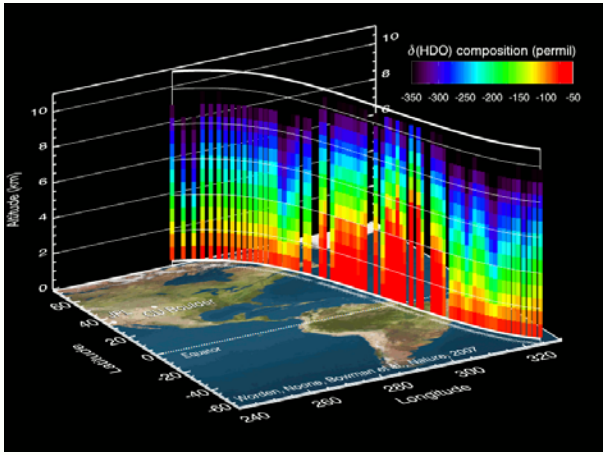
A decade of monitoring the movement of water using HDO/H2O from Aura



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With help from many, including:
John Worden, Kevin Bowman, Bob Herman, Yuk Yung, Max Berkelhammer, Camille Risi, Bronwen Konecky, Adriana Bailey, Derek Brown, Jesse Nusbaumer

NASA Atmospheric Composition program
NASA Energy and Water-cycle study
JPL

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The Abundance of O^{18} in Atmospheric Water and Water Vapour

Abstract

Investigations into the O^{18}-abundance in the precipitation from a warm front reveal a distinct process of fractionation explainable by the unequal pressures of the saturated vapours of H_2O^{16} and H_2O^{18}.

An explanation is given of the low O^{18}-abundance in glacial waters.

A method of experimental investigation into the mechanism of the process of precipitation is discussed.

Research upon the abundance in nature of the heavy oxygen isotope, O^{18}, has been carried on persistently for several years.

exchanged between CO_2 and H_2O, to the effect that equilibrium

$$CO^{16} + H_2O^{18} \rightleftarrows CO^{16}O^{18} + H_2O^{16}$$

Some basic observations

- Lower isotope ratios with colder temperature
- Air mass history matters

Models
The Rayleigh model
(equator to pole, inside clouds)
A circulation theorem regarding condensation and recharge.

Willi Dansgaard, c. 1950s

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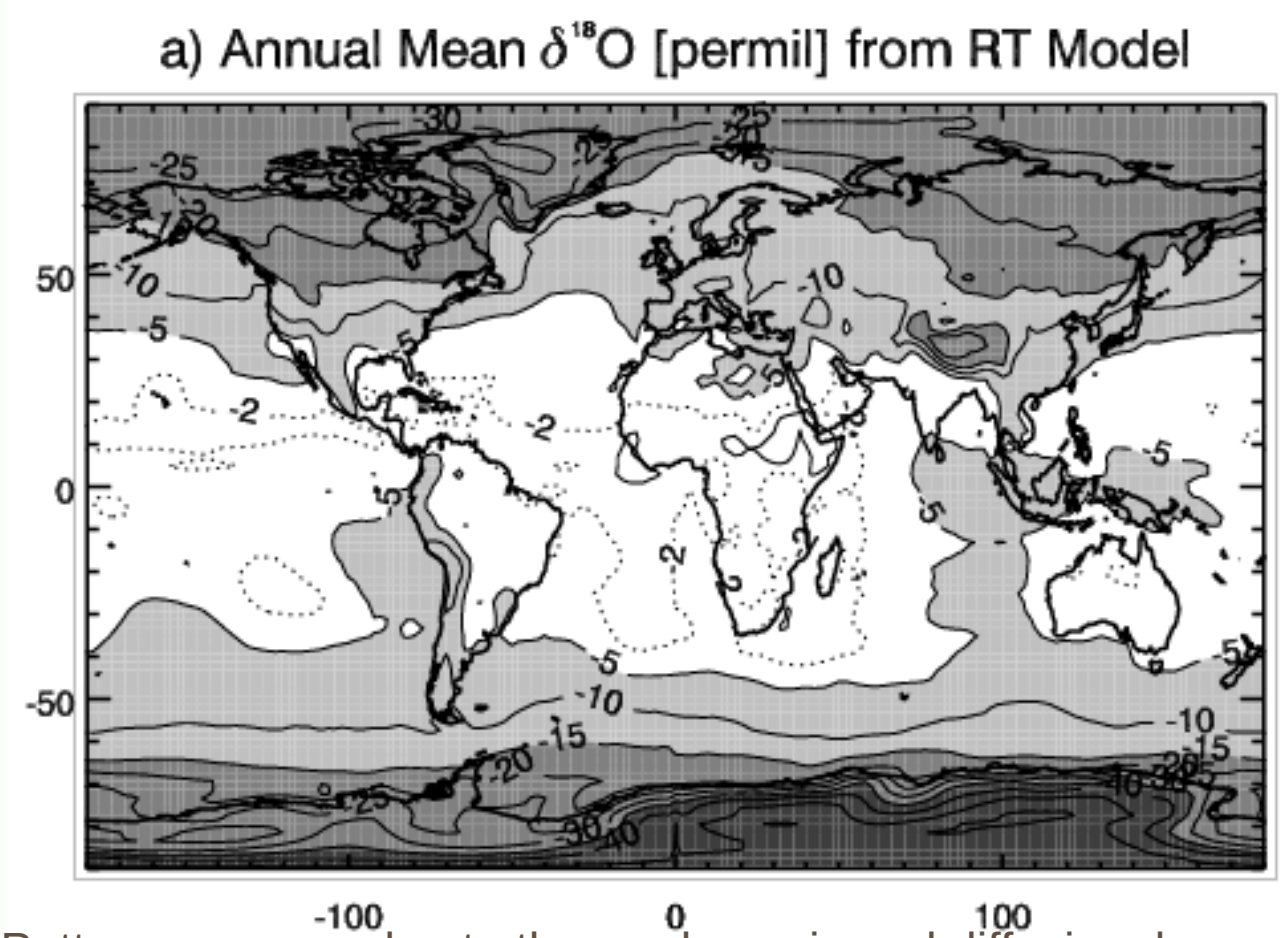
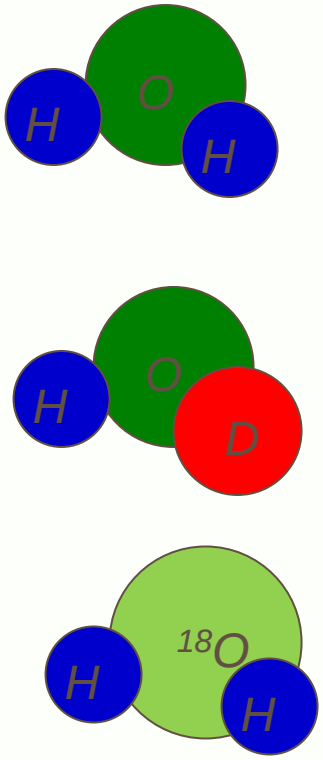
Isotope ratios in precipitation





