Experimental Pollen Forecast at NOAA GSL

Jordan Schnell

Allison Steiner, Tamanna Subba, Yingxiao Zhang, Ravan Ahmadov

CDPW-CPASW

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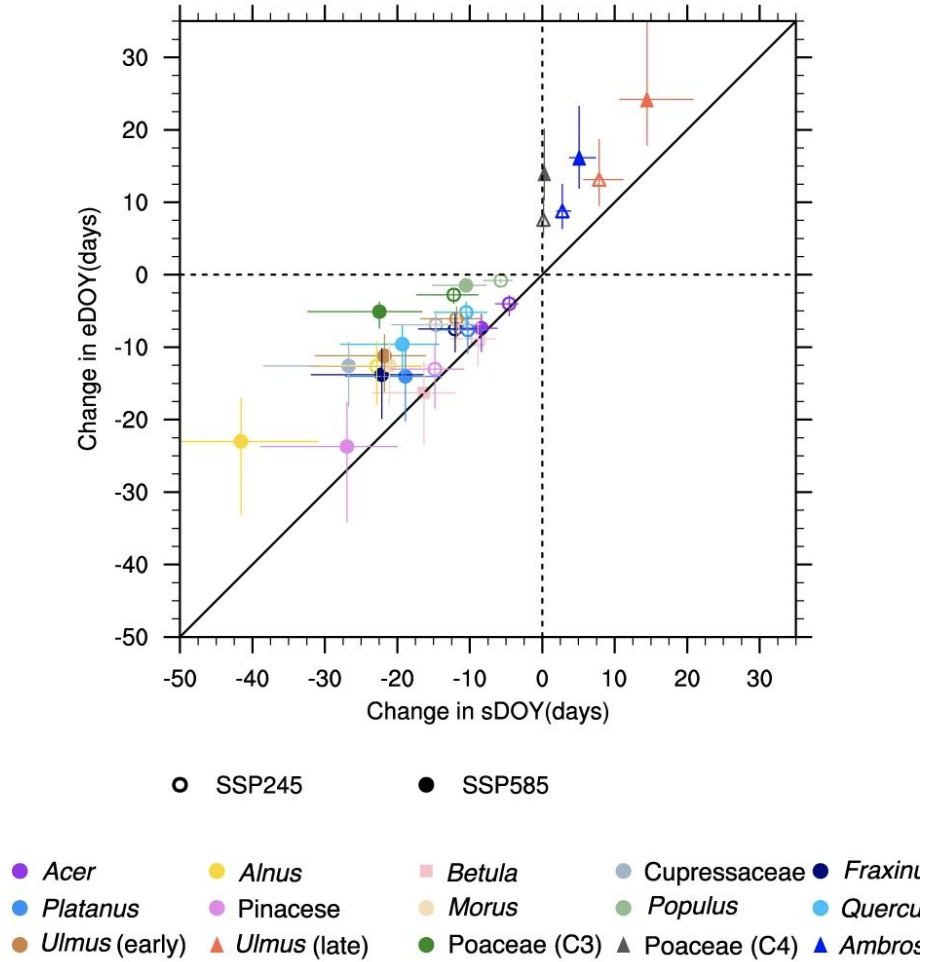
jordan.schnell@noaa.gov

Storm clouds pushing pollen over Durham, N.C., April, 2019; Credit: Reuters

Background & Motivation

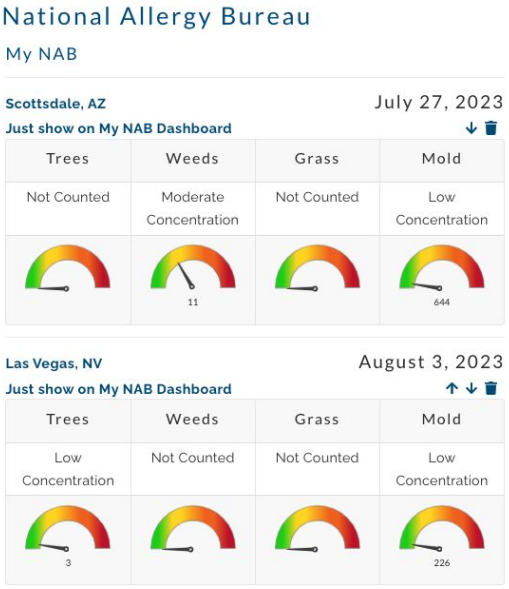
- >50 million Americans suffer from seasonal allergies due to airborne pollen with symptoms ranging from minor (congestion) to severe (anaphylaxis)
- Symptoms lead to millions of work-hours lost and billions of dollars in costs.
- Climate change has already led to an extended seasonal duration and increased pollen load for multiple aeroallergenic pollen taxa in diverse locations across the NH.

