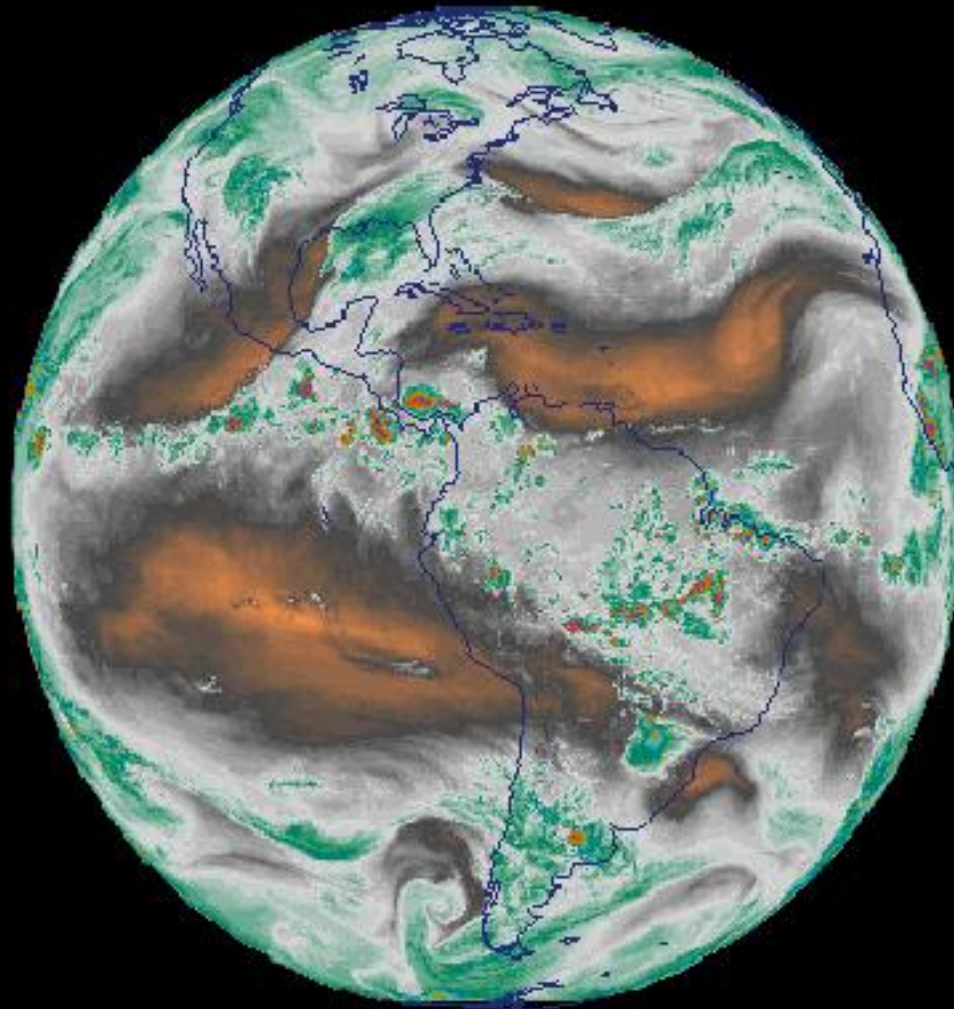


The Circulation of the Atmosphere and Oceans



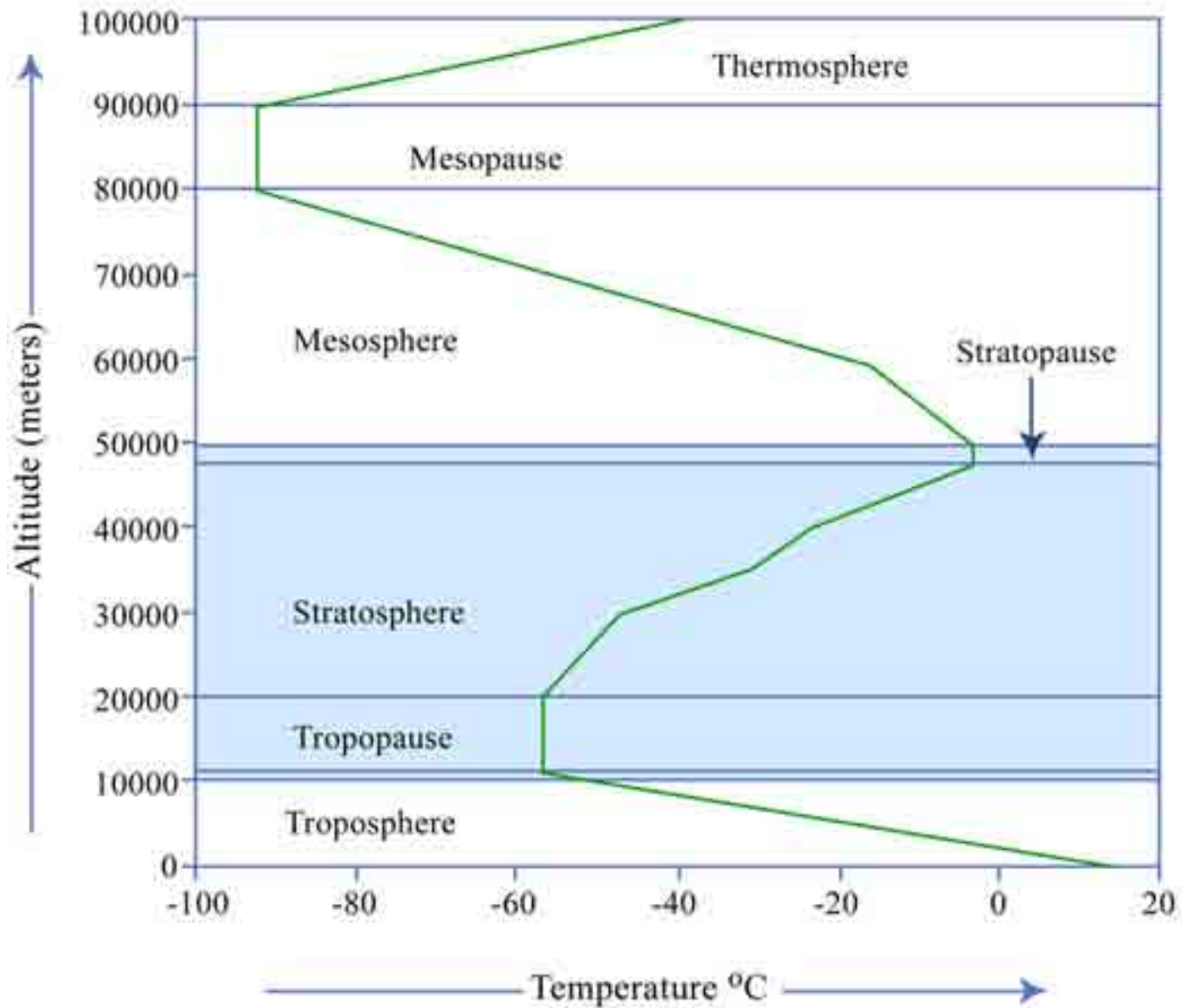


Figure by MIT OpenCourseWare.

**The Real World Environment Varies in
All Three Spatial Dimensions and Time**

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Hartmann, Dennis L. 1994. *Global physical climatology*.

San Diego: Academic Press. ISBN: 9780123285300.

