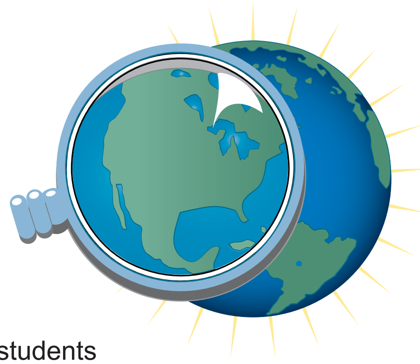
Tracking world aerosol hazards



Investigation Overview

This investigation allows students to see how geography and a spatial perspective are useful in addressing global challenges. Data gathering and organization skills are emphasized as students create maps of global aerosol hazards. In small groups, students collect either long-term or short-term data showing the distribution of global aerosols and convert the data into a map. Groups then compare their maps to identify patterns and sources of aerosols around the world. The investigation is structured to offer two options: one for students with direct access to the web in a lab setting (Option 2) and one for students without such resources (Option 1).

Time required: Three 45-minute sessions

Materials/Resources

Option 1, No Computer Lab Access:

- Transparency: Redoubt ash cloud
- Briefing (one per student or to read as a group)
- Log 1 (one per student)
- Log 2.1 (Make two transparencies per group)
- Log 3: Frequency chart (one per group)
- Log 4: World map (two per group)
- If available, a computer with access to TOMS Aerosol Animation: http://toms.gsfc.nasa.gov/aerosols/aerosols.html
- Copies of eight figures per group

Long-Term Group	Short-Term Group
Figure 1: November 23, 1990	Figure 8: August 14, 2000
Figure 2: March 15, 1993	Figure 9: August 15, 2000
Figure 3: September 15, 1996	Figure 10: August 16, 2000
Figure 4: October 21, 1996	Figure 11: August 17, 2000
Figure 5: May 29, 1997	Figure 12: August 18, 2000
Figure 6: February 14, 1998	Figure 13: August 19, 2000
Figure 7: August 8, 1999	Figure 14: August 20, 2000
Figure 8: August 14, 2000	Figure 15: August 21, 2000

- Two transparency pens per group
- Colored pencils (six per group)

Option 2, Web Access:

- Transparency: Redoubt ash cloud
- Briefing (one per student or to read as a group)
- Log 1 (one per student)
- Log 2.2: Data tally sheet (eight copies per group)
- Log 3: Frequency chart (one per group)
- Log 4: World map (two per group)
- Computer access to TOMS Aerosol Index for small groups: http://toms.gsfc.nasa.gov/aerosols/aerosols.html
- Colored pencils (six per group)

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Use geographic tools and technologies to pose and answer questions about spatial distribution and patterns on Earth.

Standard 15: Environment and Society

How physical systems affect human systems

- Analyze ways in which human systems develop in response to conditions in the physical environment.

Standard 18: The Uses of Geography

How to apply geography to interpret the present and plan for the future

- Analyze the interaction between physical and human systems to understand possible causes and effects of conditions on Earth and to speculate on future conditions.

Geography Skills

Skill Set 2: Acquire Geographic Information

- Use maps to collect and/or compile geographic information.

Skill Set 3: Organize Geographic Information

- Prepare various forms of maps as a means of organizing geographic information.

Skill Set 4: Analyze Geographic Information

- Use statistics and other quantitative techniques to evaluate geographic information.

Content Preview

Aerosols are tiny particles in the atmosphere that come from a variety of sources (primarily volcanic ash, dust, and smoke). Volcanic eruptions emit large clouds of ash, which can damage aircraft that fly through them. Desert areas produce dust clouds of sand and other light particles swept up by winds. Smoke aerosols result from burning biomass, primarily forests.

Students compare short-term and long-term observations of aerosols. Isolated sources of aerosols, such as volcanic eruptions or seasonal fires, are best observed through short-term daily observations. Long-term observations reveal areas with consistent aerosol hazards.

Classroom Procedures

Beginning the Investigation

1. Distribute the **Briefing** and display **Transparency: Redoubt ash cloud**, while students read the account of the plane's encounter with an ash cloud from the Redoubt Volcano in 1989. Explain that damage to aircraft like that mentioned in the story contributed to the establishment of worldwide Volcanic Ash Advisory Centers to help inform pilots of volcanic ash dangers. These centers receive information from volcano observatories, air traffic control towers, and meteorological agencies. One source for information about volcanic ash clouds is NASA's TOMS (Total Ozone Mapping Spectrometer).

2. Explain that volcanic ash is a serious concern for aircraft safety, but that there are many aerosols that may damage airplanes, such as ash, dust, and smoke from burning biomass.

3. Divide students into groups of four. **Option 2:** At separate computer stations (or projected for the entire class, if possible in **Option 1**), have students go to <http://toms.gsfc.nasa.gov/aerosols/aermovie.html> to observe an animation about aerosol movement over a two-month period. Assign different groups to watch for potential volcanic activity in different regions of the world.

   Option 1: If no access to the animation is available, this step may be omitted.

4. Allow students to share their observations. Ask:
   - Which region had the greatest aerosol activity during the two-month period?
   - Where did the aerosols in your assigned region travel?
   - Considering what you know about the region that you were observing, what do you think caused the aerosols? Volcanic ash? Smoke from fires? Dust?

   After students have shared their predictions, explain the causes for the aerosols in various regions.

5. Explain to students that this animation showed a two-month period of time. Pose the question: Do you think the patterns of aerosols would be different over a longer period of time?

Developing the Investigation

6. Assign equal numbers of small groups the task of either a short-term or long-term study. Some groups should collect TOMS data for eight consecutive dates (short-term). The other groups should collect TOMS data for eight random dates that they determine within a 10-year time span (long term).

   For Option 1:
   Provide the short-term groups with **Figures 8-15**, two transparency pens, and two transparencies of **Log 2.1**. Provide the long-term groups with **Figures 1-8**, two transparency pens, and two transparencies of **Log 2.1**.

   For Option 2:
   Ask student groups (in smaller subgroups if additional computers are available) to go to the TOMS website <http://toms.gsfc.nasa.gov/aerosols/aerosols.html>. Ask the short-term groups to select a series of eight consecutive dates. Ask the long-term groups to select a series of eight random dates of data. If access is limited to only a few computers, have students print the images for the dates they select.

7. **For Both Options:**
   In order to keep track of the aerosol data, students should "index" each figure by lettering the blocks across and numbering the blocks down so that each square has a reference of A1 to R14 (14 numbers down and 18 letters across).

   For Option 2: This step is more helpful if the images are printed out, but students can use the grid as mental references if printing must be conserved.

8. **Option 1:**
Students should systematically lay the transparency over each figure, carefully lining up the grid with the grid on the figure. With a transparency marker, students should place a dot in each square that contains aerosols. Using the same transparency, repeat this process for each figure.

Option 2:
Each group then inspects each square and records on **Log 2.2** "yes" if aerosols are present or "no" if they are not.

9. **For Both Options:**
When all data have been recorded, the groups should tally the results from all eight figures for each block and record the data on **Log 3**. How many times were aerosols present in each square?

Have students calculate the percentage of time aerosols were present in each square of their map by dividing the frequency observed and recorded by the number of observations (eight). If time does not permit, these calculations may be omitted and students may map their raw numbers.

10. In order to map world aerosol hazard zones, have students determine a way to categorize their data by ranking the area hazard levels as follows:
1—severe hazard area,
2—moderate hazard area, and
3—no or low hazard area.

Directions for determining equal classes are located in the **Background** section. If time does not permit, provide students with one of the following ranking schemes for their maps.

Hazard Level	Percentages	Raw Numbers
Level 3	67-100%	6-8
Level 2	34-66%	4-5
Level 1	0-33%	0-3

For example, if students observed aerosols in a particular grid cell in five of their images, they would categorize that square as a Level 2 hazard because aerosols were found 62.5 percent of the time. If aerosols were observed in seven of the images, students would label that square a Level 3 hazard because aerosols were found 87.5 percent of the time.

11. Distribute **Log 4**. Have all groups create two identical maps of their data using three colored pencils. Students should include all appropriate map elements on their maps: title, orientation, authors, dates. An appropriate title would identify the map as a *long-term* or a *short-term* aerosol study.

Note: Maps are easiest to interpret when colors are carefully chosen to reflect the data being presented. For example, a light color should signify a low risk, while a darker color should signify a high hazard risk. When students begin to analyze their maps, the patterns for high aerosol risks will be more evident.

Concluding the Investigation

12. Ask each group to analyze their maps and prepare answers to the following questions:
    - What patterns do you observe on your map? Are there concentrated areas that have high/medium/low aerosol hazards?
    - Considering what you know about global environments (locations of deserts, forests, and volcanoes), what is probably causing the patterns that you observed (volcanoes, dust, smoke from biomass burning)?

13. Ask each group to share their maps and analysis with the class.

14. Have the long-term and short-term groups compare maps. Split each group into pairs (each with a copy of the group's map) and match them with pairs from the other group. The new groups of four should consist of two students from both long-term and short-term groups.

15. In the new groups, ask students to compare the maps created by the two groups:
    - What are the pattern similarities and differences?
    - Are there areas that are shown to be dangerous on one map but not on the other?
    - Explain any differences that your group observes.

