PILOTS' VISION ON WEATHER

SESAR PROGRAMME

PROVISION OF WEATHER DATA AND CHARTS

ECA Piloting Safety

European Cockpit Association

Copyright notion:

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Overview

This paper intends to give an overview of the current regulations and projects that influence the provision of weather data and charts to pilots. After a brief introduction of current ICAO regulations, it shows the different ATM projects and major initiatives on both sides of the North Atlantic. It first introduces highlights of the approach taken by NextGen that is being developed in the United States of America, followed by excerpts from the SESAR ATM Master Plan targets which are the reference in the European Union. Both projects and their approach to weather will also be compared.

The paper will conclude on the presented data and give a recommendation of minimum standards on weather presentation that pilots can and should receive. It shows a vision that has the potential to contribute significantly to the objective of increasing safety, efficiency and capacity of air travel in Europe and worldwide.

Key messages:

Relevant Information

Deliver relevant MET (meteorological) information into the pilots' hands. Do not simply store information in computers

- Make the information human readable, i.e. good graphical representations
- Ensure access to the information, the "connectivity"
- Ban black and white printers for MET documentation

Coordination

Ensure that ATC/ATM works with relevant MET across borders, in a coordinated way

- Human readable MET information at controller and supervisor positions
- Arrangements, 'playbook' - style, pre-agreed management of traffic

MET Portal

Build a MET-Portal for Europe such as www.aviationweather.gov for easy access to information and showcase developments ("test bed") to real pilots

- Cooperation between MET-Services in Europe
- Cooperation with research institutions

GNSS Dependence

Re-think the dependence of SESAR on the GBAS and other GNSS approach procedures in light of the research results of SESAR project 15.3.4 – Task 6: GNSS vulnerability assessment. Ensure that adequate conventional navigation facilities are retained and procedures for degraded GNSS operations are developed.

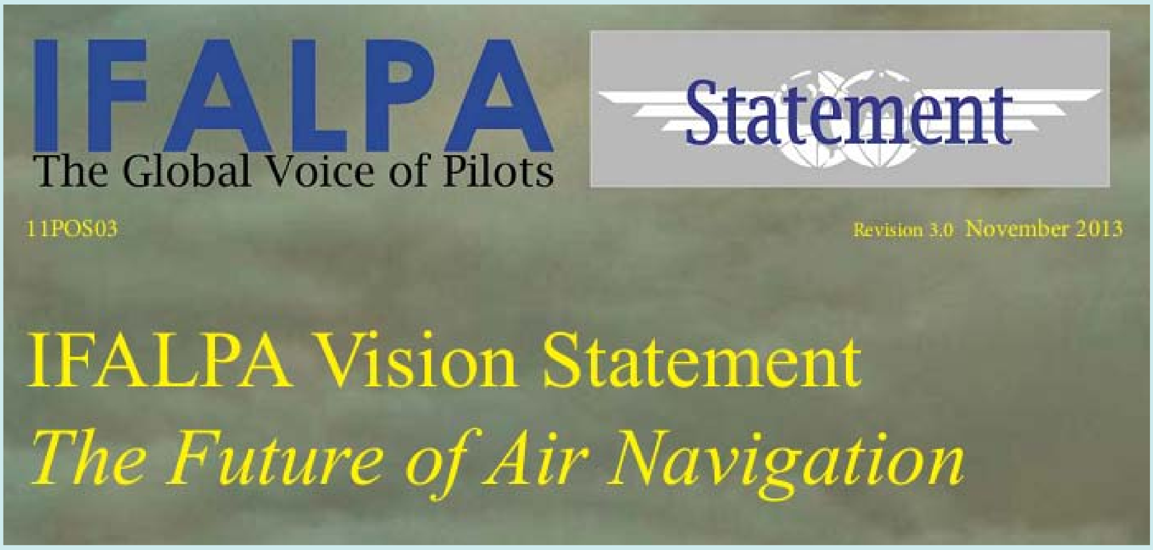
TAF

Halve the time between TAF (Terminal Aerodrome Forecast) from 6 hrs to 3 hrs in the Europe

Introduction

Weather is a worldwide phenomenon and does not only impact airline operations within Europe, but also on a global scale. The pilot community therefore believes that a unified approach is necessary to fulfil the vision of harmonised and safe air travel. The International Federation of Airline Pilot Associations (IFALPA) has issued the following criteria in its Vision Statement "The Future of Air Navigation" that can well serve as a preamble for this paper.

Global considerations



"

» **A single air navigation system**

Air transport is a global activity and it is essential that flight operations work within a common set of standards and procedures all over the world. It is essential that the resulting system is seamless, with the "right" systems (that is hardware, software, and new or enhanced technologies) being used in the "right" way in order that a total air navigation system can deliver a logical, efficient, and above all, safe, system.

» **One set of procedures worldwide**

For an integrated and collaborative air navigation system that is performance based and capable of meeting the needs of aviation in the 21st century, it is of the utmost importance that local procedures are in line with the ICAO provisions (found in the relevant Standards & Recommended Practices (SARPs), PANS, and other guidance material) to ensure that pilots are able to safely use common procedures for the same function (in terms of Communication, Navigation, and Surveillance) in a truly global and harmonized ATM environment. Clearly, the implementation of new capabilities will need to be deployed initially in the most complex and demanding airspaces and adopted aircraft with approximately advanced equipment while the system continues to accommodate less capable aircraft in less stringent requirements. The goal is to provide the best service for the most capable global operators rather than seeking to maximize efficiency by backward compatibility.

» **Performance Orientation**

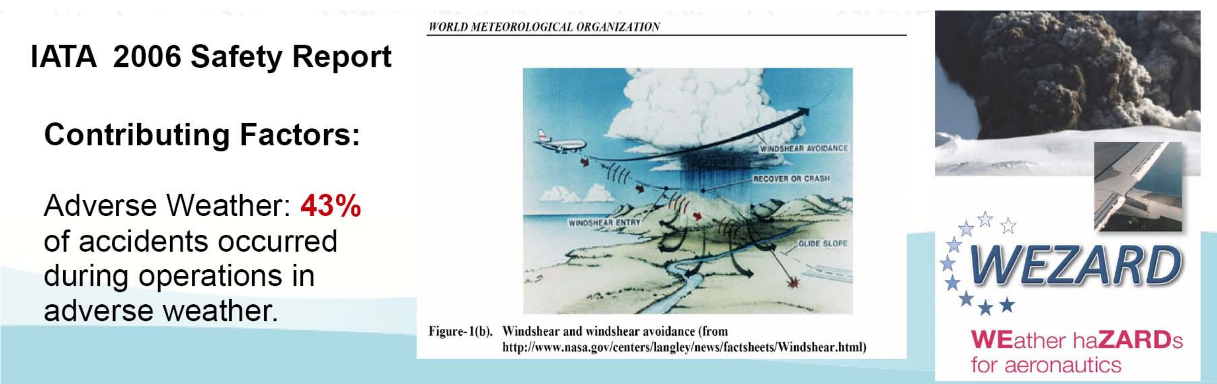
The air navigation system should deliver the performance standards that have been set out and agreed by the aviation community.

Safety is the most important performance indicator

While air transport has enviable accident rates, the fact remains that if the accident rate does not fall as traffic rises then the number of accidents and casualties will increase. Therefore, a proportional improvement in safety levels must be sought if the risk to the travelling public is avoided. Accordingly, safety enhancement is the most important performance parameter in any air navigation system and as such should never be sacrificed. In fact, the calculated safety level required should not be seen as a target to be reached but a threshold that must be exceeded.

As part of the safety matrix, a high level of security is a pre-requisite; accordingly, the ATM system must be protected from all security threats. While there is no such thing as a zero risk operation, risk must be managed as far as possible at a strategic level. At the heart of this is the application of risk management tools like Safety Management Systems (SMS).

The dangers of weather are acknowledged by IATA, well known to the WMO, and addressed in research programs of the European Union and other institutions:



The Eurocontrol Skybrary puts it this way:

Aviation Meteorology

The following can have a direct and indirect influence on flight safety:

» **Turbulence** associated with convective activity (e.g. thunderstorms), terrain (e.g. movement of air masses over mountains), jet streams and the interaction between air masses, can cause structural damage to aircraft.

» **Icing:** Ice Formation on Aircraft can alter the aerodynamic characteristics of aircraft and cause damage to or loss of function of the engines and seriously affect the performance of an aircraft. The article Aircraft and In Flight Icing Risks discusses the commonly-encountered issues whilst high level ice crystal icing of turbine engines is a recently-identified and improperly understood phenomenon which occurs outside the normal icing envelope. Ice may form on aircraft whilst they are on the ground prior to flight and this must be removed. Any further accretion on the airframe prevented by the Aircraft Ground De/Anti-Icing must also be removed so that any aircraft is free of ice deposits at the point at which it gets airborne.

» **Reduced visibility:** associated with cloud, mist, fog, or sand storms, can make safe flight difficult or even impossible, even with the help of technology (ILS, weather radar, synthetic vision systems, etc).

» **Surface contamination:** standing water, ice, or snow on take-off, landing and manoeuvre surfaces.

» **Wind Velocity:** near the ground, the influence of wind on directional control and Cross Wind Landings or take-offs can, if not dealt with effectively, lead to Runway Excursion.

» **Precipitation**: e.g. rain, hail, and snow affect aerodynamics and visibility.

» **Lightning**: a lightning strike can be very distressing to passengers (and crew!) but physical damage to an aircraft only very rarely threaten the safety of an aircraft, usually a small one. Of greater concern is the effect a lightning strike can have on avionics, particularly compass and air data systems, and in case of rear mounted jet engines, the potential for the transient airflow disturbance associated with lightning to cause engine shutdown on both FADEC and non-FADEC engines because of their close spacing and exposure to the same airflow disturbance at the same time.

Against this background, it is obvious that the relay of weather information to pilots, air traffic controllers and flight dispatchers is essential to maintain a high level of safety in order to avoid flight disruptions by weather related occurrences. This will also lead to smoother, more efficient and overall less expensive operations. Additionally, it will also have positive effect on meeting the targets of the SESAR programme, as operational staff will be able to plan for otherwise unexpected events like ad-hoc weather deviations. Good pre-flight and in-flight planning will not only help to reduce delays, but also fuel burn and capacity restrictions.

Current regulatory status

The core regulations governing the provision of meteorological information are contained in ICAO Annex 3. The first excerpt will show the different forecast types that World Area Forecast Centres (WAFC) produce. This data is usually provided in digital format.

It should be noted that Amendment 76 came into force in November 2013. One of the main changes is that the WAFCs will now regularly issue grid-formatted forecasts of Cumulonimbus Clouds, Icing and Turbulence. By removing the trial-status of these products, they will become operational. These gridded forecasts are digital products only. They have to be transformed into visual images so that the human users can interpret them. This visualisation process has not yet been defined or standardised.

The second quote of Annex 3 shows that the provisions of information relay to flight crews and operators.

“ Quote of the relevant provision for WAFC:

A Contracting State, having accepted the responsibility for providing a WAFC within the framework of the world area forecast system, shall arrange for that centre:

1 to prepare gridded global forecasts of:

- upper wind;
- upper-air temperature and humidity;
- geopotential altitude of flight levels;
- flight level and temperature of tropopause;
- direction, speed and flight level of maximum wind;
- cumulonimbus clouds;
- icing; and
- turbulence;

2 to prepare global forecasts of significant weather (SIGWX) phenomena

3 to issue the forecasts referred to in a) and b) in digital form to meteorological authorities and other users, as approved by the Contracting State on advice from the meteorological authority;

4 to receive information concerning the accidental release of radioactive materials into the atmosphere from its associated WMO regional specialized meteorological centre (RSMC) for the provision of transport model products for radiological environmental emergency response, in order to include the information in SIGWX forecasts;

5 to establish and maintain contact with VAACs (Volcanic Ash Advisory Centre) for the exchange of information on volcanic activity in order to coordinate the inclusion of information on volcanic eruptions in SIGWX forecasts.

Note: Gridded global forecasts of cumulonimbus clouds, icing and turbulence are currently of an experimental nature, labelled as “trial forecasts” and distributed only through the Internet-based file transfer protocol (FTP) services.

Note: No longer in force from Nov 2013 due to Amendment 76.

In case of disruption of the operation of a WAFC, its functions shall be carried out by the other WAFC.

