Convergence and Divergence within a Basin and Its Effect on the Vertical Mixing of Pollutants

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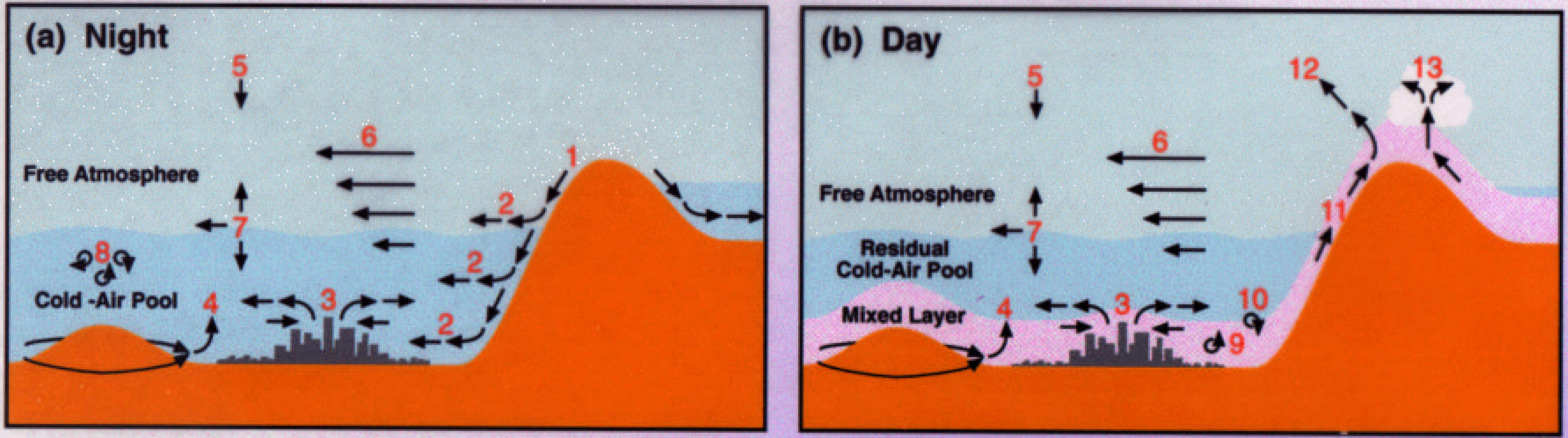
Vertical Exchange Processes



1 - drainage flow
2 - slope flow detrainment
3 - urban heat island divergence
4 - terrain-related divergence
5 - subsidence
6 - synoptic scouring
7 - waves
8 - intermittent turbulence
9 - convective mixing
10 - entrainment
11 - upslope flow
12 - mountain venting
13 - cloud entrainment

Hypothesis

- mean vertical motions within a basin can be large enough to significantly affect vertical transport and mixing of pollutants in stable conditions and to produce pollutant layers in the basin atmosphere

Photo taken from University of Utah web page
Camera located at the University, looking towards downtown

Primary Objectives

- ***determine the spatial and temporal distribution of vertical motions resulting from convergence and divergence patterns in a basin and their effect on mixing of near-surface emissions during stably stratified conditions***
- ***determine how multi-scale flows interact to either enhance or suppress the mixing of pollutants within a basin***

