Airborne Networks and Applications

Prof. David John Lary

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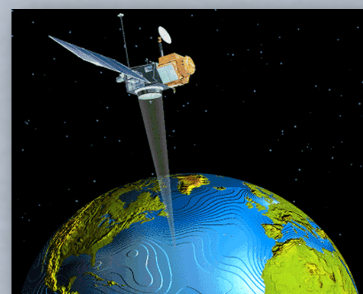
December 2014
Nanjing University of Aeronautics and Astronautics

Next Generation of High Speed Networks to Facilitate the Next Generation of Proactive Smart Health Care Applications

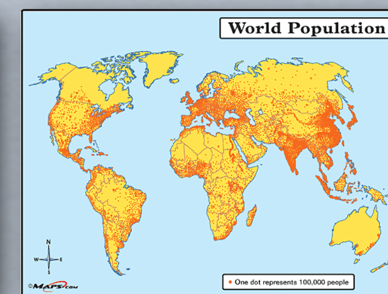
Local cloud computing coupled with widely distributed national and global sensor networks

Air Quality



Satellite Observations

Meteorological Analyses



Population Density

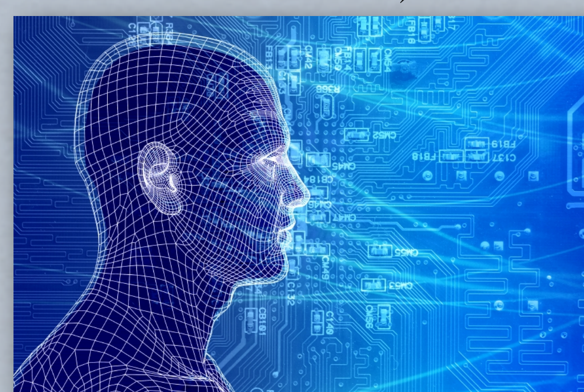
Social Media

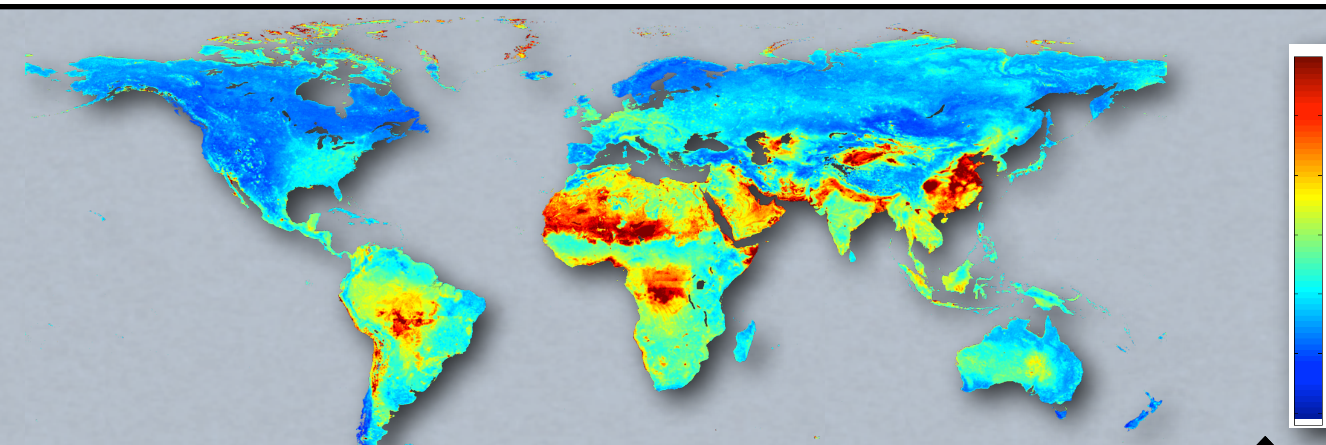
In-situ observations

Multiple global high-resolution datasets

Requires ultra-low latency gigabit to the end user

Combined Using Machine Learning to Provide a High-Resolution Global Products





Veteran's Administration
Country's Largest Health Care Provider

Combined with Electronic Health Records to provide:

1. Real time personal health alerts
2. Physician Decision Support Tools
3. Logistical Planning for Emergency Rooms
4. Improved Policy Decisions

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Next Generation of High Speed Low latency Networks to Facilitate the Next Generation of Smart Fire Detection & Water Conservation Applications

Requires ultra-low latency wireless gigabit for very-high resolution hyperspectral video imagery for real time flight control of aerial vehicles

11 drought-ridden western and central states have just been declared as primary natural disaster areas seriously threatening US food security. Further, every year between $1 and $2 billion dollars are spent on fire suppression costs alone.

A fleet of low cost aerial vehicles working together autonomously utilizing uncompressed very-high resolution hyperspectral video imagery. The geo-tagged imagery is streamed using high-speed low-latency wireless networks to communicate to a powerful cloud computing cluster running machine learning and image processing algorithms for real time direction of the optimal flight patterns, and the delivery of early warning for timely interventions.

Fire: Appropriate preemptive fire prevention can lead to massive savings in fire control costs, loss of life, and property damage.

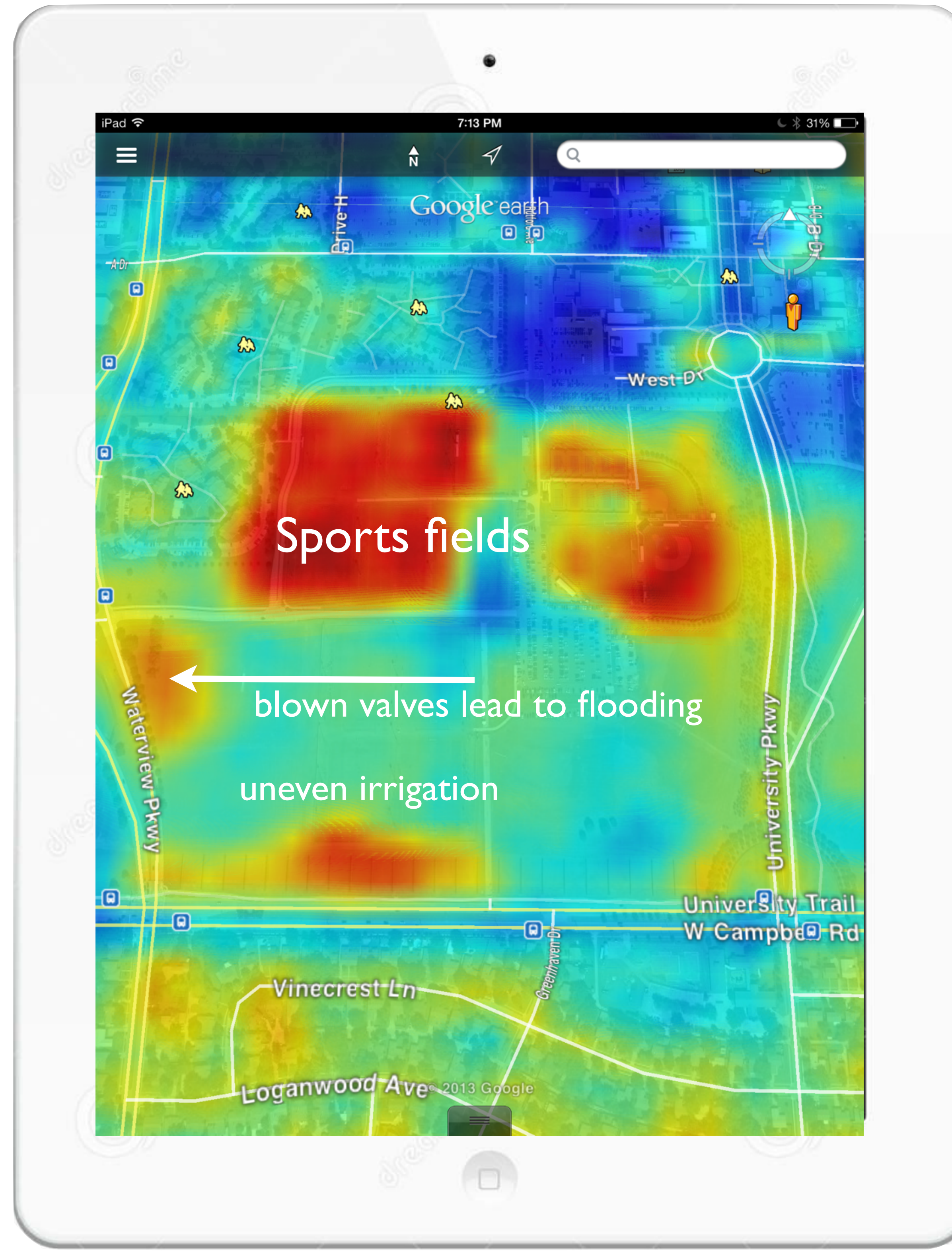
Agriculture: Appropriate and timely early warning of crop infestations, infections and/or water stress can

20 lb Airborne 385 channel hyperspectral imaging system

Prof. David Lary

Next Generation of High Speed Networks to Facilitate the Next Generation of Smart Water Management Applications

With Drought Disaster Declarations in 11 western and central states, smart water management is now more critical than ever for sustainable water conservation and US Food Security. Coupling high resolution remote sensing from satellites, with machine learning, and the next generation of high speed low latency networks is facilitating the next generation of smart water management systems. These systems will benefit individual home owners, farmers, corporate campuses, golf courses, etc. and allow optimum monitoring and control of irrigation using mobile devices.



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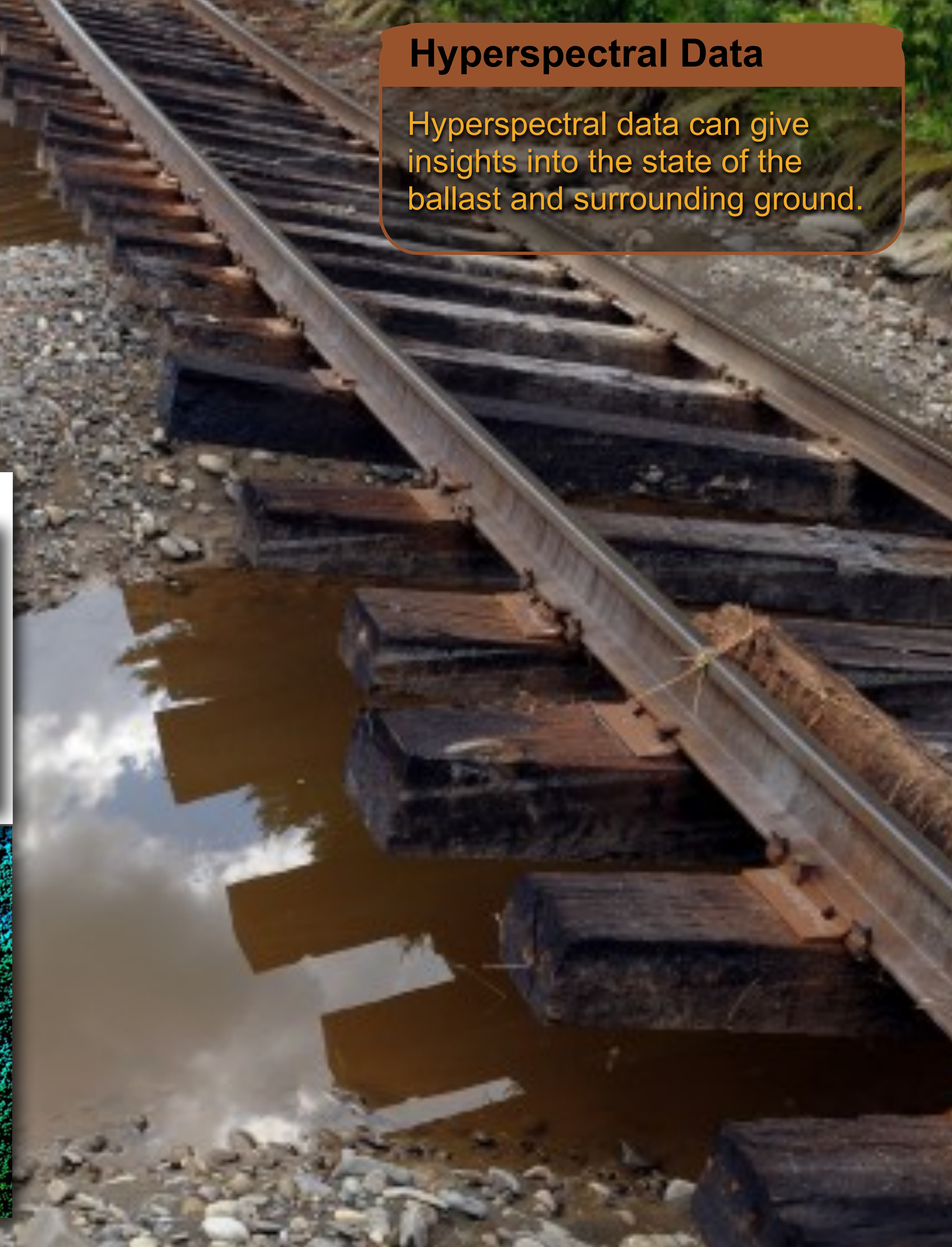
Combine Multiple Datasets

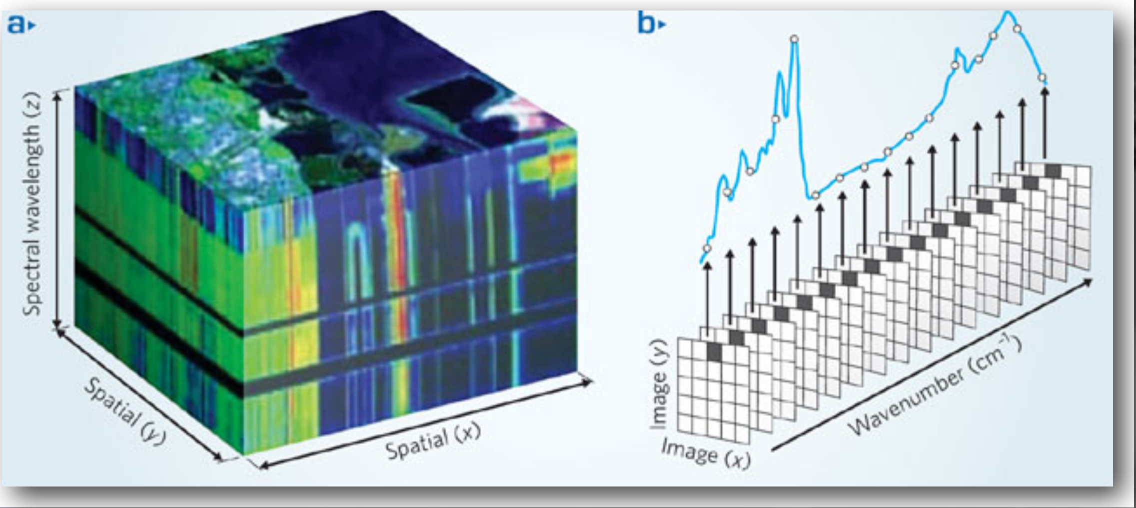
Combine historical track issue data and historical high resolution meteorological data with machine learning.

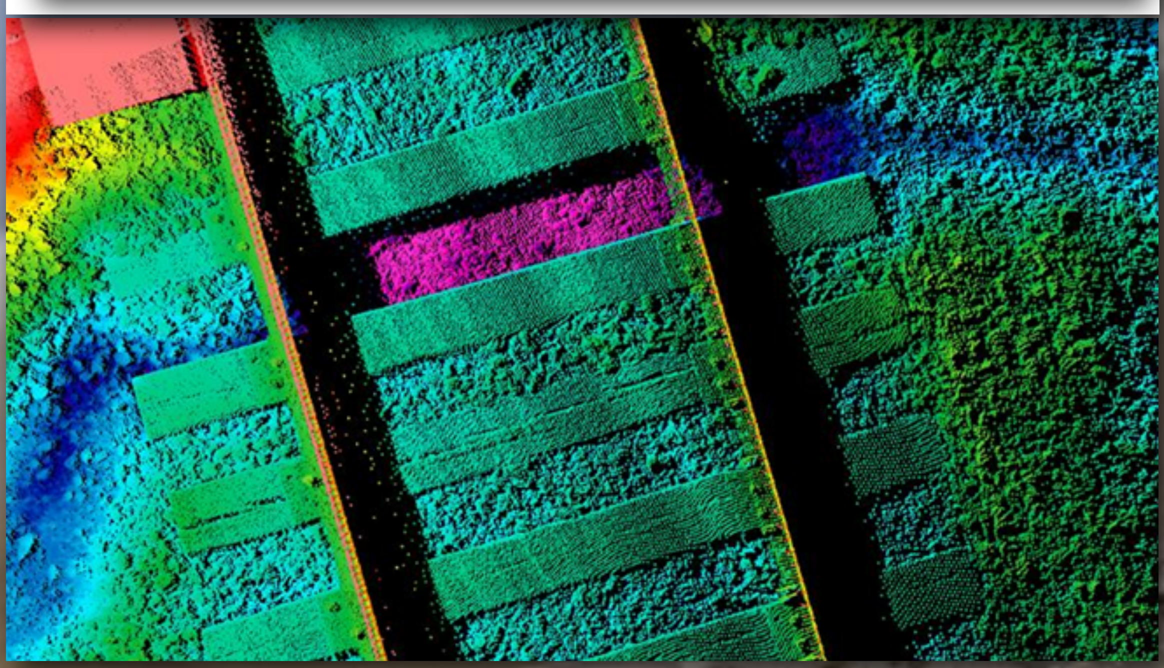
Hyperspectral Data

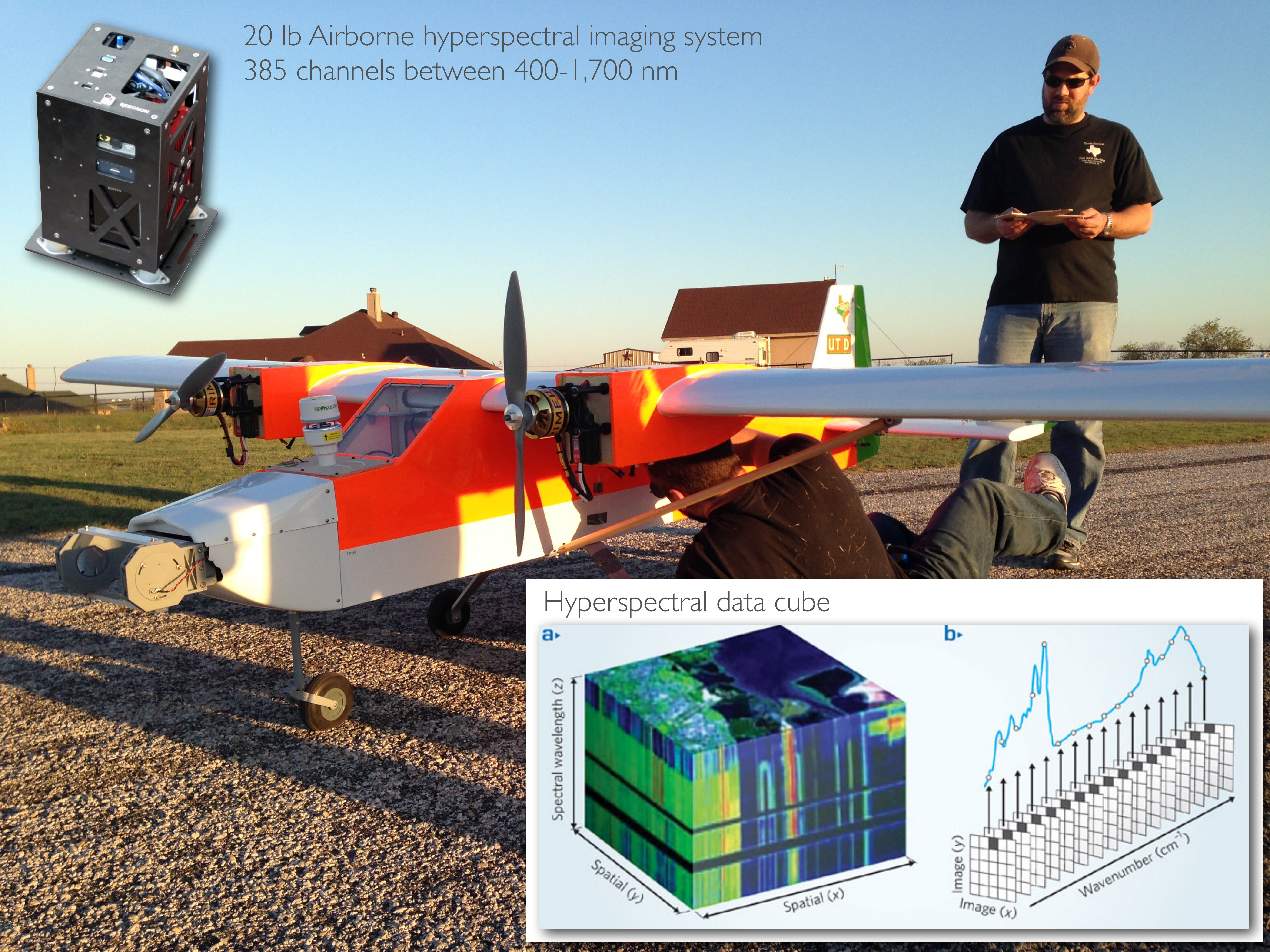
Hyperspectral data can give insights into the state of the ballast and surrounding ground.



Hyperspectral data cube

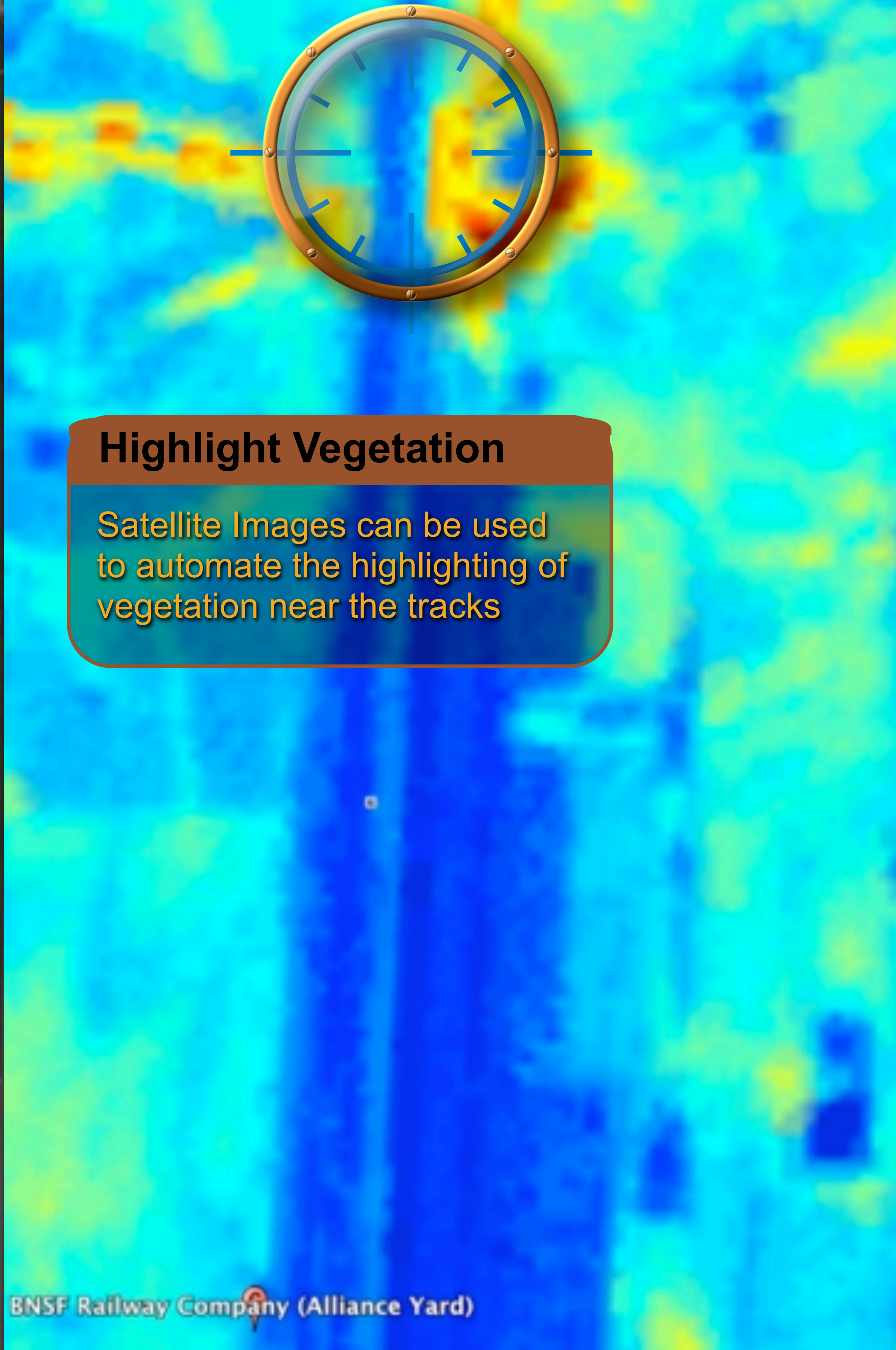





20 lb Airborne hyperspectral imaging system
385 channels between 400-1,700 nm
RESONON
UT D
Hyperspectral data cube
a
Spectral wavelength (z)
Spatial (y)
Spatial (x)
b
Image (y)
Image (x)
Wavenumber (cm⁻¹)


SAFETY
glee
AEROPOSTALE

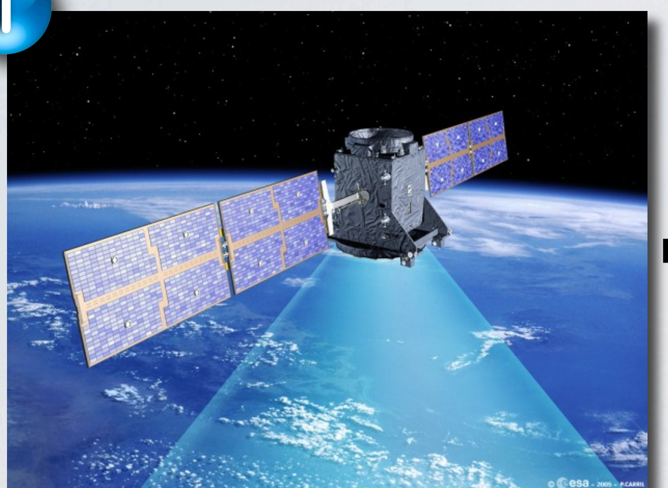

BNSF Railway Company (Alliance Yard)


Highlight Vegetation
Satellite Images can be used to automate the highlighting of vegetation near the tracks
BNSF Railway Company (Alliance Yard)

THRIVE

TRACK HEALTH INDICATORS USING REMOTE & IN-SITU OBSERVATIONS FOR THE VITALITY OF THE ENVIRONMENT

1



Routine satellite acquisition of multispectral and SAR imagery

2

Periodic high resolution ground truth from aerial surveys

3

Image processing & Machine Learning

4

BNSF Decision Support

Preparing for Routine Decision Support

The synergy between routine satellite imagery, periodic high resolution ground truth surveys and automated machine learning and image processing is a powerful combination for decision support.

Using Zero-Emission Aerial Vehicles in Support of the ACE Mission

Hanson Center for Space Sciences
Prof. David Lary

Using Zero Emission Aerial Vehicles in Support of ACE

PI: David Lary, University of Texas - Dallas

Objective

Address a key gap in existing validation capabilities for ACE by measuring the size distribution and vertical profiles in the boundary layer in the 100m closest to the surface using a small aerial vehicle. The project will

- Demonstrate feasibility of using zero emissions remote control aircraft for satellite validation
- Determine if a key gap in existing validation capabilities for the Aerosols, Cloud systems, ocean Ecosystems (ACE) can be filled with this technology
- Develop proper size distribution and vertical profiles of aerosols in the boundary layer 100m closest to the surface for ACE mission

The model aircraft is equipped with a full suite of meteorological instruments for temperature, pressure, humidity, wind speed and direction as well as an EPA certified Grimm Model 1.109 Aerosol Spectrometer & 1.320 Nano Check which provides extremely precise size distributions within the size range 12 nm - T 32 µm in 43 size channels.

Approach

Major tasks include:

- Characterize surface variability of aerosol size distribution and abundance across the ACE footprint (250 m resolution) using a Grimm Model 1.109 Aerosol Spectrometer & 1.320 Nano Check and a full weather station measuring temperature, pressure, humidity, dew point, and wind speed and direction
- Integrate the Grimm Spectrometers and full weather station into the model aircraft
- Fly at a range of locations and times to demonstrate the ability to characterize the aerosol size distribution and vertical profiles in the boundary layer in the 100 m closest to the surface

Co-Is/Partners

None

Key Milestones

•Characterize surface variability of aerosol size distribution and abundance across the ACE footprint	8/14
•Integrate aerosol spectrometer into the model aircraft	10/14
•Fly at a range of locations and times to demonstrate the ability to characterize the aerosol size distribution and vertical profiles	6/15

$TRL_{in} = 5$ $TRL_{current} = 5$

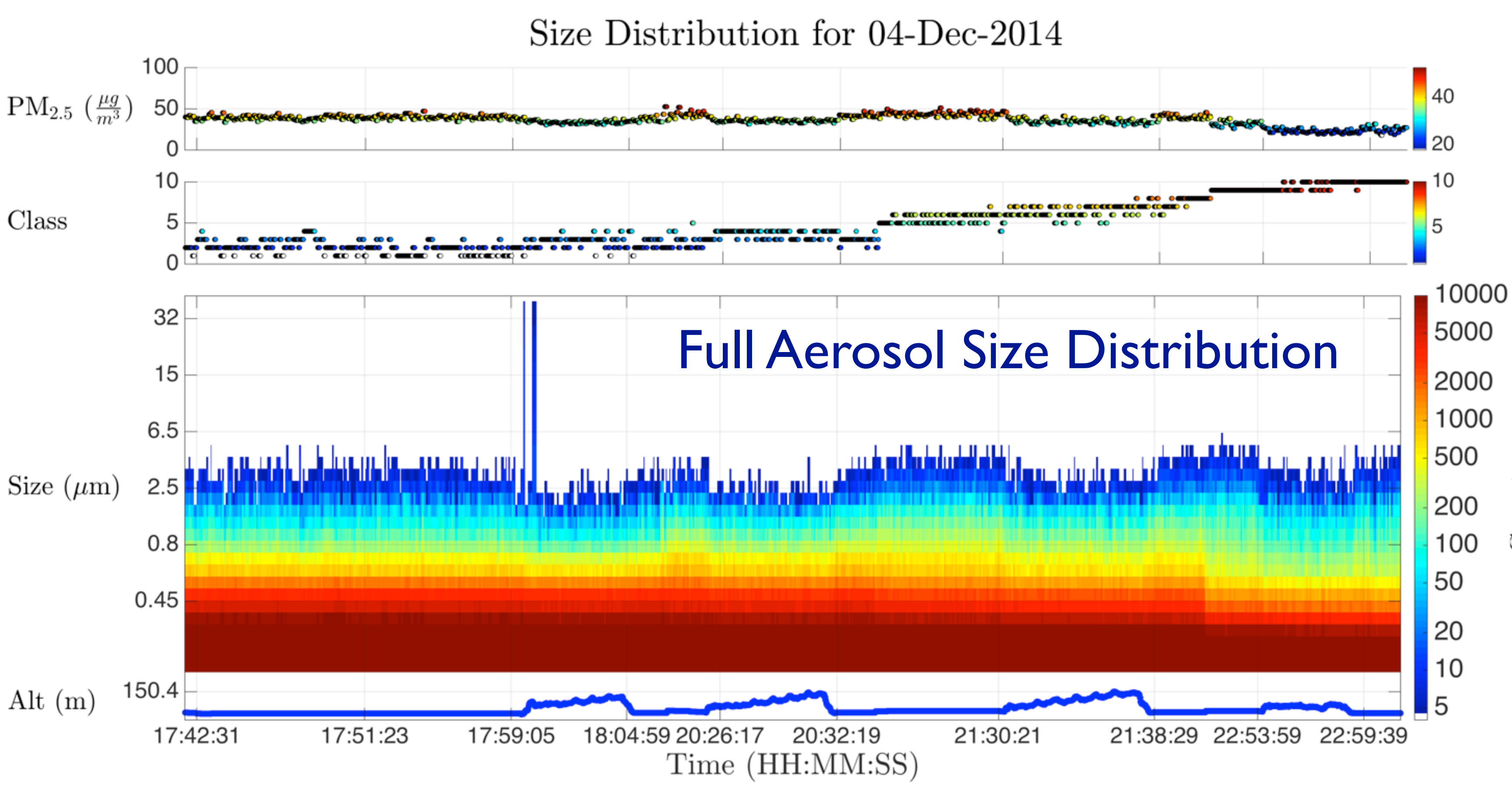
Flight Photos

Flight Photos

Accomplishments

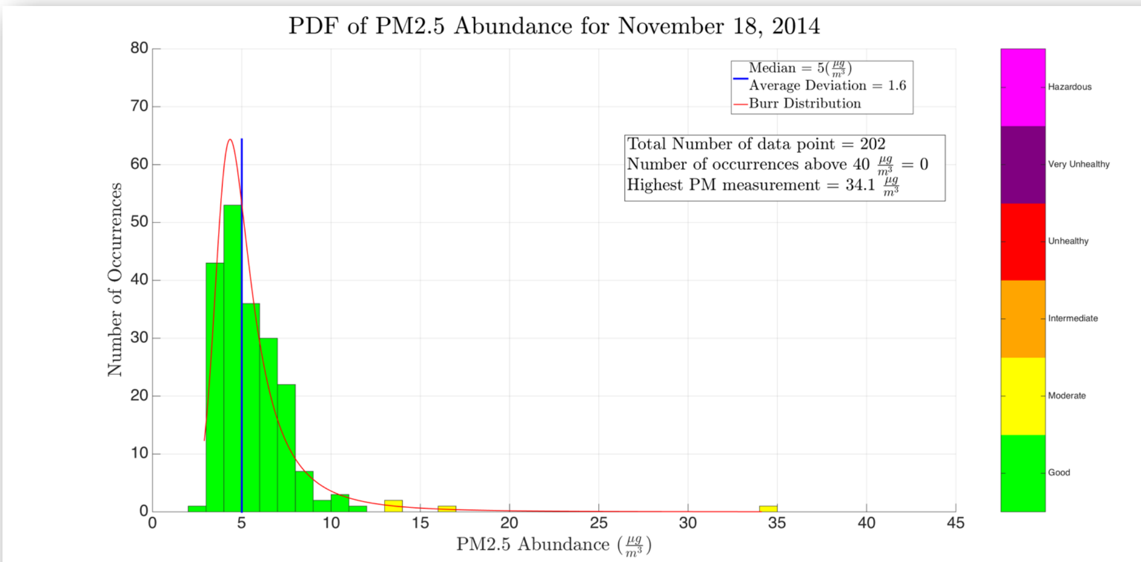
To the best of our knowledge the *first time* the **full sub-pixel aerosol size distribution has been characterized at high spatial resolution** (sub meter) **and high temporal resolution** (every second) using:

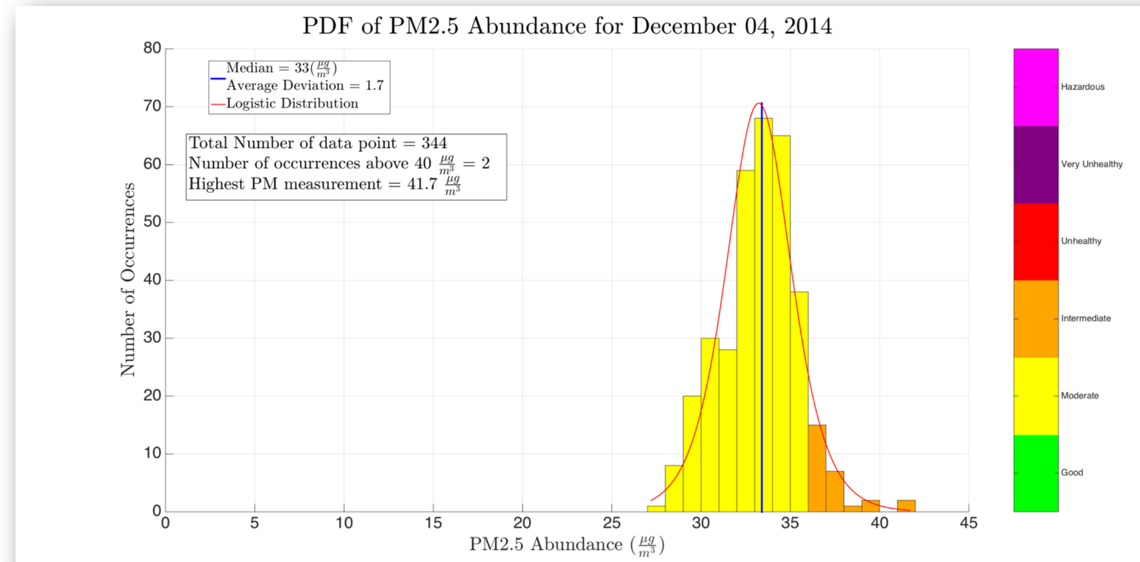
- A zero emission, low cost, electric remote control model aircraft at multiple vertical levels in the lower most 100 m of the atmosphere.
- A car driving daily across a 10 km pixel over an extended period.



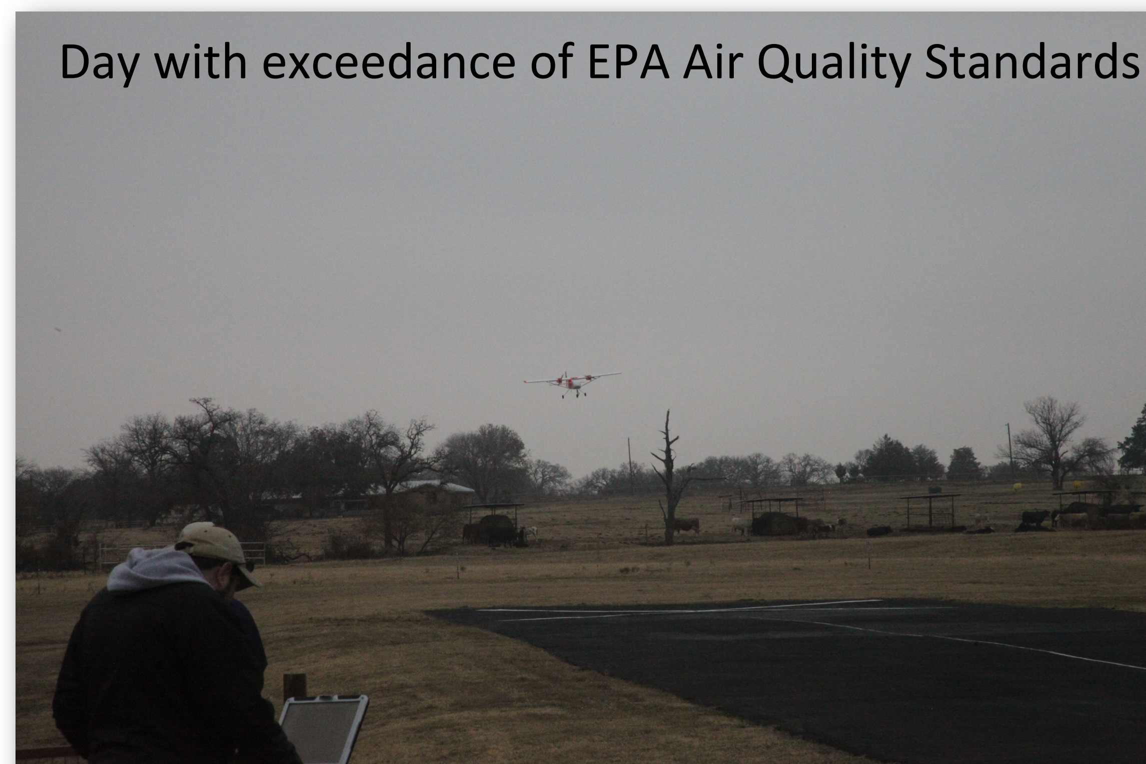
$PM_{2.5}$ Air Quality Standards

Japan	USA	WHO/EU
Annual Avg. : 15µg/m³	Annual Avg. : 12µg/m3	Annual Avg. : 25µg/m3
24 hour Avg. : 35µg/m³	24 hour Avg. : 35µg/m3	Annual Avg. :20µg/m3





Flight on Nov 18, 2014 clear skies



Flight on Dec 04, 2014 hazy/overcast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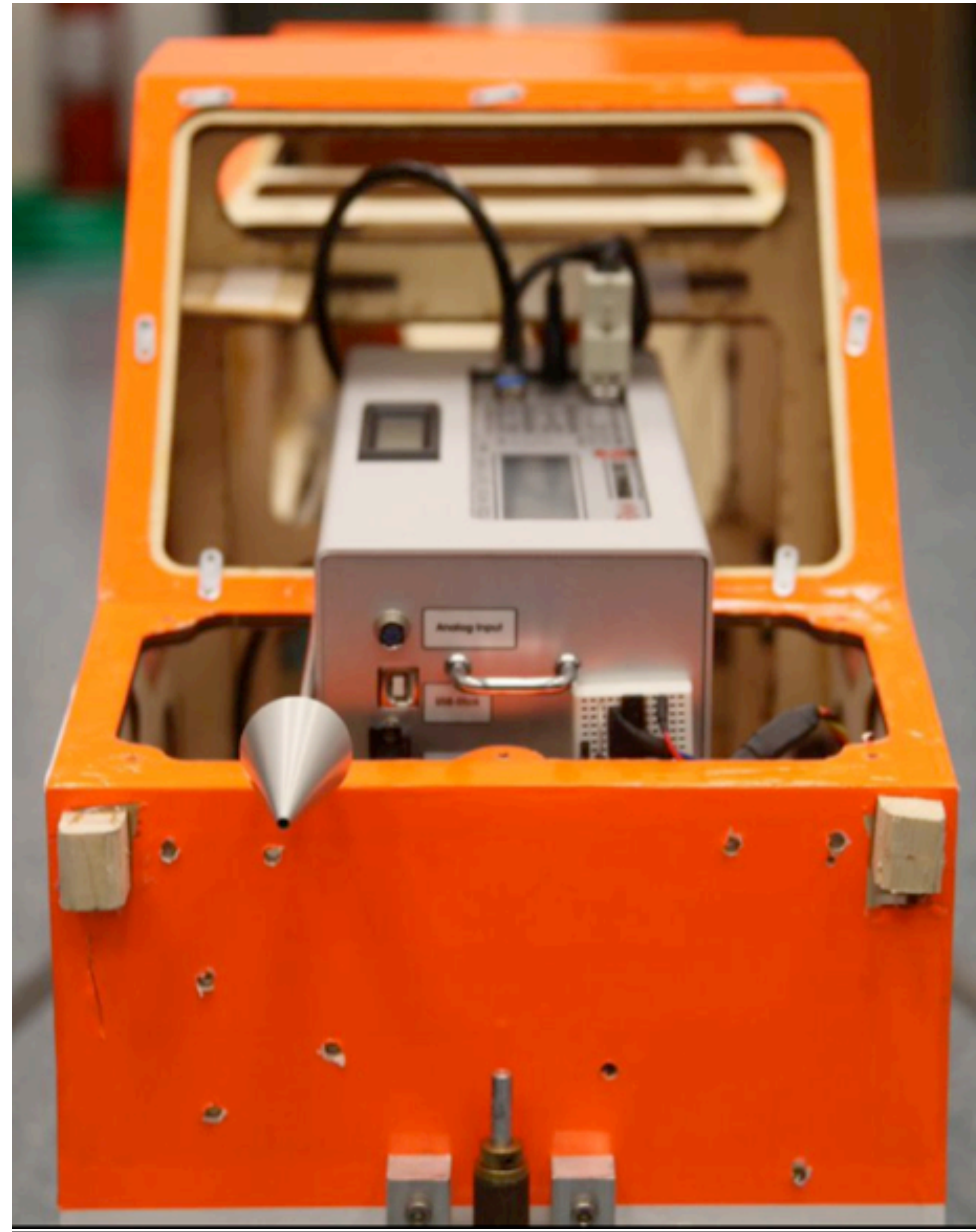
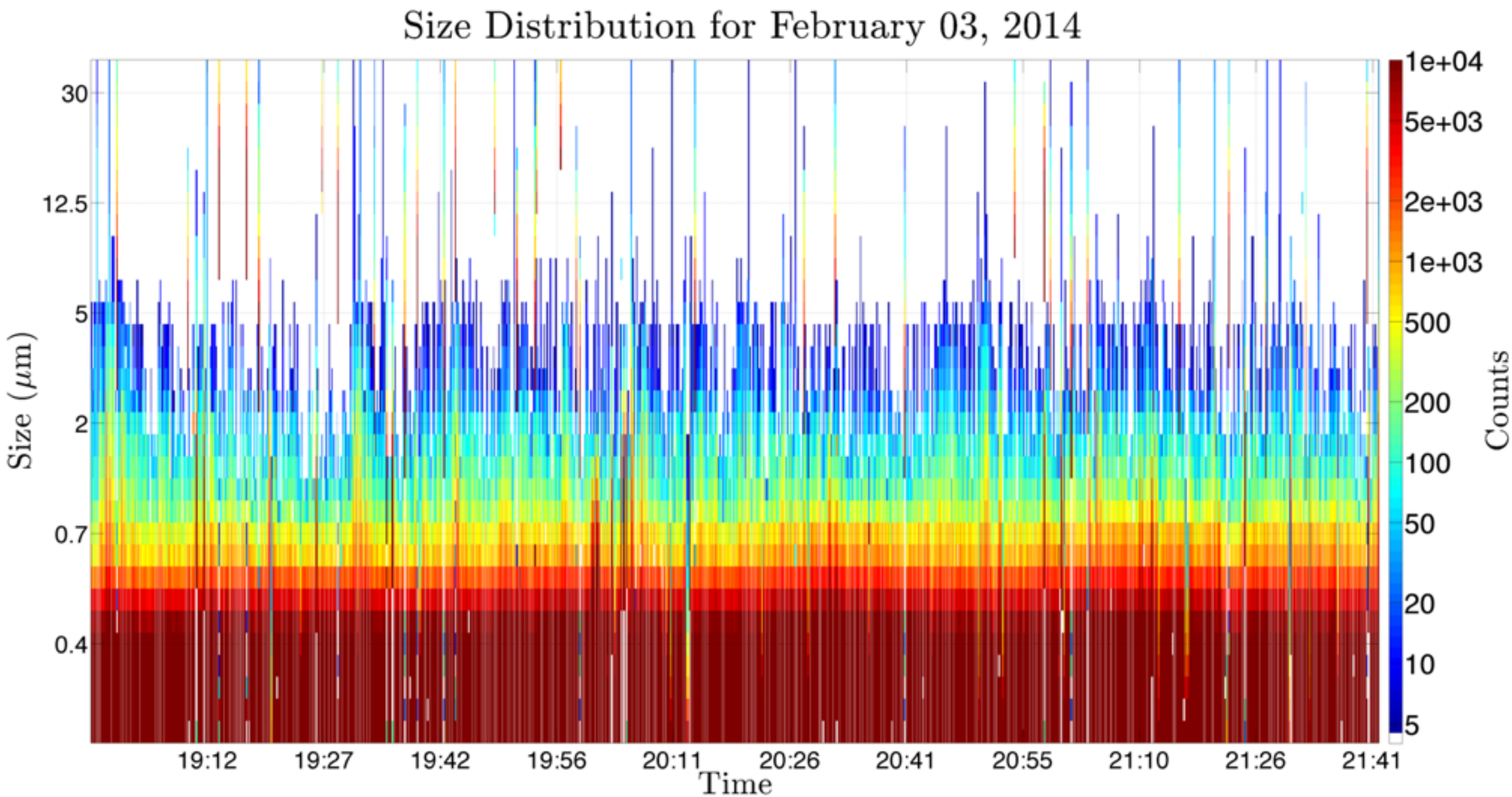
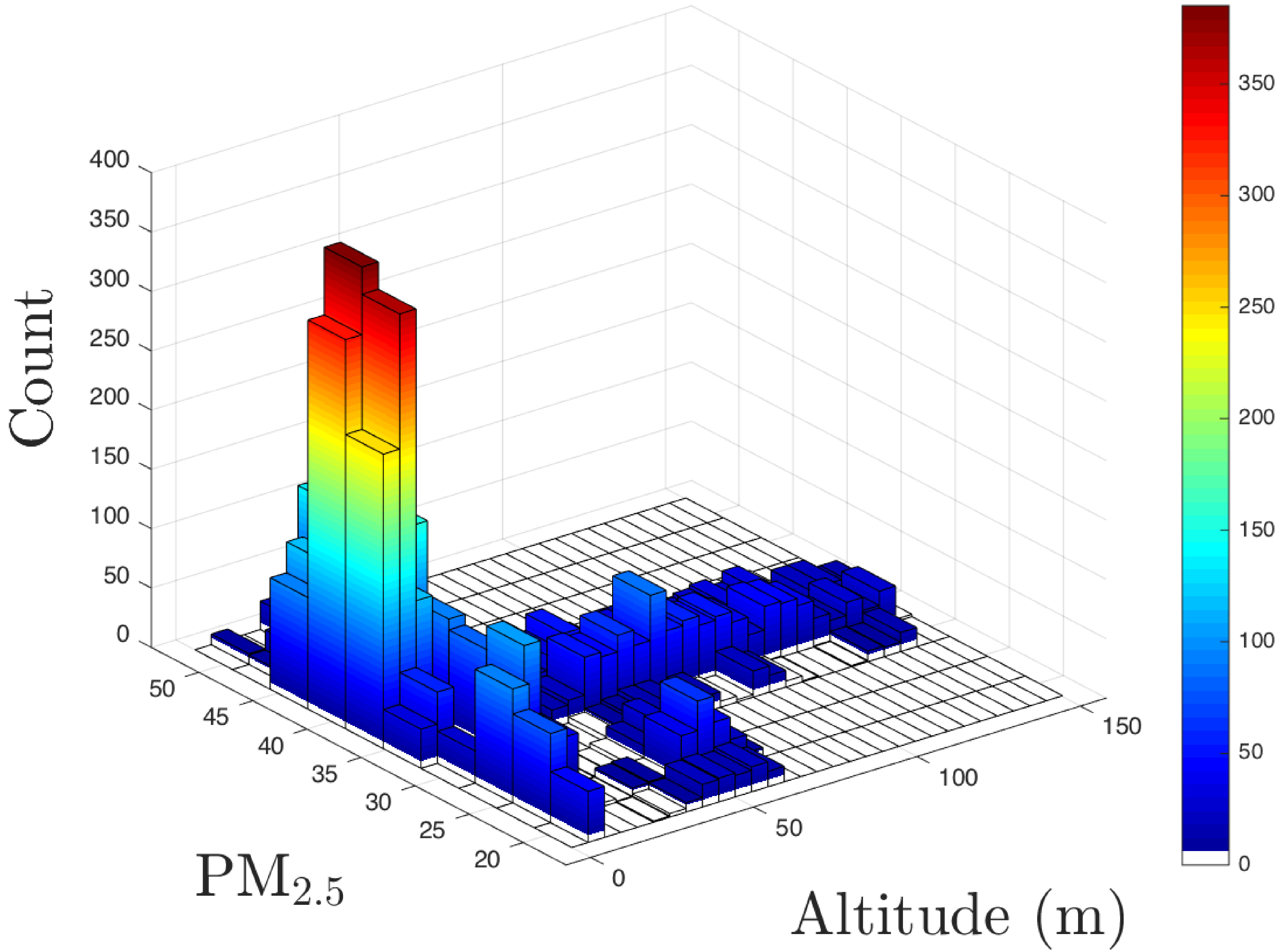