16. Provide students time to process the benefits and limitations of their research and analysis by asking the following questions:

- Which data collection method is better for identifying isolated, episodic sources of aerosols? (*Short-term or daily data collection is better because isolated sources such as volcanic events, fires, and other local aerosol-producing activities may not be identifiable if observation dates are not consecutive.*)
- Which data collection method is better for identifying persistent sources of aerosols? (*Long-term data collection is better because it minimizes the impact of isolated sources of aerosols and exaggerates the areas that consistently produce aerosols, such as dust storms and large-scale burning of forests.*)
- In which category (isolated episode or persistent source) would volcanic eruptions be considered? (*Isolated episode, although the ash ultimately travels around the globe.*)
- What type of observation of aerosols would be needed to minimize the *immediate* dangers to aircraft? (*Daily observations to quickly identify local sources of aerosols.*)
- What would be the potential benefit of each type of observation technique to the safety of airplanes? (*Daily observation can help to identify localized hazards for aircraft to avoid. Long-term observation and trend information can help to develop safe flight paths that avoid high-hazard areas.*)

Background

Determining Equal Class Ranking Scheme

Step	Example
1. Subtract the lowest possible value from the highest possible value.	100%-0% or 8-0
2. Divide the answer by the number of categories needed. Round as desired. This is the unit size.	100/3 = 33.333 (33%) 8/3 = 2.67 (3)
3. Determine the divisions for each class by starting with the lowest possible. For the second class, add one to the unit size so that any number falls into only one class.	Percentages 0-33 34-66 67-100
4. Adjust classes, if necessary, to better reflect the data to be mapped.	Raw Numbers 1-3 4-5 6-8 (Here, 6 is added to the highest class rather than being the upper boundary of the second class. This emphasizes the significance of observing aerosols 75% of the time.)

Related Resources

http://toms.gsfc.nasa.gov/aerosols/aerosols.html Images and data on aerosol index

http://capita.wustl.edu/Databases/UserDomains/SaharaDust2000/ Additional resources about the effects of dust storms from Africa using SeaWiFS data

http://volcanoes.usgs.gov/Hazards/What/Tephra/tephra.html USGS source for information on airborne volcanic hazards

http://volcanoes.usgs.gov/Hazards/Effects/Ash+Aircraft.html USGS information on volcanic ash and aircraft

http://www.avo.alaska.edu/genrl_info/pdfs/usgsfs030_97_ash.pdf USGS fact sheet on the interaction of airplanes and ash. In .pdf format.

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/ Volcanic ash clouds and aircraft safety

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/historic.html Narrative of an aircraft encounter with an ash cloud from Redoubt

Transparency: Redoubt ash cloud

Aerial view of Redoubt Volcano during a continuous, low-level eruption of steam and ash
December 18, 1989
Source: photo by W. White, USGS, http://www.avo.alaska.edu/avo3/volc/redou/photo.htm

Module 1, Investigation 3: Log 1

How can airline damage from volcanoes be minimized?

Background

When volcanoes erupt, they spew tiny particles, called aerosols, into the air. Aerosols get swirled around in the atmosphere and can cause significant damage to airplanes flying through these clouds. Between December 1989 and February 1990, five commercial airplanes were damaged because they encountered volcanic ash from Redoubt Volcano, an active volcano in Alaska. The volcanic ash caused more than $80 million in damages to just one of the airplanes! Please help to identify areas in the world where aerosols can present a hazard to aircraft safety.

Objectives

In this activity, you will

1. identify the sources of aerosols worldwide,
2. develop a time series for global aerosols, and
3. prepare a world map that ranks regions by hazard potential based on any images and data you collect.

Procedures for the Investigation

1. To get an idea about the dangers associated with volcanic ash, read the story of a plane that encountered an ash cloud from the Redoubt Volcano in Alaska. This 1989 eruption encouraged the formation of a group of nine Volcanic Ash Advisory Centers (VAACs) that use information from NASA's Total Ozone Mapping Spectrometer (TOMS) sensors, weather data, and air traffic control towers to warn pilots of ash clouds in their flight path.
2. You will be gathering, organizing, and analyzing TOMS aerosol data for eight dates to identify hazardous areas for airplanes.
3. Follow your teacher's directions to collect and record the data. Divide the work evenly among your group members so everyone has a chance to contribute.
4. After all the dates have been analyzed, total up the information from all eight of the dates and record your answers on Log 3: Frequency chart.
5. Make each tally into a percentage by dividing the number of times the square contained aerosols by the number of dates that you checked (eight). Fill in the following chart to convert days to percentages more quickly.

Dates aerosols were observed in the square		Percentage of time aerosols were present
1	1/8=	
2	2/8=	
3	3/8=	
4	4/8=	
5	5/8=	
6	6/8=	
7	7/8=	
8	8/8=	

Module 1, Investigation 3: Log 1

How can airline damage from volcanoes be minimized?

6. Based on the data, rank the regions of the world by aerosol hazard: Level 1—no or low hazard area, Level 2—moderate hazard area, Level 3—severe hazard area.

7. Create two identical world maps showing these hazard areas. Color areas according to the rating that you gave; for example, use yellow for the low hazard regions, orange for the moderate hazard regions, and red for the severe hazard regions.

   Be sure to include all appropriate map elements on the front of both the maps. The map title should be descriptive so that people know what data you mapped.

8. Share your maps with the class. Prepare an explanation of the maps using these questions to guide you.

   - What patterns do you observe on your map? Are there concentrated areas that have high, medium, and low aerosol hazards?
   - What is probably causing the patterns that you observed? Think about what you know about the locations of aerosol sources (deserts, volcanoes, and forests).

9. Divide your group into two teams. Join members from another team to analyze the two different maps. Use the following questions to guide your analysis.

   - What are similarities of and differences between the patterns on the two maps?
   - Are there areas that are shown to be dangerous on one map but not on the other?
   - Explain any differences that your group observes.

10. Based on your map comparison, which type of map (short-term or long-term) would be most helpful in identifying aerosol hazards from volcanoes? Explain your answer.

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References:

http://toms.gsfc.nasa.gov/aerosols/aerosols.html

E. E. Campbell. Recommended flight-crew procedures if volcanic ash is encountered, pp.151-156

Module 1, Investigation 3: Briefing

Volcano's ash kills 747's engines en route to Anchorage

ANCHORAGE, AK—Redoubt Volcano, near Anchorage, Alaska, began erupting on December 14, 1989. On the following day, a 747-400 airplane entered an ash cloud at 7,620 meters (25,000 feet) and experienced flameouts on all four engines.

During descent to 7,620 meters (25,000 feet), the airplane entered a thin layer of clouds when it suddenly became very dark outside. The crew also saw lighted particles pass over the cockpit windshields. At the same time, brownish dust with a sulfurous smell entered the cockpit. The captain commanded the pilot flying to start climbing to attempt to get out of the volcanic ash. One minute into the high-power climb, all four engines flamed out. Due to the volcanic ash and dust in the cockpit, the crew donned oxygen masks.

The pilot flying noticed the airspeed descending, initially at a normal rate but suddenly very fast. All airspeed indications were then lost due to volcanic dust contamination in an instrument. The pilot flying rather firmly put the nose of the aircraft down to avoid a stall and initiated a turn to the left in a further attempt to get out of the volcanic ash.

The crew noticed a "Cargo Fire Forward" warning and decided that the fire warning was caused by the volcanic ash, so no further action was taken. As the engine slowed down, the generators tripped off and all instruments were lost except for instruments powered by the batteries.

During the time the engines were not working, the cabin pressure remained within limits and no passenger oxygen masks deployed. The crew elected not to deploy the masks because the passenger-oxygen-mask system would have been contaminated by volcanic dust in the cabin air.

An emergency was declared when the airplane passed through approximately 5,181 meters (17,000 feet). The crew stated that a total of seven or eight restart attempts were made before engines 1 and 2 finally restarted. Initially, the crew maintained 3,962.4 meters (13,000 feet) with engines 1 and 2 restarted, and after several more attempts, engines 3 and 4 also restarted.

After passing abeam and east of Anchorage at 3,352.8 meters (11,000 feet), the airplane was given clearance for a wide right-hand pattern to runway 06 and further descent to 609.6 meters (2,000 feet). The captain had the runway continuously in sight during the approach; however, vision through the windshields was impaired due to "sandblasting" from the volcanic ash in such a way that the captain and the first officer were only able to look forward with their heads positioned well to the side.

Finally, the airplane did land safely, but approximately $80 million was spent to restore the plane, which included replacing four engines. The in-depth account of this incident helped researchers devise a procedure of what a crew should do when they encounter an ash cloud.

