A conceptual walking tour of ATM 210

ATM 210 -- Fall 2023 -- Fovell

From a colleague's course syllabus

"Dinosaur paleontology is the most interesting scientific discipline. Of course, those teaching other courses might think *their* material is the most interesting. **But the others are wrong**."

Nature abhors extremes

Look for the stresses,

their causes and obstacles to easy remediation

Temperature, pressure, and density are interrelated

Ideal gas law

$$p = \rho R T$$

Pressure largely reflects the force of gravity on mass

More mass = higher pressure

Pressure decreases with height

$F = ma$

where $a = g$ (acceleration of gravity)

Pressure differences are important; pressure *gradients* are crucial

PGF = pressure gradient force

Hydrostatic balance

Struggle between the huge vertical PGF and equally huge gravity force

Enormous stress

Hypsometric equation

The thickness between two isobaric surfaces is proportional to layer mean T

Pressure decreases with height… faster in colder air

Why the troposphere is shallower at the cold pole

Why hurricane winds diminish with height

Why rising air expands and cools

Objects that heat up quickly also cool off fast

(thermal inertia or heat capacity)

Why does a metal spoon feel colder than a glass at the same T?

Conduction, convection, or radiation?

The troposphere is primarily heated from below

T generally decreases w/ height in troposphere… ELR… about 6.5˚C/km

T drop stops in stratosphere… why?

Radiation emission is based on T…

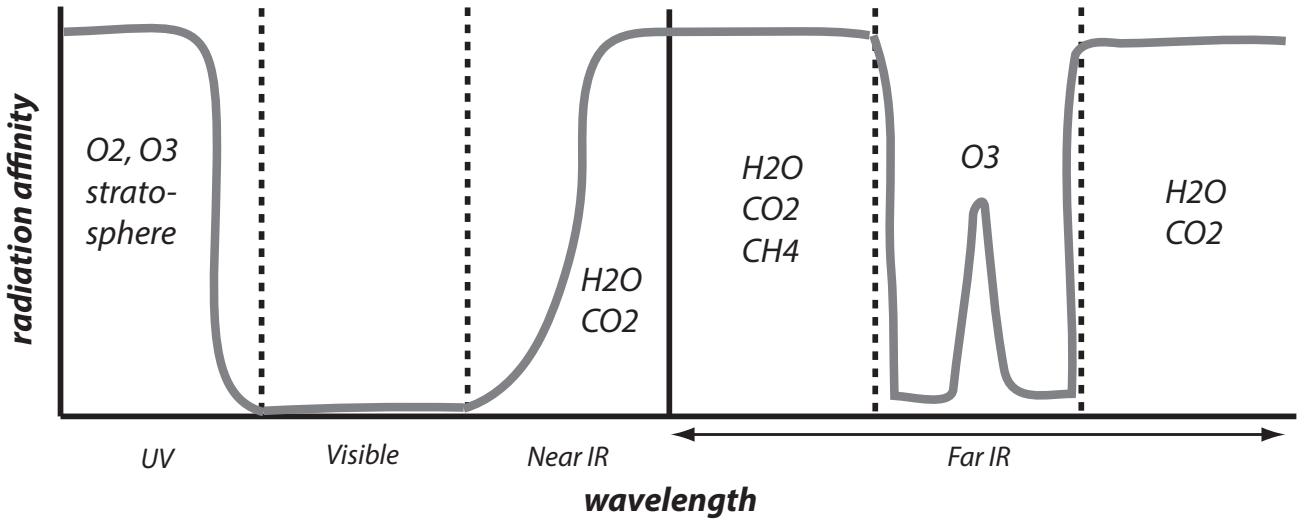
Amount, type of radiation determined by temperature

Planck curve
Stefan-Boltzmann law
Wien's law

…but absorption is based on *affinity*

"Greenhouse effect" = the reason why life exists on Earth

Absorption spectrum



"Sunburn alley" and the "ozone tonsil"

Clouds close the atmospheric window

O2 and O3 and UV → stratosphere

Small objects scatter the shortest wavelengths, large objects scatter everything

#1 Blue sky and dry haze

#2 White cloud and wet haze

#3 Red sunset

Why doesn't the tropopsphere turn over?

