Geospatial Computing, Innovation, and Sensing

Argonne NATIONAL LABORATORY

OpenCRUMS USA: Open classification of regimes in the Southeast USA

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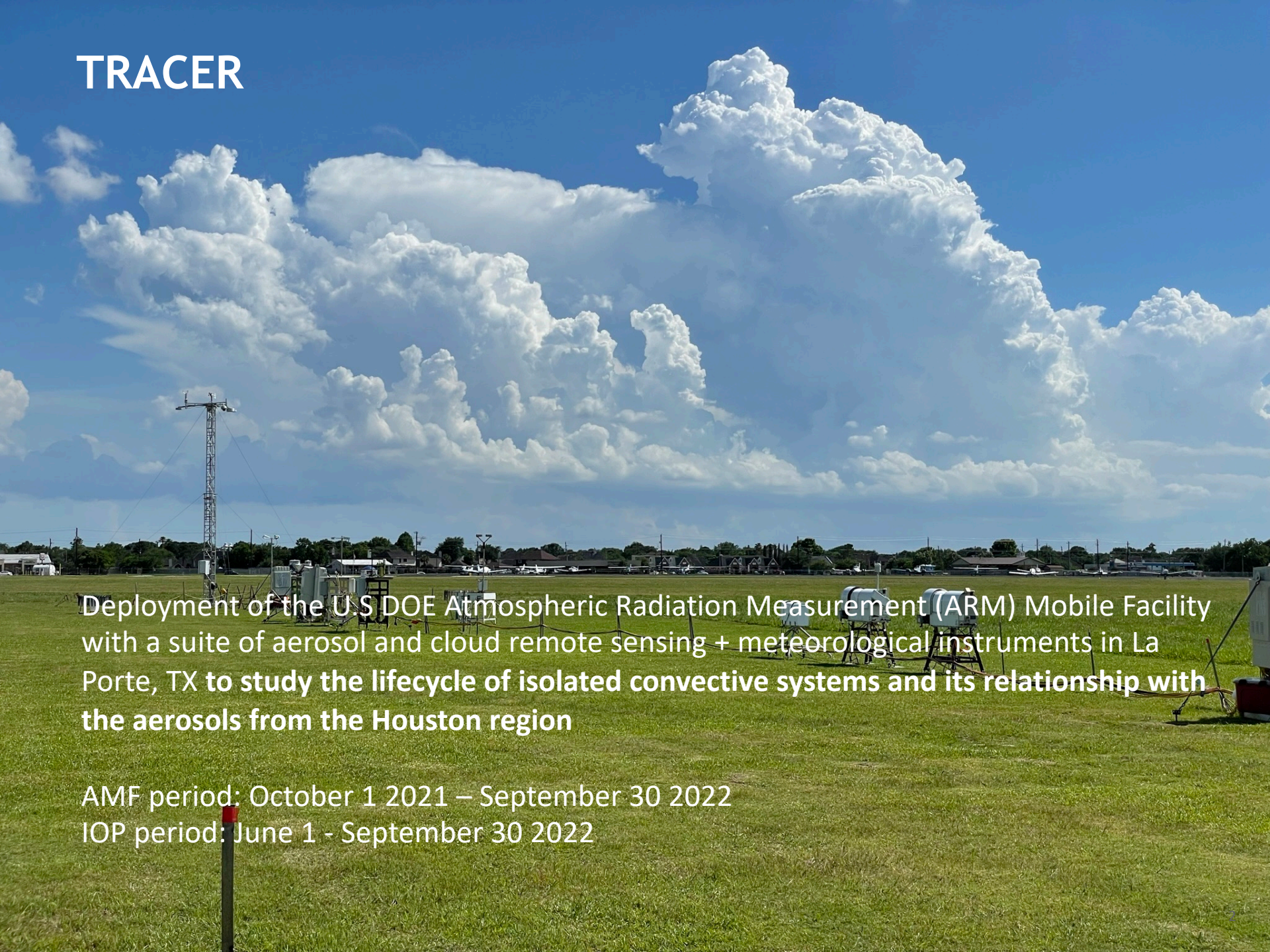
Brookhaven National Laboratory

