A METHODOLOGY FOR THE DESIGN OF METEOROLOGICAL INSTRUMENTATION NETWORKS

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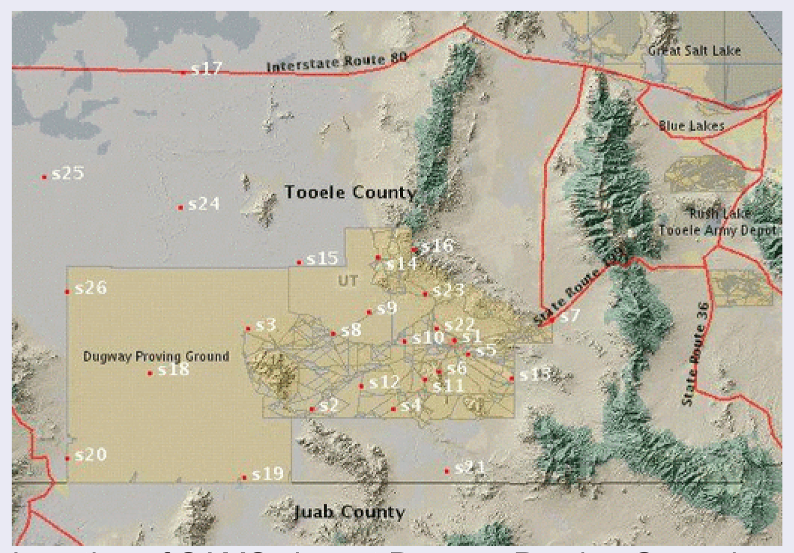
OBJECTIVE:
Design a meteorological instrumentation network at Dugway Proving Ground, UT, that has the ability to *fully characterize* the 3D environmental conditions at multiple locations on a test grid and to determine and predict impacts on agent simulant challenges. The test grid is defined as a box either 1km or 5km in the horizontal, and from 100m to 1000m deep.



Location of SAMS sites at Dugway Proving Ground.

MEASUREMENT REQUIREMENTS:

3-D Wind Direction/Speed: Directional accuracy of ±5 degrees (objective: ±1 degree), wind speed in the range of 0-40 m/sec (objective: 0-72 m/sec), and accuracy of ±0.15 m/sec.

Temperature: In the range of -40 °C to +60 °C, with an accuracy of ±0.5 °C (objective: ±0.1 °C).

Relative Humidity: In the range of 0-99%, non-condensing, with an accuracy of ±3% (objective: ±1%).

Barometric Pressure: In the range of 500-1100 hPa, with an accuracy of ±1.3 hPa.

Precipitation: In the range of 0-50 mm/hr, with an accuracy of 0.1 mm.

DESIGN CONSTRAINTS:

Maximize reuse of existing instrumentation.

Maximize collocation with chem and bio instrumentation.

Work within infrastructure, power, and data communications constraints.

METHOD:

I. Use statistical and Self Organizing Map (SOM) analysis to define characteristic meteorological conditions under which field testing has occurred.

