MAR 542 – Fundamentals of Atmosphere and Ocean Dynamics
Instructor: Marat Khairoutdinov
Room: 158 Endeavour
Time: Tuesdays and Thursday 11:30 AM – 12:50 PM

Text: Atmosphere, Ocean, and Climate Dynamics: An Introductory Text By John R. Marshall and R. Alan Plumb, Academic Press 2008

This course serves as an introduction to atmosphere and ocean dynamics. It is required of first-year atmospheric science graduate students, and it is recommended for first-year physical oceanography students. It assumes a working knowledge of differential and integral calculus, including partial derivatives and simple differential equations. Its purpose is to prepare students in atmospheric sciences and physical oceanography to move onto more advanced courses in these areas, as well as to acquaint each other with some fundamental aspects of dynamics applied to geophysical fluids outside your area of specialization. It is anticipated that the entire book will be covered. The chapter contents of this text are as follows, but some other topics will also be covered.

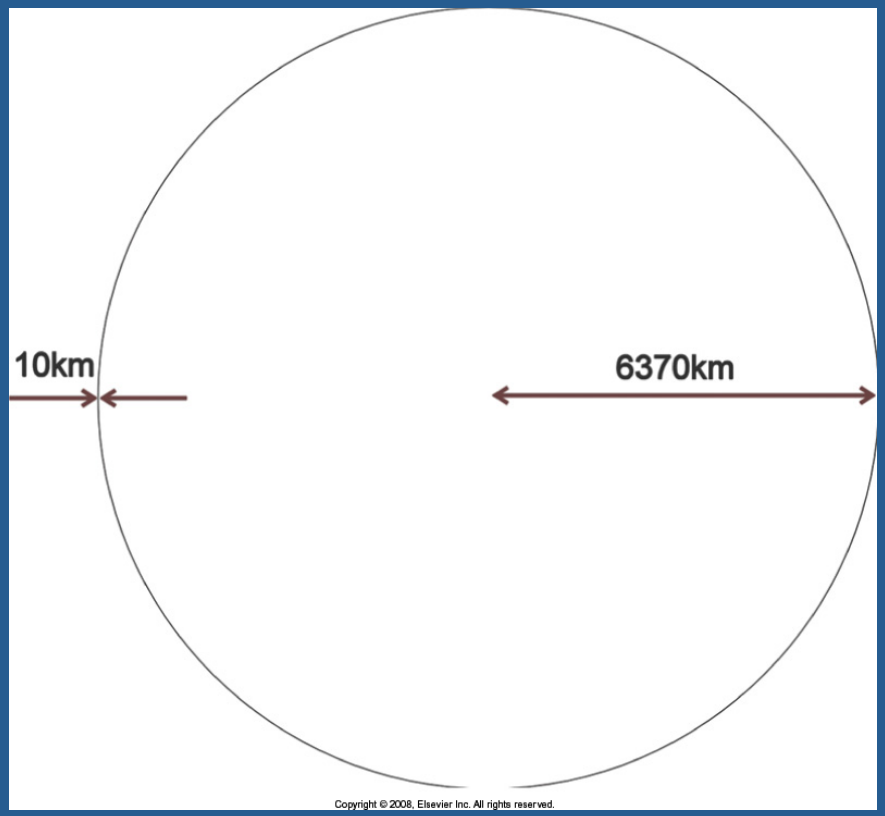
1. Characteristics of the atmosphere
2. The global energy balance
3. The vertical structure of the atmosphere
4. Convection
5. The meridional structure of the atmosphere
6. The equations of fluid motion
7. Balanced flow
8. The general circulation of the atmosphere
9. The ocean and its circulation
10. The wind-driven circulation
11. The thermohaline circulation of the ocean
12. Climate and climate variability

TABLE 1.1. Some parameters of Earth.

Earth's rotation rate	Ω	$7.27 \times 10^{-5} \mathrm{s}^{-1}$
Surface gravity	g	$9.81\ \mathrm{ms}^{-2}$
Earth's mean radius	a	$6.37 \times 10^{6}\ \mathrm{m}$
Surface area of Earth	$4\pi a^2$	$5.09 \times 10^{14}\ \mathrm{m}^2$
Area of Earth's disc	πa^2	$1.27 \times 10^{14}\ \mathrm{m}^2$

TABLE 1.3. Some atmospheric numbers.

