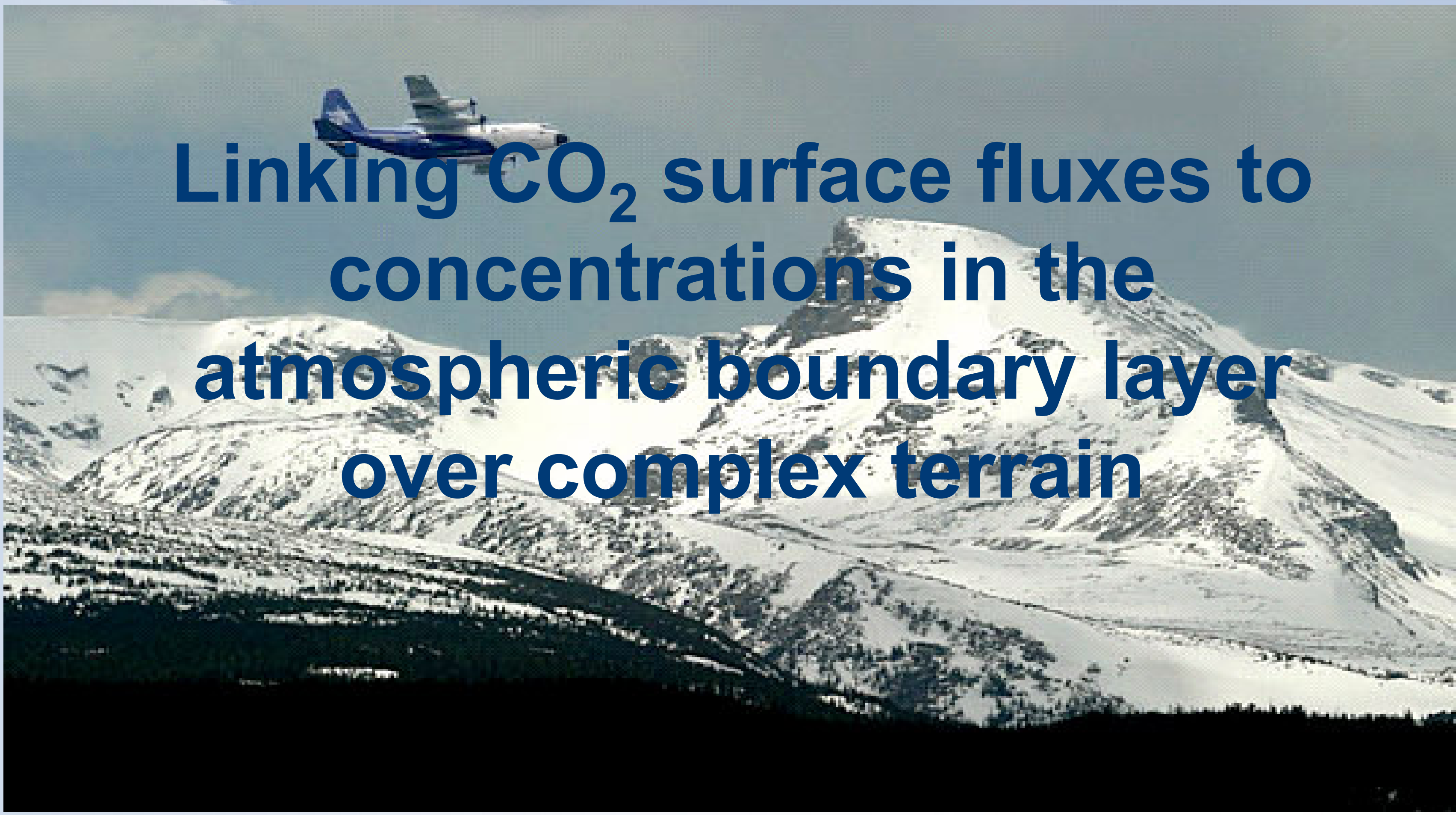

Linking CO_2 surface fluxes to concentrations in the atmospheric boundary layer over complex terrain

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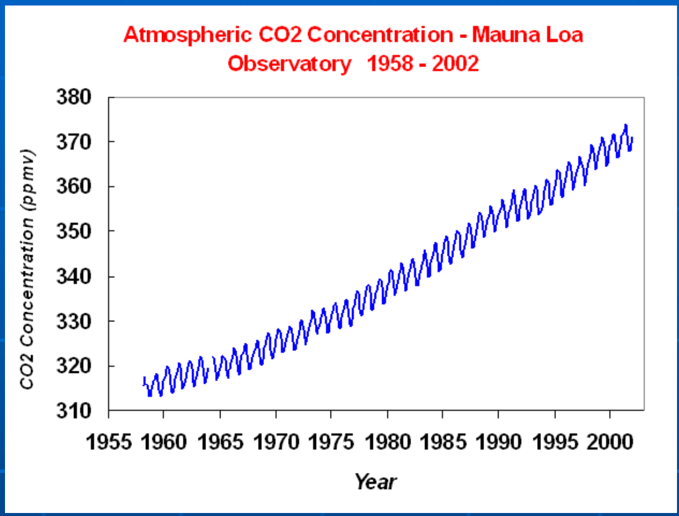
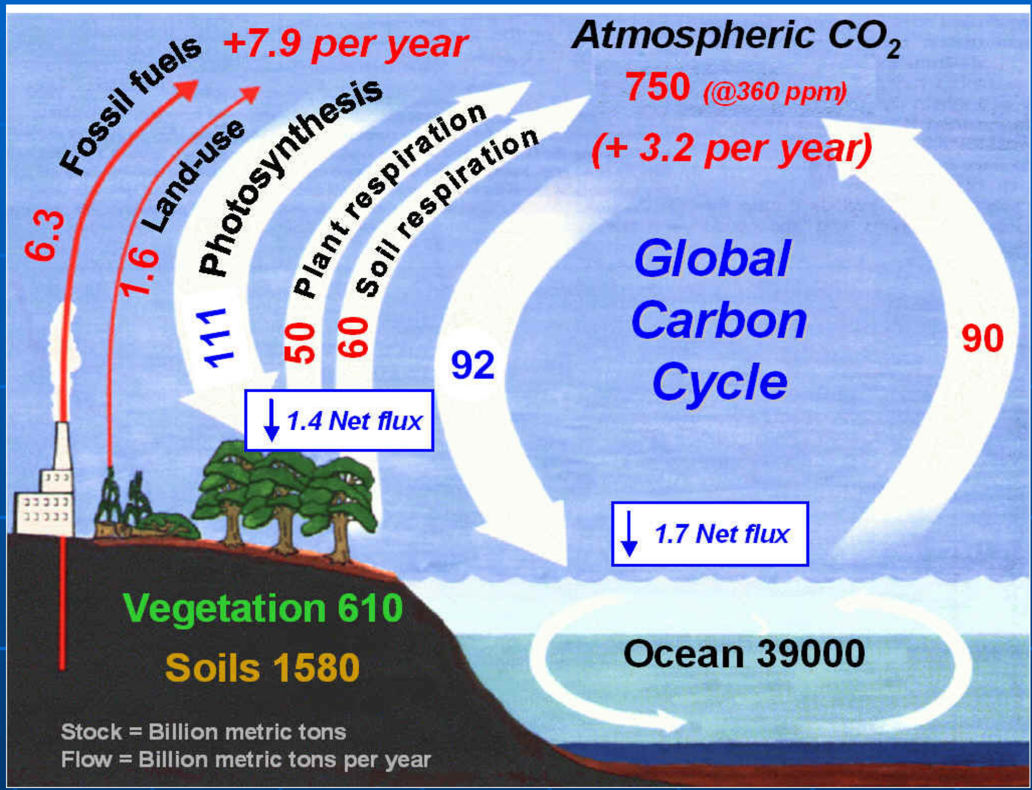
NCAR

