OBSERVATIONS OF BOUNDARY LAYER STRUCTURE FROM AIRCRAFT AND THE INTERNATIONAL TEAMx PROGRAM

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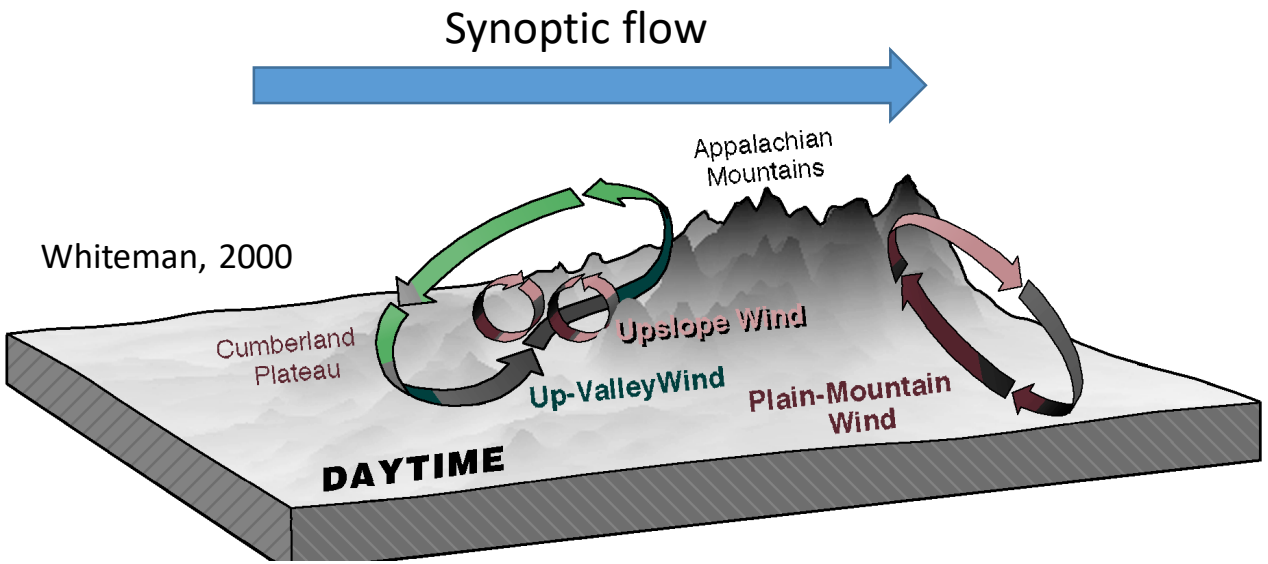
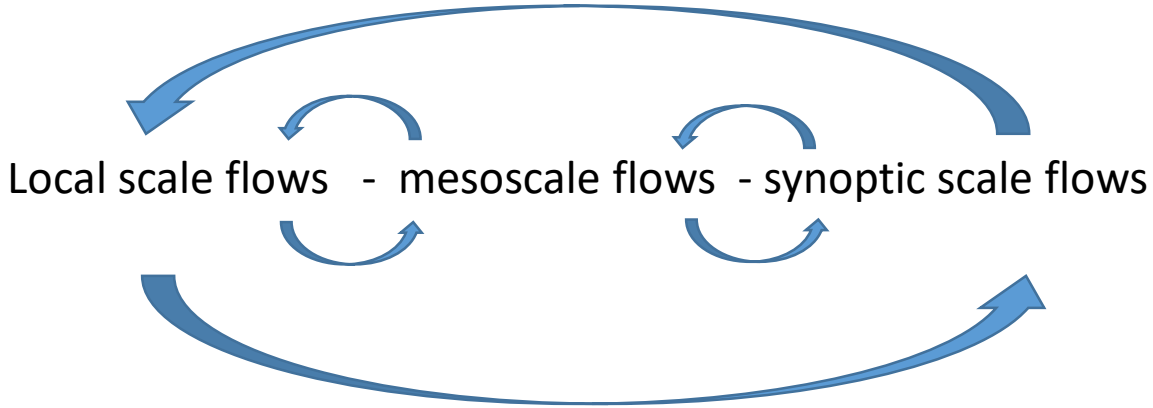
TEAMx

AQUARIUS WORKSHOP 25/26 September 2019, University of Utah
SESSION 6 : INSIGHTS FROM OTHER REGIONS

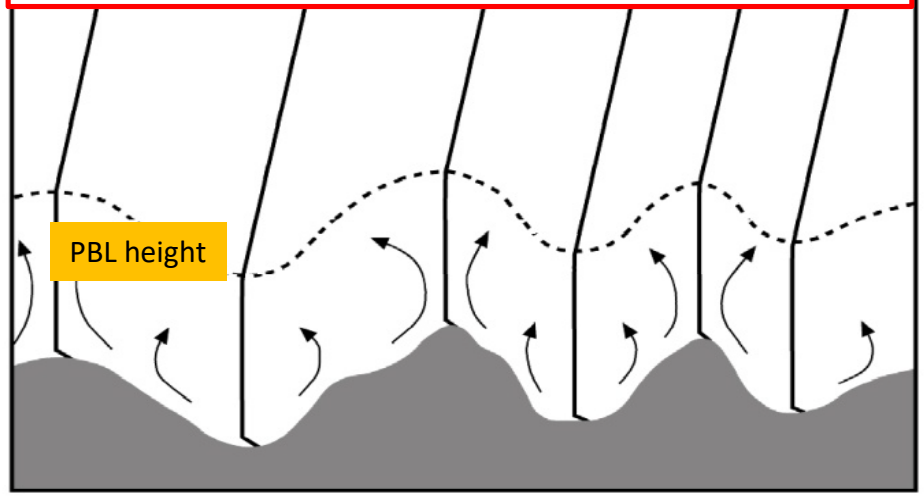
Multi-scale flow interactions and boundary layer structure





Convergence/divergence, wind shear, turbulence, etc.