Pattern emerges due to thermodynamic and diffusional differences during phase change and transport.

Nik Buenning, thesis 2011

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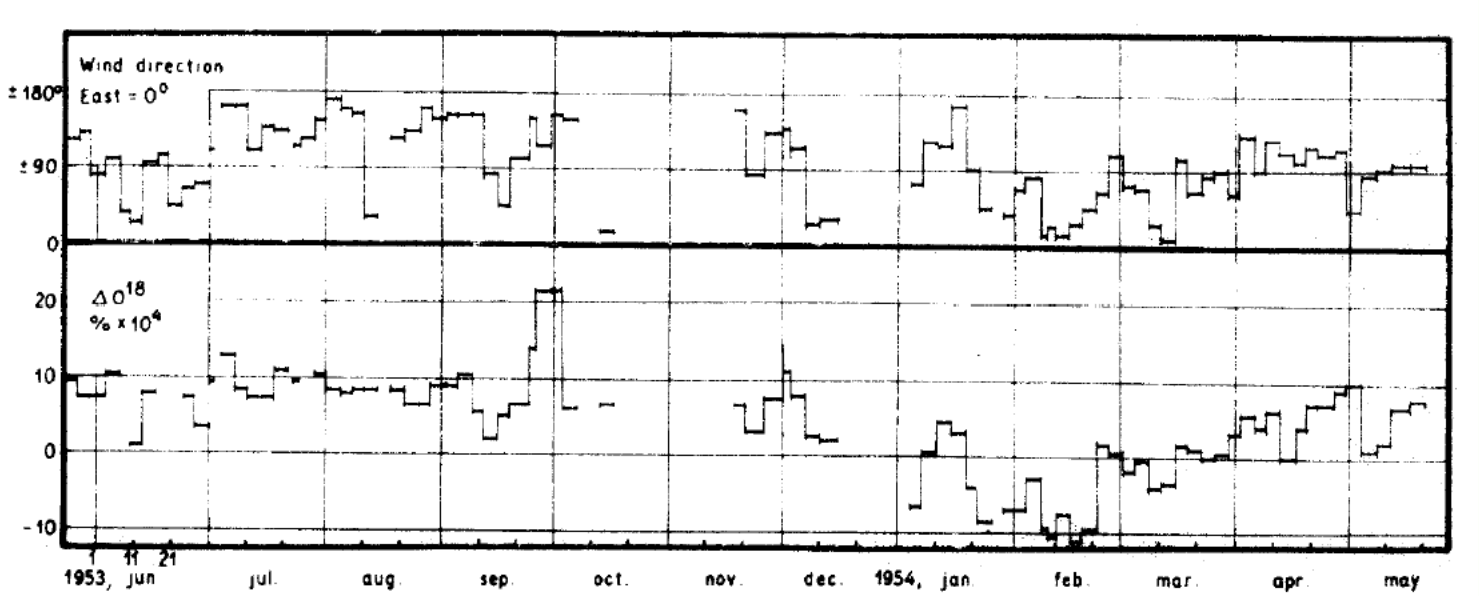

Fig. 2. In the lower part is shown deviations from the Danish standard of the O^{18}-abundance in samples of water vapour collected in 3 to 4 day periods. In the upper part for the same periods is shown the average deviation of the wind from the east point direction.

