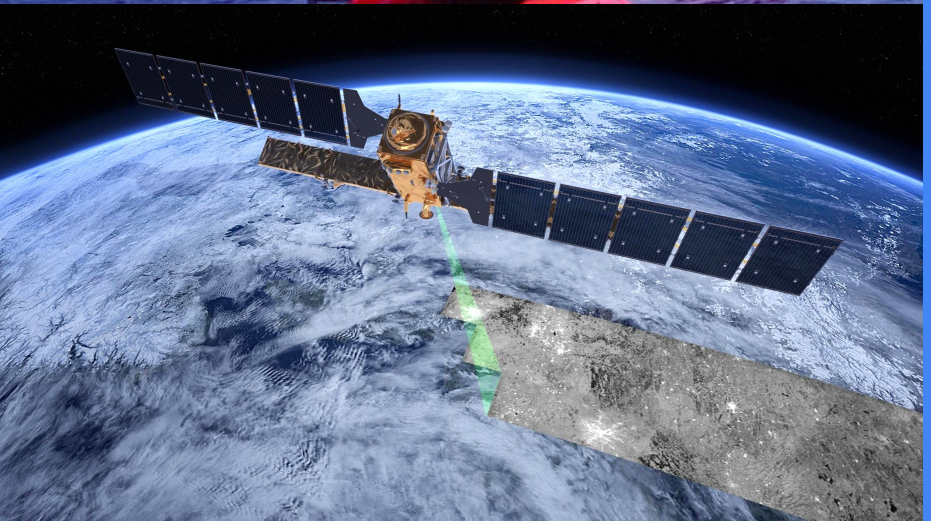
Sensors and Semantics:
understanding Earth from above

Ryan Keisler
SFI Global Sustainability Summer School, July 2019



My background

10 years in physics,
studying the cosmos.

THE UNIVERSITY OF CHICAGO

4 years in tech,
studying the earth.

Descartes Labs

Sensors

Sensors make the physical world machine-readable.

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Models

Sensors make the physical world machine-readable.

Models, built on machine-readable data, allow us to reason about the physical world.

The world is complex.

Consider a **human**, navigating this mess.

The world is complex.

Consider a **human**, navigating this mess, with

- Eyes (photons)
- Nose (molecules)
- Skin (temperature)

These **sensors** capture some specific, fleeting aspect of the world.

Our brain uses these inputs to build a **simplified, predictive model of the world**

and ultimately,
to take action to affect the world.

The world is complex.

Consider **humanity**, navigating this mess.

The world is complex.

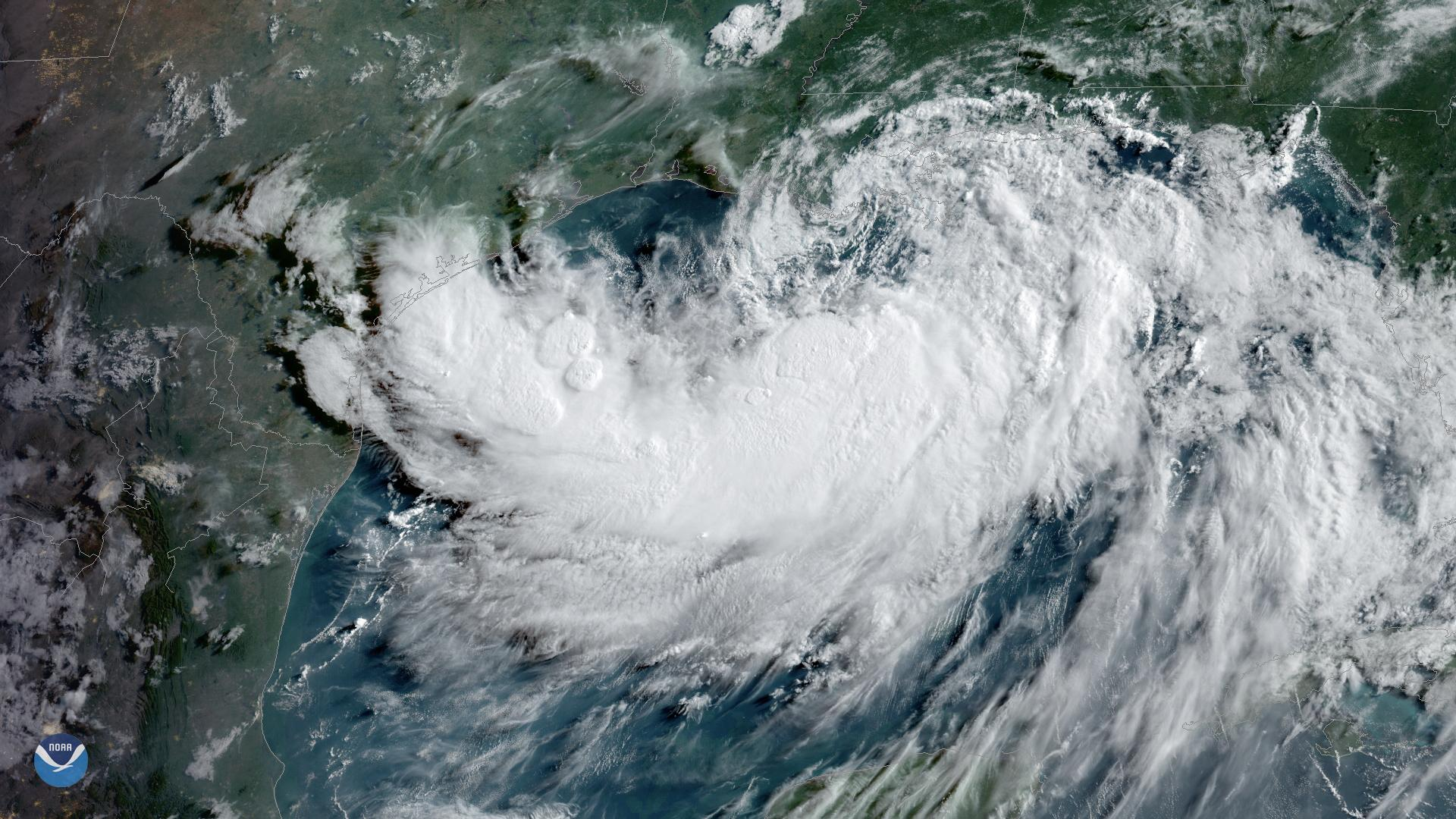
Consider **humanity**, navigating this mess, with

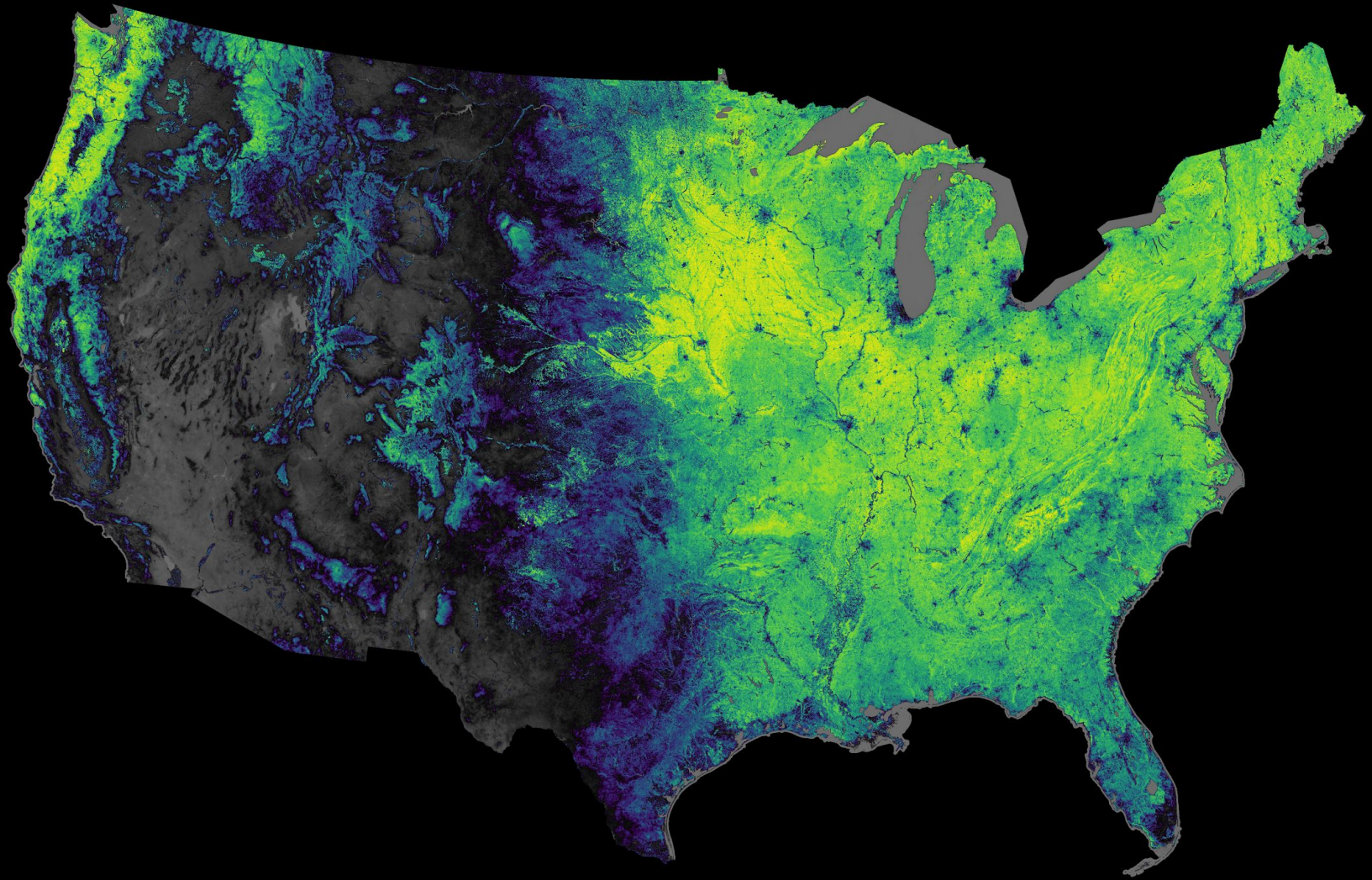
- Cameras (photons)
- Air sensors (molecules)
- Thermometers (temperature)

