Aerosol variability within the marine boundary layer off the California coast

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Overview

- Objectives
- TODWL (Twin Otter Doppler Wind Lidar)
- Particle probes
- Field experiments (2002 and 2003)
- Summary

General IPO* funded objectives

- To understand the implications of model-predicted aerosol/velocity correlations for future Doppler lidar mission design.
- To validate models of atmospheric dynamics and aerosol microphysics in the marine boundary layer (MBL).
- To demonstrate DWL accuracies for use in validation of other wind measuring systems such as Quikscat, WindSat and CMV/WVMV.

*Integrated Program Office of the NPOESS

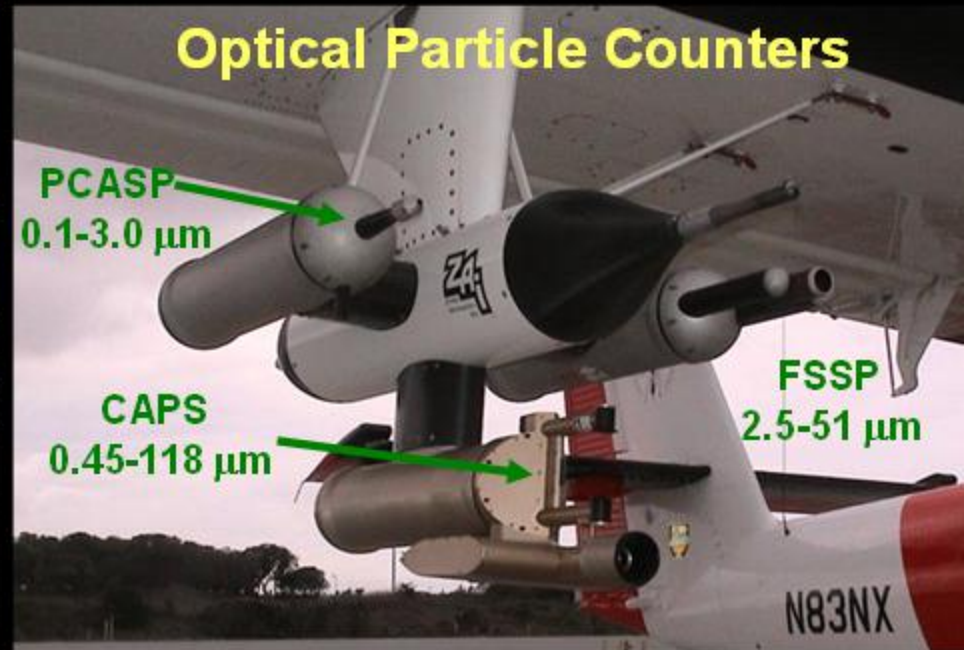
The science issue

- Many analyses currently being done using boundary layer winds are predicated on the myth that the PBL winds are homogeneous on scales from meters to 100-km.
- Our analytic studies show this is not true, predicting embedded organized large eddies (OLE) on several scales. Bulk parameterization of fluxes is not appropriate under these conditions.

TODWL

- The Twin Otter Doppler Wind Lidar (TODWL) provides the needed capability, using a pulsed 2-μm solid-state laser transmitter, coherent heterodyne detection, and a two-axis scanner, mounted on the Navy CIRPAS Twin Otter aircraft. Basic TODWL data products include simultaneous collocated range-gated measurements of aerosol backscatter and radial velocity along a given line of sight (LOS).
- Demonstrated LOS accuracies (after platform motion attitude corrections) are ~.10 m/s
- Demonstrated horizontal wind component measurement accuracy using nadir conical scans is ~ .05 m/s
- Indicated vertical velocity accuracy using nadir conical scans is ~ .05 m/s
- With shot accumulations of 100 shots (~50 meters of aircraft forward motion), the speckle effects can be removed from the backscatter signal providing useful aerosol backscatter infromation.

