

monthly dust outlooks

early results from a lightweight CNN

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Engineering and
Physical Sciences
Research Council

Challenges in producing monthly dust outlooks

early results from a lightweight CNN

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A satellite image of Earth showing a massive dust plume over Africa and the Atlantic Ocean. The dust is depicted as a large, yellowish-brown cloud originating from the Sahara Desert and extending across the Atlantic. The text is overlaid on the image.

26 million tonnes of dust
+ 500 million tonnes every year



Jerry Ferguson



Jerry Ferguson



Shutterstock/Prostock-studio

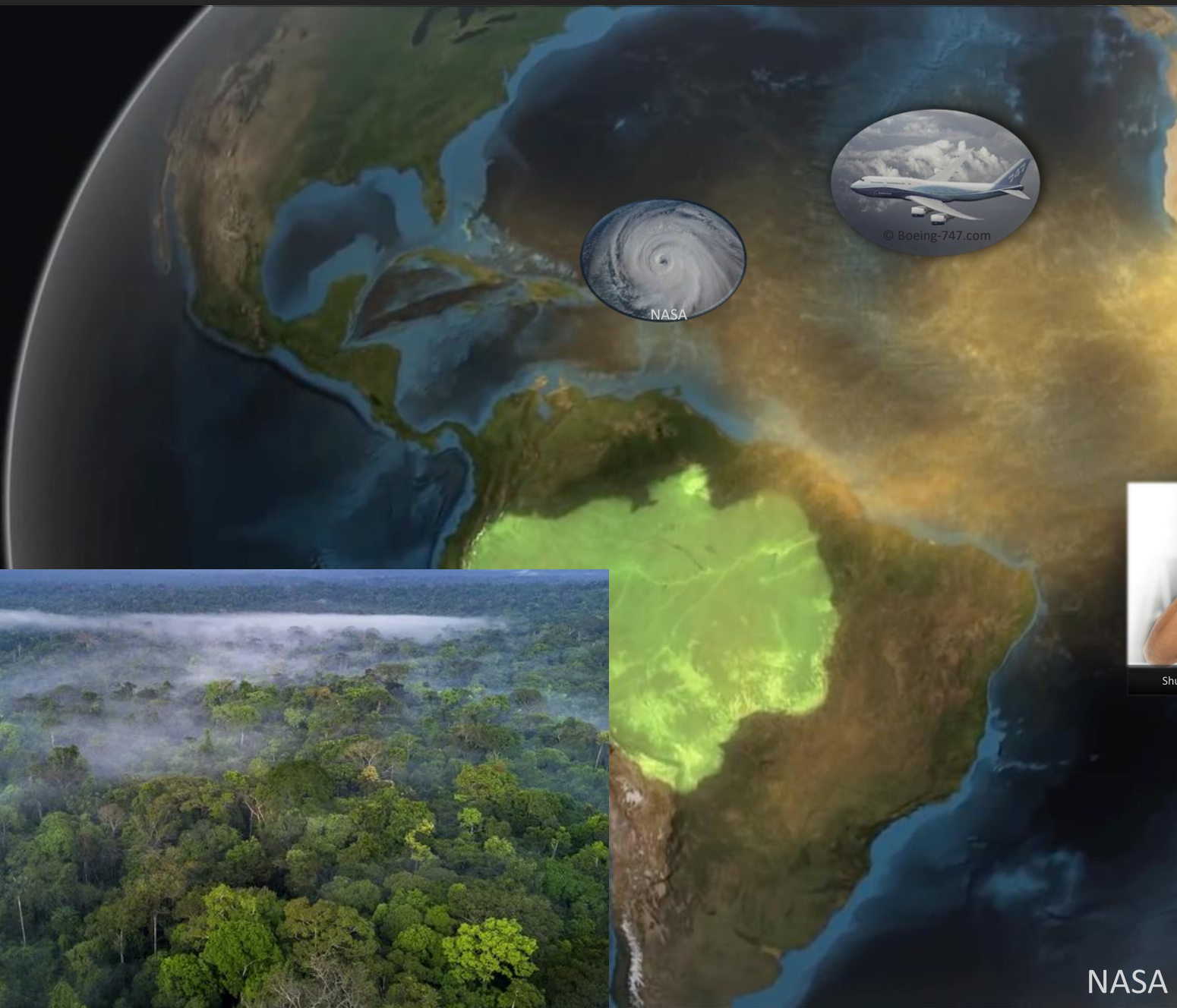


Jerry Ferguson



Shutterstock/Prostock-studio





Jerry Ferguson



Shutterstock/Prostock-studio



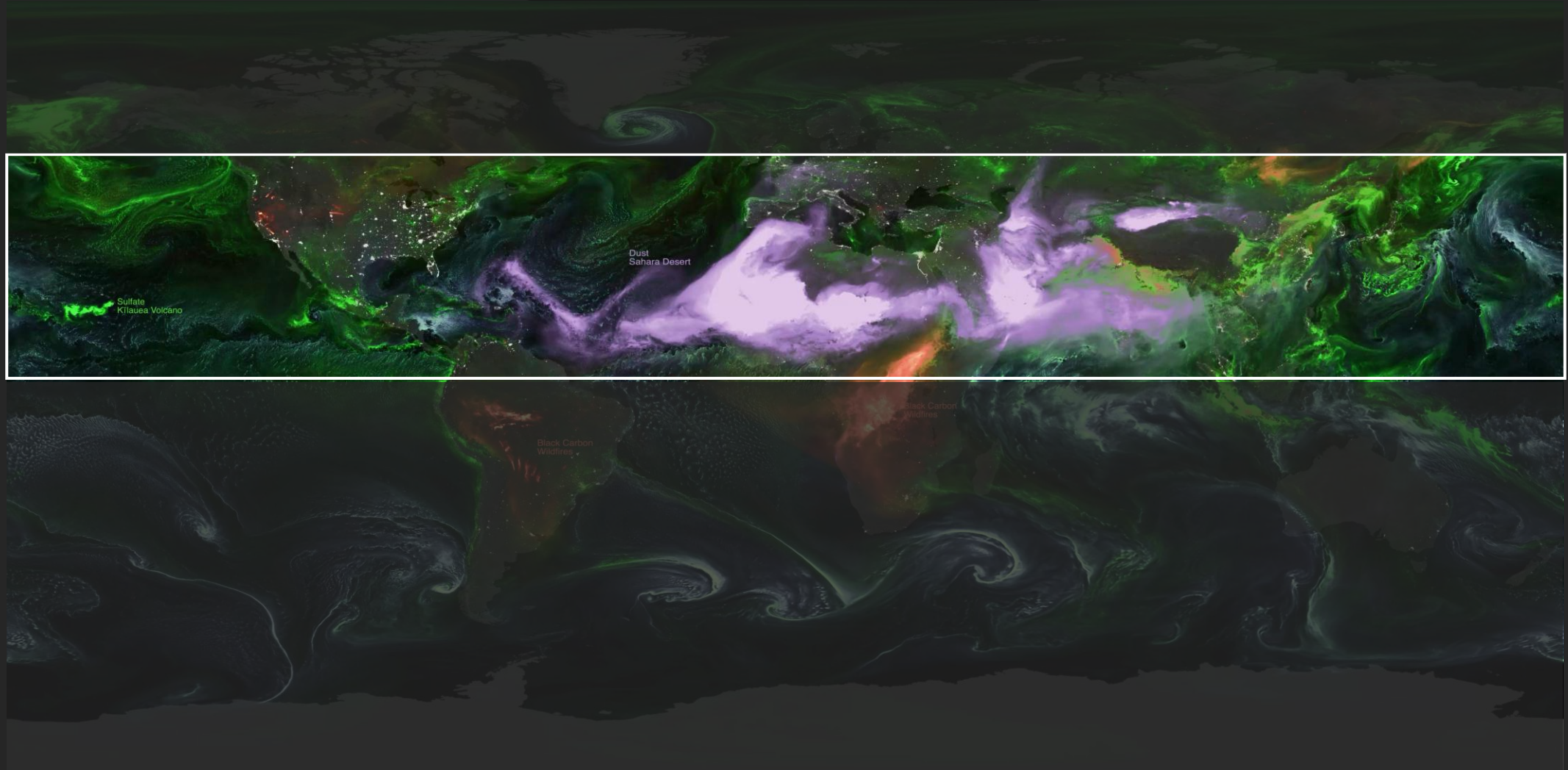
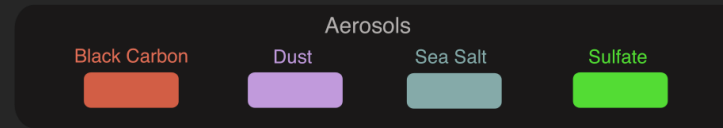
IGNACIO PALACIOS