Source: http://www.geo.mtu.edu/department/classes/ge404/gcmayber/historic.html

Module 1, Investigation 3: Log 2.1

Data-gathering grid

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		

Module 1, Investigation 3: Log 2.2

Data tally sheet

Date ____________________

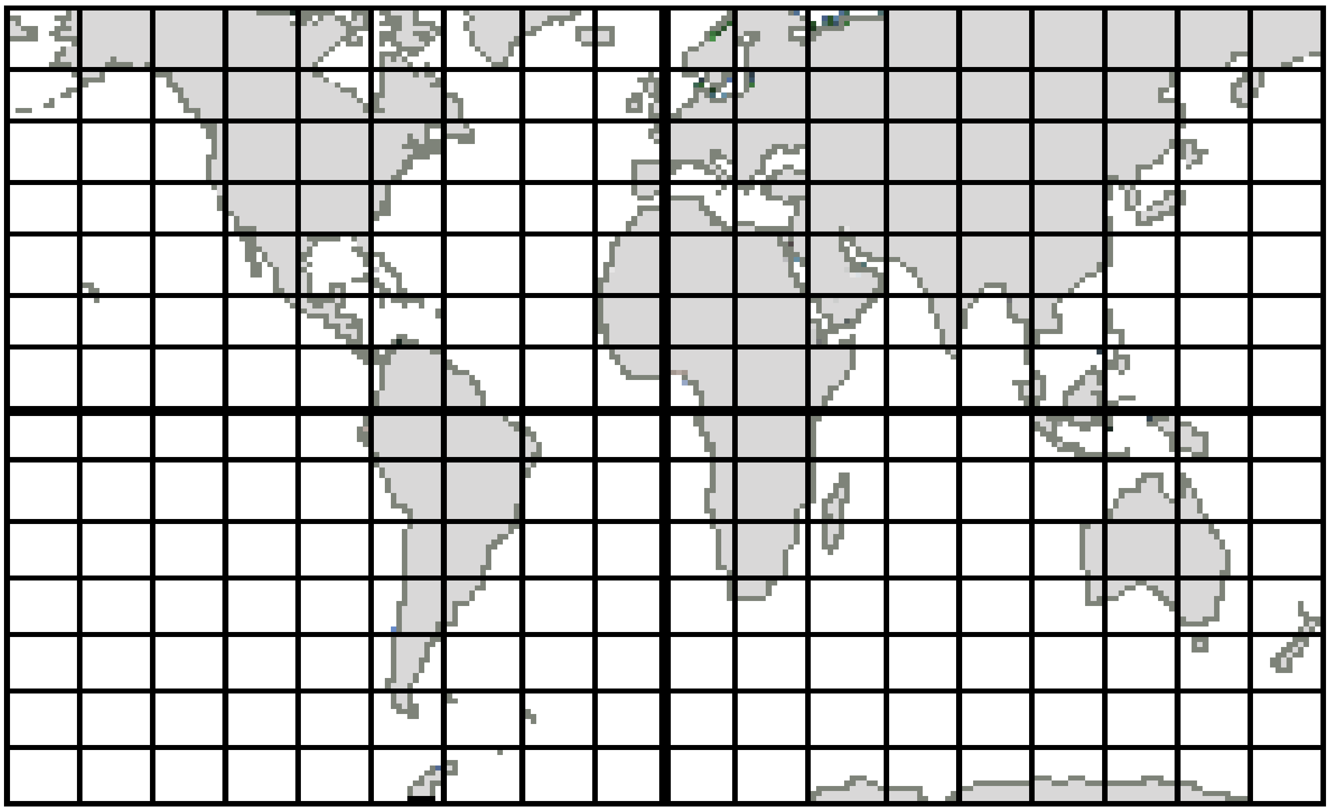
Module 1, Investigation 3: Log 3

Frequency chart

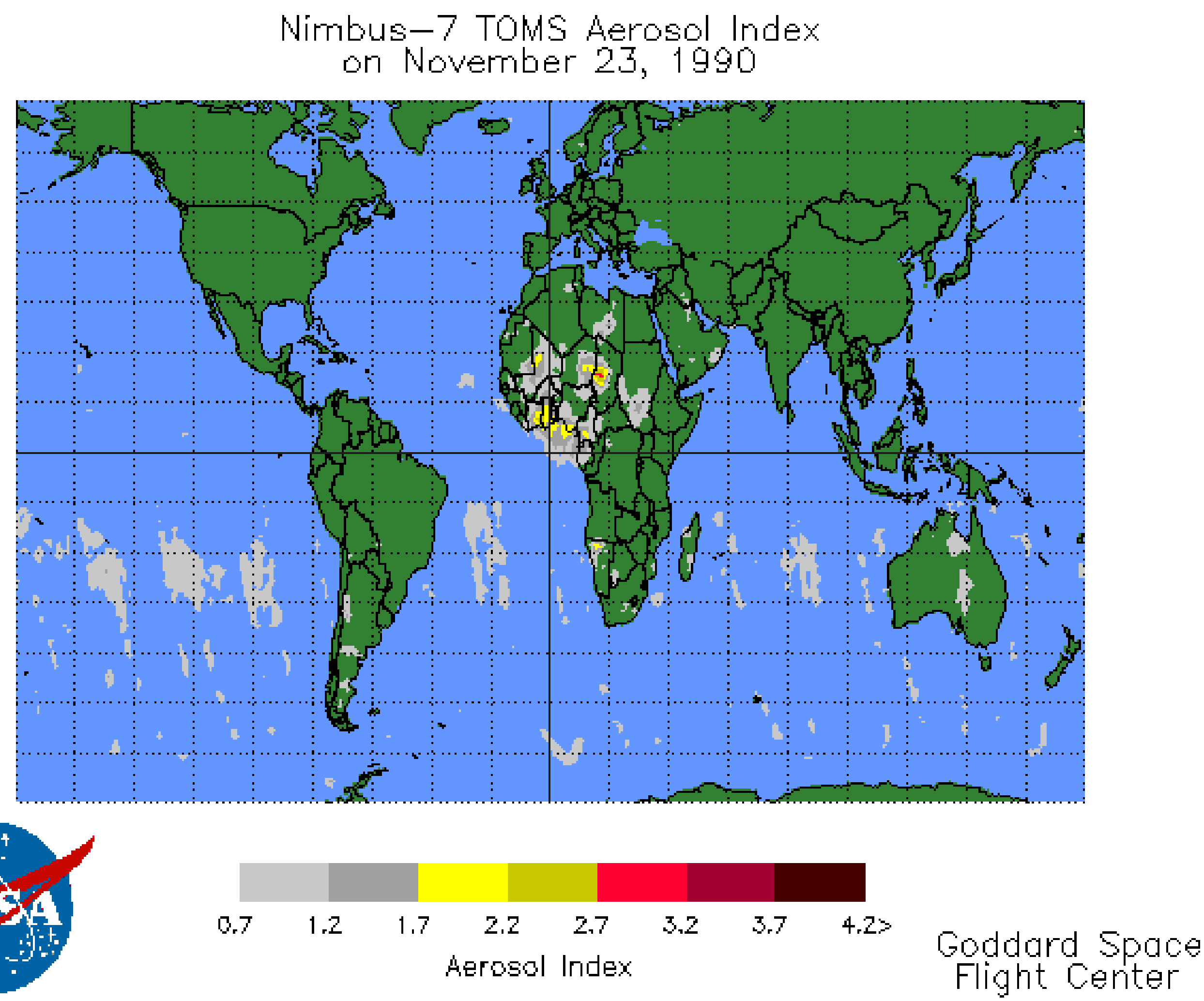
Directions: Tally each square. Then figure the percentage of time that each square contained aerosols.

