ATMS 211. Midterm exam. 7 February 2011 58 points total. *6 pages*

Name Answers

1. (4 points) Rank the planets Venus, Earth, Mars on the following criteria. The first two have been done as examples.

Distance from Sun	Mars > Earth > Venus
Size	Venus ≈ Earth > Mars
Atmospheric pressure at surface	Venus > Earth > Mars
Surface temperature	Venus > Earth > Mars
Magnitude of greenhouse effect	Venus > Earth > Mars
Planetary albedo	Venus > Earth > Mars

2. (12 points) Briefly describe or explain (2 points each):

effective temperature of a planet

T_e, defined by $\frac{S}{4}(1-A) = \sigma T_e^4$

trade winds

surface branch of Hadley cell,
from northeast (0°–30°N)
from southeast (0–30°S)

Stefan-Boltzmann law

$F = \sigma T^4$

Vostok

Russian research station in East Antarctica

atmospheric window The spectral region 8-12 μm in the infrared, where atmospheric gases do not absorb radiation (except ozone at 9.6 μm), so radiation emitted by the surface escapes to space (if the sky is clear).

Daniel Gabriel Fahrenheit: what meteorological instrument did he invent?

thermometer

3. (12 points) Two-point short answers.

(a) What are the two most common elements in the Sun?

Hydrogen, helium.

(b) The meter was defined in 1790 as a standard unit of length. How was it defined (i.e., why was this particular length chosen)?

one ten-millionth of the distance from equator to pole along a line of longitude.

(c) The Pinatubo volcano erupted in June 1991. The resulting stratospheric aerosol of sulfuric acid spread over the globe in a few months and increased the planetary albedo. During 1992 this aerosol reduced the global average absorbed solar radiation by 4 W m^{-2}. According to GCMs, the sensitivity of global surface temperature to top-of-atmosphere radiative forcing is about 0.75 K / W m^{-2}, so we might expect a response of -3 K. But the global average temperature for 1992 was only 0.4 K colder than the average of the previous 5 years. Why was the response so small? Because of the large thermal inertia of the ocean, it takes ~15 years for the ocean to respond to a climate forcing. A small fraction of the response is experienced in the first year, as observed.

(d) The surface albedo of Earth, averaged over all land and ocean, is 10%. Why is the Earth's average planetary albedo, 30%, so much higher than the surface albedo?

clouds reflect sunlight.

(e) Temperature decreases with height in the troposphere. Why does it increase with height in the stratosphere?

Ozone is in the stratosphere and absorbs ultraviolet sunlight.

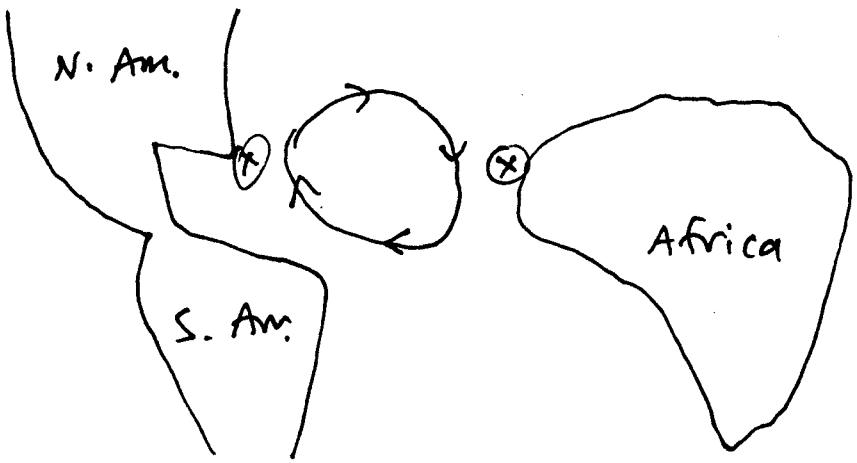
(f) If you circle the Earth along latitude 65°N in January, where will the temperature on land be warmest? Why? On the west coast of Norway. The Gulf Stream and North Atlantic circulation bring warm water to North. The winds come from the west, so this oceanic warmth affects Europe much more than Canada.