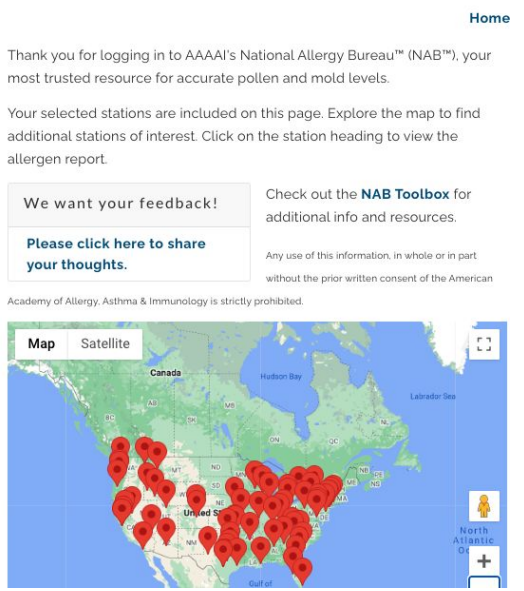


Zhang and Steiner (2022)

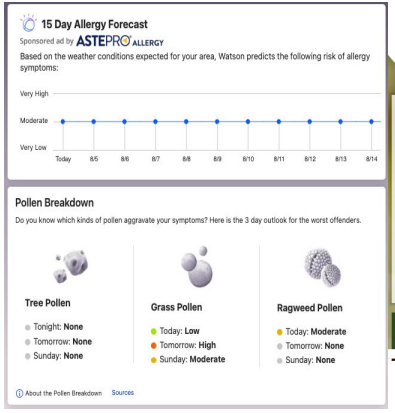
Background & Motivation

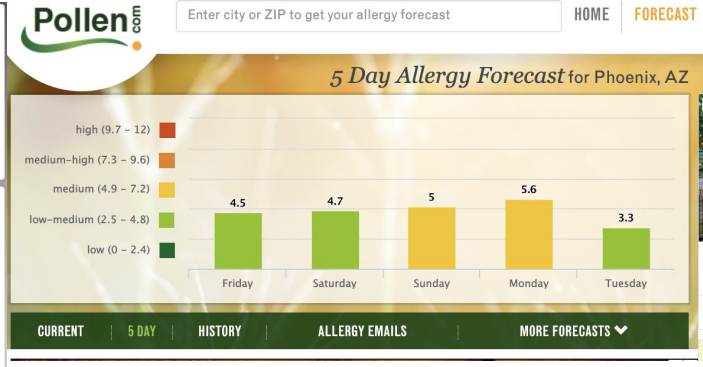
- **NO operational pollen forecasts in the US**
- **Europe (ECMWF-CAMS) includes multiple pollen species**
- The American Academy of Allergy, Asthma & Immunology (AAAAI) and National Allergy Bureau (NAB) provide pollen counts at sites around the country → Data is displayed in near-real time, but access to historical data has proved difficult
- Private companies have filled the void, and produce forecasts mostly based on empirical relationships with past pollen counts (i.e., seasonality) and local meteorological conditions (no transport) - often obtained from **NOAA NWS forecasts**
- Some of these companies utilize their own networks for forecast verification **and provide the data at a cost**





weather.com





Background & Motivation

- **No US federal operational entity produces pollen forecasts**

Indeed, from pollen.com

emy of Allergy,

Weather plays an important part for many allergy sufferers. This is why we include the extended weather forecast weather forecast on Pollen.com. We are not weather forecast specialists therefore we get this data from the experts at *NOAA* and *Weather Trends*.