Small scale variability in the horizontal & vertical

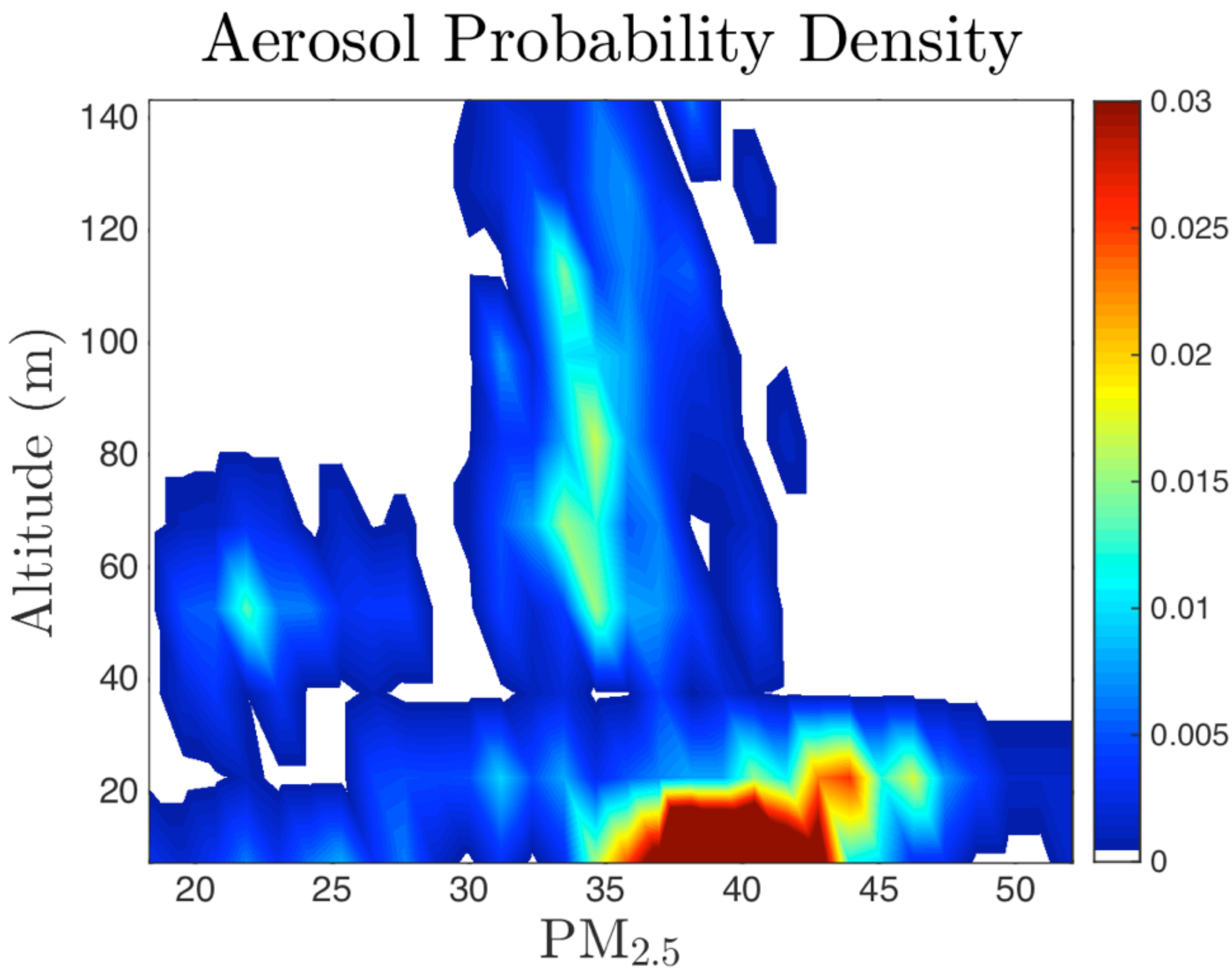

Size Distribution for February 03, 2014
Size (μm)
30
12.5
5
2
0.7
0.4
19:12
19:27
19:42
19:56
20:11
20:26
20:41
20:55
21:10
21:26
21:41
Time
1e+04
5e+03
2e+03
1e+03
500
200
100
50
20
10
5
Counts


December 4, 2014
UT D

Spatial Variability Across A Satellite Pixel



Spatial Variability Across A Satellite Pixel



Public health, environmental and social determinants of health (PHE)

7 million deaths annually linked to air pollution

World Health Organization

In new estimates released, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

Read the news release on air pollution attributable deaths

Read the feature story on air pollution

FAQs on air pollution and health
pdf, 169kb

Air pollution estimates
pdf, 1.16Mb
Summary of results and method descriptions

3.7 million deaths

attributable to ambient air pollution

Mortality from ambient air pollution for 2012 - summary of results
pdf, 293kb

4.3 million deaths

attributable to household air pollution

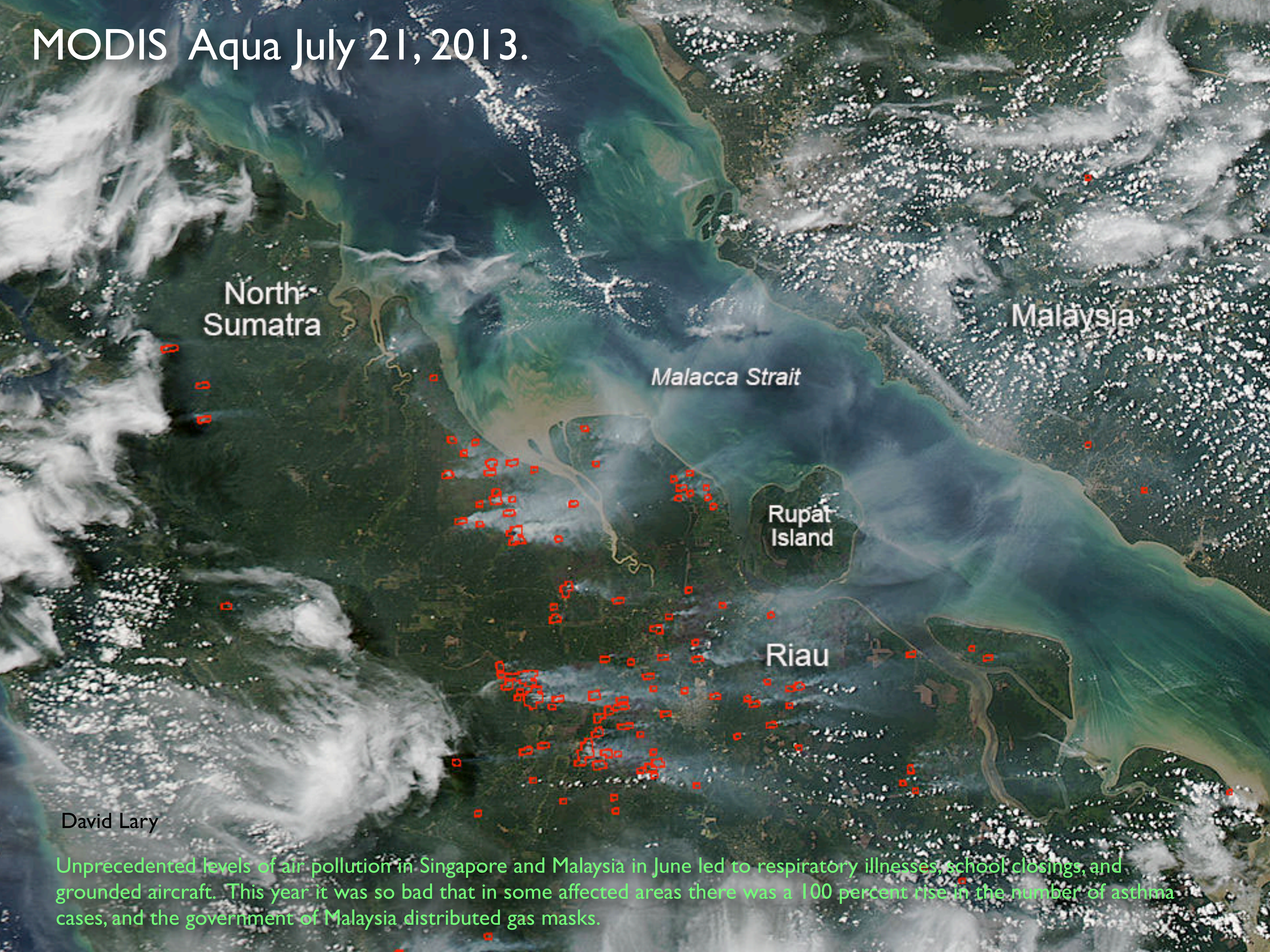
Mortality from household air pollution 2012 - summary of results.
pdf, 558kb

1600 cities

worldwide are reporting air pollution levels

Air quality in cities database – summary of results
pdf, 304kb

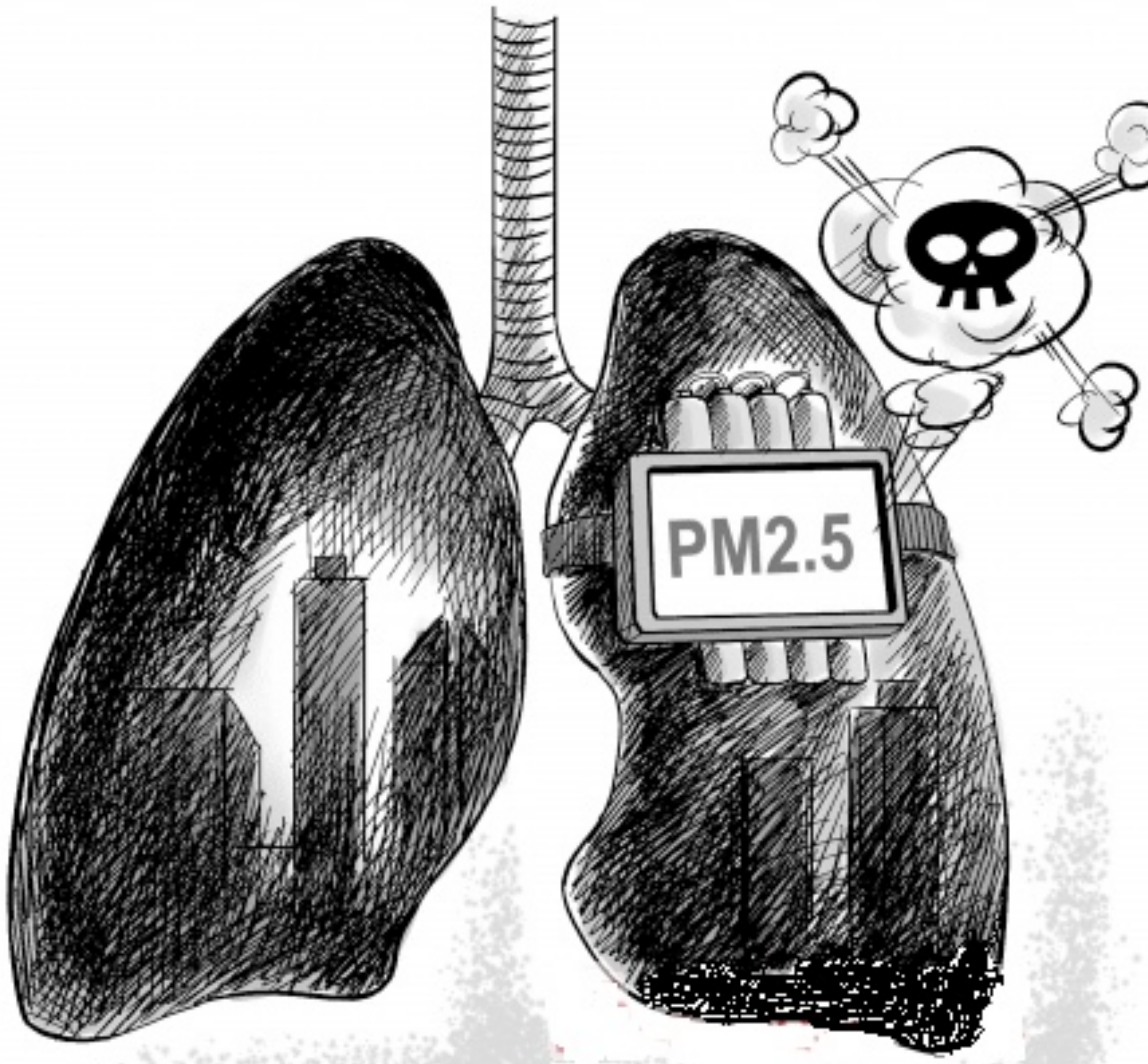
MODIS Aqua July 21, 2013.



Unprecedented levels of air pollution in Singapore and Malaysia in June led to respiratory illnesses, school closings, and grounded aircraft. This year it was so bad that in some affected areas there was a 100 percent rise in the number of asthma cases, and the government of Malaysia distributed gas masks.

Air pollution in Ulaanbaatar, Mongolia

PM2.5 Invisible Killer

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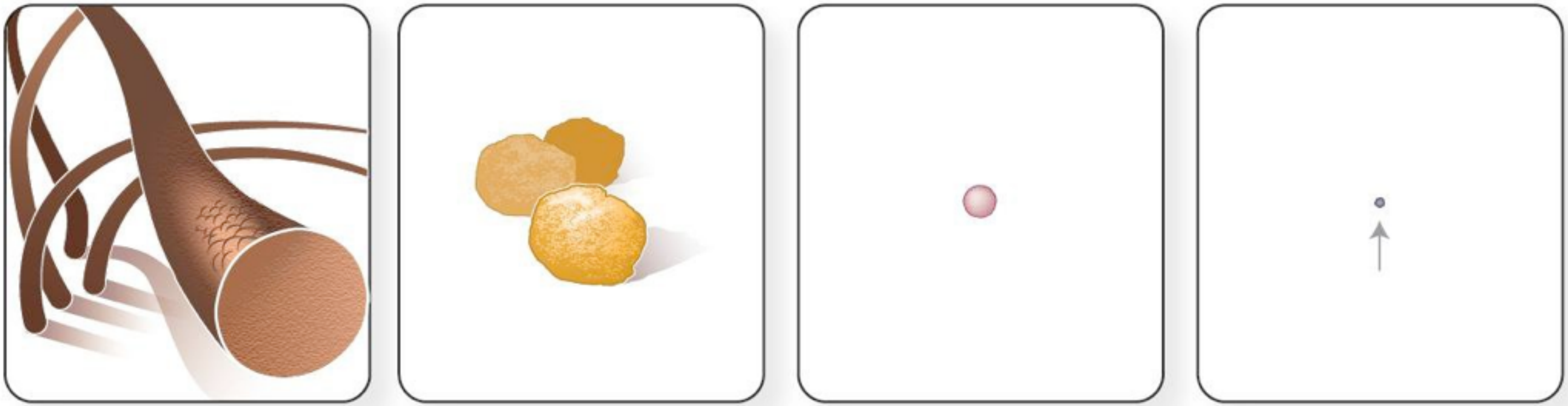
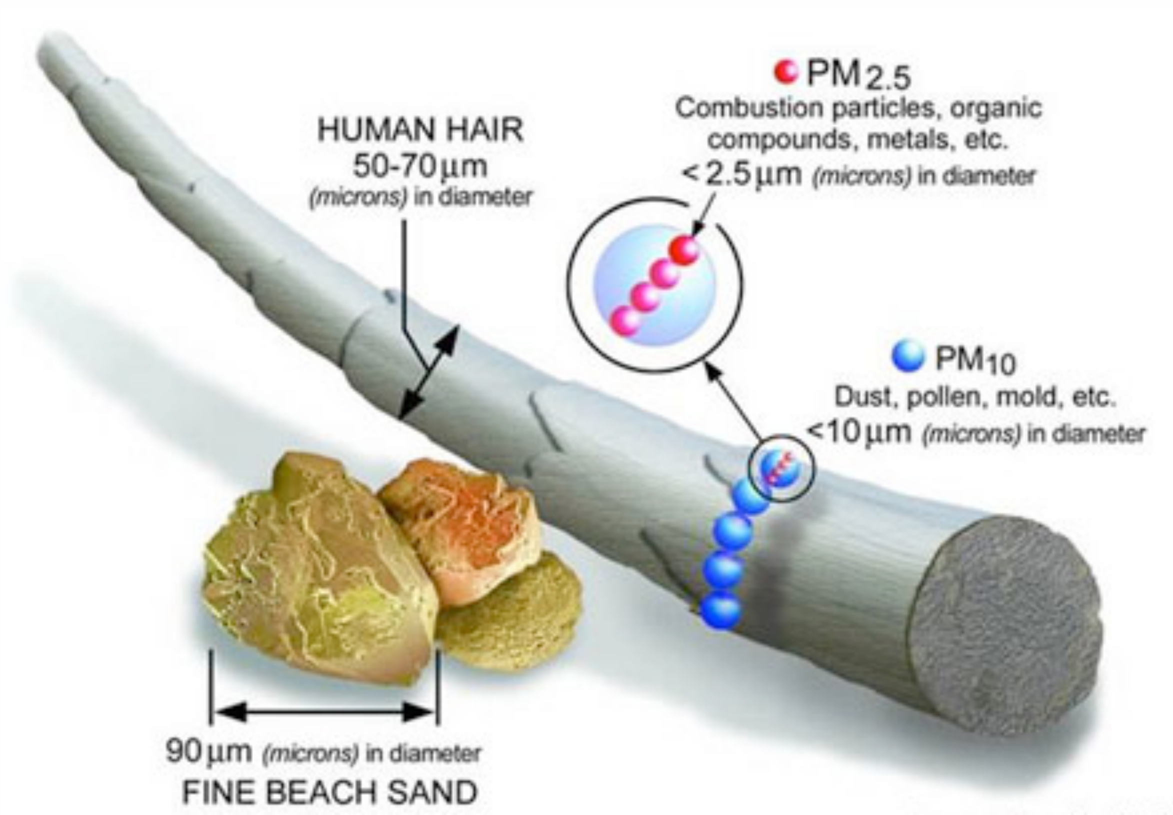
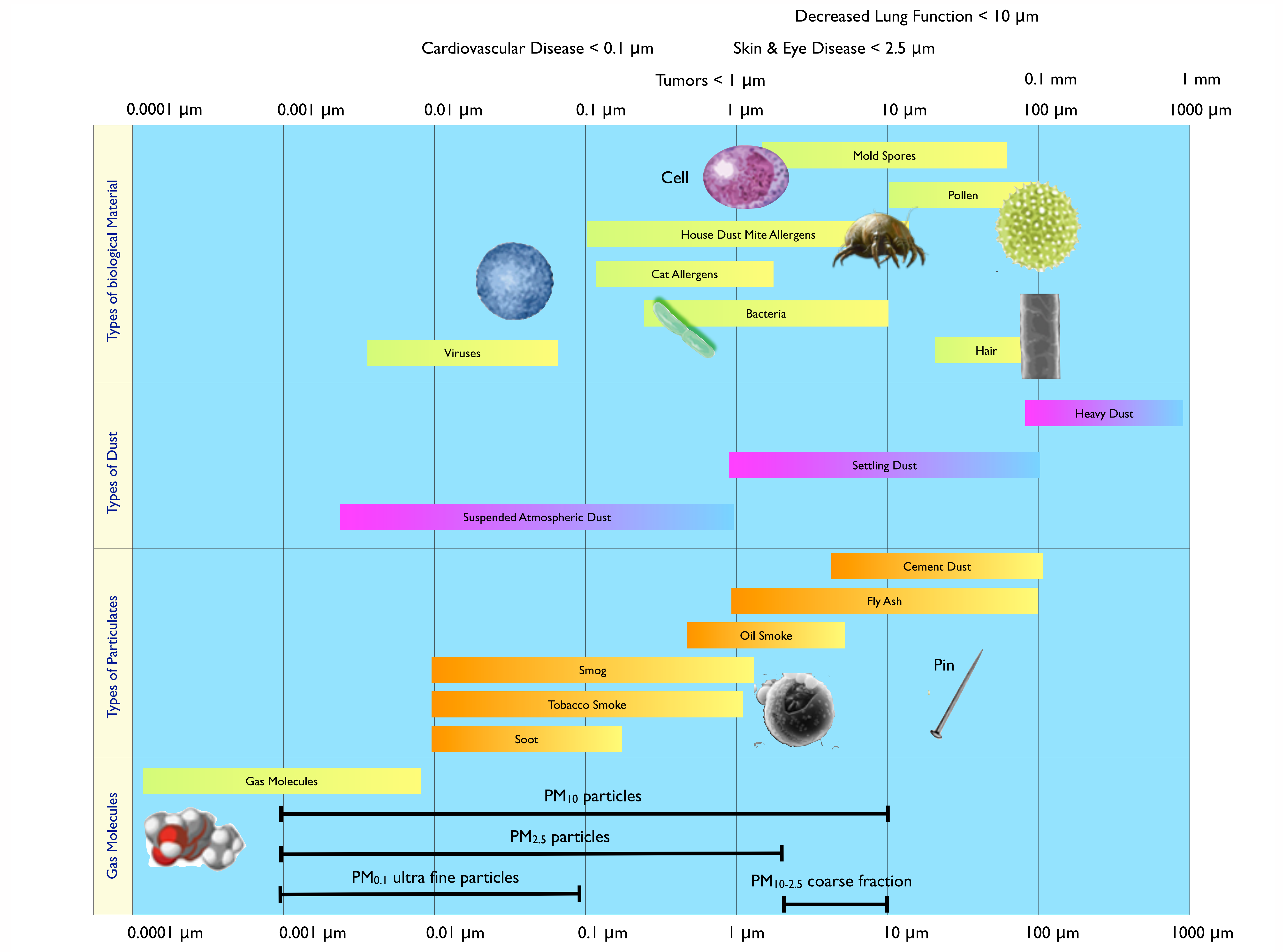
Fine Particulate Matter Size Comparison



Human hair (about 70µm wide) | Grain of sand (about 50µm wide) | PM_{10} (less than 10µm wide) | $PM_{2.5}$ (less than 2.5µm wide)

µm = micrometer



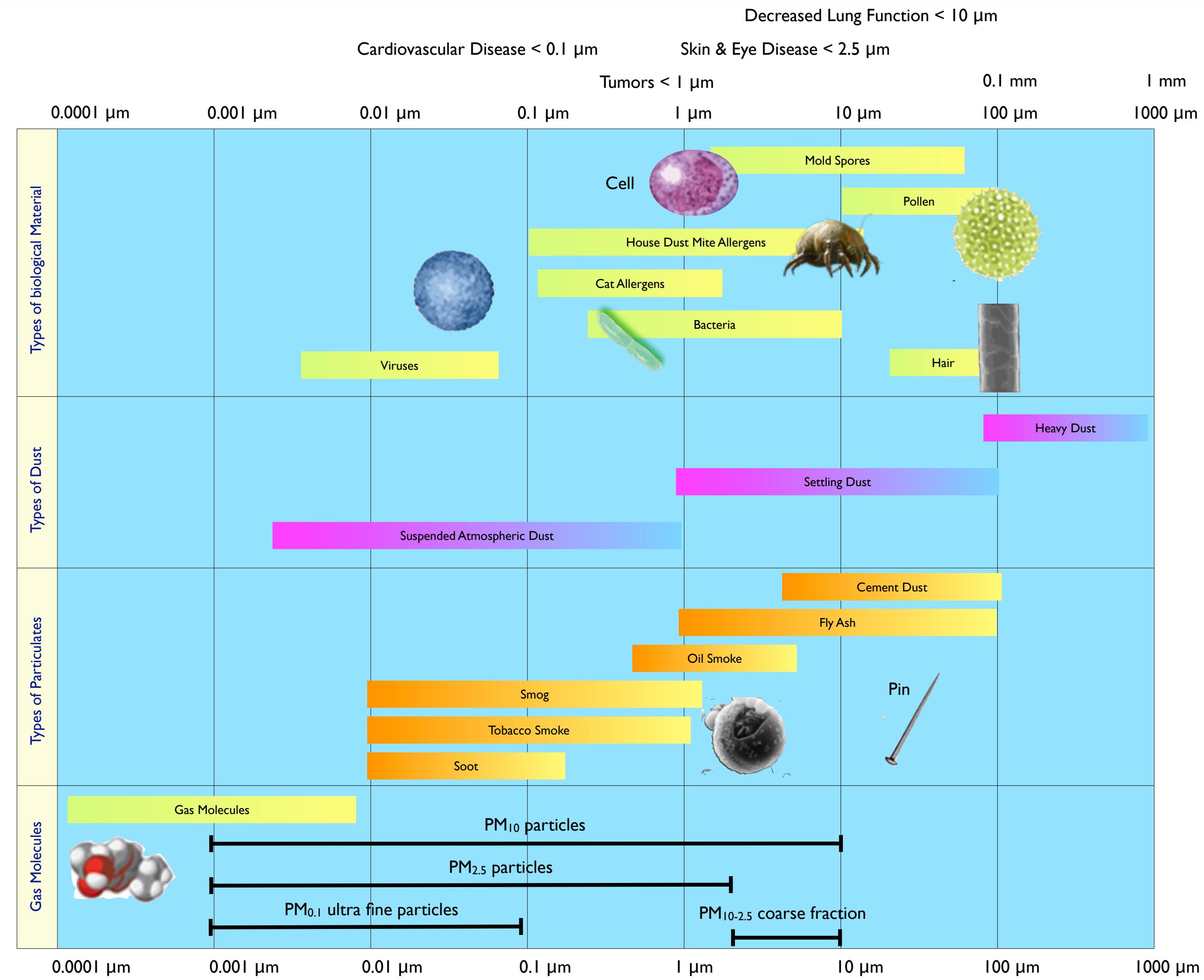


Decreased Lung Function < 10 µm
Cardiovascular Disease < 0.1 µm
Skin & Eye Disease < 2.5 µm
Tumors < 1 µm
0.1 mm
1 mm
0.0001 µm
0.001 µm
0.01 µm
0.1 µm
1 µm
10 µm
100 µm
1000 µm
Types of biological Material
Cell
Mold Spores
Pollen
House Dust Mite Allergens
Cat Allergens
Bacteria
Viruses
Hair
Types of Dust
Heavy Dust
Settling Dust
Suspended Atmospheric Dust
Types of Particulates
Cement Dust
Fly Ash
Oil Smoke
Pin
Smog
Tobacco Smoke
Soot
Gas Molecules
Gas Molecules
PM10 particles
PM2.5 particles
PM0.1 ultra fine particles
PM10-2.5 coarse fraction
0.0001 µm
0.001 µm
0.01 µm
0.1 µm
1 µm
10 µm
100 µm
1000 µm

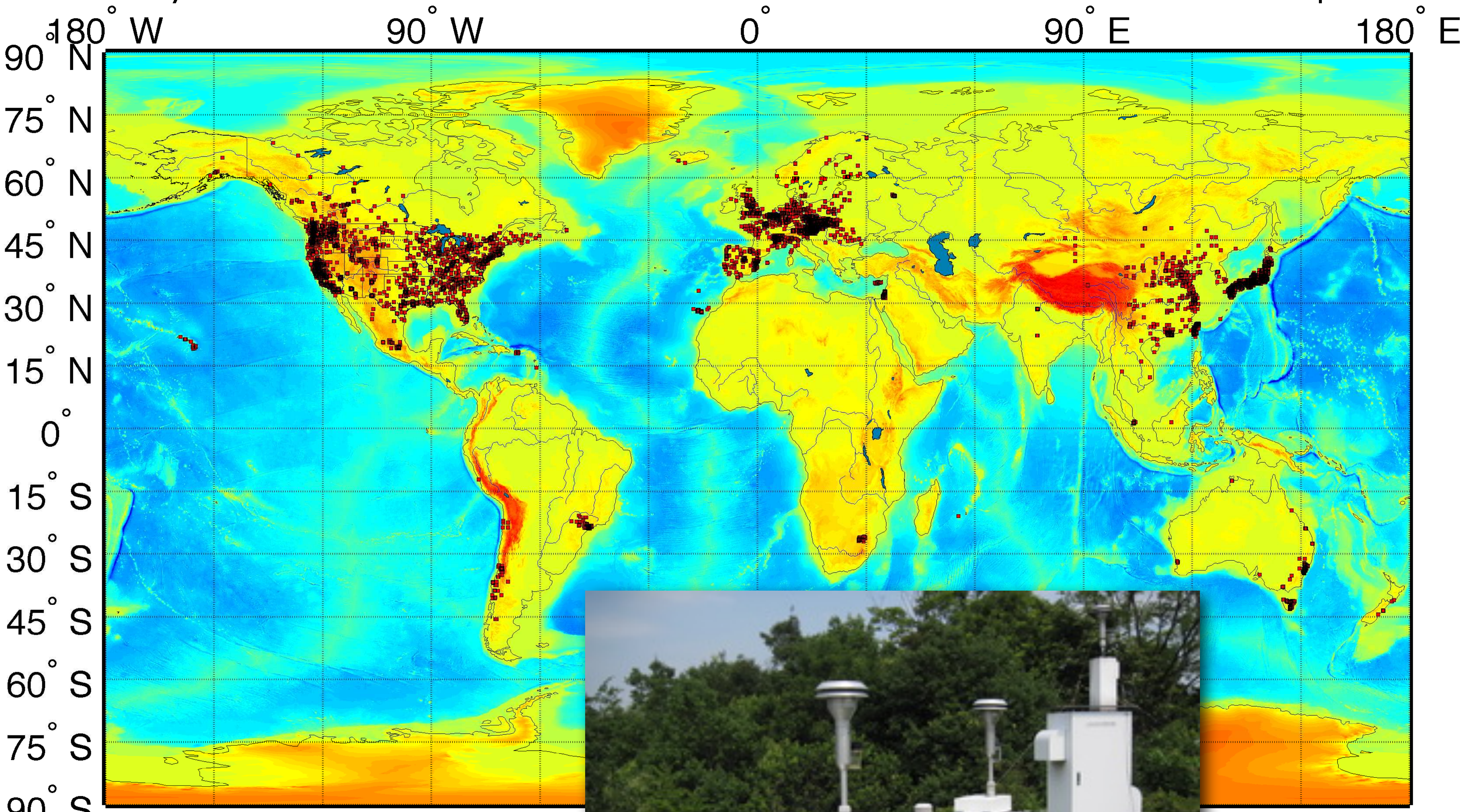
Table 1. PM and health outcomes (modified from *Ruckerl et al.* (2006)).

Health Outcomes	Short-term Studies			Long-term Studies		
	PM10	PM2.5	UFP	PM10	PM2.5	UFP
Mortality						
All causes	xxx	xxx	x	xx	xx	x
Cardiovascular	xxx	xxx	x	xx	xx	x
Pulmonary	xxx	xxx	x	xx	xx	x
Pulmonary effects						
Lung function, e.g., PEF	xxx	xxx	xx	xxx	xxx	
Lung function growth				xxx	xxx	
Asthma and COPD exacerbation						
Acute respiratory symptoms		xx	x	xxx	xxx	
Medication use			x			
Hospital admission	xx	xxx	x			
Lung cancer						
Cohort				xx	xx	x
Hospital admission				xx	xx	x
Cardiovascular effects						
Hospital admission	xxx	xxx		x	x	
ECG-related endpoints						
Autonomic nervous system	xxx	xxx	xx			
Myocardial substrate and vulnerability		xx	x			
Vascular function						
Blood pressure	xx	xxx	x			
Endothelial function	x	xx	x			
Blood markers						
Pro inflammatory mediators	xx	xx	xx			
Coagulation blood markers	xx	xx	xx			
Diabetes	x	xx	x			
Endothelial function	x	x	xx			
Reproduction						
Premature birth	x	x				
Birth weight	xx	x				
IUR/SGA	x	x				
Fetal growth						
Birth defects	x					
Infant mortality	xx	x				
Sperm quality	x	x				
Neurotoxic effects						
Central nervous system		x	xx			

x, few studies; xx, many studies; xxx, large number of studies.



Hourly Measurements from 55 countries and more than 8,000 measurement sites from 1997-present

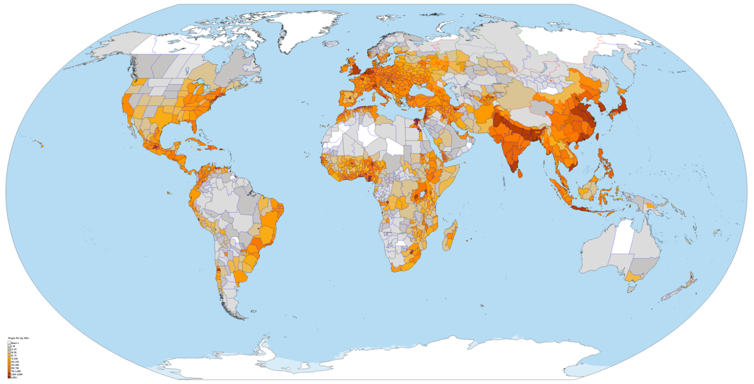


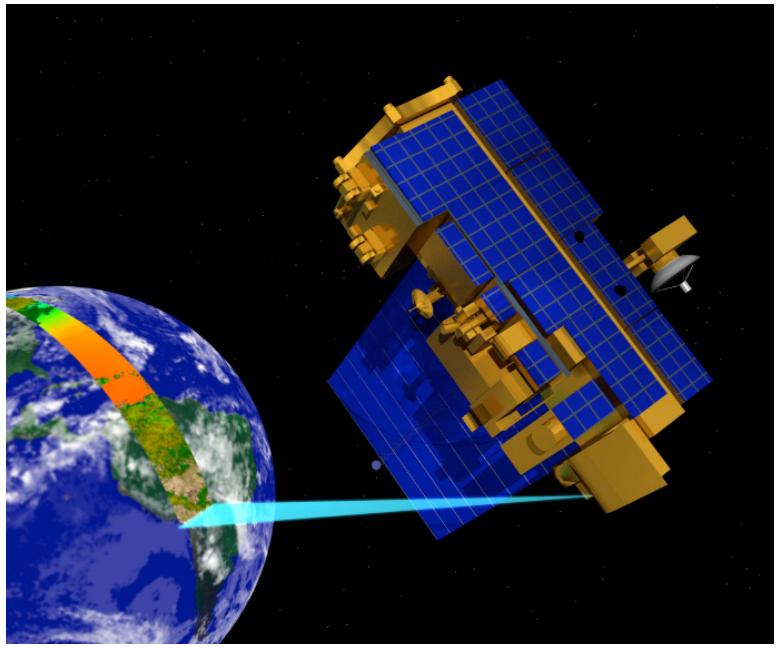
Virtual Sensors

Comes out of CAL/VAL
Inter-Instrument Inter Comparison

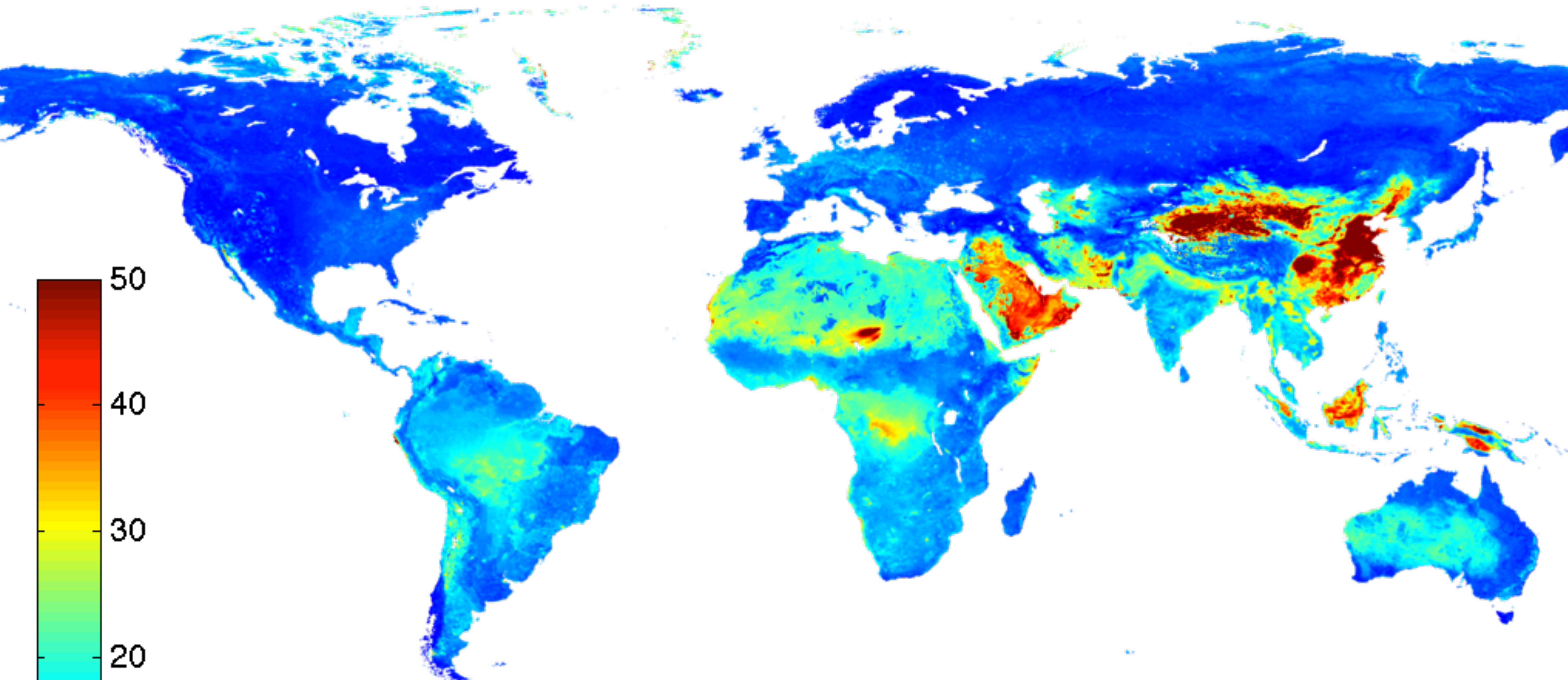
Terra DeepBlue

Rank	Source	Variable	Type
1		Population Density	Input
2	Satellite Product	Tropospheric NO_2 Column	Input
3	Meteorological Analyses	Surface Specific Humidity	Input
4	Satellite Product	Solar Azimuth	Input
5	Meteorological Analyses	Surface Wind Speed	Input
6	Satellite Product	White-sky Albedo at 2,130 nm	Input
7	Satellite Product	White-sky Albedo at 555 nm	Input
8	Meteorological Analyses	Surface Air Temperature	Input
9	Meteorological Analyses	Surface Layer Height	Input
10	Meteorological Analyses	Surface Ventilation Velocity	Input
11	Meteorological Analyses	Total Precipitation	Input
12	Satellite Product	Solar Zenith	Input
13	Meteorological Analyses	Air Density at Surface	Input
14	Satellite Product	Cloud Mask Qa	Input
15	Satellite Product	Deep Blue Aerosol Optical Depth 470 nm	Input
16	Satellite Product	Sensor Zenith	Input
17	Satellite Product	White-sky Albedo at 858 nm	Input
18	Meteorological Analyses	Surface Velocity Scale	Input
19	Satellite Product	White-sky Albedo at 470 nm	Input
20	Satellite Product	Deep Blue Angstrom Exponent Land	Input
21	Satellite Product	White-sky Albedo at 1,240 nm	Input
22	Satellite Product	Scattering Angle	Input
23	Satellite Product	Sensor Azimuth	Input
24	Satellite Product	Deep Blue Surface Reflectance 412 nm	Input
25	Satellite Product	White-sky Albedo at 1,640 nm	Input
26	Satellite Product	Deep Blue Aerosol Optical Depth 660 nm	Input
27	Satellite Product	White-sky Albedo at 648 nm	Input
28	Satellite Product	Deep Blue Surface Reflectance 660 nm	Input
29	Satellite Product	Cloud Fraction Land	Input
30	Satellite Product	Deep Blue Surface Reflectance 470 nm	Input
31	Satellite Product	Deep Blue Aerosol Optical Depth 550 nm	Input
32	Satellite Product	Deep Blue Aerosol Optical Depth 412 nm	Input
	In-situ Observation	**PM**$_{2.5}$	**Target**



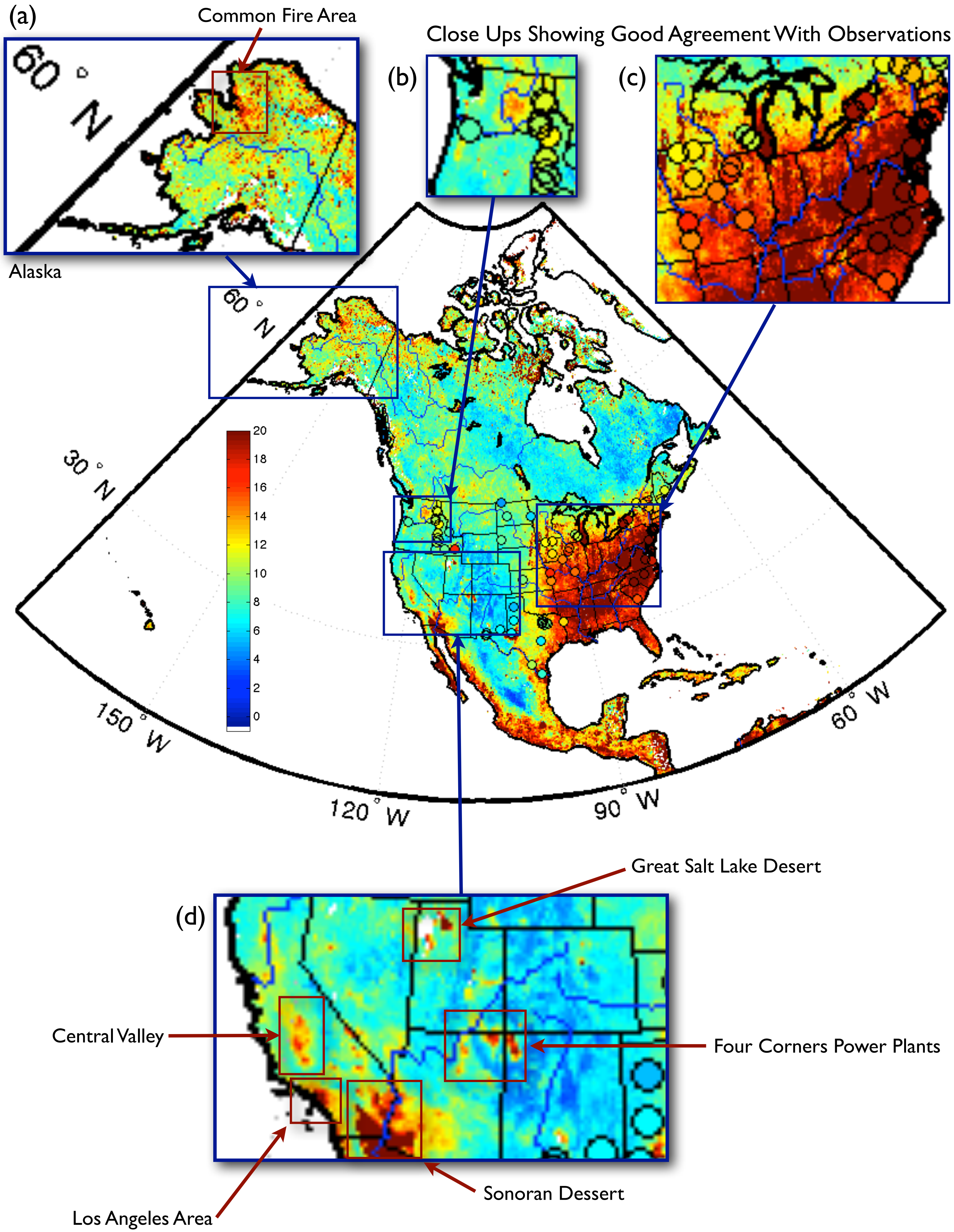


Long-Term Average 1997-present



Mobile Sensors

Wearable Sensors


(a)
Common Fire Area
60 °N
Alaska
Close Ups Showing Good Agreement With Observations
(b)
(c)
30 °N
150 °W
120 °W
90 °W
60 °W
20
18
16
14
12
10
8
6
4
2
0
(d)
Great Salt Lake Desert
Central Valley
Four Corners Power Plants
Los Angeles Area
Sonoran Dessert