Effects on spatial and temporal variability of PBL structure

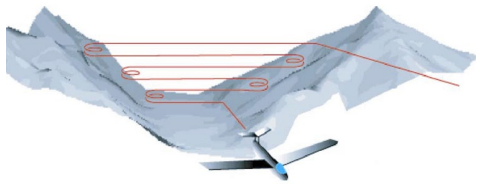


De Wekker, S.F.J., and M. Kossmann, 2015: Convective boundary layer heights over mountainous terrain: A review of concepts. Front. Earth Sci., DOI: 10.3389/feart.2015.00077

BOUNDARY LAYER STRUCTURE FROM AIRCRAFT

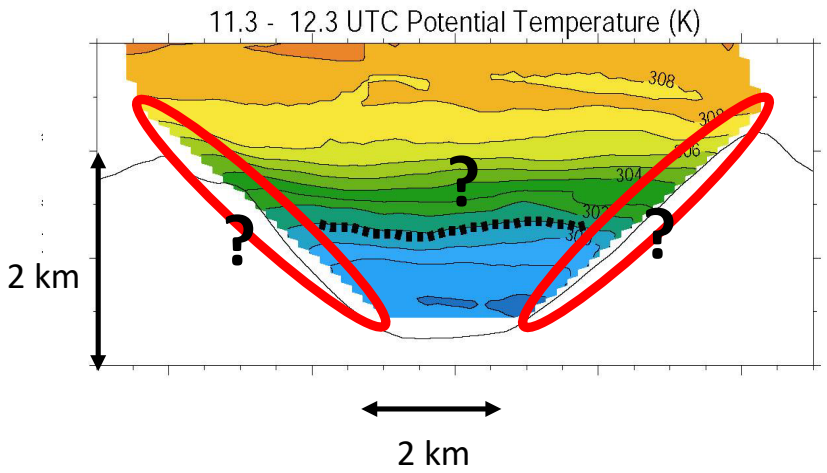
In-situ measurements

'simple' cross-valley and along valley flight legs

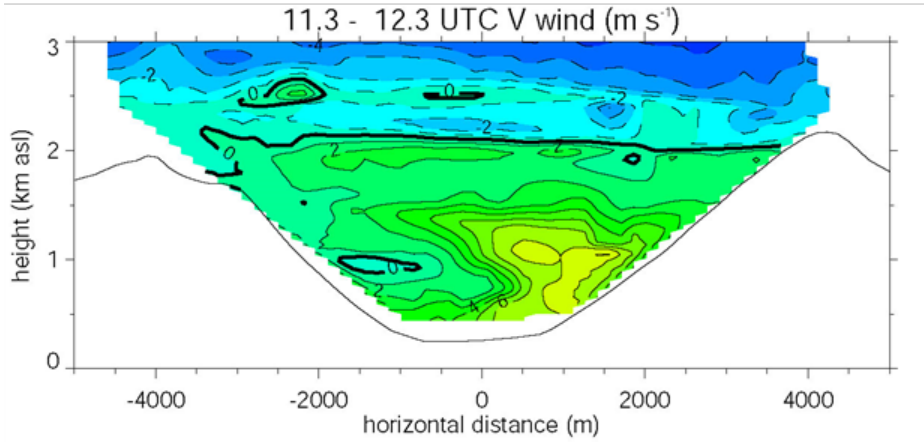


Lack of observations over ridges and slopes

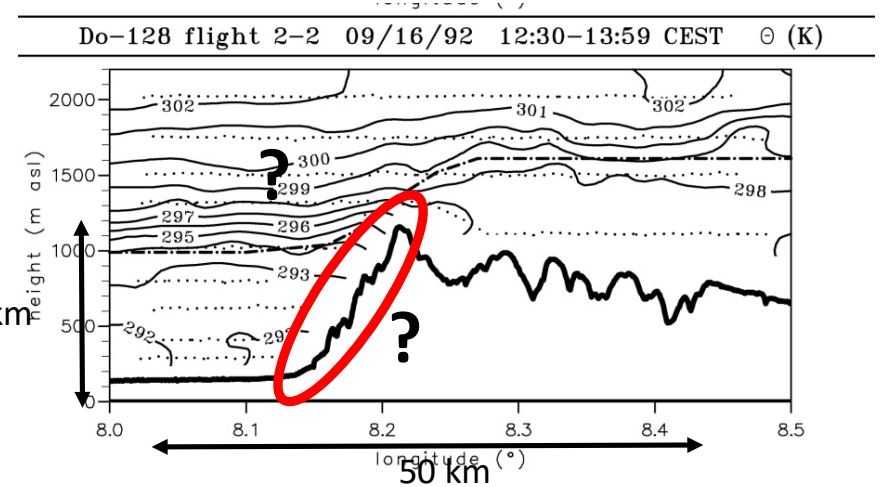
