Simon Innocent
Oct 28-29, 2015

AVIATION WEATHER

EASA workshop

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Agenda

- Weather information for safe operations
- Current deficiencies / gap
- Current and future solutions

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- **Weather information for safe operations**
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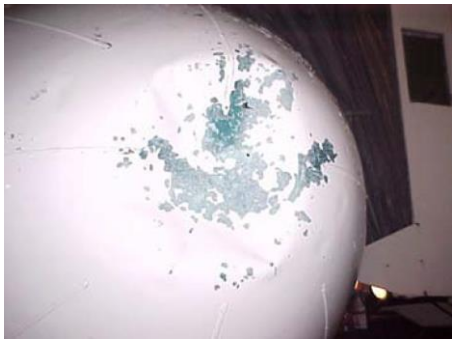
Assessing weather conditions

- Why?
  - Flight safety: avoid hazardous weather
    - Can be strategic or tactical
  - Flight efficiency: fly an optimum route

- When?
  - Before flight (flight planning)
  - During flight (flight execution and re-planning)

- Who?
  - Pilots (PIC is responsible for safety of flight)
  - AOC (for Dispatch and Flight Watch)
  - ATC (for Air Traffic Flow Management)

Significant weather hazards



Hail

Convective Turbulence

Lightning

Volcanic Ash

Icing

Micro-burst

Clear Air Turbulence

Low Visibility

- Plus surface contamination, cross-wind, strong precipitation etc

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Weather information required

- En-route
  - Winds and temperatures at various Flight Levels
  - Convective weather (Cb) top, location, intensity, trend
  - Precipitation nature and intensity (snow, rain, hail)
  - Lightning
  - Icing (High altitude ice crystals, super-cooled droplets)
  - Clear Air Turbulence, Mountain wave
  - Volcanic ash

- TMA
  - Sky cover / Ceiling
  - Precipitation nature and intensity
  - Visibility / RVR
  - Wind direction and speed
  - Wake vortex / Microburst / low level windshear
  - Lightning

A composite image of multiple weather phenomena

Observations / Forecasts

- Both are required
  - Tactical weather identification and avoidance must rely on real-time observations
  - Strategic decision-making relies on a combination of observations, observations trend and forecasts
- Weather observations
  - Surface
  - Upper air (balloons, pilot reports, and aircraft automated reports)
  - Radar (airborne and ground)
  - Satellite
- Weather Forecast and Predictions
  - Surface and upper air observations used by ground systems to compute weather forecast through complex models
  - Airborne systems can provide predictions of weather phenomena based on observations of conducive conditions

Current sources – en-route

Flight phase	Information	Sources
En-route	Winds and temperatures at various Flight Levels	AMDAR observations WAFC Winds & Temp forecasts
En-route	Convective weather (e.g. Cb) top, location, intensity, trend	WAFC SigWxcharts SIGMETs Airborne Weather radar observations Satellite observations Ground radar observations PIREPs METAR/TAF
En-route	Precipitation nature and intensity (snow, rain, hail)	Airborne Weather radar observations & prediction (Predictive Hail) Ground radar observations SIGMETs PIREPs METAR/TAF
En-route	Convective turbulence presence	Airborne Weather radar turbulence observations Automated Turbulence reports SIGMETs PIREPs

Current sources – en-route (cont'd)

Flight phase	Information	Sources
En-route	Lightning	Ground systems-based observations and predictions Airborne Weather radar (Predictive Lightning) Lightning Sensor Systems
En-route	Icing (High altitude ice crystals, super-cooled droplets)	Airborne Weather radar HAIC detection (future) WAFC icing forecasts SIGMETs PIREPs
En-route	Clear Air Turbulence, Mountain wave	WAFC CAT forecasts No observations (possibly in the future: LIDAR) Automated Turbulence reports SIGMETs PIREPs
En-route	Volcanic ash / Dust storm	SIGMETs NOTAMs

Current sources – TMA

Flight phase	Information	Sources
TMA	Sky cover	METAR observations TAF forecasts ATIS
TMA	Precipitation nature and intensity	METAR observations TAF forecasts ATIS Airborne Weather radar observations
TMA	Ceiling	METAR observations TAF forecasts ATIS
TMA	Visibility/RVR	METAR observations TAF forecasts ATIS
TMA	Surface contamination	METAR observations TAF forecasts ATIS