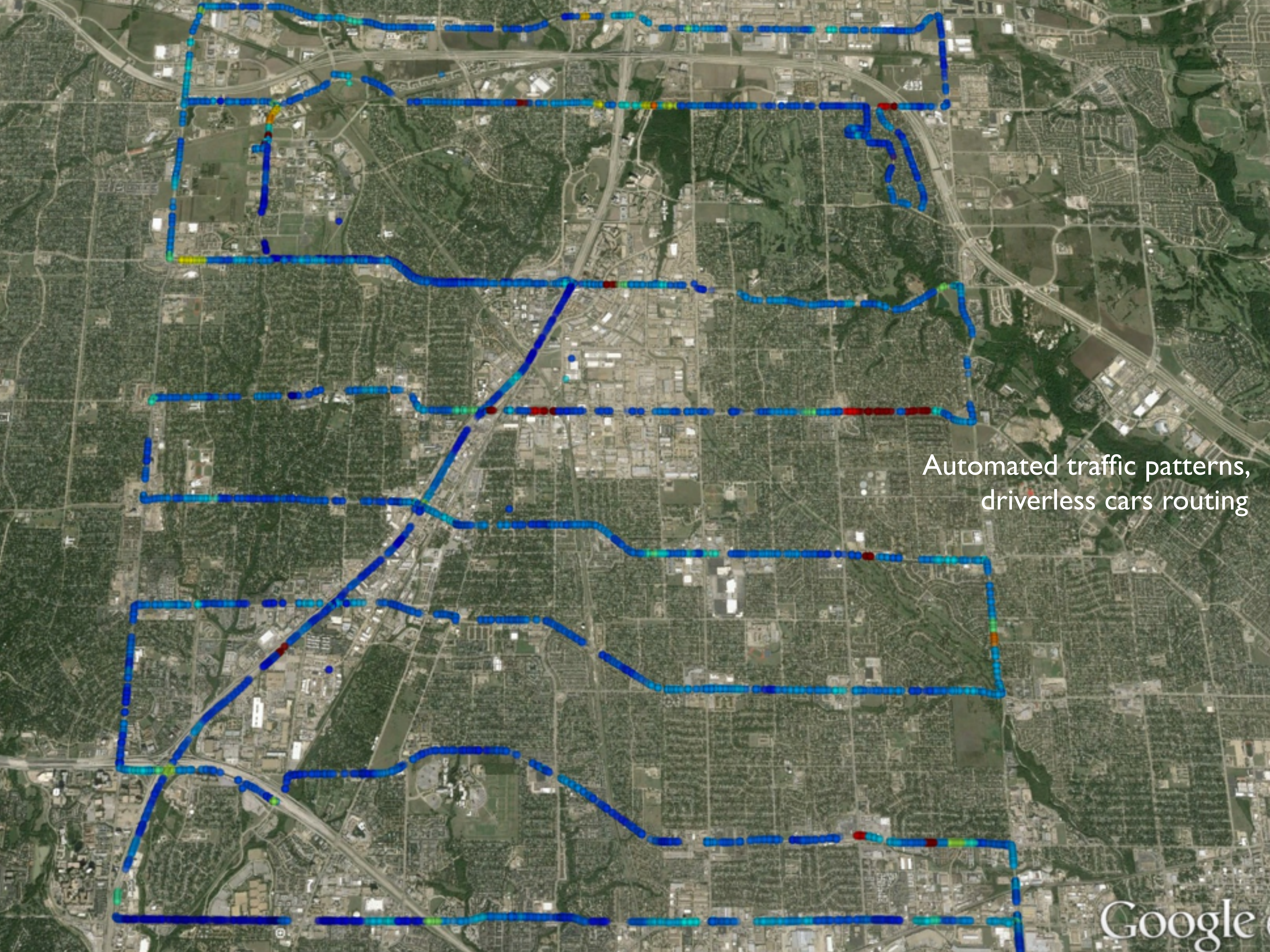

Thermo

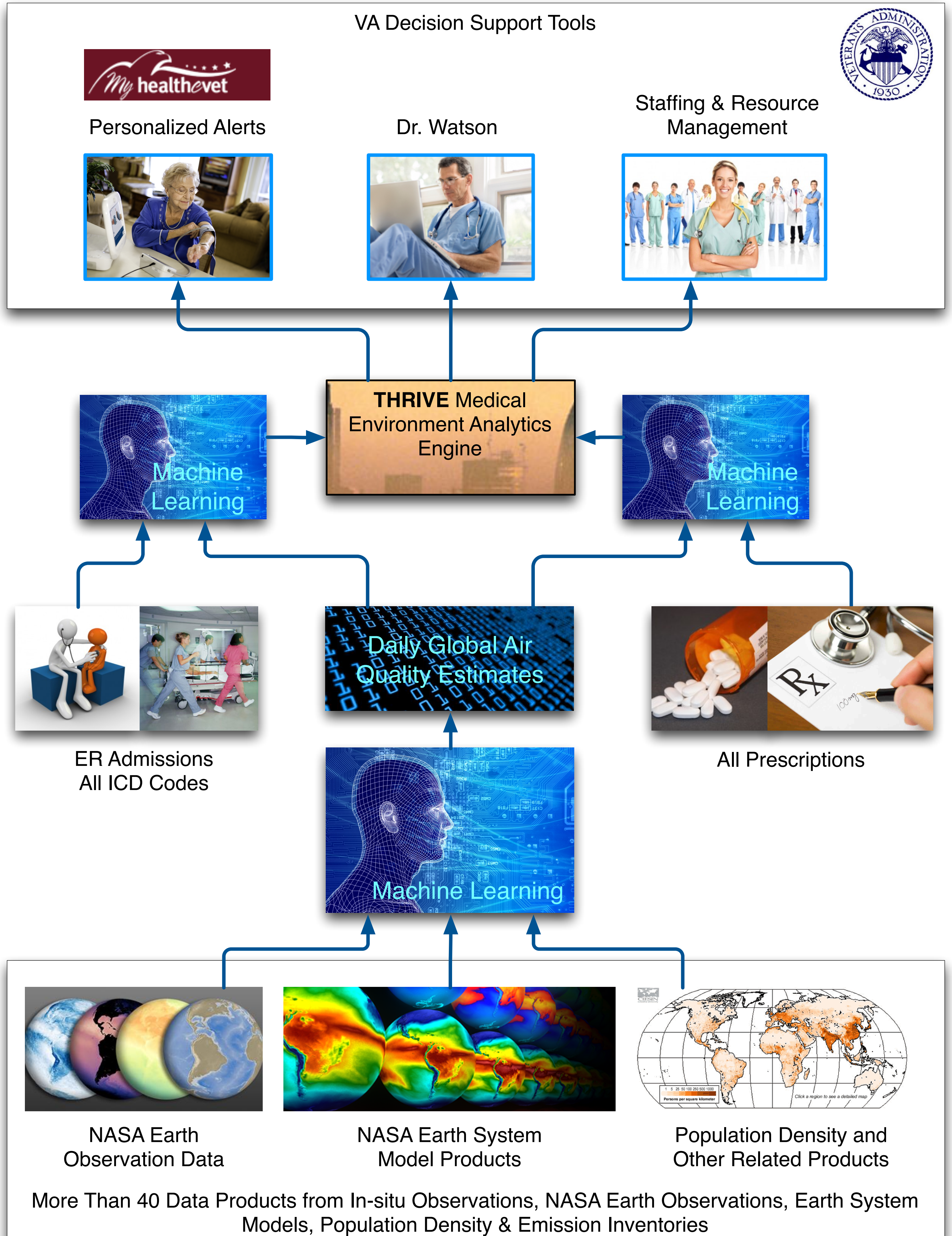
This is a BigData Problem of Great Societal Relevance

- Collecting data in real time from national and global networks requires **bandwidth**.
- With the next generation of wearable sensors and the **internet of things** this data volume will rapidly increase.
- A variety of applications enabled by **BigData**, **higher bandwidth** and **cloud processing**.
- Future finer granularity and **two way** communication will dramatically increase the size of the data bringing air quality to the micro scale, just like weather data.

	Time Taken			
	10 Mbps	**20 Mbps**	**50 Mbps**	**1 Gbps**
40 TB training data	185 days	93 days	37 days	1 day 21 hours
4 Gb update	54m	27m	11m	32s


Google


Automated traffic patterns,
driverless cars routing


VA Decision Support Tools
My healthevet
Personalized Alerts
Dr. Watson
Staffing & Resource Management
THRIVE Medical Environment Analytics Engine
Machine Learning
Machine Learning
Daily Global Air Quality Estimates
ER Admissions
All ICD Codes
All Prescriptions
Machine Learning
NASA Earth Observation Data
NASA Earth System Model Products
Population Density and Other Related Products
More Than 40 Data Products from In-situ Observations, NASA Earth Observations, Earth System Models, Population Density & Emission Inventories

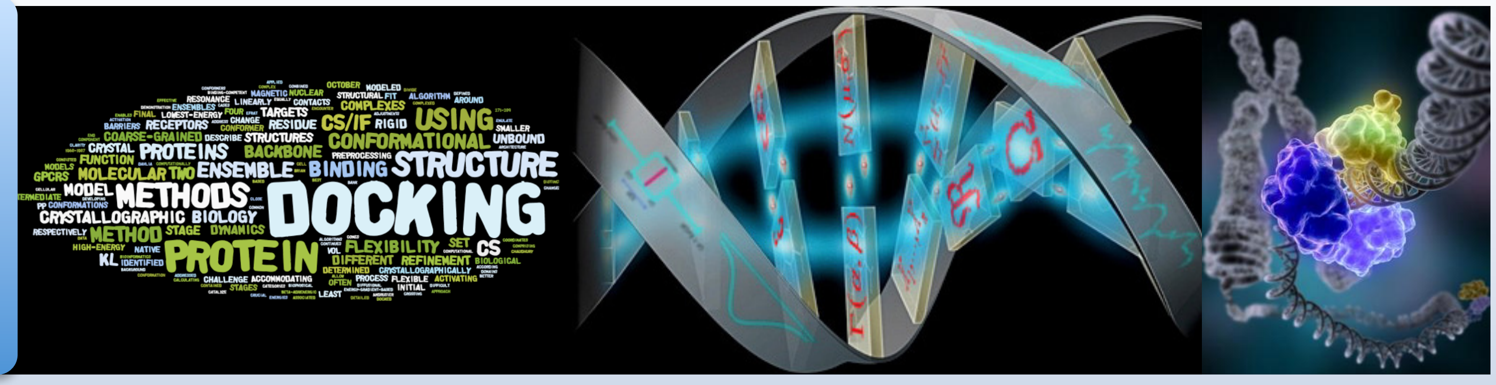
Happy Day!


212-213-0444
BREAKFAST - LUNCH

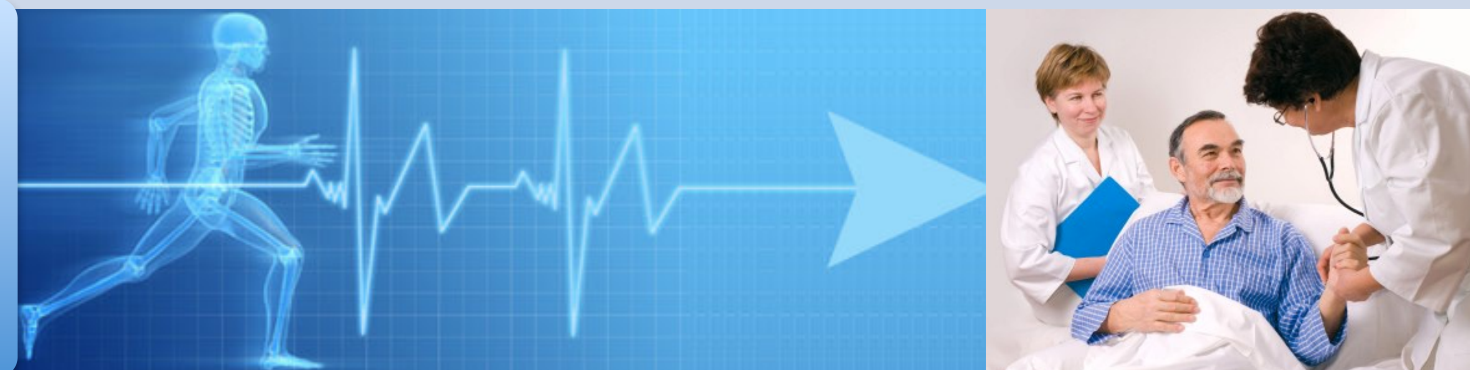

Street View
Pollution View

Think Big: Holistic & Comprehensive Informatics

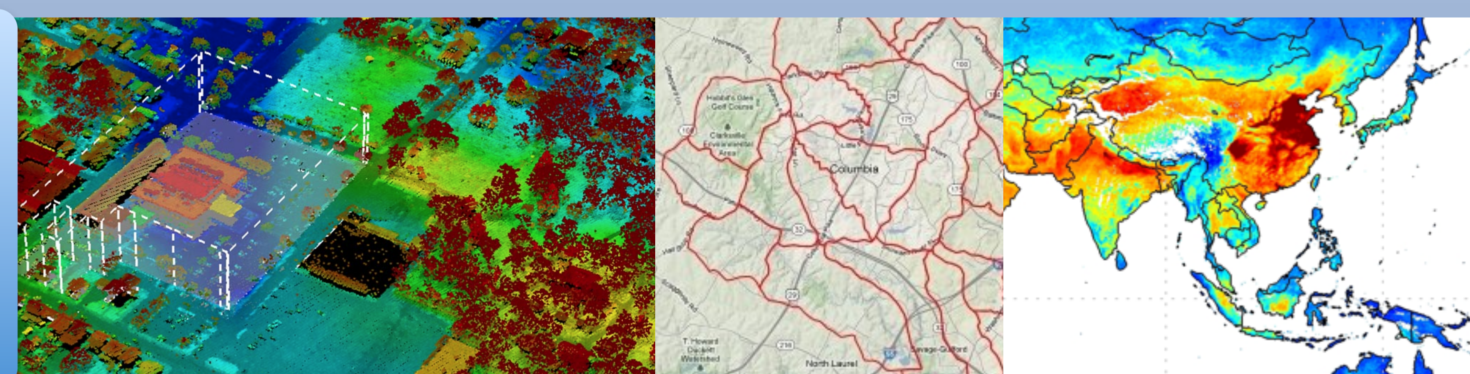
Bio Informatics



Medical Informatics



Environmental Informatics



THRIVE

Multiple Big Data + EMR + Social Media + Machine Learning + Causality

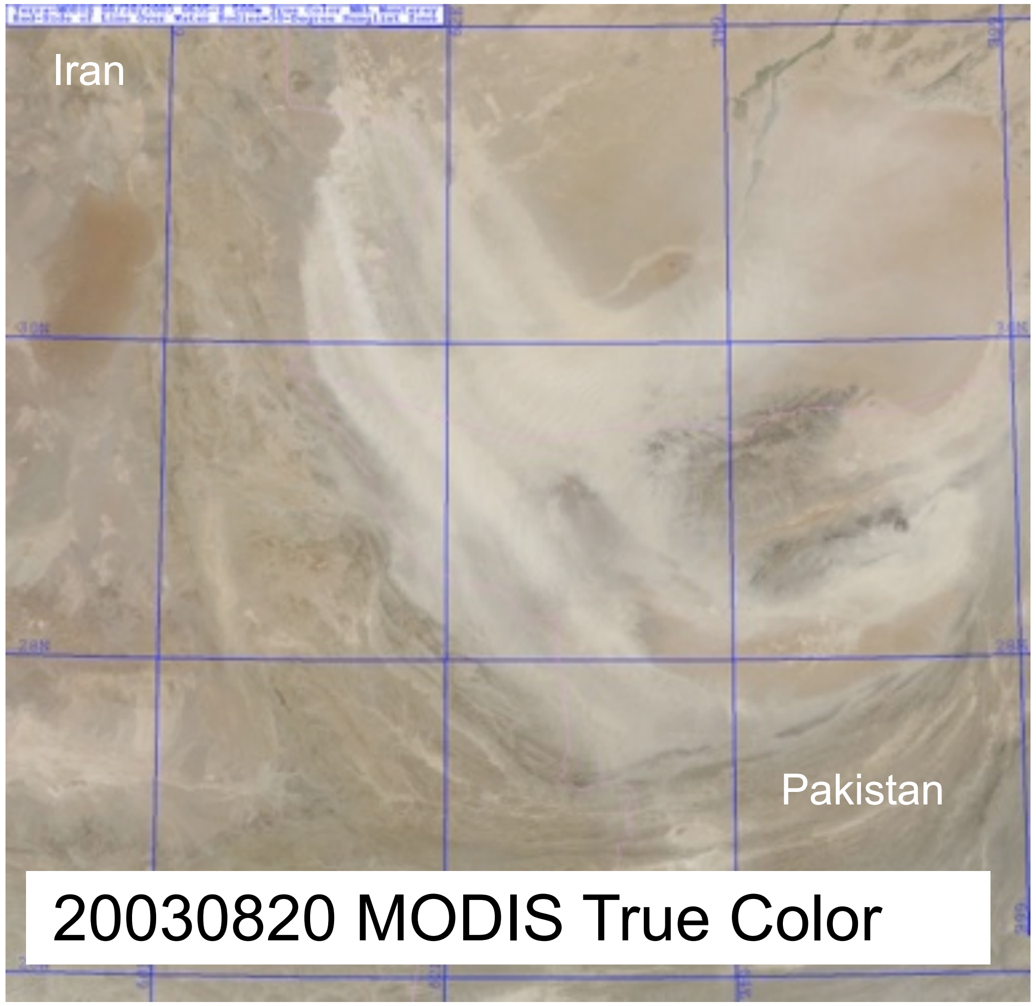
A Cross-cutting Platform for Comprehensive Informatics for **Data Driven Decisions** in **Patient Centered Care** facilitated by *High Speed Low-Latency networks,* multiple massive datasets from large distributed sensor networks, EMR, and *local cloud computing*.

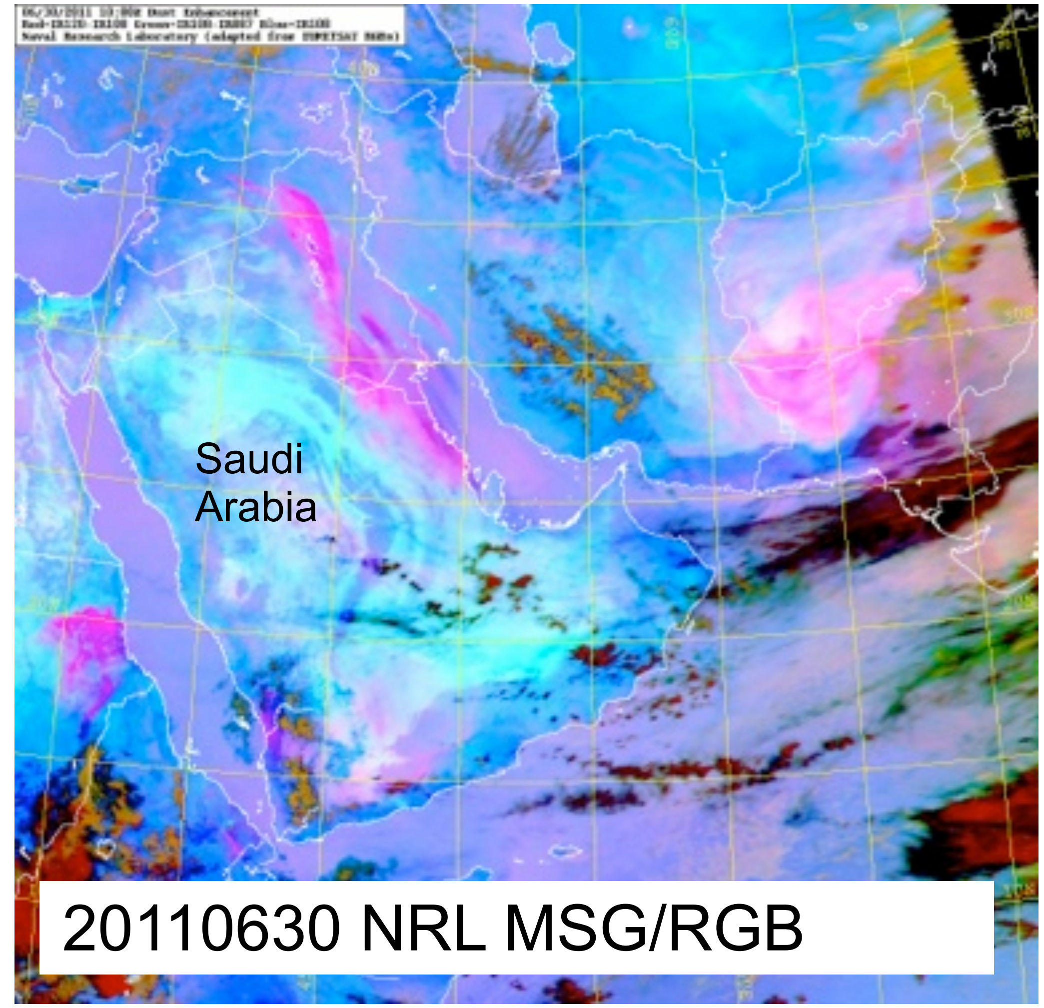
A42A-08

High Resolution Identification of Dust Sources Using Machine Learning and Remote Sensing Data

Annette Walker and David J. Lary

NRL High-resolution Dust Source Database



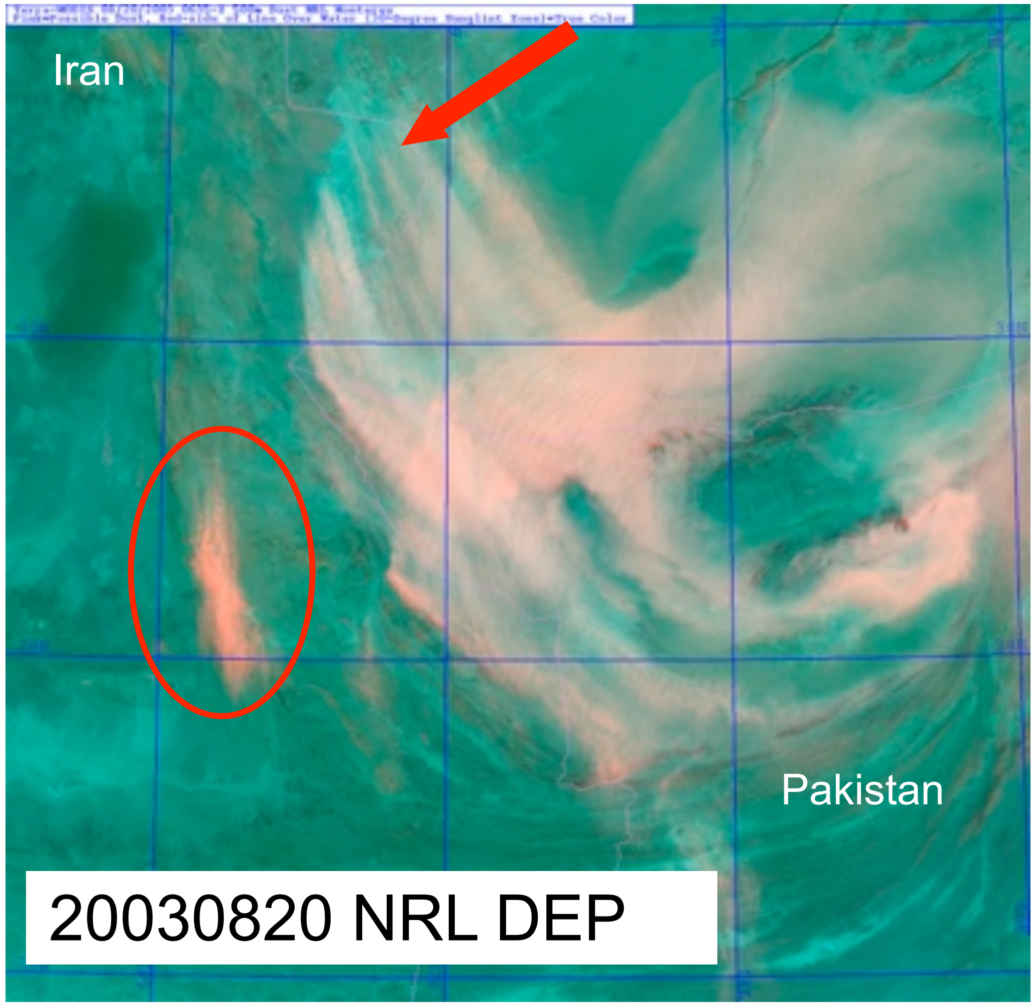


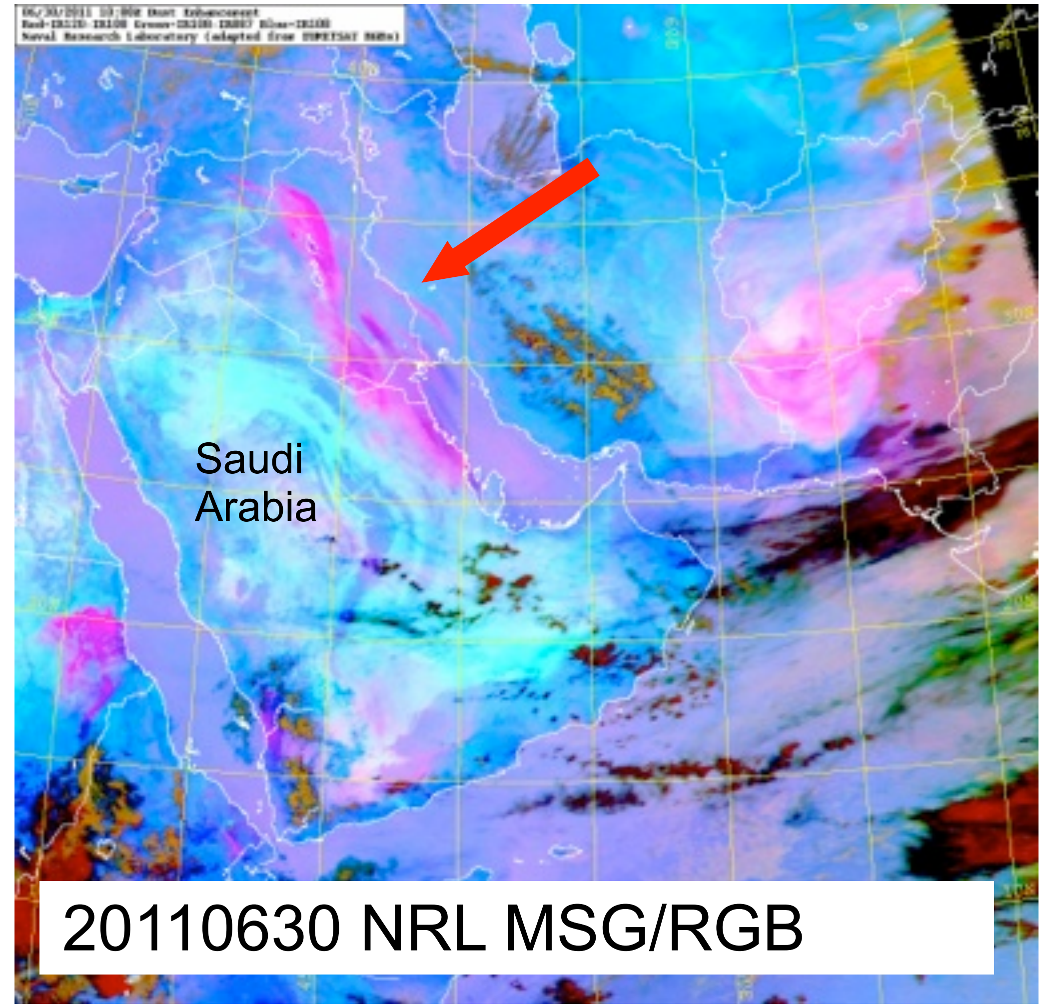
Approach and Methodology

- **10 years of DEP (2 yr MSG/RGB) imagery**
- COAMPS 10 m wind overlays
- Surface weather plots
- **ENVI (Gis-like software)**
- NGDC topographical 10ºX10º tiles
- **Overlay 0.25º grid** or use **Google Earth (GE)**

- **Dust source area entered into database** (cursor location tool = 1km precision)
- Cross-correlate land and water features using maps, atlases, Landsat images (detailed topographic, geographic, and geomorphic information, **GE**)
- Technical and governmental reports

NRL High-resolution Dust Source Database





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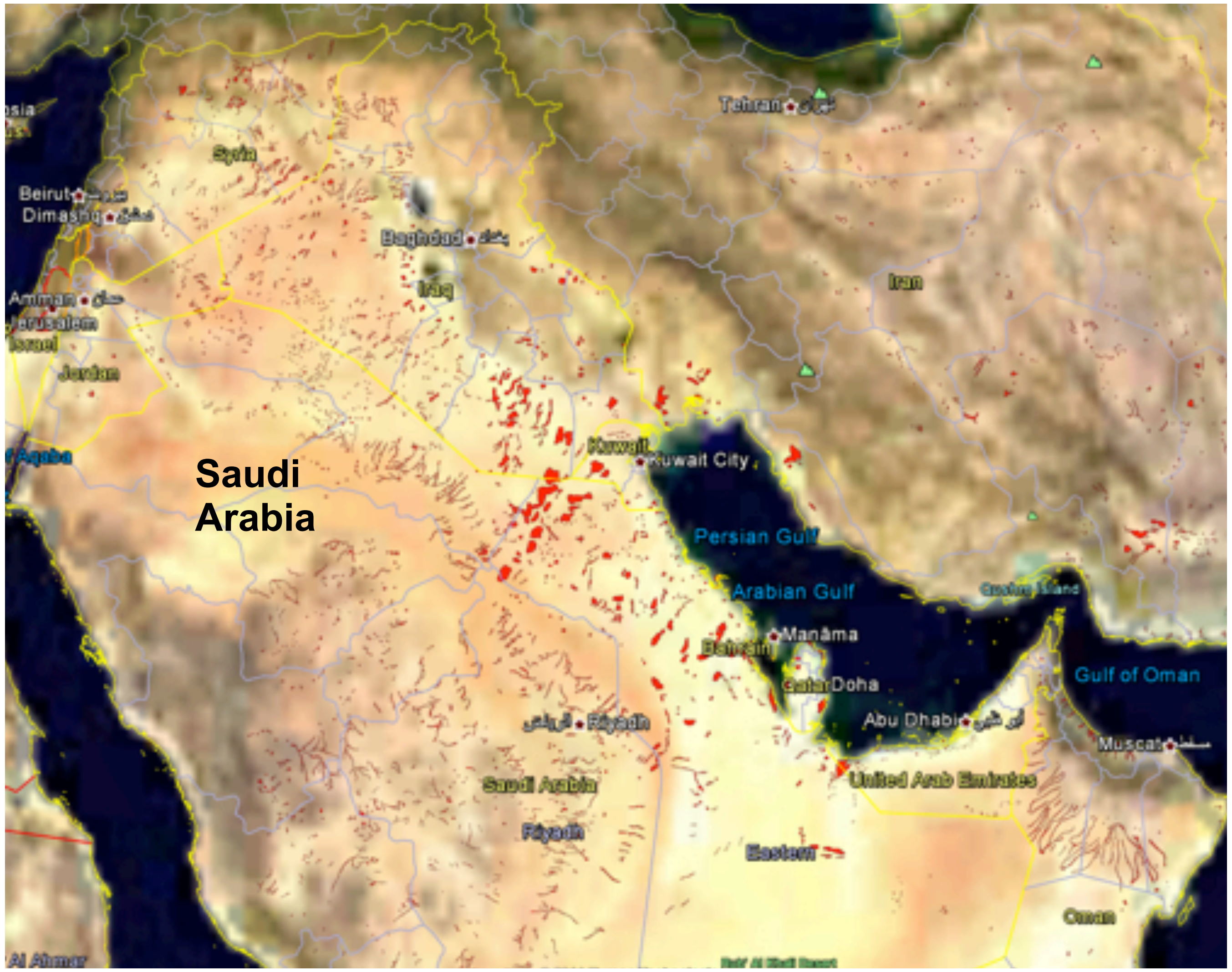
NRL High-resolution Dust Source Database

Solid red and purple shapes identify dust source areas located using DEP and MSG.

SW Asia DSD



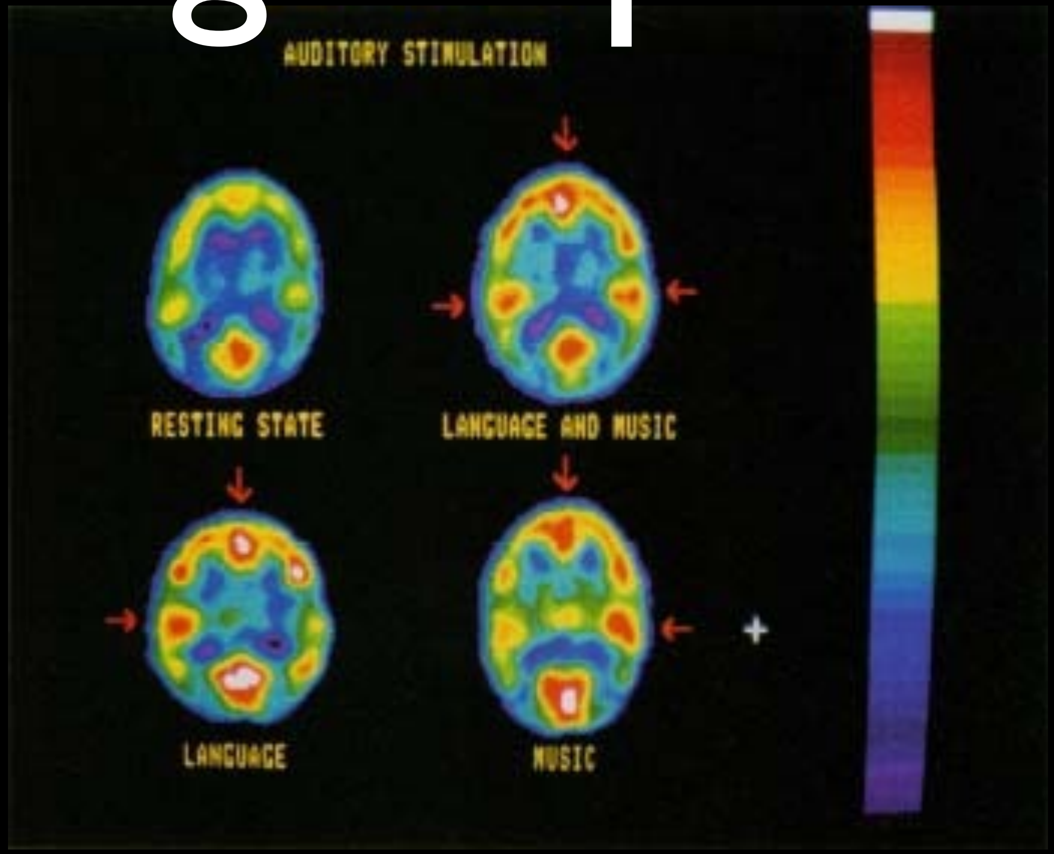
East Asia DSD

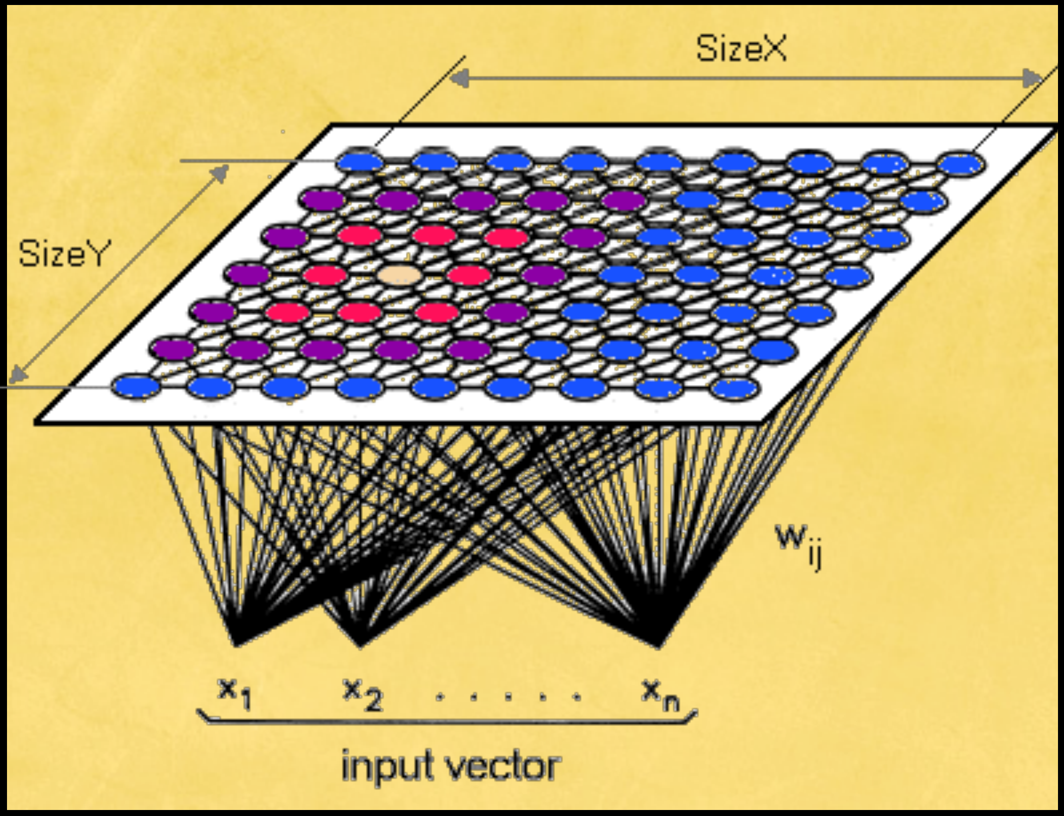
Self-Organizing Map

SOMs reduce dimensionality by producing a map that objectively plots the similarities of the data by grouping similar data items together.

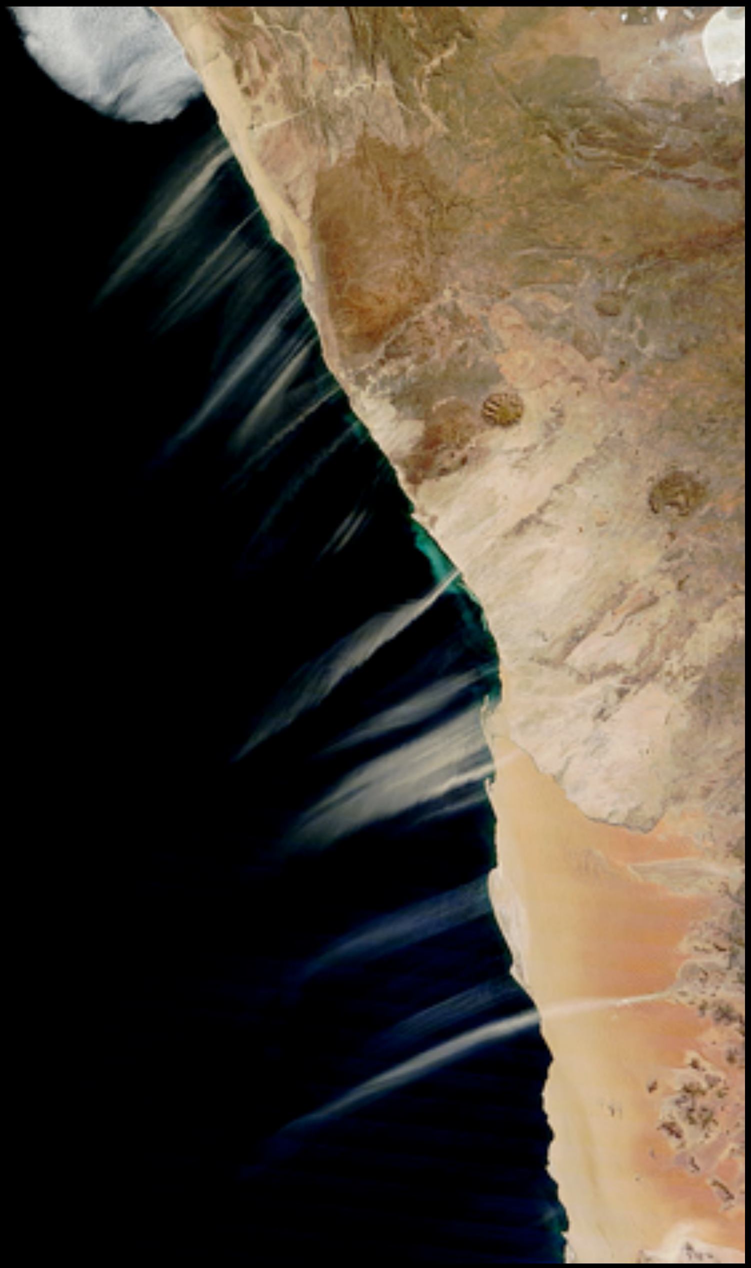
SOMs learn to classify input vectors according to how they are grouped in the input space.

SOMs learn both the distribution and topology of the input vectors they are trained on. This approach allows SOMs to accomplish two things, reduce dimensions and display similarities.





