Meteorology

Lecture Presented By: Kevin Kochersberger

In this lecture you will learn:

- Environmental factors
- Weather forecasting
- Charts and interpreting weather information

Consider environmental conditions when planning a mission

Meteorology
- **Weather scale**
- Effects on aircraft
- Forecasting
- Best practices

- The operating environment has a strong influence on the performance of RPA
  - Weather considerations need to be addressed in flight planning to reveal any adverse conditions that may occur before or during a flight activity
  - Hot, dry weather can cause dust devils to occur which are very hazardous to RPA operations
    - A dust devil is a small tornado, capable of causing the flight control system to be overwhelmed and leading to a crash
  - Convective weather activity can indicate wind shears and strong frontal boundaries with rapidly increasing wind

Meteorology is the study of weather both on a large and small scale

Meteorology
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- Weather information is either obtained from government sources or commercial services that provide details about surface conditions (on the ground) and synoptic conditions (atmospheric trends) useful for flight planning
- All available weather data should be accessed in flight planning so there are few surprises encountered during flight
  - A weather forecast can have a strong influence on the exact mission flown, overriding other planning tools used in the process.

Meteorology is the study of weather both on a large and small scale

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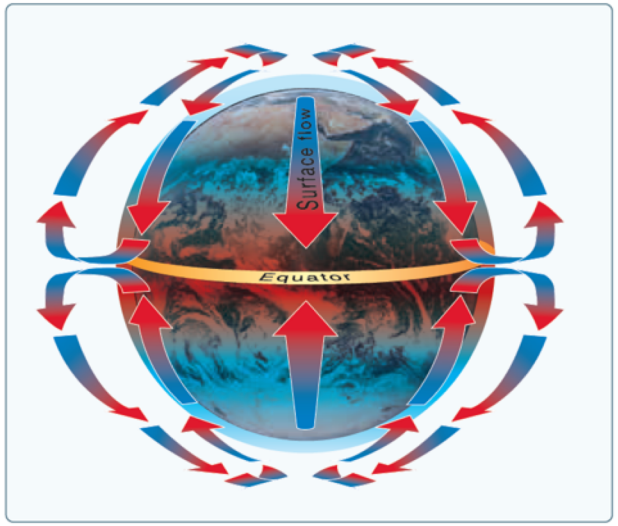
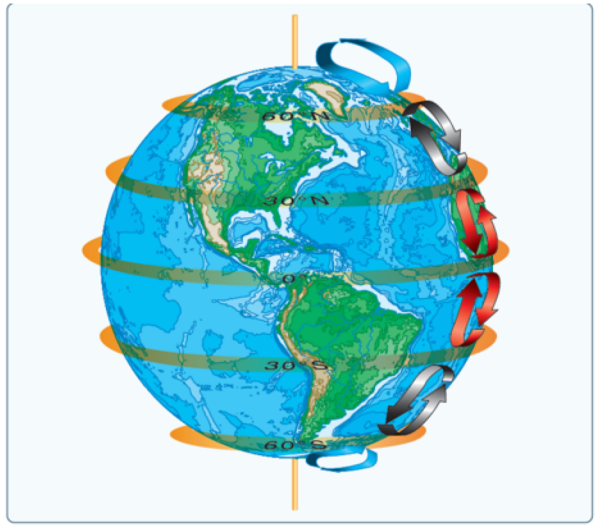
- On a large scale, global weather patterns are caused by longitudinal air circulation due to the temperature differences at the poles and at the equator
- These axial air currents in turn cause lateral air currents due to Coriolis acceleration
- The bands of circulation that result govern the weather in zones, although some of this predictability is diminishing with global warming





Large scale winds will have an effect at lower altitudes where winds interact with terrain features

Meteorology
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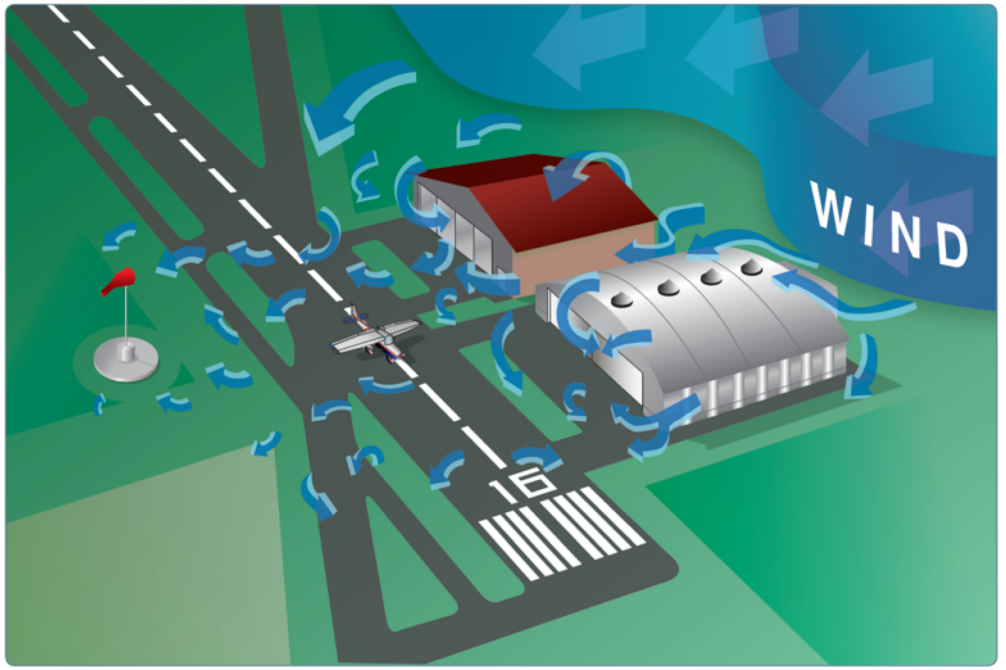
- Any time flights are taking place downwind of structures that can cause the airflow to be disturbed, expect turbulence
- Turbulent conditions - gusty and unpredictable winds - will occur whenever there is a breeze around buildings and trees
- It is always best to choose a flight location that has a relatively smooth terrain profile upwind of the flying site