Airborne Doppler Wind Lidar



TODWL Instrument

2.0125 µm, coherent detection

4-6 mJ, 330 nsec (FWHM), 80 Hz

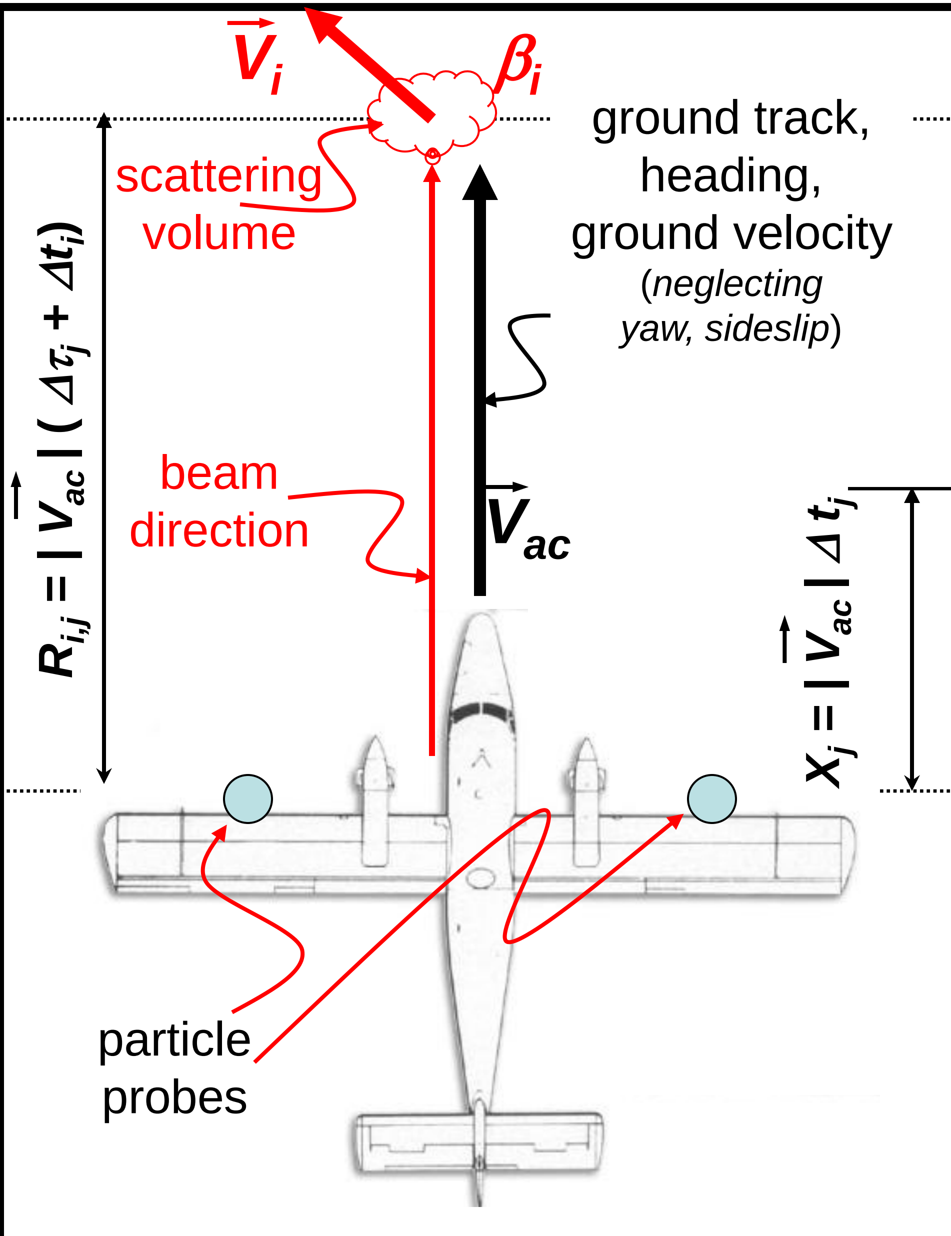
10 cm telescope

two axis scanner, ±30 & ±120 deg, side door mount

digitization rate 100 MHz

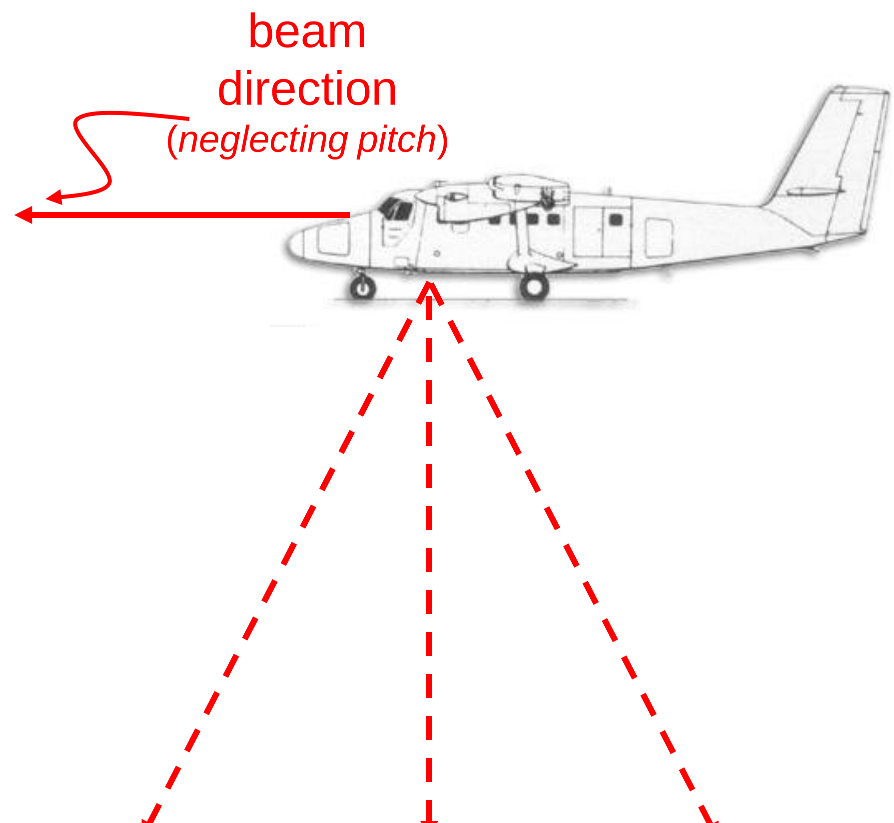
~7-10% total system efficiency

Measurement modes



Backscatter-related scan patterns

- along-track RHI step-and-stare
- forward stare
- nadir stare



Field Experiments

Schedule

• Series 1: February 9-15, 2002

• Series 2: March 12-15, 2002

•Series 3: February 8-21, 2003

Location

Series 1:
• Monterey area & San Joaquin River

Series 2:
• Monterey area
• Monterey to Boulder via Las Vegas

Series 3:
• Monterey area, ocean & land

Flight Plans

• Straight and level 50-100 km runs

• Along-wind and cross-wind runs

• Multiple altitudes over same ground track

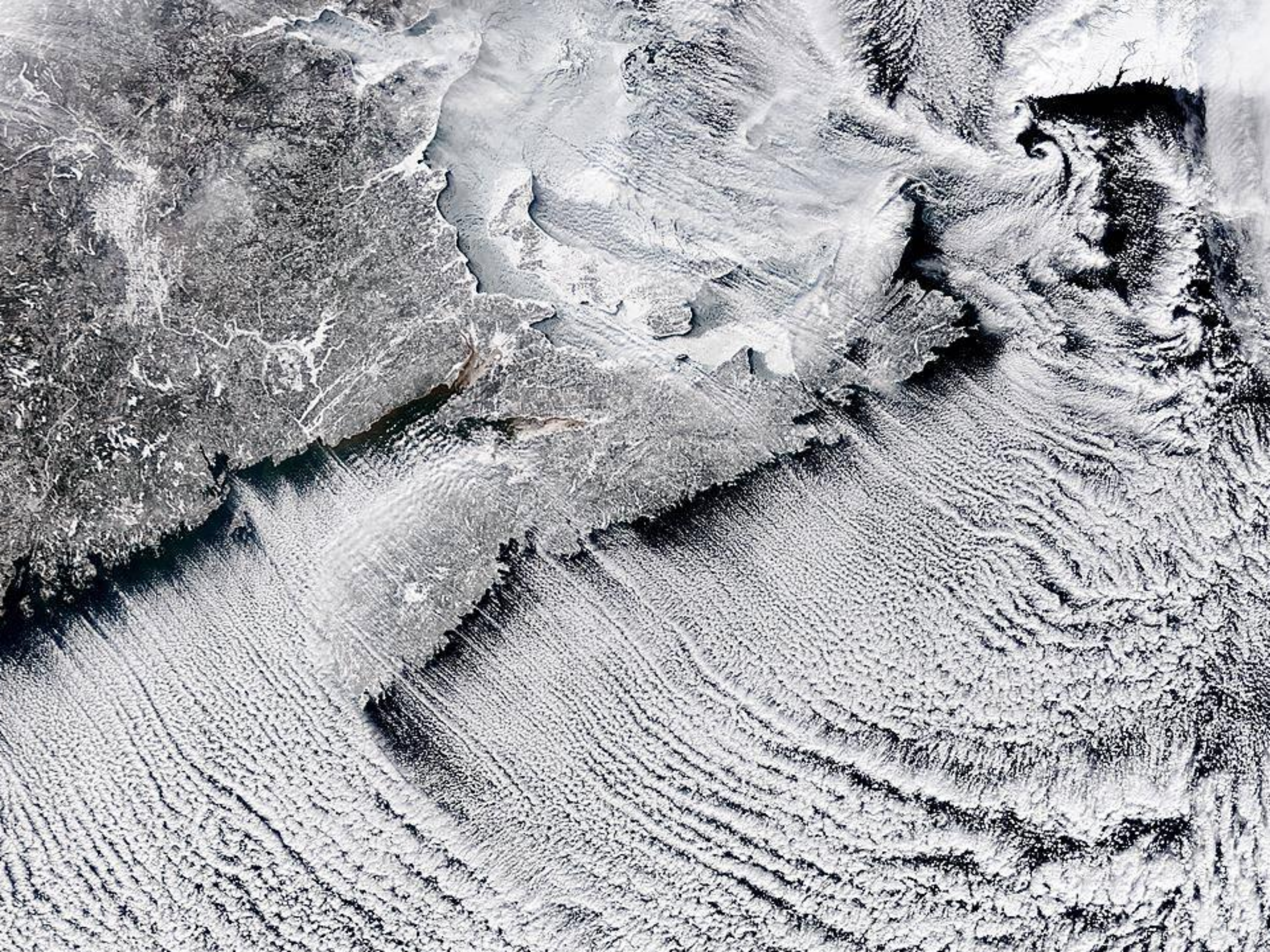
• Near surface, near and above inversion

