Balancing the Radiation Budget

Part 2

Unit 5 of Earth's Thermostat InTeGrate Module

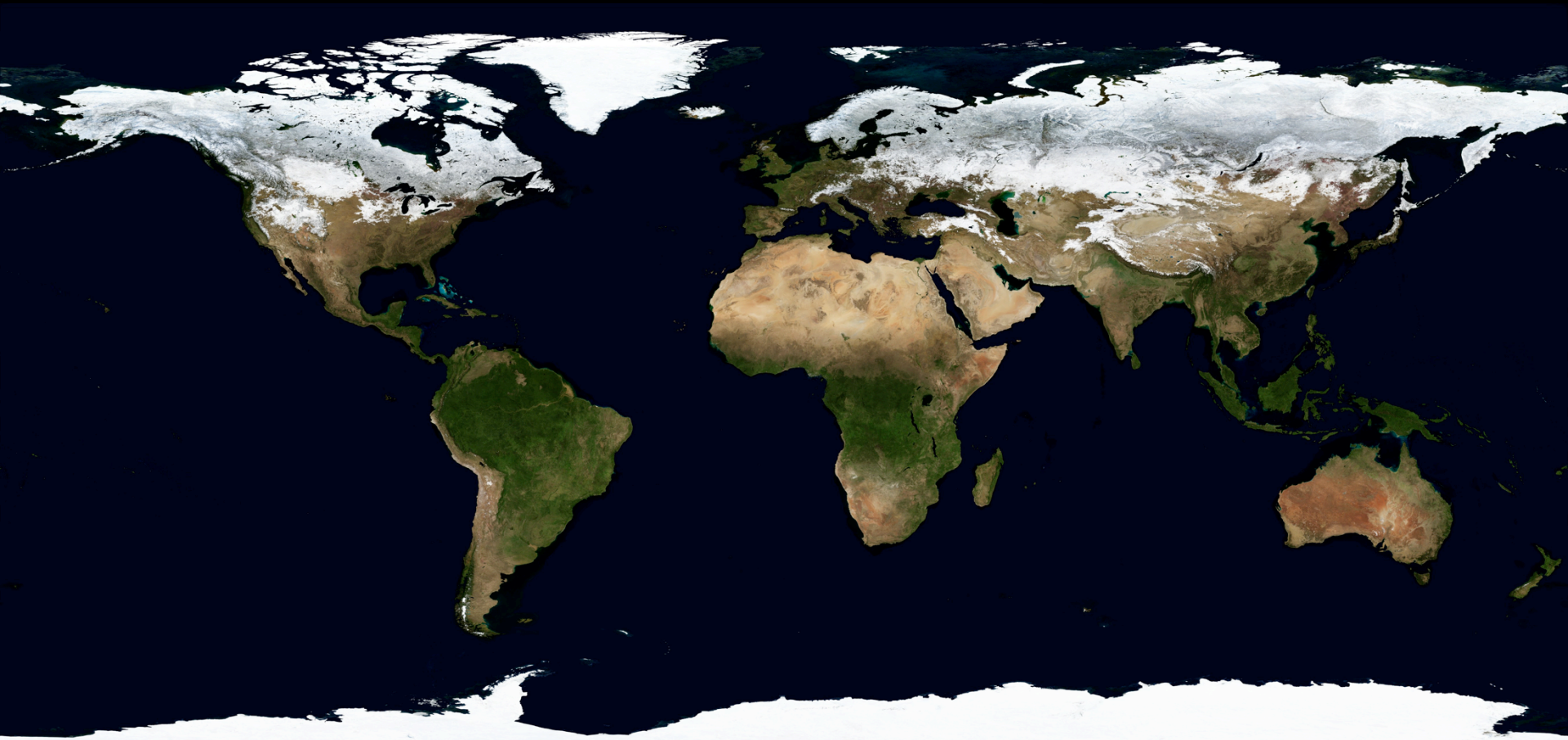


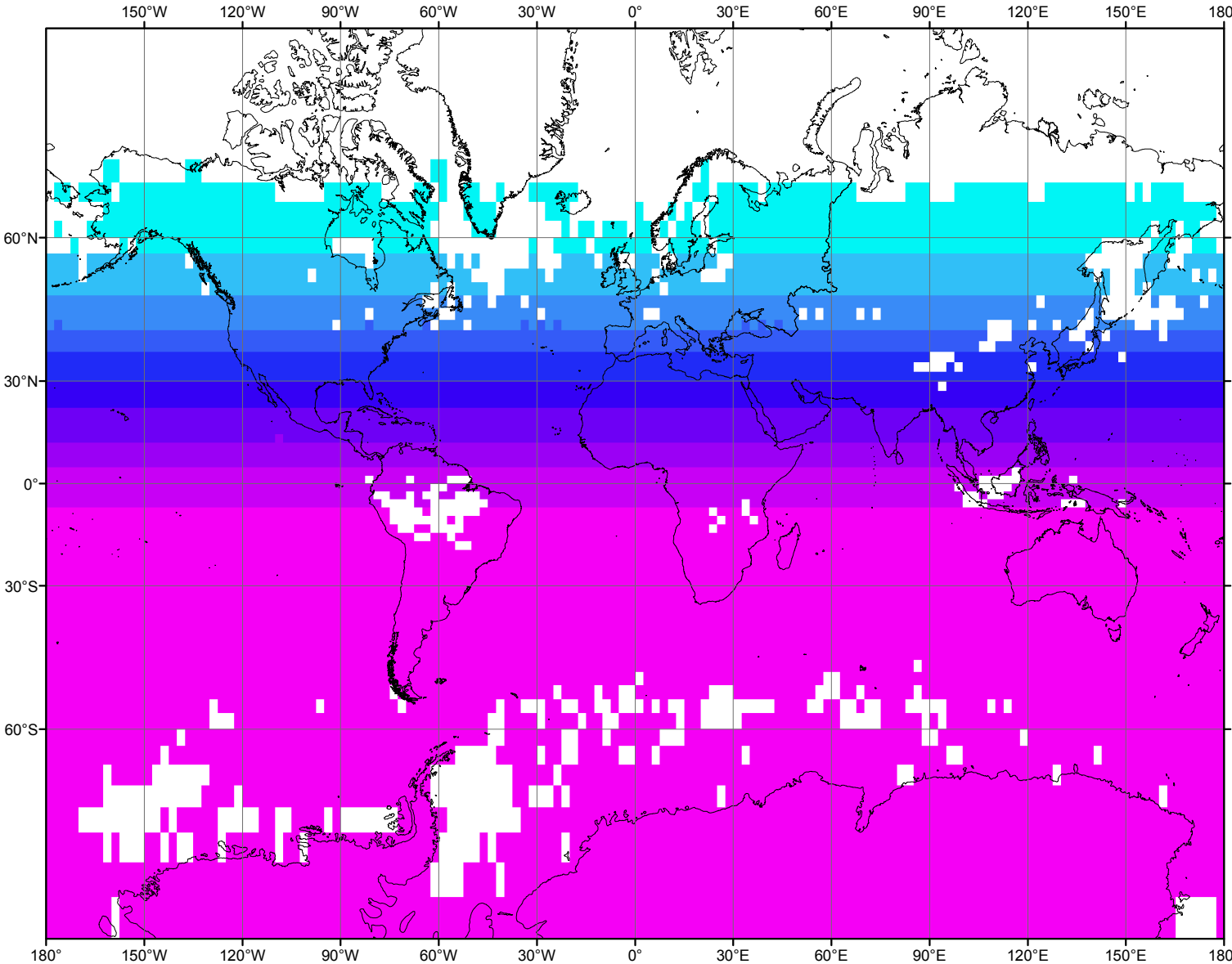
Image: January 2004 Blue Marble Composite – Reto Stöckli, NASA Earth Observatory

Learning Objectives

By the end of the unit, students will be able to:

- Estimate relative balance (balance, excess, deficit) from graphs of the major components of Earth's radiation budget.
- Create concept sketches to effectively communicate spatial variation in Earth’s radiation balance and hypothesized physical causes.
- Explain how atmospheric circulation acts to balance the radiation budget.
- Generate hypotheses for the patterns of the global impacts of climate change using their understanding of the global climate system.

Short wave in



Earth's Radiation Budget January Climatology

ERBE sensors did not directly measure the incoming short wavelength radiation. This map was created by dividing the outgoing short wavelength radiation measured by the ERBE by the albedo of the surface (Columbia climate System Course). The ERBE short wavelength sensor measures radiation between 0.2 and 5 microns.

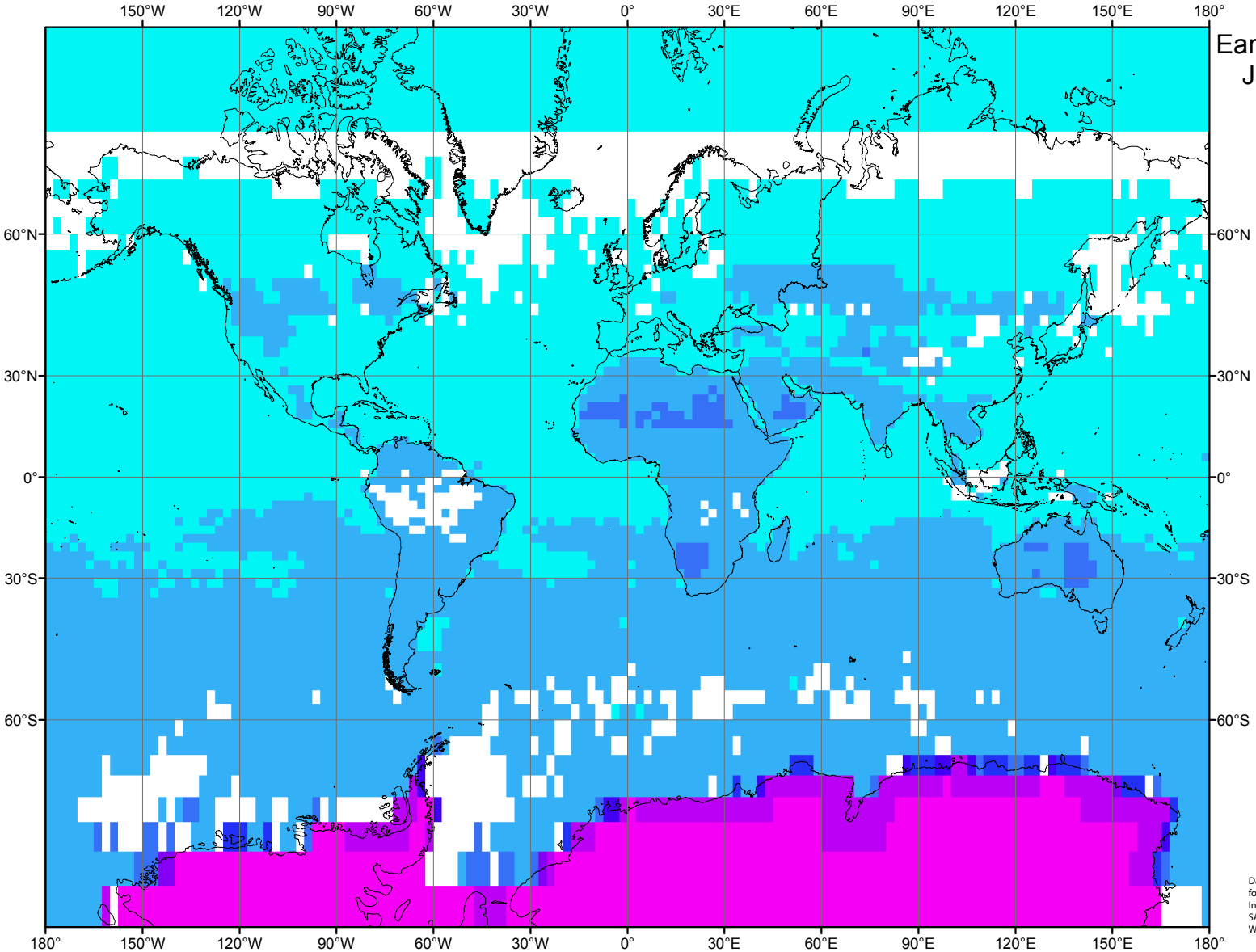
For comparison visible light ranges from 0.4 to 0.7 microns (blue to red). The short wavelength thus includes visible light and near infrared.

Short Wave Radiation In (W/m^2)

- 0 / No Data
- 2 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500

Data downloaded from International Research Institute for Climate and Society at Columbia University's Earth Institute (http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.ERBE/). Grid size is 2.5° by 2.5°. Mercator projection. WGS84 Geoid.

Short wave out



Earth's Radiation Budget January Climatology

The ERBE short wavelength sensor measured radiation between 0.2 and 5 microns traveling outward from the earth at the top of the atmosphere. This January clear sky climatology data set was created by averaging cloud-free observations for the month. Some areas of the earth were not cloud free during the time of observation and thus have no data.

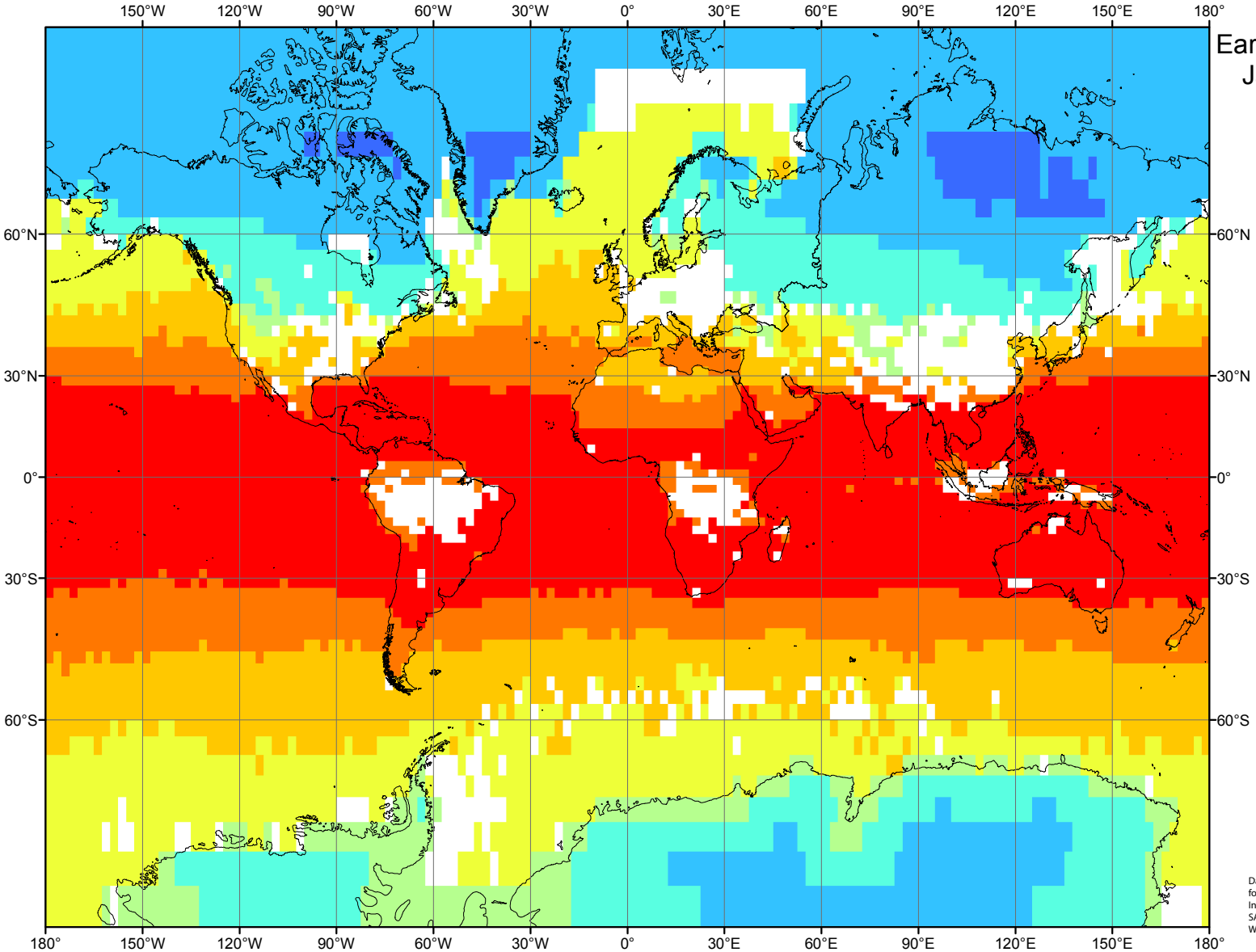
For comparison visible light ranges from 0.4 to 0.7 microns (blue to red). The short wavelength thus includes visible light and near infrared.