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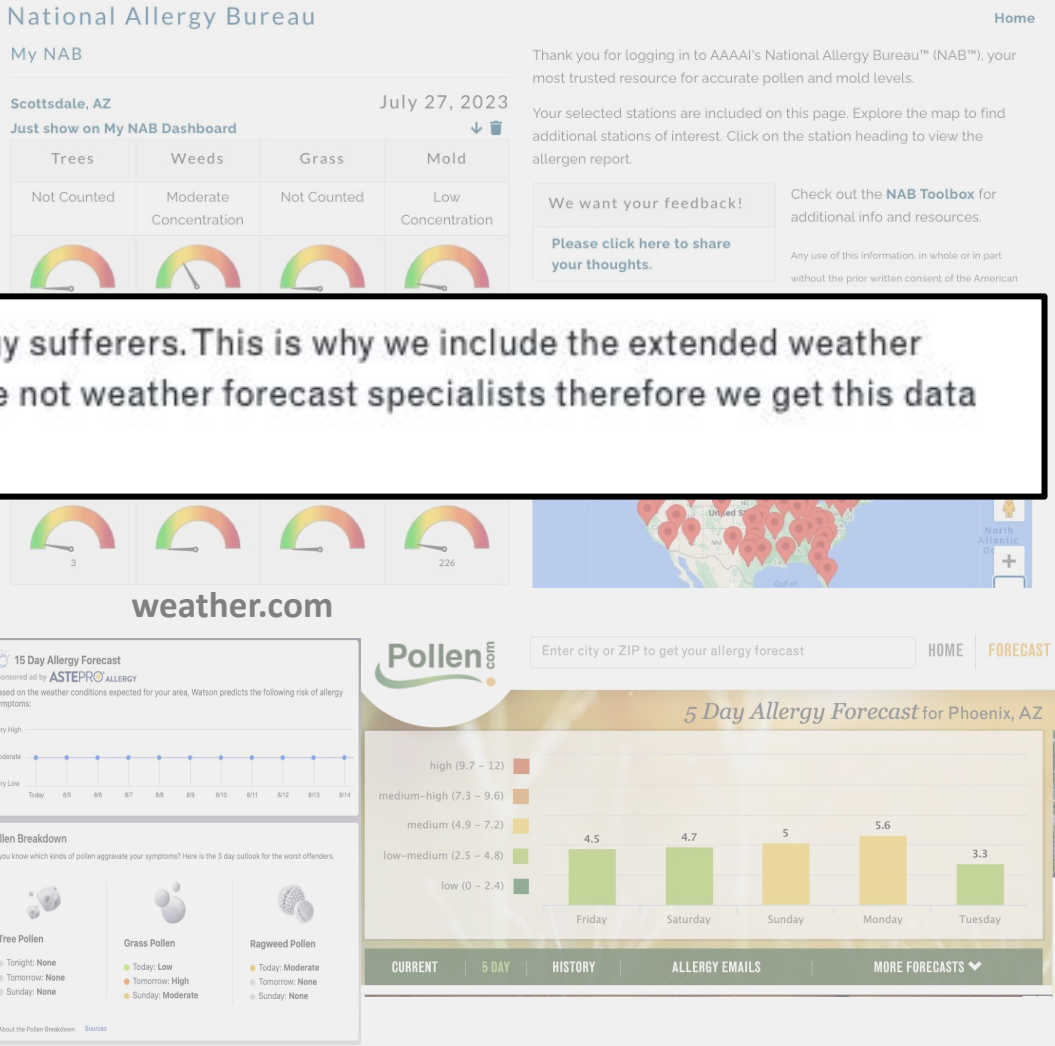


Background & Motivation

- Pollen is emitted from plants as coarse particles (>PM_{10}) and can rupture into sub-pollen particles (SPP, $PM_{2.5}$) due to high humidity and lightning

- Pollen can scatter and/or absorb incoming solar radiation, as well as serve as ice nuclei and hence influence the formation of clouds and precipitation.

