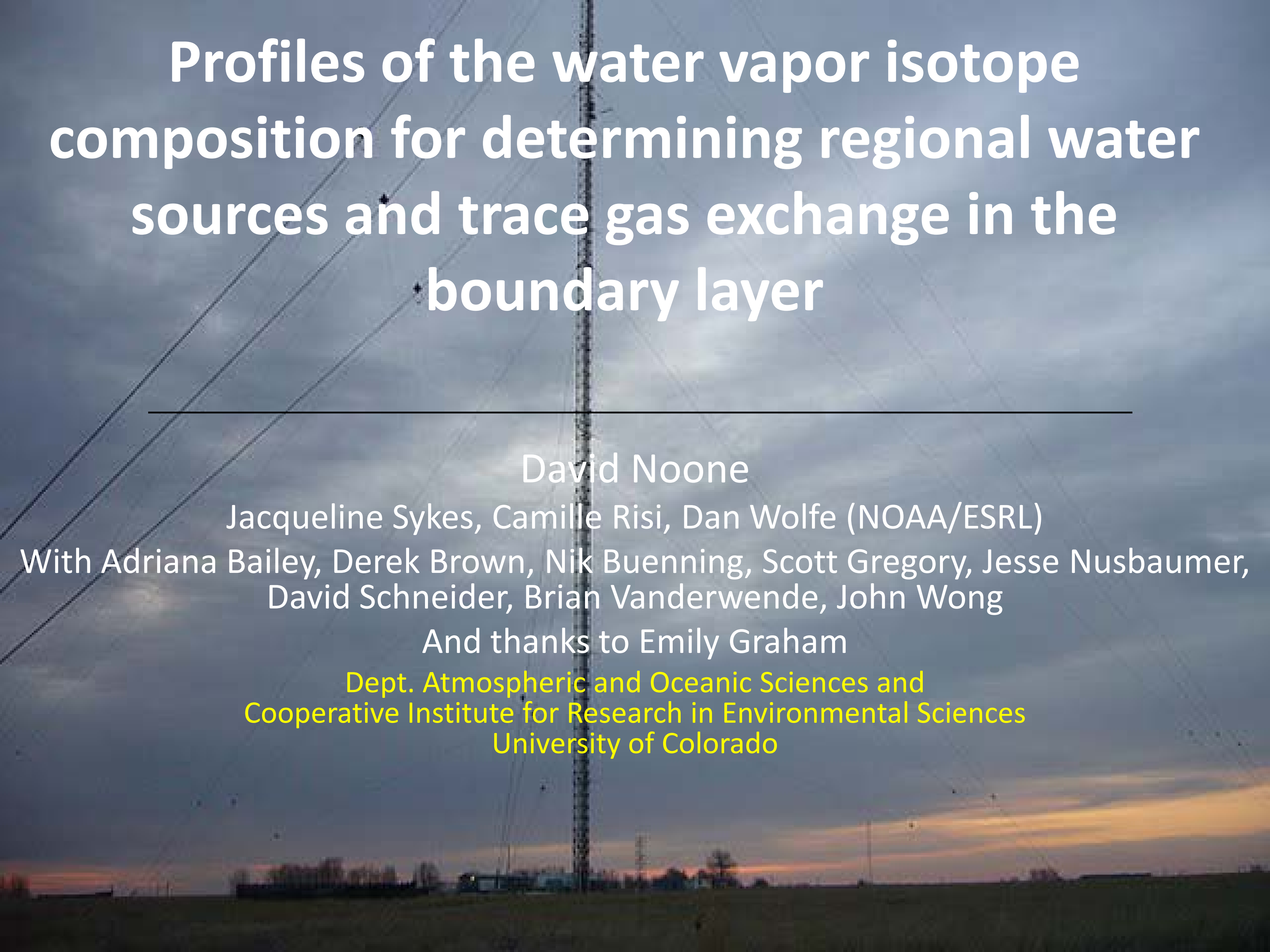

Profiles of the water vapor isotope composition for determining regional water sources and trace gas exchange in the boundary layer

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David Noone

Jacqueline Sykes, Camille Risi, Dan Wolfe (NOAA/ESRL)

With Adriana Bailey, Derek Brown, Nik Buenning, Scott Gregory, Jesse Nusbaumer, David Schneider, Brian Vanderwende, John Wong

And thanks to Emily Graham

Dept. Atmospheric and Oceanic Sciences and
Cooperative Institute for Research in Environmental Sciences
University of Colorado

I don’t care about isotopes!

