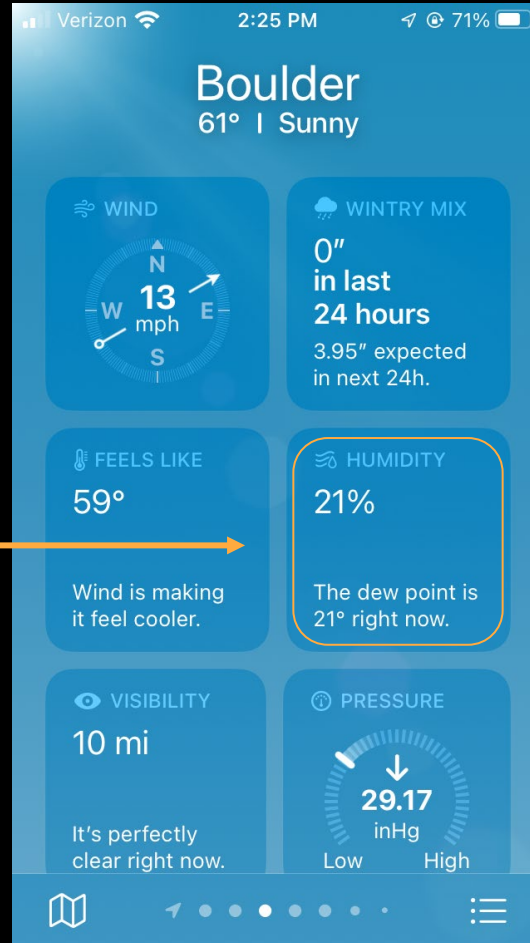# From state to process:
What (airborne) isotopic measurements tell us about moisture transport, convective mixing, and precipitation efficiency

Adriana Bailey, Climate & Space, University of Michigan

Often we have observations of atmospheric state at our fingertips
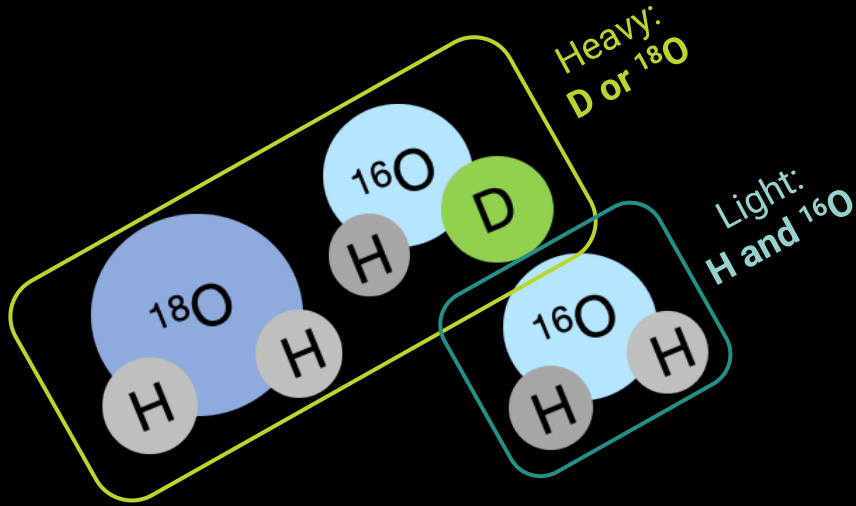
Typically dry in Boulder →

What drives climatological and anomalous moisture content?

Where does this moisture come from?

But what we really want are observations of process

Isotope ratios* reveal the moist processes that distinguish air masses by their thermodynamic states

*(D/H, $^{18}O/^{16}O$)