Short Wave Radiation out
(W/m^2, clear sky)

- No Data
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400

Data downloaded from International Research Institute for Climate and Society at Columbia University's Earth Institute (http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.ERBE/). Grid size is 2.5° by 2.5°. Mercator projection. WGS84 Geoid.

Long wave out



Earth's Radiation Budget January Climatology

The ERBE long wavelength sensor measured radiation between 5 and 50 microns traveling outward from the earth at the top of the atmosphere. This January clear sky climatology data set was created by averaging cloud-free observations for the month. Some areas of the earth were not cloud free during the time of observation and thus have no data.

For comparison visible light ranges from 0.4 to 0.7 microns (blue to red). The long wavelength sensor thus measures radiation in the thermal infrared range.

Long Wave Radiation out
(W/m^2, clear sky)

- No Data
- 135 - 140
- 141 - 160
- 161 - 180
- 181 - 200
- 201 - 220
- 221 - 240
- 241 - 260
- 261 - 280
- 281 - 300

Data downloaded from International Research Institute for Climate and Society at Columbia University's Earth Institute (http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.ERBE/). Grid size is 2.5° by 2.5°. Mercator projection. WGS84 Geoid.

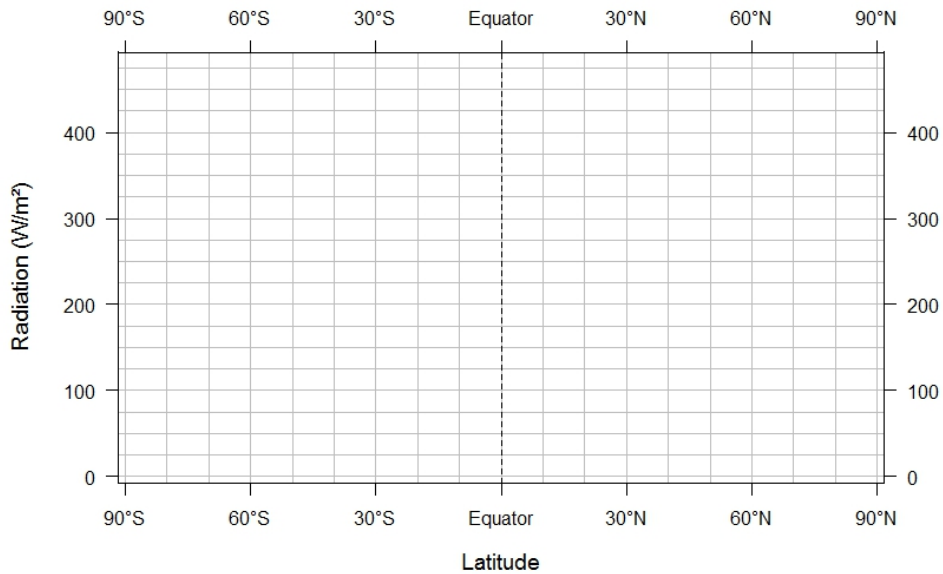
Radiation Balance

- How would you express the radiation balance in a simple equation using the three components from your specialty groups?

Radiation in = radiation out

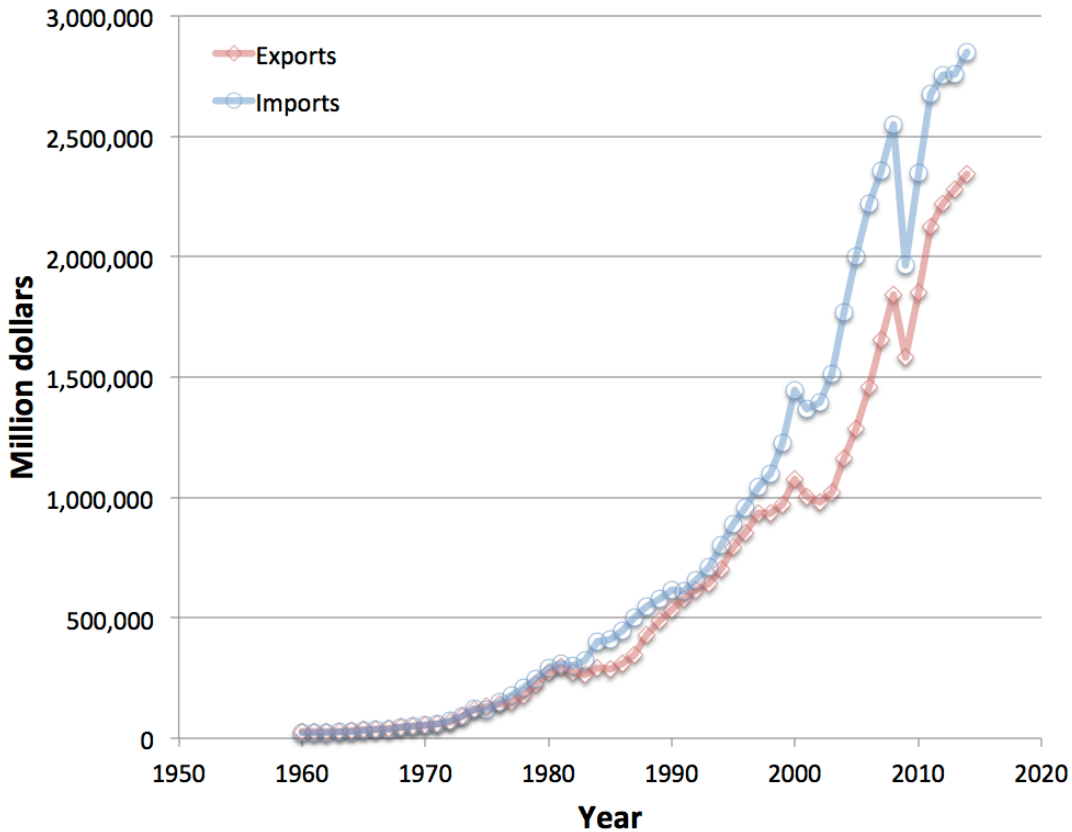
Short wave in = short wave out + long wave out

Task 1: Synthesizing your graphical data



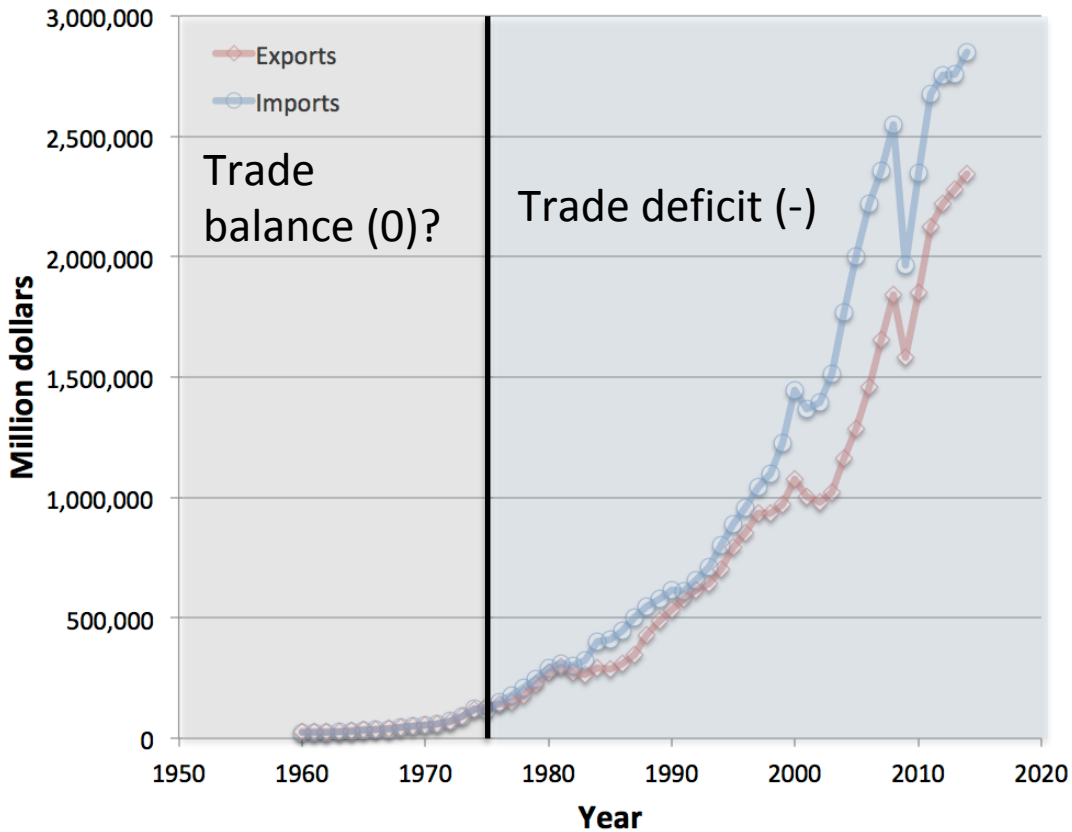
- Present your specialty map and concept sketch to your synthesis group
- Work together to graph each radiation component along your assigned longitude
- How would you determine the radiation balance (+ or -) from your graph?

Graphically determining balance
Example: U.S. trade



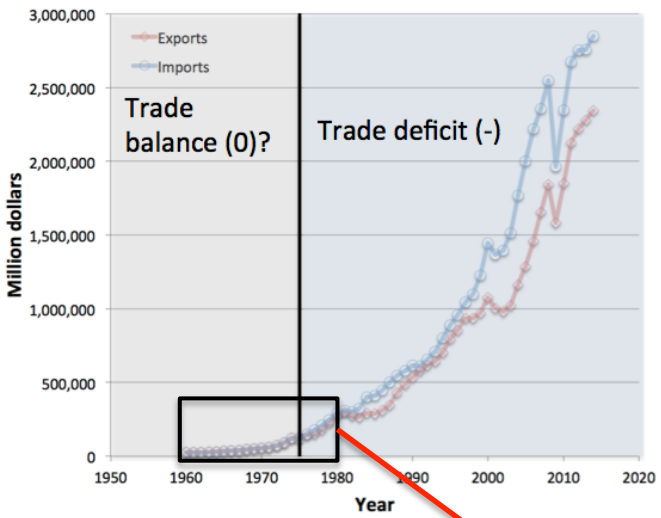
- How do we express trade balance in terms of imports and exports?
- How can we determine from the graph when the United States has run a trade deficit (negative balance) vs. surplus (positive balance)?

Graphically determining balance
Example: U.S. trade

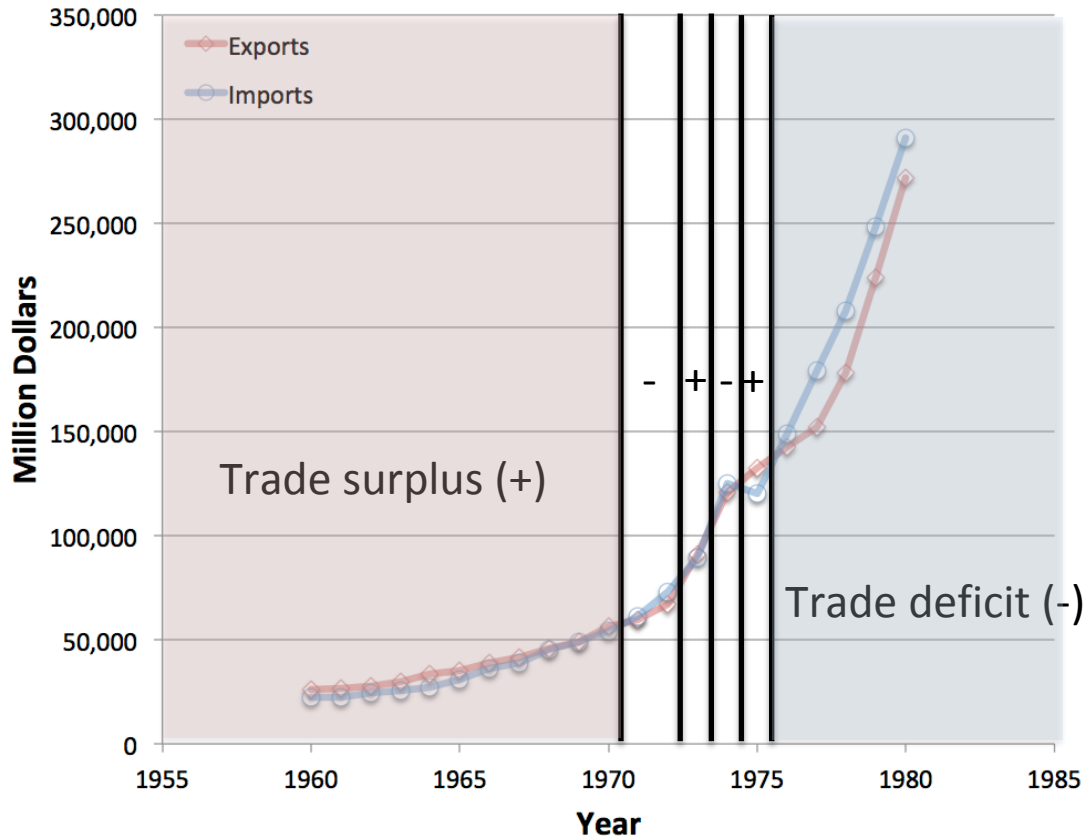


- How do we express trade balance in terms of imports and exports?
- How can we determine from the graph when the United States has run a trade deficit (negative balance) vs. surplus (positive balance)?