Current sources – TMA (cont'd)

Flight phase	Information	Sources
TMA	Wind direction and speed	Air Data sensors data displayed on PFD / ND METAR observations TAF forecasts ATIS
TMA	Wake vortex	ATC Advisories
TMA	Microburst/low level windshear	Airborne Weather radar (Predictive Windshear)
TMA	Lightning	Ground systems-based observations and predictions Airborne Weather radar (Predictive Lightning) Lightning Sensor Systems

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En-route weather observations limitations

- Radio-sondes
  - Limited number of them
- PIREPS
  - Voice or manual typing, cumbersome
- Ground radar
  - Only continental
  - No worldwide coverage and unequal quality between regions
- Automated aircraft reports
  - Do not differentiate convective turbulence from CAT
  - Communication costs
- Airborne weather radar
  - Can only detect precipitation and certain hazards associated with precipitation
  - Cannot detect Clear Air Turbulence, wake vortex, cloud mist, volcanic ash
  - Typical range 160NM, can go up to 320NM

Partial coverage of weather phenomena

Weather forecast limitations

- Frequency
  - Weather forecasts from WAFC are published only every 6 hours.
  - Forecast can be 6 hours old when flight departs!

- Granularity (temporal resolution)
  - No aviation-approved short-term forecast (i.e. nowcast)
  - WAFC models do not have the appropriate granularity and are not computed frequently enough to predict fast-changing convective cells

- Note: improving the collection of weather observations will also make weather forecasts more accurate and reliable

Update period and temporal resolution can be improved

Access to information is not continuous

- Access to rich, graphical and up-to-date strategic WX information on ground (pre-Flight Information Bulletin, specialized websites)
- Limited access to in-flight updates of strategic WX
- In-flight updates of strategic WX limited to voice or textual messages. Not easy to describe a Satellite image in a few words…

ACARS text messages

No access to up-to-date, graphical strategic WX in-flight

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Misc limitations

- ACARS Communication costs
  - Hinder adoption rate of AMDAR reporting or uplink weather solutions in Commercial Air transport

- Airborne weather radar
  - Legacy systems can be complex to operate
  - Dedicated training to airborne weather radar not widespread

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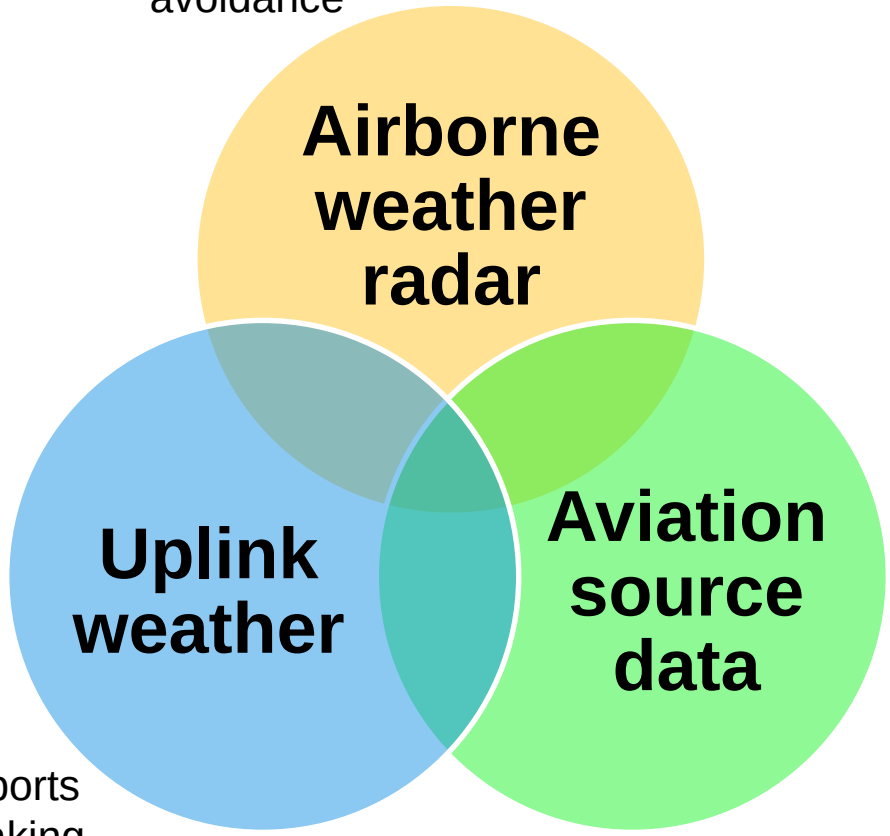
The Vision