ARM CLIMATE RESEARCH FACILITY

ASR Atmospheric System Research

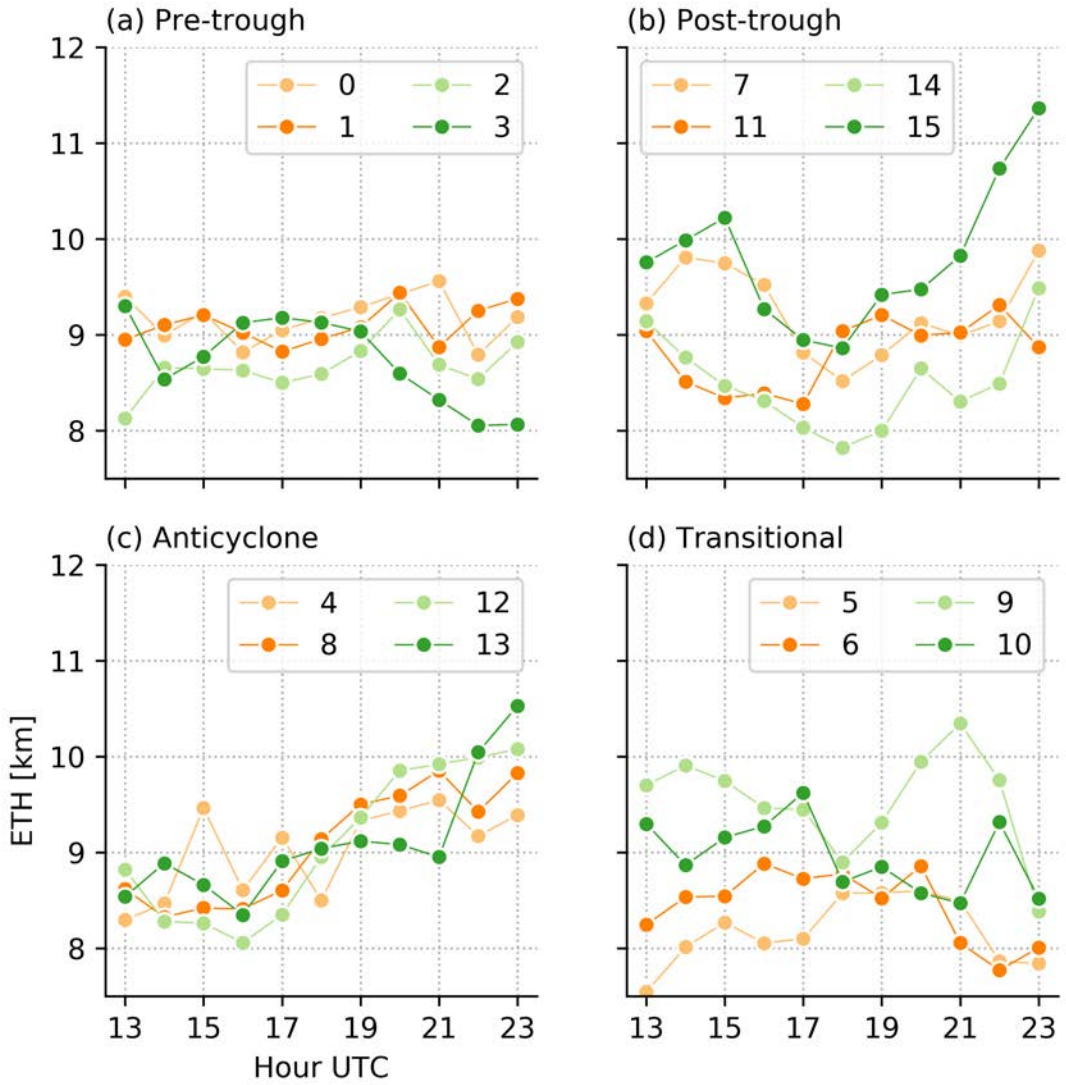
AI4ESP

TRACER



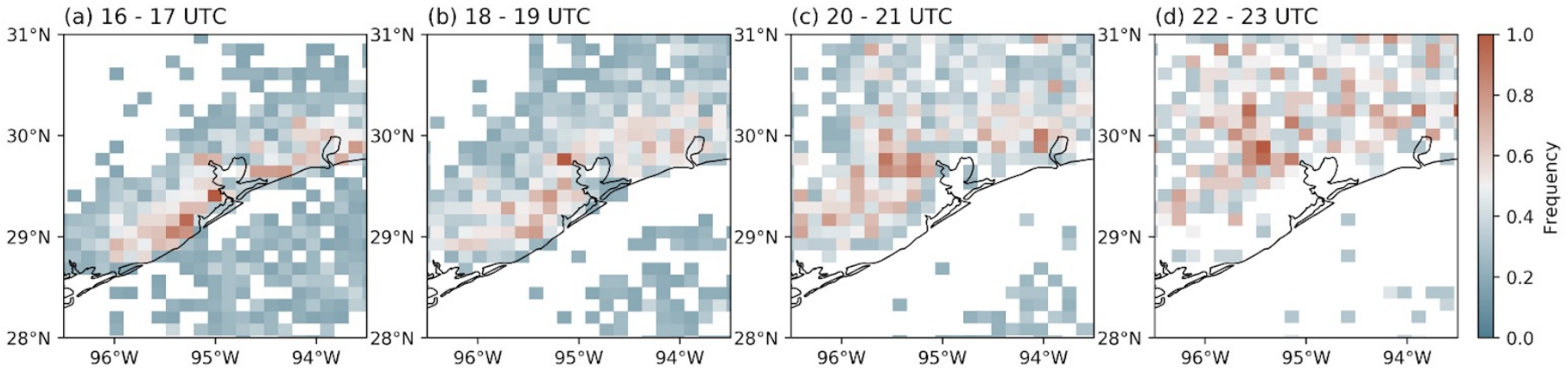
Deployment of the U.S DOE Atmospheric Radiation Measurement (ARM) Mobile Facility with a suite of aerosol and cloud remote sensing + meteorological instruments in La Porte, TX **to study the lifecycle of isolated convective systems and its relationship with the aerosols from the Houston region**

AMF period: October 1 2021 – September 30 2022
IOP period: June 1 - September 30 2022