I care about the underlying physical system: water and energy balance, and isotopes help.

But, I need to figure out what controls isotopes (model) before isotopes (data) can be used meaningfully

The challenge…

- Trace gas exchange between the boundary layer and free troposphere is the leading uncertainty in estimating surface emissions from inversions (Transcom, Gurney et al. 2003)
- Boundary layer dynamics/mixing is poorly represented in models (certainly theoretical limitations associated with the treatment of stable layers, also resolution)
- ***Aim: use water vapor isotopic measurements to resolve PBL transport, then apply to other gases (say, CO_2, aerosols,…)***

Need detailed mechanistic studies.

Cases:

1. ***BAO****/Niwot Ridge continental*
2. *Summit (AWO) Greenland, super stable*
3. ***Mauna Loa/marine boundary layer***

Conceptual basis

Water in the PBL
(non condensing case)

$$\frac{\partial q}{\partial t} = -\frac{\partial}{\partial z}\left(k\frac{\partial q}{\partial z}\right) + E$$

Isotopes (with HDO/H2O ratio R)

$$\frac{\partial Rq}{\partial t} = -\frac{\partial}{\partial z}\left(k\frac{\partial Rq}{\partial z}\right) + R_E E$$

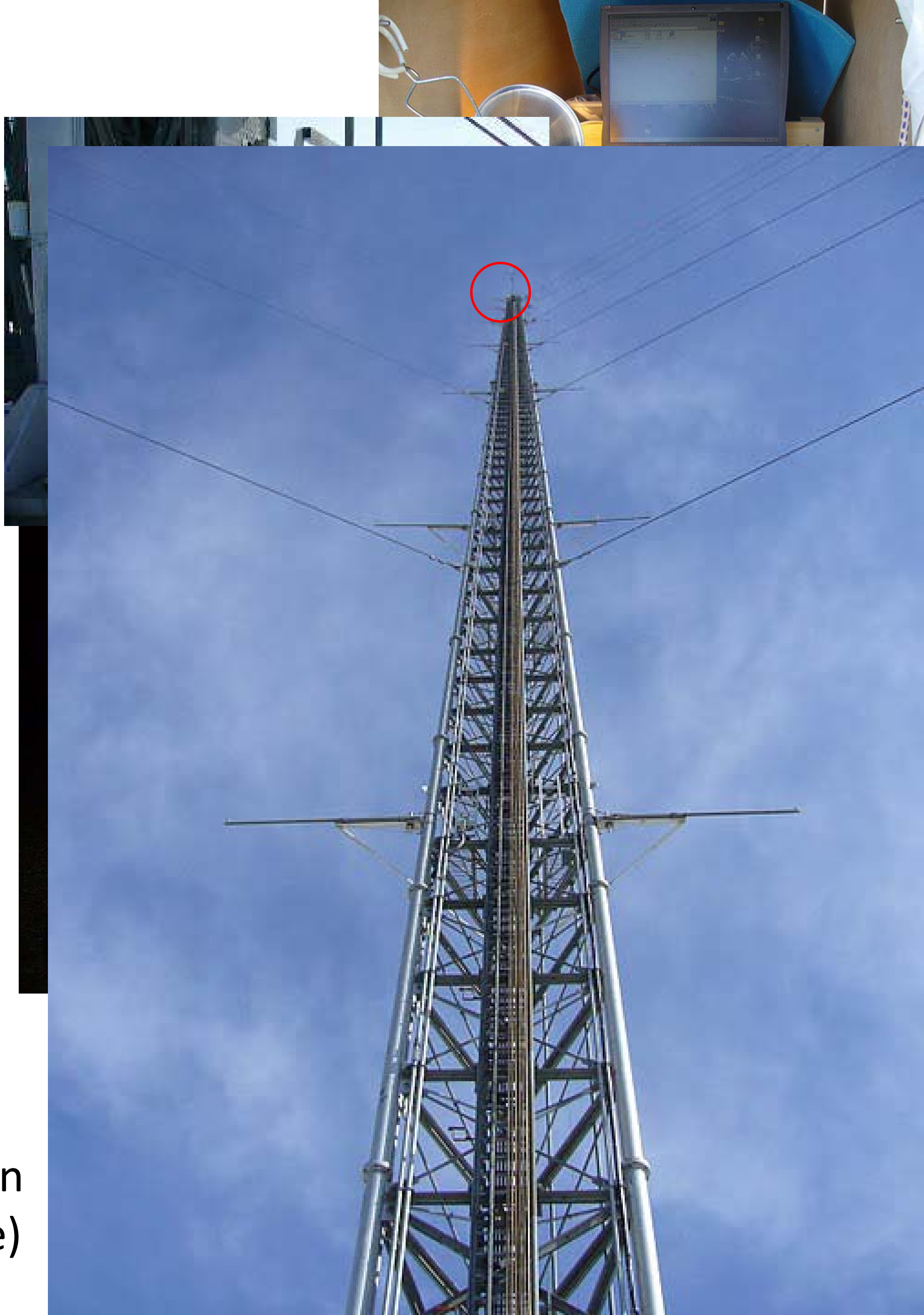
2 equations, 2 unknown (E and k).
Works exceedingly well, with hyperbolic relationship between q and R
(i.e., "Keeling plot")

