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# Interpretation of Probabilistic Surface Ozone Forecasts: A Case Study for Philadelphia

10<sup>th</sup> International Workshop on Air Quality Forecasting Research  
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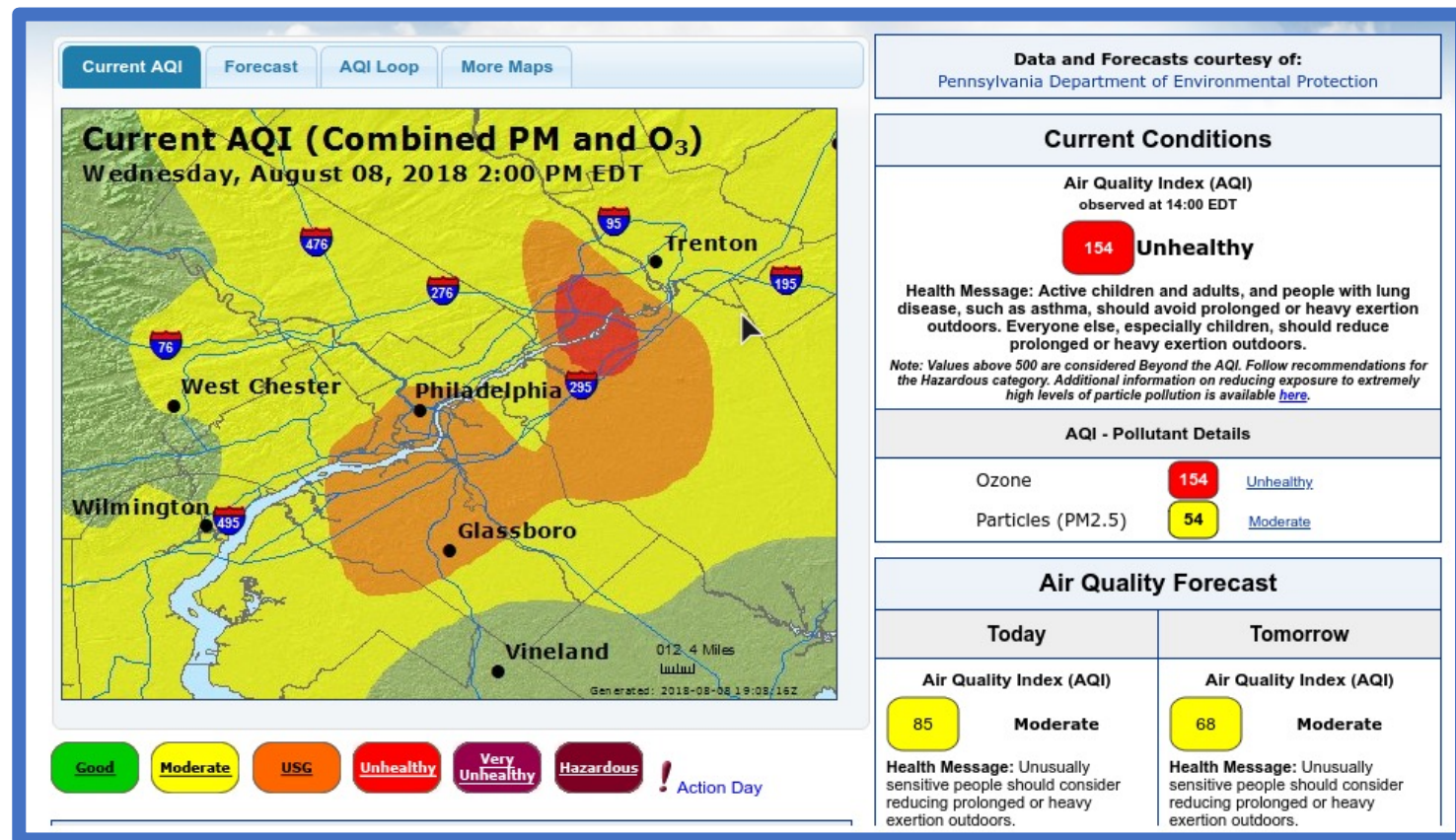
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# Operational Forecasts

- Daily operational forecast is issued in the US (by AirNow system) to warn the public of potential unhealthy air
- Forecasters who issue these forecasts use a variety of prediction tools
- These tools include NOAA National Air Quality Forecasting Capability (NAQFC) modeling system
- Recently there has been movement toward probabilistic prediction of ozone (e.g. Pinder et al., 2009)



# Probabilistic prediction

Probabilistic forecasts are vague!

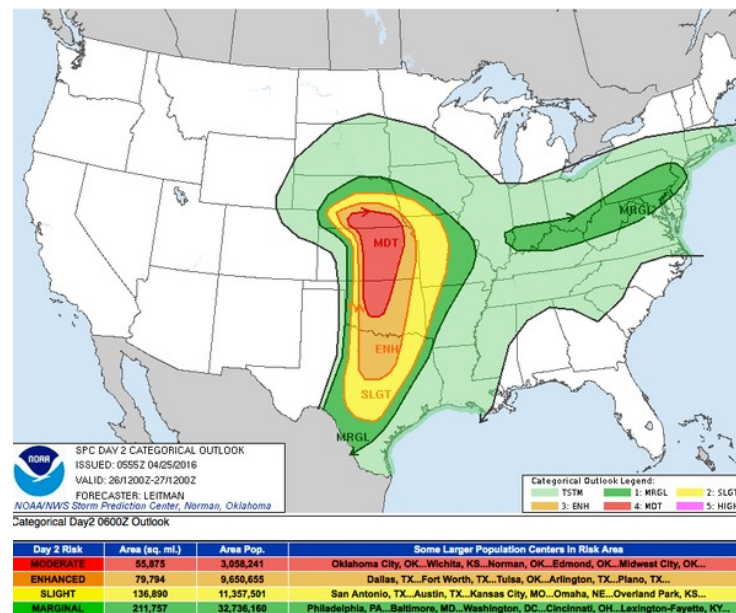
- Is it going to rain?
- Will there be a tornado?
- Will there be an exceedance?
- Decision makers want “yes” or “no” answer