Atmospheric mass	Ma	5.26×10^{18} kg
Global mean surface pressure	Ps	1.013×10^{5} Pa
Global mean surface temperature	Ts	288 K
Global mean surface density	ρs	1.235 kg m^{-3}

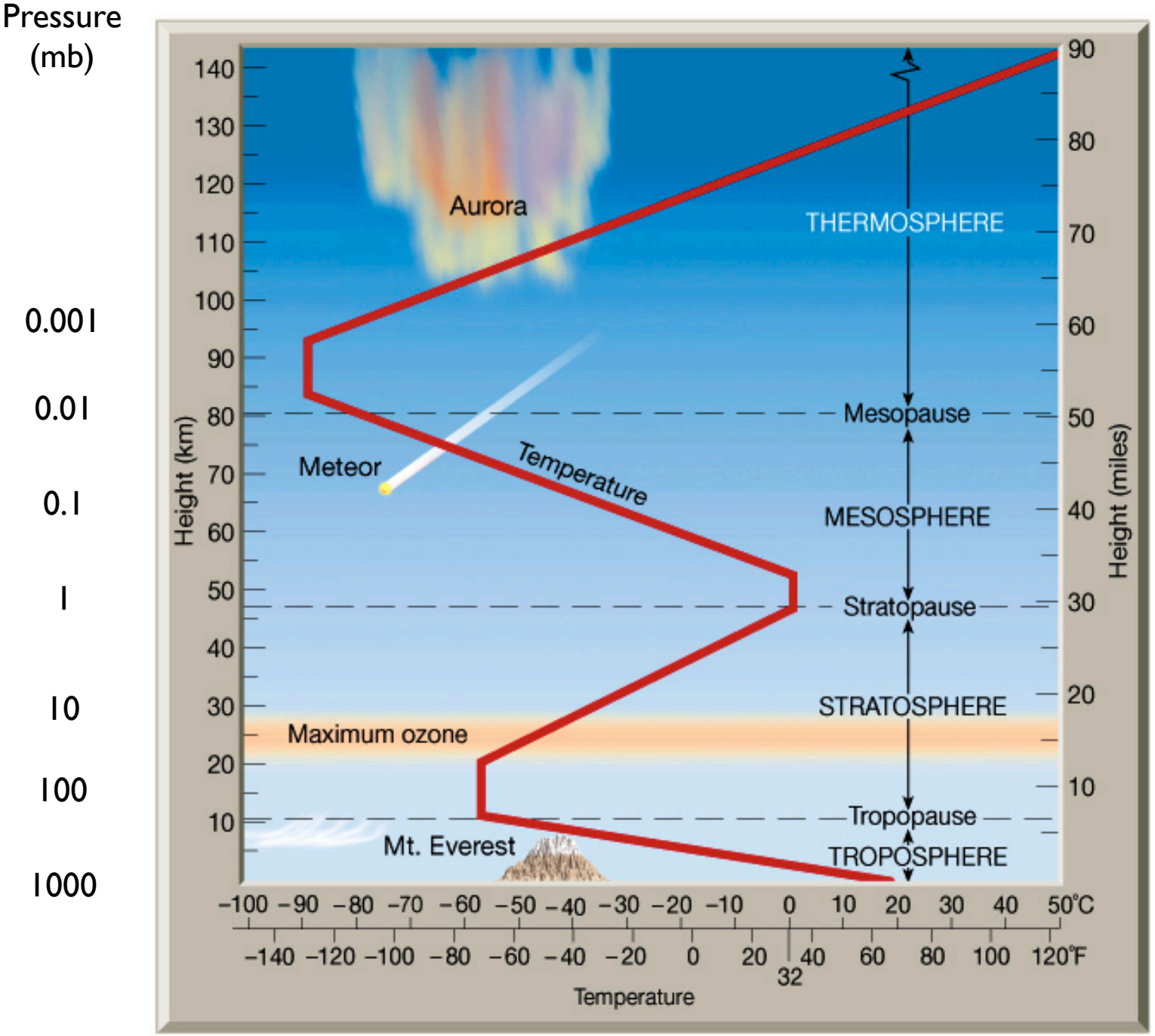


- ~ 80 % of the atmosphere's mass is below 10 km.
- Land covers about 30 % of the Earth's surface.
- The average depth of the oceans is about 4 km.
- ~70 % of the Earth's land is in the Northern Hemisphere.

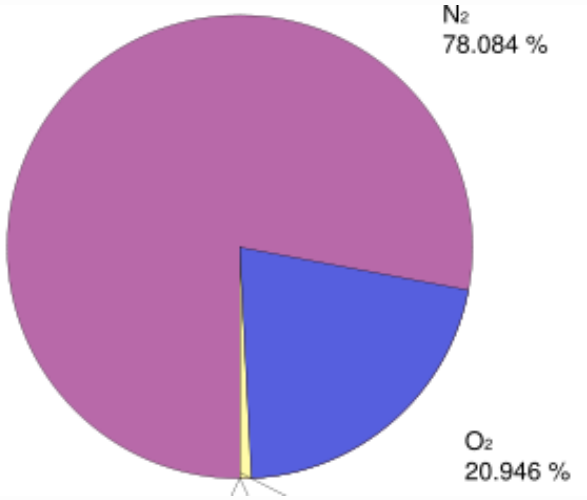
Atmosphere is very thin: 99.9% of mass is below 50 km
Compared to the Earth's radius (6500 km), it is only 1%
which is comparable to the thickness of an apple's skin

Thus, the synoptic-scale systems are quasi-two-dimensional!