- Science from rain water samples in a back yard

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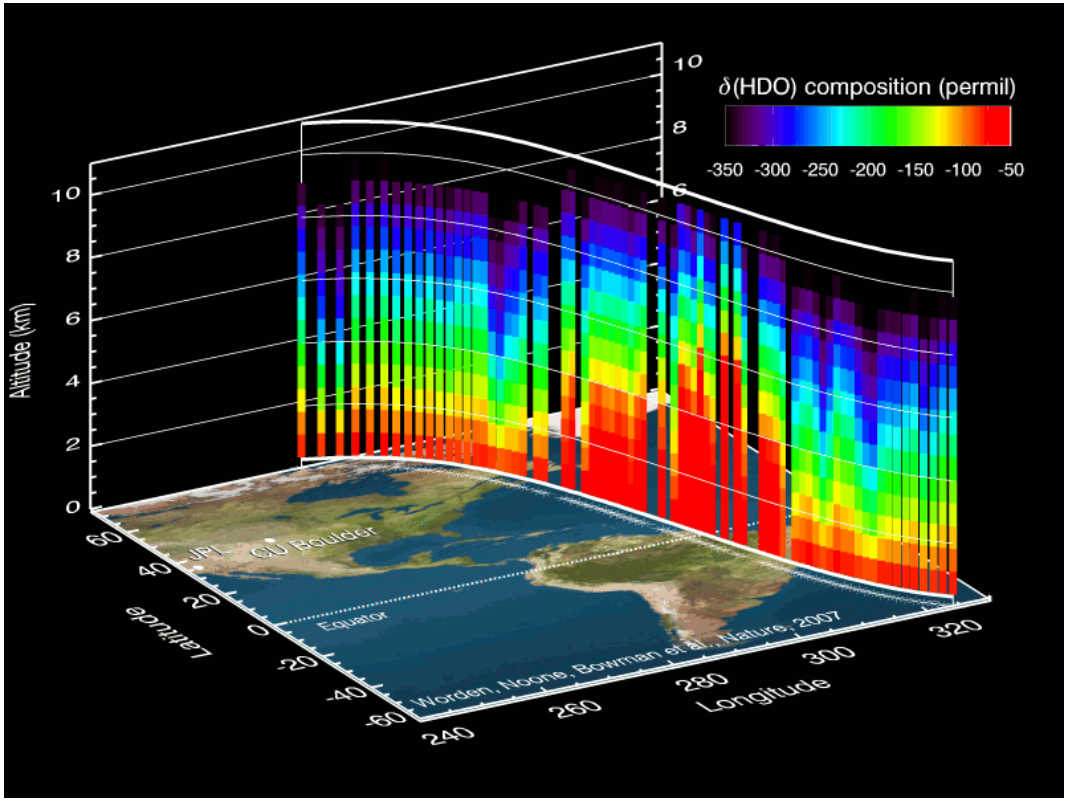
Enter Aura and TES

Joint retrieval of HDO/H_2O to obtain precise estimate of isotope ***ratio***



~10 km hoz. resolution,
~200 km sampling,
~ 2 d.o.f. in vertical

Worden, Bowman, Noone, et al. (2006)

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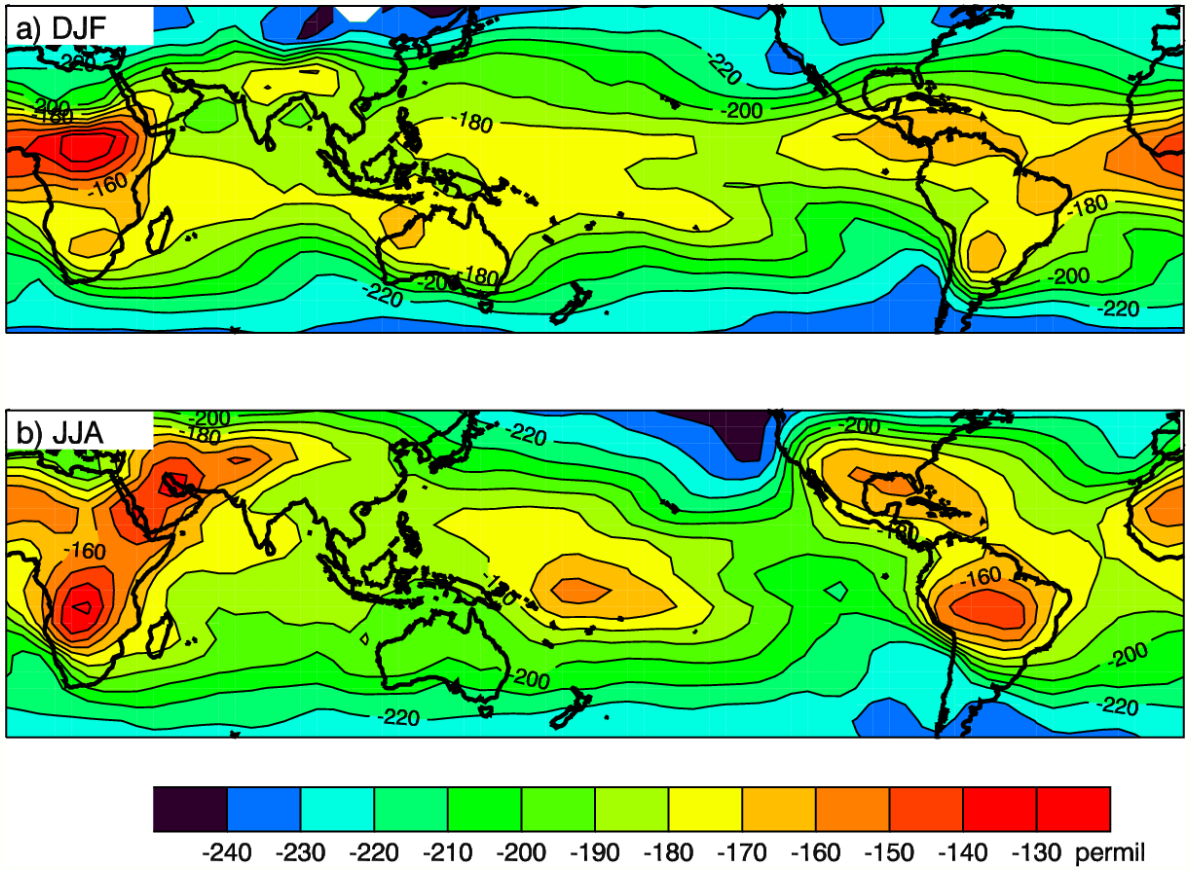
TES dD climatology (850-500 hPa)



December 2004 – August 2008

Noone 2012, Brown et al., 2011,, Helliker and Noone 2010, Noone 2012, Brown et al., 2008, Worden et al., 2007, Worden 2006, Lee et al., 2011, Field et al., 2012; Risi et al., 2012ab, 2013, …