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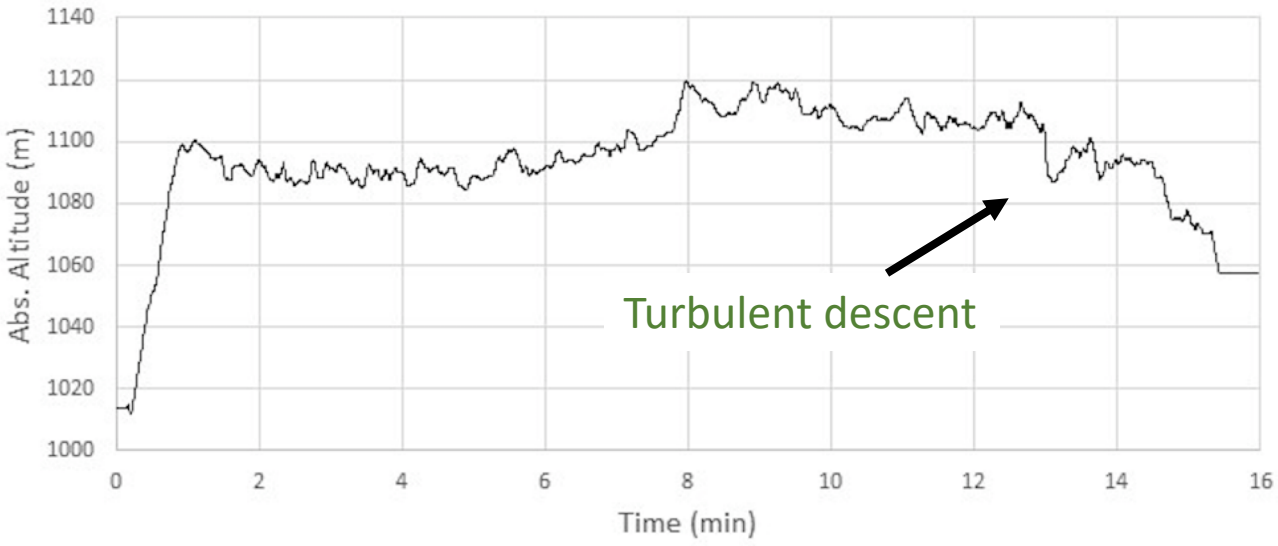
- Downwind of mountains and hills can be particularly challenging areas to fly in since the a strong downwash can be experienced, forcing the aircraft down



Altitude plot of Gogode - Kasungu flight Nov 2017

How does weather affect the aircraft?

Weather condition	Effect on aircraft	Effect on battery life	Effect on performance	Effect on controllability
Wind	Causes flight time to increase or decrease which can impact the mission	Not a direct affect unless the majority of the flight is in terrain-induced downwash	Mission may not be completed if there is a strong headwind component	Aircraft should be controllable unless turbulence exceeds the maneuvering capability of the aircraft
Precipitation	Many drones are not capable of flying in visible precipitation without damage to the electronics	Precipitation will cause more drag in the aircraft which will accelerate power consumption	If the aircraft can fly in visible precipitation, the performance will be degraded due to additional drag	The controllability of the aircraft should not be strongly impacted by precipitation
Altitude	None	None	Significant degradation of performance due to higher density altitude which reduces lifting capacity	None
Temperature	None	Batteries will have degraded performance above 40^{o}C and below 10^{o}C	A lower temperature results in a lower density altitude which increase aerodynamic performance	None

How is the aircraft effected by the weather?

Meteorology
- Weather scale
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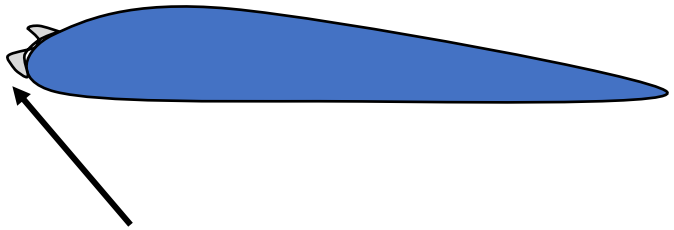
- **Airframe or propeller icing** can occur on any aircraft when flying in visible moisture (clouds) or precipitation when at or below the freezing temperature
  - An **icing condition is dangerous** because it strongly **degrades the lift** generated by the wings or propellers, and it **increases drag** which **increases power consumption**
    - An increase in power consumption will in turn reduce the flight endurance
- Icing conditions, if they exist, are usually noted in a weather briefing
  - This could be in the form of a pilot report (someone who experienced icing first hand), or in a forecast product because the temperature and moisture conditions are ideal for ice formation



Ice can form an irregular shape on the leading edge of the wing, greatly impacting the ability of the wing to generate lift while increasing the drag

A weather forecast is a critical part of the day-before flight planning

Meteorology
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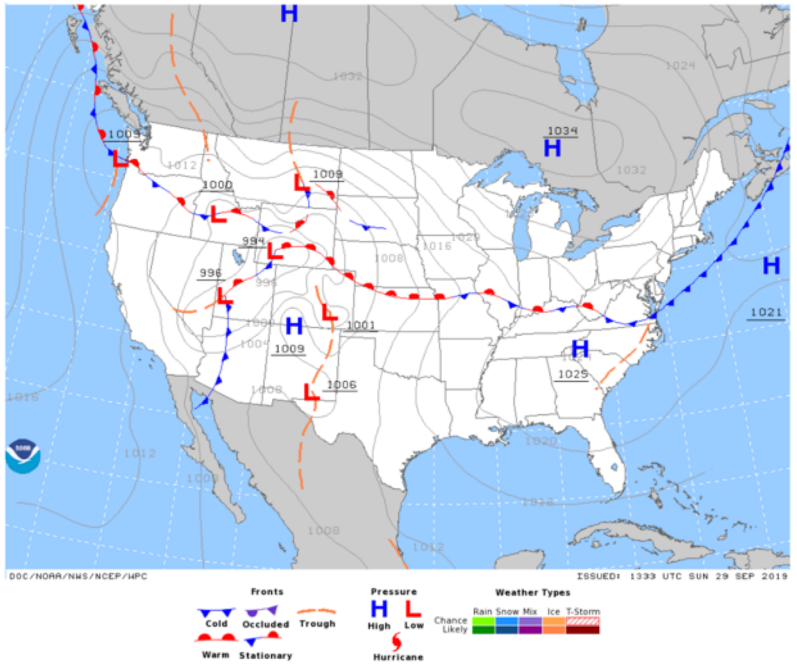
- Forecasts are based on large-scale weather models, shown on surface analysis charts that depicts fronts, high pressure systems and low pressure systems
- These systems define the behavior of winds and the trends that can be expected during the day that will affect flying conditions
- Generally speaking:
  - Fronts bring cloudy conditions
  - High pressure brings favorable conditions
  - Low pressure brings unfavorable conditions



