Local limits of detection for anthropogenic aerosol-cloud interactions

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Motivating Problem

Anthropogenic aerosol emissions can brighten or even dim clouds, impacting their radiative properties.
- Global atmospheric conditions and sources are too dynamic under for all cloud effects to have been documented at visible or infrared wavelengths.
- Physical simulation models have replicated this phenomenon only in specific, idealized cases such as ship emissions in a fairly cloud-free marine environment.

Unexplored Key Questions:
- **Can we detect impacts of local emission sources?**
- How large or concentrated does the emission need to be for detection?
- For what length of time do the emissions noticeably affect clouds?
- Under what atmospheric conditions is it possible to detect changes in clouds?
- Are there global dead zones in our source detection capabilities?

Figure: Radiative forcing from a variety of forcers and their uncertainty.. From IPCC.

Our Proposed Approach

New Technical Idea:
- *Combining data sources*: combine local emission signals with satellite observations to identify changes in cloud brightness over a range of atmospheric conditions
- *Rigorous statistical techniques:* develop spatio-temporal statistical models to predict and quantify uncertainty in aerosol-cloud interactions from individual sources
- *Ensembles of physical atmospheric models:* simulate aerosol-cloud interactions under targeted scenarios
- *Validation:* evaluate the limits of our models and simulation techniques to detect sources of interest

FY19 Goals:
- Acquire and parse relevant data sources: MODIS data, marine traffic (AIS) data, weather stations, atmospheric sampling sources, and stationary emission sources
- **Validate MODIS data with known emission sources, i.e.**
  1. Cloud-based ship tracks