Heavy:
D or ^{18}O

Light:
H and ^{16}O

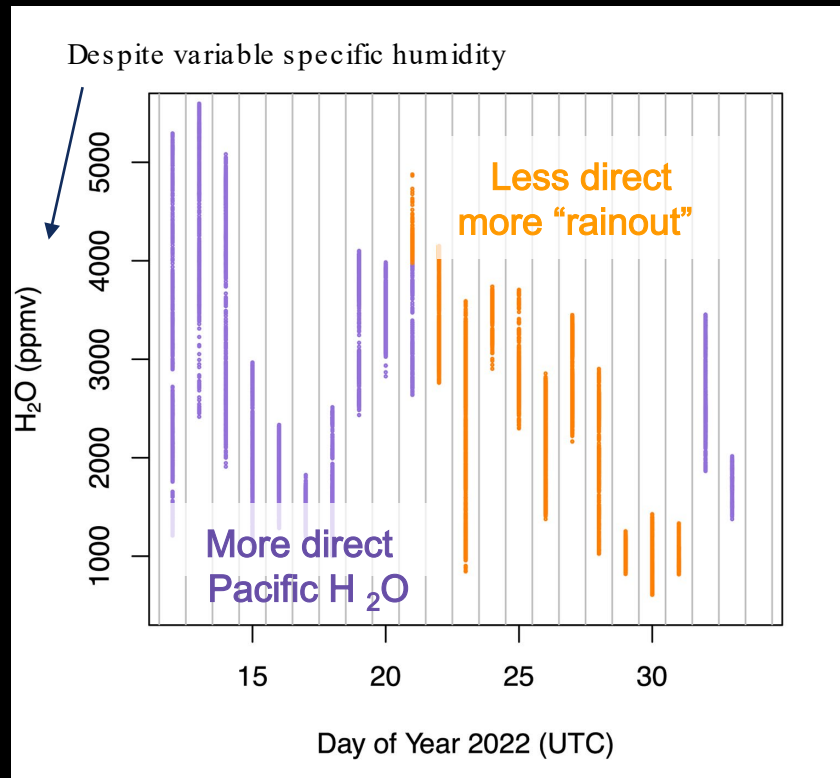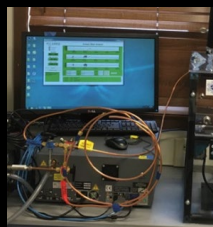Water isotopologues change phase and diffuse at different rates

Applications:

- Identify moisture provenance
- Trace mixing (including vapor, clouds)
- Quantify precipitation efficiency
- Estimate rain evaporation rates
- Identify ice particle growth pathways

Isotope ratios unambiguously identify more and less direct synoptic transport routes to Colorado's Storm Peak Lab

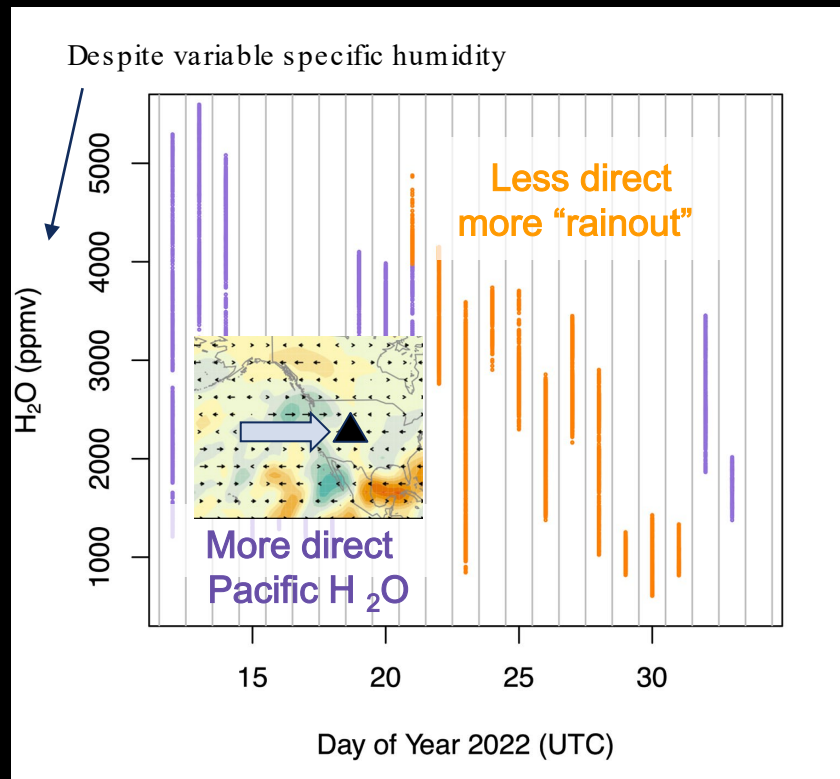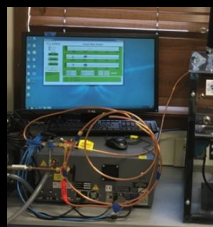Measurements from
Storm Peak Lab
~3000 masl NW Colorado

