Stable isotope constraints on post-condensation processes and precipitation efficiency during the March 5-7, 2016 atmospheric river event

Hari Mix

Sean Reilly, Andrew Martin and Gavin Cornwell

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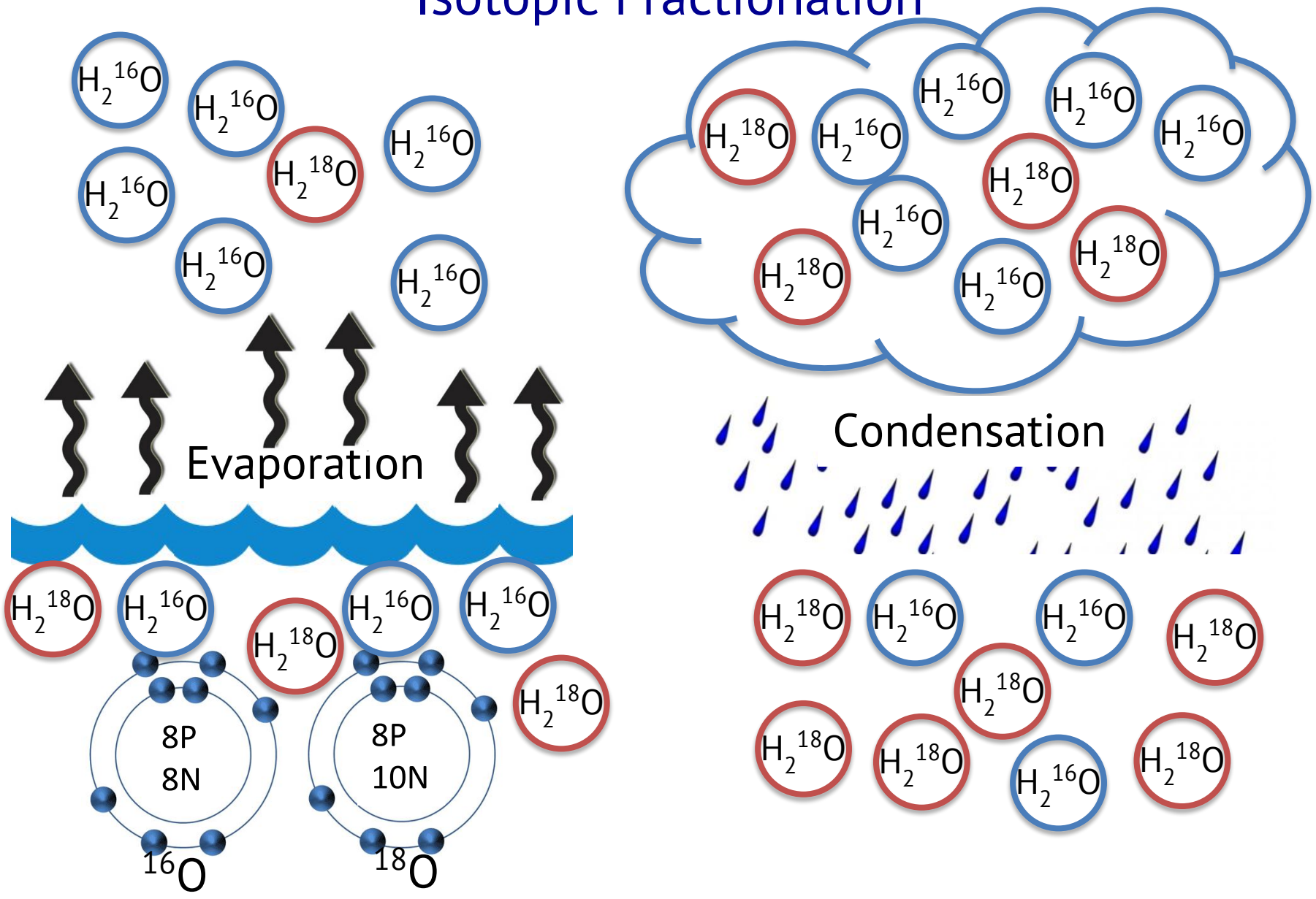
CW3E

At a glance:

- Stable isotopes as natural tracers in the hydrologic cycle
- Competing explanations for stable isotope time series in ARs
- Disentangling rainout and post-condensation processes in the March 5-7, 2016 AR

Many natural processes prefer one isotope over another
"Isotopic Fractionation"



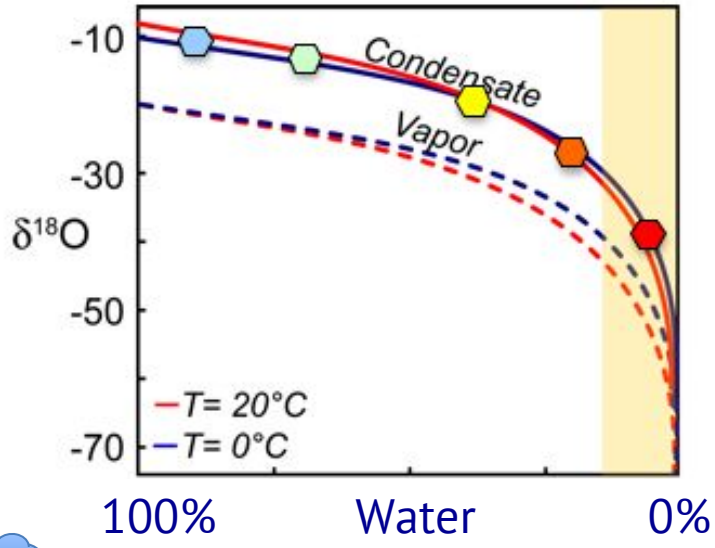
Isotope ratios record the progressive rainout of moisture: "Rayleigh distillation"

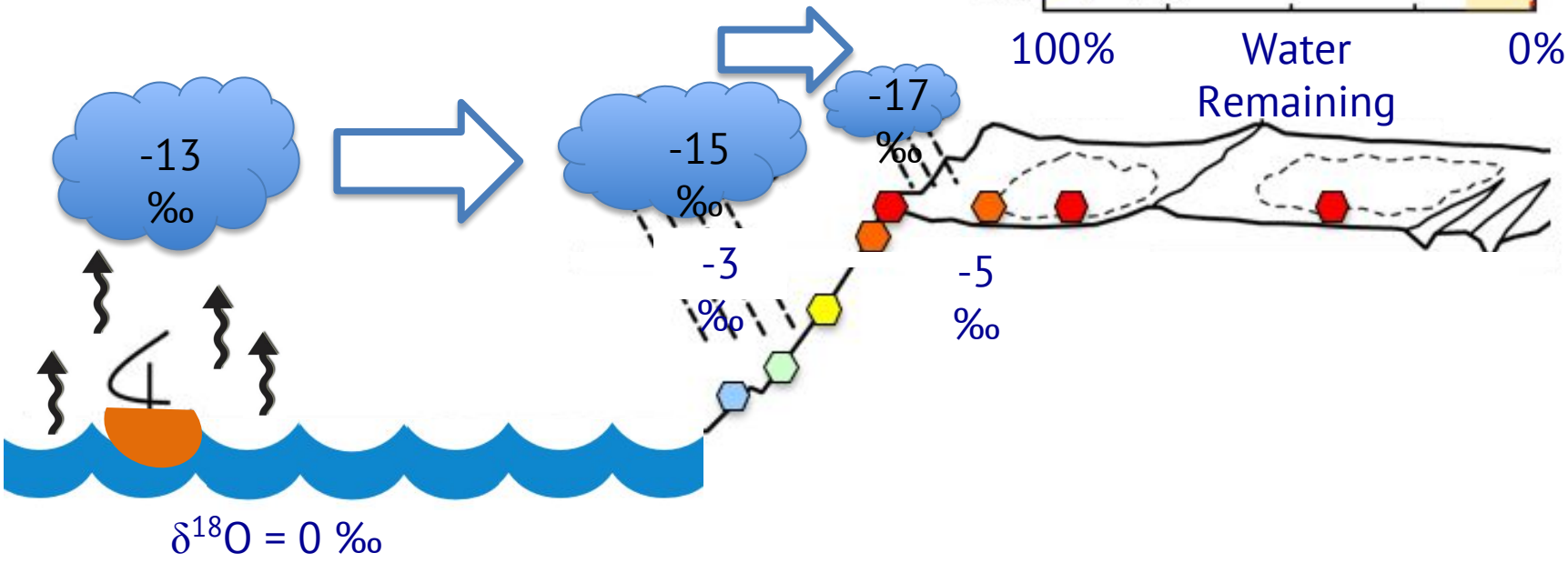
Absolute ratios are messy:

i.e. $^{18}O/^{16}O = 0.00217$

Delta Notation:

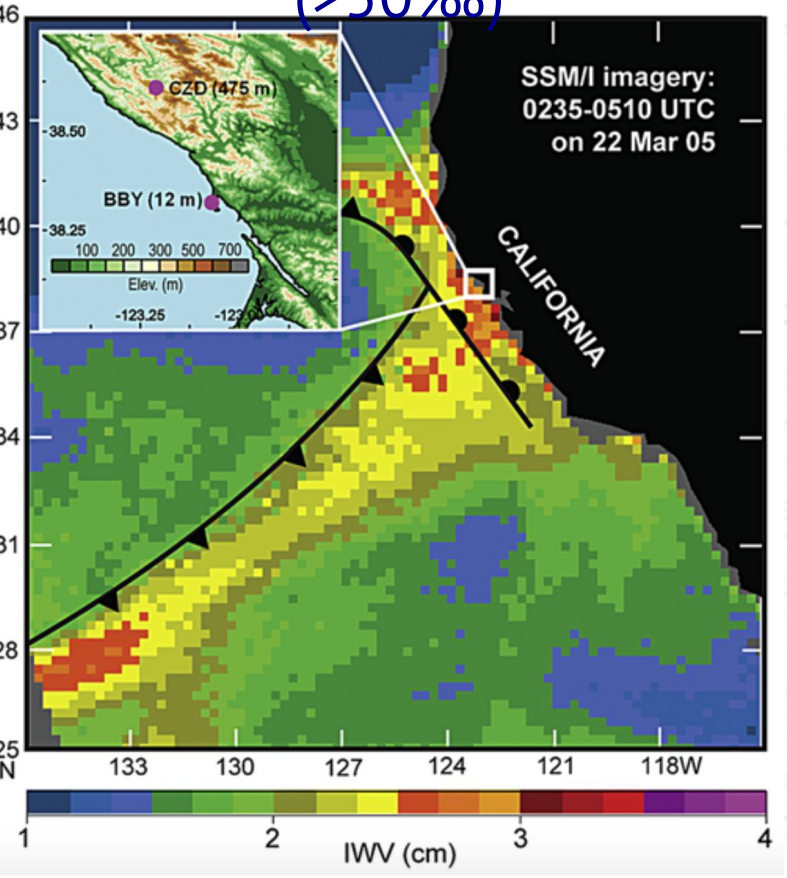
$$\delta^{18}O\ (‰) = \left[\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{ocean\ water}} - 1 \right] \cdot 1000$$