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A weather forecast is a critical part of the day-before flight planning

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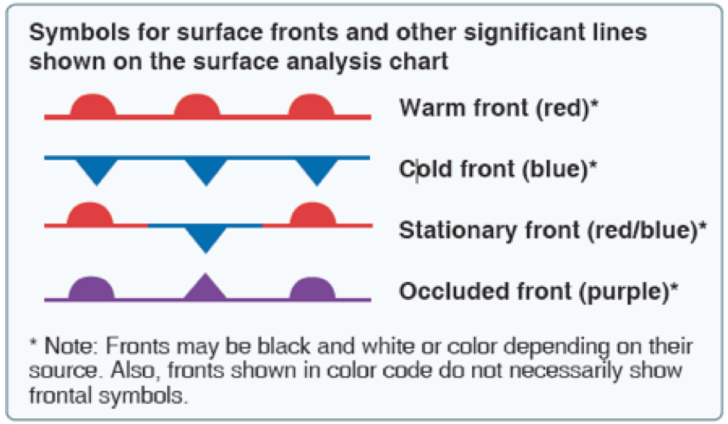
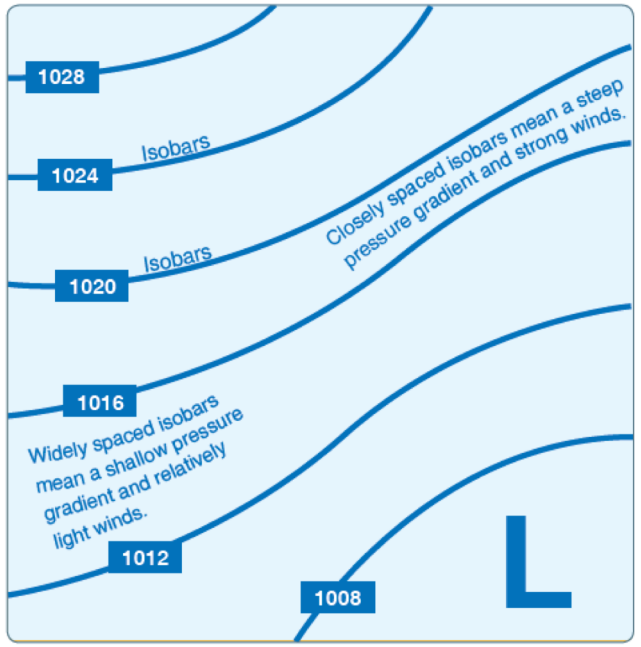
- The surface analysis (SA) chart reveals information about air masses that is helpful in understanding what kind of weather we can expect
- The SA chart shows warm and cold fronts, high and low pressure centers, and isobars that indicate changes in pressure





Warm fronts are characterized by a **temperature inversion** (warm air on top of cooler air) and bring rain and low visibility

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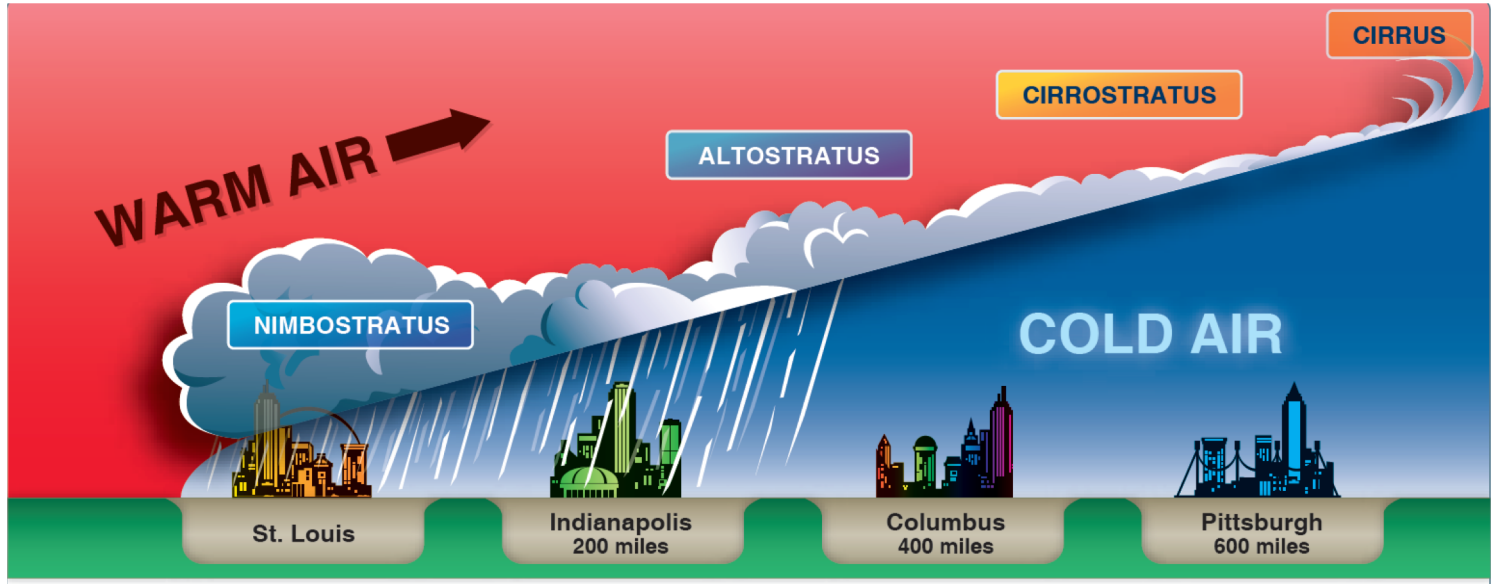