potential temperature

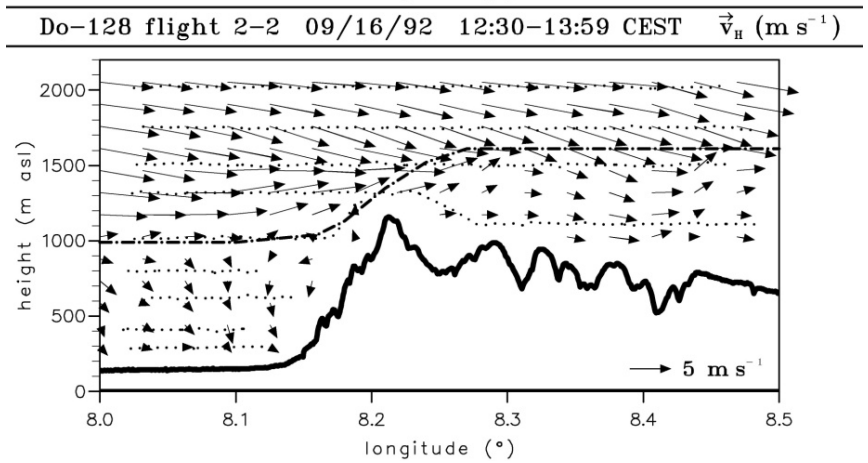


horizontal wind



MAP – Riviera Valley, Switzerland, De Wekker et al. 2004

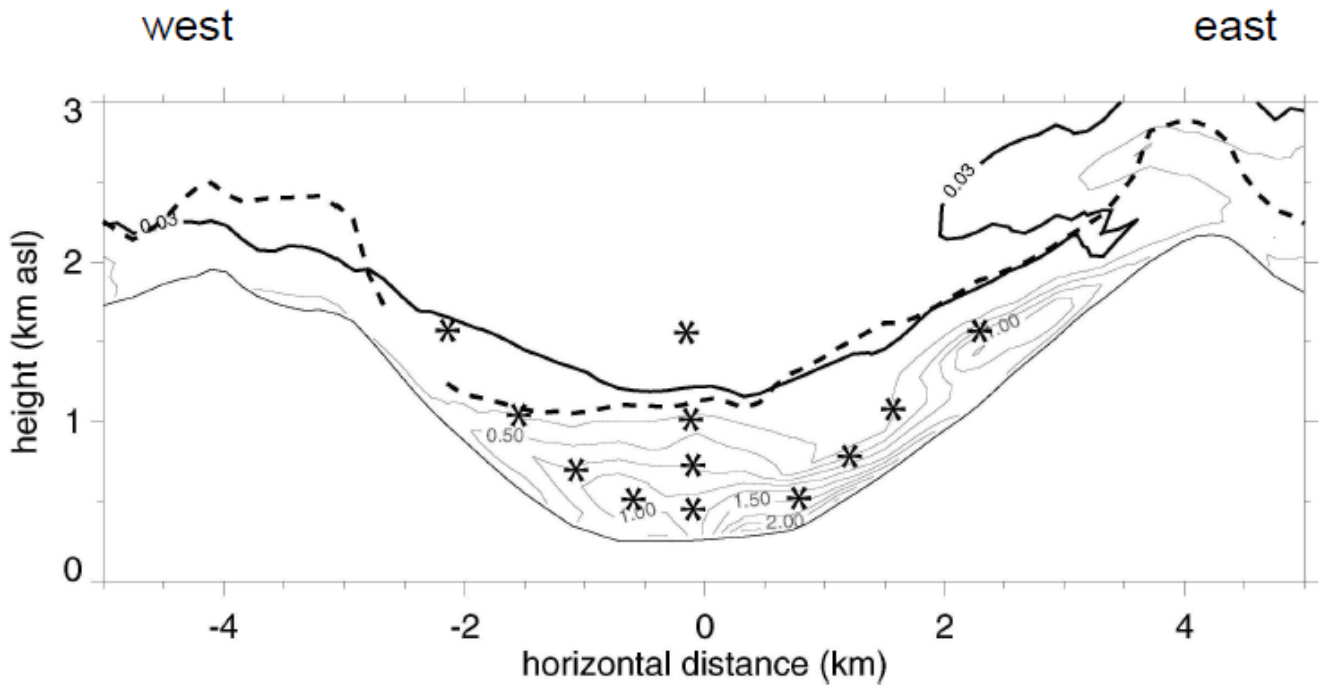




TRACT – Rhine Valley - Black Forest, Germany, Kossmann et al. 1998

BOUNDARY LAYER STRUCTURE FROM AIRCRAFT

In-situ measurements of turbulence kinetic energy



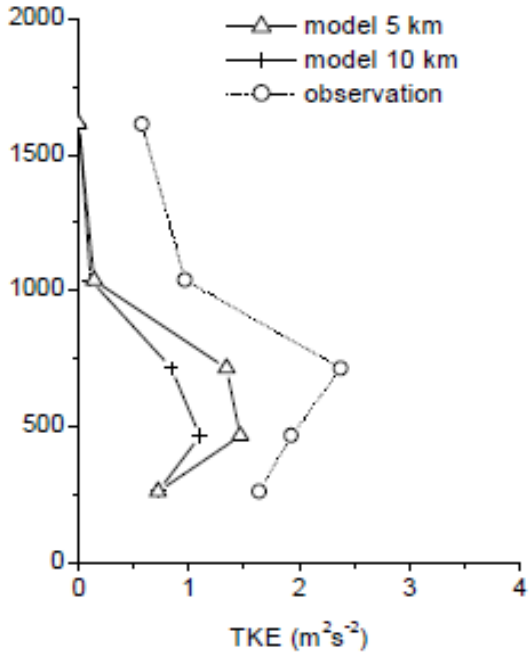


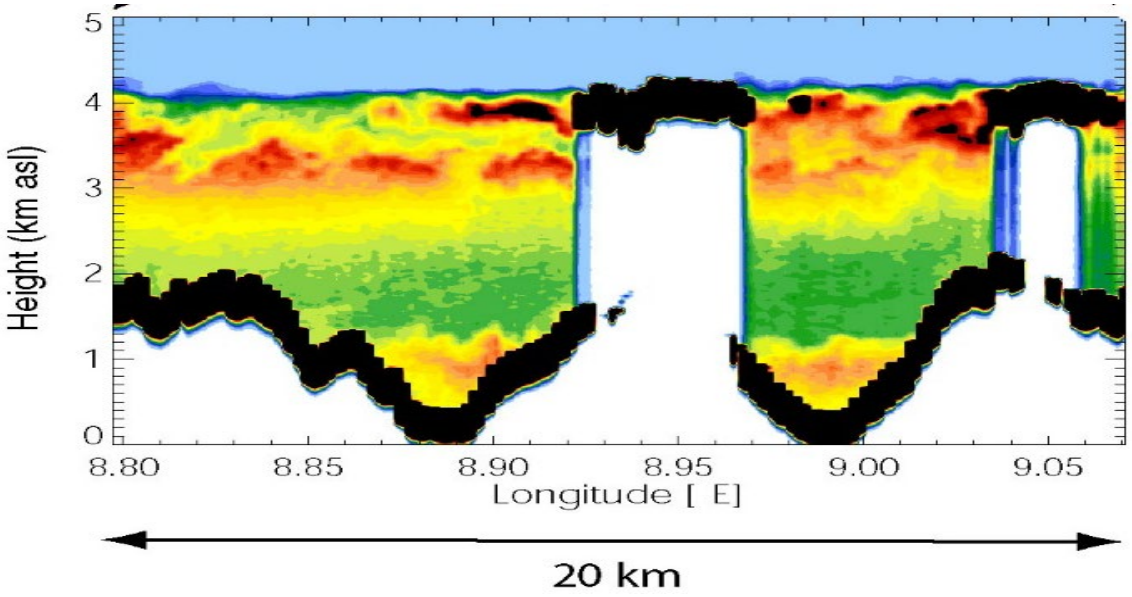
Fig. 2.24. Cross section of modeled TKE ($m^2 s^{-2}$) at 1300 UTC. The location of the west-east cross section