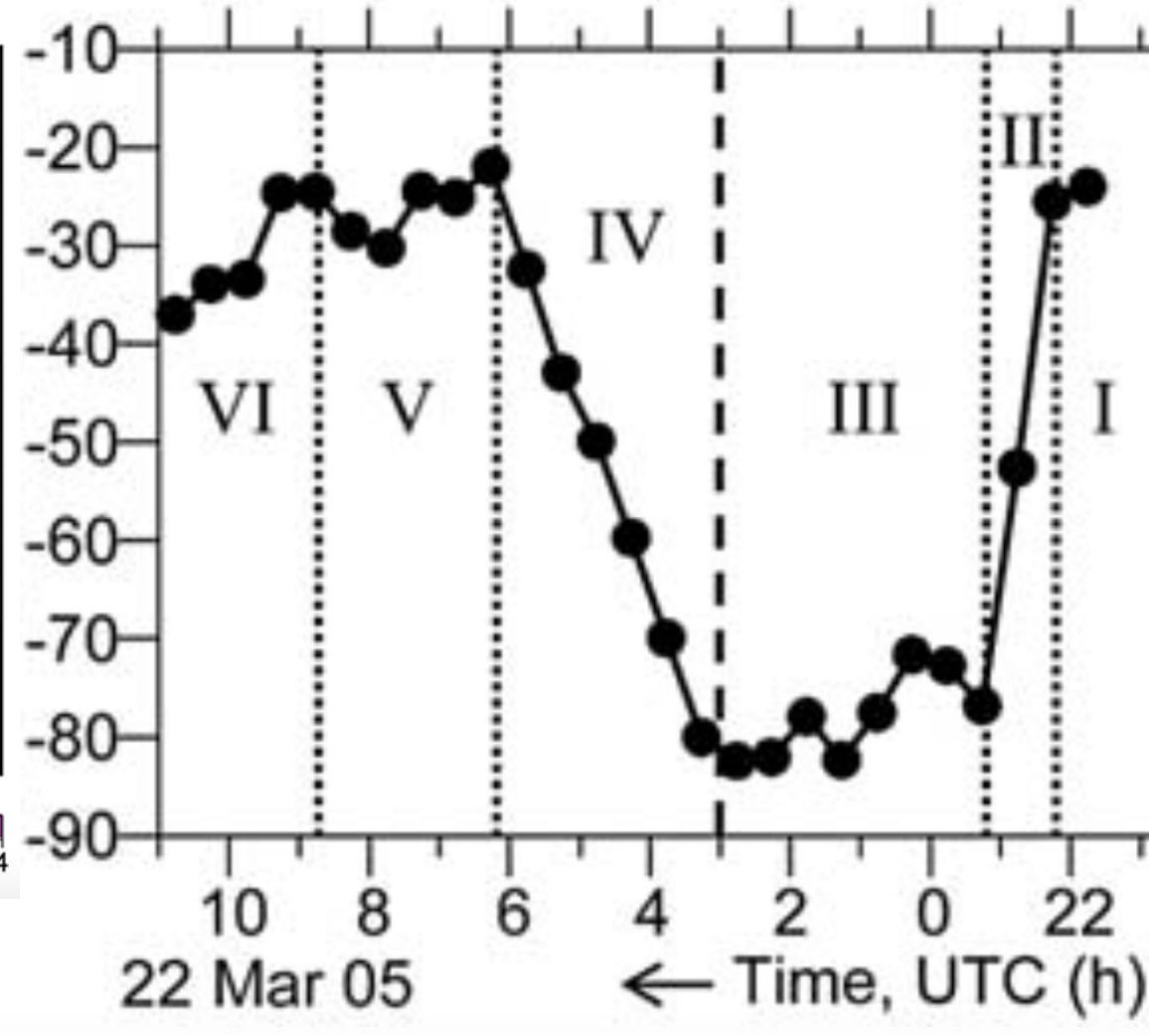




First study using stable isotopes was a small landfalling AR in 2005

δD decreases then increases dramatically (>50‰)





Coplen et al.,

Coplen argued V shape represents changing rainout efficiency

Warm, shallow precip, rainout approximately 20%

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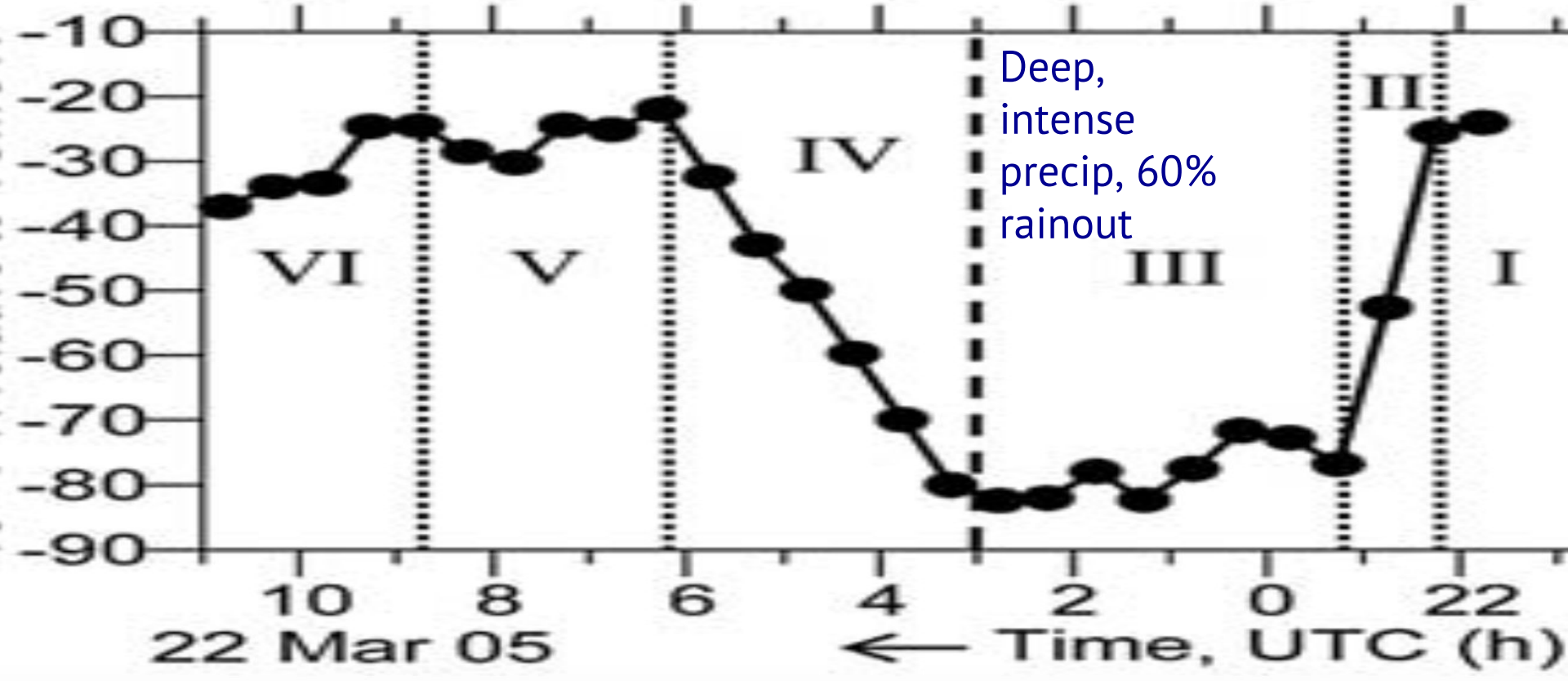
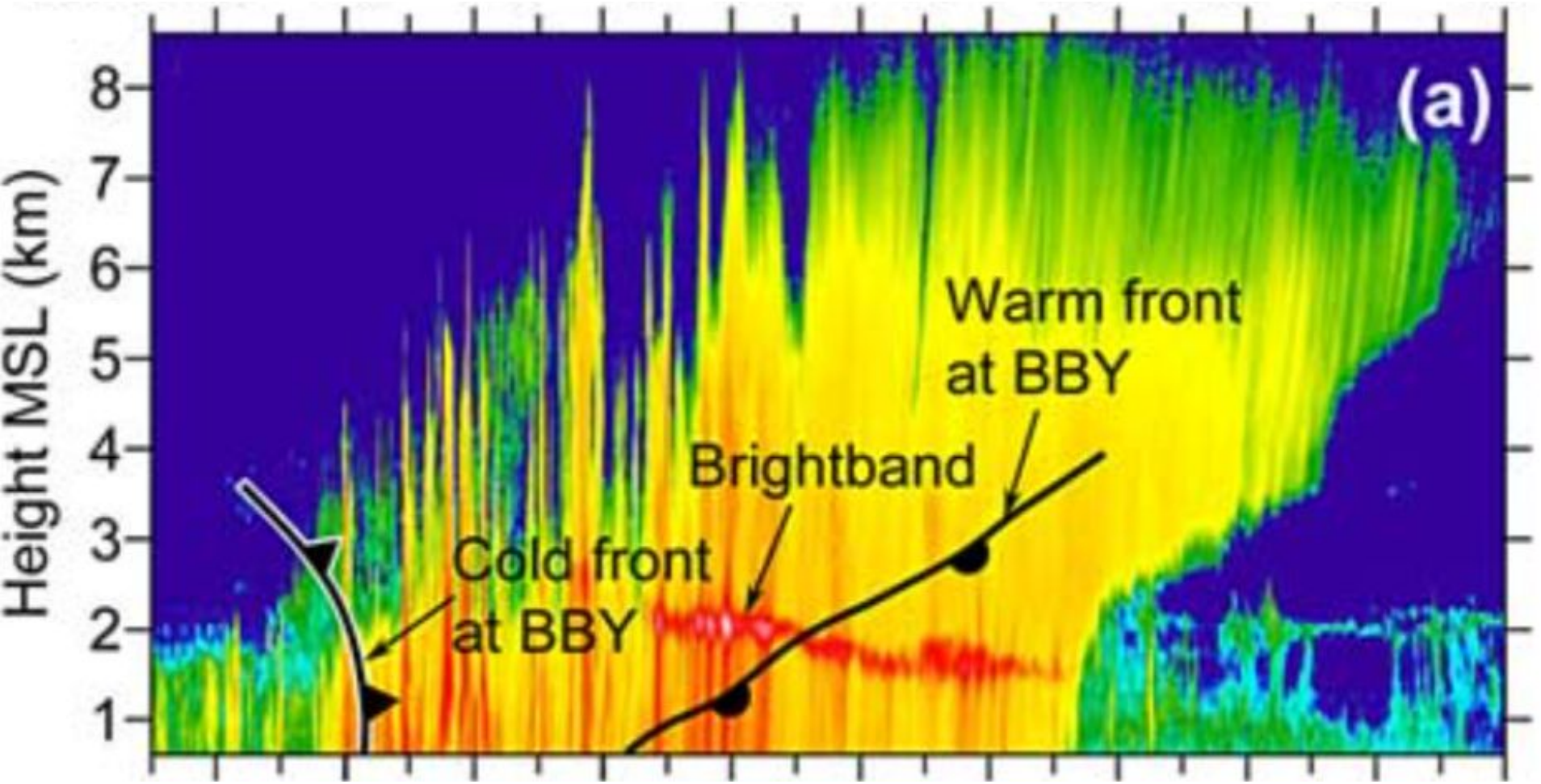