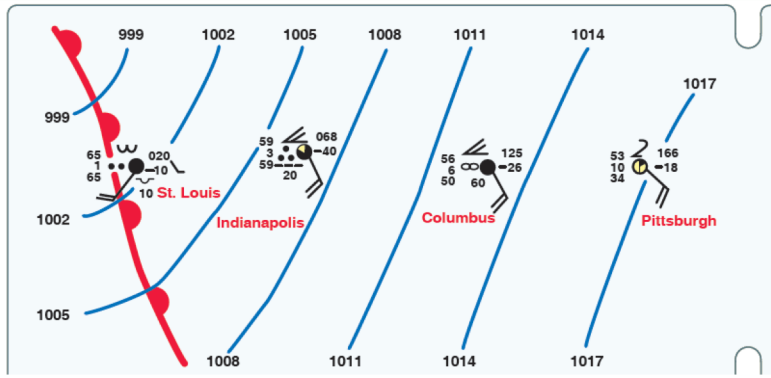

METAR	KSTL 0VC010	1950Z	21018KT 18/18	1SM A2960	–RA
METAR	KIND BKN020	1950Z	16012KT 15/15	3SM A2973	RA
METAR	KCMH 0VC060	1950Z	13018KT 14/10	6SM A2990	HZ
METAR	KPIT SCT150	1950Z	13012KT 12/01	10SM A3002	

- A warm front is characterized by a slow moving line of warm air overtaking cooler air
  - A warm front is usually indicated by warm, moist air moving into the region
  - Low visibility is typical
  - The air is **stable** and typically **does not have turbulence** associated with it

Cold fronts that move into an area usually bring wind and severe weather

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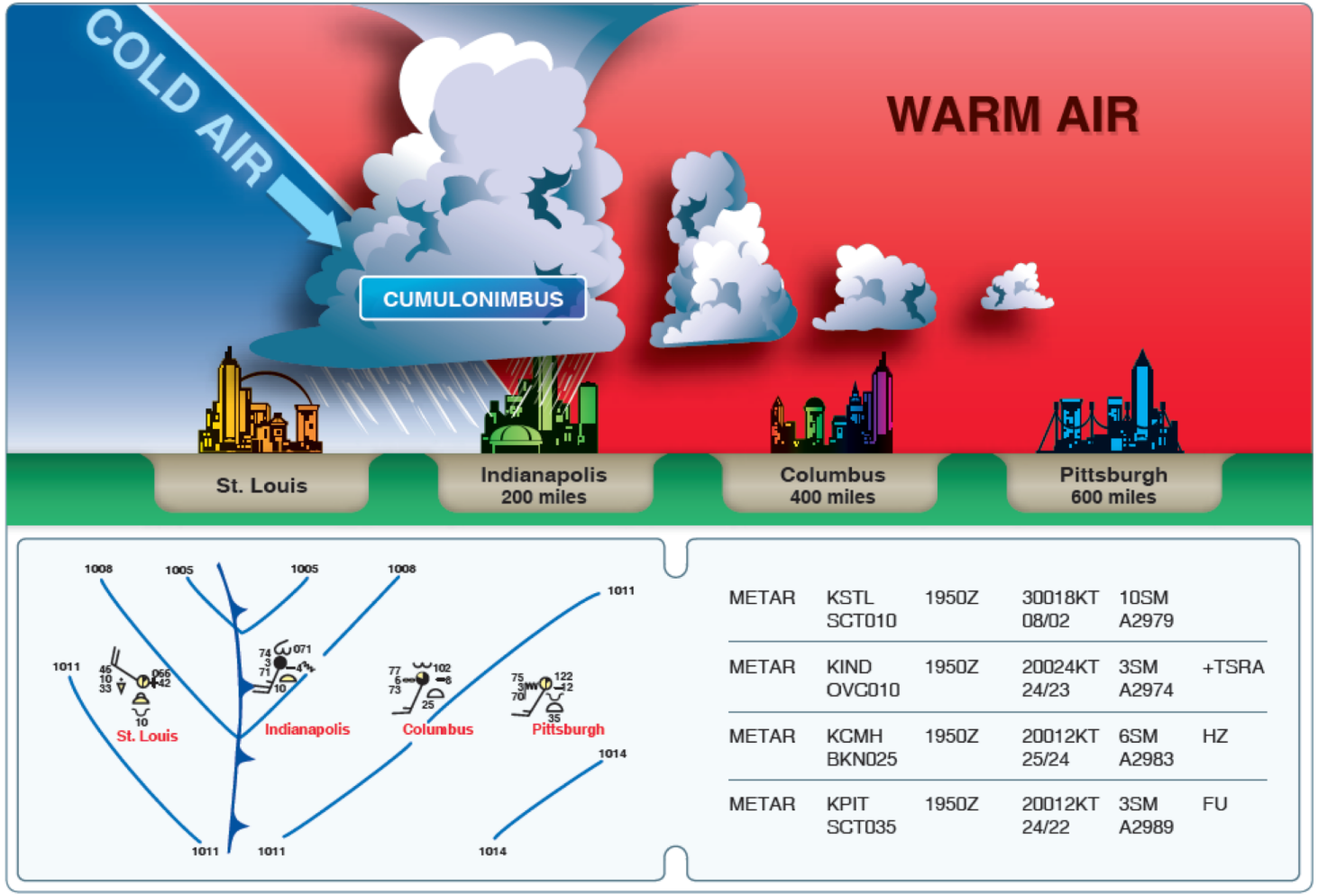

- A cold front is characterized by a fast moving line of cold air that moves in under warm air
  - Cold fronts are **stormy** and should be avoided by all types of aircraft
  - The air **is unstable** and **turbulent**