Module 1, Investigation 3: Log 4

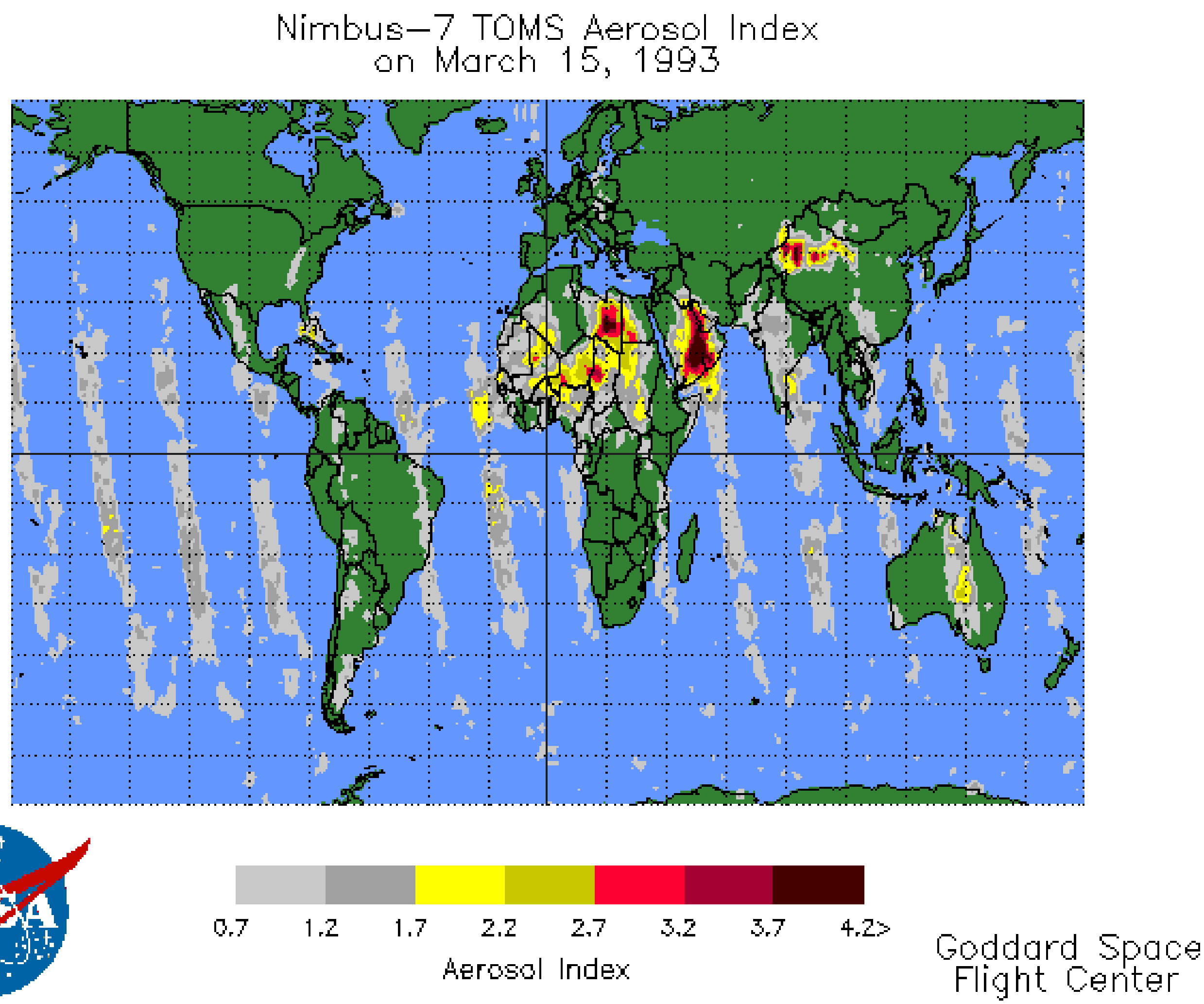
World map



Module 1, Investigation 3: Figure 1
November 23, 1990



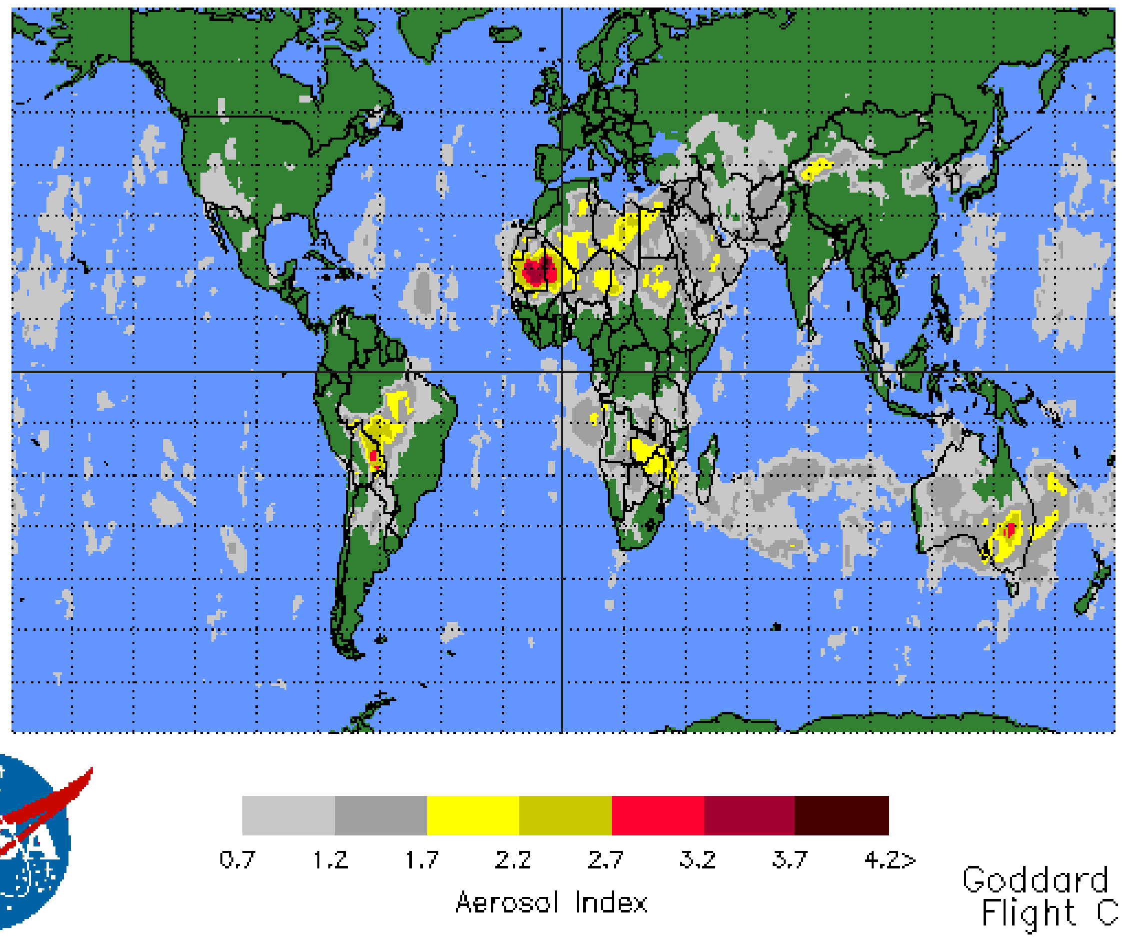
Module 1, Investigation 3: Figure 2
March 15, 1993



Module 1, Investigation 3: Figure 3

September 15, 1996

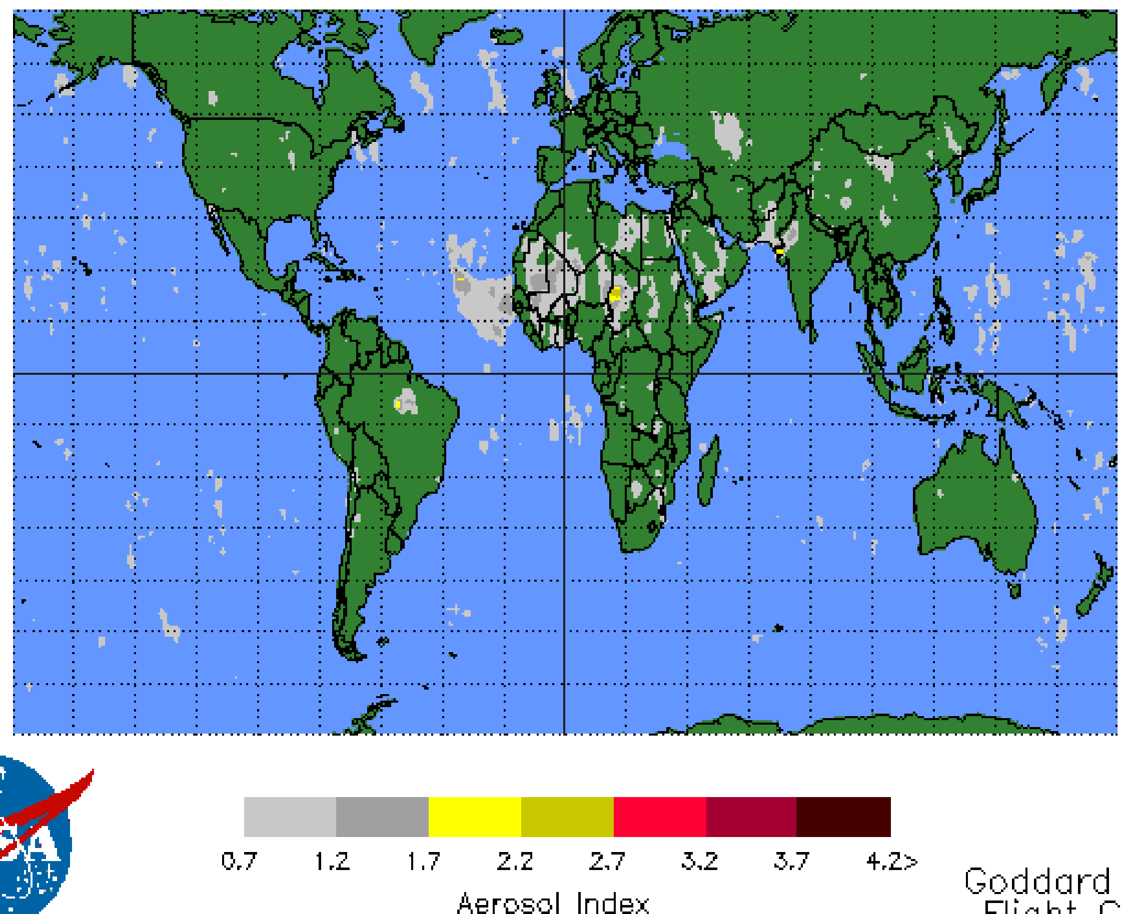
ADEOS TOMS Aerosol Index
on September 15, 1996