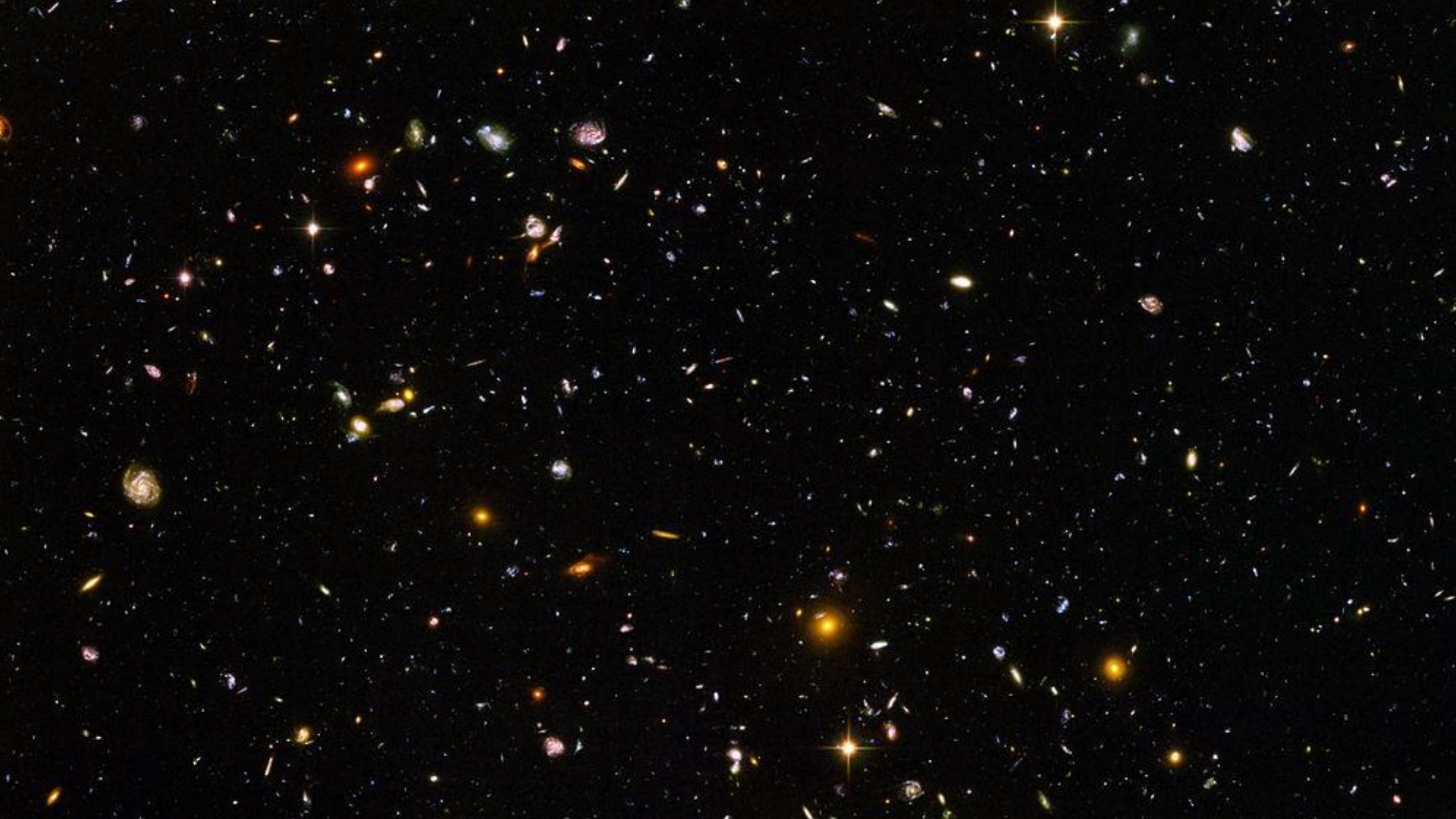
These **sensors** capture some specific, fleeting aspect of the world.

People+Computers use these inputs to build a **simplified, predictive model of the world**.

and ultimately,
to take action to affect the world.


NOAA

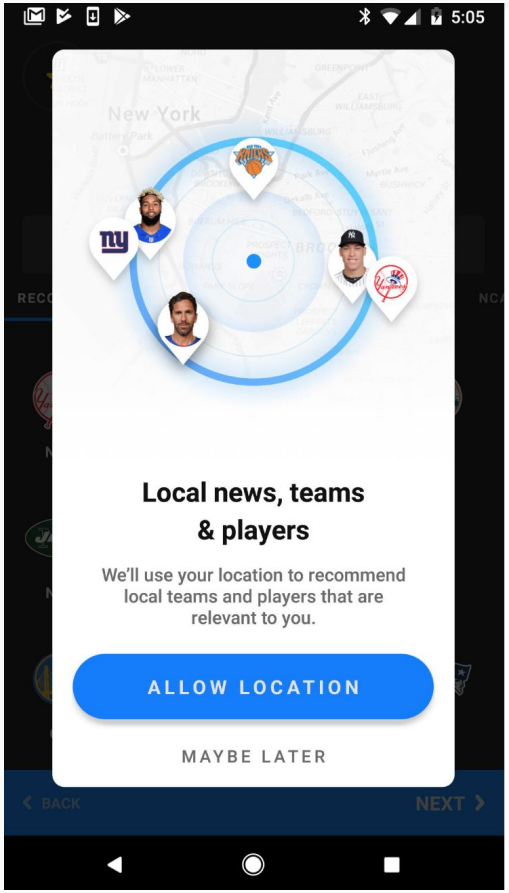


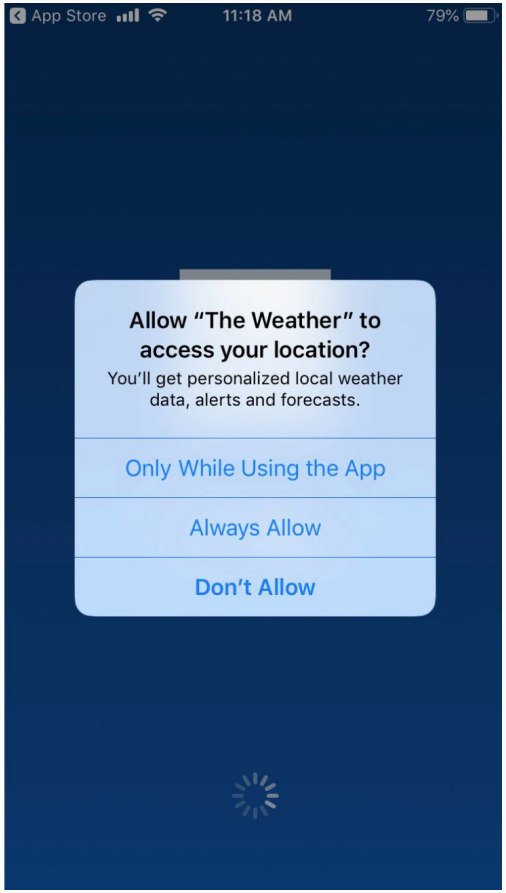


Sensors

Sensors (in space)

Cell phone geolocation





Cell phone geolocation

Data reviewed by The Times shows over 235 million locations captured from more than *1.2 million unique devices during a three-day period in 2017*.

Your Apps Know Where You Were Last Night, and They're Not Keeping It Secret - NYTimes

Cell phone geolocation

Individuals can still be identified in “anonymized” geolocation data.

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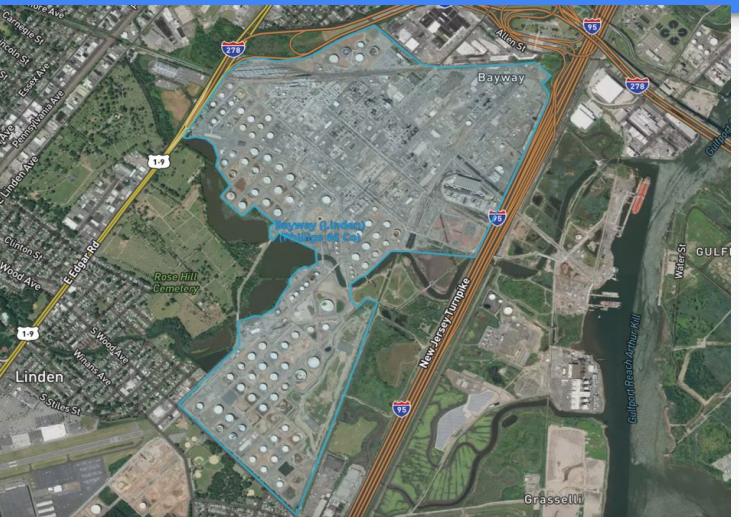
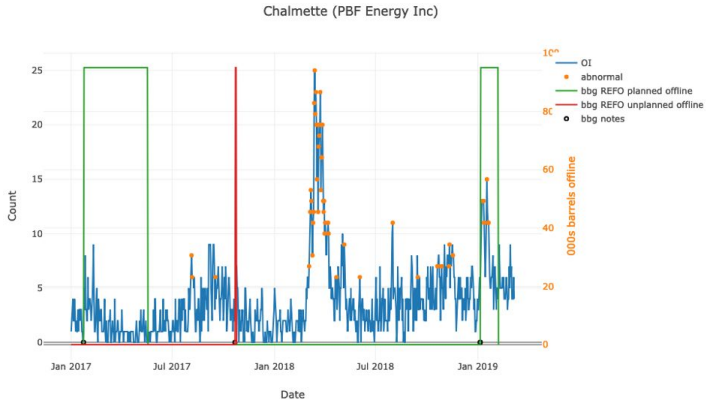




Orbital Insight

Count cell phone pings at every oil refinery.

Look for unscheduled downtime that will reduce oil supply.

Sell this signal.

Challenge question: cell phone data

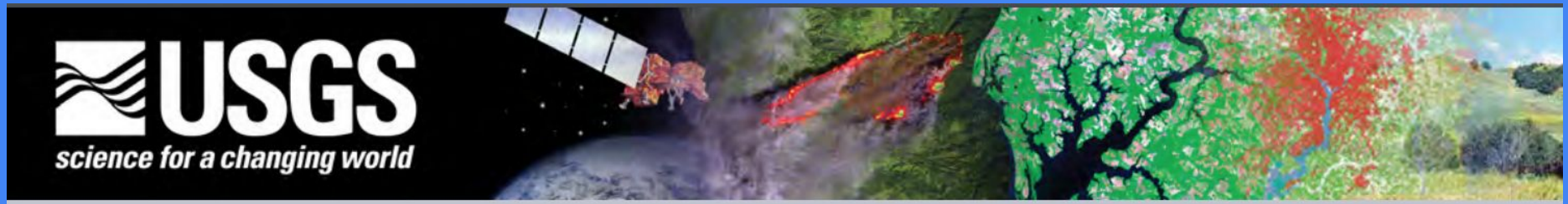
Consider three increasingly granular levels of cell phone data:

1) All counts at location A. (e.g. oil refinery)
2) All counts moving from location A to location B. (e.g. oil refinery to ship)
3) Full, unique-device information.

How could your research or work benefit from each level?
Where do you draw the line?