Clouds can indicate the types of flying conditions to be expected

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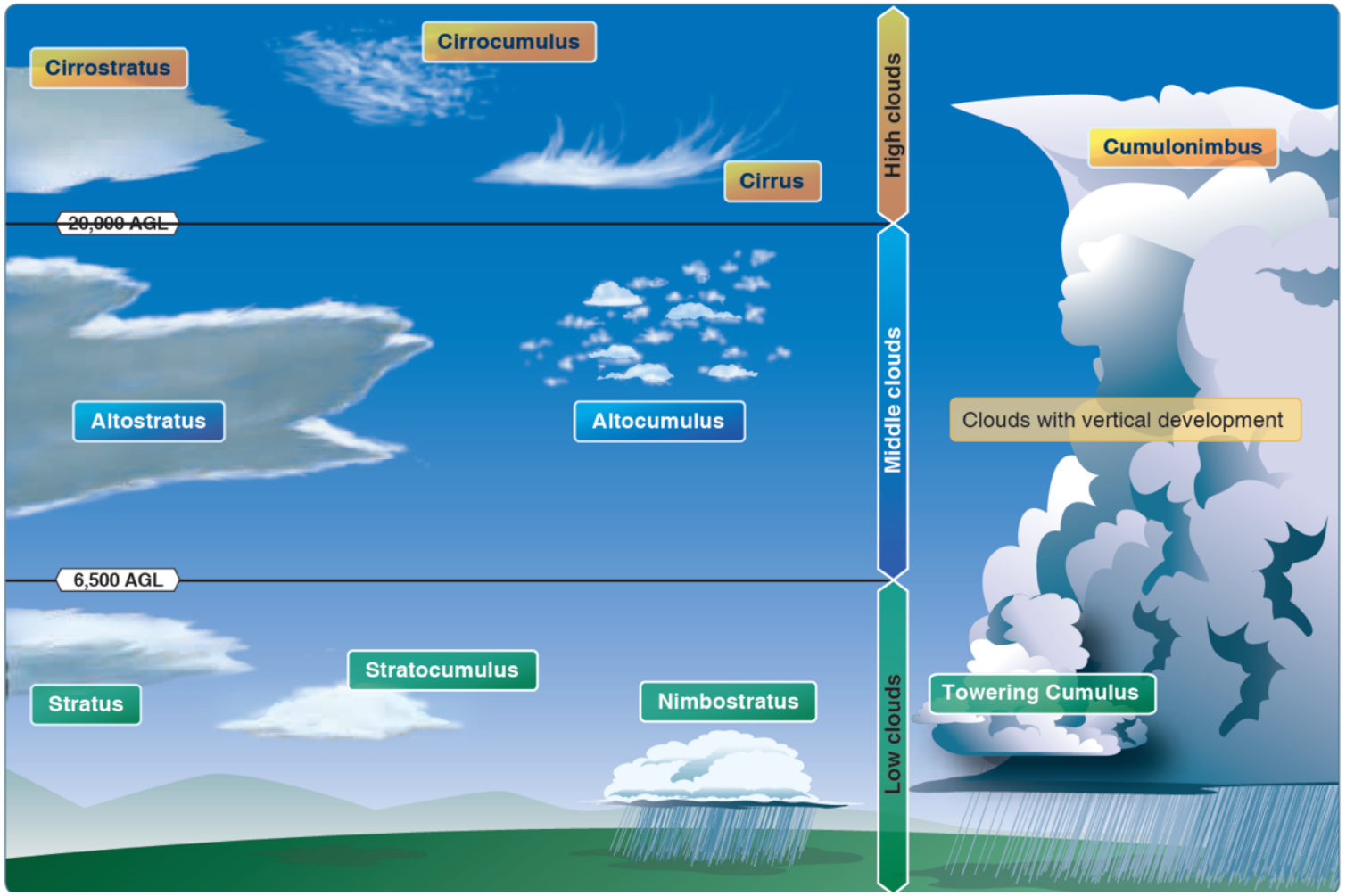

- Severe weather (convective activity) is indicated by cumulonimbus clouds - sometimes with an anvil type
  - Lightning should be expected
  - Strong, gusty winds with rain and hail

Forecasts and observations are critical to understanding the weather situation

Meteorology
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- Forecasts are also known as **TAFs** (terminal aerodrome forecast)
- They can be obtained by the South African Weather Service
- The TAF is usually accompanied by an observation report called the **METAR** (meteorological aviation routine report)
- Both the METAR and TAF use a coded system for describing weather conditions

FWKI - Lilongwe International
METAR
FWKI 291600Z 06008KT CAVOK 25/11 Q1016
NOSIG
TAF
FWKI 291500Z 2918/3024 09012KT CAVOK
BECMG 3004/3006 10006KT 8000 HZ SKC
BECMG 3010/3012 08008KT 9999 FEW030
FM301400 08008KT CAVOK

The codes used in METARs and TAFs should be understood since they contain important weather information

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Key to Aerodrome Forecast (TAF) and Aviation Routine Weather Report (METAR) (Back)

	In **METAR**, ReMarK indicator & remarks. For example: Sea- Level Pressure in hectoPascals & tenths, as shown: 1004.5 hPa; Temp/dew-point in tenths °C, as shown: temp. 18.2°C, dew-point 15.9°C	**RMK SLP045 T01820159**
FM091930	FroM: changes are expected at: 2-digit date, 2-digit hour, and 2-digit minute beginning time: indicates significant change. Each FM starts on a new line, indented 5 spaces	
TEMPO 0920/0922	TEMPOrary: changes expected for <1 hour and in total, < half of the period between the 2-digit date and 2-digit hour beginning, and 2-digit date and 2-digit hour ending time	
PROB30 1004/1007	PROBability and 2-digit percent (30 or 40): probable condition in the period between the 2-digit date & 2-digit hour beginning time, and the 2-digit date and 2-digit hour ending time	
BECMG 1013/1015	BECoMinG: change expected in the period between the 2-digit date and 2-digit hour beginning time, and the 2-digit date and 2-digit hour ending time	

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Qualifier		Weather Phenomena		
Intensity or Proximity 1	Descriptor 2	Precipitation 3	Obscuration 4	Other 5
– Light	**MI** Shallow	**DZ** Drizzle	**BR** Mist	**PO** Dust/sand whirls
Moderate (no qualifier)	**BC** Patches	**RA** Rain	**FG** Fog	**SQ** Squalls
+ Heavy	**DR** Low drifting	**SN** Snow	**FU** Smoke	**FC** Funnel cloud
VC in the vicinity	**BL** Blowing	**SG** Snow grains	**DU** Dust	**+FC** Tornado or waterspout
	SH Showers	**IC** Ice crystals (diamond dust)	**SA** Sand	**SS** Sandstorm
	TS Thunderstorms	**PL** Ice pellets	**HZ** Haze	**DS** Dust storm
	FZ Freezing	**GR** Hail	**PY** Spray	
	PR Partial	**GS** Small hail or snow pellets	**VA** Volcanic ash	
		UP *Unknown precipitation		

The weather groups are constructed by considering columns 1–5 in this table in sequence:
intensity, followed by descriptor, followed by weather phenomena (e.g., heavy rain showers(s) is coded as +SHRA).
* Automated stations only