is depicted in Fig. 2.1. The asterisks denote the height of the along-valley flight legs. The 0.03 $m^2 s^{-2}$ isoline and the CBL height calculated from the *Ri*-method are shown by the solid and dashed line, respectively.

De Wekker et al. 2002

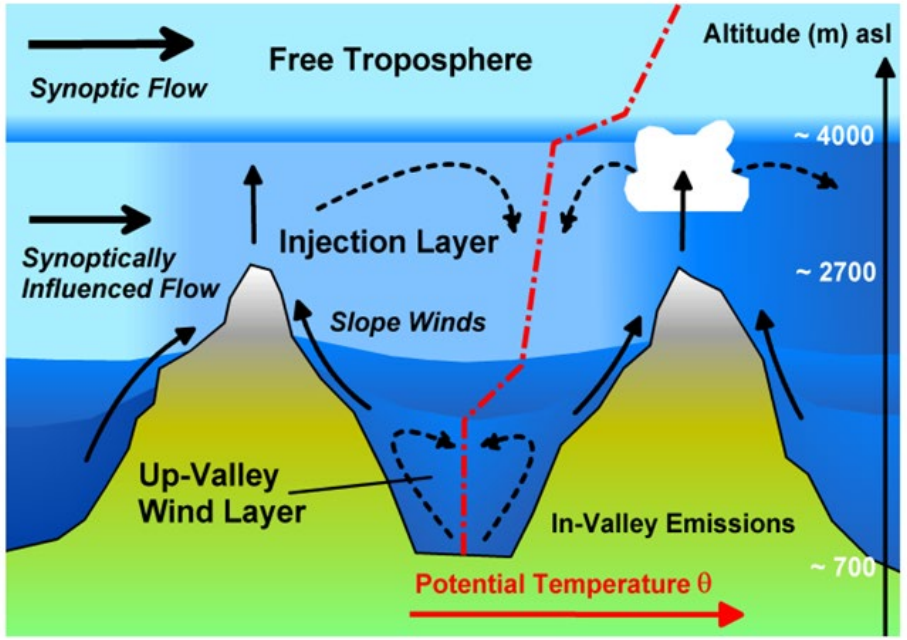
BOUNDARY LAYER STRUCTURE FROM AIRCRAFT

Remote sensing measurements

downlooking aerosol lidar



De Wekker 2002, 2015



Henne et al., 2004

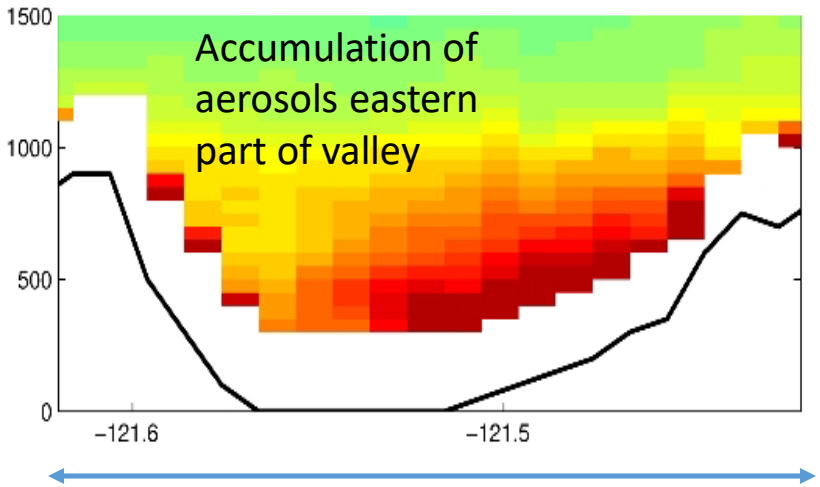
Multi-layer-structure
Spatial heterogeneities
PBL height vs. aerosol layer height

