Mid-Term Review
AOSC 200
Tim Canty

Class Web Site: http://www.atmos.umd.edu/~tcanty/aosc200

Topics for today:
Review
Review
Review
Review
Review

Lecture 15
Oct 15 2019

What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water
What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water

Meteorological Observations

Temperature: A measure of the kinetic energy of molecules

Kinetic Energy: energy of motion

Fig 1-1  Weather: A Concise Introduction
Meteorological Observations

Celsius: melting point of water is 0°C and the boiling point is 100°C.

Fahrenheit: melting point of water is 32°F and the boiling point is 212°F.

Kelvin: similar to Celsius but the coldest temperature is 0K. (Kelvin scale never goes negative)
The weather station model tells you what the conditions are like at the surface.
Recognize the fronts by the symbols!!! You might have a black and white map (like on a test….hint hint!!) and can’t rely on the colors to tell you which type of front you’re looking at.

Closed contours define regions of high pressure and low pressure.
Isobars that aren’t closed can still help us define regions of increasing ("ridges") and decreasing ("troughs") pressure.

RADAR: RAdio Detection and Ranging

RADAR measures the time it takes for the signal to return
Doppler RADAR measures changes in the return signal

Can provide information about precipitation types
rain, hail, snow, sleet

http://earthsky.org/earth/nws-upgrades-to-dual-polarization-radar-for-better-look-at-precipitation-tornadoes
Geostationary satellites: Orbits the Earth at the same angular speed as the Earth. They are “parked” in orbit over Earth and stay over the same location.

Provide a lot of information at all times but only at one location and have difficulty seeing the polar regions…

Polar orbiting satellites: Travel over the poles. Orbits wrap around the Earth. Need to travel quickly to provide cover the globe. Can be very high resolution because they orbit closer to the surface than geostationary satellites

Problems: Data gaps in time and space.
Satellite Imagery: Visible

Satellite Imagery: Infrared (heat)
Satellite Imagery: Water Vapor

What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water
Atmospheric Composition
(What are you breathing?)

<table>
<thead>
<tr>
<th>PERMANENT GASES</th>
<th>VARIABLE GASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Symbol</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₃</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
</tr>
</tbody>
</table>

*For CO₂, 400 parts per million means that out of every million air molecules, 400 are CO₂ molecules.

**Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

These gases control the chemistry of the atmosphere “variable gases” or “trace gases”
Carbon Dioxide (CO₂) Cycle

One of the most talked about Greenhouse Gases.

Some CO₂ is produced naturally

Some CO₂ produced by human activity (anthropogenic)

Once in the air, some CO₂:
  - stays there
  - goes into ocean
  - goes into land

CO₂ stays in the air for ~200yrs

Methane Sources and Sinks

http://www.giss.nasa.gov/research/features/200409_methane/
Nitrous Oxide ($N_2O$)

http://rstb.royalsocietypublishing.org/content/367/1593/1157

Ozone

Absorbs UV radiation

Smog!!!
What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water
Energy Transfer: Conduction

- Conduction – requires contact, energy transferred from molecule to molecule
- Air is not a good conductor
- Metals are excellent conductors
- Very important at Earth’s surface

Energy Transfer: Convection

- Convection – energy transferred by vertical movement of fluids (air is considered a fluid)
- Surface energy transferred upward by convection
- “Hot air rises and cool air sinks”
- Lava lamps are a good example of convection
Rising, hot air creates convective circulation

Thermals will eventually spread out, sink and move back to the starting point creating wind

Energy Transfer: Radiation

Radiative Heat – heating due to electromagnetic radiation (waves of energy that move through space)

Can be:

• Absorbed
• Reflected
• Scattered
What color is the sky?

$N_2$ and $O_2$ are really good at scattering shorter wavelengths
The energy from the Sun peaks at 0.5 μm (the visible portion of the spectrum)

**Fig 2.9: Essentials of Meteorology**

Atmospheric Absorption

The Sun releases energy at shorter wavelengths (UV, visible, near-infrared)

\[
\text{Sun} = \text{Short wavelength, incoming, downwelling, more energy}
\]

The Earth releases energy at longer wavelengths (IR)

\[
\text{Terrestrial} = \text{Thermal, outgoing, long wavelength, upwelling, less energy}
\]
Atmospheric Absorption

Incoming Solar radiation

Outgoing Terrestrial (Earth) radiation

Fig 2.11: Essentials of Meteorology

Atmospheric Absorption from O₂ and O₃

Fig 2.11: Essentials of Meteorology
Earth with the Greenhouse Effect

What happens when the “blanket gets too thick? This is called the “enhanced greenhouse effect”

Solar energy reaching the Earth’s surface

Sunlight in the tropics is more intense because the sun is higher in the sky than near the polar regions.

Less solar energy makes it through the atmosphere to the poles than the equator.

The polar regions have a higher albedo than the tropics. Why?

All of these together lead to an energy imbalance.
Solar energy reaching the Earth’s surface

Sunlight in the tropics is more intense because the sun is higher in the sky than near the polar regions.

Less solar energy makes it through the atmosphere to the poles than the equator.

The polar regions have a higher albedo than the tropics. Why?

All of these together lead to an energy imbalance.

Global Energy Balance

Fig 4.9: Weather: A Concise Introduction
The Seasons

Solar energy is most intense at noon.