Seasonal variation of solar radiation

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Sea Surface Temperature

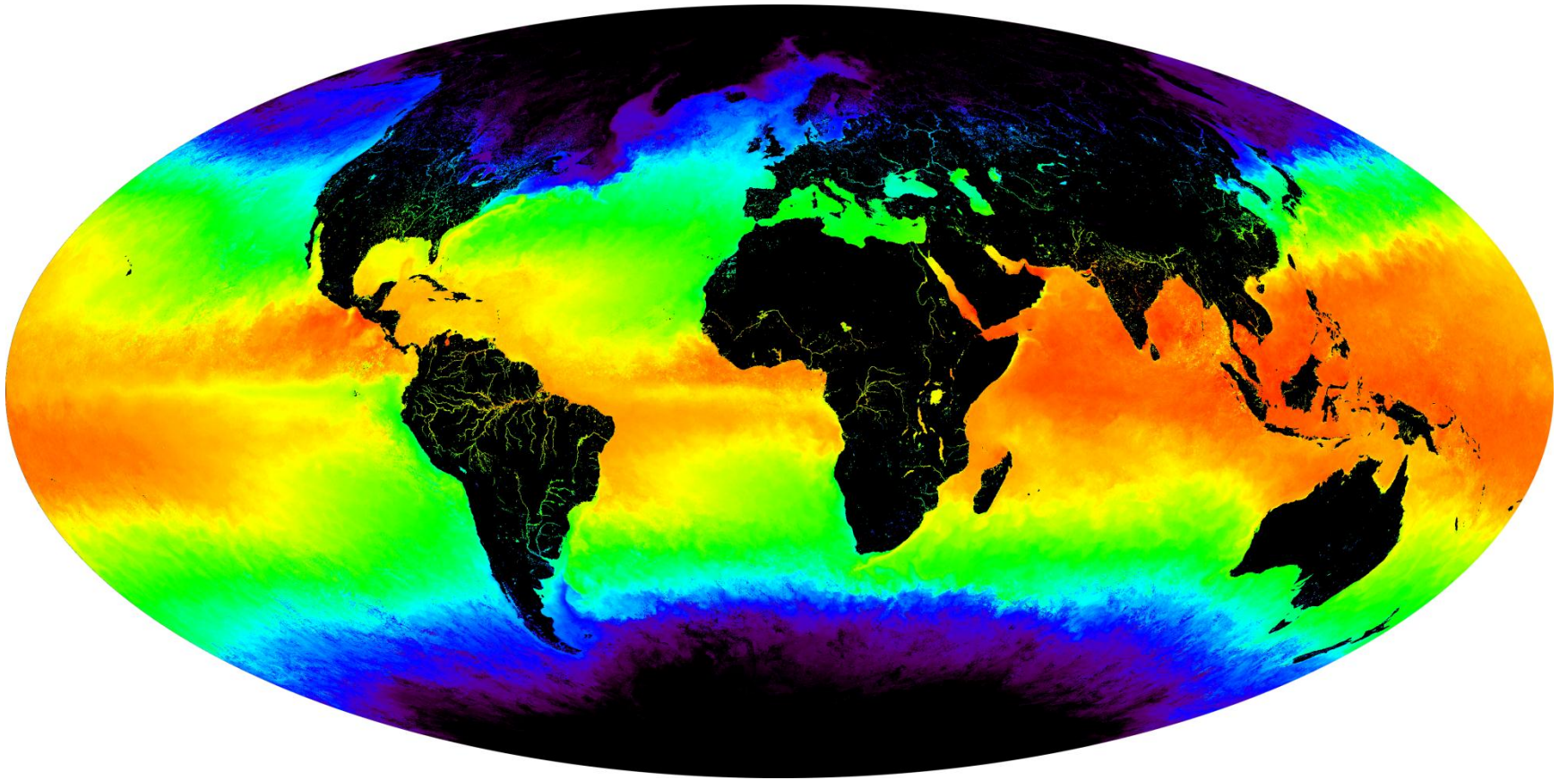


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Global average surface albedo

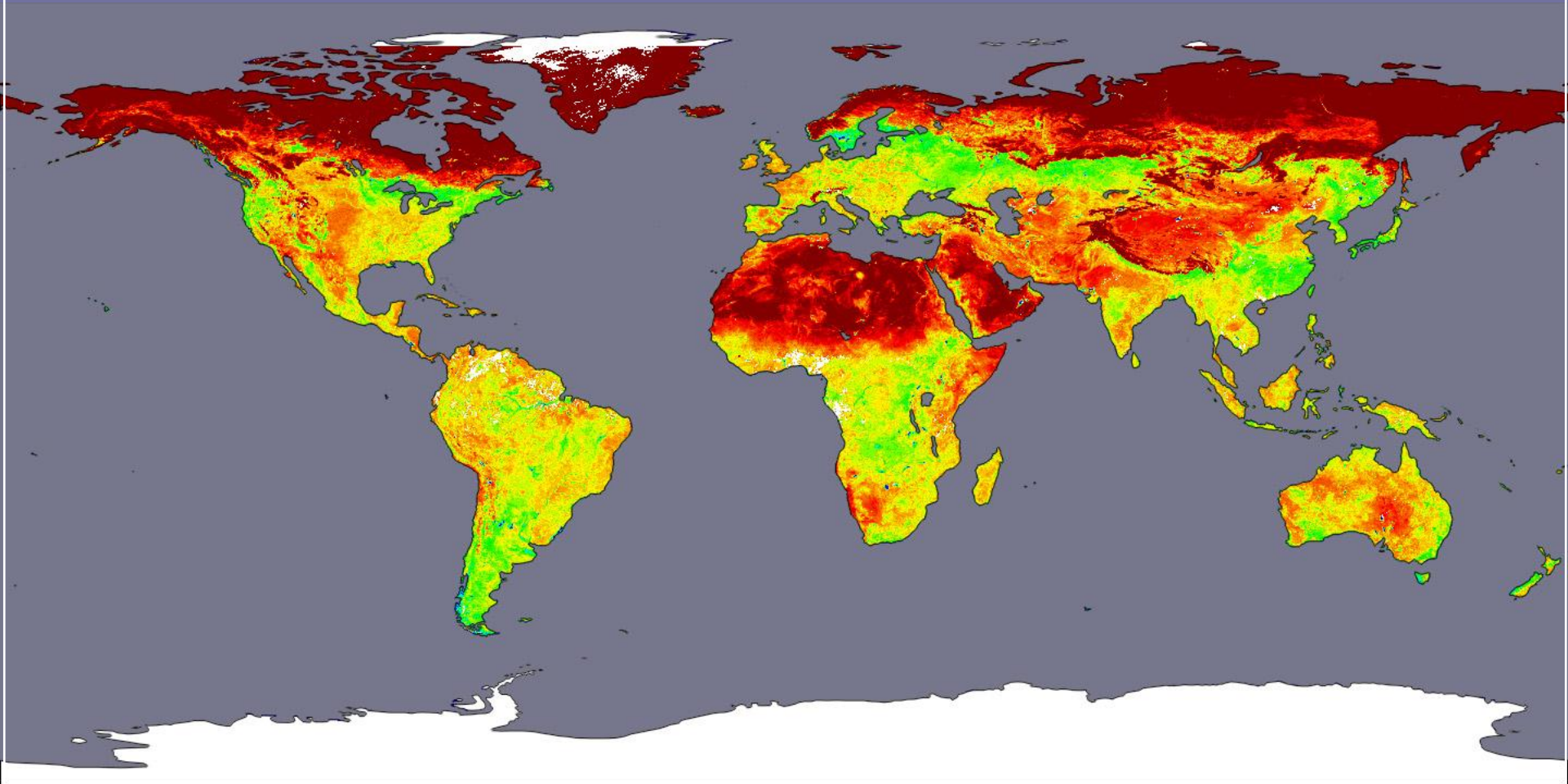


Image courtesy of NASA.