Note: Back-up procedures to be used in case of interruption of the operation of a WAFC are updated by the World Area Forecast System Operations Group (WAFSOPSG) as necessary. The latest revision can be found at the WAFSOPSG website.

Quote of the relevant provisions for Crews:

“ Meteorological information supplied to operators and flight crew members shall be up to date and include the following information, as established by the meteorological authority in consultation with operators concerned:

a) forecasts of

1) upper wind and upper-air temperature;
2) upper-air humidity;
3) geopotential altitude of flight levels;
4) flight level and temperature of tropopause;
5) direction, speed and flight level of maximum wind; and
6) SIGWX phenomena.

Note: Forecasts of upper-air humidity and geopotential altitude of flight levels are used only in automatic flight planning and need not be displayed.

b) METAR or SPECI (including trend forecasts as issued in accordance with regional air navigation agreement) for the aerodromes of departure and intended landing, and for take-off, en-route and destination alternate aerodromes;

d) forecasts for take-off;

e) SIGMET information and appropriate special air-reports relevant to the whole route;

Note: Appropriate special air-reports will be those not already used in the preparation of SIGMET.

f) volcanic ash and tropical cyclone advisory information relevant to the whole route;

g) subject to regional air navigation agreement, GAMET area forecast and/or area forecasts for low-level flights in chart form prepared in support of the issuance of AIRMET information, and AIRMET information for low-level flights relevant to the whole route;

h) aerodrome warnings for the local aerodrome;

i) meteorological satellite images; and

j) ground-based weather radar information.

Forecasts listed under a) shall be generated from the digital forecasts provided by the WAFCs whenever these forecasts cover the intended flight path in respect of time, altitude and geographical extent, unless otherwise agreed

between the meteorological authority and the operator concerned.

End quote ANNEX 3

DEVELOPMENTS

USA NextGen

Next Generation Air Transportation System

NextGen is the transformation of how airplanes traverse the sky. It affects all of us: from the pilots that fly the planes, the passengers who enjoy the flights and the controllers who ensure the safety.

The thousands of planes overhead right now are flying indirect routes over radar towers. For close to six decades we have used this World War II era technology to transit the skies. NextGen is an upgrade to satellite-based technology.

Piece by piece we are installing this new system. It is a consistent and persistent effort to bring airplanes and airports online with NextGen technology.

Source: FAA NextGen

SESAR

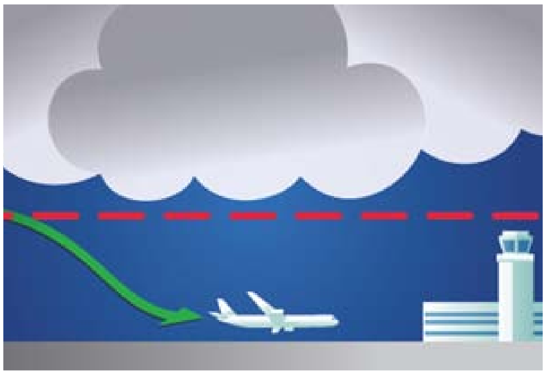
Towards a single European Sky

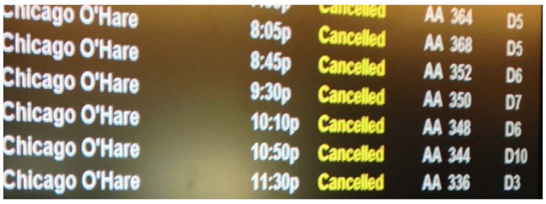
MET

The SESAR programme is the operational and technological answer to Europe's air traffic management challenges. Embedded in the EU's ambitious Single European Sky initiative, the aim of SESAR is to ensure the modernisation of the European air traffic management system by coordinating and concentrating all relevant research and development efforts in the European Union. Results delivered through the SESAR Releases will see the European ATM system gradually evolve towards full performance-based operations by the end of this decade. Through AIRE, SESAR partners perform integrated flight trials validating solutions for the reduction of CO2 emissions for all phases of flight to substantially accelerate the pace of change.

Source: SESAR Joint Undertaking

The following pages show excerpts of NextGen as well as SESAR documentation further below and information that can be found on paper or online. This will show the reader the various focus points and recommendations of both projects.





NextGen

Weather accounts for 70% of all air traffic delays within the U.S. National Airspace System (NAS)

"The total cost of domestic air traffic delays to the U.S. economy was as much as $41 billion for 2007."

The Federal Aviation Administration (FAA) has determined two thirds of this is preventable with better weather information.

Better weather information does not just mean better forecasts. It means better assimilation of weather to the FAA decision makers, as well as better consistency.

NextGen goals are not achievable without improving integration of weather information into decision support systems.

NextGen weather vision is focused on:
» Providing multiple user common weather picture
» Consistent and reliable weather information
» An improved weather information and data storage approach containing observation and forecast data enabling NextGen dissemination capabilities. This source is called the 4-D Data Cube.

A Net-centric capability is envisioned for NextGen, and it is referred to as "Network Enabled"
» An information network that makes information available, securable, and usable in real time
» Information may be pushed to known users and is available to be pulled by others
» Weather information sharing is two-way.

A "virtual" repository with no single physical database or computer:
» Conceptually unified source distributed among multiple physical locations and suppliers, of which the National Oceanic and Atmospheric Administration (NOAA) is the leading data supplier.

Today

» Not integrated into aviation decision support systems (DSS)
» Today's requirements can lead to inconsistent info
» Low temporal resolution (for aviation decision making purposes)
» Disseminated in minutes
» Updated by schedule
» Fixed product formats (graphic or text)

NextGen (new requirements)

» Totally integrated into DSS
» Updated requirements/Nationally consistent
» High temporal resolution
» Disseminated in seconds
» Updated by events
» Flexible formats

An FAA weather study " Weather in the cockpit: priorities, sources, delivery and the needs in the next generation air transport system" came up with the following recommendations:

> Recommendations:
> » Provide integrated display of weather data
> » Incorporate decision-making aids referenced to a specific pilot and flight profile
> » Emphasize hazardous weather directly relevant to flight profile (per known pilot prioritisations)
> » Indicate reliability of forecast information (i.e. probabilities associated with specific forecasts)
> » Provide access to lower levels of detailed data without full-time display of same

There is more - much more - very concrete R&D going on.

Aviation Weather Research - NextGen

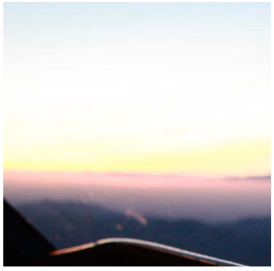
Improve in-flight icing forecasts
» now: CIP/FIP on NWS ADDS
» mid-term: enhanced CIP/FIP and Icing Product Alaska
Improve turbulence detection and forecasts
» now: GTG on NWS ADDS
» mid-term: enhanced GTG
Improve C&V analyses and forecasts
» now: CVA on NWS ADDS
» mid-term: Partnering w/ NWS to develop CVF
Research results then led to legislative action:

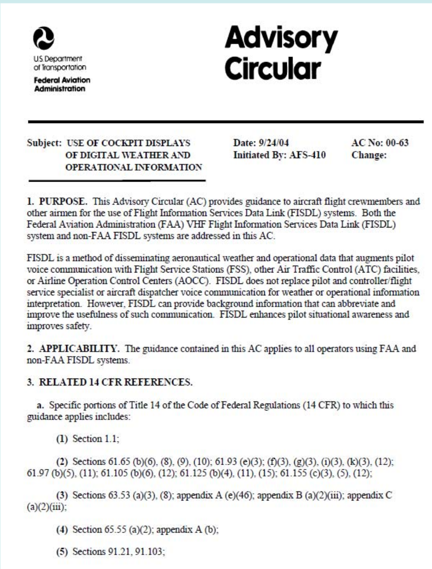
This research has an extensive base, e.g. :

Weather Technology in cockpit

Project description:

- Portfolio of research initiatives used to develop, verify, and validate requirements for standards related to weather information and technology in the cockpit
- Identifies requirements that improve the quality and quantity of meteorological (MET) information in the cockpit
- Supports multiple NextGen goals: reduce weather delays; route flexibility to avoid adverse weather; enhance safety-reduced weather-related accidents and incidents.





U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: USE OF COCKPIT DISPLAYS OF DIGITAL WEATHER AND OPERATIONAL INFORMATION

Date: 9/24/04
Initiated By: AFS-410

AC No: 00-63
Change:

1. PURPOSE. This Advisory Circular (AC) provides guidance to aircraft flight crewmembers and other airmen for the use of Flight Information Services Data Link (FISDL) systems. Both the Federal Aviation Administration (FAA) VHF Flight Information Services Data Link (FISDL) system and non-FAA FISDL systems are addressed in this AC.

FISDL is a method of disseminating aeronautical weather and operational data that augments pilot voice communication with Flight Service Stations (FSS), other Air Traffic Control (ATC) facilities, or Airline Operation Control Centers (AOCC). FISDL does not replace pilot and controller/flight service specialist or aircraft dispatcher voice communication for weather or operational information interpretation. However, FISDL can provide background information that can abbreviate and improve the usefulness of such communication. FISDL enhances pilot situational awareness and improves safety.

2. APPLICABILITY. The guidance contained in this AC applies to all operators using FAA and non-FAA FISDL systems.

3. RELATED 14 CFR REFERENCES.

a. Specific portions of Title 14 of the Code of Federal Regulations (14 CFR) to which this guidance applies includes:

(1) Section 1.1;

(2) Sections 61.65 (b)(6), (8), (9), (10); 61.93 (e)(3); (f)(3), (g)(3), (i)(3), (k)(3), (12); 61.97 (b)(5), (11); 61.105 (b)(6), (12); 61.125 (b)(4), (11), (15); 61.155 (c)(3), (5), (12);

(3) Sections 63.53 (a)(3), (8); appendix A (e)(46); appendix B (a)(2)(iii); appendix C (a)(2)(iii);

(4) Section 65.55 (a)(2); appendix A (b);

(5) Sections 91.21, 91.103;

“

Advisory Circular

This Advisory Circular (AC) provides guidance to flight crew members and other airmen on the use of data link to access Flight Information Services (FIS). This AC addresses both the Federal Aviation Administration (FAA) FIS Broadcast (FIS-B) provided through Automatic Dependent Surveillance - Broadcast (ADS-B) Universal Access Transceiver (UAT) network and non-FAA FIS systems.
Source: DoT AC- 0063

Global Information Sharing

Aircraft Access to SWIM (AAtS). AAtS is an effort to define how aircraft will connect to SWIM, enabling access to a common collection of aeronautical services provided from multiple official sources to create a globally interoperable and shared aviation information environment. This will facilitate common situational awareness so that flight crews can be involved in the collaborative decision making process. It is important to understand that the AAtS initiative will not implement a specific infrastructure to create the actual link to the aircraft. Rather, AAtS defines a set of operational and technical requirements and provides guidance that will be used to implement that infrastructure.

Note: At the time of this writing, the FAA AAtS initiative will conduct a series of technical research and validations as well as operational demonstrations. These efforts, while wide-in-scope and performed over a length of time, will include data linking Meteorological Information and AI Aeronautical Infromation data to the flight deck. The operational demonstrations will provide data to support efficient use of strategic and tactical traffic management operations up to, but not including uses that directly affect aircraft trajectories. Multiple vendors and multiple AAtS demonstration partnership teams will perform the operational demonstrations to validate the AAtS concepts.

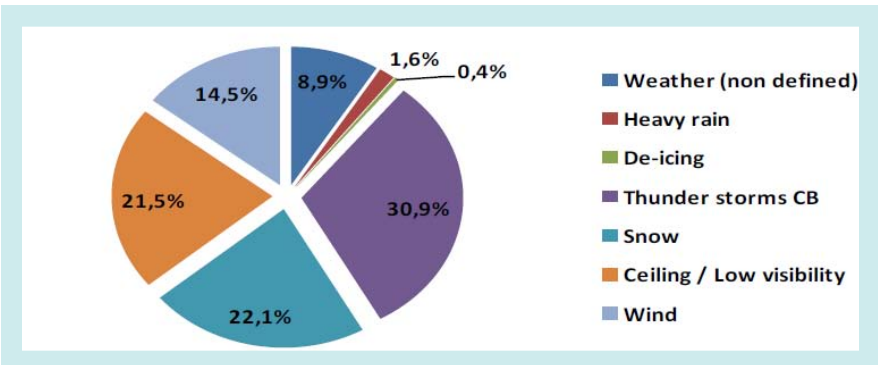
Europe & SESAR

The SESAR documentation mentions weather on several occasions: e.g. SESAR Concept of Operations Step 1, Definitions, etc.