State College, PA

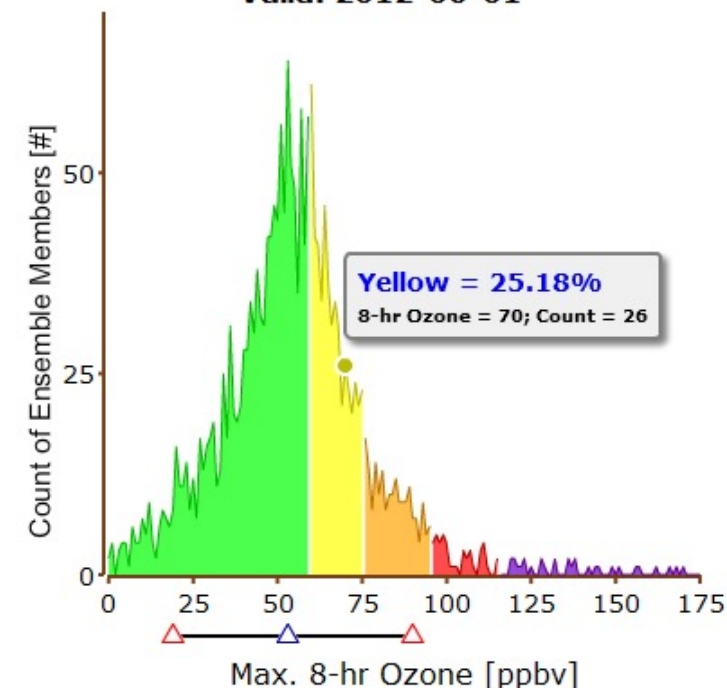
Fri

Thunderstorm

28 °F | °C

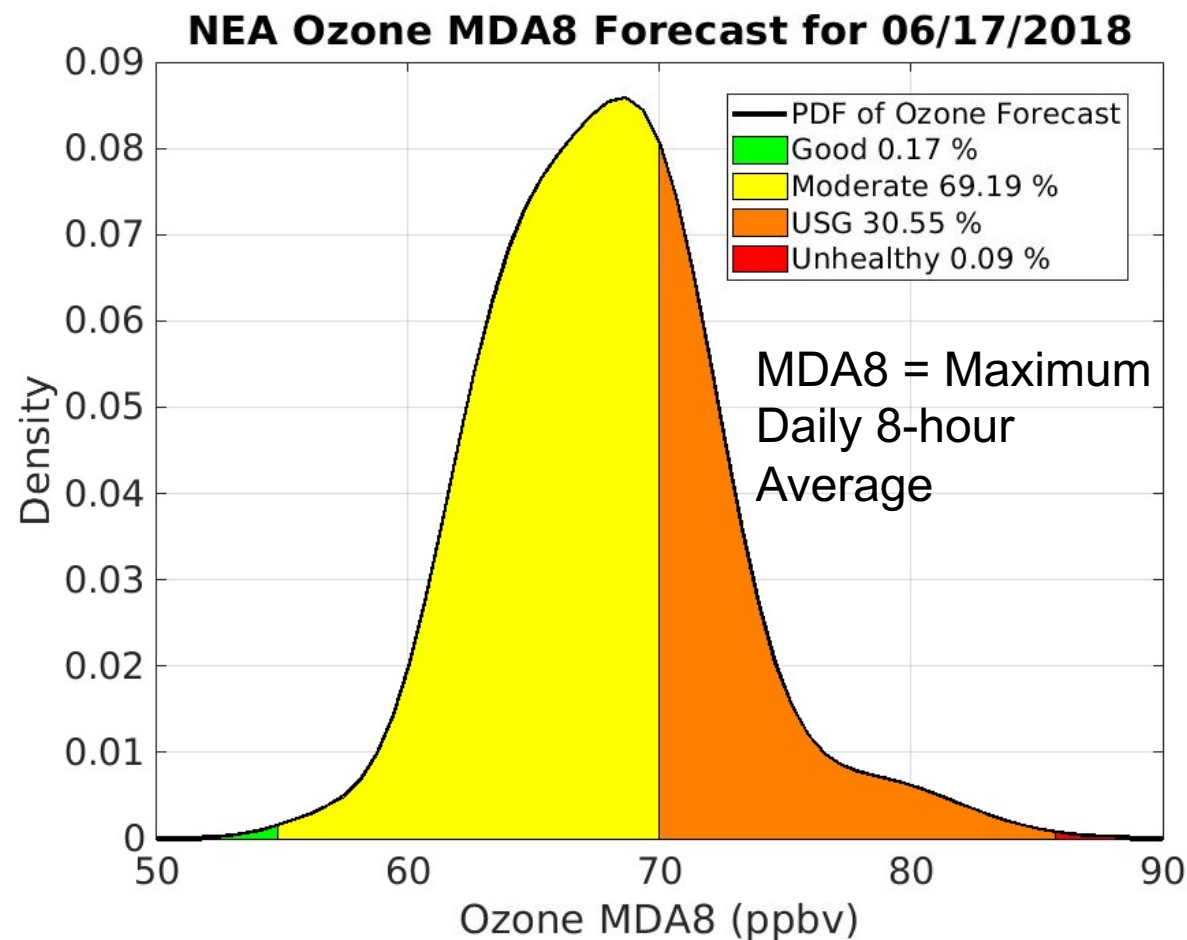


Valid: 2012-06-01



## Exceedance (yes) or no exceedance (no)?

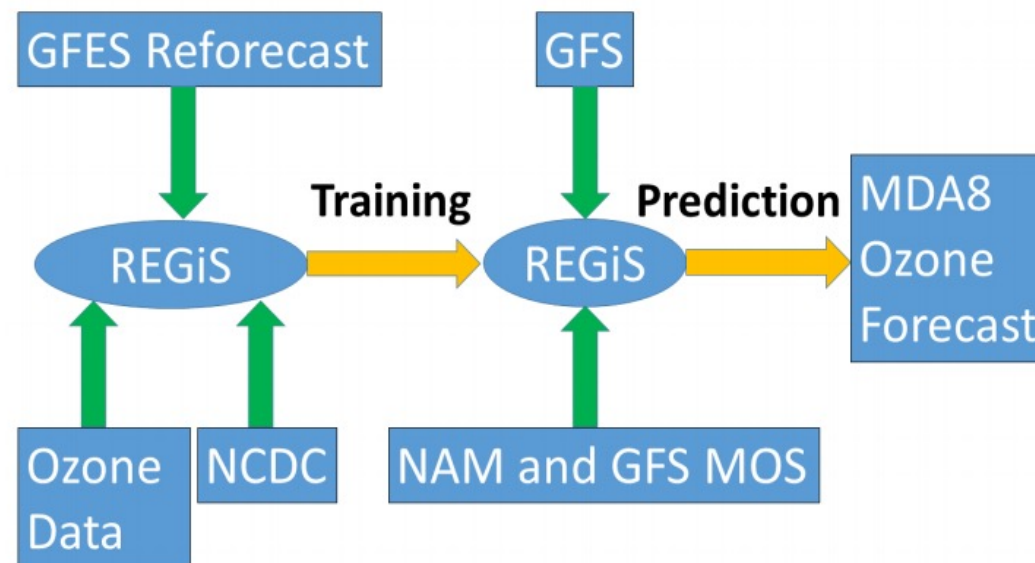
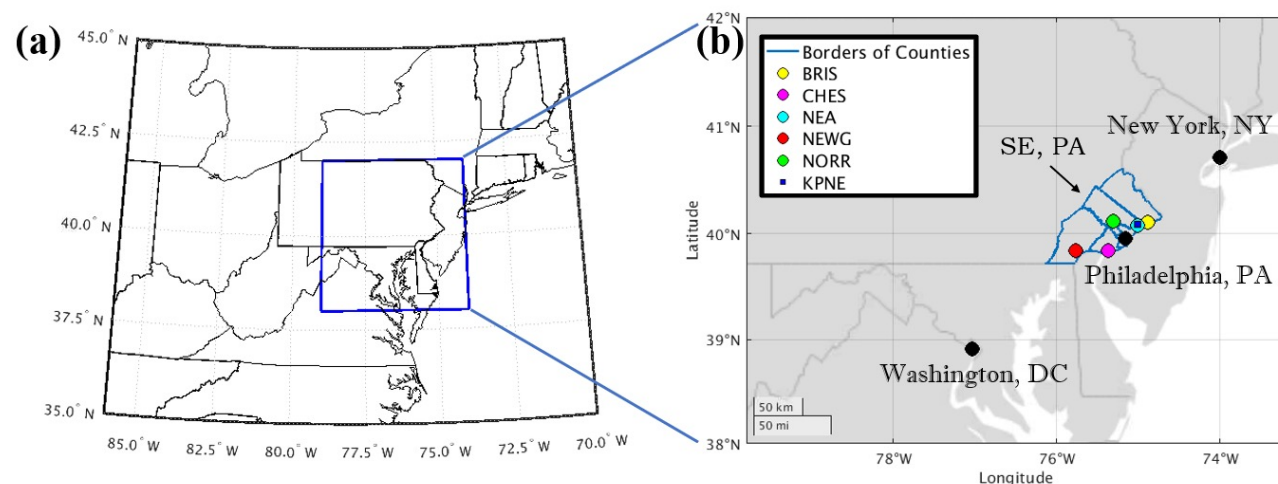
- Probabilistic forecasts contain more information than deterministic ones and decision makers would like to make use of these probabilistic forecasts
- But their interpretation can be challenging
- One approach is to consider ozone exceedance: current EPA ozone standard is 70 ppbv maximum daily 8-hour average (MDA8)
- For instance, should we forecast exceedance or not in the example forecast shown on the right?