Module 1, Investigation 3: Figure 4

October 21, 1996

Earth Probe TOMS Aerosol Index
on October 21, 1996

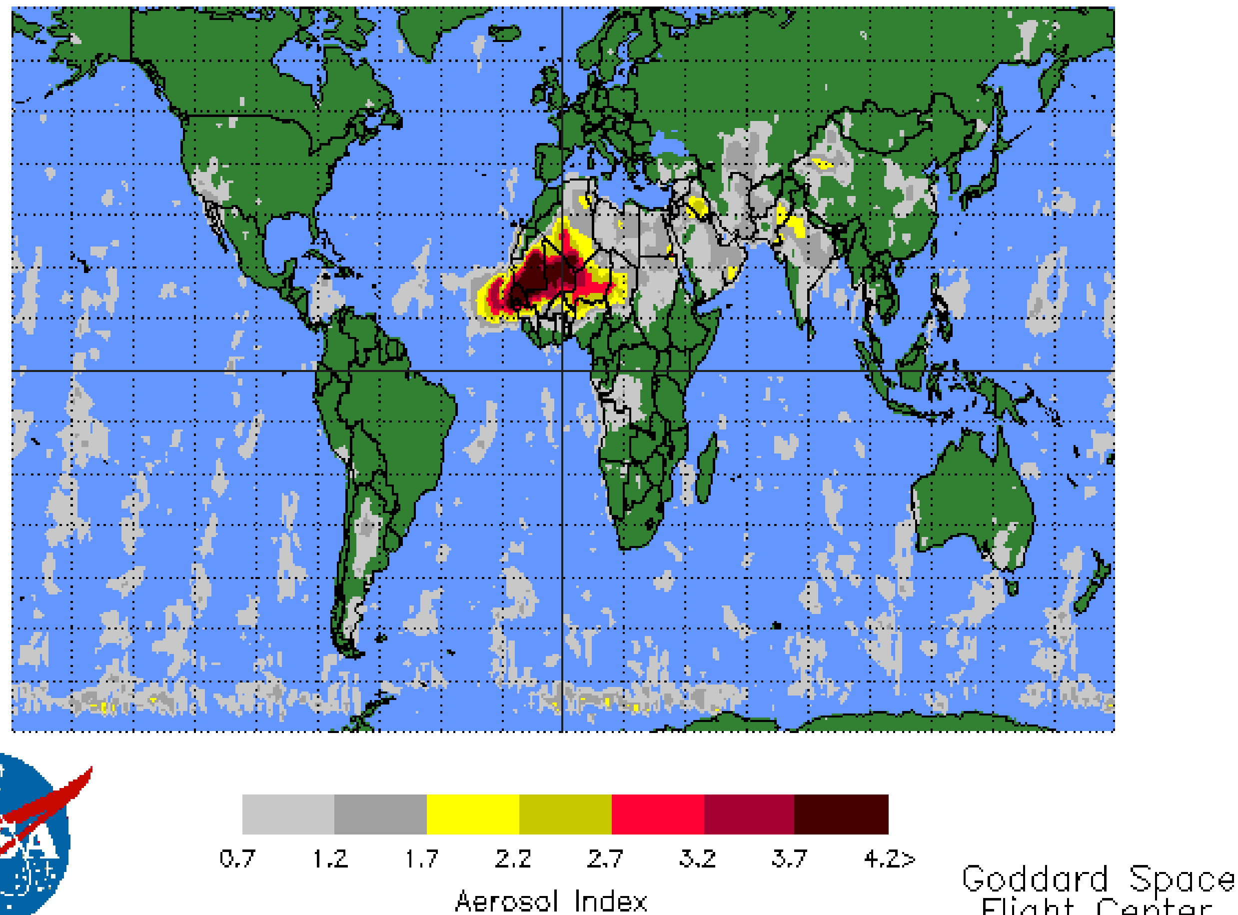


Goddard Space
Flight Center

Module 1, Investigation 3: Figure 5

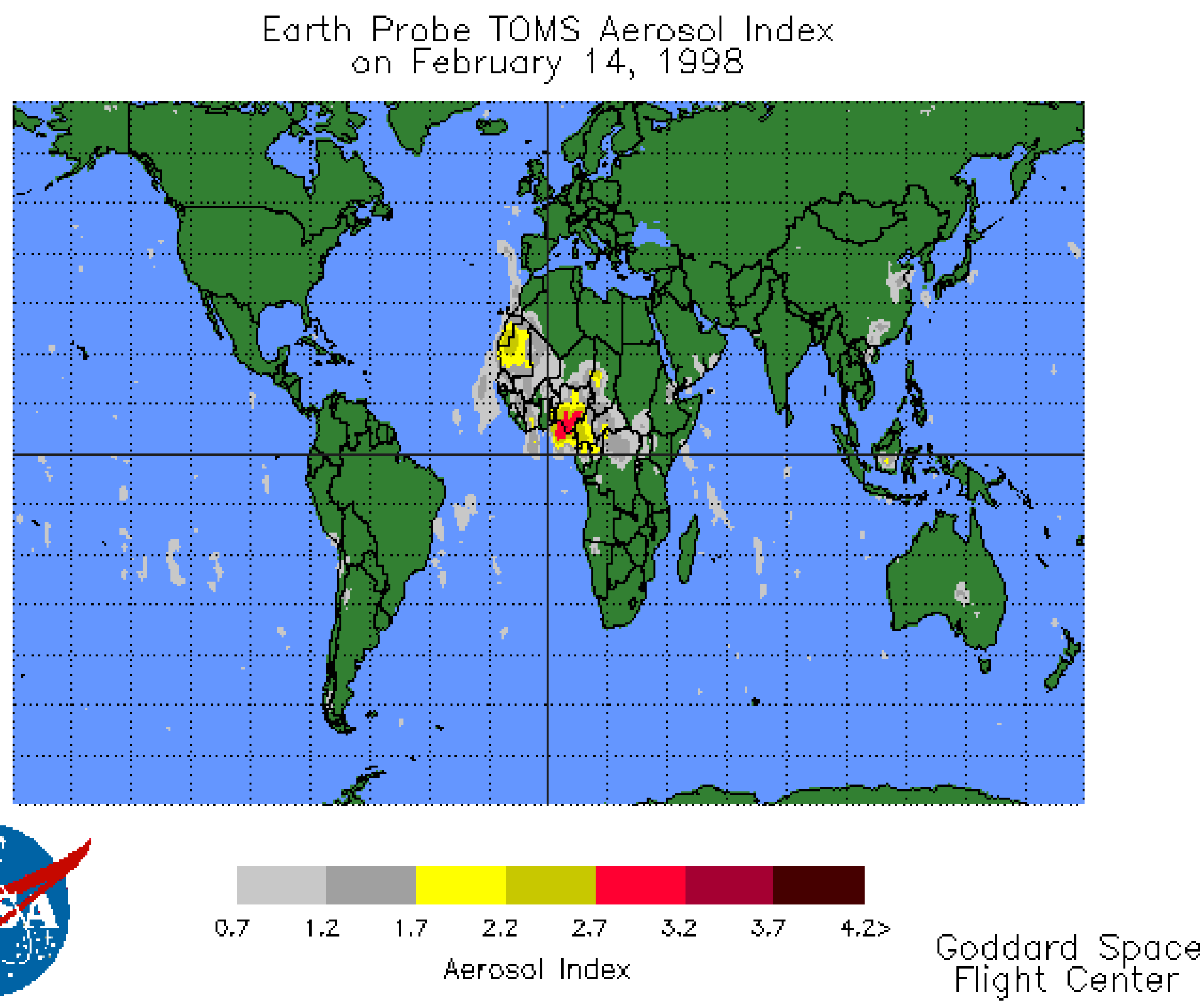
May 29, 1997

ADEOS TOMS Aerosol Index
on May 29, 1997

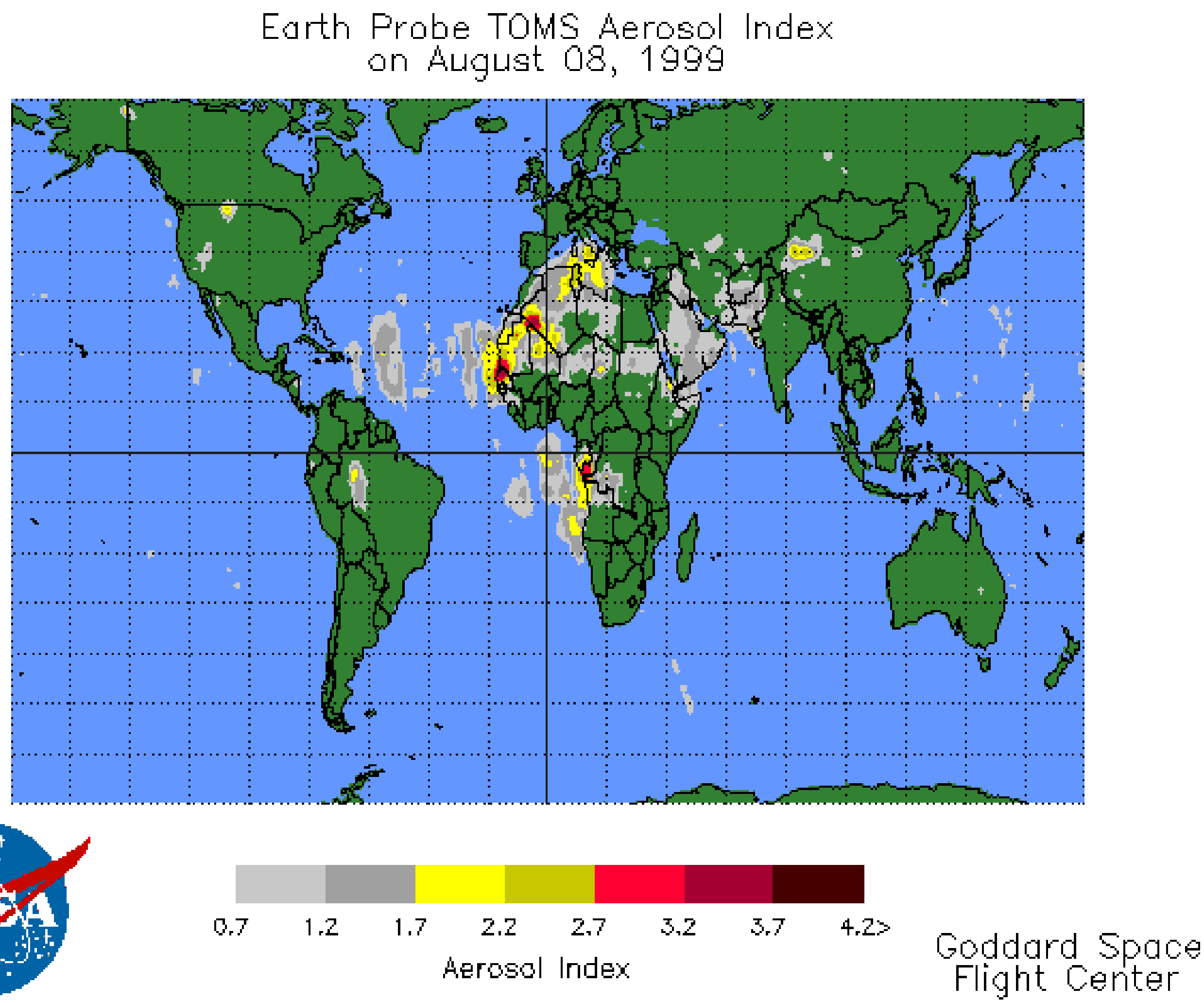