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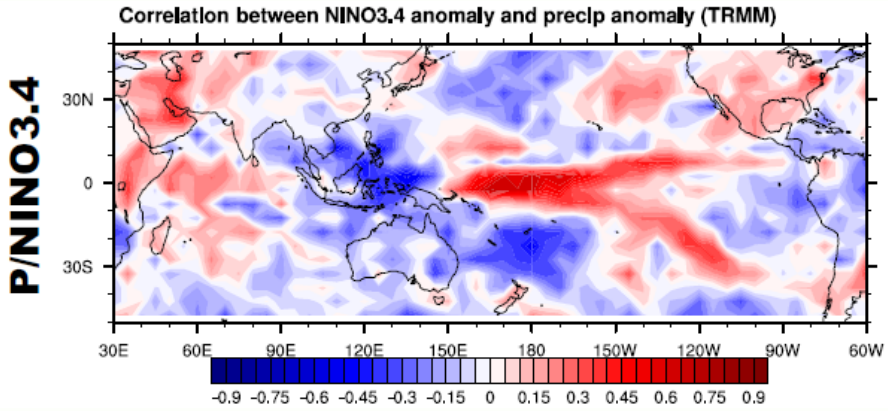
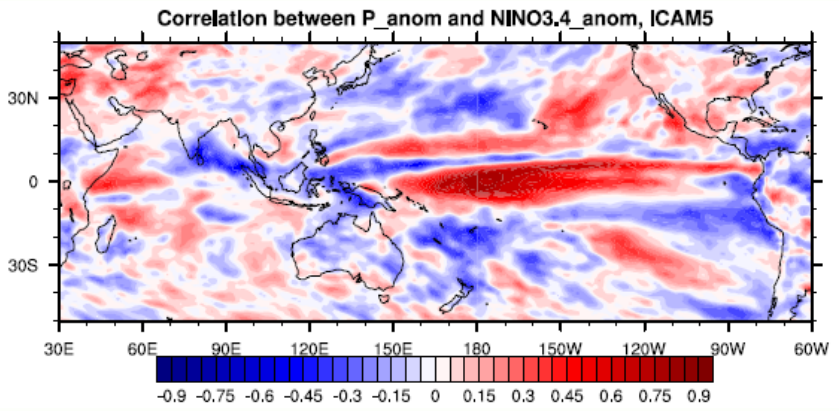
ENSO variability in the mid-troposphere





Describes manner in which water vapor transport changes with ENSO.

(Also, climate models broadly capture many features)

Isotopic version of NCAR climate model

Courtesy Bronwen Konecky and Jesse Nusbaumer

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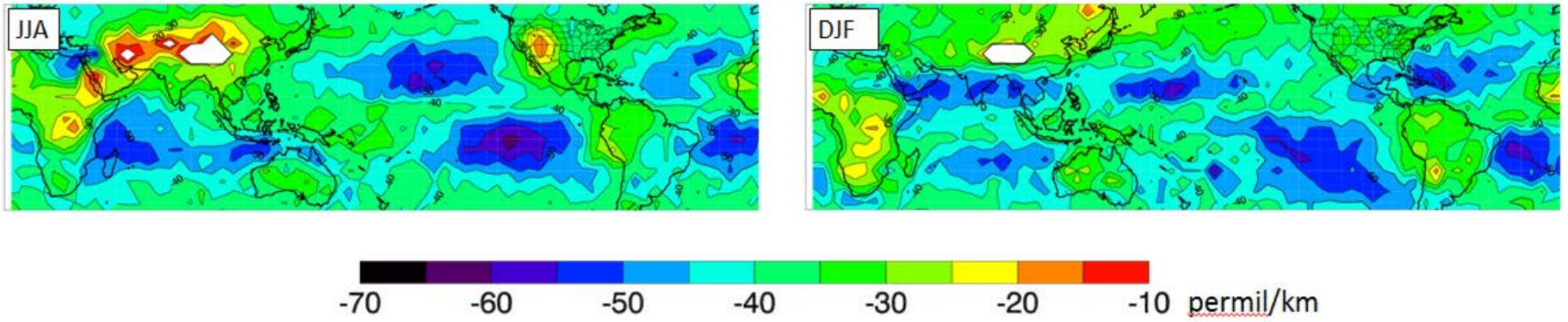
Isotope variation with height



Not well explained by simple theory
(i.e., need a better model)

Clearly contains useful geographical information

Water balance controlled by difference processes in different places.