- The question is not trivial and depends on the model, location, and stake holders' objectives
- Here we will perform a case study to examine this problem in more detail





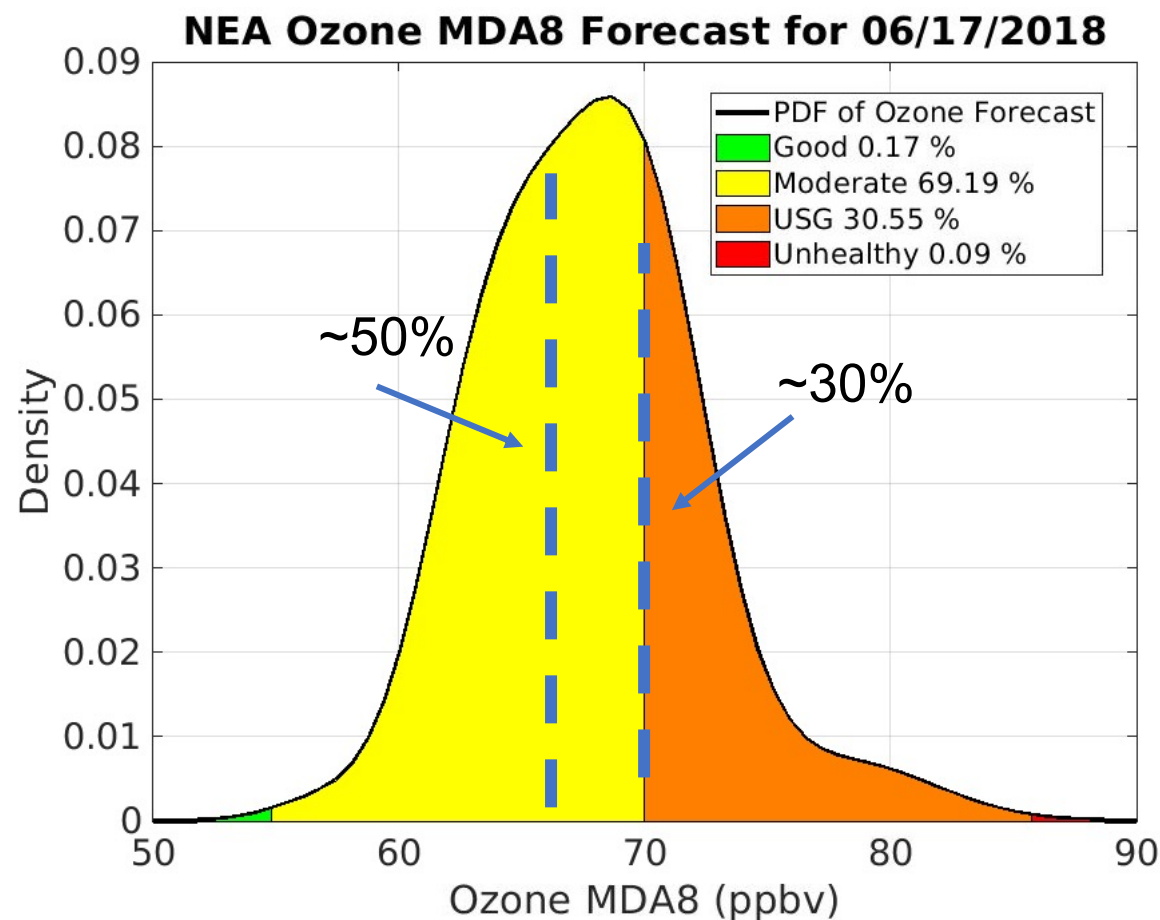
## Case study set-up

- We perform our experiment in Southeastern PA – Philadelphia
- We use experimental statistical probabilistic model REGiS developed by *Balashov et al., 2017*
- The probabilistic forecast is the result of ozone prediction based on a variety of synoptic patterns
- REGiS operational model schematic is shown below the maps
- Training data for REGiS: 2000-2011
- Calibration data: 2012-2014
- Evaluation data: 2015-2018



