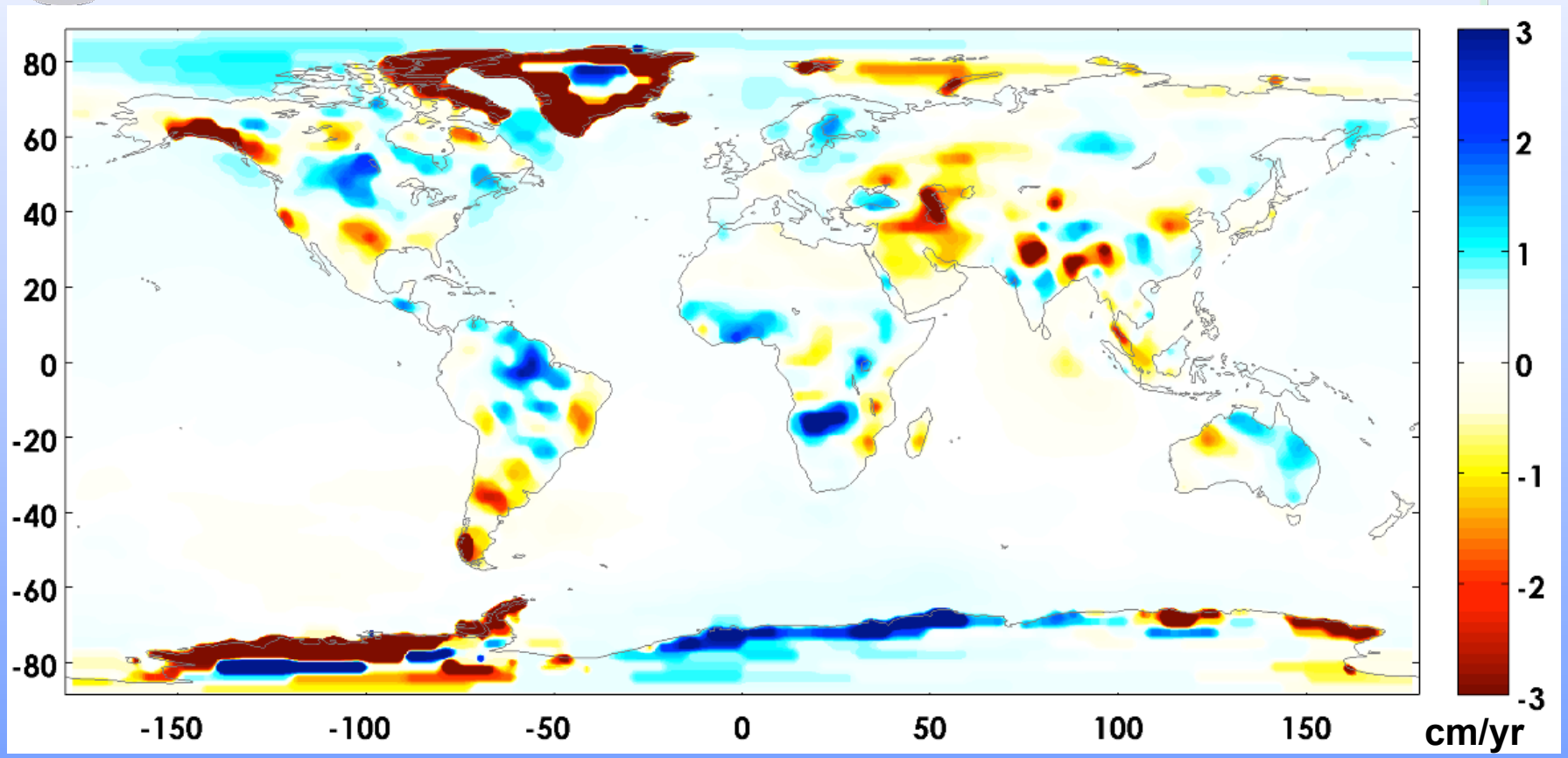
Emerging Trends in Terrestrial Water Storage from GRACE



- "Trends" in GRACE derived terrestrial water storage, 2002-2015.
- Best fit linear rate of change of TWS (cm/yr).
- Based on JPL/Tellus GRACE mascon land hydrology product.
- Which apparent trends are real and likely to continue?