Scientific Questions

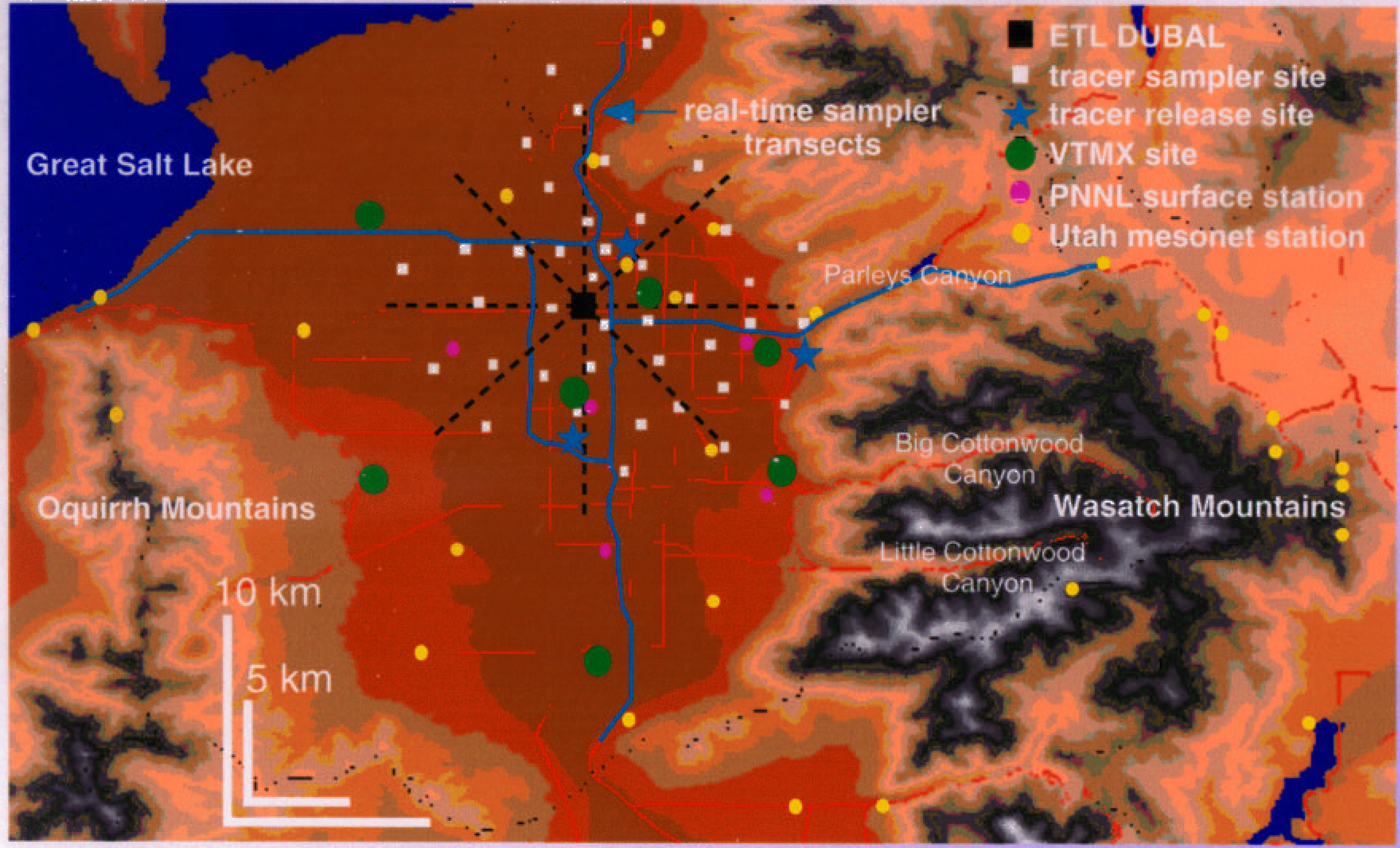
- ***What processes contribute to convergence and divergence in the Salt Lake City basin?***
- ***Are there preferred regions where rising or sinking motions occur or where pollutants accumulate?***
- ***What is the magnitude of vertical motions? Are they large enough to influence vertical mixing?***
- ***How does the urban canopy and local terrain variations perturb basin-scale circulations?***
- ***How much data does a mesoscale model need to assimilate to adequately represent the wind, temperature, and humidity fields in a basin?***

Approach

➡ **measurements and mesoscale model simulations will be used to address the project objectives**

- ***Measurements***
  (1) Perfluorocarbon tracers - BNL collaboration
  (2) Lidar - NOAA / ETL collaboration
  (3) surface meteorological stations - PNNL
- ***Modeling***
  (1) mesoscale model (RAMS, MM5, or ETA)
  (2) Lagrangian particle dispersion model
  (3) chemical transport model

Field Campaign Design



Rational for VTMX Sites

- ***Northern site*** *- flows into and out of basin, effects due to the Great Salt Lake*
- ***Southern site*** *- flows into and out of basin, dynamic effects due to gap in the terrain*
- ***West site*** *(Whiteman's site) - slope flows over the gentle slopes near the Oquirrh Mountains*
- ***East sites*** *- flows along the Wasatch Front are likely to be more complex than other areas, slope flows*
- ***Central site*** *- downwind effects of drainage flows, wind shears far from the basin sidewalls*
- ***Downtown site*** *- urban canopy effects, area where trace gas and particulate emissions are the highest*