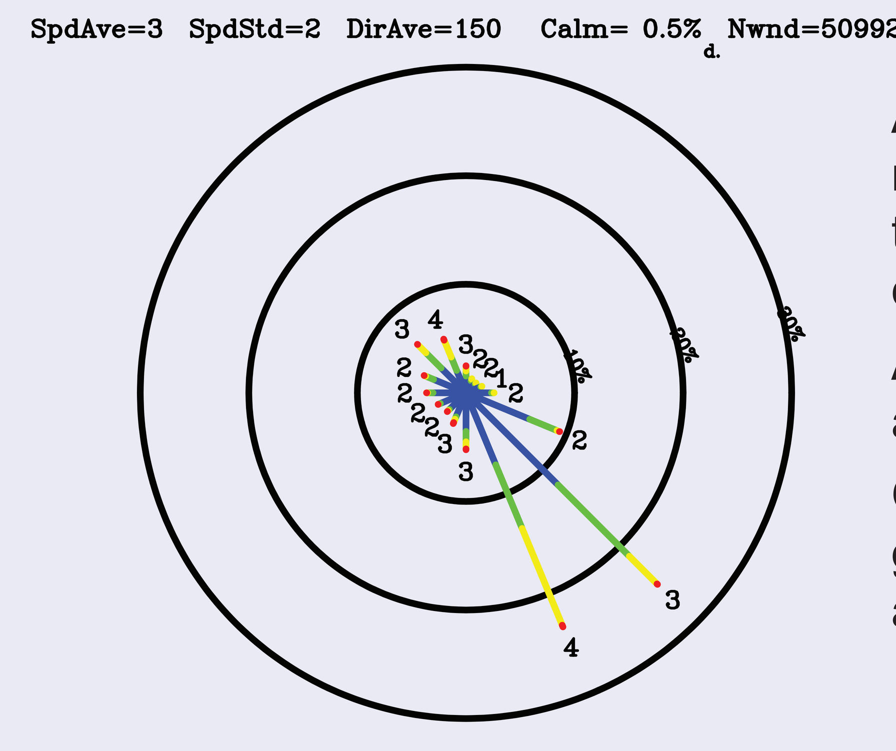
II. Carry out high resolution numerical simulations of the characteristic conditions, and analyze the key scales in the required fields to determine ideal instrumentation density on the 1km test grid.

III. Perform Observing System Simulation Experiments (OSSE) to determine the impact of proposed instrumentation arrays on the 5km test grid.

I. CLIMATE ANALYSIS

Hourly SAMS observations for the period April through October, 1994-2007. Over 50,000 observations at each site are used in the wind rose analysis.

Go/No-Go criteria for testing are:
- Time - 12am to 6am local
- Wind Speed - 2 to 8 m/s
- Direction - SE or NW
- Temperature - greater than 40F
- Relative Humidity - less than 80%
- Precipitation - none

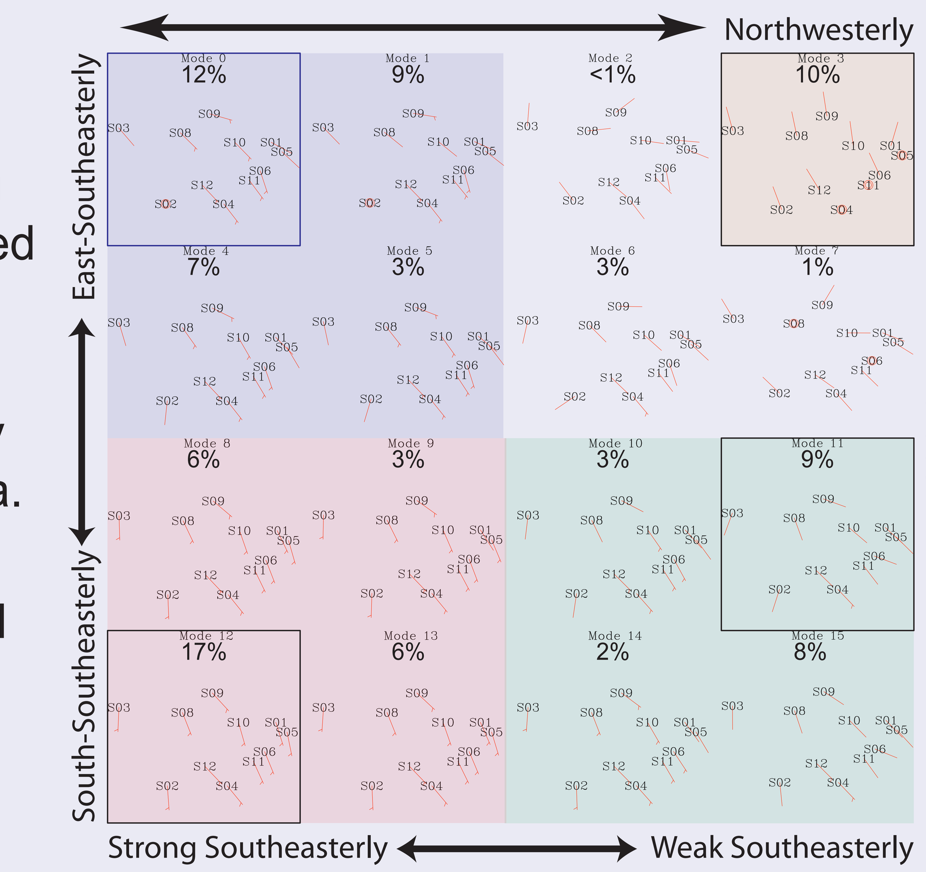


Wind Rose for SAM 4

A SOM is an unsupervised-learning neural-network algorithm that is used to reduce the dimensionality of the data.