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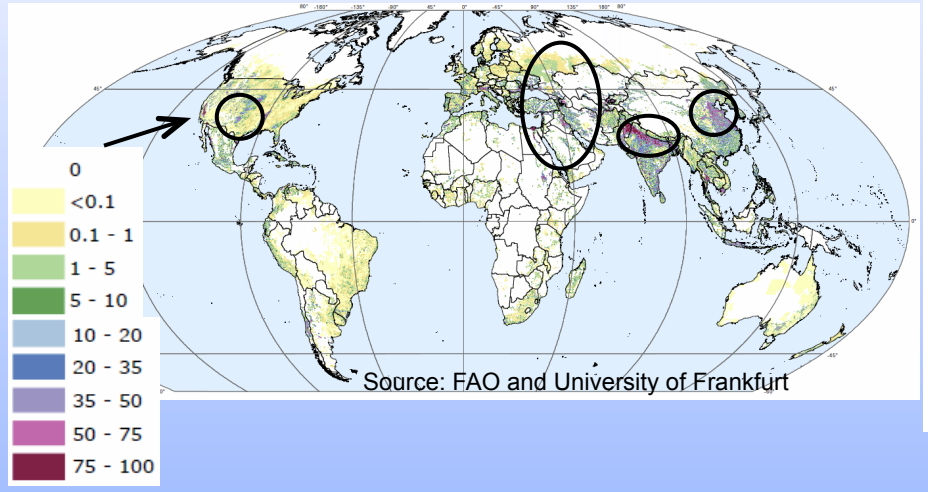
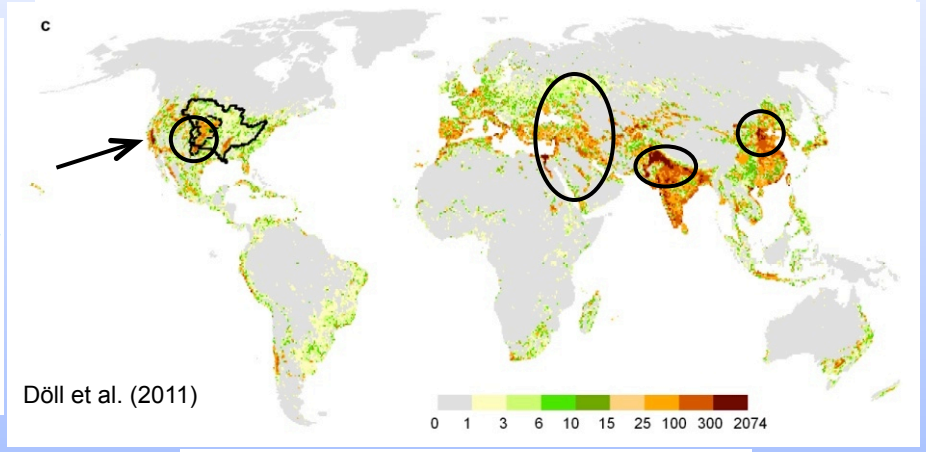
Exploitation of Water Resources