Detecting Dust Sources



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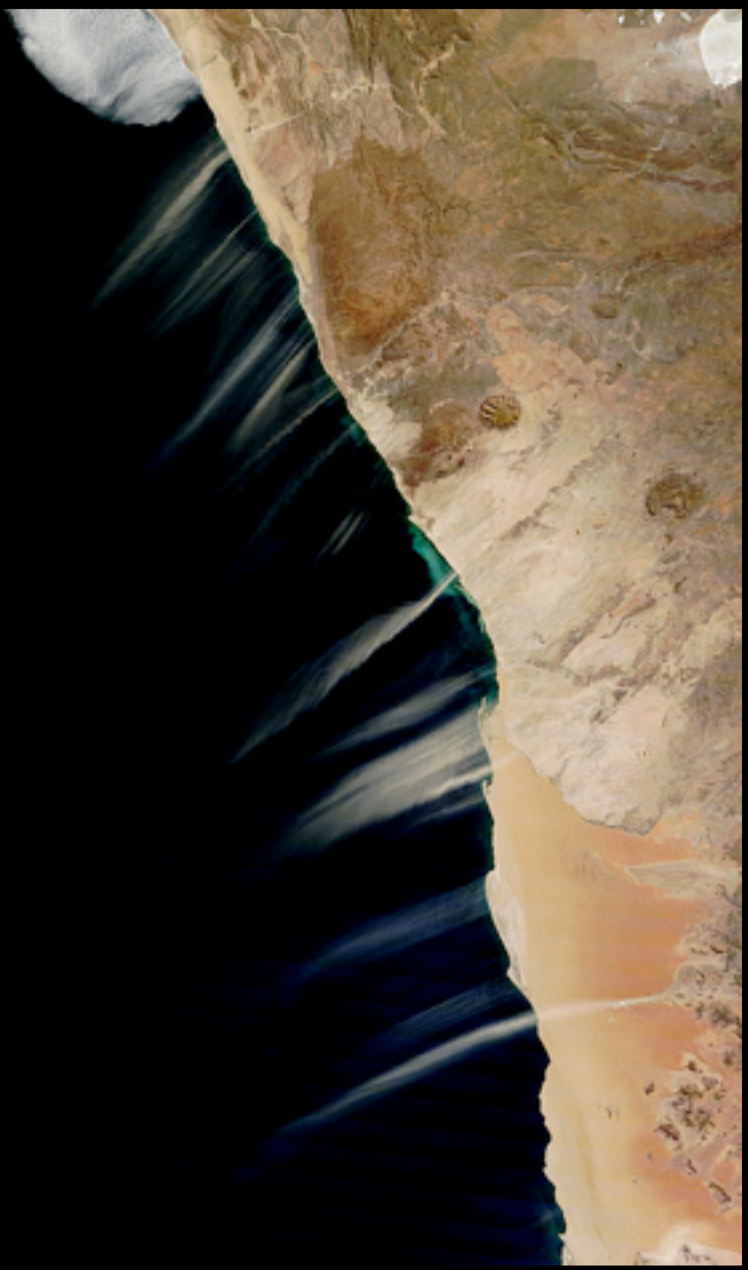
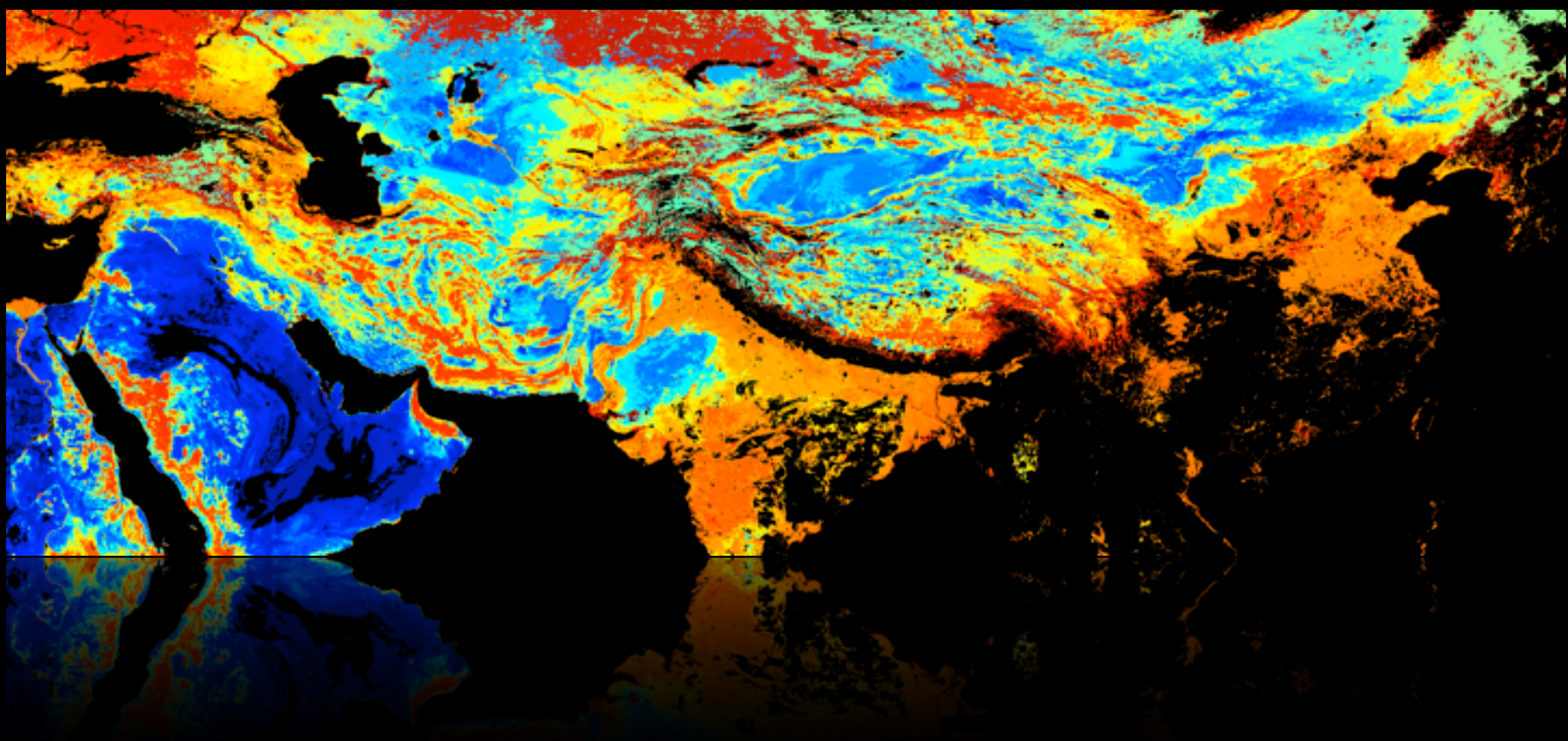
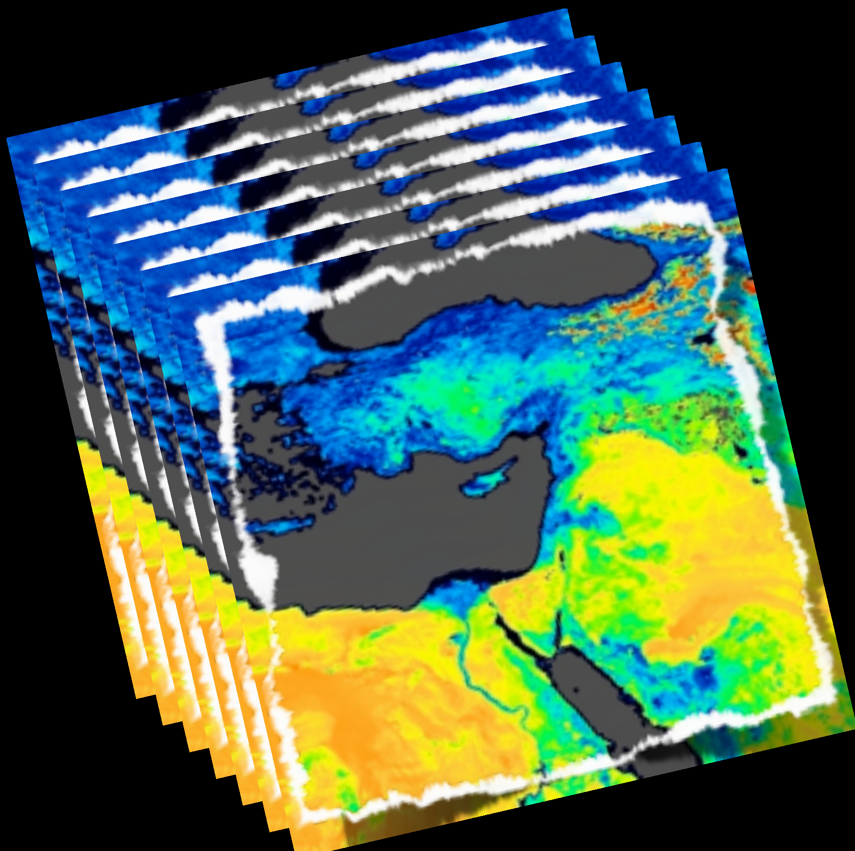


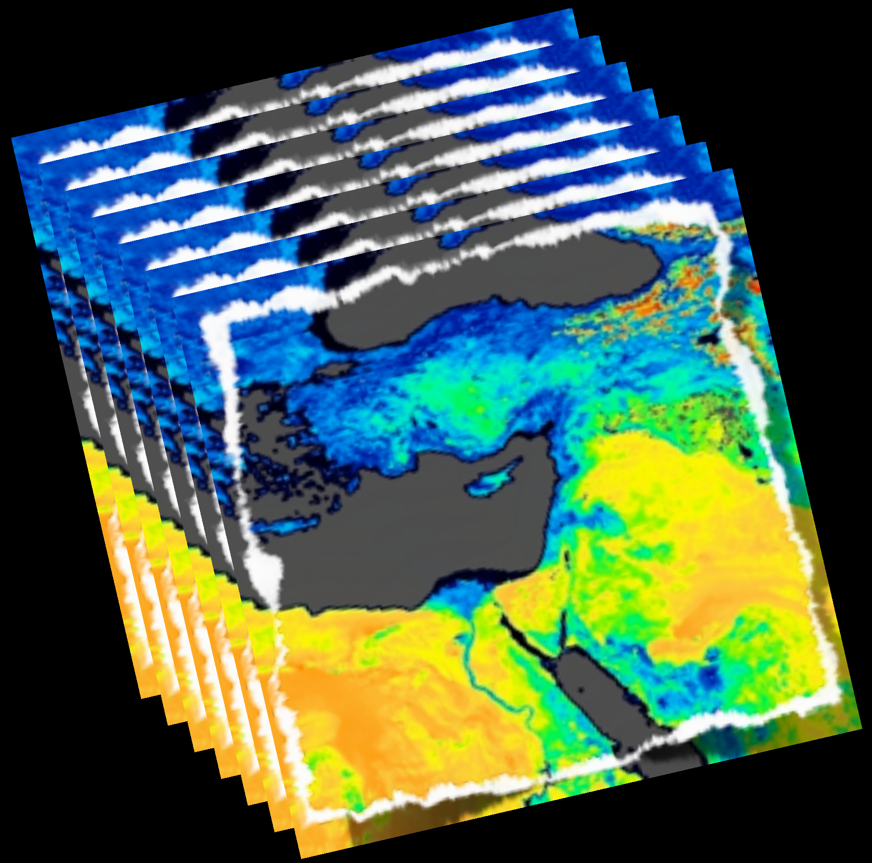


Self Organizing Map Classification



7 Bands
MODIS MCD43C3
bihemispherical reflectance

Self Organizing Map Classification



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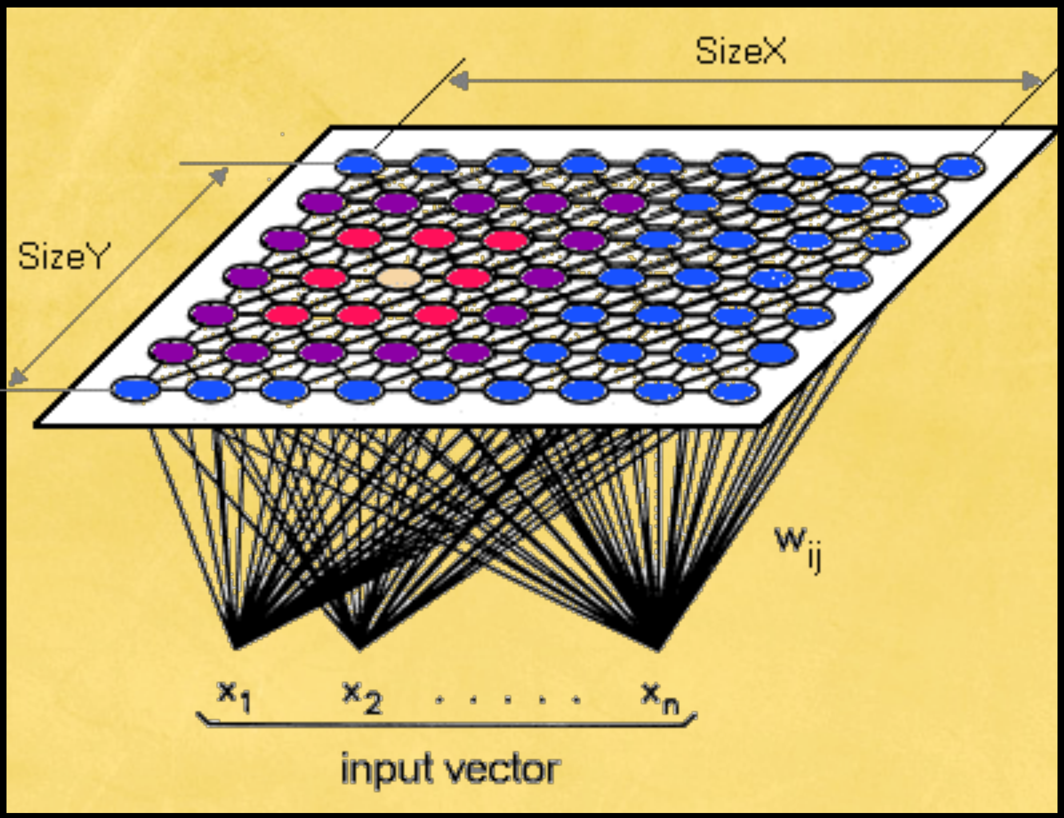

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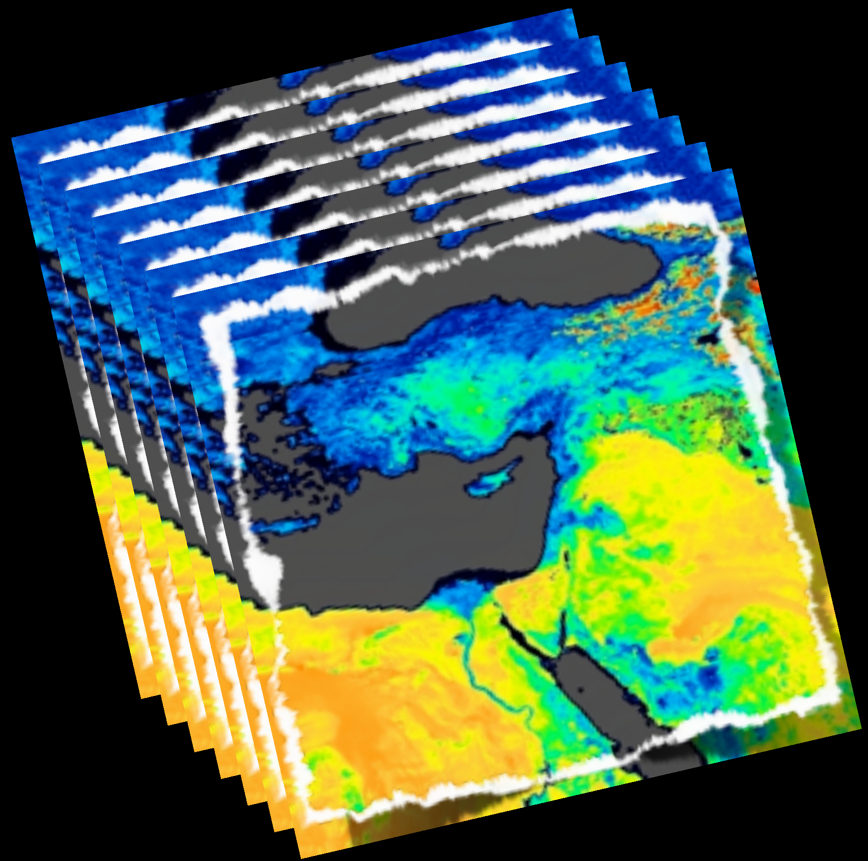

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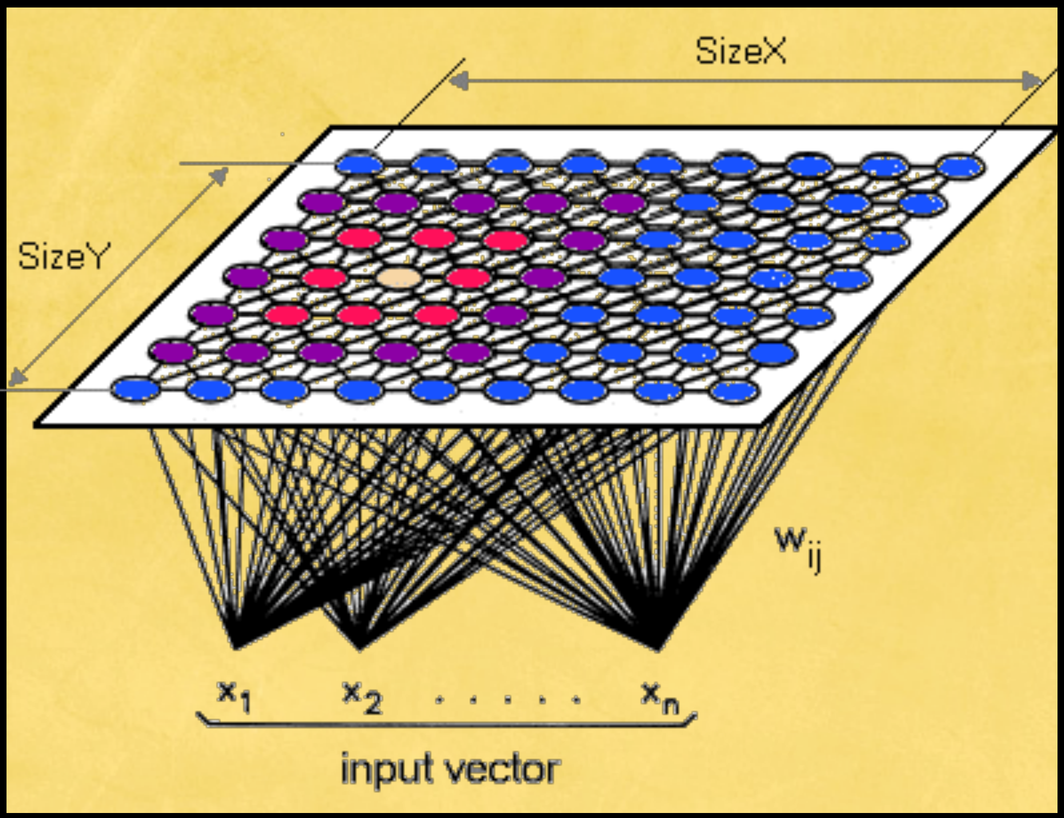
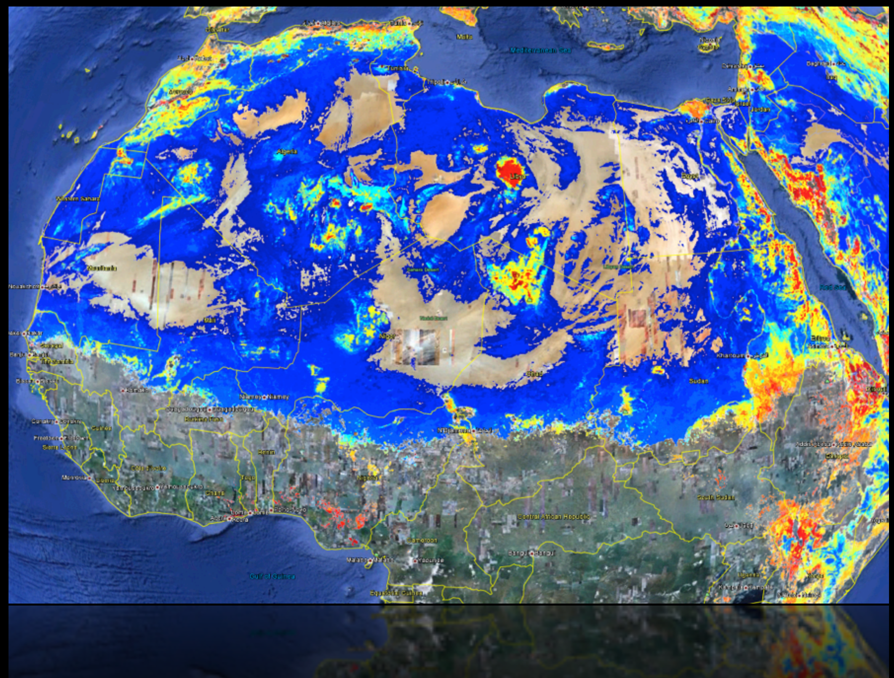
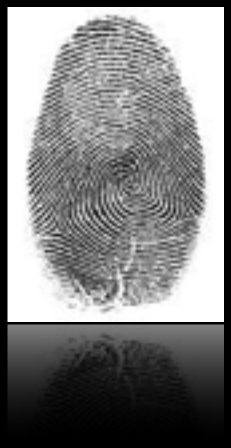
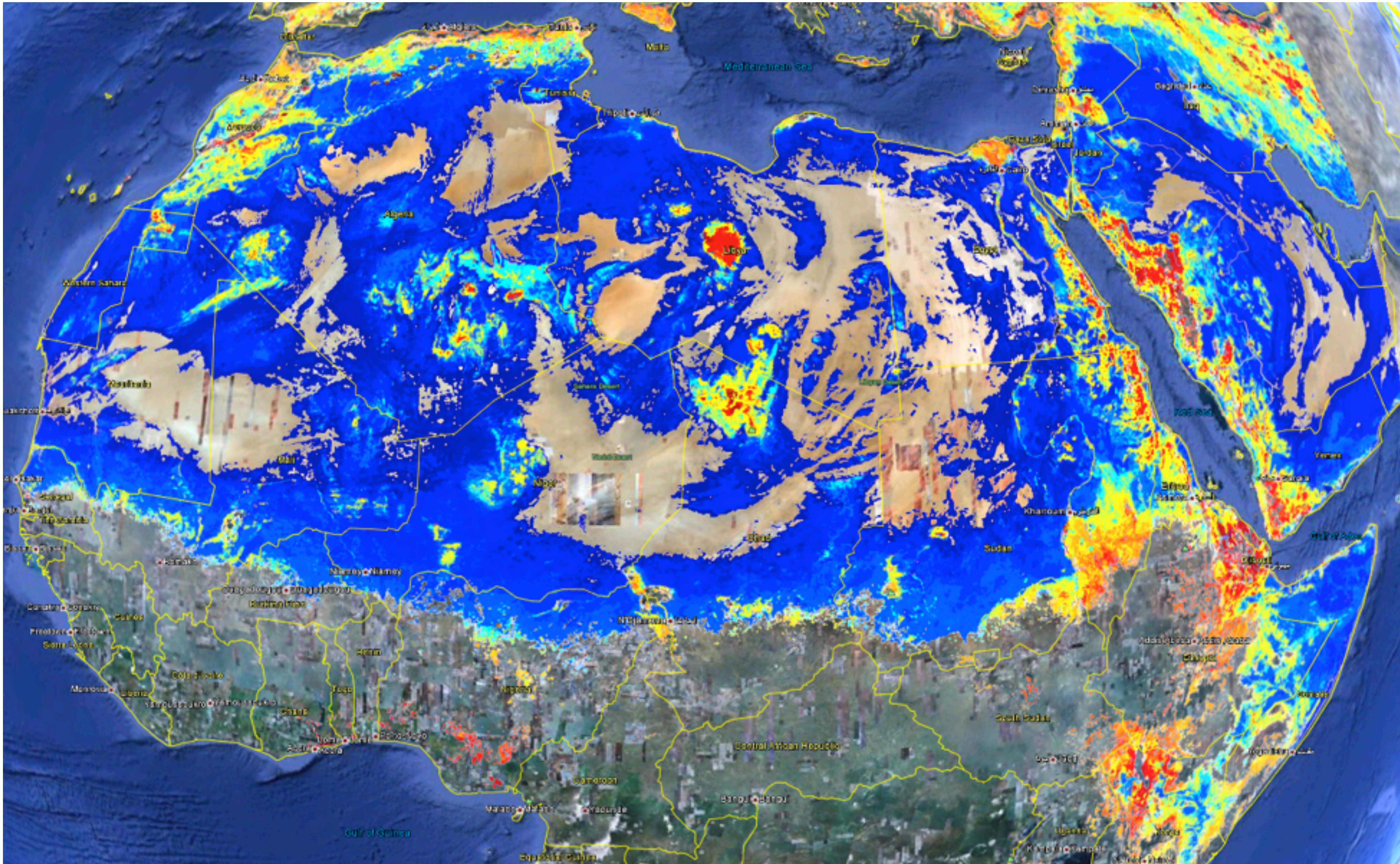






All 1000-Classes mapped for North Africa



Libyan Dust Event: May 9, 2010 (8Z – 12Z)

Jabal al Akhdar (الجبل الأخضر *Al Ǧabal al 'Aẖḍar*, English: *Green Mountains*)

A coastal mountain range with height 1.0-1.5 km.

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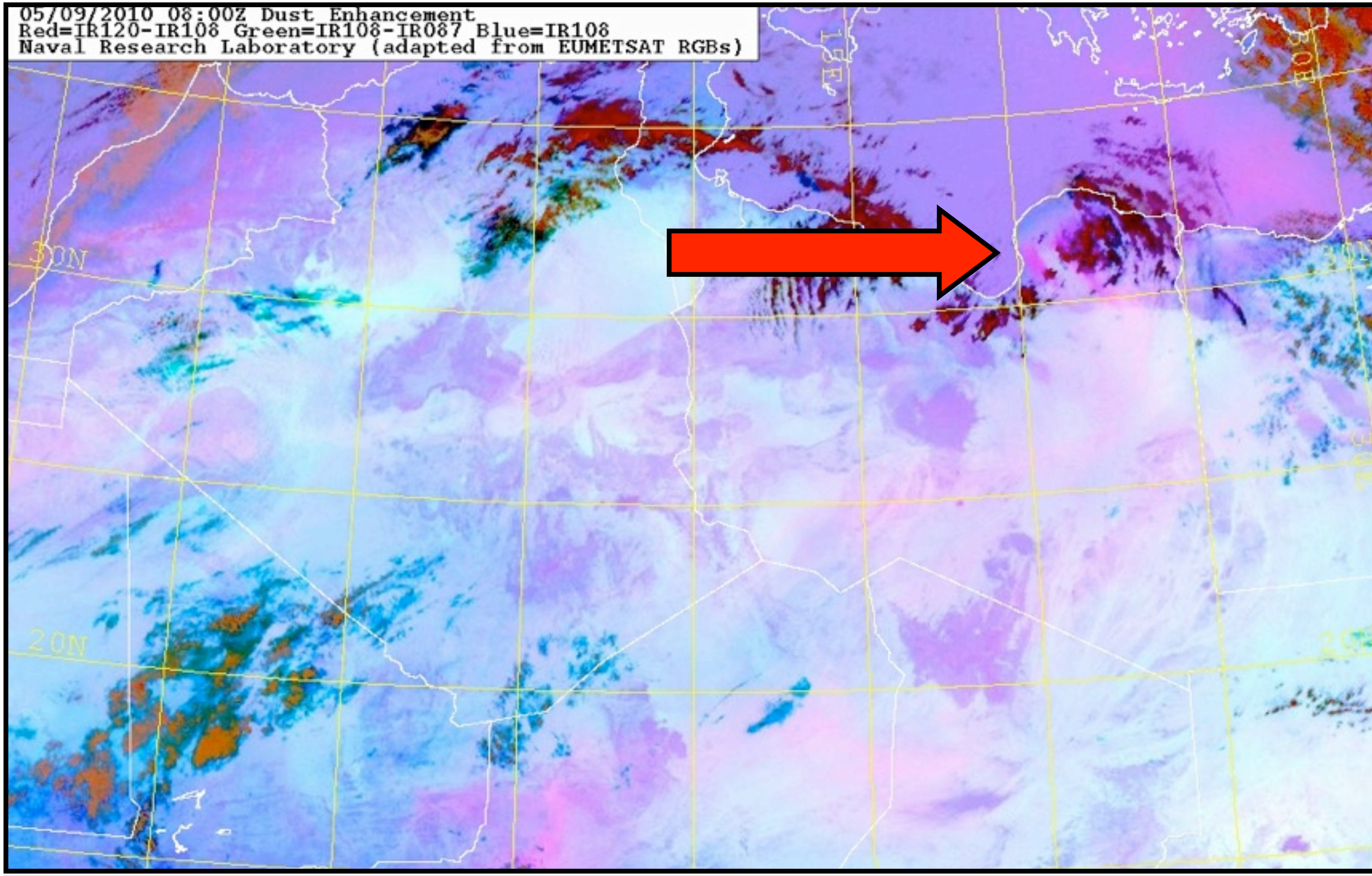

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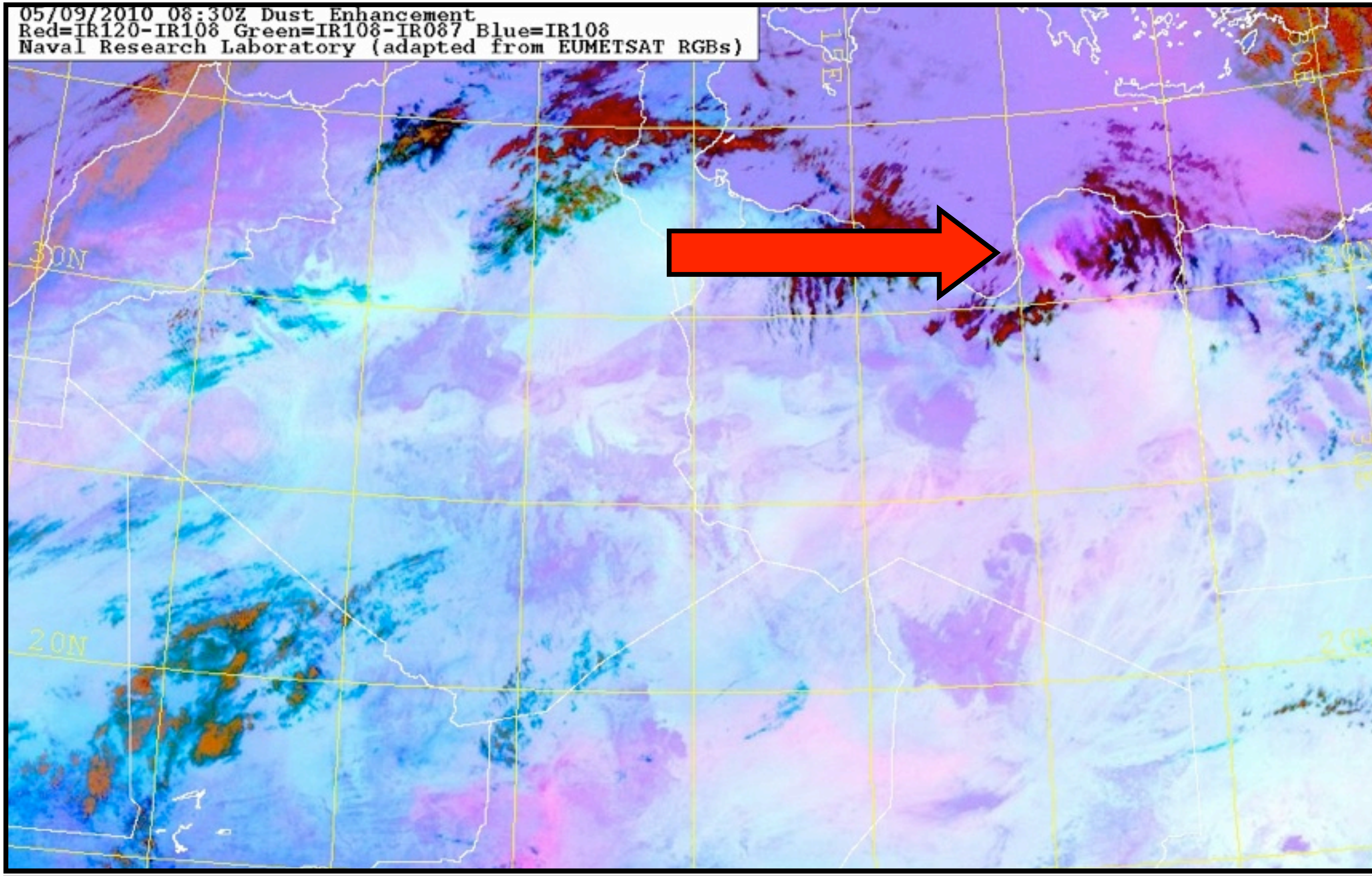

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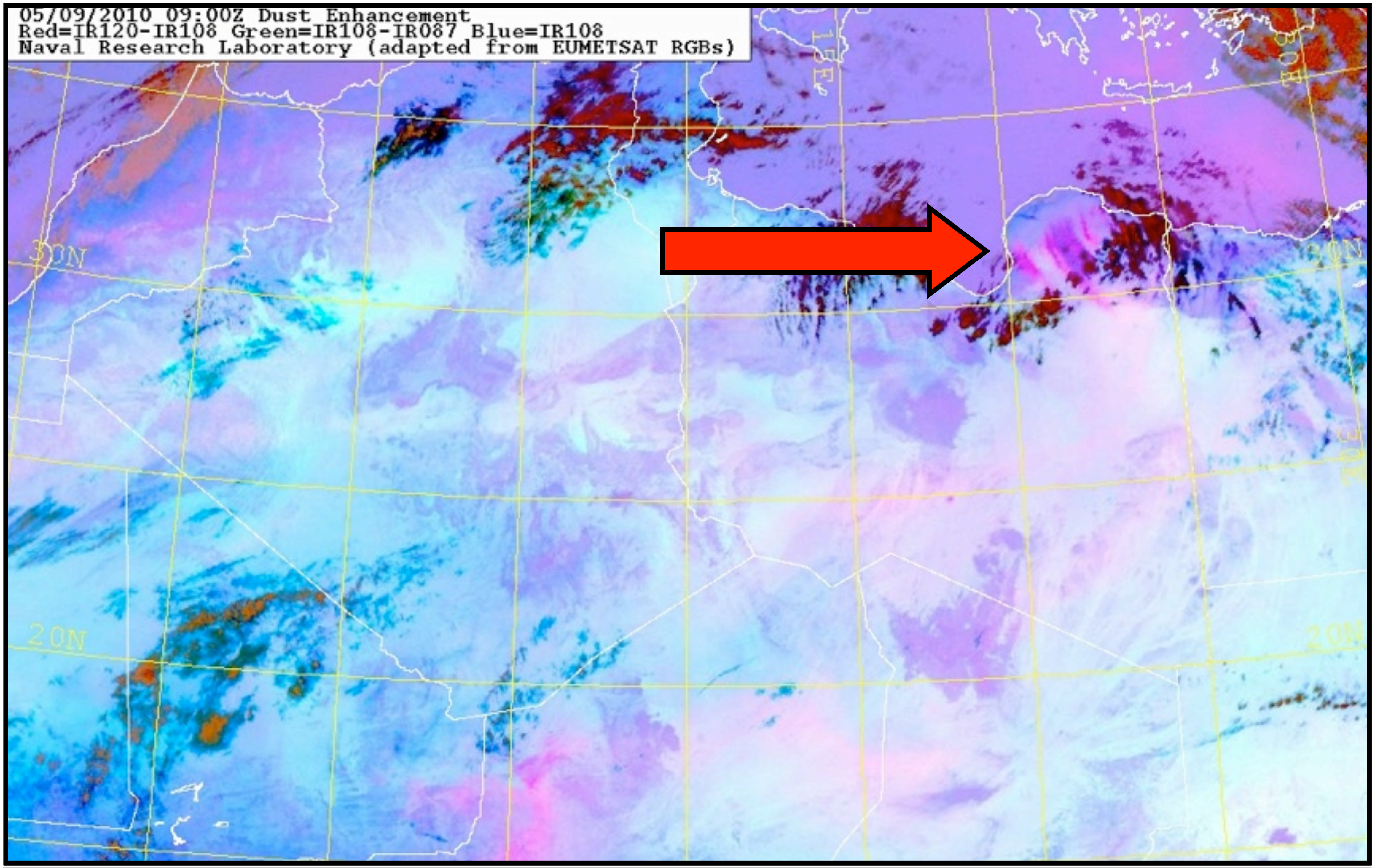

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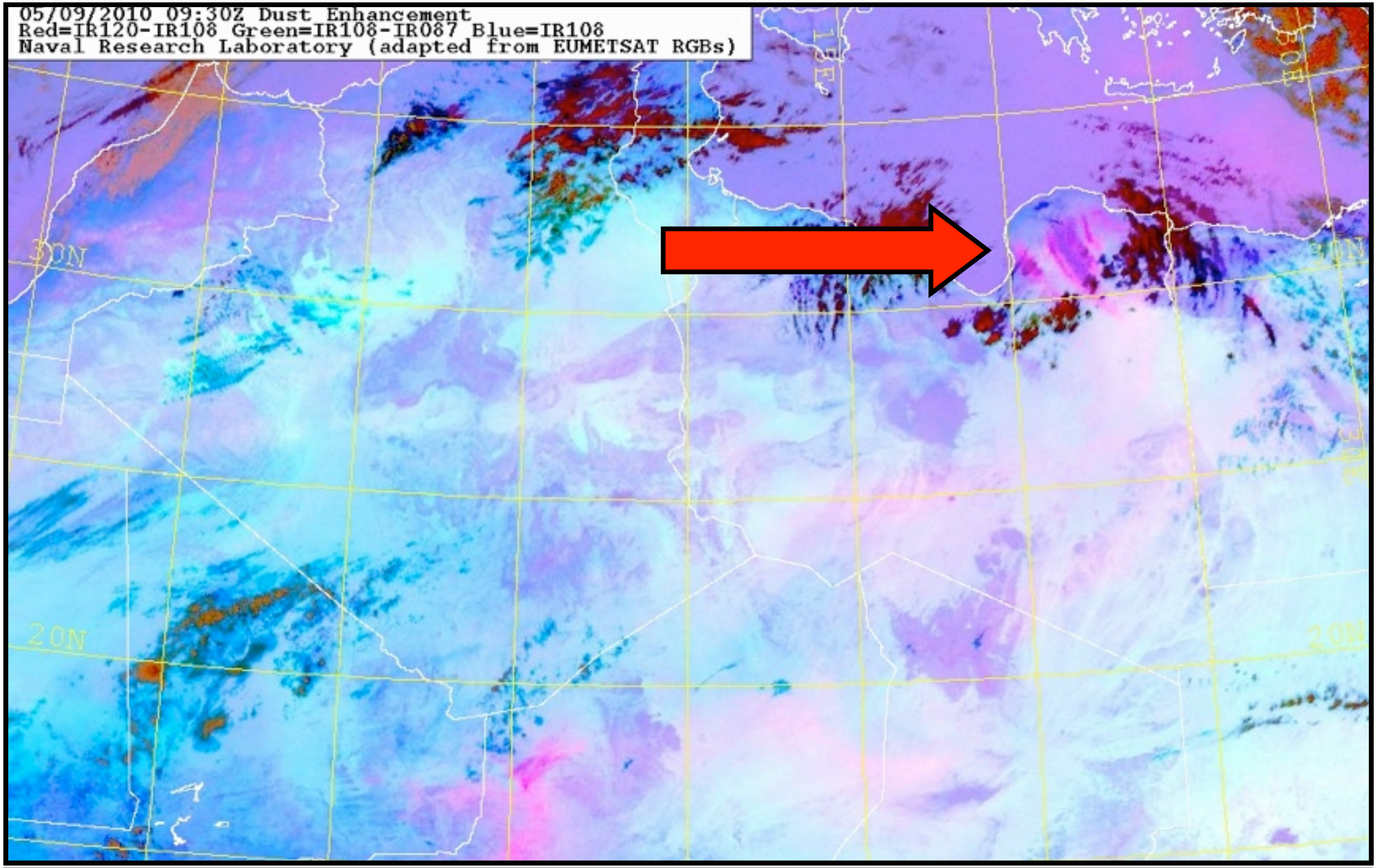

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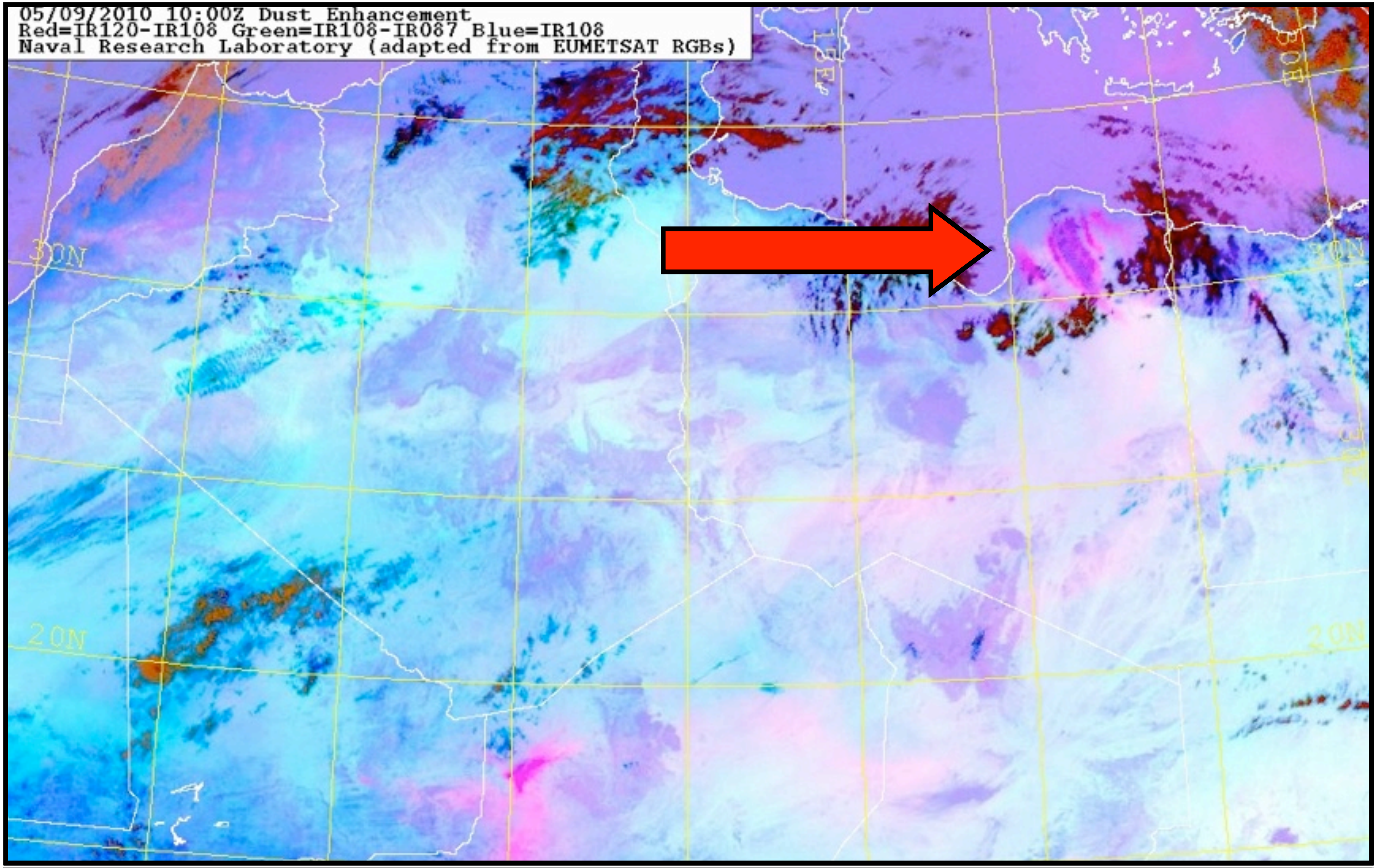

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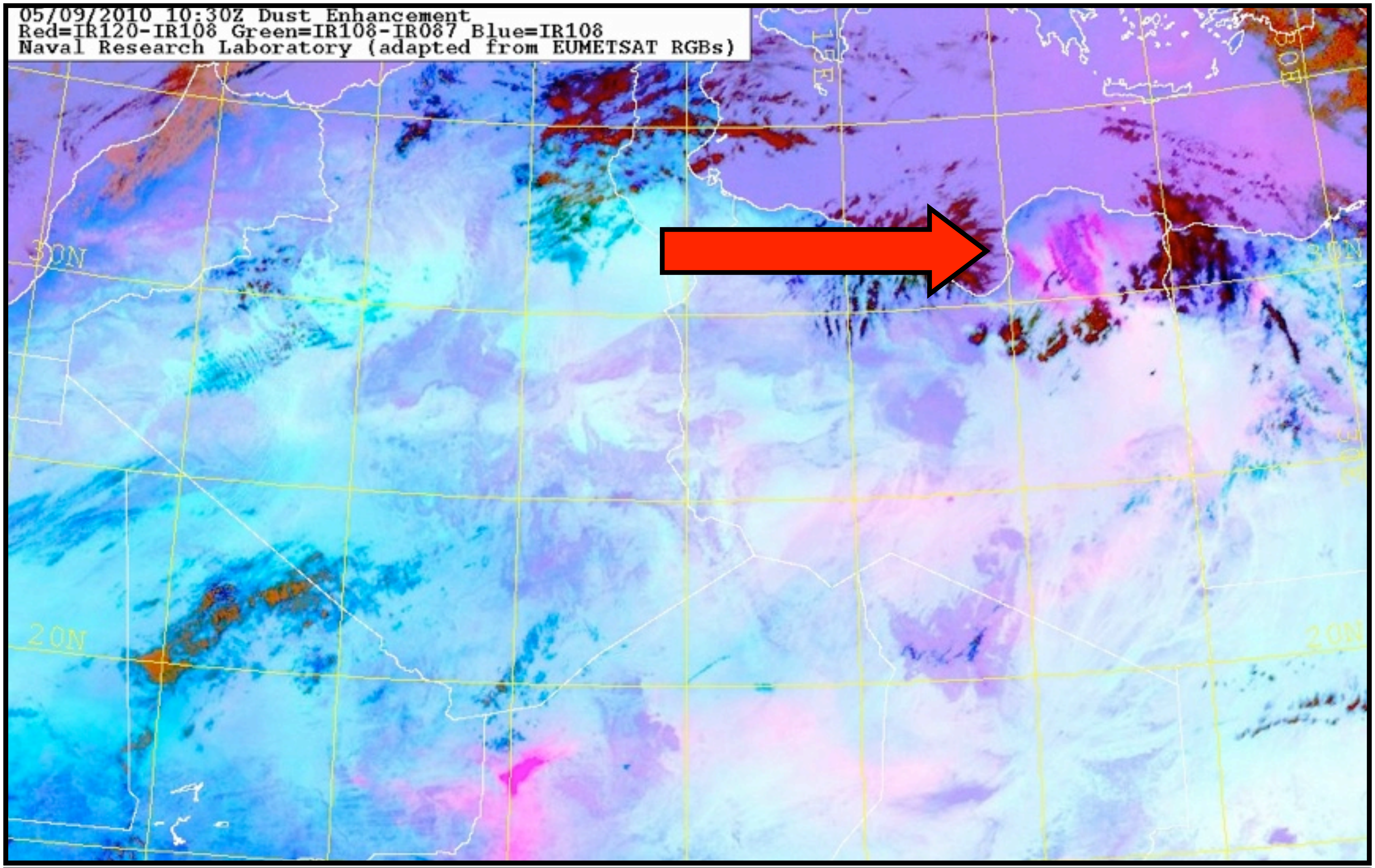

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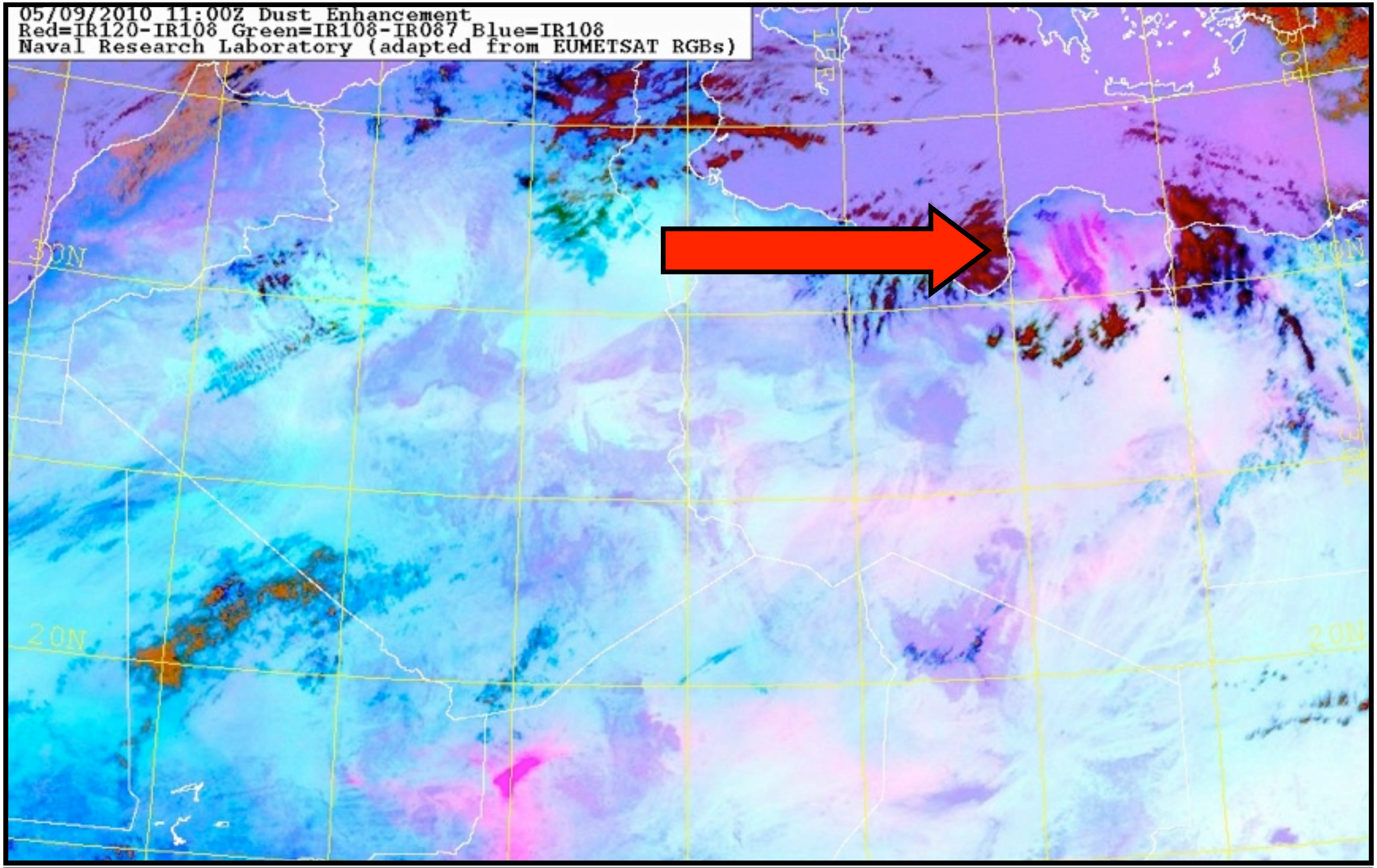

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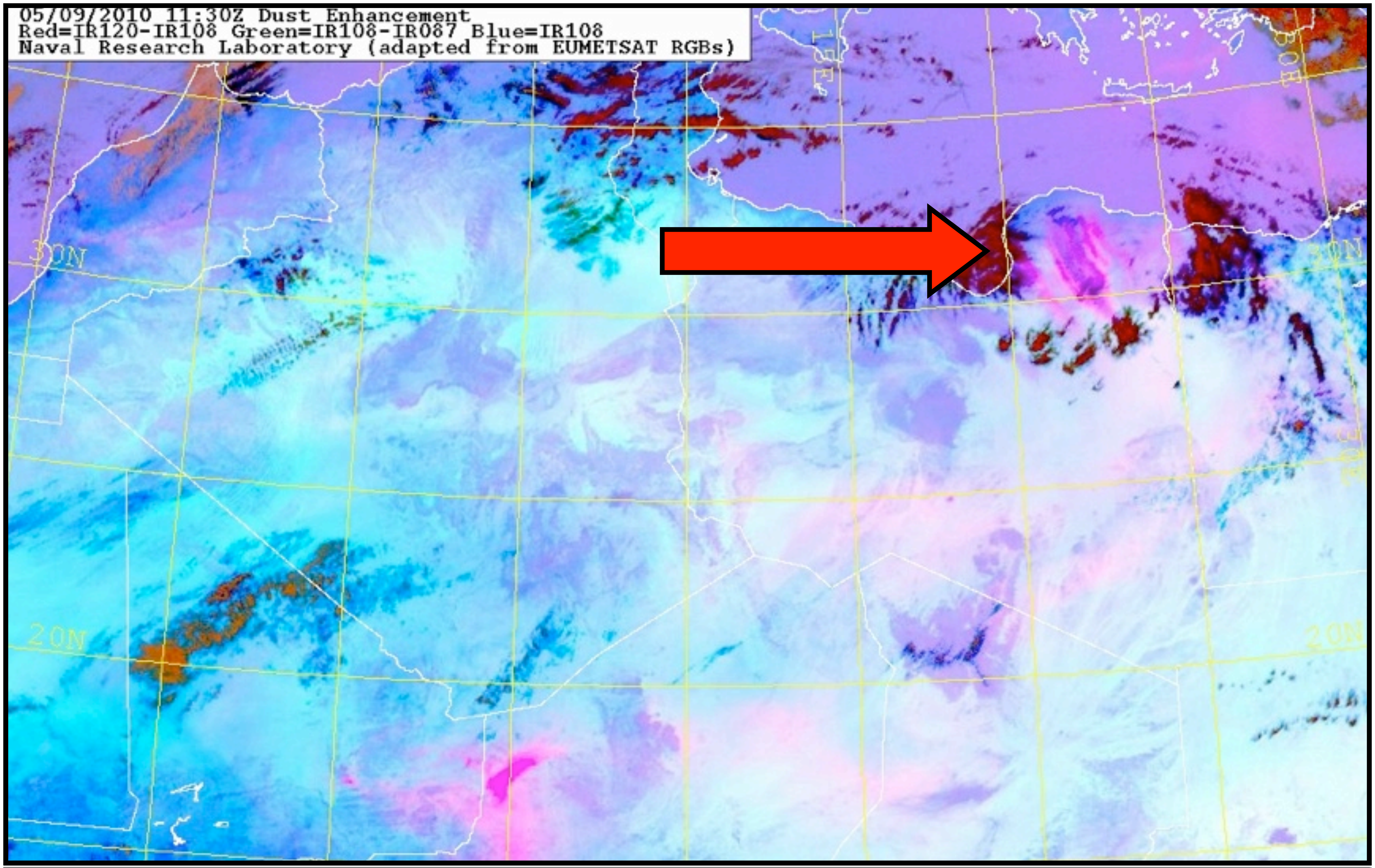

