Advantages of Earth-Sun Observations from Lagrange 1

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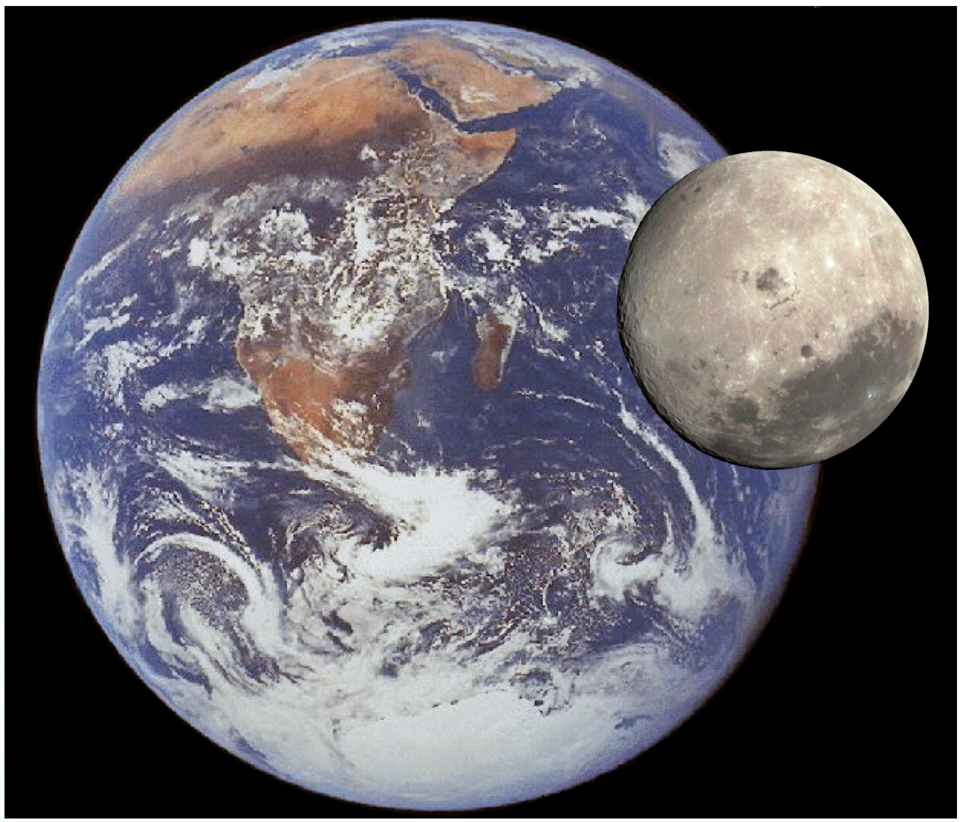
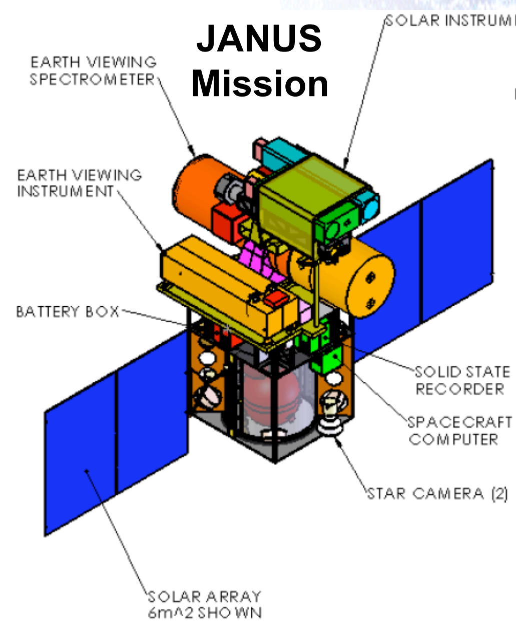
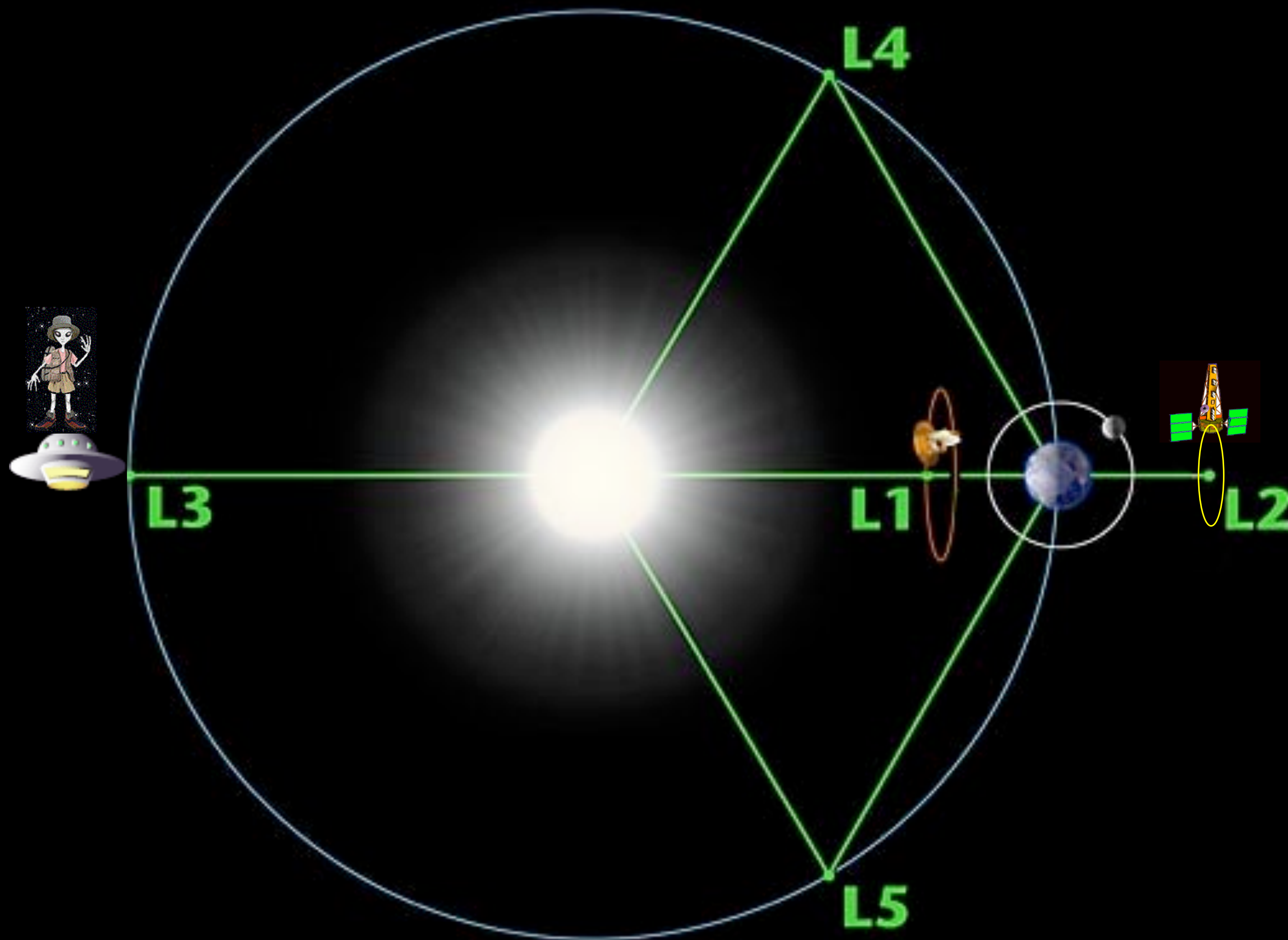
& Advanced Tech

Staff

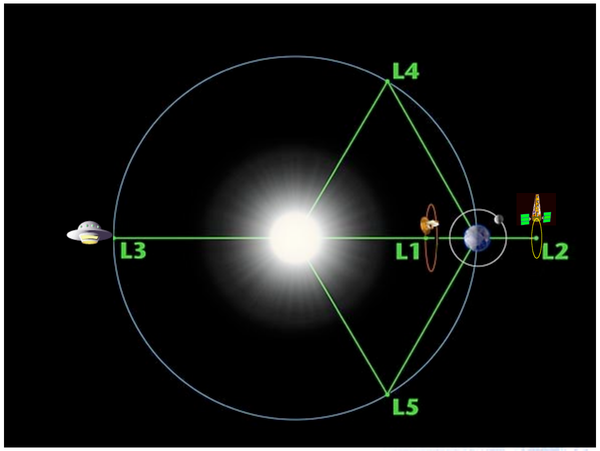




Earth-Sun Libration Points



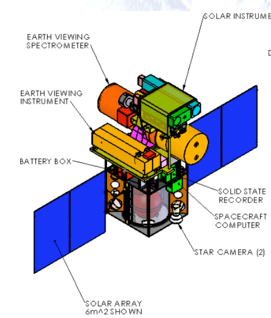
What so special about L1?



1. Continuously View the Daylight Earth with 3 to 6 km spatial resolution from ±70° latitude and a range of ±85° longitude. See over the poles every 6 months.
2. Nearly constant scattering and reflection angle that is just outside the "hot-spot" view angles.
3. L1 is the only viewpoint where frequent synoptic measurements are possible from sunrise to sunset.
4. Lots of constant solar power
5. Constant spacecraft thermal environment.
6. Usually, a benign radiation environment, except during solar flares.
7. The mission cost is the same as a single equivalent geostationary mission.
8. Trivial de-orbit concerns at the end of mission.
9. Good location to spectrally image other planets (Mars to Saturn) as well as the Moon.

More Advantages of a Lagrange Viewpoint for Earth Observations

1. View of the entire Earth from a single satellite.
2. Moderate resolution (~2-4 km) and high SNR (>500:1)
3. From L-1and L-2, the view is synoptic from sunrise to sunset and over a wide range of latitudes.
4. It would take 4 to 5 geostationary satellites for the equivalent coverage. These are not synoptic, they are 5 to 6 hours UT apart.
5. Since the entire Earth subtends only 0.5^{o}, optical design is simplified for the sunlit view from L-1.
6. Launch costs are similar to that for geostationary satellites, since cost is driven by energy required to orbit.
7. Simultaneous Sun-Earth Observations (JANUS)
8. Solar Wind & Solar Storm Observations
9. <u>All</u> LEO satellites are always in daytime view



Disadvantages of a Lagrange Viewpoint for Earth Observations

1. The major disadvantage is the $1.5x10^6$ km distance of either L-1 or L-2 from the Earth.
2. From L-1, the Sun causes communication problems when near the Earth-Sun line
3. Large on-board data storage and one or more Ka-band high-speed ground stations are required.
4. To achieve reasonable spatial resolution (2-4 km) requires moderate to large apertures (~0.5 to 0.75 m).
5. Good spatial resolution implies the need for good pointing accuracy and active image stabilization.
6. Spatial resolution is limited (~2 km) by spacecraft jitter, the Earth's rotation (~0.5 km/sec), exposure time, and aperture size.