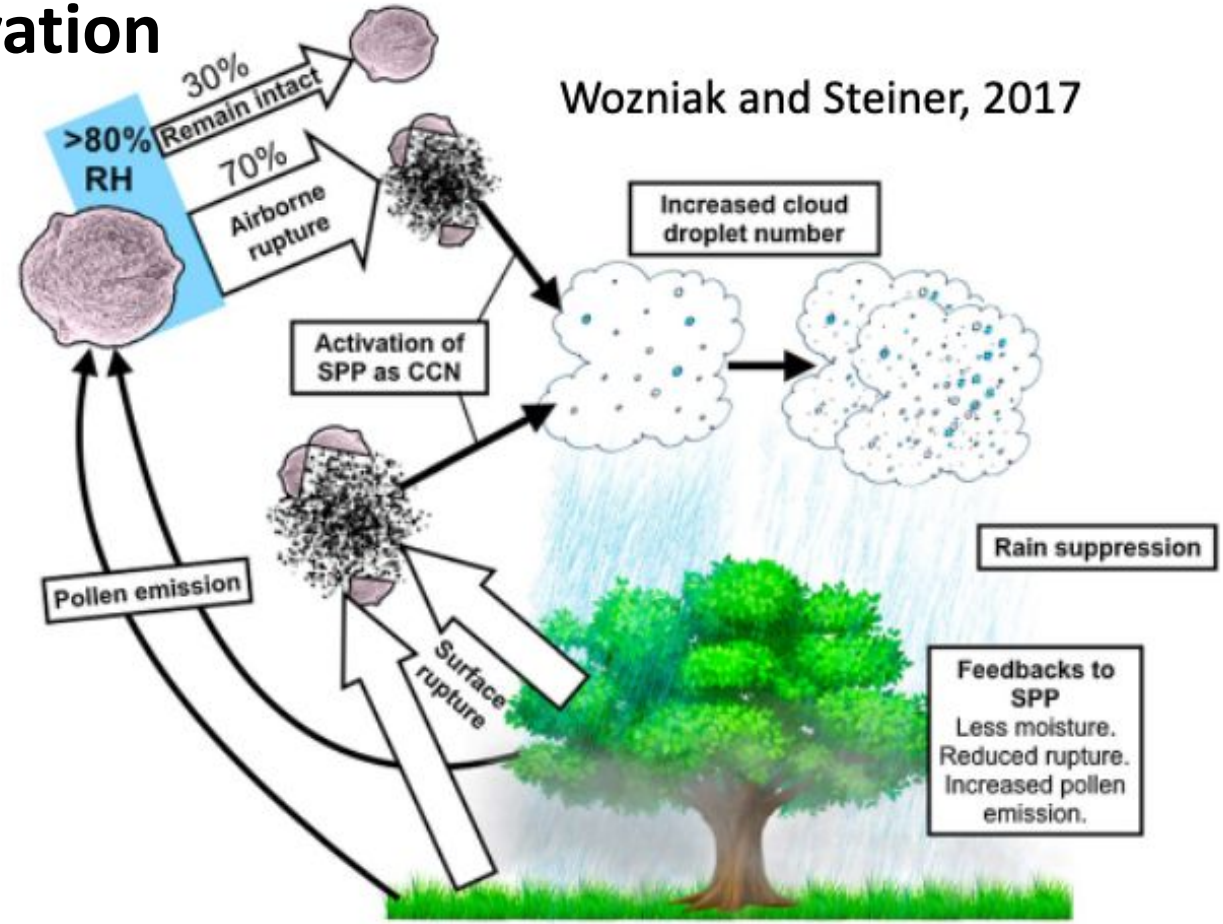
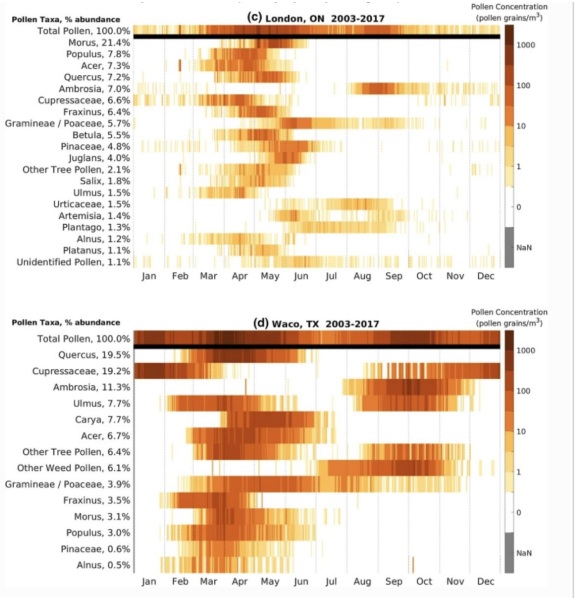


Figure 1. Conceptual diagram of pollen emissions, rupture, SPP production, and impact on precipitation processes. CCN = cloud condensation nuclei; RH = relative humidity; SPP = subpollen particle.

Pollen emissions are location specific, and seasonal in both magnitude and dominant plant type and species