But this interpretation doesn't match meteorological structure of storm and ignores the potential role of post-condensation processes



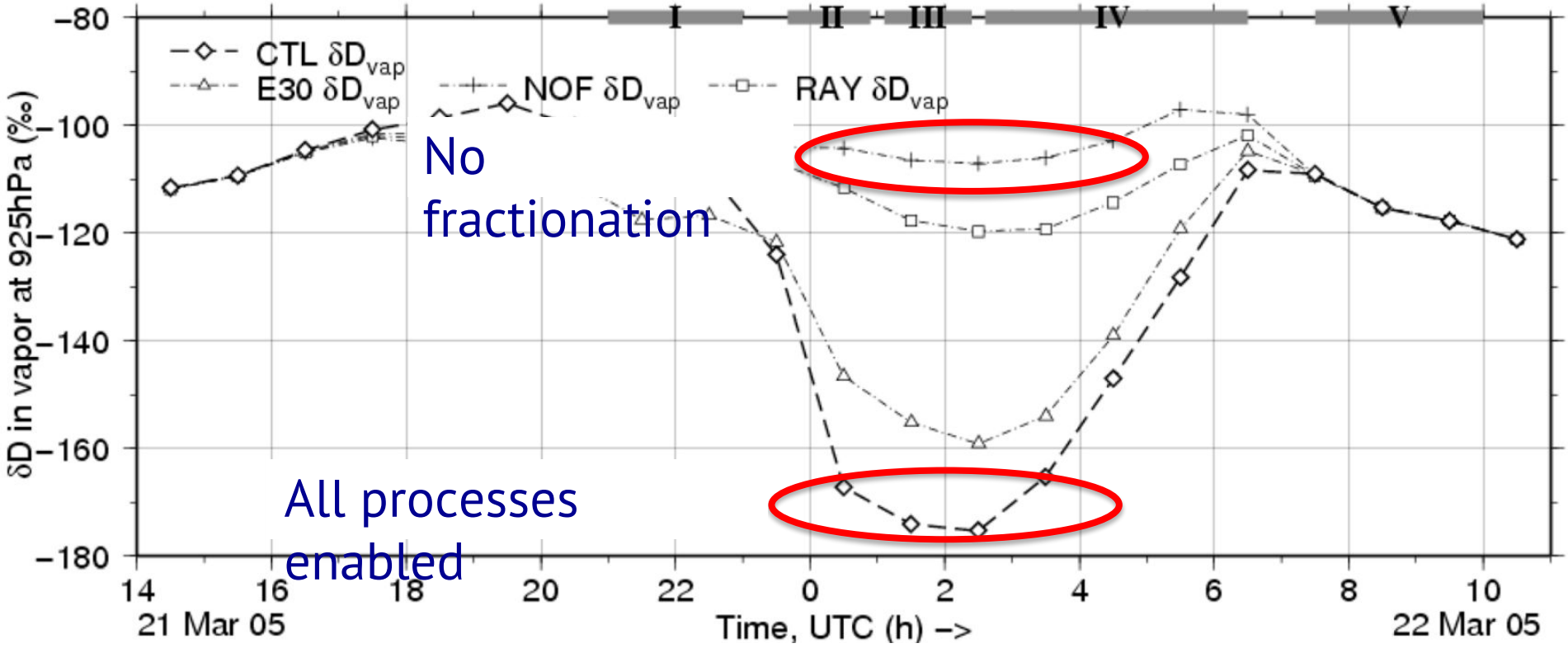
Below-cloud evaporation

- RH < 1
- Increases δprecip
- Usually lowers δvapor
- Decreases d-excess of precip and increases d-excess of vapor

Kinetic isotope exchange

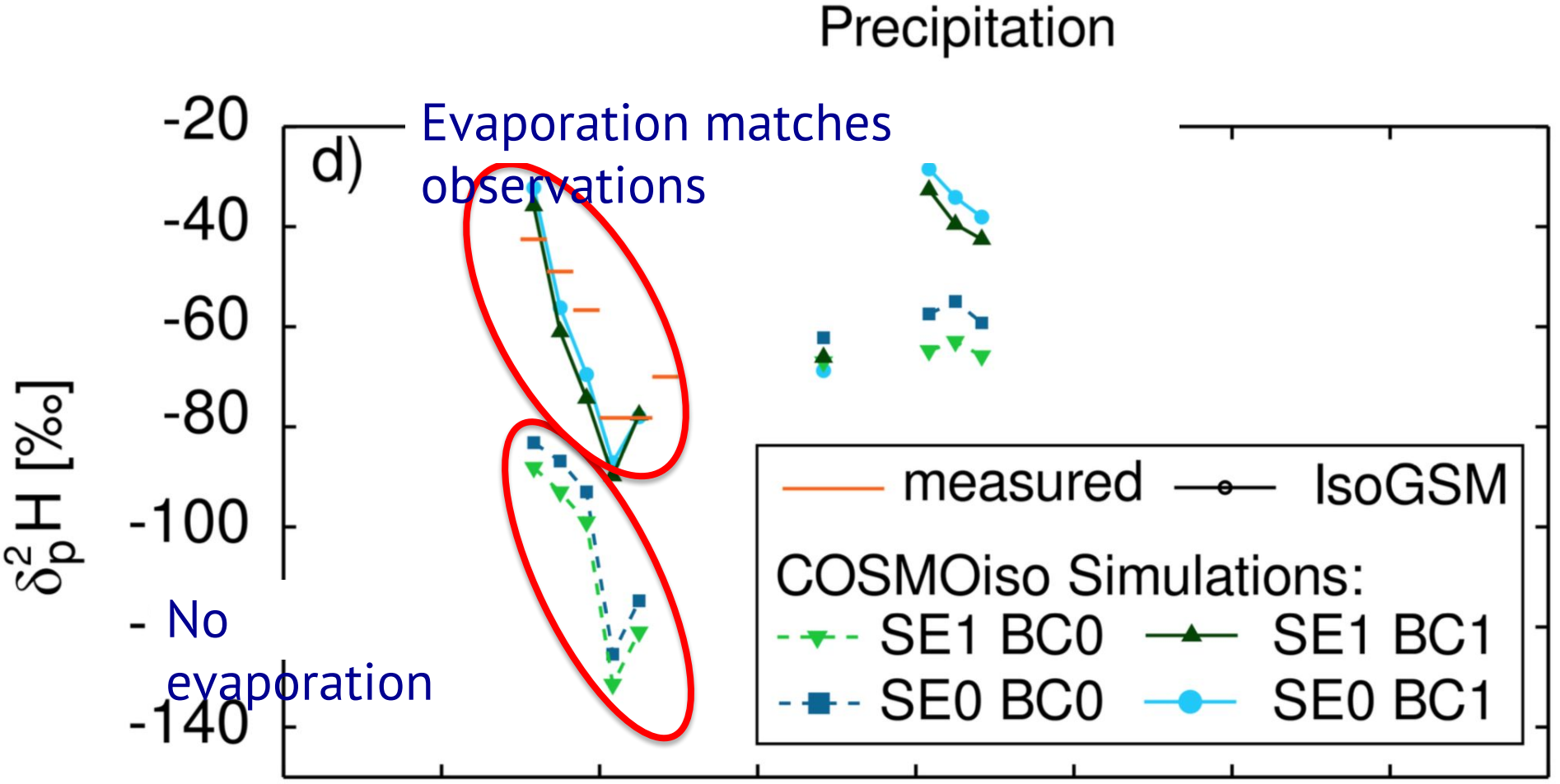
- RH ≈ 1
- δprecip approaches equilibrium with vapor
- Usually lowers δvapor

Yoshimura et al., (2010) revisited the 2005 AR with an isotope-tracking GCM



Yoshimura et al.,

Aemisegger et al., 2015: V shapes in European cold fronts linked to below-cloud evaporation



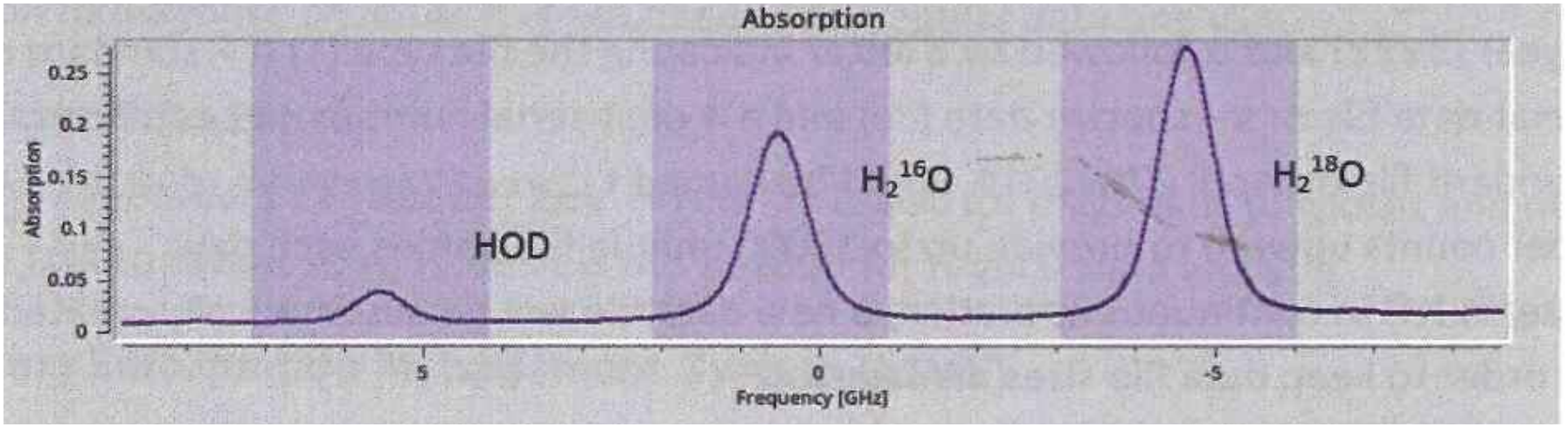
Potential mechanisms for V-shape: Which one is right?