Percentage of Irrigated Area

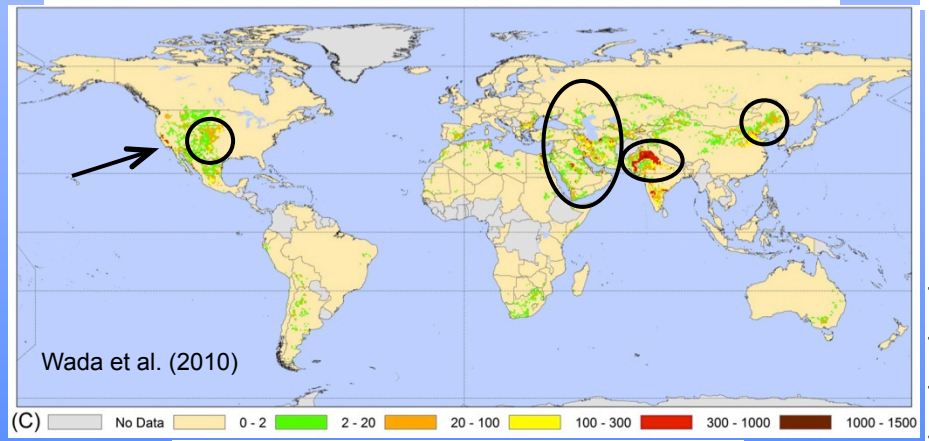


Net Consumptive Use of Ground and Surface Waters, 1998-2002



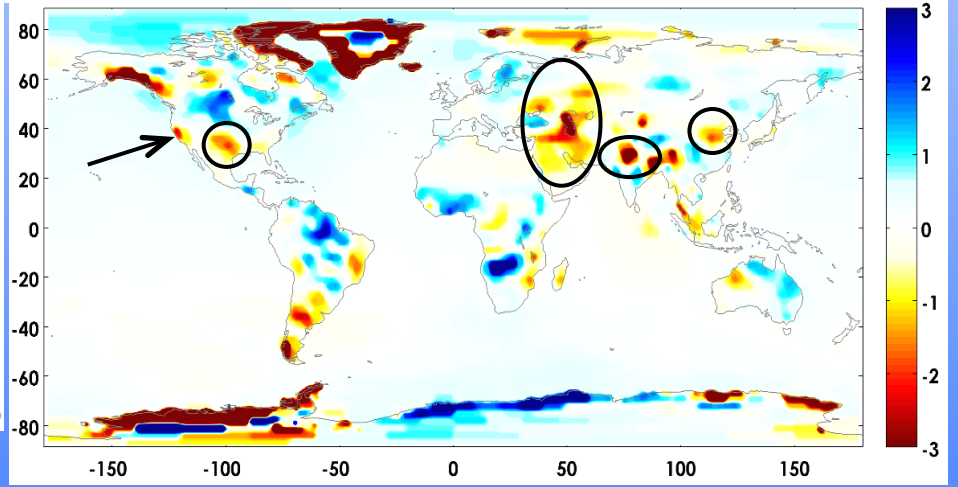
Equivalent height of water (mm/yr)

Groundwater Depletion Rate (ca. 2000)



Equivalent height of water (mm/yr)

Terrestrial Water Storage "Trends" from GRACE



Equivalent height of water (cm/yr)

