Geography Review Exam I

Test bank of questions at:
http://www.msubillings.edu/sciencefaculty/Spring%202010%20handouts.htm
The Earth is a sphere
The Shape of the Earth

the Earth’s shape is very close to spherical (oblate ellipsoid or spheroid (flattened at the poles))

\[ D_{\text{polar}} = 7900 \text{ miles} = 12,714 \text{ km} \]

\[ D_{\text{equator}} = 7926 \text{ miles} = 12,756 \text{ km} \]
The Geographic Grid

a) **Latitude (Parallels)**

1 degree latitude = a constant 111 km

b) **Longitude (Meridians)**

1 degree of longitude = 111 km at the equator and 0 at the poles

Figure 1.3, p. 28
Earth’s Revolution around the Sun

sun is not in the middle of the plane of the ecliptic

**Aphelion** - the Earth furthest away from Sun (July 4)

**Perihelion** - the Earth closest to Sun (January 3)

variation in distance of ~ 3%

When are we closest to the Sun?
the Earth rotates about its axis from west to east once every 23 hours and 56 minutes

the Earth’s axis always points the same way as it revolves around the sun
at **equinox**, the circle of illumination passes through both poles

the **subsolars point** is the equator

each location on Earth experiences 12 hours of sunlight and 12 hours of darkness
Earth’s Revolution around the Sun

**Solstice** (“sun stands still”)  
On June 22, the subsolar point is $23\frac{1}{2}^\circ$N (Tropic of Cancer)  
On Dec. 22, the subsolar point is $23\frac{1}{2}^\circ$S (Tropic of Capricorn)
Map Projections

**Polar Projection**

centered on north or south pole

meridians are radiating straight lines

parallels are concentric circles

spacing of parallels (scale fraction) increases outward from the pole
**Mercator Projection**

Rectangular grid of meridians (straight vertical lines) and parallels (straight horizontal lines).

Meridians are evenly spaced, spacing of parallels increases with latitude.

Used to show surface flows, e.g. weather, oceans.
Map Projections

Goode Projection

indicates the true sizes of the Earth’s surface but distorts the shapes of areas

Used to show land features

Figure 1.10, p.32
Global Time Zones

How many degrees does the Earth rotate in an hour?

the Earth rotates 15° per hour so time zones differ by 1 hour \( (360°/15° = 24 \text{ hours}) \)
The Atmosphere and the Global Radiation Budget
Atmospheric Pressure and Density

- Gravity holds most of the air close to the ground.
- The weight of the overlying air is the pressure at any point.
Composition of the Atmosphere

Constant gases in the Troposphere

Nitrogen 78% (converted by bacteria into a useful form in soils)

Oxygen 21% (produced by green plants in photosynthesis and used in respiration)

Argon ~1% (inert)

Figure 2.12, p. 62
The atmosphere is layered according to its temperature structure.

In some layers the temperature increases with height.

In others it decreases with height or is constant.

Why?

“pause” is a level; “sphere” is a layer.
Electromagnetic Radiation

- Everything above -273°C (absolute zero, 0 Kelvin) emits radiation
- Hotter objects emit more energy at shorter wavelengths
- Colder objects emit more energy at longer wavelengths
What happens to the Sun’s radiation as it travels through the atmosphere?

- It can be reflected
- It can be scattered
- It can be absorbed
- It can be transmitted
Earth's annual energy balance between solar insolation and terrestrial infrared radiation.

A global balance is maintained by transferring excess heat from the equatorial region toward the poles.
Heat is transported to the Polar regions.
Planetary Energy Balance

Energy In = Energy Out

\[ S(1-\alpha)\pi R^2 = 4\pi R^2 \sigma T^4 \]

\[ T \approx -18^\circ C \]

But the observed \( T_s \) is about +15° C
Greenhouse Effect

Increasing Greenhouse Gases increases the amount of heat absorbed by the atmosphere and re-radiated back (counter-radiation) to the Earth’s surface.

The Earth is 33°C (~60°F) warmer as a result.
Greenhouse gas concentrations

- Human activities have caused dramatic increases in greenhouse gas concentrations

**FIGURE 1.4**
Measurements of CO₂ in parts per million (ppm) at Mauna Loa Observatory, Hawaii. Higher readings occur in winter when plants die and release CO₂ to the atmosphere. Lower readings occur in summer when more abundant vegetation absorbs CO₂ from the atmosphere.
Winds and Global Circulation
Winds and Global Circulation

- Atmospheric Pressure
- Winds
- Global Wind and Pressure Patterns
- Oceans and Ocean Currents
How is Energy Transported to its “escape zones?”