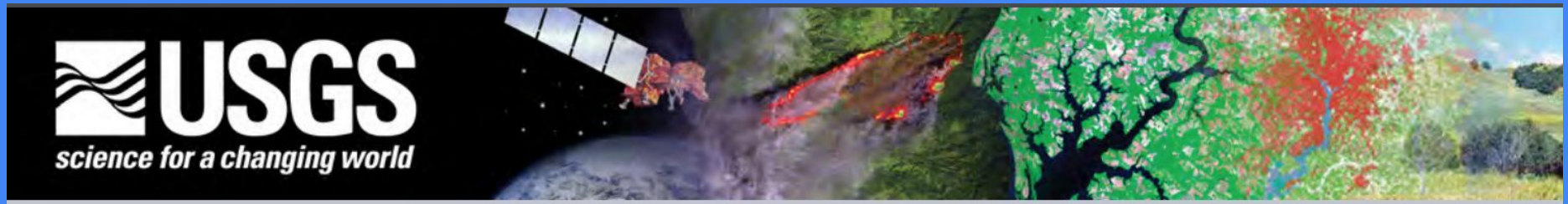
Sensors (in space)

Public satellites



Opening the Landsat Archive

On April 21, 2008, the United States Geological Survey (USGS) announced plans to provide all archived Landsat scenes at no charge to all users. By early December of that year, all Landsat data were available for free.



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And then, circa 2015, Landsat was moved into Google Cloud and AWS.

Public Satellites, a few examples

Sentinel-2

Sentinel-1

Sentinel-5

VIIRS Nighttime lights

ASTER

GOES-16

Public Satellites, a few examples

Sentinel-2: optical/infrared, 10-meters, every 5 days

Sentinel-1: radar from space (SAR), 20-meters, every 10 days

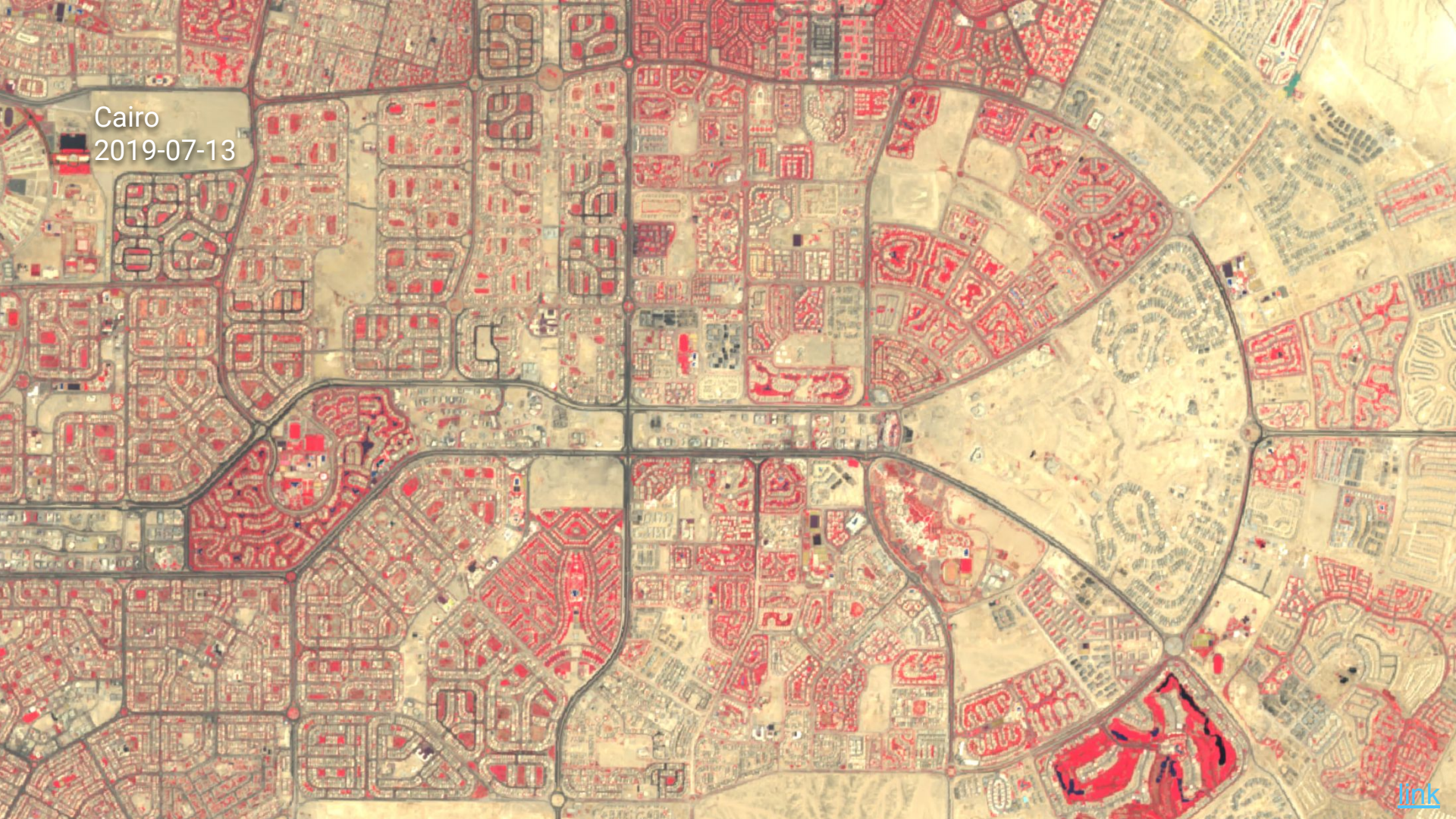
Sentinel-5: emissions from space, 7-km, every day