Suns rays are more “focused” at noon.

Solar radiation (incoming radiation) greater than surface radiation (outgoing radiation) until later in afternoon.

Lowest temperature occurs shortly after sunrise when outgoing radiation is greater than incoming.
Daily temperature changes are largest near the surface.

Daytime Temperatures: Clouds

Clouds have a high albedo and will reflect incoming solar radiation.
Nighttime Temperatures: Clouds

How is temperature affected by:

- Altitude
- Latitude
- Surface type
- Proximity to water
What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water

The Water Cycle

Fig 4.1: Essentials of Meteorology
Specific Heat

<table>
<thead>
<tr>
<th>Substance</th>
<th>Specific Heat (cal/g/°C)</th>
<th>Specific Heat (J/kg/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.0</td>
<td>4,186</td>
</tr>
<tr>
<td>Ice</td>
<td>0.50</td>
<td>2,093</td>
</tr>
<tr>
<td>Air</td>
<td>0.24</td>
<td>1,005</td>
</tr>
<tr>
<td>Sand</td>
<td>0.19</td>
<td>795</td>
</tr>
</tbody>
</table>

The specific heat of a substance is the amount of heat required to increase the temperature of 1 gram of the substance 1° C

Water takes longer to heat (and cool) than dirt

Table 2-1 Meteorology: Understanding the Atmosphere

Saturation

Water evaporates and enters dry air

Eventually, some of the water vapor hits the surface through collisions and random motion (condensation)

When evaporation and condensation are equal the air is said to be saturated

Fig 5.3 Weather: A Concise Introduction
Two ways to get water to condense

1) Decrease the air temperature
2) Increase the amount of water vapor
Relative humidity: the ratio of the saturation vapor pressure divided by the actual vapor pressure.

As temperature drops, relative humidity rises. The air can’t “hold” as much water.

Relative Humidity

RH = 10 mb / 23.8 mb = 0.42 or 42%

RH = 10 mb / 12 mb = 0.83 or 83%
Temperature and relative humidity are “anti-correlated”

Dew Point: the temperature air has to be cooled to for saturation to occur. Dew point is a measure of how much water vapor is in the air.
If the air is very dry, it will cool by 10°C for every km in altitude. This is called the dry adiabatic lapse rate. The air expands and cools as it rises. It contracts and heats as it sinks.

Unstable Air

Air can rise when it is warmer than the air around it.

Air Parcel

Cold

Warm
Air can rise when it is warmer than the air around it. The parcel will stop rising when it is the same temperature as the air around it.

**Lapse Rate: Unstable Atmosphere**

- **Altitude (km)**
- **Temperature (C)**

---

**Actual Temperature**
Lapse Rate: Stable Atmosphere

温度 (C)

高度 (km)

实际温度

Putting it all together

Fig 6.22 Weather: A Concise Introduction
Dry adiabatic lapse rate: if no cloud forms, air will cool at 10°C per kilometer.

Once water begins to condense, latent heat is released. The air parcel cools at a slower rate (6°C per kilometer) than if the air parcel was dry.
Cloud Development: Orographic Lifting

Air is forced up the side of a mountain and cools as it rises

(b) Lifting along topography

Cloud Development: Convergence

When wind meets from different directions, the air in between has no place to go but up

When the leading edge of the wind slows down, the wind behind “piles up”
Cloud Development: Frontal Lifting

Fig 6.12 Weather: A Concise Introduction

Warm air will ride up over cold air

Cloud Development: Convection

Fig 5.10 Essentials of Meteorology

As surface air is warmed by the sun, it becomes less dense and rises
As air rises up a mountain side, it cools at the dry adiabatic lapse rate. Once it reaches saturation, it cools at the saturated lapse rate. Also, precipitation (rain or snow) falls out of the cloud and the vapor pressure decreases.

The air parcel has lost a lot of water. As it sinks down the mountain side, the air in the parcel warms and dries out the cloud. The parcel warms only at the dry lapse rate. When the parcel reaches the ground, it’s warmer than when it started.
Fog types and how they’re formed

- Radiation
- Upslope
- Advection
- Evaporation (Steam)

Clouds!!!

**TABLE 4.1 The Four Major Cloud Groups and Their Types**

<table>
<thead>
<tr>
<th>Cloud Group</th>
<th>Sub-Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>High clouds</td>
<td>Cirrus (Ci)</td>
</tr>
<tr>
<td></td>
<td>Cirrostratus (Cs)</td>
</tr>
<tr>
<td></td>
<td>Cirrocumulus (Cc)</td>
</tr>
<tr>
<td>Low clouds</td>
<td>Stratus (St)</td>
</tr>
<tr>
<td></td>
<td>Stratocumulus (Sc)</td>
</tr>
<tr>
<td></td>
<td>Nimbostratus (Ns)</td>
</tr>
<tr>
<td>Middle clouds</td>
<td>Altostratus (As)</td>
</tr>
<tr>
<td></td>
<td>Altocumulus (Ac)</td>
</tr>
<tr>
<td>Clouds with vertical development</td>
<td>Cumulus (Cu)</td>
</tr>
<tr>
<td></td>
<td>Cumulonimbus (Cb)</td>
</tr>
</tbody>
</table>

Cloud groups have sub-categories
Clouds!!!

Fig 4.36: Essentials of Meteorology