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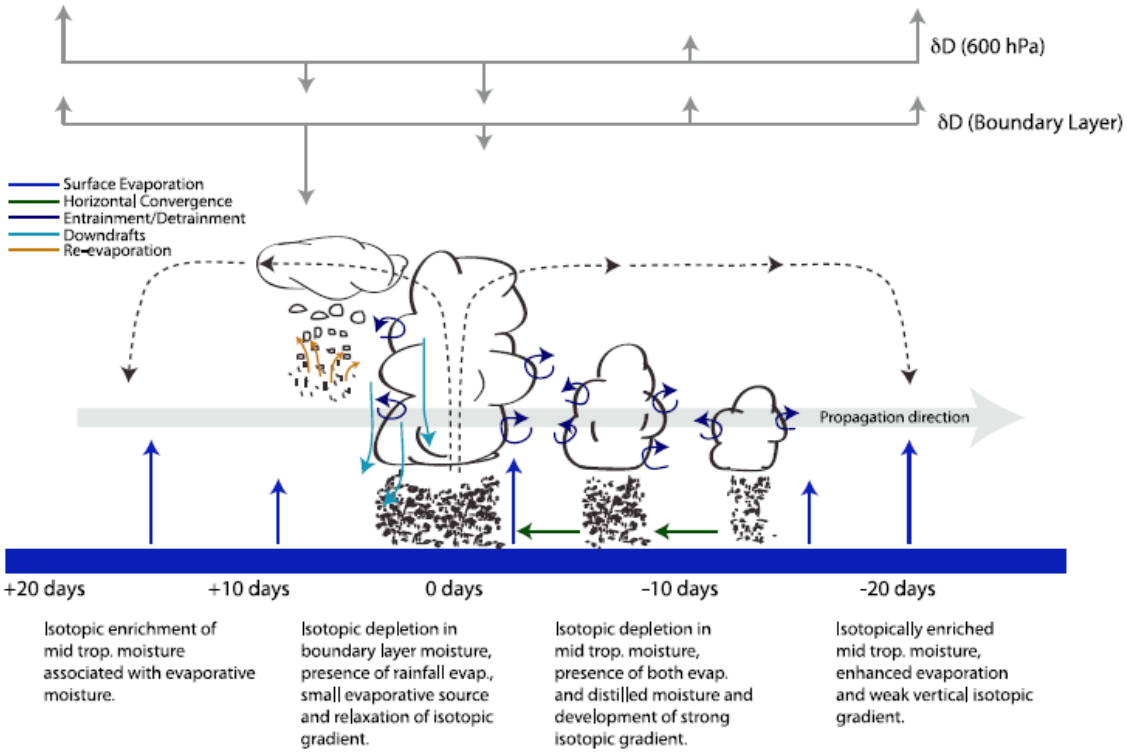
Mechanisms in the water cycle

Origin of water matters

Cloud physics also matters… probably…



Relative role of latent heating and moistening at the onset of the MJO

(Berkelhammer et al, 2012)

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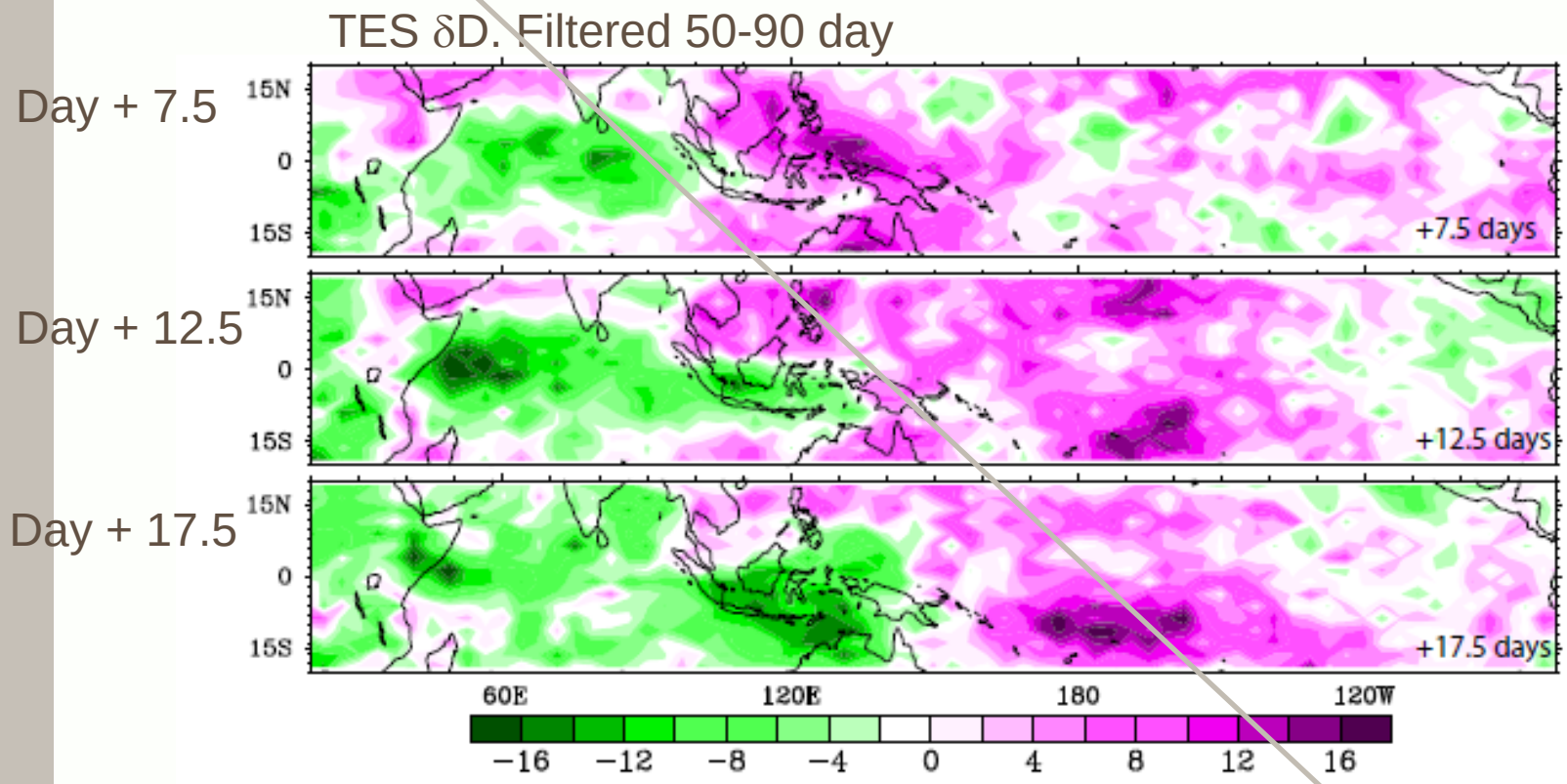
Changes in water "type" during the MJO