- Both atmospheric and ocean transport are crucial
- Buoyancy-driven convection drives vertical transport
- Latent heat is at least as important as sensible heat
Atmospheric Circulation in a nutshell

- Hot air rises (rains a lot) in the tropics
- Air cools and sinks in the subtropics (deserts)
- Three ‘convective’ cells develop in each Hemisphere
- Coriolis causes direction of prevailing surface winds
- Poleward-flow is deflected by the Coriolis force into westerly jet streams in the temperate zone
- Jet streams are unstable to small perturbations, leading to huge eddies (storms and fronts) that finish the job
Atmospheric Circulation in a nutshell

- Winds are initially generated by differences in heating at the Earth’s surface.
- Geostrophic winds result in rotational movement around high and low pressure centers.
How winds are made
Two columns of air—same temperature same distribution of mass
Cool the left column; warm the right column

The cooled column contracts

The heated column expands

500 mb

original 500 mb level

1000 mb  1000 mb

500 mb
Air moves from high to low pressure at the surface...

Air is rising in the column on the right. There is a low pressure center at the surface.

Air is sinking in the column on the left. There is a high pressure center at the surface.
Global Circulation
But heat is transported from the Equator to the Poles - how?
How is Energy Transported to its “escape zones?”

- Both atmospheric and ocean transport are crucial.
- Buoyancy-driven convection drives vertical transport.
- Latent heat is at least as important as sensible heat.
What a single cell convection model would look like for a non-rotating earth

- Thermal convection leads to formation of convection cell in each hemisphere
- Energy transported from equator toward poles
- What would prevailing wind direction be over N. America with this flow pattern on a rotating earth?
Coriolis Force acts to the right in the Northern Hemisphere
Geostrophic Winds
low pressure

Coriolis Force

gradient force

geostrophic winds

high pressure

992
996
1000
1004
1008
1012
1016
1020
High pressure (anticyclone)

From above

surrounding air is relatively low

Side View

air descends
Low pressure (depressions, cyclone)

From above

surrounding air is relatively high

Side View

air ascends
Global Temperature patterns and weather
Temperature Patterns

- Stronger seasonal heating and cooling on land produces asymmetry
- Poleward distortion of isotherms over northern high latitude oceans
- Equatorward distortion over subtropics
Seasonal Migration of ITCZ

- Mean position is somewhat north of Equator
- Strong departures from zonal mean position driven by seasonal heating over land
  (Especially over Asia, S. America, Africa)
**Monsoons**

In **July** the position of the ITCZ moves North

- low pressure over land causes winds to flow off the ocean
- this brings heavy rainfall

Figure 5.20, p. 167
Monsoons

In January high pressure over the land produces dry winds

Air is flowing towards the ITCZ

Figure 5.20, p. 167
• Fast air currents, 1000’s of km’s long, a few hundred km wide, a few km thick
• Typically find two jet streams (subtropical and polar front) at tropopause in NH
• When would you expect the jets to be strongest?
Rossby Waves

Smooth westward flow of upper air westerlies

Develop at the polar front, and form convoluted waves eventually pinch off

Primary mechanism for poleward heat transfer

Pools of cool air create areas of low pressure

Waves are strongly developed. The cold air occupies troughs of low pressure. When the waves are pinched off, they form cyclones of cold air.
Ocean Circulation in a nutshell

- Surface winds cause large, clockwise rotating gyres in the northern hemisphere and counterclockwise gyres in the southern hemisphere.
- Salinity and temperature differences in water cause sinking of water (deep water formation) in the North Atlantic and Southern Ocean (Antarctic).
- EL Nino is a quasi periodic rocking of the Ocean-Atmosphere system in the tropical Pacific.
Ocean surface currents

- large continuously moving loops (gyres)
- produced by winds, Coriolis force and land masses
**The Ocean Deep Currents**

**Deep-sea currents**

- driven by differences in temperature and salinity
- much bigger and slower than surface currents
Global Temperatures
Main Points