Inhomogeneity of Water Vapor

www.ghcc.nasa.gov

1 Sep 2000
19:15 UTC

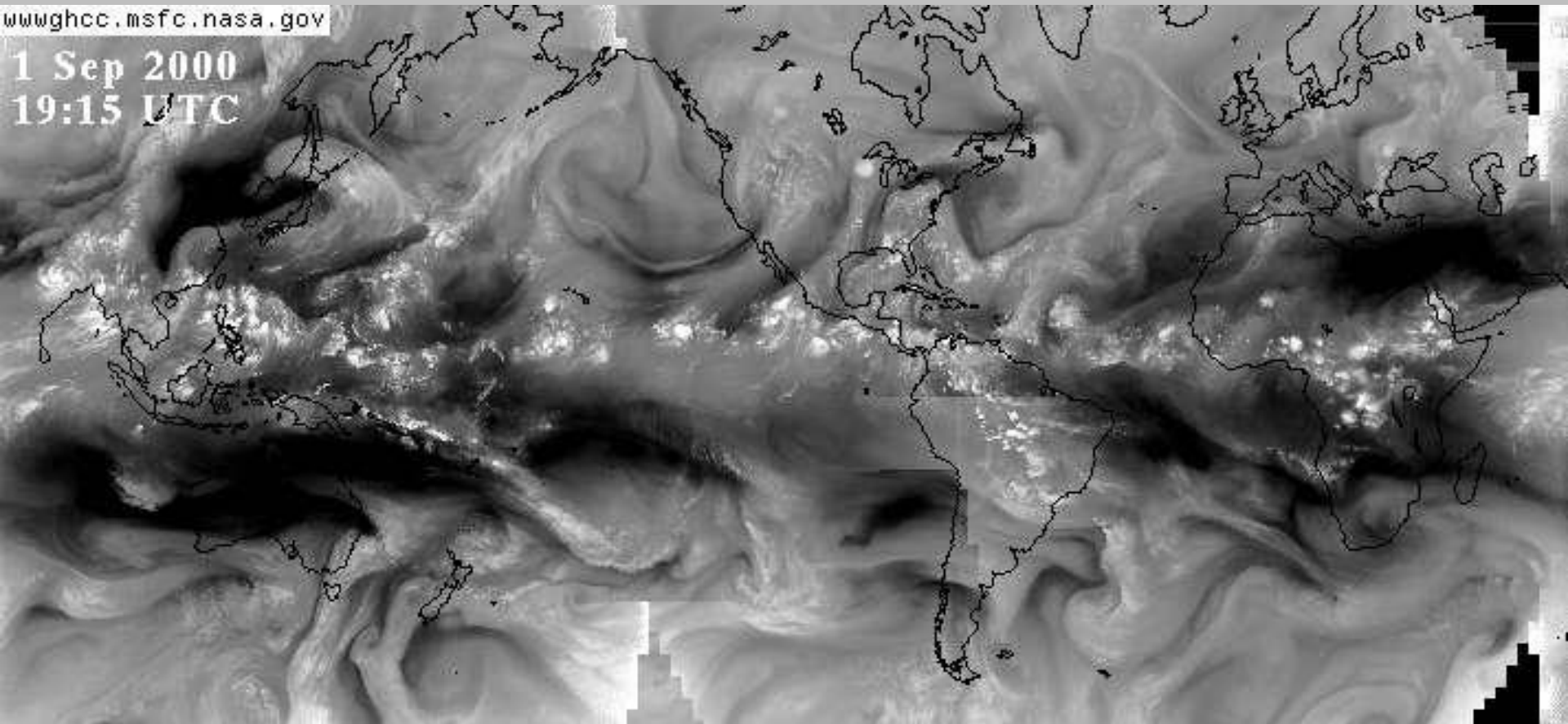
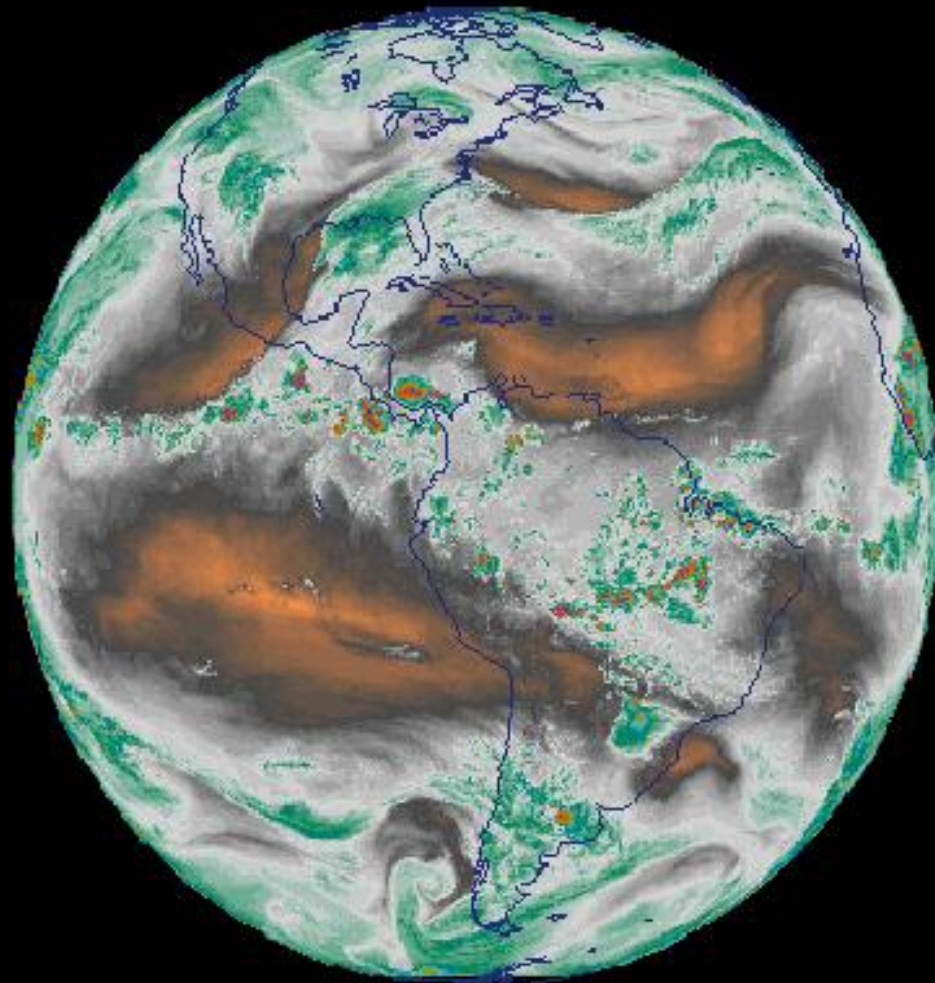


Image courtesy of NASA.



