VISUALIZATION AND QUANTIFICATION OF WIND-INDUCED VARIABILITY IN HYDROGEN CLOUDS FOLLOWING RELEASES OF LIQUID HYDROGEN

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DOE Hydrogen Program
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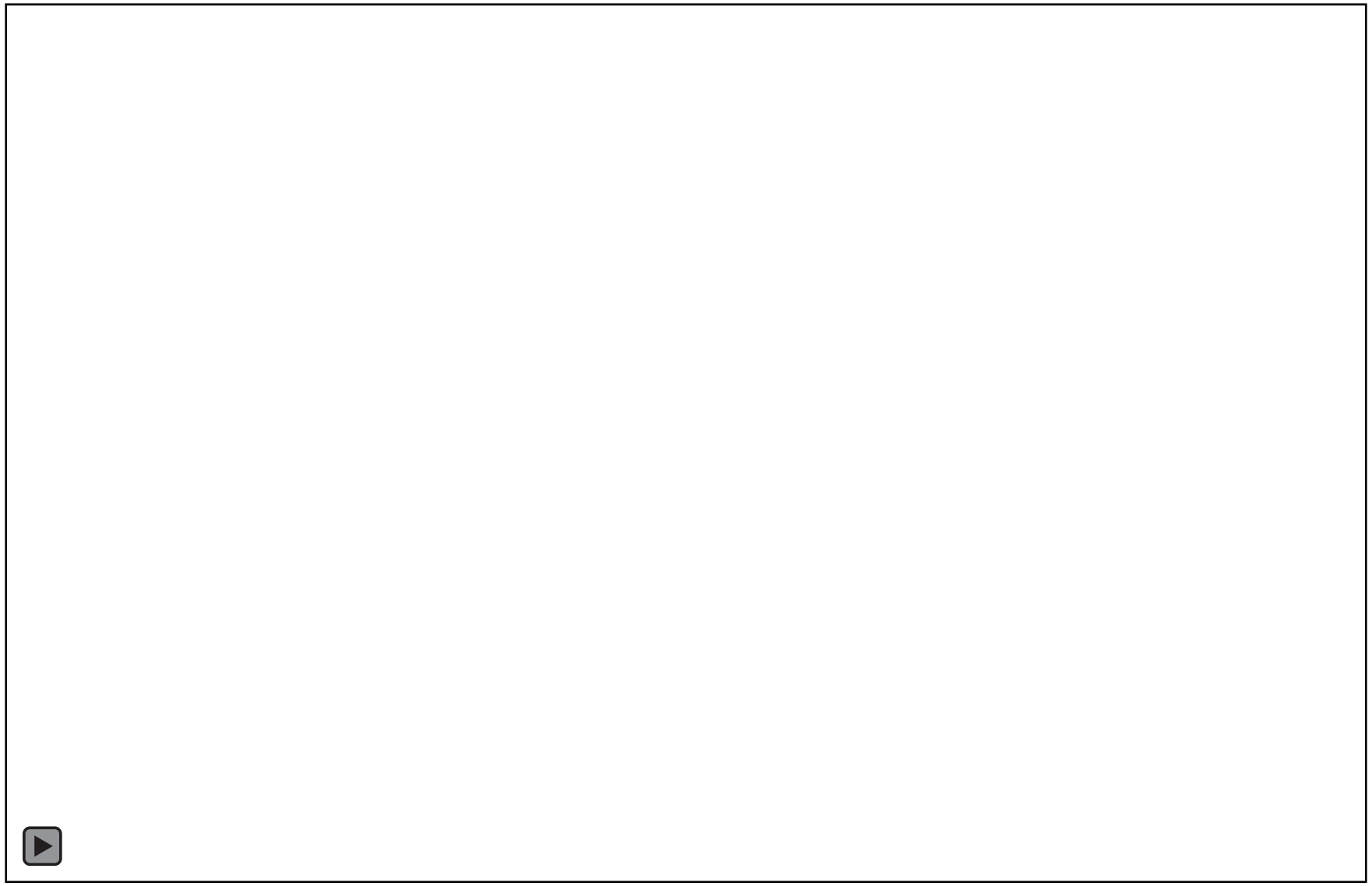
Project Background

- Liquid Hy release and ignition trials performed by HSE to study pluming and explosive effects
- Hydrogen sensor array provided by NREL
- Work performed under the auspices of PRESLHY work package 5 (combustion)