Rational for VTMX Sites

- ***Expect near-surface winds and winds in the middle basin atmosphere to be significantly different at each site; all are needed to provide 3-D information of the flow field within the basin***
- ***Sites need to be "evenly" distributed over the entire basin to characterize convergence and divergence***
- ***Expect mean vertical motions to be stronger on the east side of the basin***
- ***Other measurements outside of basin (i.e. Dugway) can by used to characterize regional-scale flows***

Perfluorocarbon Tracer Releases

- ***6 experiments conducted during stable conditions***
- ***5 perfluorocarbon tracers released at 3 sites***

***(1) Basin site** - to examine how flows along the basin floor affect plume transport, rising or sinking motions inferred from areas of convergence or divergence*

***(2) Parleys Canyon site** - to examine how long it takes for tracers released above the near-surface stable layer to be mixed to the surface*

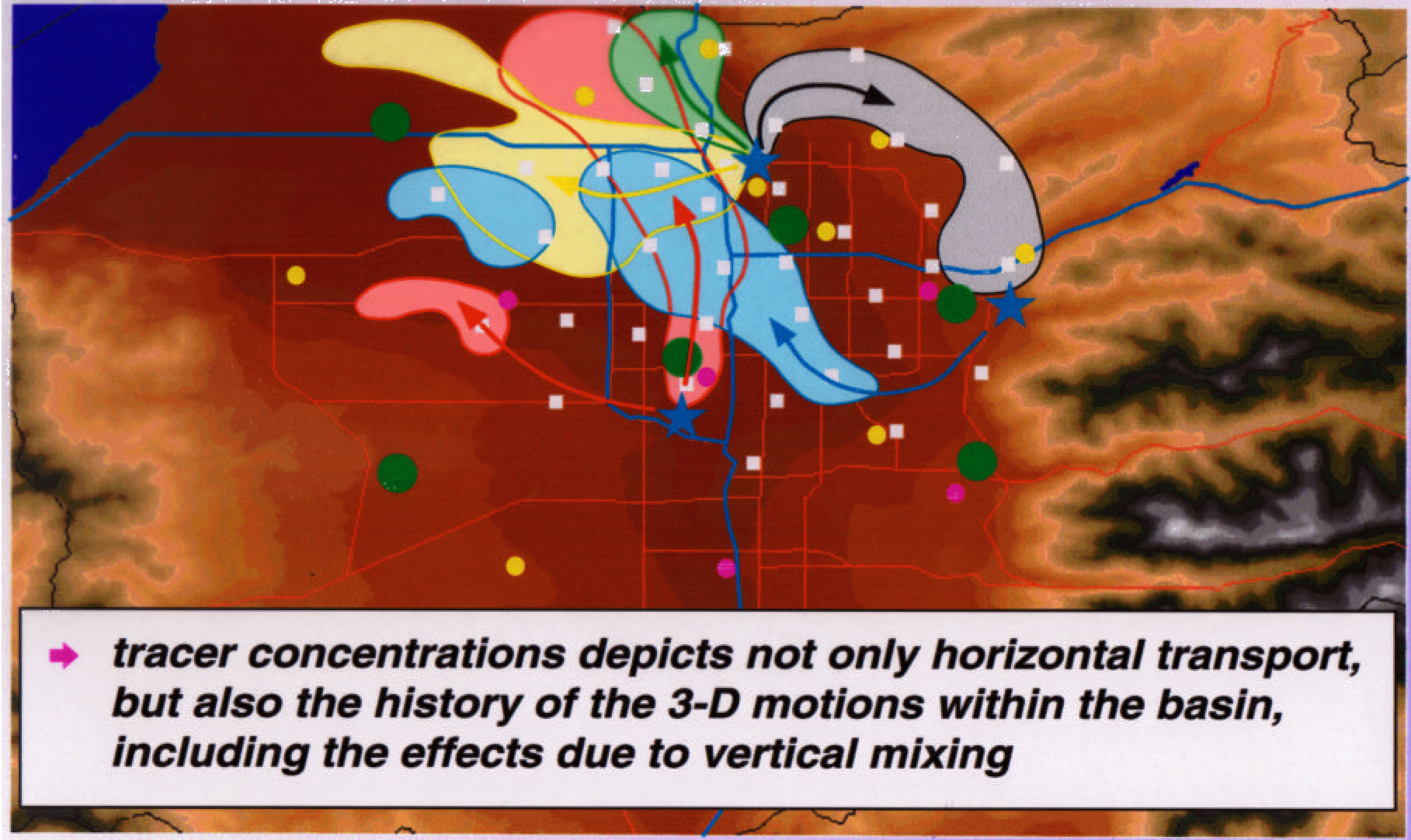
***(3) Downtown site** - 3 tracers released at different elevations to examine the effect of wind shears within the stable boundary layer on vertical mixing*