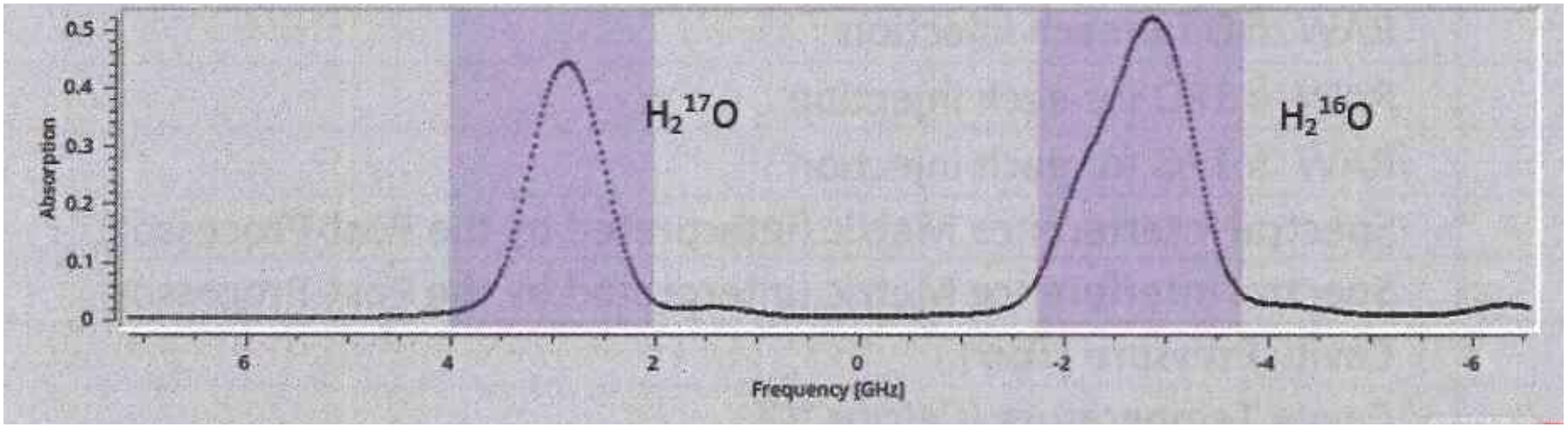
	Initial enrichment phase	Depletion phase	Rebound phase
Coplen et al., 2008	Warm shallow precip Low degree of rainout	Deeper cloud, seeder-feeder mechanism and more efficient rainout	Warm, shallow locally-generated orographic rain
Yoshimura et al., 2010	Below-cloud evaporation	Below-cloud evaporation shuts off	Warm shallow moisture advects in from AR core

We sampled hourly precip and vapor in ARs at a network of sites:

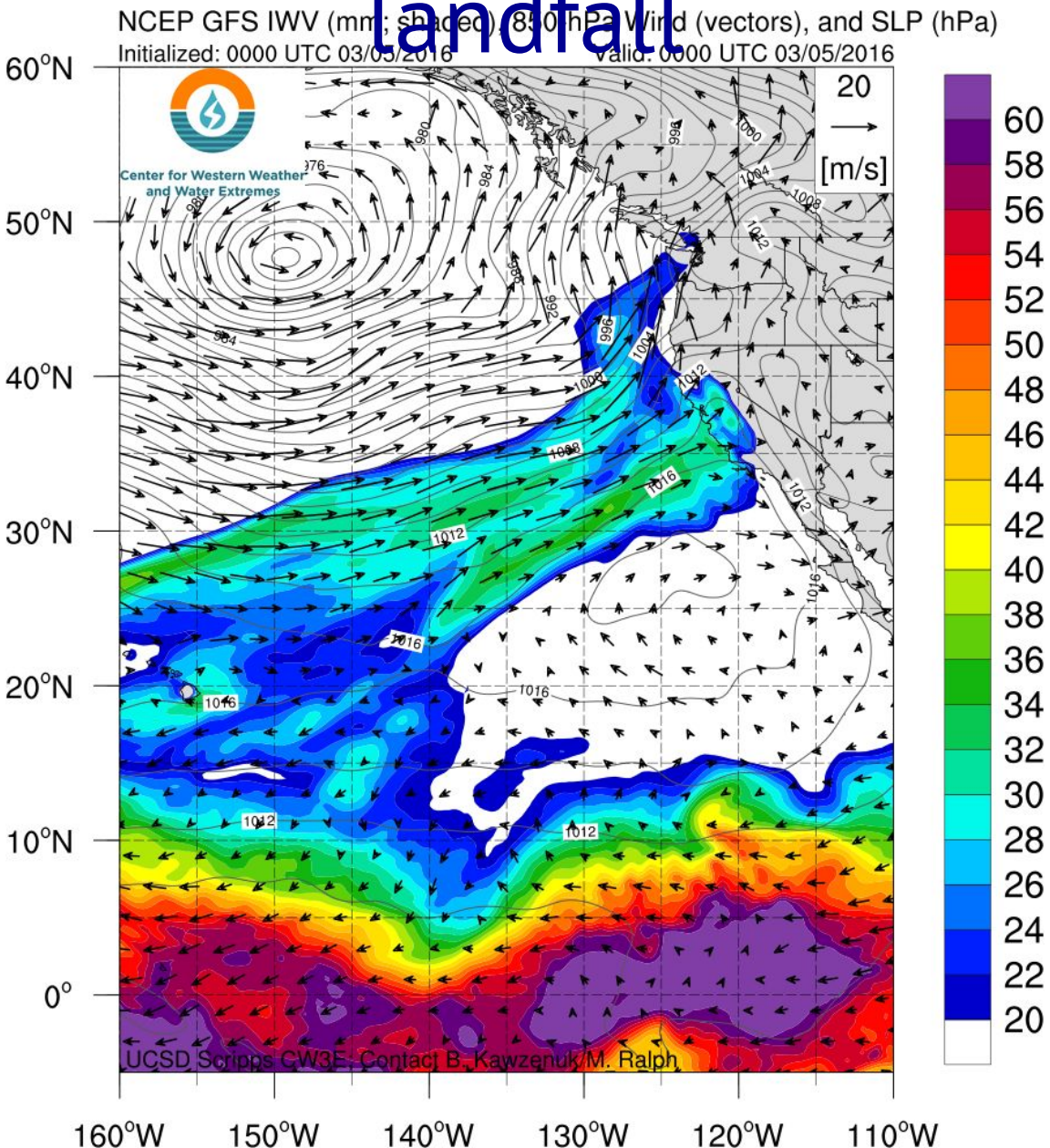

Cloud
Condensa
Nuclei
Counter

Laser absorption spectroscopy allows us to measure isotope composition of water and water vapor