Hint: Warm air rises and cold air sinks is NOT always true…

#1 *Less dense* air rises,
more dense air sinks

#2 You can't lift hot air very far

Expansion cooling at DALR is FAST… ~ 10˚C/km

…but if that air has *moisture…*

The ability of air to hold water vapor is a very, very strong function of T

(even if it's really the ability of vapor to *resist condensing*…)

You can saturate air via cooling

Expansion cooling,

diabatic (external direct) cooling,

or evaporation cooling

Adiabatic, dew point, and wet bulb approaches to saturation

The condensation and freezing processes need a surface to start on

Condensation nuclei are common, ice nuclei are more rare

Hygroscopic and hydrophobic nuclei

Heterogeneous nucleation ($T \geq -40^{\circ}$)

Supercooled liquid

Aircraft icing and cloud seeding

Rising saturated air cools at a slower rate

Expansion cooling is partially opposed by condensation warming

MALR ~ 5˚C/km

MALR < typical tropospheric ELR (~6.5˚C/km)

"metastability" or sensitivity to the amount of lifting

Lifting air to saturation: LCL

If the air parcel becomes warmer than its surroundings:

LFC and CAPE

Condensation loss produces warmer & drier air on descent

Why there are often deserts on the lee sides of mountains

Temperature difference make pressure differences and winds…

The intent, if not the reality, of winds is to reduce the T differences that provoked them

It is more natural for the one-cell (sea/land breeze) surface wind to blow from cold towards warm

Thermally direct; influence of vertical air motions on horizontal T differences

In the absence of other forces, the wind blows from H → L

On the large scale, other forces are rarely absent

PGF, Coriolis, Centripetal, Friction

Earth's shape, spin, and tilt represent profound complications

Shape = unequal heating

Tilt = seasons

Spin = the 1-cell model fails, leading to storm and desert belts & winds that largely fail to accomplish their goals

Earth rotation forces a 3-cell structure per hemisphere

Polar cell, Ferrel cell, Hadley cell

Deserts and subsidence

at 30˚N and 30˚S

Complicated by land and ocean currents

Coriolis force turns air to the right following the motion in the NH

Clockwise ocean currents (NH)