1st iLEAPS conference
Boulder, 1/25/05

Background



Atmospheric CO2 Concentration - Mauna Loa Observatory 1958 - 2002
CO2 Concentration (ppmv)
380
370
360
350
340
330
320
310
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000
Year



Fossil fuels
+7.9 per year
Atmospheric CO_2
750 (@360 ppm)
(+ 3.2 per year)
Land-use
Photosynthesis
Plant respiration
Soil respiration
6.3
1.6
111
50
60
92
90
Global Carbon Cycle
1.4 Net flux
1.7 Net flux
Vegetation 610
Soils 1580
Ocean 39000
Stock = Billion metric tons
Flow = Billion metric tons per year

CO_2 concentration measurements in the atmosphere

↓

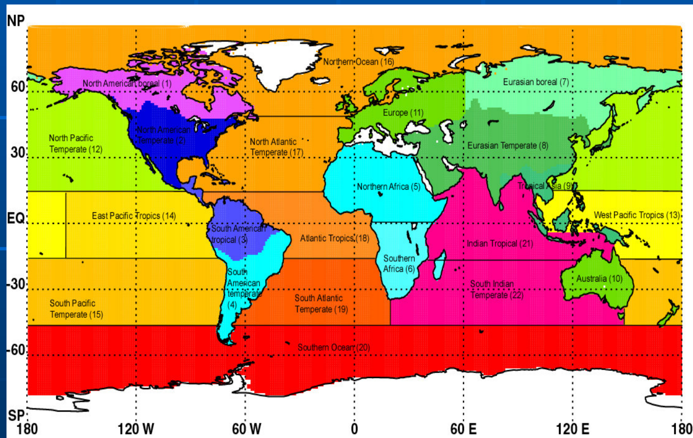
Inverse modeling ← Atmospheric numerical model

↓

Spatial distribution of surface CO_2 fluxes

<u>TransCom</u>:
(Gurney et al, 2002)

16 different global transport models to make estimates of the carbon flux for 22 global regions (continental scale).

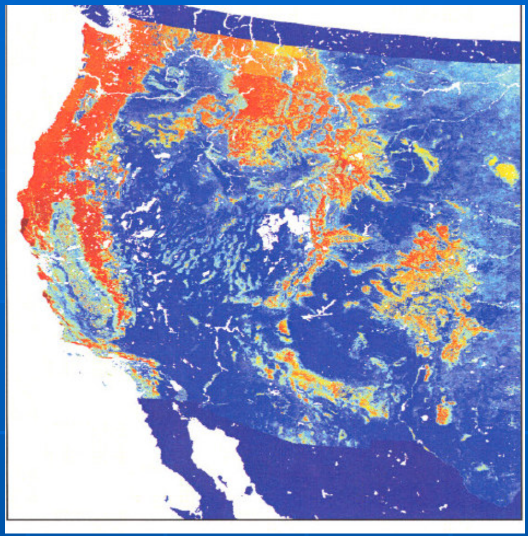


→ For the temperate North American region and for carbon dioxide data obtained from 1992-1996:

carbon uptake of 0.9 ± 0.6 Gt C yr-1

Transport errors in boundary layer cause uncertainty

Global scale -> continental scale -> <u>regional scale/meso-scale</u>



GPP estimated from remote sensing

Half or more of US GPP is in mountainous regions (Schimel et al., 2002)

GPP: Gross Primary Production: The amount of carbon that is 'fixed' (removed from the atmospheric pool of CO_2) by photosynthesis

- need to develop techniques for constraining fluxes in mountainous terrain, and to link those fluxes to underlying processes

Key challenges in the mountains include:

- Complex atmospheric boundary layer transport processes; e.g.,valley, slope flows, venting processes
- Observational, e.g. flux measurements, remote sensing
- complex hydrology due to seasonal snow cover
- Numerical modeling