Geostationary: Advantages and Disadvantages

Advantages vs L-1

1. Better spatial resolution possible
2. Easier Communications
3. Night and day views

Disadvantages vs L-1

1. 4 to 5 satellites for full Earth coverage
2. Cost ~ $2 billion
3. No polar views (Lat < 70°)
4. More complex optical design
5. Poor thermal environment
6. Requires Large Battery
7. Higher radiation levels
8. Larger View Angles
9. Single equatorial location for nadir view

Commonality

Both L-1 and each Geo obtain synoptic data

Both L-1 and Geo can use longer integration times for enhanced SNR

Both L-1 and Geo use equally expensive launch vehicles

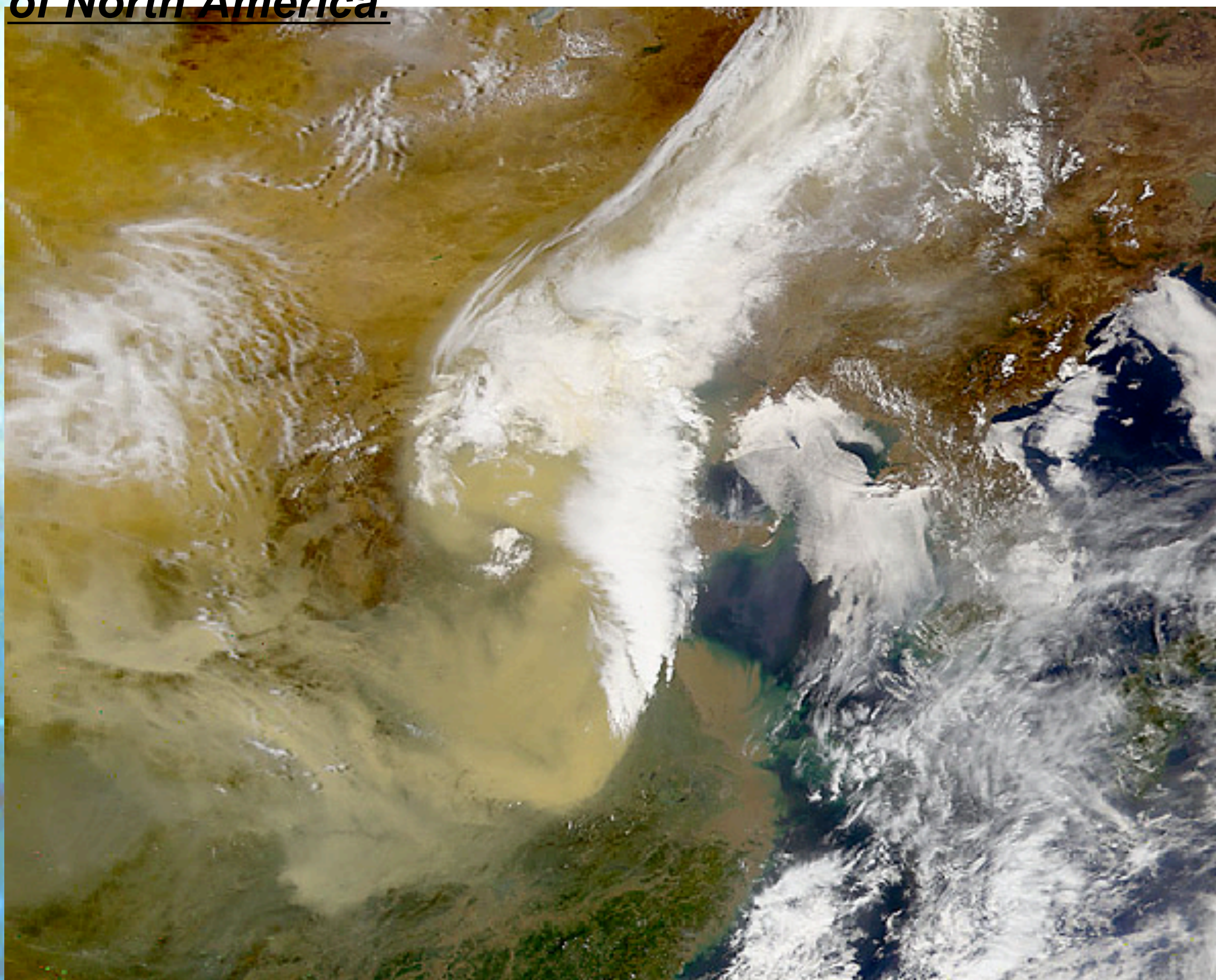
Early Visible Wavelength Aerosol Observations

*H.M.S Beagle
With dust cloud
from Africa*

"The wind had been for twenty-four hours previously E.N.E., and hence, from the position of the ship, the dust probably came from the coast of Africa. The atmosphere was so hazy that the visible horizon was only one mile distant."

Charles Darwin, 1845

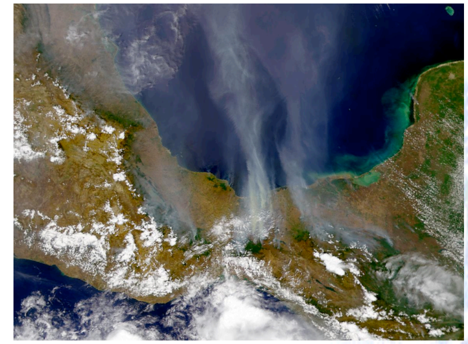
A large dust storm in China and its interaction with a meteorological system that carried the dust far out into the Pacific Ocean. On April 16, 1998, the bright yellowish-brown cloud near the coast is the center of the storm, being pushed by a frontal system. On April 25, dust from this event reached the West Coast of North America.



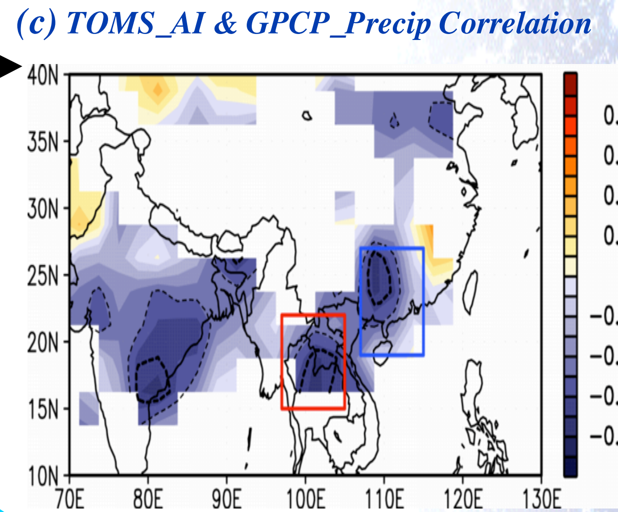
Early Observations

H.M.S Beagle
1845

Detection of Aerosols is easy →



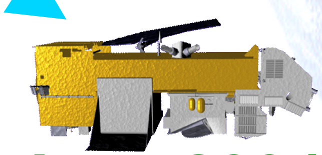
Quantification of Cloud, Pollution, and Aerosol effects on Climate, UV, and Health is a challenge that requires cross-cutting scientific research →



Cimel Sunphotometer
Brewer Spectrometer

←We need well designed programs In the laboratory, ground, and in space (LEO, GEO, and L-1).

Minimization of aerosols, pollution, and UV is essential →

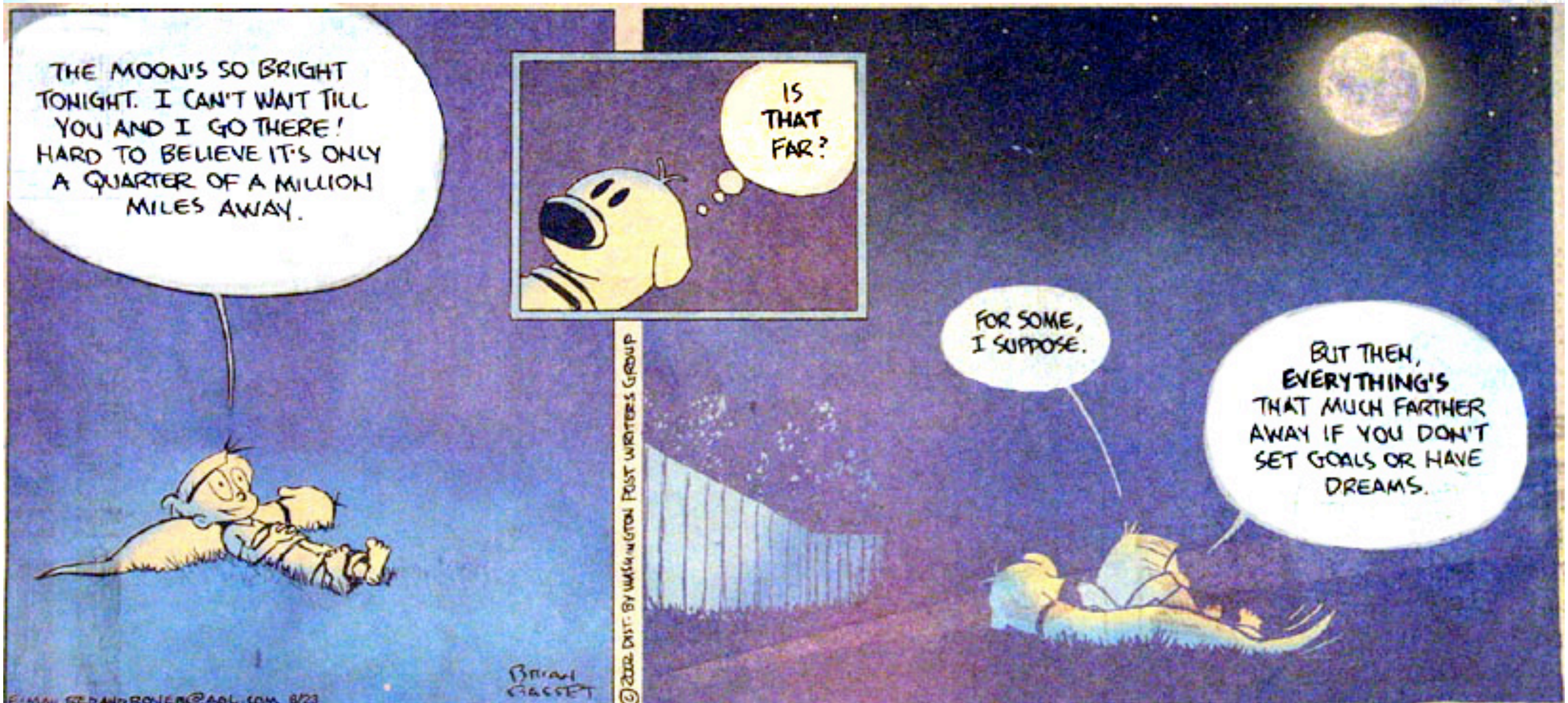


Aura 2004

Clouds, Aerosols, Pollution & Ozone have been observed from the Earth's surface and from nearby space perspectives, LEO, and to a much lesser extent, GEO