MBL Database

• 8 flights, approx 30 hours

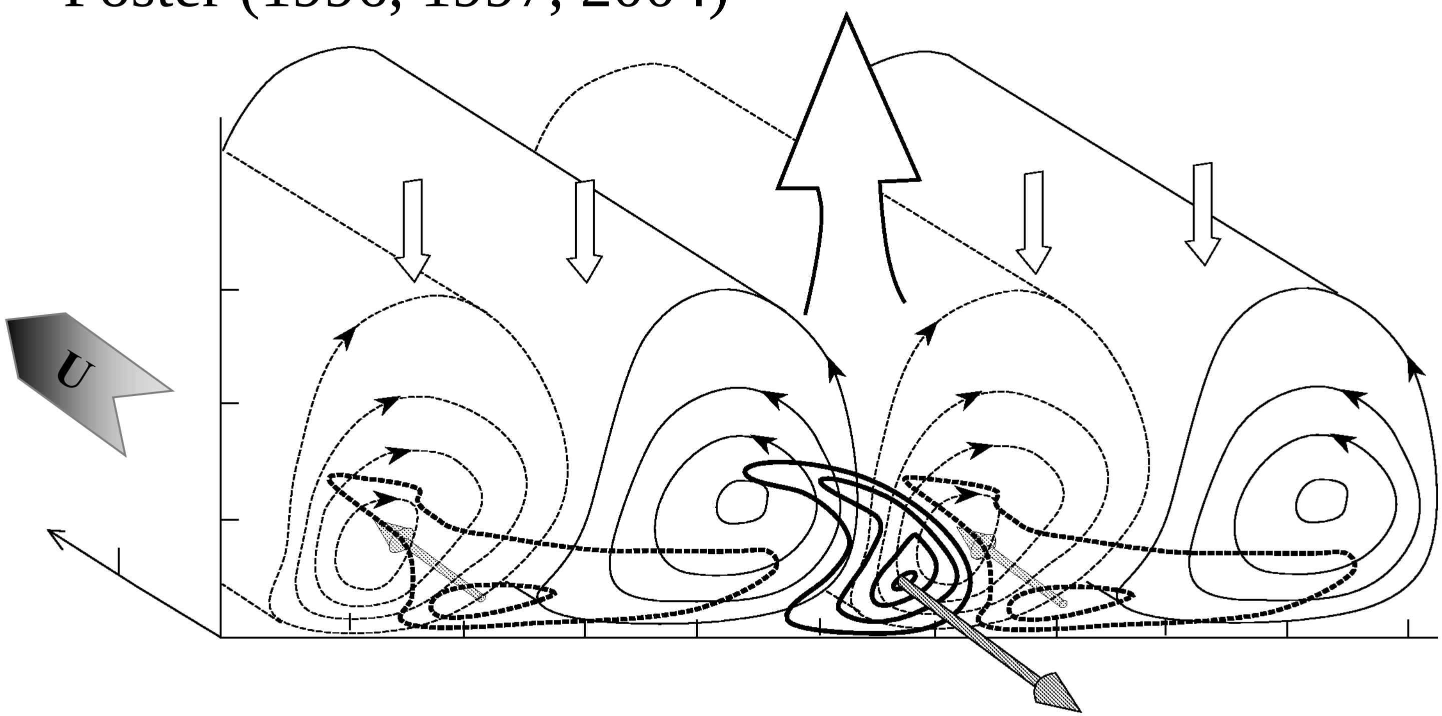
• multiple scanning patterns

• concentrate on February 20, 2003



Theoretical Model

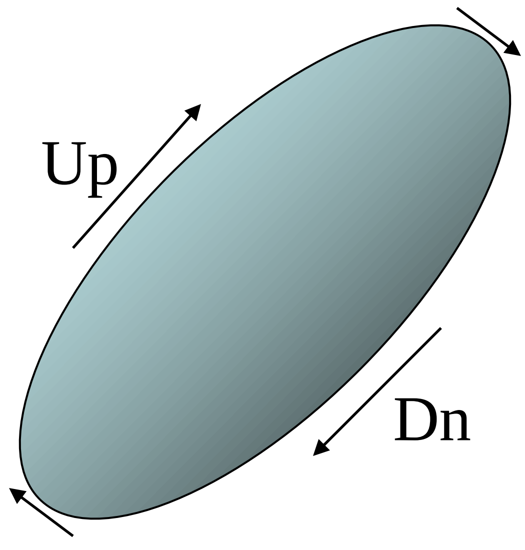
- •Nonlinear Instability High-Order Expansion
- •Equilibrium Found in Modified Mean Flow
- •Predicts Roll Perturbation Winds/Temperature
- •Simulate Foreword Stare, VLOS wind
- •Foster (1996, 1997, 2004)