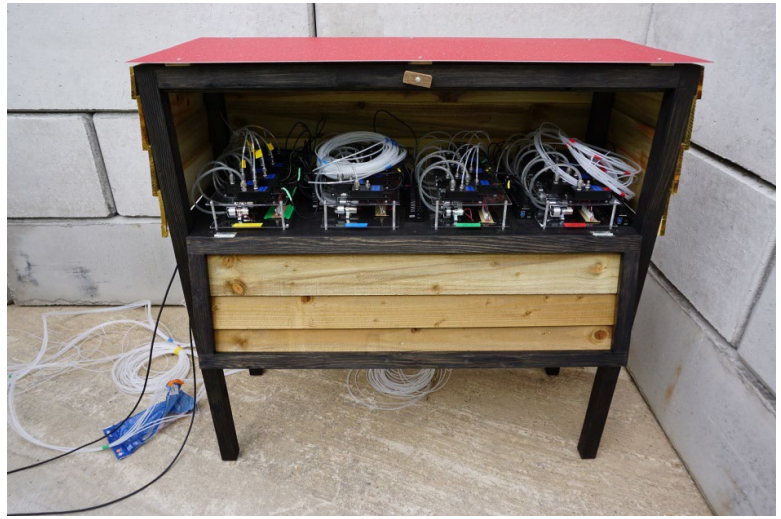
This analysis aimed to find a method of visualizing and quantifying the dispersion based on isolated sensor data

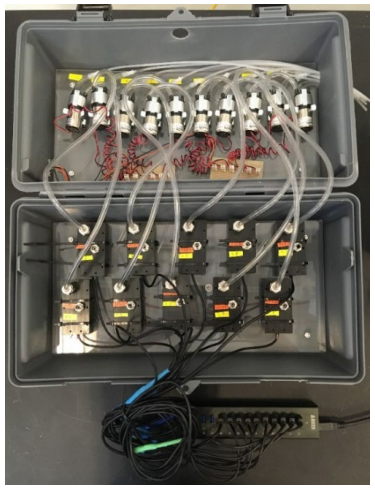
Video



HyWAM system

- The Hydrogen Wide Area Monitor is a tool developed by the NREL Sensor Laboratory to evaluate the hydrogen concentration at many locations simultaneously (0-100 vol%).
- The system uses pumps to pull gas samples down tubes to Hydrogen sensors.
- This deployment used thermal conductivity sensors.





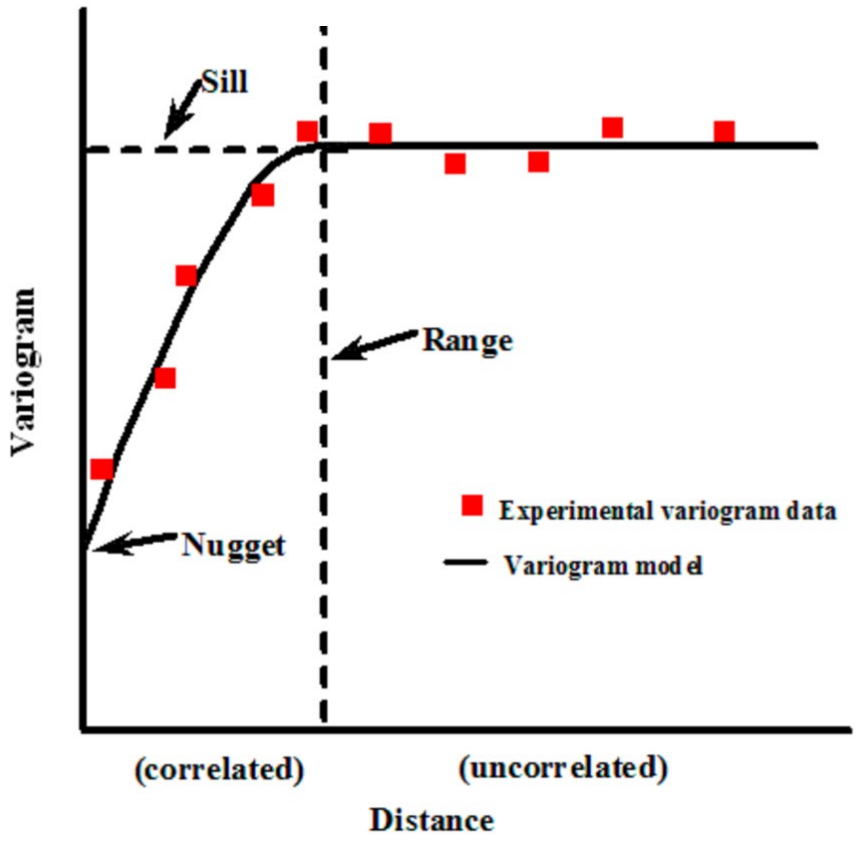
The NREL HyWAM Sensor Module (2019)

(2023)

Gaussian Process Regression

- GPR is a machine learning spatial interpolation technique.
- Dependent on knowledge of the variogram or function describing the spatial dependance of the data.