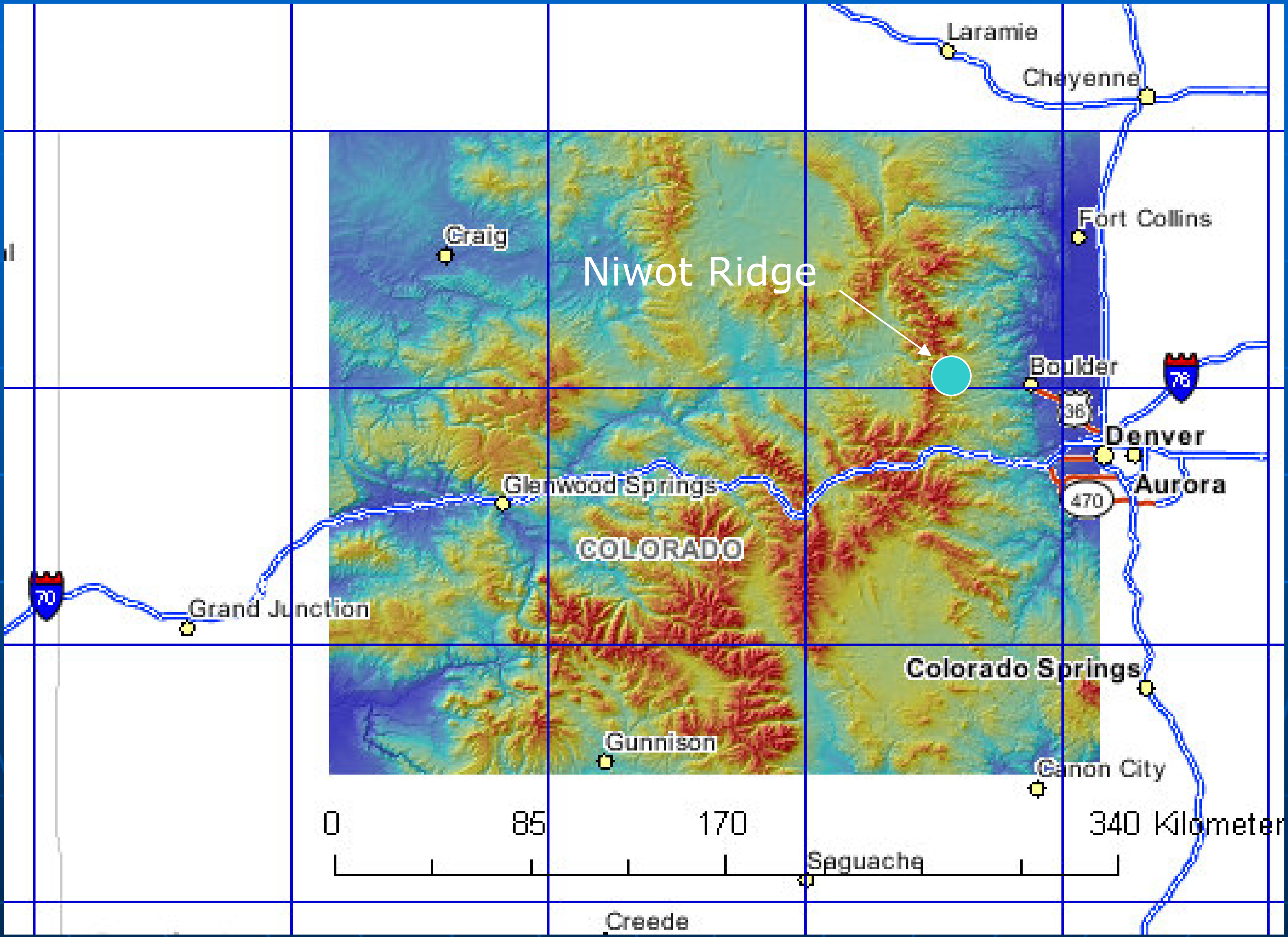
-> Airborne Carbon in the Mountains Experiment (ACME)

ACME field campaign

May and July 2004

- NCAR C-130 aircraft 54 hrs, 16 flights
- Niwot Ridge towers
- Sodar

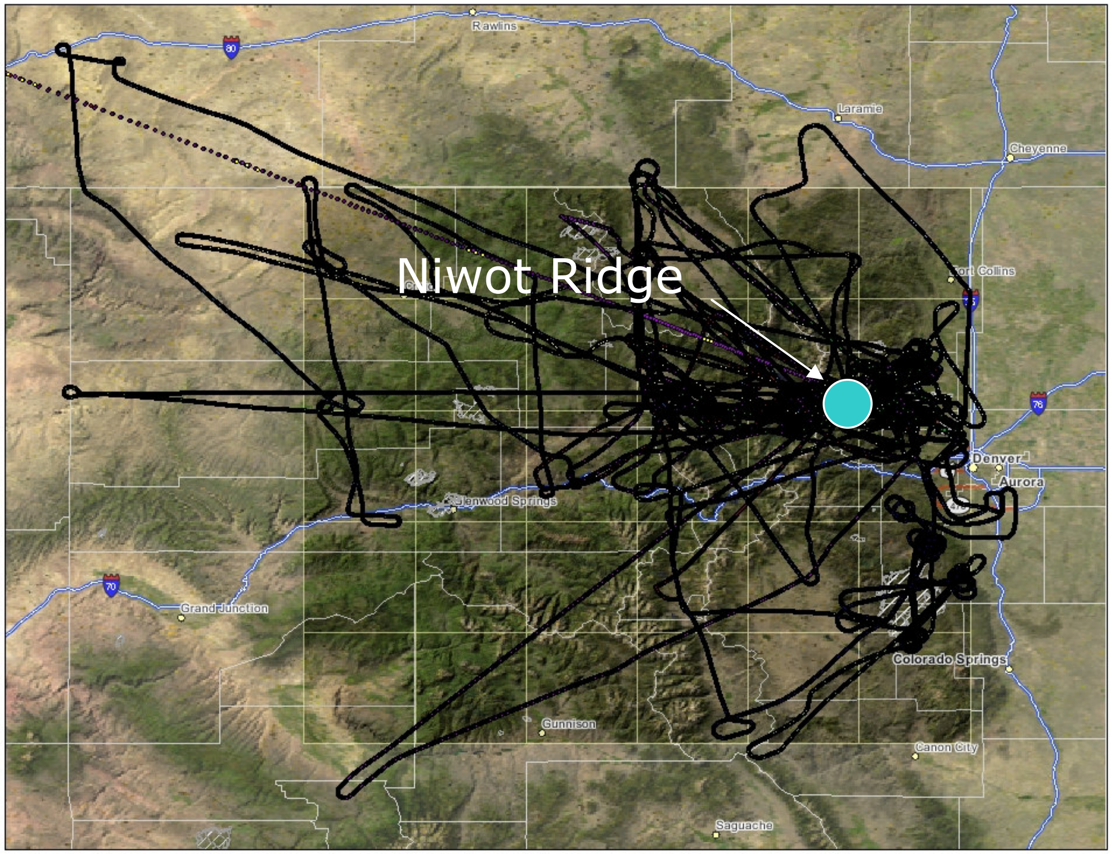
ACME Domain



Laramie
Cheyenne
Fort Collins
Craig
Niwot Ridge
Boulder
36
76
Denver
Aurora
470
Glenwood Springs
COLORADO
70
Grand Junction
Colorado Springs
Gunnison
Canon City
0
85
170
340 Kilometer
Saguache
Creede