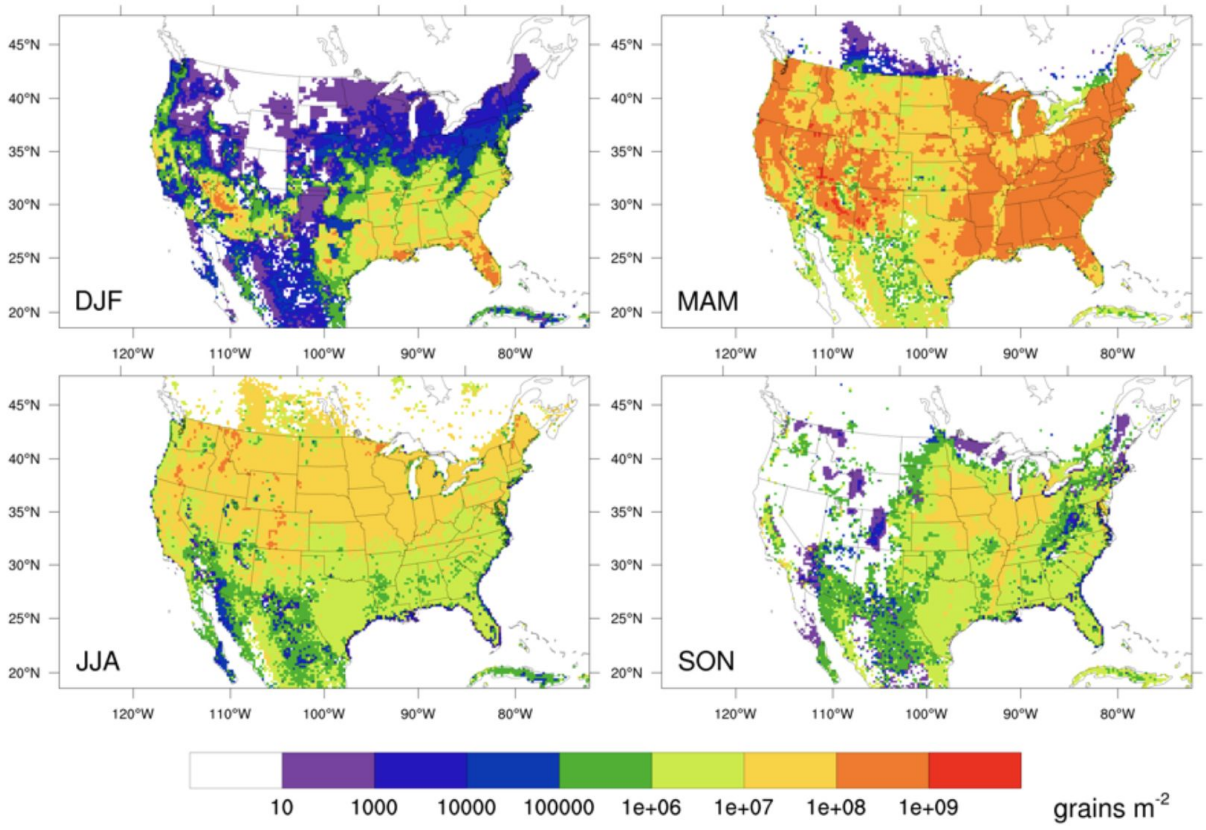


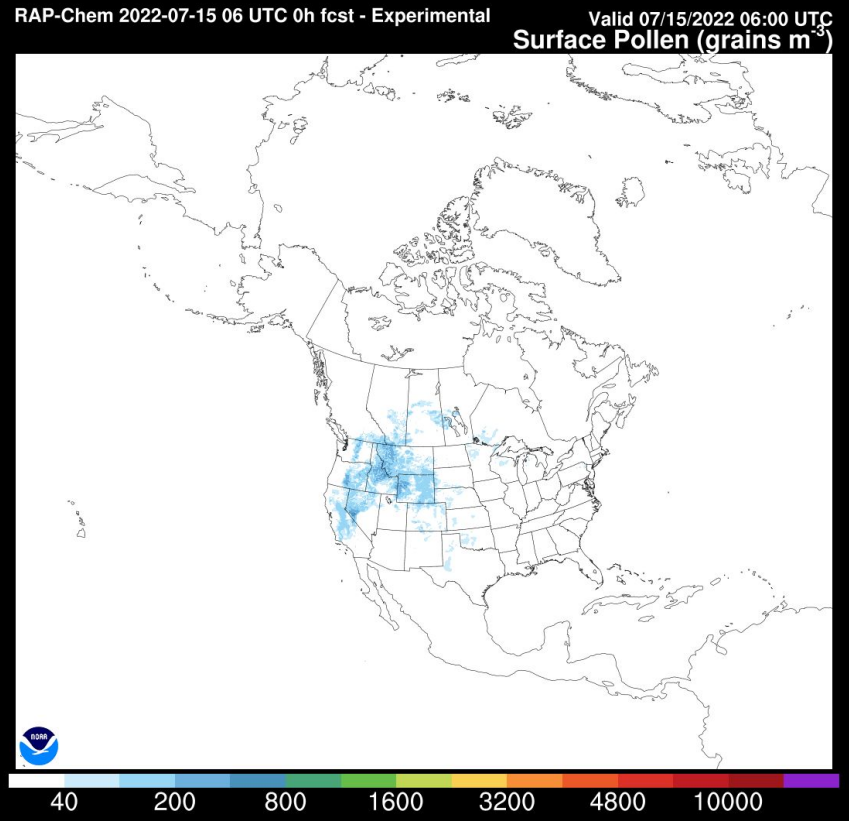
Figure 1. Average (2000-2008) simulated total pollen emissions flux (grains m^{-2} d^{-1}) by season (DJF/MAM/JJA/SON) (Wozniak and Steiner, 2017).

Experimental RAP-Chem

- Uses **operational** **RAP** IC/BCs
- **48-h** forecasts **initialized at 06Z**
- Began in July 2022, pollen added in spring 2022
- **Plots** available online