Effects of Clouds on Radiative Transfer

- Responsible for much of Earth's albedo
- Important greenhouse effect from longwave absorption and re-emission

-135

-90

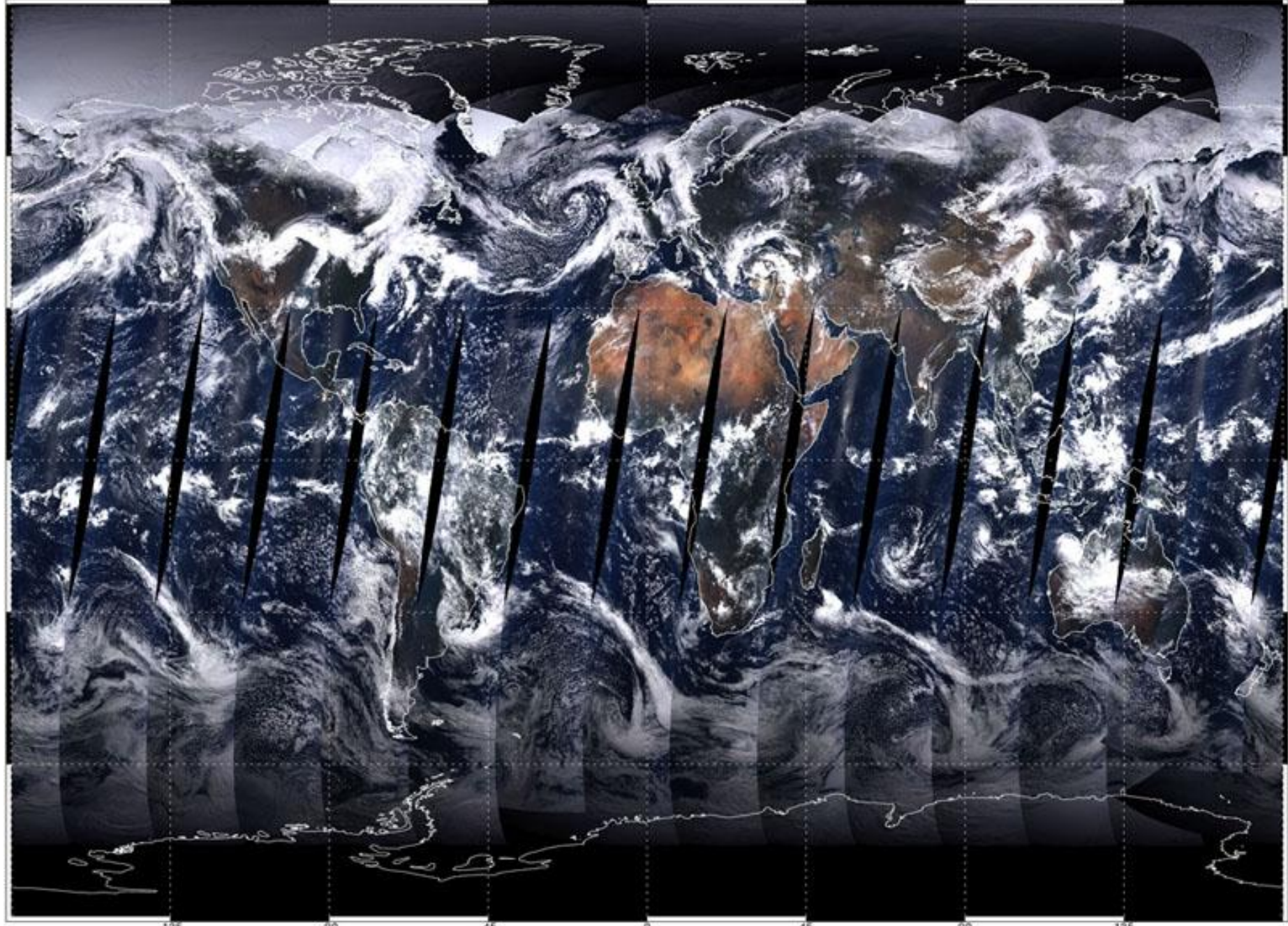
-45

0

45

90

135



Annual Average Cloud Fractional Area

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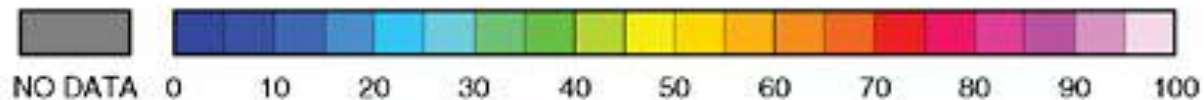
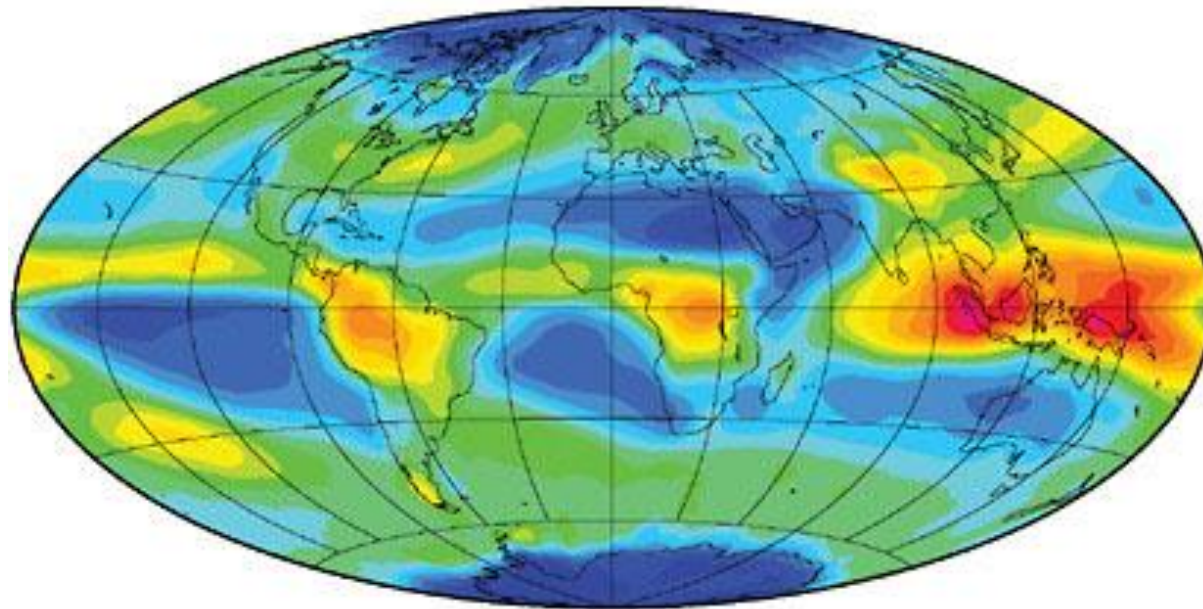
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Observed cloud effects on radiation

Longwave Cloud Forcing
1985-1986



W/m²

OLR reduction (W/m²)