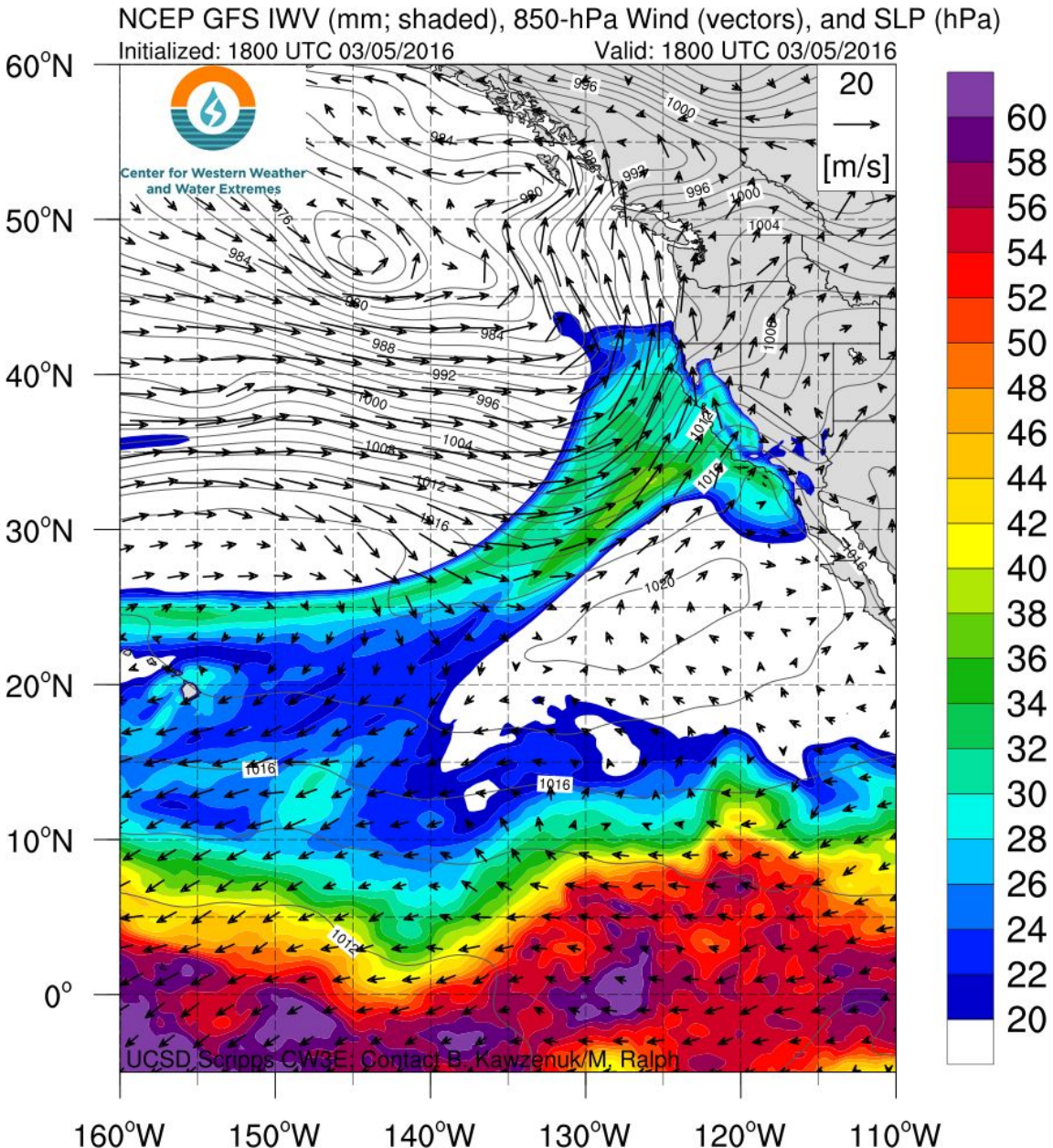




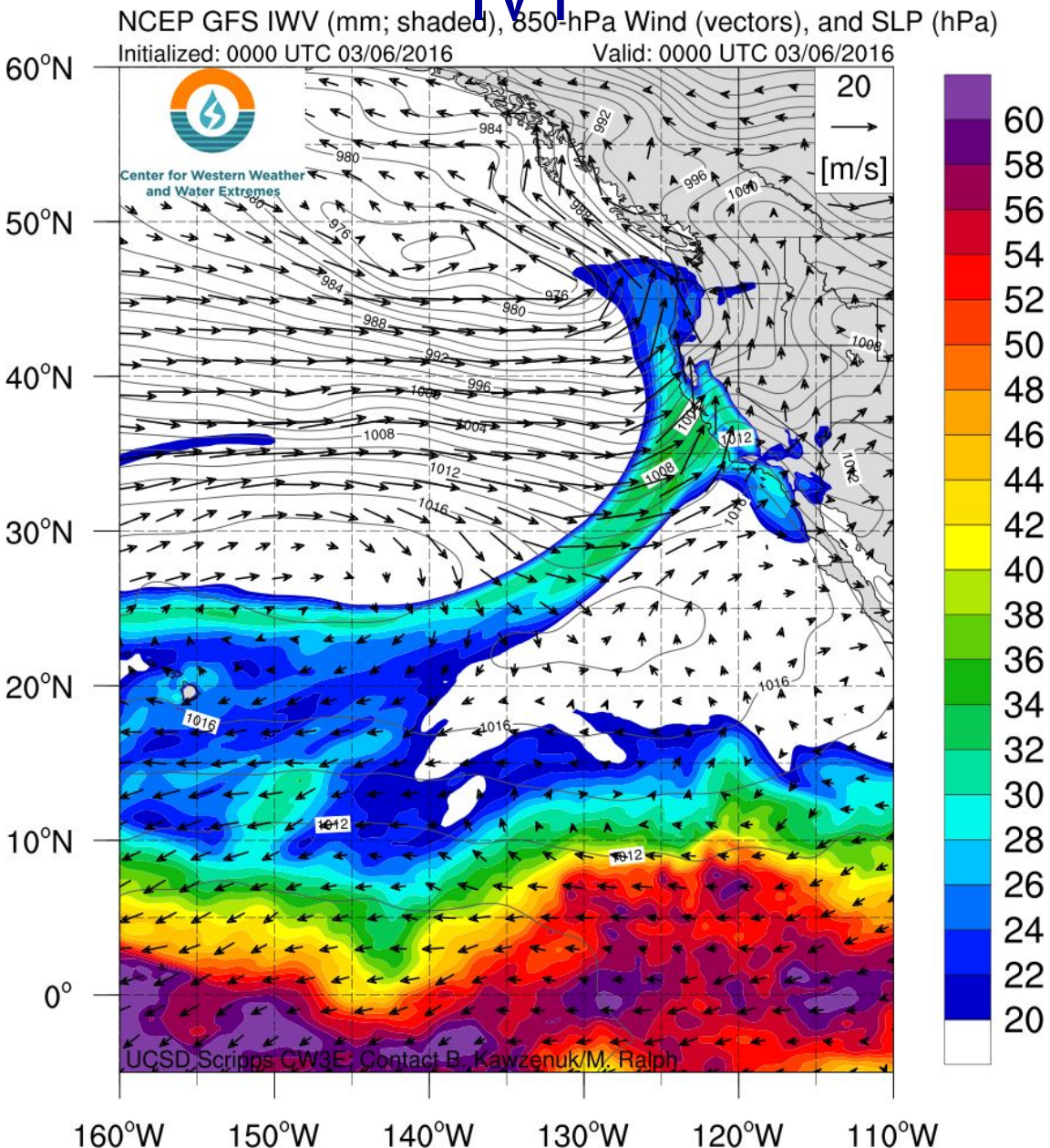
0 UTC 3/5/16: A strong AR makes landfall