Module 1, Investigation 3: Figure 6

February 14, 1998

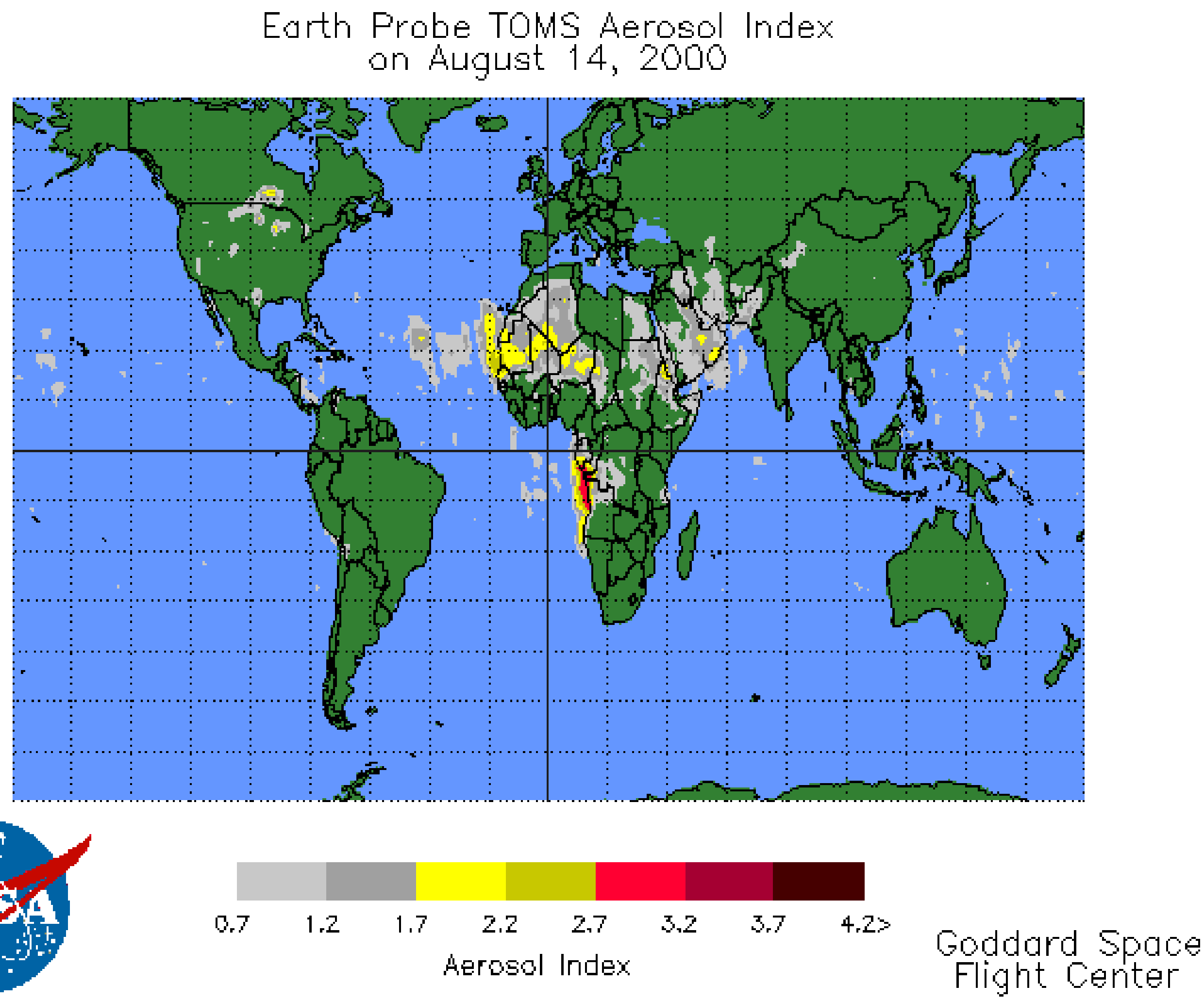


Module 1, Investigation 3: Figure 7
August 8, 1999



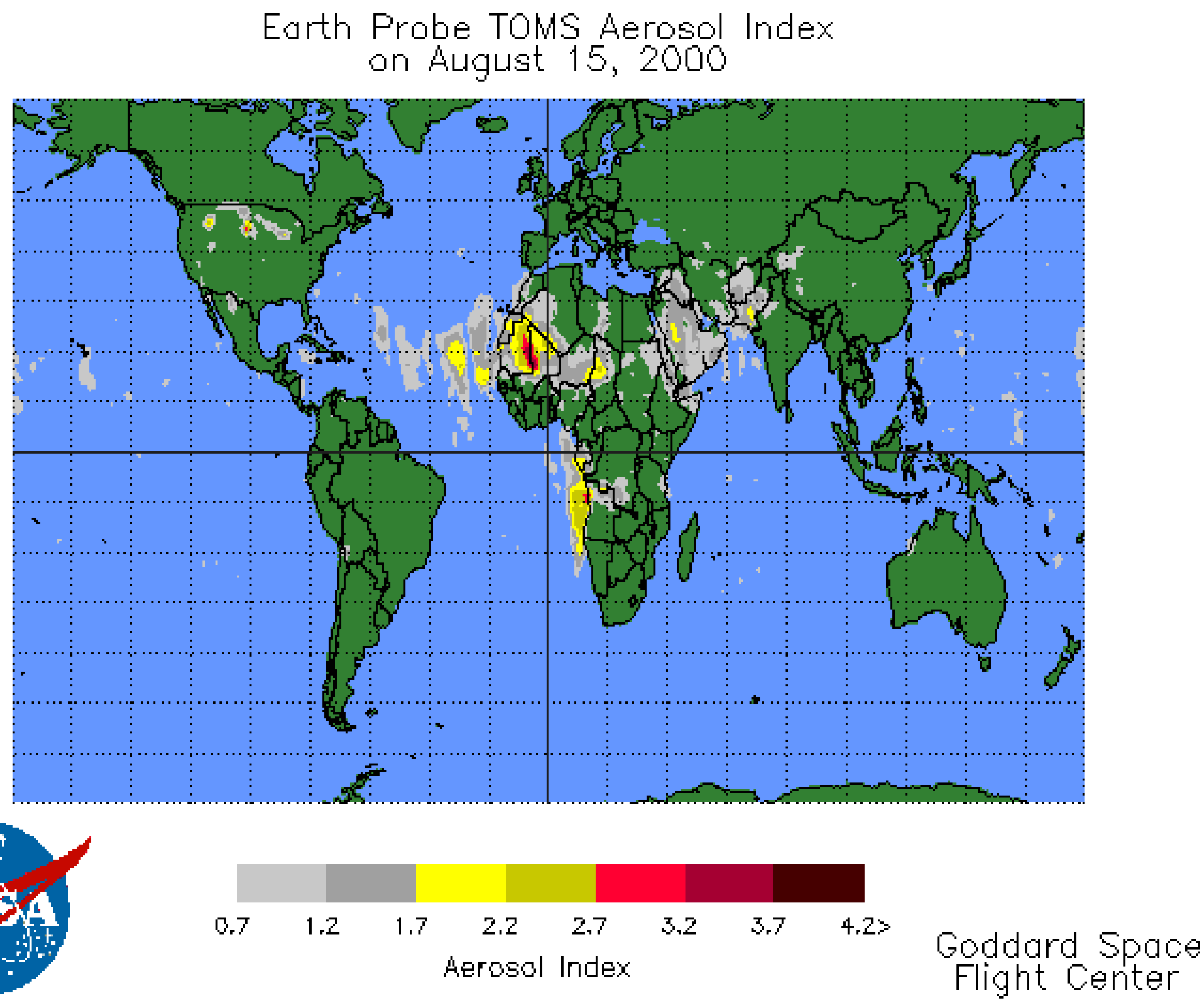
Module 1, Investigation 3: Figure 8

August 14, 2000

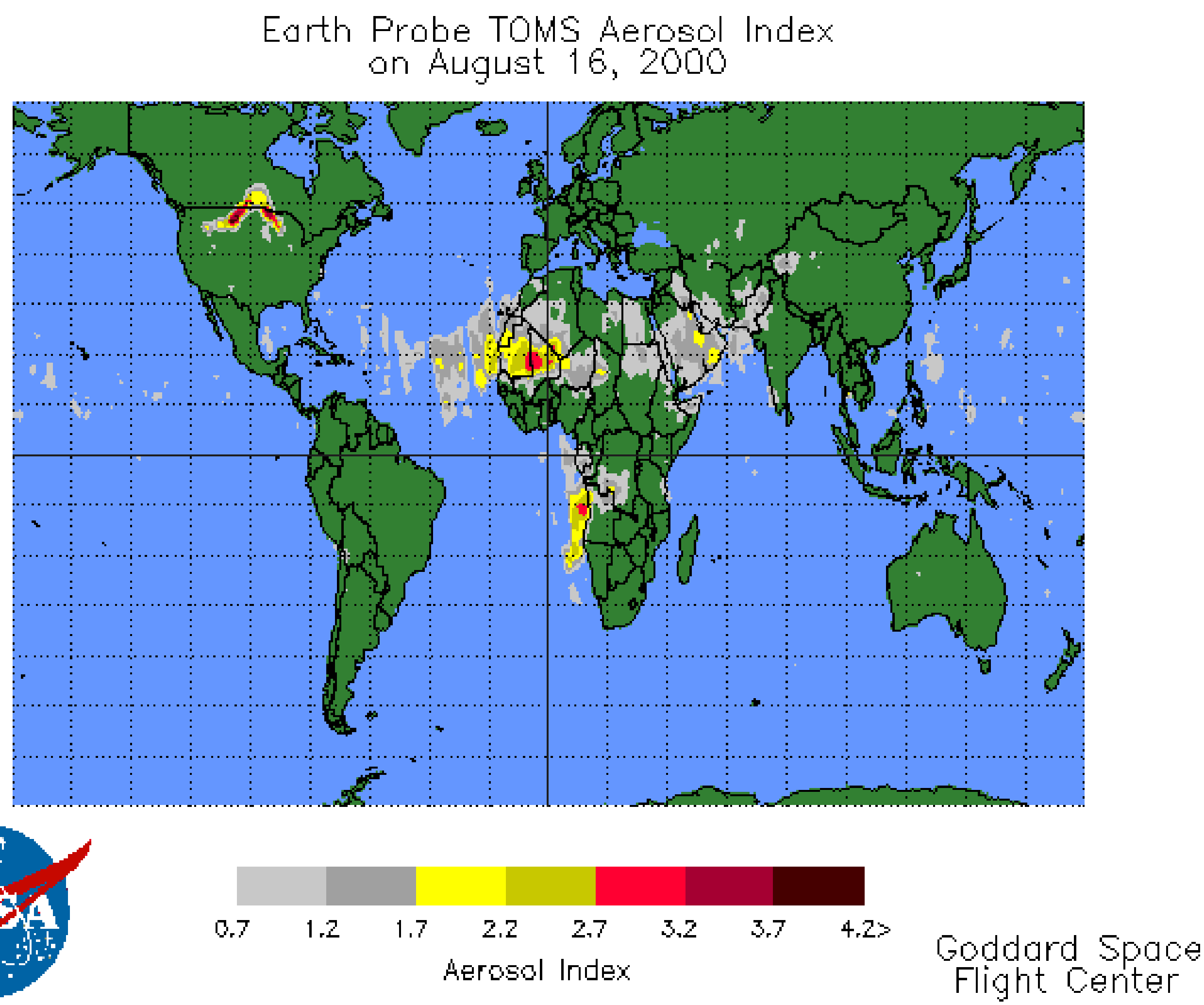


Module 1, Investigation 3: Figure 9