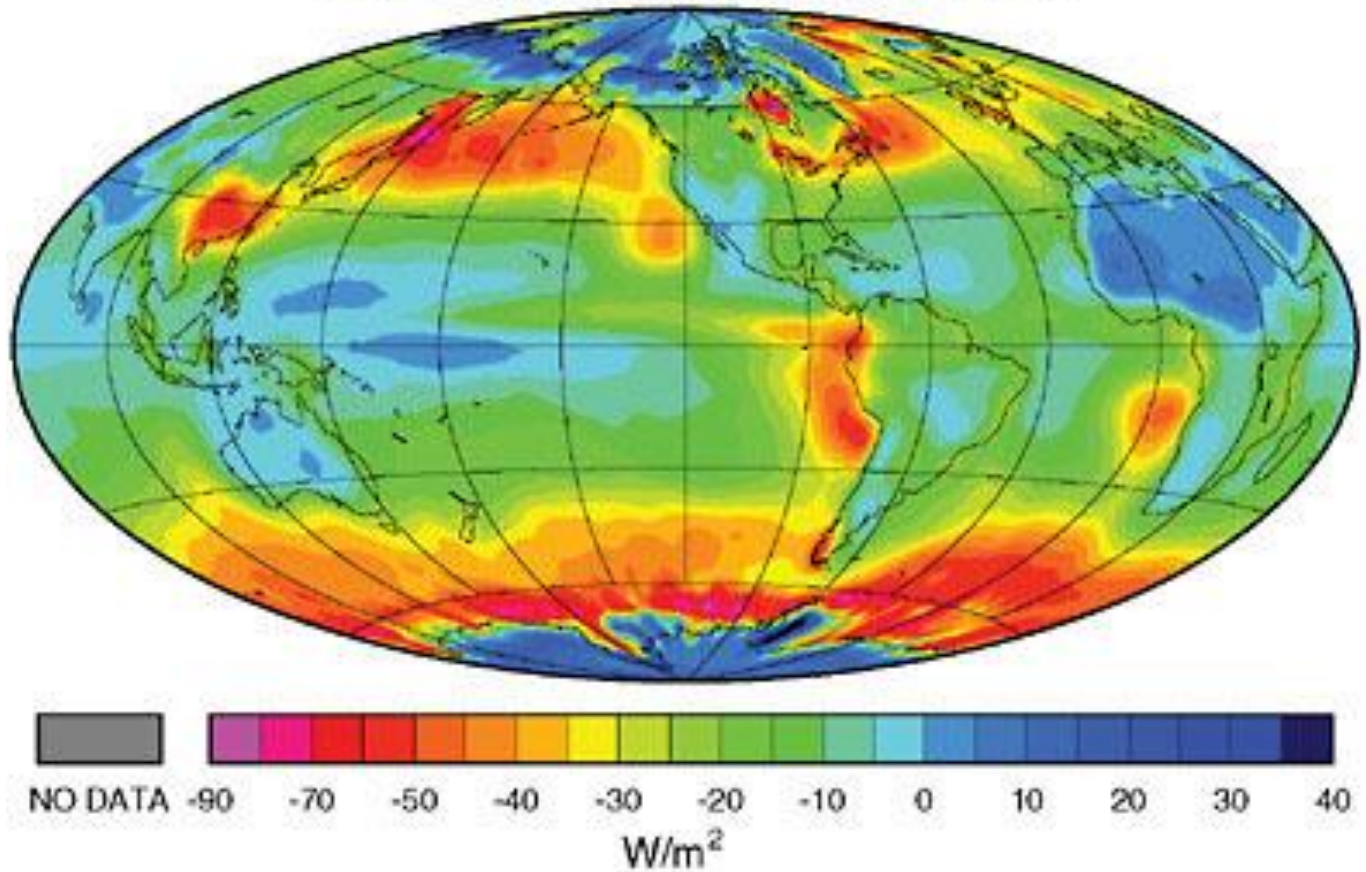
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Change in shortwave radiation (W/m^2)

Annual ERBE Net Radiative Cloud Forcing



Increase in net radiation (W/m^2)

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CL 3 (Cumulonimbus without Anvil) Frequency-of-Occurrence (DJF)

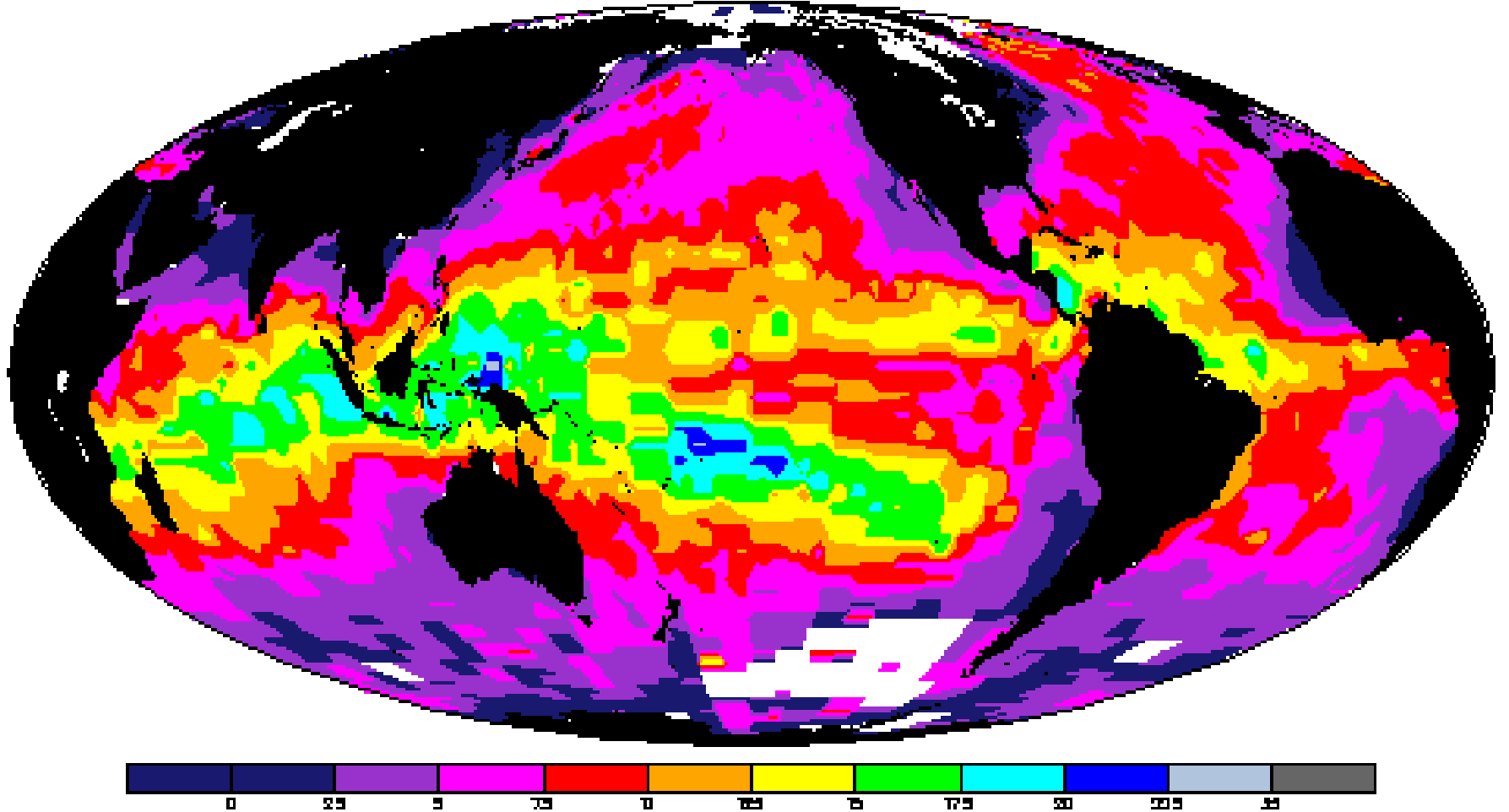


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Annual Average Lightning Frequency (from Space)