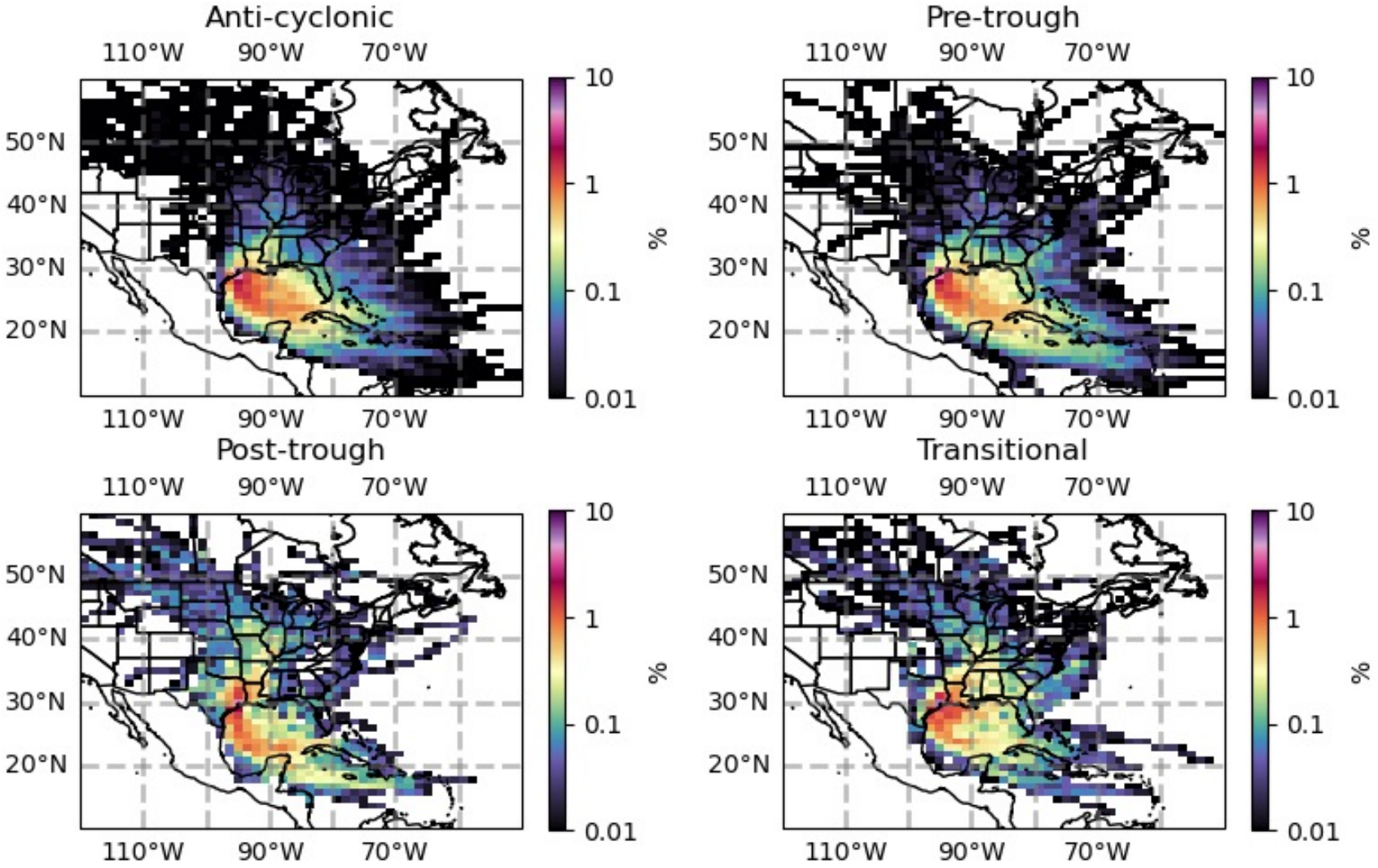
Wang D, M Jensen, D Taylor, G Kowalski, M Hogan, B Wittemann, A Rakotoarivony, S Giangrande, and J Park. 2022. "Linking synoptic patterns to cloud properties and local circulations over southeastern Texas." *Journal of Geophysical Research: Atmospheres*, 127(5), e2021JD035920, 10.1029/2021JD035920.

Self-organizing maps categorized meteorology in Houston into four regimes.



Seabreeze convection initiates off the coast of Houston in the afternoon hours in the anticyclonic regime.

D. Wang, R. Jackson, M.P. Jensen, S. Gupta, A.F. Prein, S.E. Giangrande, and Z. Lebo,
Life Cycle of Deep Convective Clouds in the Southeastern Texas Region, in preparation



More days with airmasses from Carribean/Gulf in anti-cyclone/pre-trough

OpenCRUMS USA

- Machine learning (ML) techniques provide new opportunity to discover regimes in large climate datasets.
- Aerosol regimes in Houston are also of interest to aerosol and cloud communities
- Investigate different ML techniques for classifying aerosol/meteorological regimes over Houstonusing Modern Era Retrospective Reanalysis 2 (MERRA2) data from 2010-2022
- Resulting software published as open cookbooks called the Open Classification of Regimes in the Southern USA (OpenCRUMS USA)