Graphically determining balance
Example: U.S. trade with world

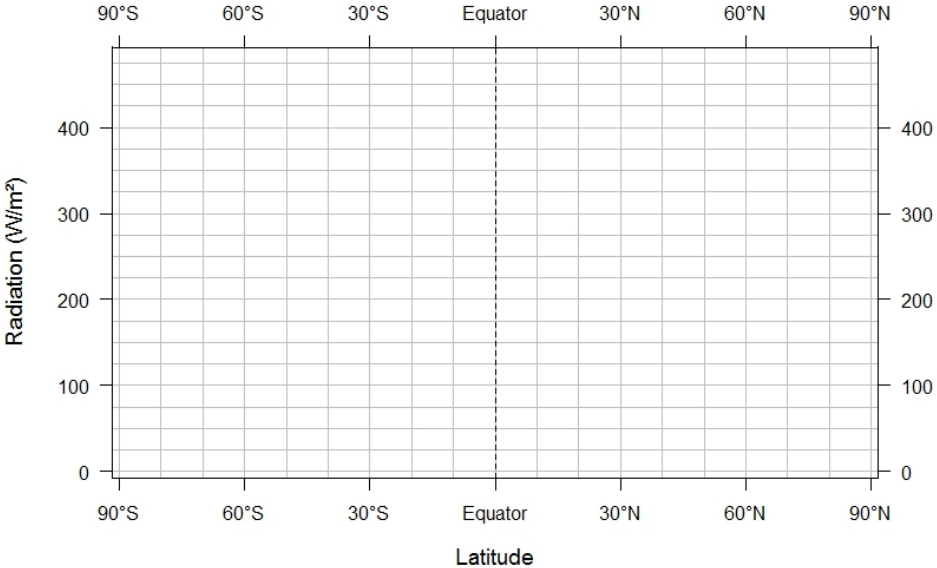


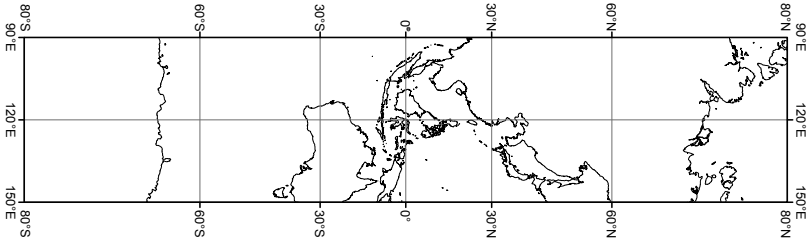
Zooming in…



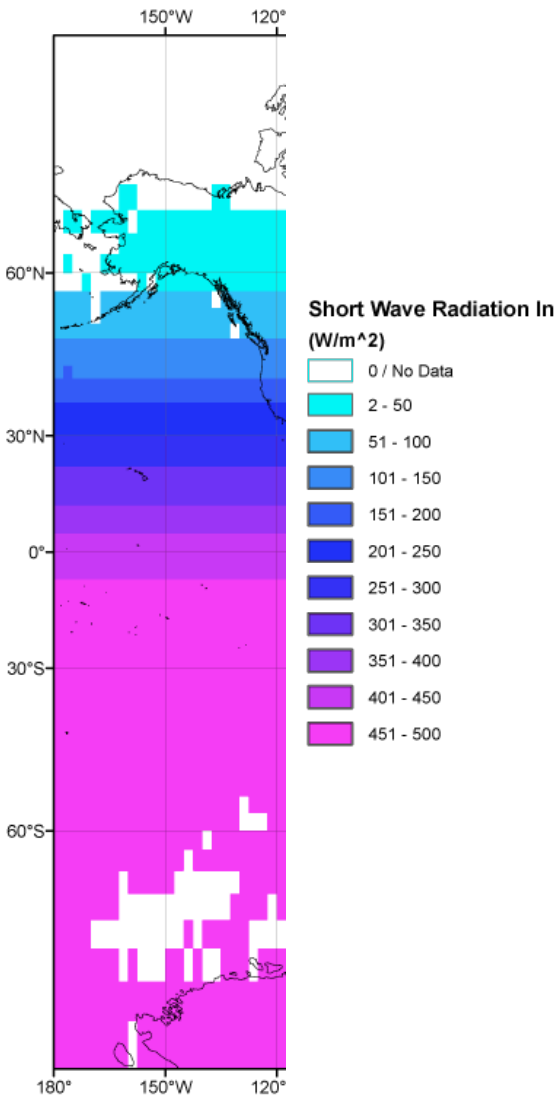
Task 2: Determining the balance and interpreting its causes

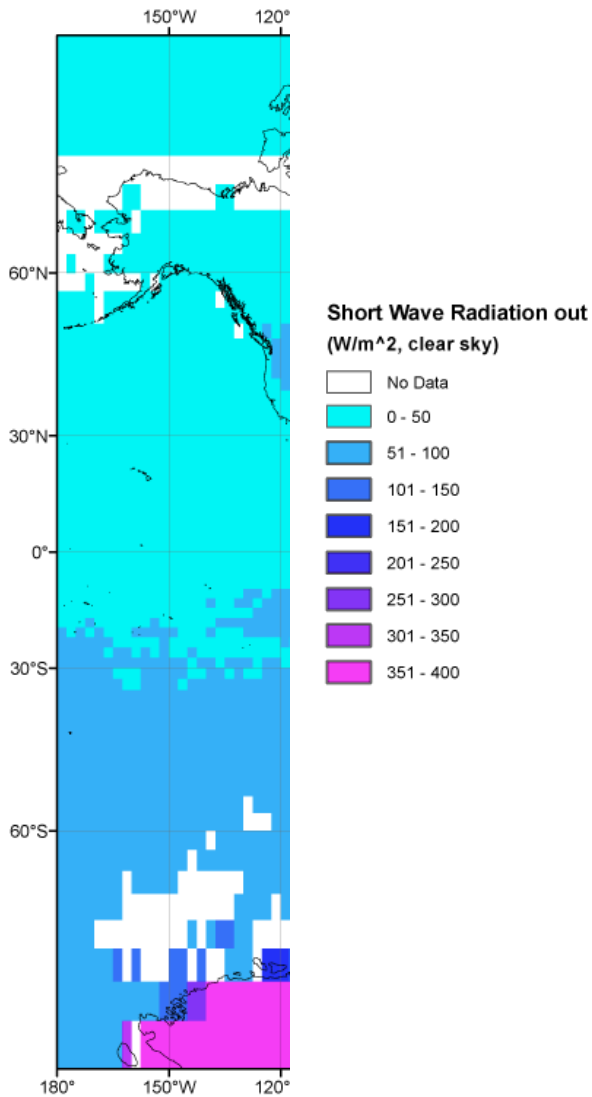
- Annotate your graph and map highlighting:
  - regions of radiation excess (+)/deficit (-)
  - interpretation of physical causes