Trial METAR interpretation

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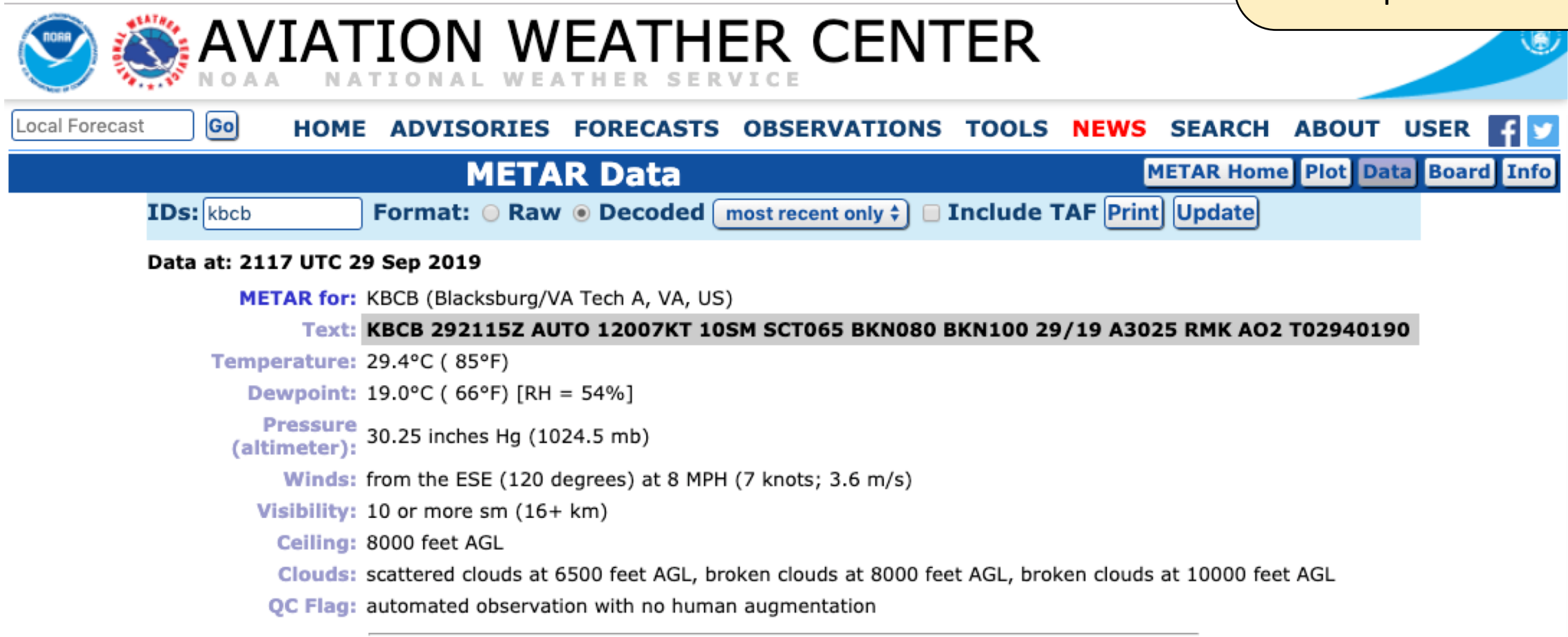

Cool and dry air is associated with high pressure and brings favorable (stable) weather conditions

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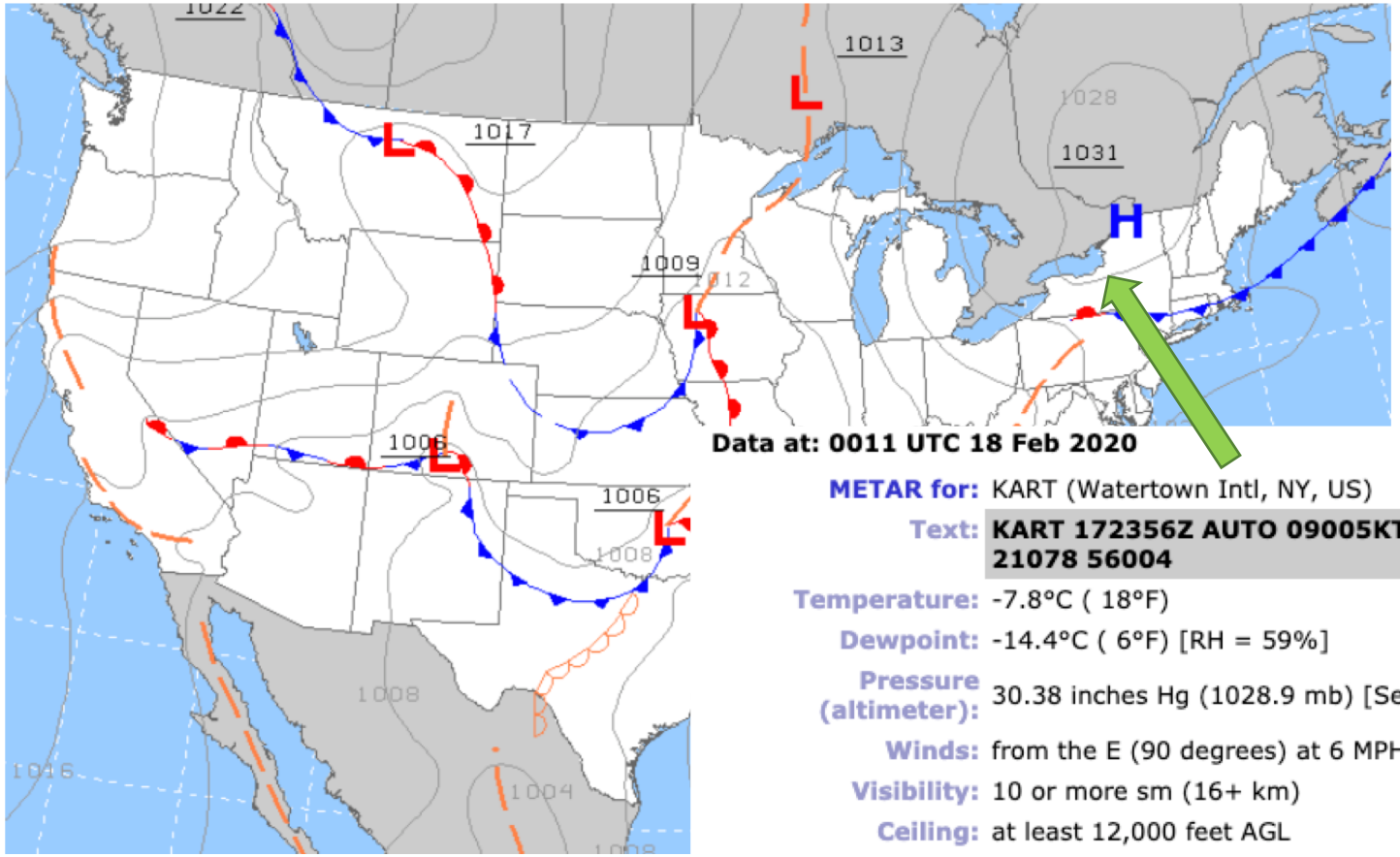