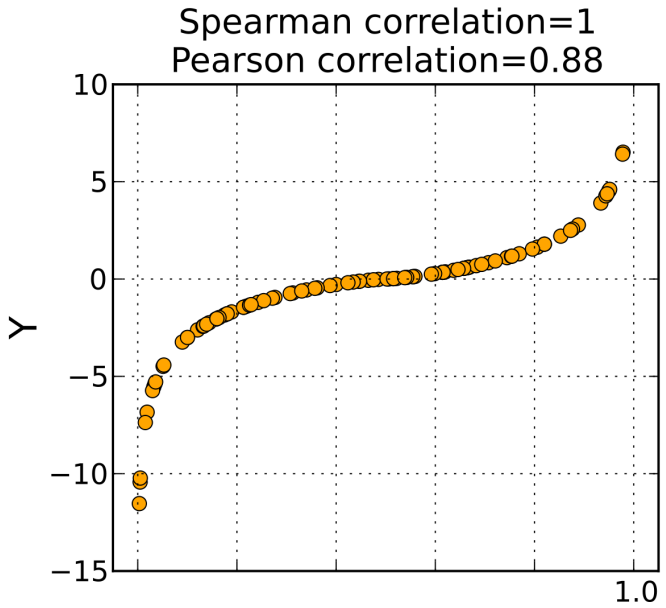
$$P \cdot \left(1 - e^{-\left(\frac{d^2}{\left(\frac{4}{7}r\right)^2} \right)} \right) + n$$



In this analysis we assume our data to have a **gaussian spatial dependance.**

Parameter Optimization

- To optimize the variogram parameters we used the **spearman correlation coefficient.**
- We created a python function that takes a set of parameters, performs GPR on all trials, and returns the Spearman coefficient.
- We then used Scipy's optimize function to vary the input parameters seeking the most correlated output.



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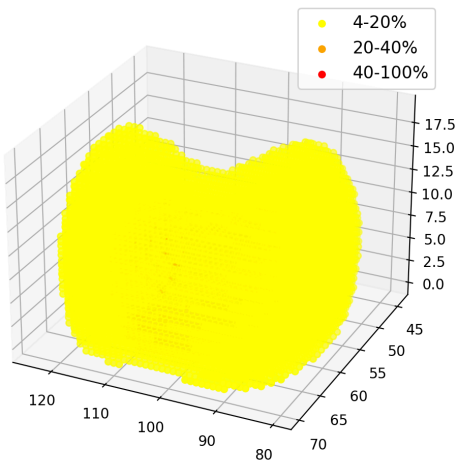
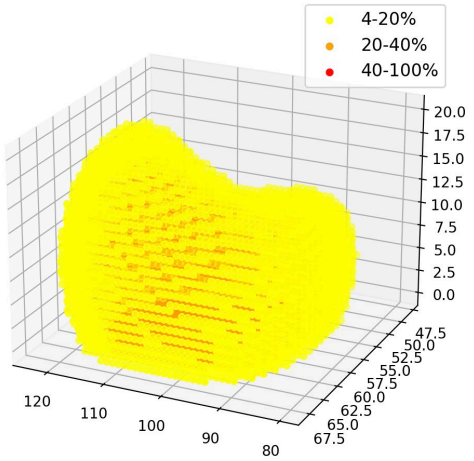
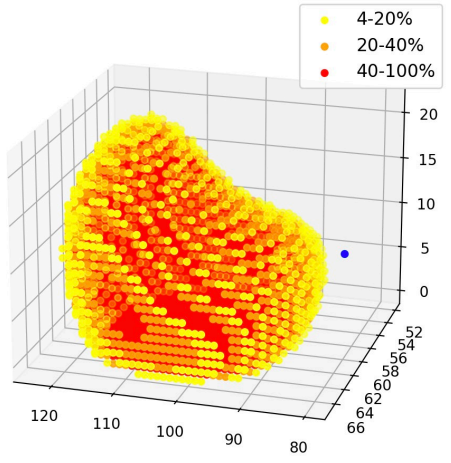