VIIRS Nighttime lights: 1-km, every day

ASTER: shortwave infrared, 30-meters, no longer taking data

GOES-16: optical/infrared, 3-km, every 5 minutes


Cairo
2019-07-13


Cairo
2019-07-13
link

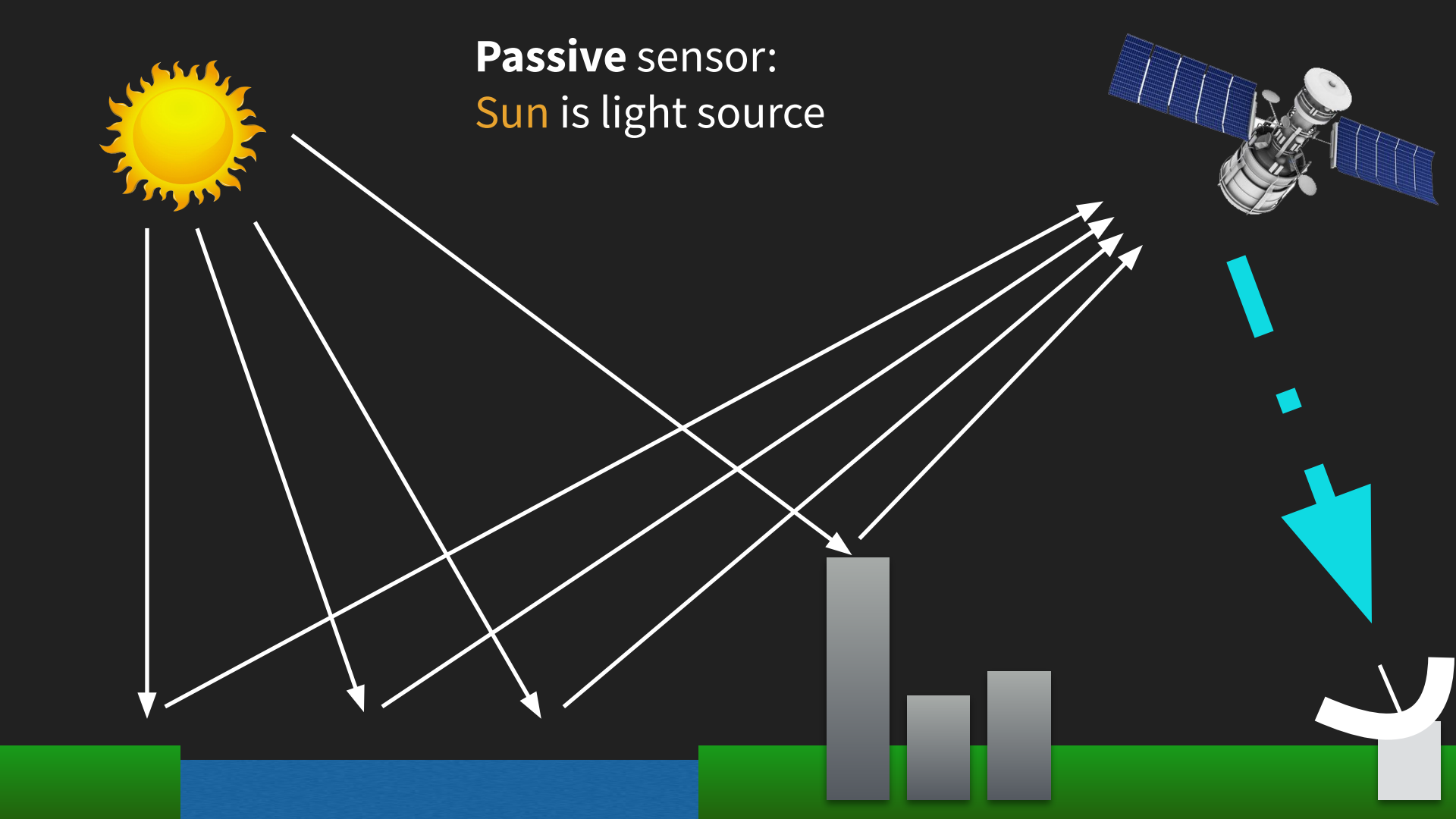

Cairo
2019-07-15
link

Seeing change

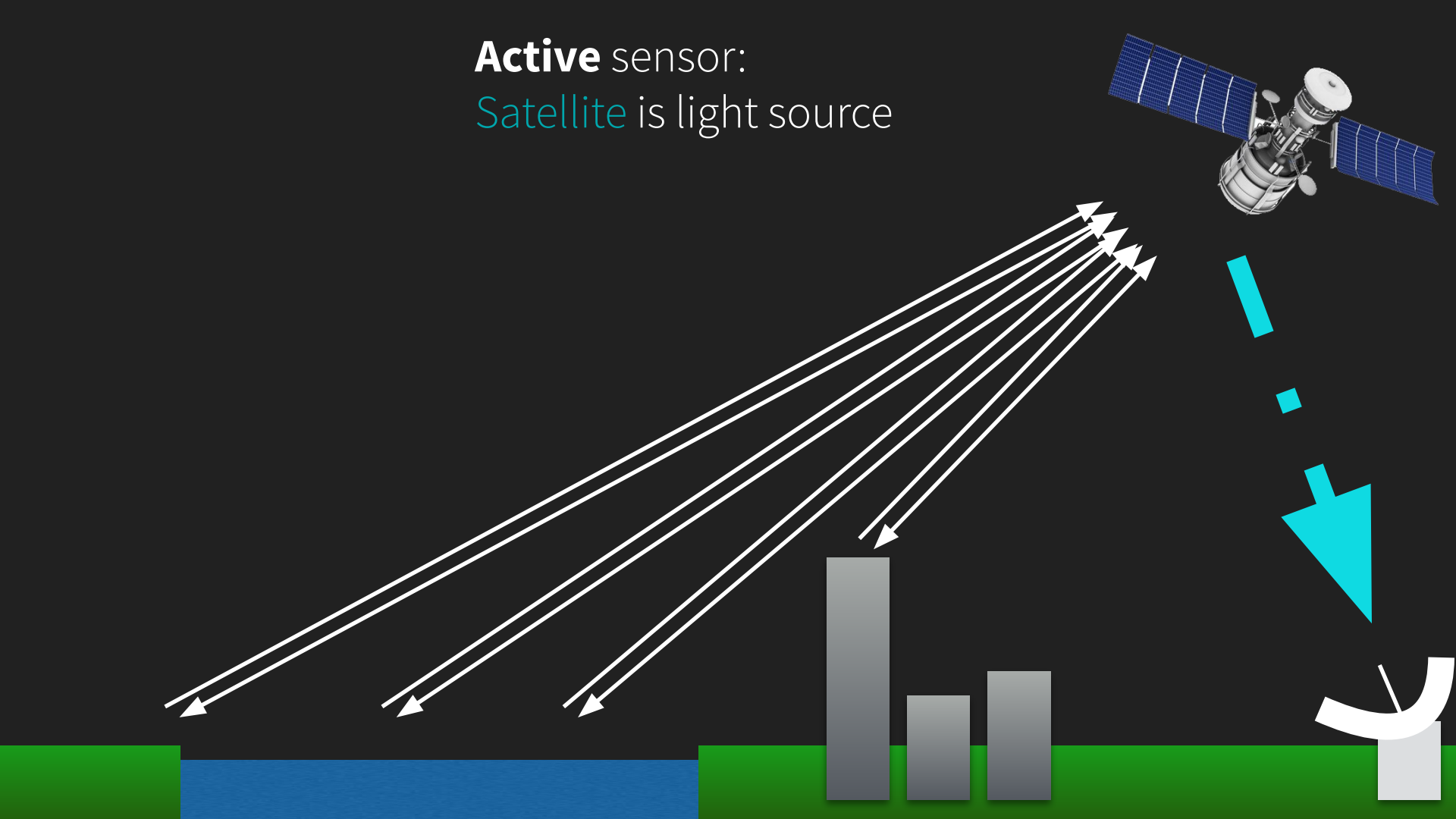
Check out Google Timelapse!

https://earthengine.google.com/timelapse/

Radar, from space


Passive sensor:
Sun is light source

Active sensor:
Satellite is light source



Radar, from space

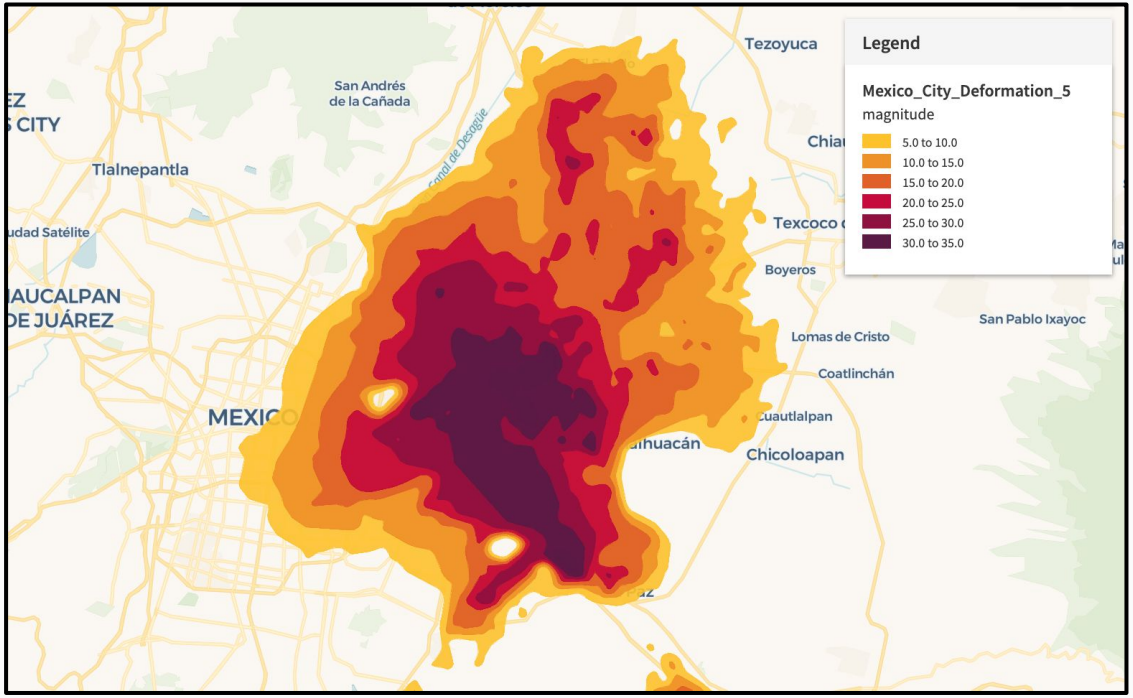
"InSAR" =
Interferometric
Synthetic Aperture Radar

Three key quantities:

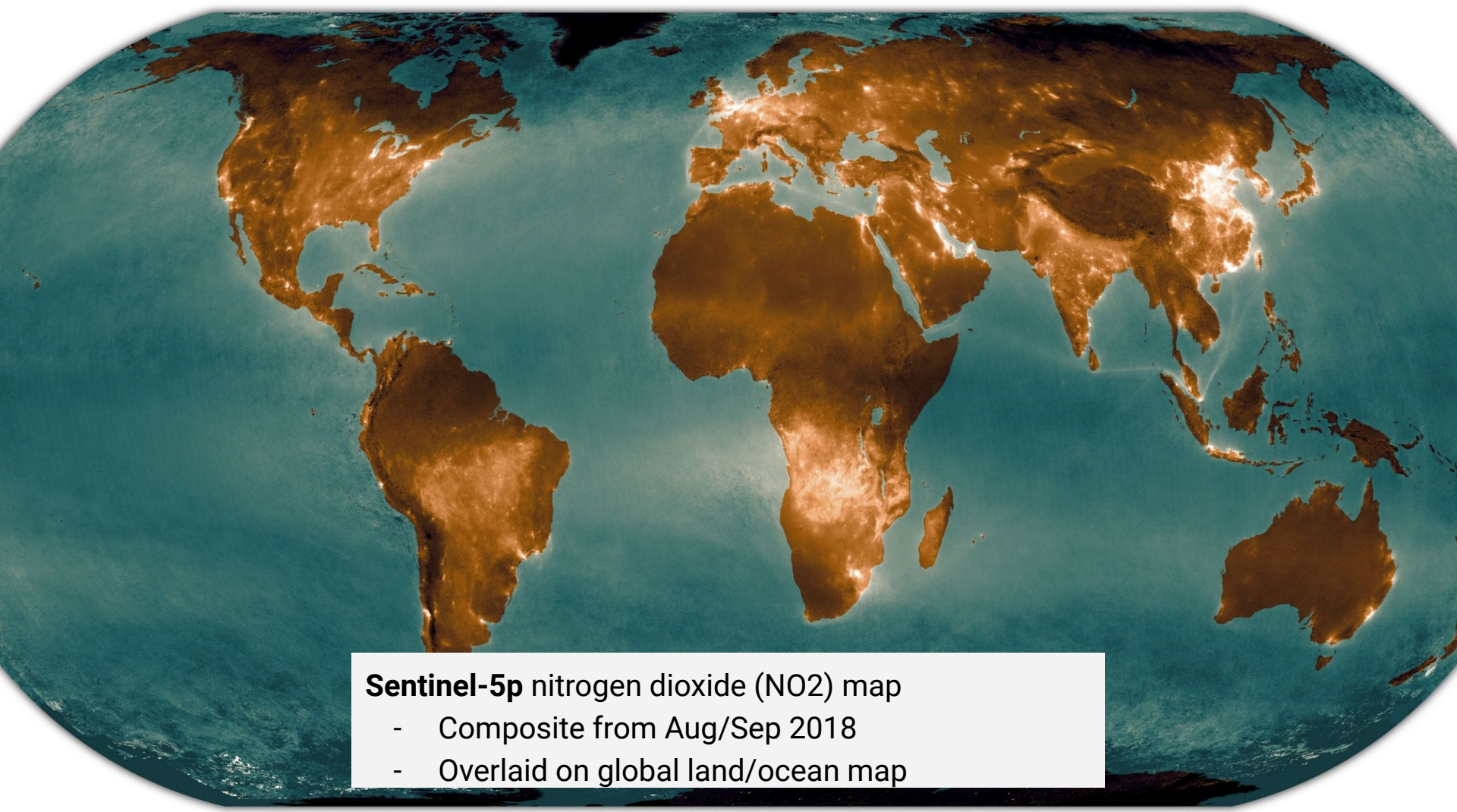
1) **Backscatter**: how much radar came back?

2) **Displacement**: how much did ground move since last time?

3) **Coherence**: how much did texture of ground change since last time?



Centimeter-level subsidence in Mexico City



Sentinel-5p nitrogen dioxide (NO2) map

- Composite from Aug/Sep 2018
- Overlaid on global land/ocean map

VIIRS Nighttime Lights

ASTER Shortwave Infrared
- sensitive to different mineral and geological formations

GOES-16

Weather satellite in geostationary orbit

Image of USA every 5 minutes (~kilometer resolution)

For example, Northern New Mexico

Private satellites

Private Satellites

And it’s getting easier

“Rocket Lab now delivers an all-inclusive spacecraft build and launch service that enables small satellite customers to focus on delivering their service...rather than building their own satellite hardware.

Our customers simply bring their payload or idea and we do the rest, taking care of the complete satellite design, build and launch as a bundled and streamlined experience.”

...and cheaper

Semantics

What kind of model?

Physical

Write down as much of the physics as you can.

Press go.

*Example: **emissions mapping**. Use 3d model of wind and atmosphere to invert the data observed emissions back to the ground.*

What kind of model?

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Press go.

*Example: **emissions mapping**. Use 3d model of wind and atmosphere to invert the data observed emissions back to the ground.*

Statistical

Could be “fitting a line”

Could be “statistical outlier”.

Could be a machine learning algorithm.

*Example: find all of the **power substations** in the world using a deep learning computer vision model.*

What kind of model?

Physical **Statistical**

In practice, this is a spectrum,
and most useful models use a hybrid approach.