Idealized OLE

Dn = -Up

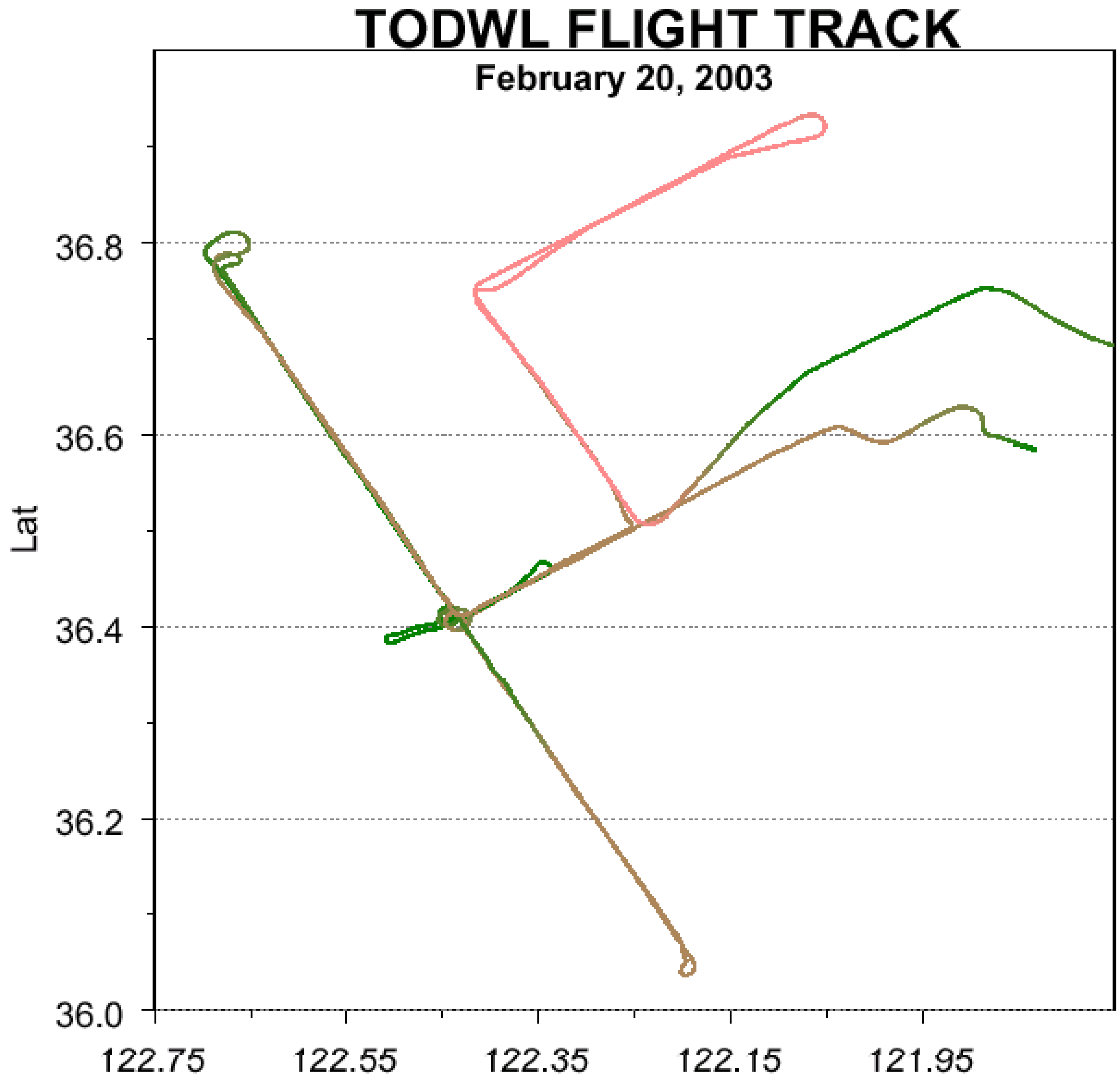
Sigup = 2 Sigdn



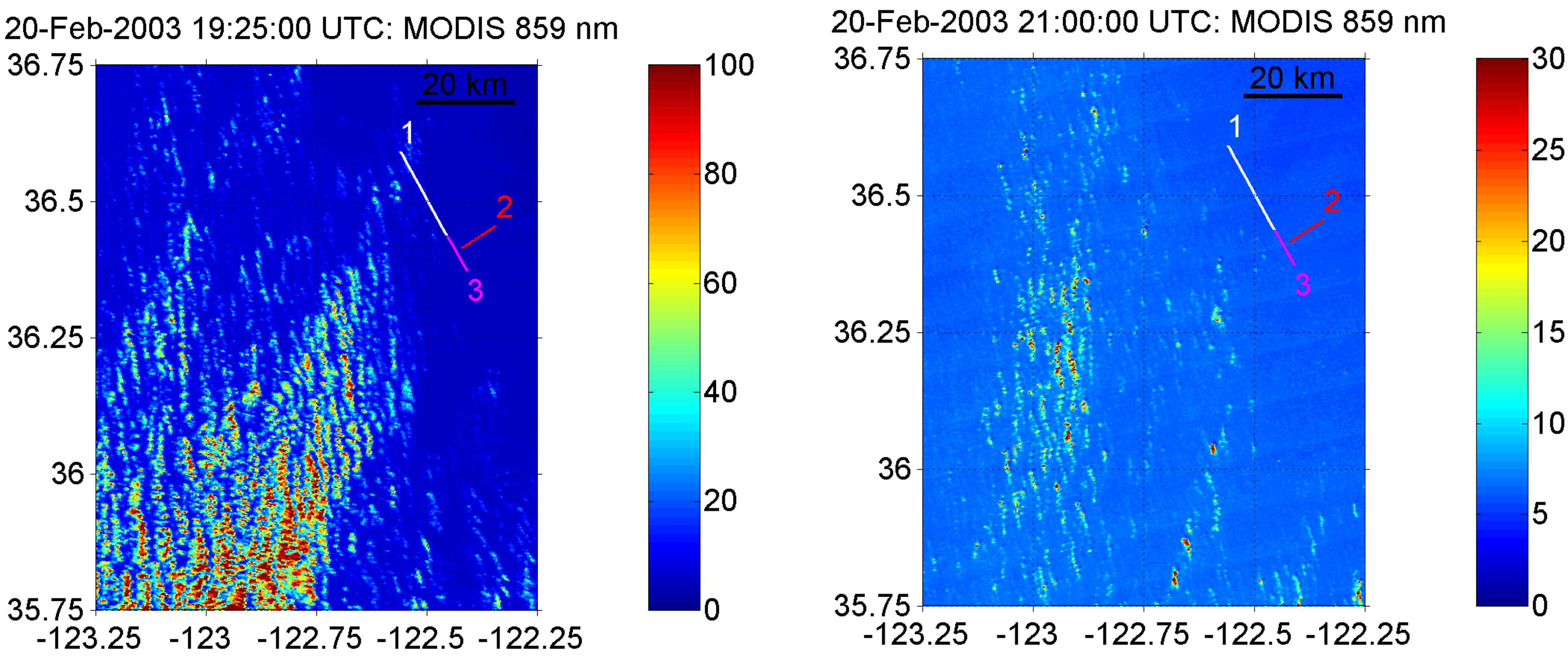
Average LOS speed contribution = .33 Up

With 30 degree off nadir viewing, HLOS error = .66 Up

Bias data requirement is < .1 mps

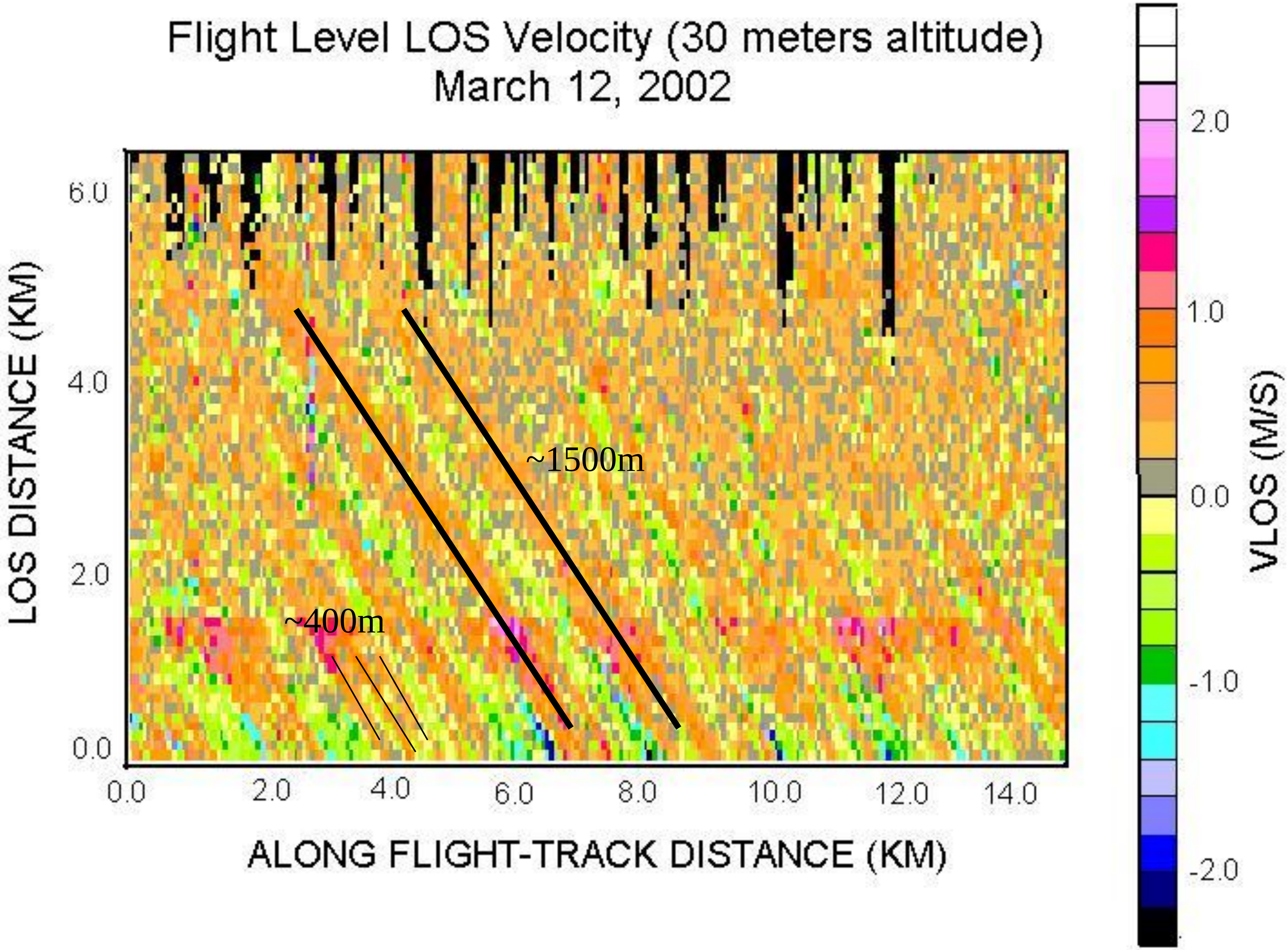

TODWL FLIGHT TRACK
February 20, 2003
Lat
36.8
36.6
36.4
36.2
36.0
122.75
122.55
122.35
122.15
121.95