Trace gas "X", known k find source (respiration, … etc)

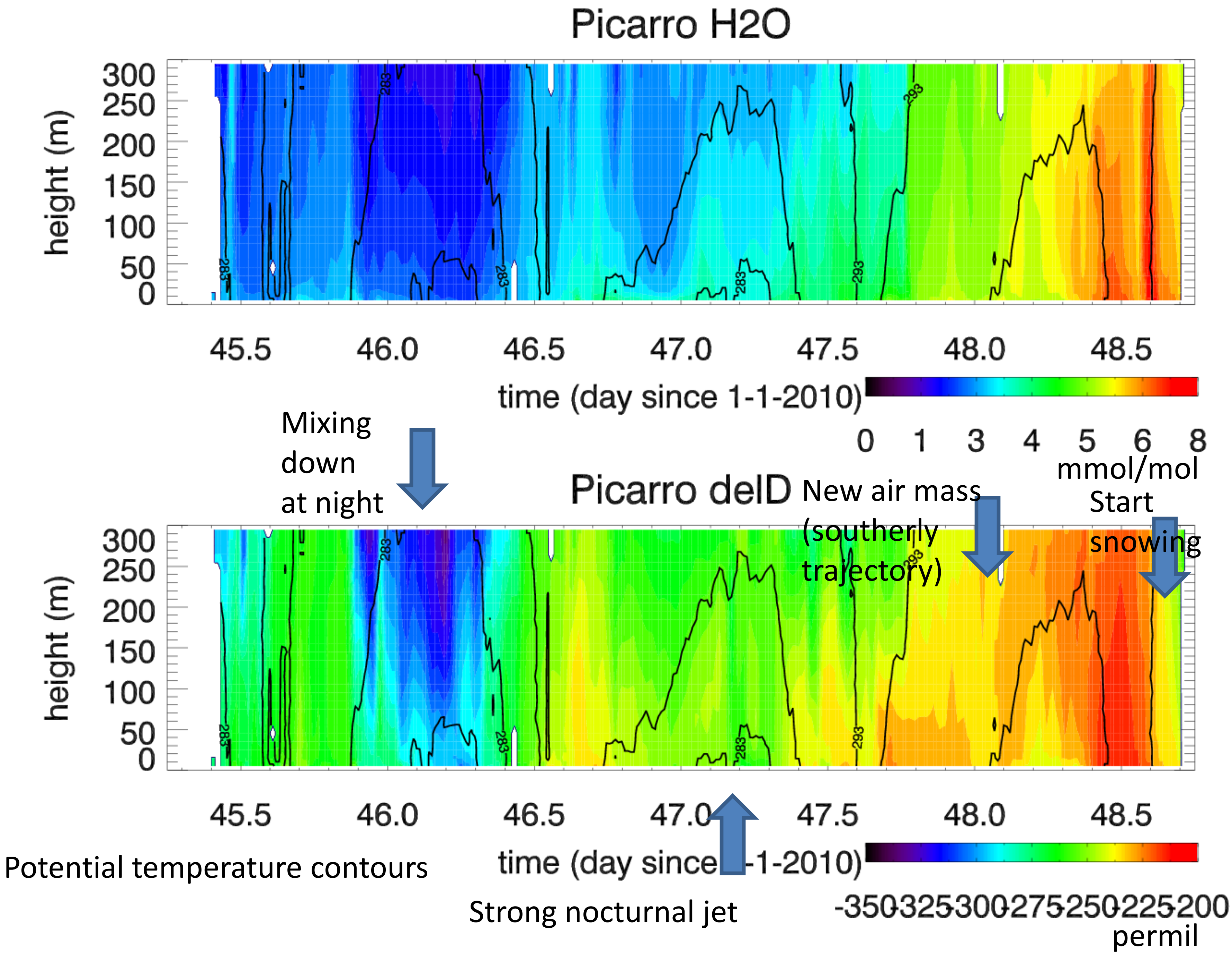
$$\frac{\partial X}{\partial t} = -\frac{\partial}{\partial z}\left(k\frac{\partial X}{\partial z}\right) + \text{source}$$