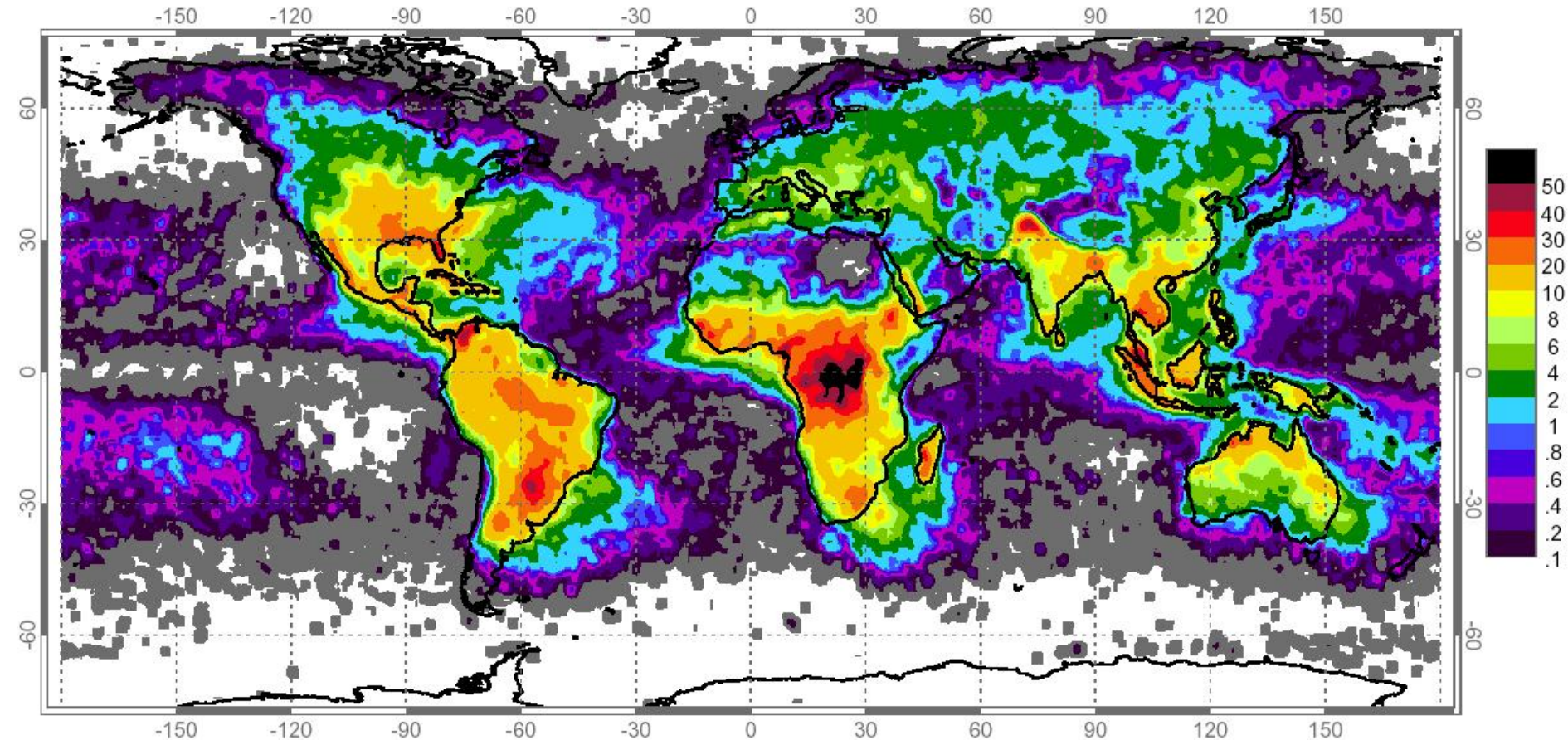


Image courtesy of NASA.

CL 5 (Ordinary Stratocumulus) Average Cloud Amount (JJA)