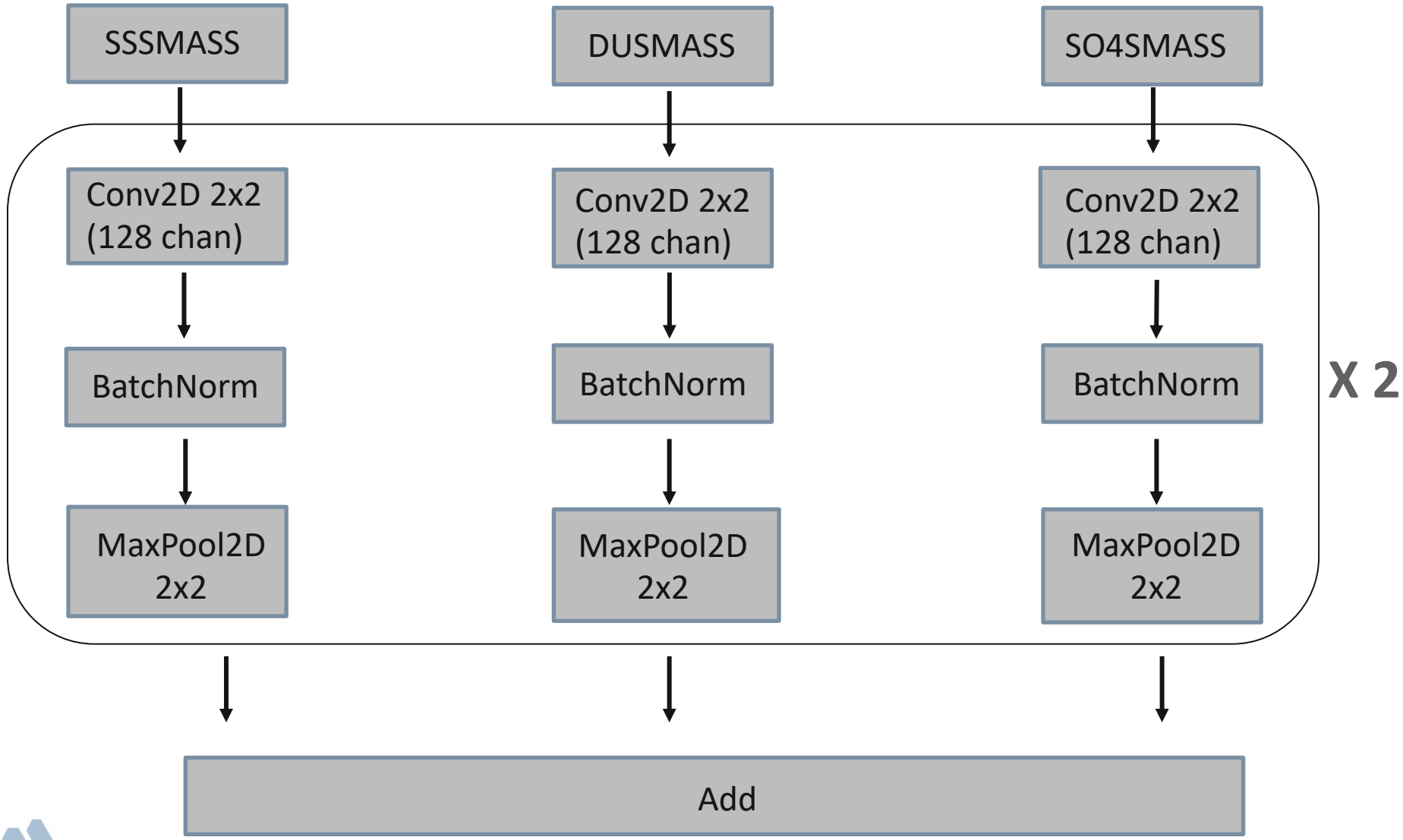
https://rcjackson.github.io/opencrums_cookbook/

Open Classification of Regimes in the Southeast USA

The U.S. Department of Energy (DOE) Office of Science's AI for Earth System Predictability (AI4ESP) initiative looks to explore how various AI techniques can help improve our ability to analyze weather and climate data as well as how it can improve climate prediction. As a part of this initiative, Open Classification of Regimes in the Southeast USA (OpenCRUMS USA) is a seed effort to explore how AI can be used on reanalysis datasets to cluster reanalysis observations over U.S. DOE Atmospheric Radiation Measurement (ARM) sites. Having objective classifications of the aerosol and meteorological conditions over the ARM sites will help investigators by providing a labelled dataset for periods of interest to the investigator (i.e. polluted and pre-trough, etc.). With this, investigators studying aerosol-cloud interactions can look for cases with different aerosol loadings and synoptic forcing.