NASA SCIENTIFIC VISUALISATION STUDIO



NASA SCIENTIFIC VISUALISATION STUDIO

Aerosols (AOD) and the Global Dust Belt

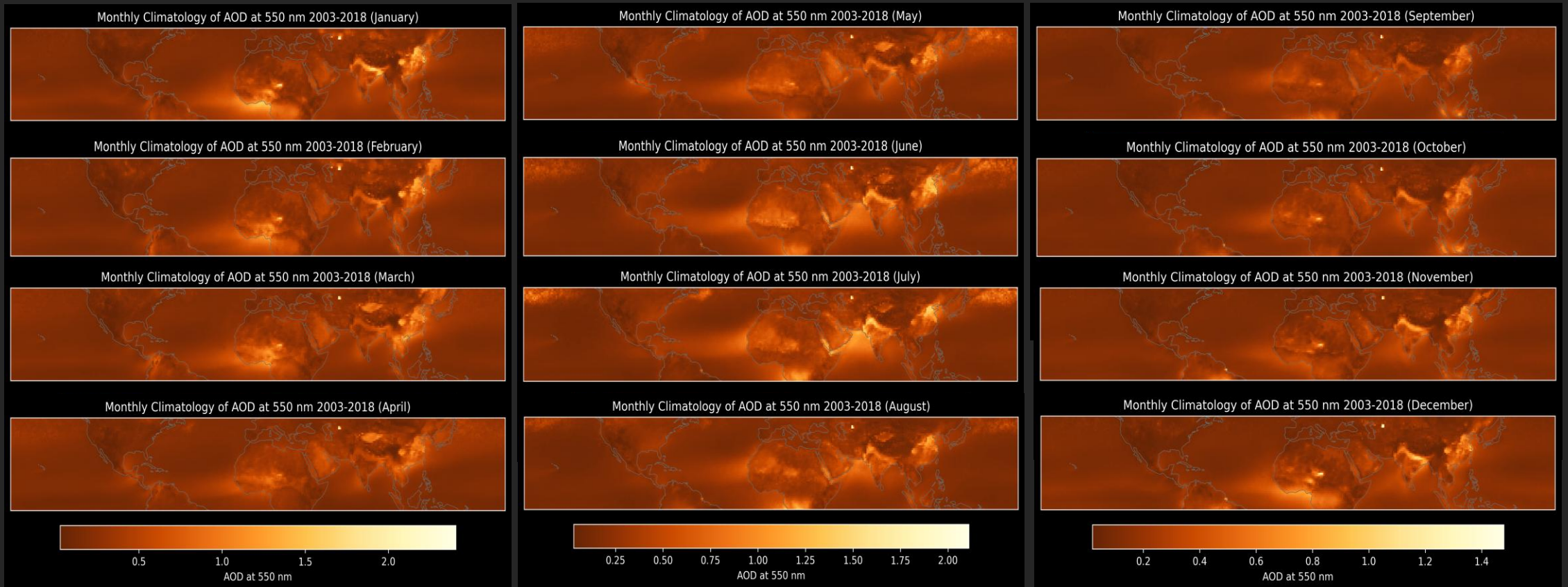


Current monthly AOD forecasts



Current monthly AOD “forecasts”

Monthly climatological means only



3-months ahead AOD model

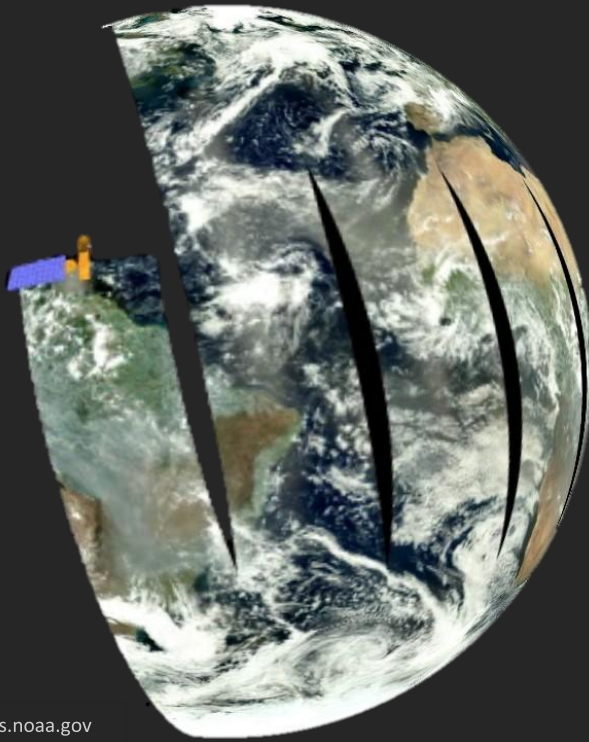
DustTempoNet

Data

Model

Results

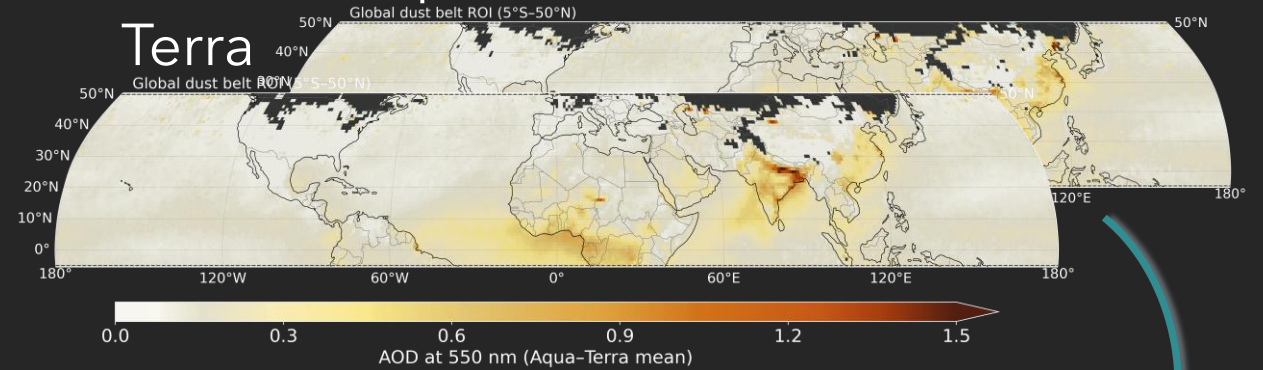
Aerosol Optical Depth Data (AOD) 2003–2025



22 years
276 monthly means

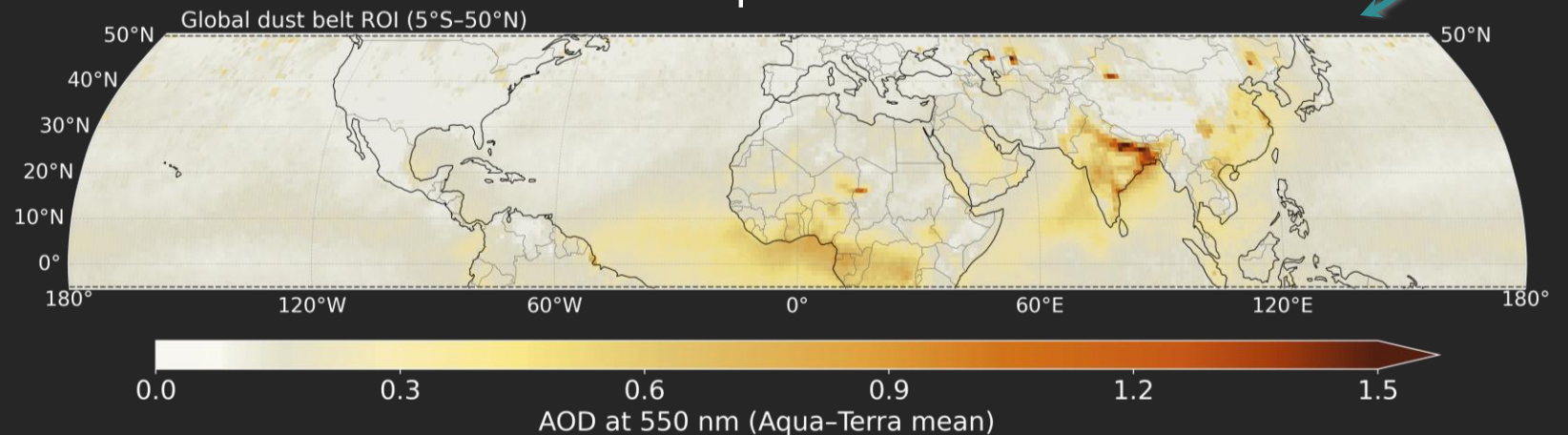
MODIS

Aqua
Terra



Target:

Imputed

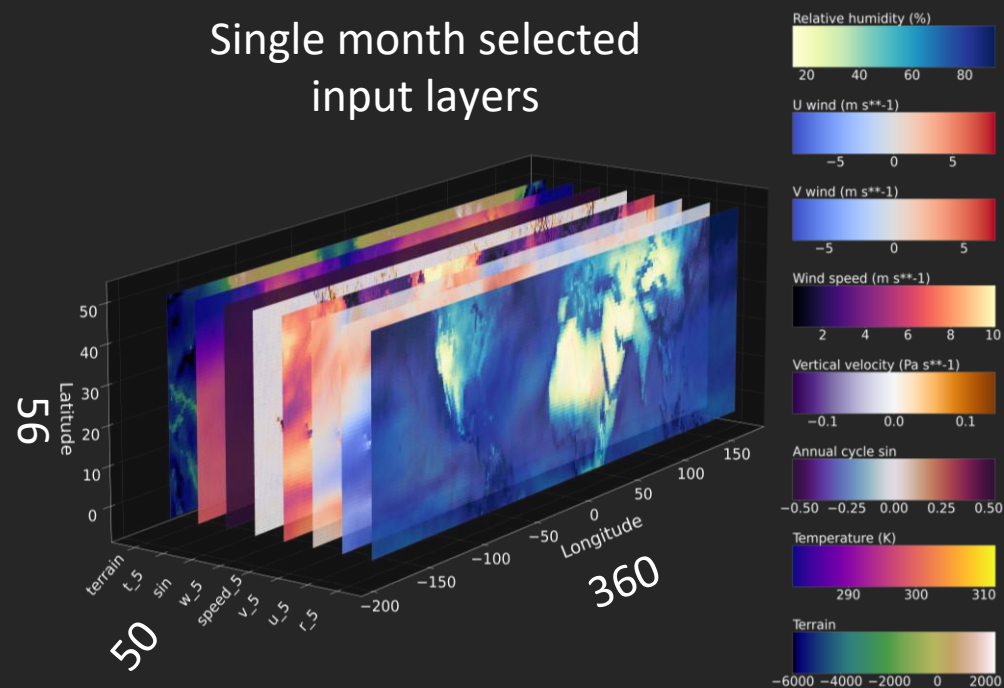
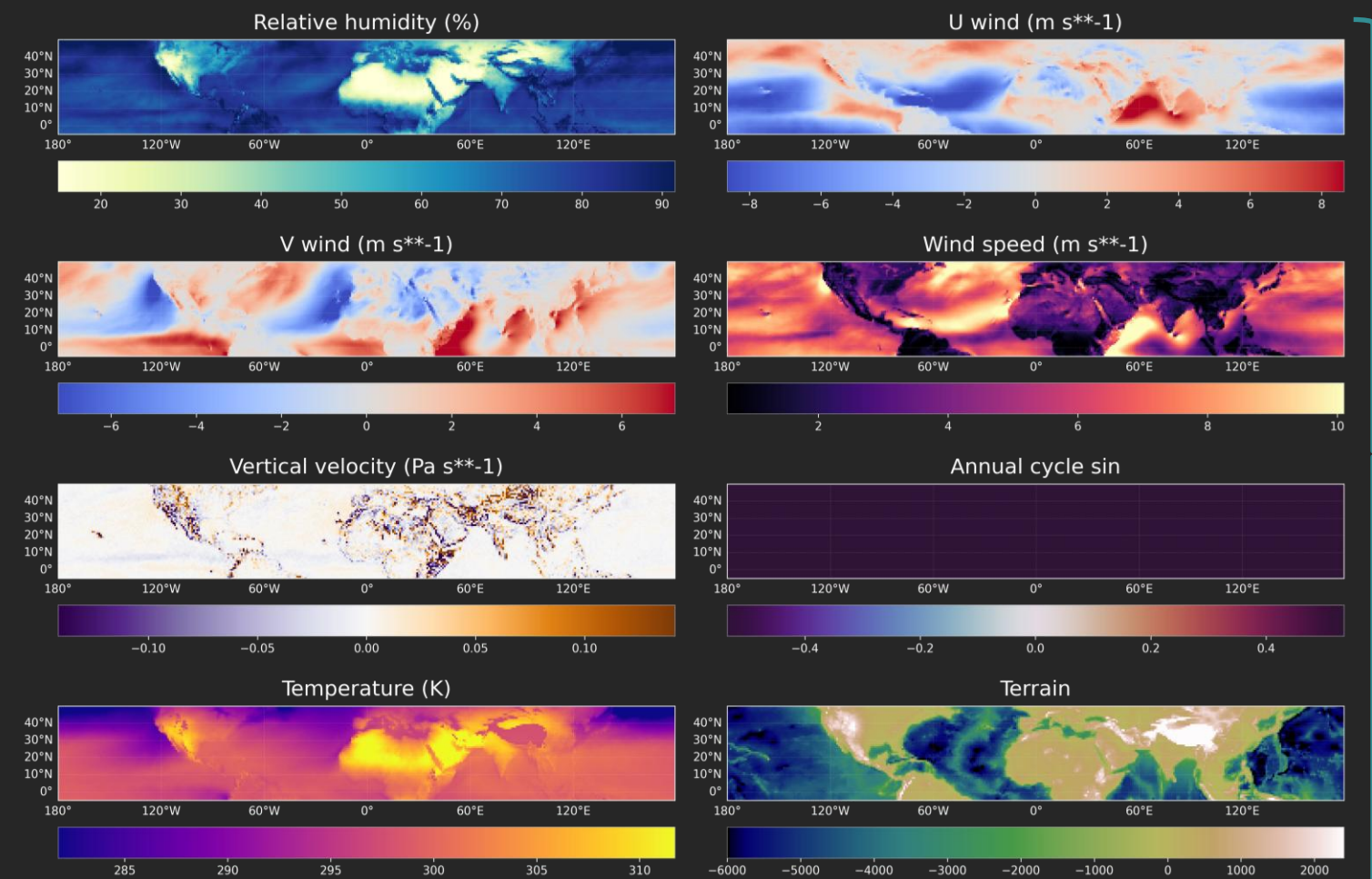


Input features (channels)

ERA5 on 5 pressure levels: 1000hPa to 550hPa

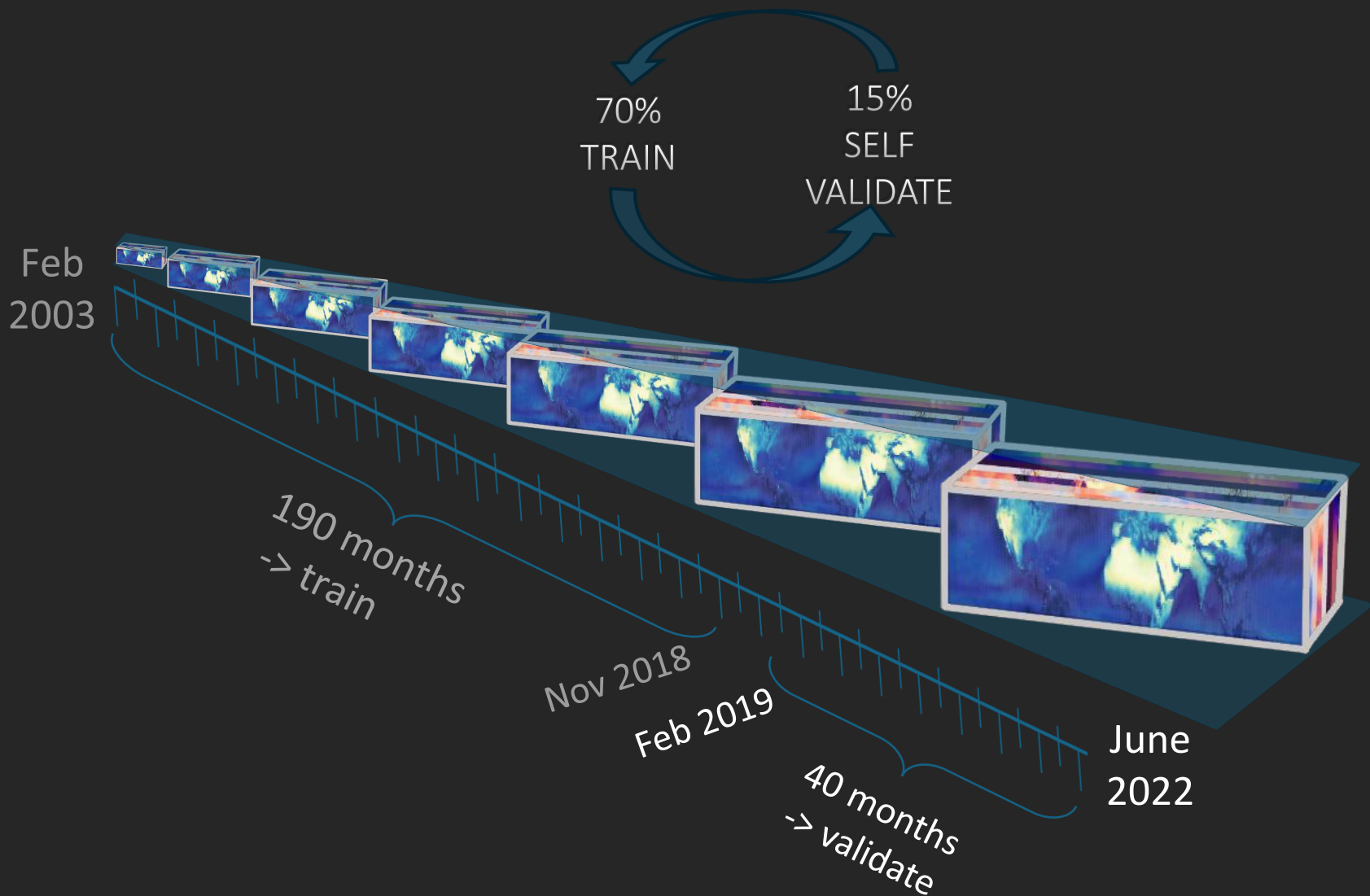
Lagged by 1 month ($t-1$)