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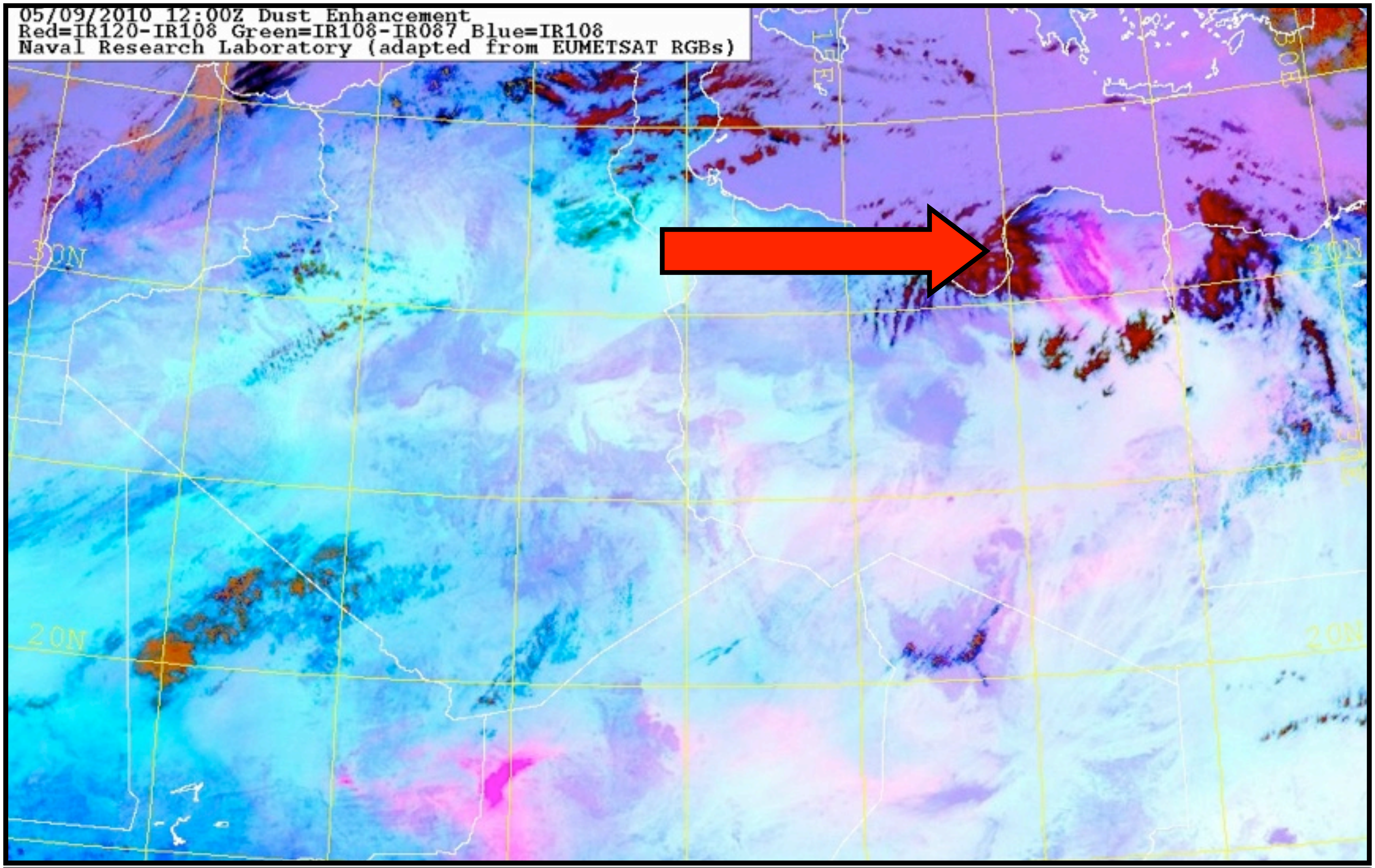

Libyan Dust Event: May 9, 2010 (6Z – 8Z)

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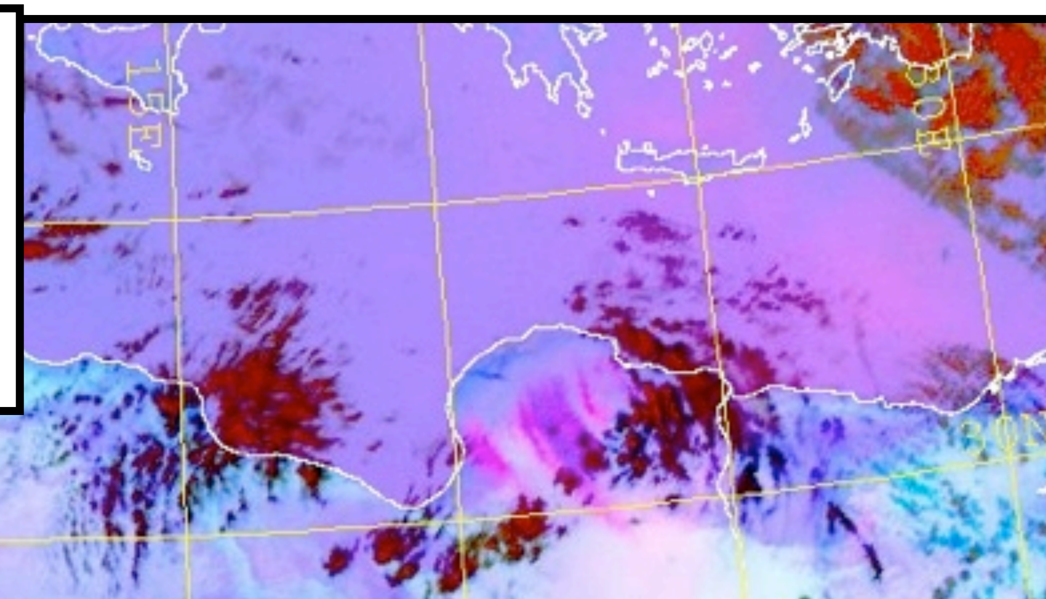
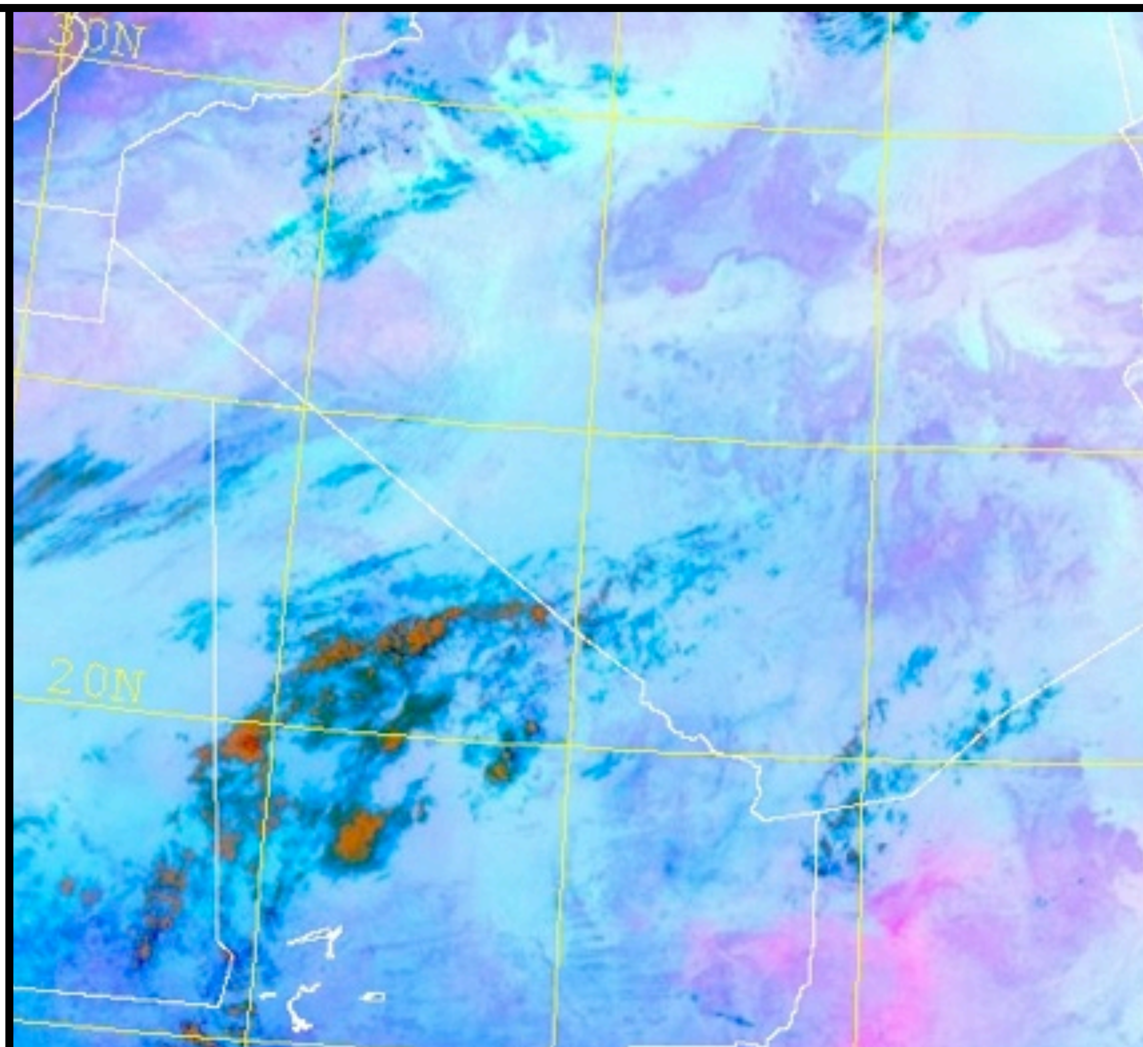
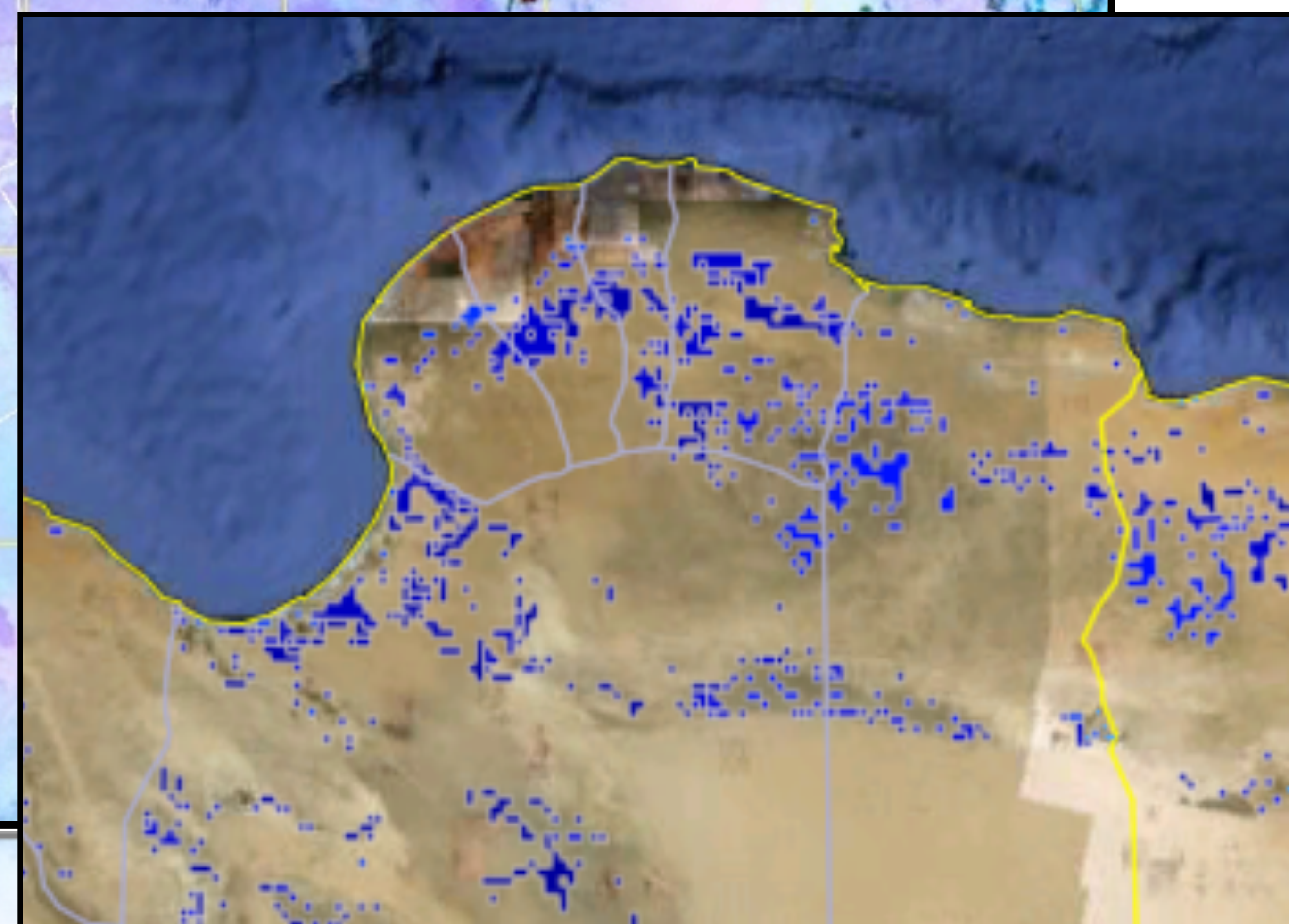
Plumes originate on leeward side of Al Jabal al Akhdar where drainage occurs along slopes.

Corresponding SOM-Classes: 49, 93, 94

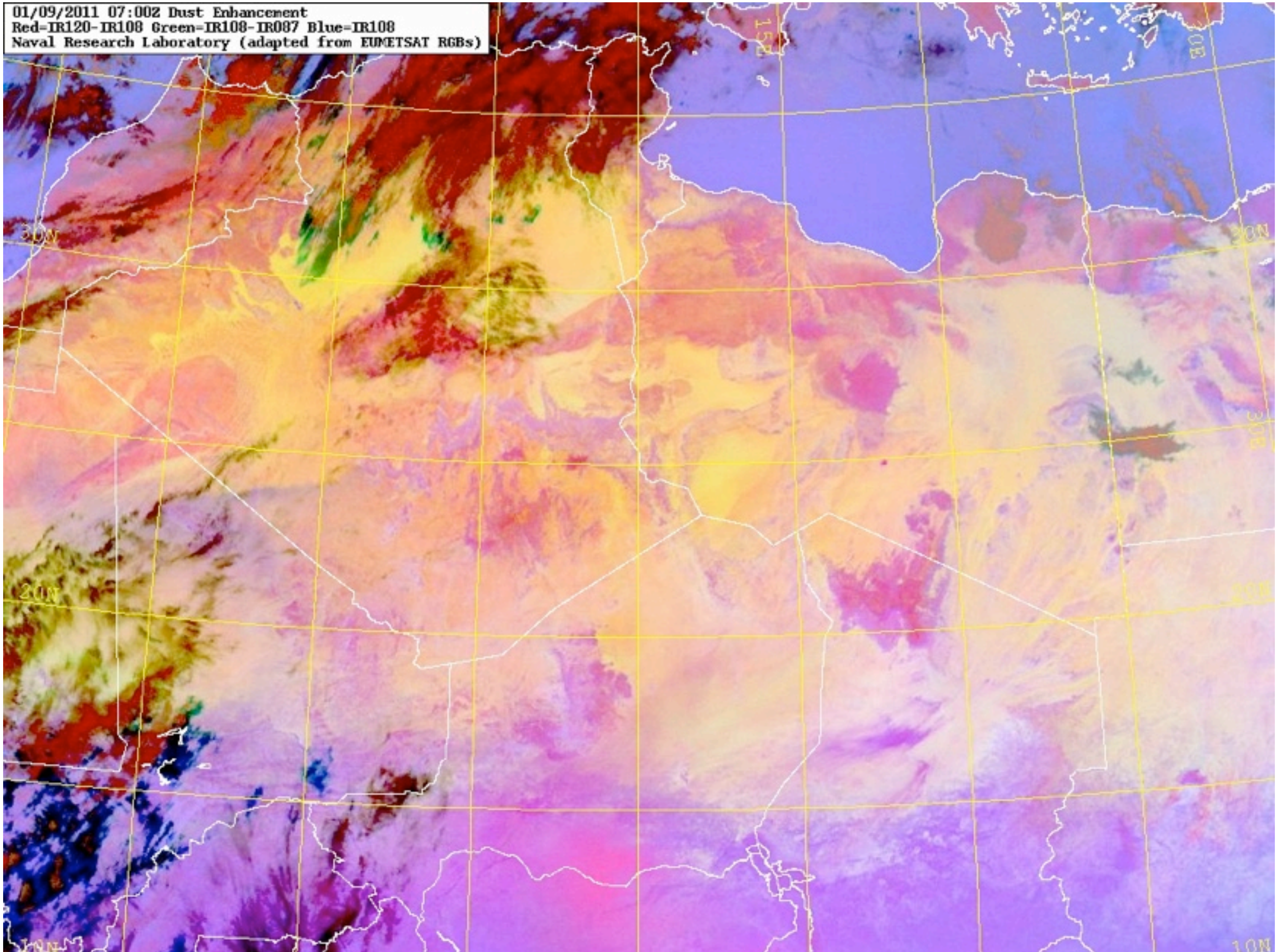






Chad: Bodélé Depression
Dust Event: March 16, 2010 (7Z -12Z)

Located at the southern edge of the Sahara Desert in north central Africa, is the lowest point in Chad. Dust storms from the Bodélé Depression occur on average about 100 days per year. The Bodélé depression is a single spot in the Sahara that provides most of the mineral dust to the Amazon forest.



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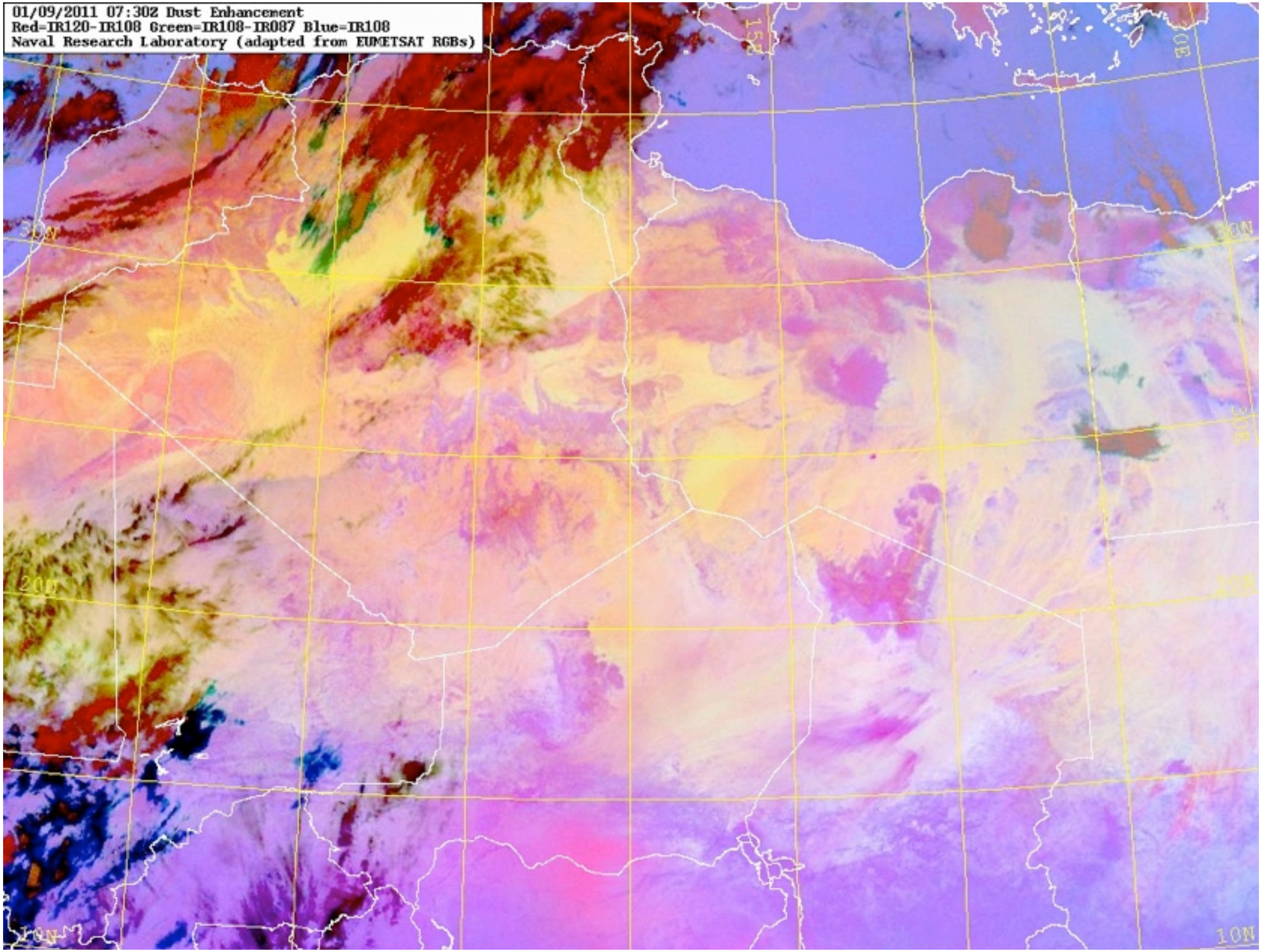

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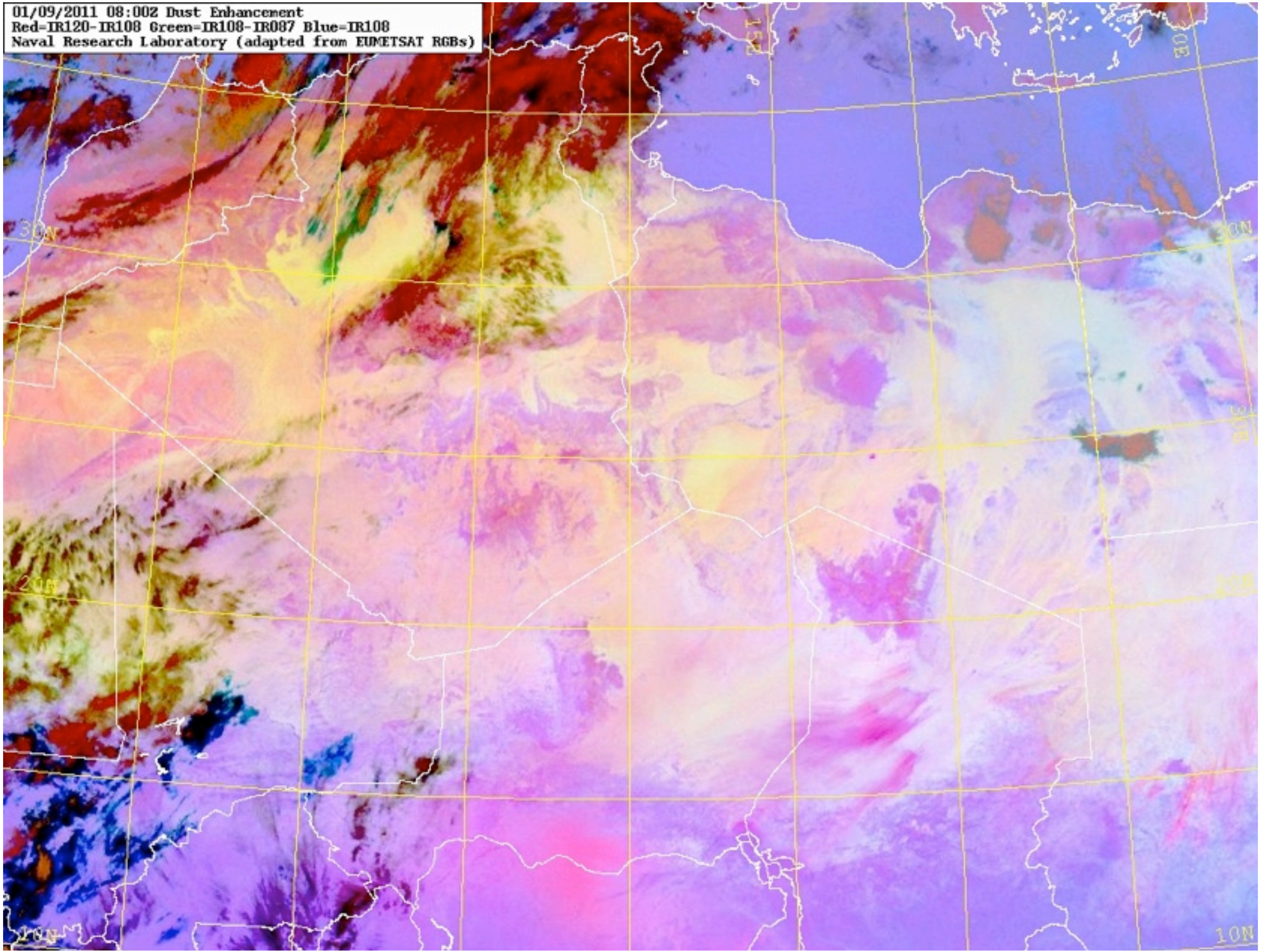

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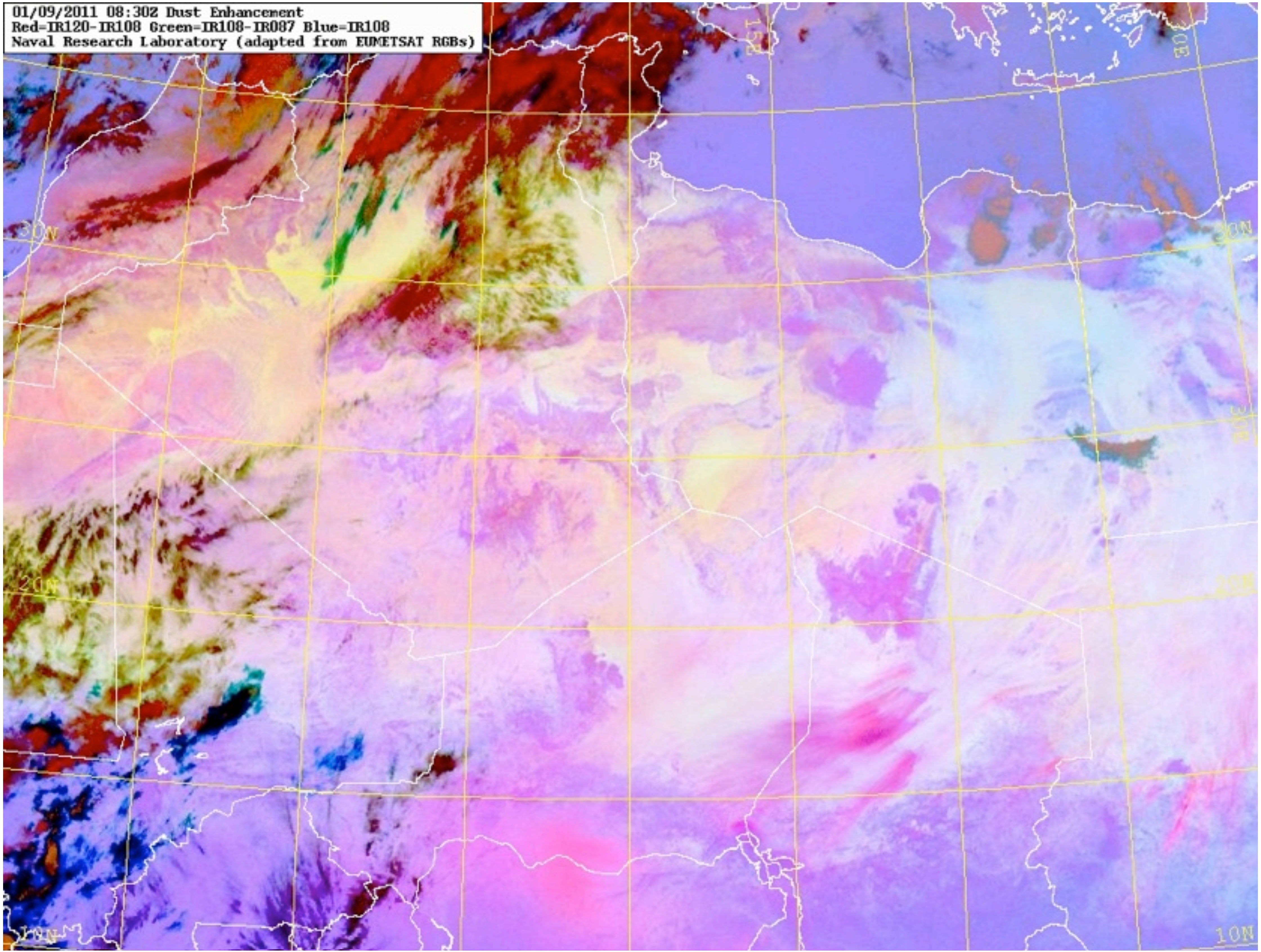

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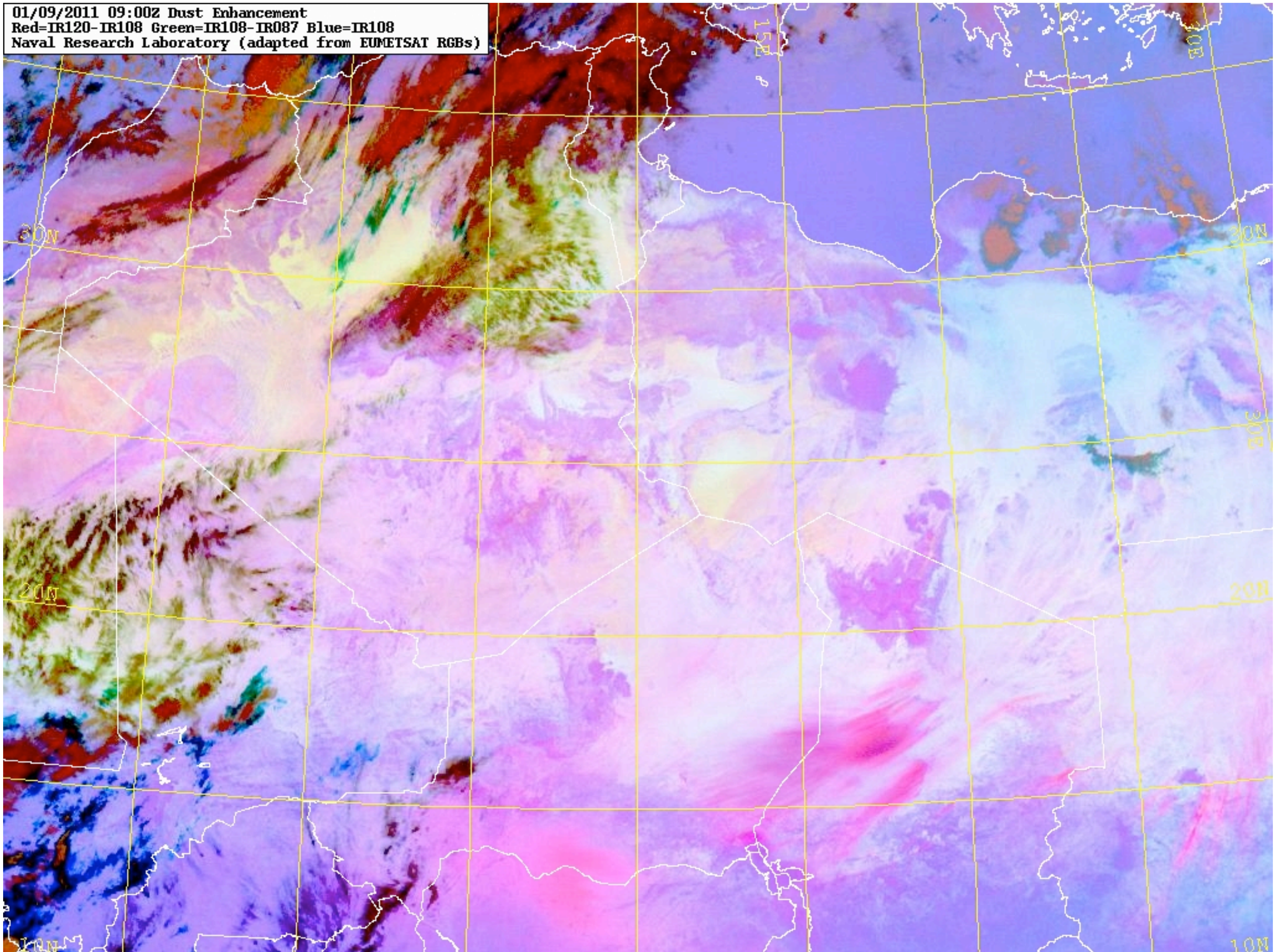

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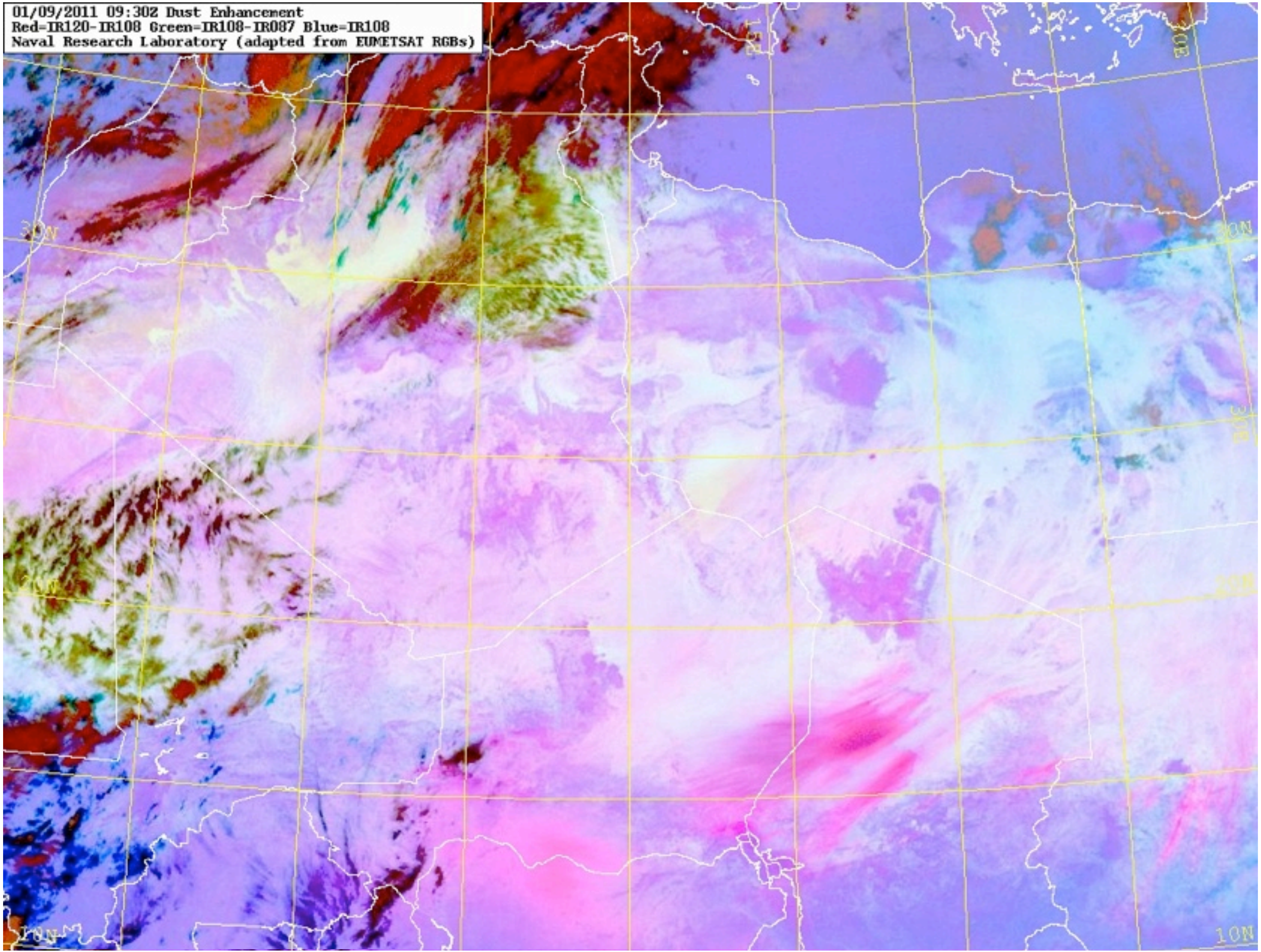

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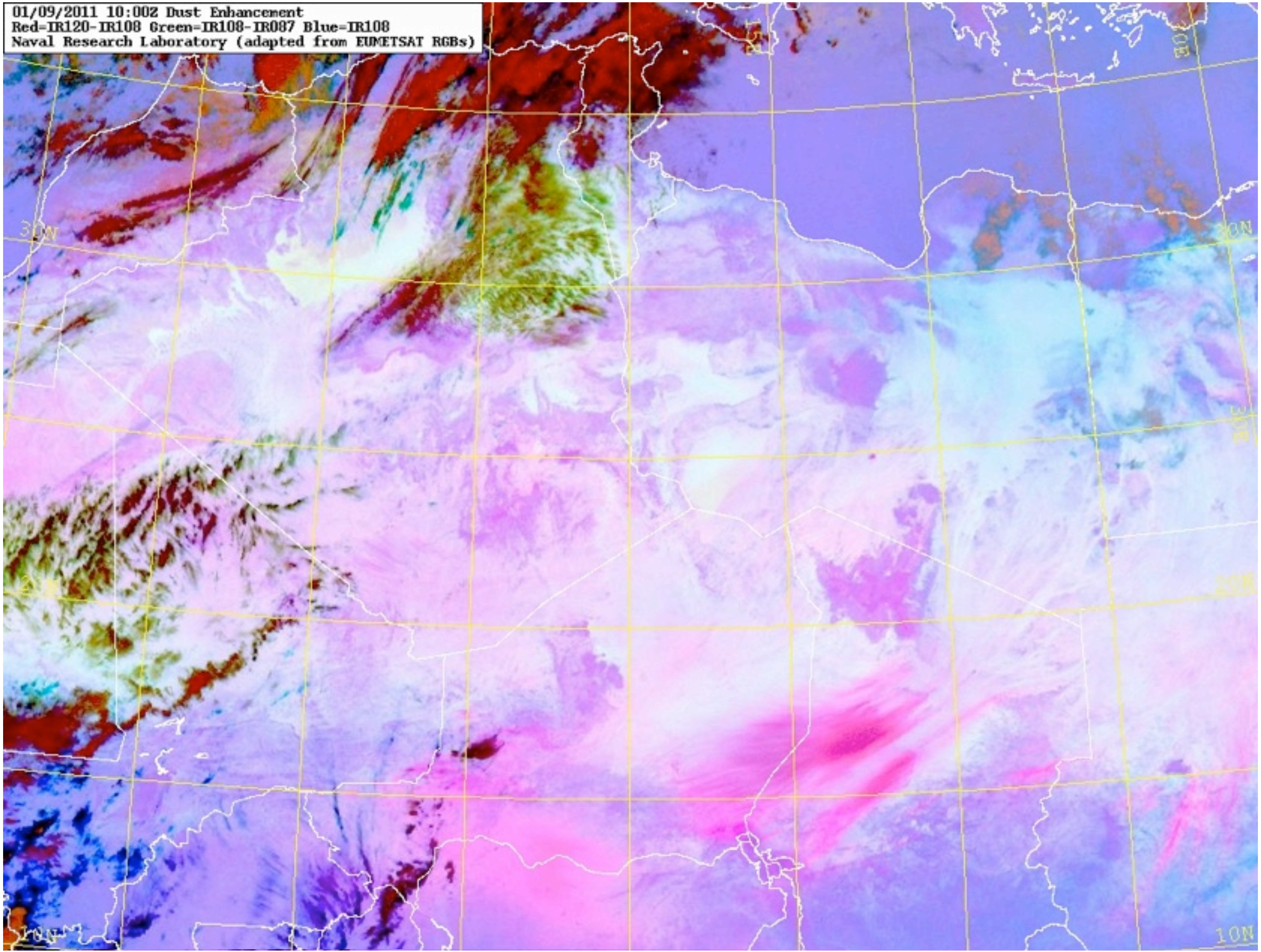

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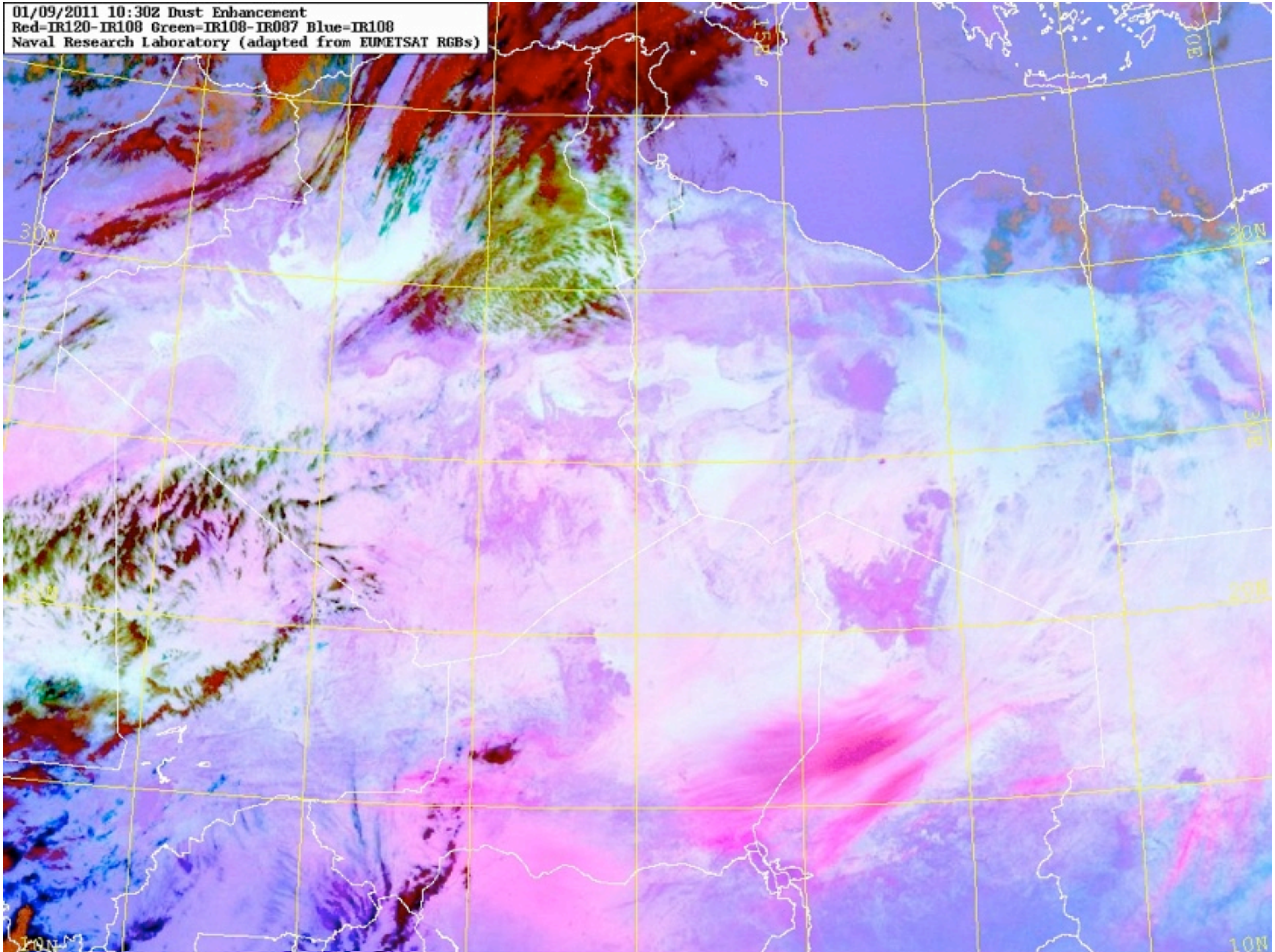

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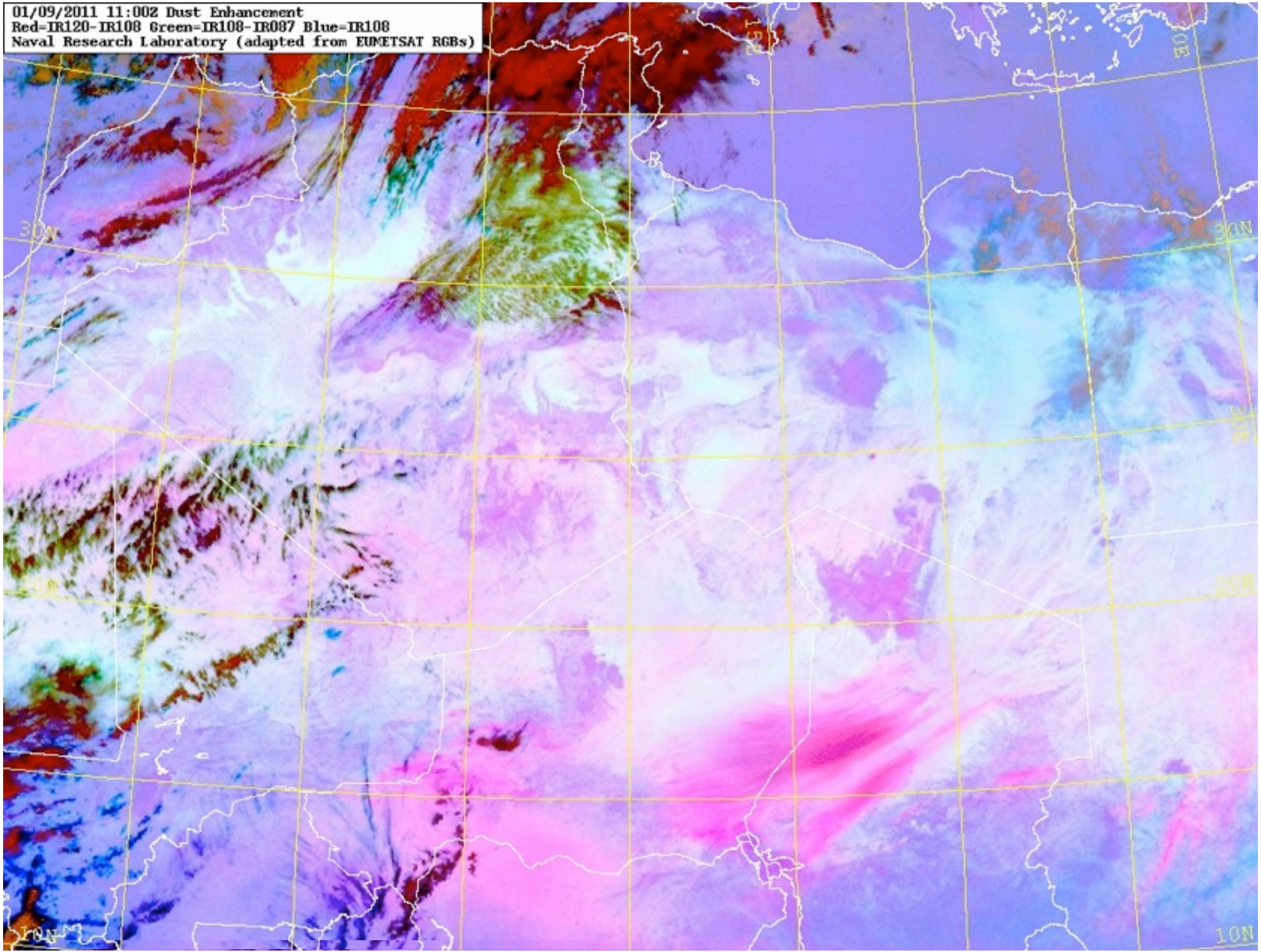