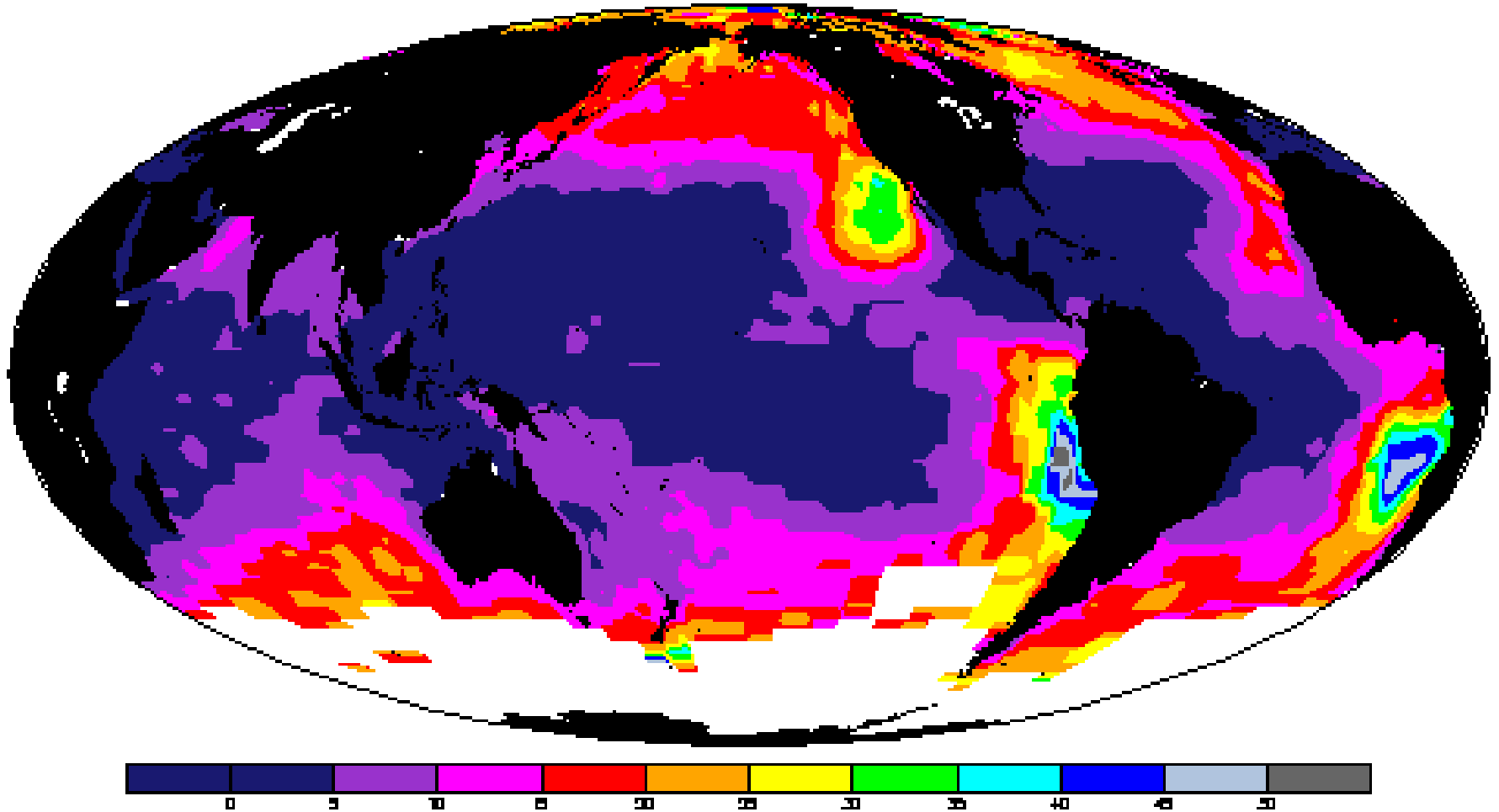
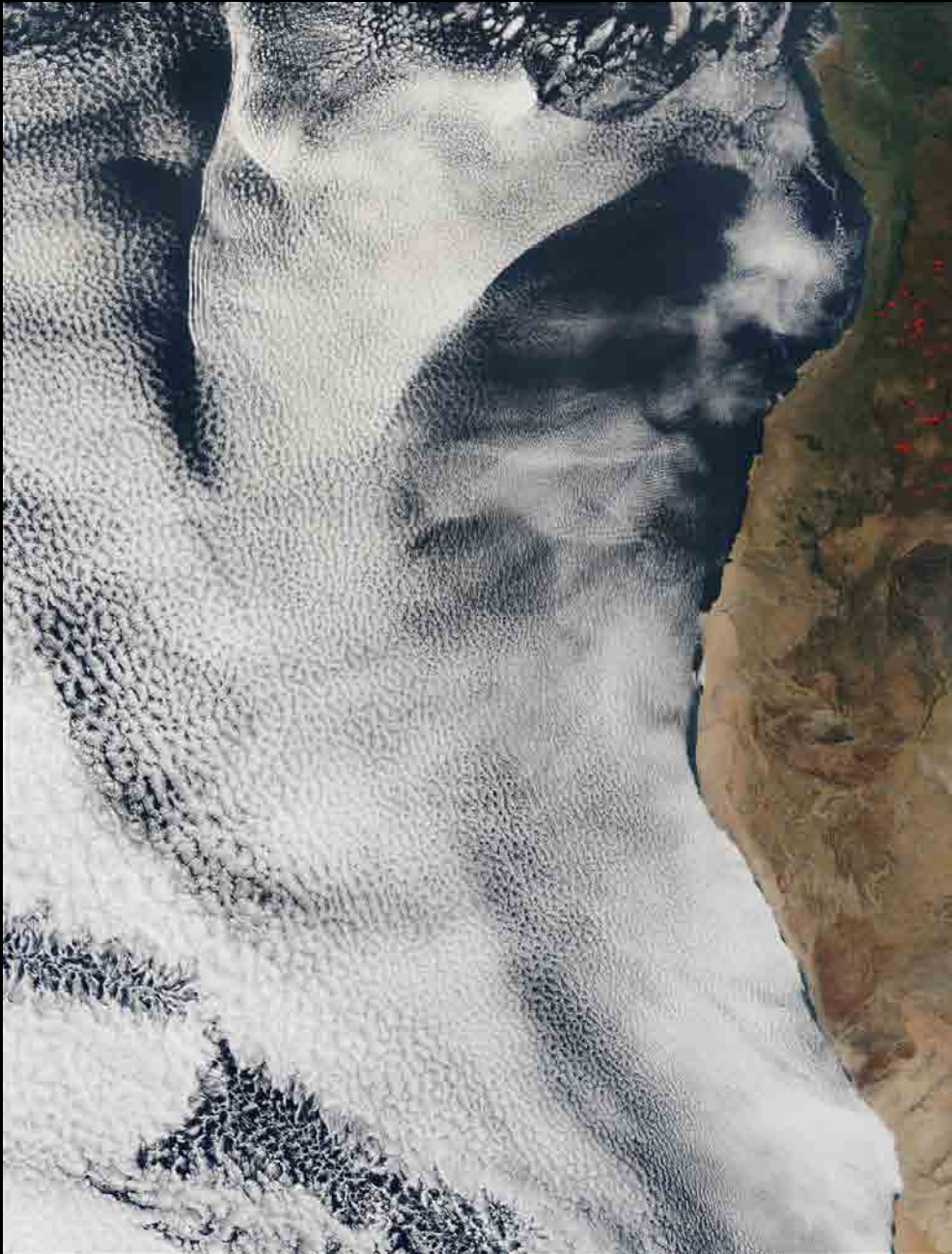
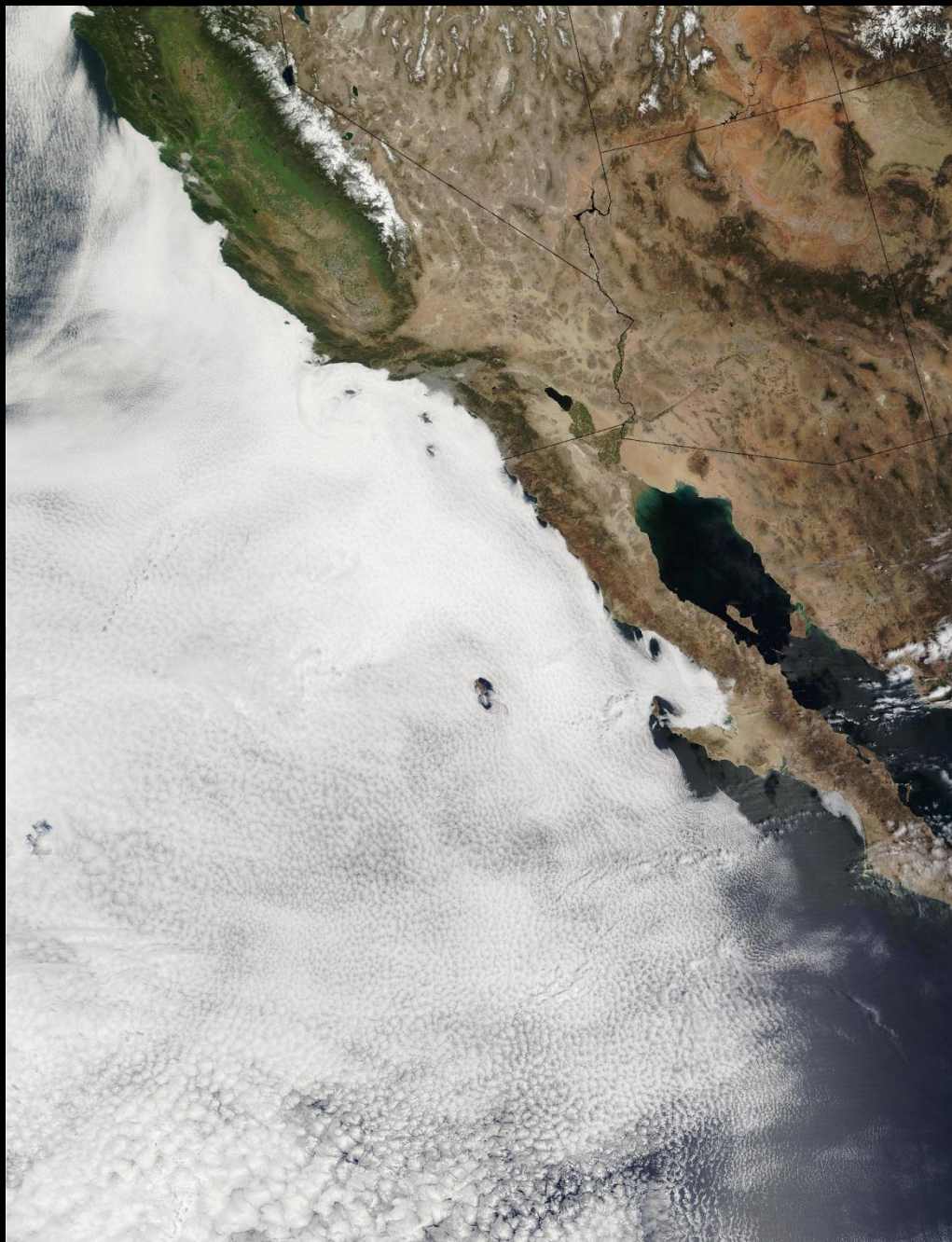