Links convection, ocean surface, large scale atmospheric dynamics
Assume either coupling not well resolved, ***or processes wrong behavior***

Berkelhammer et al., 2012

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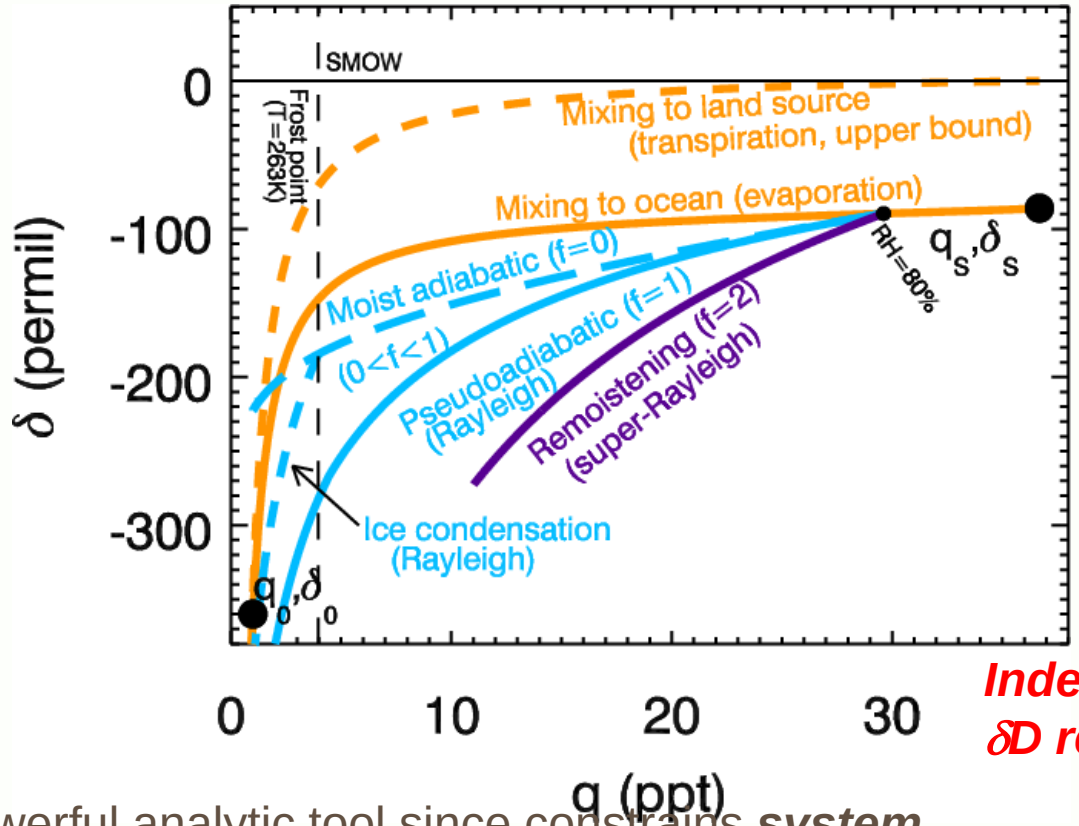
Framework for interpreting HDO



(Noone, 2012)

"6 easy pieces"

Independent information with δD relative to H_2O

Very powerful analytic tool since constrains ***system***

Two things to worry about:

1) What is source composition? (end members, balance of sources)
2) What is *slope*? (rainfall efficiency, type of cloud)

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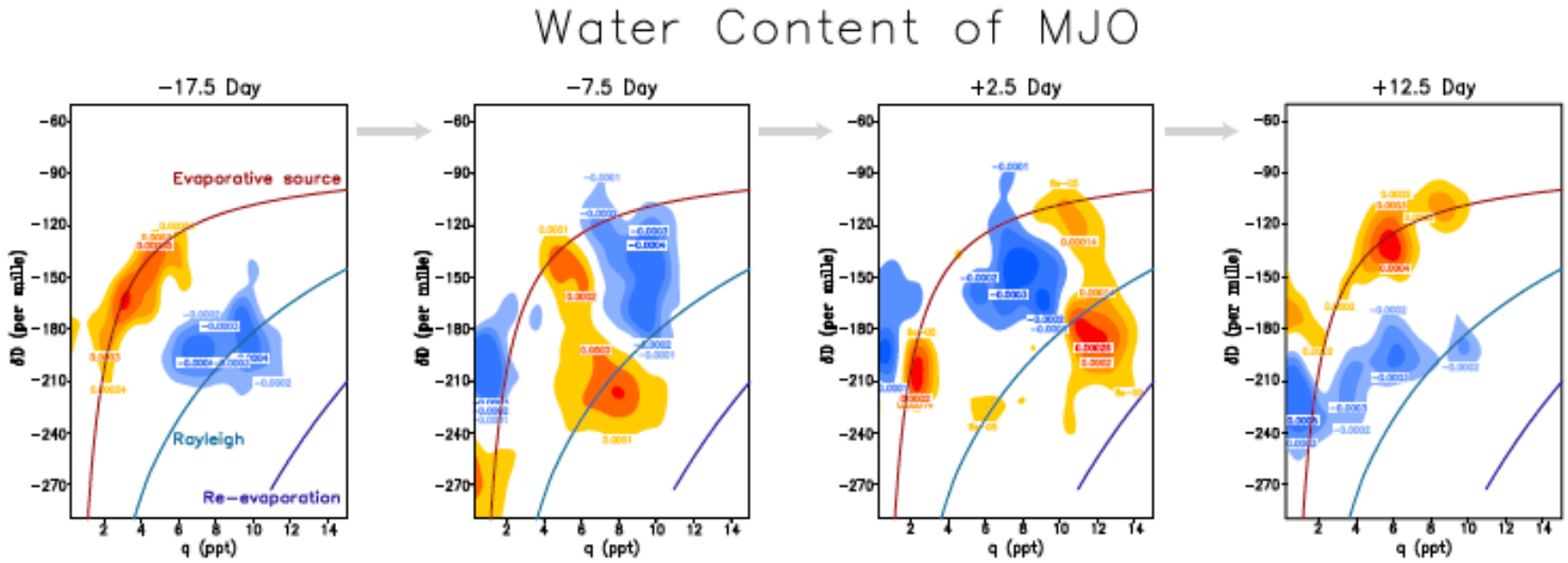
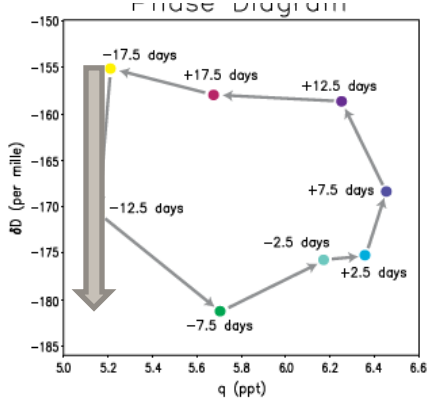
Sequence of processes in the MJO