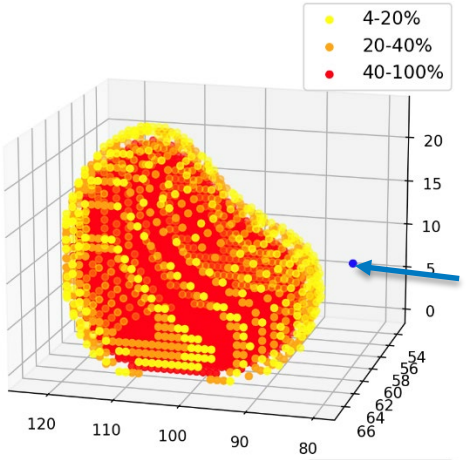


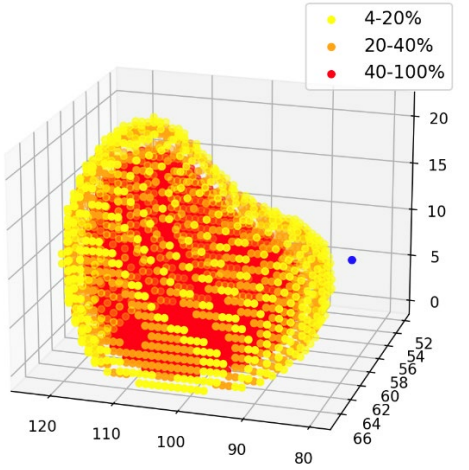


Dispersion Visualization

- To visualize the interpolation, we plotted every interpolated data point using Matplotlib.
- We compared these interpolations qualitatively to the video footage.
- We observed 3 different modes of dispersion

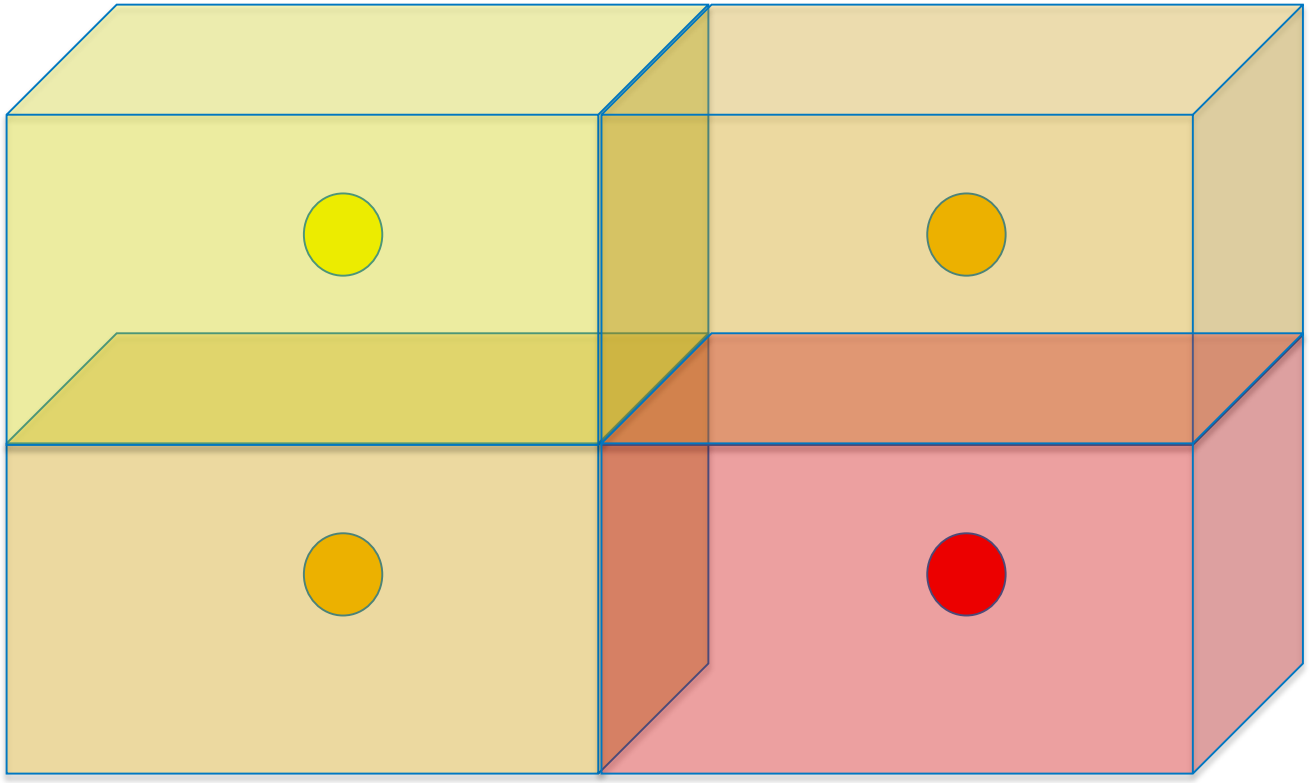
Our interpolation visually matched the high density, low velocity dispersion