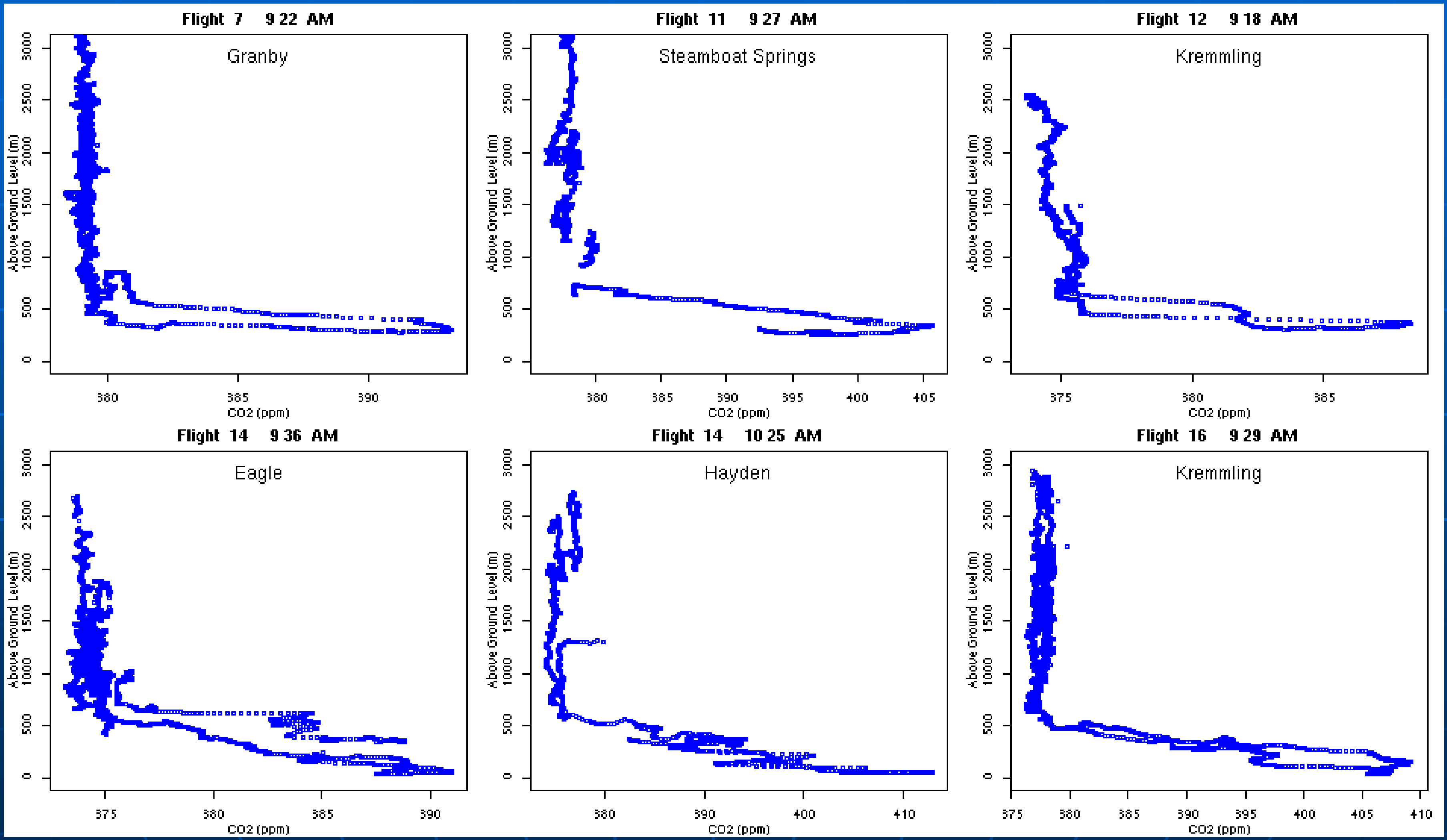
ACME: Flight Project Execution

16 flights

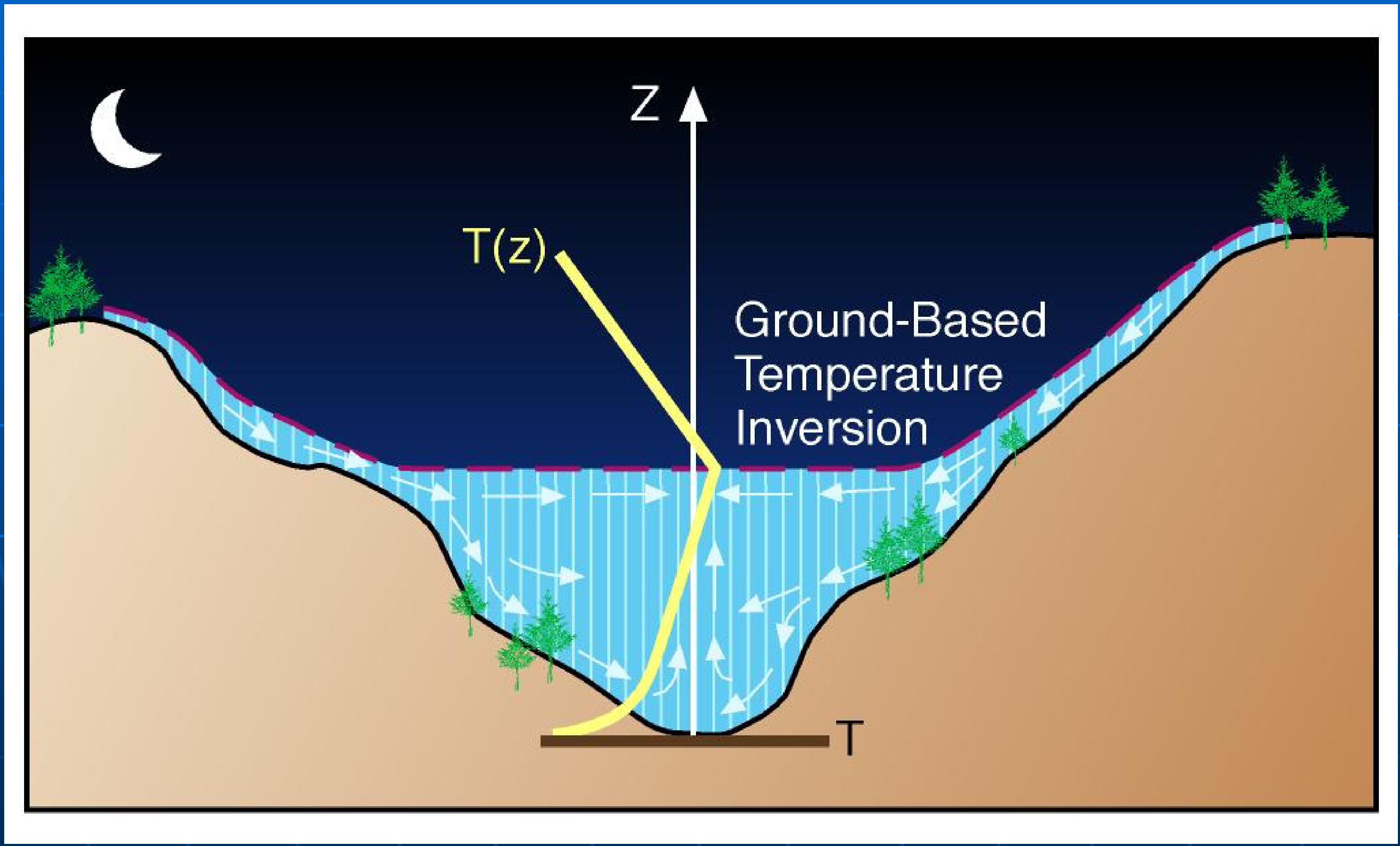


-morning sampling of nocturnally respired CO2 in mountain valleys
-morning to afternoon lagrangian flux measurements