Vertical structure of the atmosphere



Permanent vs. Variable Gases



Ar

+

H2O
CO2
O3
CH4

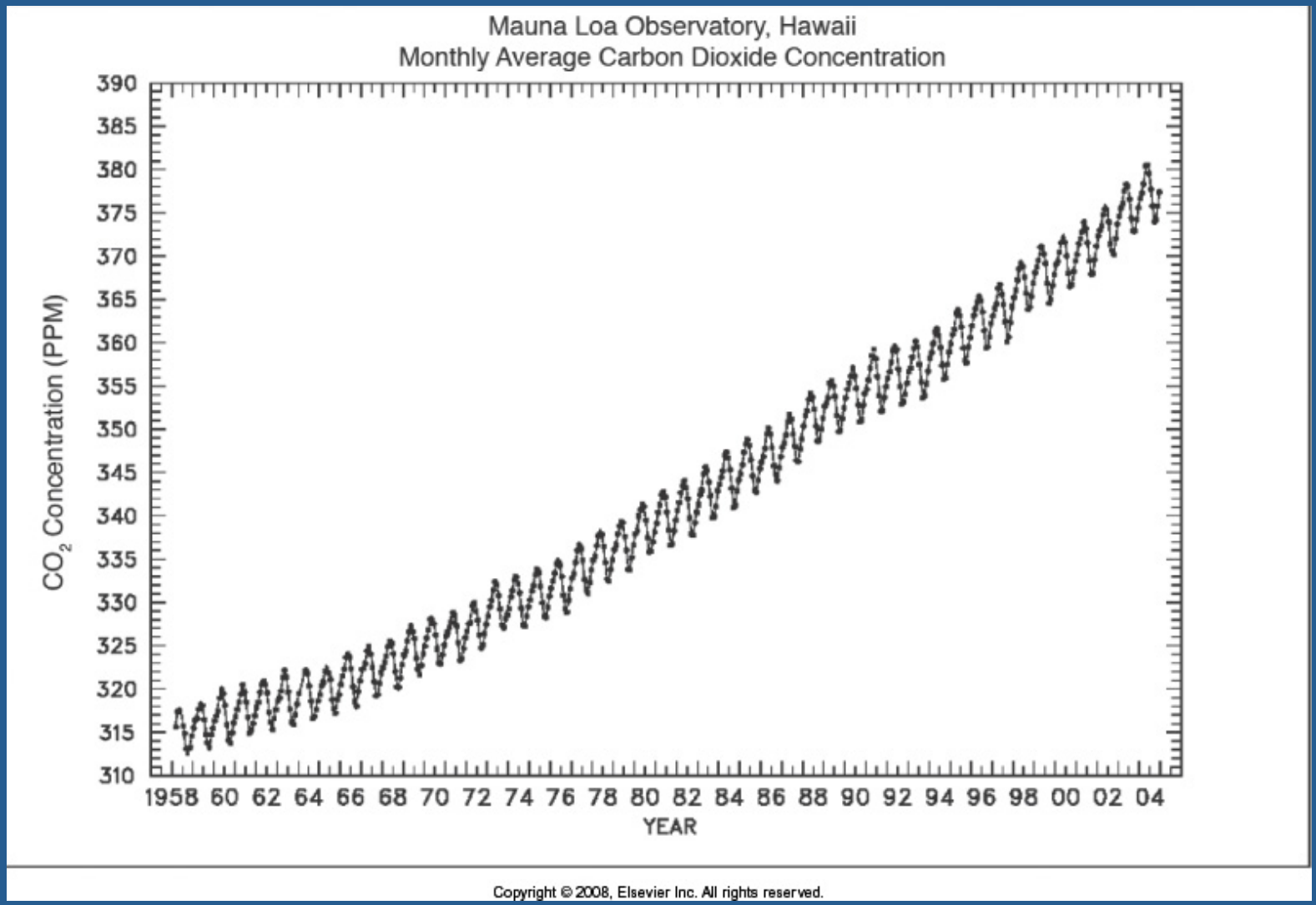
Table 1–1 Permanent Gases of the Atmosphere

Constituent	Formula	Percent by Volume	Molecular Weight
Nitrogen	N_2	78.08	28.01
Oxygen	O_2	20.95	32.00
Argon	Ar	0.93	39.95
Neon	Ne	0.002	20.18
Helium	He	0.0005	4.00
Krypton	Kr	0.0001	83.8
Xenon	Xe	0.00009	131.3
Hydrogen	H_2	0.00005	2.02

