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National Water-Quality Assessment (NAWQA) Project

Decadal-scale changes in uranium and bicarbonate in groundwater in the U.S.: Effects of irrigation on the mobilization of uranium

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Primary hypothesis

- Jurgens et al. (2010) showed that in the eastern San Joaquin Valley of California, increased concentrations of uranium (U) in groundwater are related to increases in bicarbonate (HCO3) concentrations due to irrigation development
- Question: is this same process affecting other parts of the arid western U.S.?

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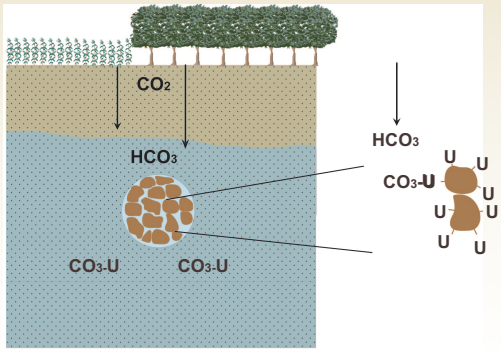
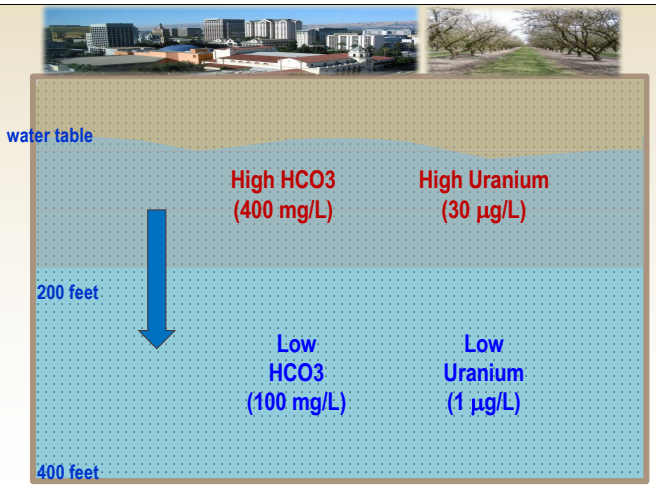
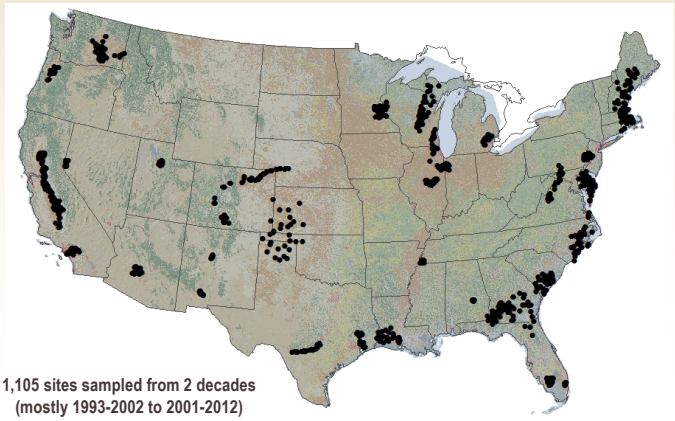
Uranium source and mobilization





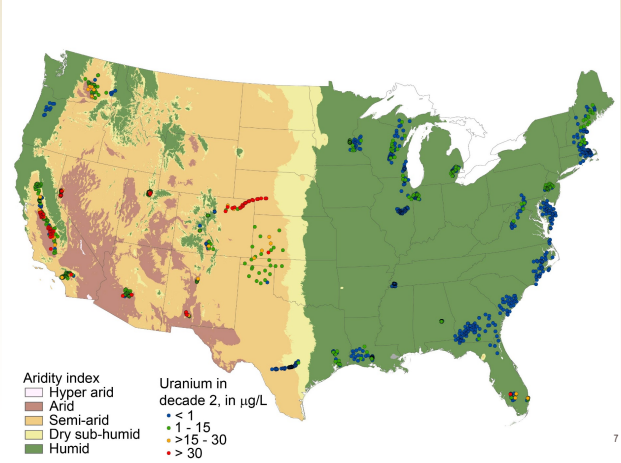
Not to scale

Sites used in decadal analysis of U and HCO3

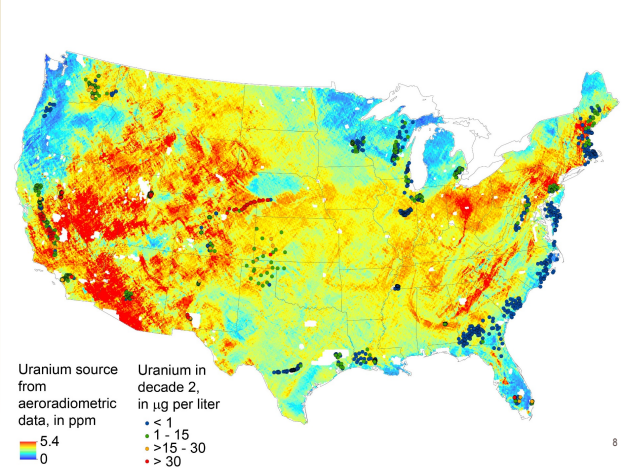


1,105 sites sampled from 2 decades (mostly 1993-2002 to 2001-2012)