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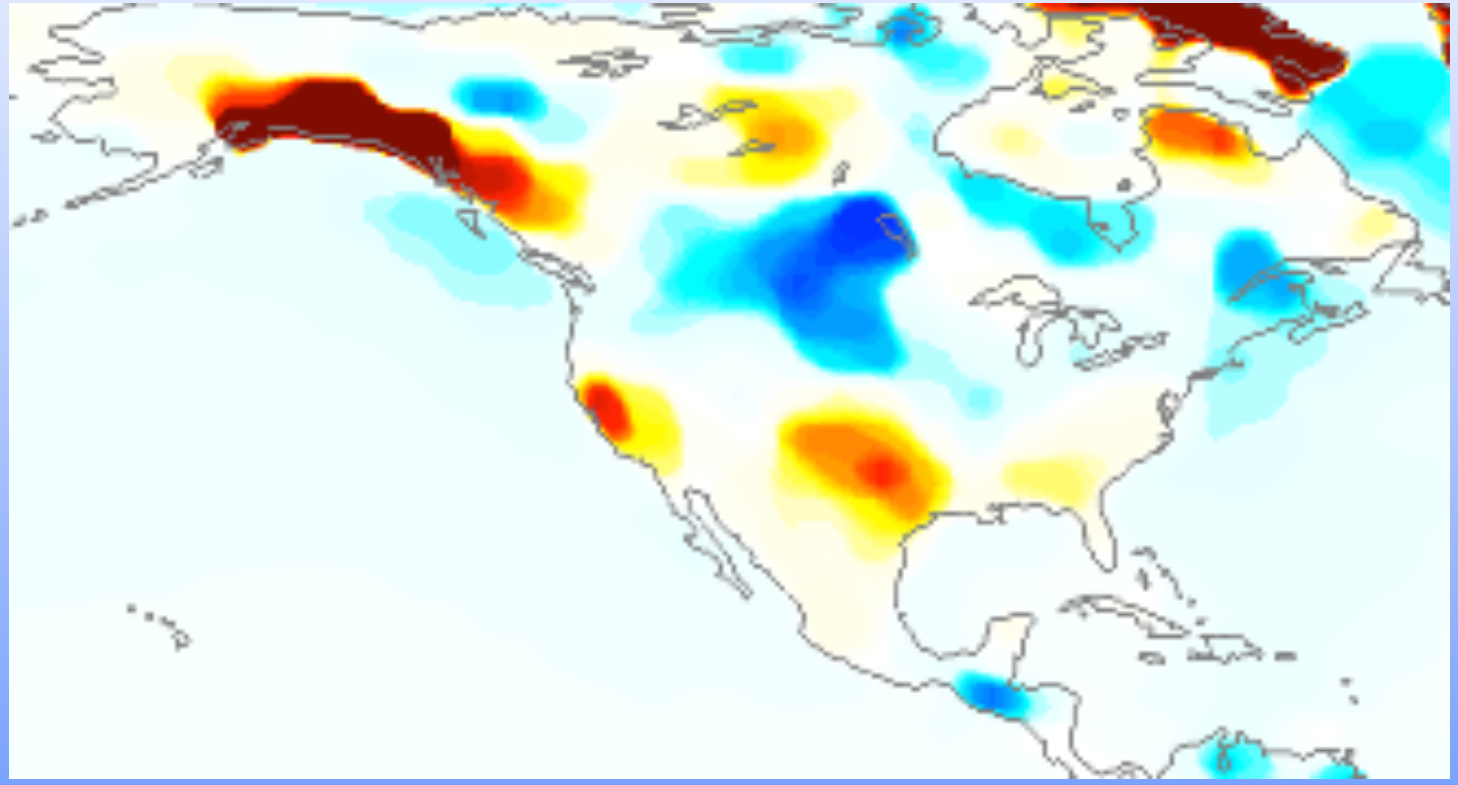

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Total U.S. Water Withdrawals, 2010