Clouds and Cloud Shadows

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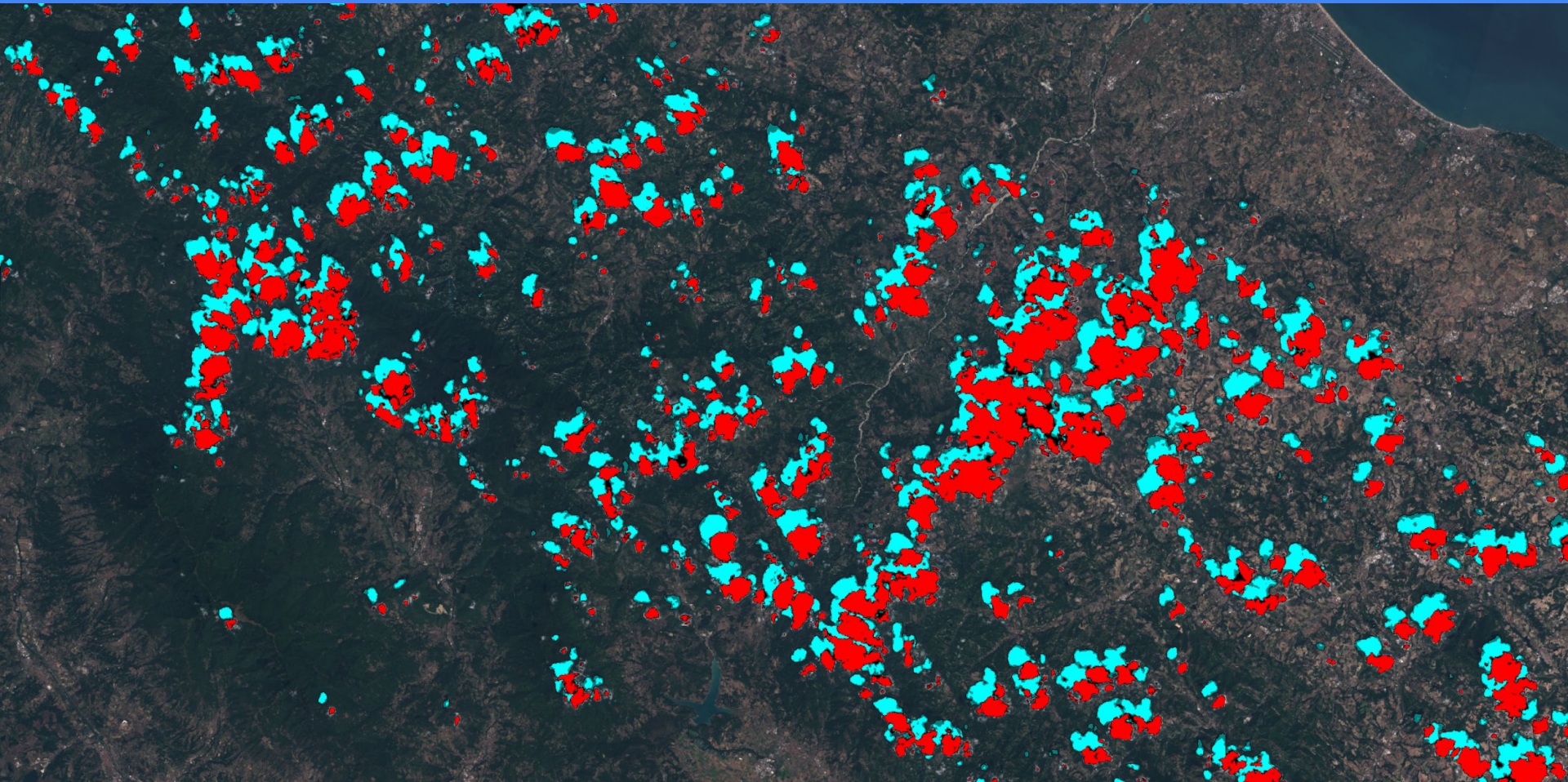
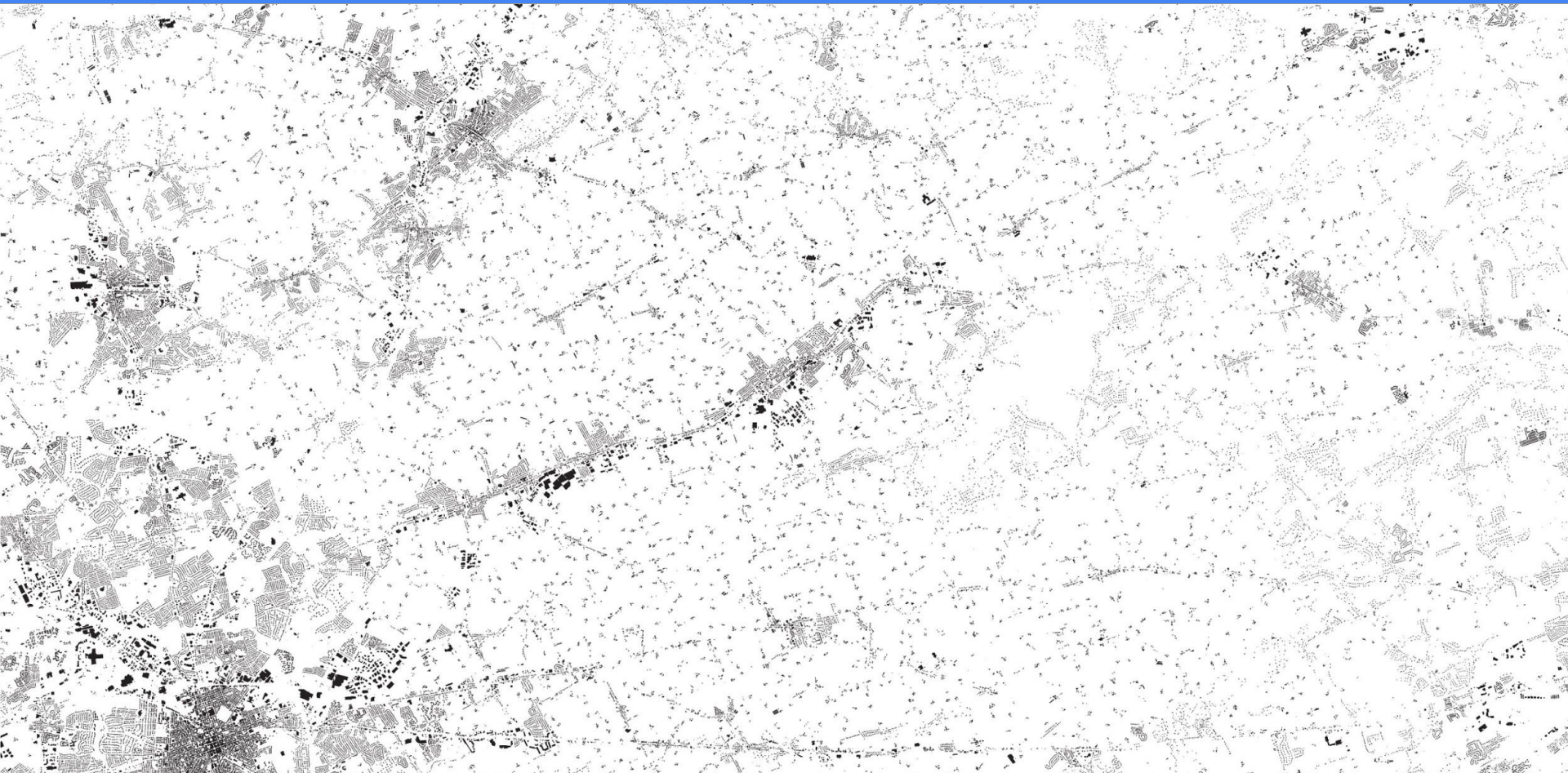