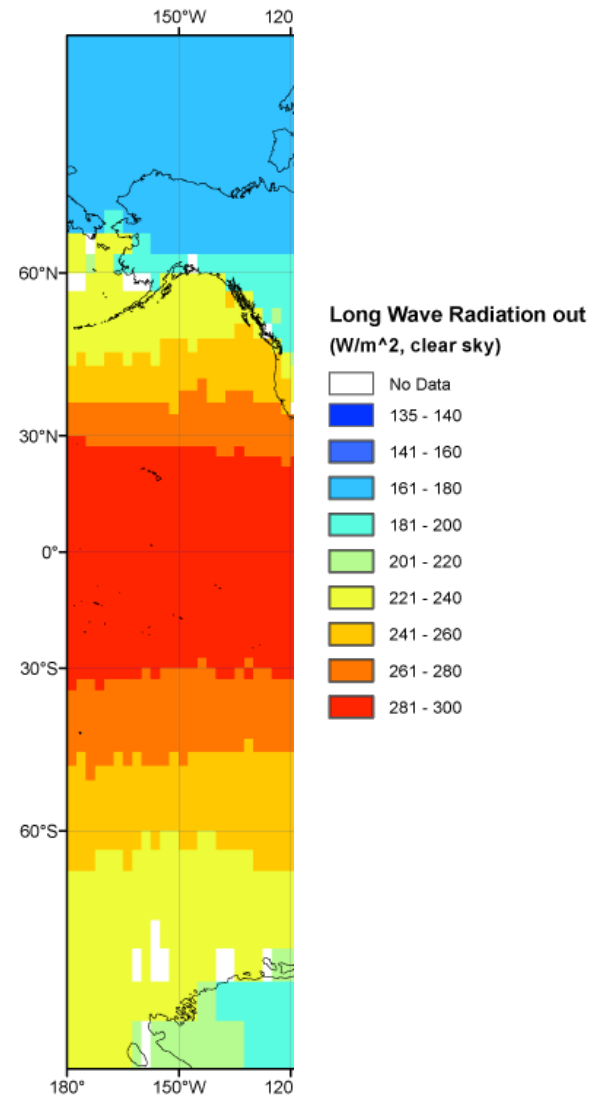




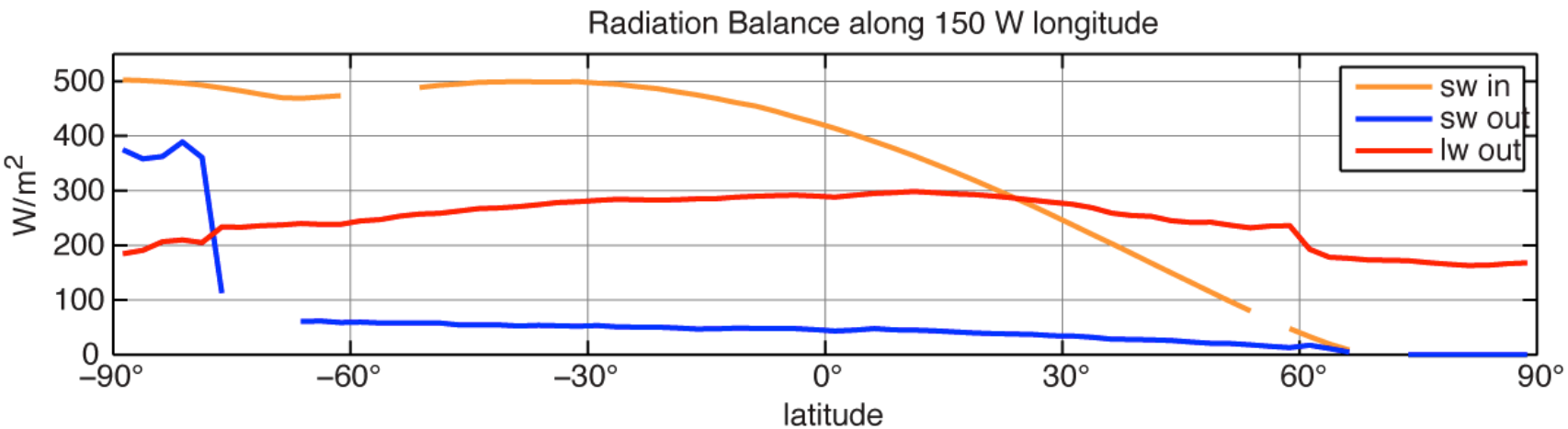
Discussion 150 West

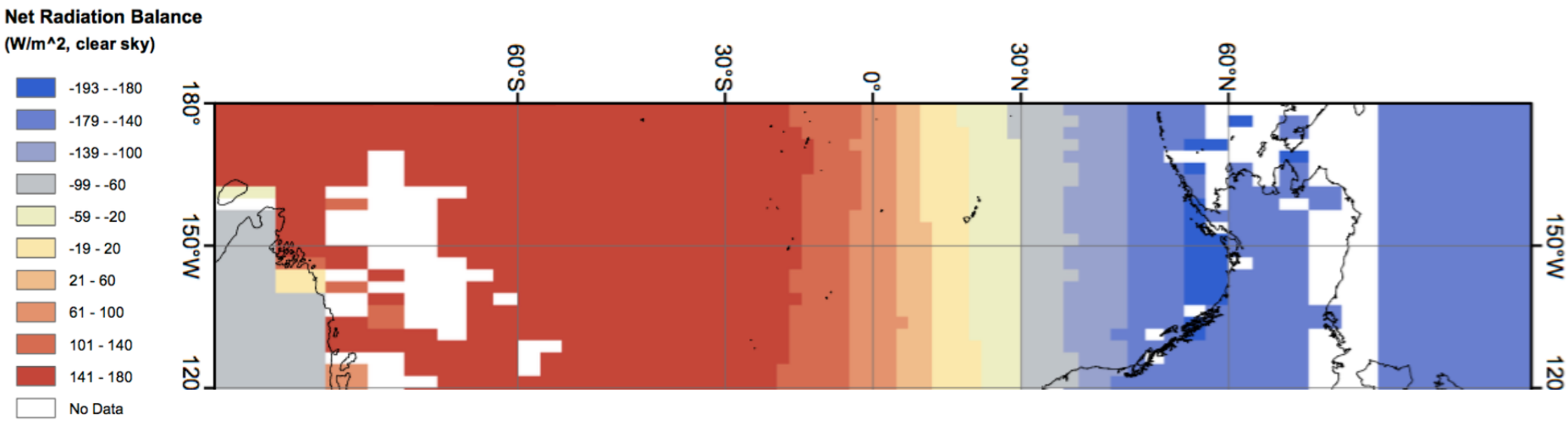




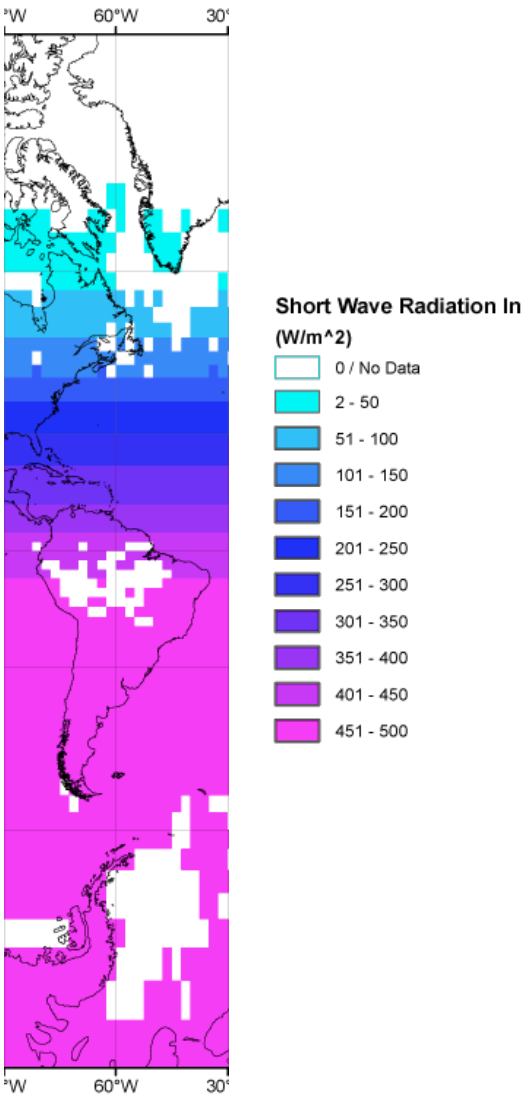


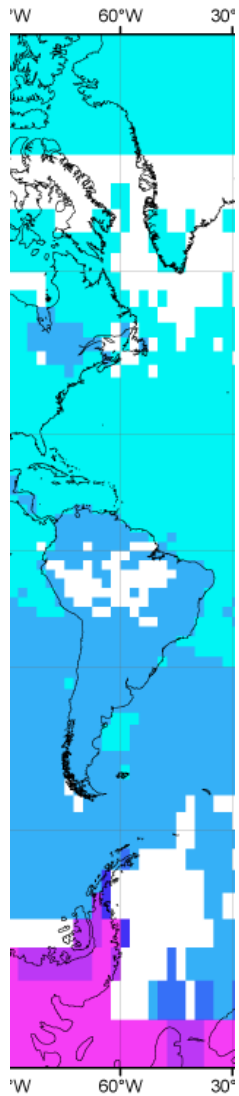
Radiation Balance: 150 West

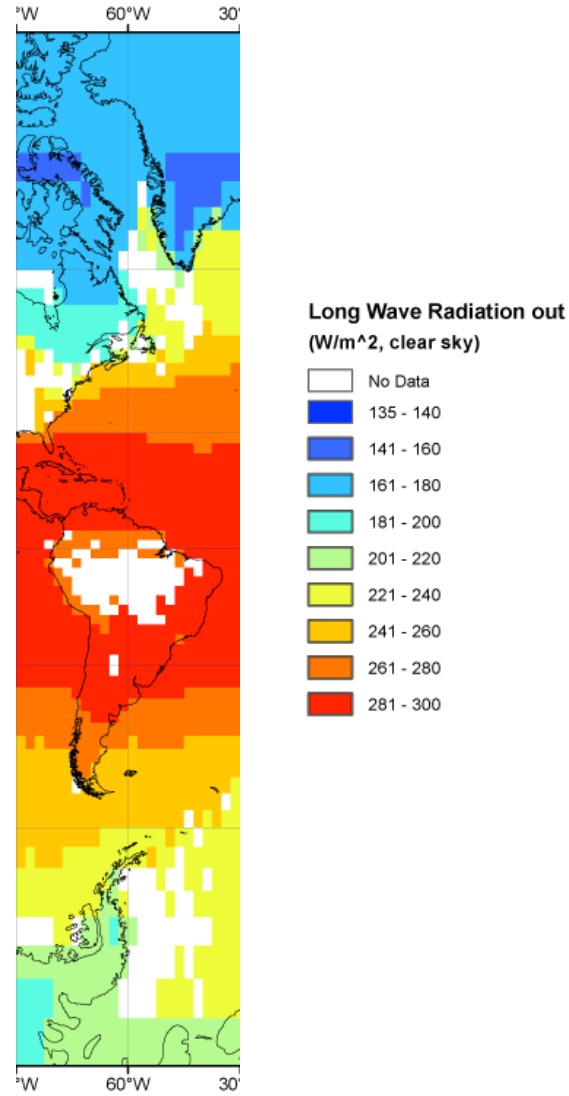




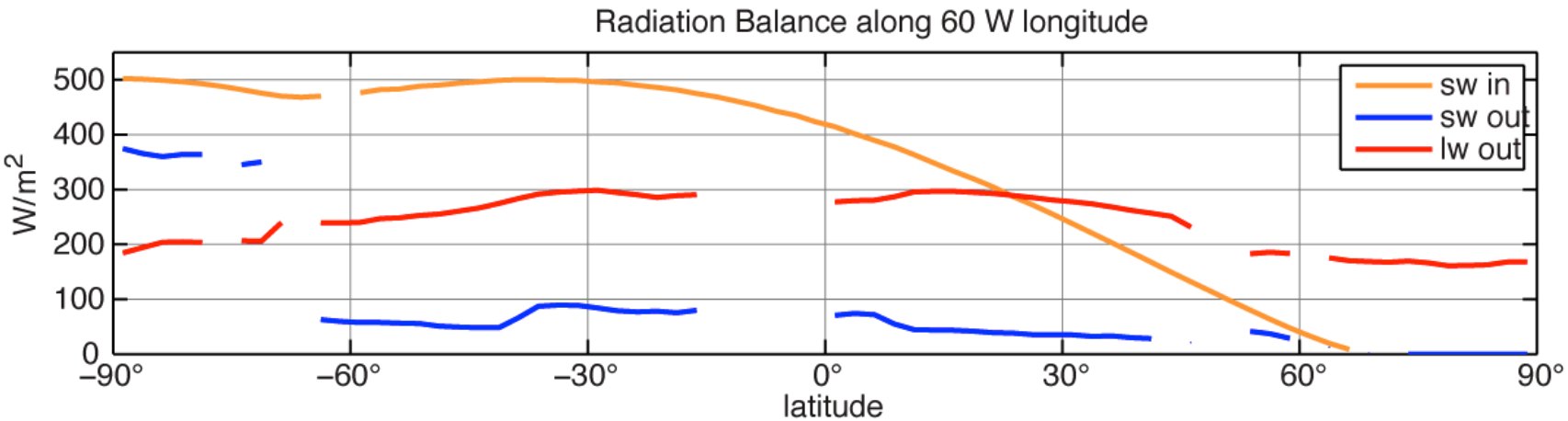
Discussion 60 West

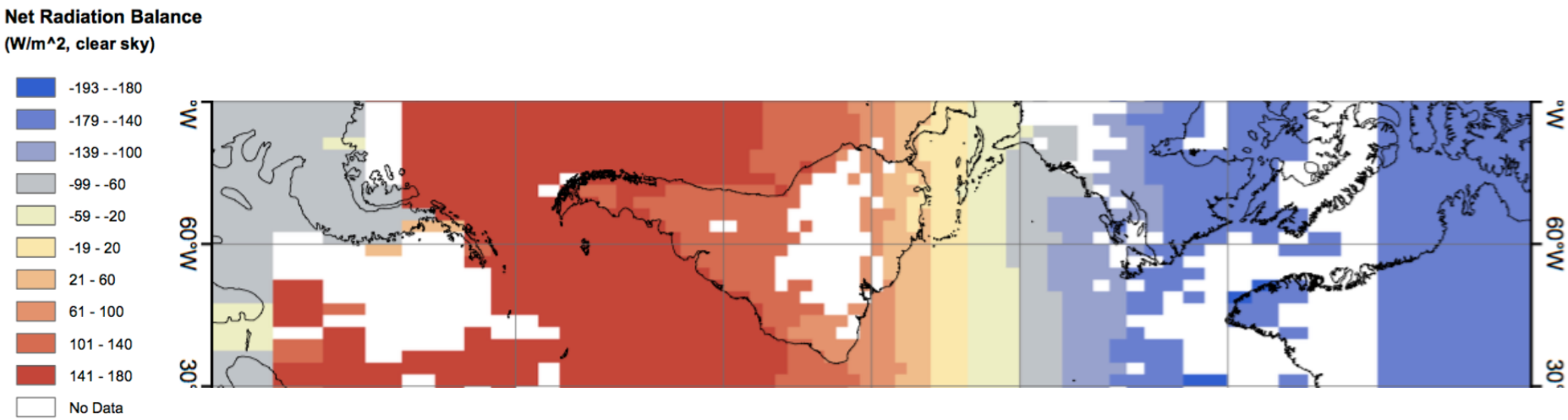




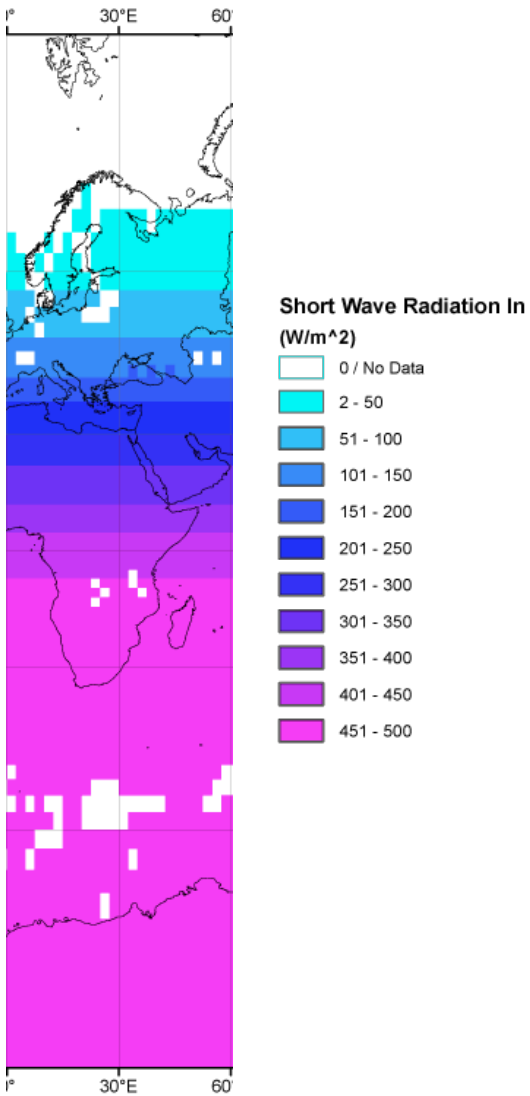


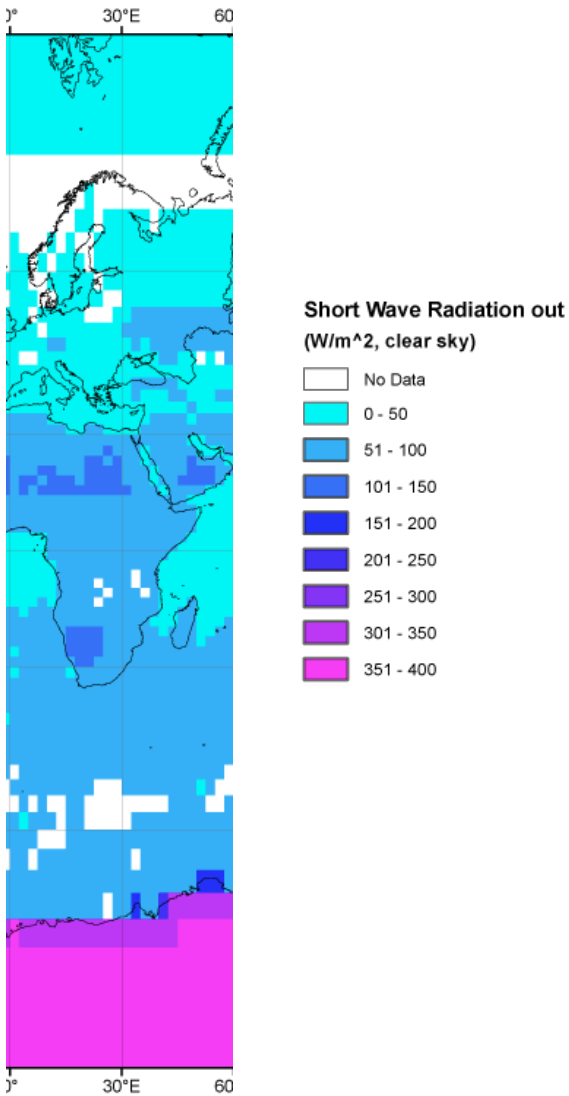
Radiation Balance: 60 West

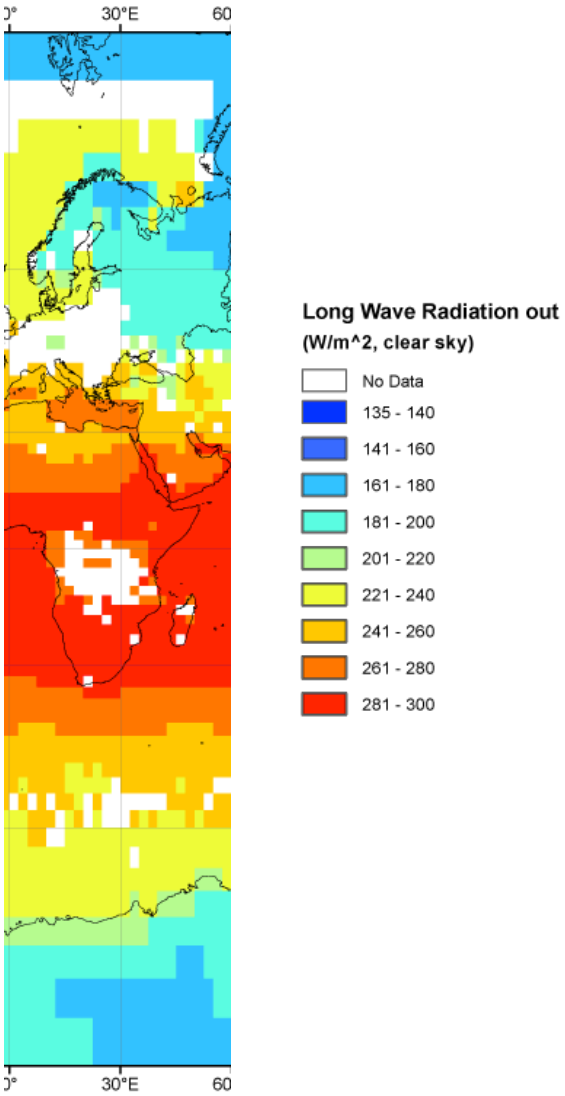