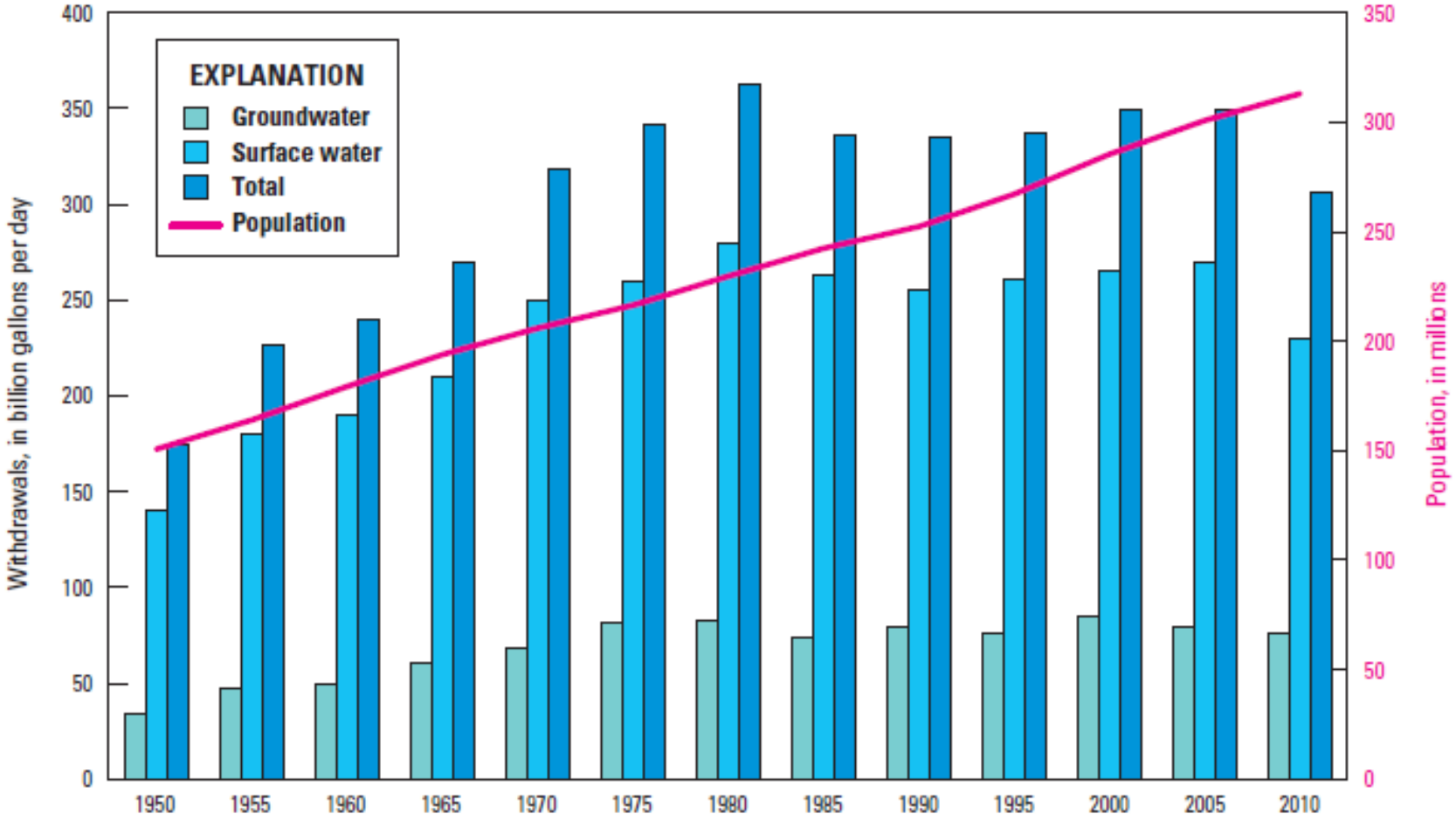

Figure 13. Trends in population and freshwater withdrawals by source, 1950–2010.

Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L. and Linsey, K.S., 2014. *Estimated use of water in the United States in 2010* (No. 1405). US Geological Survey.

