The Circulation of the Atmosphere and Oceans
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The Real World Environment Varies in All Three Spatial Dimensions and Time
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Seasonal variation of solar radiation

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Hartmann, Dennis L. 1994. *Global physical climatology.*
Sea Surface Temperature

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Global average surface albedo

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Inhomogeneity of Water Vapor

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Effects of Clouds on Radiative Transfer

• Responsible for much of Earth’s albedo
• Important greenhouse effect from longwave absorption and re-emission
Annual Average Cloud Fractional Area

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Observed cloud effects on radiation

OLR reduction (W/m²)

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Please see Figure 3.22 (b) in the book

**Change in shortwave radiation (W/m²)**
Increase in net radiation (W/m²)

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

Image courtesy of Joel Norris. Used with permission.
Annual Average Lightning Frequency (from Space)

Image courtesy of NASA.
Stratocumuli off Angola and Namibia

Image courtesy of NASA.
Stratocumuli off Baja California

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Ship tracks off California

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Outgoing Longwave Radiation

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Lateral Heat Transport by Atmosphere and Oceans

1 PW = \(10^{15}\) W

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