https://rapidrefresh.noaa.gov/RAPchem/

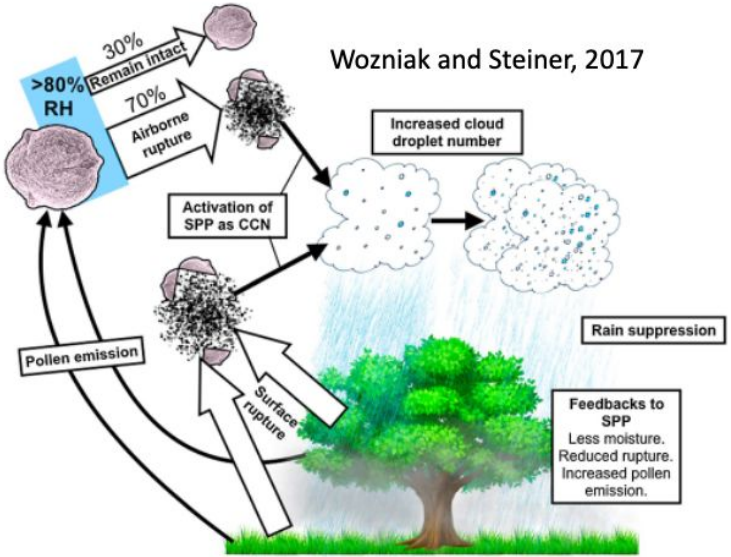
- **Chemical mechanism**: simplified carbon-bond coupled to VBS-SOA (**85 species, 96 RXNs** vs 217 species, 366 RXNs in NOAA/NWS NAQFC)
- **Online emissions**: dust, sea salt, biogenics, wildfires + plumerise, and **pollen**
- **Photolysis**: TUV + aerosol direct effects
- **Radiation**: RRTMG + aerosol direct effects
- **Microphysics**: Thompson-Eidhammer *loosely* coupled to prognostic aerosols
- **Chemical vertical mixing**: Inline with MYNN
- **Chemical LBCs**: RAQMS + total O_3 from GFS
- **Near Real-Time Verification**: O_3, $PM_{2.5}$, CO, NO_2, AOD_{550}, Temperature, ~~pollen~~



RAP-Chem forecasts use **WRF-Chem chemistry packages**

- Daily primary pollen emissions potentials (Zhang and Steiner 2022), based on the PECM model (Wozniak and Steiner, 2017)
- Modified online by precipitation, wind speed, sunlight
- Coupled to the MADE-SORGAM aerosol scheme w/ cloud-borne species (Subba et al. *in prep*)
- **2 species, primary (PM_{10}) and sub-pollen particles (SPP, $PM_{2.5}$).**
- SPP form from the rupture of primary pollen particles due to humidity and lightning (e.g., T-storm asthma)

- Species-specific emissions are available, but we have not yet coupled this to the mechanism and would require additional computational resources
- All work thus far has been through in-kind support, but we have recently received funding through **NOAA OAR CPO**!



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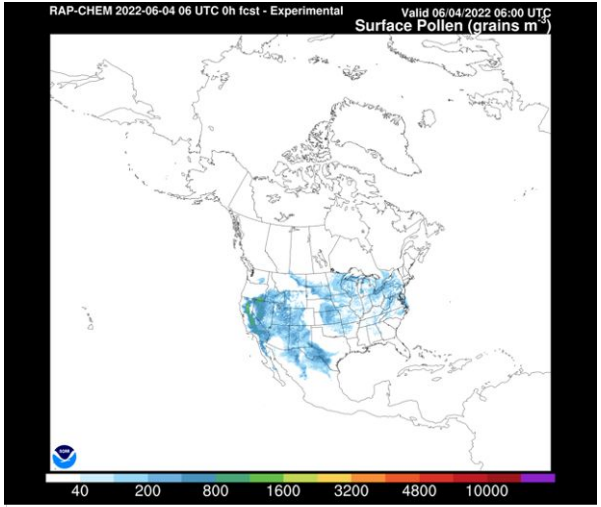
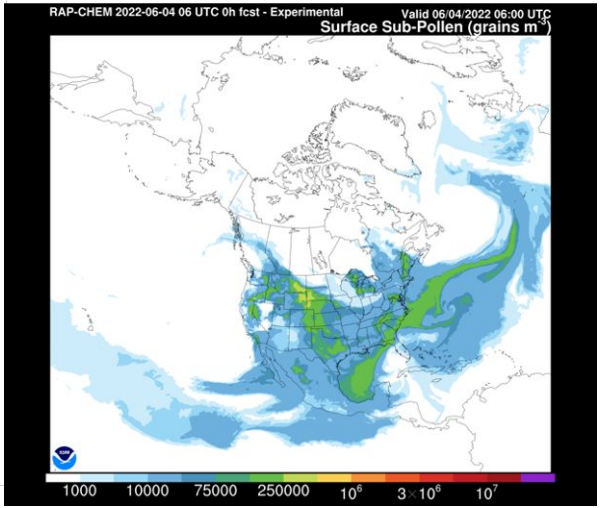
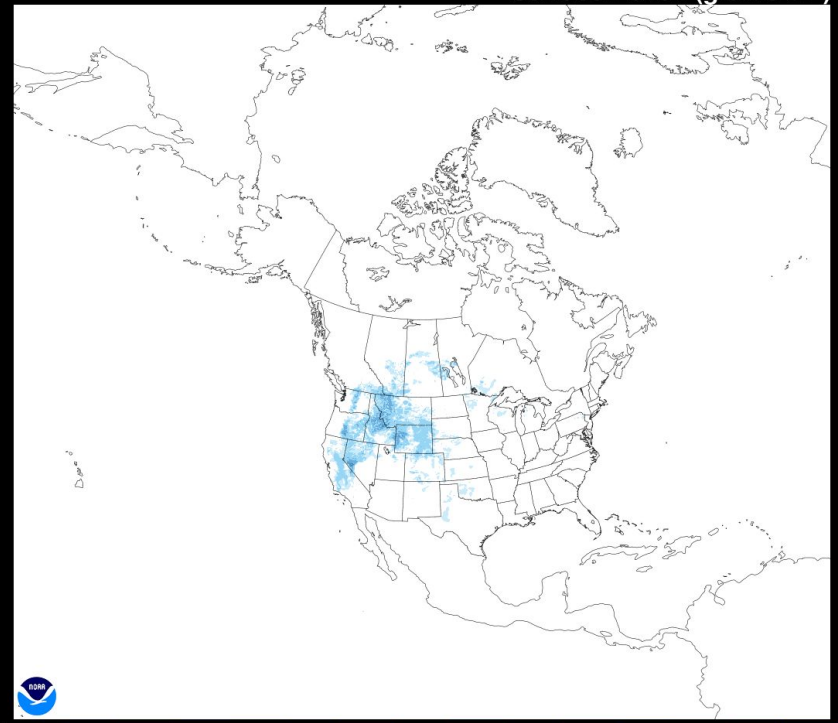