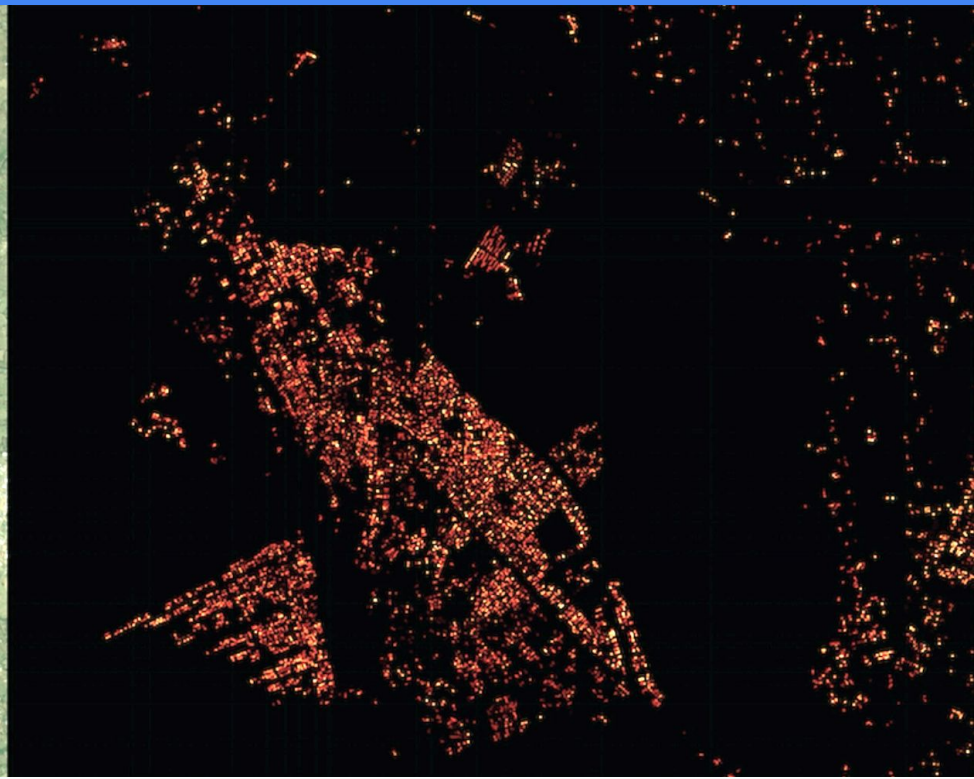
Water

Buildings

Microsoft Buildings, via NYTimes



Population Density



Population Density

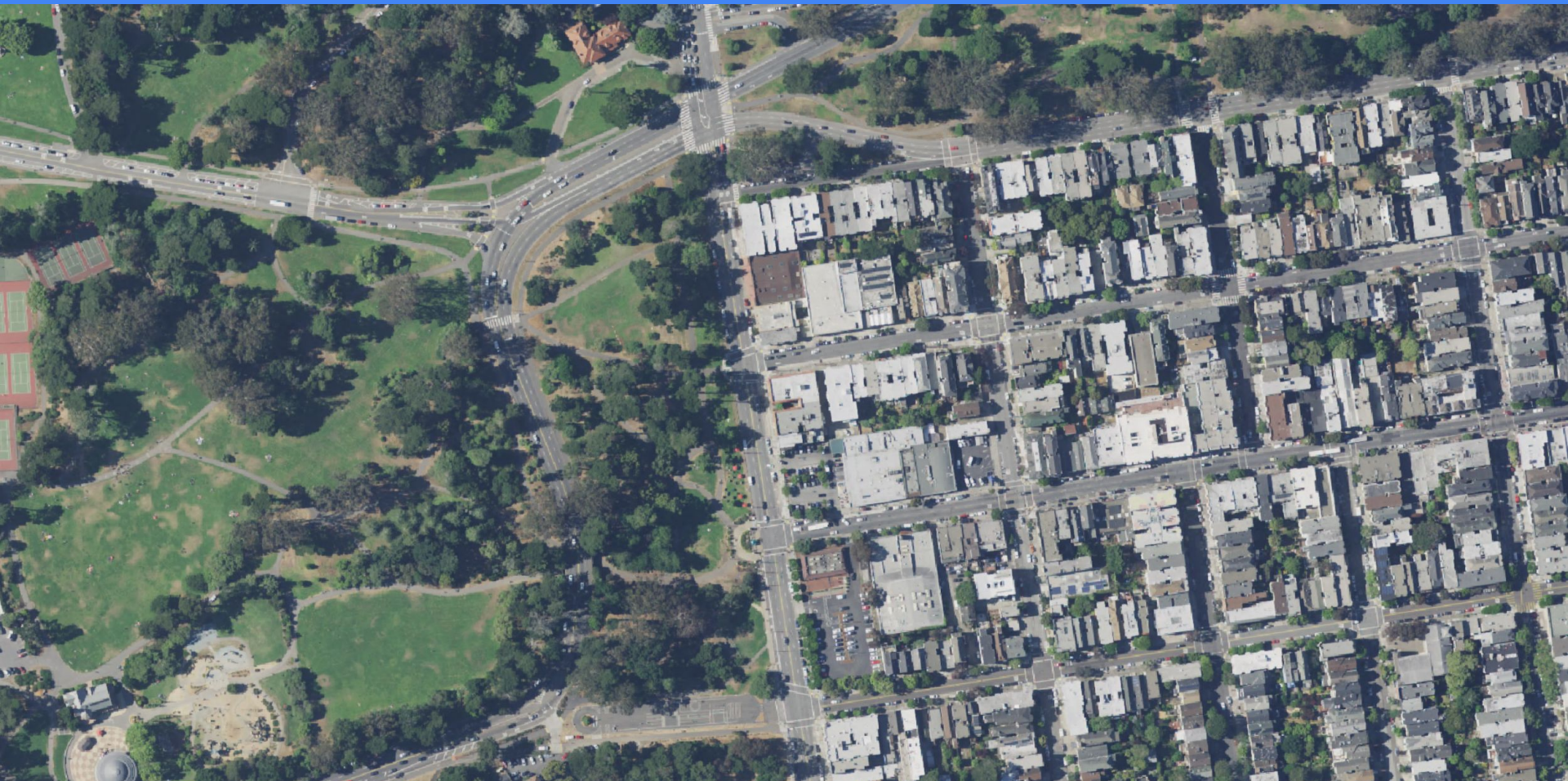
Challenge question: bias in sensor data

Sensor datasets are “objective”, but they have potential sources of bias. Examples:

- Homes in Africa don’t look like homes in USA.
- Nightlights: not all communities
- Cell phones: not everybody has a cell phone.

Think of a problem that is important to you that could be addressed by sensor data. What are potential sources of bias?

Trees



Trees


Toulouse
Paris
Tucson
Moscow
Naples
Nairobi
Mumbai
Urban Trees

High-resolution landcover

High-resolution landcover

Infrastructure: **substations**, wind, solar

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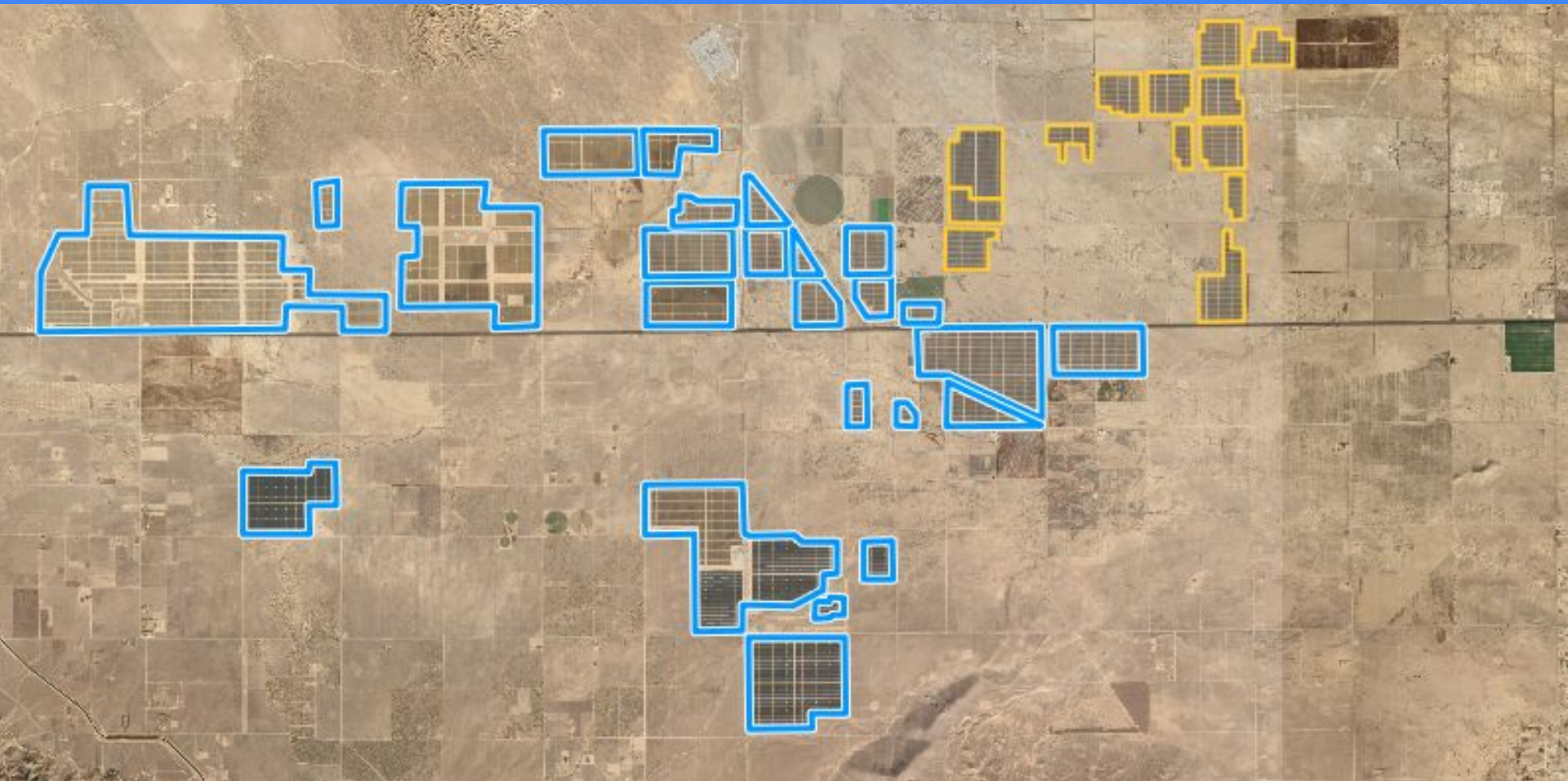
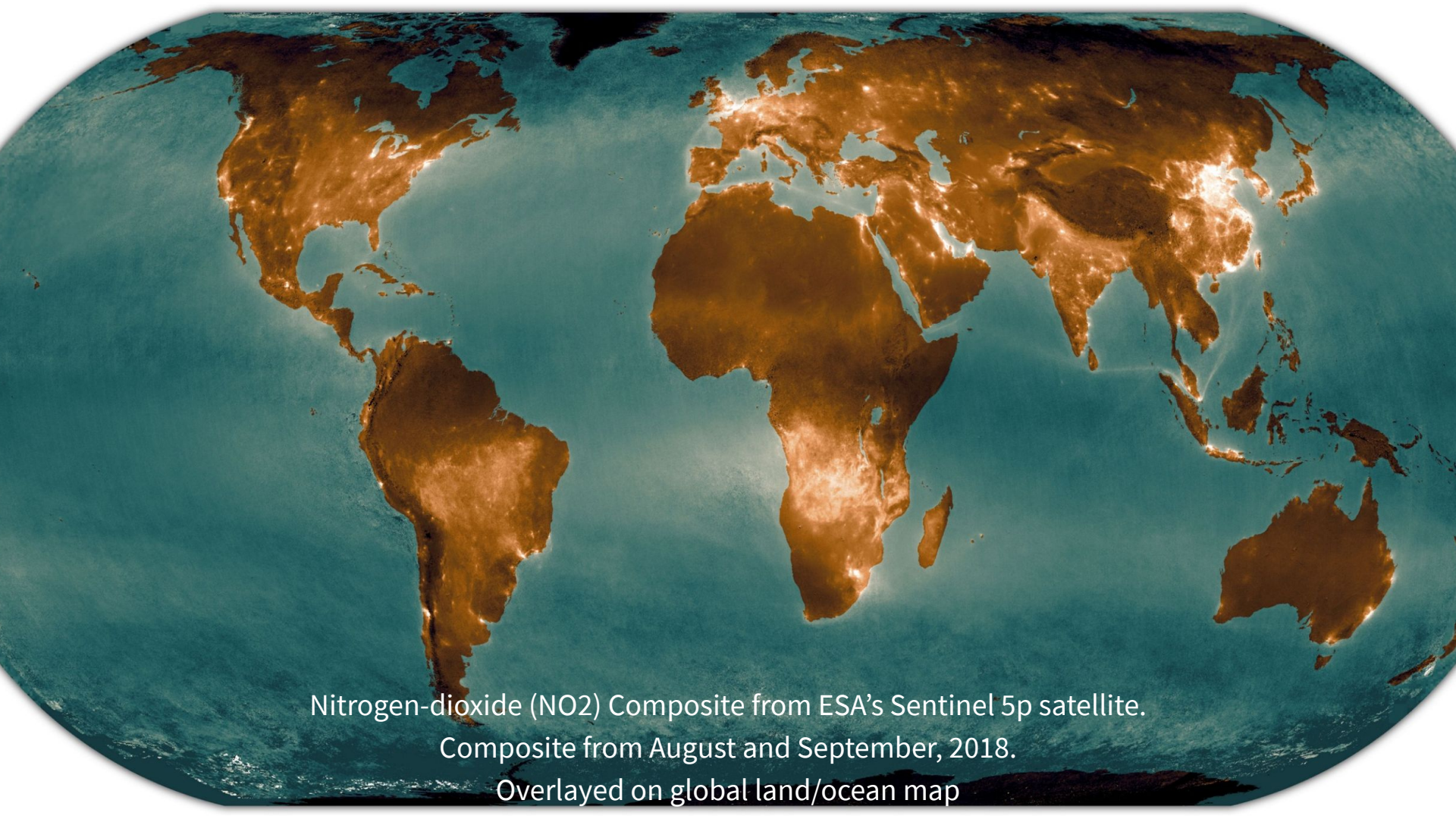
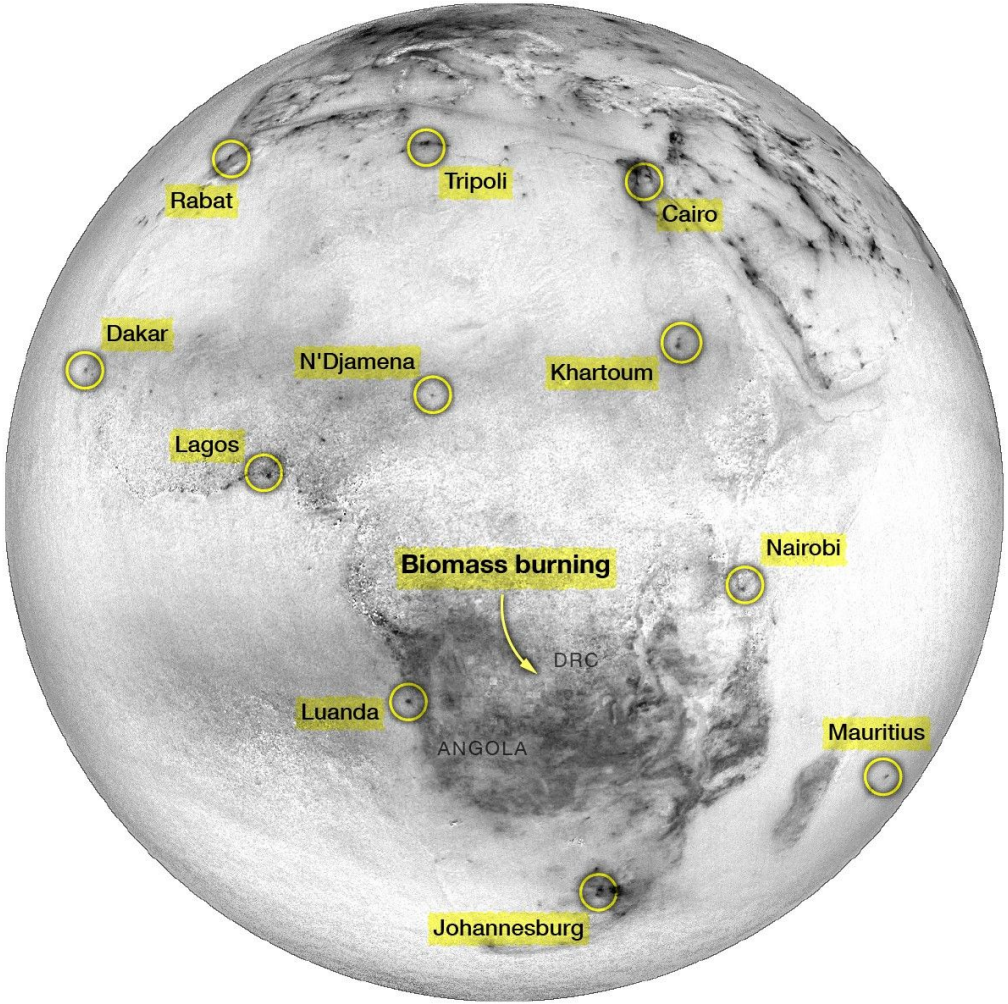
Infrastructure: substations, wind, **solar**