The weather in Watertown, NY is clear and pleasant

Data at: 0011 UTC 18 Feb 2020

METAR for:	KART (Watertown Intl, NY, US)
Text:	**KART 172356Z AUTO 09005KT 10SM CLR M08/M14 A3038 RMK AO2 SLP295 T10781144 11028 21078 56004**
Temperature:	-7.8°C (18°F)
Dewpoint:	-14.4°C (6°F) [RH = 59%]
Pressure (altimeter):	30.38 inches Hg (1028.9 mb) [Sea level pressure: 1029.5 mb]
Winds:	from the E (90 degrees) at 6 MPH (5 knots; 2.6 m/s)
Visibility:	10 or more sm (16+ km)
Ceiling:	at least 12,000 feet AGL
Clouds:	sky clear below 12,000 feet AGL
QC Flag:	automated observation with no human augmentation

Warm(er) and humid air is associated with low pressure and brings unfavorable (unstable) weather conditions

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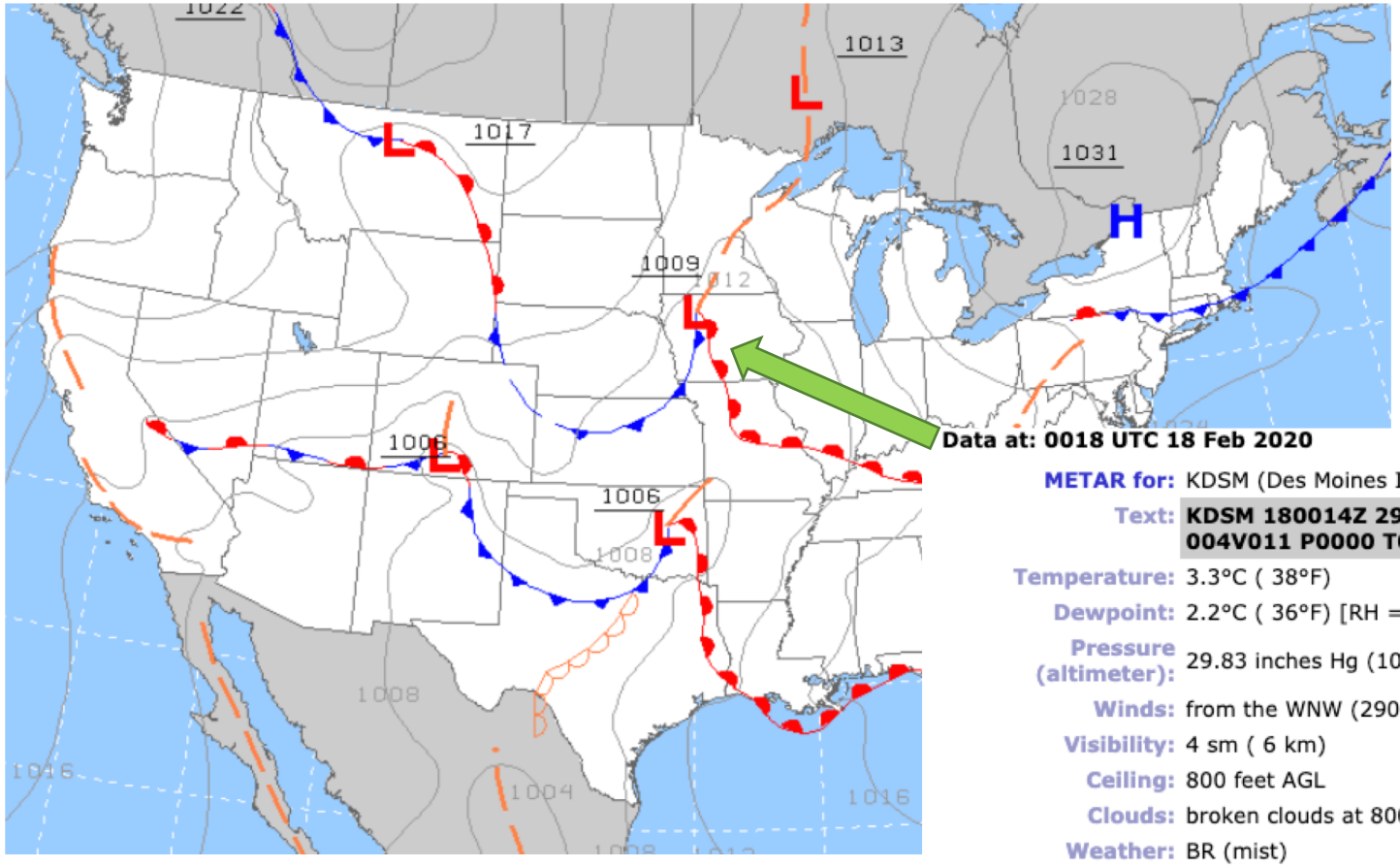

The weather in Des Moines, Iowa is wet with low visibility

Data at: 0018 UTC 18 Feb 2020

METAR for:	KDSM (Des Moines Intl, IA, US)
Text:	**KDSM 180014Z 29011KT 4SM BR BKN008 OVC014 03/02 A2983 RMK AO2 RAE05DZB05E11 CIG 004V011 P0000 T00330022**
Temperature:	3.3°C (38°F)
Dewpoint:	2.2°C (36°F) [RH = 92%]
Pressure (altimeter):	29.83 inches Hg (1010.2 mb)
Winds:	from the WNW (290 degrees) at 13 MPH (11 knots; 5.7 m/s)
Visibility:	4 sm (6 km)
Ceiling:	800 feet AGL
Clouds:	broken clouds at 800 feet AGL, overcast cloud deck at 1400 feet AGL
Weather:	BR (mist)

Generally speaking, the TAF is used for day before flight planning, and both the TAF and METAR are used the day of the flight

Meteorology
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- Winds, visibility and ceiling are the most important information for flight planning
  - Most countries only only allow RPAs to fly up to 400 ft. AGL (above ground level), so clouds are usually not a problem
  - The operator must always maintain visual line of sight of the aircraft, meaning that if the visibility is poor, then the flight radius will be small
  - Winds are reported as steady and gusts (02010KTG20). The maximum predicted windspeed (steady or gust) cannot exceed the operational limits of the aircraft

In addition to weather concerns for the aircraft, the visual observer should know visual line-of-sight limitations