MODIS 250 m Radiance

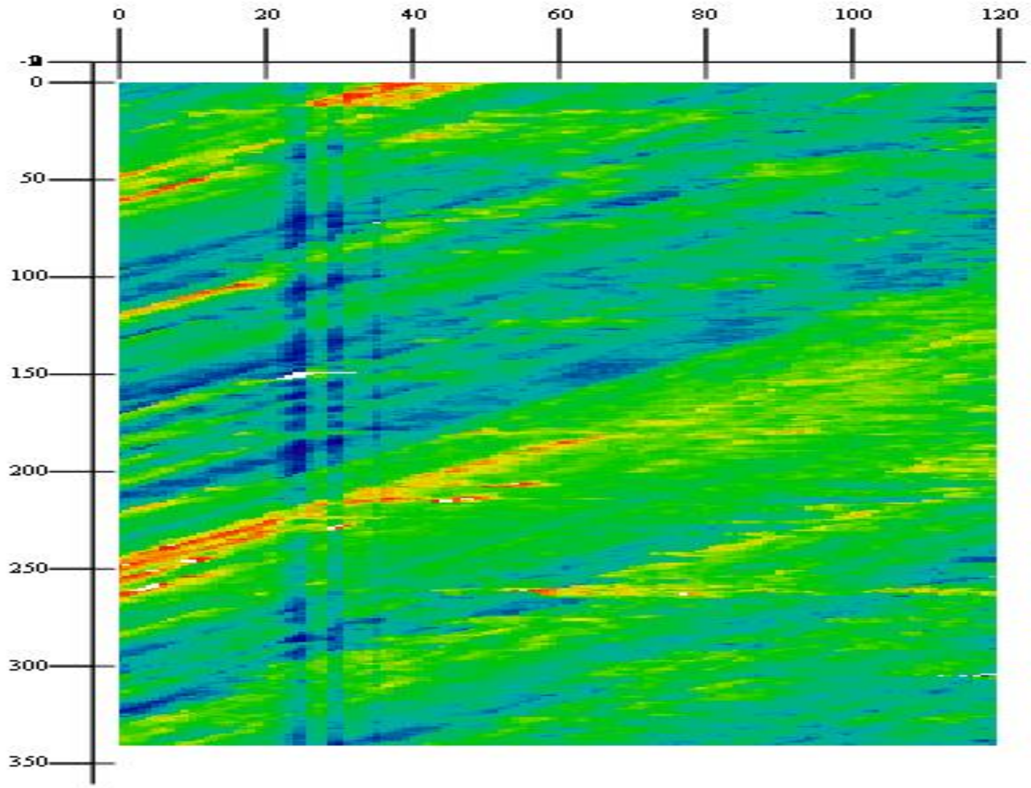


h_{PBL} ~800 m, Coupled

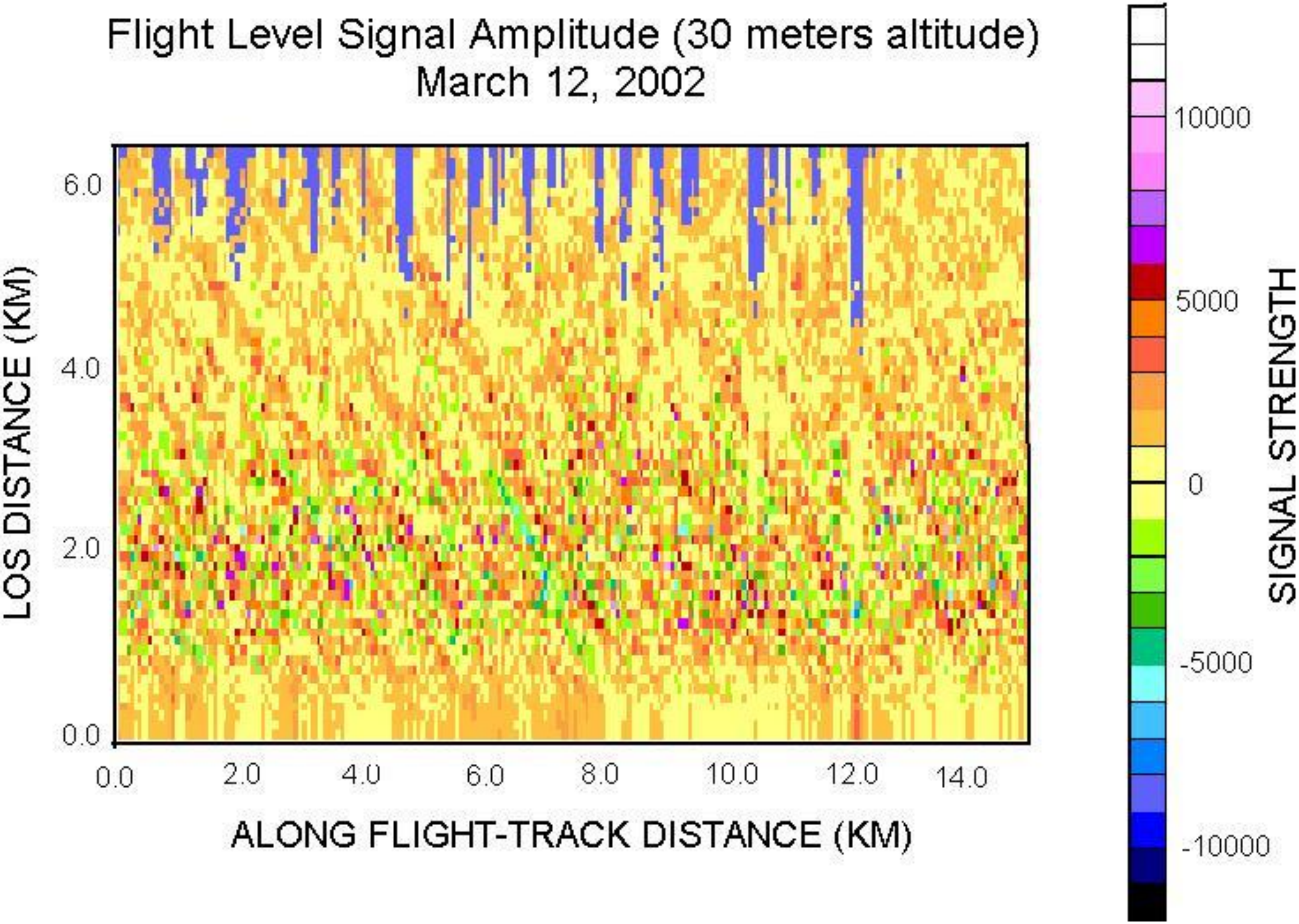
λ ~ 1.7-2.0 km Cloud Streets

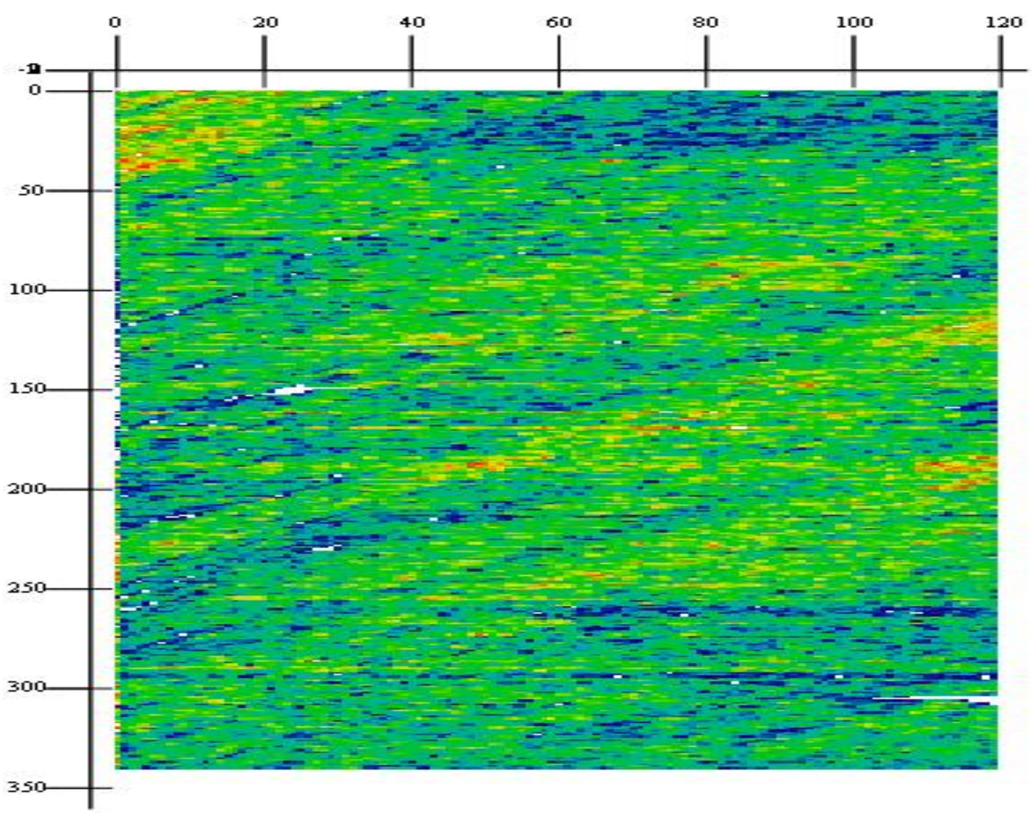


Flight Level LOS Velocity (30 meters altitude)
March 12, 2002
LOS DISTANCE (KM)
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