Infrastructure: substations, wind, **solar**

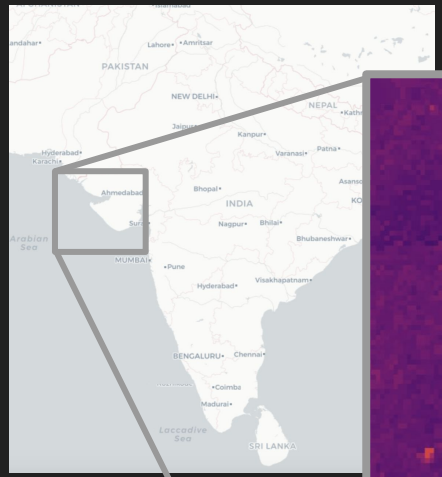


Nitrogen-dioxide (NO2) Composite from ESA's Sentinel 5p satellite.
Composite from August and September, 2018.
Overlayed on global land/ocean map

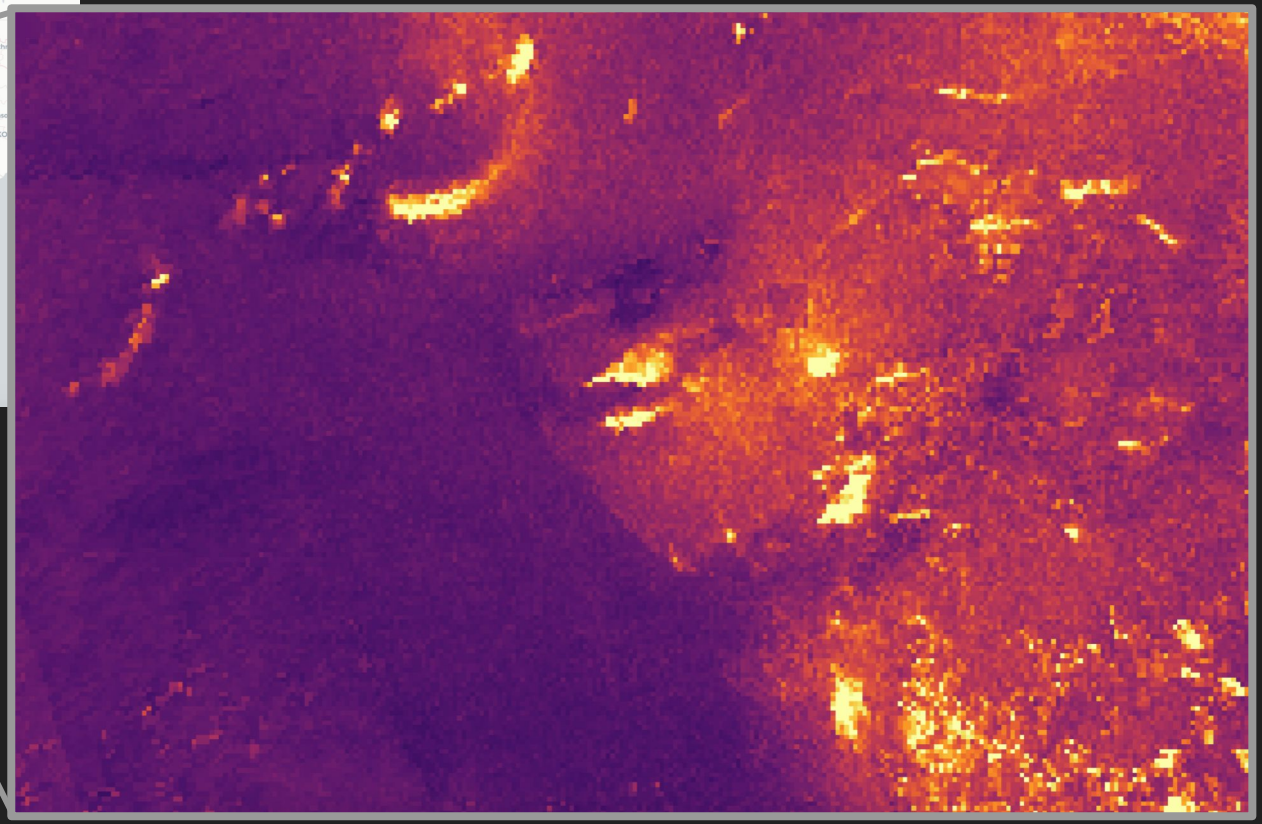


https://medium.com/descarteslabs-team/what-we-burn-creates-an-eerily-navigable-map-of-earth-5e02fbe39f58

Pollutants & Greenhouse Gases (NO2, SO2, CH4, etc)



NO2 density over Northwestern India (Sentinel-5p)



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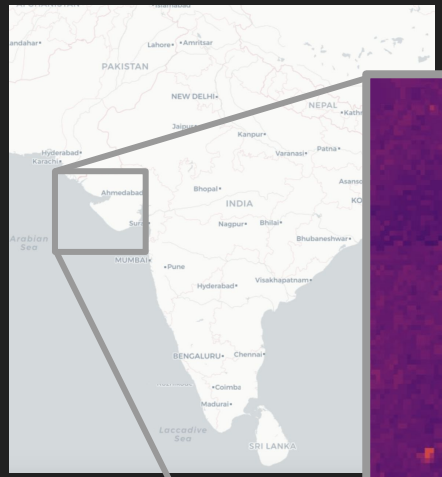