1. We measure air temperature in Celsius and/or Fahrenheit

2. Surface temperature changes as a result of changes in NET energy flows resulting from seasonal and daily changes in insolation and radiation from the surface

3. Air temperature is a function of Insolation, Latitude, Surface Characteristics, nearness to water bodies and elevation

4. Cities can produce heat islands

5. The atmosphere is divided into discrete layers based on temperature differences and patterns

6. The Environmental Lapse Rate is the ‘normal’ change in temperature with elevation

7. Land areas are colder in the winter and hotter in the summer than adjacent areas of water

8. At present global temperatures are rising due to increased Greenhouse gases
Earth's surface temperature is a balance between incoming solar radiation and outgoing terrestrial radiation.

Peak temperature lags after peak insolation because surface continues to warm until infrared radiation exceeds insolation.
the heat island tends to persist over night
parks can reduce the heating
desert urban areas often do not exhibit heat islands since irrigated vegetation may make the city cooler
Stratosphere is bounded by the stratopause.

Immediately above is the mesosphere where temperatures decrease with altitude (bounded by the mesopause above).

Immediately above is the thermosphere.
Temperature Structure of the Lower Atmosphere

The troposphere is the lower most atmospheric layer

Temperature decreases on average by 6.4°C per 1000 meters (3.5°F per 1000 feet) in the troposphere (environmental lapse rate)
Heat Transfer in the Atmosphere

**Conduction** (direct heat transfer from the heated ground surface to the atmosphere)

**Convection** (heat transfer by warm air moving to colder upper atmosphere)  >>  vertical motion:  warm air rising and cold air sinking

**Advection** (heat transfer by warm air mixing with colder adjacent air)  >>  Horizontal winds
July Isotherms

Southern hemisphere has fewer land masses and ocean currents that encircle the globe, creating isotherms that are more regular than those in the northern hemisphere.
1. No penetration of radiation
2. Land heats quickly (low specific heat)
3. No mixing
4. Less evaporation

- More evaporation
- Radiation penetrates to depth
- Water heats slowly (high specific heat)
- Mixing of warm and cold waters
Main topics for today

• The Hydrosphere and the Water Cycle

• Water’s properties are due to its polar nature

• Water has a very high heat capacity and high heat of fusion

• Warm air can contain more water vapor than cold air

• Relative Humidity and Dew Point Temperature are the most common ways to express how much water is in the air

• The Environmental Lapse rate is the observed change in air temperature with change in elevation

• An Adiabatic Process is the expansion or contraction of an air mass without heat loss or gain
Main points for today (cont)

• Clouds are classified by altitude and shape

• Precipitation can occur because of
  • 1) convection,
  • 2) orographic lifting, and/or
  • 3) frontal processes

• Air Quality
The Water Cycle

1. Water storage in ice and snow
2. Water storage in the atmosphere
3. Condensation
4. Evaporation
5. Evapotranspiration
6. Surface runoff
7. Streamflow
8. Ground-water storage
9. Freshwater storage
10. Spring
11. Ground-water discharge
12. Water storage in oceans
13. Precipitation
14. Snowmelt runoff to streams
15. Infiltration

U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html
Energy associated with phase change

- 80 calories for melting
- 100 calories for warming
- 540 calories for evaporating

Latent heat of fusion—80 calories
Latent heat of vaporization—540 calories
Basic Humidity Facts

• Humidity is the amount of water vapor in the atmosphere

• Warm air can hold much more than cold air

• Cold dry air can have close to 0%

• Warm tropical air may have 4-5%

• Several ways to describe humidity (Dew Point and relative humidity are most common)
Relative Humidity

• a measure of the amount of water vapor present in air relative to the maximum amount that the air can hold at a given temperature (％)

• e.g. if relative humidity is 50%, then it contains 1/2 the amount of water vapor it could hold at a given temperature

• relative humidity decreases as temperature increases (assuming no water vapor is added)
Relative Humidity and Temperature

The diurnal cycle

if no water vapor is added or removed from the air mass,

then Relative Humidity decreases as Temperature increases

The diurnal cycle is the inverse of Temperature
Vertical Motion and Temperature

Rising air expands, using energy to push outward against its environment, adiabatically cooling the air.