- Continuous improvement of airborne weather radar
- Detect a wider scope of phenomena, at a higher range, more accurately
- Tactical weather identification and avoidance



- Deployment of uplink weather solutions
- Graphical and textual weather forecast / reports
- Strategic decision-making
- Synchronization with Airlines Operations Center

- Improve frequency, temporal resolution, reliability and coverage
- New weather products - in particular, observations

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Airborne WX radar - generalities

- Receives and processes radar return power from precipitation (reflectivity i.e. rainfall rate)

- X-band frequencies (in the range of 9.3 to 9.5 GHz)
  - Can detect stratiform or convective systems (requires a fair amount of precipitation to yield detectable returns)
  - Not generally capable of measuring clear air phenomenon, ice crystals, volcanic ash or mist associated with clouds
  - But can see weather behind those conditions

- Doppler measurements
  - Scatterers velocity
  - Turbulence, windshear threat levels

Airborne WX radar – legacy

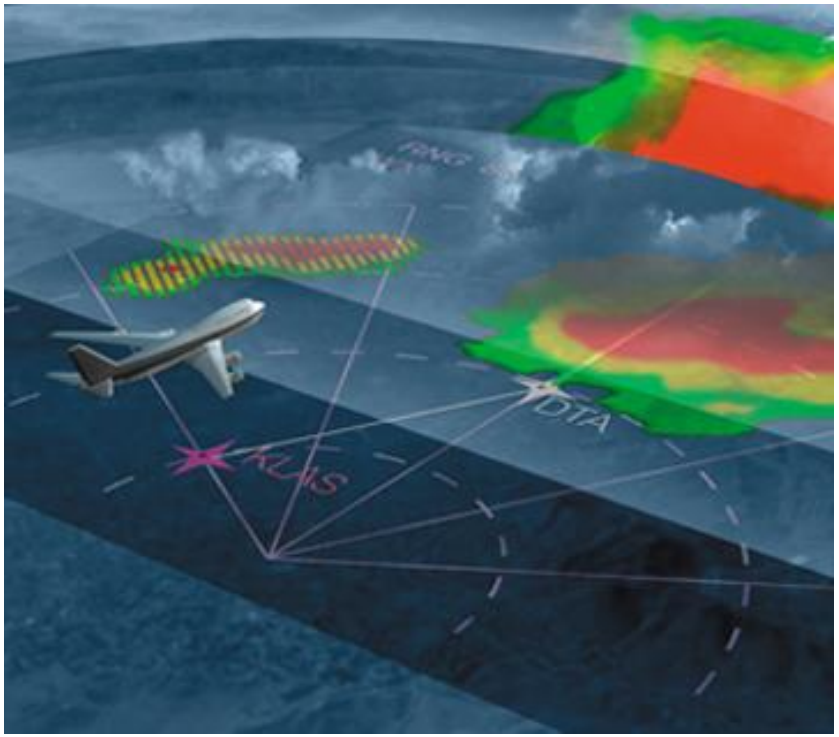
- Basic “Tilt-Based” Weather Radar
  - Requires manual control by the flight crew of the antenna tilt (vertical) angle to analyze the radar returns
  - Tilt setting critical to convective weather discrimination
  - Requires some crew interpretation, factoring in tilt angles (e.g., estimated radar tops), range, characteristic shapes, PIREPs and known weather conditions.
- Tilt-Based with Turbulence Detection
  - Detection of turbulence within precipitation using Doppler techniques.
  - Limited range (40-50 NM depending on model)
  - Generally used for terminal operations to discriminate between “bad” and “worse” weather cells
  - Also requires crew tilt management
- Tilt-Based with Turbulence and Predictive Windshear Detection
  - Predictive Windshear (PWS) refers to detection and alerting of low-level microbursts on departure and approach phases
  - PWS is fully automated