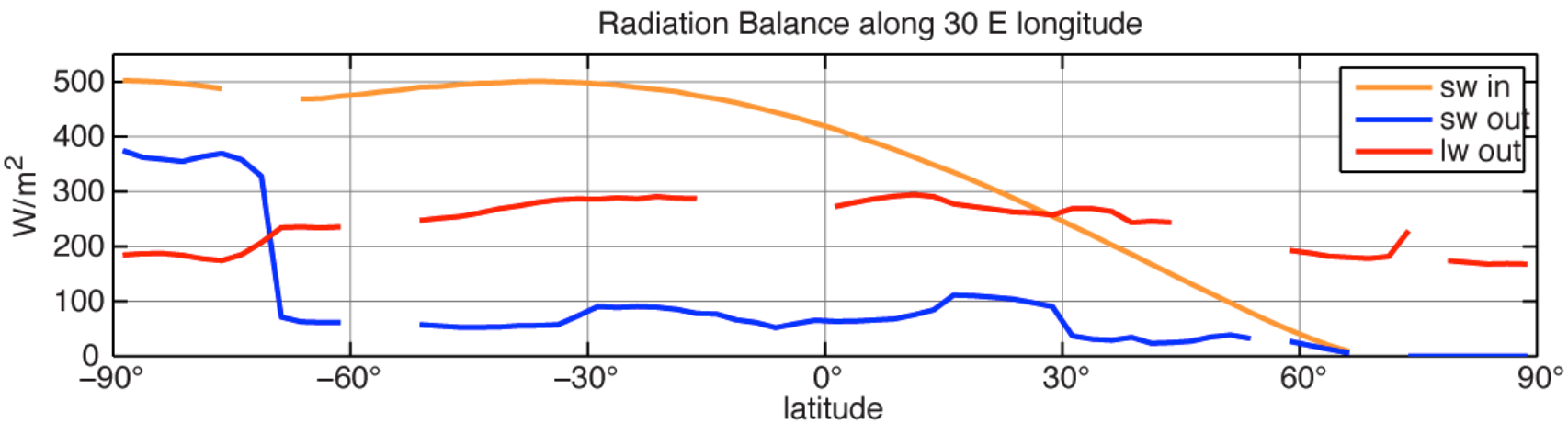
Discussion 30 East

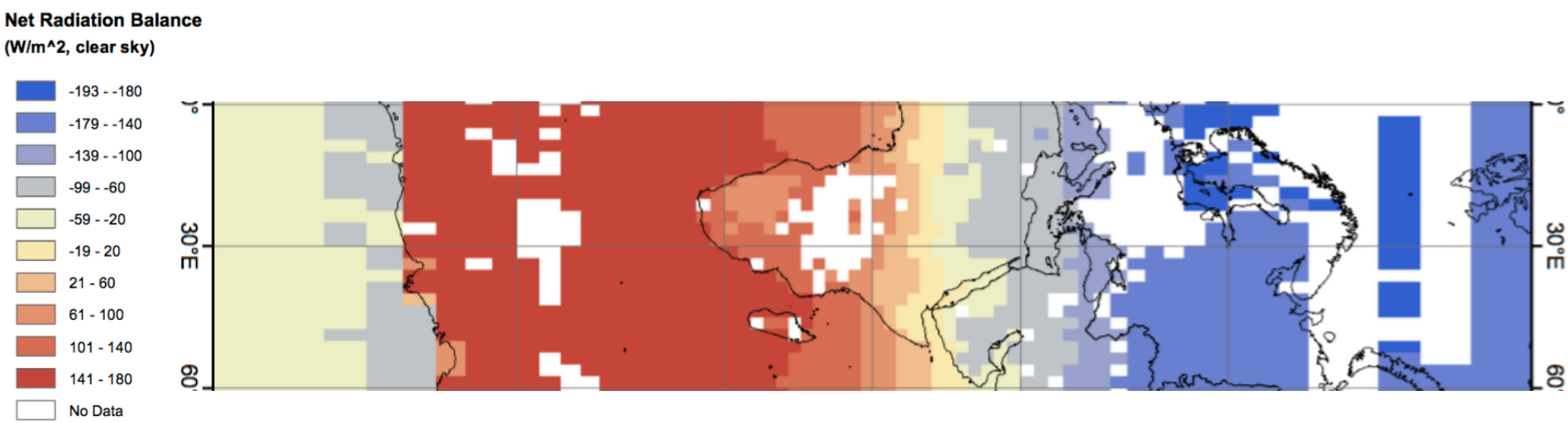




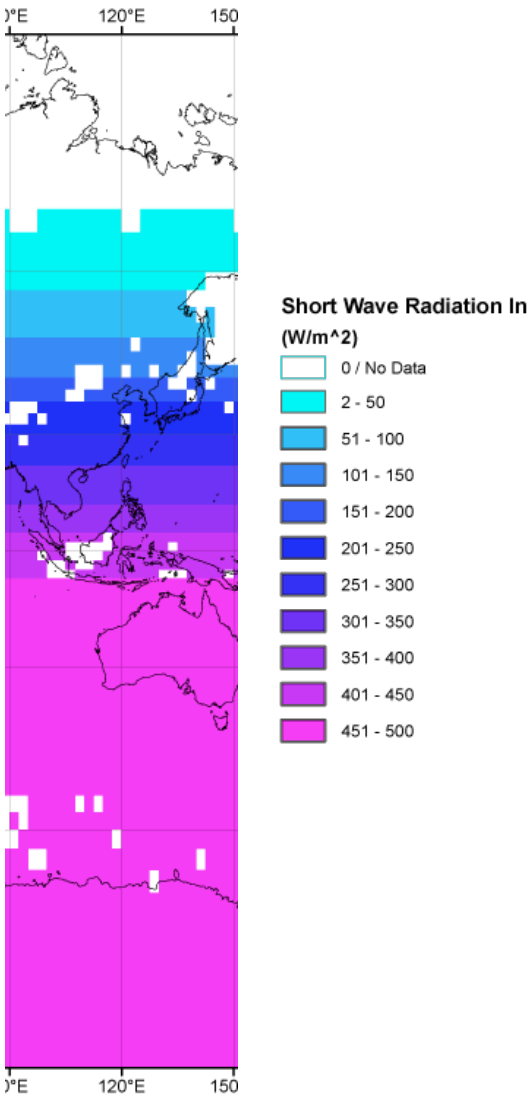


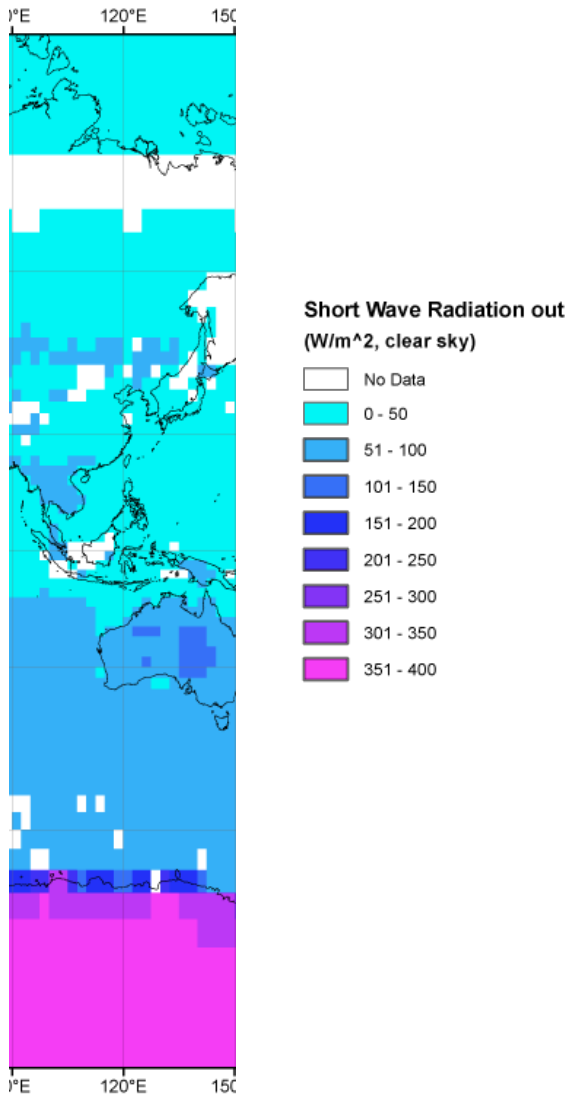
Radiation Balance: 30 East

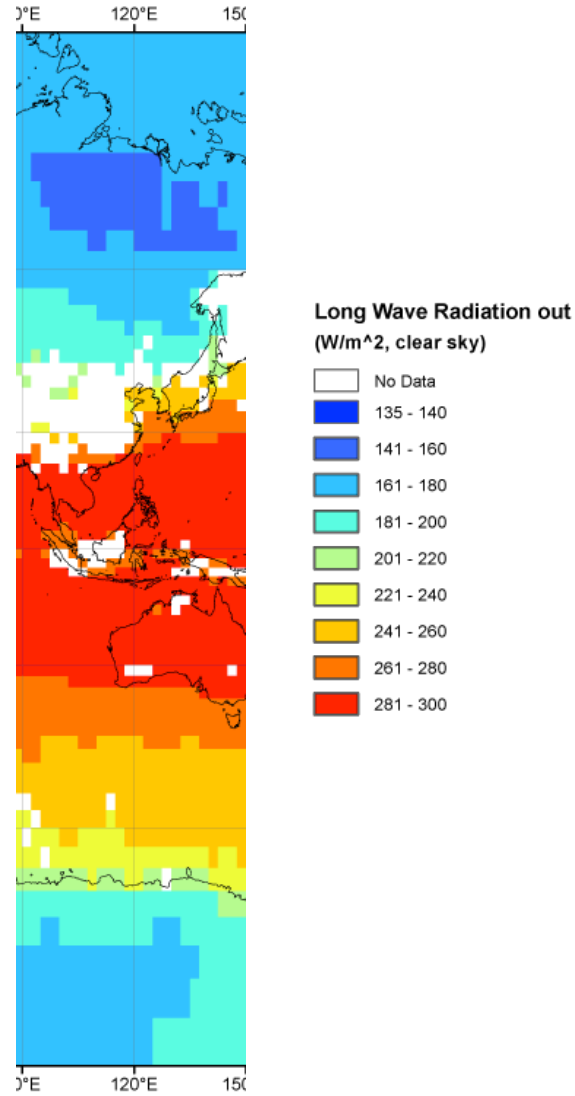




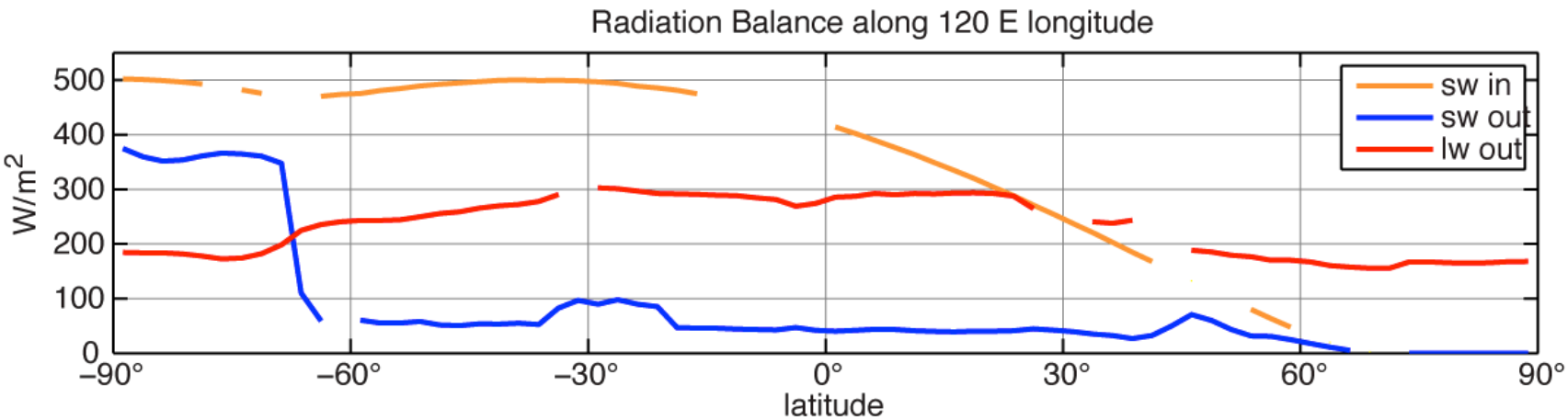
Discussion 120 East

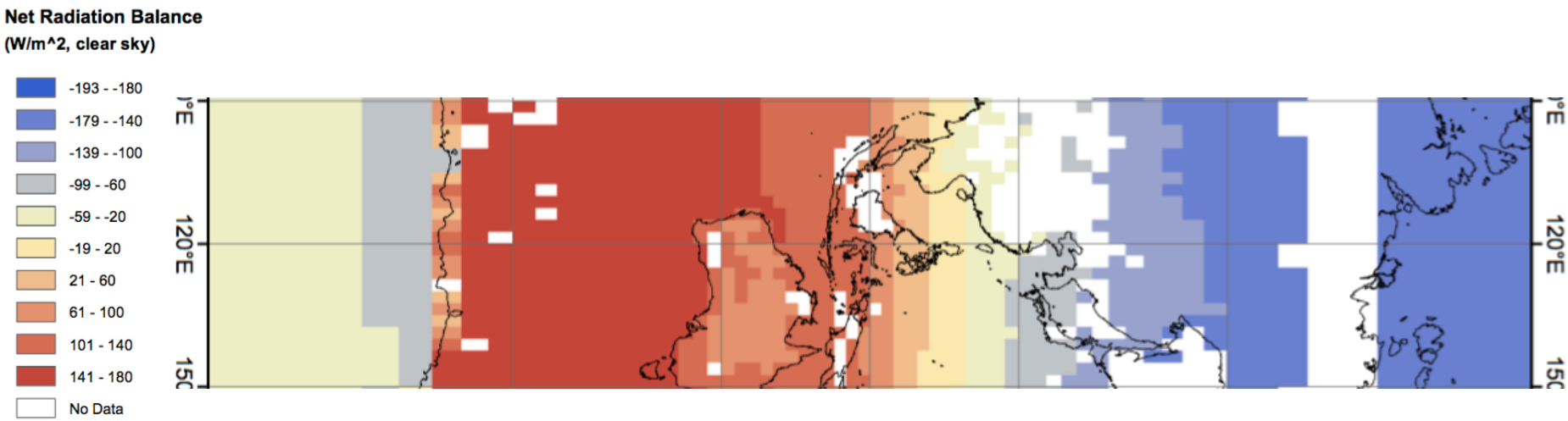






Radiation Balance: 120 East





Balancing the global budget

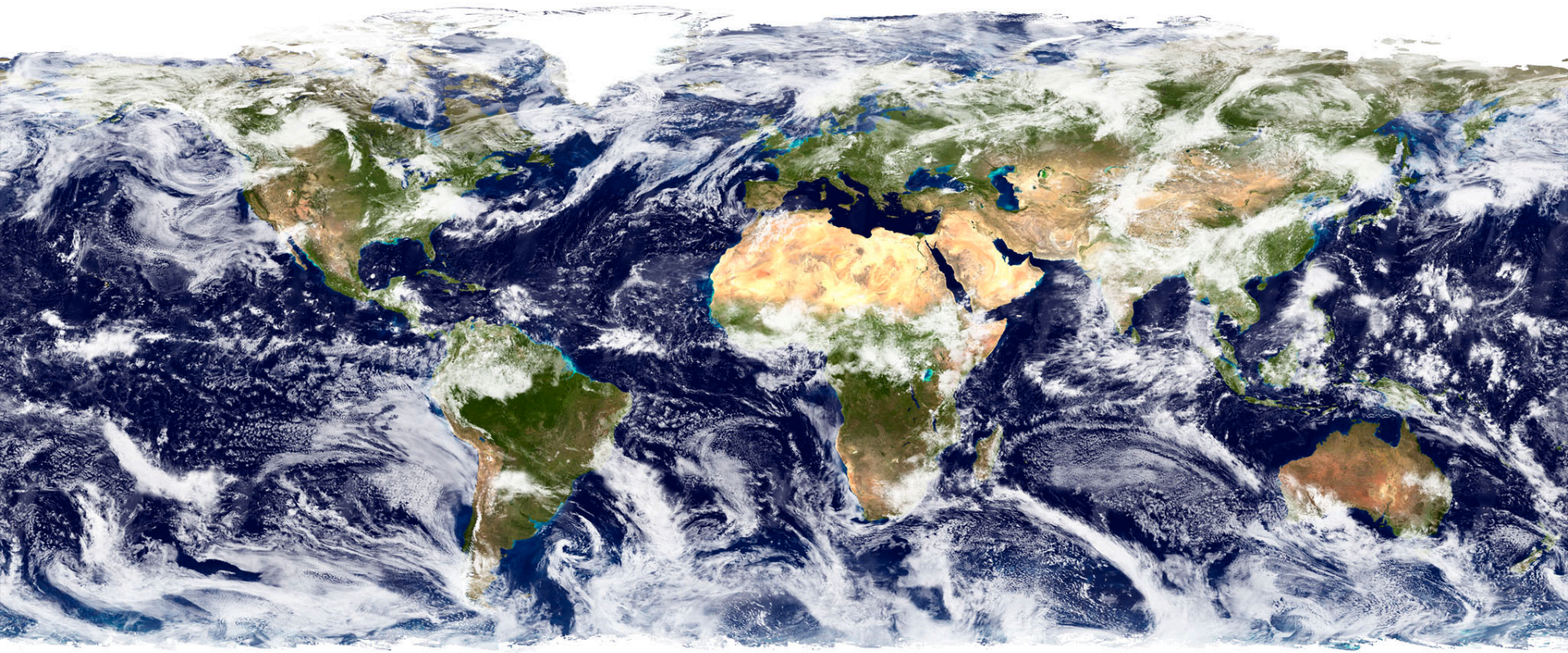
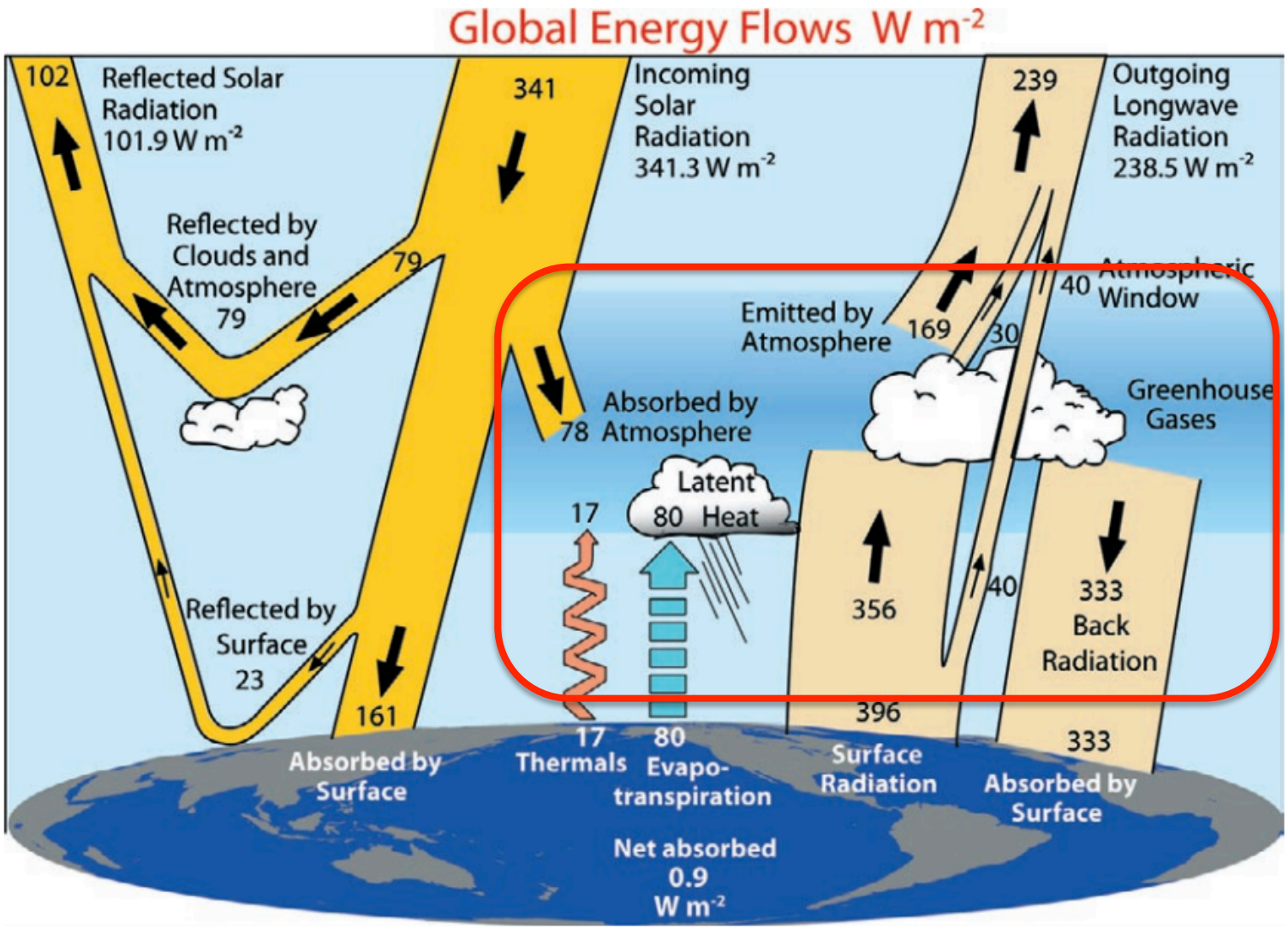


Image: February 2002 Blue Marble Composite – Reto Stöckli, NASA Earth Observatory