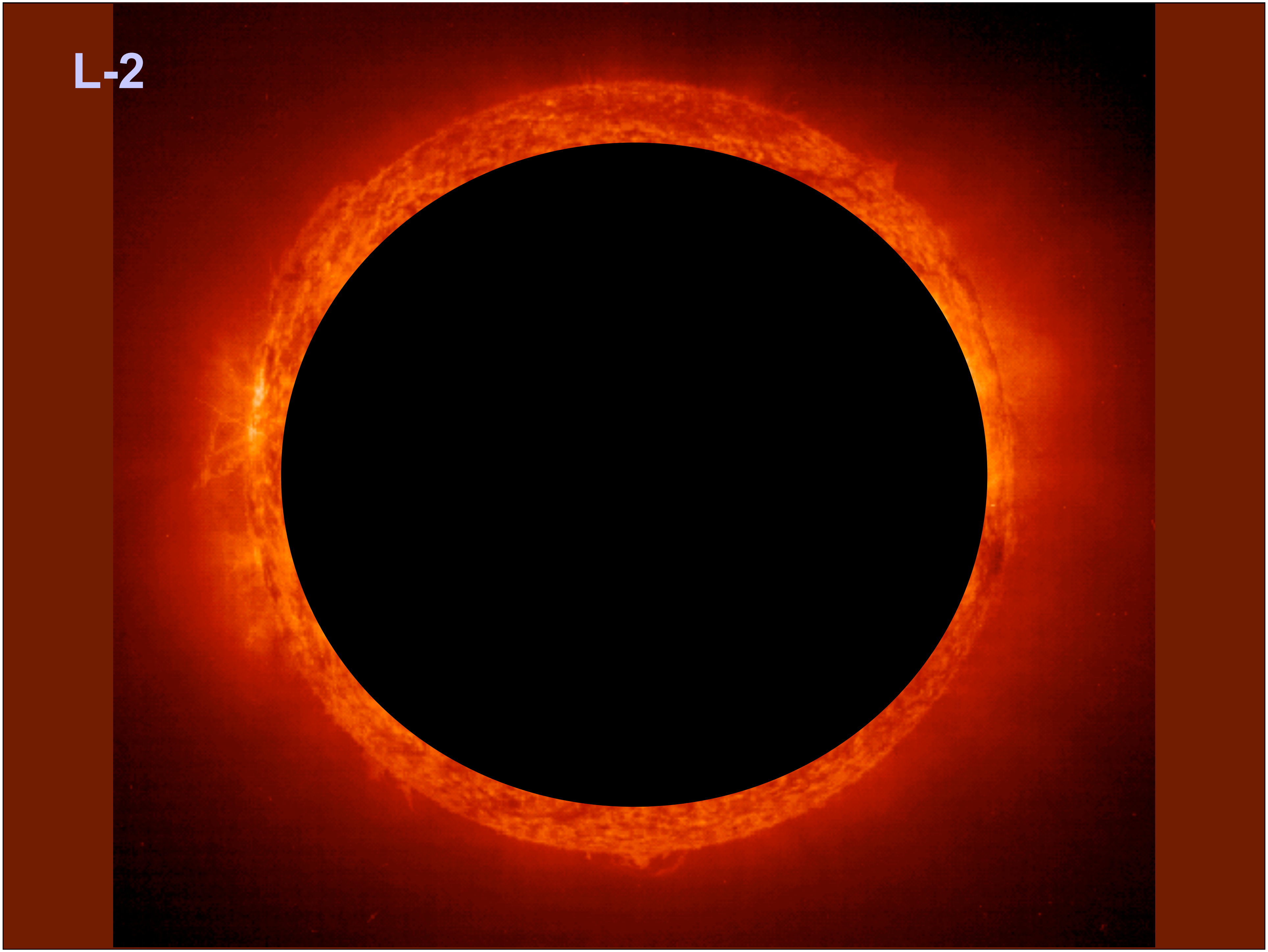
It's time to view Earth from a new perspective to obtain new information about our planet and its atmosphere that cannot be obtained from LEO

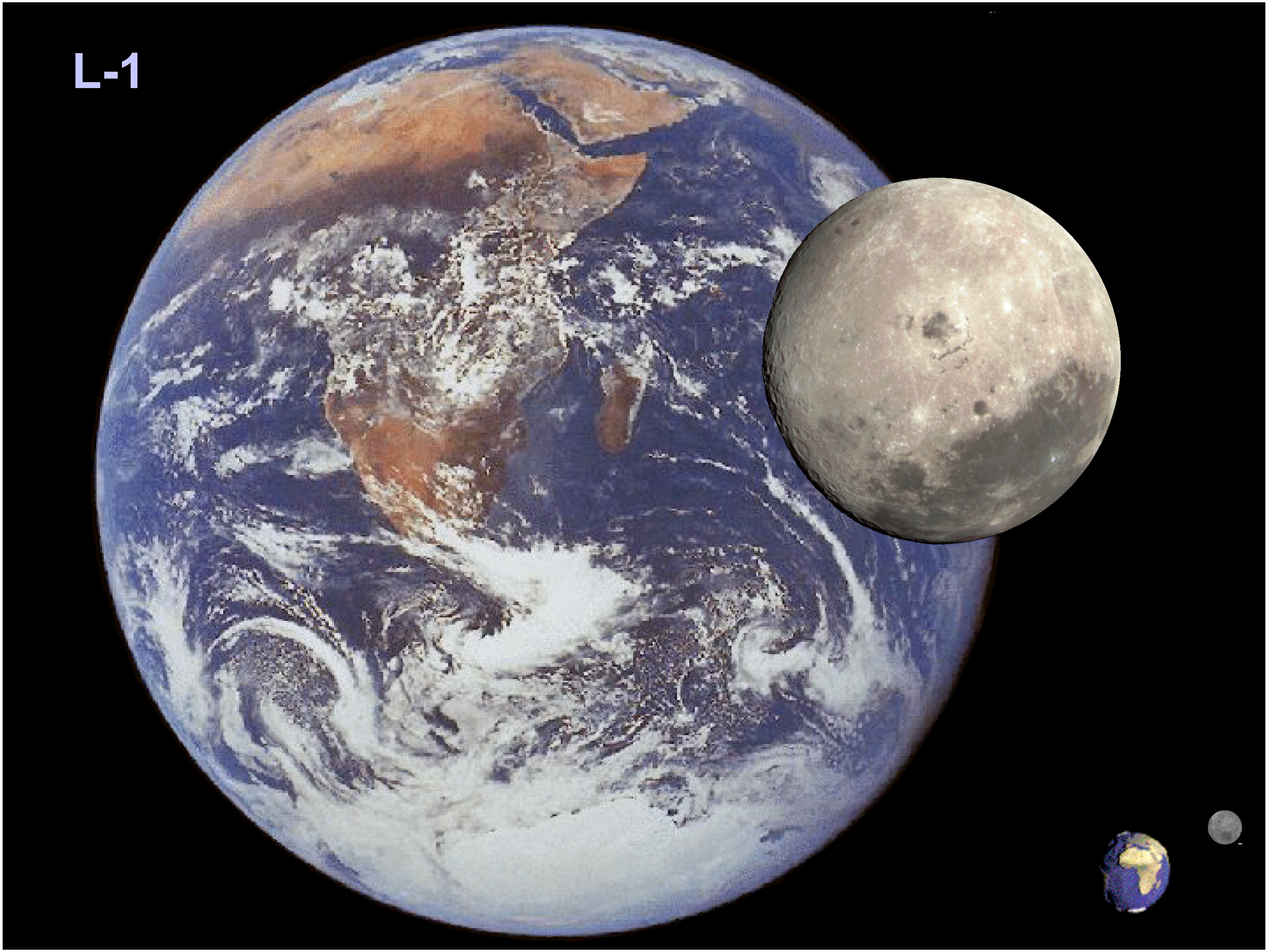
Don't Get Stuck in LEO
There is New Science with New Perspectives

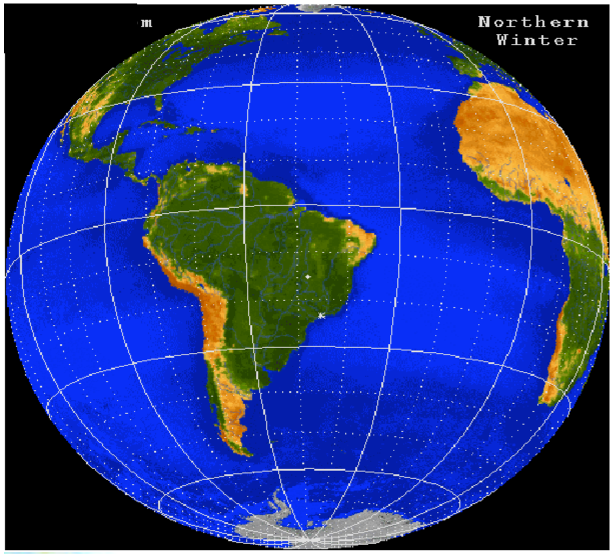


It may seem strange to go 1.5 million kilometers away from Earth in order to take close-up science data. However, the view and the science are unique.

