

Prospecting for Thermals Using an Airborne DWL

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WGSBWL
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Overview

- SkyWalker (DARPA) driven objectives
 - A National Institute of Aerospace and LaRC project
- Background on TODWL (Twin Otter Doppler Wind Lidar)
- October 16-20, 2006 SkyWalker flights
- Presentation of a few case studies
- No-cost extension flights in April, 2006
- Envisioned “Prospecting for UAV Atmospheric Advantages”

Objectives and strategy

- The SkyWalker project requested the use of an existing airborne DWL to explore the feasibility of using Doppler lidar to prospect for vertical motions within the atmosphere existing in reasonable proximity of an aircraft.
- The expectation was that future UAVs could be equipped with a modest (whisker class) DWL that would be used autonomously to locate nearby vertical air motions that could serve to increase the altitude of the aircraft and thus increase mission duration over that achievable with just onboard fuel.

Objectives and strategy (2)

- The basic strategy proposed by SWA was to conduct a series of airborne experiments using the TODWL system to collect data that could be used for the following:
 - Identify the DWL detectable signatures of vertical structures observed ahead of the aircraft at or near flight level;
 - Determine the vertical extent of vertical motion structures that can be reached from the current aircraft position;
 - Rank multiple coincident vertical motion structures based upon risk/benefit metrics.

Thoughts on detecting vertical motions to enhance UAV operations

- Objective is to detect vertical motions in the atmosphere that can be used by a UAV for adaptive flight
 - Upward motions (thermals and waves) can be used to regain altitude and increase flight times
 - Downward motions (downdrafts and waves) can be avoided
 - Knowledge of shear of the horizontal wind can be used to augment platform performance (similar to the hot air balloon directional control strategy)

Model/Lidar combinations

- Lidar scanned in a 2 - 5 degree cone looking forward
- Lidar scanned in raster pattern to obtain multi-layer input to a simple mass continuity model
- Lidar scanned to validate model analyses



The TODWL system

A CIRPAS instrument

(Twin Otter Doppler Wind Lidar)



The instrument

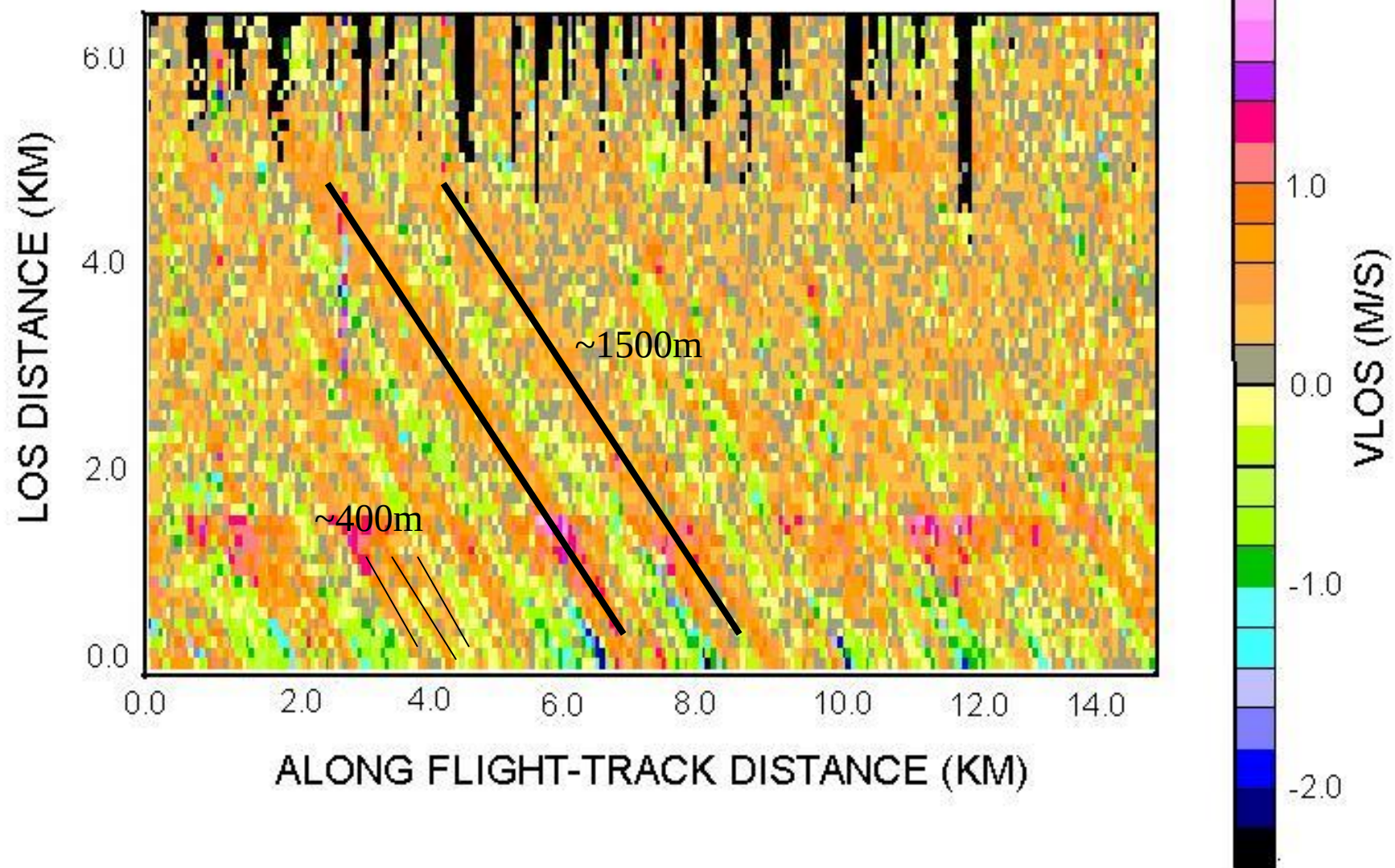
- 2 μ m coherent detection
- 2 mJ (330 nsec pulse)
- 500 Hz
- water cooled
- ~7-10% total system efficiency
- 10 cm two axis scanner, side door mounted
- GUI with realtime instrument control and data display
- Weight: 450lb Power: 1.5 KW

Background

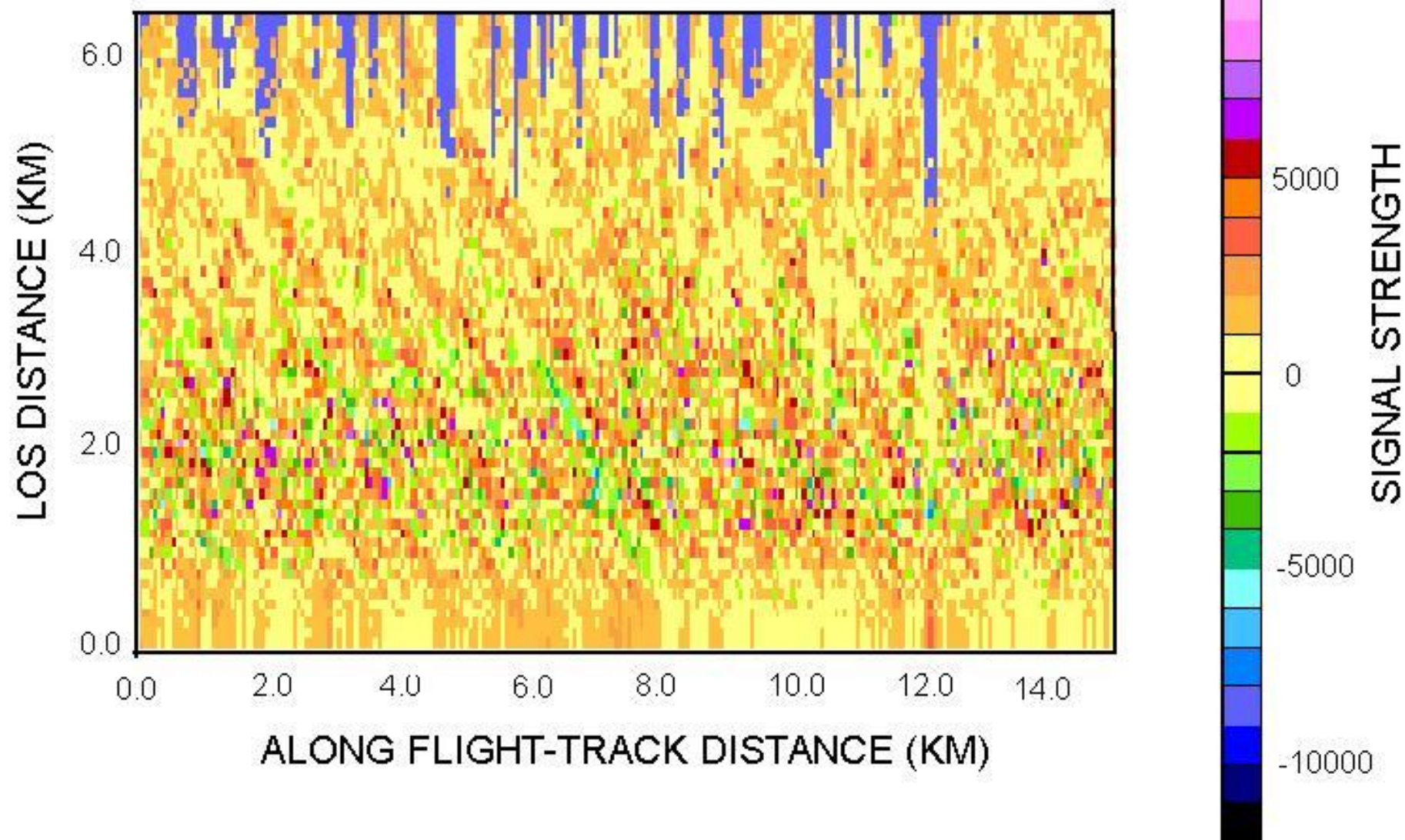
- TODWL has been operated (since 2002) by CIRPAS (Center for Interdisciplinary Remotely Piloted Aircraft Studies), a part of the Naval Postgraduate School, Monterey, CA.
- Used by NOAA for investigating lidar performance over the ocean in planning for a future space-based DWL
- Used by DoD for studies of UAV wind profiling in complex terrain and urban areas.