Isotopic composition decreases, but ***H_2O*** stays about the same.
Change in "which water" is a pre-condition



Models (one) broadly fail to capture the extent of this dynamic. HDO/H_2O constrains ***how fluxes balance***.

(Berkelhammer et al., 2012; Kurita et al., 2011)

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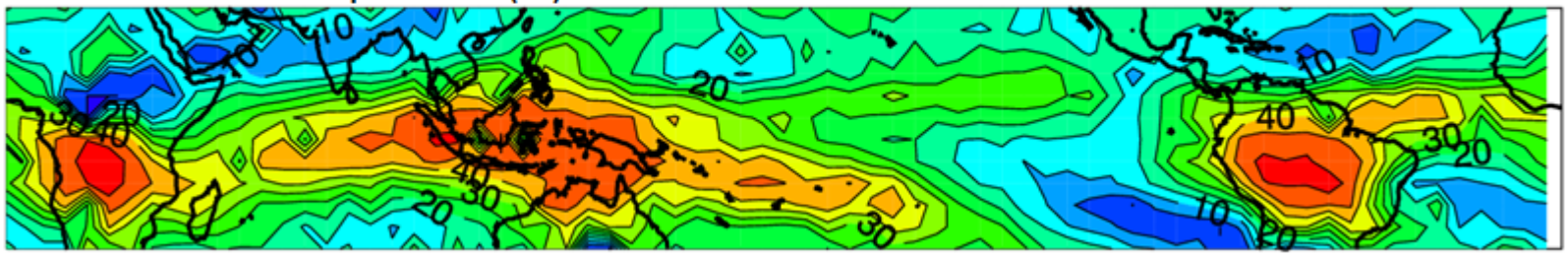
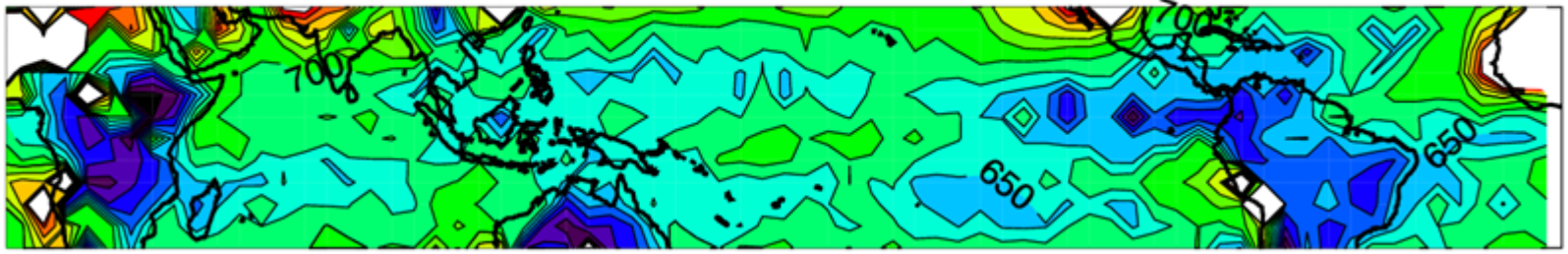
Rate of atmospheric moistening

Fraction of rain evaporated (%)



Pressure of PBL/mixed layer top (hPa)



Obtained a geochemical constraint on the parameter identified to be the strongest control on climate sensitivity.

Many climate models too weak, so true climate sensitivity might optimistically low.