Photo Credit: Storm Peak Lab

Water vapor isotope analyzer

Despite variable specific humidity

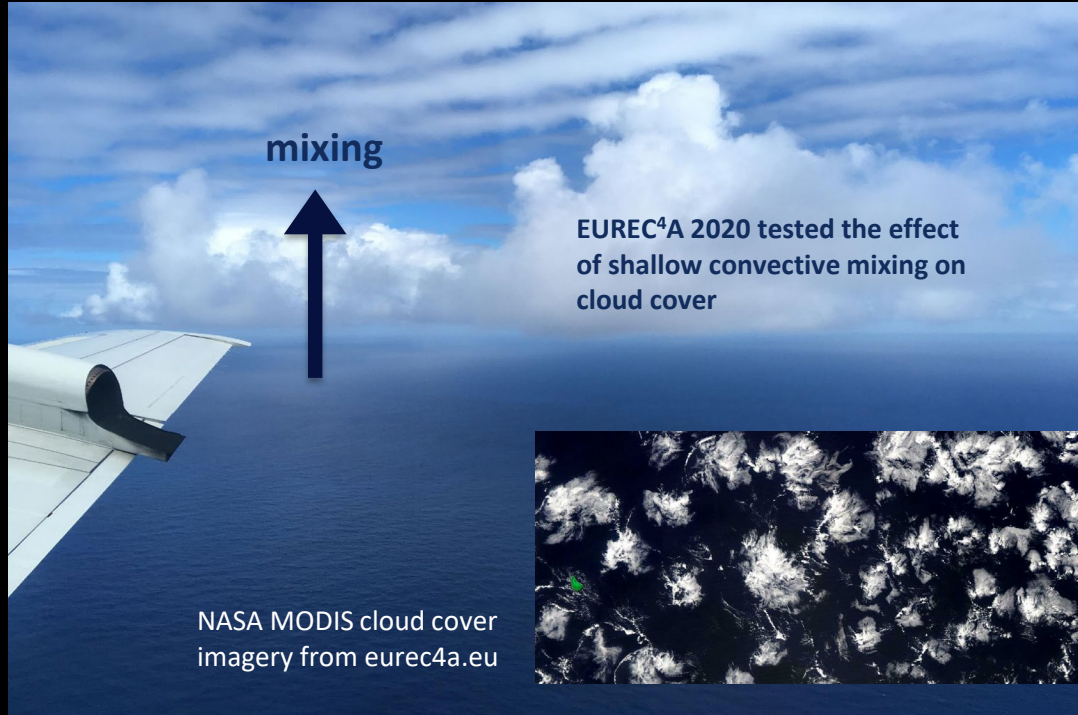Less direct more "rainout"

More direct Pacific H_2O

H_2O (ppmv)

Day of Year 2022 (UTC)

Isotope ratios unambiguously identify more and less direct synoptic transport routes to Colorado's Storm Peak Lab

Measurements from
Storm Peak Lab
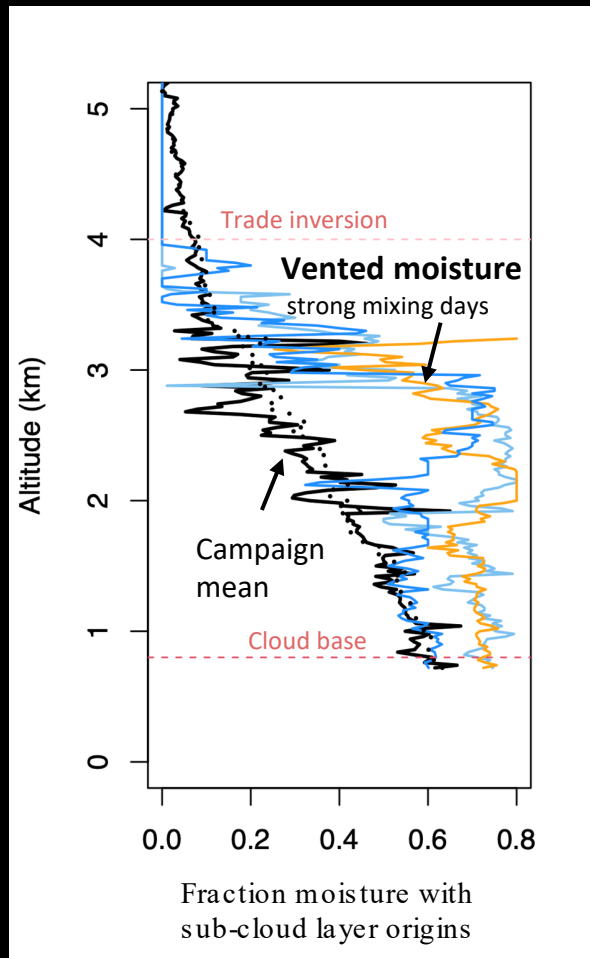~3000 masl NW Colorado

Photo Credit: Storm Peak Lab

Water vapor
isotope analyzer

Despite variable specific humidity

Less direct
more "rainout"

More direct
Pacific H$_2$O

H$_2$O (ppmv)

Day of Year 2022 (UTC)