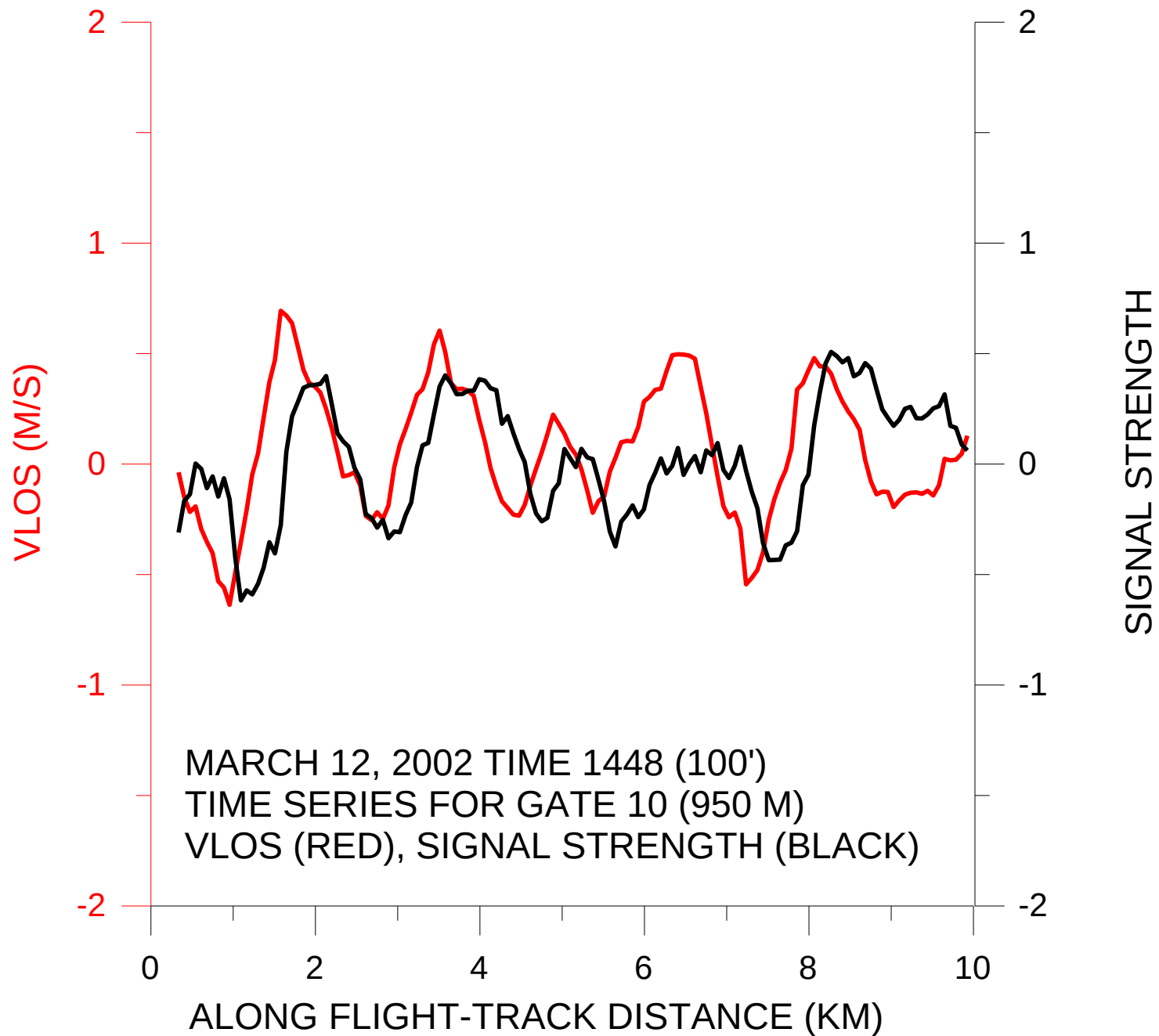


Flight Level LOS Velocity (30 meters altitude)
March 12, 2002



Flight Level Signal Amplitude (30 meters altitude)
March 12, 2002





SkyWalker Flights

October 2006 near Monterey, CA

- 8 hours of flight time
- Explored several strategies for scanning lidar
 - Forward conical (5 degree cone angle)
 - Stepped raster
 - Continuous raster
- Flights targeted ground rooted thermals, orographic waves and cloud updrafts