There are other places for NASA to go
New Perspectives – Search for Life

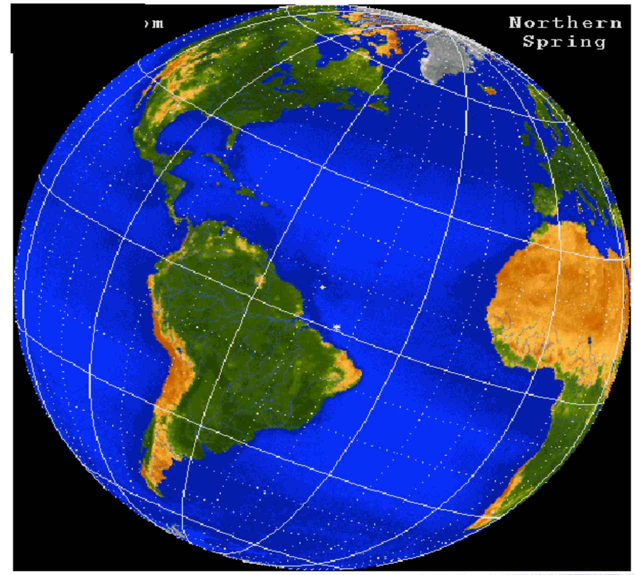

L-2


L-1

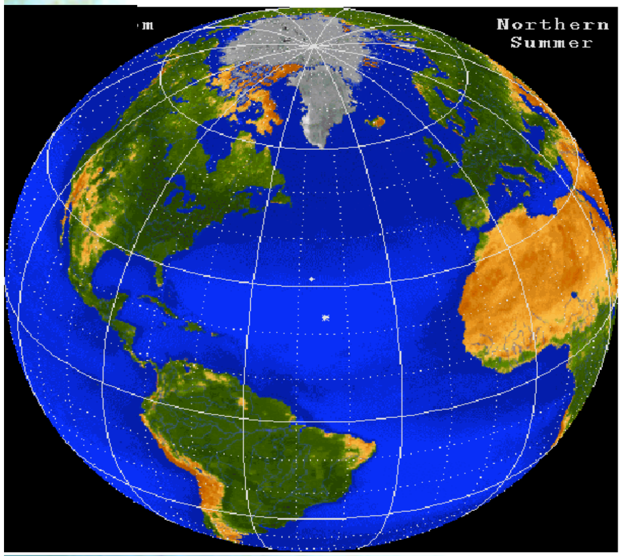


DECEMBER

MARCH

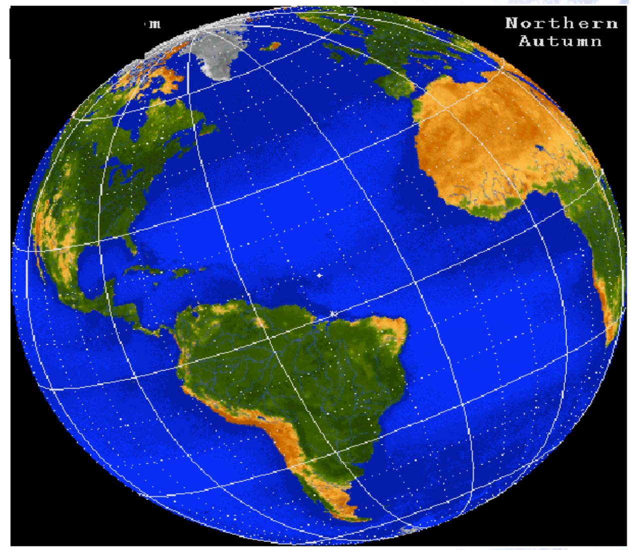


BASED ON A 4 DEGREE
LISSAJOUS ORBIT ABOUT
THE EARTH-SUN LINE



JUNE

SEPTEMBER



Views from Lagrange-1 for December, March, June, and September

NO_2 : An Example of Pollution

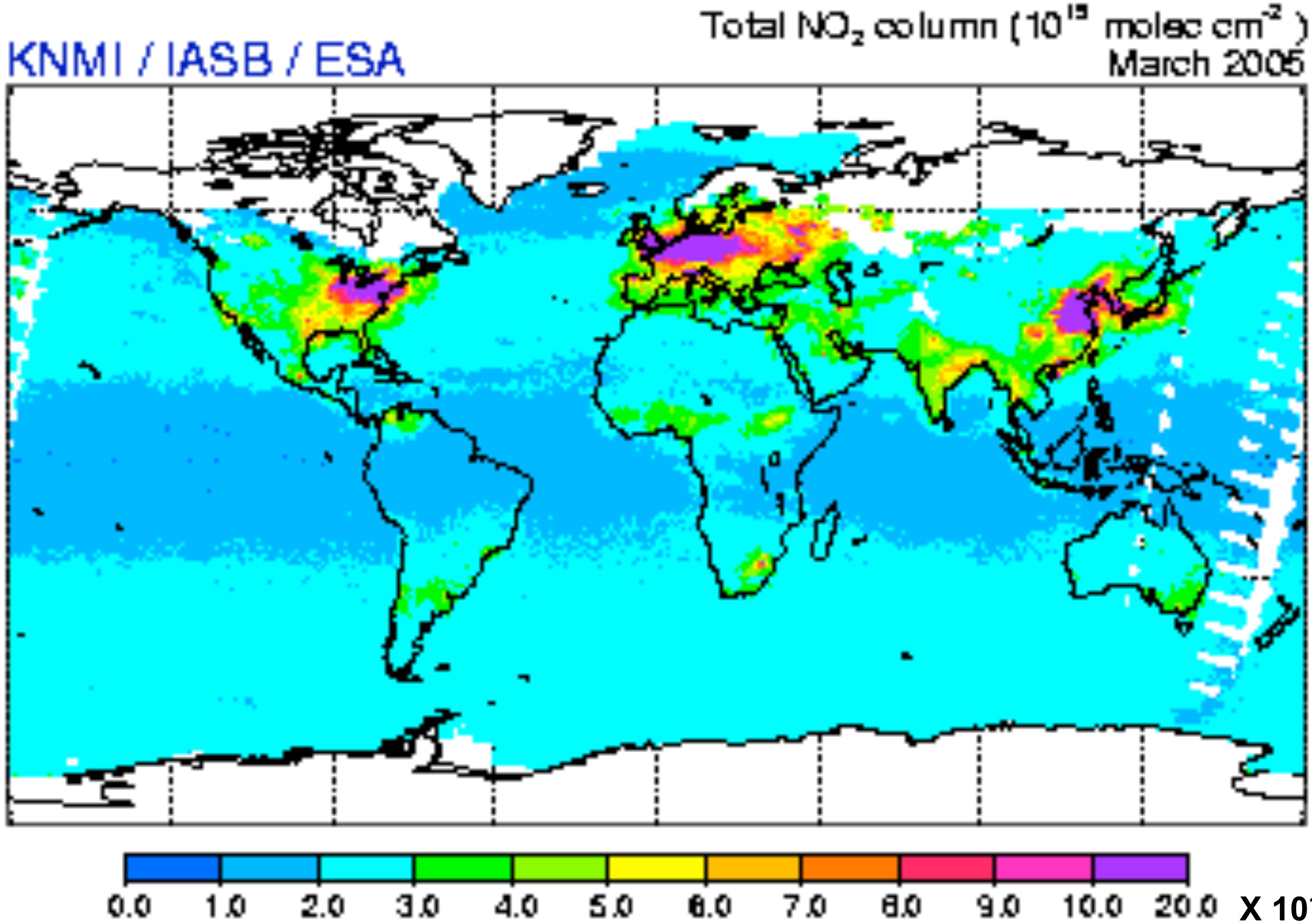
Why should we look at NO_2 from L-1 when we seem to get a good view from LEO?