Table 1–2 Variable Gases of the Atmosphere

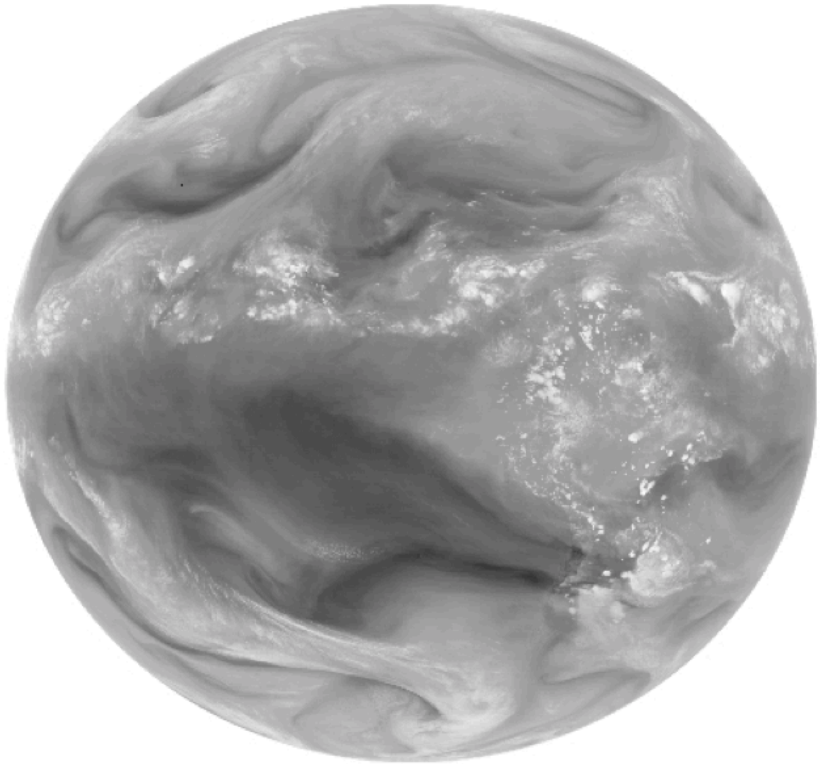
Constituent	Formula	Percent by Volume	Molecular Weight
Water Vapor	H_2O	0.25	18.01
Carbon Dioxide	CO_2	0.036	44.01
Ozone	O_3	0.01	48.00

Methane CH4

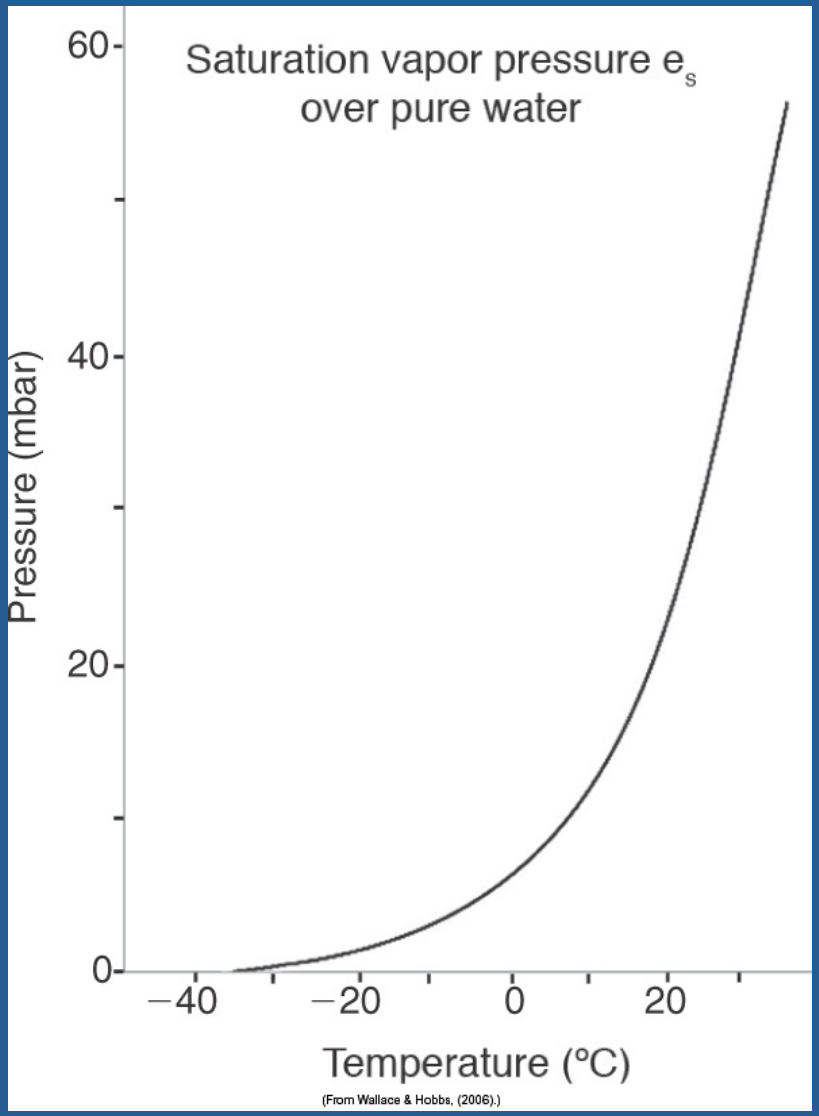


Water Vapor

- Water Vapor
  - The most abundant *variable* gas.
  - Concentrations vary from nearly 0% over desert and polar regions to nearly 4% near tropics.
  - Important in many atmospheric processes.
    - Most important greenhouse gas.
    - Provides fuel for hurricanes and other severe storms.