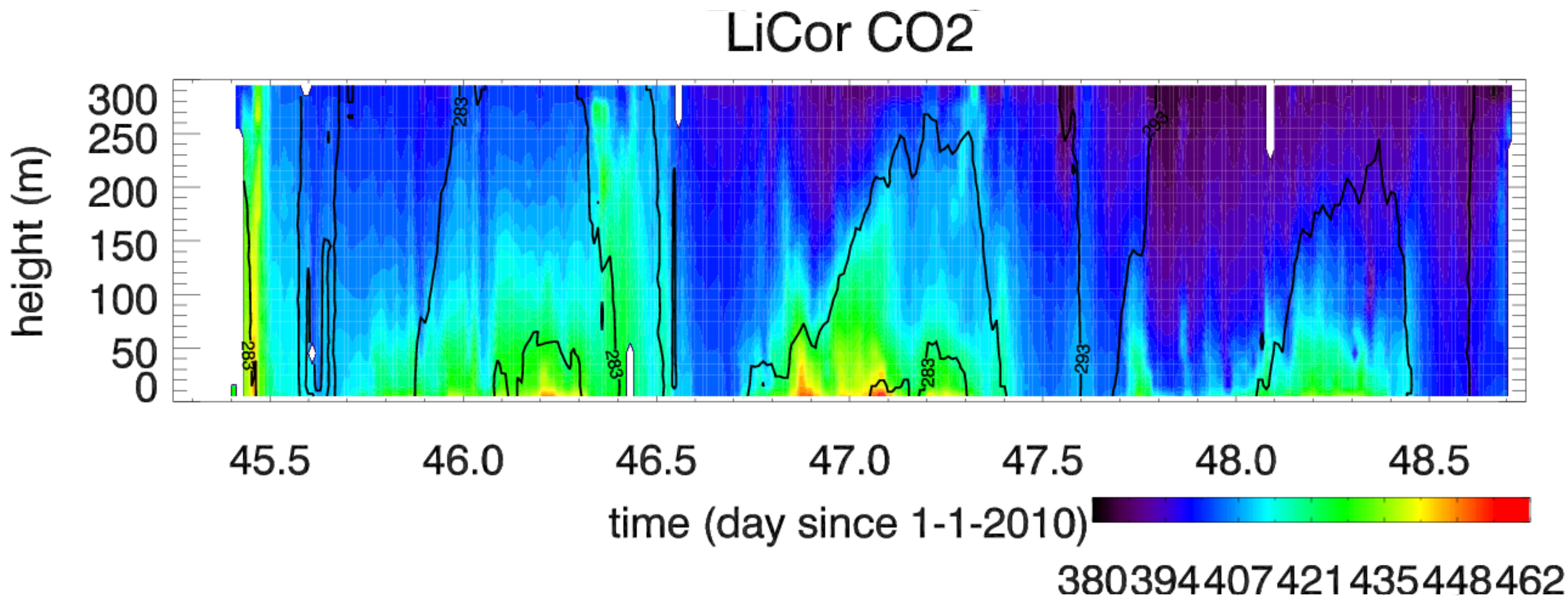
Experiment

- Mounted a Picarro Water Vapor Isotope Analyzer on the BAO instrument carriage.
- Along with additional sensors
- LiCor open path CO_2/H_2O, temperature, pressure, sonic wind (Peter Blanken, Emily Graham and Dan Wolfe)
- Every 15 minutes, elevator went up or down for about 4 days (Feb 15-18, 2010)
- Ascent takes 8m50s, decent 8m30s
- Data mapped to high resolution profiles
- 312 profiles 0-300 meters with approximately 5-20 meter resolution (depending on instrument response)