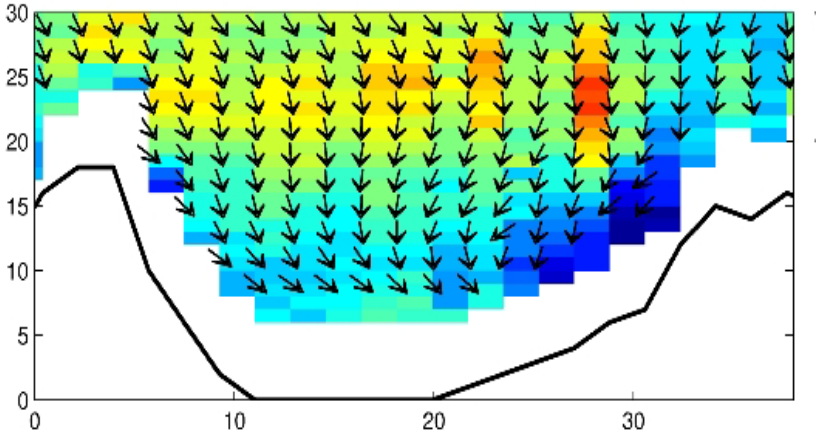
BOUNDARY LAYER STRUCTURE FROM AIRCRAFT

Remote sensing measurements *downlooking* ***Doppler*** *lidar*

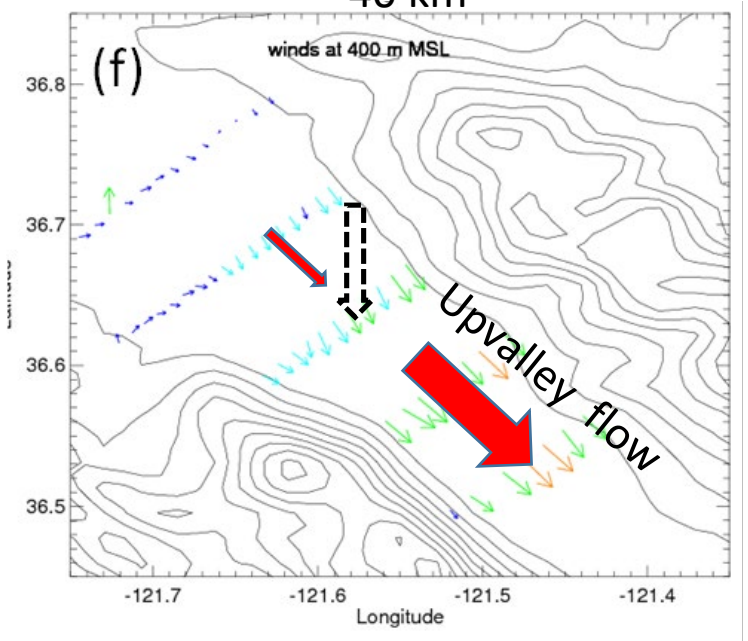
1500 m

0 m





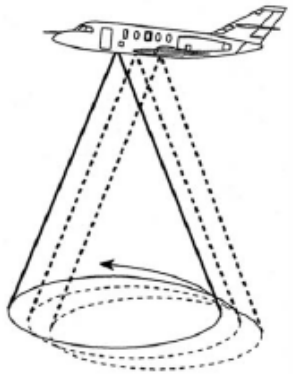
~ 40 km



Salinas Valley, CA, De Wekker et al., 2012

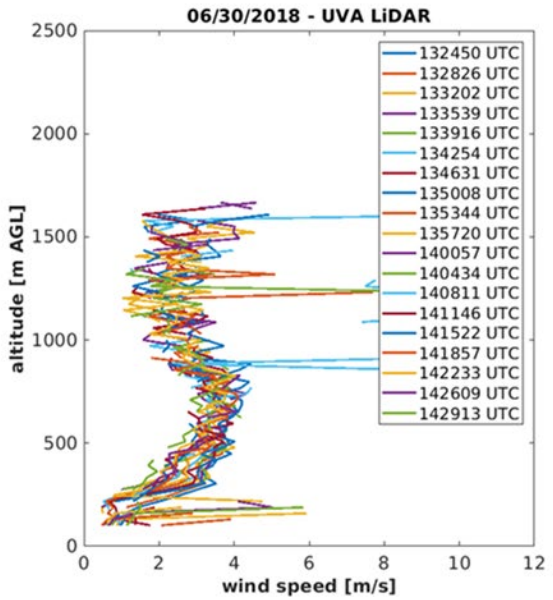
Accelerating valley flow
-> sinking motions

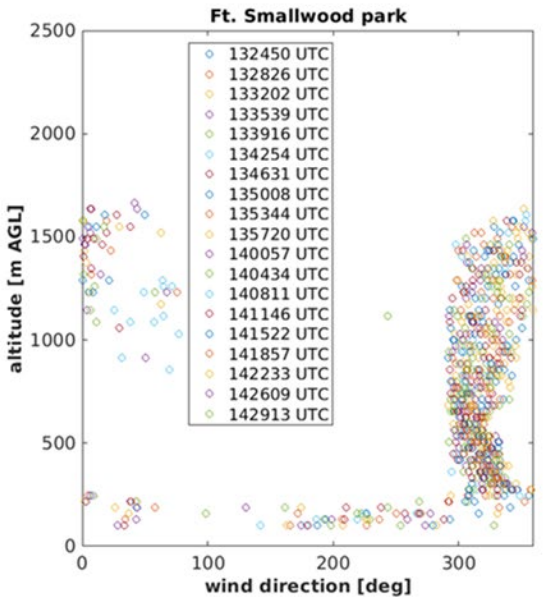
Navy Twin Otter



BOUNDARY LAYER STRUCTURE FROM GROUND VEHICLE (UVA – Wind Observatory on Wheels- **UWOW**)

The UWOW can collect measurements at stationary fixed location AND as it travels along the roads and highways.