ALONG FLIGHT-TRACK DISTANCE (KM)
~1500m
~400m
VLOS (M/S)
2.0
1.0
0.0
-1.0
-2.0



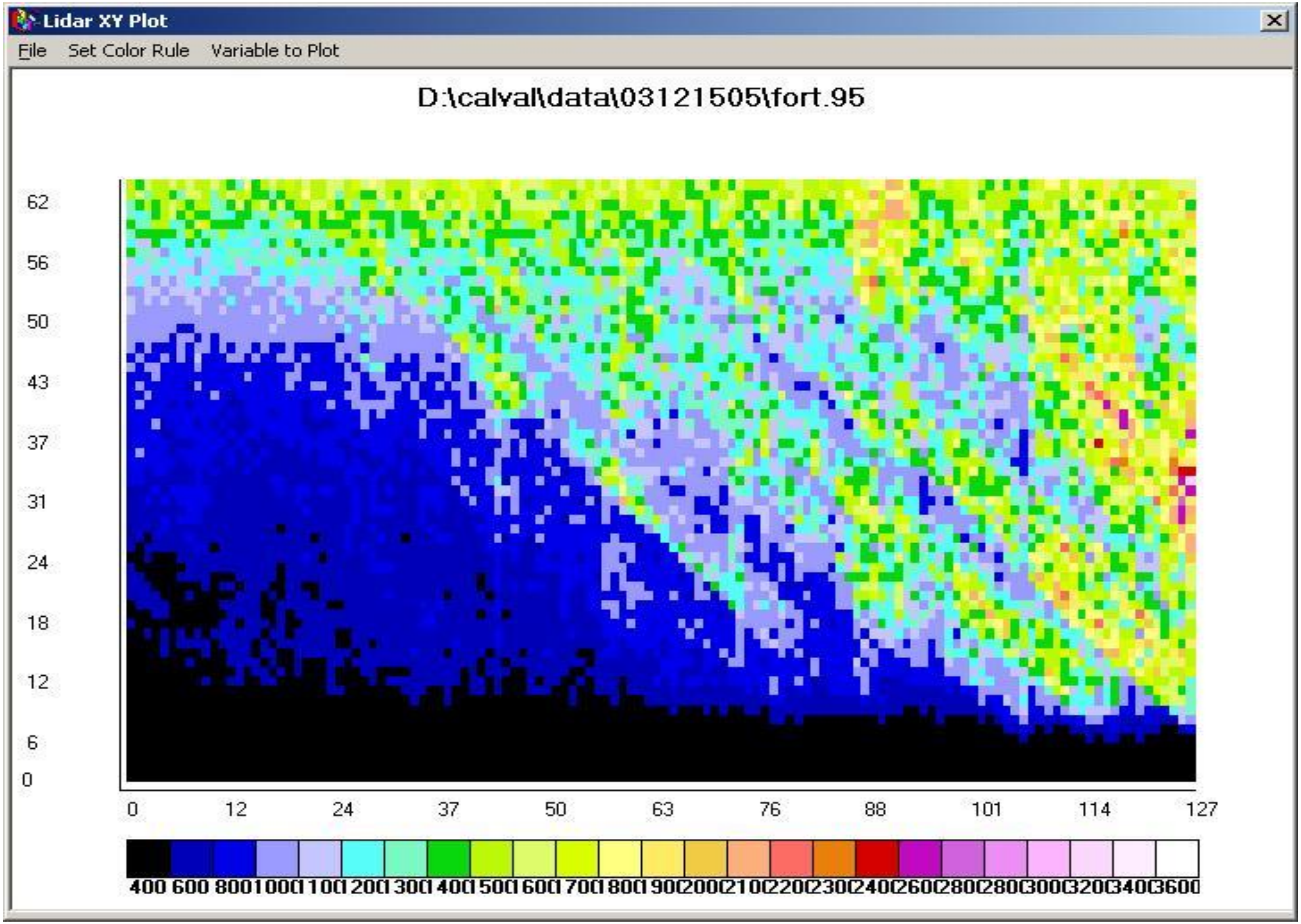
VLOStturb


Flight Level Signal Amplitude (30 meters altitude)
March 12, 2002
LOS DISTANCE (KM)
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
ALONG FLIGHT-TRACK DISTANCE (KM)
SIGNAL STRENGTH
10000
5000
0
-5000
-10000