The majority of energy is transferred through the atmosphere



Layers of the atmosphere

Image NASA

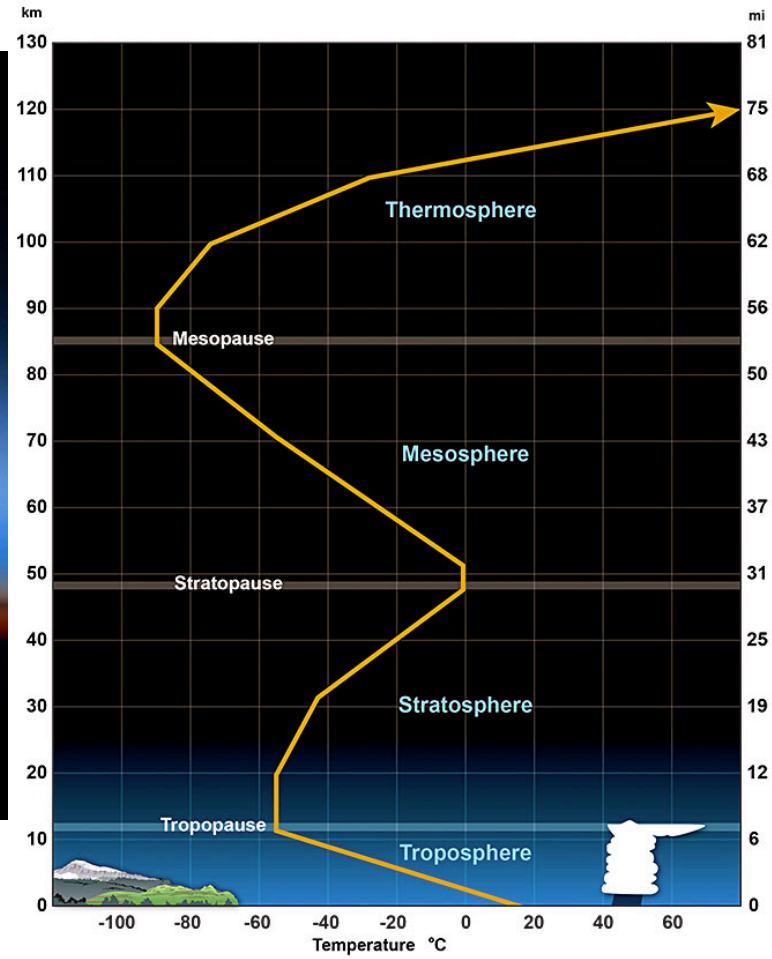


Image NOAA

Mechanisms of heat transfer

Conduction and Radiation

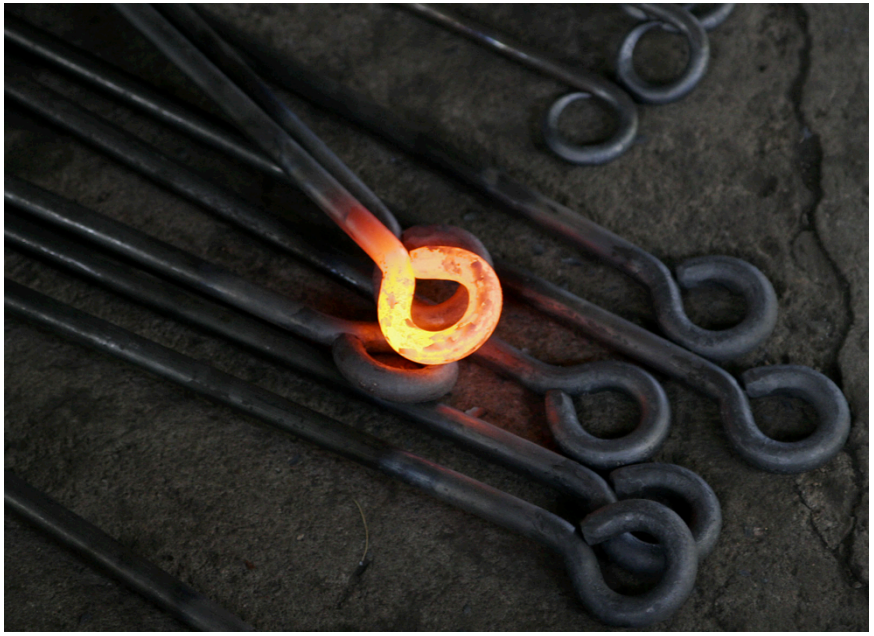


Image Fir0002/Flagstaffotos

Convection

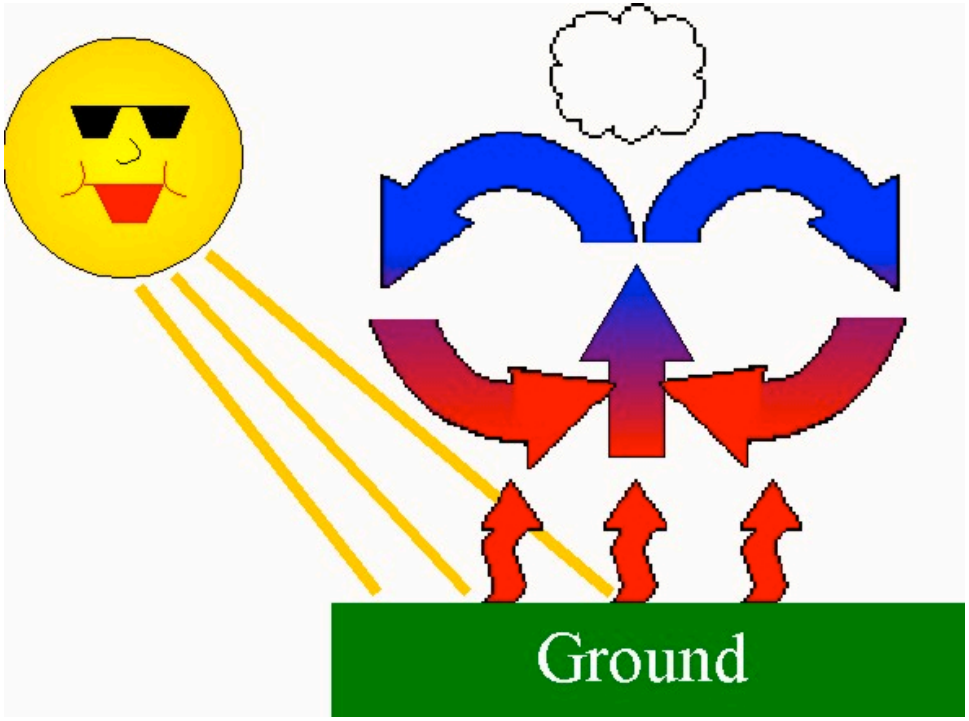
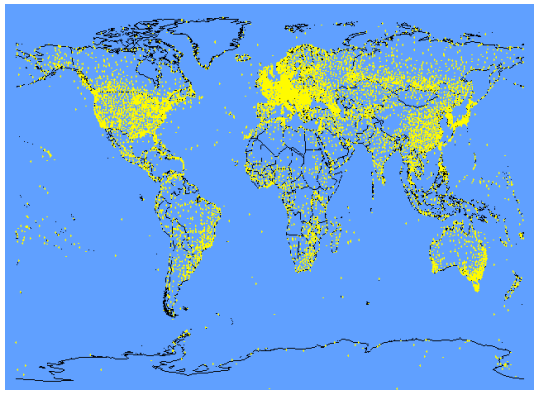


Image NOAA

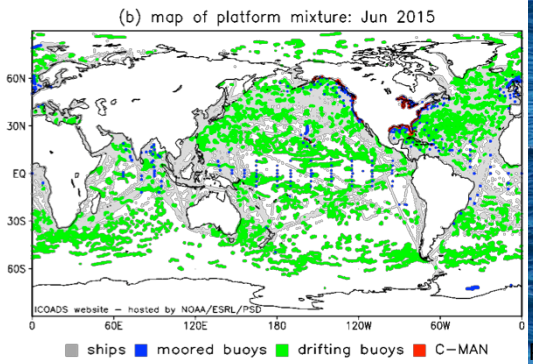
Historic weather data

Photo: Michael Boice

Land surface



Ocean surface



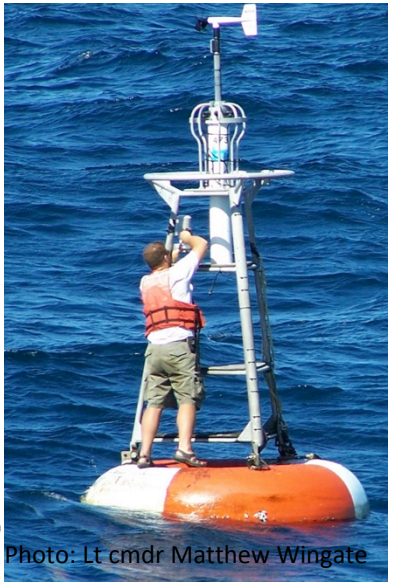
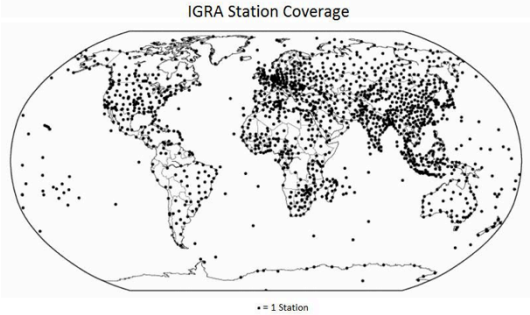