-regional measurements for assimilation into a high-resolution atmospheric model

morning sampling of nocturnally respired CO_2 in mountain valleys

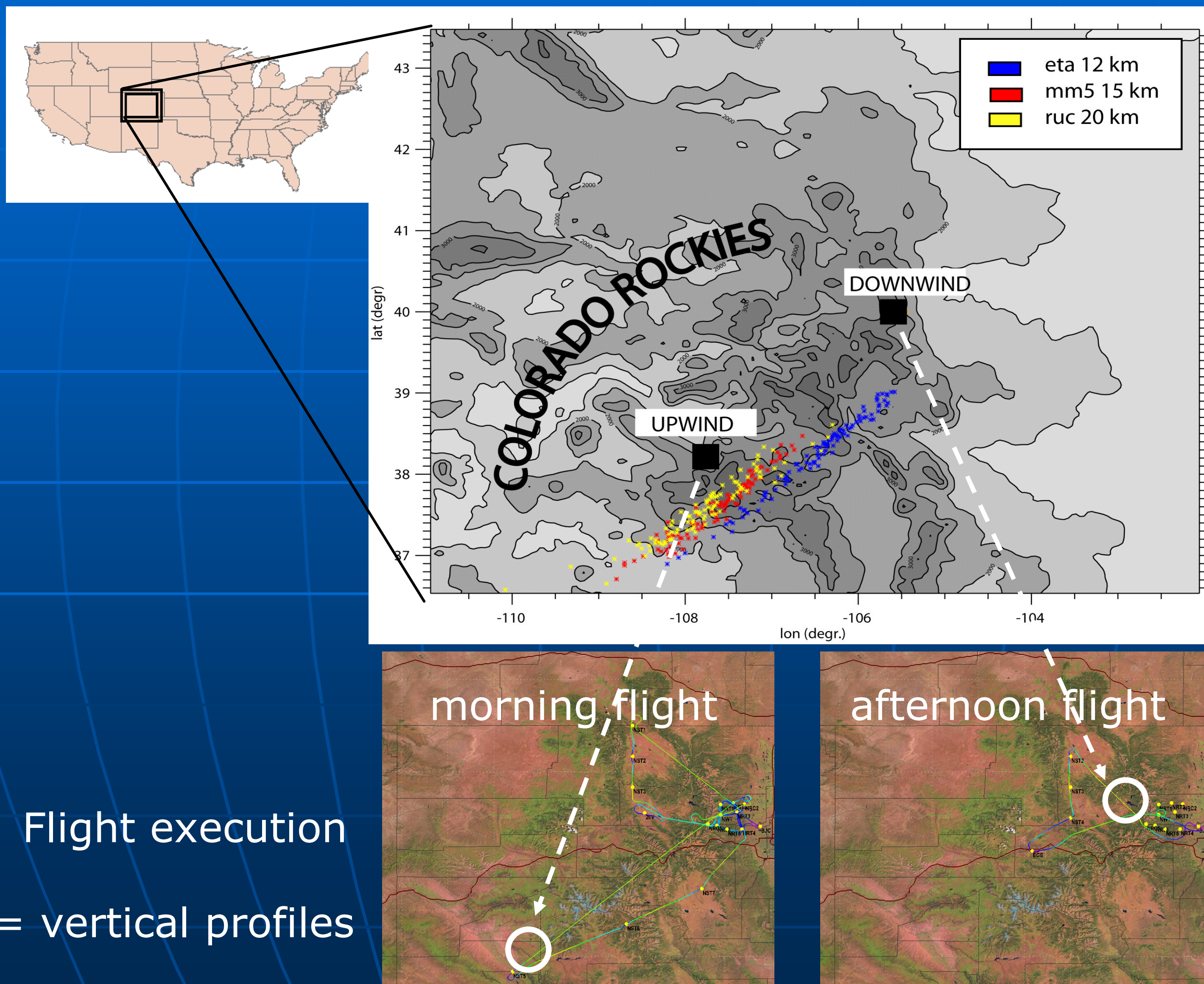


Pooling of cold air, CO_2, etc, at night



Whiteman (2000)