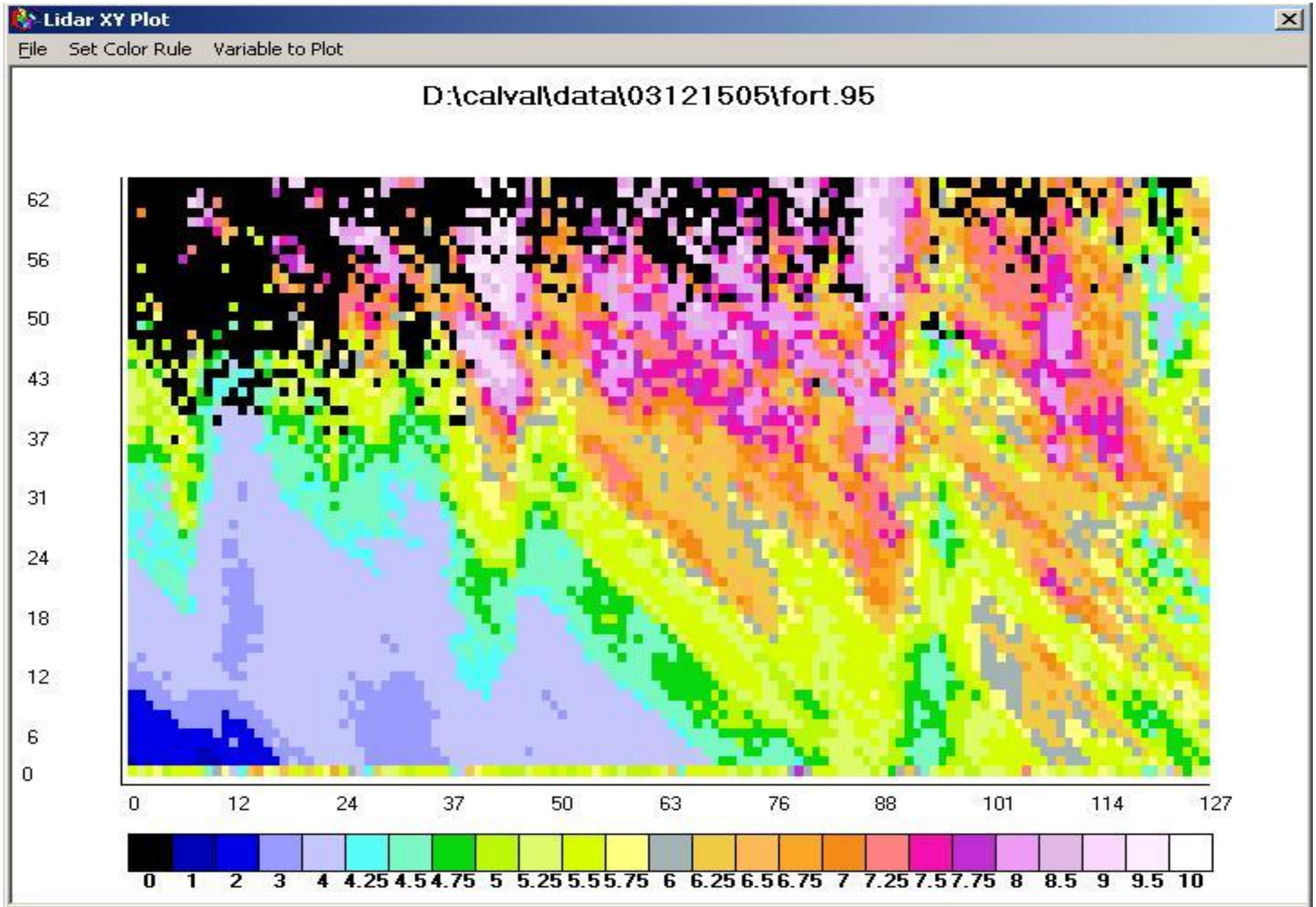


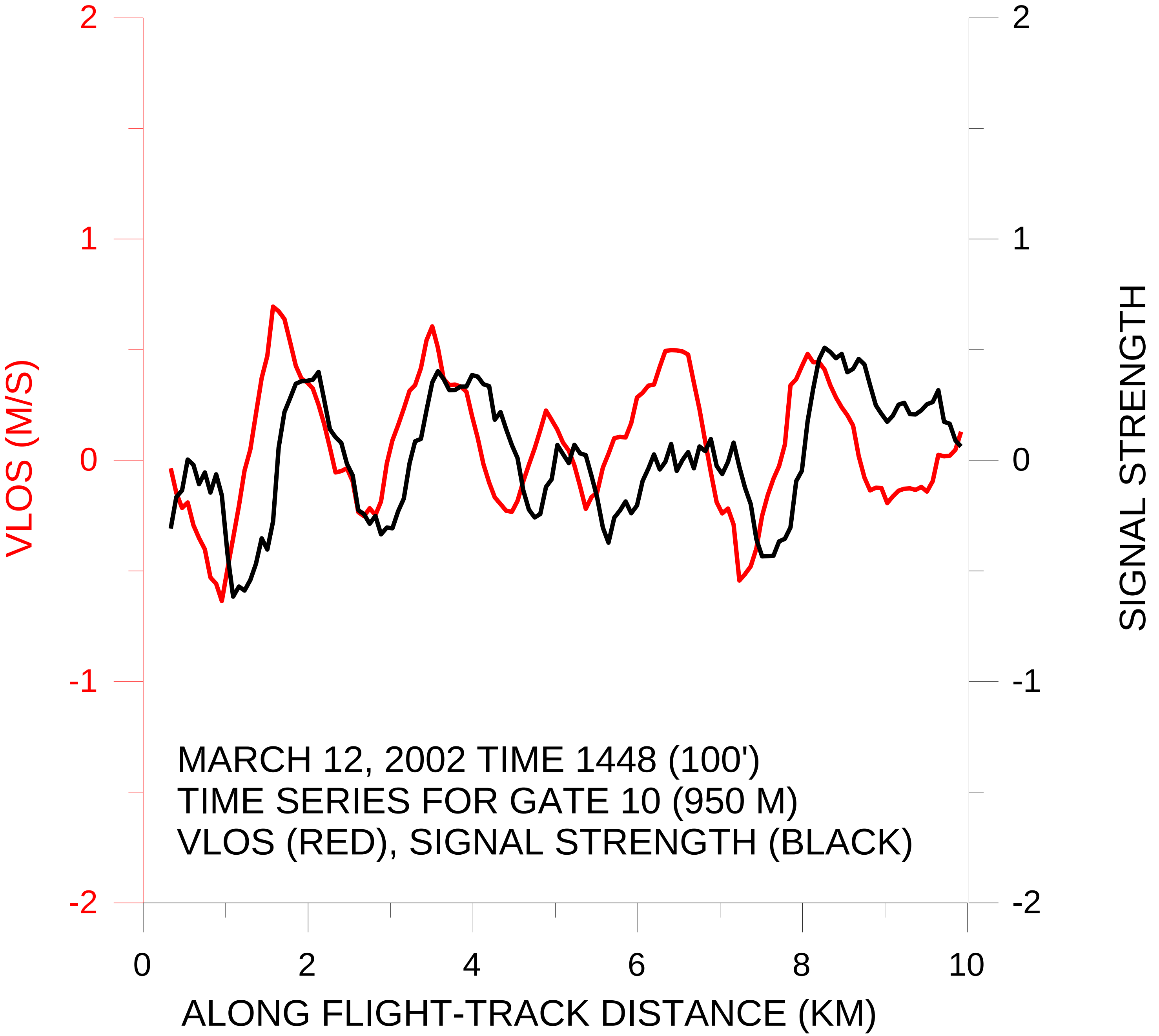
SNR turb

Flight level LOS signal amplitude (450 meters altitude)