Salinas Valley



Monterey Mountains



500 feet over Salinas Valley floor



Over Salinas Airport

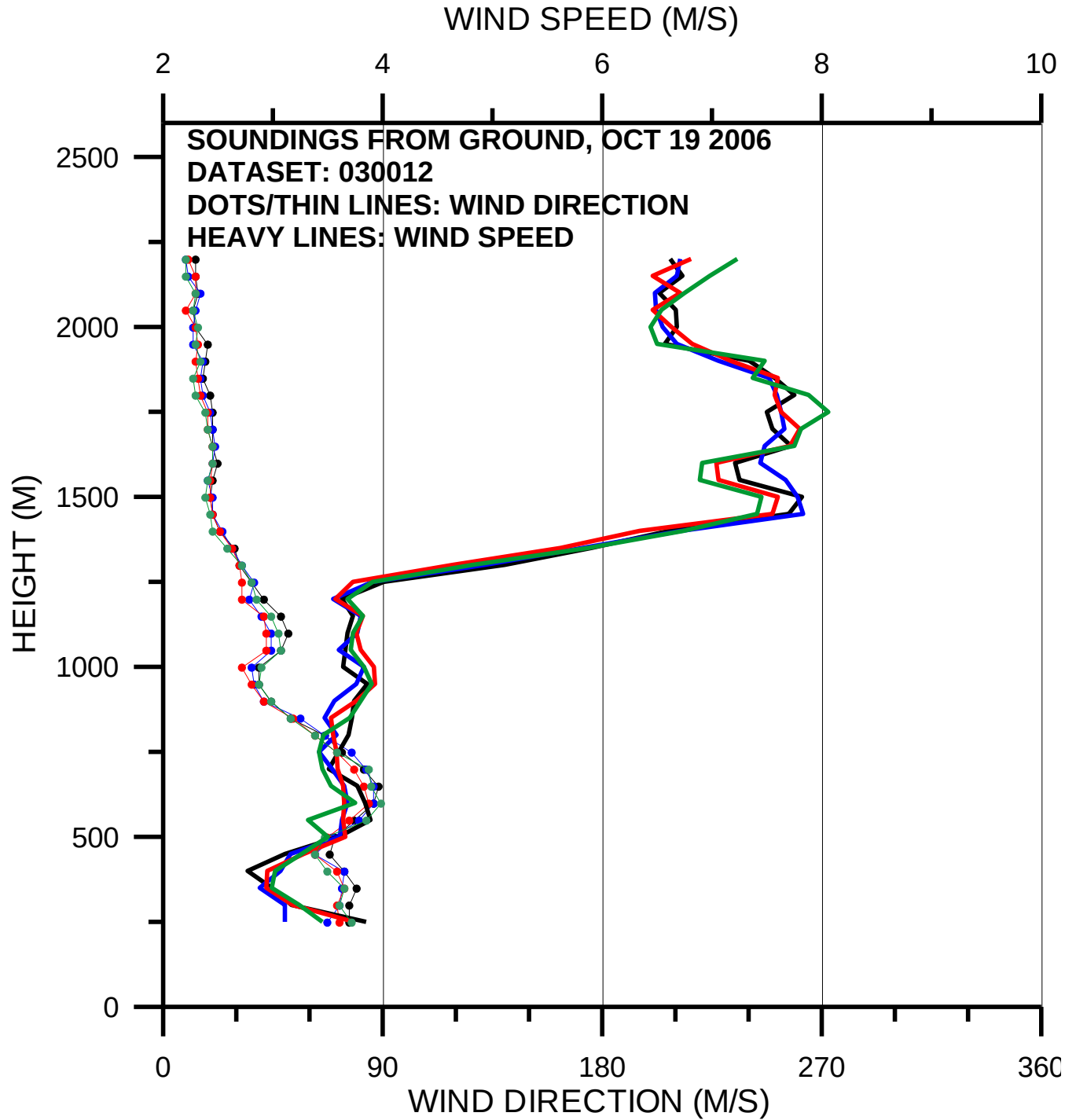


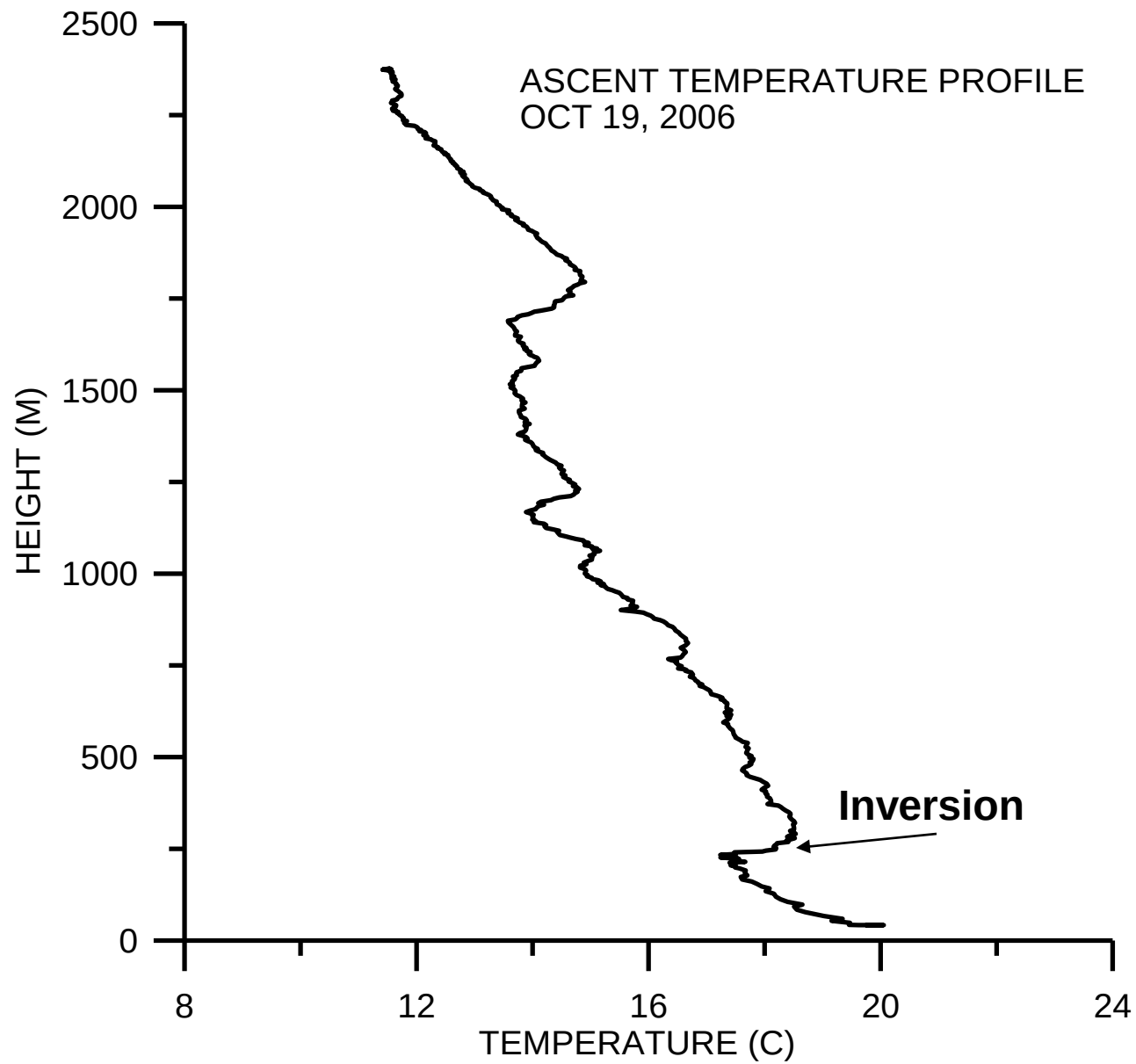
South Monterey Ridge burn



Soundings

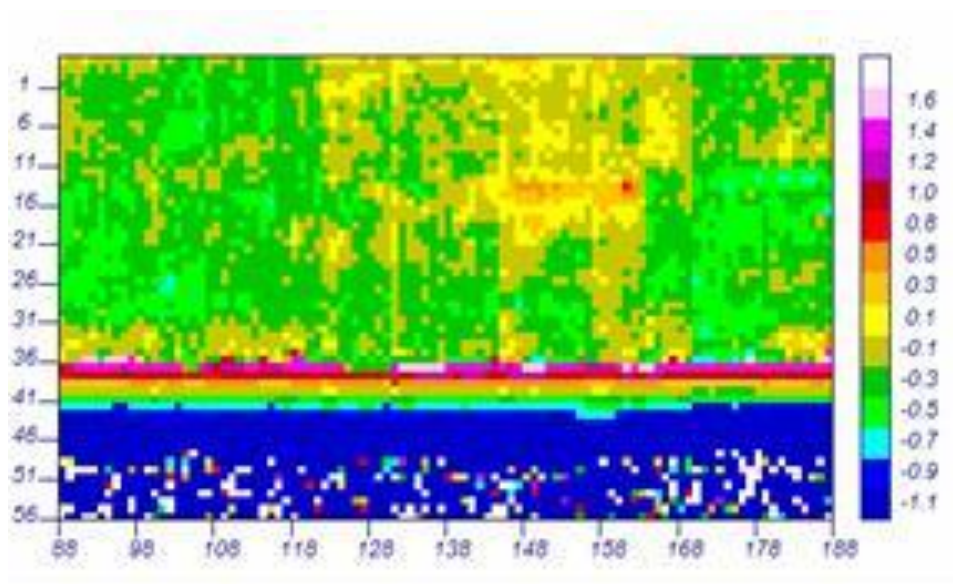
- Occasionally vertical soundings of the horizontal wind were taken.
- Vertical resolution is 50 meters
- Accuracy is ~ 10 cm/second
- Soundings in general showed weak flow below 1500 meters from the NE.