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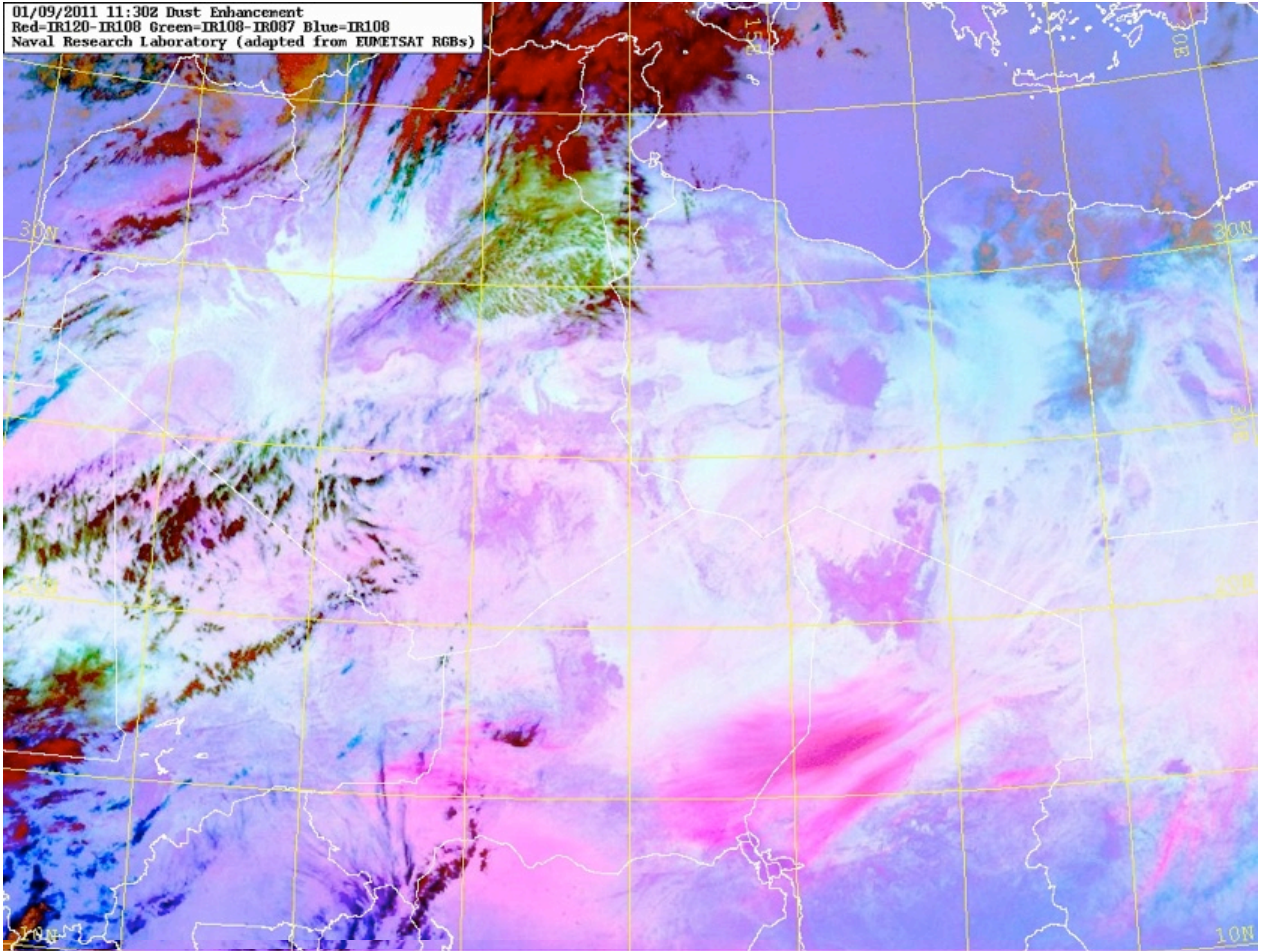

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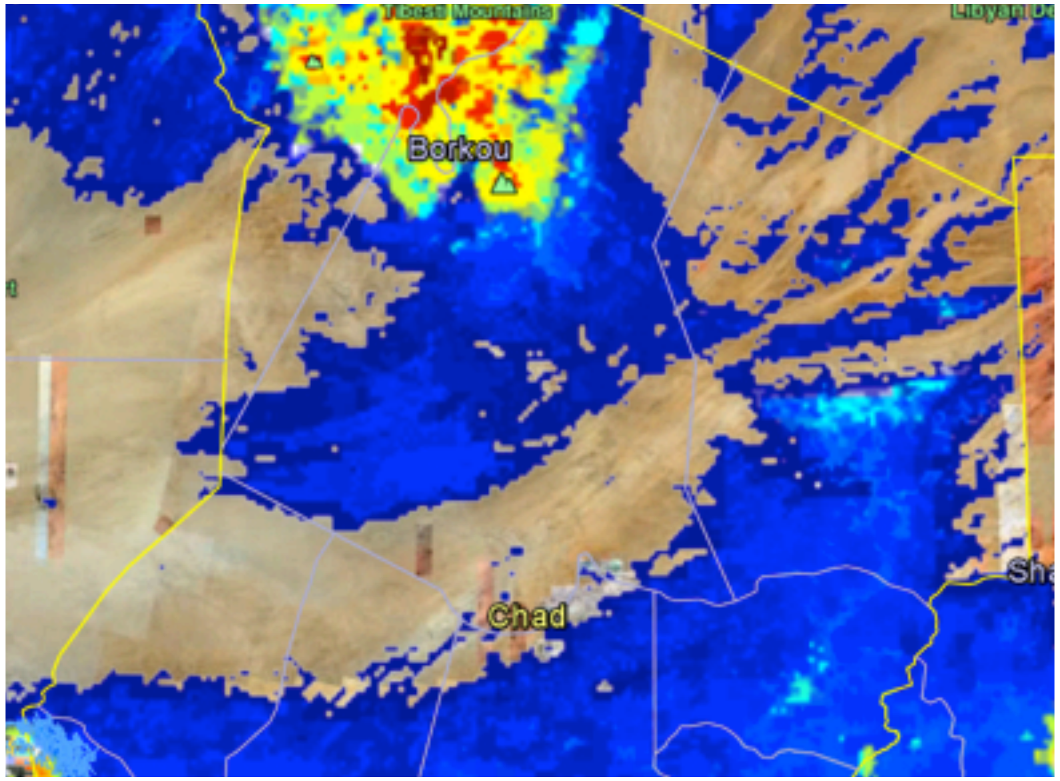
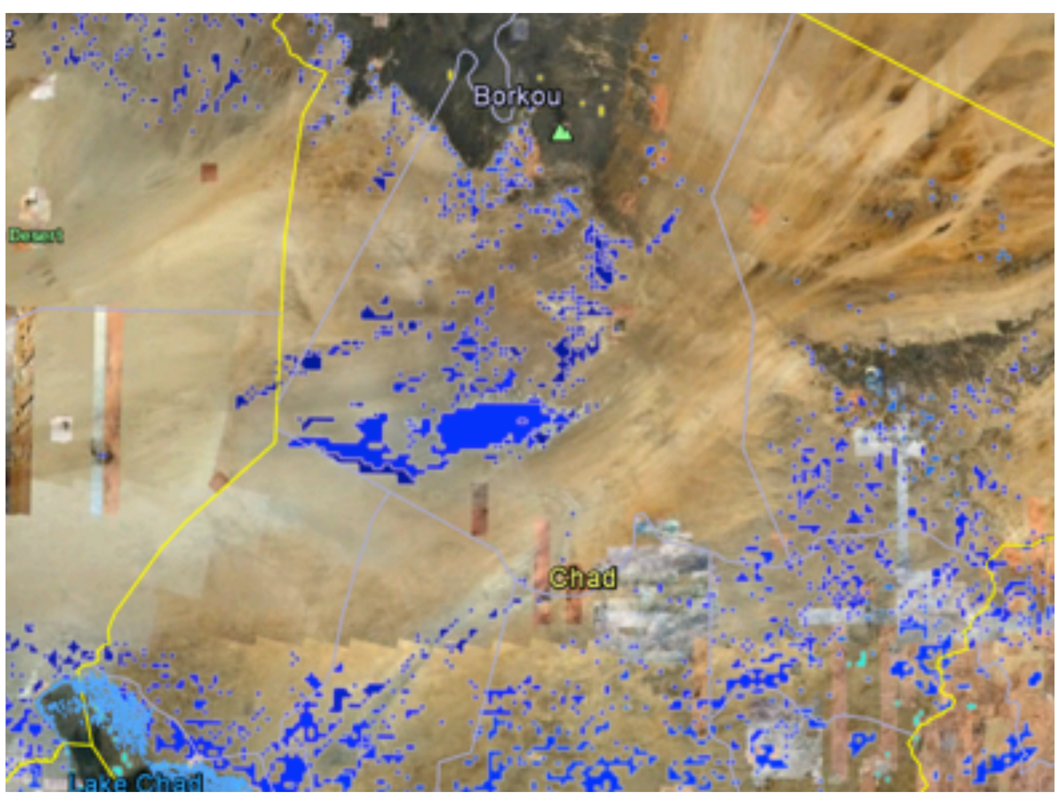
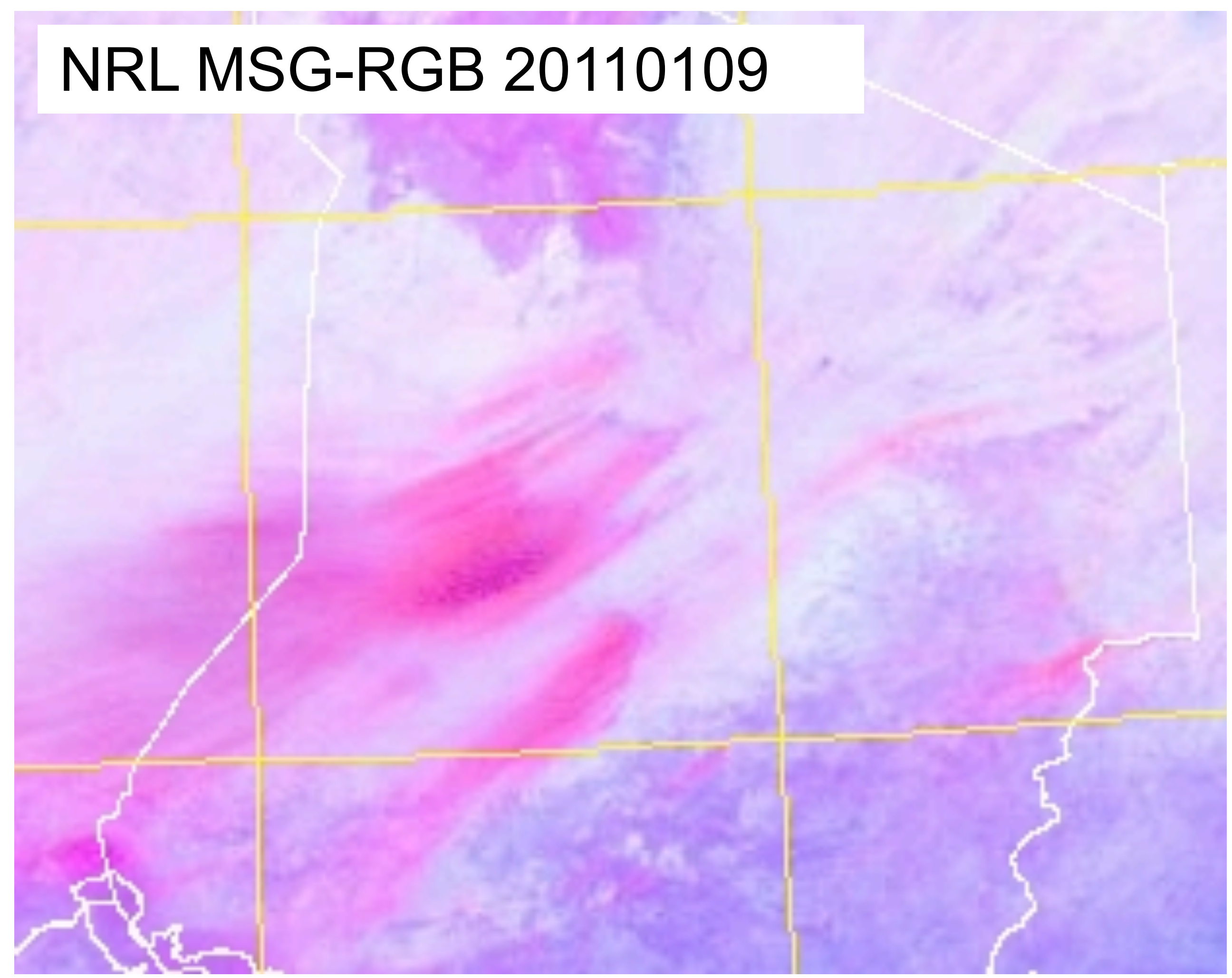


1000 SOM Classes

Source area is not designated in first pass of MODIS reflectance and land surface classification.



Selected SOM Classes



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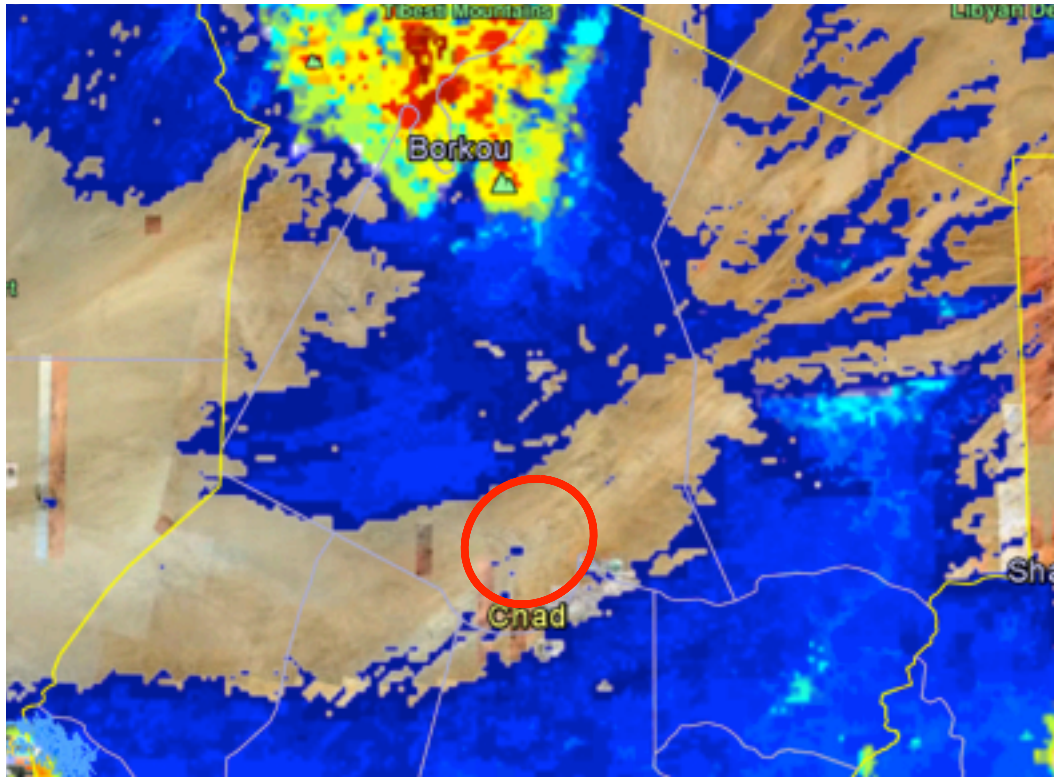

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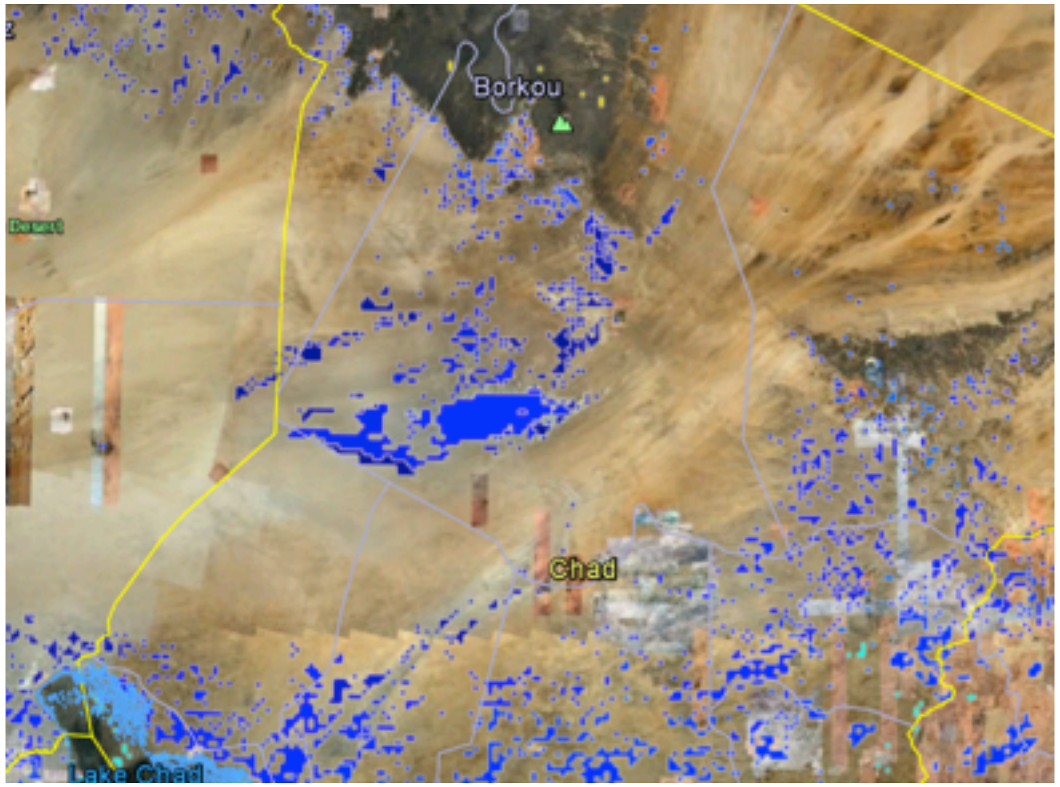

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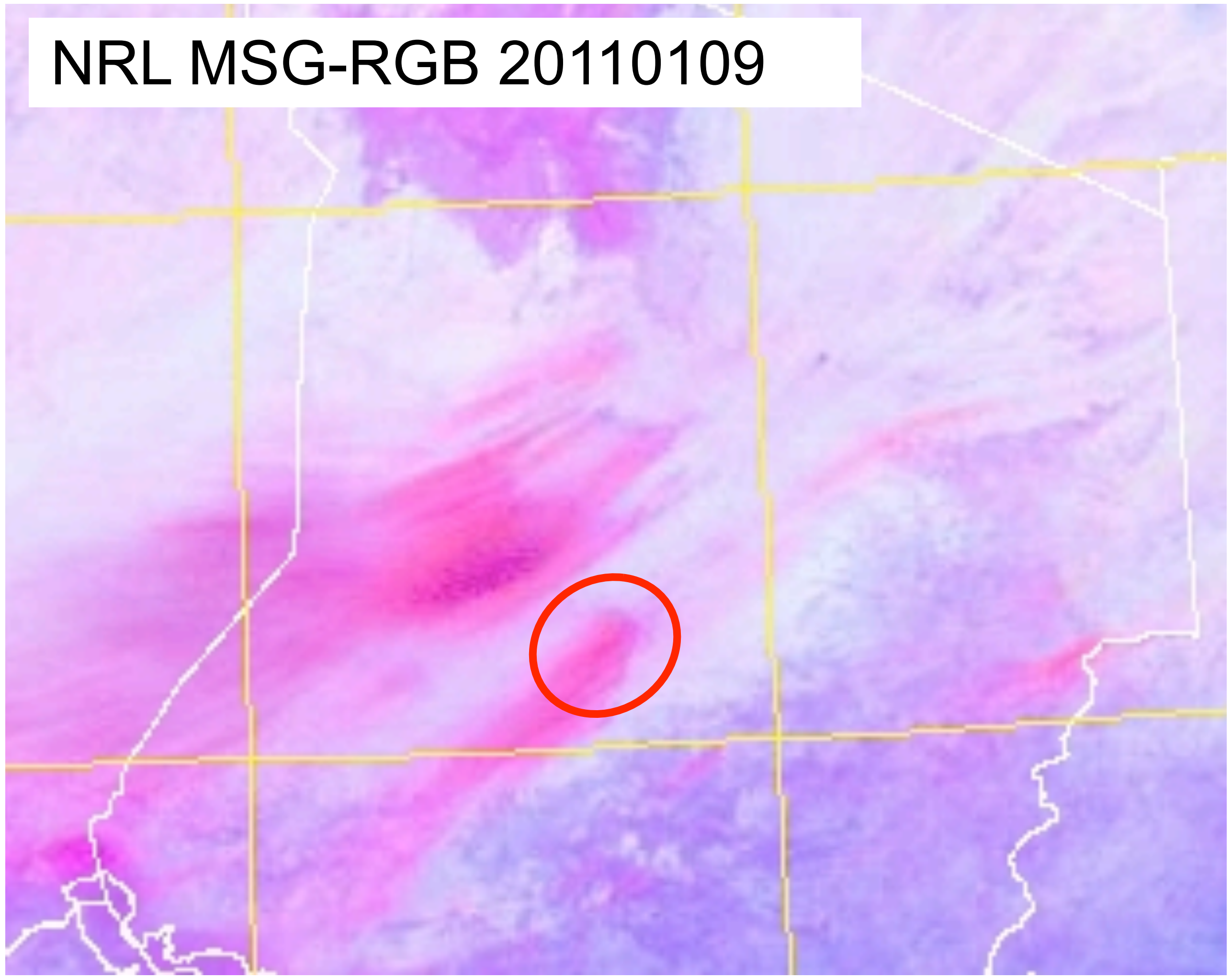

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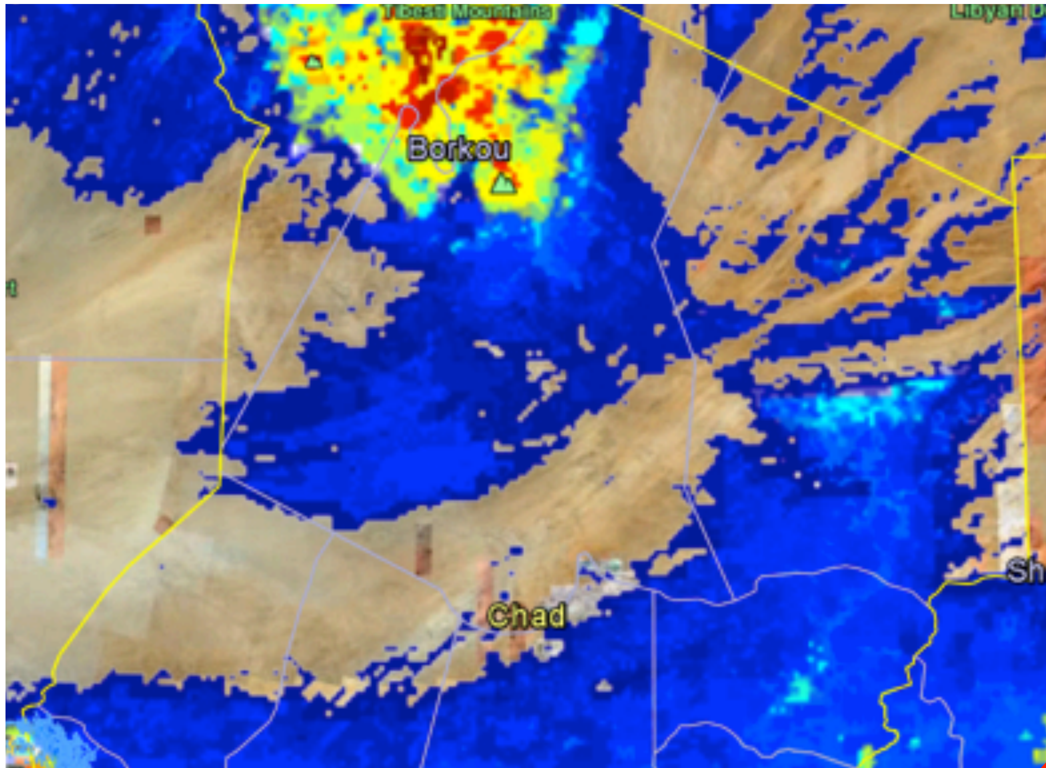

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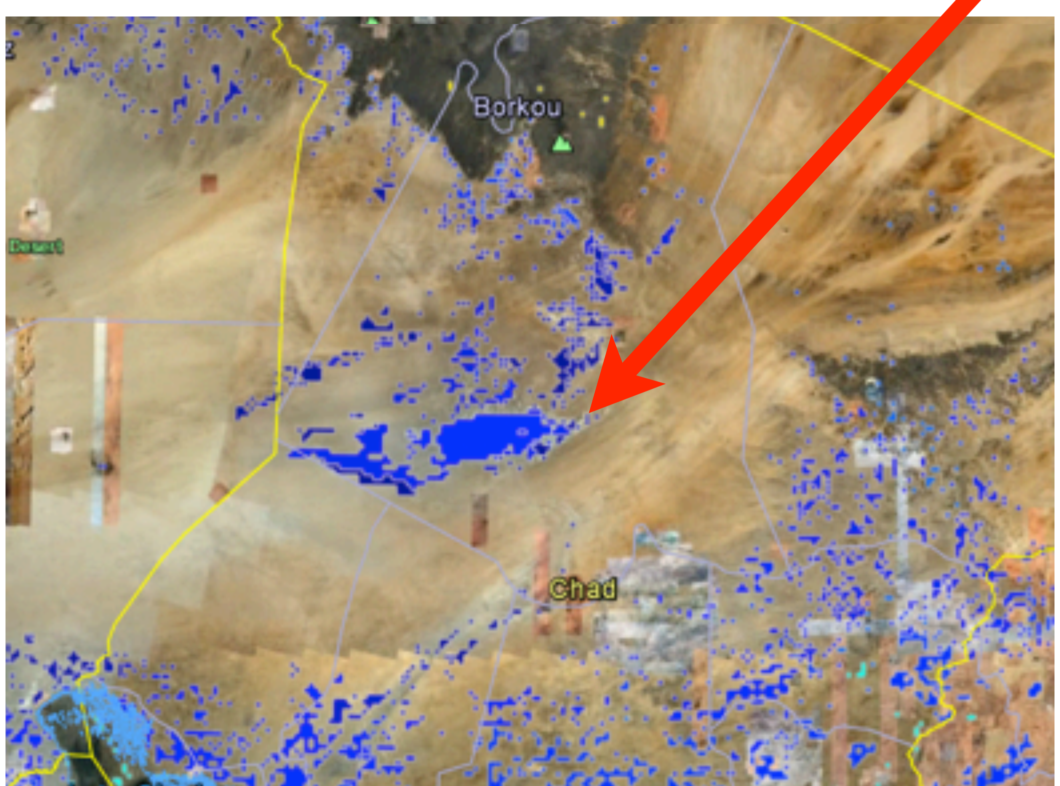
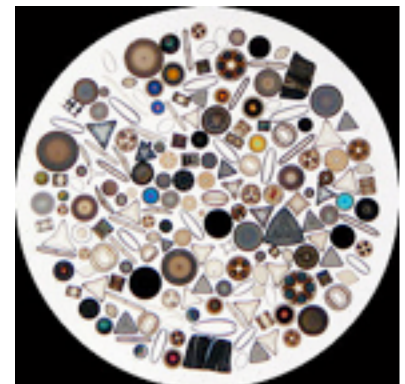
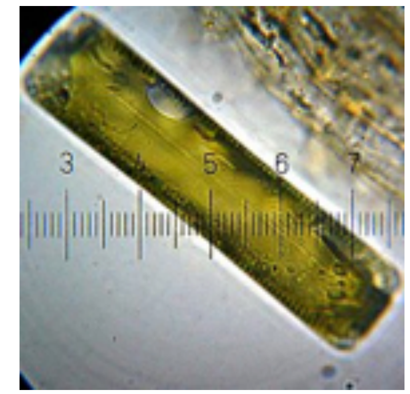
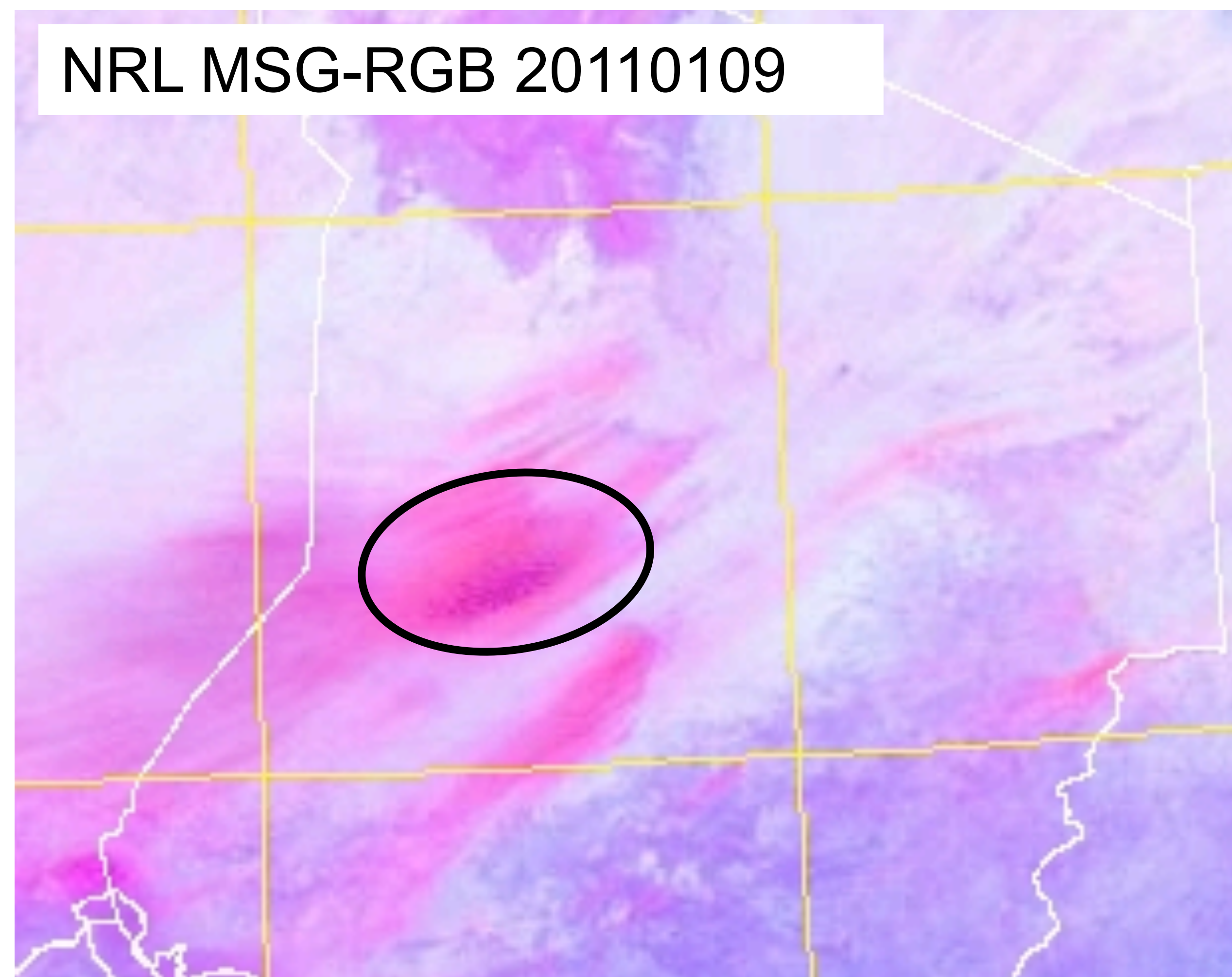


Selected Classes with Class 137

Class 137 maps diatom sediment in depression.







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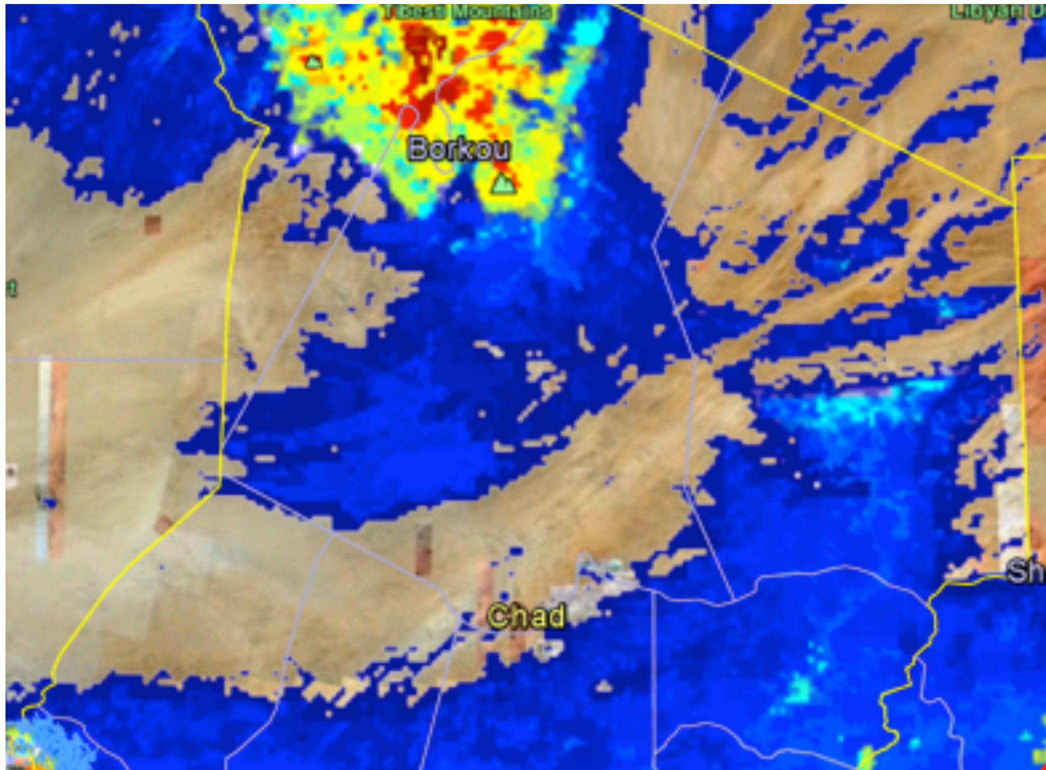

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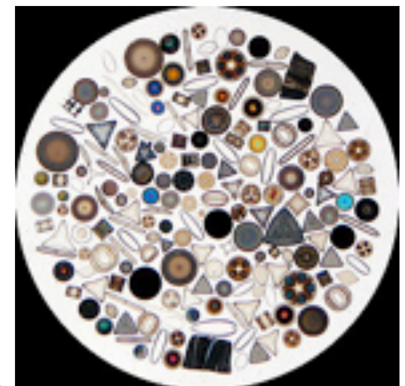
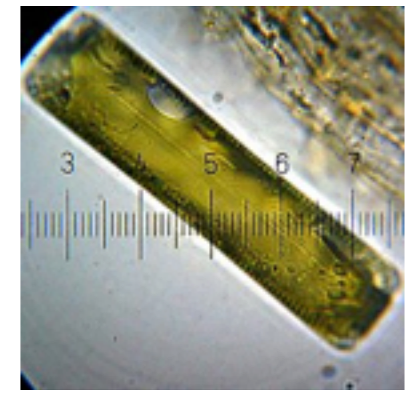
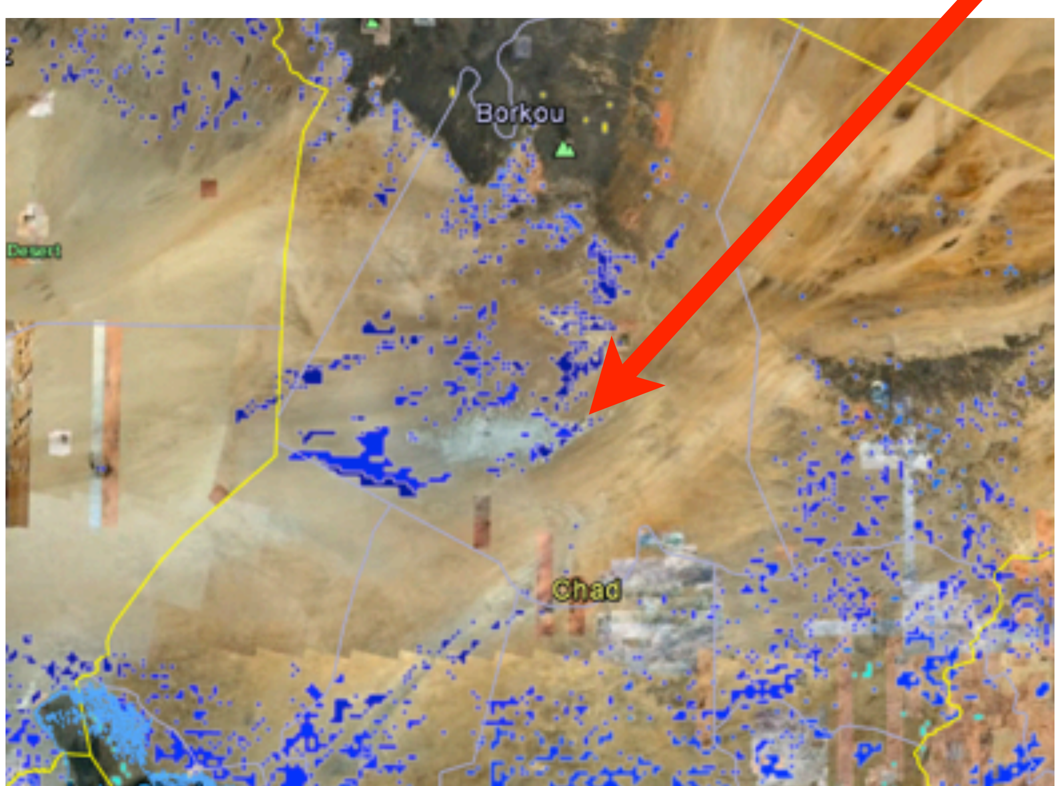
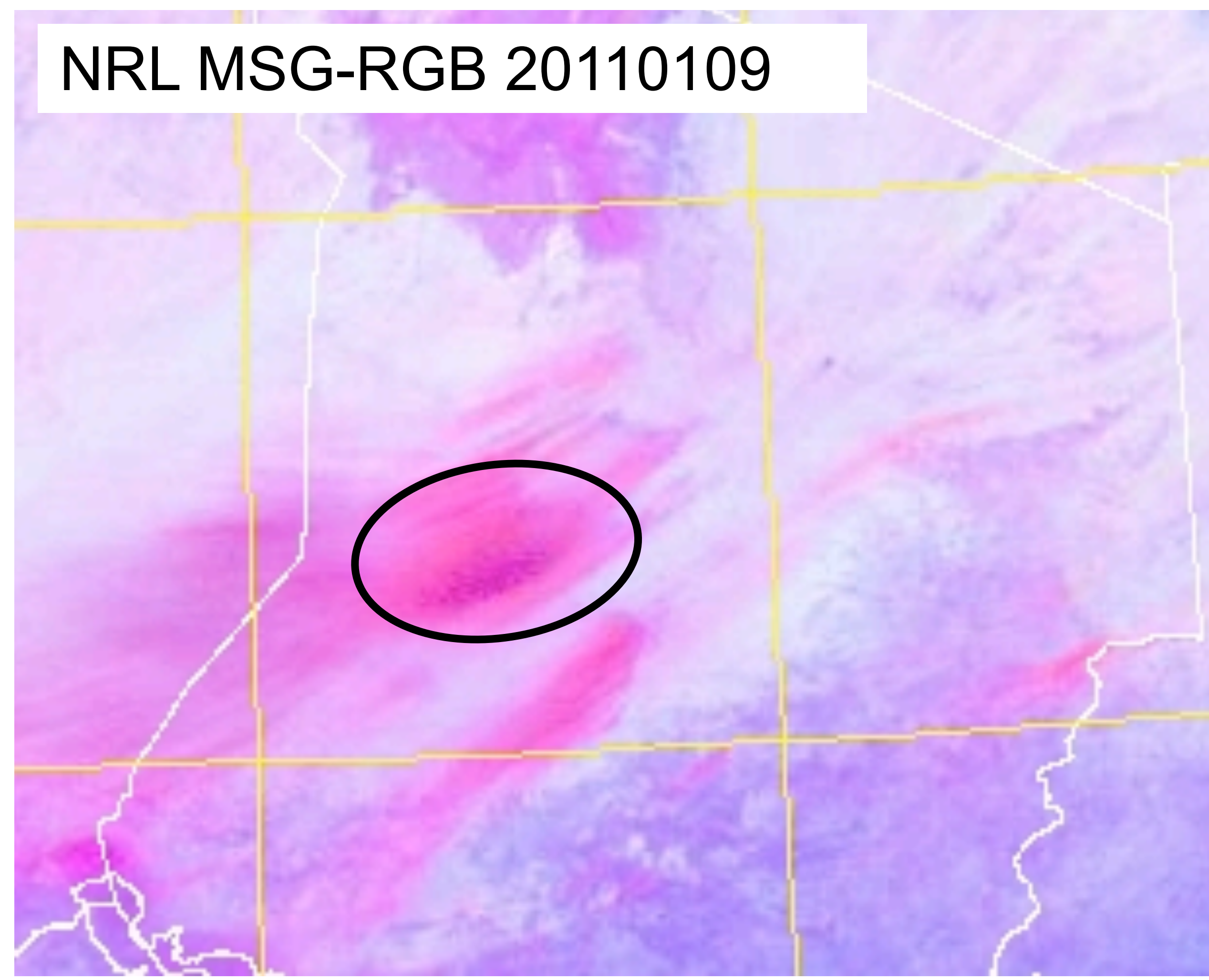