"The main weather conditions affecting airports and network performances are poor visibility, freezing conditions, strong winds and convective weather. These factors have an adverse impact on predictability of operations and on system capacity, due to higher uncertainty margins around trajectory predictions and in order to guarantee safety. Sensitivity of different Airspace Users to weather conditions can considerably vary depending on the type of aircraft operated (type of airframe, on-board equipment, etc.).

The arrival and departure airport capacity often drops in adverse weather conditions, requiring the application of ATFM (Air Traffic Flow Management) regulations and the consequent generation of delay on flights. En-route capacity can also be affected by weather phenomena, e.g. due to the presence of cumulonimbus associated with thunderstorms or of ash clouds limiting the airspace access and determining flight re-routings or cancellations. This was the case in April 2010, when the eruption of Eyjafjallajokull volcano in Iceland had a major impact on European civil aviation, mainly through cancelled flights. Apart capacity, other impacts of adverse weather conditions on en-route operations include trajectory changes, inability to respect a time constraint, ground trajectory predictions degradation, less accuracy of controller support tools, conflict and/or complexity resolution solutions non applicable, work load increase, aircraft diversion etc.

The figure below illustrates the impact of weather on ATFM delays in Europe in 2010 (PRR 2010):



» **Nominal weather conditions,** which are the conditions in which the airport operates in more than 90% of time and where the declared capacity for scheduling purposes is based on. Nominal conditions translate in conditions like no wind (or light wind under a certain threshold), no snow, no visibility constraints etc.
» **Adverse, degraded weather conditions,** within the operational envelope of the airport, which have a significant negative impact on operations unless an appropriate response is organised; Adverse weather conditions may be reduced visibility conditions (e.g. Cat 2) or strong and gusting wind.
» **Disruptive weather,** adverse conditions which are very unlikely to occur and would have a severe impact on airport performance but the airport cannot be expected to provide resources to mitigate the condition like snow at a Mediterranean airport.

Other important mentions of weather are in the “Definitions” part of the SESAR Concept of Operations: e.g. Definitions

Flight intent

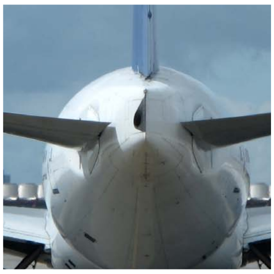
The future aircraft trajectory expressed as a 4-D profile until destination (taking account of aircraft performance, weather, terrain, and ATM service constraints), calculated and “owned” by the aircraft flight management system, and agreed by the pilot.

source: ICAO doc 9854

Tailored arrival

Tailored arrival procedures are defined from Top of Descent to Initial Approach Fix (IAF) or to runway taking in account the other traffic and constraints, to optimize the descent. The concept is based on the downlink to the ANSP of actual aircraft information (like weight, speed, weather etc.) and the uplink of cleared route (STAR) calculated by the ANSP.

source: OI AOM-0704 new



Revision of the Reference Business of Mission Trajectory

The revision of the Reference Business or Mission Trajectory (RBT/RMT) is triggered at Controller or Flight Crew initiative when there is the need to change the route and/or altitude constraints and/or time constraints, mainly due to hazards (traffic, weather), fine sequencing (CTA or CTO allocation) or inability for the aircraft system to meet a constraint (CTA missed).

source: SESAR Def. Phase

User Preferred 4D Trajectory

The User Preferred 4D Trajectory (UP4DT), or from a Military perspective the Requested Mission Trajectory (ReqMT), is the user preferred 4D trajectory integrating the known ATM constraints. Airspace User agree to fly and ANSPs & Airports will strive to facilitate; it corresponds to the operational flight plan currently provided by Airspace User to Flight Crew that has been shared with ATM actors to take into account static and known dynamic constraints in ATM system (airspace reservations, capacity short falls, weather, etc.); it represents the initial step toward the Shared Business / Mission Trajectory (SBT) and the Reference Business / Mission Trajectory (RBT).

new

Source: SESAR Concept of Operations Step 1 (ConOps)

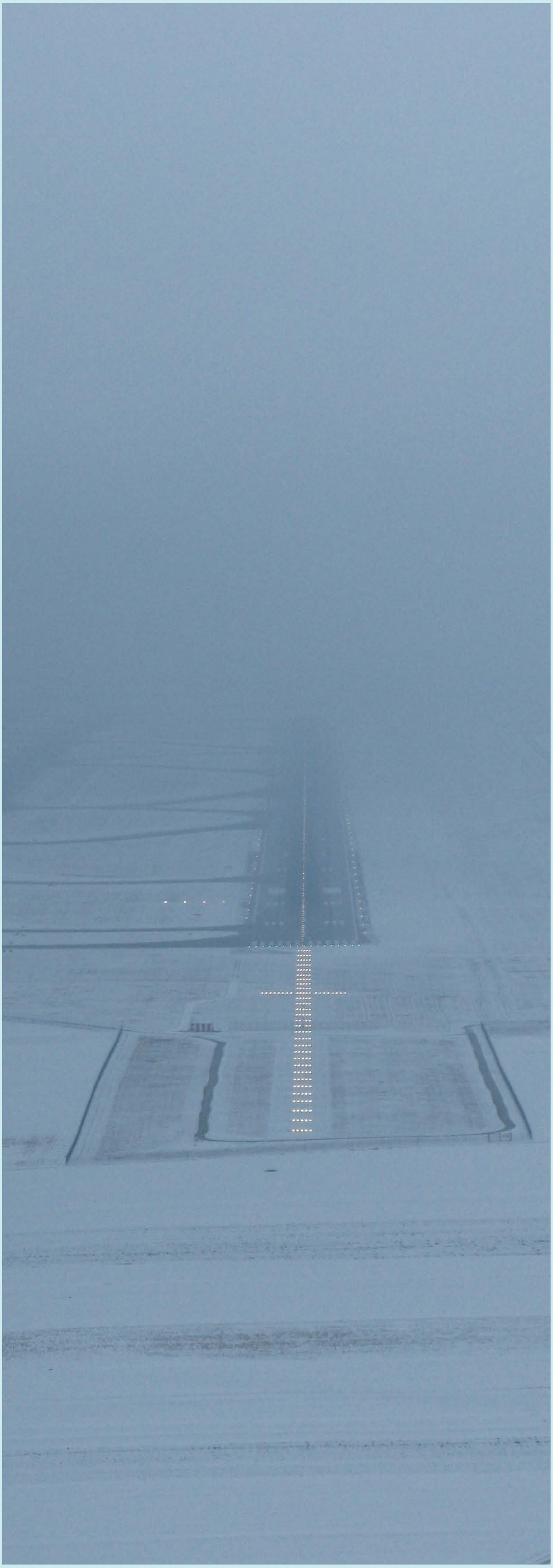
It is clear that without precise and timely weather information, the actors in ATM will not be able to perform their roles effectively. Laying out the flight trajectory, checking its safety and flyability, is a primary responsibility of the flight crew. From this, it follows that high-quality weather information needs to be available to the crew from planning through flight execution. The ConOps recognises this, e.g., in the section dedicated to Aircraft Operators.

The Flight Crew remains ultimately responsible for the safe and orderly operation of the flight in compliance with the ICAO Rules of the Air, other relevant ICAO and CAA/EASA provisions, and within airline standard operating procedures. It ensures that the aircraft operates in accordance with ATC clearances and with the agreed Reference Business Trajectory. For military, some additional rules not covered by ICAO may be implemented by the States for State Aircraft.

And finally, obtaining weather information is among the top responsibilities of the flight crew:

The Flight Crew's responsibilities include furthermore:

1. Obtain information about weather forecasted for the planned flight route
2. Check NOTAM and other environmental information relevant to the flight.
3. Conform to the issued departure slot, if any.



Weather will also continue to be important aspect in the future, as indicated in the SESAR Concept of Operations Step 2:

"4DWxCube

A virtual repository of MET information produced by multiple contributors (MET service providers), from diverse locations, that will provide end users with a common weather picture.

The 4DWxCube can be viewed as the interface between SWIM and the providers of MET information, being a single point of contact for all ATM MET information. It will "hide" the complexity of the MET system infrastructure from the ATM domain. This net centric approach allows each request over SWIM for MET information to be directed in the most optimal way, to return the required result(s), irrespective of the data origin. Standards and specifications developed and used by the 4DWxCube will be layered on top of core services provided by the SWIM infrastructure.

Source: WP11.2PIR

Finally, a reminder that 'space weather' is a real concern: SESAR Vulnerability Report

This document is the result of SESAR project 15.3.4 – Task 6: GNSS vulnerability assessment. The main objective of Task 6 (the problem of the task) is to assess the vulnerability of GNSS-based aviation operations towards impact from ionosphere effects and interference.

The document presents the methodology used and results obtained, and the conclusion provides the result of the assessment (the answer to the problem) as described below.

For the ionosphere; three different ionosphere monitoring systems have been developed and described. The systems monitor ionosphere activity over Europe (EUROCONTROL), Germany (DFS), and Norway (NORACON) respectively. Eight real ionosphere events encountered from fall 2011 to the end of 2012 have been selected, the events have been analysed by the monitor systems and the results are discussed.

The selected ionosphere events are the largest encountered during the monitoring period, but none of the events are characterised as severe to extreme. Anyhow, all five events have been identified by the monitoring systems, and the monitoring reveals that an impact on the GNSS signals is detected also during these ionosphere events.

The monitoring is followed by an ionosphere impact assessment on GNSS receivers and a review of the operational requirements leading to an assessment of the impact on operations. This is followed by a review of mitigation actions for the most affected operations. The impact assessment is based upon monitoring results but also on literature review and expert advice in order to assess the impact expected during severe to extreme ionosphere events.

The conclusion of the ionosphere impact assessment in the report is that the ionosphere effects are considered as a threat to aviation operations during severe to extreme ionosphere storms.

Various operations are expected to be vulnerable to varying degree, and the operations are here listed based on the vulnerability:
Less vulnerable:
En-route and terminal navigation, LNAV non precision approach, Terrain Awareness and Warning Systems (TAWS), Applications based on GNSS timing
More vulnerable:
Surveillance applications (especially in Non-Radar Airspace)
Most vulnerable:
SBAS/LPV non precision approach, GBAS precision approach CAT I, II, III

Severe to extreme ionosphere storms happen statistically one to ten times during an 11-year solar cycle.

The ionosphere monitoring carried out analyses the eight largest ionosphere events which happened during the project period. The events are categorized as minor to strong. Although severe to extreme events have not been observed during the project, the monitoring has revealed that the impact of the same ionosphere event on the three monitoring systems does vary with latitude and also minor ionosphere events impact GNSS at low latitudes (Canary Islands) and at high latitudes (Iceland, Norway, Finland).

It is therefore expected that ionosphere impact on aviation operations happens more often at high and low latitudes (e.g. Scandinavian Peninsula and southern part of the Mediterranean), than at mid latitudes (France, Germany etc.).

As a conclusion, we can say that there is a requirement for timely, concise reports and forecasts for ionospheric conditions (“Space Weather”).

Source: SESAR Vulnerability Report - Issue 2

SESAR / NextGen differences

NextGen and SESAR projects were compared in 2008 to identify similarities and differences of both projects with regards to weather. The following excerpt seems to be correct at present as well.

Source: SESAR and NextGen Concepts of Operations 2008

The primary difference between SESAR and NextGen concerning weather is the manner in which information is acquired. In NextGen, a centralised government-run weather service is anticipated, while in SESAR the information will be derived from a variety of traditional sources. A more net-centric solution would be to allow each carrier to be able to choose whatever information is available from certified sources to provide maximum safety.