A SOM can be used to help classify and categorize high-dimension data.

Over 20,000 observations meet the go criteria and are used in the SOM analysis.



SOM and wind rose analysis show that there are two dominant modes, Southeasterly (85% frequency) and Northwesterly (10% frequency).

The Southeasterly conditions can be further subdivided into Strong South-Southeasterly (32% frequency), East-Southeasterly (31% frequency), and Weak Southeasterly (22%).

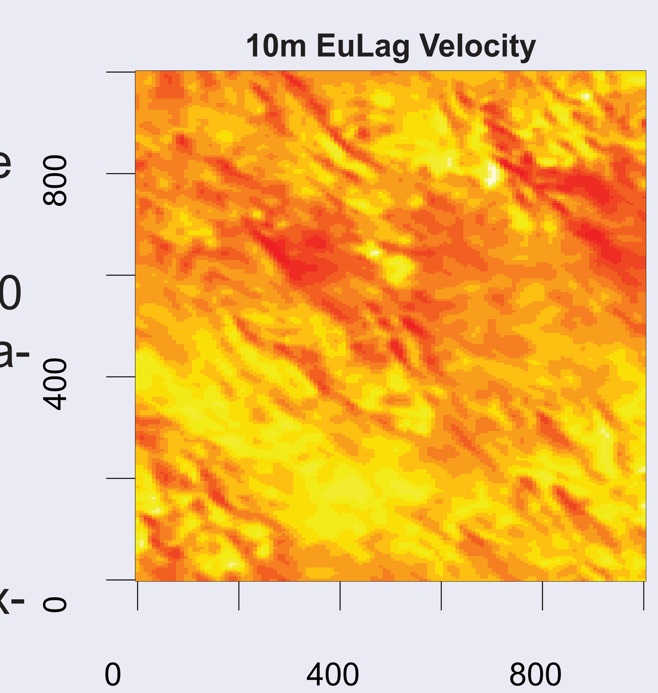
Observations can be classified by the SOM as to which mode they best match and characteristic days can then be selected for use in the scale analysis and OSSE simulations.

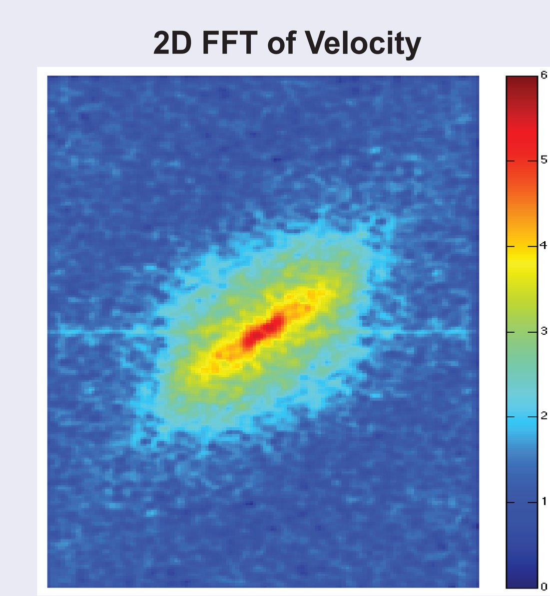
II. SCALE ANALYSIS

EuLag, an LES model, is run using characteristic conditions identified in the climate analysis.

The model is run with a 10 meter horizontal grid separation over the 1km test grid domain.