# Calibration 1

- Now that training is done (2000-2011), we come back to our initial example shown earlier
- We will use calibration data (2012-2014) to decide at what **threshold** we should declare exceedance
- REGiS **exceedance threshold** decides what is “yes” and what is “no” (Is it 50%? Is it 30%?)
- *Wilks 2012* recommends 4 different methods to determine such **exceedance threshold**



## Calibration 2

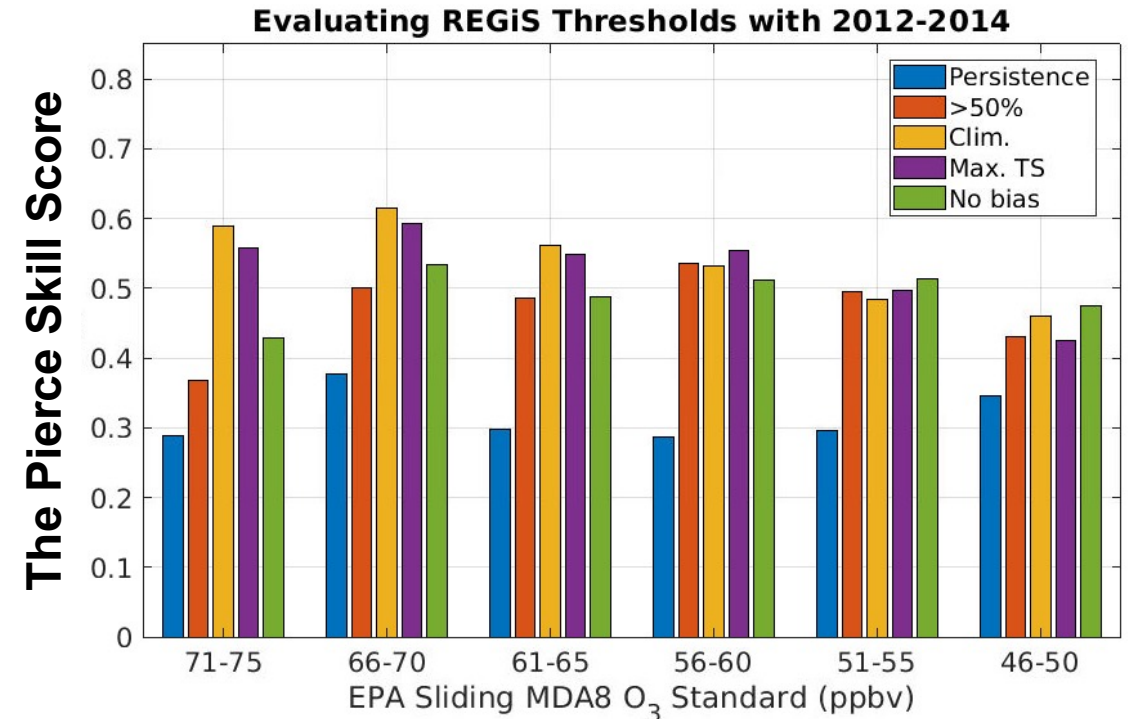
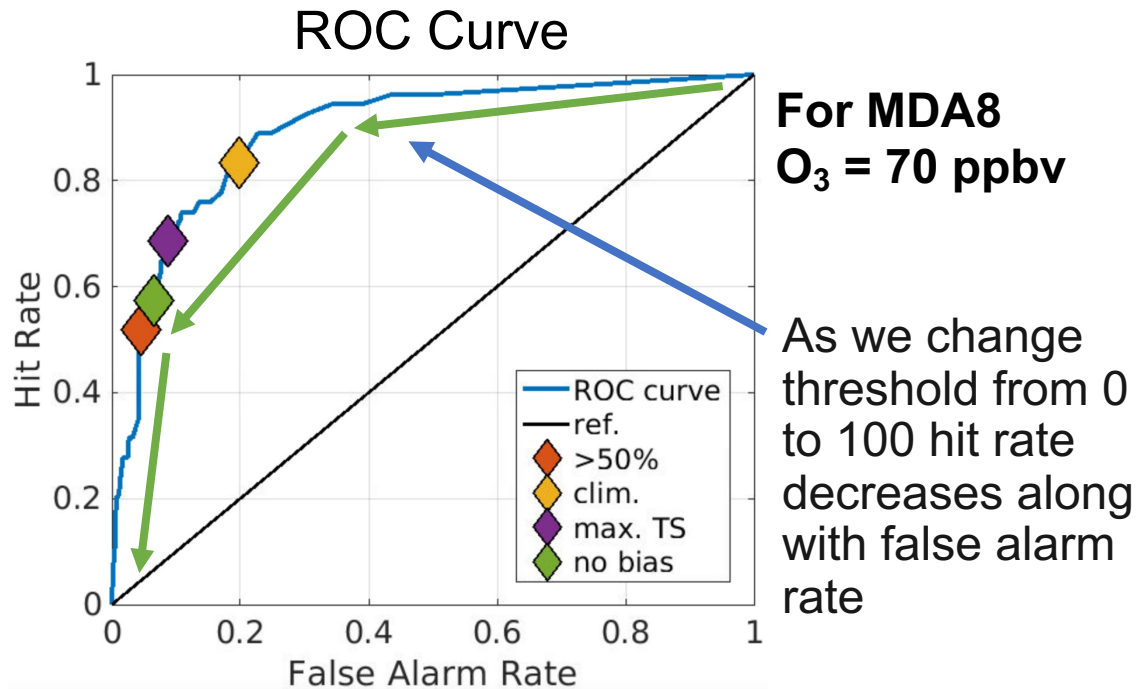
Depending on what **exceedance threshold** we pick we are going to have different combinations of metrics based on the 2 by 2 contingency table shown below:

|       |     | OBSERVATIONS     |                          | Total                        |
|-------|-----|------------------|--------------------------|------------------------------|
|       |     | YES              | NO                       |                              |
| MODEL | YES | a<br>(hit)       | b<br>(false alarm)       | a+b<br>Yes (Model)           |
|       | NO  | c<br>(miss)      | d<br>(correct rejection) | c+d<br>No (Model)            |
| Total |     | a+c<br>Yes (OBS) | b+d<br>No (OBS)          | N=a+b+c+d<br>Total of events |