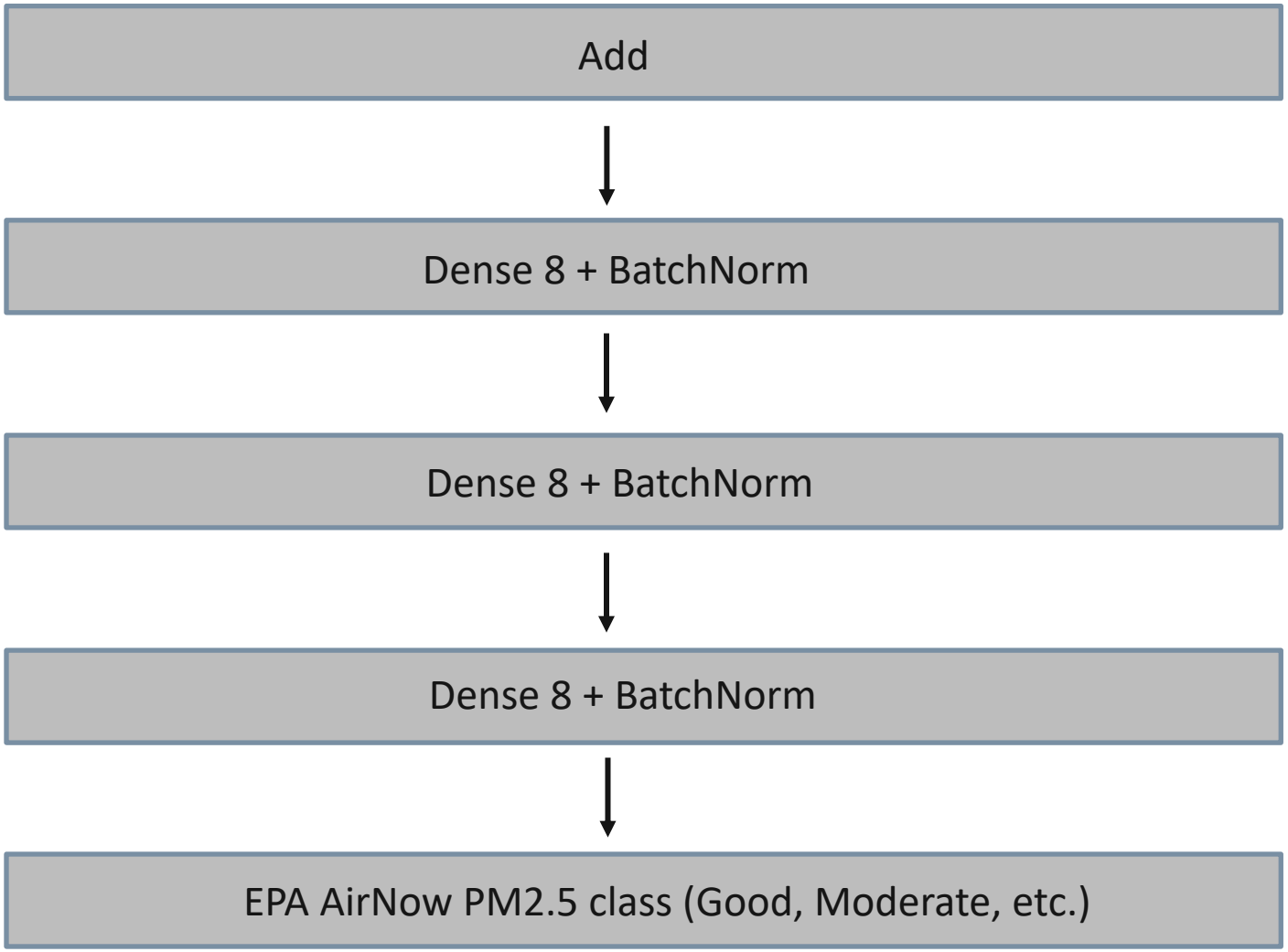
Of particular interest to OpenCRUMS USA are Houston, TX where the DOE TRacking Aerosol Cloud Interactions ExpeRiment (TRACER) took place during Summer 2022 as well as the ARM Mobile Facility deployment in the Southeastern United States that will commence in 2023. For the TRACER field experiment the U.S. DOE deployed the ARM Mobile Facility to Houston, TX with aerosol and meteorological measurement instruments. The primary focus of TRACER was to characterize the lifecycle of deep convection and its interaction with aerosols. The TRACER domain provides a natural laboratory for doing so by providing an environment favorable for isolated seabreeze convection to form off of the Gulf Coast to then enter the more polluted Houston region. The isolated nature of the convection allows for easier tracking of the convective lifecycle and the gradient of clean to polluted air as one moves inland into the Houston metro provides an aerosol perturbation. Therefore, this motivates OpenCRUMS to characterize potential aerosol regimes and sources. Since meteorological factors can influence both convective and aerosol properties, OpenCRUMS is also interested in exploring machine learning techniques for characterizing meteorological regimes over Houston and the Southeastern United States.

NN design (feature extractor)