Perfluorocarbon Tracer Sampling

- ***~50 samplers; 3-h average concentrations obtained for a 21-h period between 18 and 15 LST***
- ***transects along the interstates will be made by a real-time sampler in a van to obtain high spatial and temporal resolution***
- ***explanation of tracer distributions will require the use of meteorological data and models***

- ➡ ***need assistance to locate sampler sites***
- ➡ ***need volunteers to help with collection of samples***
- ➡ ***need to consider deploying real-time sampler on small aircraft to obtain tracer concentrations aloft?***

Perfluorocarbon Tracer Example



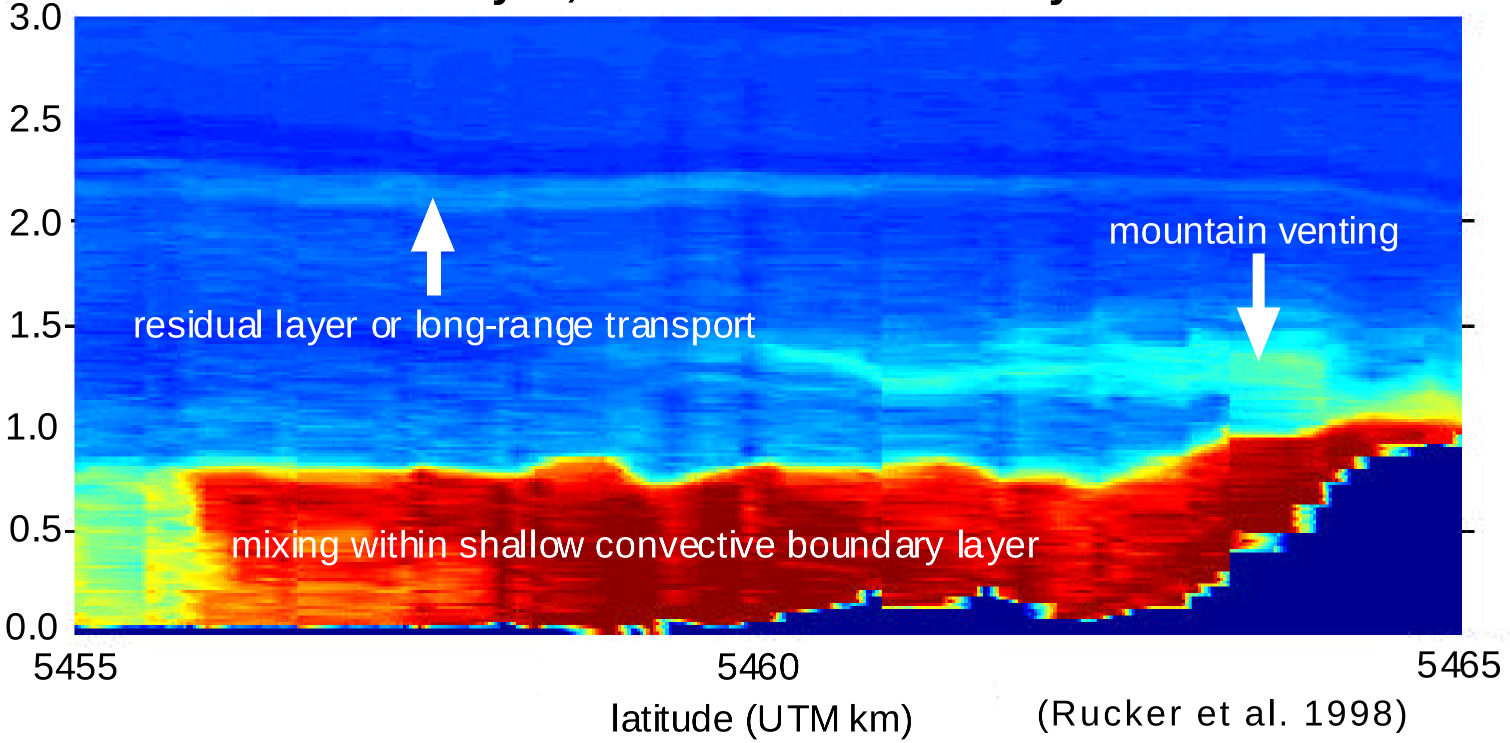
- *tracer concentrations depicts not only horizontal transport, but also the history of the 3-D motions within the basin, including the effects due to vertical mixing*