Isotope ratios quantify moist venting by shallow convection during EUREC⁴A

mixing

EUREC⁴A 2020 tested the effect of shallow convective mixing on cloud cover

NASA MODIS cloud cover imagery from eurec4a.eu

Isotope ratios quantify moist venting by shallow convection during EUREC^{4}A

mixing

EUREC^{4}A 2020 tested the effect of shallow convective mixing on cloud cover

NASA MODIS cloud cover imagery from eurec4a.eu

Trade inversion

Vented moisture
strong mixing days

Campaign mean

Cloud base

Altitude (km)

Fraction moisture with sub-cloud layer origins
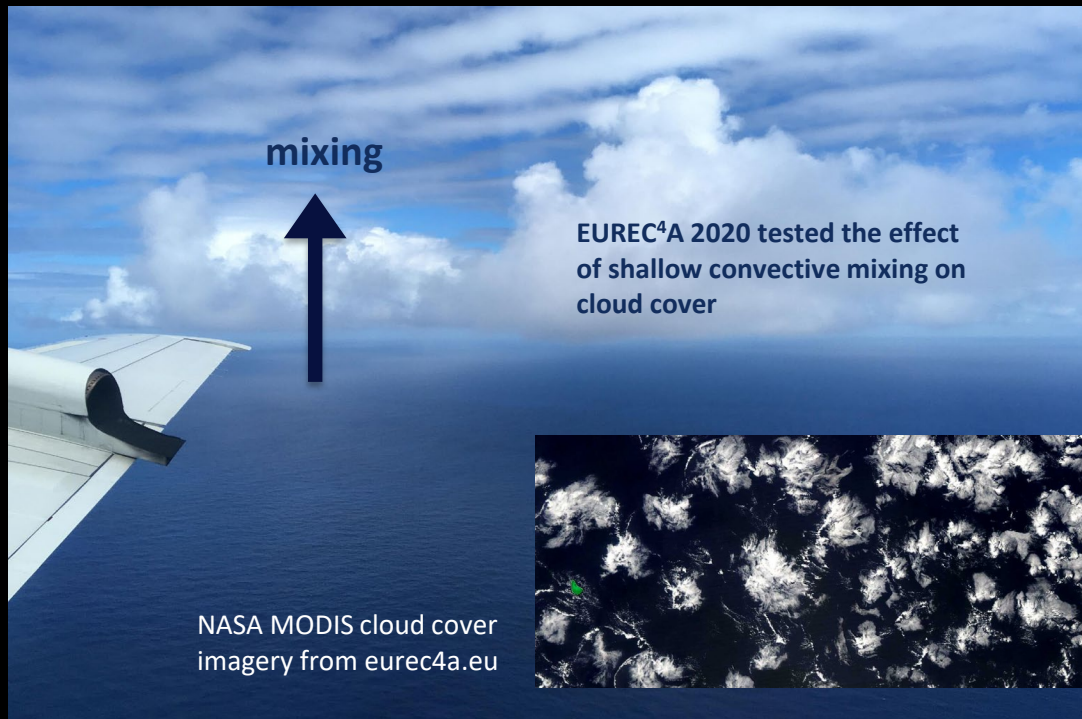
EUREC⁴A isotopic data also provide estimates of rain evaporation

(a key climate sensitivity parameter) - work by Mampi Sarkar, former NCAR-ASP postdoc

Contours = Deuterium excess (isotopes)
Proportional to rain evaporation

Ship-based isotopic
observations
(yellow)

Microphysical model
initiated with aircraft
observations
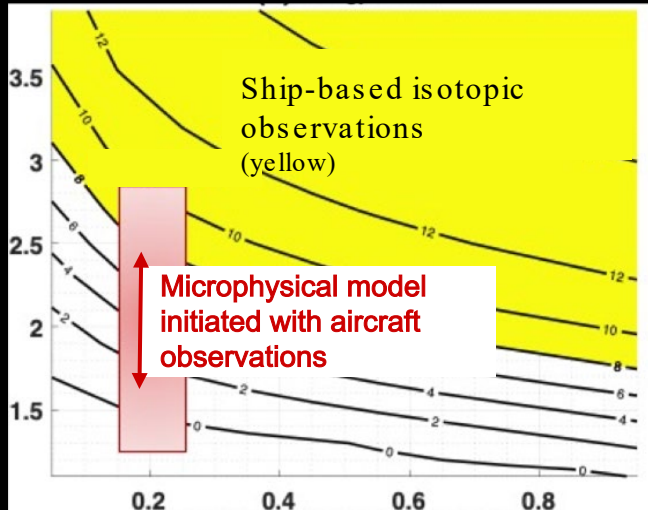
Variability in
raindrop size
(Distribution width)

Size of raindrops
Geometric mean (mm)

Isotopic data help place aircraft
observations within the broader
spatiotemporal context of the
month-long EUREC⁴A field mission

Aircraft observations are often targeted
for process-oriented studies

Why not measure process-oriented
variables?

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