Wind profiles from about 100 m to ~3000 m or more (depending on atmospheric conditions and lidar settings) at ~1 km horizontal spacing and 30 m vertical spacing.

Great opportunities to merge with mobile chemistry labs!

When focus is on investigating boundary layer structure, experimental design for airborne observations often relatively simple and straightforward

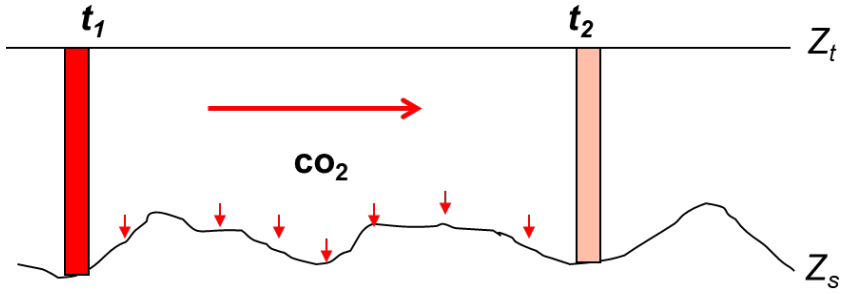
What happens if the project becomes multi-disciplinary?

Example: Airborne Carbon in the Mountains Experiment (ACME) 2004, 2007. Major objective: estimating CO2 budget in the Colorado Rocky Mountains: experimental strategy focused on following airmasses

A MULTISCALE AND MULTIDISCIPLINARY INVESTIGATION OF ECOSYSTEM–ATMOSPHERE CO_2 EXCHANGE OVER THE ROCKY MOUNTAINS OF COLORADO

BY JIELUN SUN, STEVEN P. ONCLEY, SEAN P. BURNS, BRITTON B. STEPHENS, DONALD H. LENSCHOW, TERESA CAMPOS, RUSSELL K. MONSON, DAVID S. SCHIMEL, WILLIAM J. SACKS, STEPHAN F. J. DE WEKKER, CHUN-TA LAI, BRIAN LAMB, DENNIS OJIMA, PATRICK Z. ELLSWORTH, LEONEL S. L. STERNBERG, SHARON ZHONG, CRAIG CLEMENTS, DAVID J. P. MOORE, DEAN E. ANDERSON, ANDREW S. WATT, JIA HU, MARK TSCHUDI, STEVEN AULENBACH, EUGENE ALLWINE, AND TERESA COONS

Sun et al., 2010

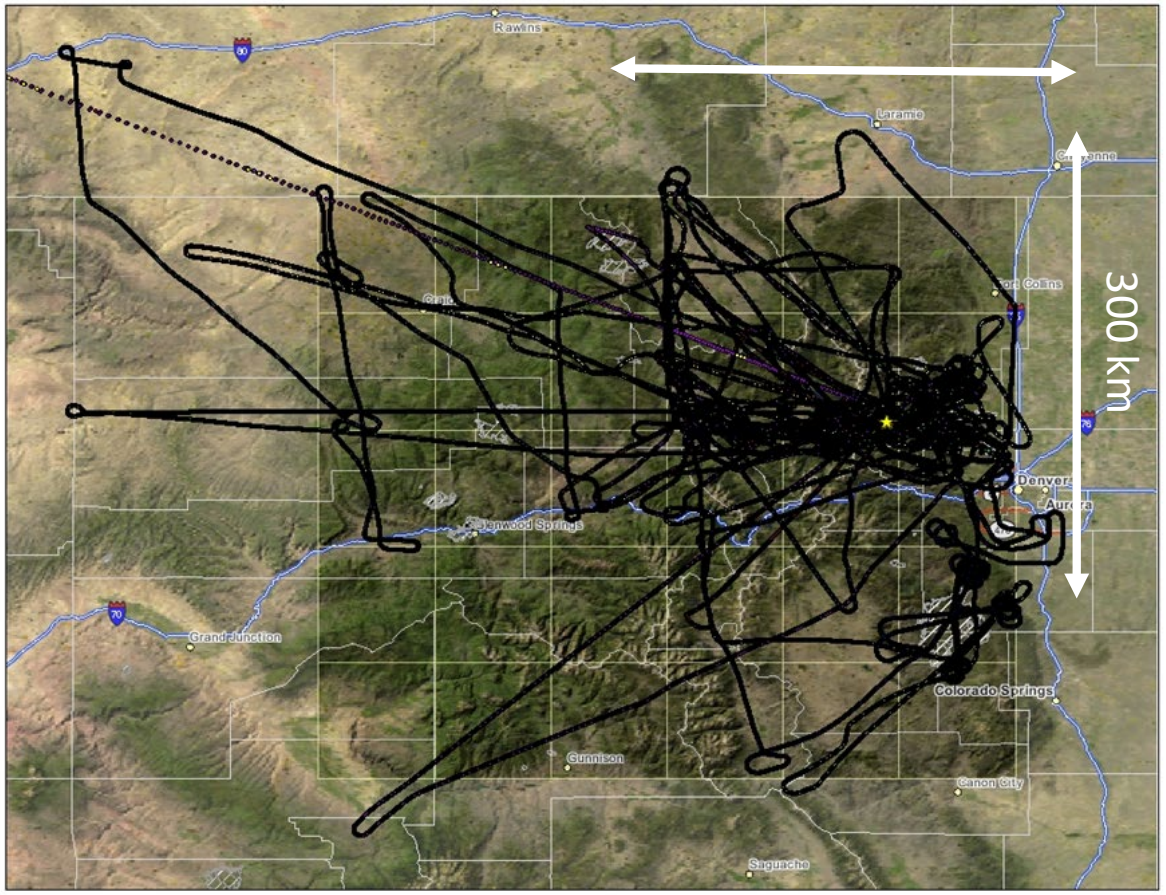


$$F_{co2} = \int_{Zs}^{Zt} \frac{dC_{co2}}{dt} dz$$

MULTI-DISCIPLINARY AIRCRAFT MISSIONS

Conflicting thoughts about optimal experimental design. Large challenges in attempting to ‘measure it all’