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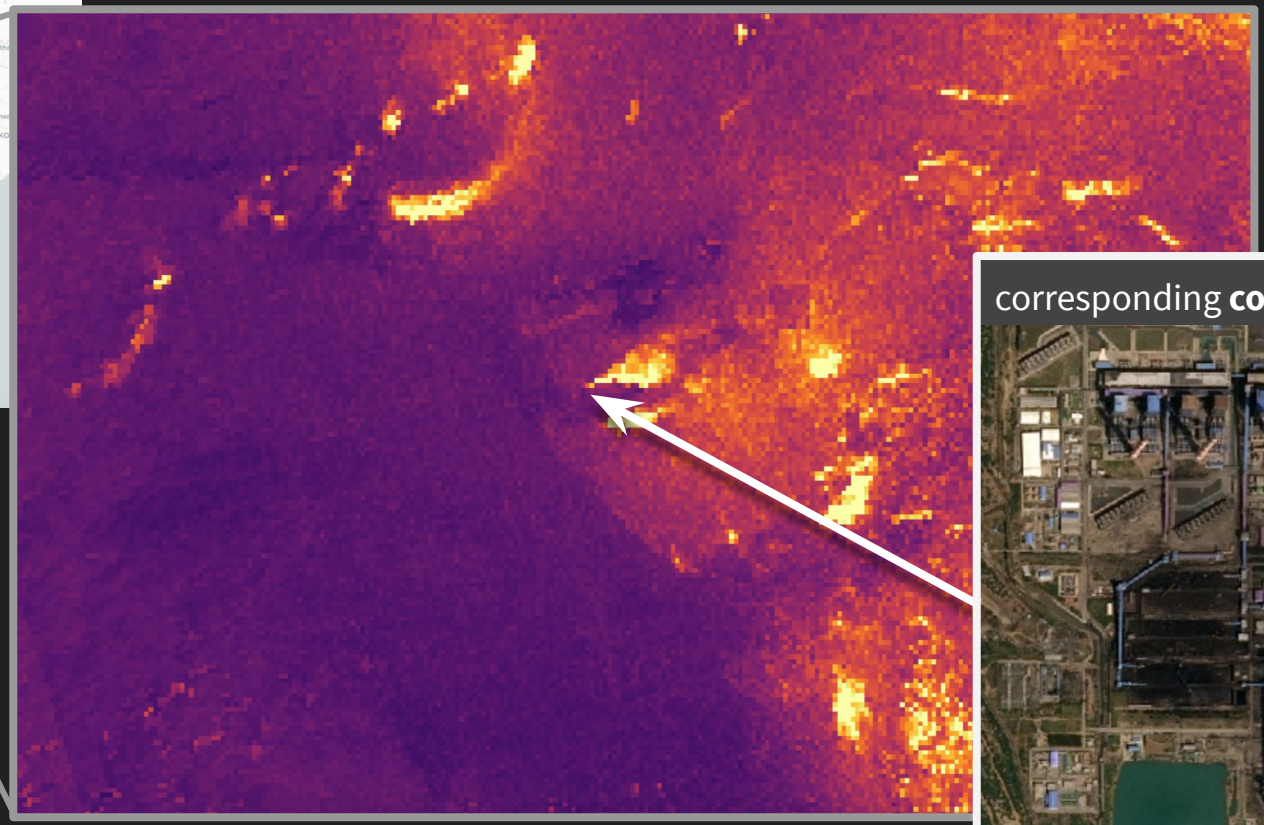
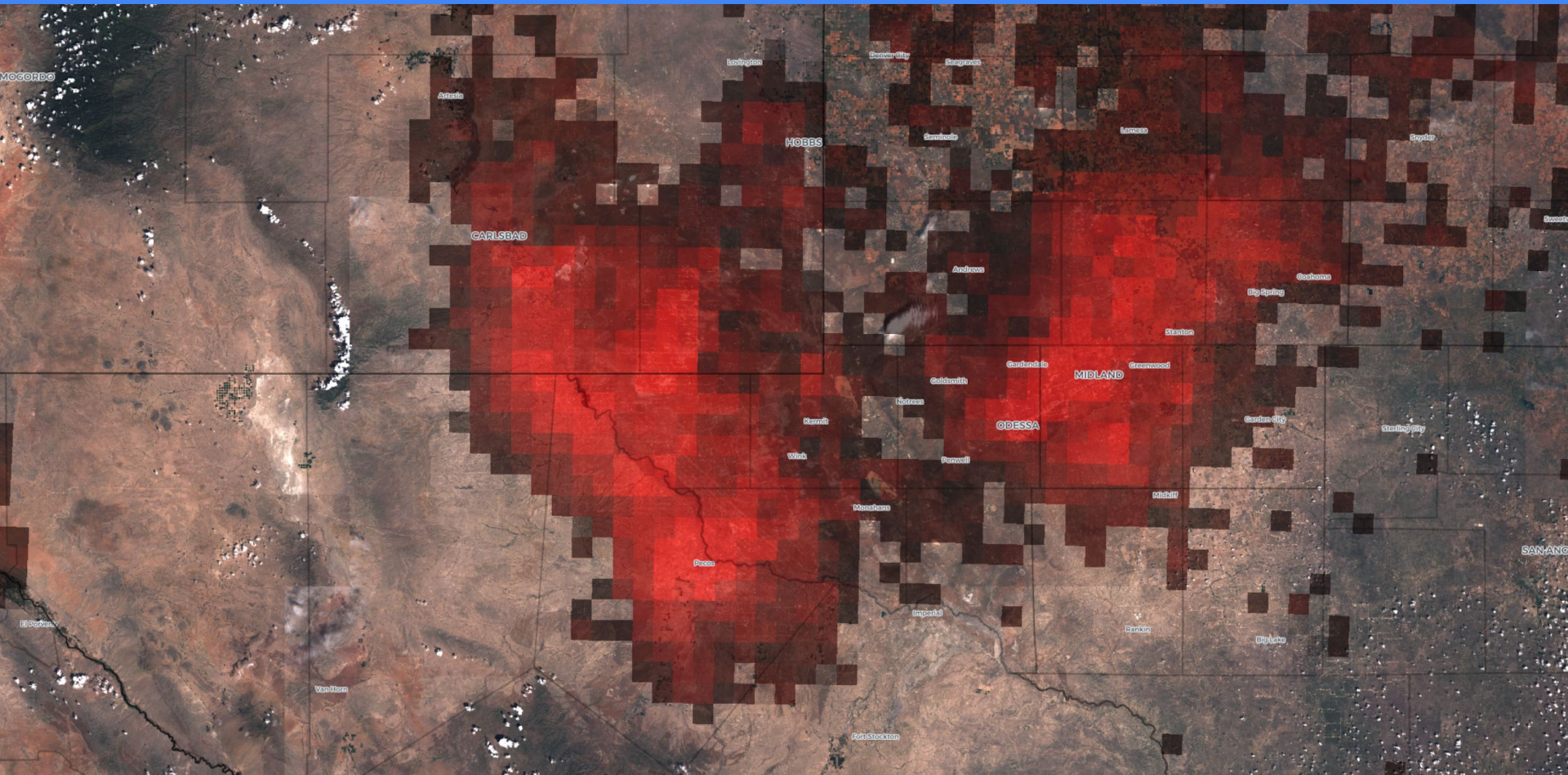


corresponding **coal power plant**

Methane from Oil & Gas Infrastructure



Wildfire Detection and Alerts

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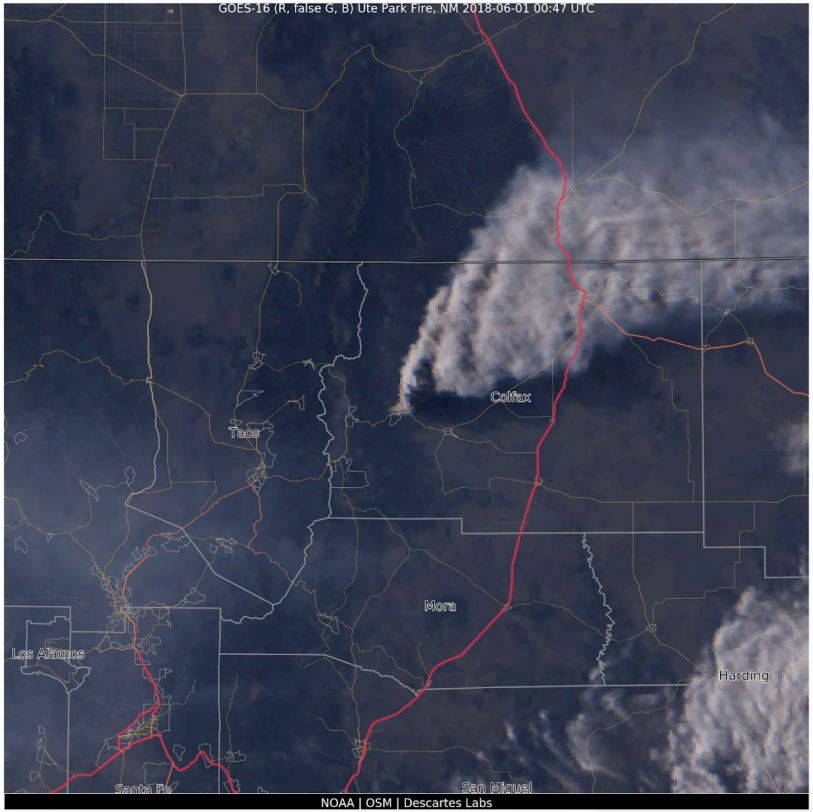

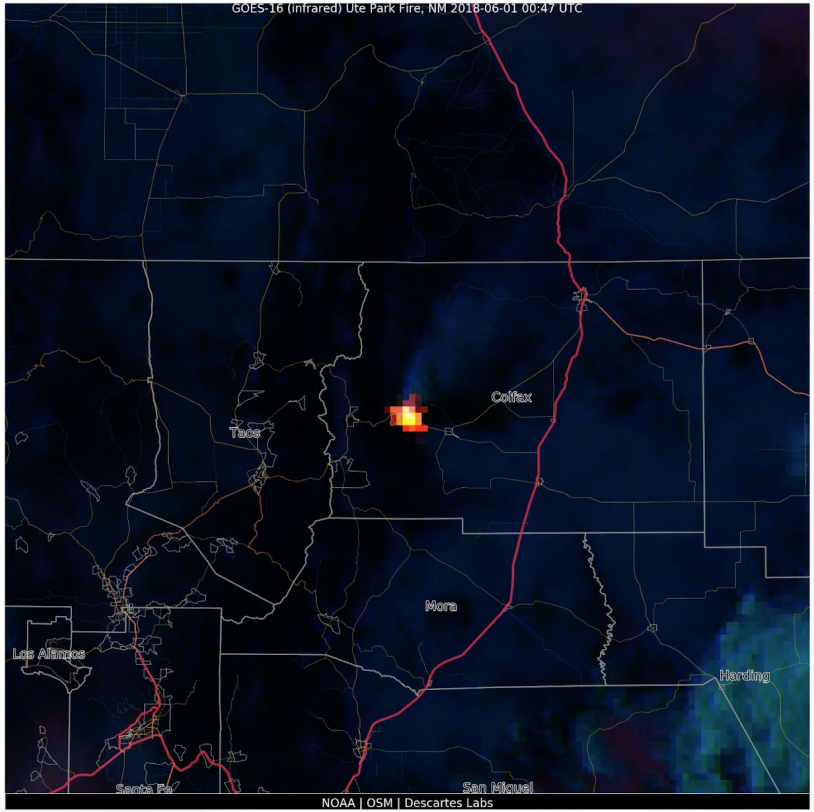

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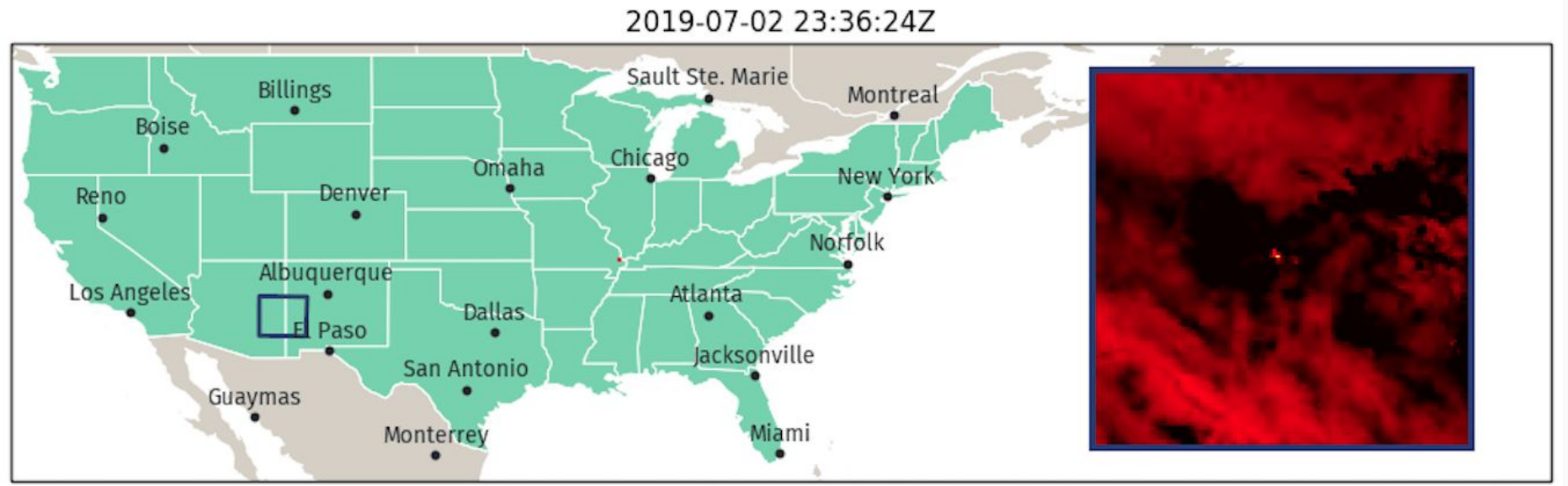

Thanks!

ryan@descarteslabs.com
@RyanKeisler