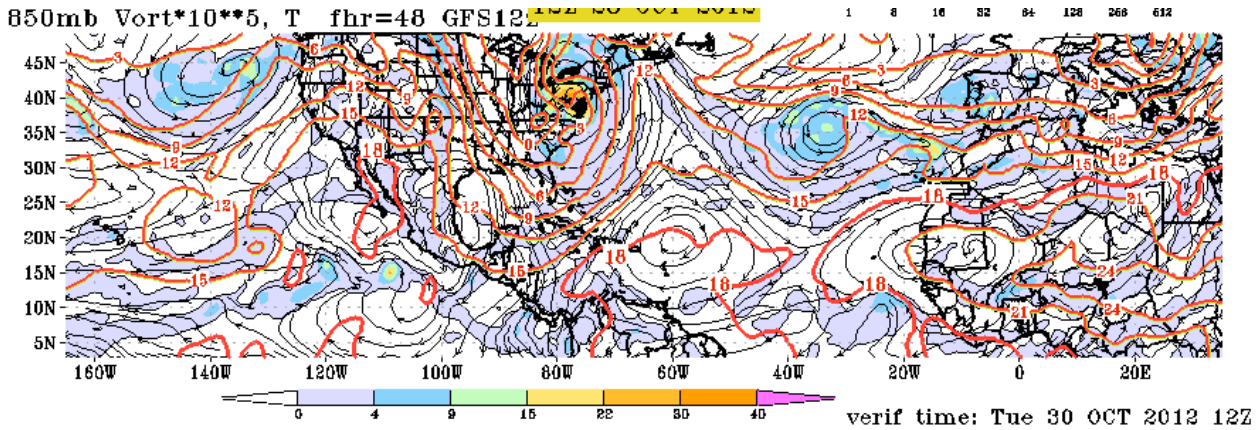
Photo: Lt cmdr Matthew Wingate

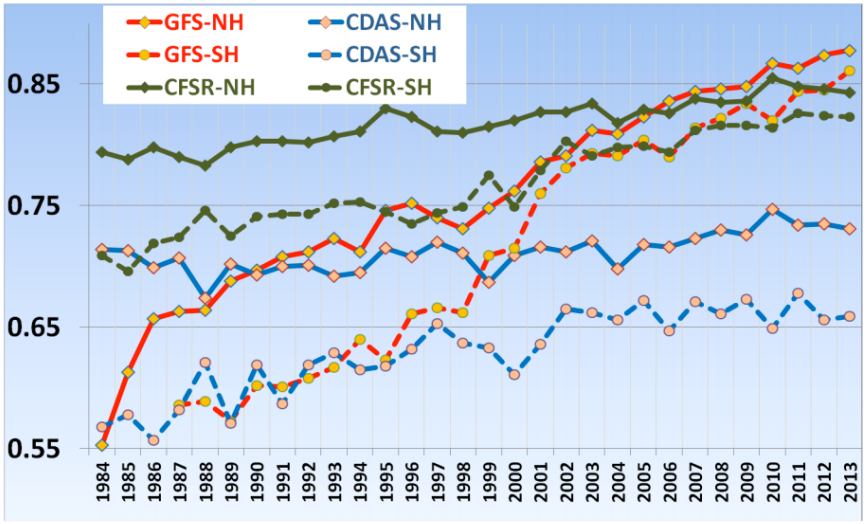
Atmosphere (launched from land)



All images: NOAA

Data are integrated and interpolated using atmospheric models (reanalysis)

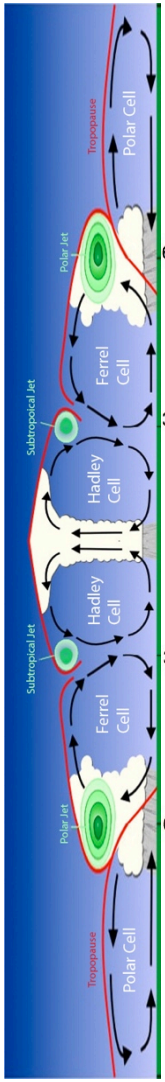


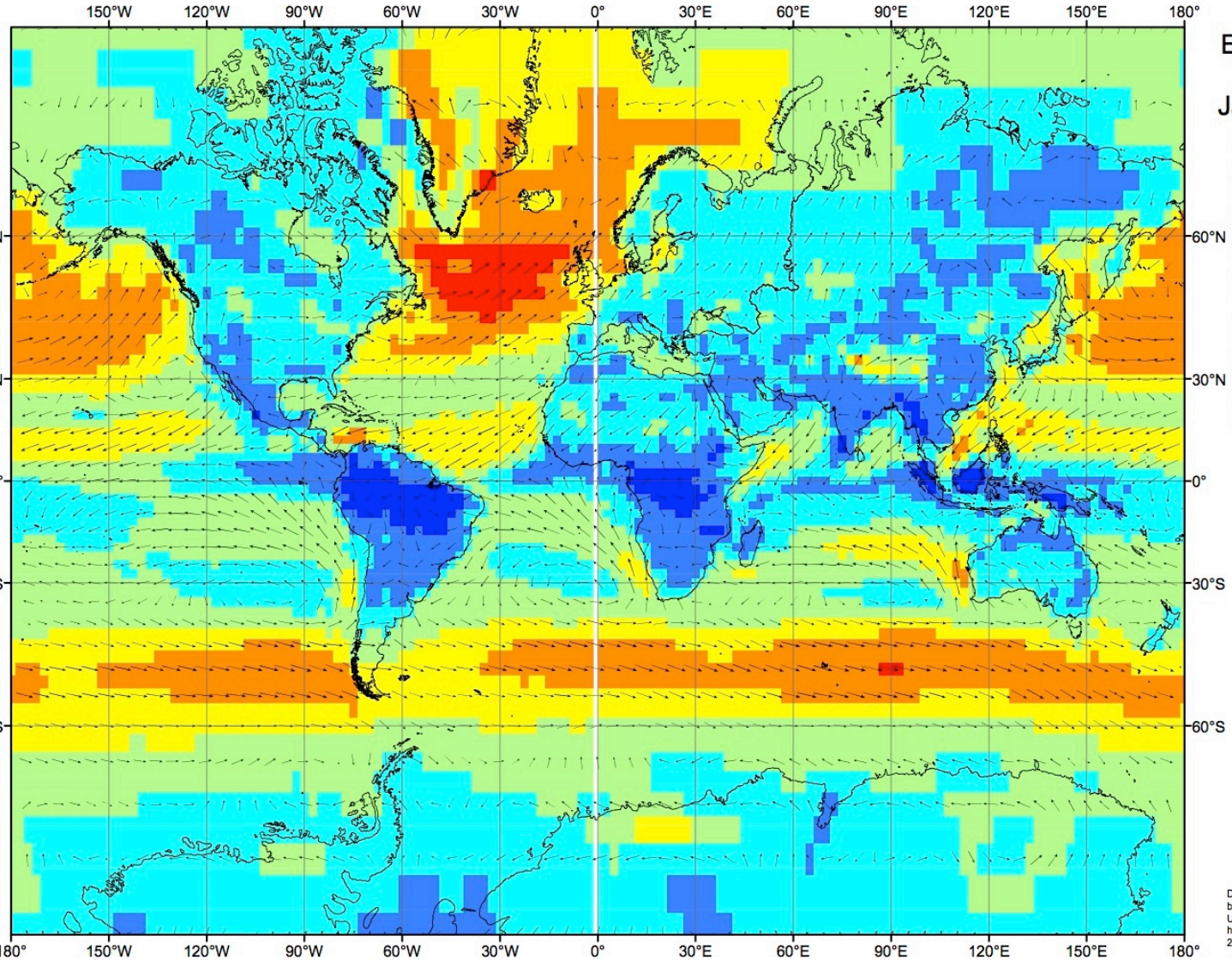


CDAS is a legacy GFS (T64) used for NCEP/NCAR Reanalysis circa 1995.
CFSR is the coupled GFS (T126) used for reanalysis circa 2006.

All images: NOAA

How does atmospheric circulation balance the global radiation budget? (move heat (energy) from from regions of excess toward regions of deficit)





Earth's Atmospheric Circulation January Climatology

The NCEP-NCAR reanalysis uses a consistent forecasting model (state of the art in 1995) to integrate observations from surface, aerial, and satellite systems into a consistent model of the atmosphere for research and monitoring purposes.

Surface winds are calcualted at or near the elevation of the earth's surface. Monthly long-term averages are calculated for the period from 1981-2010.

Horiztontal wind at earth's surface

velocity (m/s)	speed (m/s)
10+	12-14
8-10	10-12
6-8	8-10
4-6	6-8
2-4	4-6
0-2	2-4
	0-2

Data downloaded from NCEP Reanalysis provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. Grid size is 2.5° by 2.5°. Mercator projection. WGS84 datum.

Coriolis effect

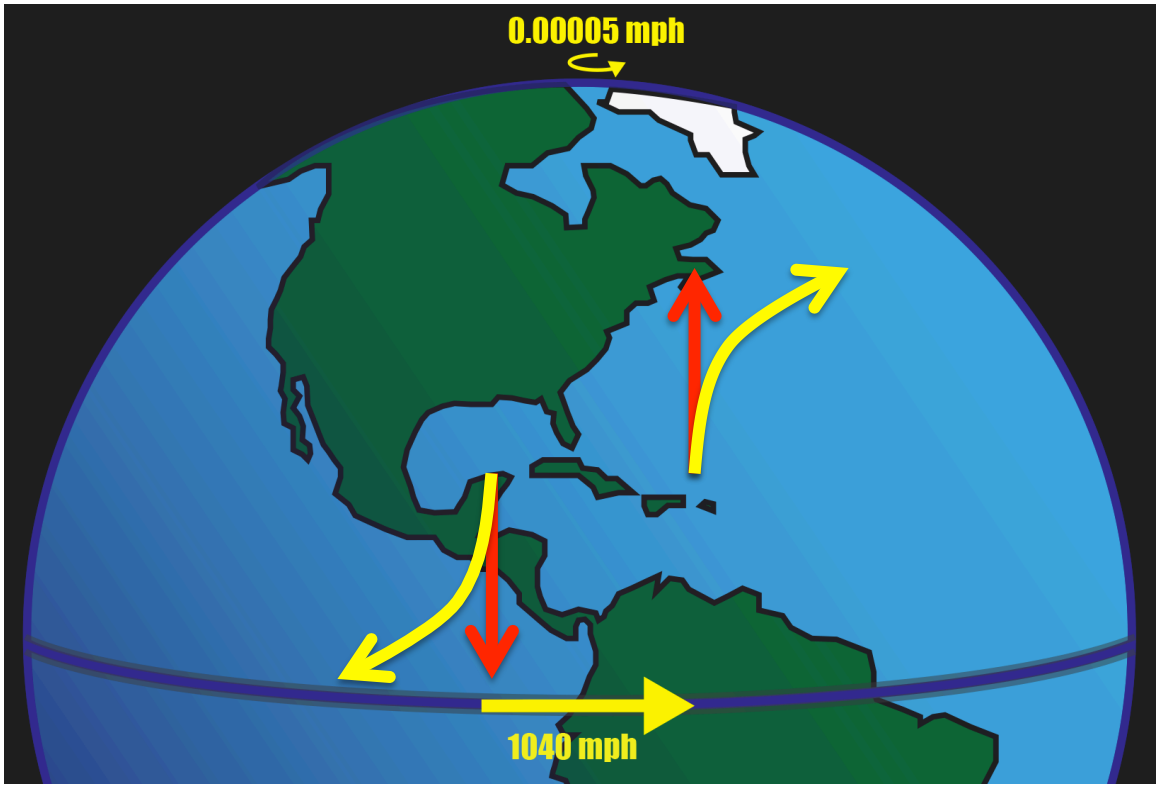
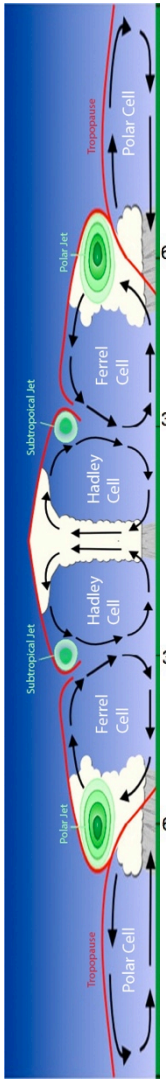
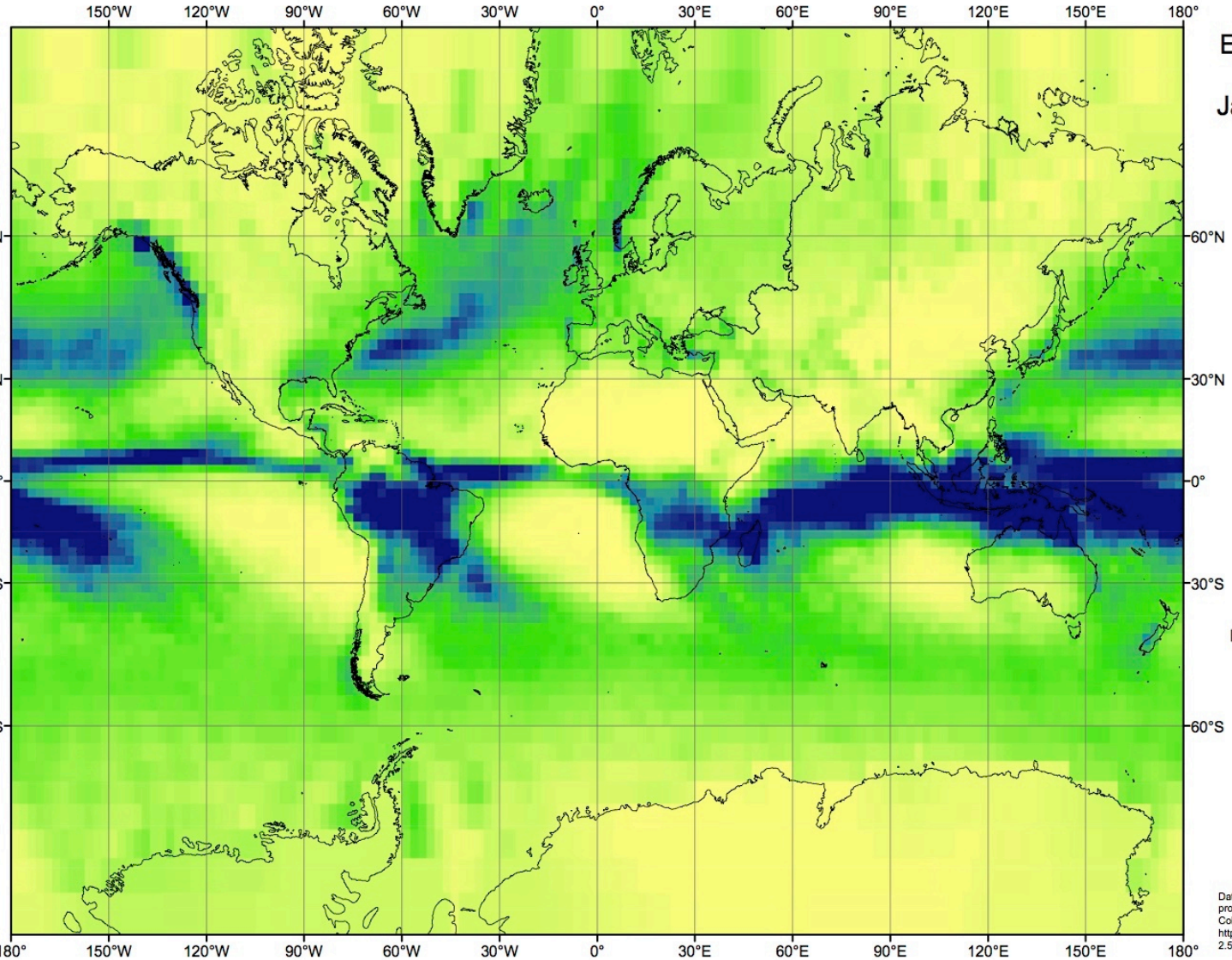


Image from NOAA/NASA SciJinks

How does global atmospheric circulation affect patterns of precipitation?
(explain regions of unusually high or low precipitation)





Earth's Atmospheric Circulation January Climatology

The CMAP precipitation analysis merges gauge, satellite, and numerical model (NCEP-NCAR reanalysis) data to estimate global precipitation.