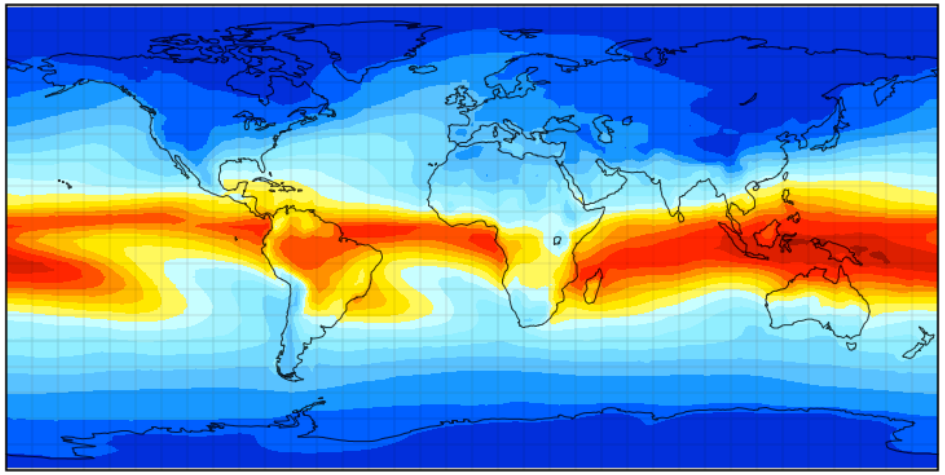


$e_s(T)$

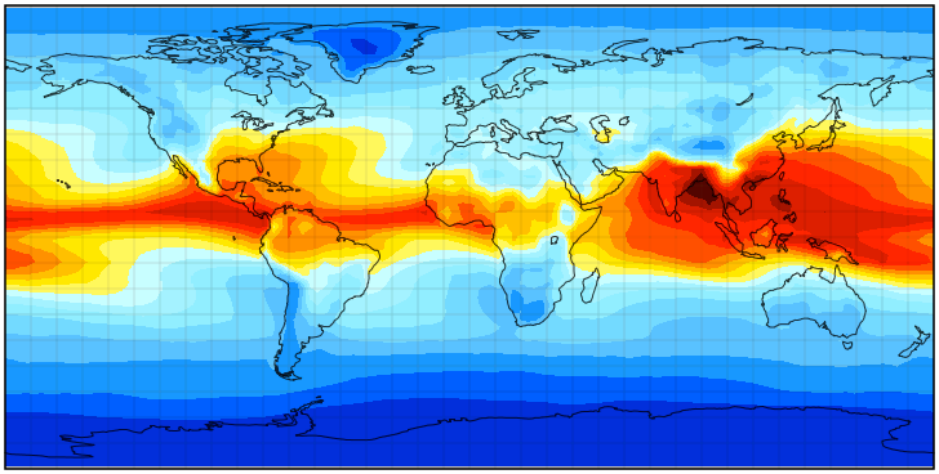

Saturation vapor pressure e_s
over pure water
Pressure (mbar)
60
40
20
0
−40
−20
0
20
Temperature (°C)
(From Wallace & Hobbs, (2006).)

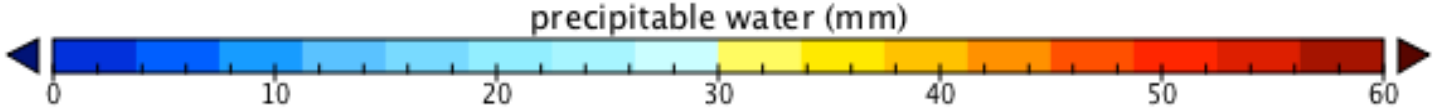
Integrated column water (precipitable water), mm per m^2