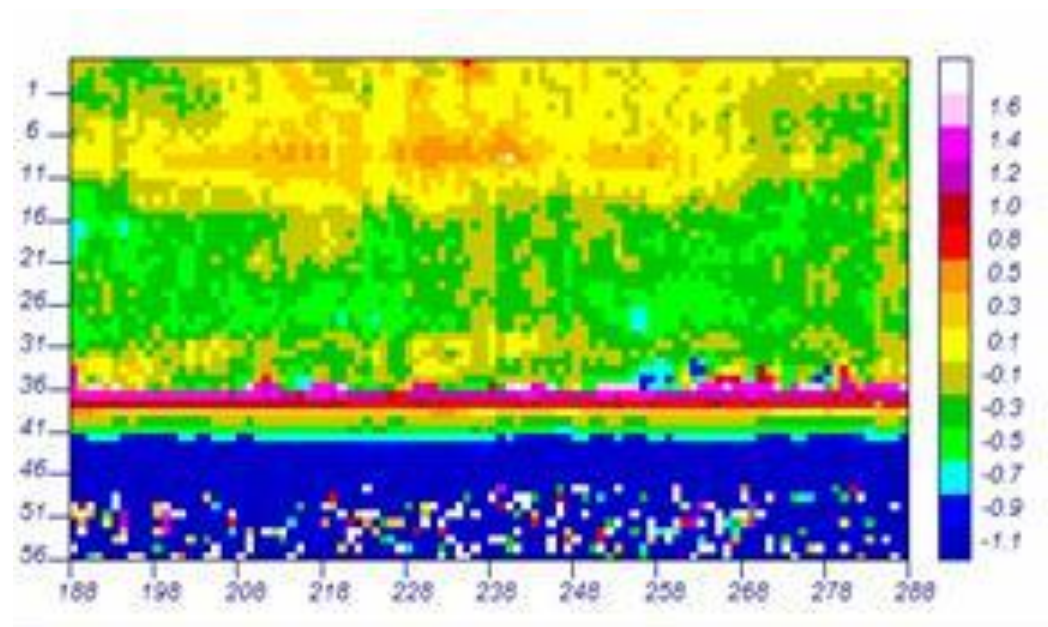
Flight over valley: 7500' FL

- Flight was conducted at 7500 feet on a heading of 125 degrees down the Salinas Valley
- Lidar beam was pointed straight down to measure only w'



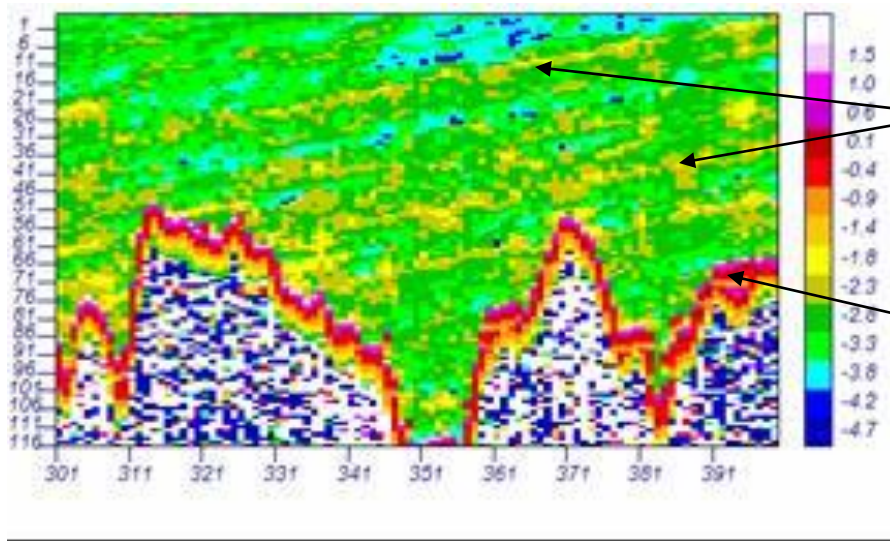
Elevated and detached waves?

Bright surface return
confounds detection of
surface rooted plumes
more shallow than 200 meters



Flight over valley: 150m (~500') FL

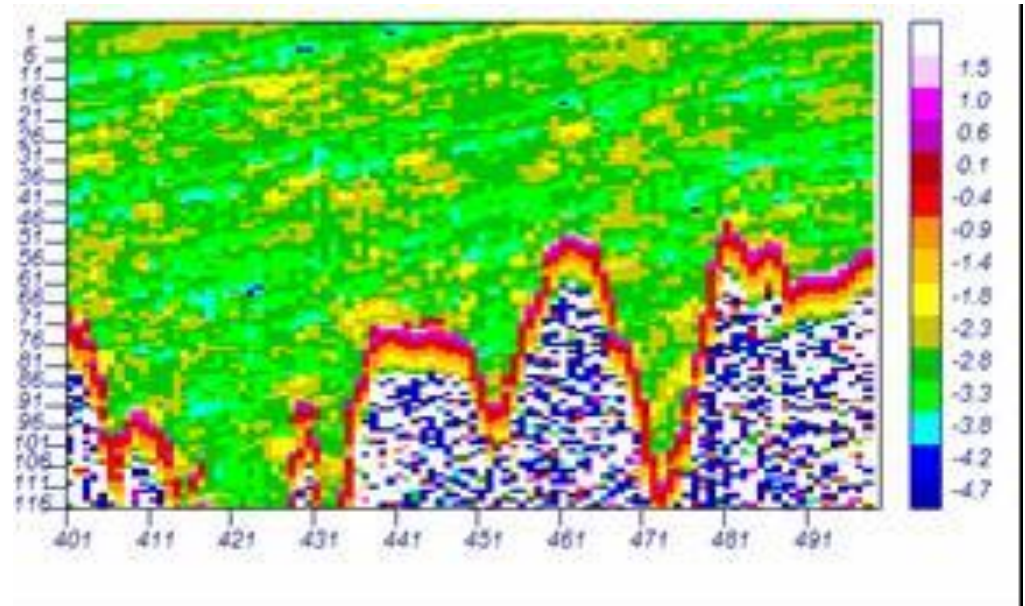
- Purpose was to look ahead of the aircraft for convergence zones that may portend coherent vertical motions
- Scanning strategy was to scan beam on a plane oriented ~ 5 degrees below the flight level; scanning was to right side of the aircraft and subtended ~ 10 degrees.