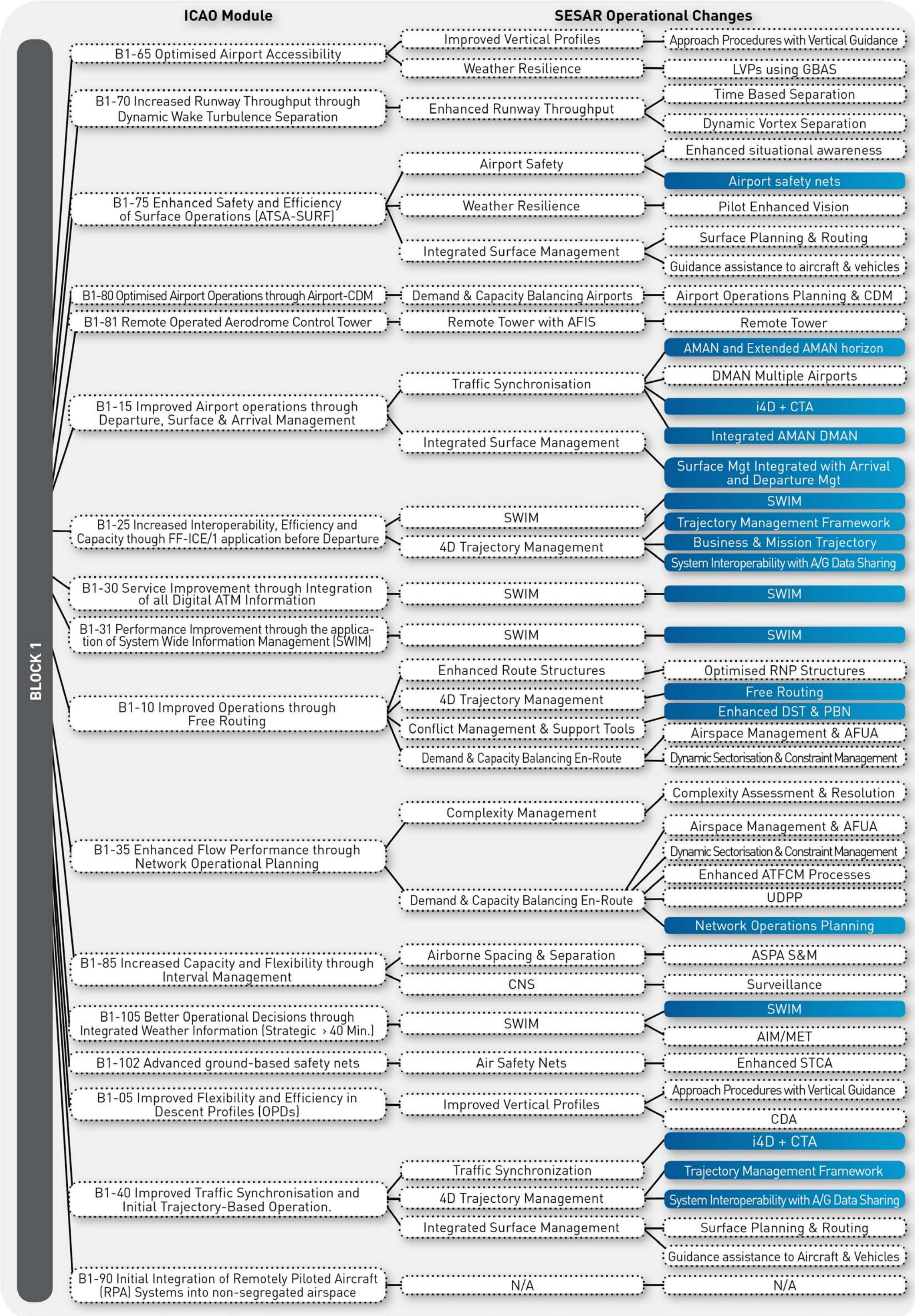
SESAR

The information will be derived from a variety of (traditional) sources including an Increased reliance on remote sensing systems, aircraft derived data and satellite-based weather information. With enhanced digital communications services, the provision of Meteorology (MET) information will encompass ground-based and potentially airborne automation systems and human users.

NextGen

NextGen foresees weather as moving from a stand-alone display to an integrated decision making element. A primary objective of NextGen is the establishment of a single authoritative weather service available to all systems communicating within the network. While little is said about how this service will be run, a great detail is provided on what type of service will be available. The service will draw data from traditional weather reporting systems, aircraft and other sensors in route including UAVs specifically deployed for weather collection, commercial weather services which will augment the system at the basic provision rate and presumably at premium rates as a choice of individual carriers and aircraft and potentially airborne automation systems and human users as well as from weather national service.

Figure 29 **ICAO Block 1 / SESAR operational changes**



Source: European ATM Master Plan, SESAR JU

Why vision on weather is needed?

From the Graph of the European ATM Master Plan, it is clear that the weather related efforts of SESAR are concentrated here:

» B1– 65 Weather Resilience - GBAS
» B1- 75 Weather Resilience - Pilot enhanced vision .
» B1-105 Information exchange via SWIMM - but without much progress towards integrating or including the cockpit-crew

Looking at SESAR itself, the impression is that details, like high resolution wind and temperature updates for descent-trajectory planning and management, are addressed. However, SESAR does not seem to address ´real´ weather such as rain, thunderstorms, high winds, icy runways and its effects on flight operations. SESAR is lacking plans for fully integrating ´Weather´ in all aspects of flight operations and there are only few attempts to make the weather information that pilots need available - at all stages - from flight planning to conclusion of flight at destination.

As planning and flight execution go hand in hand, it is clear that access to information needs to be uninterrupted, from early pre-flight planning maybe days in advance until the flight is completed. Several information transfer technologies will have a role to play, like the internet, which should deliver access to a pan-European portal of weather information. This obviously should cater to medium and long haul flights to the extent practicable include information for all areas of the world as far as it can be provided. Then, wireless devices have to support laptops, tablets, eFBs that pilots might use. This support has to be available in the whole airspace of Europe, restricted only by limits of interspace VHF or satellite technology. Global standardisation would be a worthy goal, but should not be allowed to serve as an excuse for not improving weather information for pilots within the SESAR context.

ECA's vision on weather has been developed based on a thorough analysis of the available information and operational experience of European pilots.

ECA'S VISION ON WEATHER

Pilots have ultimate safety responsibility for the airplanes they fly. They are also responsible for economic operation of the aircraft as well as the well-being of the passengers, cargo and crew under their care.

In order to be able to discharge these duty effectively, they need complete situational awareness with respect to other aircraft, air traffic control - and weather. Today's demands for on-time, gate-to-gate operations make it easy to overlook that weather events can on occasion control, dictate and govern when and where airplanes fly.

Therefore, pilots need continuous access to weather information that has the same information content as that available on the ground and in automatic systems.

Detailed requirements

» Access to information has to be continuous, it has to be available on the ground and in the air.
» Information content has to be displayed in easy to grasp, graphical form
» Weather graphics shall make use of colour to highlight important phenomena
» Real-time advanced radar and satellite pictures with flight path added, continuously updated forecasts that have 3 hrs or less between forecast times, continuously updated
» Pilot-selectable, specialised weather information for special situations, i.e. tropical systems, high winds, volcanic eruptions, winter weather, fog
» Playback capability for all information

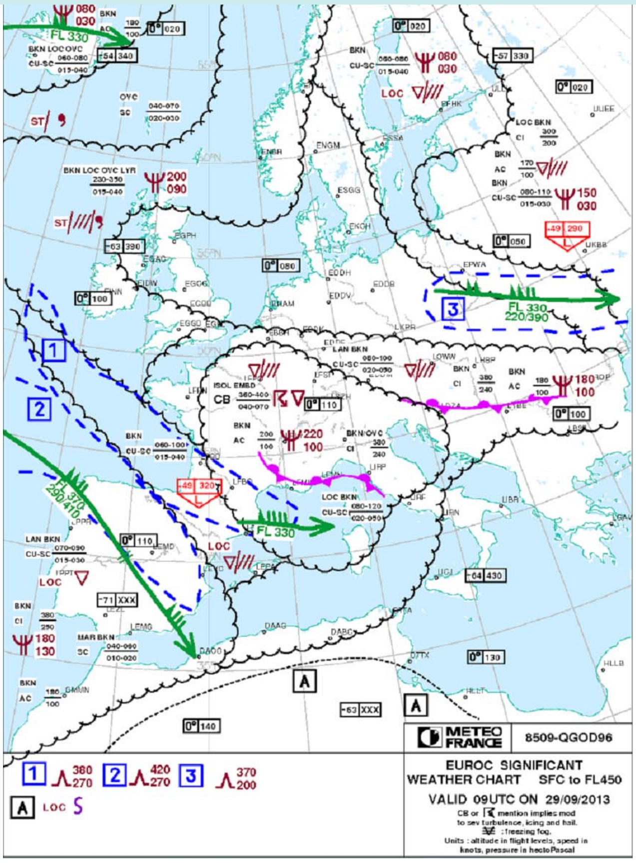
In today's flight operations, weather information is all too often presented in black and white.

This may have been a good standard in past years, but today, colour-printers are ubiquitous and, moreover, all mobile electronic devices like laptops, eFBs or tablet-computers used by pilots have colour screens. As colour has great advantages in information display, in highlighting important weather features, it should be used as a tool to enhance information transfer and ergonomics. All charts should display the planned flight trajectory.

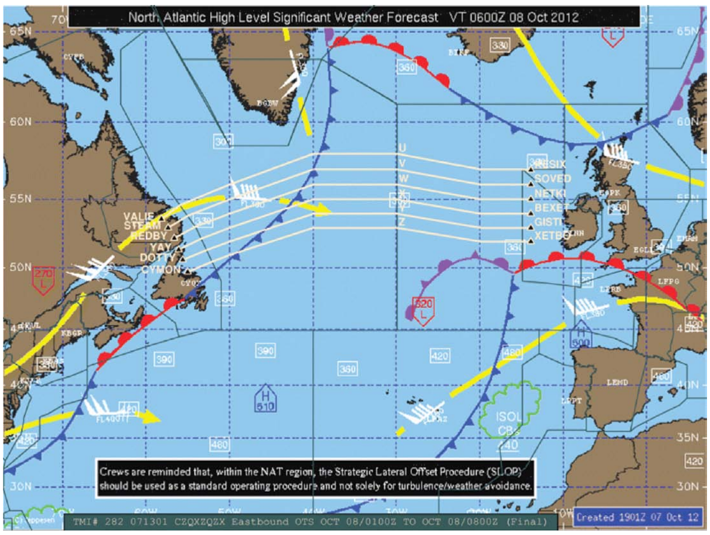
Common Information set for all flights

The following pages show one or two examples of essential meteorological information available today for each topic. They are nearly all in colour, and the information displays often have often added value letting the pilots decide which layer of air to display, which time-step to select.

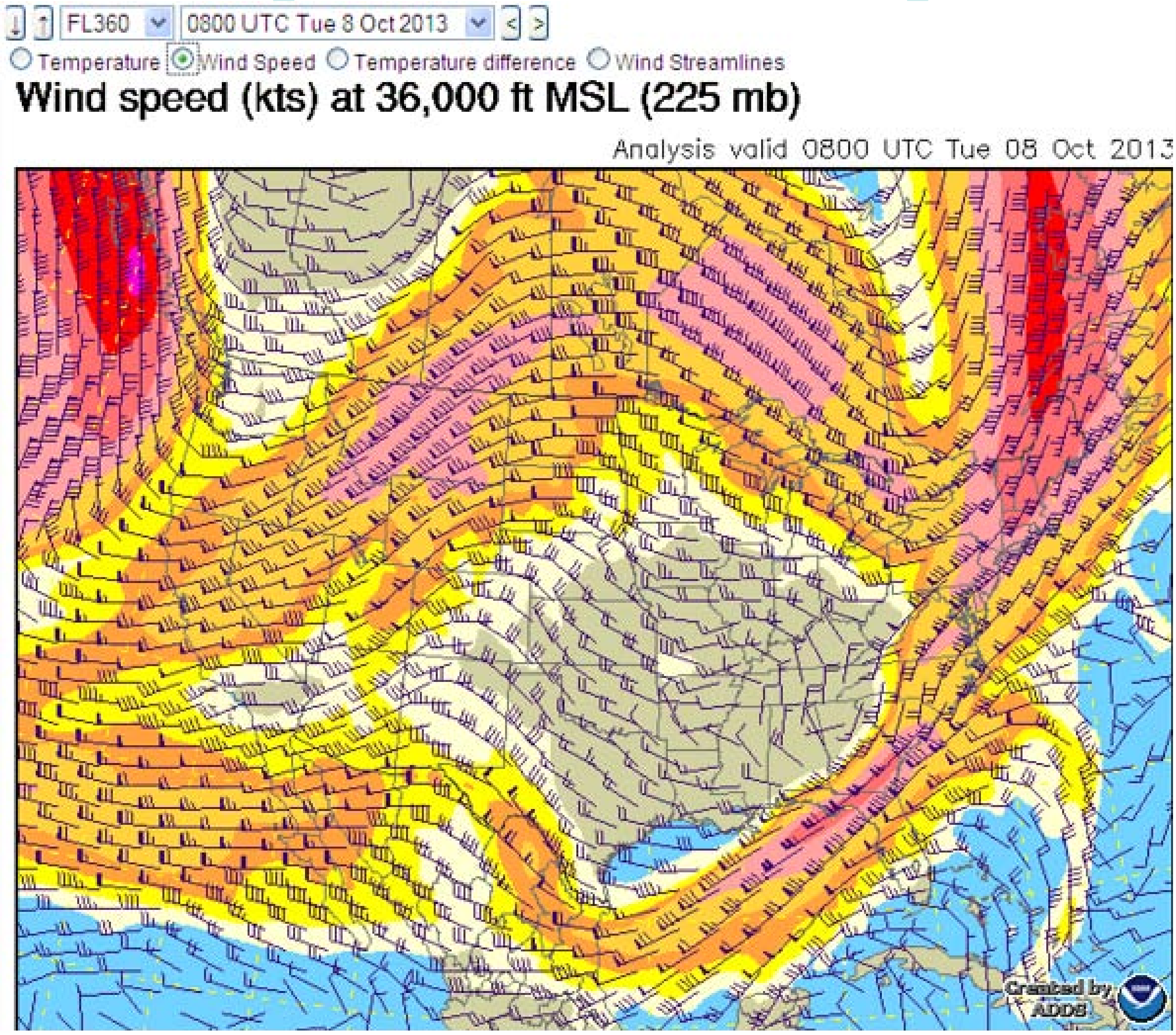
This common information set is followed by examples of information that may be required for special cases, but not with every set of flight documentation.