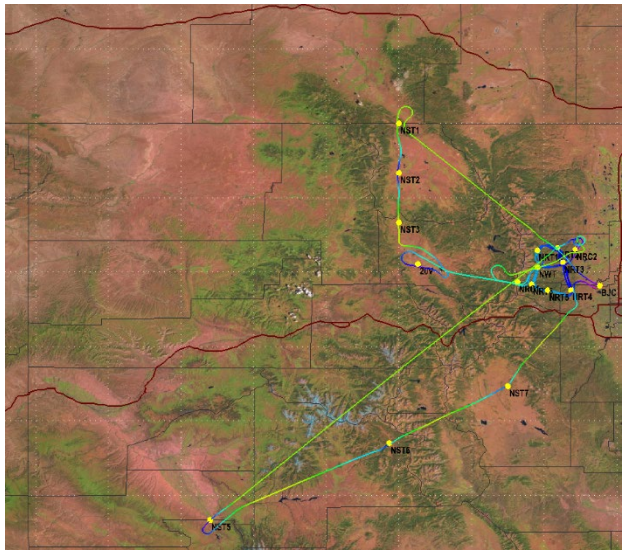
~flight tracks of ~15 flight missions



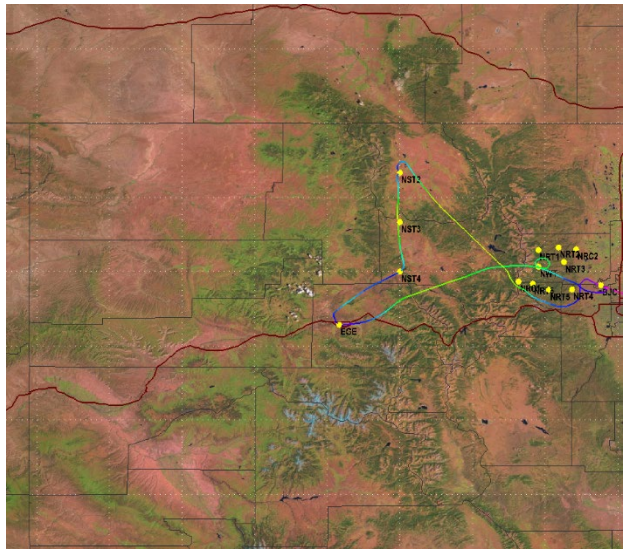
Quite chaotic flight patterns
every mission is unique