Airborne WX radar - Honeywell IntuVue®

- Automatic Operation

- Volumetric scanning and 3D memory
  - Antenna azimuth and tilt pre-programmed to sweep a volume of the atmosphere
  - 30 seconds for one volumetric scan
  - From 0 to 60,000 ft MSL and out to 320 nm

- Separates return between weather reflectivity returns, turbulence returns and ground returns
  - Ground returns stored in 2D memory
  - Weather and turbulence information stored in separate 3D memories



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Airborne WX radar - Honeywell IntuVue®

- Advantages over tilt-based:
  - Automatic displays with discrimination between weather in proximity to anticipated aircraft path and other weather
  - Manual modes based on intuitive altitude “cuts” of the weather at constant flight levels
  - Vertical weather display at arbitrary azimuth angles, or even along arbitrary flight plans
  - Correction for Earth curvature effects
  - Simultaneous and independent right/left side displays (either side can display data in any mode and range; some automated radars have a limitation on this regard)

Airborne WX radar - Honeywell Hazard 2.0

- Additional set of features for Honeywell IntuVue®

- Hail and lightning prediction
  - Automatically analyzes stored 3D reflectivity data integrated with other sensor information such as static air temperature

- Turbulence detection extended to 60 NM

- Rain Echo Attenuation Compensation Technology (REACT)
  - Compensates for signal attenuation
  - Provides indications of severely attenuated areas.

- Enhanced discrimination between convective and stratus weather

Airborne WX radar - Future

- More information about convective cells
- High Altitude Ice Crystal Detection
- No foreseeable means of adapting airborne weather radar to measure:
  - Temperature
  - Humidity
  - General wind conditions
  - Visibility
  - Volcanic ash or birds
  - Stratiform conditions which can lead to wing surface icing (super cooled droplets)

HAIC flight test campaign
May 2015

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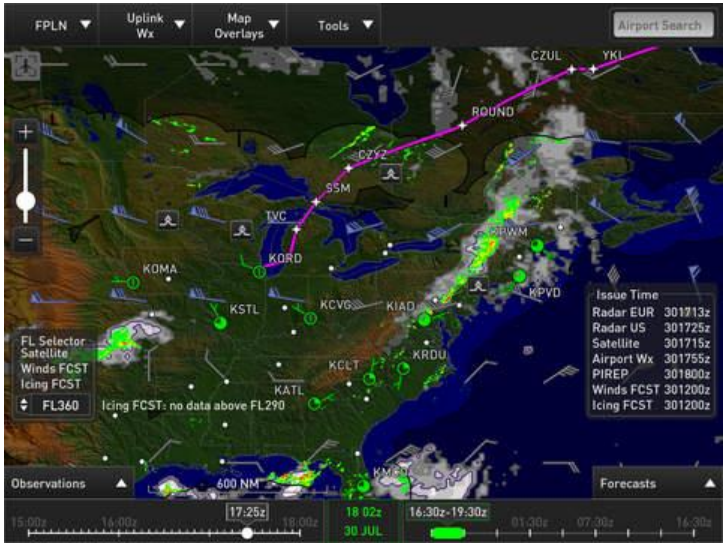
Uplink Weather – Current & Near Future

- Existing Uplink Weather solutions for Commercial Air Transport
  - Winds & Temp uplink to FMS
  - ACARS AOC text messages on MCDU/MFD – Ubiquitous
  - EFB strategic weather applications (Type B) – Supplemental to regulatory sources of Wx information