August 15, 2000

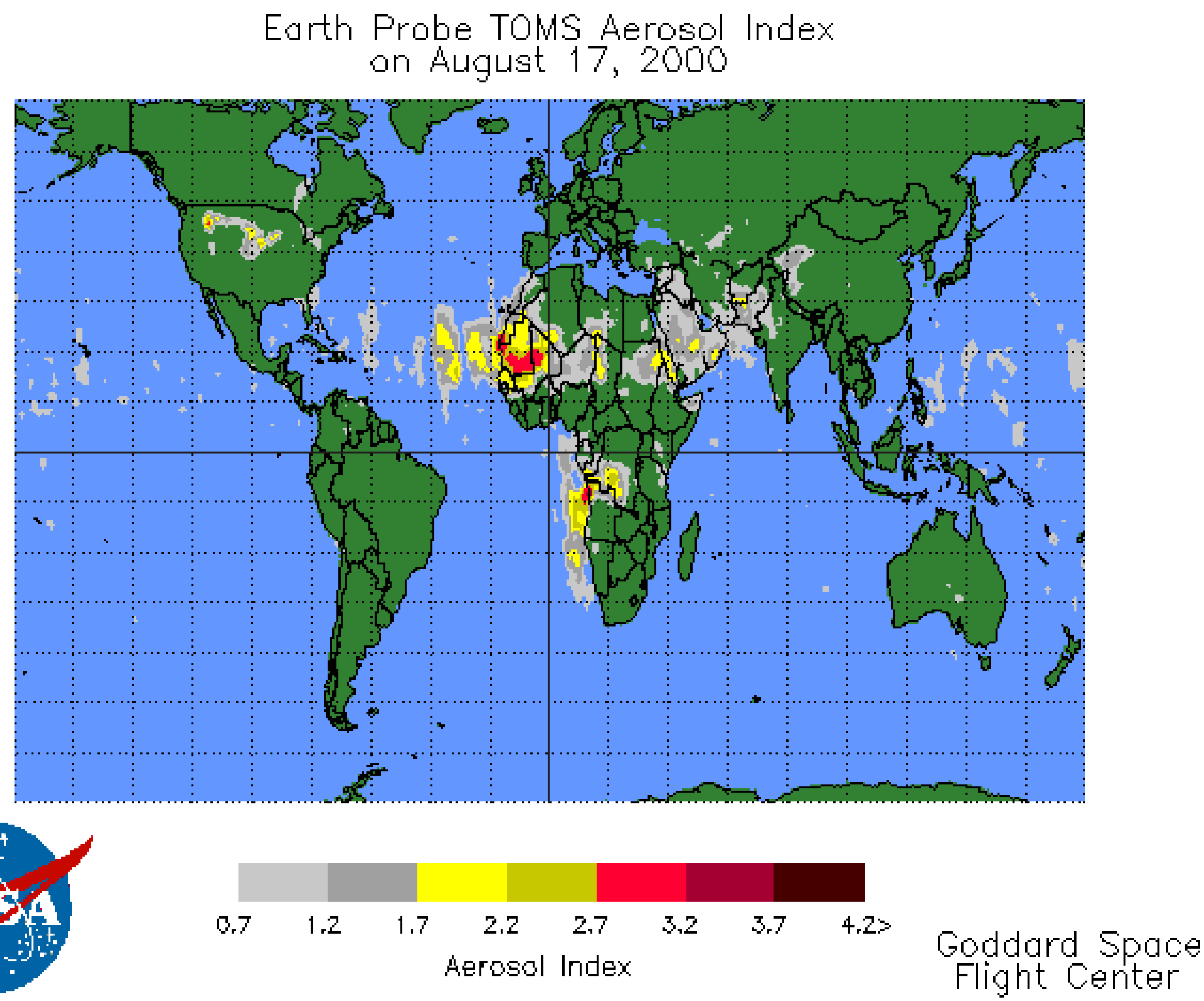


Module 1, Investigation 3: Figure 10
August 16, 2000



Module 1, Investigation 3: Figure 11

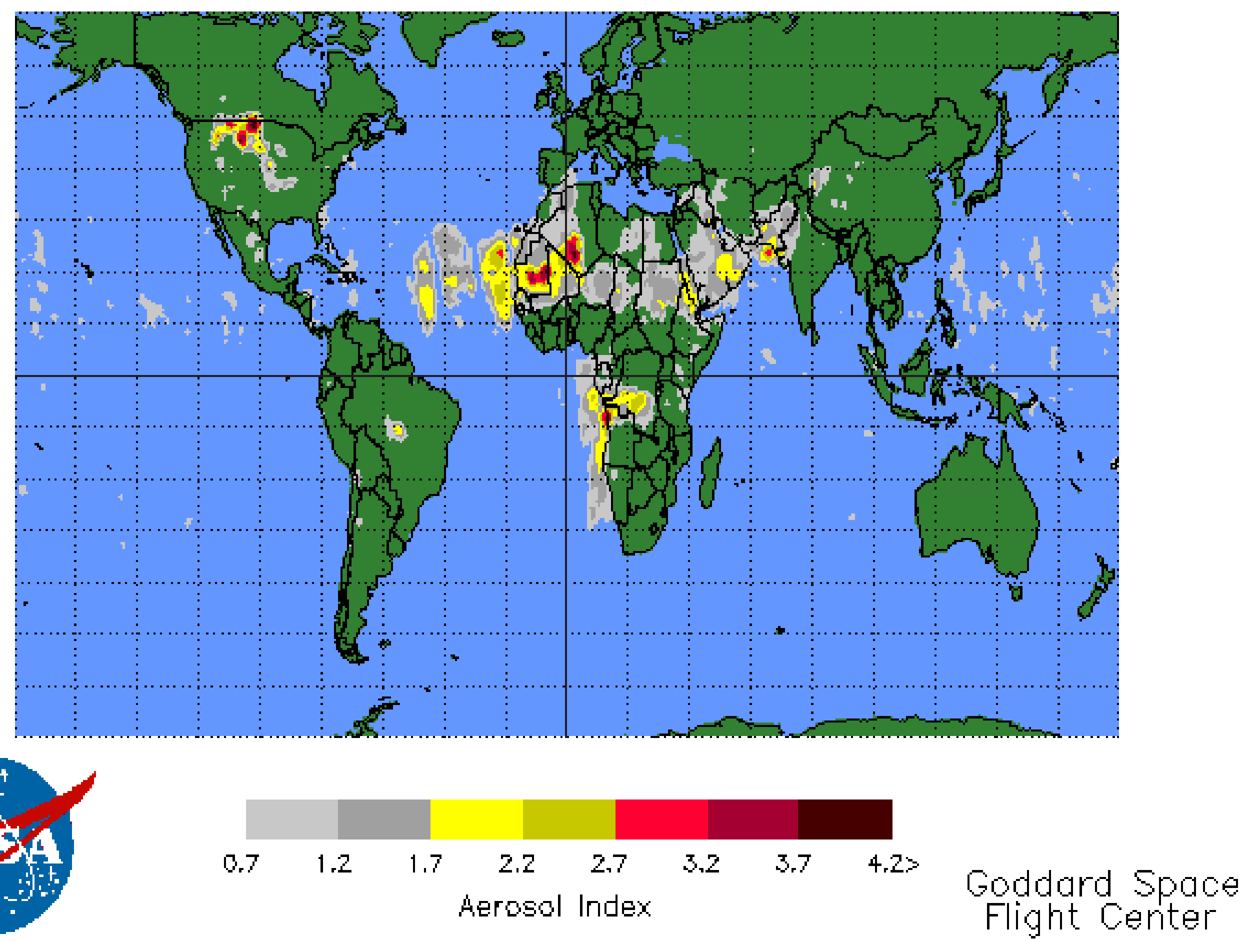
August 17, 2000



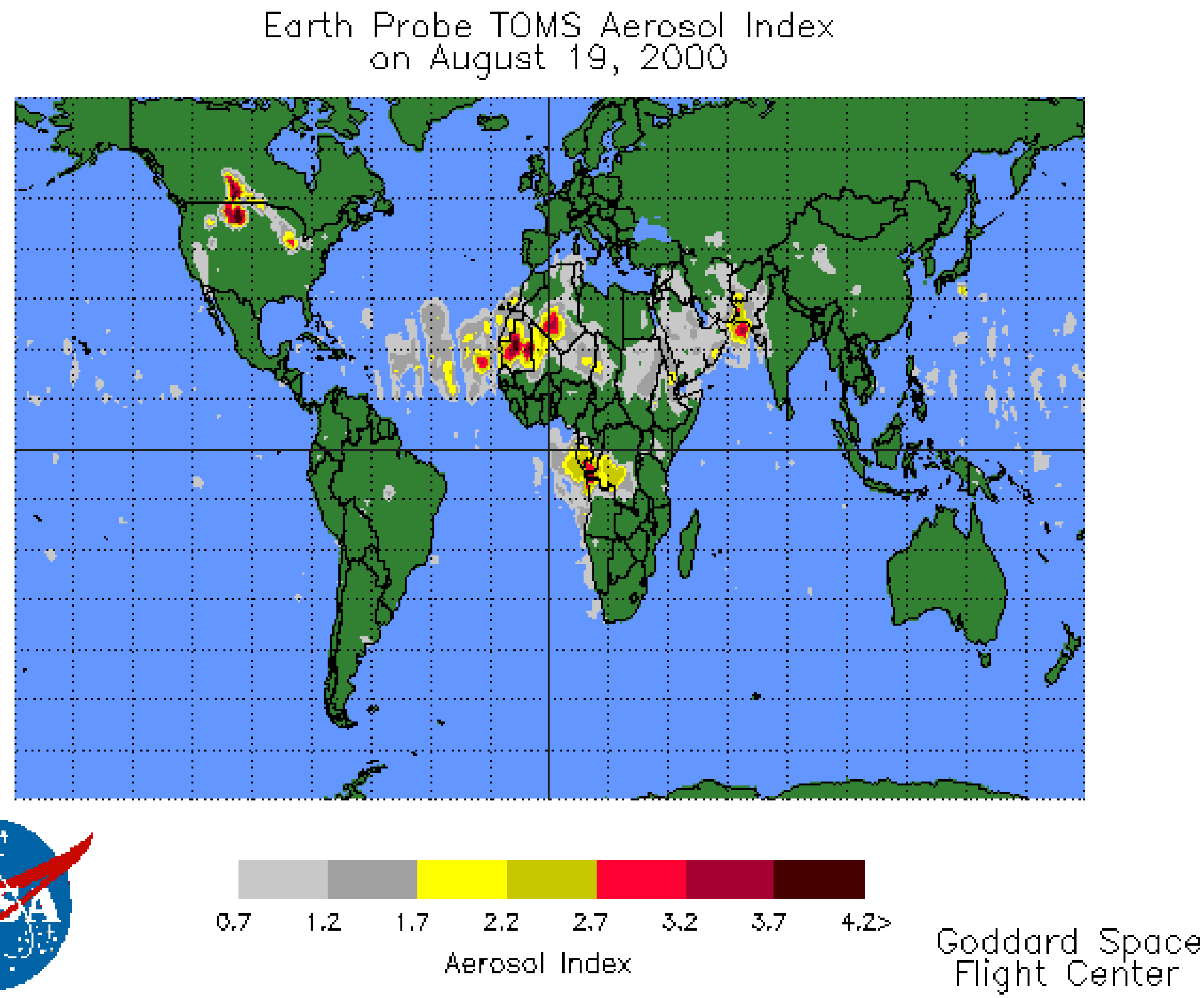
Module 1, Investigation 3: Figure 12

August 18, 2000

Earth Probe TOMS Aerosol Index