RAP-Chem 2022-07-15 06 UTC 0h fcst - Experimental

Valid 07/15/2022 06:00 UTC

Surface Pollen (grains m^{-3})



RAP-Chem 2022-07-15 06 UTC 0h fcst - Experimental

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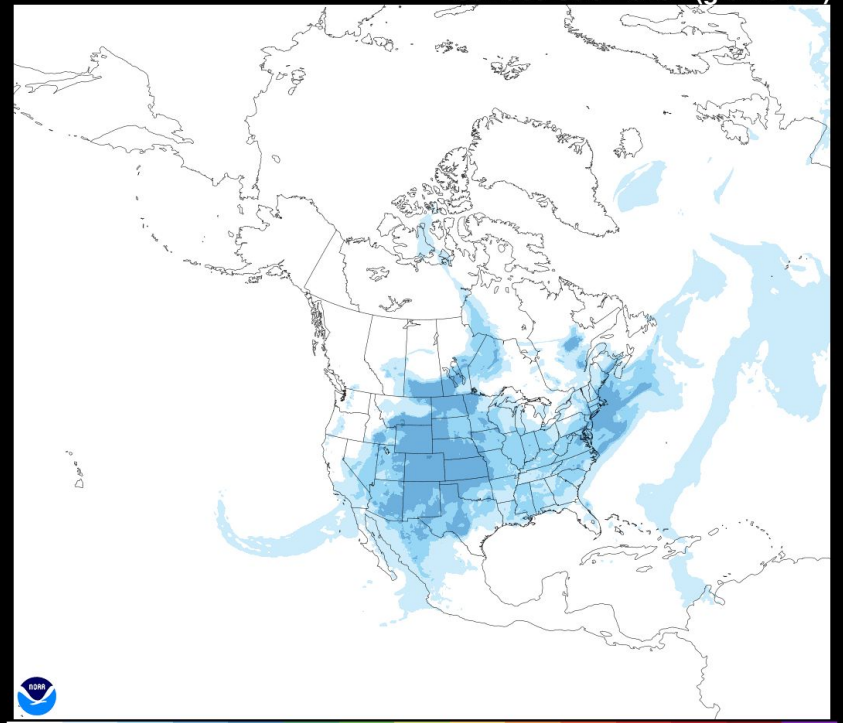
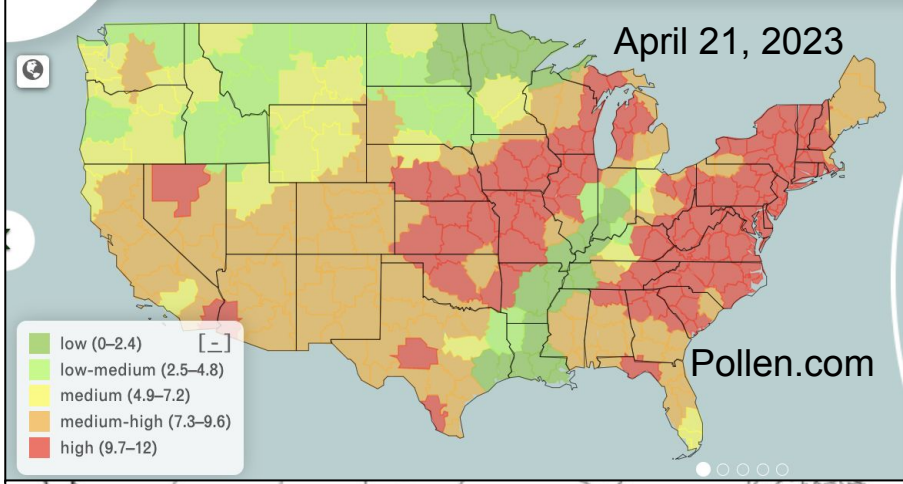
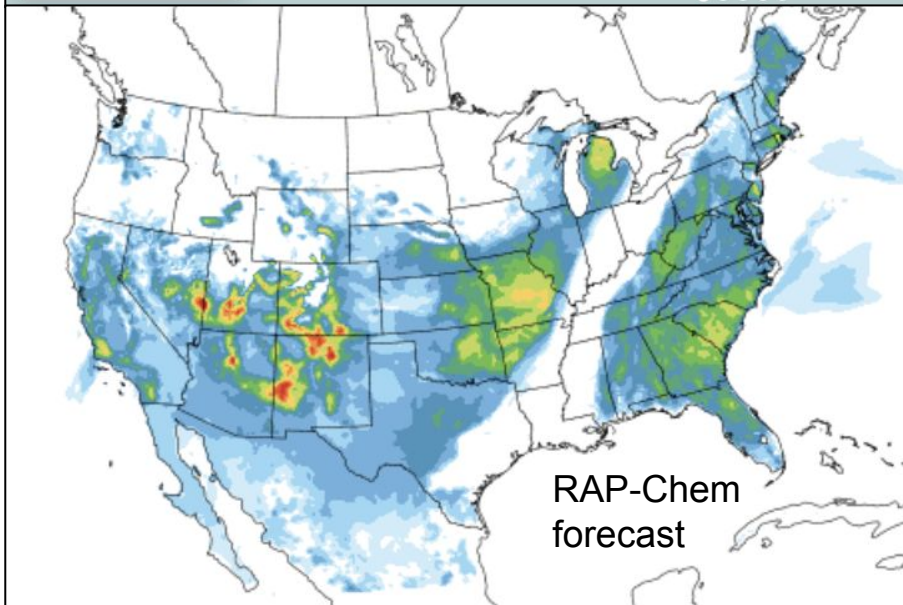
Surface Sub-Pollen (grains m^{-3})