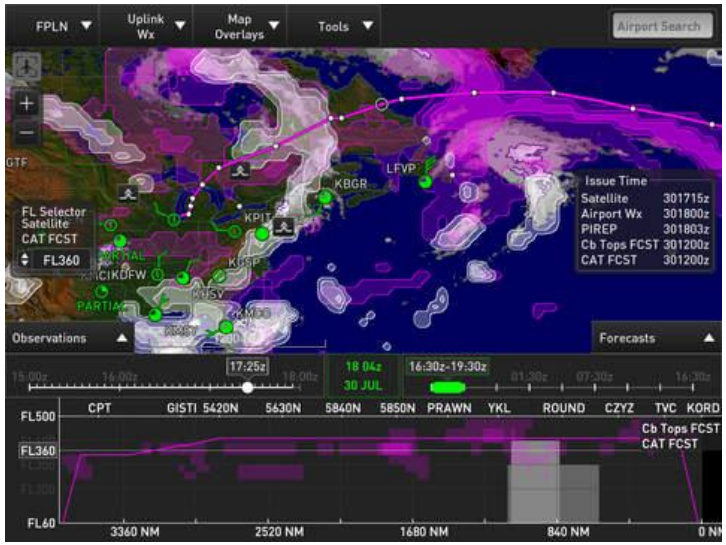
- EFB strategic weather apps
  - Connected to ground systems via datalink
  - Very few aircraft equipped but mature solutions do exist (e.g. Honeywell Weather Information Service)
  - Adoption rate will increase as more aircraft are equipped with affordable SATCOM and in-flight WiFi connectivity solutions

Uplink Weather – EFB strategic WX apps

- Observations:
  - Ground radar
  - Satellite
  - Lightning
  - PIREPs
  - Airport weather
- Forecasts:
  - Cb Tops
  - Clear Air Turbulence
  - Winds aloft
  - Icing
  - SIGMETs
  - Airport weather
- Flight plan overlay
- Vertical Cut



Honeywell Weather Information Service



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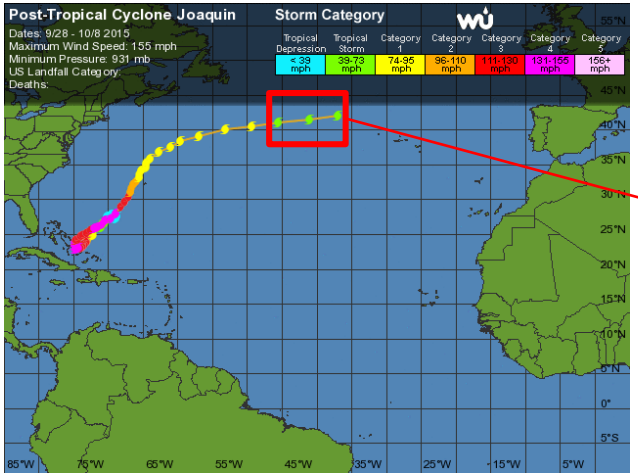
Uplink Weather – EFB strategic WX apps

