METEOROLOGY CLASS #4

NOTES

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- We will be learning about:
  - Fog
  - Thunderstorms
  - METARs and TAFs

Definition of Fog

Different types of Fog

FOG

What is Fog?

- Fog is a low stratus cloud
- What do we need to create fog?
  - **High humidity** (we need moisture in the air!)
  - **Atmospheric cooling** (we need a way to cool the moisture below the dew point level = clouds will form)
  - **Condensation nuclei** (we need something to "sponge" together the water droplets)
  - **Shallow "spread"** (we need a small temperature-dewpoint spread)
  - **Light winds** (fog will not form in still air… instead dew will form)

Types of Fog

- There are 6 primary types of Fog... and we will explore each of them in detail
  - –Radiation Fog
  - –Advection Fog
  - –Upslope Fog
  - –Steam Fog
  - –Precipitation-induced Fog
  - –Ice Fog

Radiation Fog
(Ground Fog)

- See Figure 4-A
- This type of fog forms on clear nights with light winds (less than 5 knots)
  - can be 100's of feet thick
- Recall: radiation cooling involves a stationary air mass cooling at night because it's overtop the Earth's surface that is also slowly cooling
- If the air is moist (high humidity) and the "spread" is shallow (not much cooling is required in order for water vapour to condense), then fog will form

Radiation Fog con't

- Clear skies permit maximum cooling
  - Recall: cloudless nights are colder than cloudy nights
  - We want the air to be cold so that the air mass does not have to cool by much in order to reach the dewpoint level
- Light winds spread the cooling process over the land and into the lower layers of the atmosphere
- Radiation fog will dissipate in the morning due to daytime heating (the ground heats in the morning because of the increasing amount of solar radiation from the rising sun and the low laying fog is 'burnt' off)
  - The air is no longer cool, the "spread" increases and the cloud dissipates

Figure 4-A
(Radiation Fog)

Advection Fog

- See Figure 4-B
- Recall: advection cooling involves a non-stationary air mass being cooled as it comes into contact with the cooling Earth's surface below
- This type of fog forms with light winds and usually forms near coastal area (near large bodies of water)
  - Light winds are required to **move** the warm air along the cooling Earth's surface

Advection Fog con't

- Caused by drifting warm damp air over a cold surface
  - –The warmer air cools and condenses and forms a cloud that we call Advection Fog
- Advection fog is most commonly known by its duration
  - –It may persist for days in coastal areas
  - –Although advection fog may dissipate slightly during the day due to residual daytime heating, it will be back in full strength at night

Figure 4-B
(Advection Fog)

Upslope Fog

- See Figure 4-C
- Recall: moist air cools, expands and condenses to form clouds when it rises up in the atmosphere
- Upslope fog forms with light winds in mountainous regions
- Caused by warm air rising up a mountain and as a result of atmospheric cooling, the warm moist air cools and condenses into fog (a cloud) as it rises up the mountain.
  - A light wind is thus required to force the warm air mass up the mountain range!
  - Its now understandable why a mountain range (or significant change in elevation) is required for the creation of upslope fog!

Figure 4-C
(Upslope Fog)

Steam Fog

- See Figure 4-D
- Recall: when cool air is heated, it will evaporate
- This type of fog occurs near lakes and rivers during autumn
- Forms when cold air passes over a warm surface
  - The warm water surface below heats the cool air above, causing the cool air to evaporate into water vapour
  - As the water vapour expands, it cools, expands and forms fog
    - Since we need a significant amount of moisture to create steam fog, a warm lake or river is required (a puddle isn't going to suffice ;)

Figure 4-D
(Steam Fog)

Precipitation-Induced Fog

- See Figure 4-E
- Recall: when warm air overrides cold air at a gradual angle, the transition zone between these two air masses is called a warm front
- This type of fog occurs with warm fronts and precipitation!
- Also known as Frontal Fog
  - Associated with warm fronts hence the name, Frontal Fog
- As warm precipitation falls towards the ground, it encounters the cold air below
- The moist precipitation is instantly cooled and condensed and fog (a cloud) is formed very near to the ground
  - We call this cloud Precipitation-Induced Fog because fog is created because of the moist precipitation encounters cold air