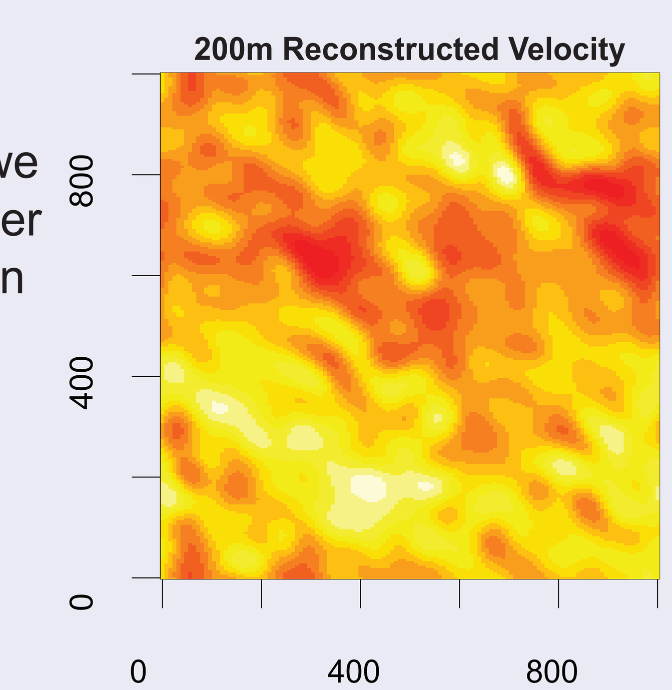
A 2D spatial FFT is applied to EuLag fields to examine key spatial scales.

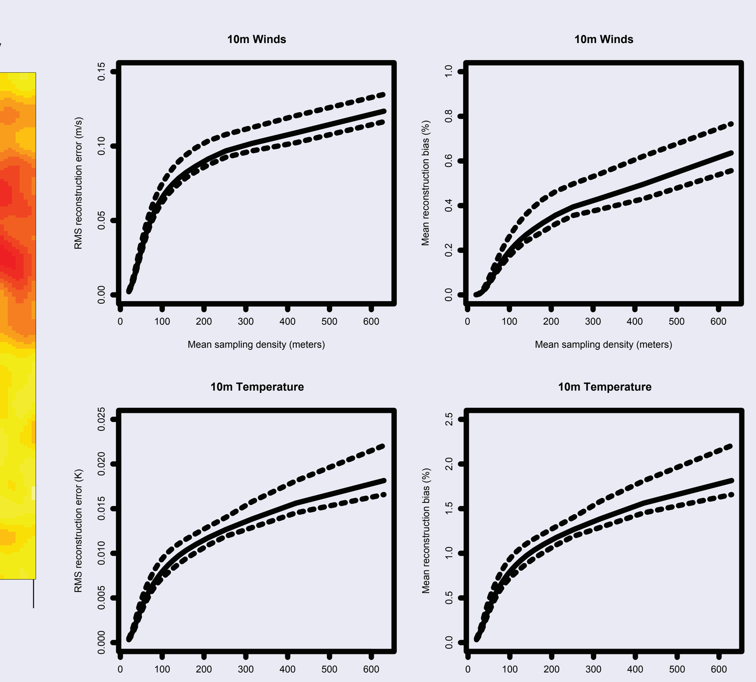




To simulate the effects of observing the test grid at varying sensor densities we apply a 2D Butterworth filter to the FFT results and then reconstruct the field.

Comparison is then made with the original model output to determine the quality of the reconstruction.



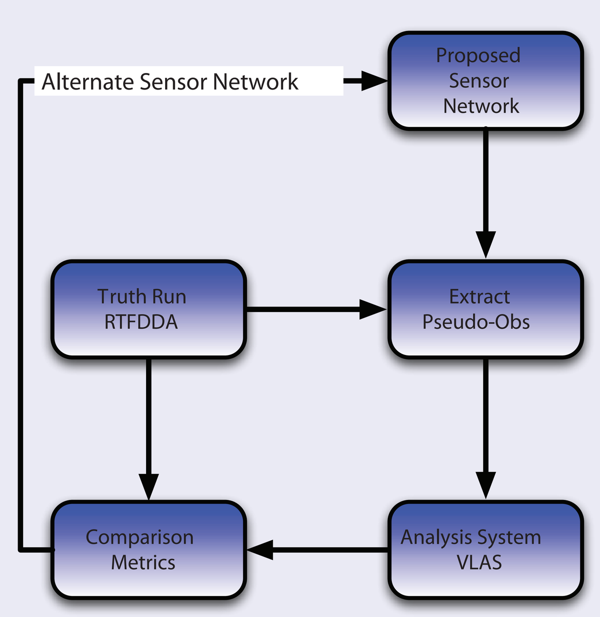


This process is repeated for a wide range of scales and for all cases.