Lidar

- ***ETL Depolarization and Backscatter Unattended Lidar (DABUL)***
- ***elevation scans obtain a vertical slice of the particulate distribution; instrument can be rotated to obtain multiple scans in different directions***
- ***4 km range (horizontal and vertical) with a 30-m resolution, but data can be obtained up to 10 km***
- ***unattended system designed to run for extended periods of time***
- ***mixed layer height, cloud base and cloud top height, and phase identification can be obtained***

Lidar Example

Aerosol concentration from a dial lidar between 1355 and 1406 LST on May 8, 1993 in the vicinity of Vancouver



(Rucker et al. 1998)

- ***Lidar will provide information aloft, supplementing perfluorocarbon tracer concentrations at the surface***

Transport Modeling

Lagrangian particle dispersion model:

- ***mimic emission of tracer point sources and compare results with perfluorocarbon tracer data***
- ***mimic emissions from the urban area source and compare results with particulate data from DABUL***
- ***illlustrate and quantify the effect of vertical exchange processes***

Photochemical model:

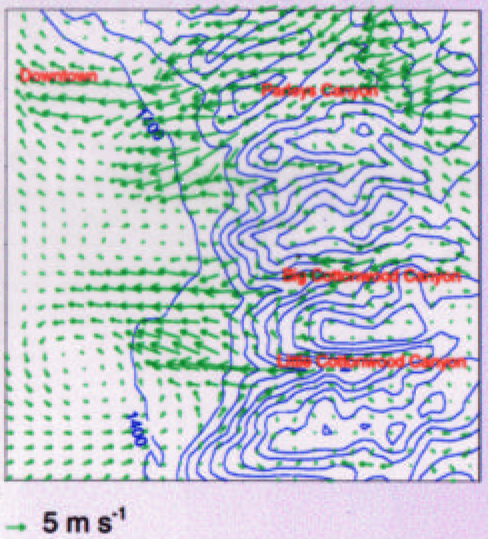
- ***mimic emissions from urban area sources and compare results with surface CO, NO_x, SO_2, O_3 data***
- ***illustrate and quantify the effect of vertical exchange processes***

Mesoscale Modeling

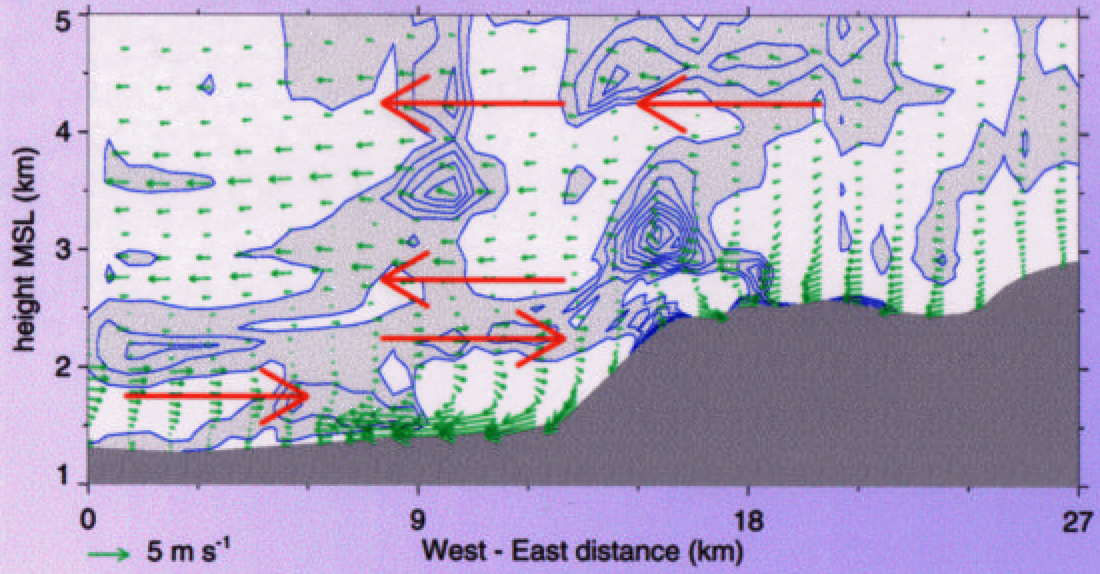
Field experiment design simulations:

- ***prior to the VTMX field campaign, basin circulations and vertical exchange processes will be examined to identify instrumentation sites***

Near-surface winds, 02 LST



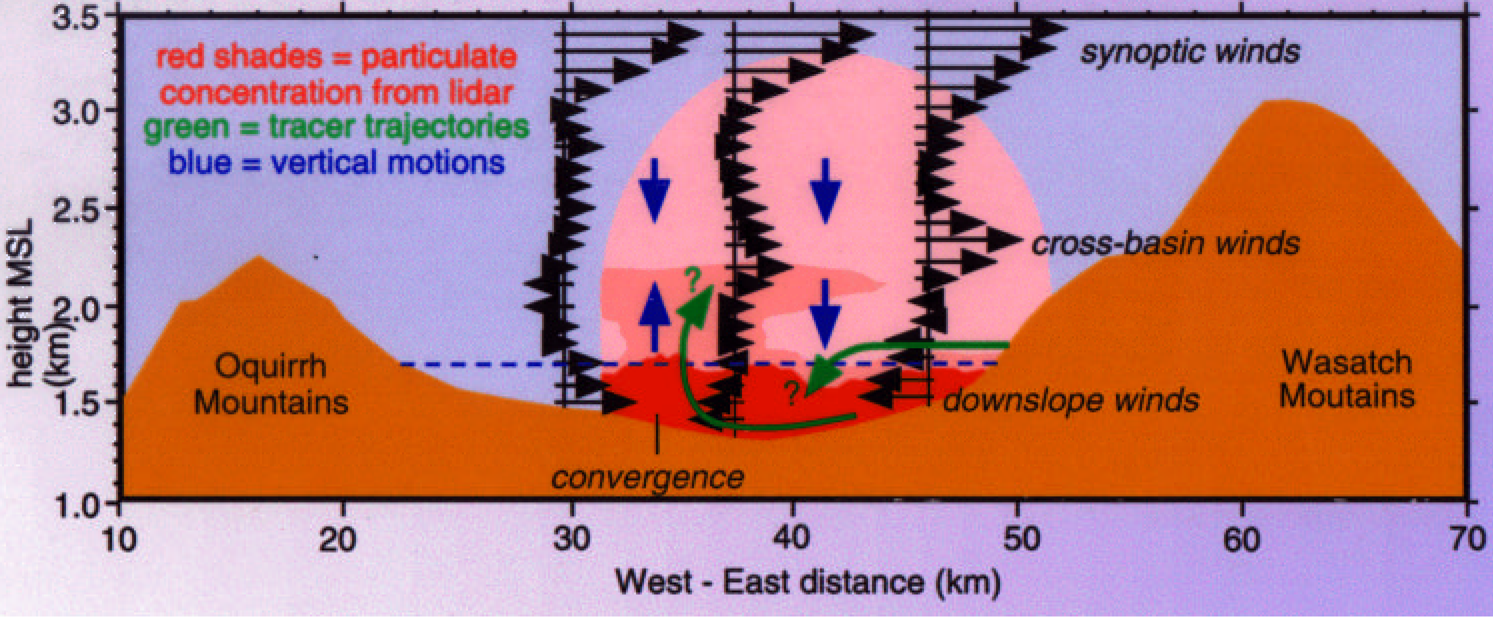
Cross section near Little Cottonwood Canyon, 02 LST (rising motions shaded, 5 cm s^{-1} interval)



Mesoscale Modeling

4-dimensional data assimilation (4DDA) simulations:

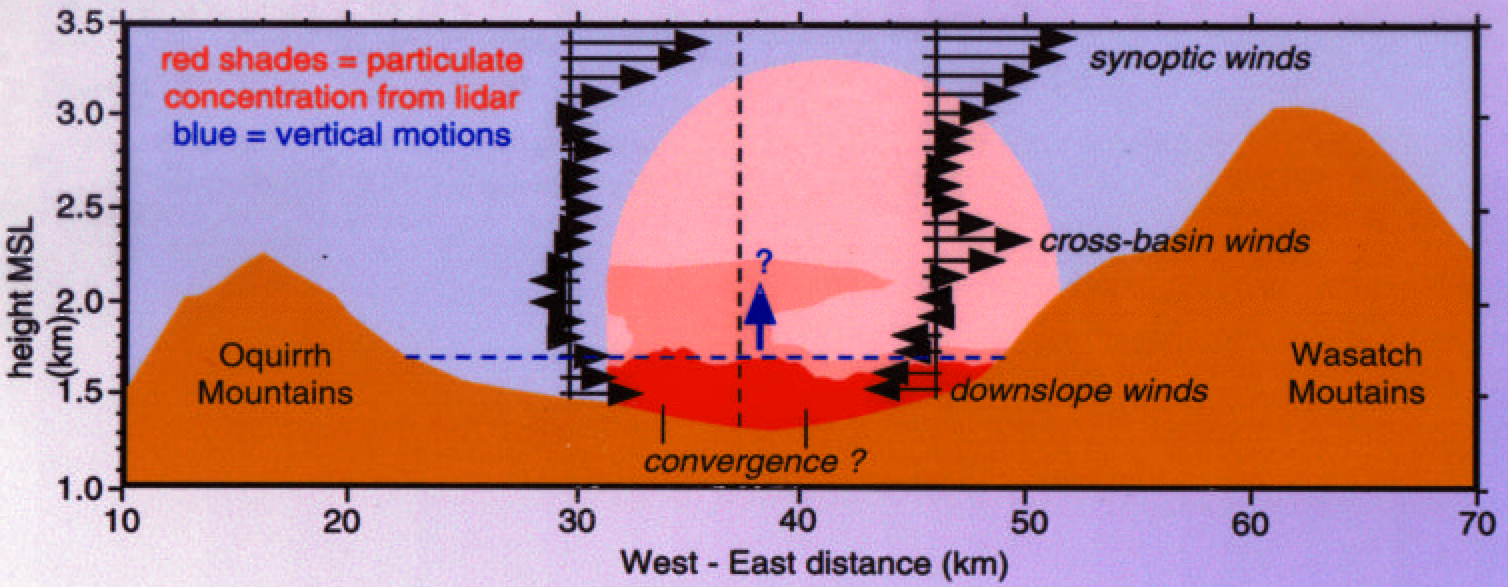
- ***reconstruct mesoscale features (~ 1 km) with a high degree of confidence so that the predicted vertical motions associated with regions of convergence and divergence can be used to interpret how they affect the vertical mixing of pollutants***



Mesoscale Modeling

4-dimensional data assimilation (4DDA) simulations:

- ***VTMX field campaign measurements can be used to determine how much and what type of data is needed to adequately describe the circulations in the basin***



Mesoscale Modeling

Forecast simulations:

- ***determine mesoscale model forecast errors and assess their effect on simulated vertical transport***
- ***sensitivity simulations to examine how the urban canopy influences the the basin-scale convergence and divergence***
- ***sensitivity simulations to examine how synoptic, regional, and local flows interact to either enhance or suppress vertical mixing***
- ***other sensitivity studies***

Critical Measurements

- ***horizontal wind profiles:*** ***radar wind profiler, minisodar, tethersonde*** ***(Astling, Coulter, Fernando, Parsons, Shaw, Whiteman, Astling)***
- ***temperature and humidity profiles:*** ***airsonde, tethersonde*** ***(Fernando, Whiteman)***
- ***vertical velocity profiles: derived from*** ***radar wind profiler, minisodar*** ***(Coulter, Frasier, Parsons, Shaw)***
- ***turbulence:*** ***radar wind profiler, sonic anemometer*** ***(Cooper, Frasier, Nappo, Shaw)***
- ***3-D wind fields:*** ***Doppler lidar*** ***(Banta, Cooper)***
- ***surface meteorology: Utah*** ***mesonet*** ***(Horel)***
- ***trace gas and particulate:*** ***CO, SO_2, NO_x, $PM_{2.5}$*** ***(Watson)***