50% Automobiles

25% Power Plants

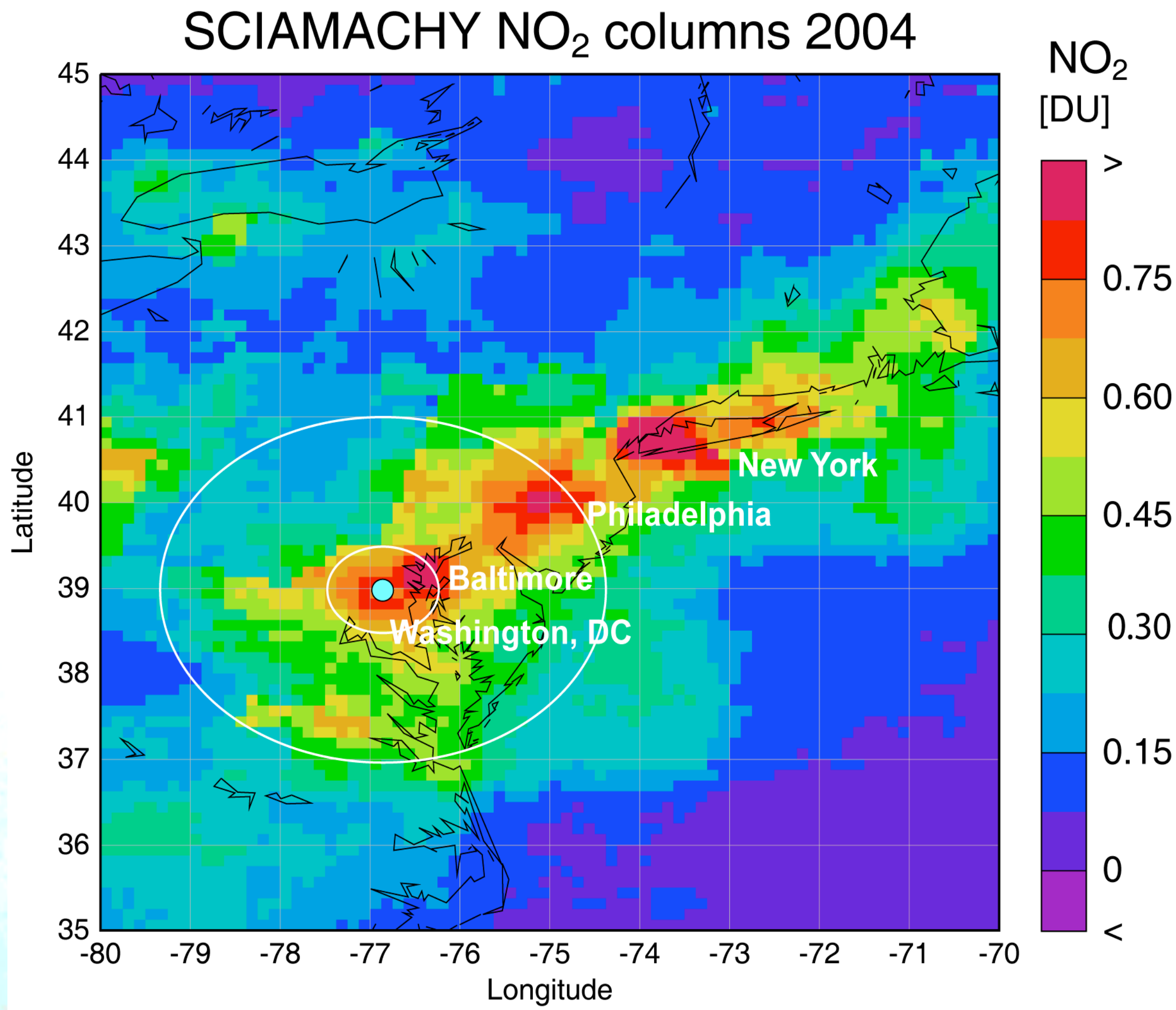
25% Ground Emissions

Global Distribution of NO_2



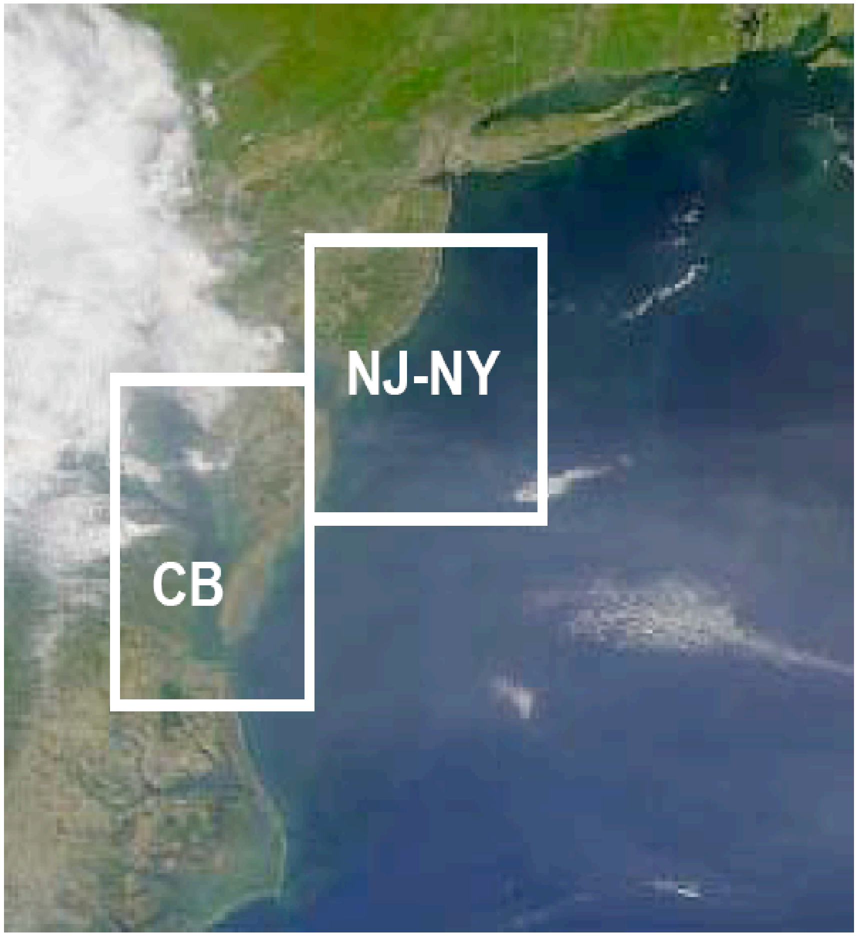
X 10^{15} cm^{-2}

Sciamachy
March 2005



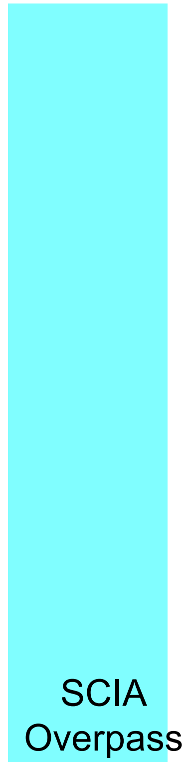
Averaged tropospheric NO_2 columns derived from SCIAMACHY measurements for 2004. The white ellipses show the 200km and 50km region around the ground-location. The NO_2 hot-spots coincide approximately with the locations of the labeled cities. 1DU $\equiv 2.7 \times 10^{16} cm^{-2}$.

Chesapeake Bay and NJ-NY near shore regions (Natural Color image, SeaWiFS).



Light semitransparent plume off of the US east coast is a mixture of aerosols, NO_2, and clouds.

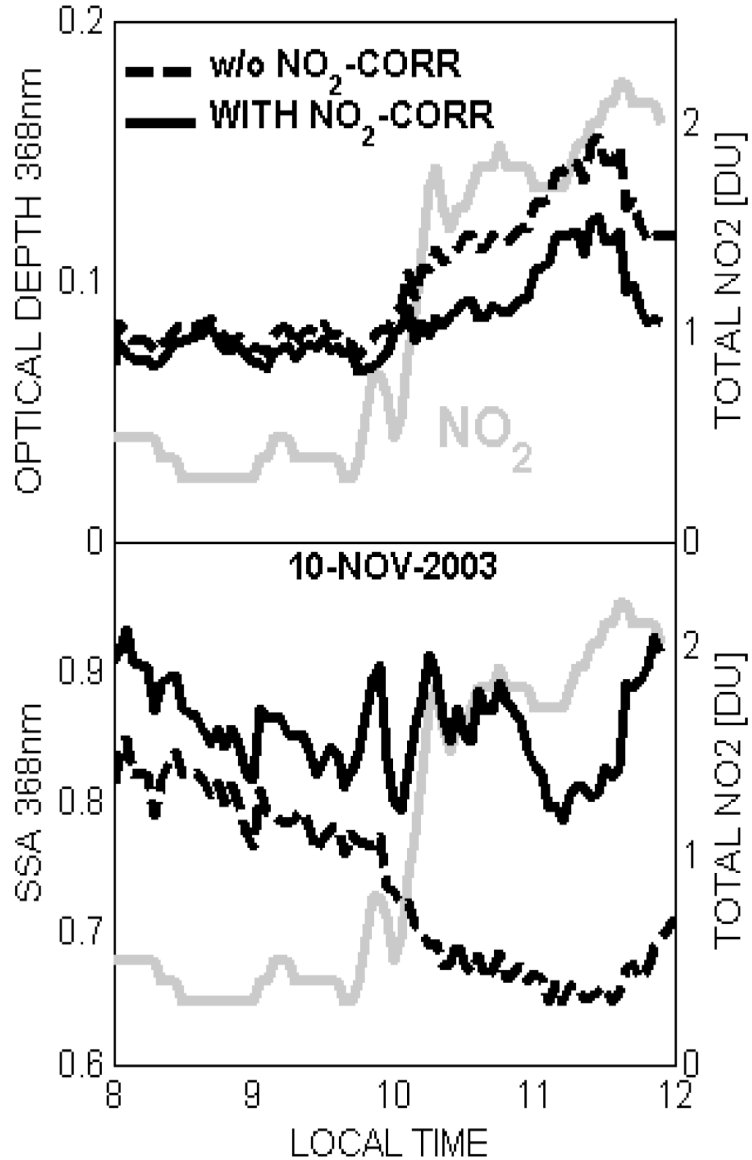
The hourly variability of NO_2 is missed by polar orbiting satellites, but is easily seen from L1



Average diurnal behavior of NO_2 total column at GSFC for meteorological seasons. Dashed black line shows the correlation coefficient between the OMI data within 25km and the Brewer data at different times of the day. Gray area indicates the OMI overpass time and the Green area indicates the Sciamachy overpass time.

The effect of neglecting NO_2 in Aerosol Retrieval

Total NO_2 measurements (gray line), retrieved aerosol optical depth (black lines upper panel) and single scattering albedo (black lines lower panel) at 368nm from a UV-MFRSR on 10 November 2003 without (dashed lines) and with (solid lines) NO_2 correction.