Quantitative Estimates

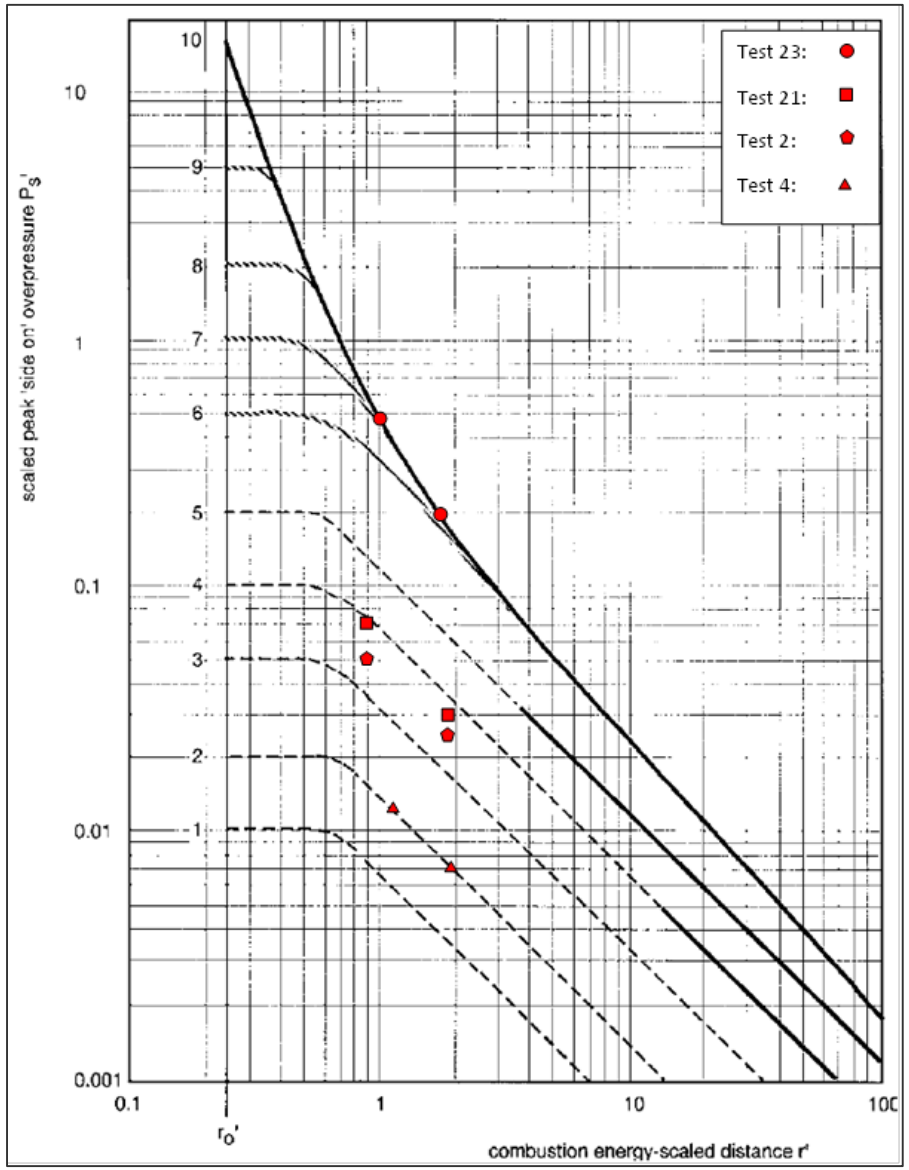
- Quantitative estimates were made by:
  - Letting each point represent the surrounding area's volume percent concentration.
  - Assuming the pressure in the plume to be equal to the ambient pressure.
  - Using the ideal gas law to reach moles of hydrogen and convert to mass.



TNO Explosion Severity Estimates

- Mass estimates did not fully correlate to TNT equivalence.
- Based on energy scaled distance.
- Allowing for variability in TNO severity level our mass estimates correlated reasonably with expected values.

Test	Condition	TNO severity level
23	High congestion, counter flow wind	7-10
21	High congestion	3-4
2	Low congestion, counter flow wind	3-4
4	Low congestion	2



Conclusion

- Allowing for variation in TNO severity, the mass estimates match the expected ranges to produce the explosions that were observed.
- The use of Gaussian Process Regression was shown to have both qualitative and quantitative applications.
- The GPR variogram was not very stable; there may exist a variogram which is more stable and/ or one which describes the high momentum jet stream.

Thank You

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