Single month selected
input layers



Final array shape:
(276, 56, 360, 50)

TRAIN

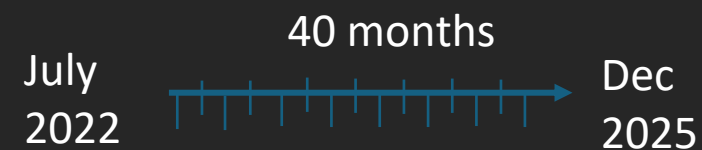
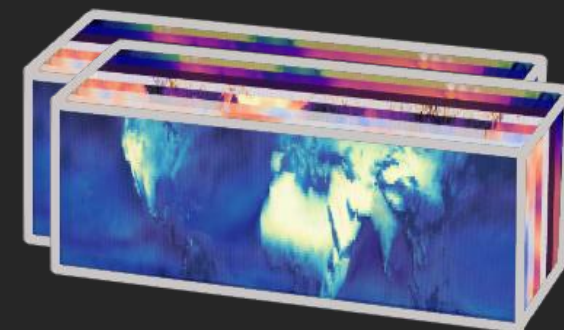


TEST

15%

SET ASIDE

- LEAD 1: July 2022 – Oct 2025
- LEAD 2: Aug 2022 – Nov 2025
- LEAD 3: Sept 2022 – Dec 2025





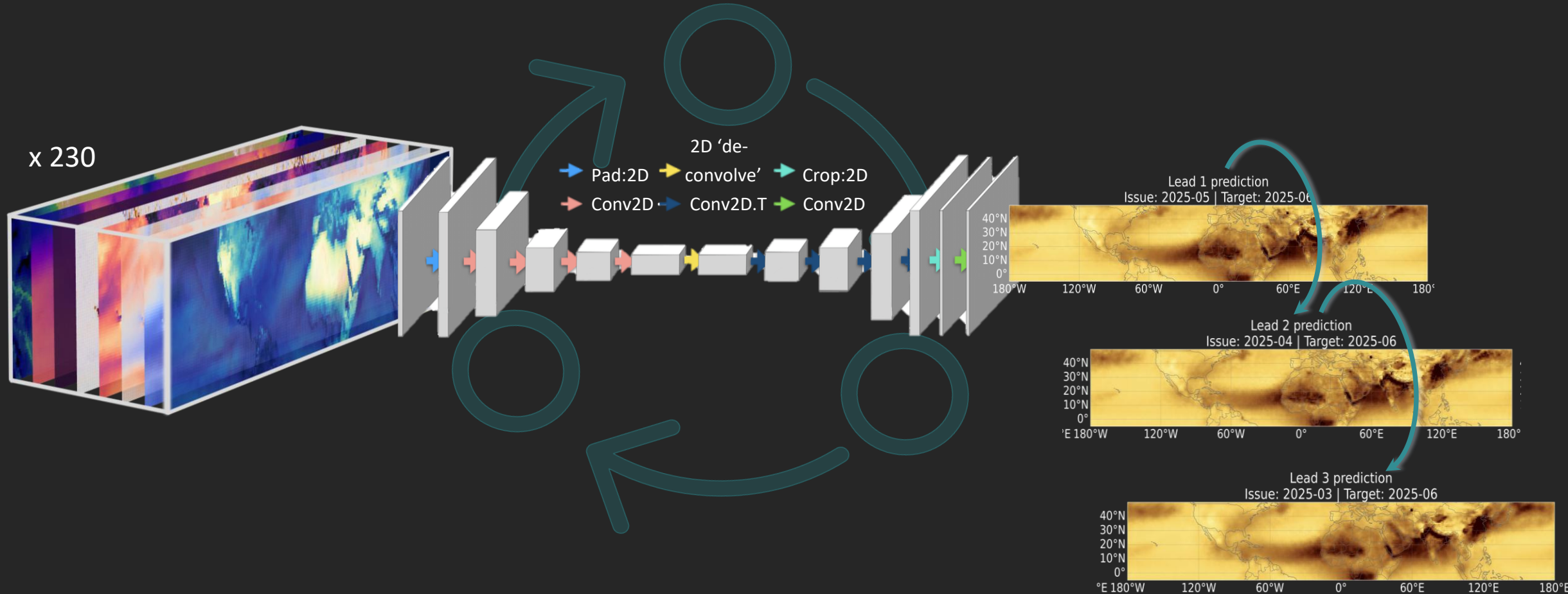
DustNet (v1)

DustTempoNet Model

No GPU's

Trains < 48 min

Predicts < 1s



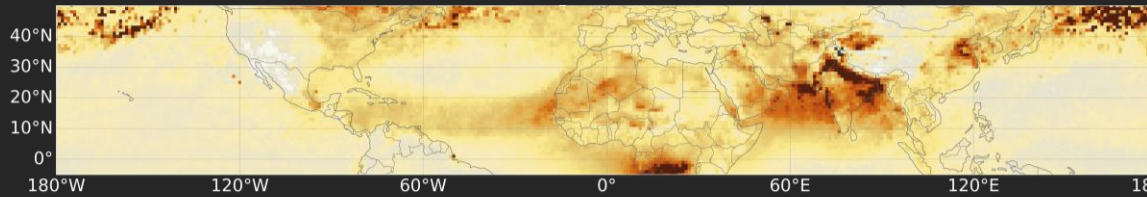
Results

Test set: 38 months

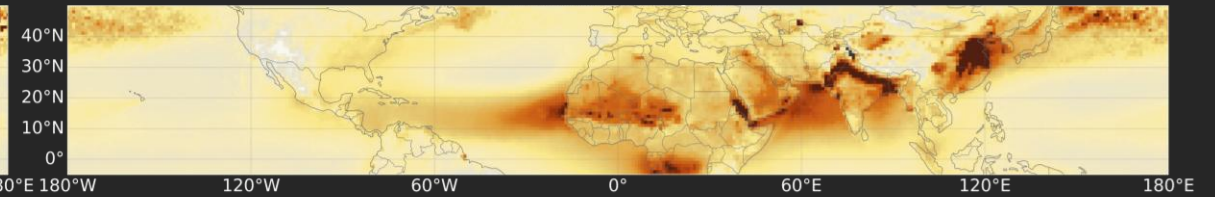
Sept 2022 – November 2025

Example target month results: June 2025

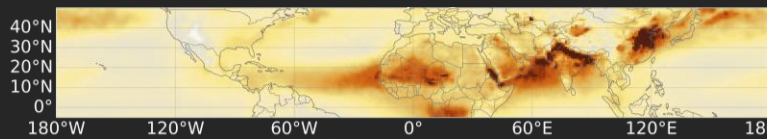
Satellite (MODIS)