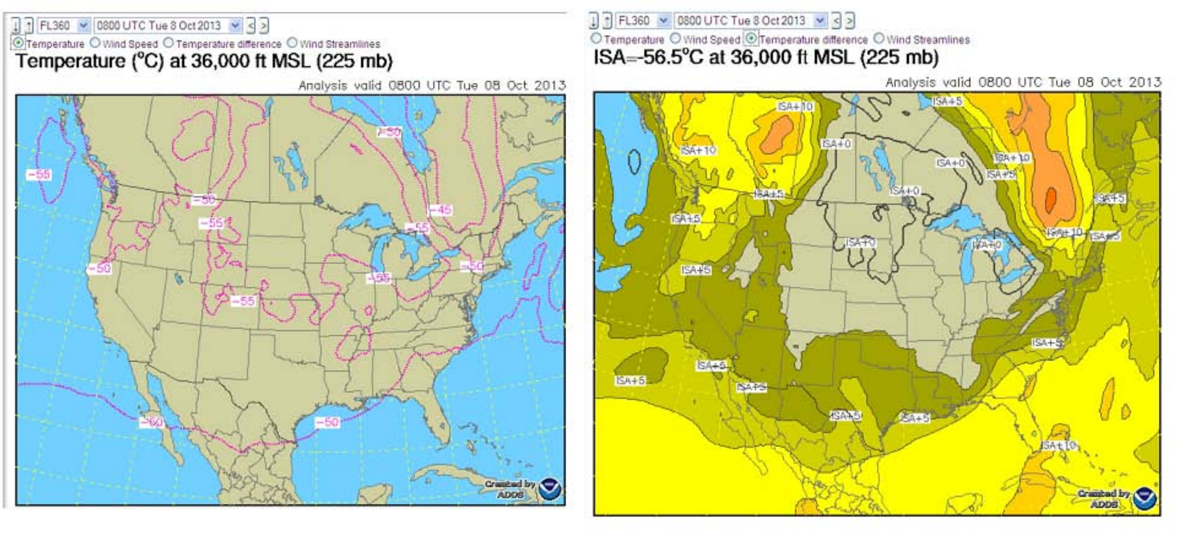
Graphic 1: Significant weather chart (use of colour)



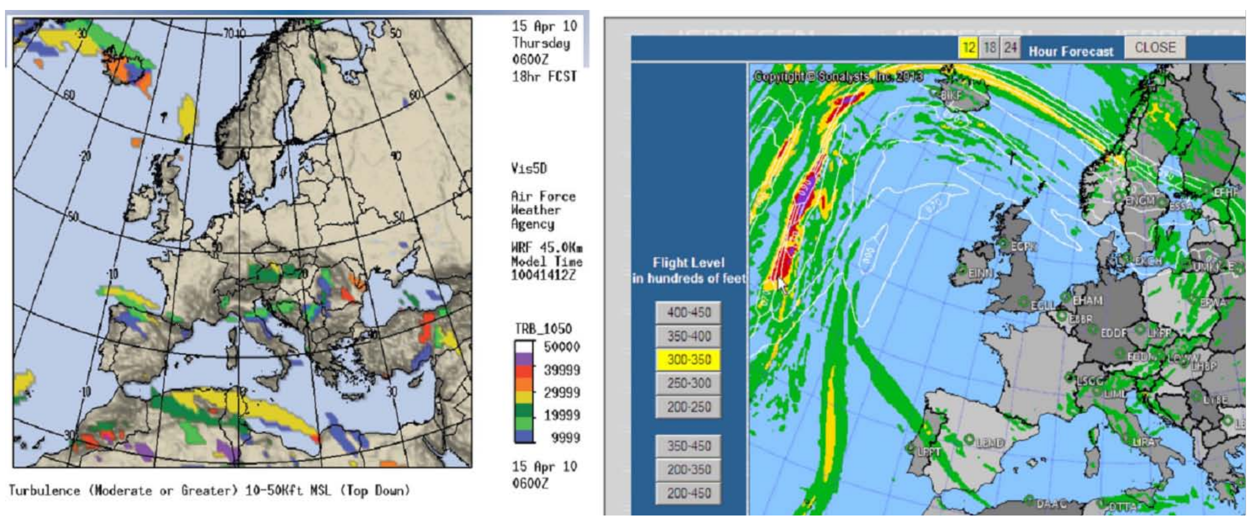
Graphic 2: Note the NAT-tracks - a valuable addition. Source: Jeppsesen



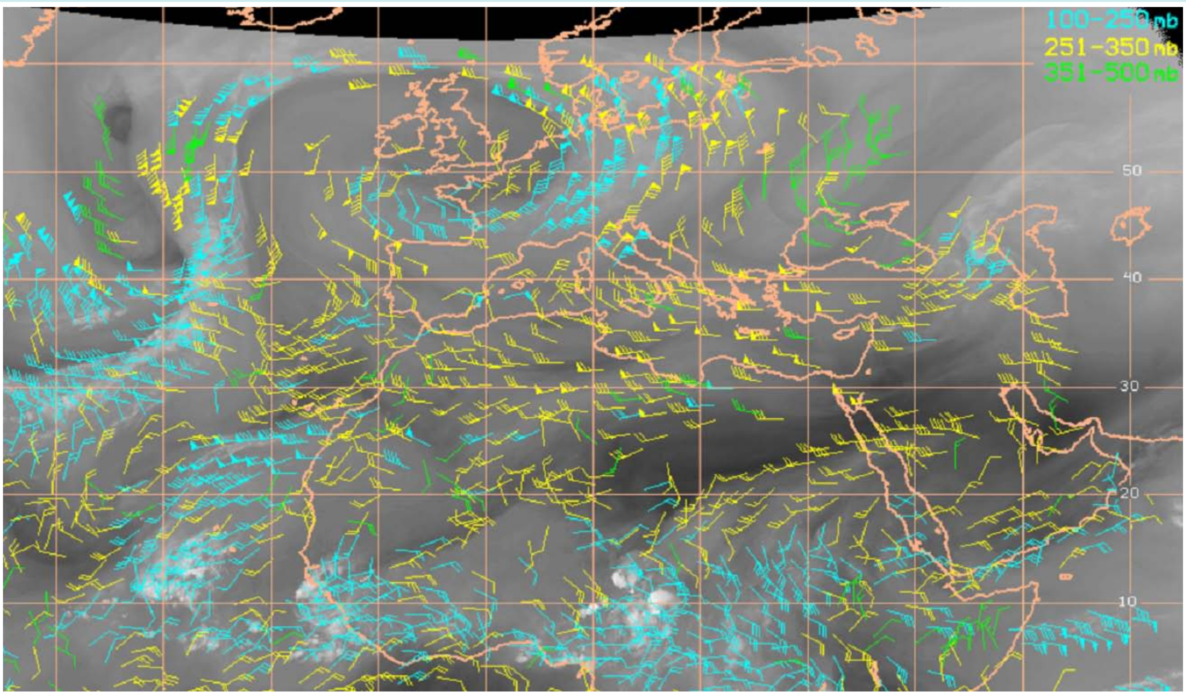
Graphic 3: High-level wind and temperature charts, similar to these.



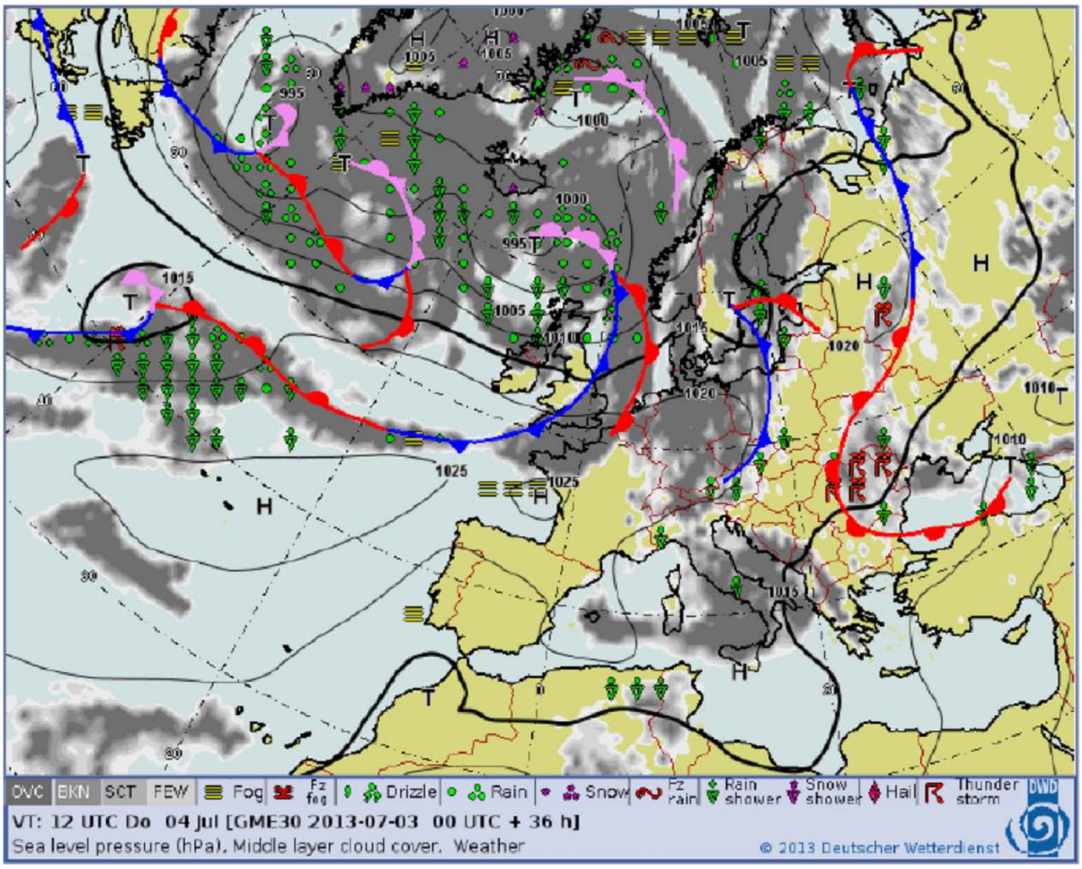
Graphic 4: Temperature & temperature difference to ISA. Note that the time and FL to be displayed are easily selectable from the menu.