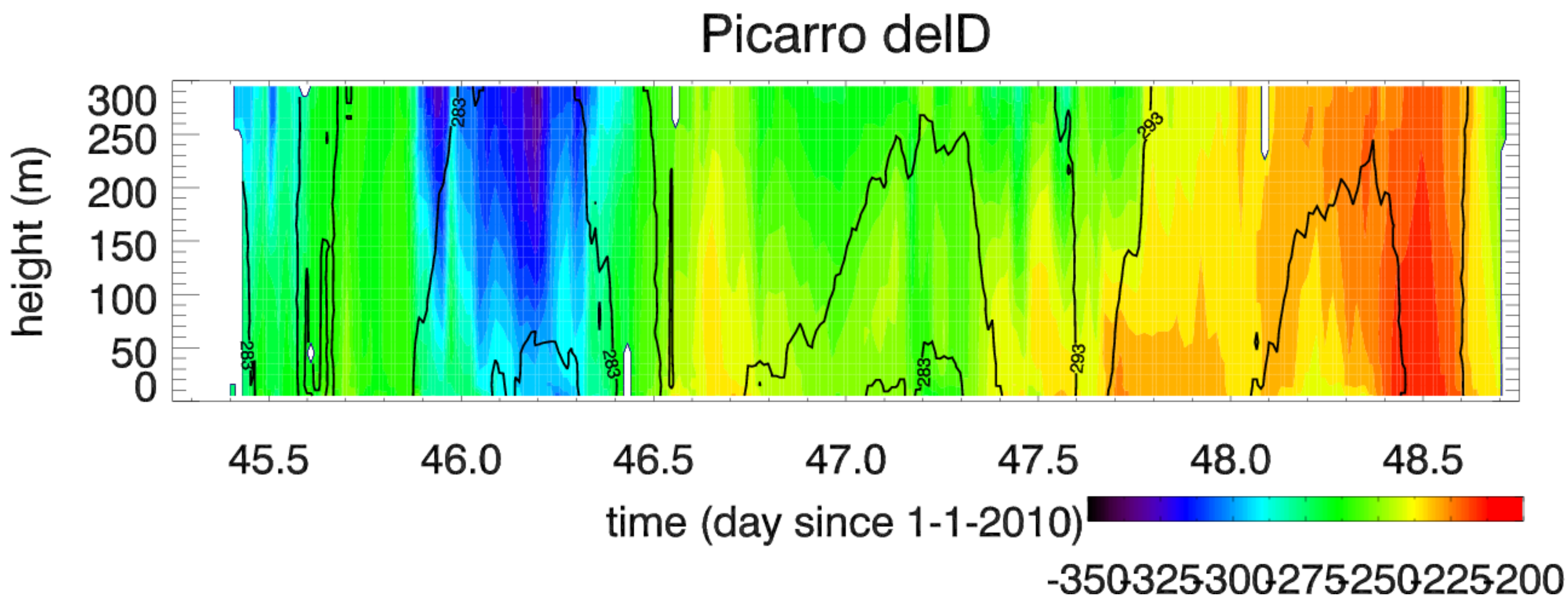



Cement
factory
(~20 km)


Picarro H2O
height (m)
300
250
200
150
100
50
0
283
293
45.5
46.0
46.5
47.0
47.5
48.0
48.5
time (day since 1-1-2010)
0
1
3
4
5
6
8
mmol/mol
Mixing
down
at night
Picarro delD
New air mass
(southerly
trajectory)
Start
snowing
height (m)
300
250
200
150
100
50
0
283
293
45.5
46.0
46.5
47.0
47.5
48.0
48.5
time (day since 1-1-2010)
-350325300275250225200
permil
Potential temperature contours
Strong nocturnal jet