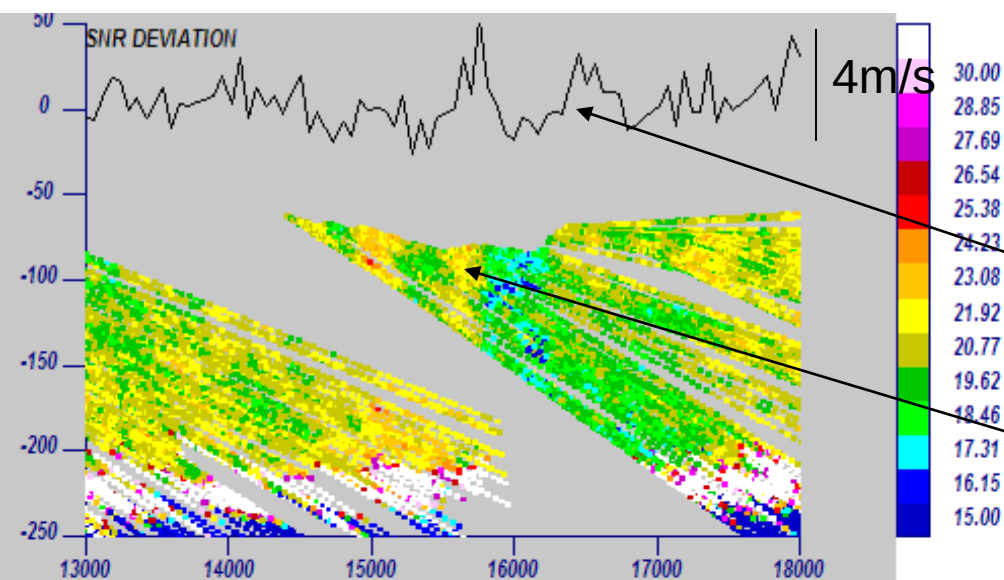


High aspect ratio vertical features

Ground intercept

Not so well organized
or persistent features



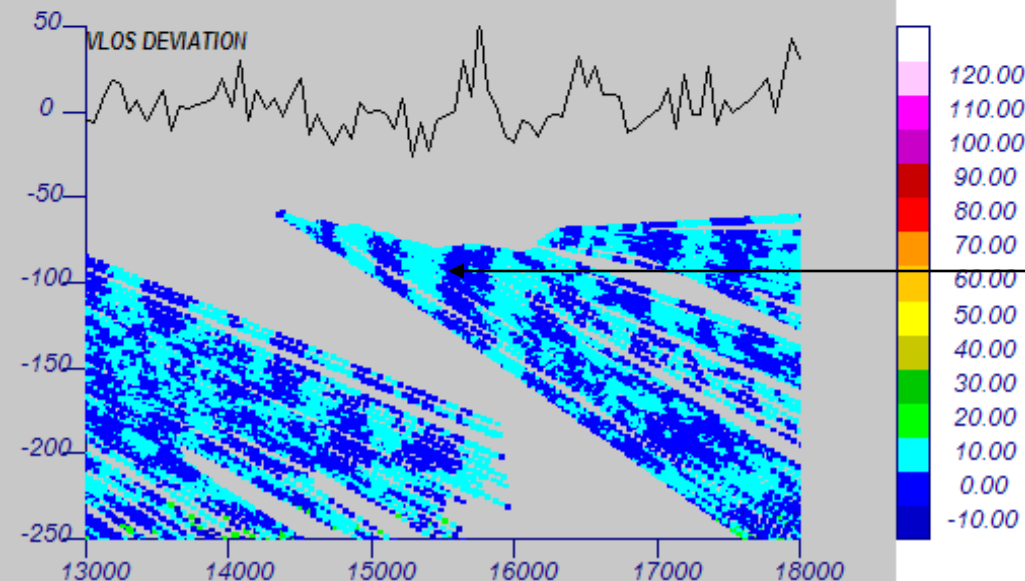


Example of forward sweeping scan of velocity and backscatter

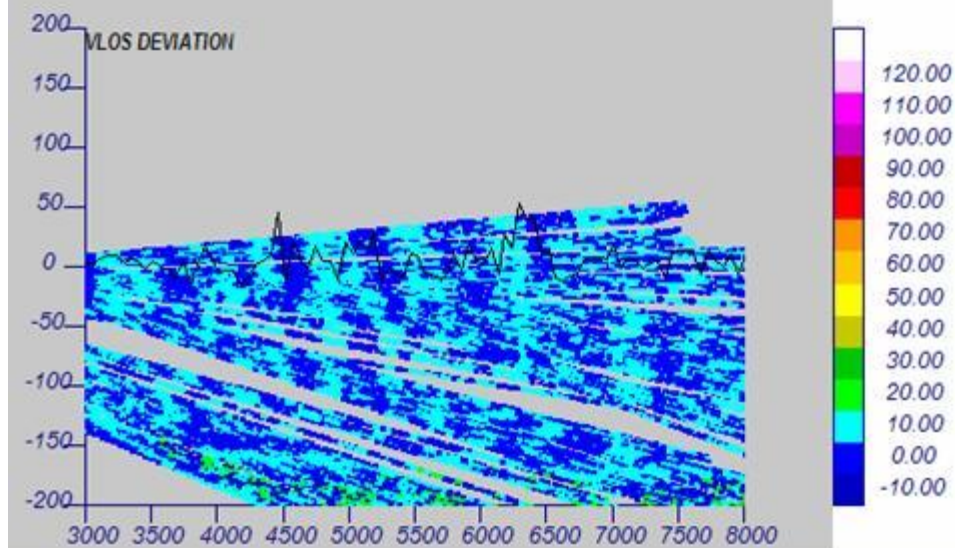
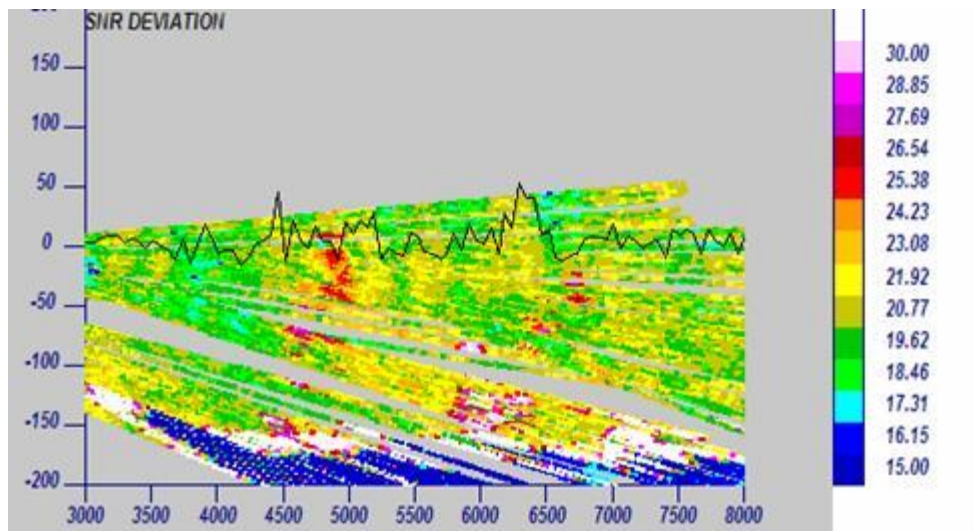
Vertical velocity of aircraft measured by INS on Twin Otter

Aerosol loading appears greatest in upward moving features

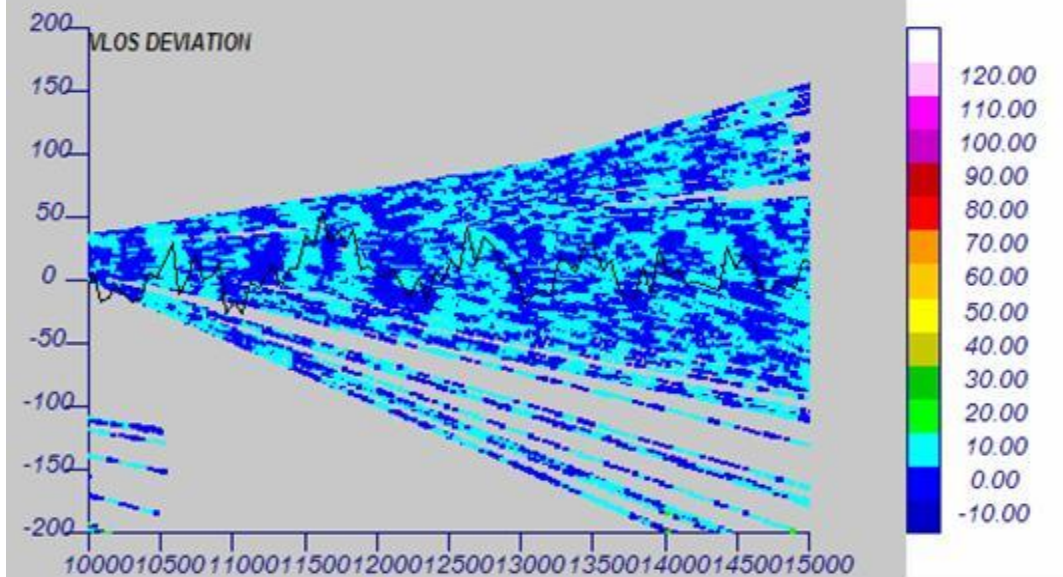
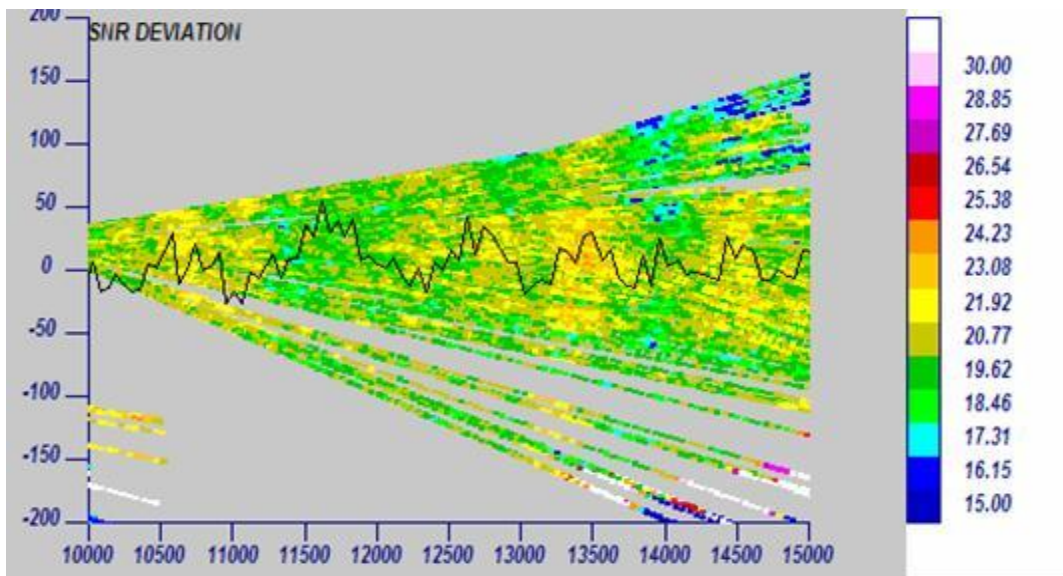
XZ slice w/ x being along track