A parcel of air may be forced to rise or sink, and change temperature relative to environmental air.
Dry Adiabatic Lapse Rate (DALR)

- decrease in temperature with altitude: $10^\circ\text{C}/1000\text{m}$

Figure 4.10, p. 127
Wet Adiabatic Lapse Rate

as a parcel of air rises, it cools and becomes saturated at the dew point.

dew point lapse rate (1.8 degrees per 1000 meters) means that the dew point of the air parcel decreases as the air rises.

when it reaches its dew point, condensation occurs (lifting condensation level)

Figure 4.10, p. 127
Conditionally unstable air

- What if the environmental lapse rate falls between the moist and dry adiabatic lapse rates?
  - The atmosphere is unstable for saturated air parcels but stable for unsaturated air parcels
  - This situation is termed **conditionally unstable**
- This is the typical situation in the atmosphere
Precipitation: three mechanisms

Convection
Orographic
Frontal (cyclonic)
3.) **Frontal (cyclonic) precipitation**

where air masses with different temperatures come together

warm air lifted by cold dense air along a weather front

leads to frontal precipitation

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**Cold air**  

**Warm air**
Air pollutants are *undesirable* gases, aerosols, and particulates injected into the atmosphere by human and natural causes.
Weather
Major points for today

1. Most weather in the continental US results from interactions between large air masses coming from the tropics and the polar regions.

2. Cold and Warm Fronts are masses of cold and warm air, respectively.

3. Cold fronts are quickly moving masses of cold air that thrust moisture-laden warm air up to form storm clouds.

4. Warm fronts are more slowly moving fronts in which warm air slides up over more dense cold air.

5. Mid latitude cyclones are common in North America and result from a breakout of cold air in the far north.
6. Thunderstorms are caused by rapid uplift of moist air in an unstable atmosphere. They are characterized by strong updrafts and downdrafts.

7. Tropical storms, hurricanes, etc., start as low pressure troughs in easterly trade winds. If conditions are right, they can intensify into massive storms.

8. In the big picture, horizontal winds are all about transferring heat from the equator to the poles; whereas severe storms are all about vertical motion of the atmosphere.
Air Masses
Cold and Warm Fronts
A Front - is the boundary between air masses; normally refers to where this interface intersects the ground (in all cases except stationary fronts, the symbols are placed pointing to the direction of movement of the interface (front).
Air Mass Fronts

Two air masses entering a region, such as the U.S. middle latitudes, have a front, or transition zone, between the strong temperature and humidity differences.

Four different fronts are used on weather maps.
Typical Warm Front Structure
Cirrostratus with Halo

-- Photograph by Robert M. Rauber --
-- U. of Illinois Cloud Catalog --
Altostratus

Alto Stratus Castellanus
Midlatitude Cyclones

- Cold air
- Warm air
- Cold front
- Warm front
- Cool air
- L (Low Pressure System)
Large-Scale Setting

Hemispheric westerlies typically organized into 4-6 "long waves"
Lifecycle of a Midlatitude Cyclone

- **Stationary front**
- **Incipient cyclone**
- **Open wave**
- **Mature stage**
- **Occlusion**
- **Dissipating**

Green shading indicates precipitation.

Takes several days to a week, and moves 1000's of km during lifecycle.
Weather Changes Associated with Wave Cyclones

Figure 6.10, p. 193
Temperature (°F)

12 Hour forecast valid 0900 UTC Sat 26 Apr 2008

RUC (21z 25 Apr)
Cyclone Tracks

- Wave cyclones tend to form in certain areas and travel common paths.
- Mid-latitude wave cyclones tend to travel eastward.
- Tropical cyclones tend to move westward.

Figure 6.11, p. 194
Severe Weather
Tropical Cyclones

hurricanes (western hemisphere) and typhoons (western Pacific in Asia) and cyclone in Indian Ocean develop over warm ocean surfaces between 8° and 15° latitude, migrate westward and curve toward the poles

Tropical cyclones often create tremendous damage due to high winds, high waves, flooding (storm surges) and heavy rains
Easterly Waves

A simple form of tropical weather system is a slow moving trough of low pressure within the tropical easterly wind belts (trades)

Figure 6.16, p. 197
The Atmospheric Circulation

[Diagram showing atmospheric circulation, with labels for condensation, evaporation, Hadley cells, and subsidence in high pressure areas.]