on August 18, 2000

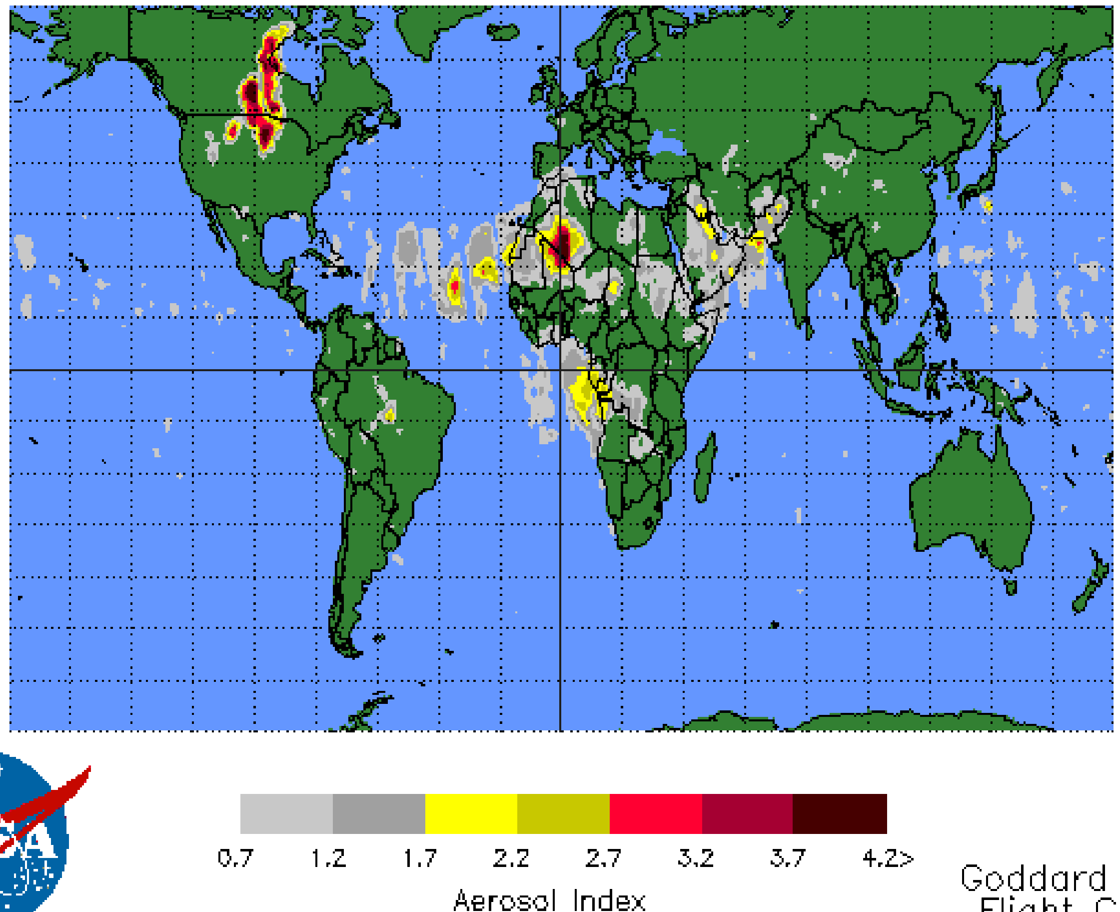


Module 1, Investigation 3: Figure 13
August 19, 2000



Module 1, Investigation 3: Figure 14
August 20, 2000

Earth Probe TOMS Aerosol Index
on August 20, 2000



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Module 1, Investigation 3: Figure 15

August 21, 2000