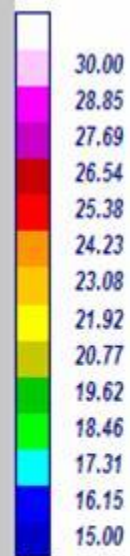
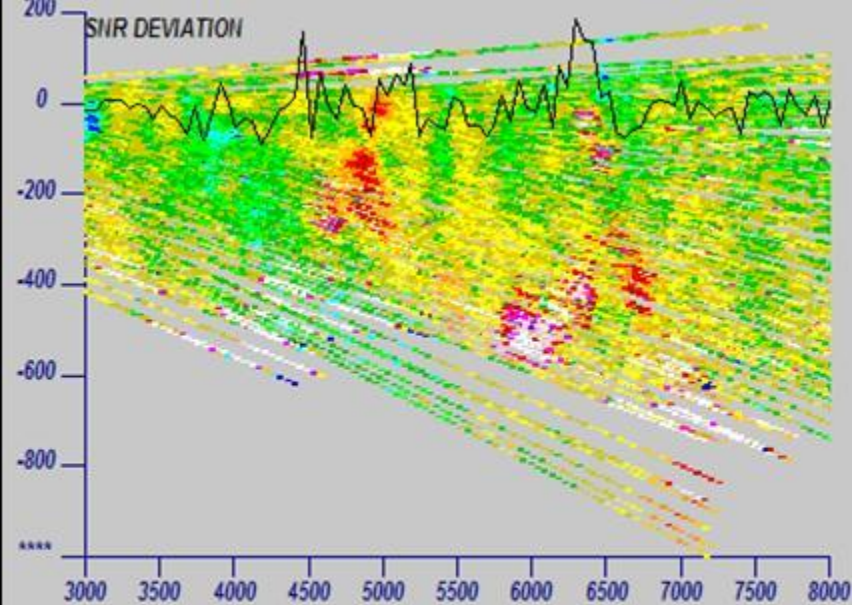
Expect (ideally) that upward motion would occur near switch from positive to negative velocity deviations



XY plot showing organization
on horizontal plane
(total Z projection)

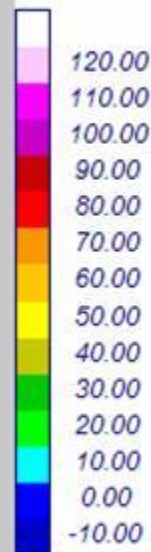
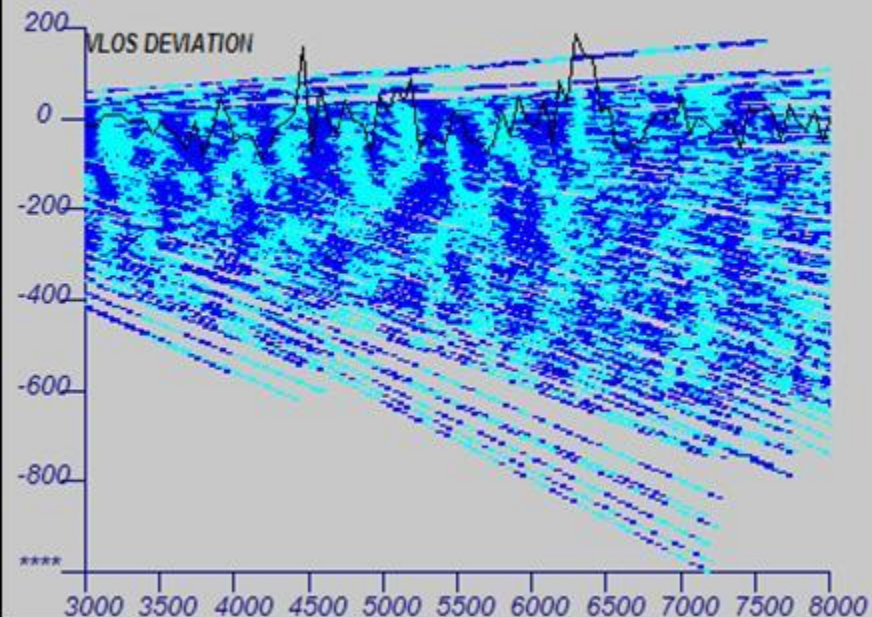


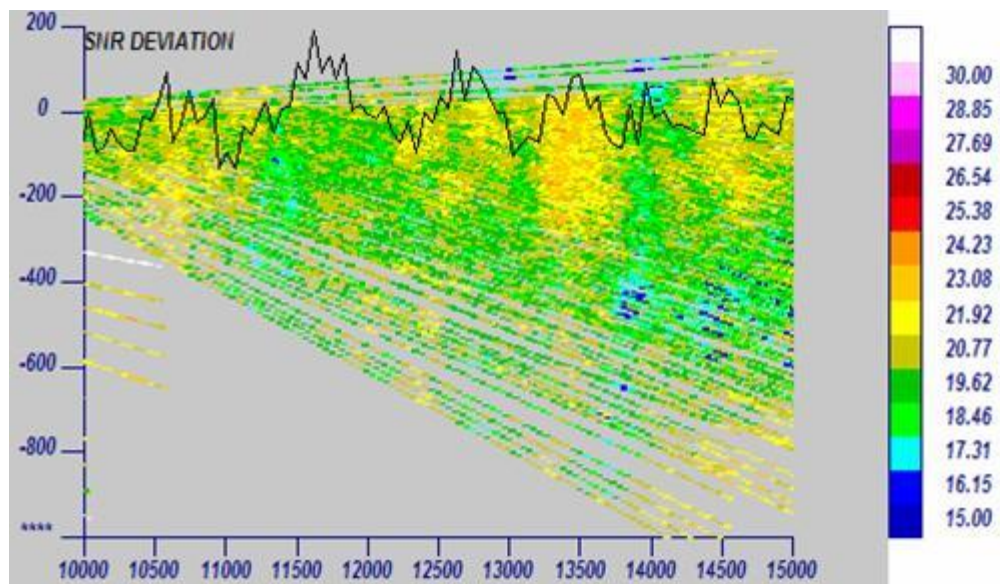
Additional XY cross sections



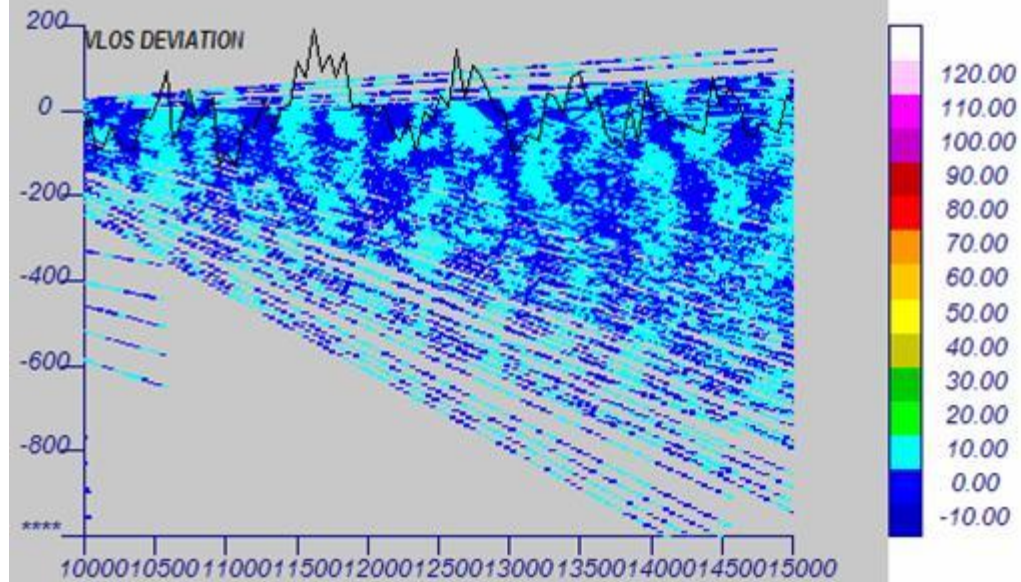
XY horizontal plane
w/ Z between -25 and 0m