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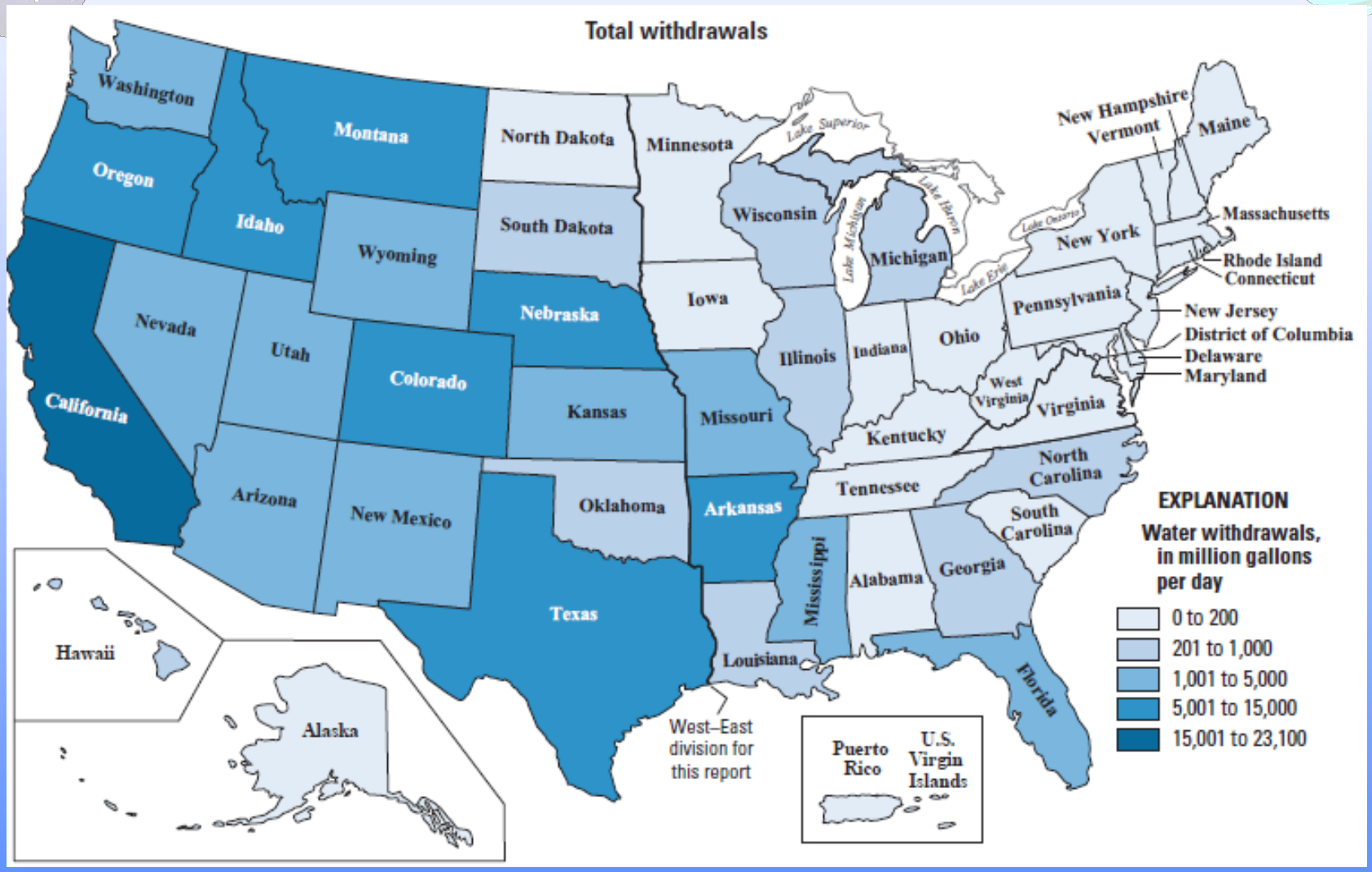
Irrigation Water Withdrawals, 2010