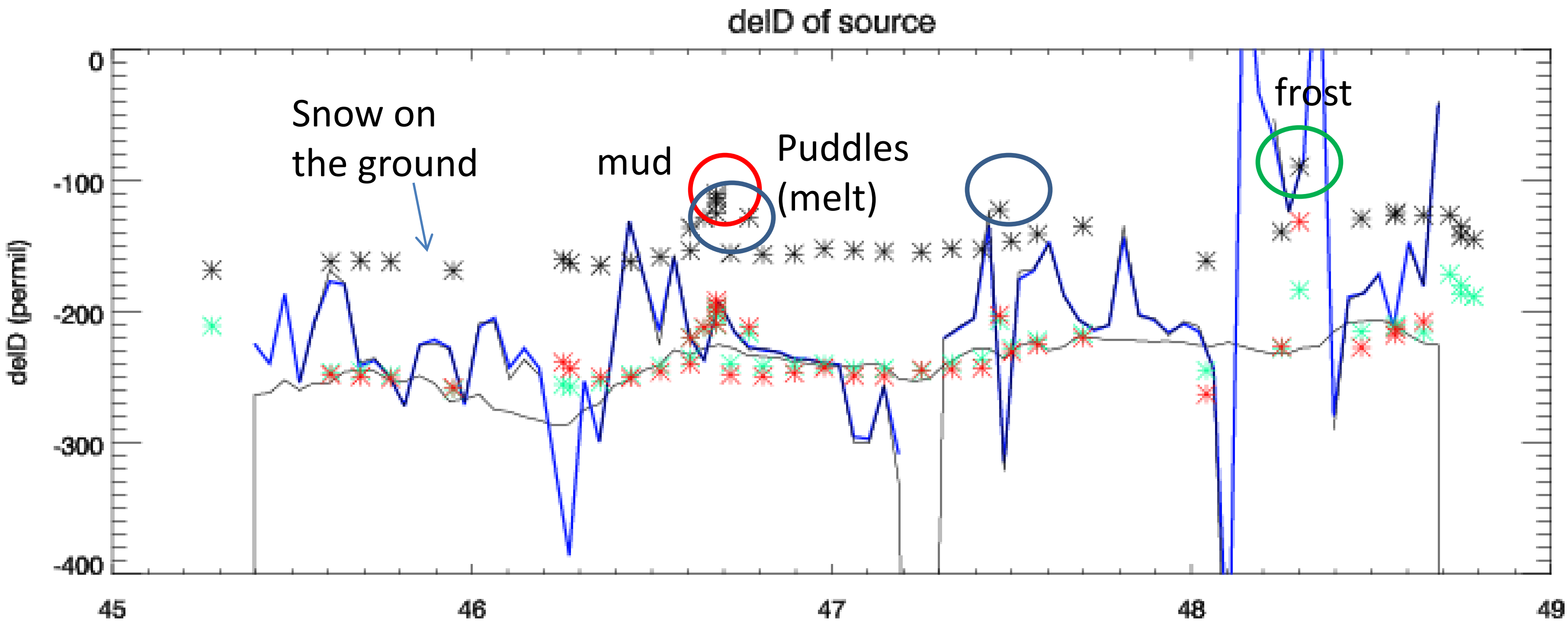
LiCor CO2
height (m)
300
250
200
150
100
50
0
283
293
45.5
46.0
46.5
47.0
47.5
48.0
48.5
time (day since 1-1-2010)
380394407421435448462



Picarro delD
height (m)
300
250
200
150
100
50
0
283
293
45.5
46.0
46.5
47.0
47.5
48.0
48.5
time (day since 1-1-2010)
-350-325-300-275-250-225-200

Constrain moisture source

Flux gradient/profile method, equivalent to “Keeling plot”



Blue curve: isotopic composition derive from profile

Red and cyan: isotopic composition of evaporation derived from measured surface water