Noone, in prep, 2014

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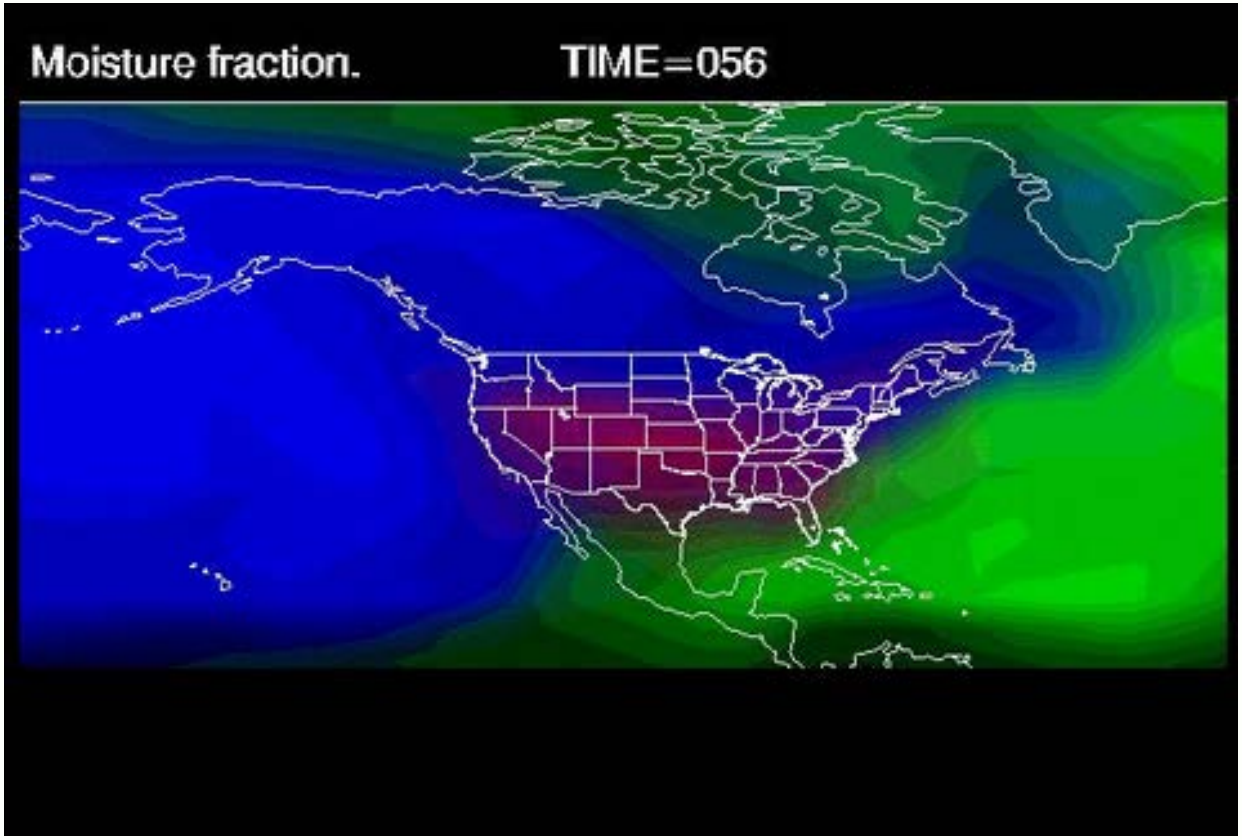
Water movement in the atmosphere



Water transport in NCAR Climate model

Jesse Nusbaumer et al., AGU and in prep.

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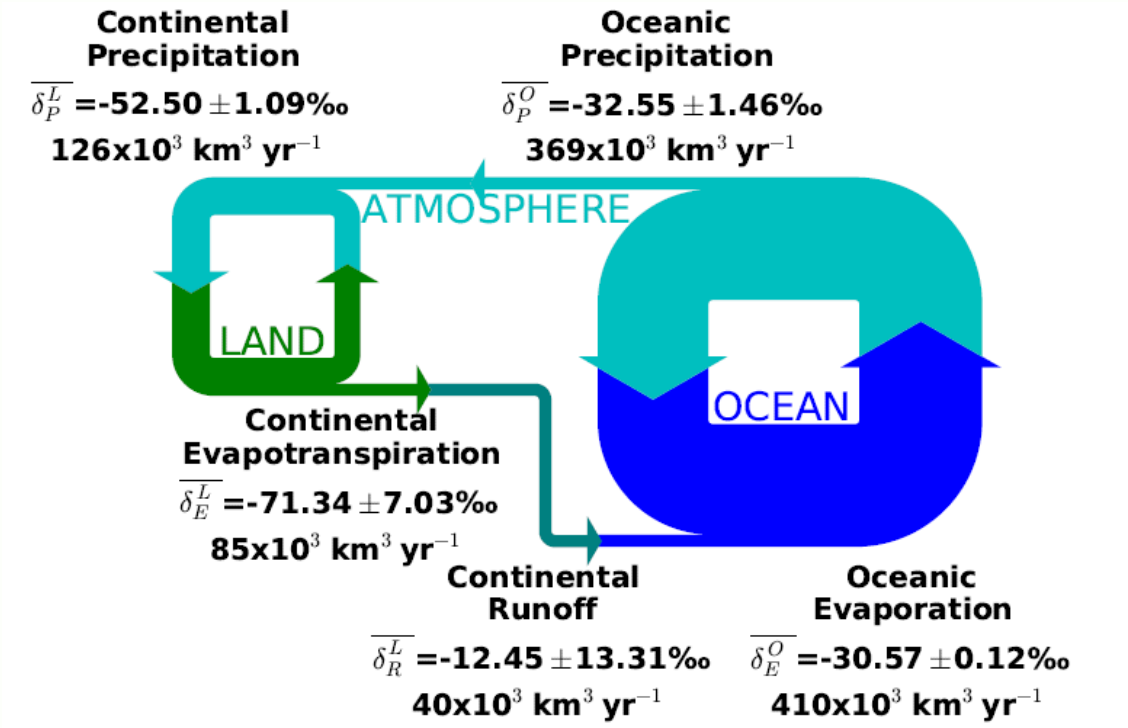
Global water balance: Land vs Ocean



Independent estimate of water budget

Result enables evaluation of what fraction of land water is E vs T

Steven Good and others, in prep

Conclusions and outlook

Accomplishments

- First continuous global dataset of water vapor isotope records
  (It is important that HDO was part of the operational mission)
- Science results on regional and global water balance
- Process studies on cycling mechanisms
  (convective cloud/precipitation efficiency, rain evaporation, MJO and ENSO, climate sensitivity…)
- Critical test bed for climate models
  (water fluxes, clouds)

Outlook?

NASA is poised to continue a leading role in water cycle research and providing information to water managers.

AURA HDO has shown how ***local integrates with global*** water