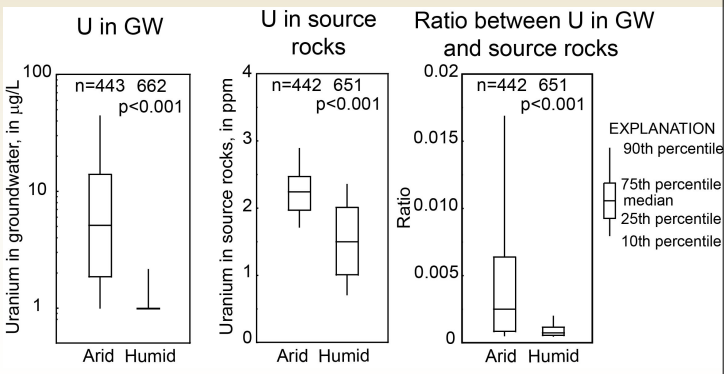
Highest U in arid or semi-arid climate zone



U in wells and source rocks



U in GW and U in source rocks highest in arid zone



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Uncertainty analysis: replicate data for U and HCO3

- **U: 408 replicates ➔ +/- 10% difference falls between 90-95th percentile of differences**
- **HCO3: 151 replicates ➔ +/- 10% difference falls between 90-95th percentile of differences**

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Definition of terms

- **"Large difference" = difference greater than 10% between decades**
- **"Small difference" = difference within range of uncertainty**
- **"Concordant" – U and HCO3 are changing in same direction**
- **"Discordant" – U and HCO3 are changing in different direction**

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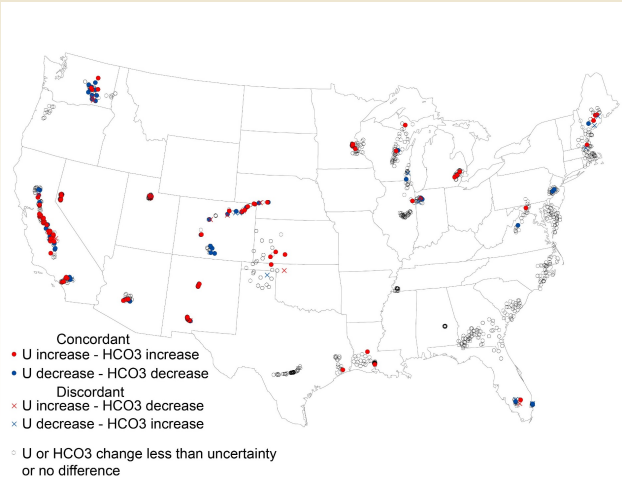
Differences in U and HCO3 between decade 1 and 2



U and HCO3 are concordant for most wells

Large differences in U and HCO3		
	HCO3 increased	HCO3 decreased
U increased	109 *(80% arid or semi-arid)*	15
U decreased	16	76 *(79% arid or semi-arid)*