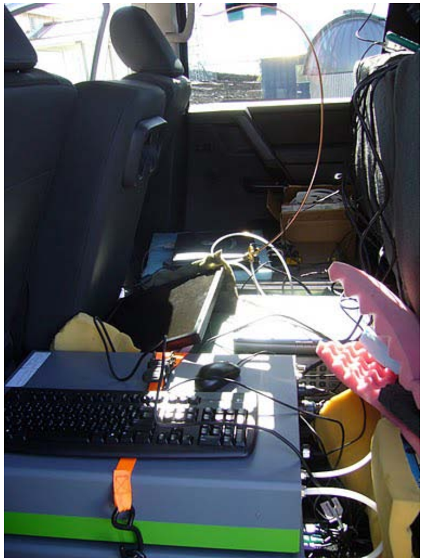
Sneak peek: new results from MLO

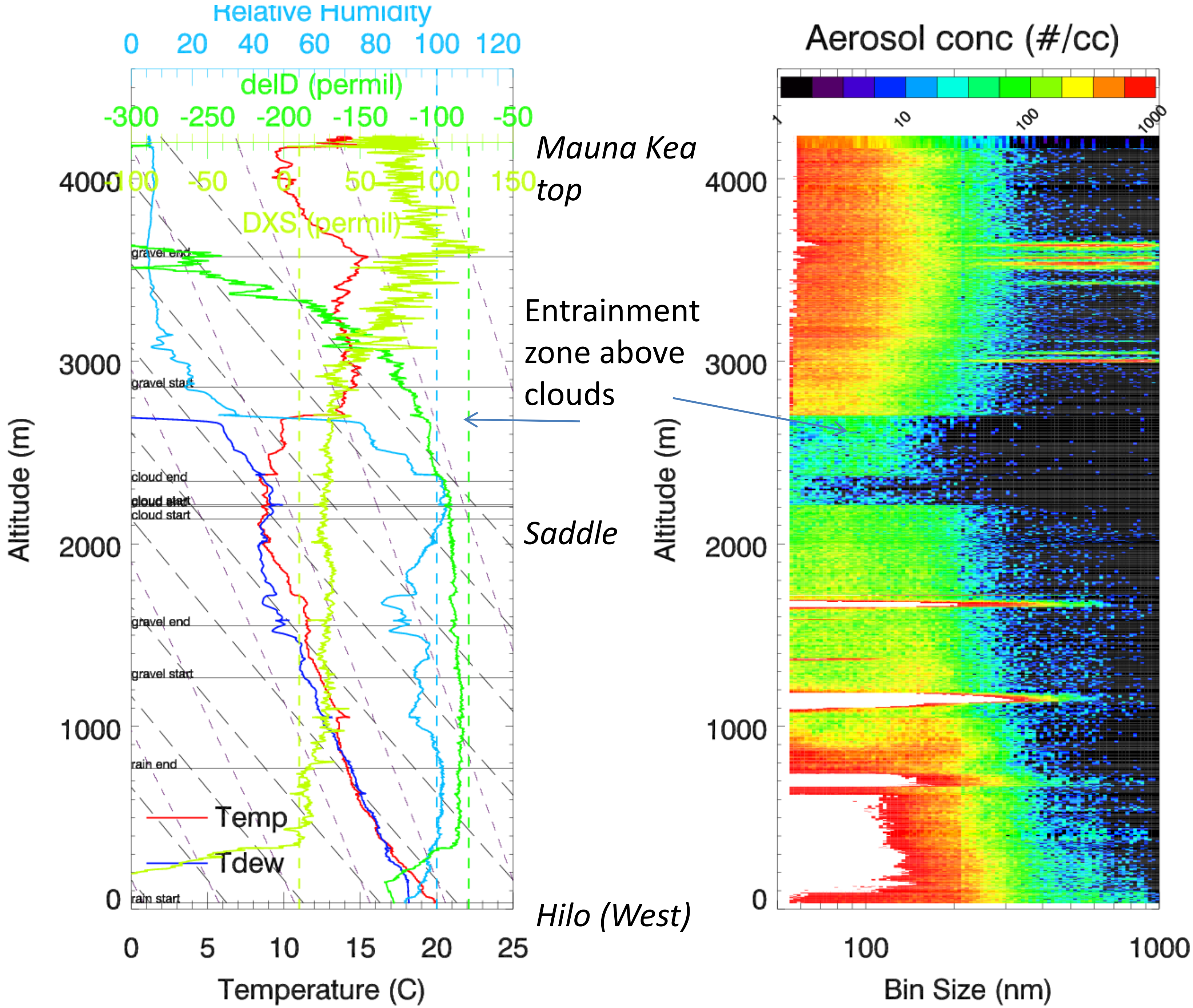
Similar approach, applied to the marine boundary layer.

Isotopes and aerosols at MLO provide metrics on vertical/local and long ranged air mass influence on baseline measurements