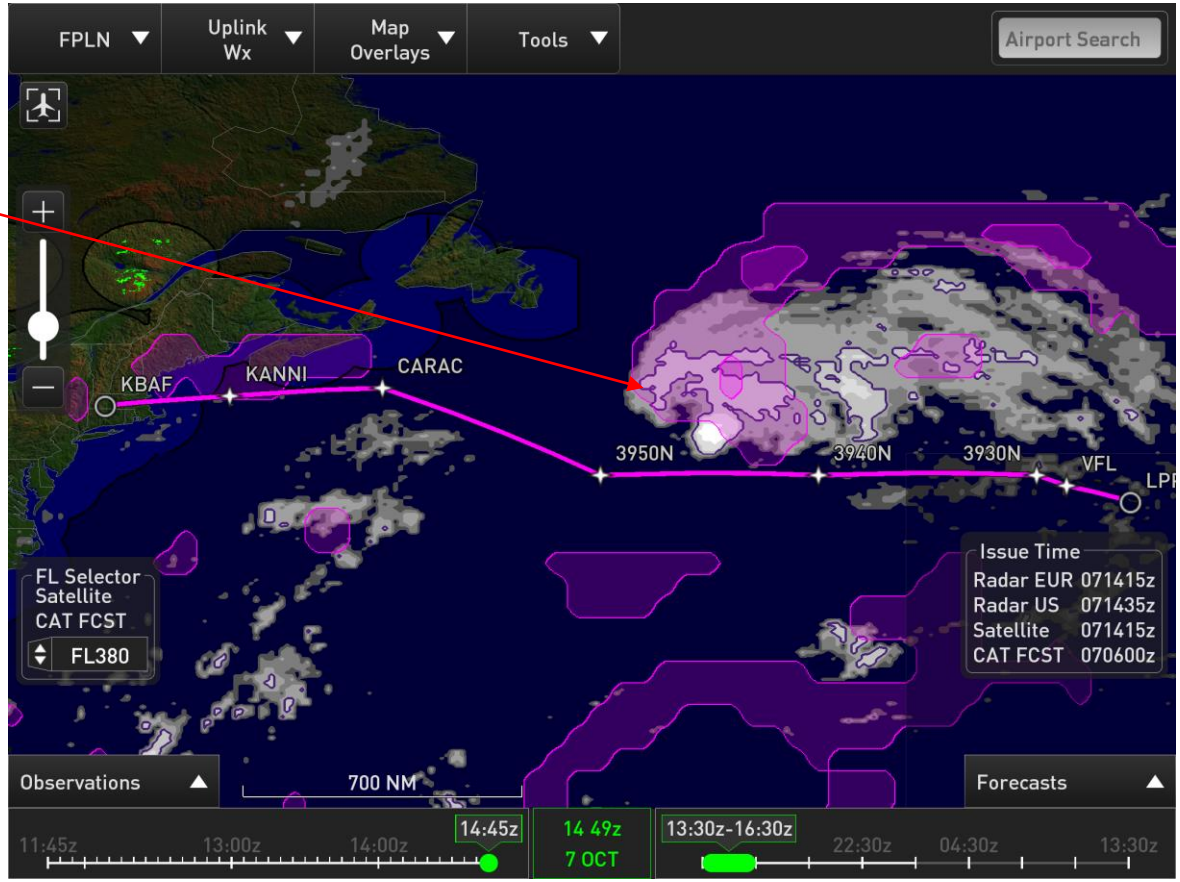
- Real-time observations and updated forecast (as opposed to one-shot data set at pre-flight briefing)
- Graphical depiction of weather phenomena as opposed to legacy ACARS text messages
- Observations for weather phenomena that cannot be detected by on-board systems (outside the range of the WXR or not detectable)
- Common data between flight crew and ground crews (dispatch, flight watch) for making operational decisions
- Flexibility to add new weather products as they become available
- At affordable communication costs (IP)

Strong benefit for long-haul flights

Uplink Weather – EFB strategic WX apps



Hurricane Joaquin turning into a tropical storm when reaching latitude 41°N on Oct 7 1500 GMT



Honeywell B757 flight test aircraft N757HW traveling across the Atlantic from the Azores, easily avoiding Joaquin with Honeywell Weather Information Service (Oct 07)

Strong benefit for long-haul flights

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Uplink Weather – Future

- EFB strategic WX apps
  - New weather products
  - More integration with airborne systems (GPS, FMS etc)
  - Regulatory-wise:
    - may progressively replace some legacy sources of strategic weather such as the weather portion of the Pre-flight Information Bulletin
    - while still meeting the criteria for EFB Type B applications

- For new aircraft design: uplink WX could be ported onto avionics displays
  - Still strategic intended function but more integrated user experience
  - E.g. some Business Jets

- Long-term: uplink WX on Nav Display with tactical intended function
  - SESAR 9.48 research project
  - SC-206 / WG-76 AIS/MET Datalink Apps standardization committees

Uplink WX full of future promise

Aviation Source data

- Resolution, reliability and update frequency of weather source data is critical to safety and economy of flight operations.

- Currently, good level of performance but possible to further improve current WX products or offer new ones

- Areas of particular interest:
  - Frequency of forecast updates: 6 hours today, would benefit from faster rate (e.g. 3 hours)
  - Worldwide coverage: the quality of some products such as ground radar is highly dependent on the region of the globe.
  - Nowcasting: traditional forecast provide information for 3-hour periods, nowcast products provide a shorter-term prediction of the weather development (e.g. active convective cells growth and movement)
  - Improve sources of weather observations.
    - Example: better leverage flying aircraft as network of weather observations sources