Mean for December-January-February



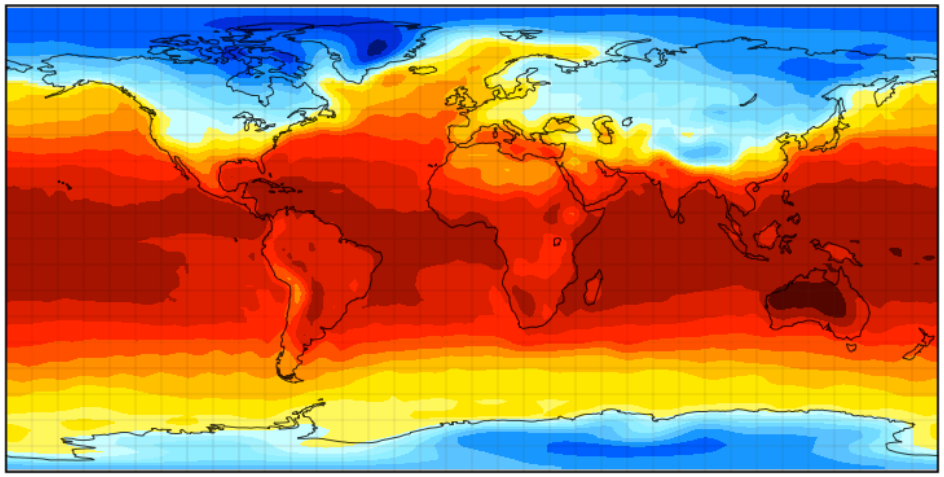
Mean for June-July-August



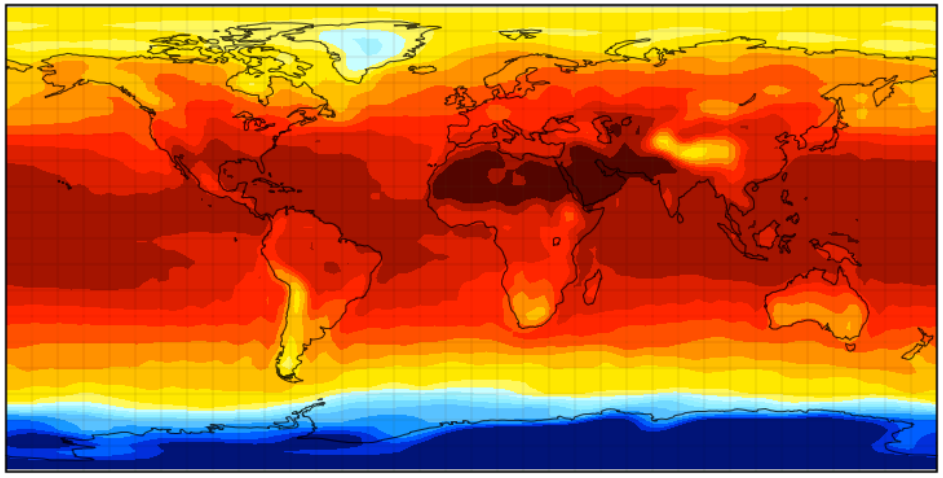


Surface temperature, °C

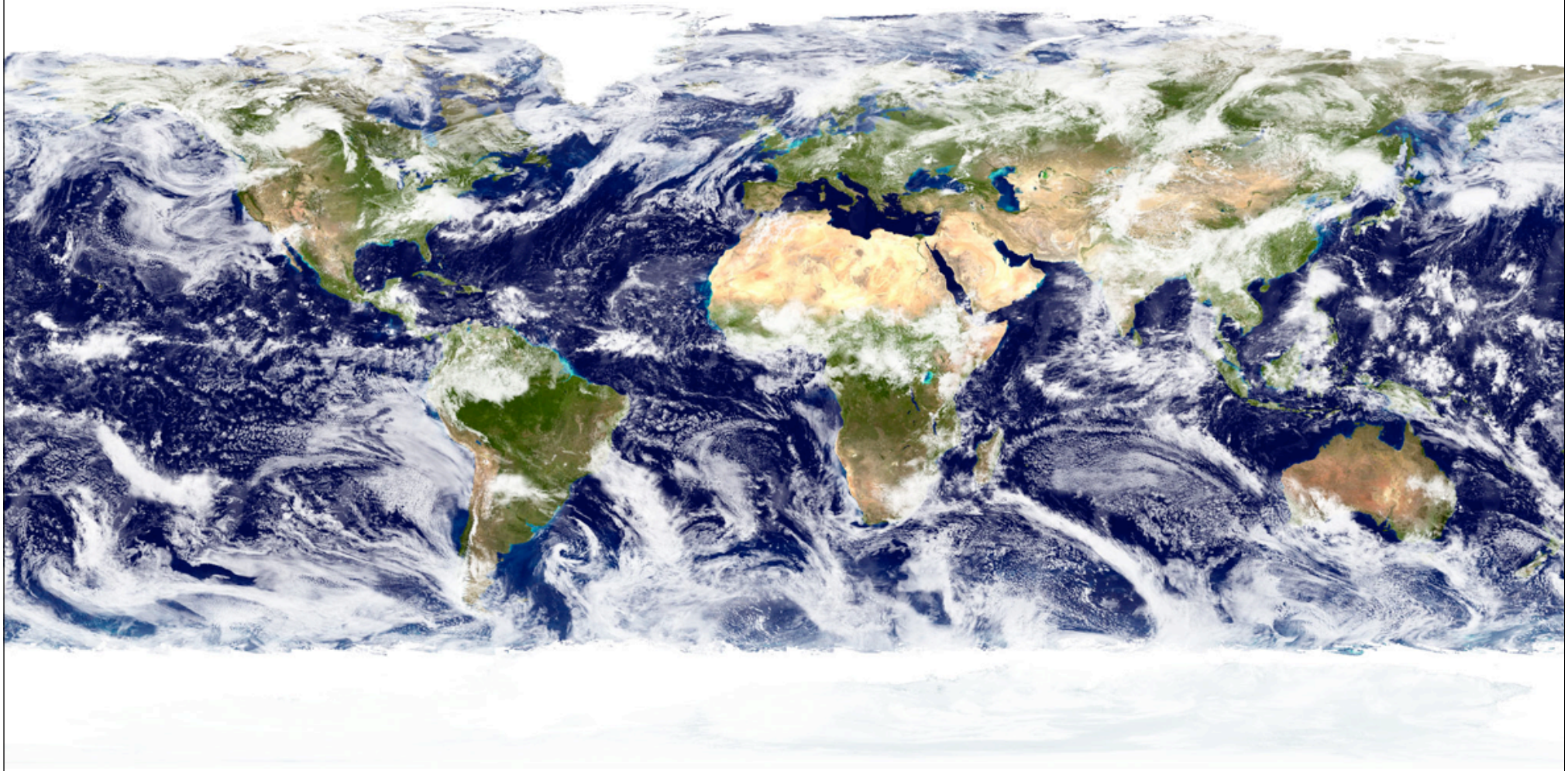