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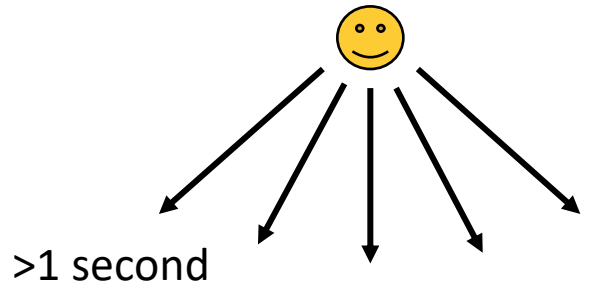
- The visual observer is tasked to apply their knowledge of aircraft performance and weather phenomenon to alert an RPIC of dynamic hazards
  - The VO should recognize that degraded weather conditions will greatly limit the ability to see oncoming traffic
  - *An aircraft traveling at **80 kts in 1000m visibility** will only be seen for **24 sec** before arrival*

Scan techniques that are effective include a stop and stare technique: Move in 10 degree increments while observing for at least 1 second at each position.



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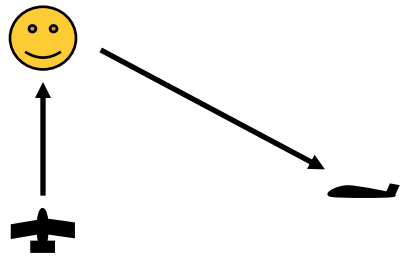
- Atmospheric effects can have a strong effect on visual cues when acting as the visual observer
  - **Dust** and **humidity** greatly **reduces visibility** and the perception of speed and direction can be distorted
  - Referencing the aircraft and understanding its direction of travel requires more concentration in degraded, night or distant observations

Your peripheral vision is effective at detecting motion across the sky, while your central vision is good for detecting approaching or retreating aircraft



UAV Forecast® is a useful app to check weather immediately before flight

Meteorology
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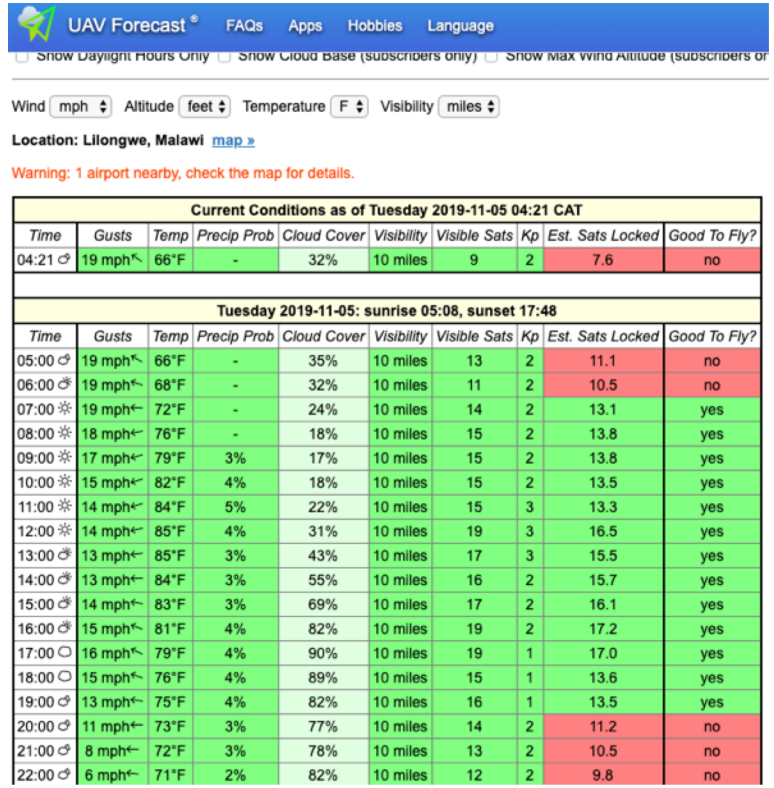
- The UAV Forecast app can provide surface winds and wind profiles at low altitudes which is useful for drone flight
- Local forecasts may be obtained by accessing local airport weather data
  - Consult with the air traffic control authorities for available weather data products



UAV Forecast® FAQs Apps Hobbies Language

Wind mph Altitude feet Temperature F Visibility miles

Location: Lilongwe, Malawi map »

Warning: 1 airport nearby, check the map for details.

Current Conditions as of Tuesday 2019-11-05 04:21 CAT

Time	Gusts	Temp	Precip Prob	Cloud Cover	Visibility	Visible Sats	Kp	Est. Sats Locked	Good To Fly?
04:21	19 mph	66°F	-	32%	10 miles	9	2	7.6	no

Tuesday 2019-11-05: sunrise 05:08, sunset 17:48

Time	Gusts	Temp	Precip Prob	Cloud Cover	Visibility	Visible Sats	Kp	Est. Sats Locked	Good To Fly?
05:00	19 mph	66°F	-	35%	10 miles	13	2	11.1	no
06:00	19 mph	68°F	-	32%	10 miles	11	2	10.5	no
07:00	19 mph	72°F	-	24%	10 miles	14	2	13.1	yes
08:00	18 mph	76°F	-	18%	10 miles	15	2	13.8	yes
09:00	17 mph	79°F	3%	17%	10 miles	15	2	13.8	yes
10:00	15 mph	82°F	4%	18%	10 miles	15	2	13.5	yes
11:00	14 mph	84°F	5%	22%	10 miles	15	3	13.3	yes
12:00	14 mph	85°F	4%	31%	10 miles	19	3	16.5	yes
13:00	13 mph	85°F	3%	43%	10 miles	17	3	15.5	yes
14:00	13 mph	84°F	3%	55%	10 miles	16	2	15.7	yes
15:00	14 mph	83°F	3%	69%	10 miles	17	2	16.1	yes
16:00	15 mph	81°F	4%	82%	10 miles	19	2	17.2	yes
17:00	16 mph	79°F	4%	90%	10 miles	19	1	17.0	yes
18:00	15 mph	76°F	4%	89%	10 miles	15	1	13.6	yes
19:00	13 mph	75°F	4%	82%	10 miles	16	1	13.5	yes
20:00	11 mph	73°F	3%	77%	10 miles	14	2	11.2	no
21:00	8 mph	72°F	3%	78%	10 miles	13	2	10.5	no
22:00	6 mph	71°F	2%	82%	10 miles	12	2	9.8	no