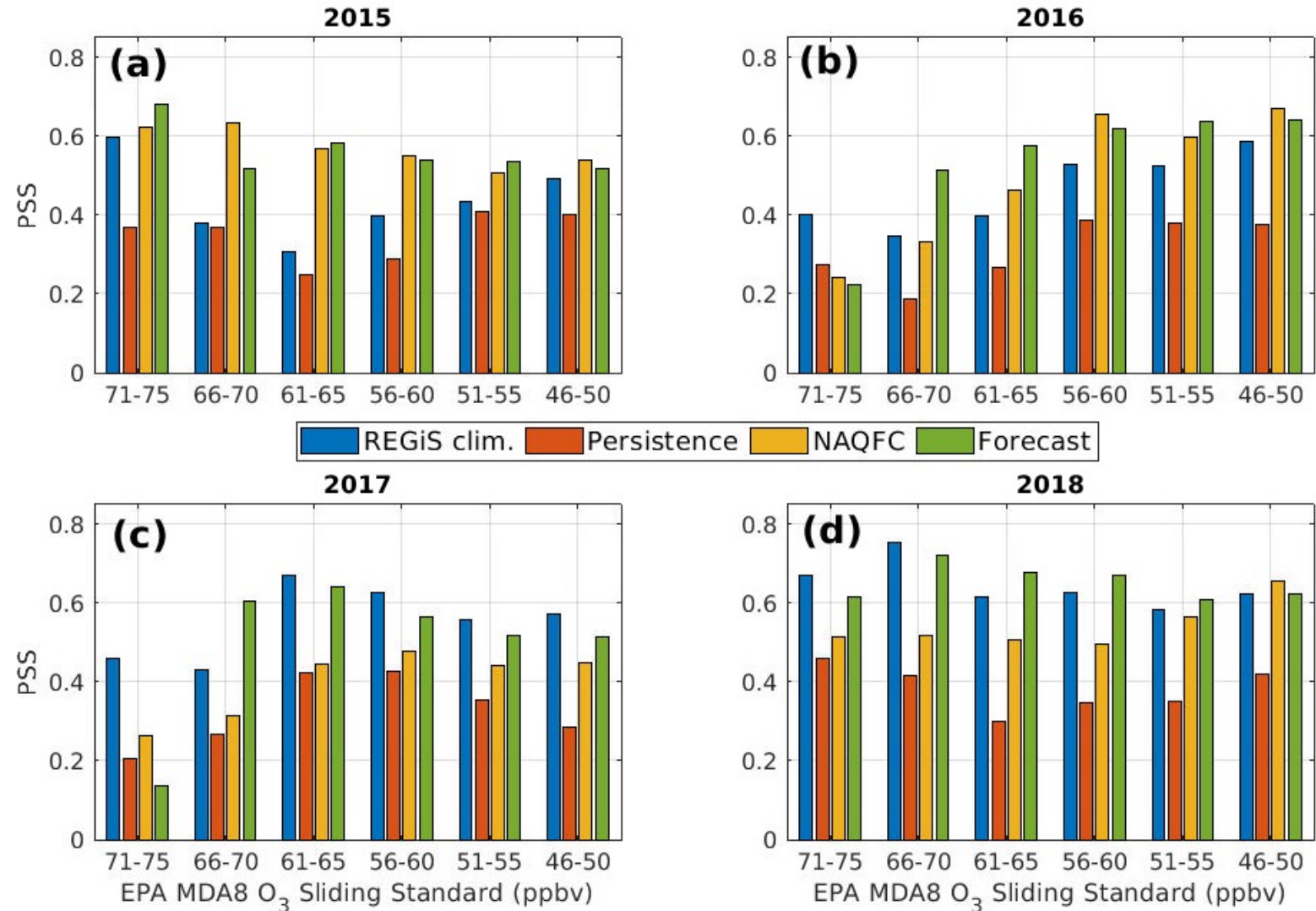
# Determining exceedance threshold

- 1) More likely event (>50%)
- 2) Forecast probability is greater than a given climatology
- 3) Maximize *the threat score* ( $TS$ ) = 
$$\frac{hits}{hits+misses+false\ alarms}$$
- 4) Minimize *the bias ratio* = 
$$\frac{hits+false\ alarm}{hits+misses}$$



# Evaluation (2015-2018)

- We evaluating calibrated REGiS against persistence, NAQFC (NOAA ozone model), and operational forecast
- Operational forecasters tend to outperform other predictions
- REGiS calibrated by climatology and NAQFC are comparable, and even occasionally REGiS outperforms NAQFC
- As expected, persistence shows lowest skill



# Summary

- Reducing probabilistic forecast to "yes" and "no" is an important and relevant problem
- In this work we test probabilistic statistical ozone model called REGiS at Philadelphia
- We find that calibrating REGiS exceedance threshold using climatology produces the most skillful forecast based on the PSS
- It is possible that for other probabilistic models different thresholds need to be used, but the process of calibration nonetheless is recommended