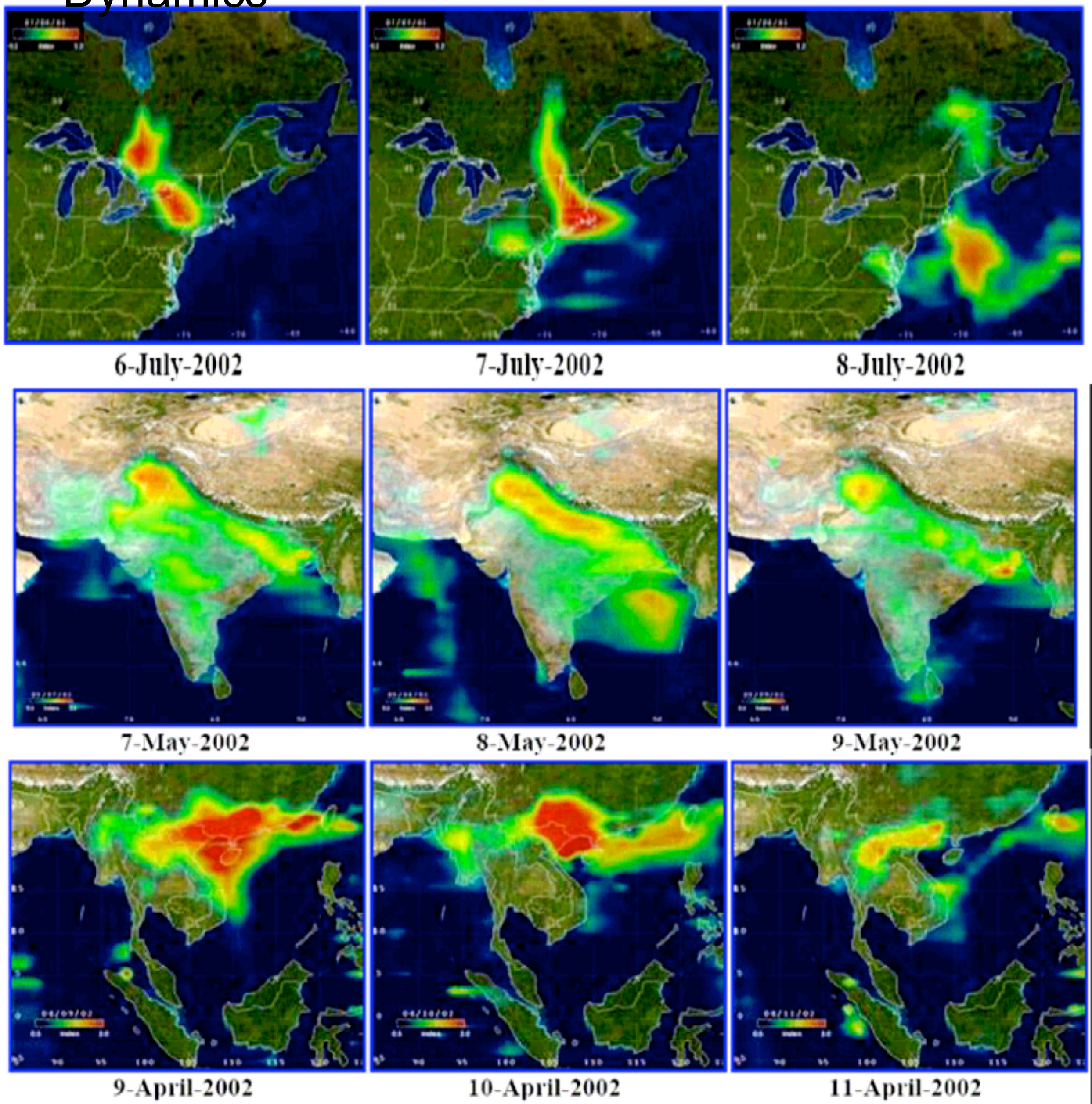


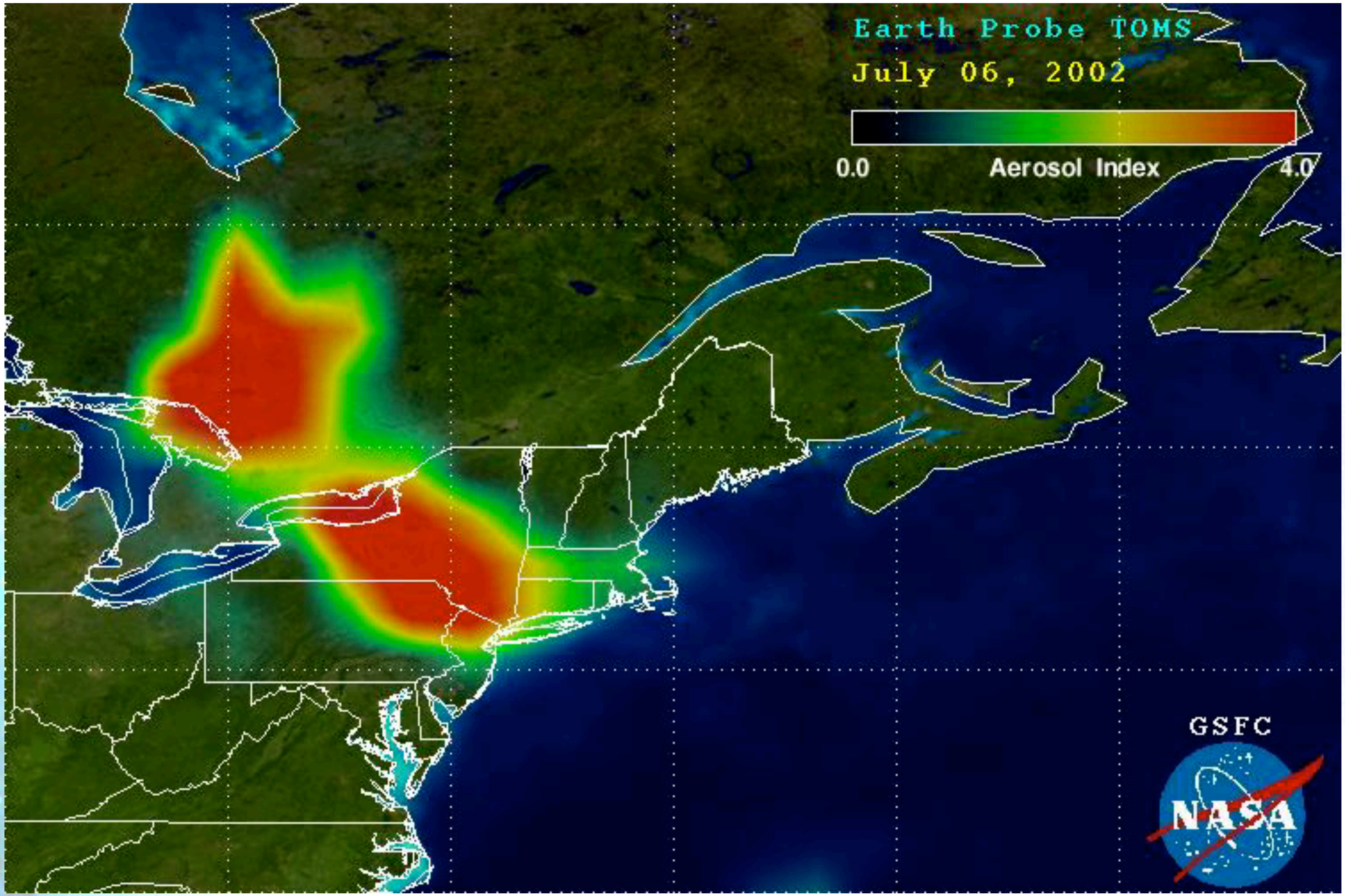
The reason for going to L-1 to view NO_2, other pollutants, and aerosols is for the unique global and synoptic view of time-dependent processes.

GCM models of the Earth’s atmosphere always use a synoptic time scale.

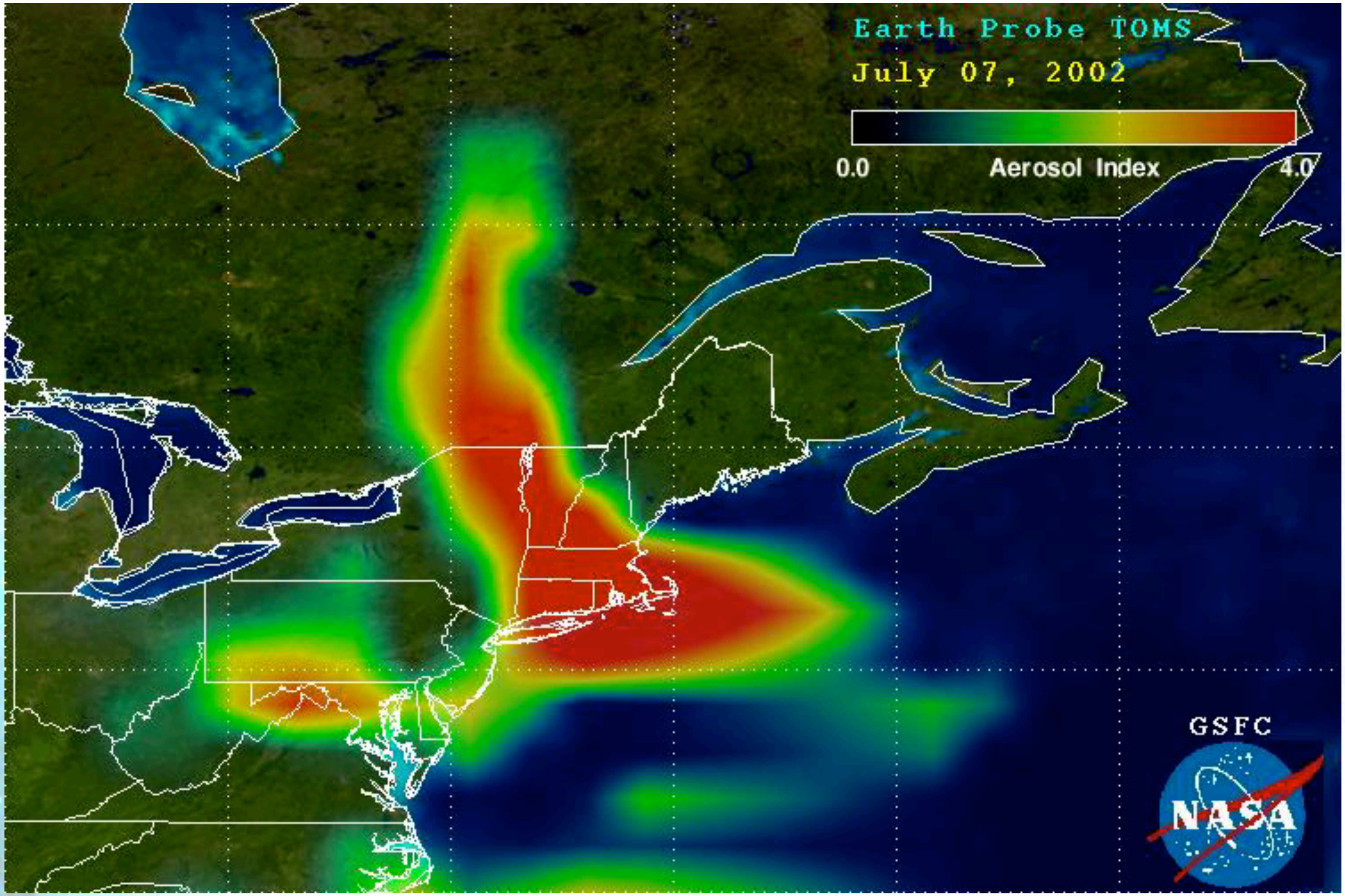
L-1 is the only location that can provide the global synoptic data at least once every 30 minutes needed for process studies and model input and validation.

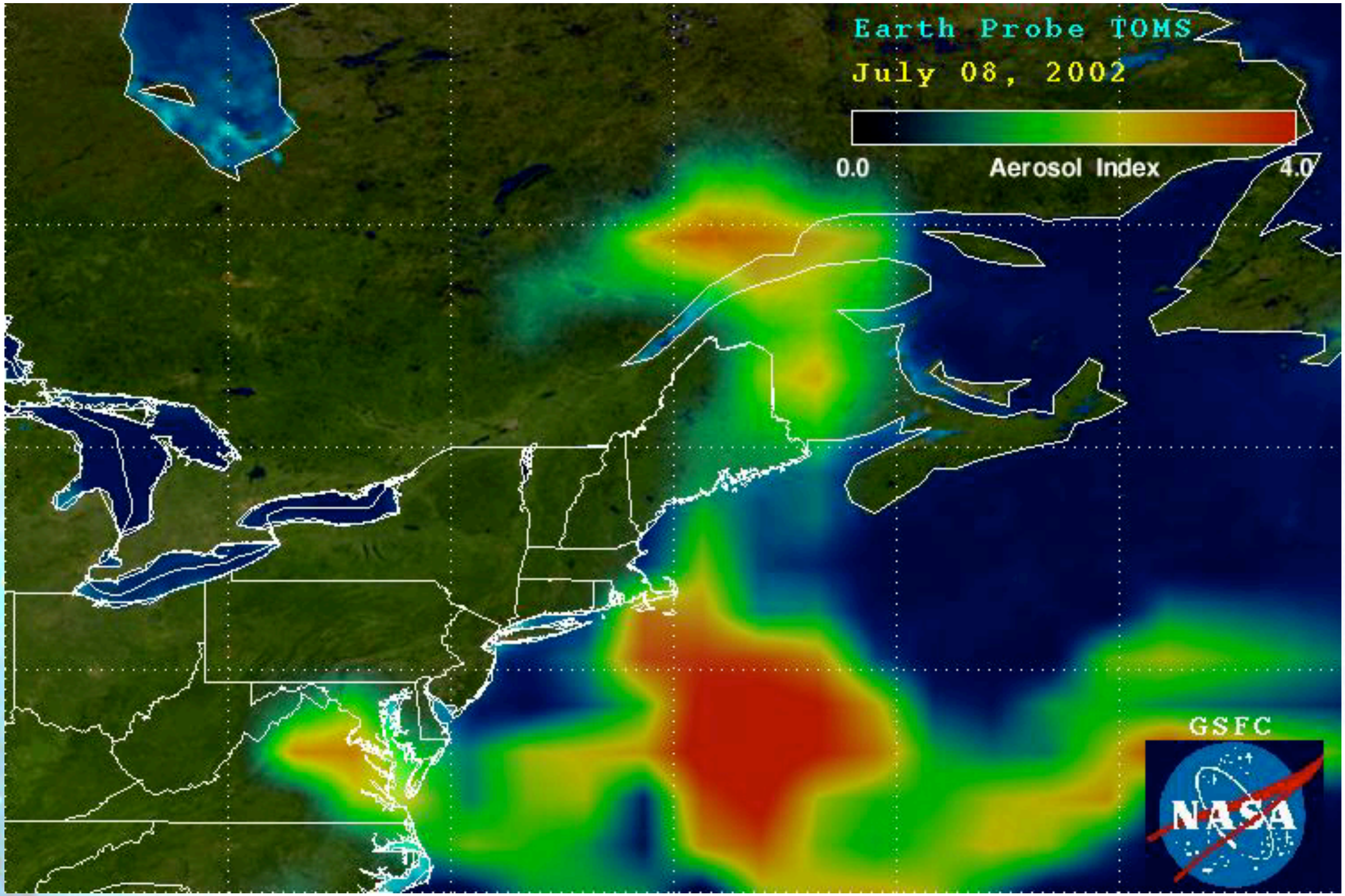
Aerosols: A Tracer of Boundary Layer Dynamics





