

SLATT UNDERGRADUATE STUDENT FELLOWSHIP

CHECK ONE: UPDATE X FINAL REPORT

SLATT SCHOLAR:	Eric Lee
FACULTY ADVISOR:	STEFANO CASTRUCCIO
REPORT PERIOD:	Fall 2018 and Spring 2019
PROJECT TITLE:	Stochastic Generator for Dust in Saudi Arabia
CONNECTION TO ND ENERGY'S RESEARCH AREAS (CHECK ALL THAT APPLY):	<input type="checkbox"/> Energy Conversion and Efficiency <input type="checkbox"/> Sustainable and Secure Nuclear <input type="checkbox"/> Smart Storage and Distribution <input type="checkbox"/> Transformation Solar <input type="checkbox"/> Sustainable Bio/Fossil Fuels <input checked="" type="checkbox"/> Transformative Wind

MAJOR GOALS AND ACCOMPLISHMENTS:
 List your major research goals and provide a brief description of your accomplishments (1-2 sentences). Indicate the percentage completed for each goal. Please use a separate sheet to share additional details, technical results, charts, and graphics.

MAJOR RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Statistical Hierarchical Model of MERRA-2 Wind Data	Fully implemented hierarchical model using machine learning and spatio-temporal statistical methods	100%
Climate Averaging Model of Earth	Created a weighted average model of CO2 behavior over defined geographical regions	100%
Create/Present Poster at SWGEN	Created a concise research poster of my findings and methodology. Presented work in poster session at the Stochastic Weather Generators Conference.	100%

RESEARCH OUTPUT:
 Please provide detailed information below regarding any output resulting from your research project. Please check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS	(Sponsor, Project Title, Pls, Submission Date, Proposal Amount)
EXTERNAL AWARDS	(Sponsor, Project Title, Pls, Award Date, Award Amount)
JOURNAL ARTICLES	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
BOOKS AND CHAPTERS	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS, SEMINARS, LECTURES	Stochastic Weather Generators Conference, Stochastic Generator for Dust in Saudi Arabia, 10/02/2018, Boulder, Colorado
AWARDS, PRIZES, RECOGNITIONS	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail)

RESEARCH EXPERIENCE:
 Please let us know what you thought of your research experience: Did this experience meet your expectations? Was there something else that could have been done to improve your research experience? Were lab personnel helpful and responsive to your needs? What could have been done differently, if anything, to achieve additional research results?

I felt that I adequately accomplished the goals that I had set for myself throughout this research period. I set out to create a statistical model to be able to model dust behavior within Saudi Arabia in order to analyze viability for wind farms within the country. I had never undertaken a research program before this endeavor, and it proved to be a great challenge. Many of my initial statistical models did not work as intended and I would say I even failed more than I had success throughout my experience. However, thanks to the help of my research advisor I was able to salvage these failures into progress. I continuously learned from my mistakes and developed my abilities to code and learn statistics. At the same time, one of my other goals aside from the research itself was to develop my ability to present complex information to large groups. Thanks to continual practice with my advisor, I was able to give a poster presentation and developed a valuable skill that will stay with me for the rest of my career. Ultimately, I felt that the support that was given to me both from my research advisor and from the funds from this fellowship were invaluable. My advisor helped me develop as a researcher by accommodating complex tasks to me skill and education level. The funding allowed me to travel to the unique location of Boulder, Colorado and network with the top minds of my research field. Receiving feedback on my work as well as career advice was a rewarding experience. If I could do anything differently, I would have started researching earlier in my college career. I wish that I had more time to sink my teeth into deeper topics before graduating but nevertheless, I am grateful that I was able to have this experience in the first place.

MAJOR GOALS AND ACCOMPLISHMENTS

Stochastic Generator for Dust in Saudi Arabia

Eric Lee and Professor Stefano Castruccio, Department of ACMS

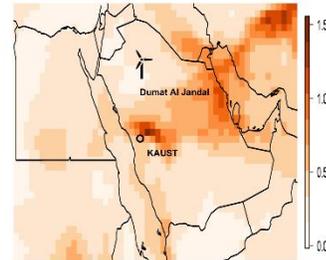


MOTIVATION

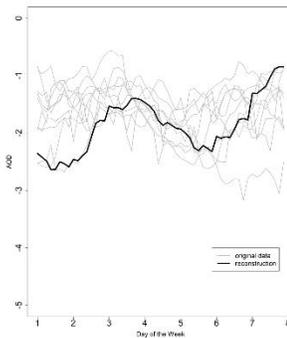
In 2016, Saudi Arabia laid out 'Vision 2030', its first plan for energy sustainability. Yet to date, no wind turbines are operating in the country. **Where should we build wind farms?** For this plan to be economically viable in a dust-rich country like Saudi Arabia, the **effect of frequent dust storms, which deteriorate turbine efficiency**¹ must be considered. This project seeks to **predict dust concentrations** from past measurements so that this variable can be factored in during wind farm installation.

DATA

MERRA-2 is a NASA dataset that uses satellite observations to provide a gridded record of the global atmosphere. We focus on **AOD**, an optical indicator of the **quantity of dust** in the air. We focus on a site at the **KAUST** campus in Saudi Arabia in 2015.



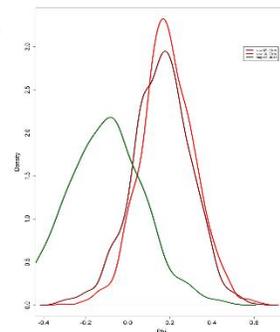
PRINCIPAL COMPONENT ANALYSIS



HIERARCHICAL MODEL

Data Level	$y_{d,h} \sim \varphi_d y_{d,h-1} + \varepsilon$
Process Level	$d = 1, \dots, 365 \quad h = 1, \dots, 7$
Parameter Level	$\varphi_d \sim \rho \varphi_{d-1} + \tau$
	$\varepsilon \sim N(0, \sigma_\varepsilon^2)$
	$\tau \sim N(0, \sigma_\tau^2)$
	$\rho \sim U(-1, 1)$

CHANGE OF PHI DENSITY OVER TIME



FUTURE WORK

- Adapt to multiple sites across Saudi Arabia
- Relationship between wind and dust?
- Spatial dependence with high resolution data
- Different priors for hierarchical modeling

TOWARDS SUSTAINABILITY

As part of 'Vision 2030', Saudi Arabia seeks to generate 3.45 gigawatts of renewable energy by 2020. **Dumat Al Jandal** has been chosen as the site of the country's **first utility-scale wind farm**⁴. This work is meant to provide the first assessment on the **technology's durability** in the site, and more broadly in the entire country.

REFERENCES

1. Sareen, A., Sapre, C. A., & Selig, M. S. (2013). Effects of leading edge erosion on wind turbine blade performance. *Wind Energy*, 17(10), 1531-1542.
2. Team, E. W. (2005, October 01). ESRL Global Monitoring Division - GRAD - Surface Radiation Budget Network (SURFRAD).
3. Rao, P. G., Hatwar, H. R., Al-Sulaiti, M. H., & Al-Mulla, A. H. (2003). Summer shamals over the Arabian Gulf. *Weather*, 58(12), 471-478.
4. 18 July 2017 by Jan Dodd. (n.d.). Saudi launches 400MW tender at Dumat al Jandal. *Wind Power Monthly*.