MULTI-DISCIPLINARY AIRCRAFT MISSIONS

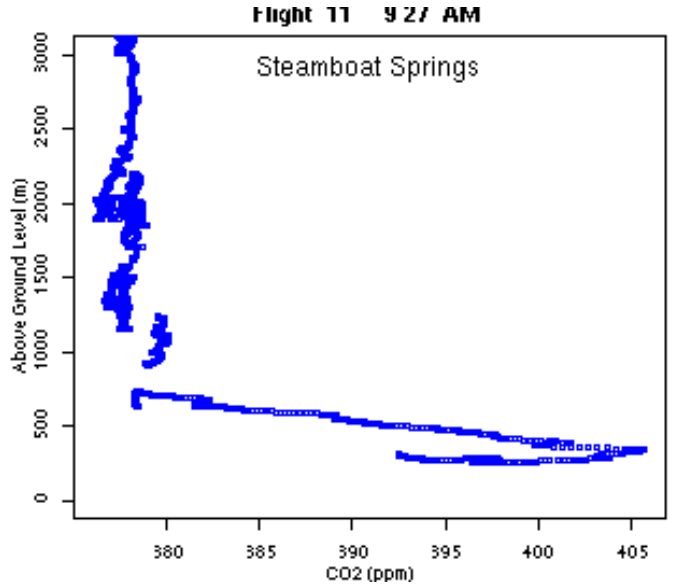
Morning flight path



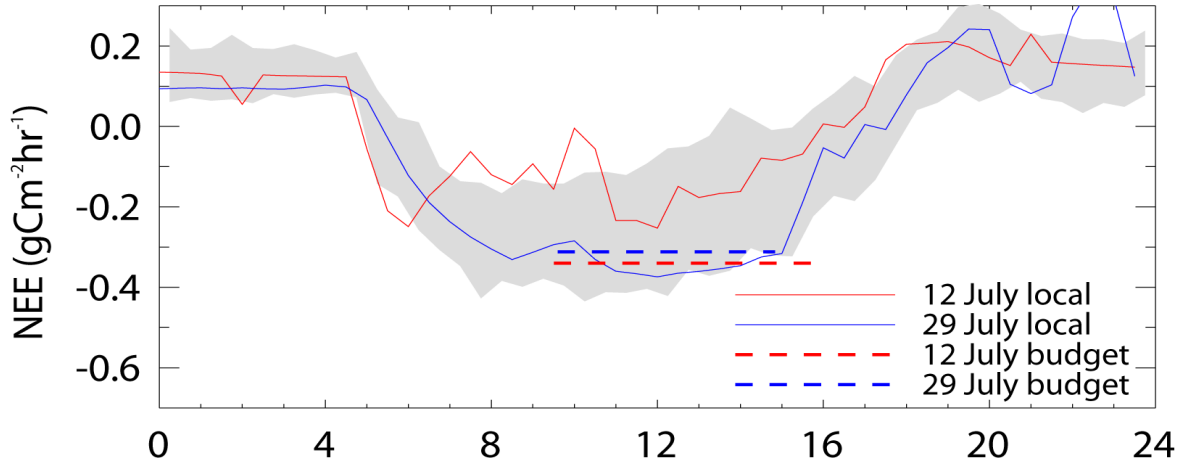
afternoon flight path



Morning Mountain Valley CO_2 Profiles



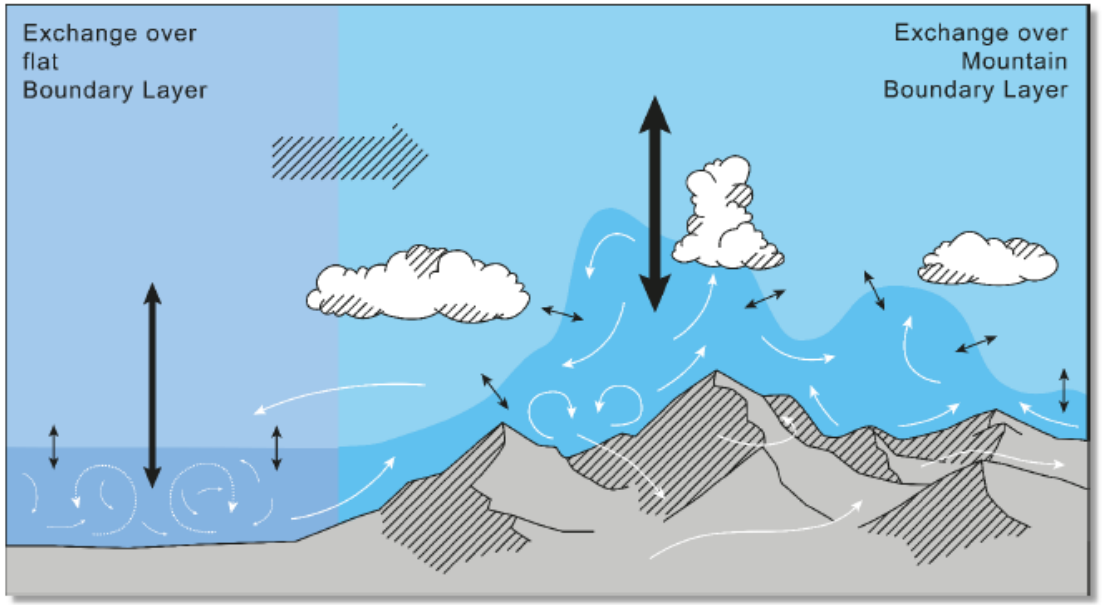
incomplete observations of boundary layer structure make it difficult to quantify uncertainties in applying boundary layer budget method for estimating CO_2 fluxes



De Wekker et al., 2006; Sun et al., 2010

Multi-scale Transport and Exchange Processes in the Atmosphere over Mountains

Programme and experiment



TEAMx is an international research program with the general aim to measure exchange processes in the atmosphere over mountains and to evaluate how well these are parameterized in NWP and climate models.

Steering committee:

Mathias W. Rotach[1], Marco Arpagaus[2], Joan Cuxart[3], Stephan De Wekker[4], Vanda Grubišić[5], Norbert Kalthoff[6], Dan Kirshbaum[7], Manuela Lehner[1], Stephen Mobbs[8], Alexandre Paci[9], Elisa Palazzi[10], Stefano Serafin[1], Dino Zardi[11]

[1]University of Innsbruck, [2]MeteoSwiss, [3]University of the Balearic Islands[4]University of Virginia, [5]NCAR EOL, [6]Karlsruhe Institute of Technology, [7]McGill University [8]National Centre of Atmospheric Sciences, [9]Meteo France, [10]ISAC CNR, [11]University of Trento

TEAMx

First TEAMx workshop 28-30 August 2019, Rovereto (Italy)

TEAMx Memorandum of Understanding between the institutions of the CIG members. Signed by 9 institutions (U. Innsbruck, Meteo Swiss, Meteo France, U. Virginia, McGill U, U. Trento, C2SM, NCAS, KIT. Open to new partners

Publication of 9 review articles in **special issue "Atmospheric Processes over Complex Terrain"** (editors M. Rotach and D. Zardi) in journal "Atmosphere"

https://www.mdpi.com/journal/atmosphere/special_issues/Complex_Terrain

White paper. Draft available. To be finalized soon

www.teamx-programme.org

Workshop topics (addressed in White Paper)

Mountain Boundary Layer Flows

Land atmosphere exchange

Orographic convection

Orographic flow dynamics

Air chemistry and atmospheric dispersion modelling

Climate processes / climate change in mountains

Strategy for field experiment

Strategy for numerical modelling

TEAMx

Some examples of research questions

- What processes contribute to daytime/nighttime exchange in the mountain boundary layer? How can the “overall exchange” be quantified?
- What vertical and horizontal length scales are most relevant for mountain BL exchange? How do we define the mountain BL height?
- Do current models account for exchange processes in the mountain BL?
- Is subgrid-scale parameterization of mountain-induced exchange of heat and mass necessary for O(10 km) grid-spacing models? (e.g., similar to orographic drag)

TEAMx Field experiment

- Planned for 2023
- In the European Alps
- various ‘super sites’ addressing multi-scale processes
- One of the supersites near Innsbruck, Austria – “i-Box” (network of surface flux stations)
- Request of UK and German research aircraft planned
- US efforts are planned (e.g. request of aircraft, ground-based observing facilities, SPO, EDO) - air chemistry component currently not well developed
- Scoping meeting on Wednesday 9 October at NCAR (after UCAR meeting), 5 – 7 PM MT (remote participation possible)

Please contact Stephan de Wekker dewekker@Virginia.edu