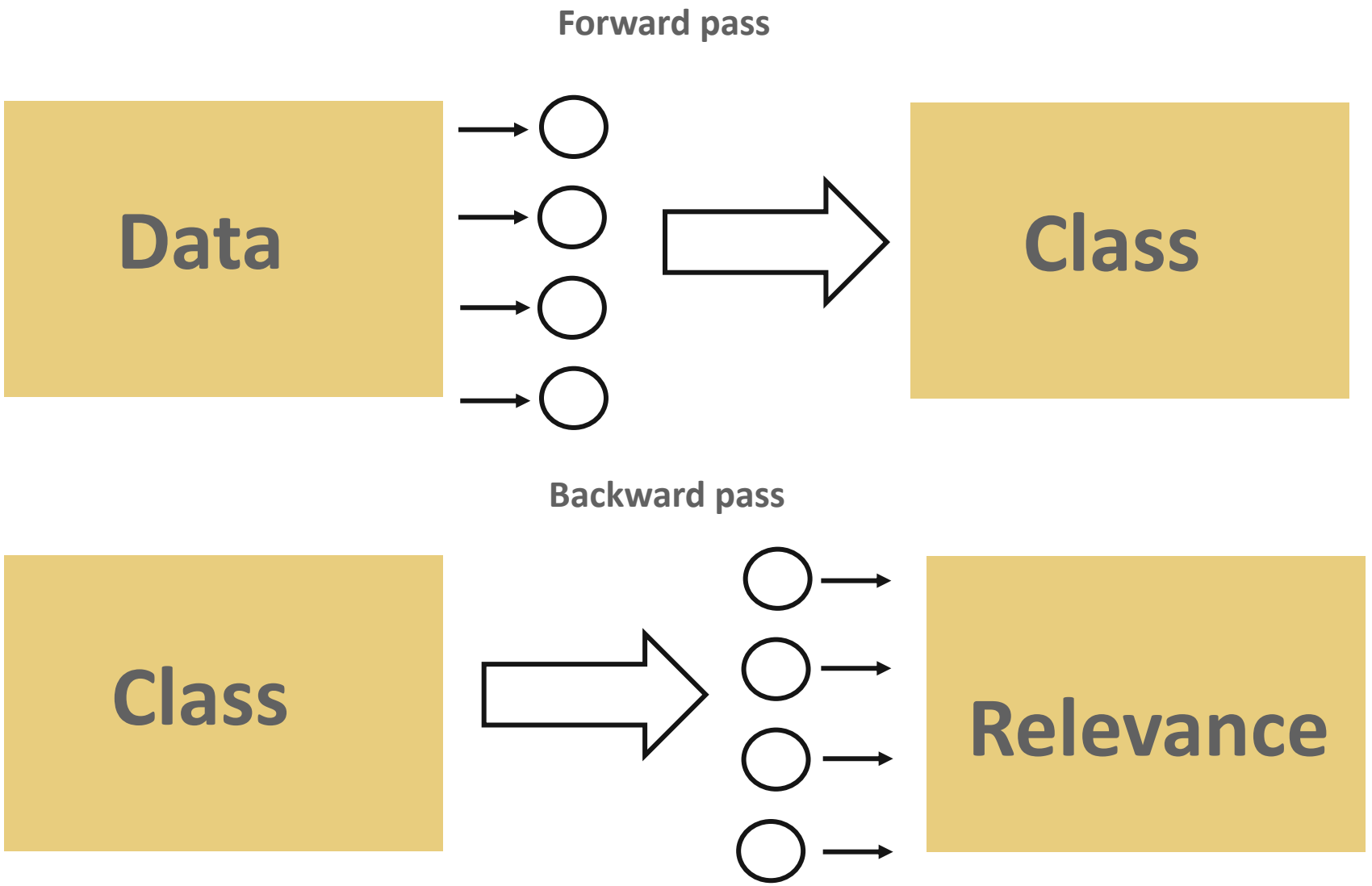


97% accuracy on testing dataset

NN design (classifier)