Earth Probe TOMS
July 06, 2002
0.0
Aerosol Index
4.0
GSFC


Earth Probe TOMS
July 07, 2002
0.0
Aerosol Index
4.0
GSFC
NASA


Earth Probe TOMS
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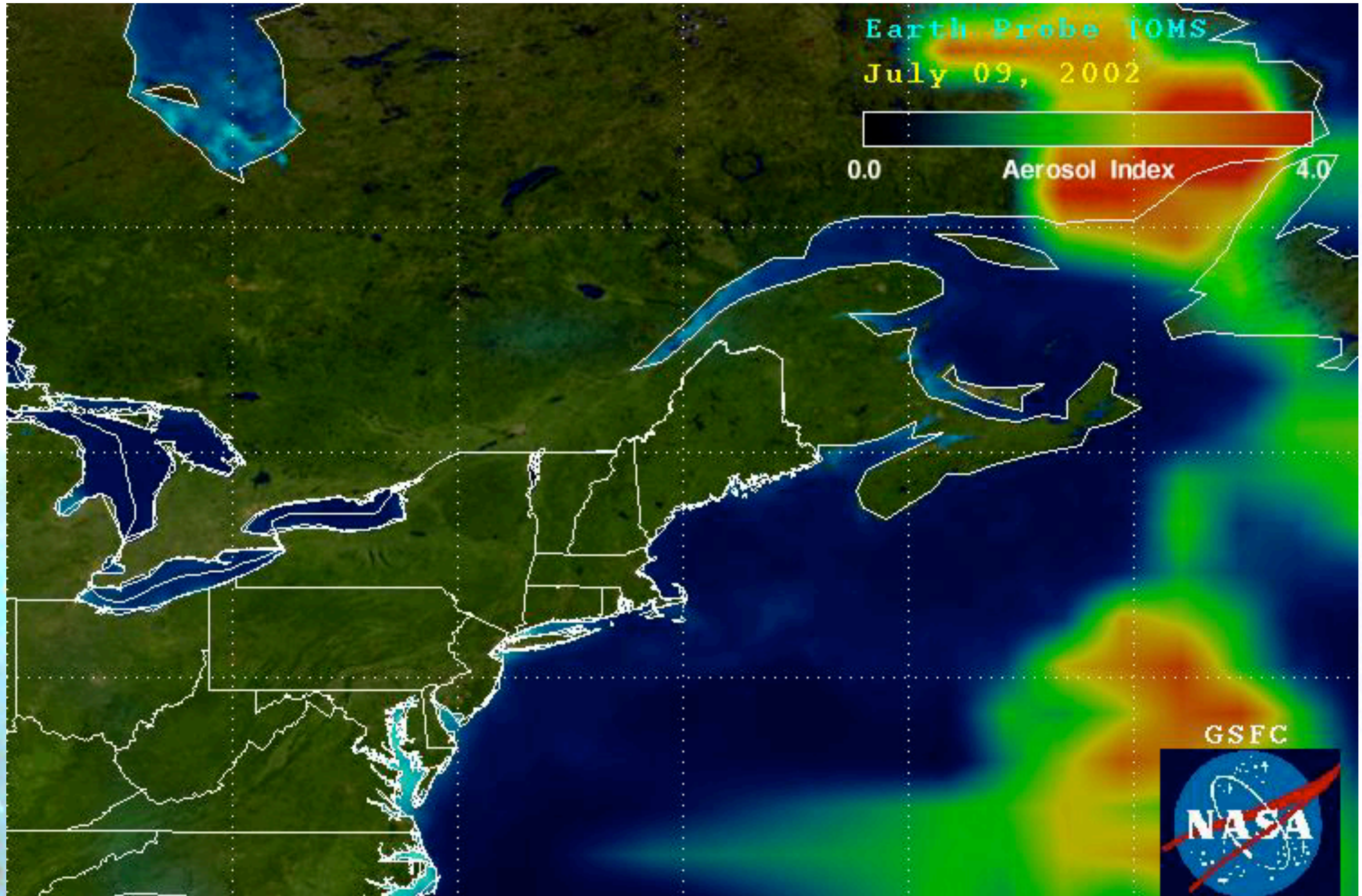
0.0
Aerosol Index
4.0
GSFC
NASA


Earth Probe TOMS
July 09, 2002
0.0
Aerosol Index
4.0
GSFC
NASA

Janus: Exploration of the Earth-Sun System from L-1

Earth: Global Composition Surface to the Mesosphere

Solar: CME, EUV and X-ray Spectrum, Solar Wind

J. Herman (GSFC) J. Davila (GSFC) C. Korendyke (NRL) Daniel Jacob (Harvard)

Earth Viewing Spectrometers
FUV, EUV, UV-VIS
NIR (Multiple Focal Planes)

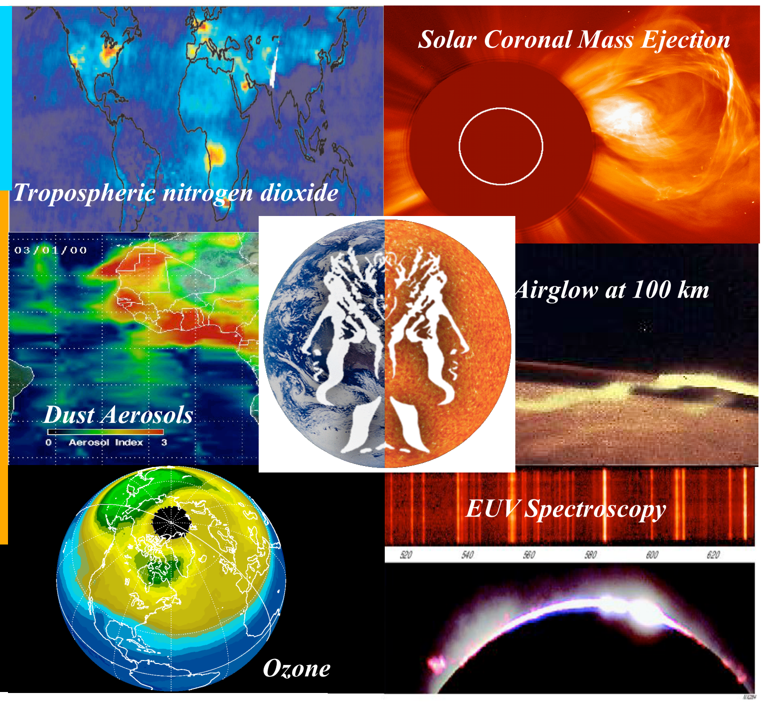
Sun Viewing Package:

Solar Coronagraph (Vis)

Solar EUV Spectrometer

Soft X-Ray Spectrometer

Solar Wind Package
Mag. Field + Particles

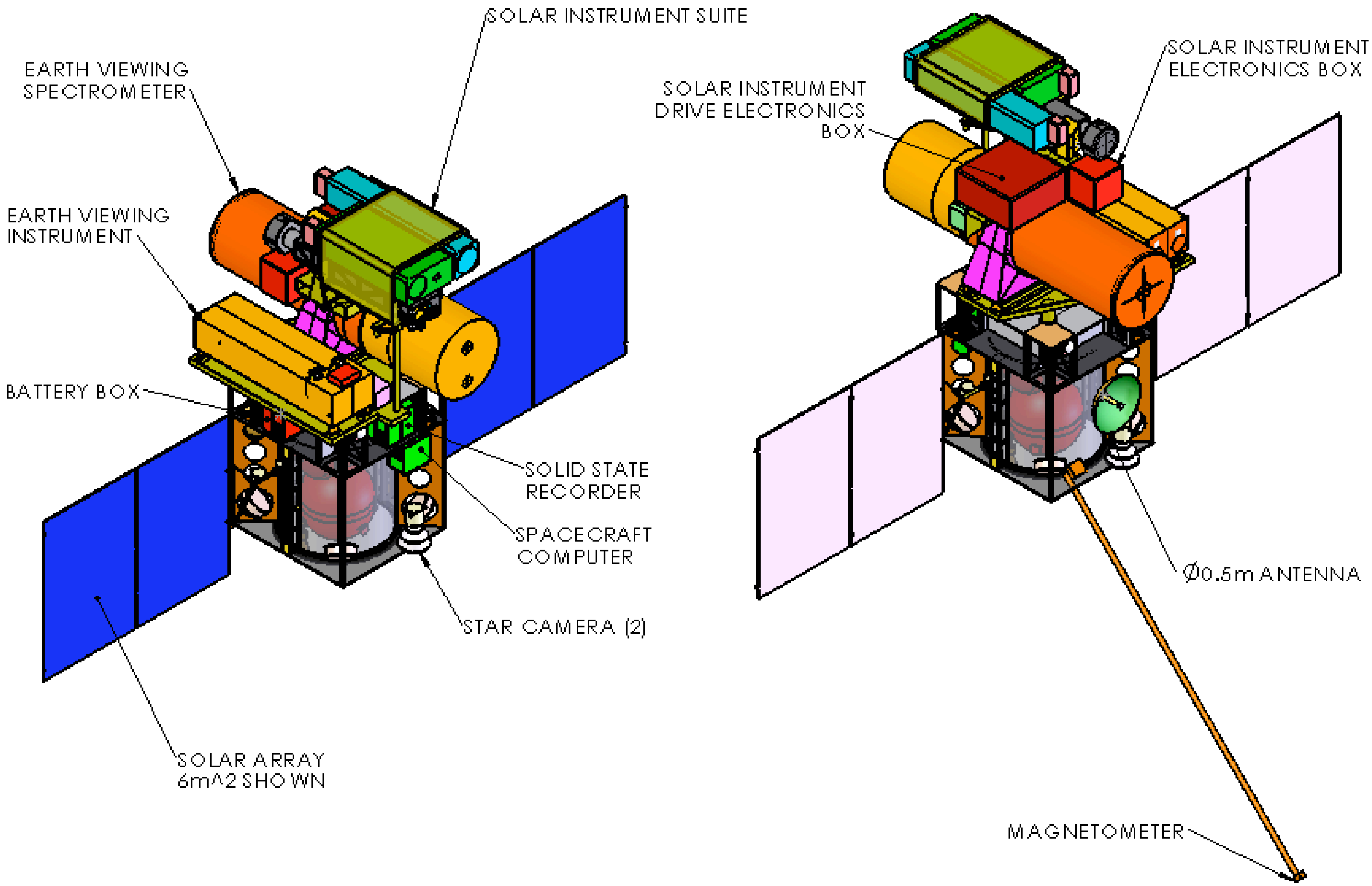


Comprehensive measurements of the Earth, Sun, and Solar Wind to explore the relationship between the Earth's atmospheric changes and solar activity.