     - Where do we see an abundance of cloud-based ship tracks (MODIS)?
     - Do we have marine traffic data (AIS) that match what we see?
  2. Stationary emission source, e.g. power plants
     - Continued exploration of conditions under which cloud changes are visible.
     - How well can a stationary source serve as proxy for ship-based emissions?

- **Exploratory Data Analysis to look for significant spatio-temporal trends among the data**

If we accomplish our FY19 goals, we plan to pursue in FY20-FY21:
- Use atmospheric simulation models to conduct planned experiments to explore the unanswered key questions previously highlighted
- Develop rigorous spatial models to use aerosol-cloud interaction science to identify and follow anthropogenic emission paths
- Rigorously evaluate the expected limits of detection as a function of source type, atmospheric conditions, and geolocation
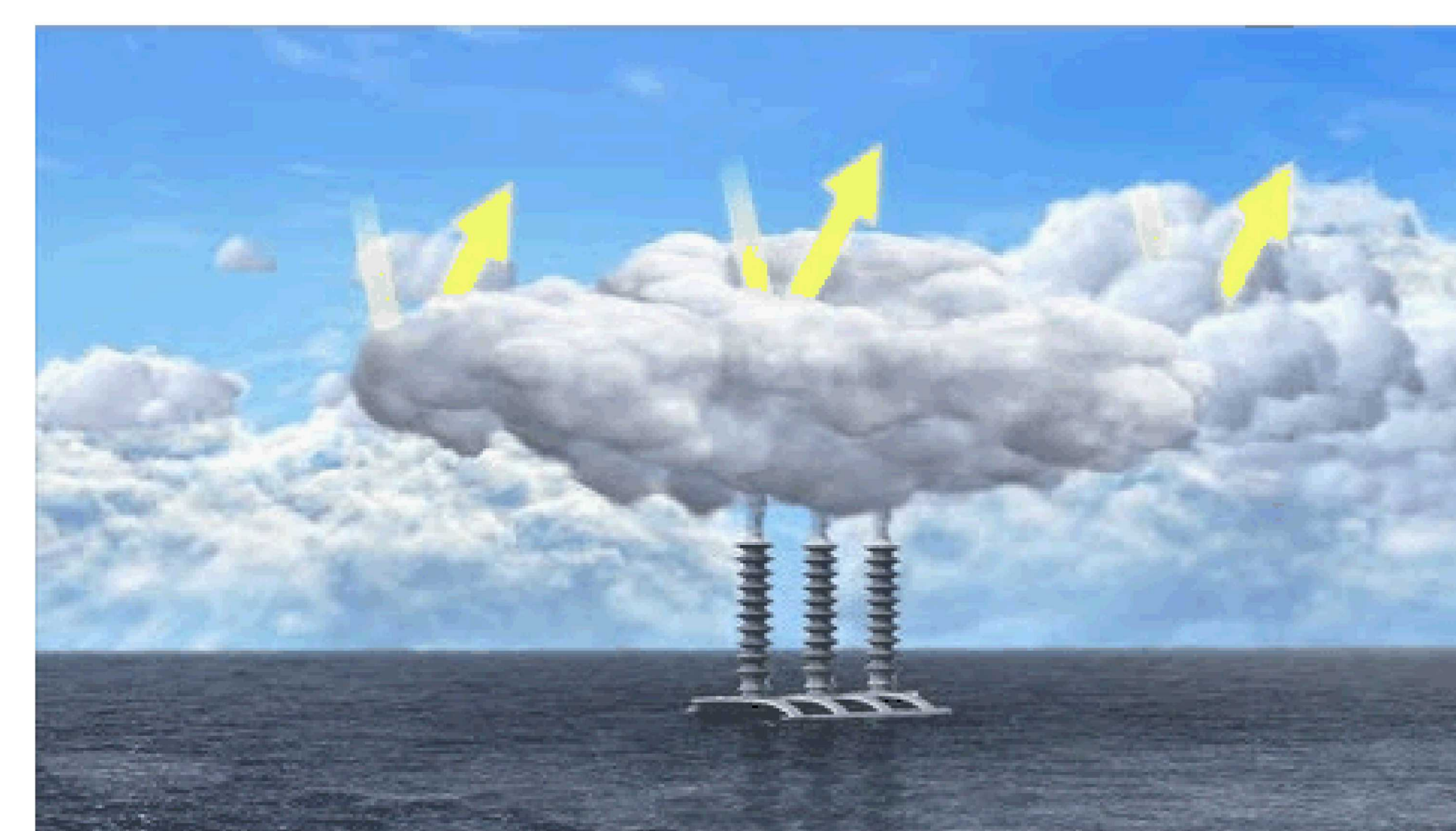

Figure: Example of Marine Cloud Brightening from Futuristic Autonomous Ships spraying sea salt aerosol into the marine boundary layer.
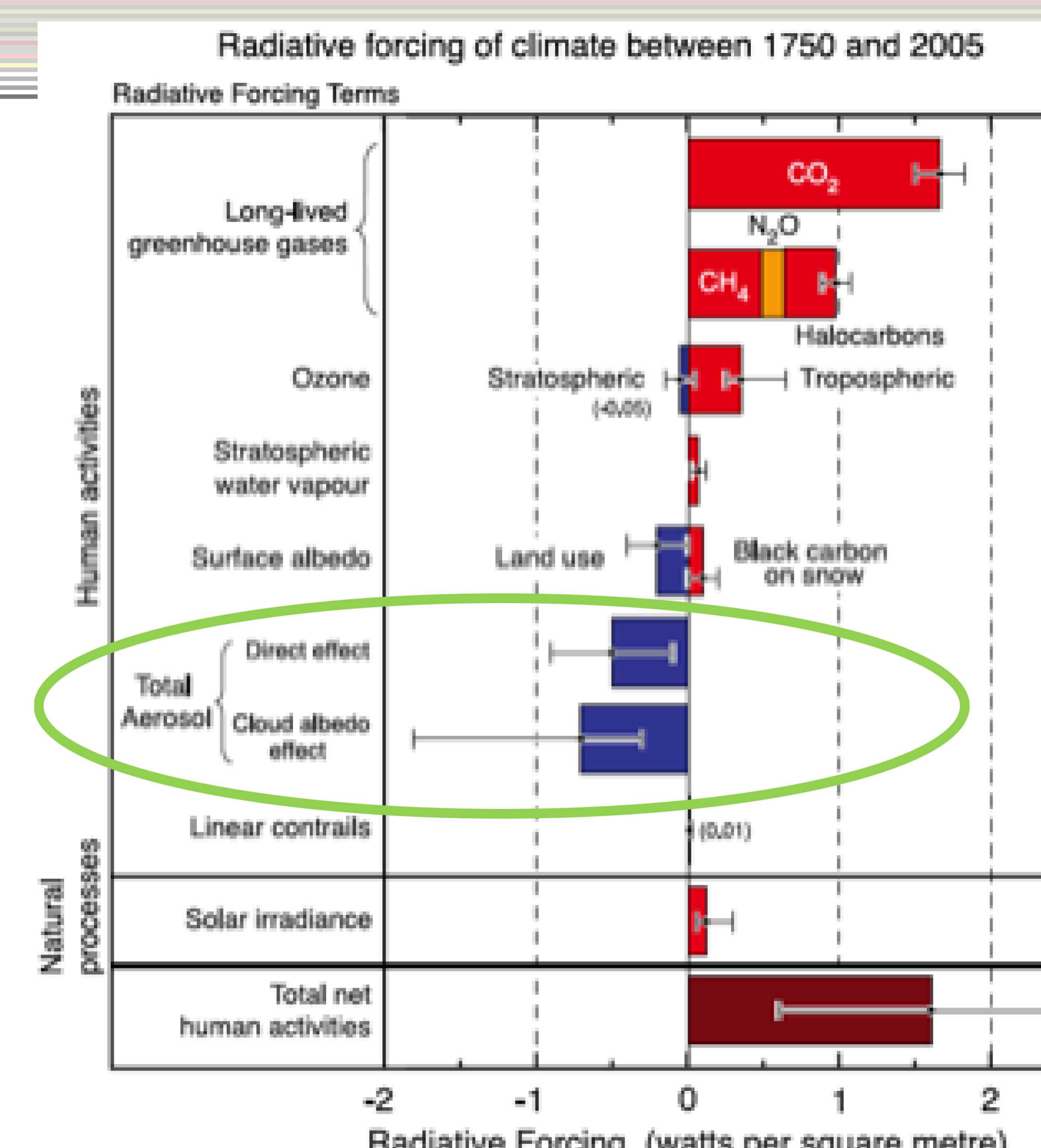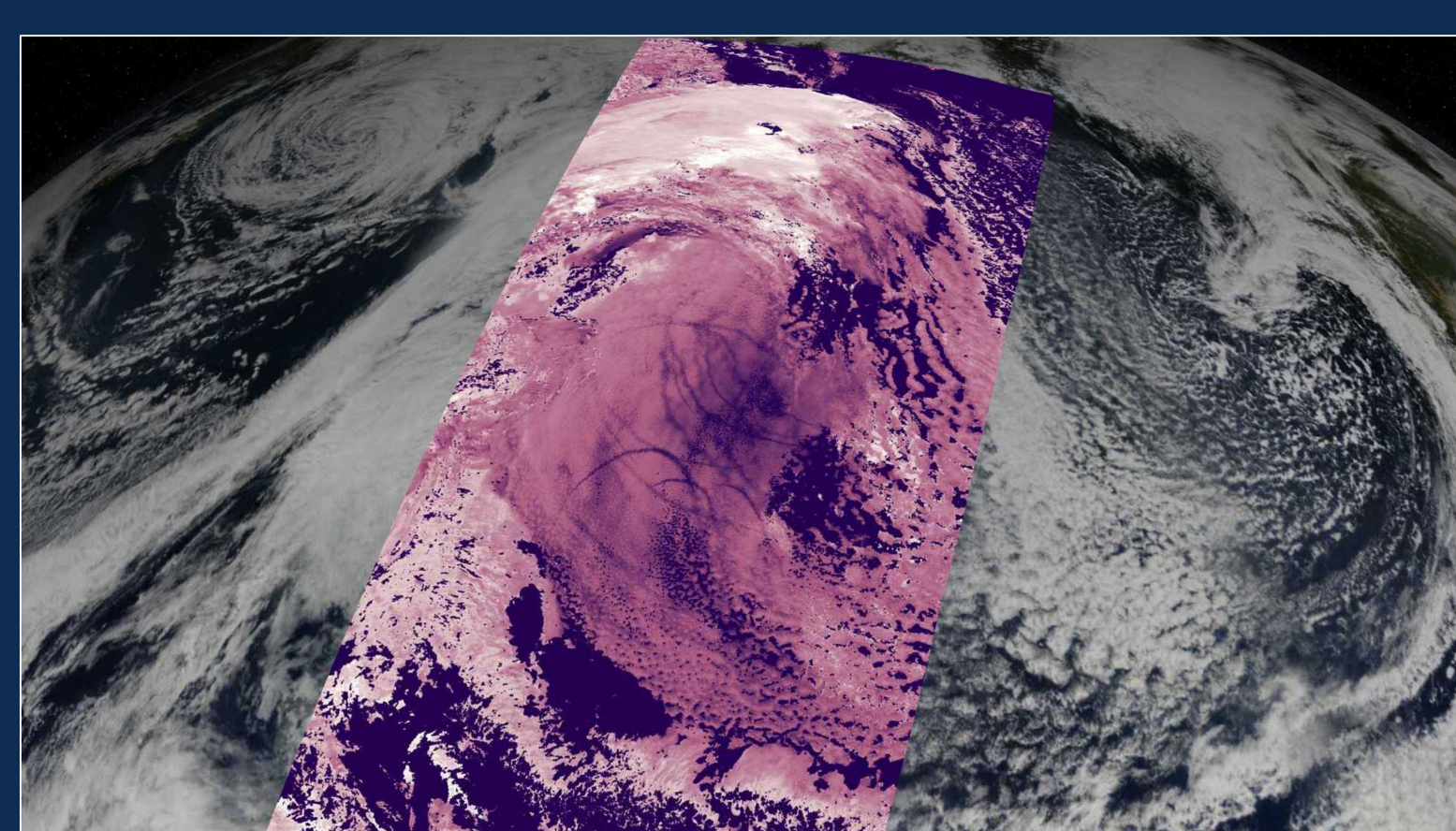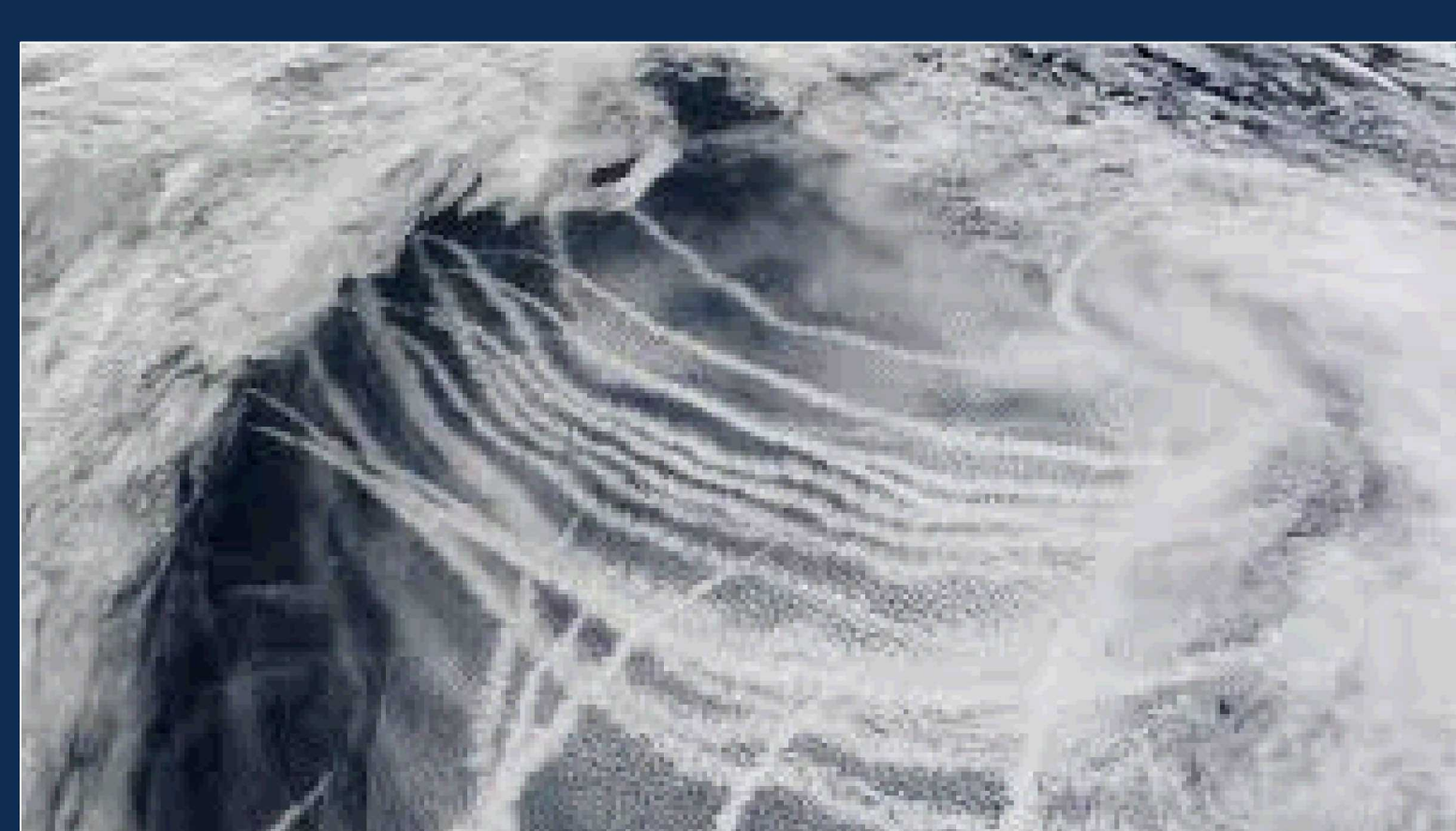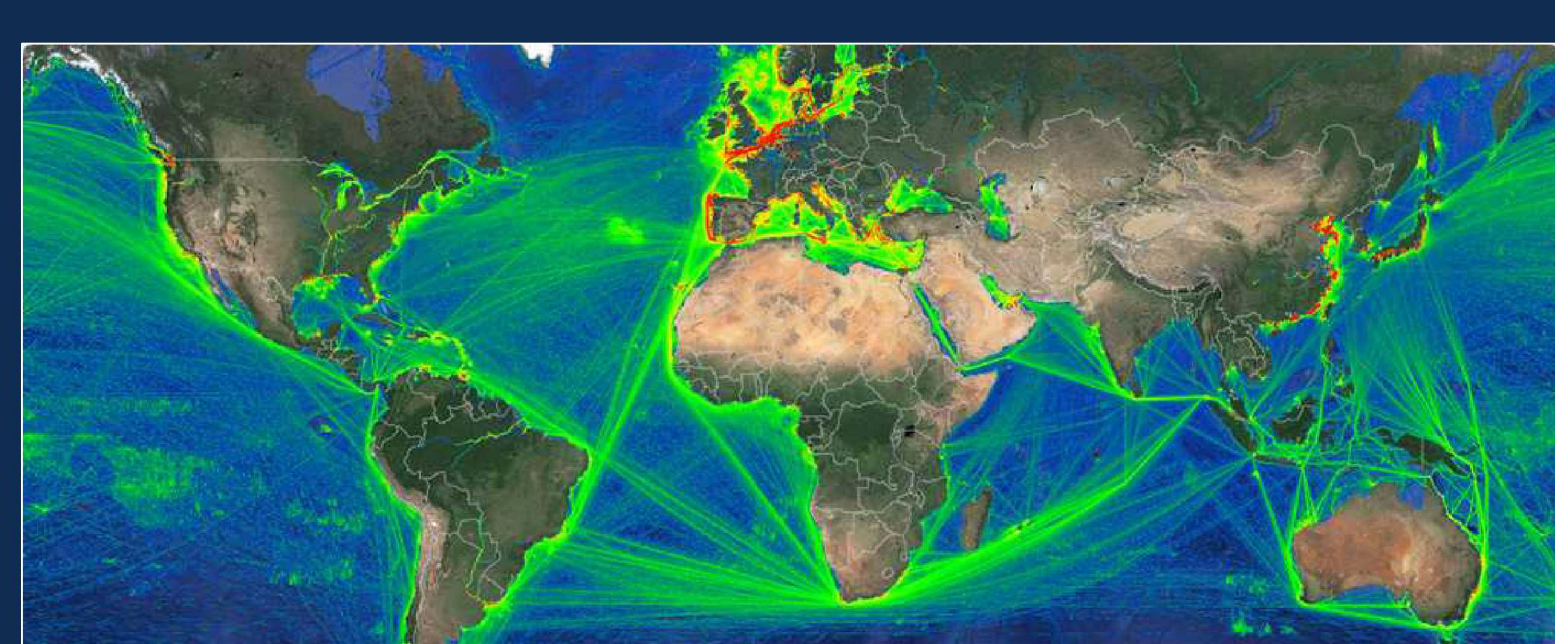https://www.youtube.com/watch?v=cgJyw2cTrW4
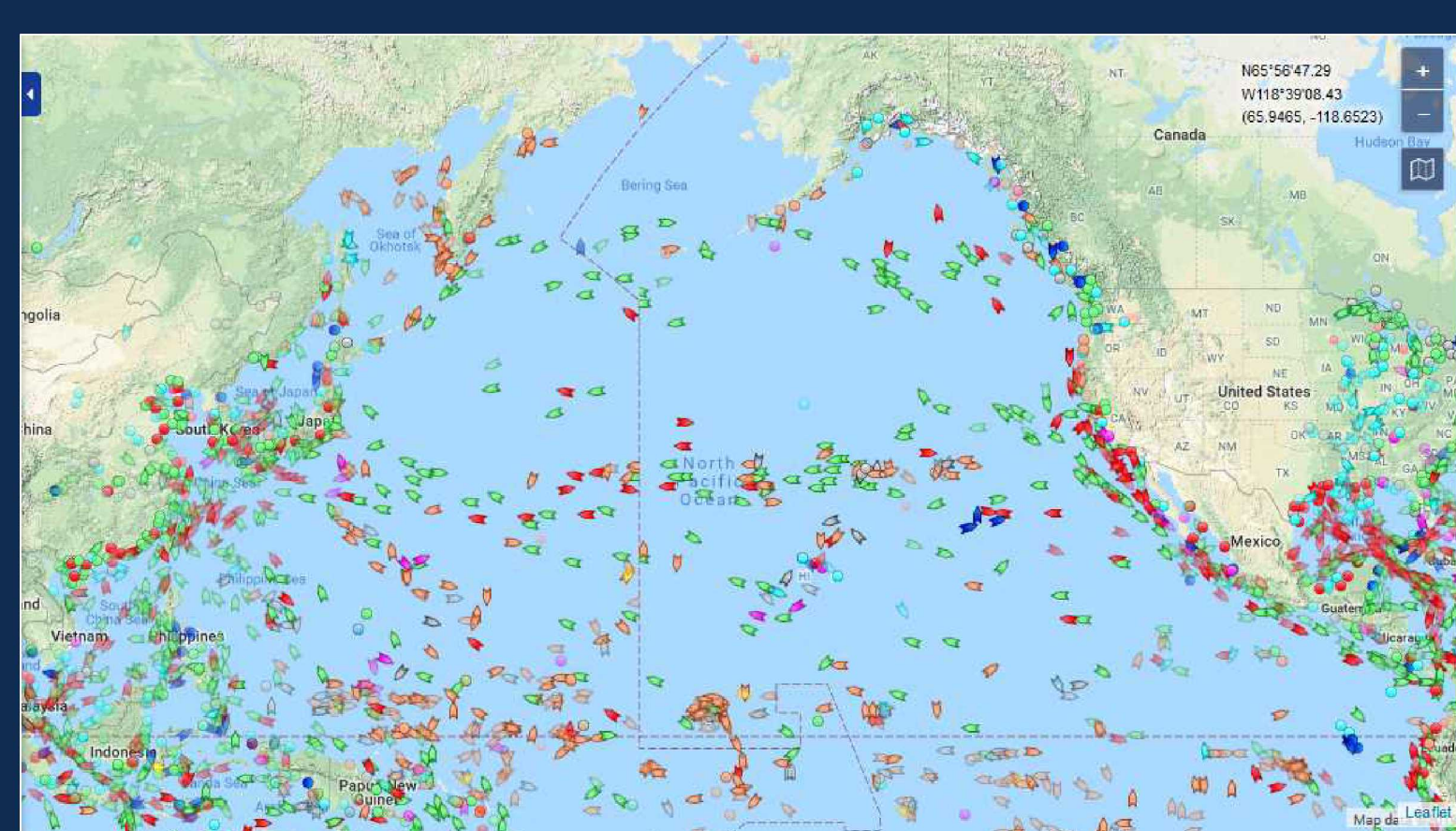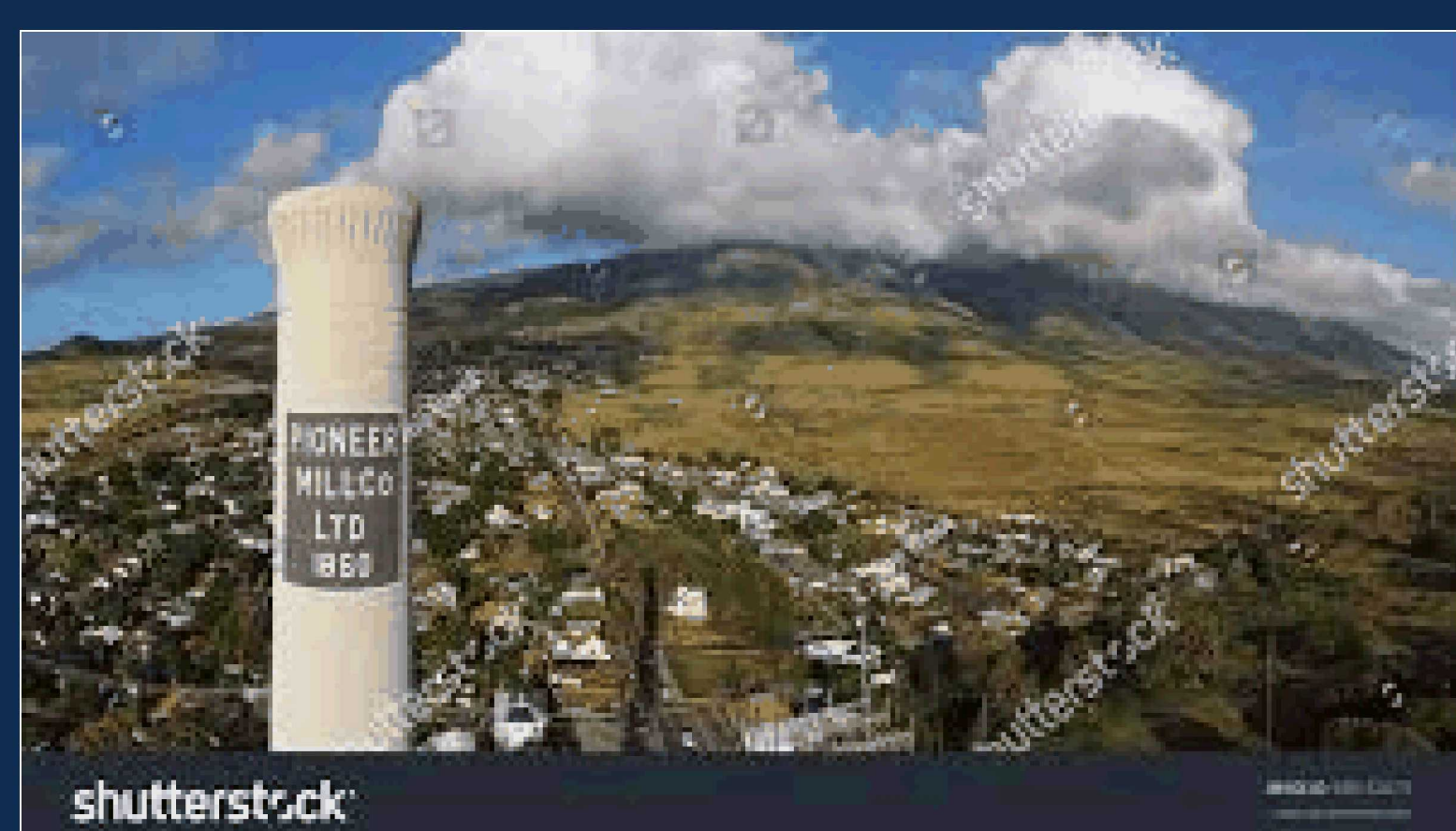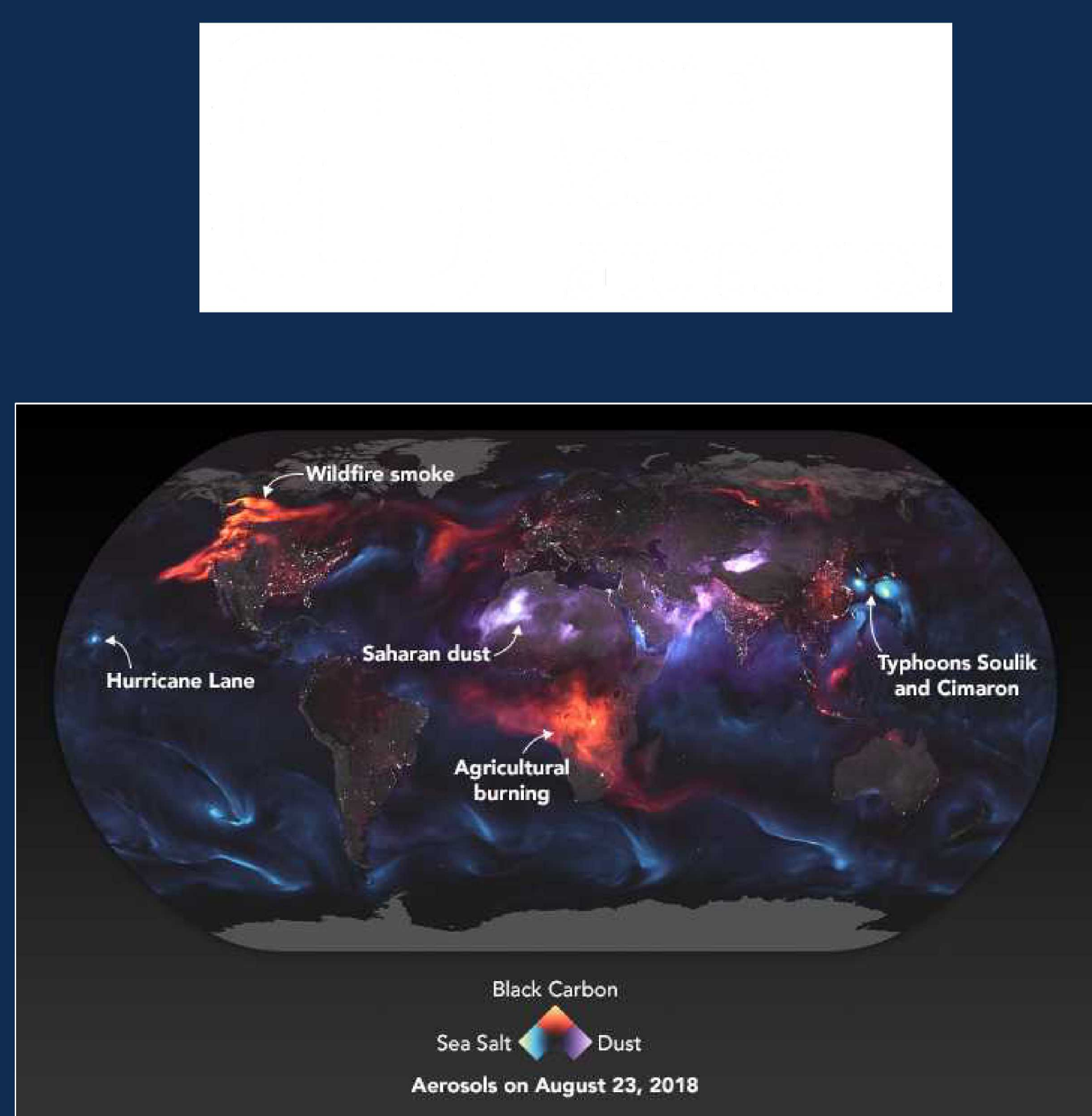
Figures: (top to bottom) NASA global aerosol observation snapshot; a local, stationary source emission; local, mobile source emission points; local, mobile source emission paths; visible ship tracks from mobile source emission paths in the North Pacific Ocean from MODIS; and the combined impact on cloud properties as seen in invisible ship tracks in infrared mode as seen from MODIS in the North Pacific Ocean near the Aleutian islands in 2009.