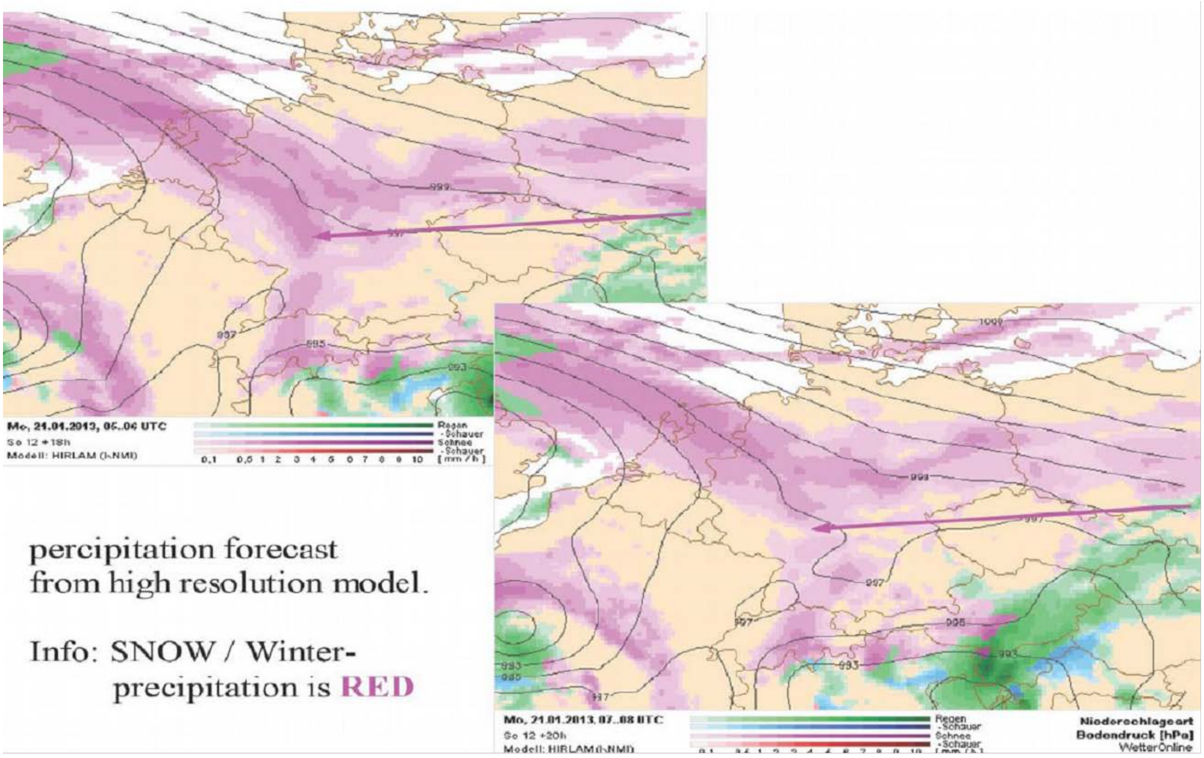
Graphic 5: Turbulence forecasts. Note that both the valid time & the flight level are easily selectable.



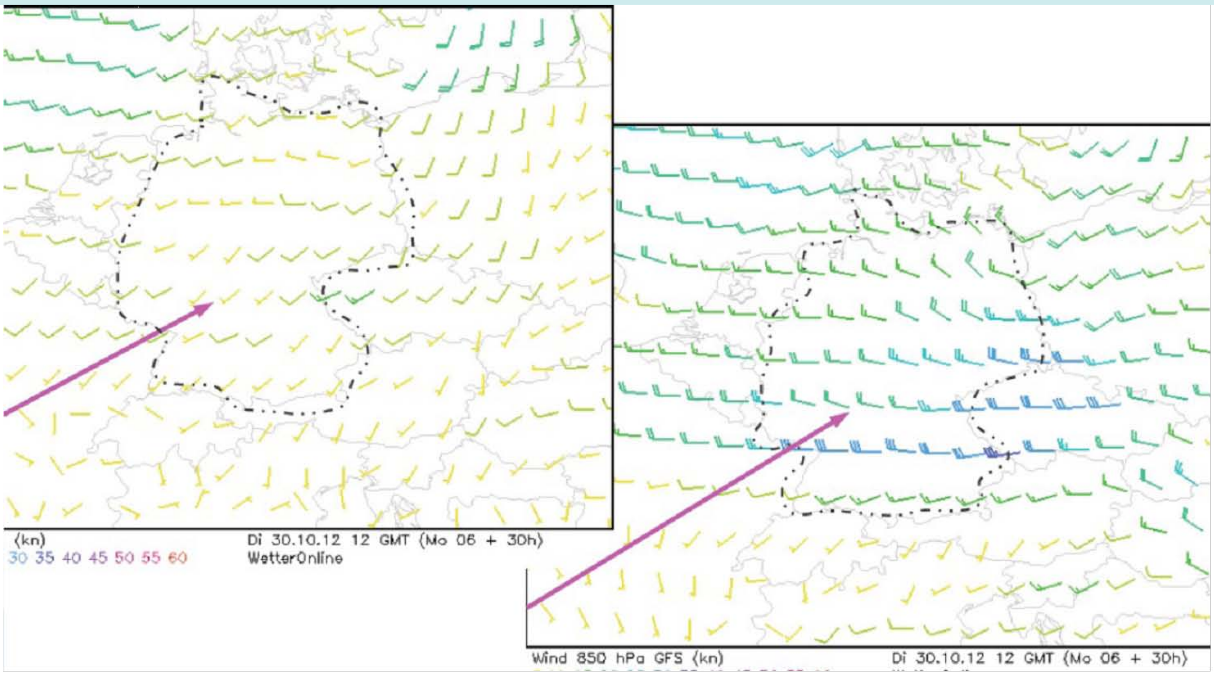
Graphic 6: Winds as detected in near-real-time by satellite, sorted by height. Source: CIMSS



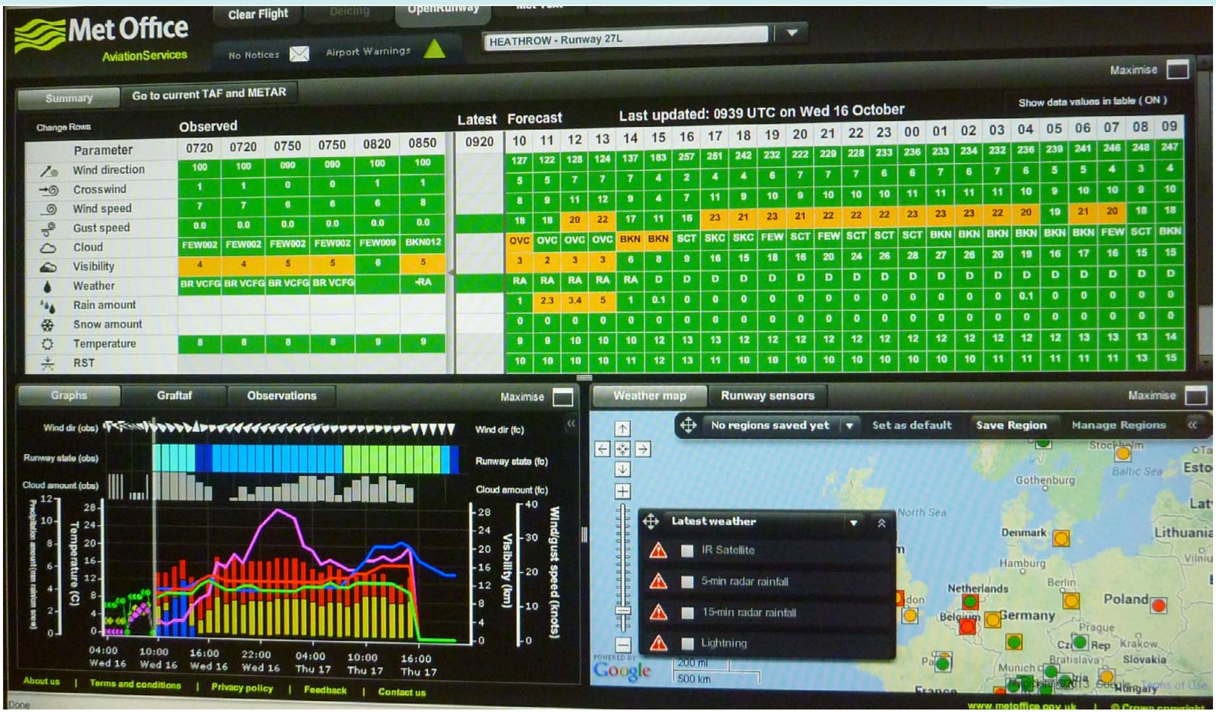
Graphic 7: Overview forecast of weather in the region of flight.



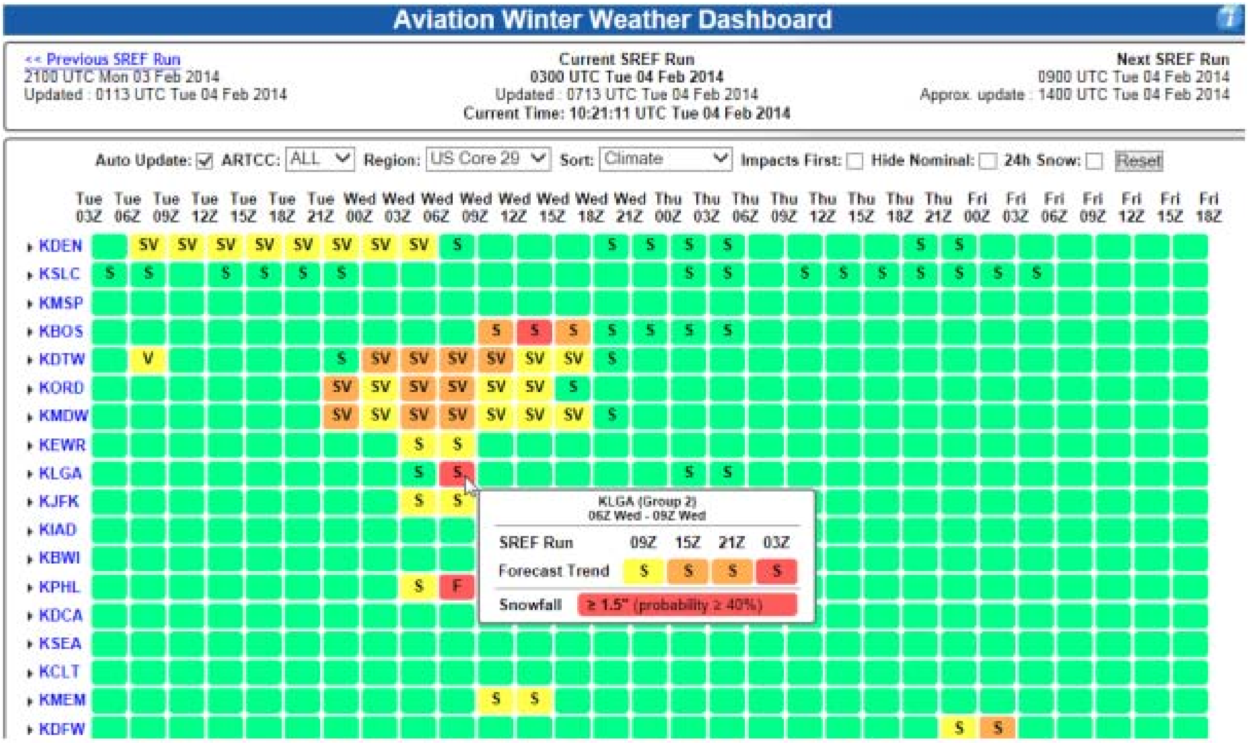
Graphic 8: Precipitation forecast for destination in hourly intervals.