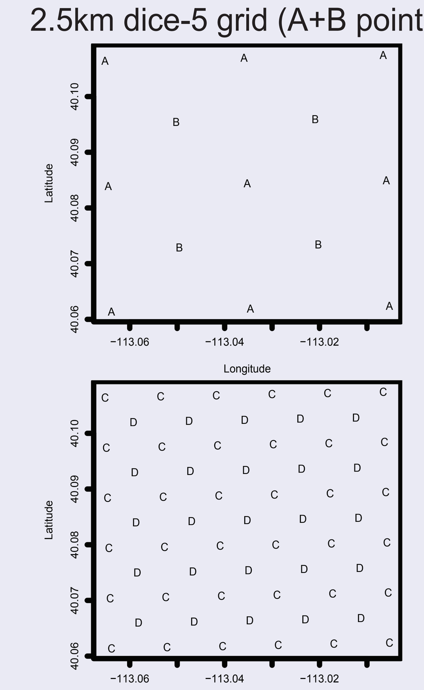
Critical transition occurs at length scales of 150 to 200 meters.

Scales below this range are purely turbulent and best observed via traditional time averaged turbulent statistics methods.

III. OSSE



2.5km 4-square grid (A points) and 2.5km dice-5 grid (A+B points)



1km 4-square grid (C points) and 1km dice-5 grid (C+D points)

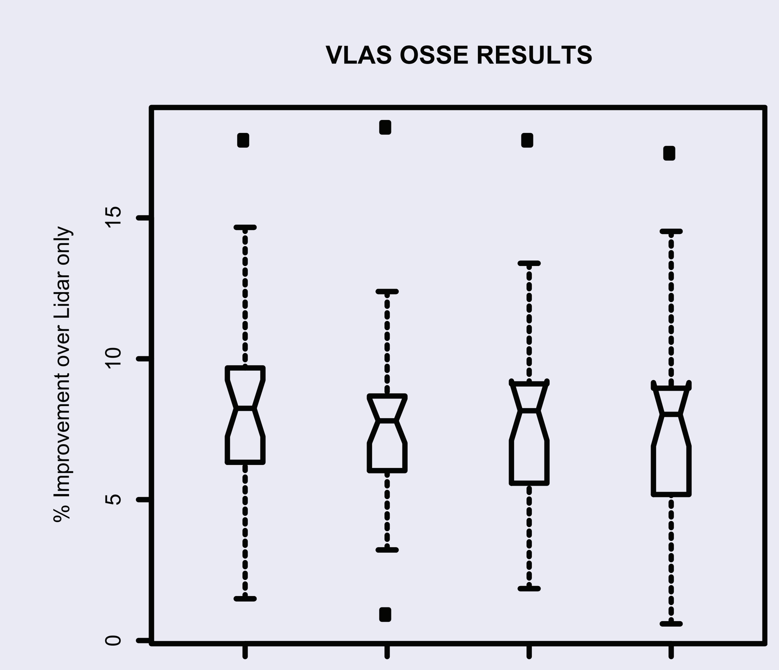
Pseudo-obs of winds, temperature, and humidity are extracted from RTFDDA simulations at 2 and 10 meter heights at points A,B,C, and D.

Pseudo-lidar radial winds are extracted from RTFDDA for a proposed lidar located 1km northwest of the grid.

Realistic errors are added to all pseudo-obs and lidar data.

Data ingested by VLAS (Variational Lidar Assimilation System) to create 3D analysis of meteorological state variables.

Compare analysis results with RTFDDA *truth* simulation



Use of 2 and 10 meter obs make a significant, ~7%, improvement on the quality of the analysis compared to using only lidar radial winds.

Quality of analysis not sensitive to density of sensors used. Most likely this is a result of the resolution of the truth simulation, 500m. All sensor networks used are capable of resolving existing scales of motion.

Differences in results due more to simulated sensor error than sensor density.

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