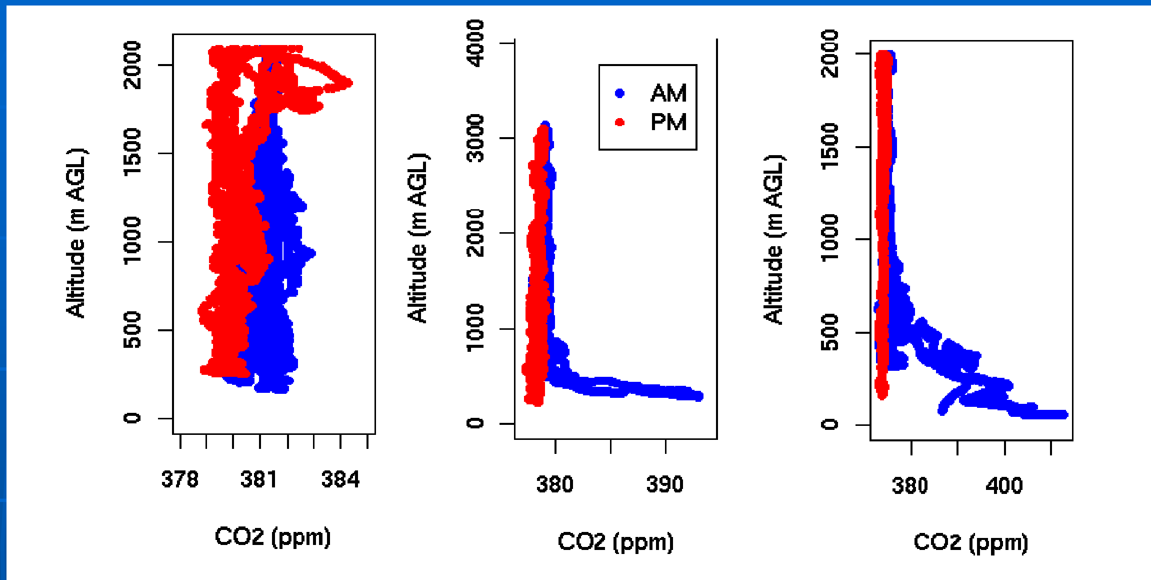
morning and afternoon lagrangian flights



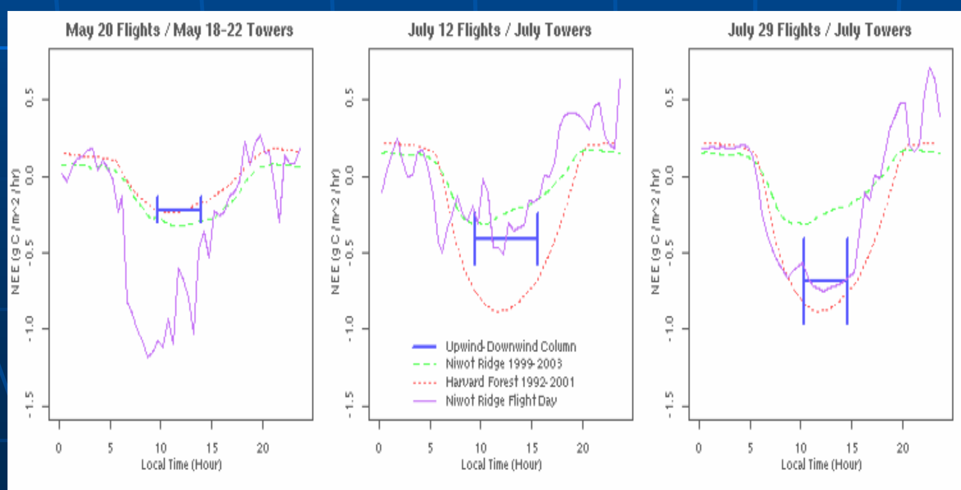
Flight execution

○ = vertical profiles

Boundary-layer budget of CO_2



May 20 July 12 July 29



Differences can be explained
Agreement = coincidence?

ACME Atmospheric Modeling Activities

- Forward Atmospheric Modeling

Goal: -simulate atmospheric flows in ACME modeling domain+ capture complex terrain effects with appropriate parameterizations and model setup parameters
-simulate horizontal and vertical distribution of CO_2 in mountainous terrain

- How well does boundary layer budget method work over complex terrain?

- Inverse Atmospheric Modeling

Goal: - estimate spatial and temporal pattern of surface CO_2 fluxes in mountainous terrain using:

- the adjoint of a mesoscale model
- a particle dispersion model coupled to a mesoscale model (calculating backward trajectories)

Model Setup

- Numerical model: Regional Atmospheric Modeling System (RAMS), LEAF2 for land-atmosphere exchange
- 1 domain, 277 x 247 grid points
- horizontal grid spacing: 1.5 km
- 70 m vertical grid spacing near surface, increasing to 1000 m at model top (~16 km)
- 24 hrs simulation (07/12/04 00 UTC to 07/13/04 00 UTC)
- initialized with EDAS analysis data
- lateral and top boundary nudging towards EDAS fields every 3 hours; no interior nudging

- USGS topography and vegetation
- Soil type: silty loam
- included HRLDAS soil moisture
- CO_2 flux (NEE) f(Rad, GPP, vegetation,elevation)