Monthly long-term averages are calculated for the period from 1981-2010.

The data are presented here using a standard deviation stretch. Values close to the mean are colored green while extreme (> 2.5 standard deviations) are colored blue or yellow.

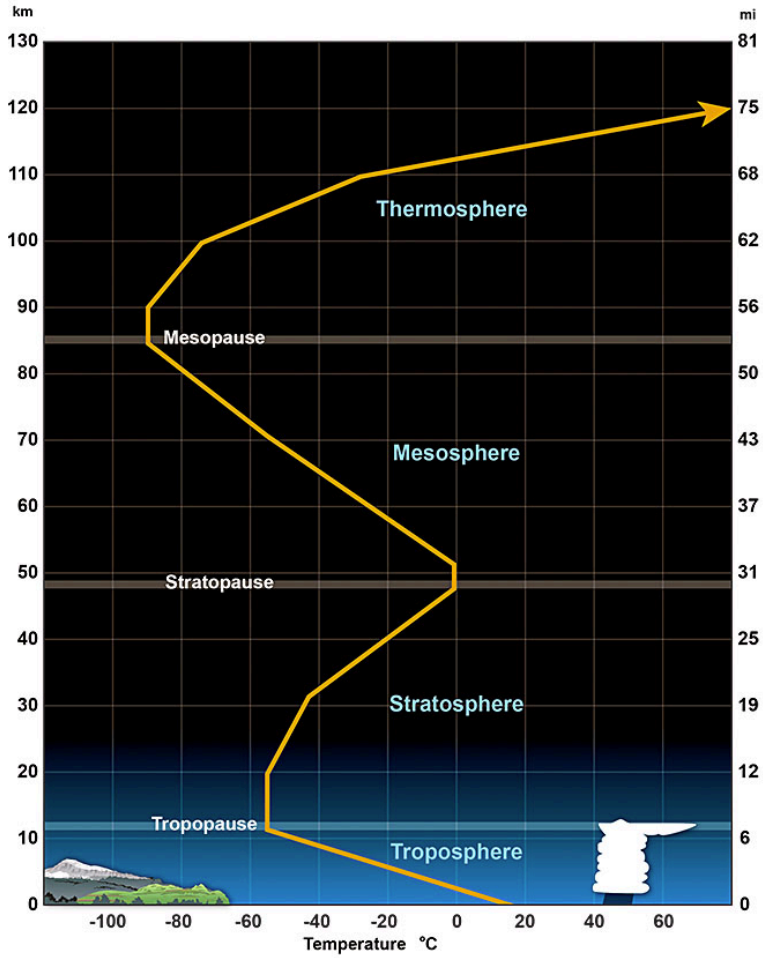
precipitation rate (mm/day)

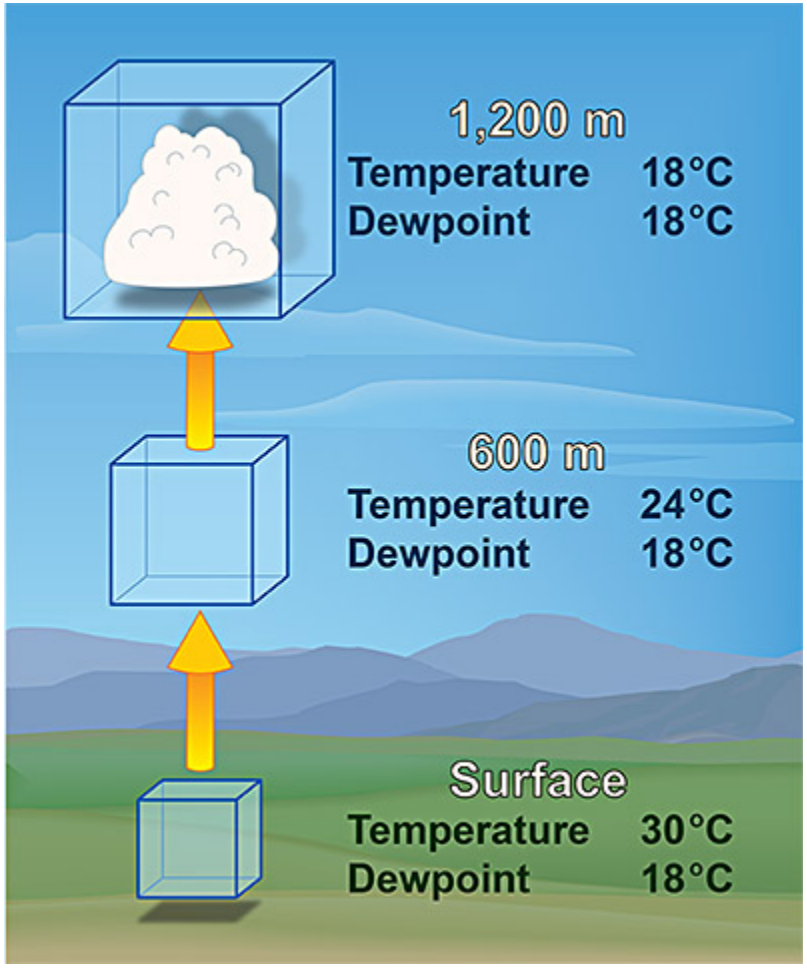
19

0

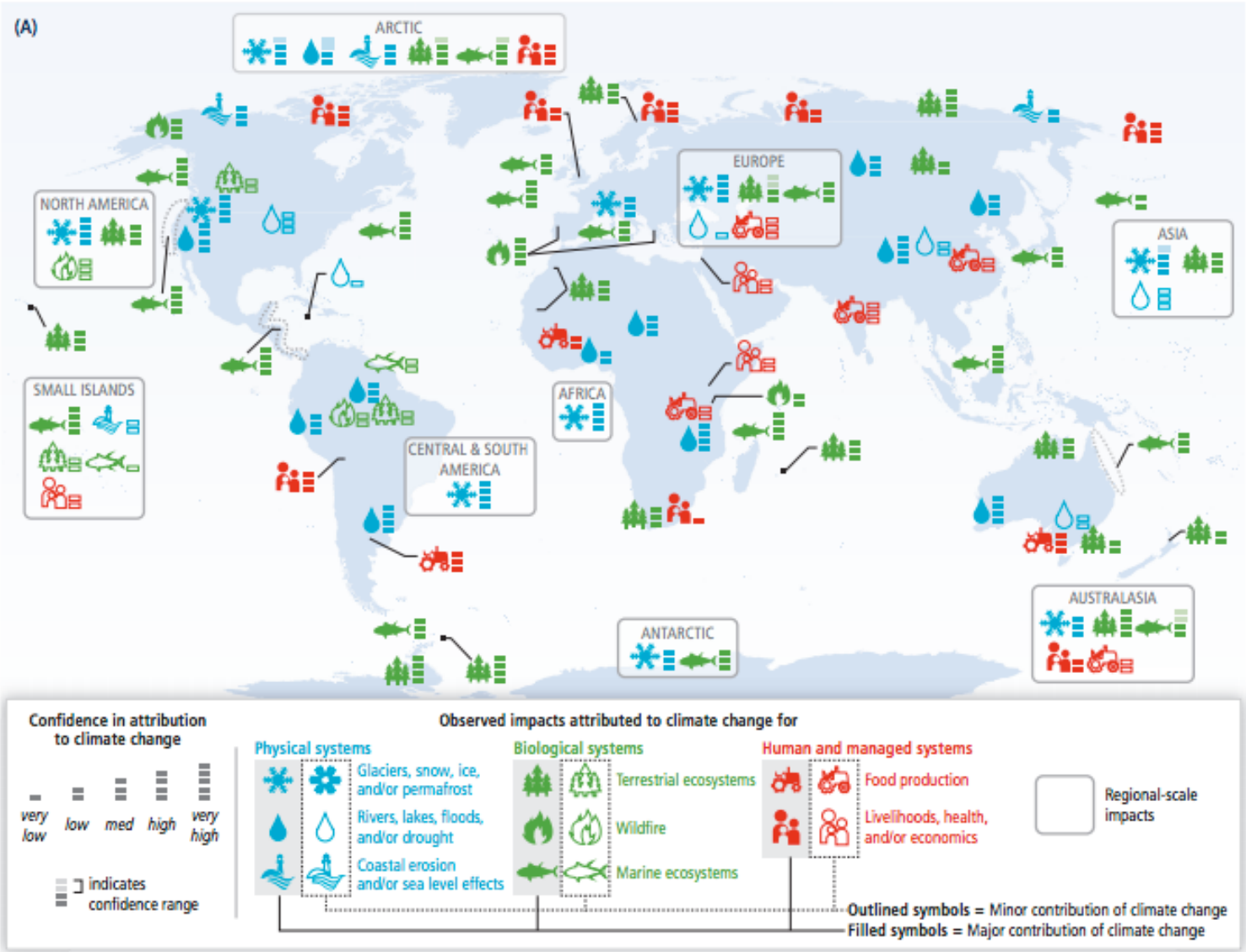
Data downloaded from CMAP Precipitation analysis provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/ Grid size is 2.5° by 2.5°. Mercator projection. WGS84 datum.

Why do clouds form?



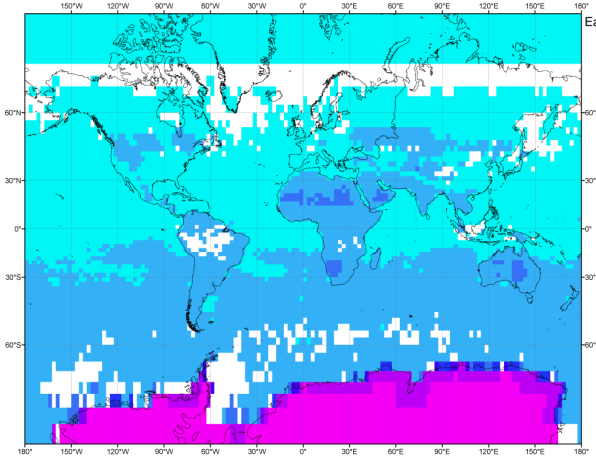


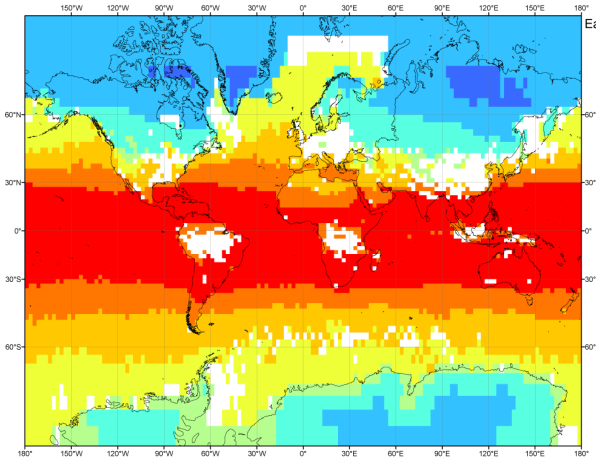
One consequence of a warming climate may be an expansion of Hadley (tropical) cells toward the poles (1-3 degrees over the last 30 yr). Identify a climate change impact that may be caused by this expansion and/or its impact on precipitation.

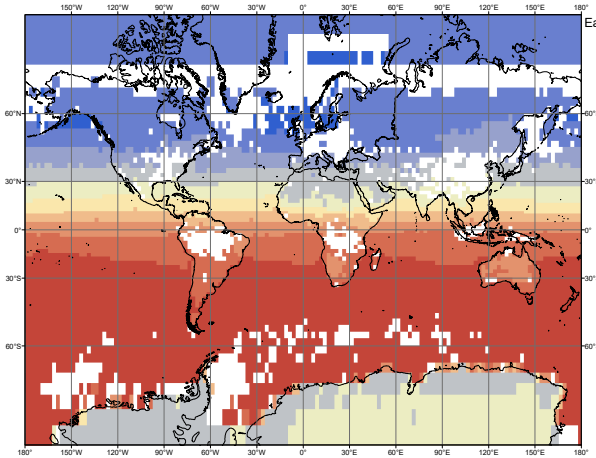
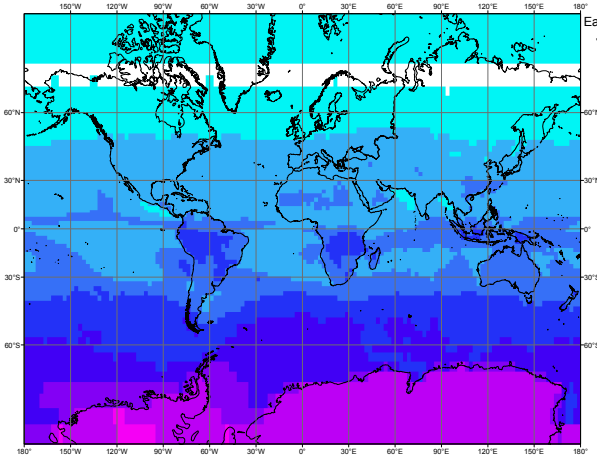
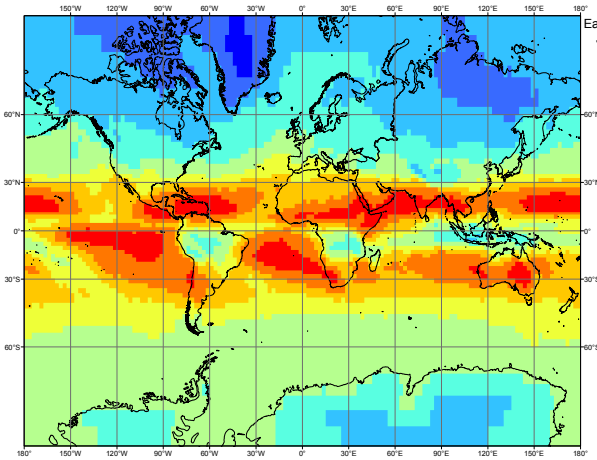
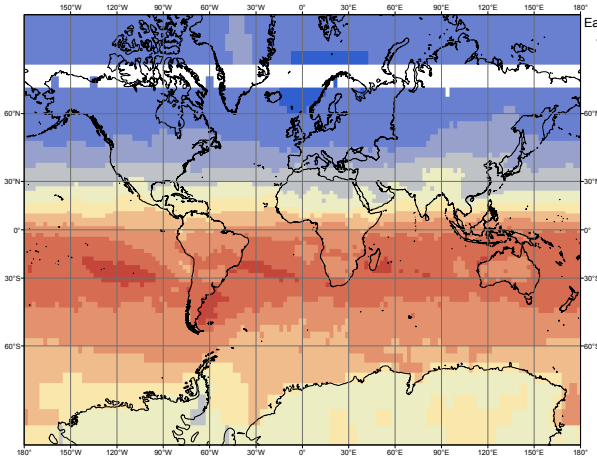


IPCC, 2014

Clear sky







With clouds