4. (6 points) Three-point short answers

(a) The Earth is now approximately in radiation balance, with absorbed solar radiation = 240 W m^{-2} and outgoing longwave radiation (OLR) = 240 W m^{-2}. Suppose that the Sun were suddenly to brighten by about 2%, so that the absorbed solar radiation increased to 245 W m^{-2}. The planet would then be out of radiation balance, gaining energy at the rate of 5 W m^{-2}. The planet would start warming as a result of the extra heating. Would the temperature continue to rise indefinitely? If not, what would stop it?

No, it would not rise indefinitely. Temperature would rise until OLR increased to equal absorbed solar; then temperature would stay at the new equilibrium value.

(b) The annual rainfall at Miami, Florida (60 inches) is more than ten times the annual rainfall at Tefia, Canary Islands (just off the west coast of Africa; 5 inches), even though they are at the same latitude (26°N). Why are their climates so different?



Ocean circulation brings warm water up from the equator to Florida, causes evaporation, convection, rainfall. Otherwise this latitude is desert.

5. (3 points) Multiple choice (circle the correct answer)

(a) In the oasis of Ghardaia in Algeria, where does the water supply come from to irrigate the date-palms:

rainfall, glacial meltwater, subterranean aquifer, Nile River

(b) The city of Darwin, Australia, was destroyed in 1975 by:

earthquake, hurricane, landslide, surging glacier, burial in drifting sand

(c) The town of Ain Salah in Algeria is at risk of:

earthquake, hurricane, landslide, surging glacier, burial in drifting sand

6. (6 points) Multiple choice.

midlatitude value of precipitable water (centimeters)	0.3	3	30	300
variation of solar constant over a sunspot cycle	0.1%	1%	10%	100%
mixing ratio of CO_2 in 1940 (parts per million)	0.3	3	30	300

On the March-equinox at noon, what is the flux of solar radiation received on a horizontal surface at the top of the atmosphere ($W\ m^{-2}$)

at the Equator	0	1370	1370/2	1370/4	1370/8
at 60°N	0	1370	1370/2	1370/4	1370/8
at the North Pole	0	1370	1370/2	1370/4	1370/8

7. (5 points) Some climate researchers believe that the water-vapor content of the atmosphere will increase if the Earth's surface and lower atmosphere warm as a result of increased carbon dioxide.

(a) Explain why you think this is or is not a reasonable expectation. Give evidence if possible.

Yes, it's reasonable. Measurements show more water vapor in summer than in winter, and more water vapor at low latitude than at high latitude. With increasing CO_2 we expect warming and therefore more water vapor.

(b) If water vapor content of the atmosphere were to increase as the climate warms, would this produce a positive or negative feedback effect, or no feedback at all? Explain your reasoning.

Positive (i.e. amplifying)

↑ greenhouse ⟹ ↑ temp. ⟹ ↑ water vapor

⇓

↑ temp. ⟸ ↑ greenhouse

8. (4 points)
Cirrus is a high thin cloud; stratus is a low cloud. An increase in cirrus cloud cover is expected to warm the climate, but an increase in stratus cloud cover is expected to cool the climate. Why?

For cirrus, the cloud is colder than the surface ($T_c < T_s$), so introduction of cirrus causes reduction of OLR. And because it's thin it doesn't reflect much sunlight.

Stratus has $T_c \approx T_s$ so it has little longwave effect; albedo effect dominates.

9. (6 points) The continent of Australia spans the latitude range 11°S to 39°S and therefore contains several different climatic regions. The western and central part of the continent can be divided into a small number of latitude zones differing in their seasonal rainfall patterns. Give
- the approximate boundaries of each zone (latitude in °S),
- a label that describes the climate of each zone (e.g. "summer rains", etc.),
- the time of year (name the month or months), if any, in which most of the rainfall occurs.