# Thank you!

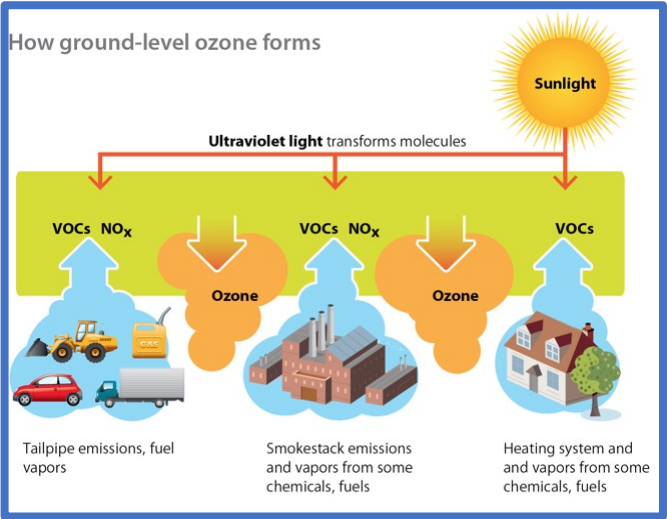


# Extra Slides





# National Ambient Air Quality Standard (NAAQS) for Ozone



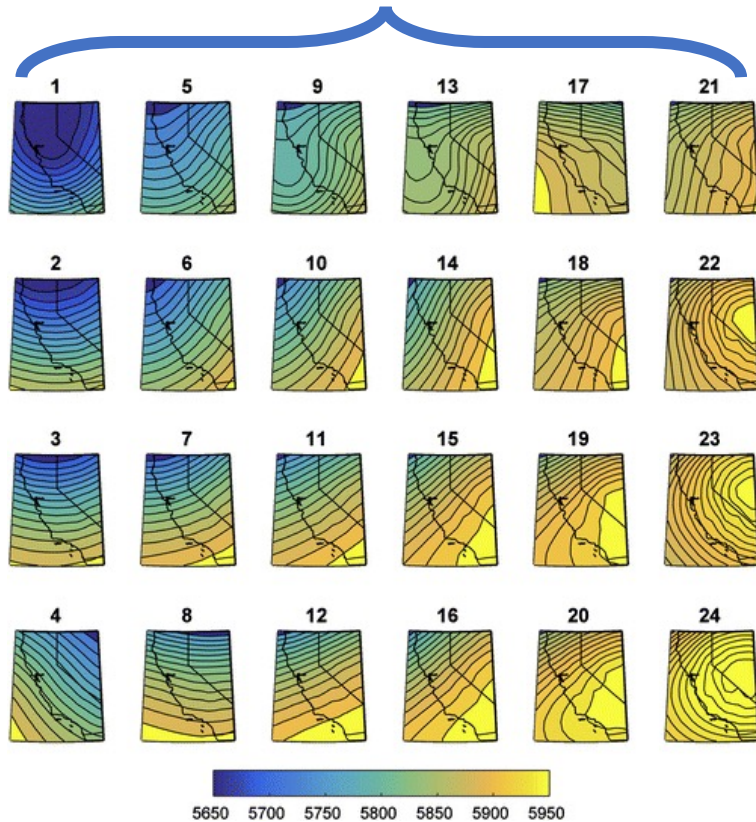
- Prolonged exposure is harmful for humans, animals, plants, etc.
- Ozone daily maximum 8-hour average (MDA8) – is regulated (running average)
- Exceedance threshold – MDA8 of 70 ppbv (set by EPA – lowered it periodically)

| O <sub>3</sub> (ppbv) | Category                       |
|-----------------------|--------------------------------|
| 0-54 (8-hr)           | Good                           |
| 55-70 (8-hr)          | Moderate                       |
| 71-85 (8-hr)          | Unhealthy for Sensitive Groups |
| 86-105 (8-hr)         | Unhealthy                      |
| 106-200 (8-hr)        | Very Unhealthy                 |
| 201-500 (8-hr)        | Hazardous                      |

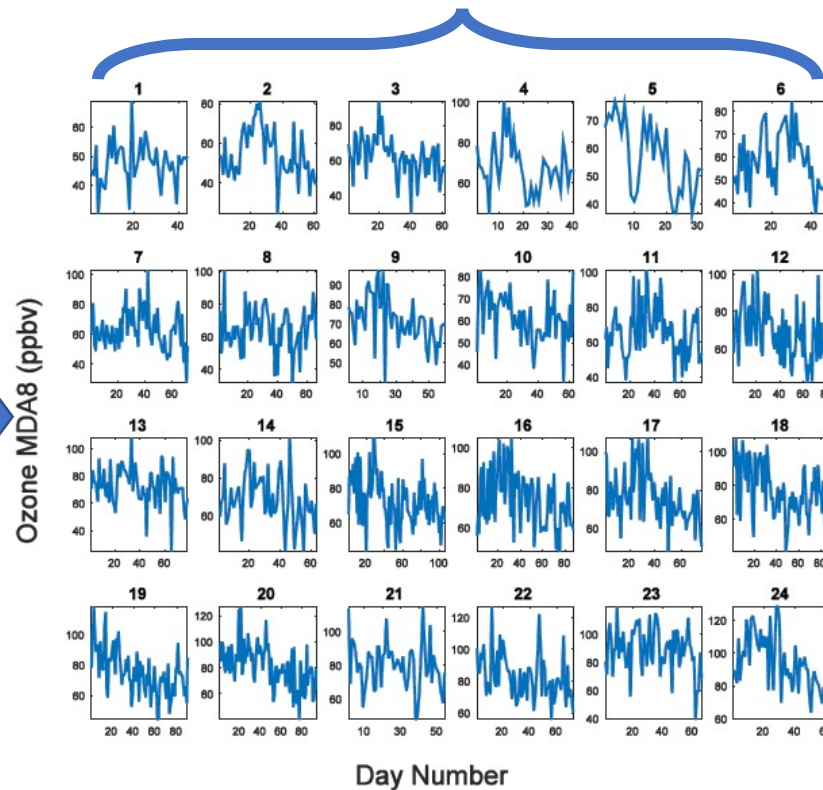
# What is REGiS?