Figure 4-E
(Precipitation-Induced Fog)

Ice Fog

- See Figure 4-F
- This type of fog forms near airports with moist air in extremely cold and calm conditions
- Suppose you start an aircraft engine (at an airport) on an early winter morning where temperatures are extremely cold.
- The moist air (exhaust) being outputted by the engine is immediately cooled and sublimated (vapor --> ice instantly) when it hits the cold winter air
- The result is a blinding cloud that we call Ice Fog
- This fog can be very problematic for VFR pilots who wish to start their aircraft and go flying on a cold early winter morning
  - This fog can literally turn a VFR airport into an IFR airport just by a pilot starting the aircraft engine
  - Recall: VFR = visual flight rules & IFR = instrument flight rules

Figure 4-F

(Ice Fog)

Definition of a thunderstorm
The thunderstorm recipe book
The 3 Stages of a thunderstorm
Avoidance
Types of thunderstorms **OPTIONAL**

THUNDERSTORMS

What is a Thunderstorm?

- Thunderstorms are often regarded as cumulus clouds gone wild!
- A Thunderstorm is a cumulonimbus (CB) cloud that develops upwards to the tropopause where heavy precipitation falls from (rain and often hail).
- They are weather phenomenas that create extremely hazardous flying conditions for all pilots

What is a Thunderstorm? con't

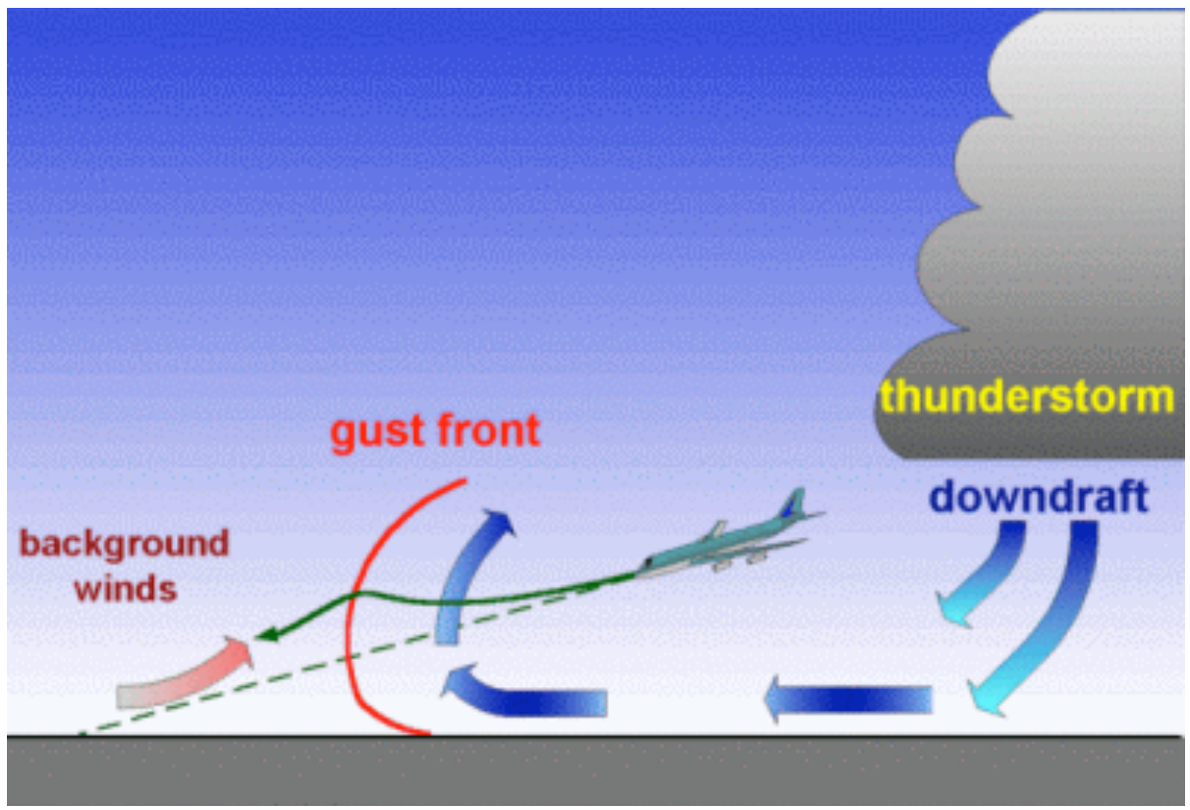
- There are many hazards that are associated with thunderstorms (besides heavy precipitation) that create hazardous flying conditions:
  - Thunder and Lightning
    - They are created from "charge" differences between '+' and '–' charge forces within the cloud and the ground below... since these charge differences are always associated with thunderstorms, thunder and lightning are almost always associated with thunderstorms!
  - Strong winds and severe gusts
    - Strong winds that can get up to 160km/h (approx. 80kts)
    - Recall: gusts are short irregular fluctuations in the wind speed **and** direction
  - Strong updrafts and downdrafts
    - These refer to the updrafts and downdrafts not only within the cloud itself (this is what makes the cloud vertically develop so rapidly) **but also** underneath the cloud as well