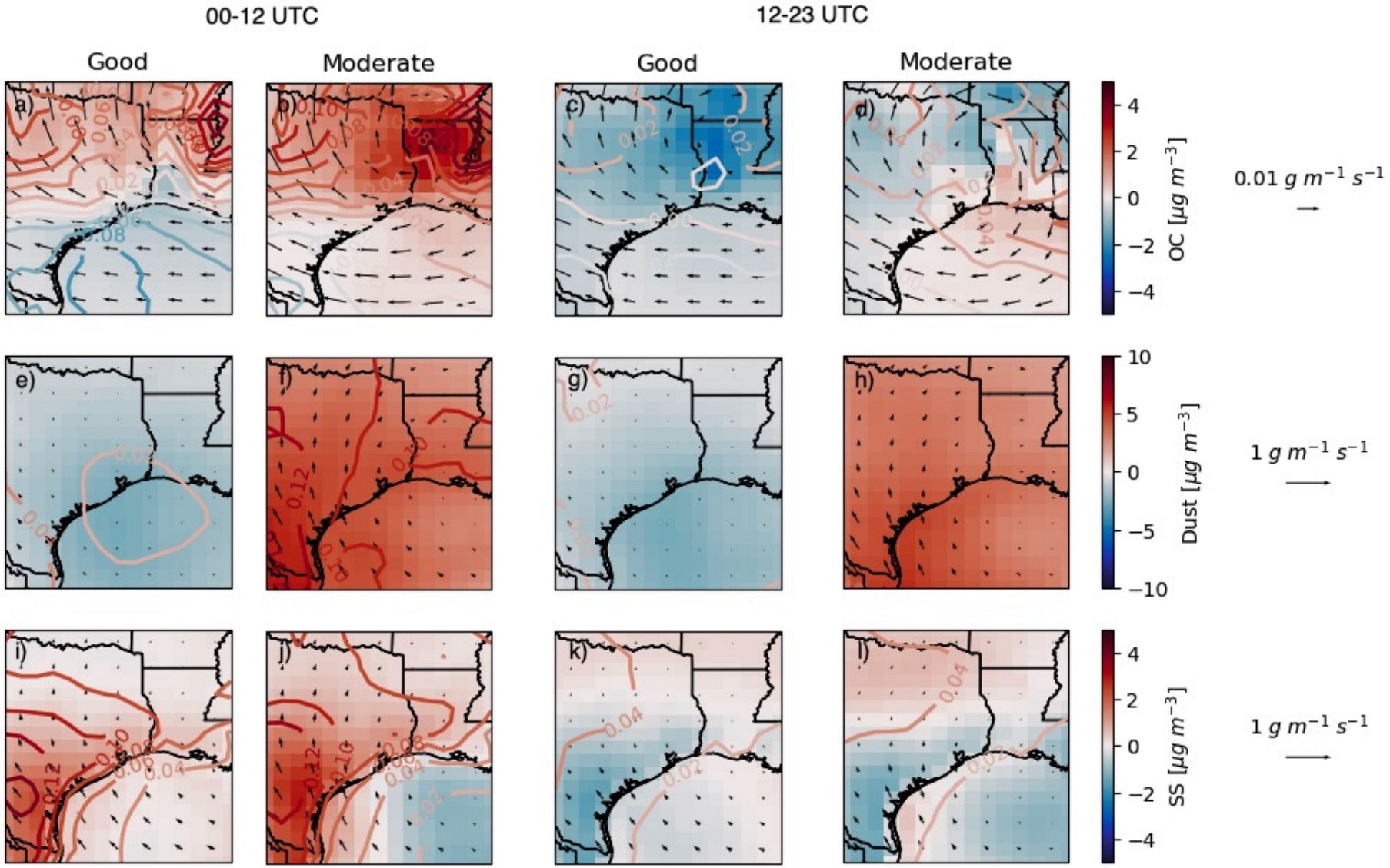


Layerwise Relevance Propagation

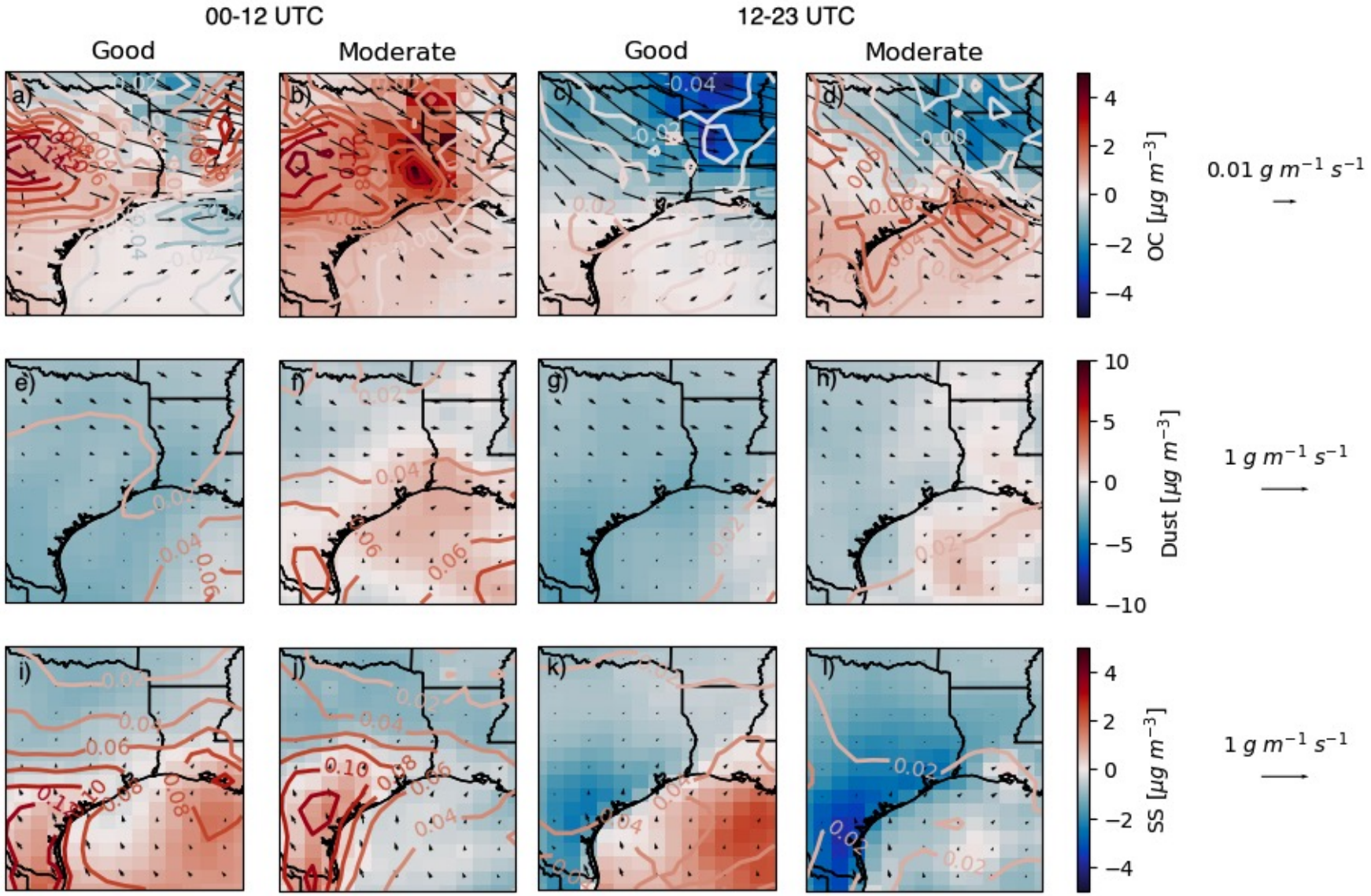


Toms, B. A., Barnes, E. A., & Ebert-Uphoff, I. (2020). Physically interpretable neural networks for the geosciences: Applications to Earth system variability. Journal of Advances in Modeling Earth Systems, 12, e2019MS002002. https://doi.org/10.1029/2019MS002002

JJAS surface PM2.5 mass anomalies in anti-cyclone



JJAS surface PM2.5 mass anomalies in post-trough



K-means clustering on TRACER AOS observations

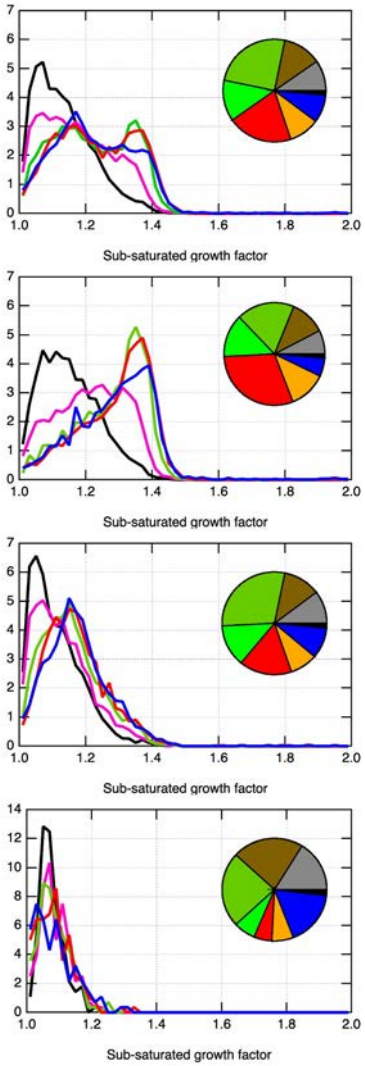
- 54% of hourly AOS observations were classified as “clean”: those were associated with marine aerosol with higher hygroscopicity
- 40% of hourly AOS observations were classified as “regional”: aged continental aerosols with lower hygroscopicity
- ~2% of hourly AOS observations fall into the ”local-polluted” category

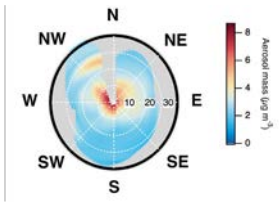
All TRACER observations