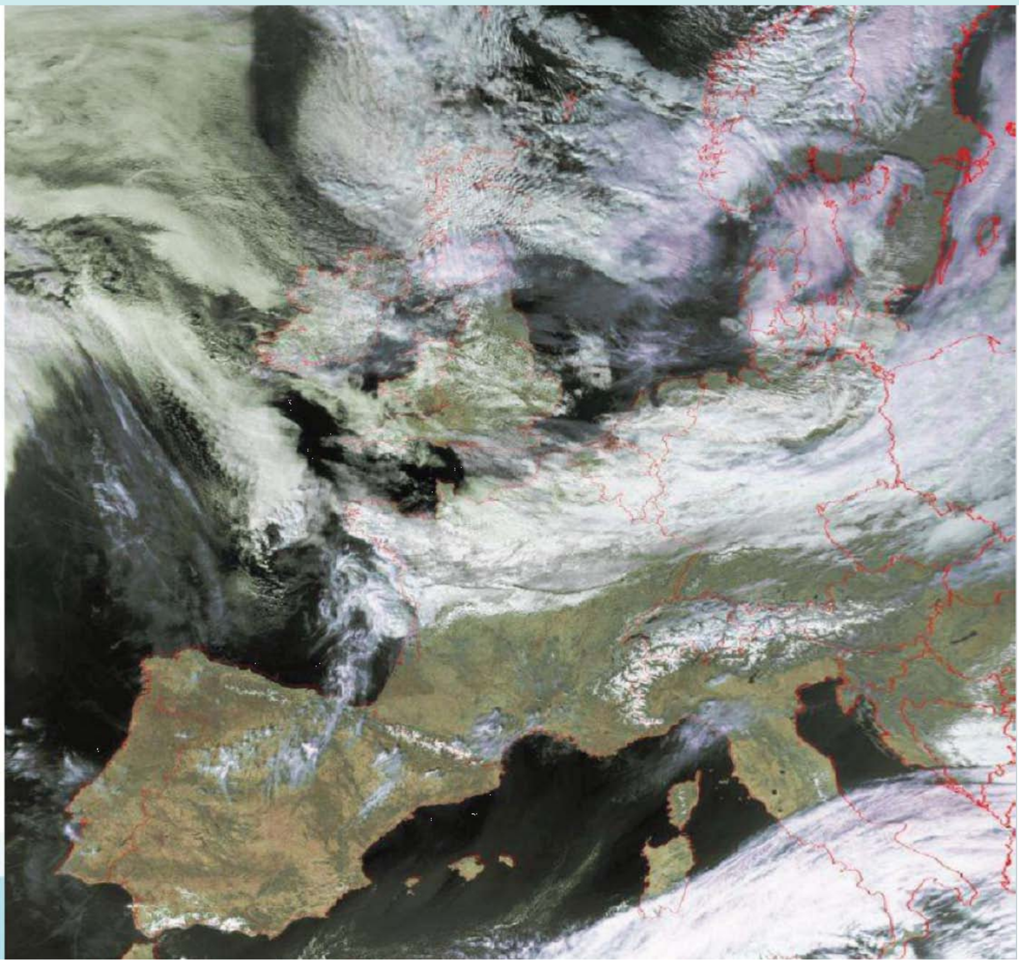
Graphic 9: Grounds and winds at 4,000 - 5,000 ft. agl, e.g. 800Mb chart (to identify storms, wind-shear)



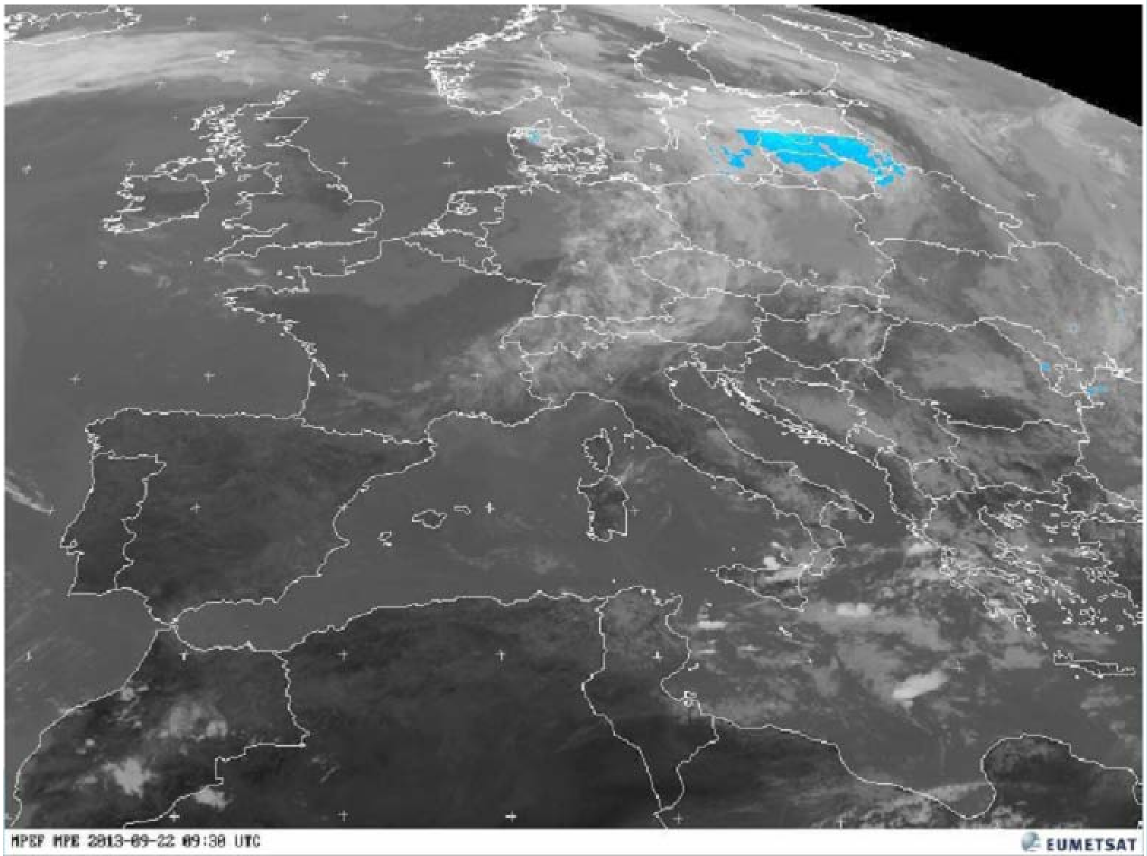
Graphic 10: Graphical analysis of weather-impact on departure, destination & alternate airports. Source: UK MET



Graphic 11: Weather impact indication system



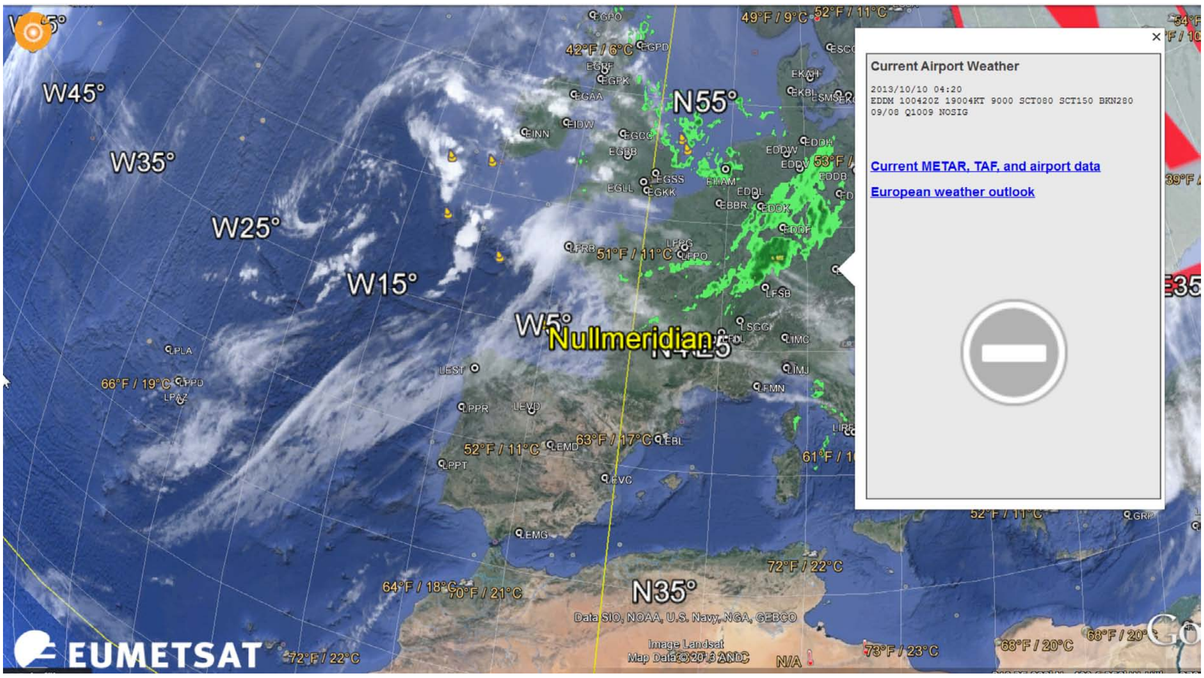
Graphic 12: High-quality satellite pictures with appropriate resolution, near real-time. Day picture. Source: NOAA, Bern University



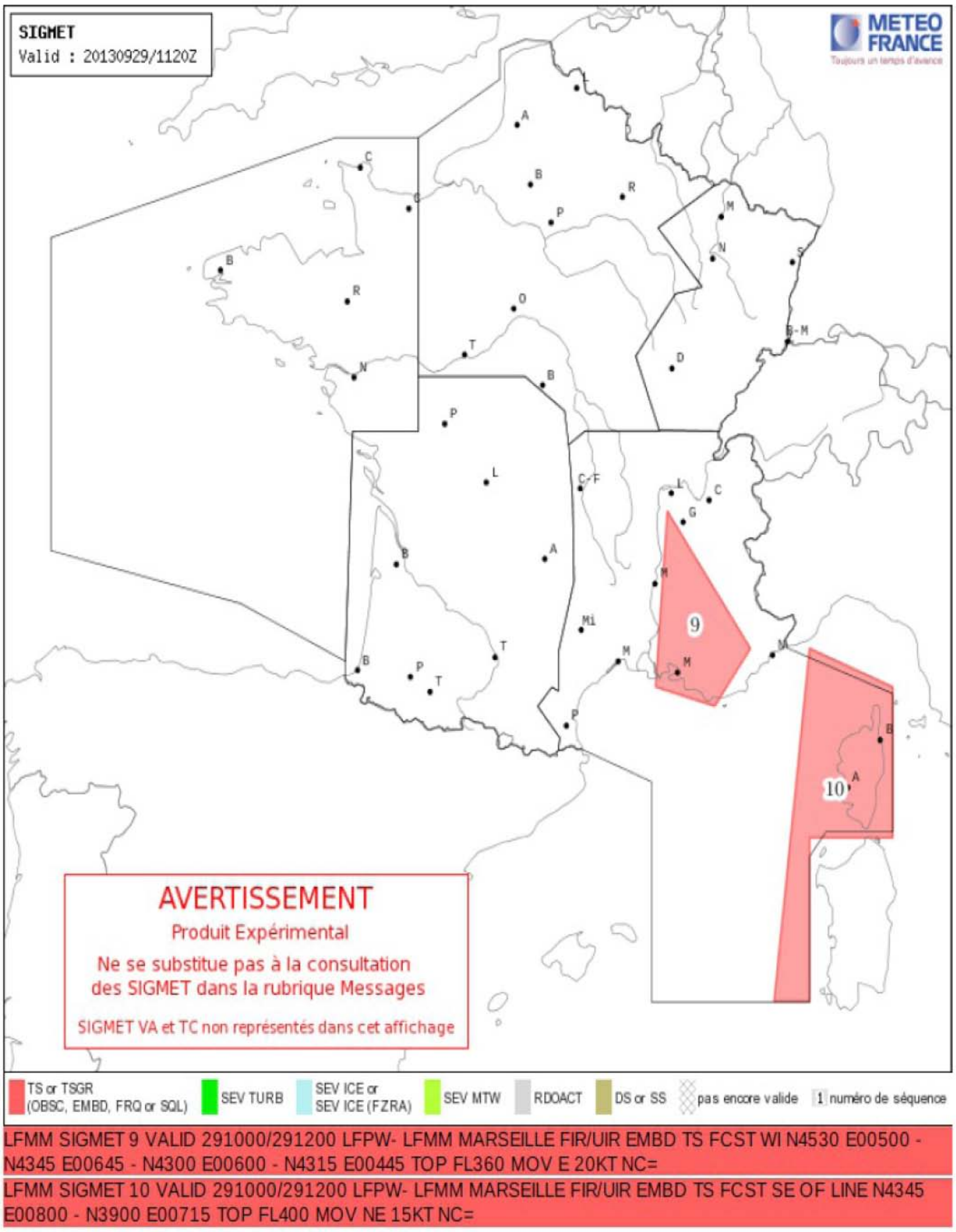
Graphic 13: 24 hours: Infrared picture with precipitation analysis. Source: Eumetsat