What is a Thunderstorm? con't

- Severe turbulence
  - Since thunderstorms are very unstable cumuliform clouds, severe turbulence is always associated with thunderstorms
- Microbursts and Macrobursts
  - They are 'bursts' of energy in the form of wind blowing outwards and sometimes ahead of the thunderstorm cloud
  - Microbursts are **shorter** in duration than macrobursts!
- Tornadoes
  - Recall: tornadoes are very deep, concentrated low pressure systems
  - Because of their nature, they are sometimes associated with thunderstorms
- Severe wind shear
  - Recall: wind shear is the sudden change in wind direction and/or wind speed, usually encountered when arriving or departing an airport
  - Wind shear will always be associated with thunderstorms

Gust Front

- When strong downdrafts escape from the cloud and hit the ground below, they will move along the surface and ahead of the storm.
- This “leading edge” of moving air ahead of the storm is called a Gust Front.



The Thunderstorm "Recipe" Book

- There are 3 key ingredients that are required for a Thunderstorm to develop:
  - Unstable air
    - This is why thunderstorms can grow up to 45,000 feet high
  - Lifting agent
    - Recall: there are 5 atmospheric lifting agents
    - In terms of Thunderstorm development, either **convection, orographic lift or frontal lift** will suffice for Thunderstorm development
  - High moisture content
    - We **need** high humidity => the air is very saturated and thus clouds can easily form
- Note that these are also the requirements for the development of any cumuliform cloud... the only difference is when the above 3 ingredients go wild... then thunderstorms will develop

The Life of a Thunderstorm

- There are 3 distinct stages to the life of a Thunderstorm
  - –Cumulus Stage
  - –Mature Stage
  - –Dissipating Stage

Stage 1: The Cumulus Stage

- Recall: Thunderstorms develop when a cumulus cloud goes wild!
  - This is why the first stage is called the Cumulus Stage
- Just like how any cumulus cloud would develop, when warm moist air rises, the warm moist air mass will cool, condense and create a cumuliform cloud (in this case, a cumulus cloud)
  - Recall: a steep lapse rate will intensify the instability of the developing cumulus cloud
- However, if a mass of **superheated moist air** rises rapidly, it will cool and condense very rapidly and as a result, there will be a large imbalance because of the superheated air mass rising so quickly!
  - Recall: the atmosphere always wants to stay in balance. So an atmospheric imbalance => weather will happen (in this case, a thunderstorm will happen!)
  - This also means that the temperature inside of the cloud will be higher than the surrounding air because of the superheated air mass inside.