**REGiS is a machine learning model that generates probabilistic ozone forecasts (Balashov et al., 2017)**

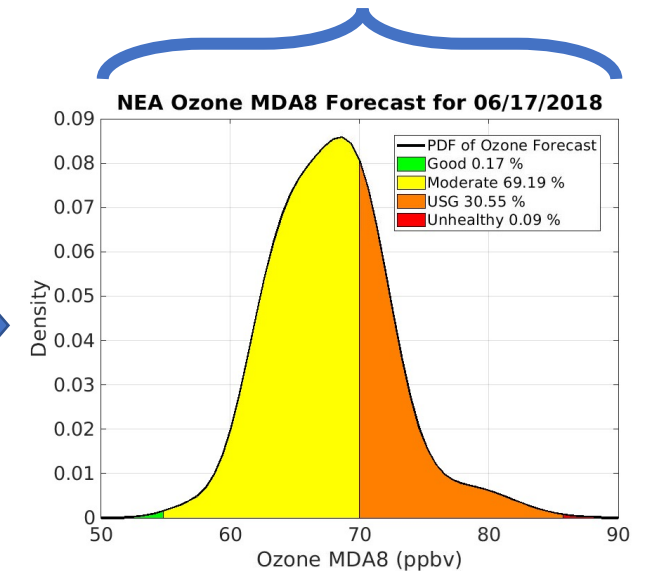
Use Self-Organizing Maps (SOMs) to classify multiple synoptic patterns



Create regressions using meteorological predictors as a function of synoptic pattern