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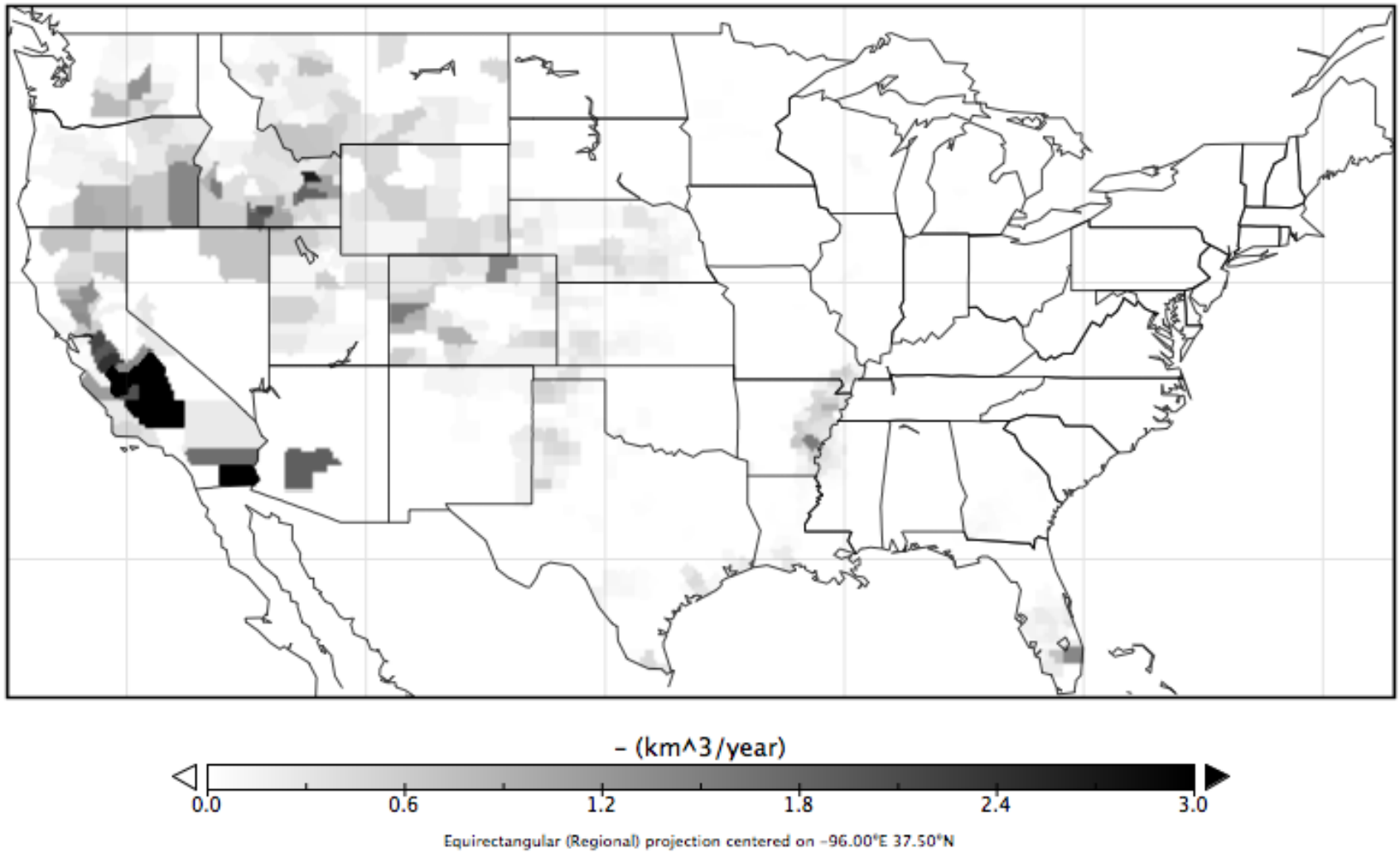
Irrigation Water Withdrawals, ca. 2000



Annual irrigation water use ca. 2000 reported by the USGS at the county level in cubic kilometers, from *Ozdogan et al., J. Hydrometeor., 2010*.