An L-1 Mission is on the Earth-Science and Solar Physics Roadmaps

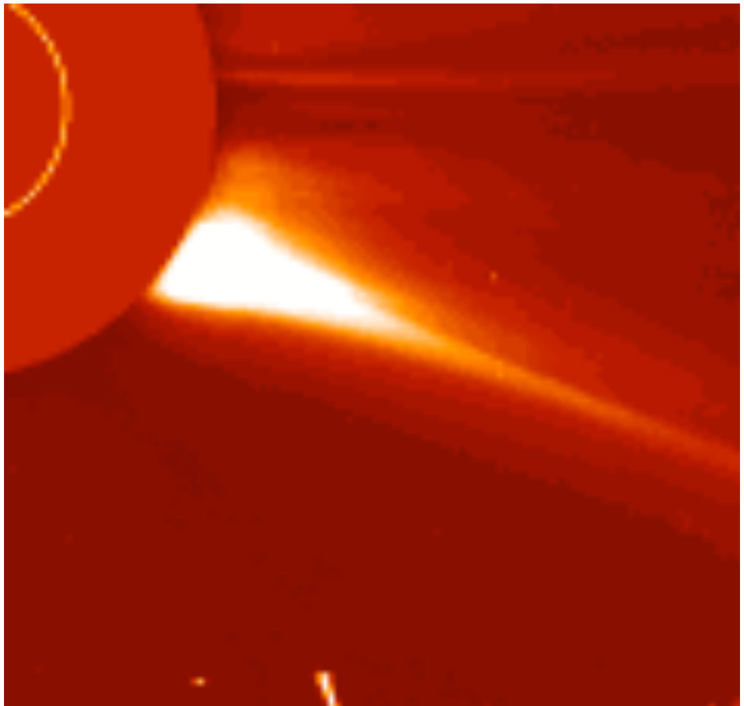
Component Layout

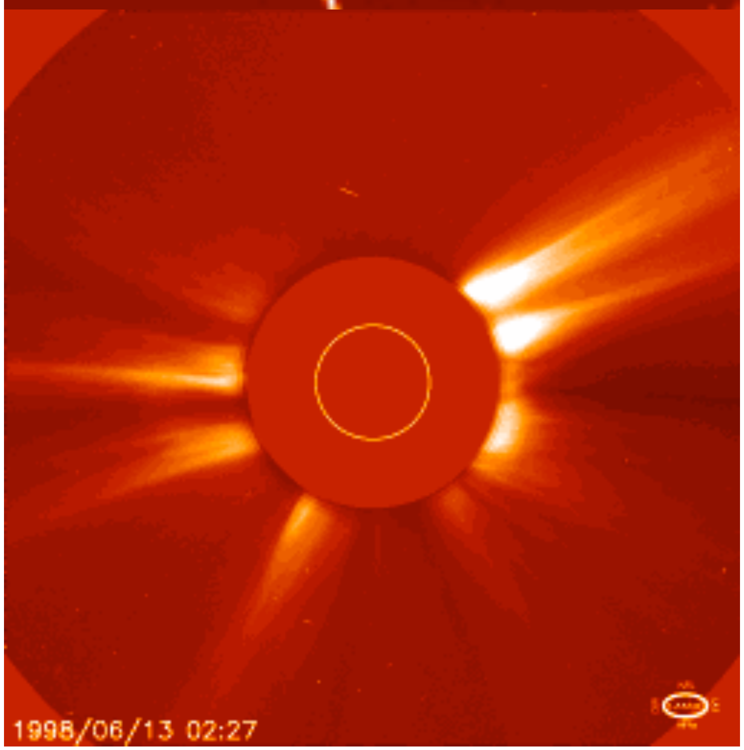
Integrated Mission Design Center



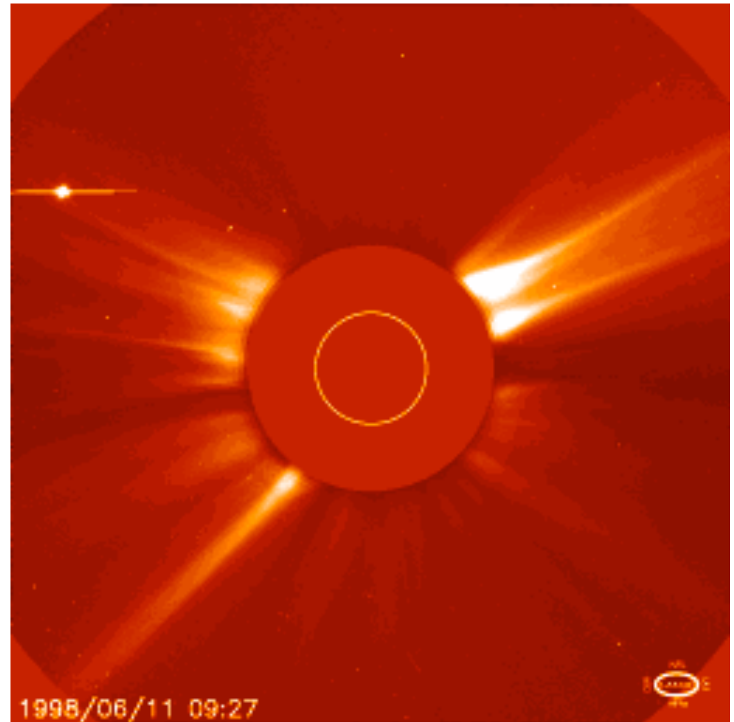
Janus Science Objectives

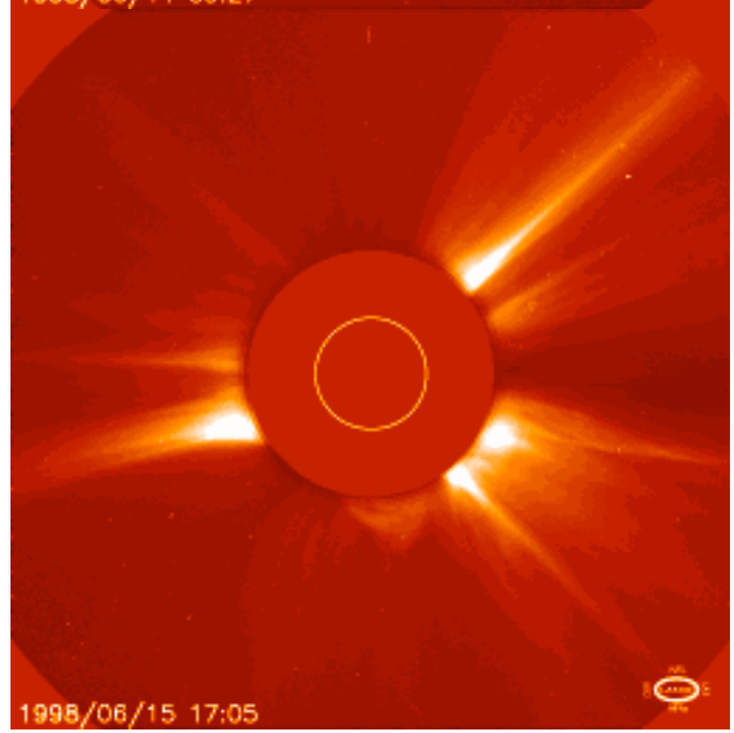
- **Understand the relationship between solar activity and the structure and dynamics of Earth's atmosphere from the surface to the thermosphere-ionosphere for a range of seasons, solar radiation and energetic particle inputs.**
- **Understand the role of plasma dynamics in coronal heating, solar wind acceleration, flares and transients, and UV irradiance variations.**
- **Understand the role of transport and source distribution using high-resolution synoptic mapping of environmentally important species, tracking of pollution plumes, and ozone layer dynamics with the input to GCM chemistry models.**
- **Provide real-time space weather data for predictive modeling of the space environment and Earth's upper atmosphere.**
- **Provide solar storm data for the purpose of protecting satellite communication, astronaut safety, ground power distribution assets.**





Solar Flares Duration ~ 3 hours





Janus Key Science Capabilities

Earth-Viewing
Synoptic Global Maps

(Stratosphere/Troposphere)
O_3 Column O_3 Profile
SO_2 NO_2, HCHO, BrO col
Aerosol optical depth
and absorption
H_2O, Cloud Height
CO_2, CO, CH_4 column

(Ionosphere/Mesosphere)
NO, O, O^+, He, H_2
O/N_2

Connection of observed motions and composition to solar activity using comprehensive GCM-chemistry models

Solar Viewing

- Address physical processes driving soft x-ray and EUV irradiance variations and large scale solar energetic phenomenon (CMEs and flares). Quantify the role of plasma flows to reveal the fundamental physics of energy and mass transport in the solar corona.
- Measure soft x-rays as the source for ionizing radiation that plays a critical role in the Nitrogen Oxide chemistry in the thermosphere and mesosphere.
- Image the evolving coronal streamer belt to detect coronal mass ejections that are the primary solar drivers of large, geomagnetic storms and solar energetic particle events.
- Measure solar wind properties: magnetic field and energetic particles

Janus Science Impact

Determination of the dominant physical processes within the Earth's whole atmosphere by measuring composition, energy balance and evolution of the dayside globe through many seasons and over a range of solar activity conditions. Janus will obtain the first synoptic global measurements from sunrise to sunset and from the surface to outer space concurrent with observations of the critical solar and space weather inputs that drive the upper terrestrial atmosphere.

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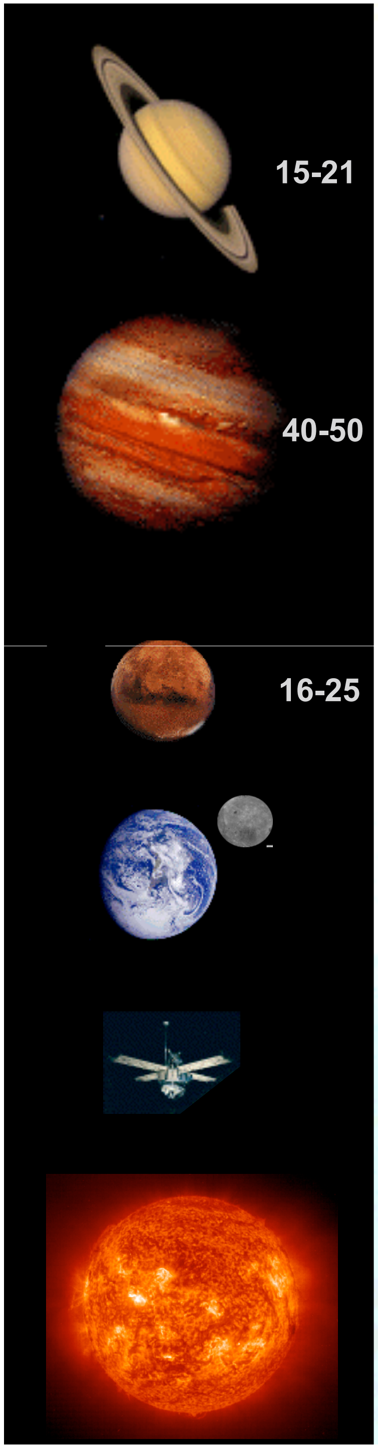
1) Earth Science Applications and Societal Need

2) Weather (including chemical weather and space weather)

3) Climate Variability and Change

4) Human Health and Security (air quality, volcanic eruptions, communications, astronaut safety, etc.)

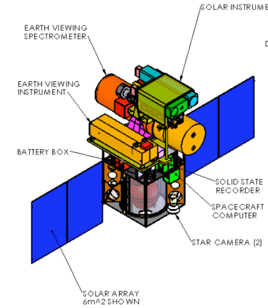
5) Replace and expand the functions of the failing SOHO and near end-of-life ACE missions



L-1 JANUS Project Status

HQ 2005 2006

Summary



L-1 Janus

1. Lagrange-1 provides the opportunity to view almost the entire Earth synoptically from sunrise to sunset with a single spacecraft at moderate spatial resolution (2 km).
2. The equivalent view from GEO would require 4 to 5 equally expensive spacecraft requiring continuous inter-calibration.
3. An L-1 spacecraft could also observe the Sun and solar wind, providing the influence of space weather on the Earth and provide astronaut safety warnings.
4. The benign L-1 environment (low radiation and constant temperature) would lead to more stable spacecraft instrument calibrations and longer life than from either GEO or LEO.
5. Secondary objectives, the Moon and outer planets (Mars, Jupiter, and Saturn) can be observed with the same instruments at moderate spatial resolution (~0.25 arc seconds)