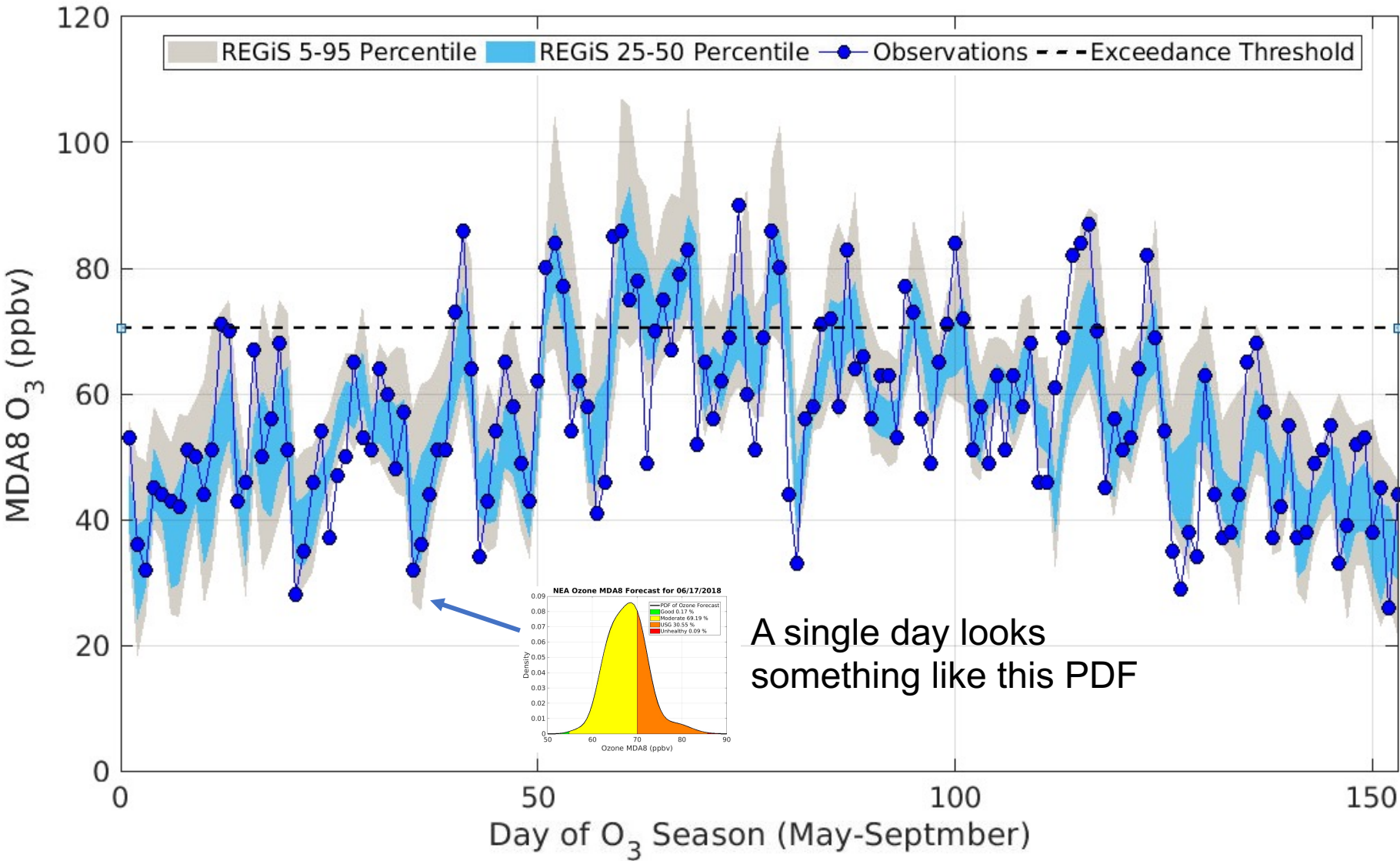


Combine into probabilistic forecast



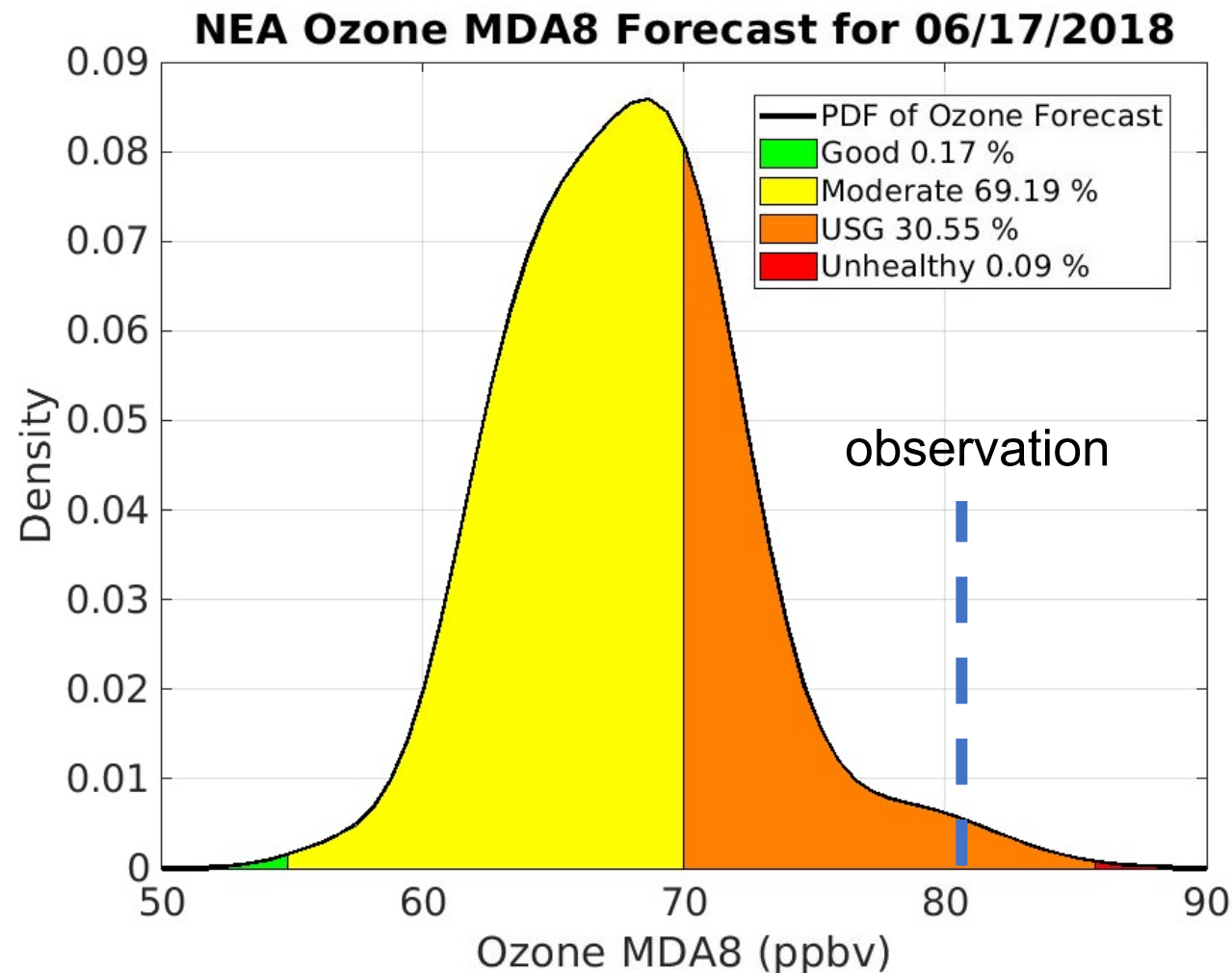


# MDA8 Ozone 2012, NEA (ozone station in Philadelphia) Obs. (blue) vs. REGiS (light blue/gray)

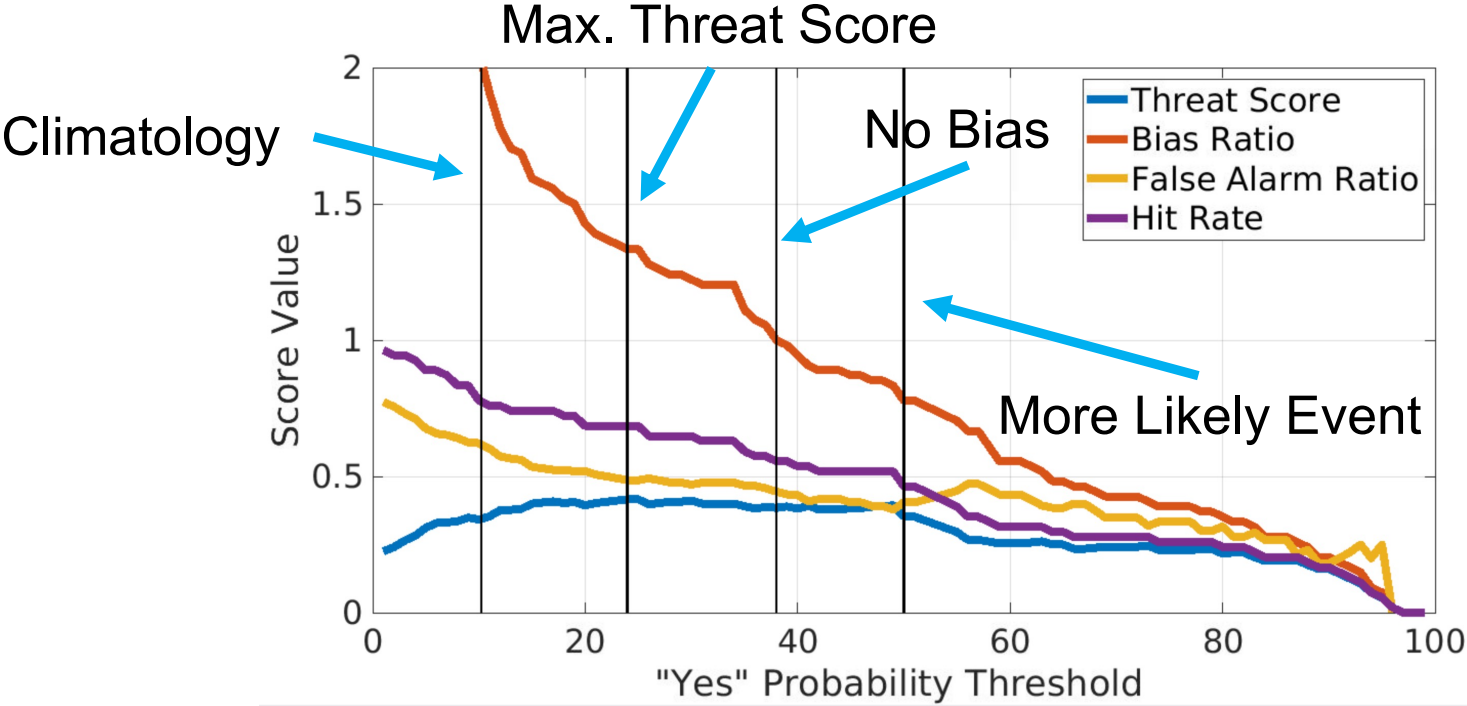


## So, is it exceedance (yes) or no exceedance (no)?

- Here we come back to the the probabilistic forecast shown earlier (forecast is derived from REGiS)
- Using climatology and maximum TS will give us correct answer here
- Other thresholds that are above 31% would yield a wrong answer here









# Evaluation 1

- We evaluate REGiS using Pierce Skill Score (PSS) – an equitable Score
- X-axis shows sliding EPA MDA8 exceedance scale
- Sliding scale allows for simulation of a variety of exceedances
- Evaluating calibrated REGiS using independent 2015-2018 data indicates that in the given case **climatology** gives highest PSS score (especially when there are few exceedances), while using **more likely event** produces lowest PSS score