Verification

- To date, there has been **no verification** of the RAP-Chem forecasts
- Qualitative comparisons with pollen.com (right) generally show good agreement, with clear responses in both products to weather (e.g., frontal passage from Texas through Ohio)
- Recent collaboration with **CDC** will correlate pollen predictions with epidemiological factors
    - Two (2022, 2023) pollen seasons
- A real-time verification system is ideal, providing potential stakeholders of an experimental product with immediate guidance on its capability
- NOAA GSL has developed a **real-time interactive verification platform** through **in-kind support** for regional and global air quality models, providing a framework for future verification





Next Steps

- The **RRFS-SD** (smoke and dust) is the next-generation HRRR-Smoke, and will include three chemical tracers (smoke, fine dust, coarse dust). Work has begun to couple the pollen emission to the RRFS (or UFS) codebase.
- In RAP-Chem, only two **bulk** pollen species were included (coarse = PM10, fine = PM2.5)
- For the **RRFS-SD** implementation, we plan to add separate pollen species for **tree, grass, and weed (coarse + fine).**
- Forecasts will be initialized once per day (**00Z**) and run for a period of **48-60 hrs** over **CONUS** at a much finer resolution (**3km vs. 13km)**
- The forecast will also include the same smoke and dust parameterizations as the operational RRFS-SD (boundary conditions provided by the operational forecast).
- This **testbed** will provide a framework for improving (realtime?) emission estimates (e.g., NDVI, greenness, LAI), process controls (e.g., wind, temperature, time of day), and physics interactions (e.g., radiation, cloud microphysics).
- Ultimately, the hope would be to include pollen in additional NWP+tracer models (e.g, UFS-Aerosols, S2S)

Stakeholders of a experimental pollen forecast

- **Weather Forecasters:** pollen can serve as both CCN and IN and scatters or absorbs radiation. Lightning and deep convection can lead to ‘thunderstorm asthma’
- **Air Quality Forecasters:** millions of Americans suffer from seasonal allergies due to pollen, and it may be a co-stressor to other pollutants (or heat)
- **Climate Scientists:** clouds and their interaction with aerosols are one of the greatest sources of uncertainty in climate assessments. Pollen likely contributes significantly to cloud processes in a world without anthropogenic aerosols and this process is not explicitly included in climate models.
- **Biologists/Conservationists:** a forecast that includes transport could be utilized for source-receptor relationships and population/genetic diversity.
- **Citizens:** pollen outlook is already included with many app-based weather forecasts. This information should ideally come from NOAA in addition to other air quality information.
- **Others?**

It is imperative that pollen is included in numerical weather, air quality, and climate model simulations

RAP-Chem
03/25/2024 06Z
48 hr Pollen Forecast

Thank you!