On vertical axis is the distance to the right of the aircrafts flight path. This gives cross section of features



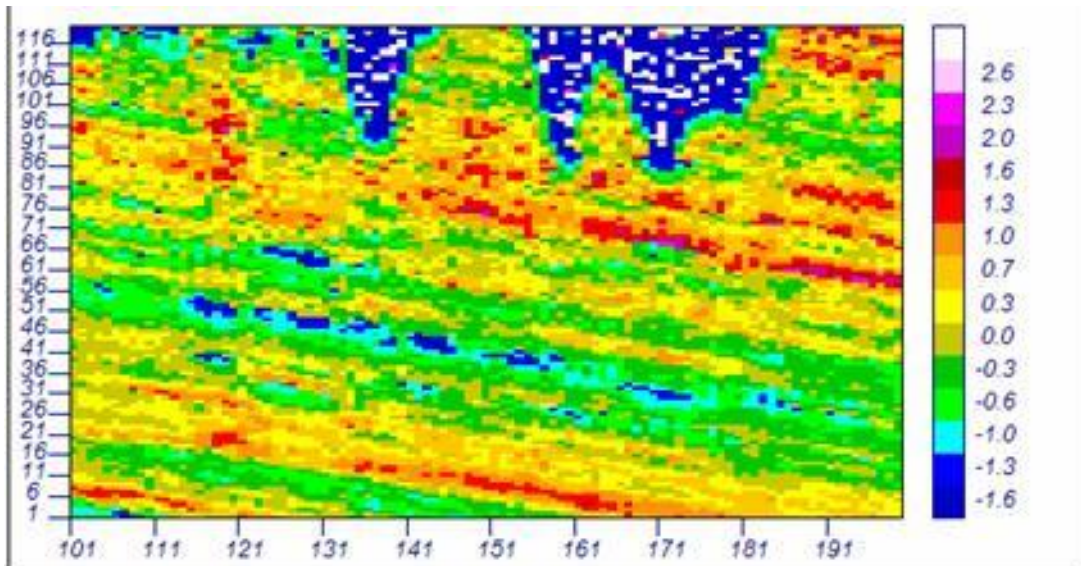


Additional XY cross sections



Scanning beam using porpoising, rolling and yawing of aircraft

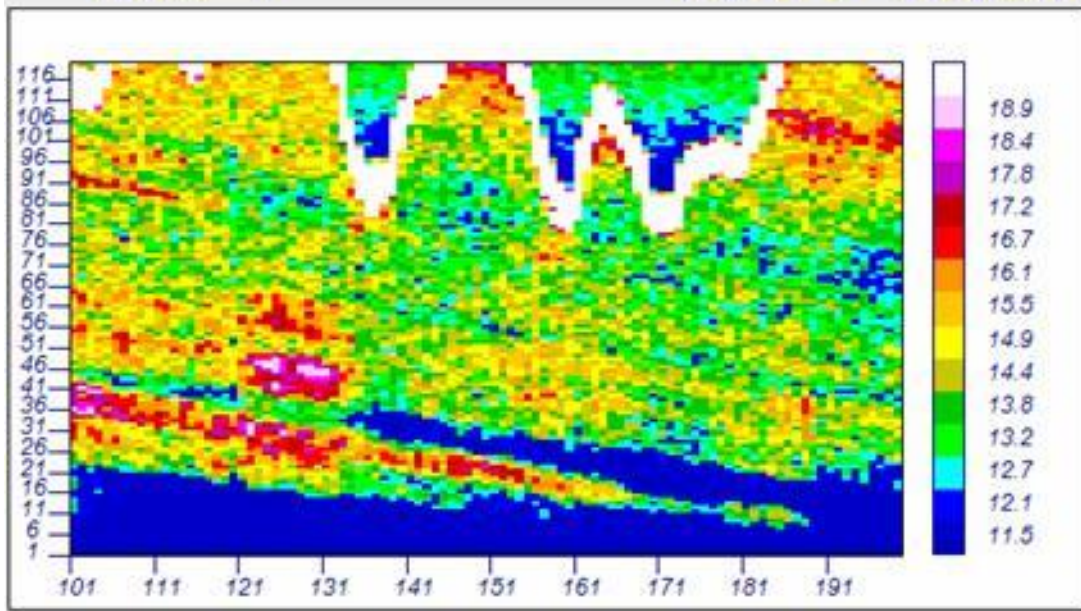
- Purpose was to explore the idea of using the aircraft to scan the beam in order to eliminate the need for a beam scanner on a UAV.
- Rolling action achieved best volume scan since excursions were in all three components (r,p,y)