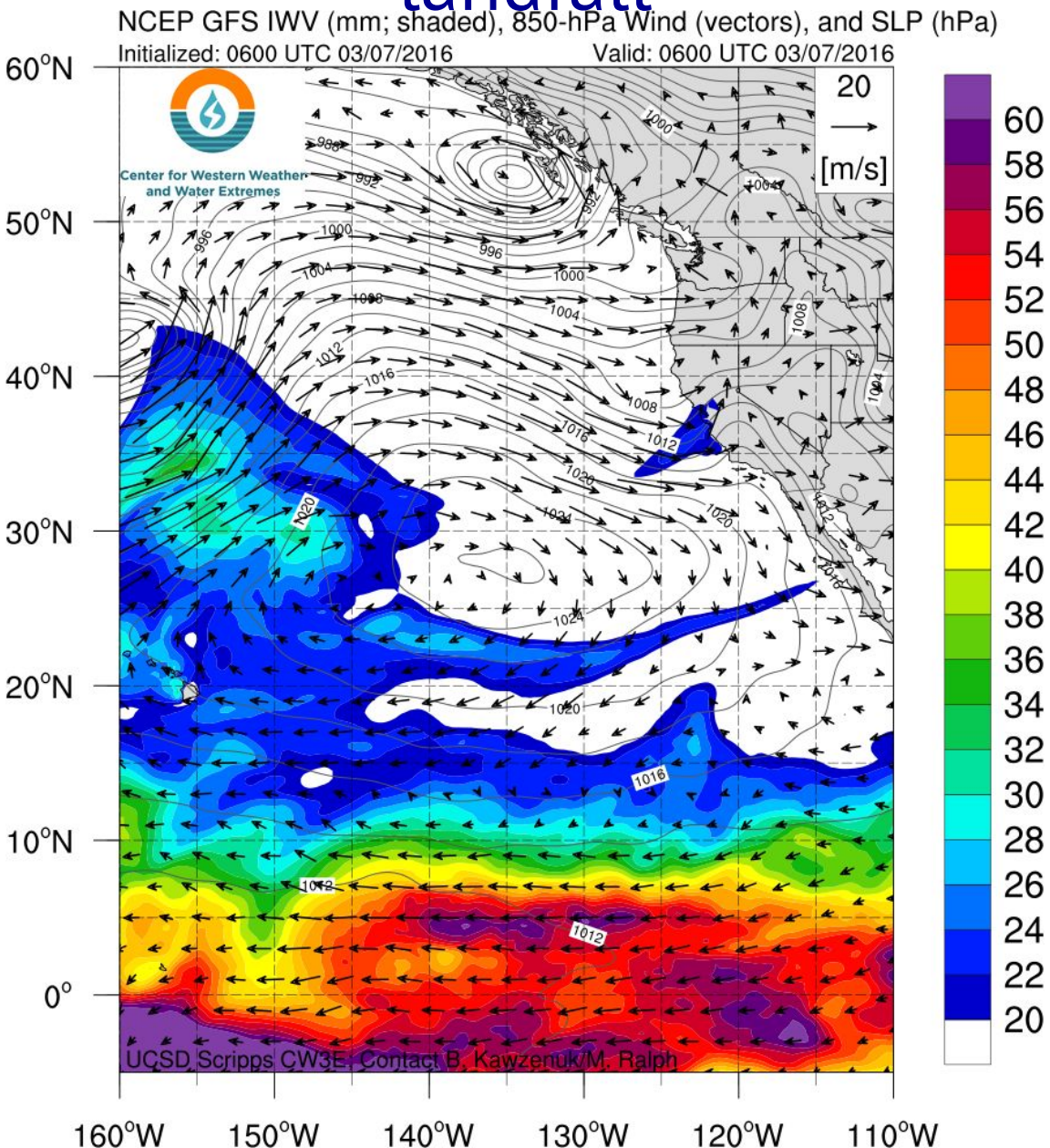
1800 UTC 3/5/16: 500 kg/m/s IVT



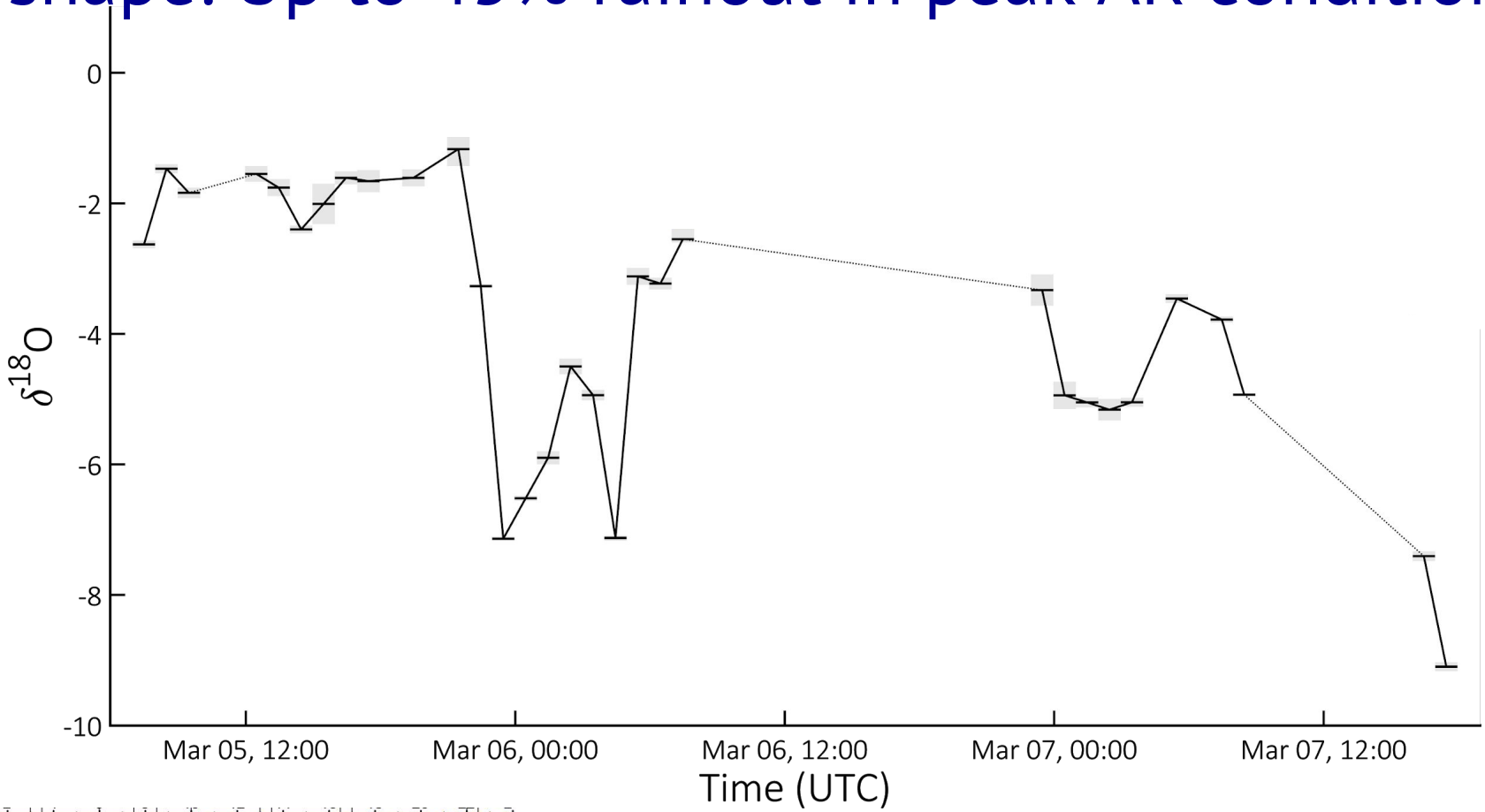
0 UTC 3/6/16: Peak AR conditions, 956 kg/m/s IVT