Stage 1: The Cumulus Stage con't

- An equal amount of cold air from above will then rush down to the surface to replace all the rapidly rising hot air… these are called updrafts and downdrafts and they can become quite strong!
- So how about those ingredients… why do we need them?
  - Unstable air is the only way a cumulus cloud can form… so unstable air is a must!
  - Without a lifting agent (like convection, orographic lift or frontal lift), the superheated air mass will not rise… so a lifting agent is a must!
  - Without a high moisture content, only weak storms will develop because the intensity of a Thunderstorm is largely based on how must water content is in the cloud… so a high moisture content is a must!
- As a result of this extreme atmospheric imbalance (along with all the 3 ingredients of a thunderstorm), the cumulus cloud is then able to go wild and form the beginnings of a Thunderstorm!
- This is the part of the storms where you would start saying: "it's gonna be a big storm! Just look at those clouds!"

Stage 2: The Mature Stage

- As the cumulus cloud grows and towers into the upper atmosphere (reaching the tropopause), the updrafts and downdrafts intensify within the cloud
- As the water droplets are violently circulated within the cloud (because of the updrafts and downdrafts), the grow in size and weight... hail also develops among other bad things.
  - This is when the most precipitation will fall from a Thunderstorm cloud... this is when the storm begins to release its energy!!

Stage 2: The Mature Stage con't

- Lightning, Thunder, microbursts, wind shear and sometimes tornadoes will also start during this stage.
  - The storm is releasing its energy that has been built up during the Cumulus Stage
  - A microburst is a strong downdraft of air that is short lived.
- This stage usually lasts for 15-20 minutes but may extend up to one hour.
  - This is the part of the storm where you would say: "wow, it's sure raining cats and dogs!"

Stage 3: The Dissipating Stage

- This is when the storm begins to dissipate and weaken
  - The storm has released all of its energy and now it begins to weaken and dissipate as it moves along the ground (moving left to right)
  - Think about how you feel after a long and intense workout!
- The downdrafts, although they are weakening, spread along the surface of the Earth around the dissipating storm cell... surface winds will usually increase even after the storm has begun to dissipate
- The rainfall will gradually stop
- The top of the thunderstorm cloud will also form its famous anvil head (see next page)
- This is the part of the storm where you say: “that was one big storm!”

A Pacific Thunderstorm

Thunderstorm Avoidance

- The best rule of thumb is to always avoid a thunderstorm!
  - Never fly through a thunderstorm! Why?... why don't I let you think about that one ;)
  - AF 447
- If you encounter a storm where it is impossible to fly around it, you can always turn around and fly back to where you came from because at least you know the weather was VFR back there
- However if you can't avoid the storm, always pass the storm to the far **right!**
  - **Why?** The storm is moving left to right. Passing on the right means you are flying around the storm where the storm has not been yet so the weather over there should be good with no surprises.

Types of Thunderstorms
OPTIONAL

- There are two types of Thunderstorms:
  - Air Mass Thunderstorms
  - Frontal Thunderstorms

Air Mass Thunderstorms
OPTIONAL

- These types of thunderstorms usually form a single storm or in small clusters on hot, summer days with warm moist air
- Because this particular type of thunderstorm forms either as a single storm cell or a small clustered cell, you can usually fly around them and avoid them.
- Air Mass Thunderstorms will either form because of convection or orographic lift

Frontal Thunderstorms

OPTIONAL

- Frontal Thunderstorms are **more intensified** than Air Mass Thunderstorms
- They are associated with the advance of a cold front and sometimes a warm front
  - Recall: thunderstorms frequently form in advance of a cold front
  - Recall: in a warm front, if the warm air being pushed aloft **is unstable**, then the clouds that form will be unstable… as a result, thunderstorms may then develop at a warm front.
- Thunderstorms that form in advance of a cold front often form along the frontal edge that may stretch 100's of miles in length
  - This line of thunderstorms is called a Squall Line
- These storms often appear to be smaller and as a result, pilots must use extreme caution when flying around squall lines
  - Squall lines = Extreme weather + death

1) METARs
- Definition
- Validity period
- Decoding a METAR
2) TAF
- Definition
- Validity period
- Decoding a basic TAF
3) GFA
- Definition

WEATHER PUBLICATIONS

SEE HANDOUTS

QUESTIONS?