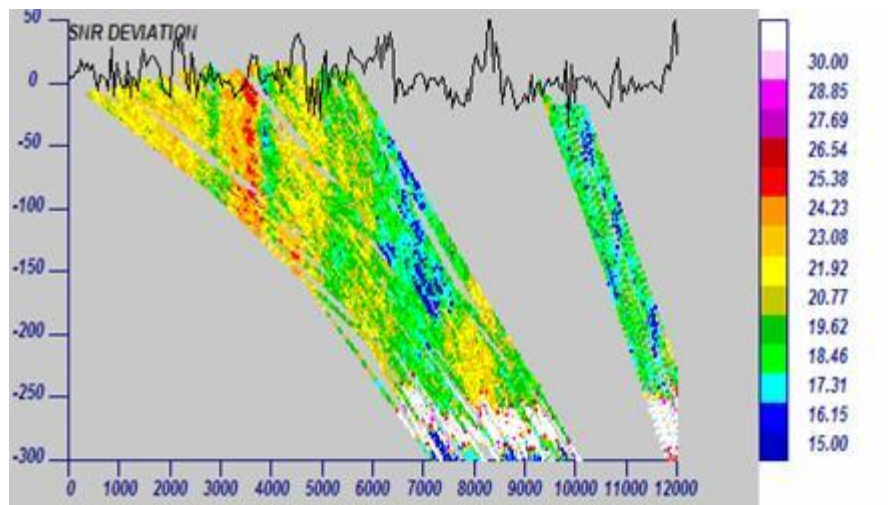
PREV 50

NEXT 50

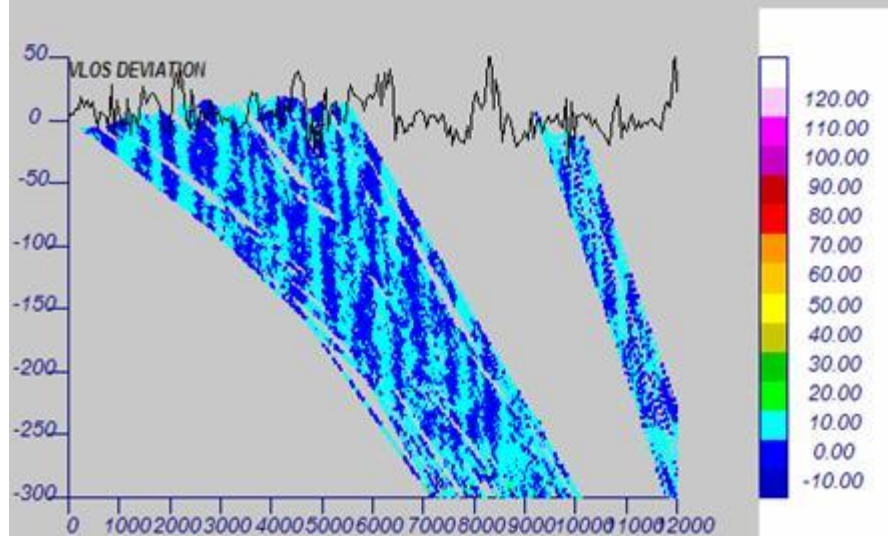
RESET COLORS



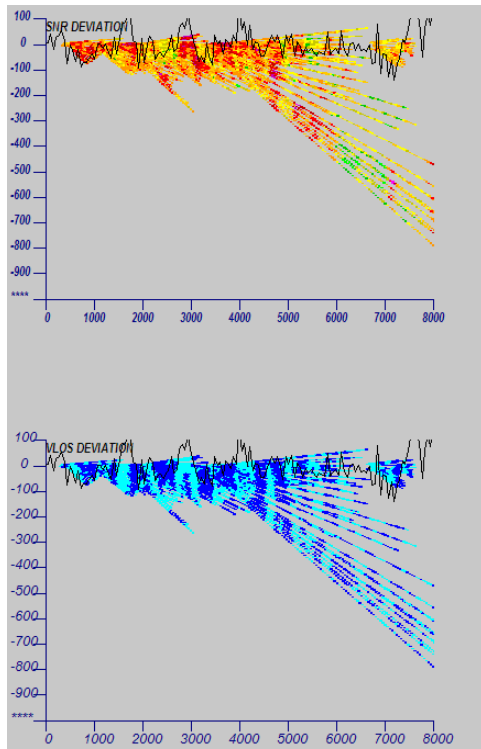
Rolling: time vs. range



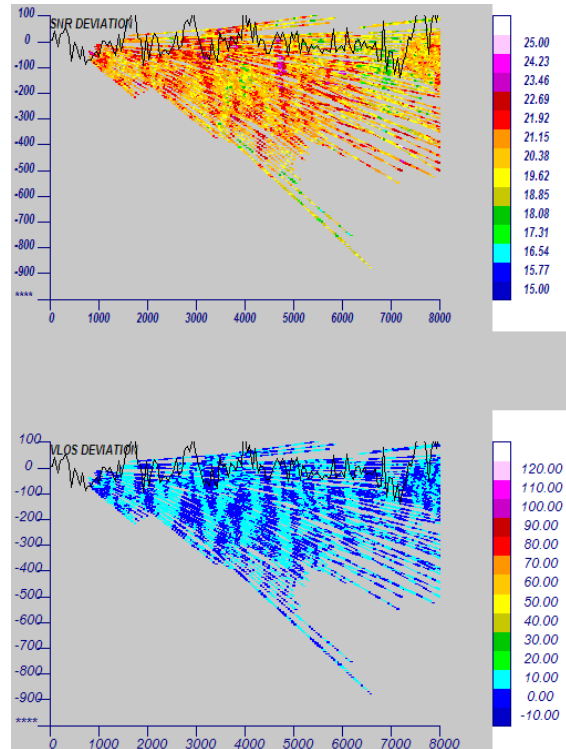
XZ plot (while rolling)



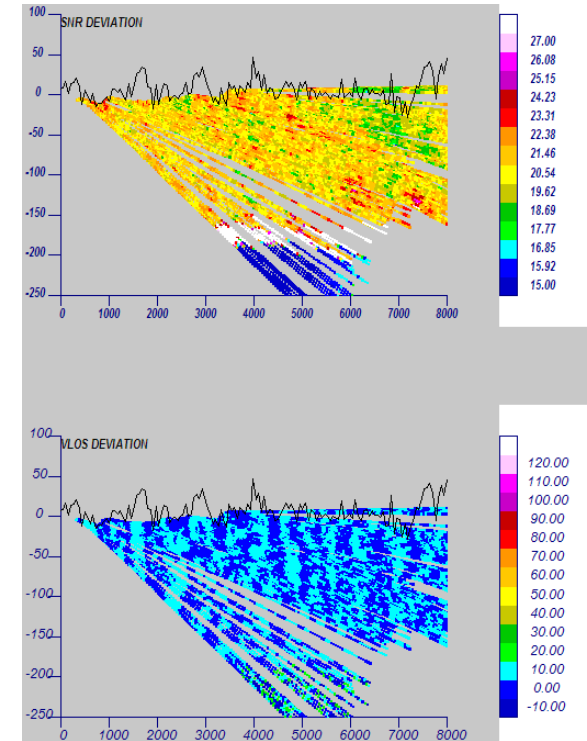
Example slices through 500' FL data set



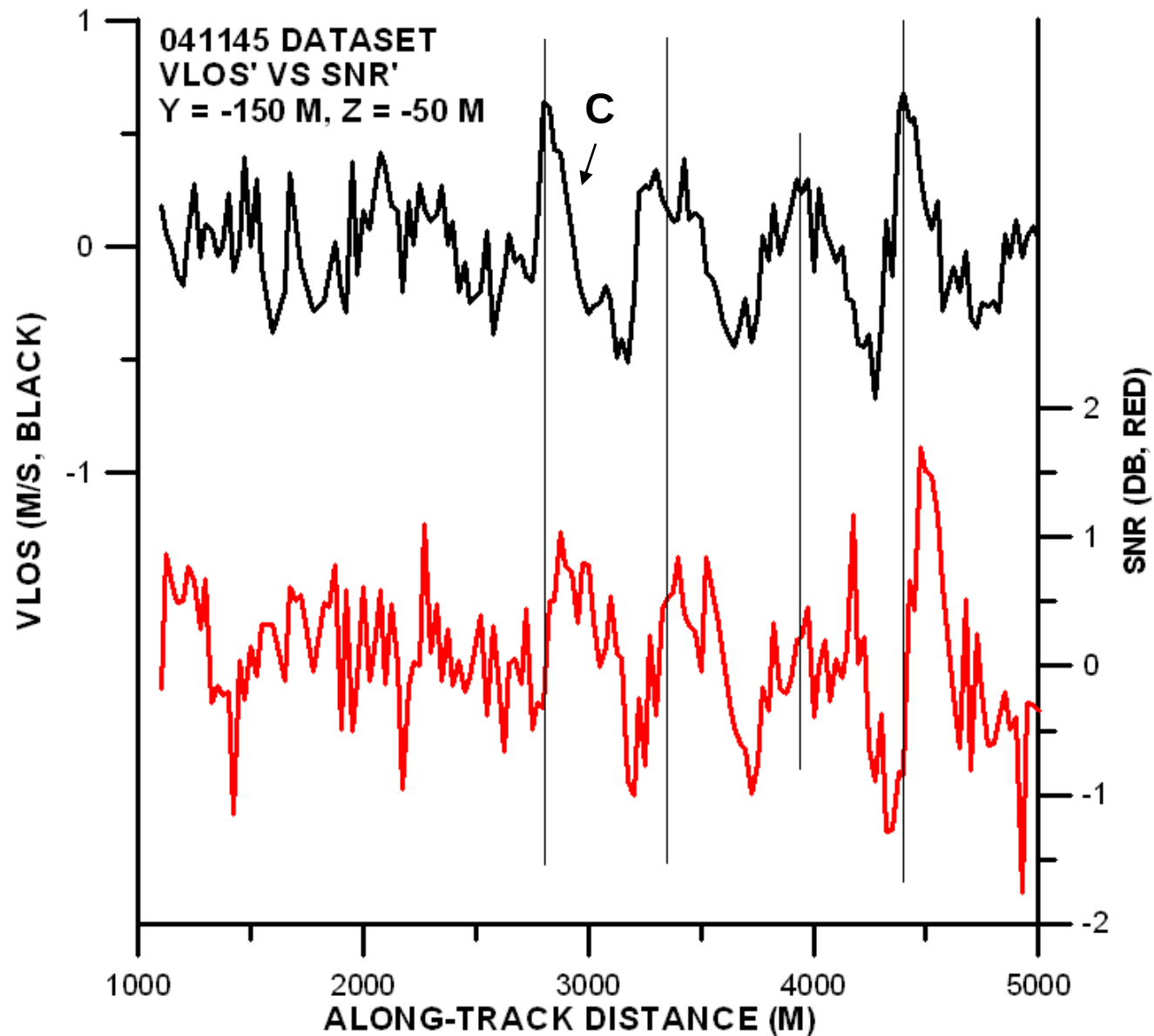
XY plane
w/ z= -25m - +25m



XY plane
w/ z= -75m - -25m



XZ plane
w/ all Y



C = convergence

Summary

- The continuous or random raster scans are the best options for the detection and characterization of vertical velocity features
- The vertical velocities inferred from the LOS convergence/divergence observations appear to be reasonable and useful
- The correlation of aerosol loading and vertical motion may be useful. However, the interpretation of this relationship requires further study.
- Airborne prospecting for clear air vertical motion features appears very feasible and may easily be extended to clouds, waves and shear situations.

Planned April flights

- Primary purpose is to sample near cloud bases of small cumulus
- Secondary purpose is to sample ridge and valley systems under modest horizontal wind conditions and strong surface heating.
- Current NCE (through June 30, 2007) will cover 2 hours of flight and the review of the data collected.
- Data deserves future funding support to develop rules for UAV prospecting and flight adjustments

Flight over Ft Ord Fire

- A prescribed burn on Fort Ord was overflowed twice.
- Purpose was to demonstrate the complexity and detectability of significant vertical motions ahead of the aircraft.



Fort Ord prescription burn