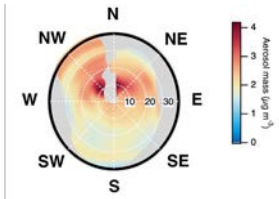
Clean

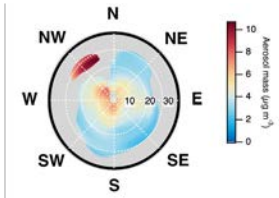
Regional

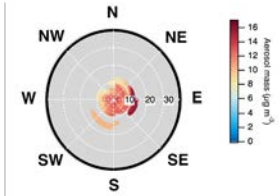
Local, polluted

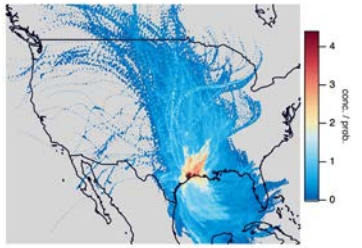


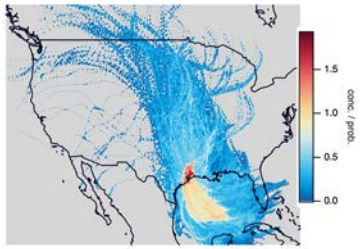


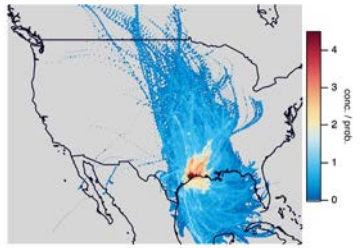


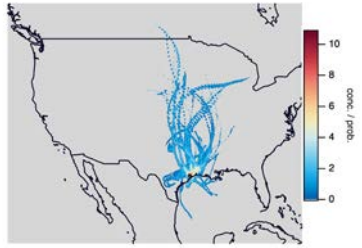












Summary

- CNN-based network can classify EPA AirNow PM2.5 index with ~99% accuracy
- This shows how LRP can be used to describe physical mechanisms occurring in different aerosol regimes:
  - Saharan Dust flow into Houston
  - Influence of organics from inland
  - Sea Salt from marine sources
- Ability to discern localized mechanisms more limited → limitation of using coarse reanalysis data.
- Resulting software published as open cookbooks called the Open Classification of Regimes in the Southern USA (OpenCRUMS USA)

https://rcjackson.github.io/opencrums_cookbook/

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