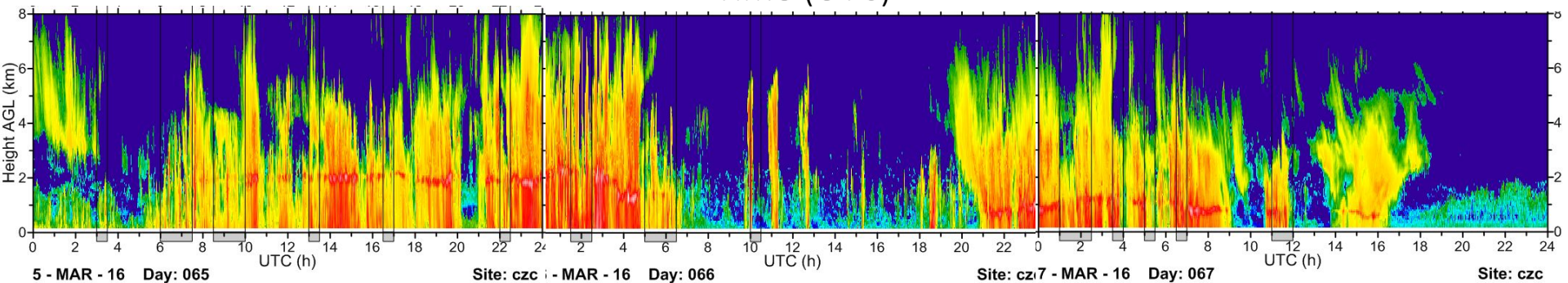


0600 UTC 3/7/16: A secondary system makes landfall

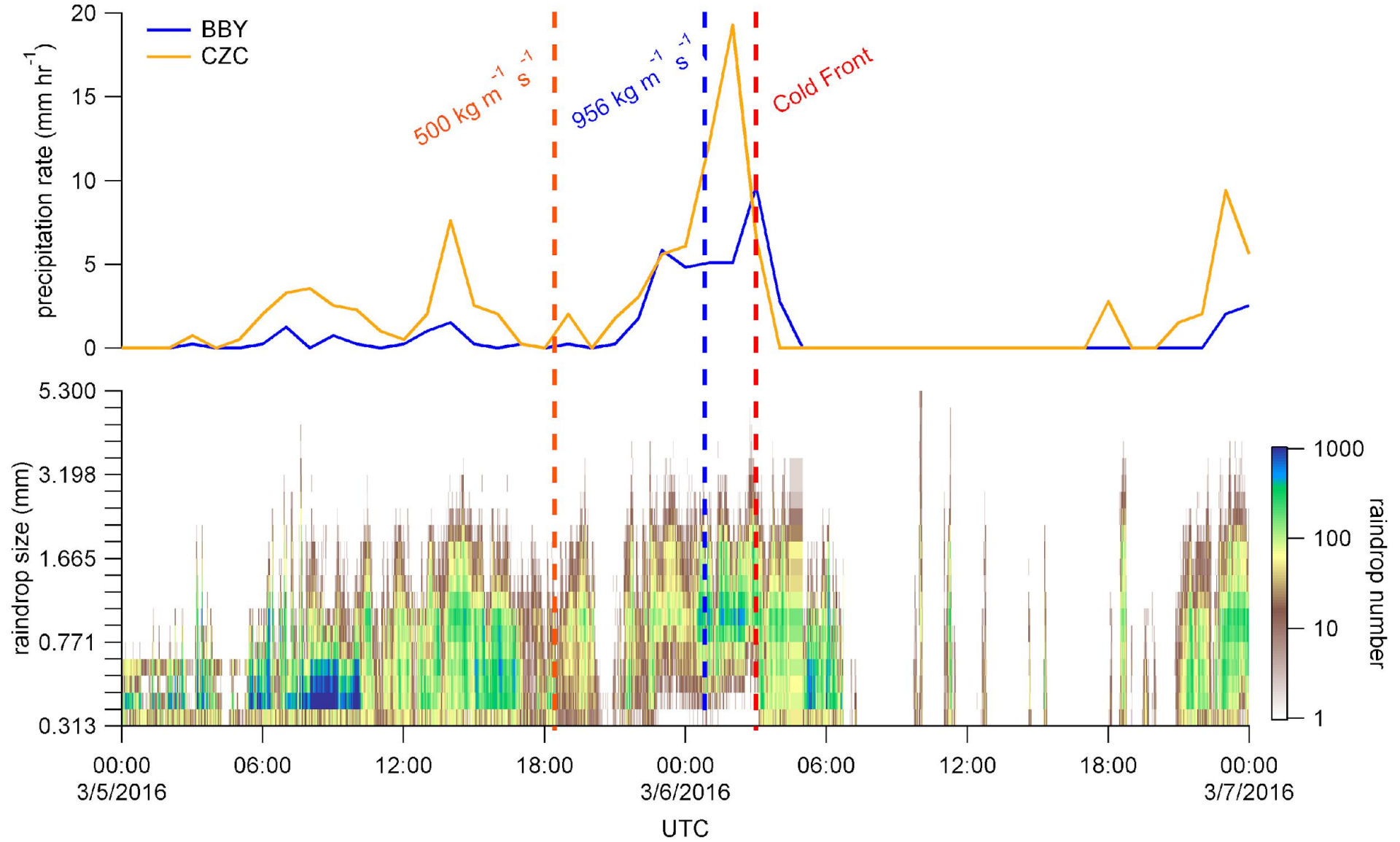


1. March 5-7 AR event exhibits an asymmetrical V shape: Up to 45% rainout in peak AR conditions

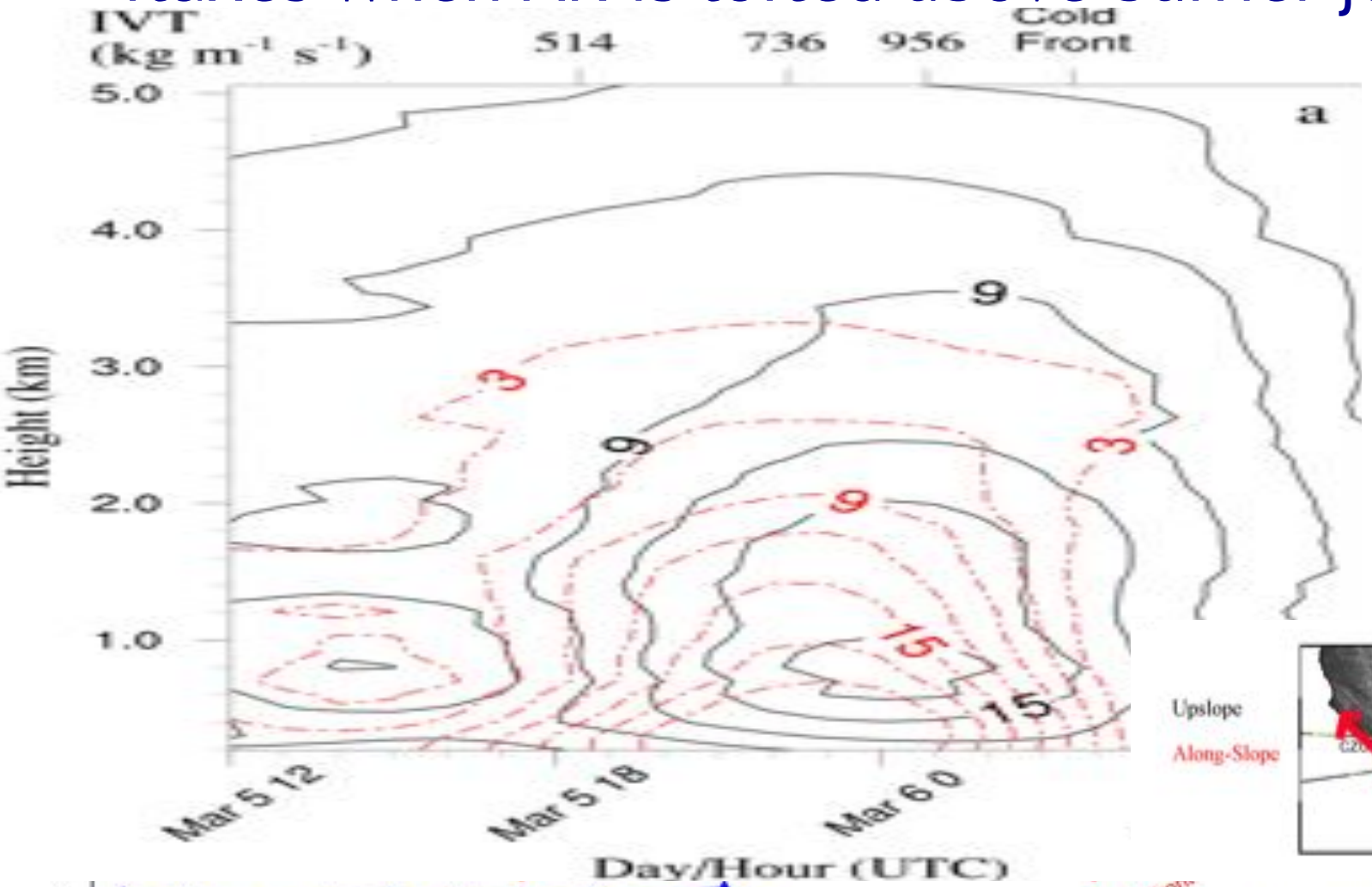




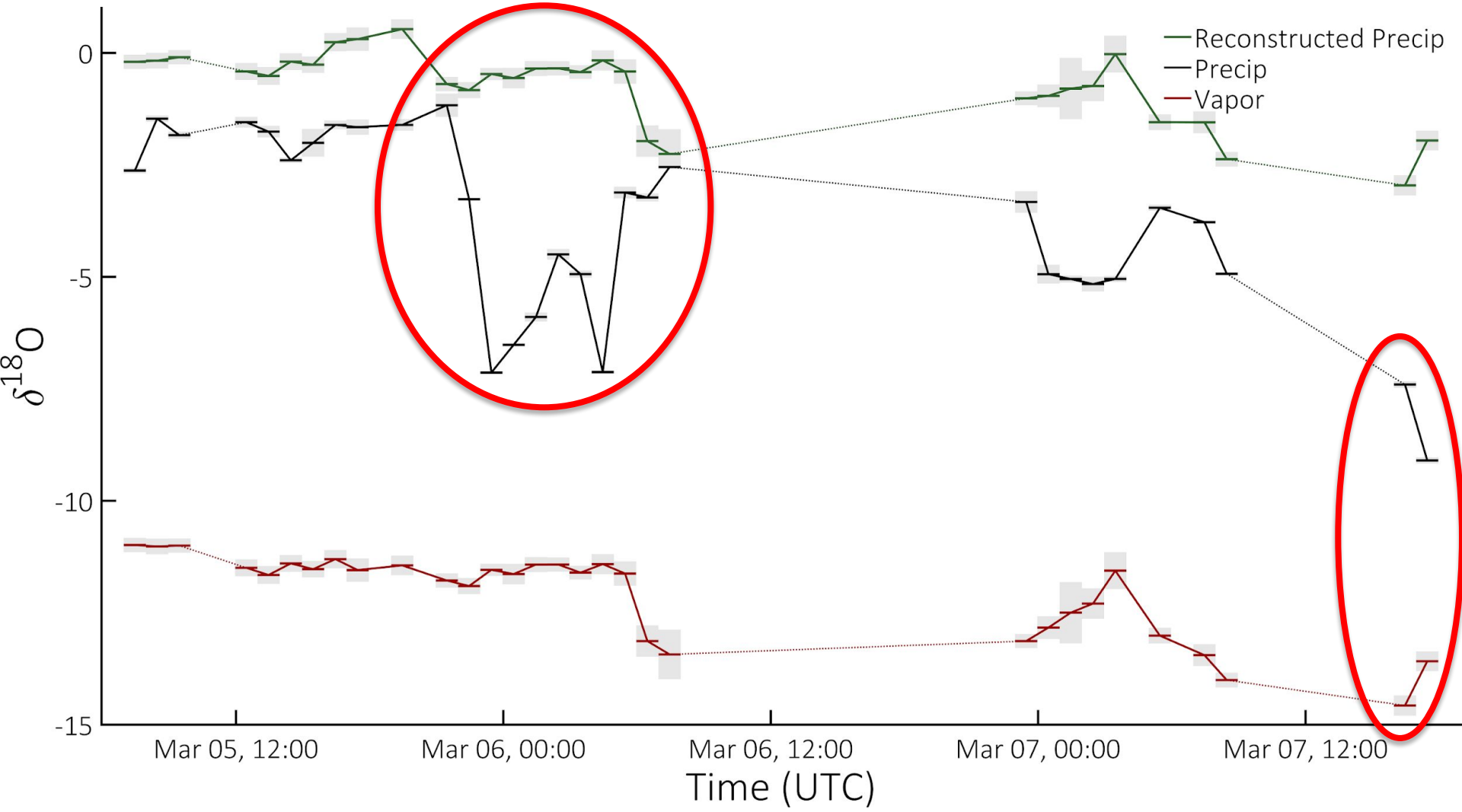
V shape corresponds to period of greatest rainout



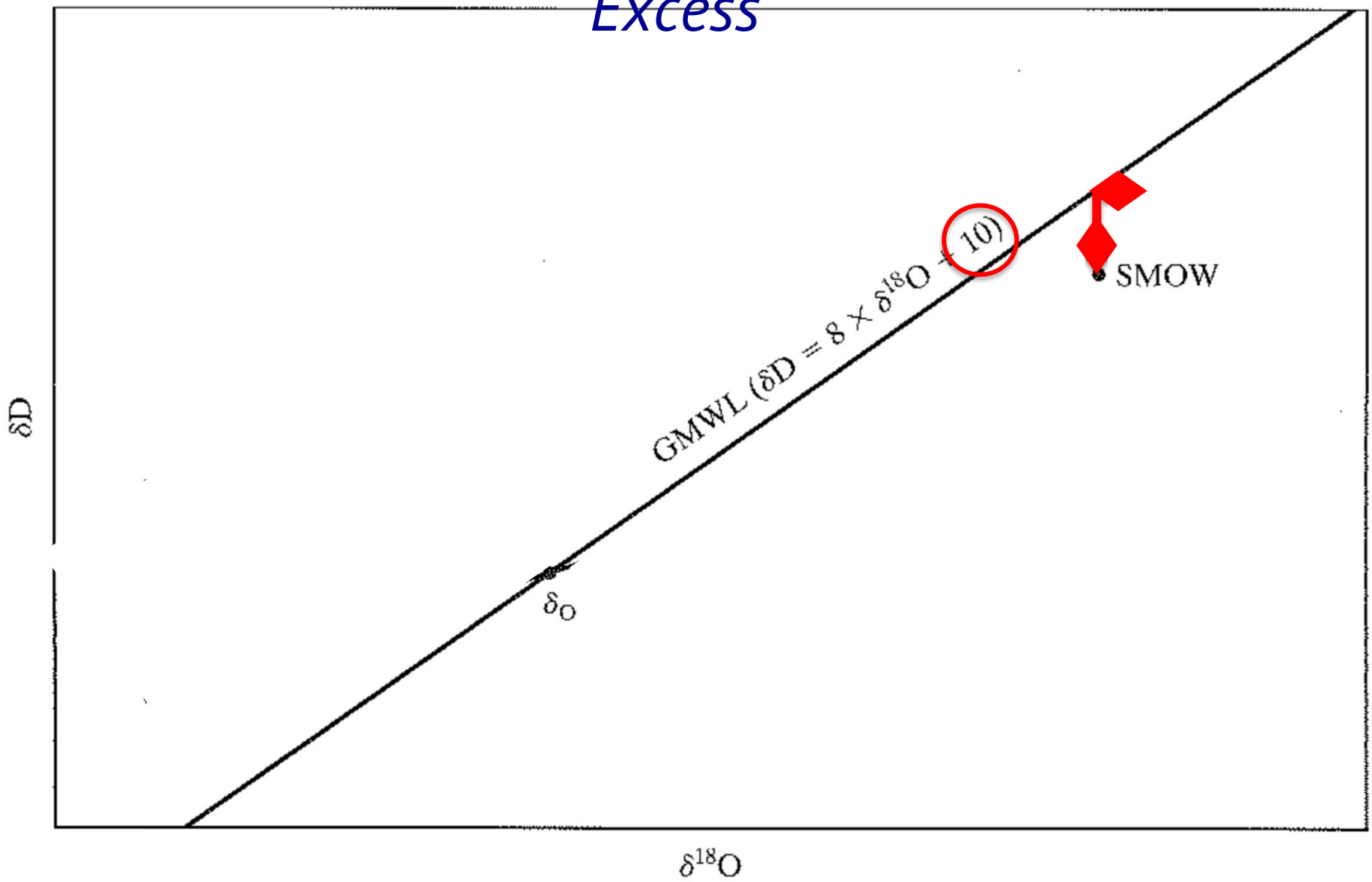
2. V corresponds to greatest along-slope vapor fluxes when AR is lofted above barrier jet