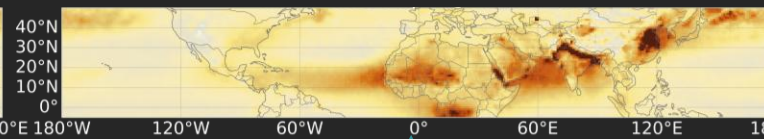
Climatology



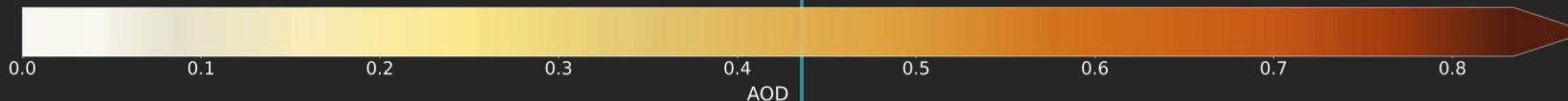
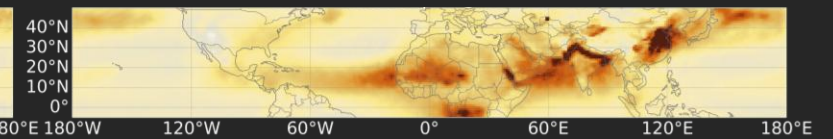
1 month ahead



2 months ahead



3 months ahead



Issue:
May 2025

Issue:
April 2025

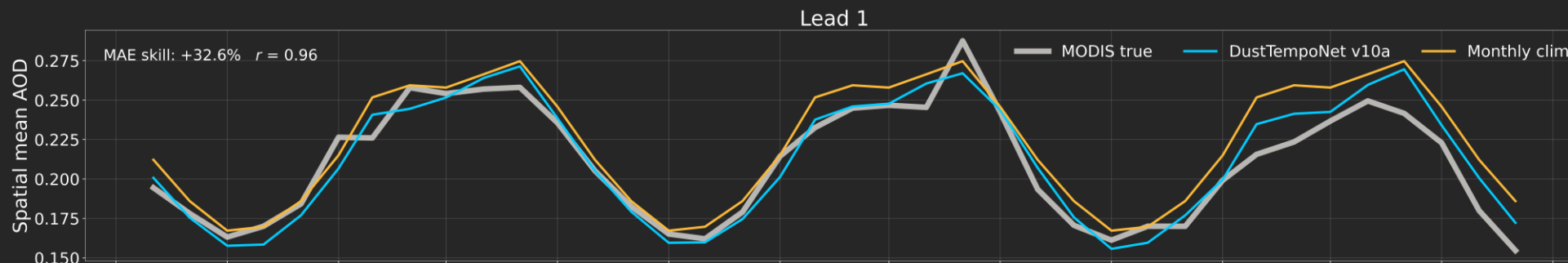
Issue:
March 2025

Temporal MAE comparison: DustTempoNet • MODIS • Climatology

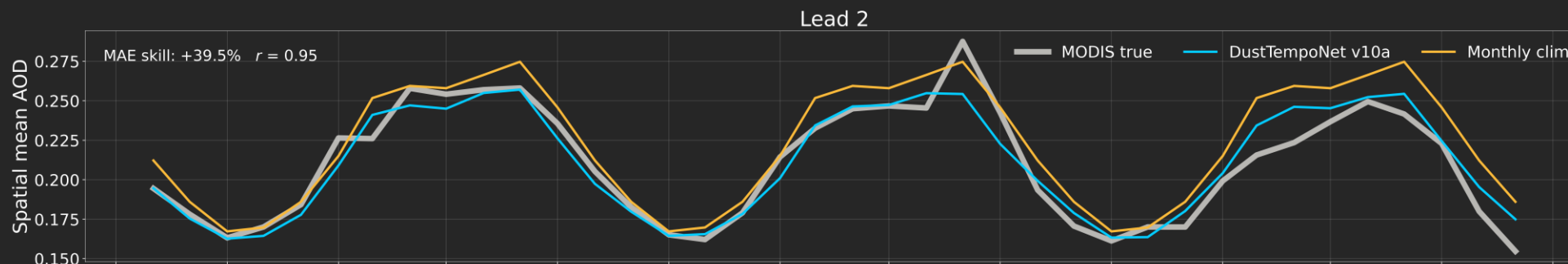
DustTempoNet monthly AOD predictions vs MODIS and monthly climatology

MAE skill:

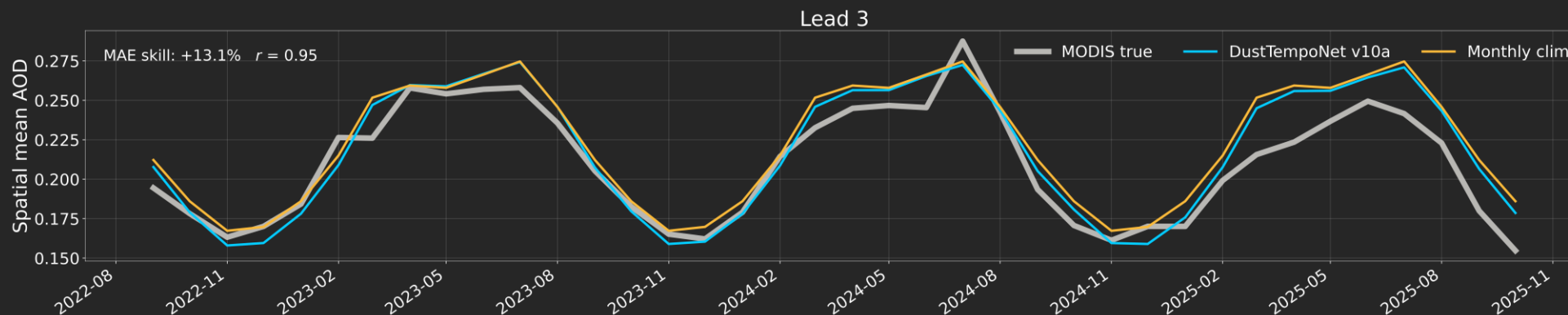
+ 32.6%



+ 39.5%

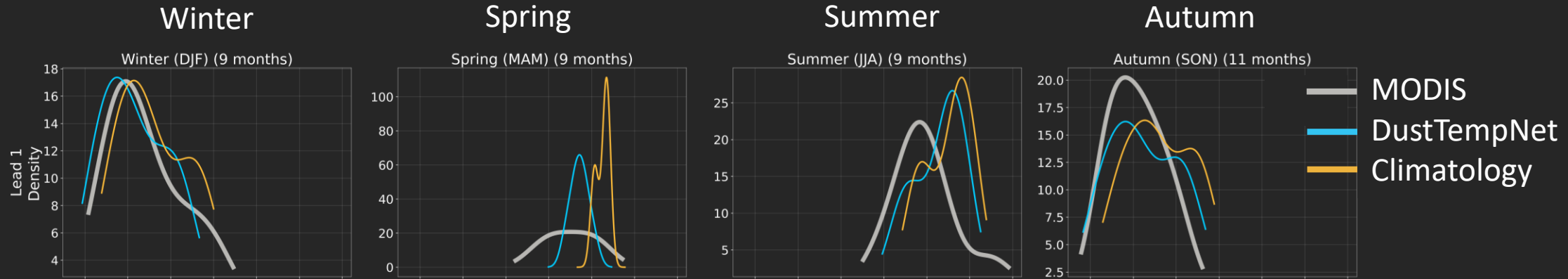


+ 13.1%

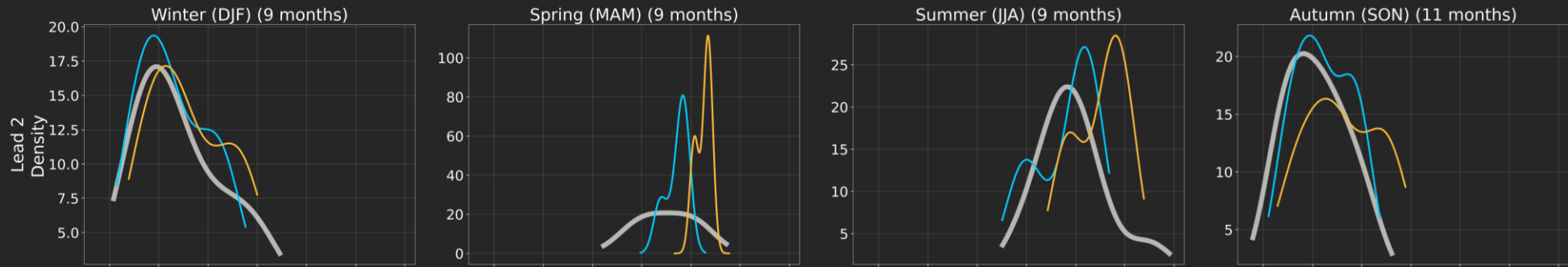


Seasonal density curves per lead head

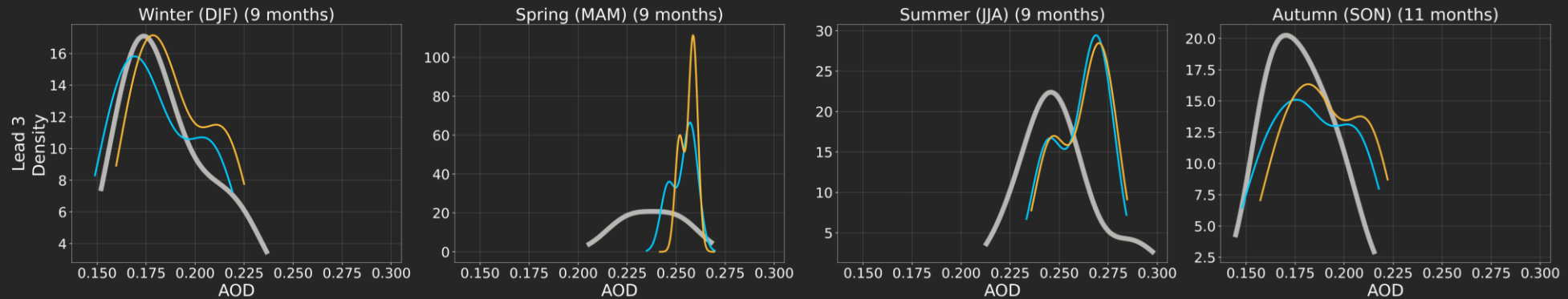
1 mth ahead



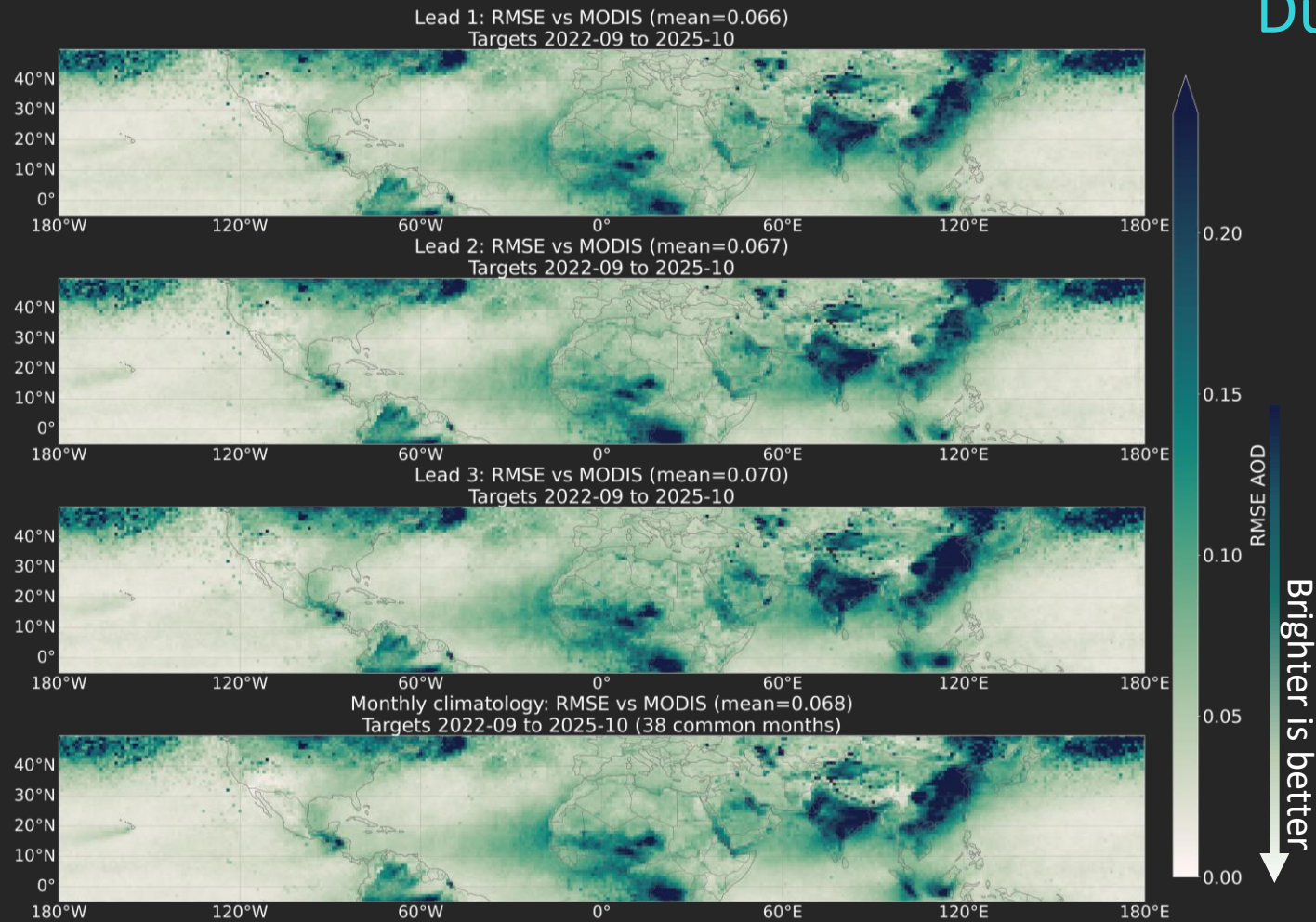
2 mths ahead



3 mths ahead



RMSE vs monthly MODIS fields ($\text{RMSE} \leq 0.07$)



DustTempoNet:

1-month ahead mean = 0.066

2-months ahead mean = 0.067

3-months ahead mean = 0.070

Climatology mean = 0.068

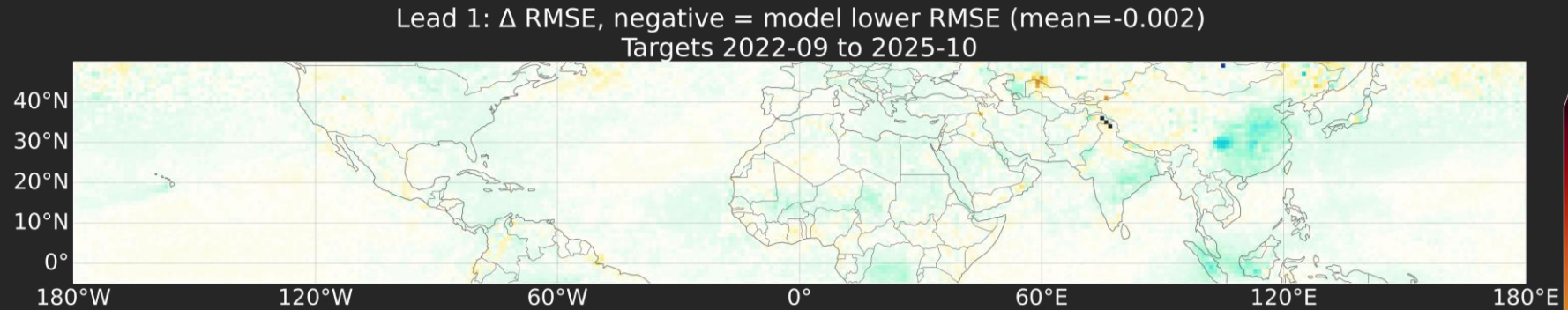
AOD: < 0.1 = clear sky

> 0.5 = dimmed sun

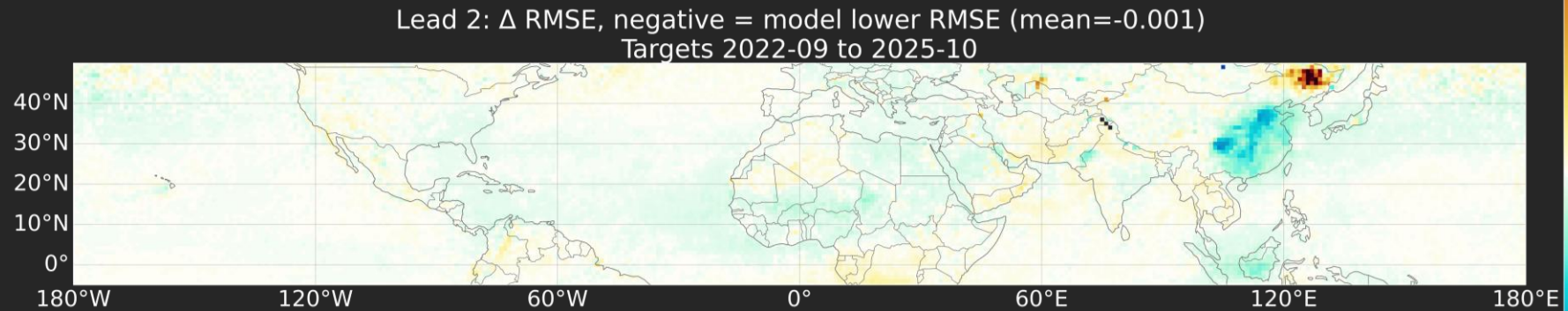
> 1.0 = severe haze/obscured sun

DustTempoNet and Climatology Δ errors vs MODIS

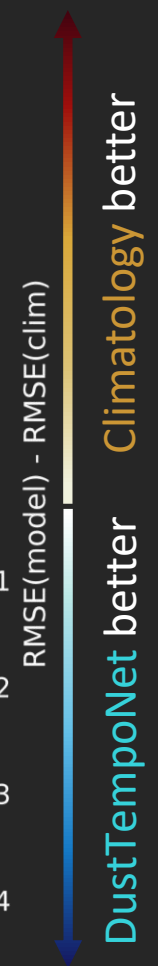
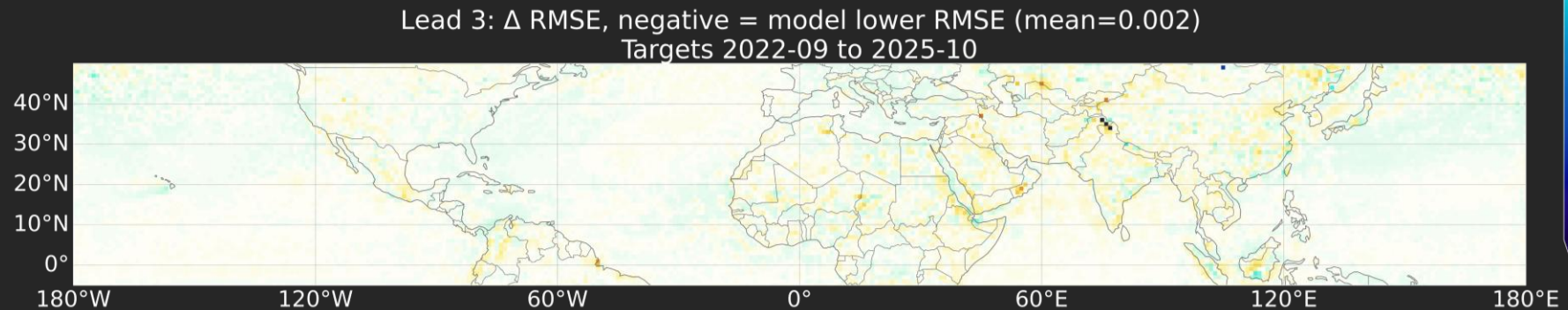
1-month ahead



2-months ahead

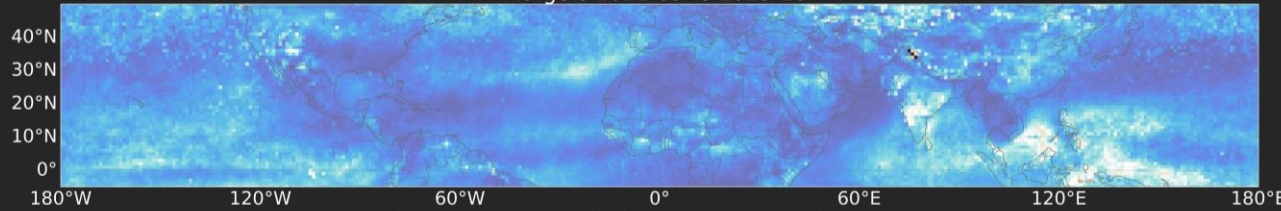


3-months ahead

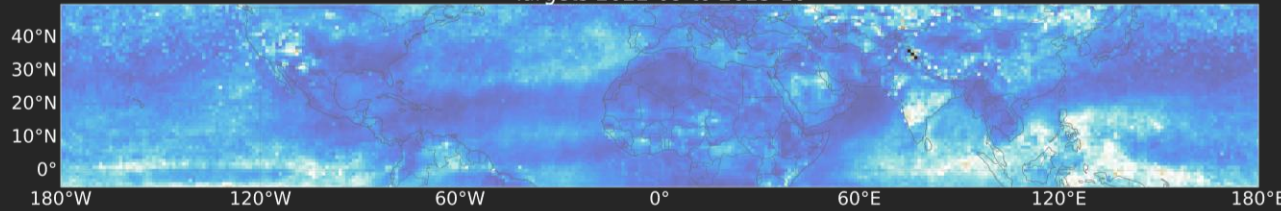


Pearsons $r \geq 0.64$

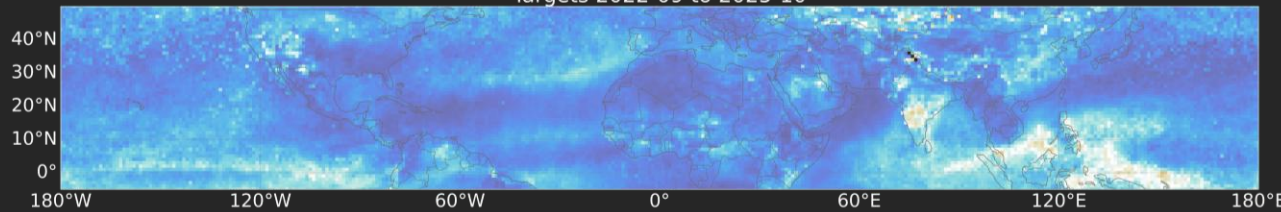
Lead 1: Pearson r, prediction vs raw MODIS (mean=0.656)
Targets 2022-09 to 2025-10



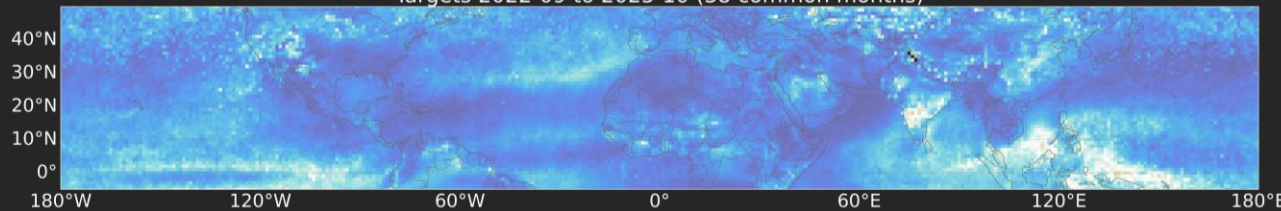
Lead 2: Pearson r, prediction vs raw MODIS (mean=0.641)
Targets 2022-09 to 2025-10



Lead 3: Pearson r, prediction vs raw MODIS (mean=0.645)
Targets 2022-09 to 2025-10



Pre-test monthly climatology: Pearson r vs raw MODIS (mean=0.658)
Targets 2022-09 to 2025-10 (38 common months)



DustTempoNet:

1-month ahead mean = 0.656

2-months ahead mean = 0.641

3-months ahead mean = 0.645

Climatology mean = 0.658

Darker blue is better
Pearson r

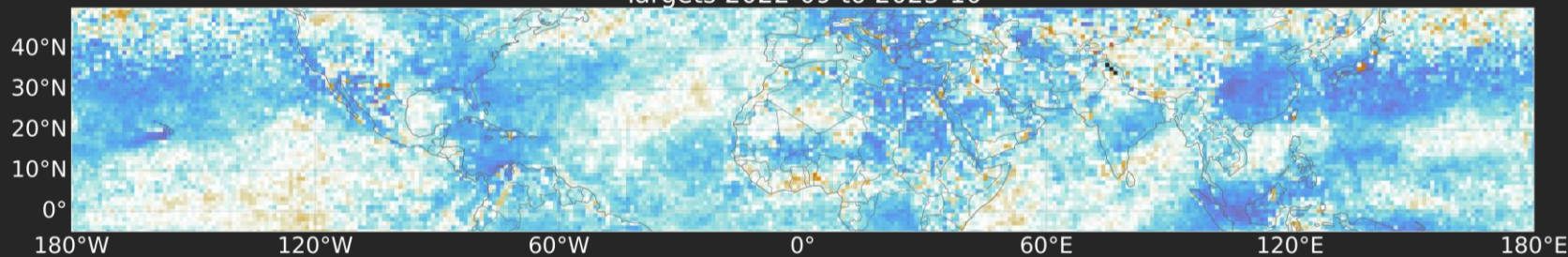


ANY QUESTIONS
WELCOME

Anomaly correlation coefficient

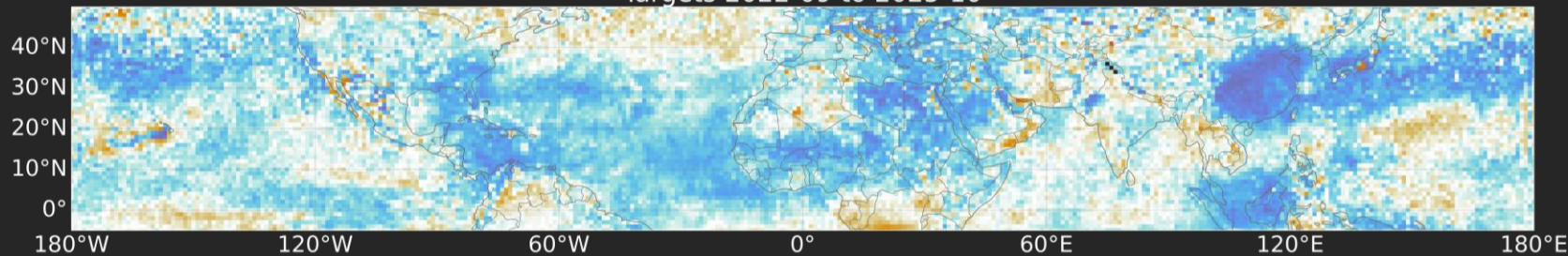
Lead 1: ACC, prediction anomaly vs MODIS anomaly (mean=0.276)

Targets 2022-09 to 2025-10



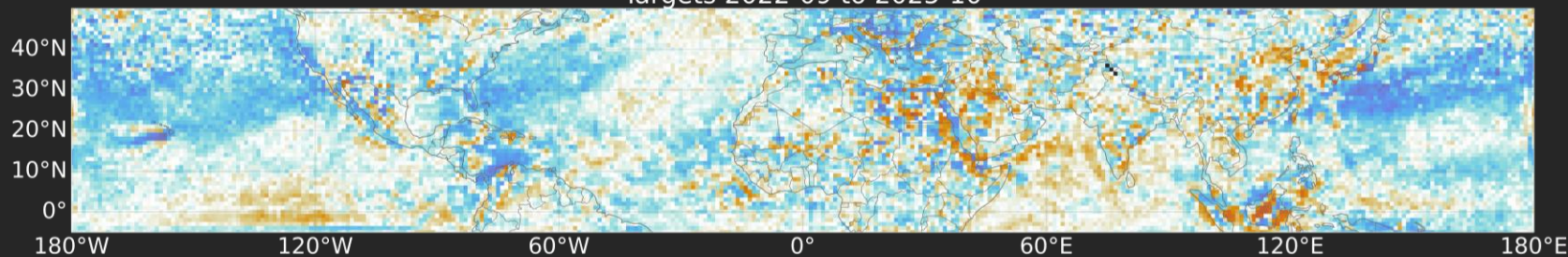
Lead 2: ACC, prediction anomaly vs MODIS anomaly (mean=0.219)

Targets 2022-09 to 2025-10

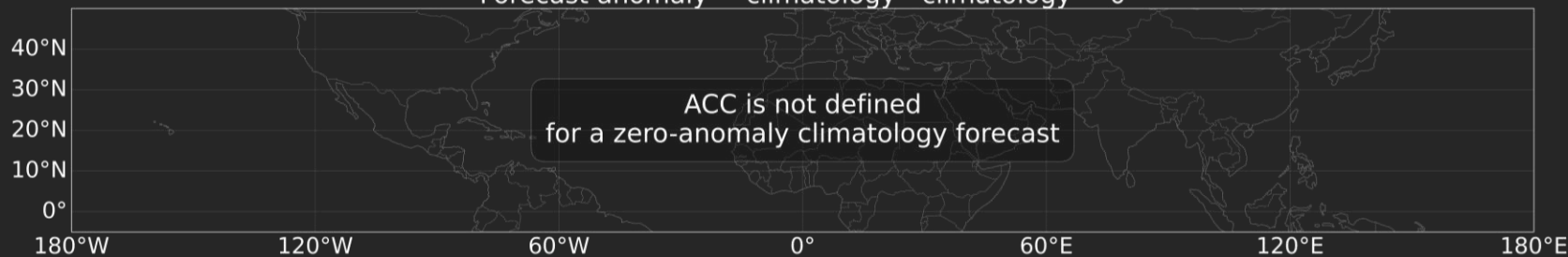


Lead 3: ACC, prediction anomaly vs MODIS anomaly (mean=0.128)

Targets 2022-09 to 2025-10



Monthly climatology: ACC undefined
Forecast anomaly = climatology - climatology = 0

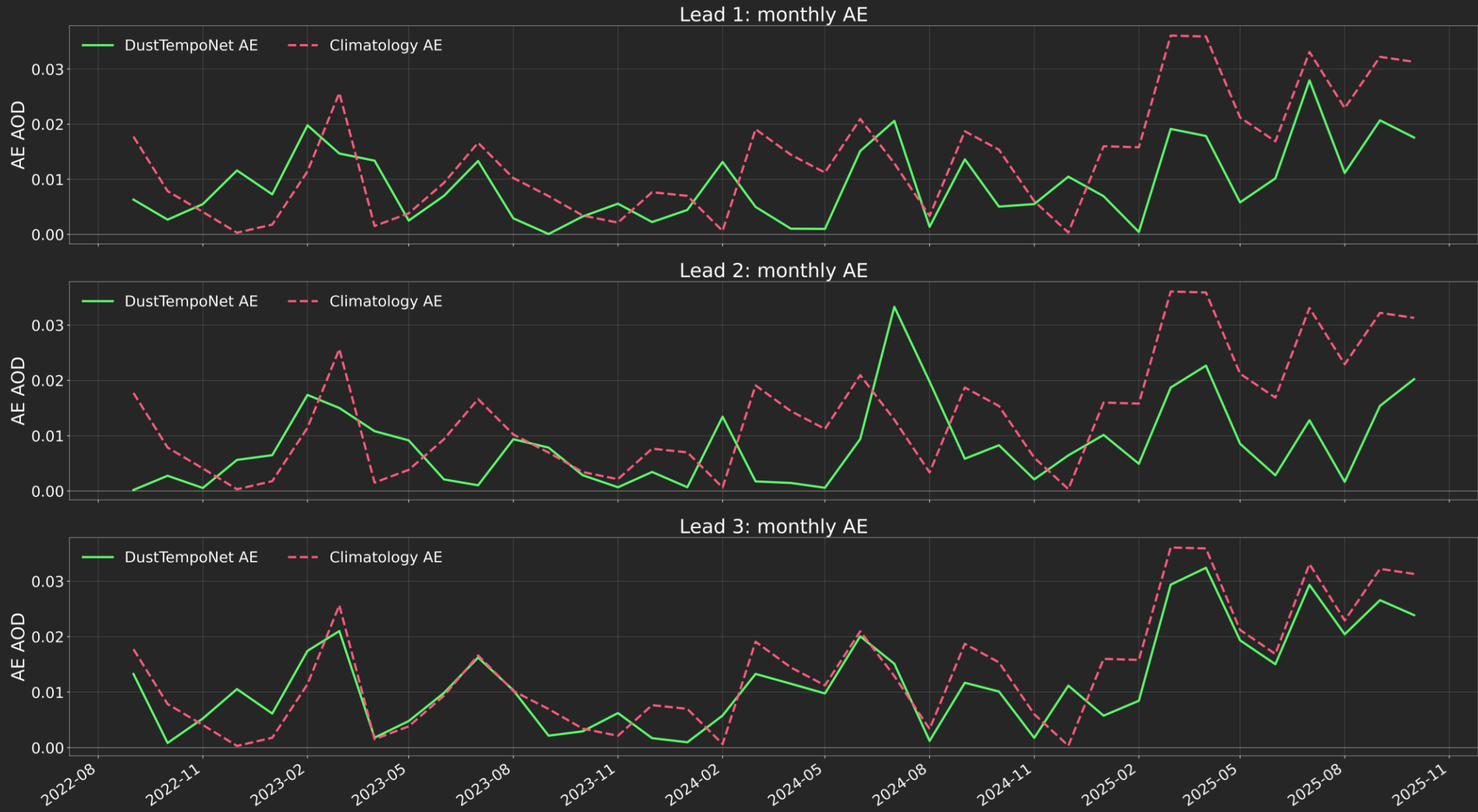


Informative forecast

ACC

Misleading

Temporal Absolute Error



Example: picked month skill June 2025

Lead 1: 2025-06 absolute-error skill, positive = model lower error (mean=0.002)

Targets 2022-09 to 2025-10