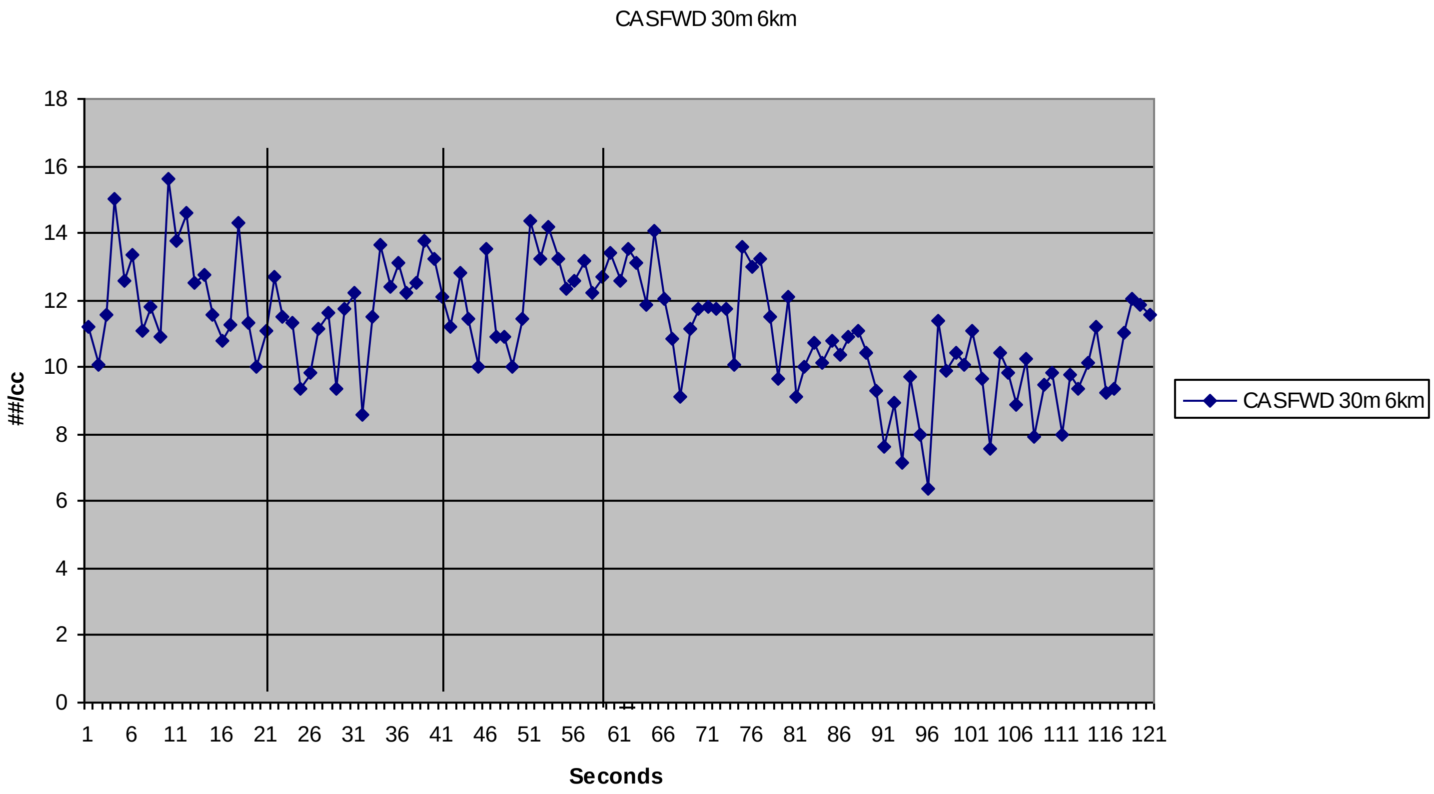


Flight level LOS Velocity (450 meters altitude)

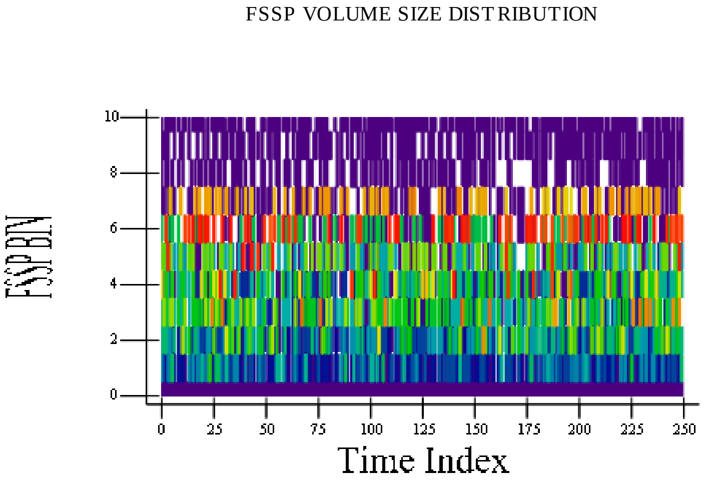



VLOS (M/S)
SIGNAL STRENGTH
2
1
0
-1
-2
0
2
4
6
8
10
MARCH 12, 2002 TIME 1448 (100')
TIME SERIES FOR GATE 10 (950 M)
VLOS (RED), SIGNAL STRENGTH (BLACK)
ALONG FLIGHT-TRACK DISTANCE (KM)

CASFWD data for flight segment at 30m altitude

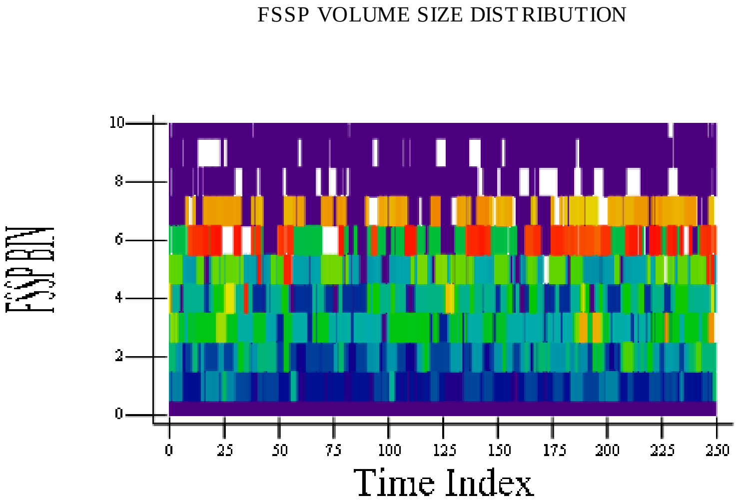


1 second (50m)



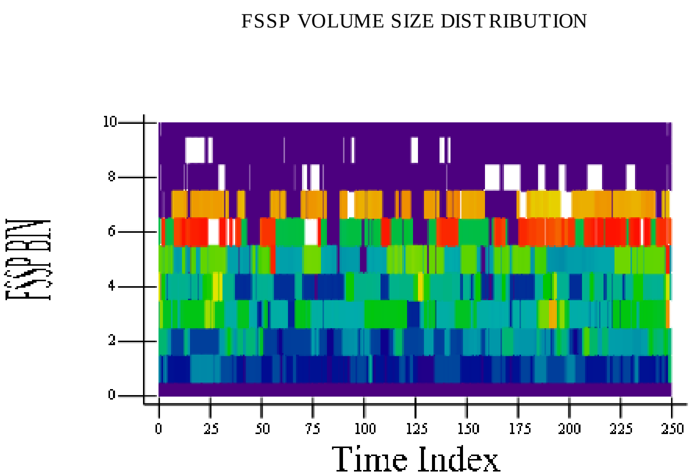
FSSPVOL

5 seconds (250m)



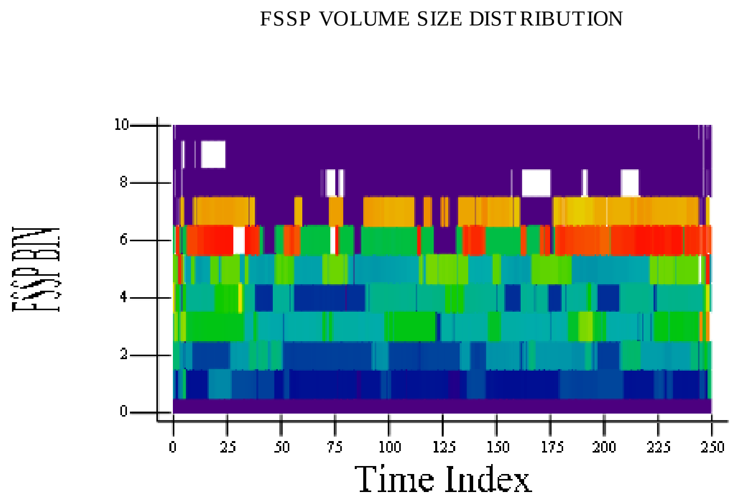
FSSPVOL

7 seconds (350m)



FSSPVOL

13 seconds (650m)



FSSPVOL

Findings (1)

- The TODWL provides coincident aerosol and wind observations in a manner necessary for evaluating ß/U correlations for their potential impacts on spacebased DWL data products
- Within MBL, biases of order 1.0 m/s can be reasonably expected for aerosol direct detection systems.
- Even larger biases may be realized in the presence of wave-like structures in the mid and upper troposphere
- Particle probes tending to smooth the aerosol features easily detected with lidar

Summary

- The TODWL provides an excellent tool for investigations of the MBL wind and aerosol interactions, with the lidar being more revealing of subtle (but significant) aerosol structures than particle probes
- Organized Large Eddies (OLE) are clearly confounders for obtaining unbiased wind observations from photon counting lidars in the MBL
- Theoretical model of OLEs and data agree very well for a test case. More cases need to be studied before generalizing the implications of these findings to bulk parameterization of air/sea energy and momentum fluxes

Acknowledgements

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• IPO co-funded the lidar adaptation to the Twin Otter.

• IPO solely funded the mission planning, flight hours, data collection, and the post-flight installation of the lidar in a trailer for inter-flight research.