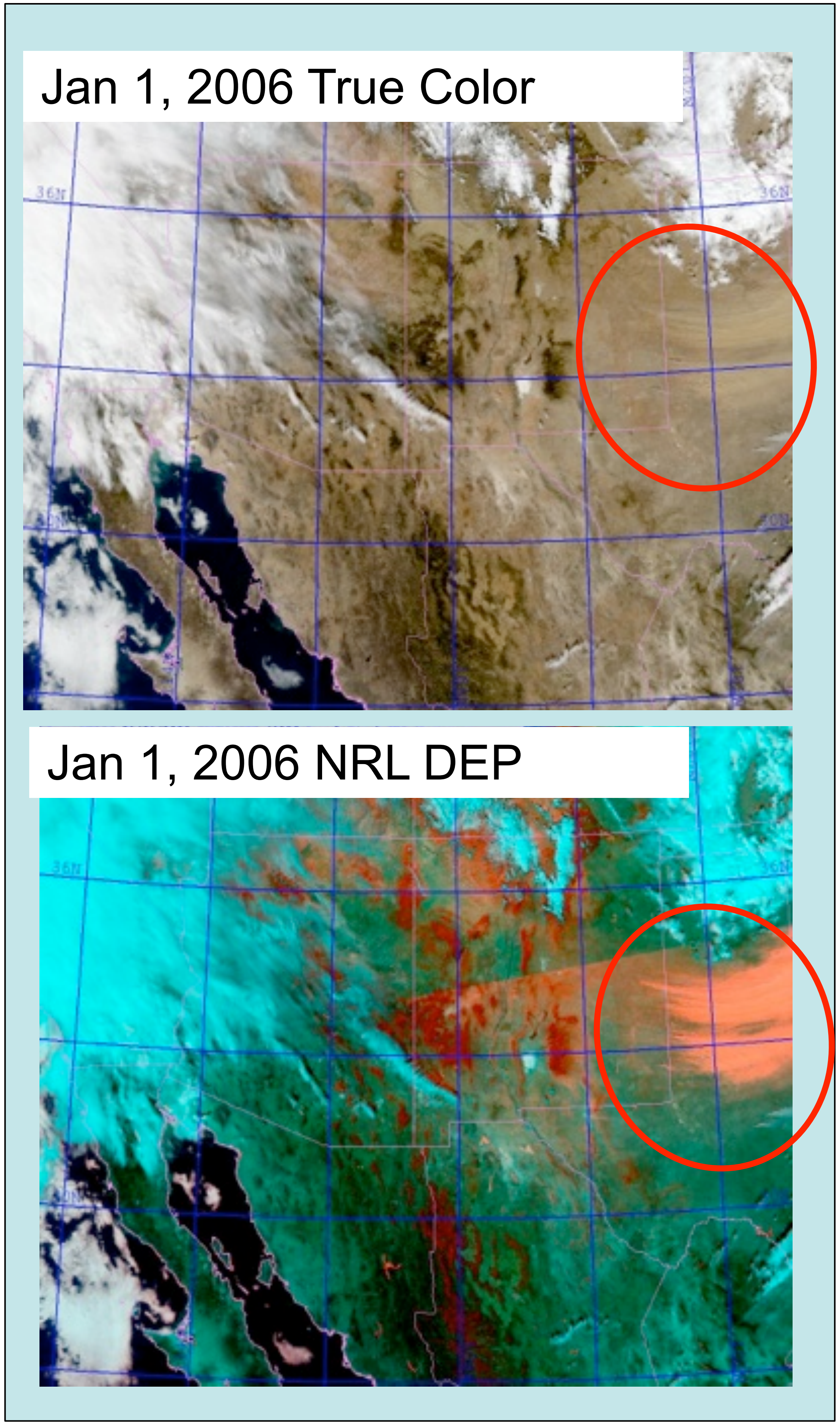




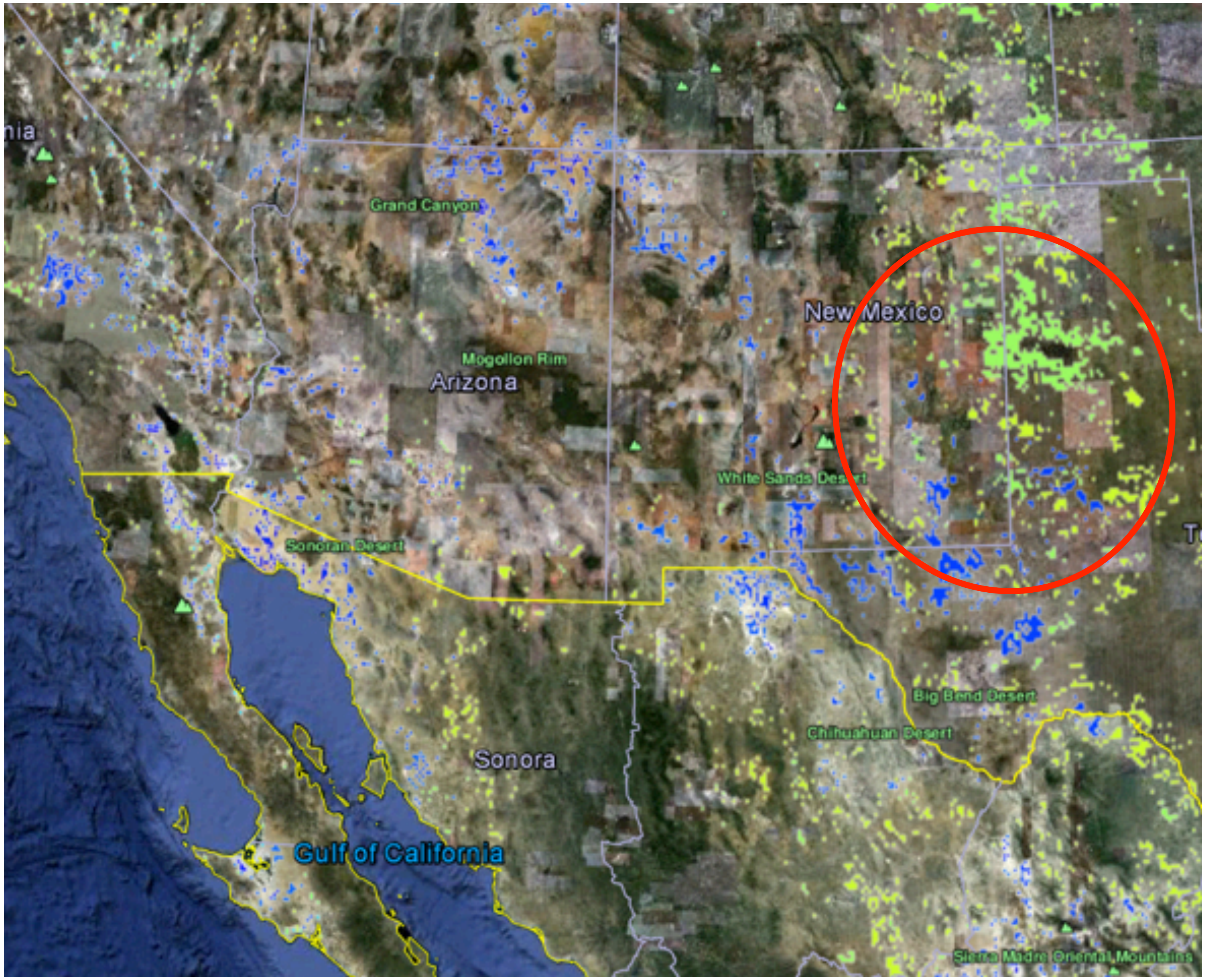
Selected Classes **Without Class 137**



Sources along New Mexico/Texas border

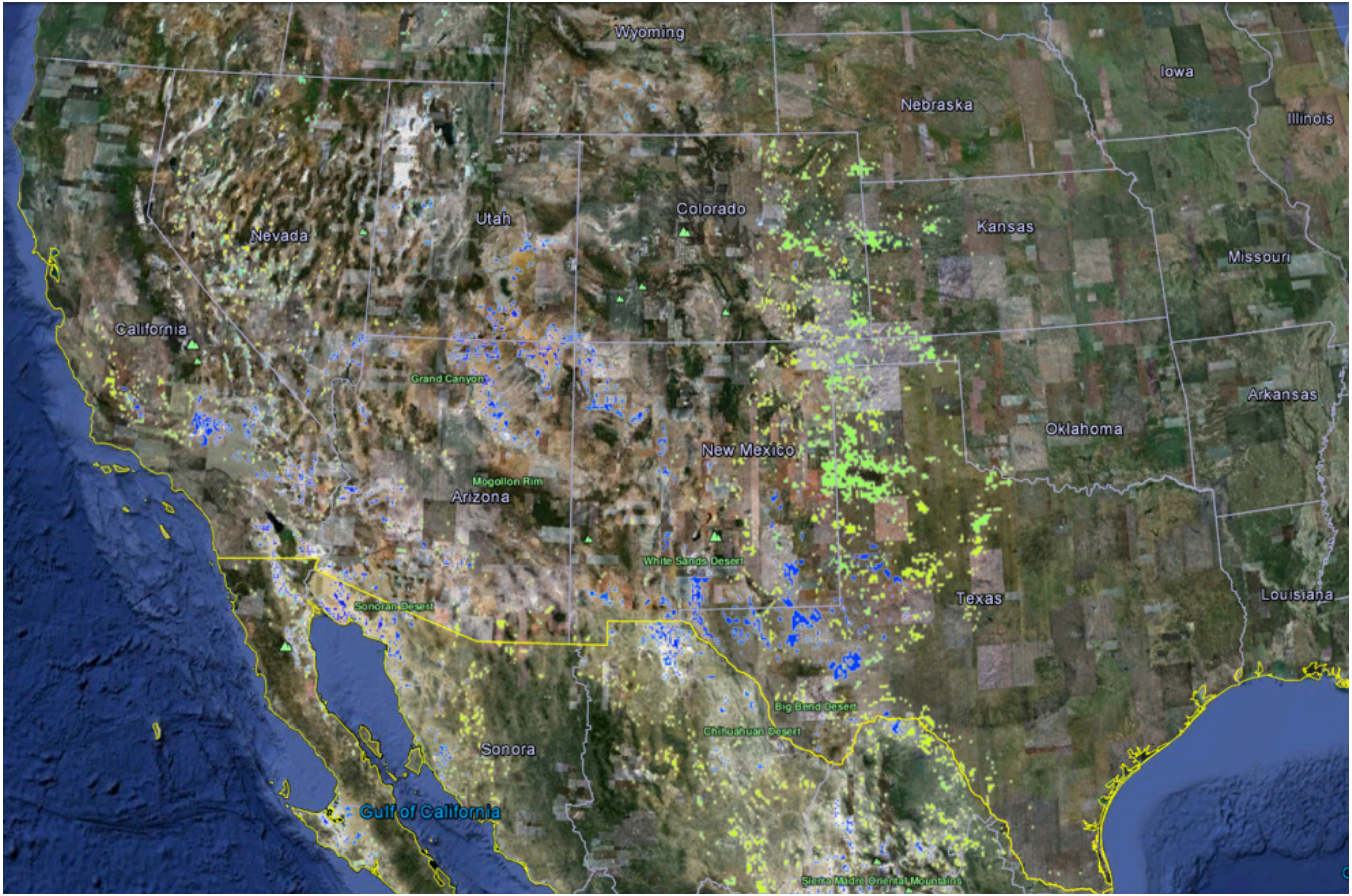


Agricultural on high planes
Blue dessert areas

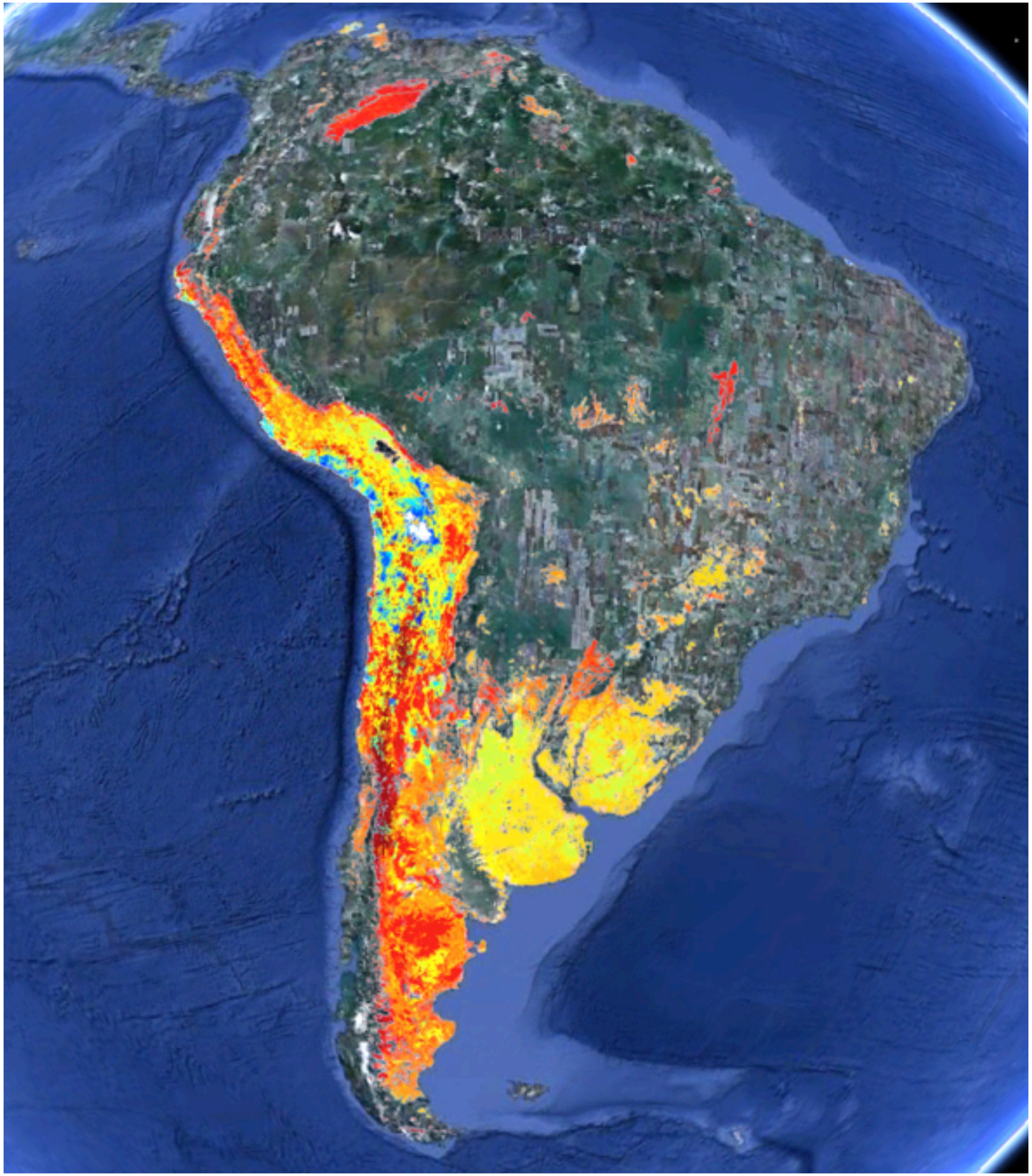


The North American sources have a different spectral signature than those we saw in SW Asia

Selected Classes for North America (n=64)



All 1000-Classes mapped for South America



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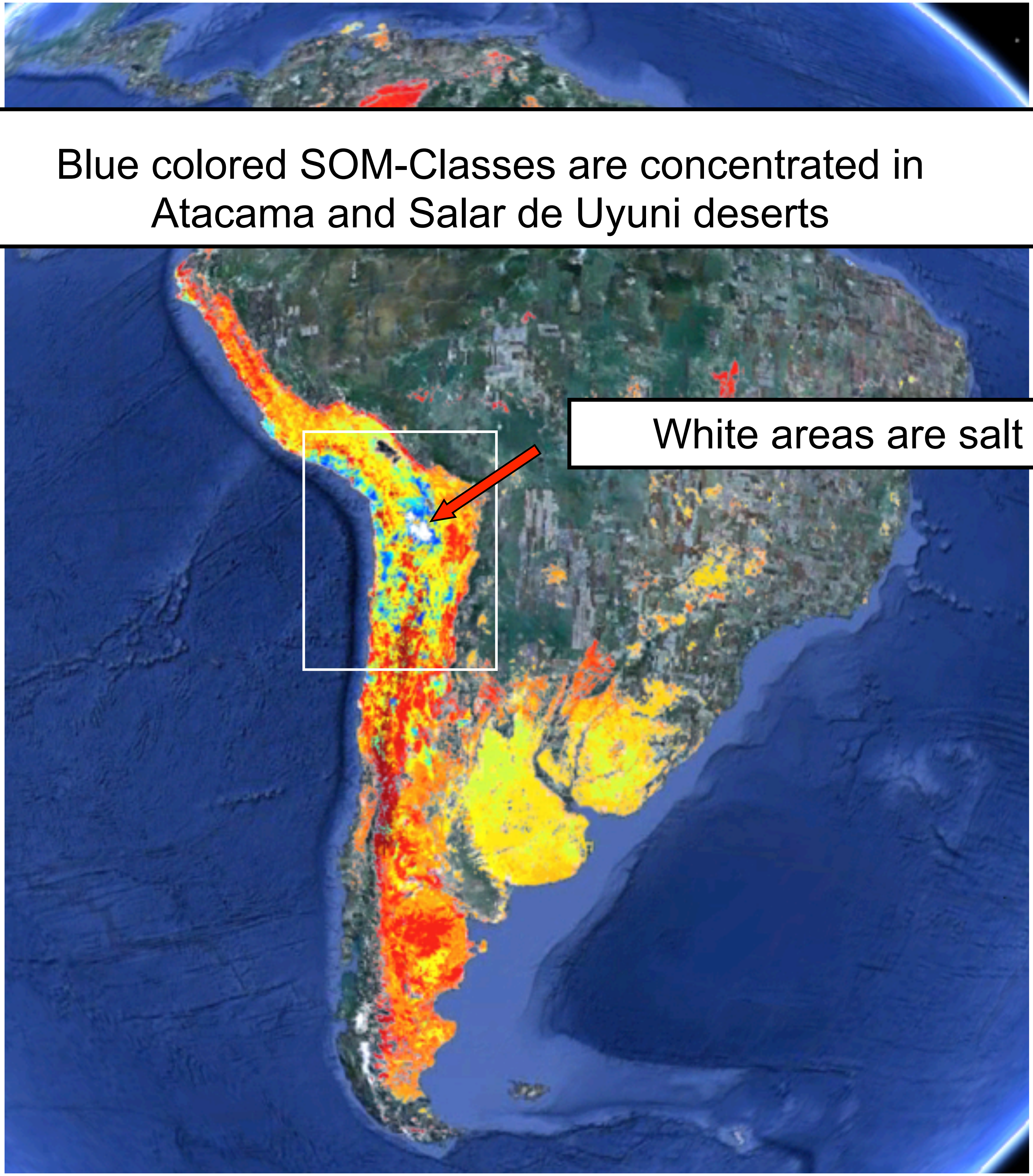
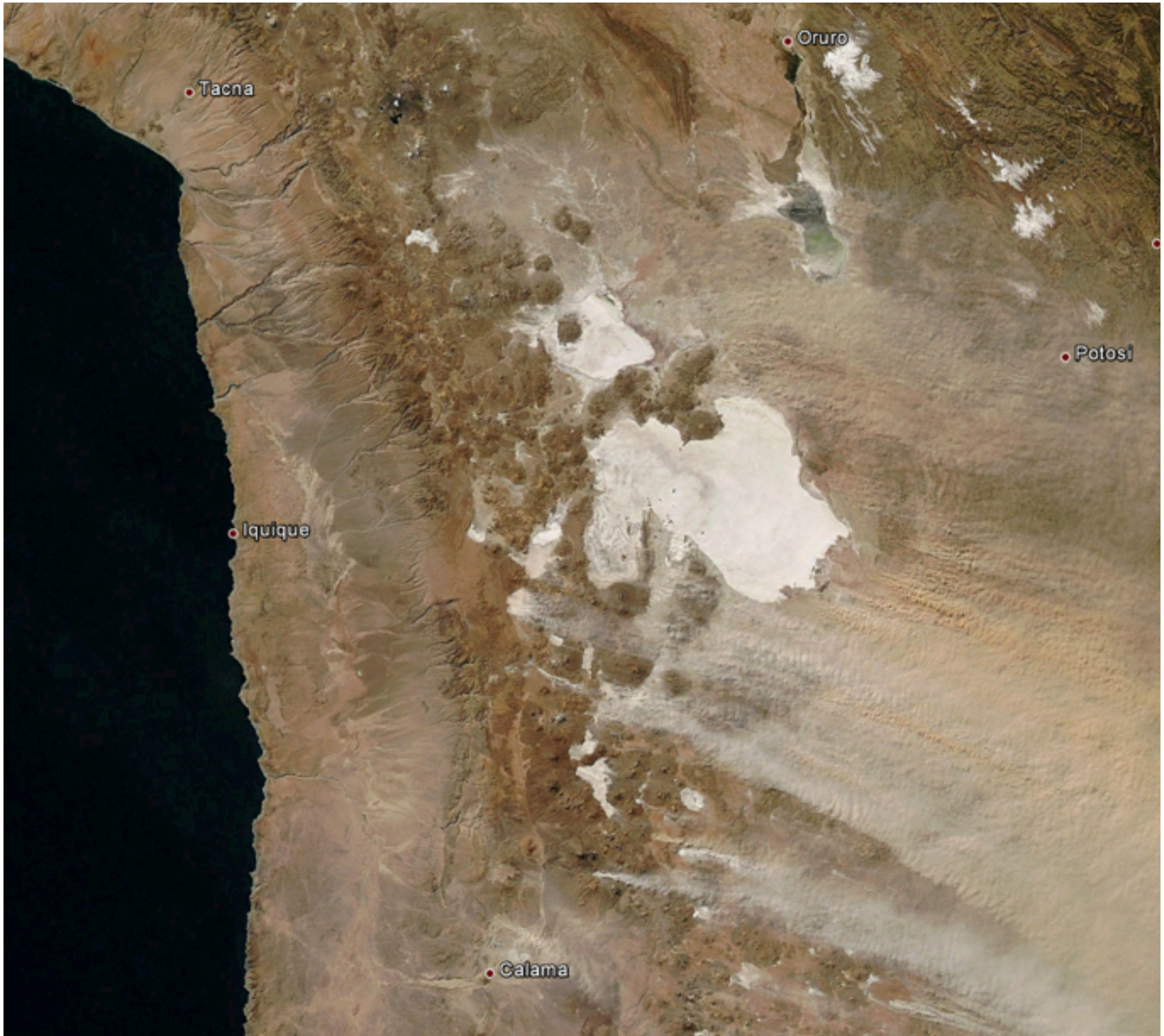


Blue colored SOM-Classes are concentrated in Atacama and Salar de Uyuni deserts

White areas are salt flats

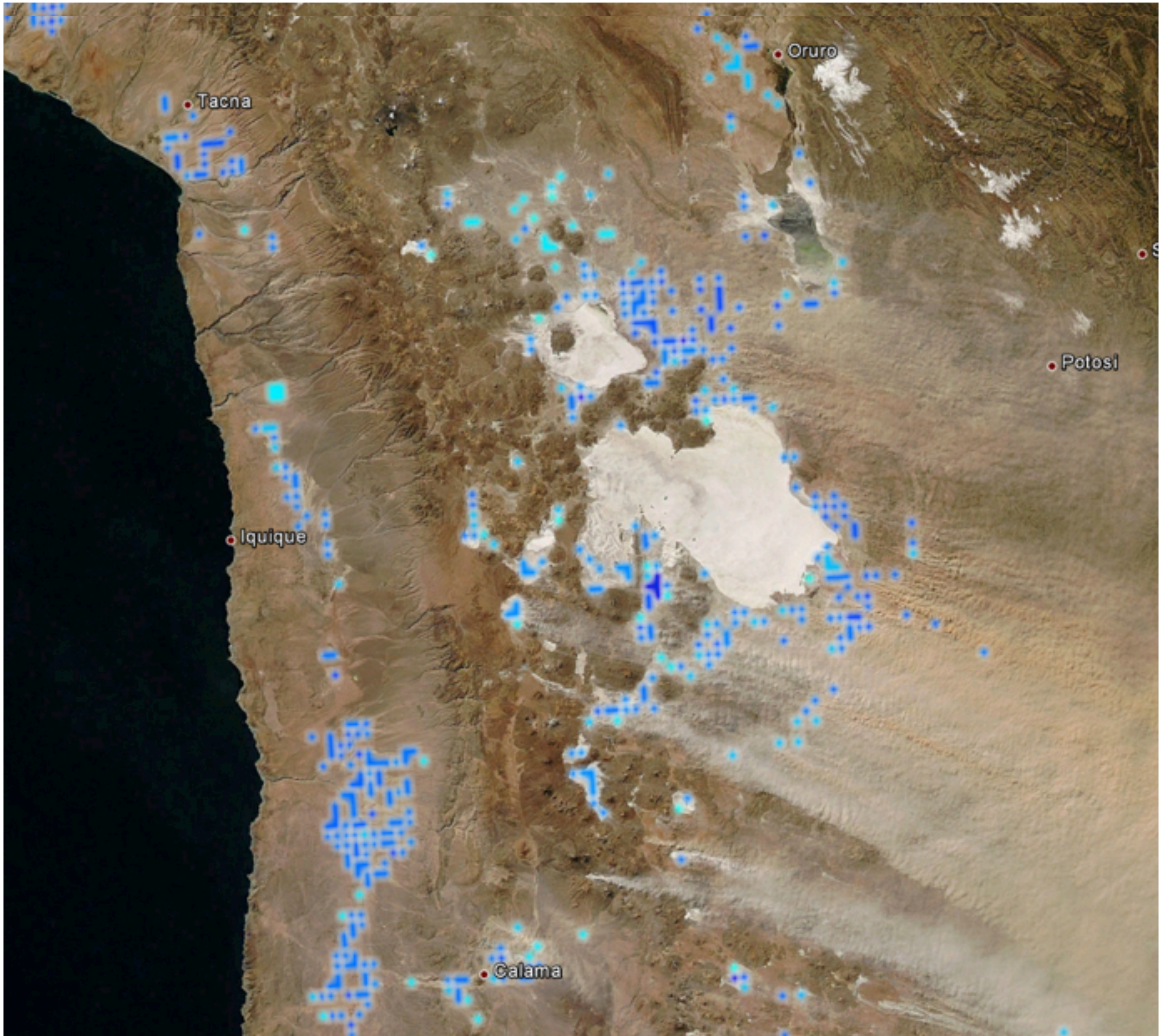
South America: Bolivia and Chile

July 18, 2010 MODIS Terra True Color



South America: Bolivia and Chile

Selected SOM-Classes in 200s, 300s, and 400s



An Objectively Optimized Earth Observing System

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The project was inspired by two ancient sayings:

1. "Wisdom is profitable to direct!"
   This inspired the automation of observation direction
2. "The knowledge of ignorance is the beginning of knowledge"
   This inspired using quantitative measures of uncertainty (ignorance) to select our targets.

What issues can we address with this system?

- With flexible pointing instruments:
  - What is the optimum real time pointing?
- With flexible mode instruments:
  - What is the optimum real time use of zoom in mode?
- When should balloons be launched?
- What are the optimum trajectories for UAVs and aircraft?

Autonomous Observing System

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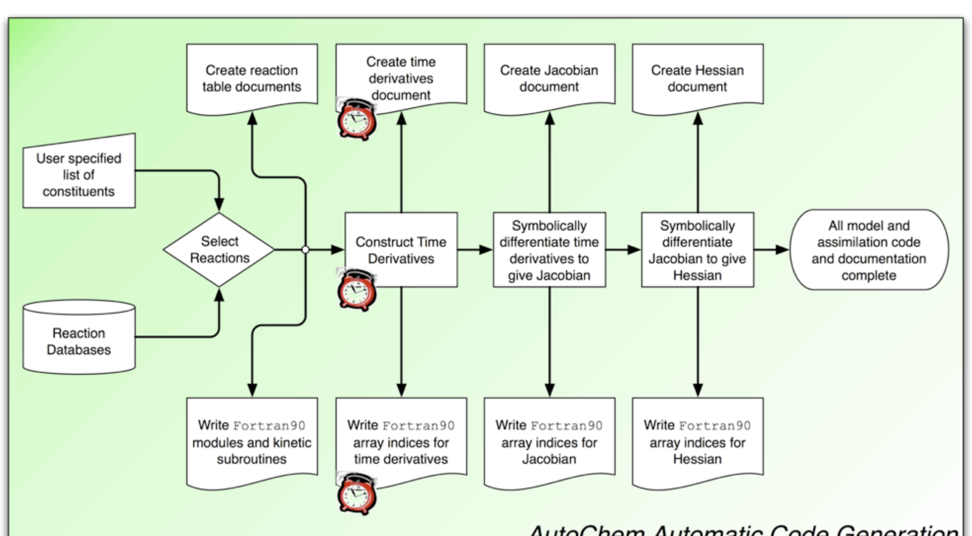

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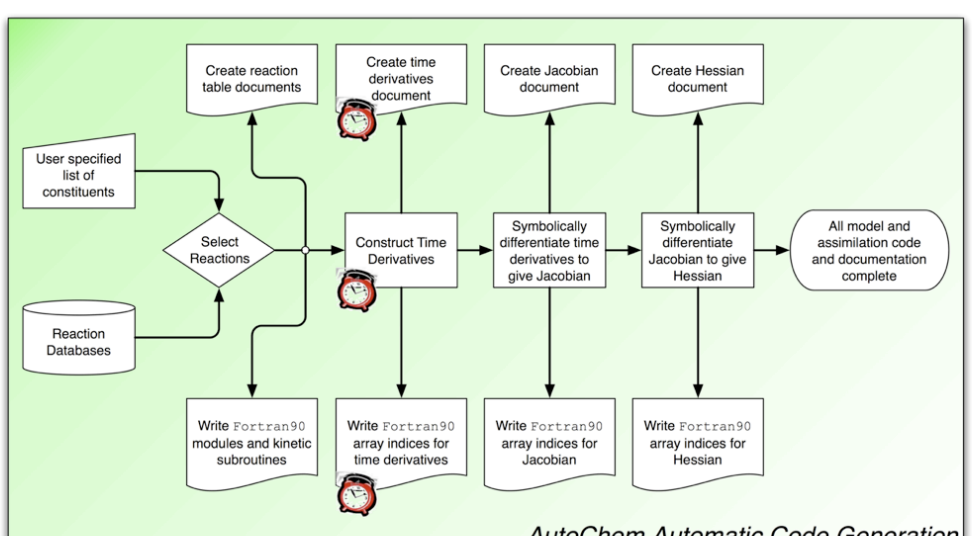

AutoChem Automatic Code Generation

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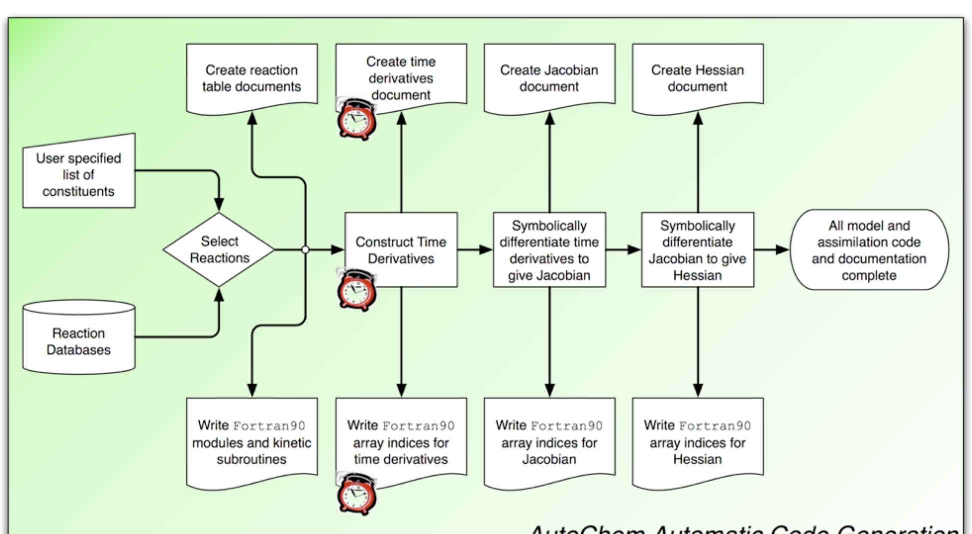

AutoChem Automatic Code Generation

- What we do not know is quantified by the **state vector uncertainty** supplied by the assimilation system.
- How important it is to make the observations is quantified by **information content** also supplied by the assimilation system.
- The **geographic extent** of the uncertainty maxima is one metric that can be used to determine whether zoom in or survey mode is required.

The Assimilation System

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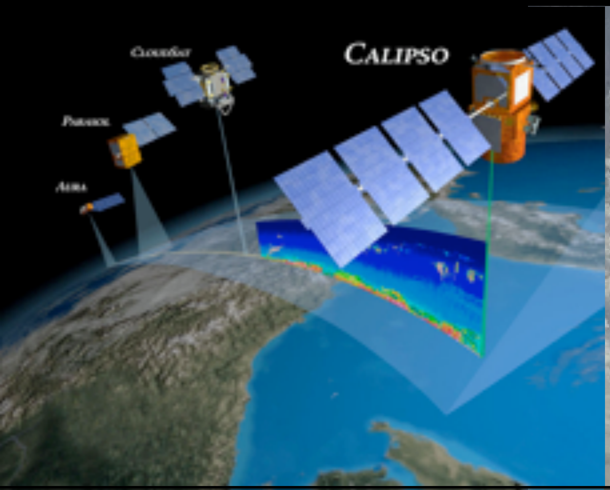
  - Each source of information is weighted by **how much we trust it**, quantified by its uncertainty.
  - The sources of information we use here are:
    1. Observations
    2. Theory (encapsulated in a theoretical deterministic model).

Autonomous Observing Systems

Autonomous Observing Systems

- The requirements will be varied depending on the application.
- The observing system will contain many components, orbital and suborbital.






How do we achieve this?

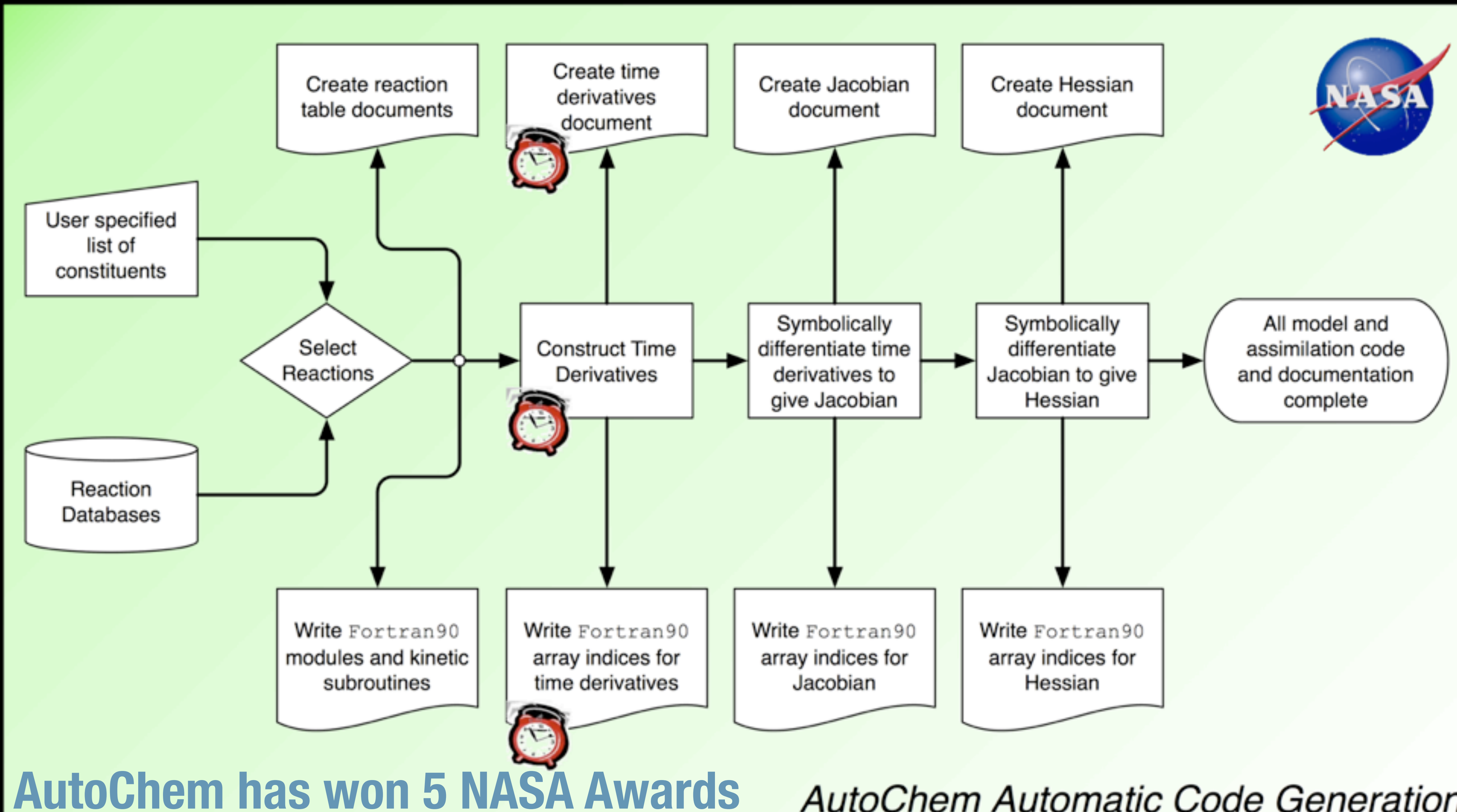
How do we achieve this?

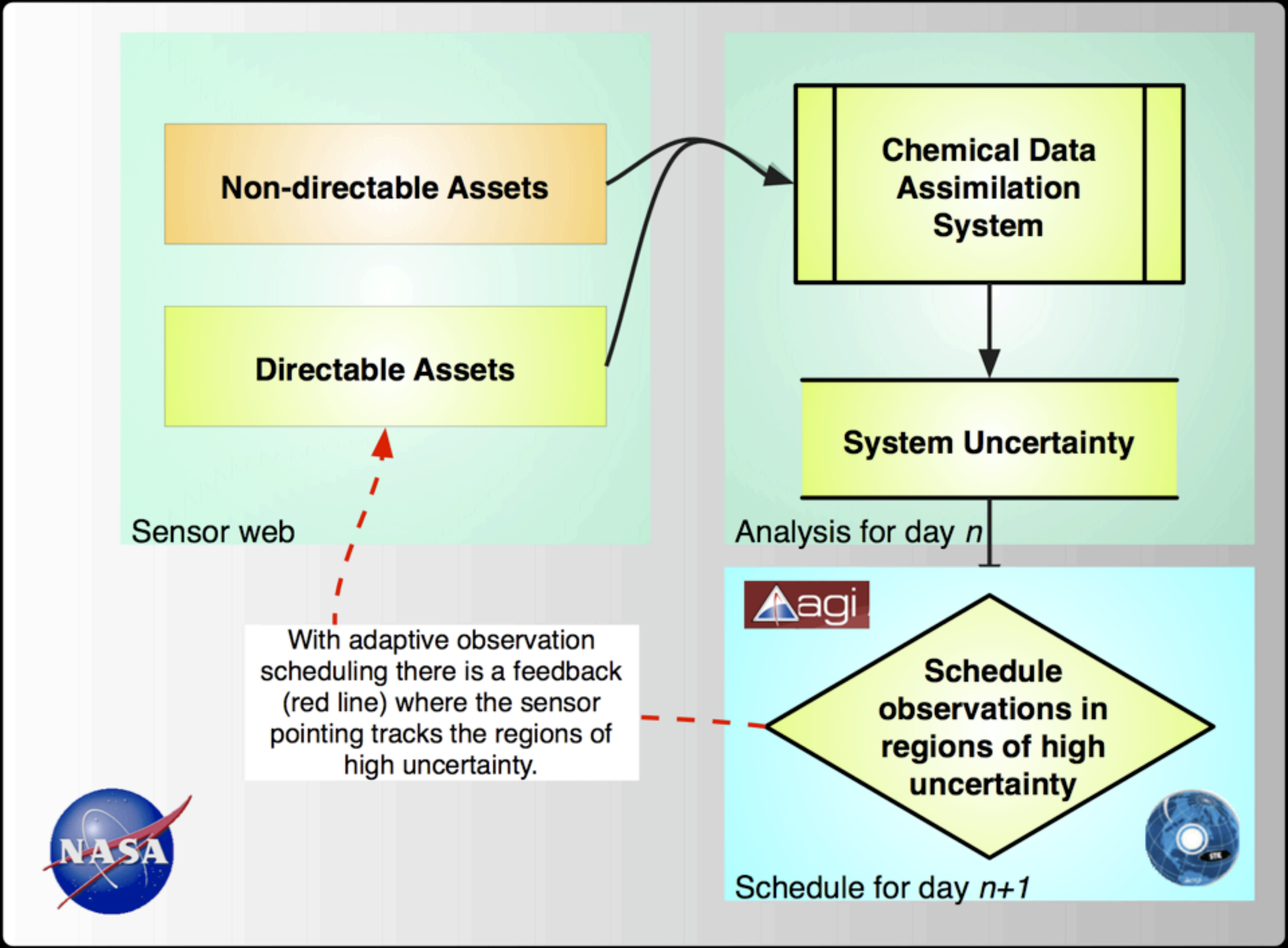
The knowledge of ignorance is the beginning of knowledge

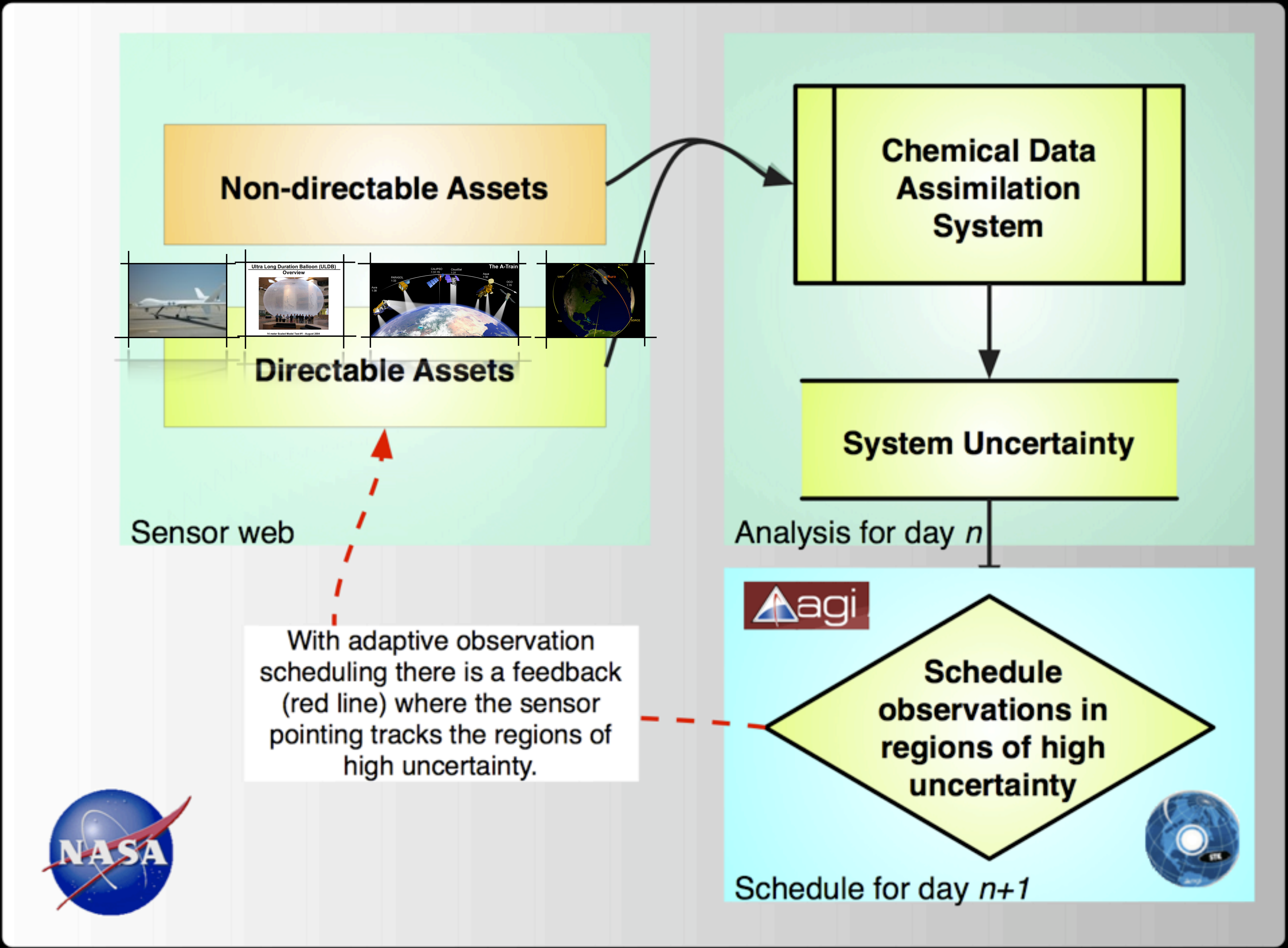
Ancient Greek Saying

Automatic Code Generator for Chemical Kinetics

Automatic Code Generator for Chemical Kinetics




Non-directable Assets
Directable Assets
Sensor web
Chemical Data Assimilation System
System Uncertainty
Analysis for day n
agi
Schedule observations in regions of high uncertainty
Schedule for day n+1
With adaptive observation scheduling there is a feedback (red line) where the sensor pointing tracks the regions of high uncertainty.
NASA


Non-directable Assets
Ultra Long Duration Balloon (ULDB)
Overview
The A-Train
Directable Assets
Sensor web
Chemical Data
Assimilation
System
System Uncertainty
Analysis for day *n*
agi
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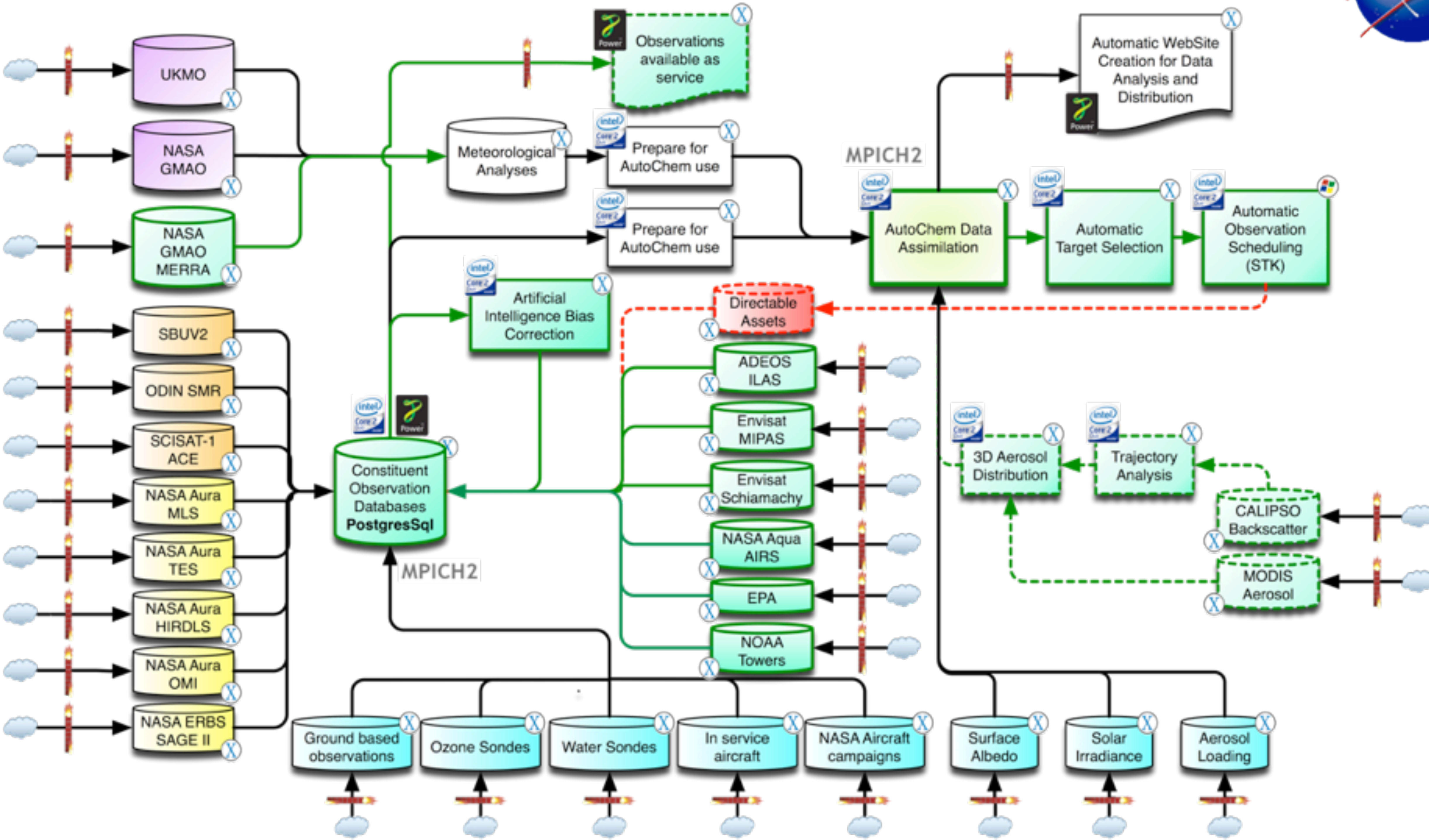
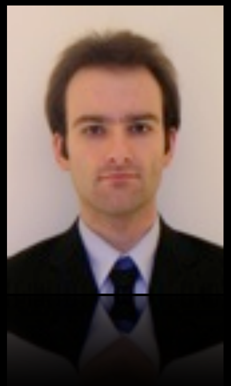
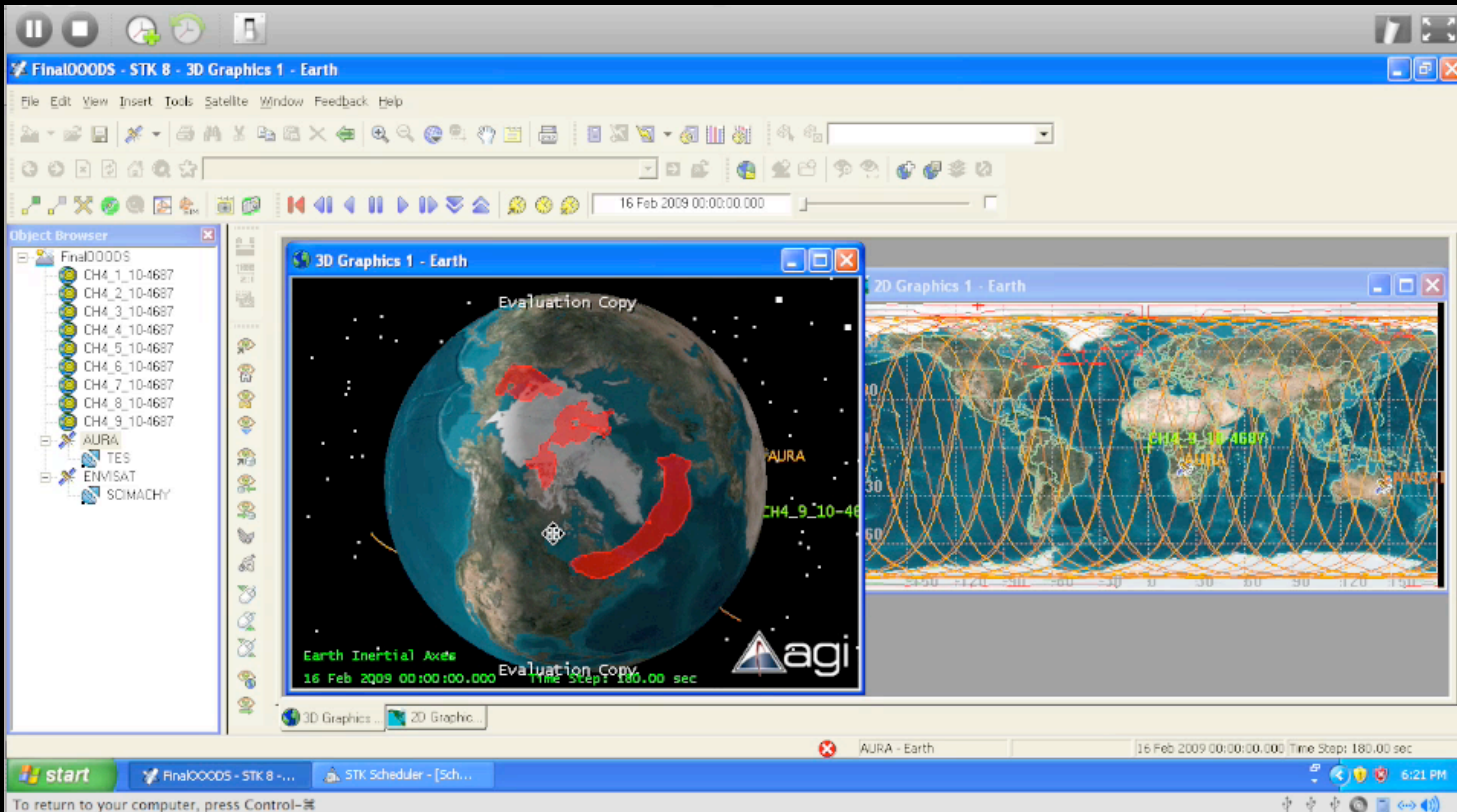
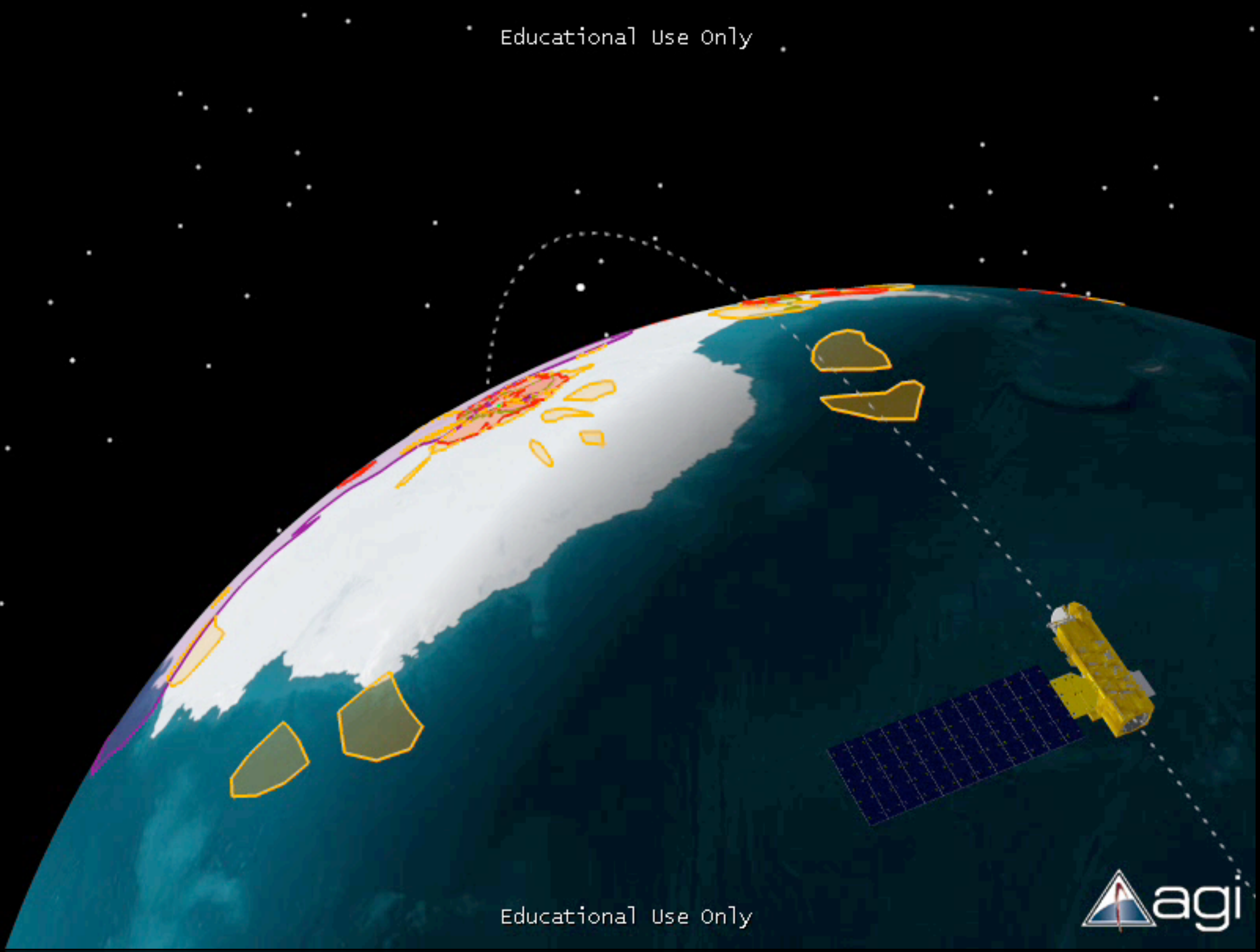


The lines represent data flow. Green lines represent new or recently updated elements. Dashed lines represent elements in preparation. Portions yet to be completed are in red. The cloud symbol represents that the data comes from an external data repository. The wall with a flame represents the firewall. The operating system used for a given element is indicated by the operating system logo, for OSX, and for Windows. The hardware platform is indicated by the processor logo, for PowerPC and for Intel. The elements that are implemented as parallel components using MPICH2 have the MPICH2 logo.