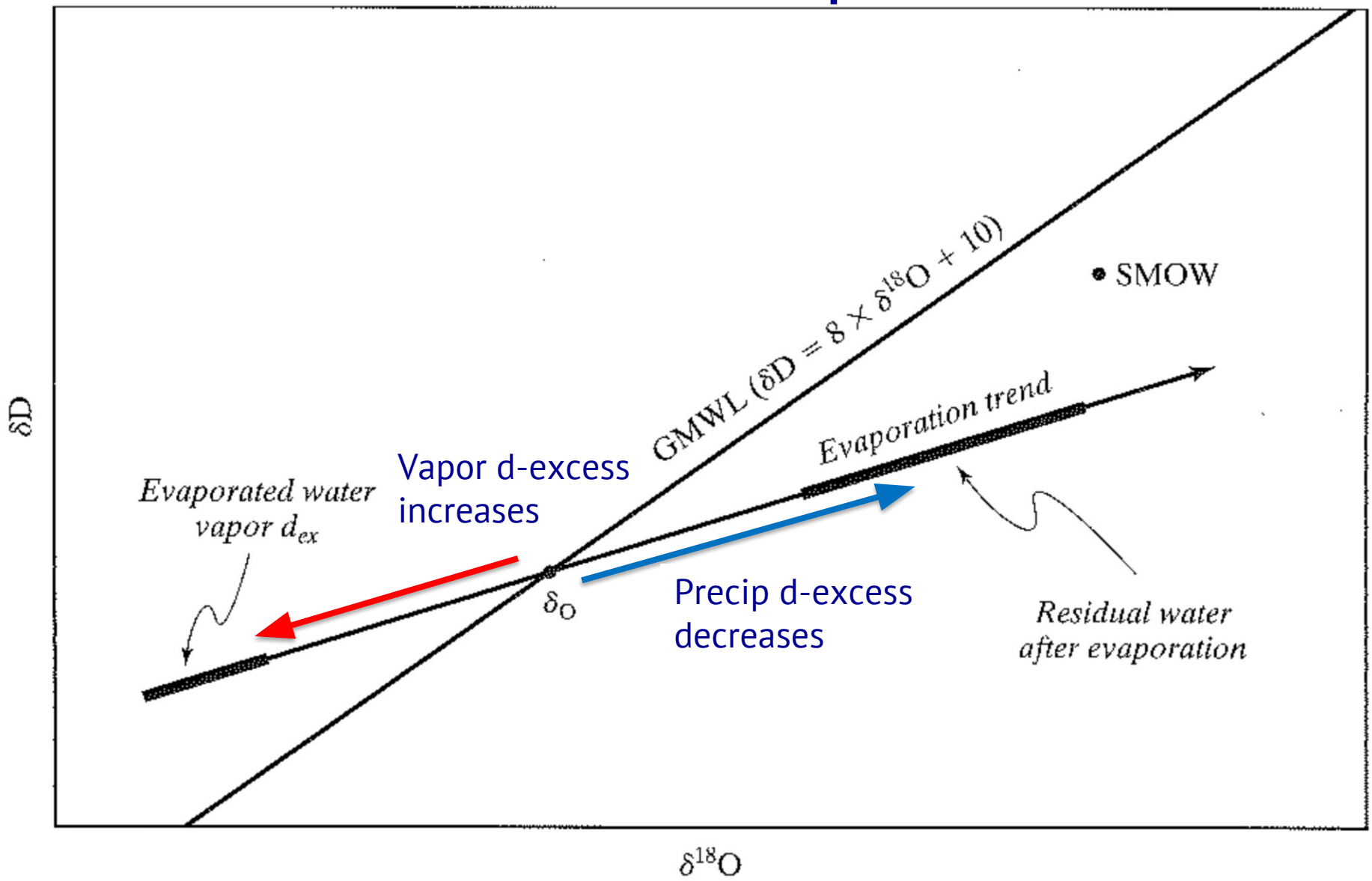
3. Precipitation and vapor time series reveals varying degrees of disequilibrium



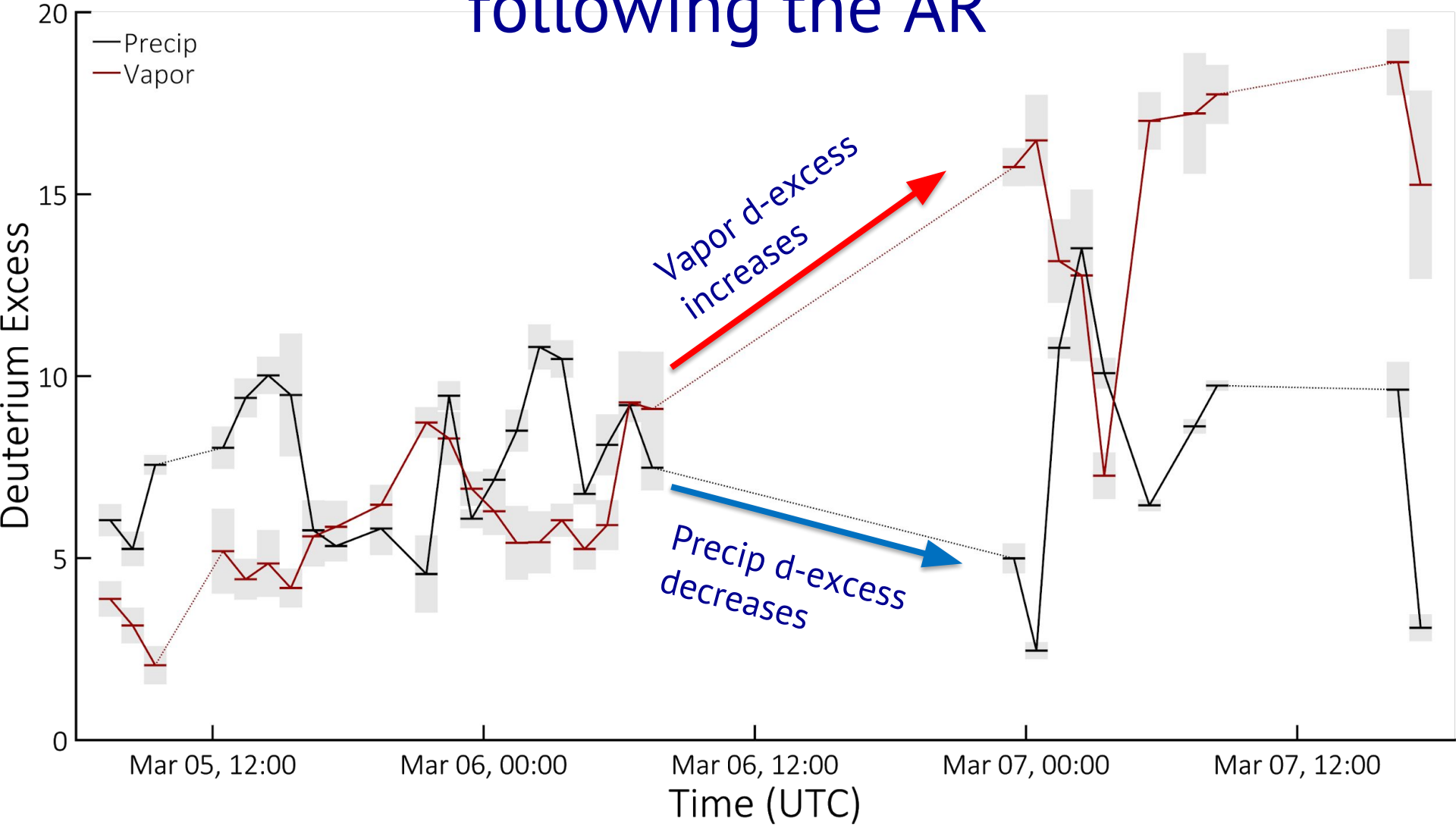
Differences in kinetic fractionation between oxygen and hydrogen give rise to "*Deuterium Excess*"



Deuterium excess as an indicator of below-cloud evaporation



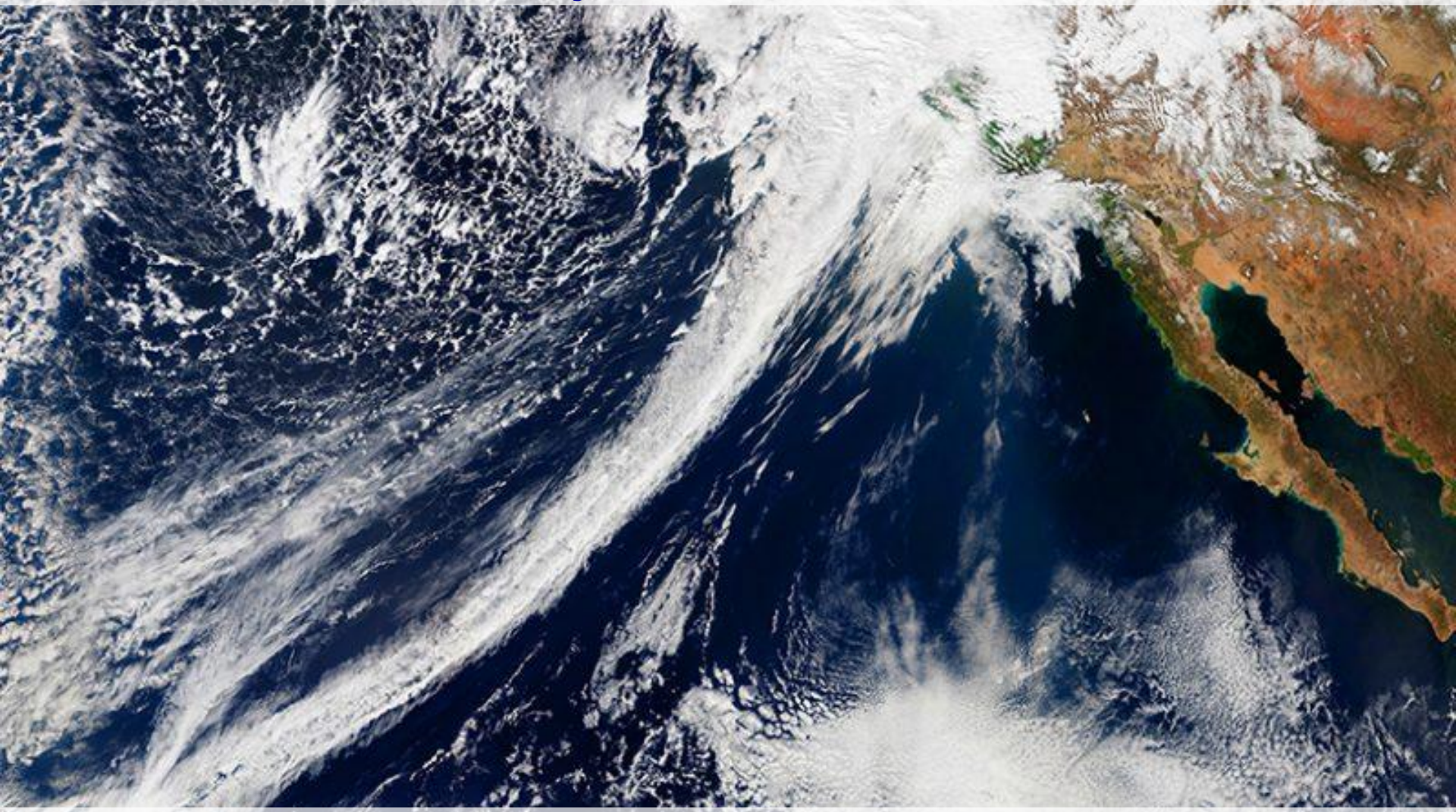
4. Evidence for below-cloud evaporation following the AR



In summary:

1. March 5-7, 2016 AR exhibits a characteristic V shape
   - Precedes cold front passage
   - Coincides with barrier jet phase of the AR, suggests that this meteorological structure promotes most efficient rainout (over 45%)
2. Post-condensation processes are evident, particularly in drizzly times:
   - Below cloud evaporation is responsible for rebound of V after passage of AR core
   - At end of 2nd storm, possible kinetic isotope exchange
3. Precipitation and water vapor isotopes can be used to constrain rainout fraction and reveal microphysical processes in future events

Thank you! Questions?



Additional thanks: Ayesha Ahmed, Matthew Fogarty and Brian Kawzenuk