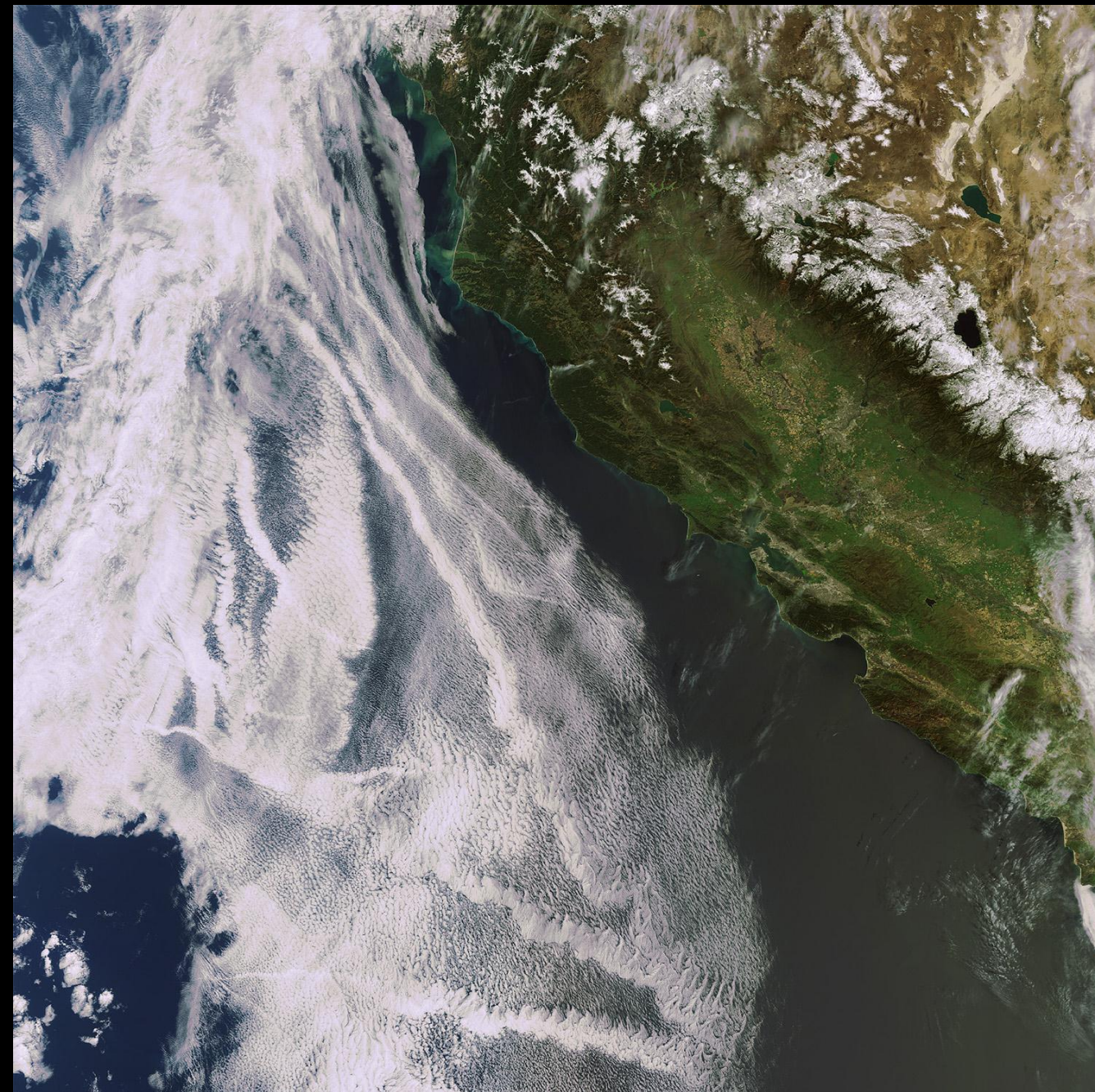
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Stratocumuli off Angola and Namibia



Stratocumuli off Baja California



Ship tracks off California

Image courtesy of NASA.

Total Albedo

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Outgoing Longwave Radiation

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Net Incoming Radiation

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Lateral Heat Transport by Atmosphere and Oceans

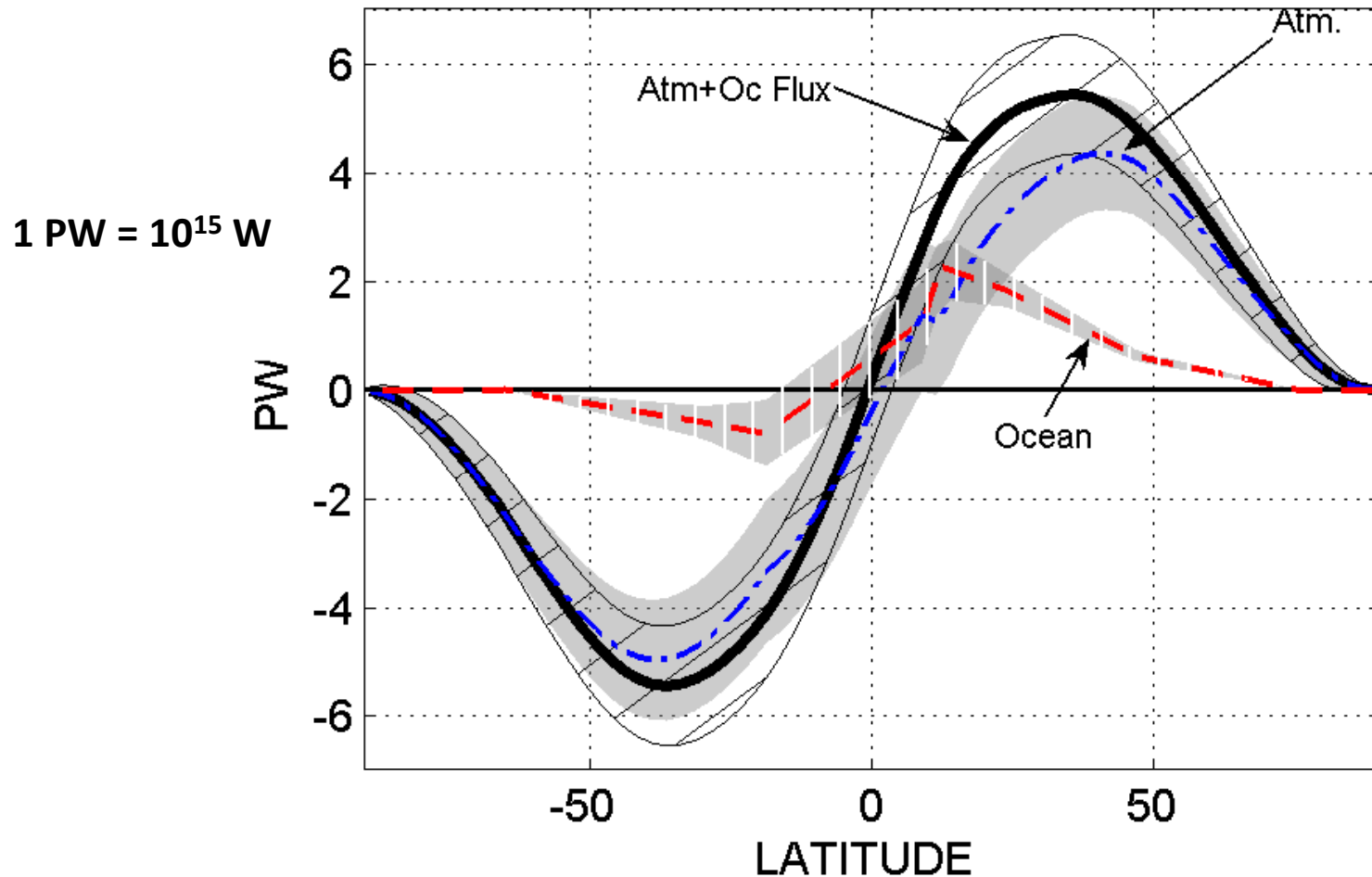


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12.340 Global Warming Science
Spring 2012

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