Chi-squared p<0.001

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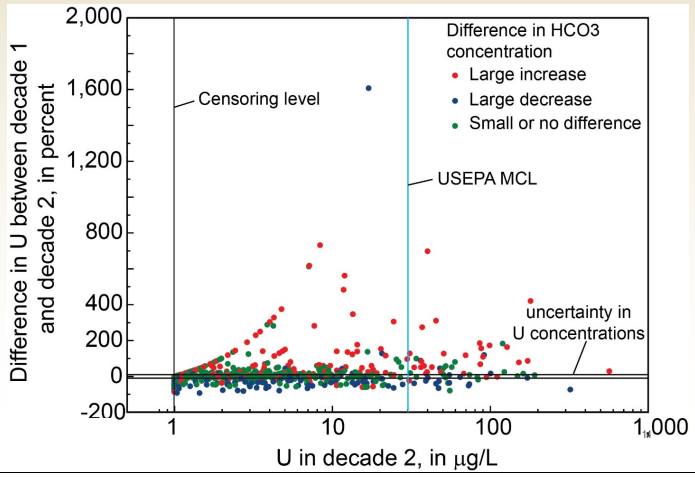
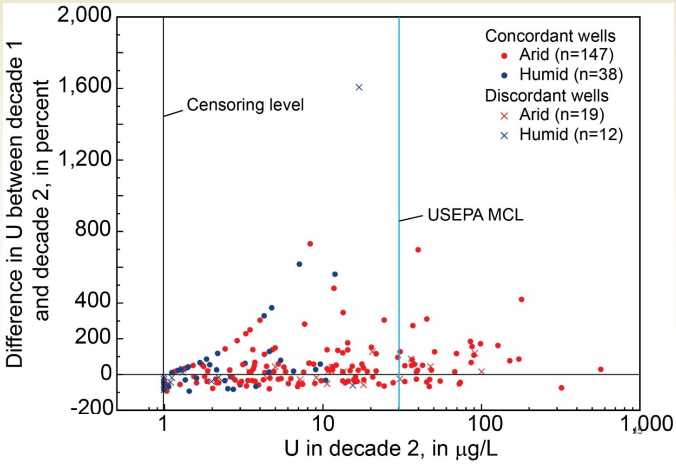
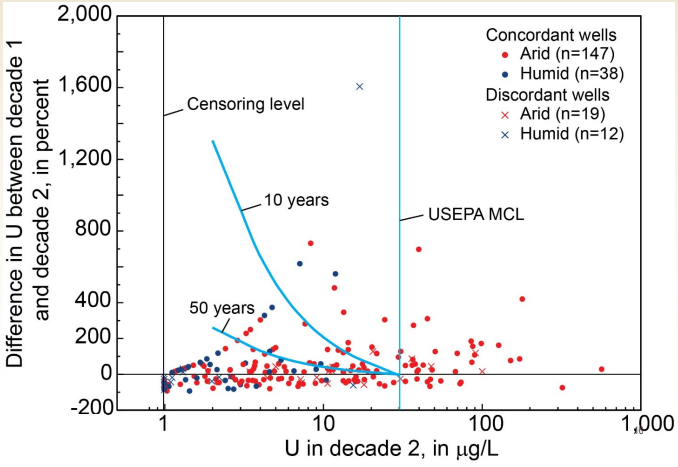
Large percentage increases in U correspond to large increases in HCO3



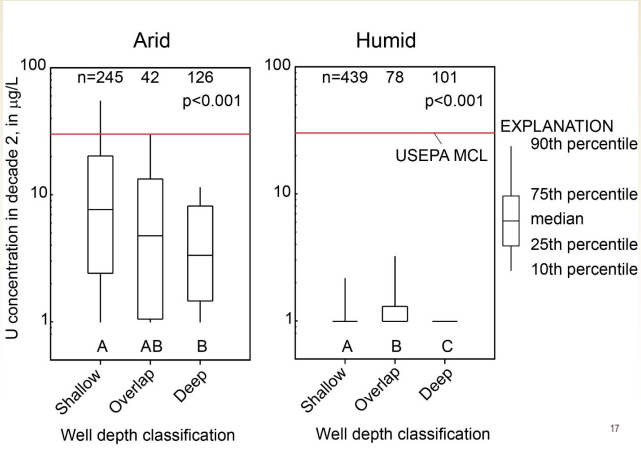
Large percentage increases in U mostly in arid climate



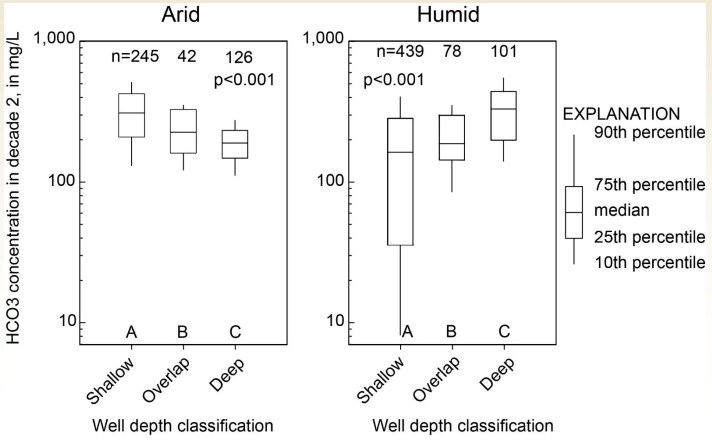
Potential for U to increase over MCL



U highest in shallow GW in arid climate



HCO3 highest in shallow GW in arid climate



PHREEQC speciation results

Criteria for 521 wells U detected in both decades	Wells meeting specified criteria	% of all wells meeting criteria
U(VI) is dominant in both decades	498	96
U(IV) is dominant in both decades	7	1
U(IV) is dominant in one decade and U(VI) is dominant in the other	13	2

Criteria for 1,012 samples where U(VI) is dominant species	Samples meeting specified criteria	% of samples meeting criteria
CO3 species are dominant (U(VI))	1,004	99
CaCO3 species are dominant	994	98

- Consistent w Jurgens et al. (2010)

Summary and Conclusions

- Most high concentrations of U occur in arid climate; low U in humid climate
- U changes are concordant with HCO3 changes and occur mostly in the irrigated arid climate
- Largest changes in U are where HCO3 increasing by large amount
- Most of these large changes are in irrigated arid climate
- U and HCO3 are highest in shallow GW in arid climate
- If U increases at current rate, more wells will exceed 30 μg/L