Mean for December-January-February



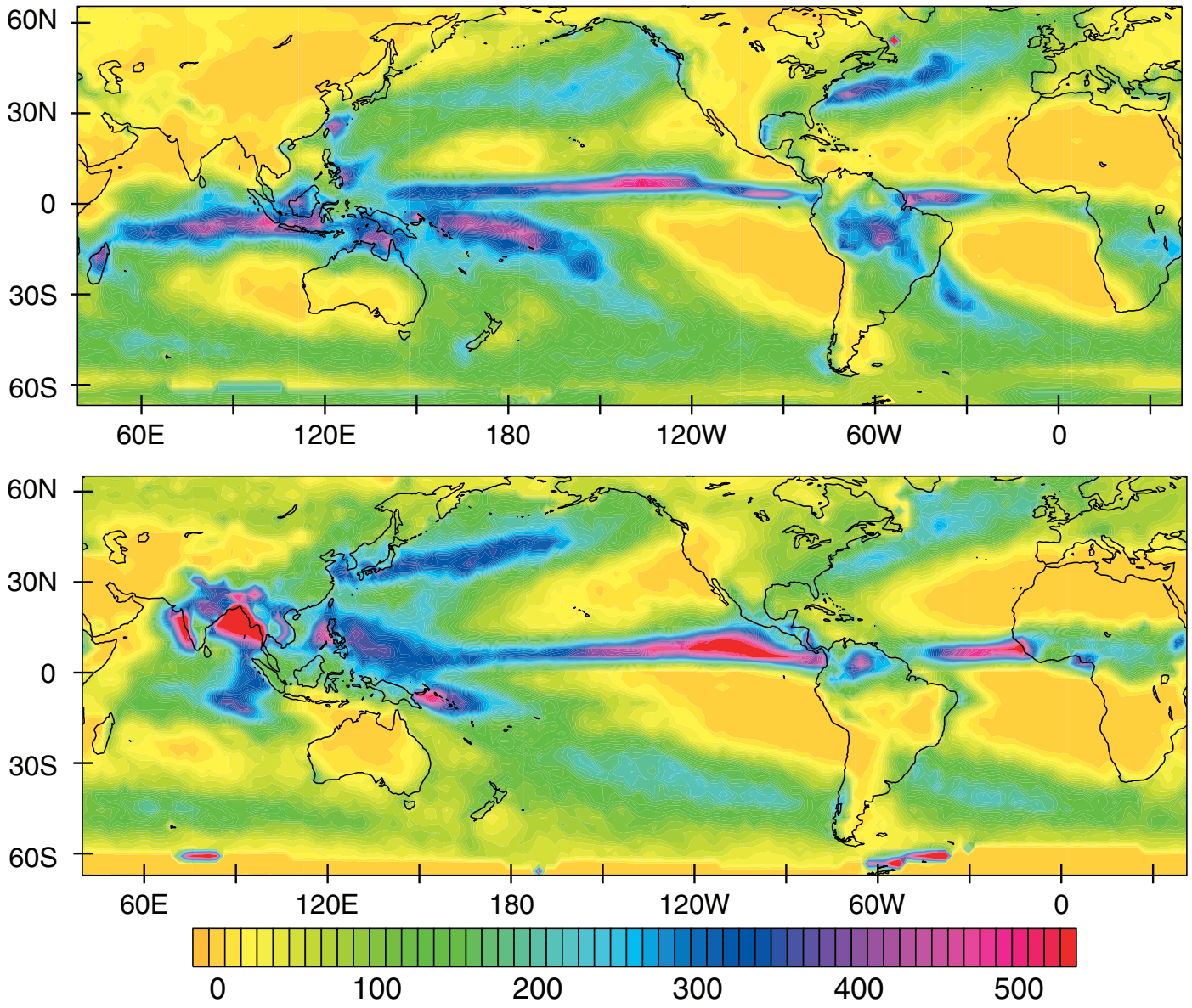
Mean for June-July-August

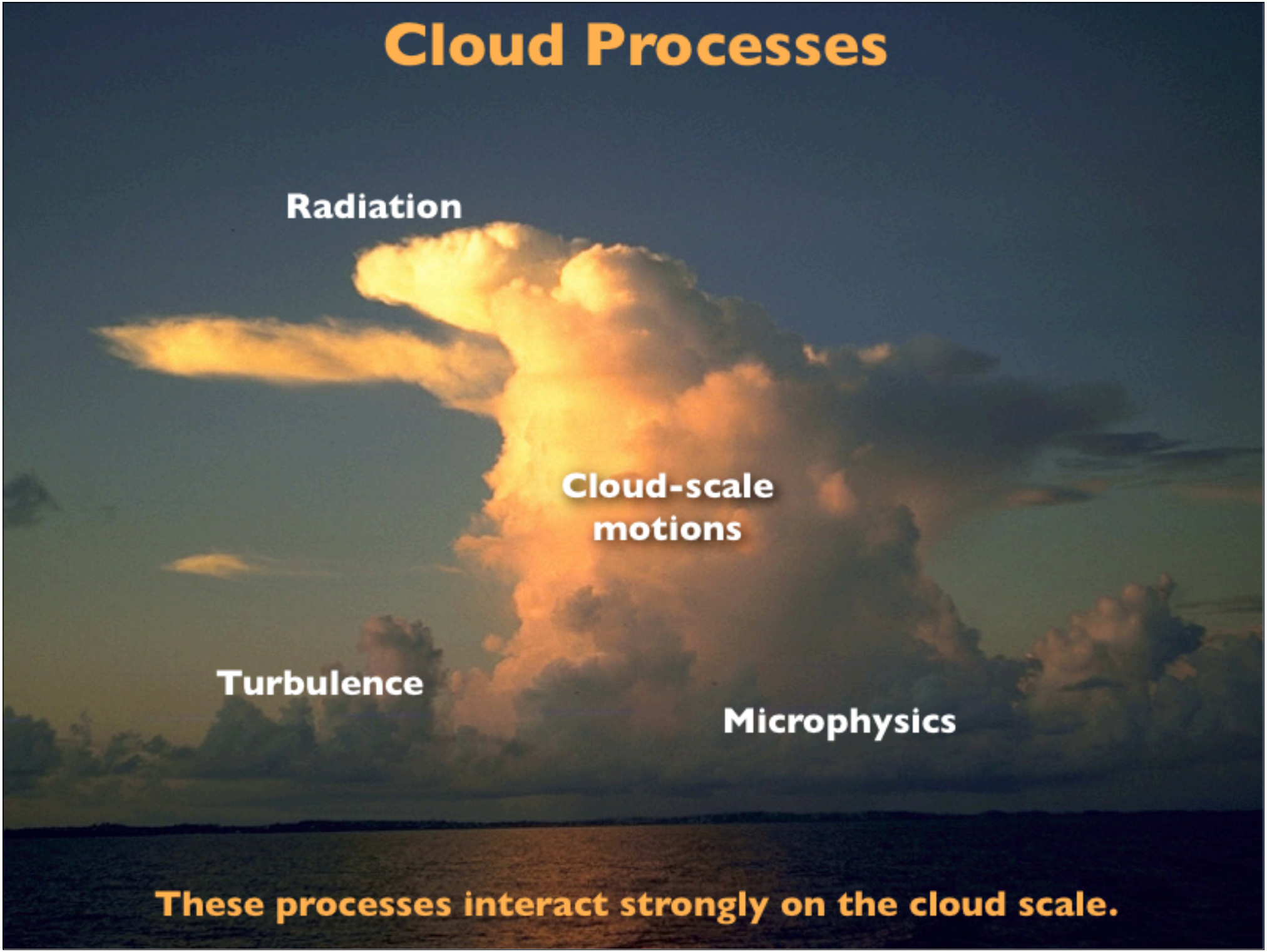


clouds



January (top) and July (bottom) climatological mean precipitation




Cloud Processes
Radiation
Cloud-scale motions
Turbulence
Microphysics
These processes interact strongly on the cloud scale.

Clouds, radiation and boundary layer play central roles in the Earth climate system