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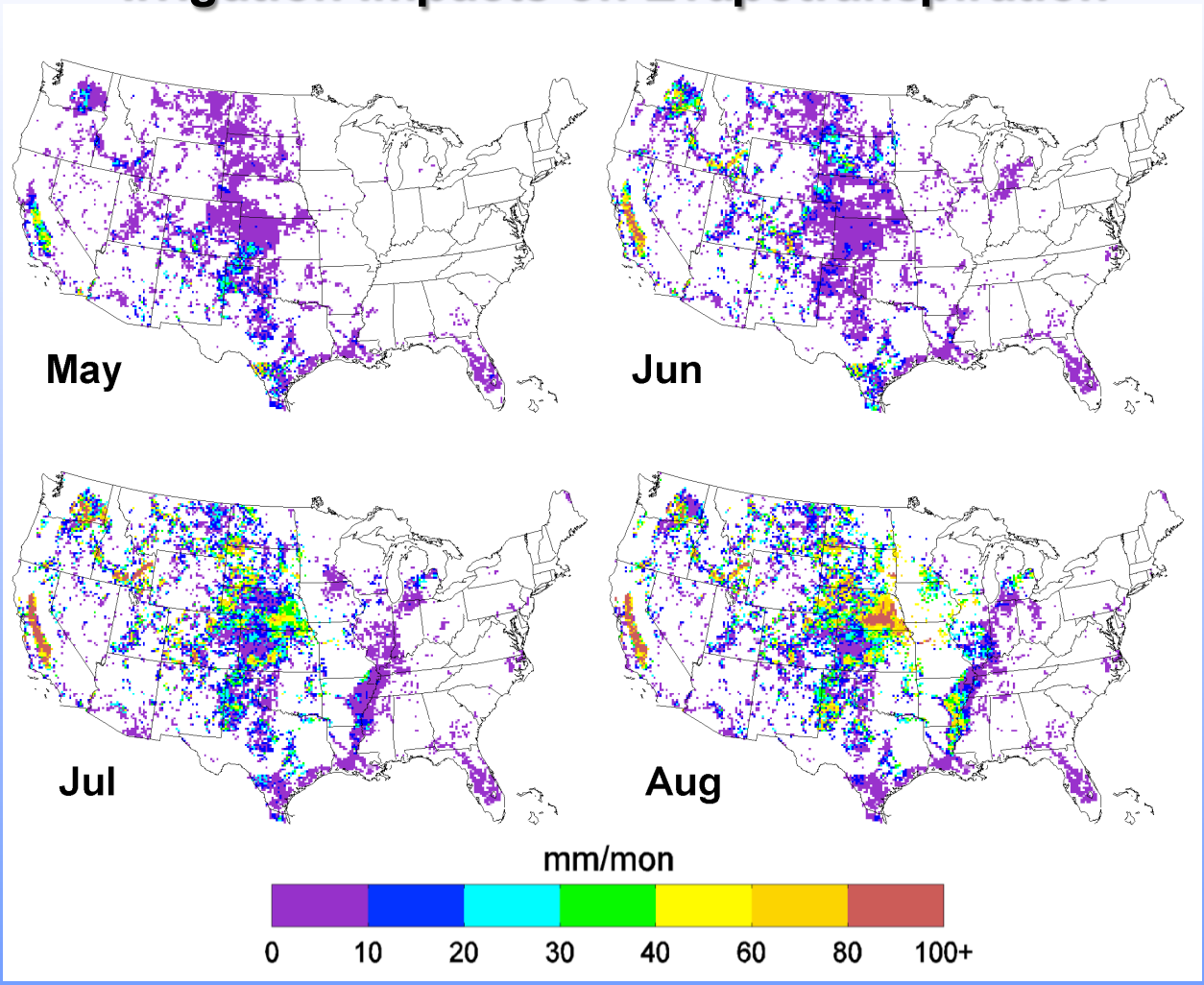
Irrigation Impacts on Evapotranspiration



Increase in evapotranspiration due to irrigation, from *Ozdogan et al., J. Hydrometeor., 2010*. The increase in ET due to irrigation, averaged over the entire contiguous U.S., was 4% during the growing season, which is a huge impact on the water budget that also affects temperature and the energy budget.

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