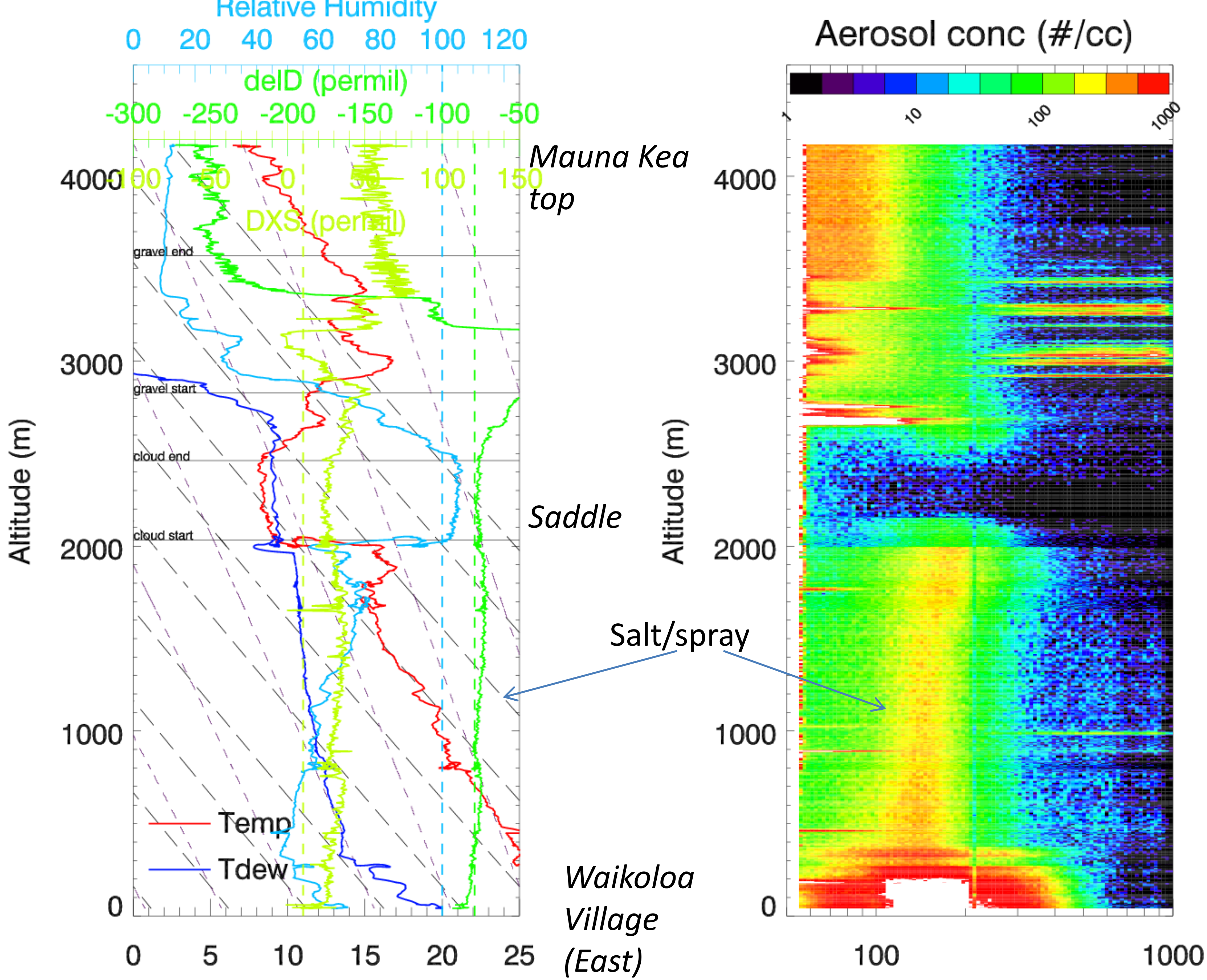
- *What is the degree of exchange between the MBL and the free troposphere, versus horizontal transport?*

- PBL profiles obtained by car mounted instruments
- Ascent from sea level to the top of Mauna Kea (4200 m)





Relative Humidity
0 20 40 60 80 100 120
delD (permil)
-300 -250 -200 -150 -100 -50
-100 -50 0 50 100 150
DXS (permil)
Mauna Kea top
Entrainment zone above clouds
Saddle
Hilo (West)
gravel end
gravel start
cloud end
cloud start
rain end
rain start
Temp
Tdew
Altitude (m)
0 1000 2000 3000 4000
0 5 10 15 20 25
Temperature (C)
Aerosol conc (#/cc)
1 10 100 1000
Bin Size (nm)


Relative Humidity
0 20 40 60 80 100 120
delD (permil)
-300 -250 -200 -150 -100 -50
-100 -50 0 50 100 150
DXS (permil)
4000
3000
2000
1000
0
gravel end
gravel start
cloud end
cloud start
Altitude (m)
Temp
Tdew
0 5 10 15 20 25
Temperature (C)
Mauna Kea top
Saddle
Waikoloa Village (East)
Salt/spray
Aerosol conc (#/cc)
1 10 100 1000
Altitude (m)
100 1000
Bin Size (nm)

Conclusions

- Combination of H_2O and isotopic measurements provides ***very clear signature of air mass mixing*** (vertical, and distinct lateral air masses)
- This can be used to identify strong transport conditions for other trace gases (here, CO_2 and aerosols…)
- Local water sources can be identified. (This study, snow melt, then evaporation from "puddles")

- Expect growing season water source to be dominated by transpiration, this can tie to photosynthesis (knowing water use efficiency) to partition biospheric CO_2 source
- Study to continue at BAO (thanks to NSF)