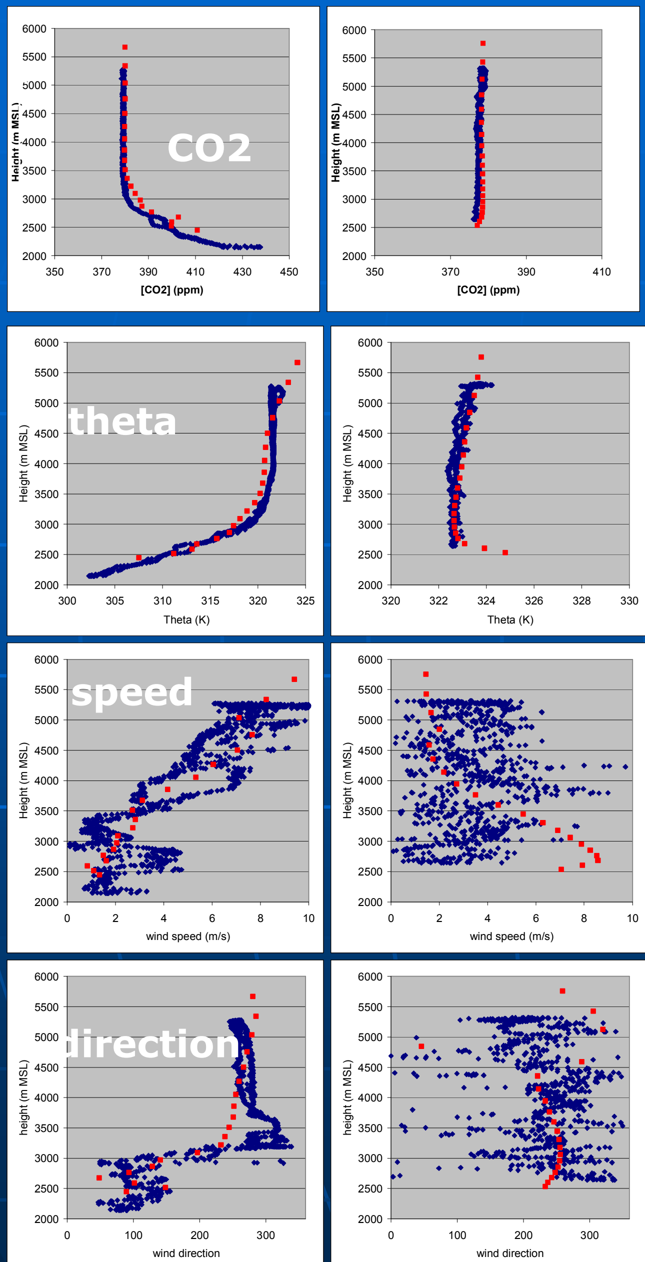
RAMS Model evaluation

- model
- observations

Aircraft vertical profiles

morning afternoon

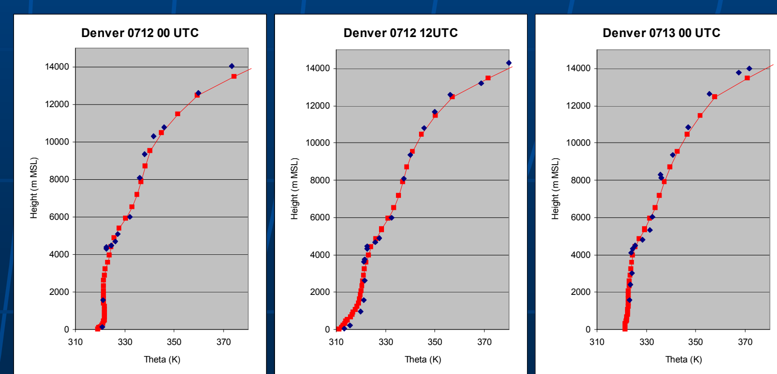
4000m



Denver sounding

0712 00 UTC 0712 12 UTC 0713 00 UTC

15000m



RAMS Model results

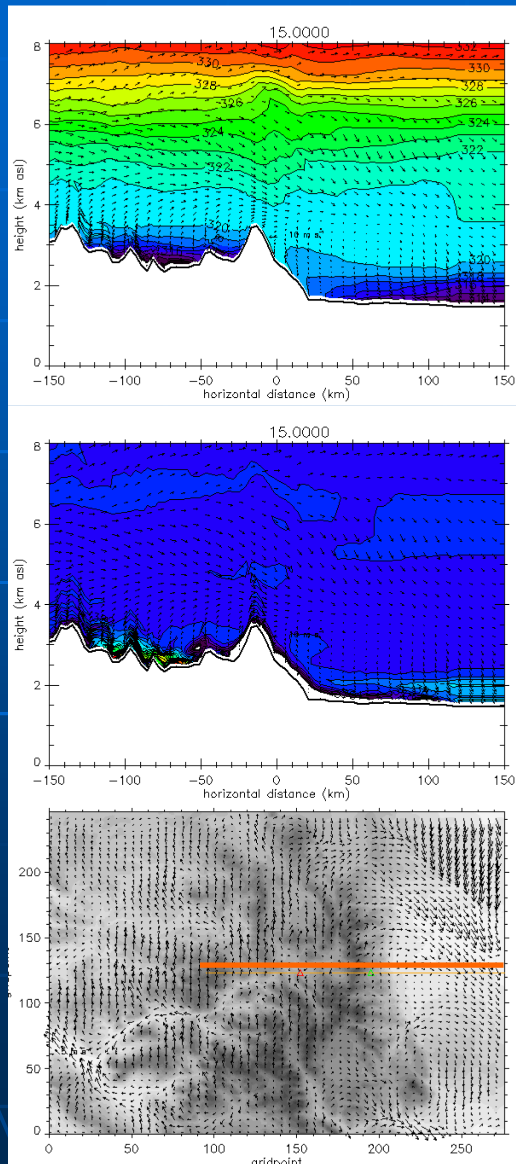
morning

afternoon

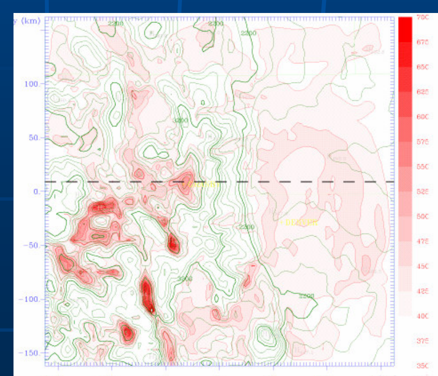
Potential temperature

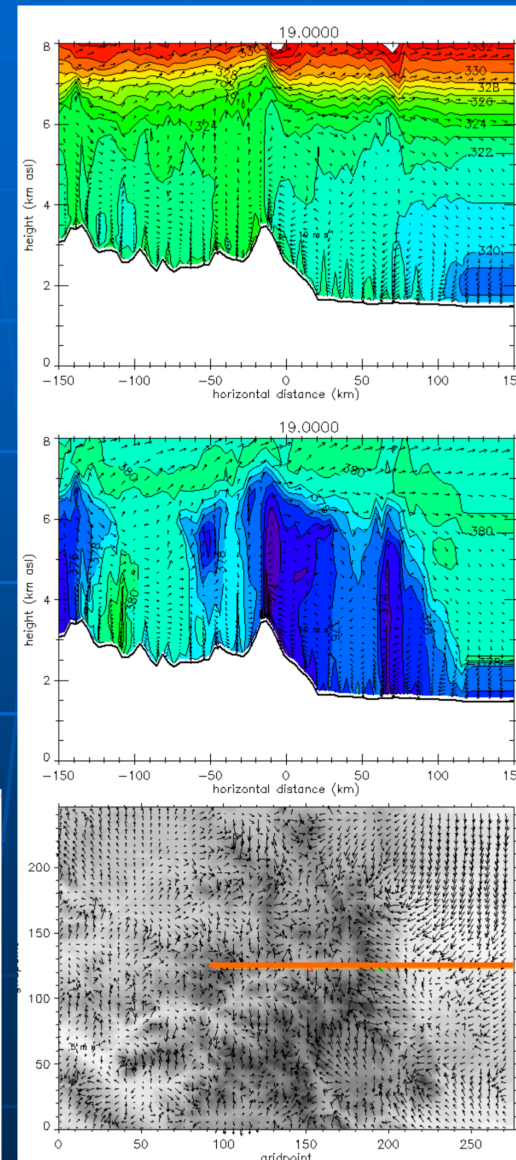
CO_2

winds



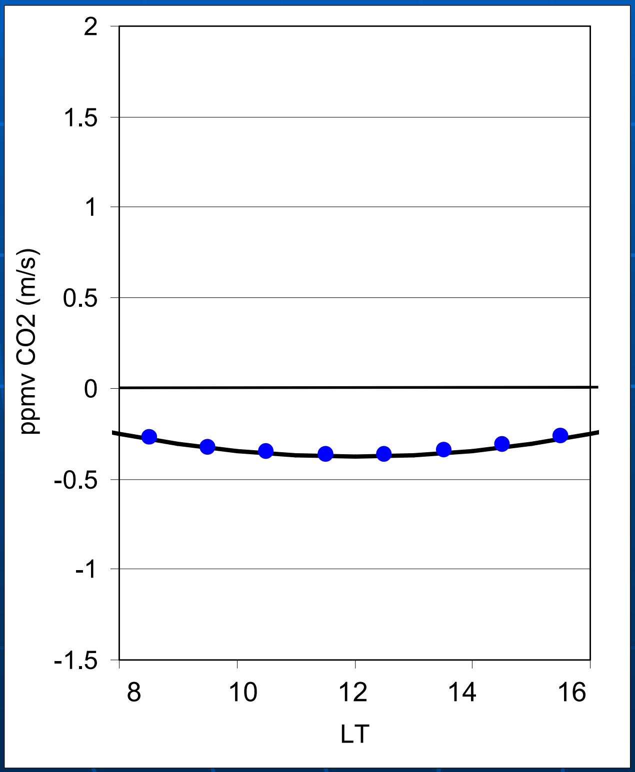
Morning CO_2 pools



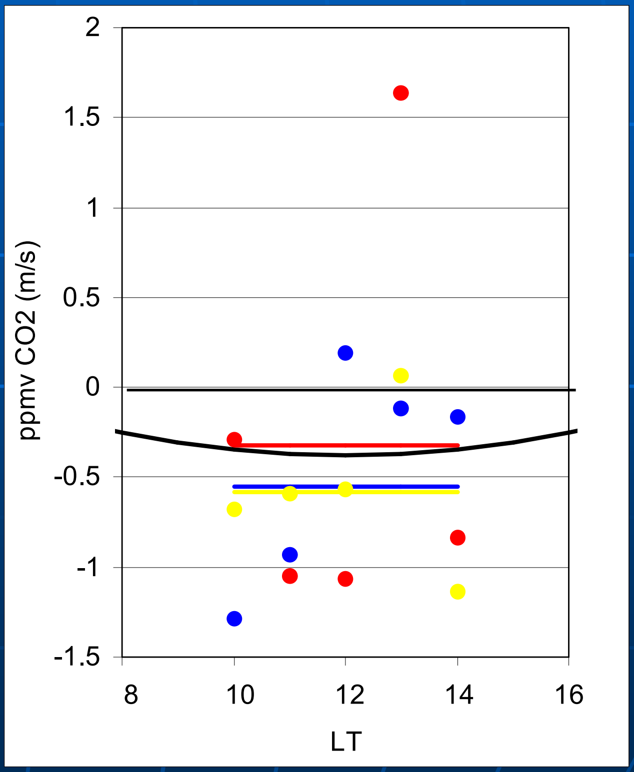


Fluxes from budget method using RAMS output

Idealized case
flat terrain



Realistic case
complex terrain



Summary

- Mountains potential large sink of CO_2 but processes poorly understood
- Airborne Carbon in the Mountains Experiment: comprehensive atmospheric and CO_2 data set
- Forward modeling effort underway, good agreement with observations; atmospheric variables, CO_2
- Potential for boundary layer budgeting techniques in complex terrain but boundary layer processes in mountainous terrain need to be taken into account (thermally-driven flows, venting processes)

- Future plans:
  - Continue case study flight days
  - Further investigation boundary-layer budget in complex terrain
  - Inverse numerical modeling using RAMS adjoint