Sensor Web Simulation in STK

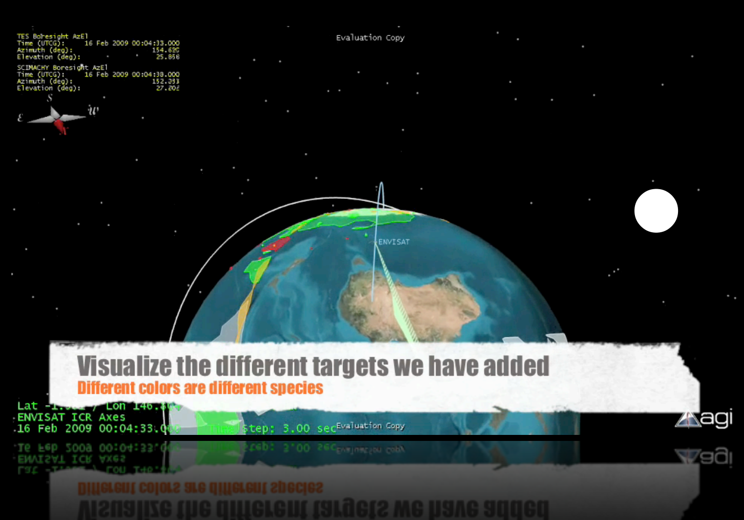


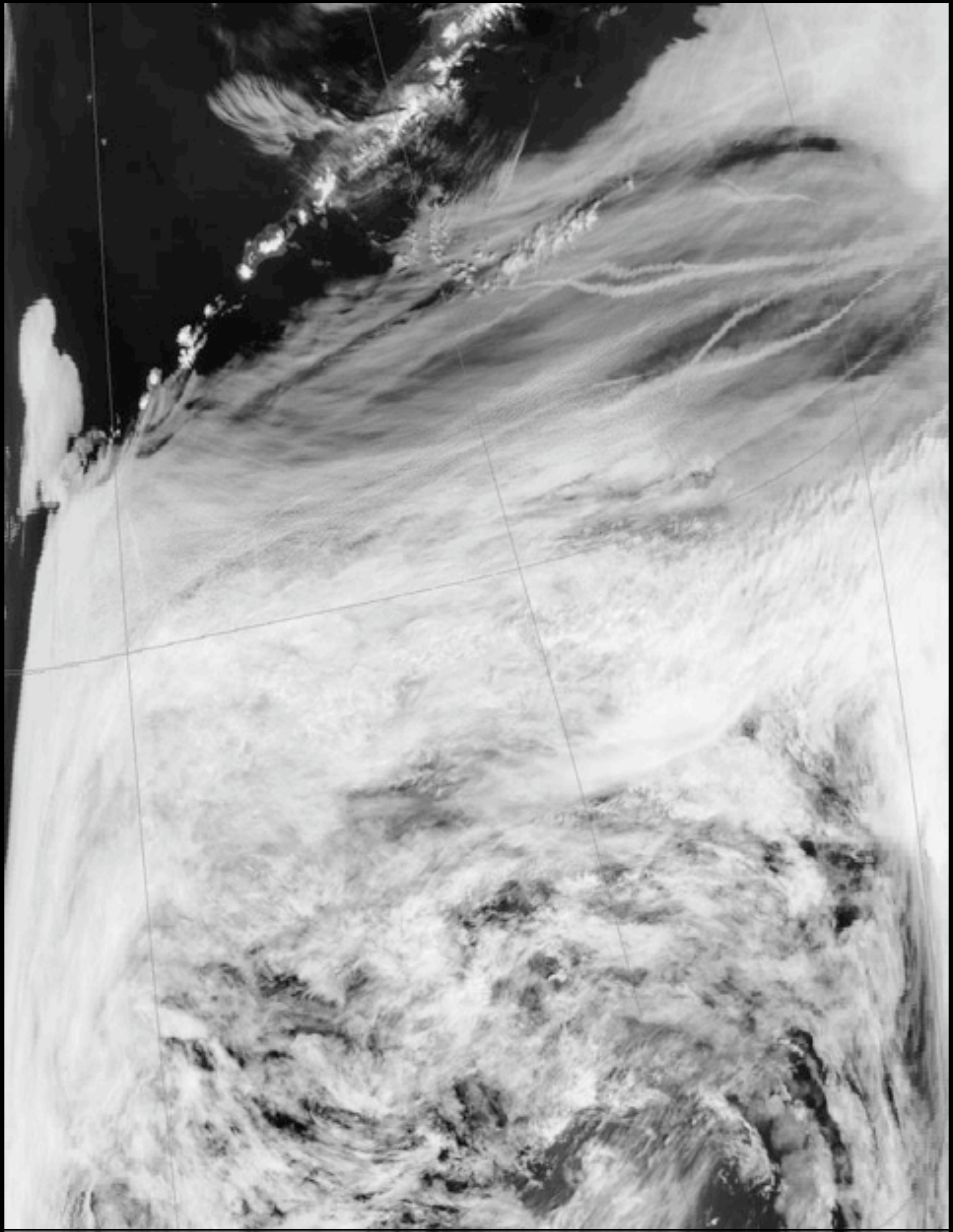

FinalOOODS - STK 8 - 3D Graphics 1 - Earth
File Edit View Insert Tools Satellite Window Feedback Help
16 Feb 2009 00:00:00.000
Object Browser
FinalOOODS
CH4_1_10-4687
CH4_2_10-4687
CH4_3_10-4687
CH4_4_10-4687
CH4_5_10-4687
CH4_6_10-4687
CH4_7_10-4687
CH4_8_10-4687
CH4_9_10-4687
AURA
TES
ENVISAT
SCIMACHY
3D Graphics 1 - Earth
Evaluation Copy
AURA
Earth Inertial Axes
16 Feb 2009 00:00:00.000
Time Step: 180.00 sec
agi
2D Graphics 1 - Earth
AURA - Earth
16 Feb 2009 00:00:00.000 Time Step: 180.00 sec
start
STK Scheduler - [Sch...
6:21 PM
To return to your computer, press Control-⌘


Educational Use Only
Educational Use Only
agi

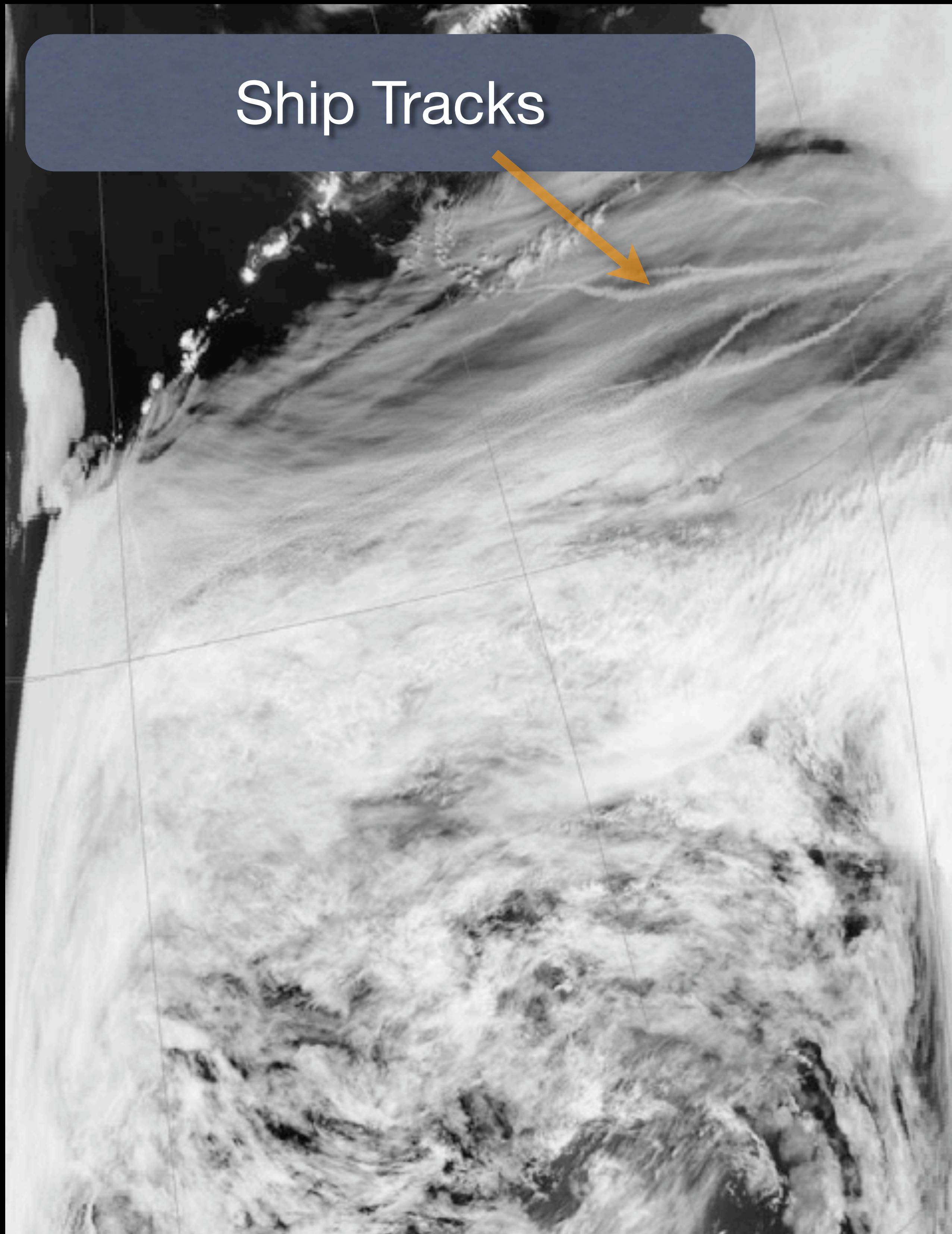
Autonomy

- Autonomous sensor web control is a challenging task. So we have used a modular and distributed approach.
  - The autonomy selection criteria are likely to be different depending on the application, hence the advantage of modularity. For example:
    - For validation campaigns we may want to use regions of highest “certainty” as targets. For regular operation we may want to use regions of lowest “certainty” as targets.
    - We may want to use feature recognition in other applications.





Feature recognition



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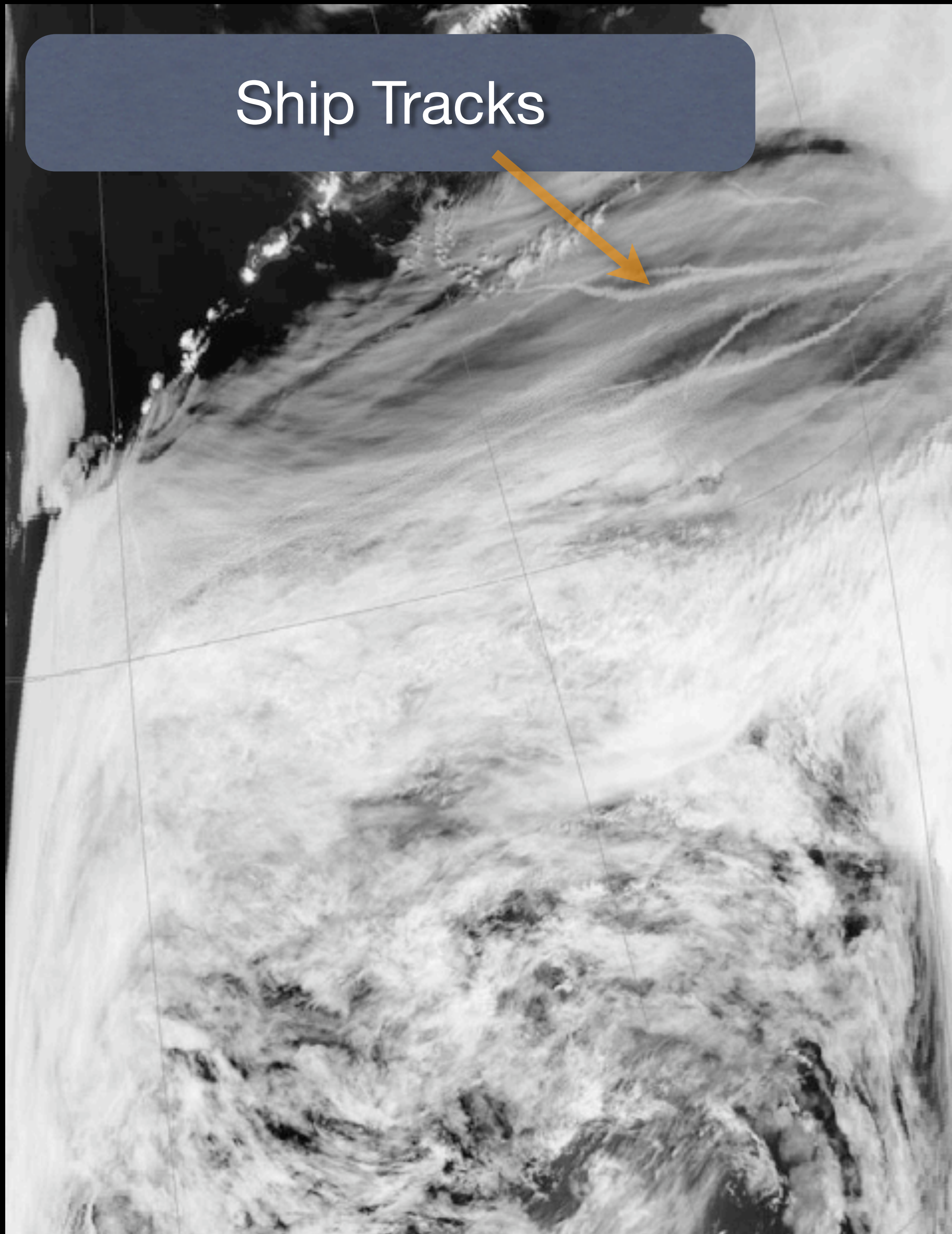

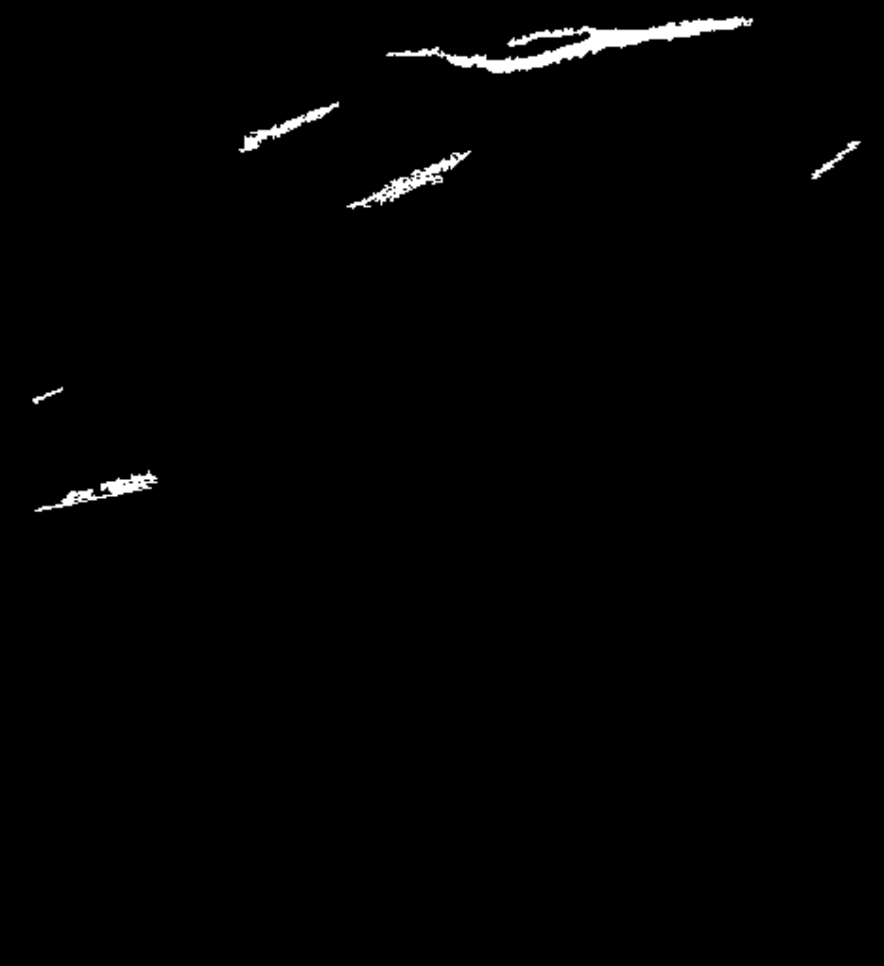

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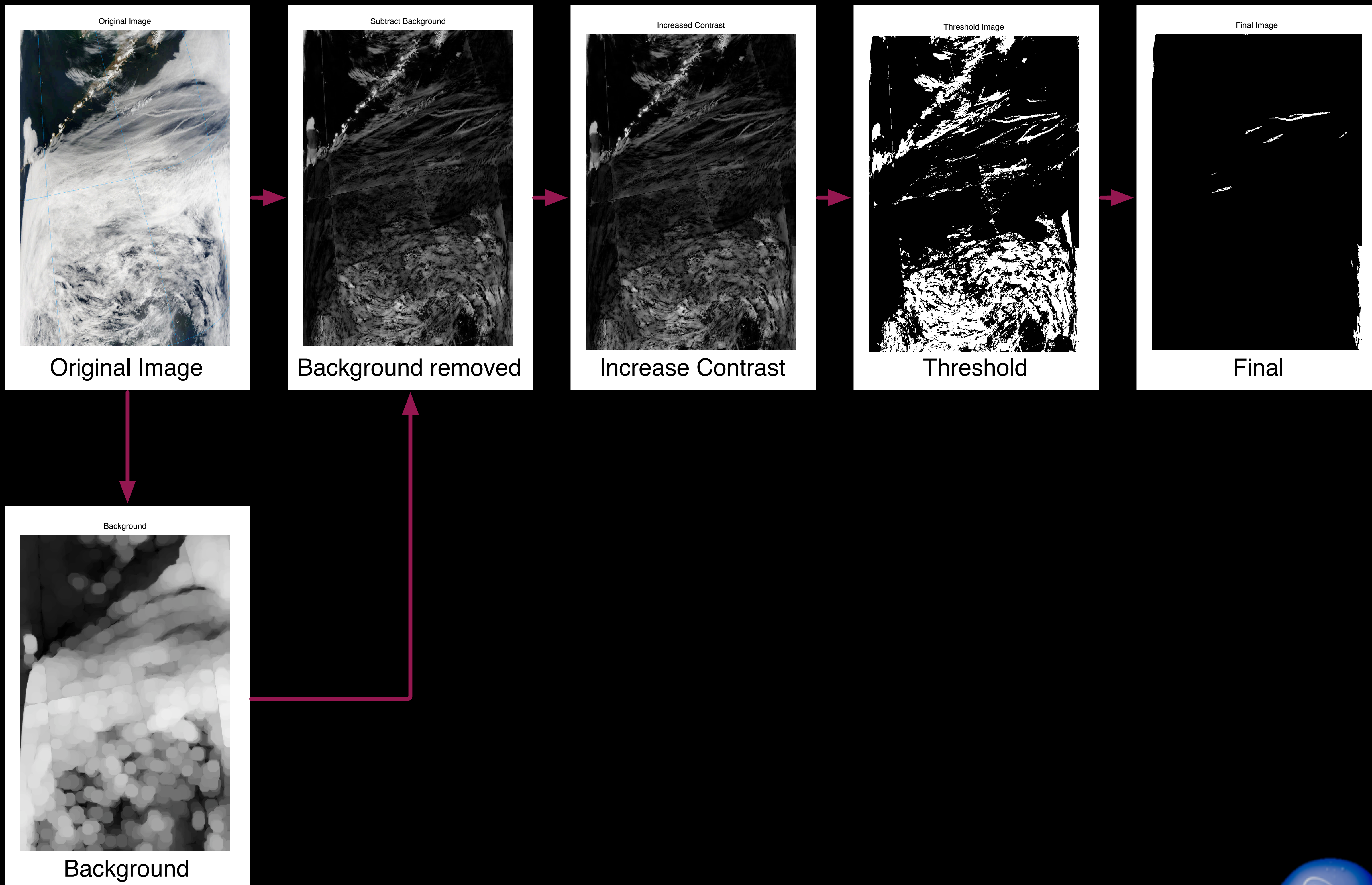
Original Image
Original Image
Subtract Background
Background removed
Increased Contrast
Increase Contrast
Threshold Image
Threshold
Final Image
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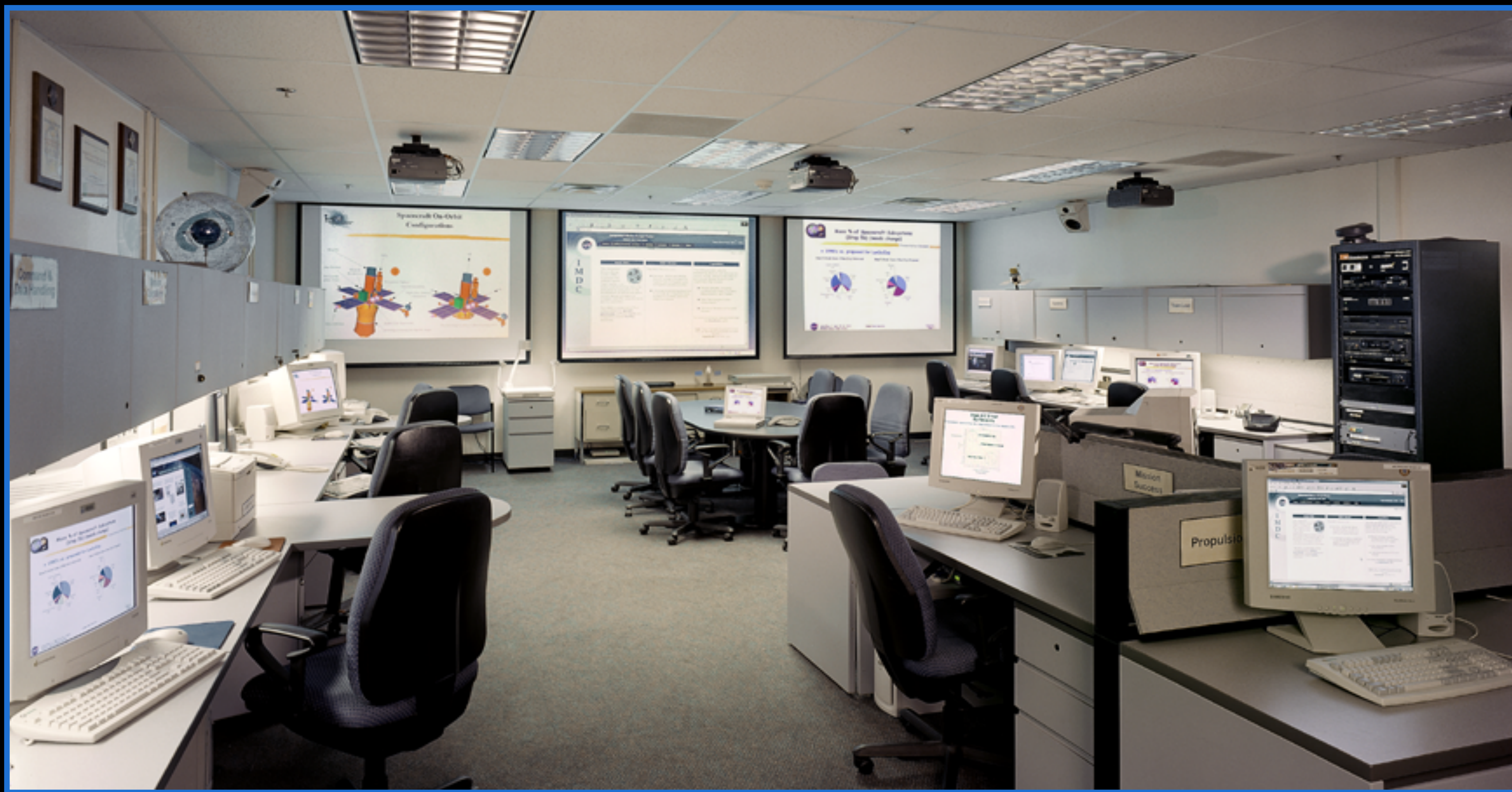
Background
Background

Objectively Optimized Mission Planning



A Web 2.0 design application can run on each of these workstations. It both explicitly facilitates communication between the discipline engineers and enables objective quantitative optimization of the mission design.

Large Trade Space
Driven by Science Objectives

- Possible Optimization for:
  - Science goals
  - Cost
  - Mass
  - Power
  - Coverage (polar?)
  - Detector Life
  - Retrieval Error
  - OSSE scores

- Trade variables:
  - Resolution (spatial, spectral)
  - Orbit (type, altitude, inclination)
  - Swath width
  - Repeat times
  - View
  - Spectral regions
- Each requirement is quantified with a cost function.
- **Multi-objective optimization**.

Team Building

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Ideas!

- Augment human experience with objectively optimized design
- Build on the experience we have had with:
  - Objective design of neural networks using genetic algorithms
  - Software Infrastructure for Autonomous observing systems
- Incorporate artificial intelligence and a modeling/assimilation system

Why?

- Constrained budget
- Better meet requirements
- Possible route to out of the box solutions
  - Antenna example
- Make greater use of resources
- Make decisions less political

.... go one step further and have an observing system architect

Potential Payoff: This structured, analytical approach just might take us to a different region or point in the tradespace, with more science per dollar and lower cost missions

Motivation for a Great Architecture

- Architecture is design at the system level
- We have before us the design of an ***unprecedented*** system to observe the earth and monitor climate, fundamental to the future of humanity
- The system will have many stakeholders with differing and **changing** needs
- We must design and execute system **responsive** to these needs; that is flexible, and returns maximum benefit for the investment
- This is what well architected systems do!

Courtesy of Ed Crowley, MIT

Elements of an Architecture

An architecture is a description of the entities of a system and the relationship between those entities (Crawley et al.)

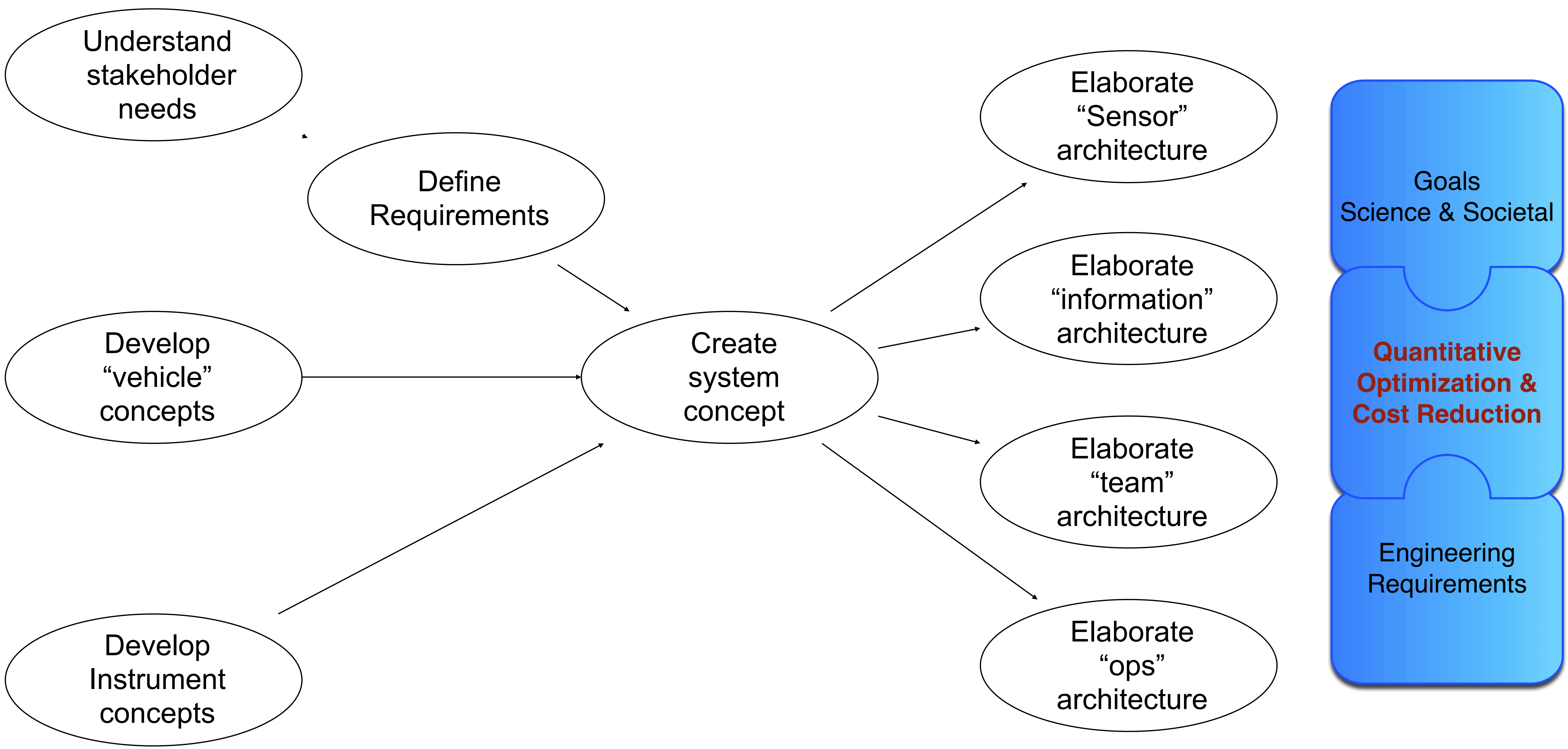
An architecture must be responsive to the needs of all stakeholders, as reflected in the system requirements

Partitions the system into elements, that can be built by individual projects, but which will integrate into a agency/ national/ international system (of systems) that will best inform us of the changing planet.

Describes the function of the system (that delivers benefit), the form of the system (what is built), and the operations of the system

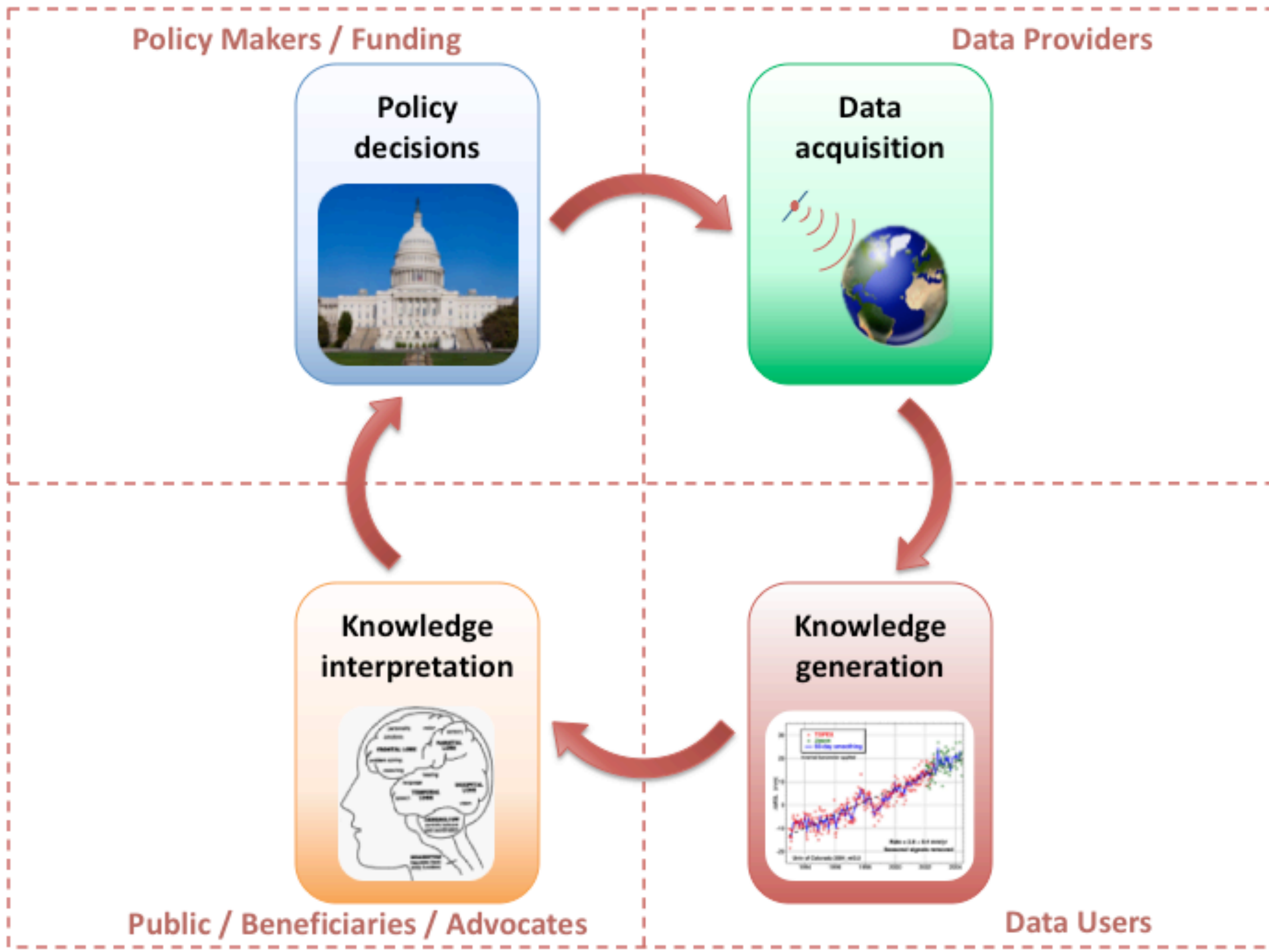
Courtesy of Ed Crowley, MIT

Workflow to Architecture



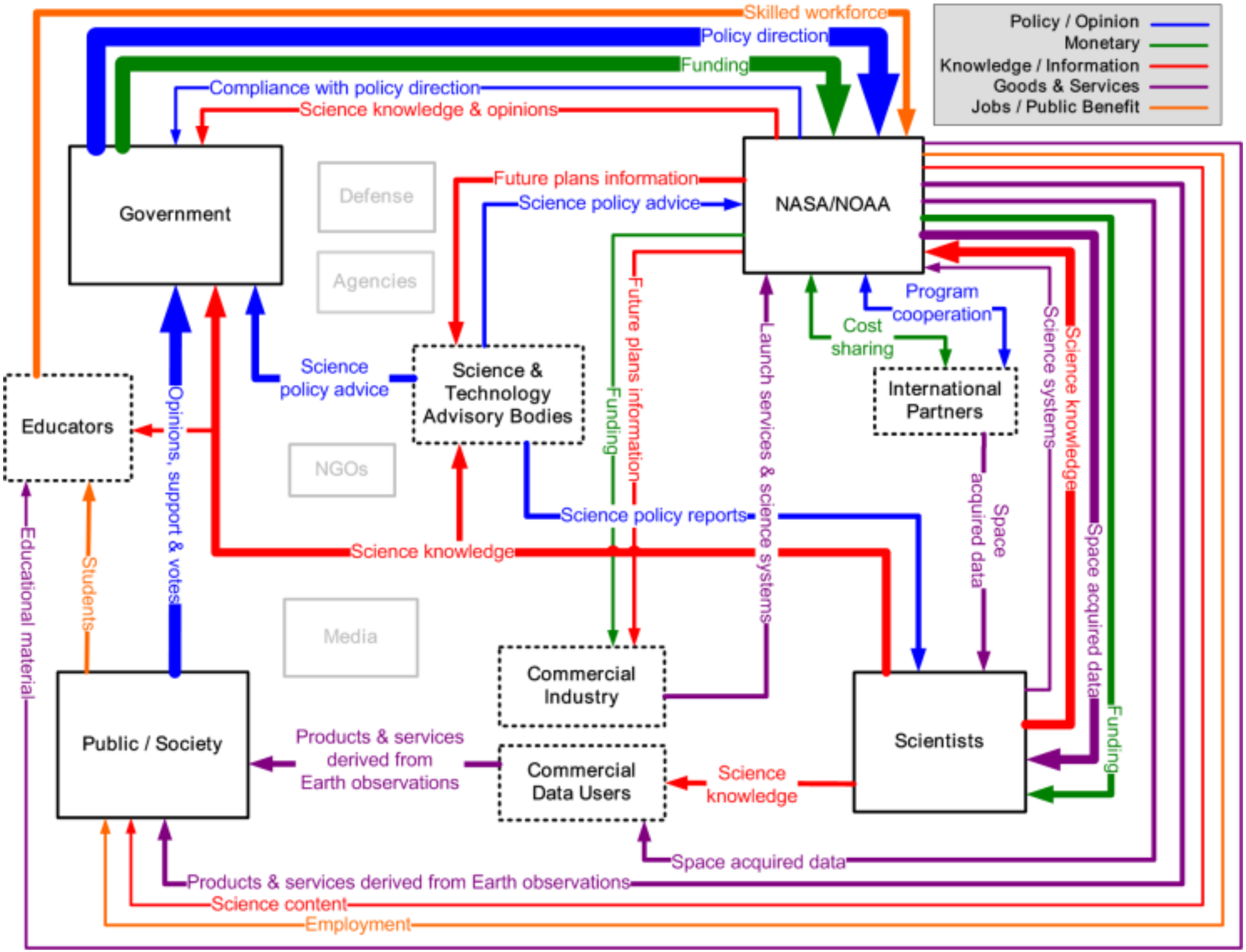
Courtesy of Ed Crowley, MIT

Tracing Stakeholder Value



How do we build a system that produces the greatest value not only to the climate scientists, but to all of the stakeholders, including commercial, other agencies, and the public?

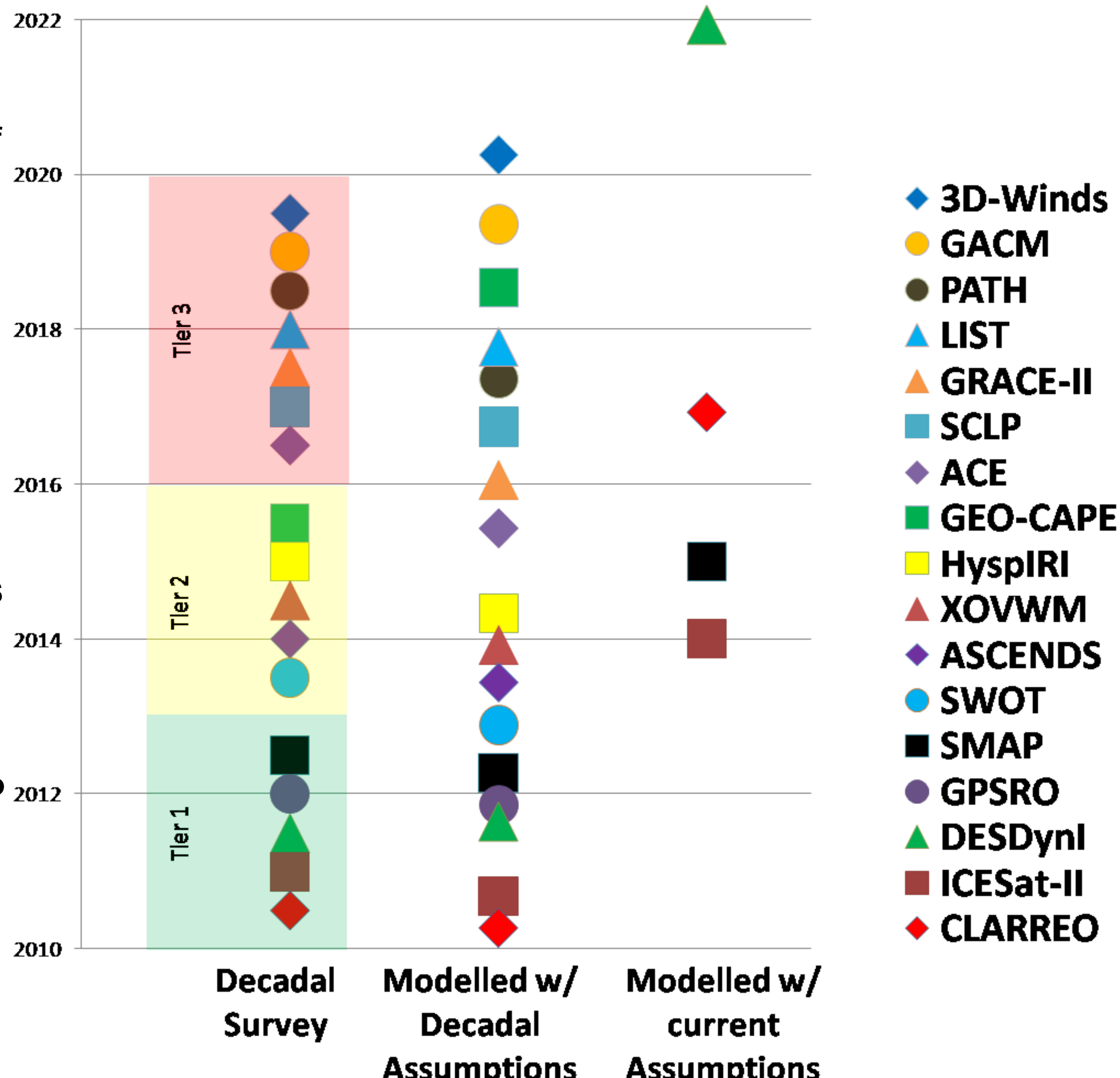
Courtesy of Ed Crowley, MIT



Courtesy of Ed Crowley, MIT

CAMPAIGN DESIGN

- Enumerate and evaluate all feasible architectures
  - Systems architecture principles applied to the scheduling and implementation of large, complex space satellite systems
  - Used "OPN" to enumerate constrained space
  - Utilized value functions and decision metrics to evaluate and rank set of feasible architectures
  - Down-select to a handful of favorable concepts to be carried forward for more detailed study and development
- Calibrated to Decadal Survey
  - Extensive interviewing process captured tacit decision rules used by DS panel members to arrive at recommended architecture
  - Reproduced recommended campaign order of 17 DS missions
- Used to explore reordering optimized to more realistic budget and costs
  - Implement new measurement objectives, and study affects on campaign architecture
  - Adapt campaign to various budget constraints



Courtesy of Ed Crowley, MIT