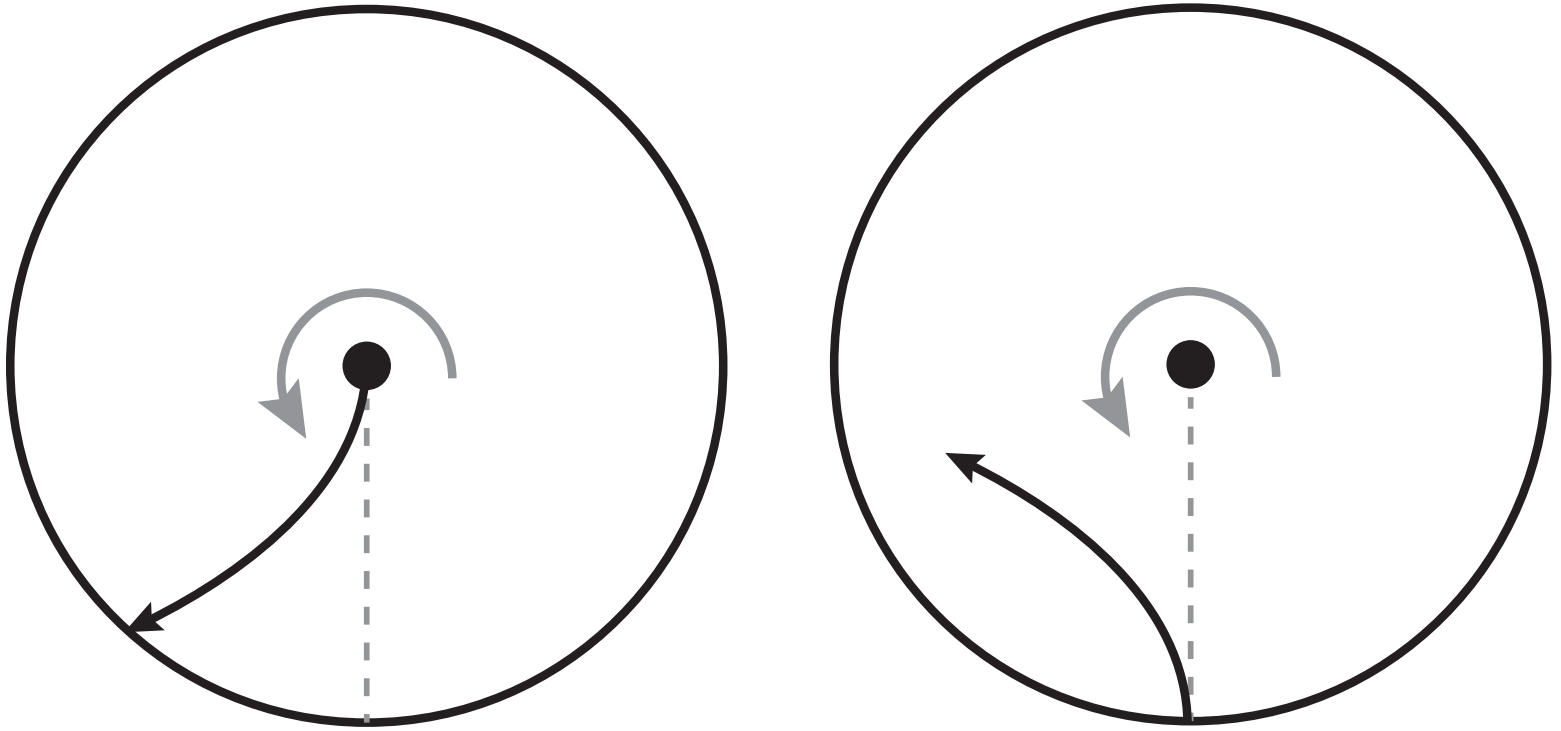
Geostrophic balance: PGF + Coriolis

Why to the right?

Conservation of angular momentum

Objects at Equator spin fastest

Flat disk experiment



Why did this fail?

Coriolis reshapes the large-scale near-surface winds

Polar easterlies

Midlatitude westerlies

Tropical trade winds

ITCZ

Why are the polar easterlies so shallow?

Coriolis influence on large scale winds

Geostrophic wind = PGF + Coriolis → parallel to isobars/isoheights

Large-scale L (CCW in NH) and H (CW in NH) = Gradient wind = PGF + Coriolis + Centripetal

CCW curvature makes the large-scale wind subgeostrophic (in NH)

But we see much stronger winds around CCW lows than around CW highs…

{why was that?}

Friction allows the large-scale wind to blow across isobars towards low pressure

Slows and turns the wind

Surface convergence into L, divergence out of H

Consequences for vertical motion → weather

Why don’t hurricanes form on, or cross, the Equator?

fV

$f = 2\Omega\sin\phi$

Air of different densities do not want to mix

Exploited in the “air parcel concept”

Fronts form at air mass boundaries

cP, cT, mP, mT

Cold fronts and warm fronts are not the same

Cold air pushes better

Cold fronts move faster

Implications for precipitation and extratropical cyclone life cycle

Cyclone fronts “zip up”

Occlusion → to choke

Again… pressure decreases with height faster in colder air

This means not only do temperature differences make winds but also…

Therefore, T differences also create *vertical wind shear*

Shear makes spin

Spin can get tilted and stretched

Spin makes low pressure [cyclostrophic]

#1 The supercell storm and origin of tornado rotation

#2 The large-scale L and H, in which spin supports the L & hurts the H

#3 How extratropical cyclones can spin up in the first place

Therefore, T differences also create *vertical wind shear*

The midlatitude westerly jet

Located at the tropopause

Where the N-S horizontal T gradient vanishes

Therefore, T differences also create *vertical wind shear*

We have two jets!

Both located at the tropopause

But the polar jet above 60˚ meanders

Extratropical cyclones have fronts

Hurricanes have no fronts

No horizontal T gradients = no vertical wind shear

Hurricane winds weaken with height [warm core]

The ingredients of the tornadic supercell thunderstorm: vertical wind shear + CAPE

Why are tornadoes more common in spring (specifically April-June) than summer?

Why do supercells split?

From a colleague's course syllabus **[corrected]**

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[end]