Info set for special cases

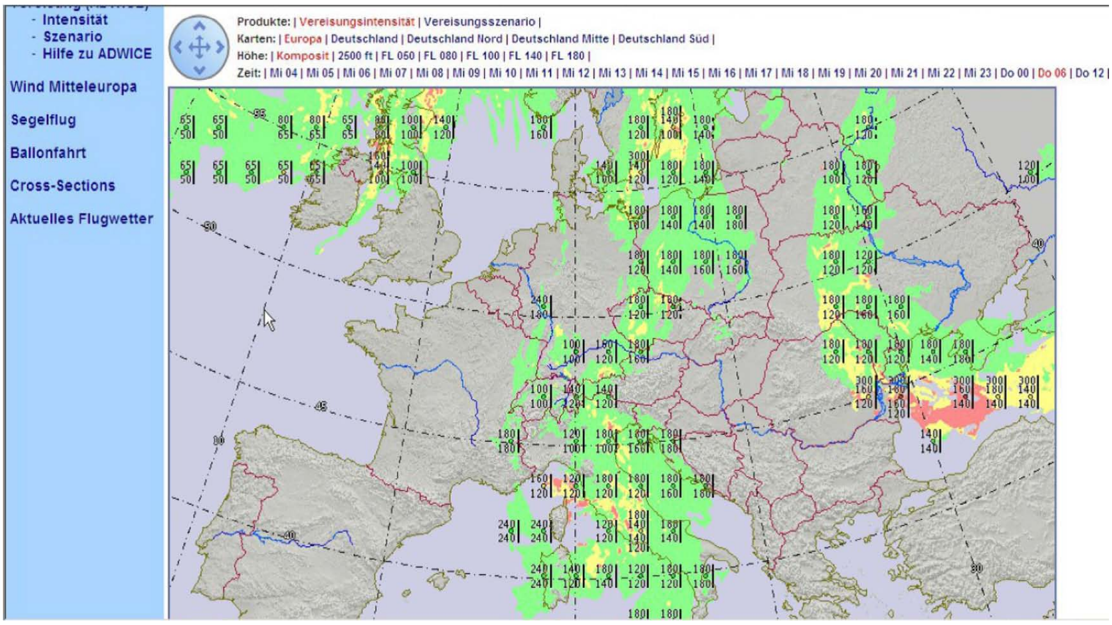
- phenomenon-driven
- provided when necessary
- provided automatically
- available upon request



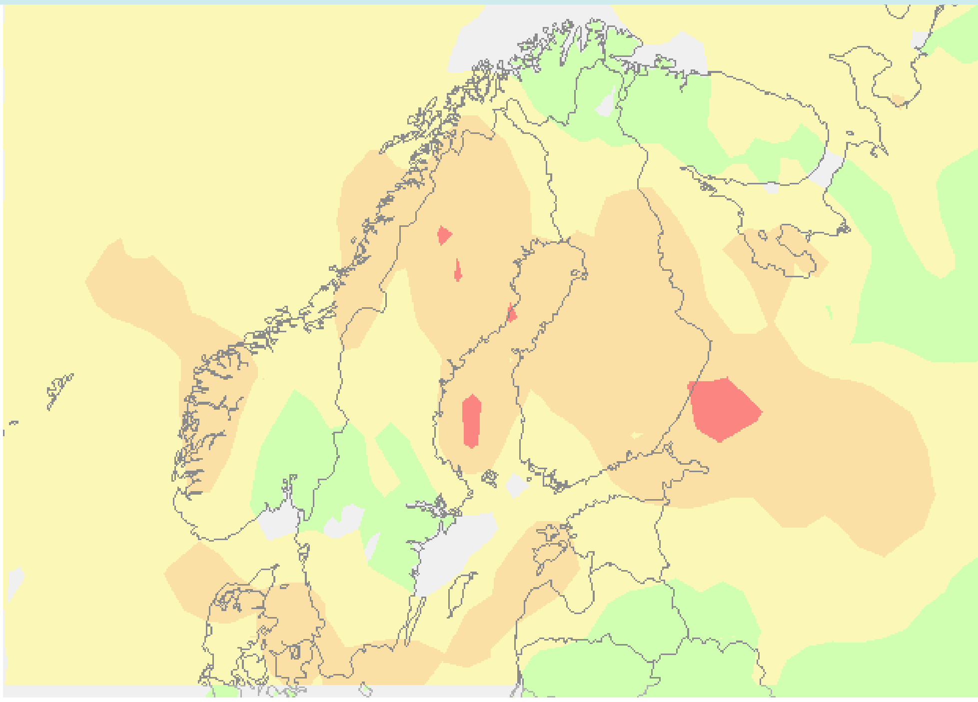
Graphic 14: Integrated display of weather radar, infra-red satellite picture. Clickable airport weather.



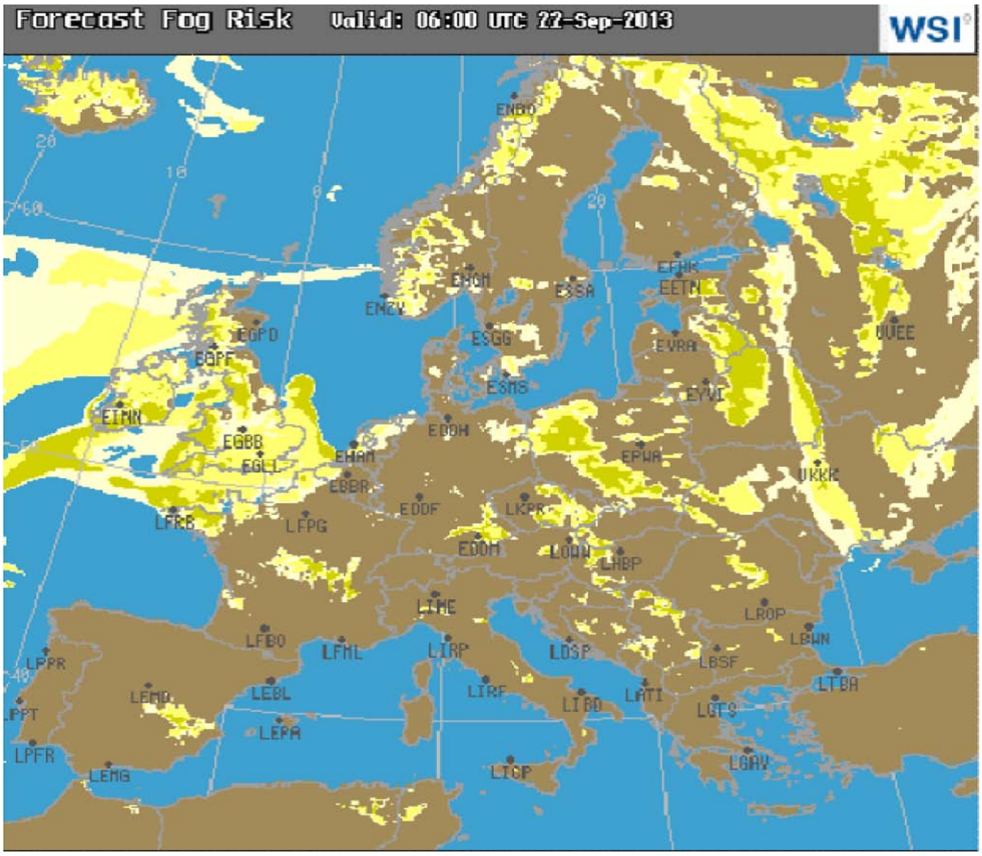
Graphic 15: Text and graphic SIGMET - improved visualisation of weather compared to traditional sets of co-ordinates.



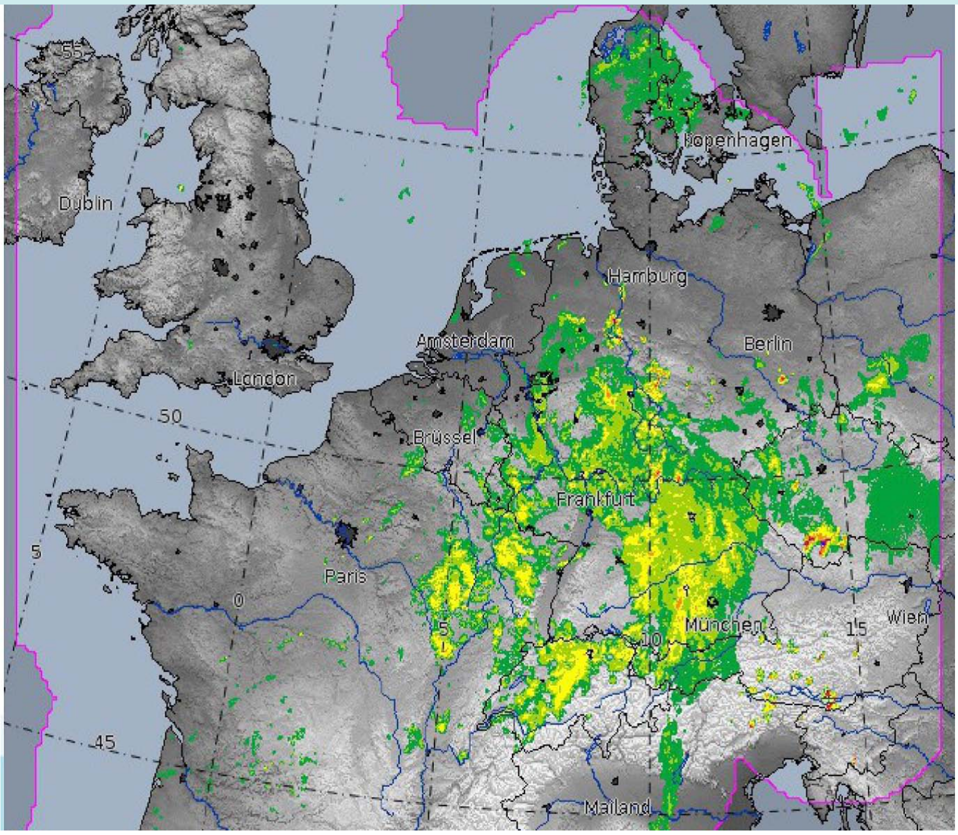
Graphic 16: Icing intensity. Note that the time and area are selectable.



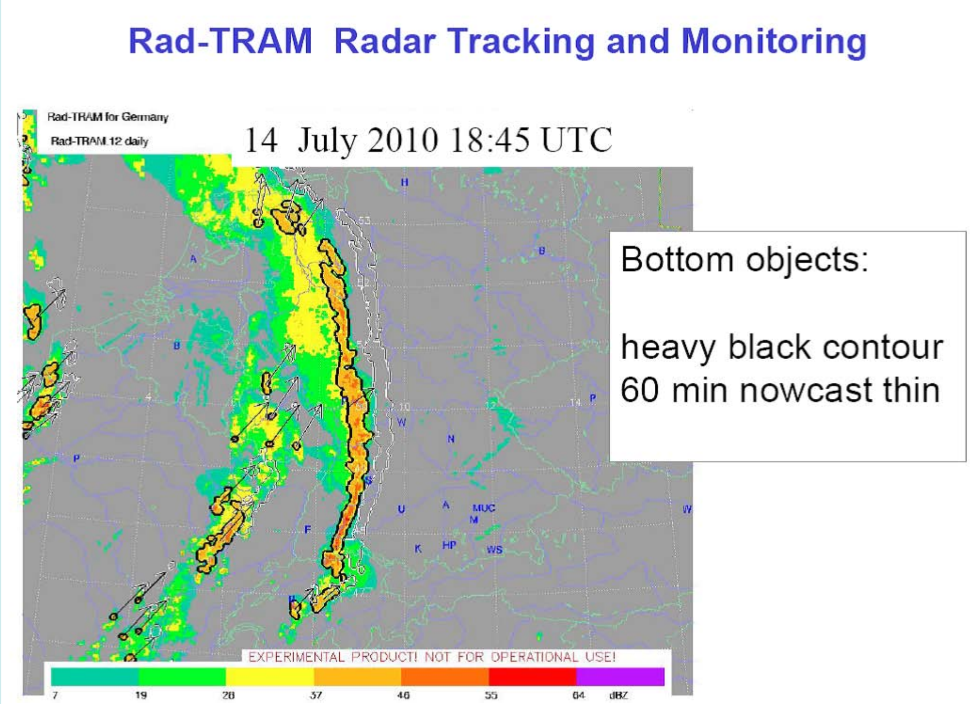
Graphic 17: Visibility highlighting areas of widespread fog



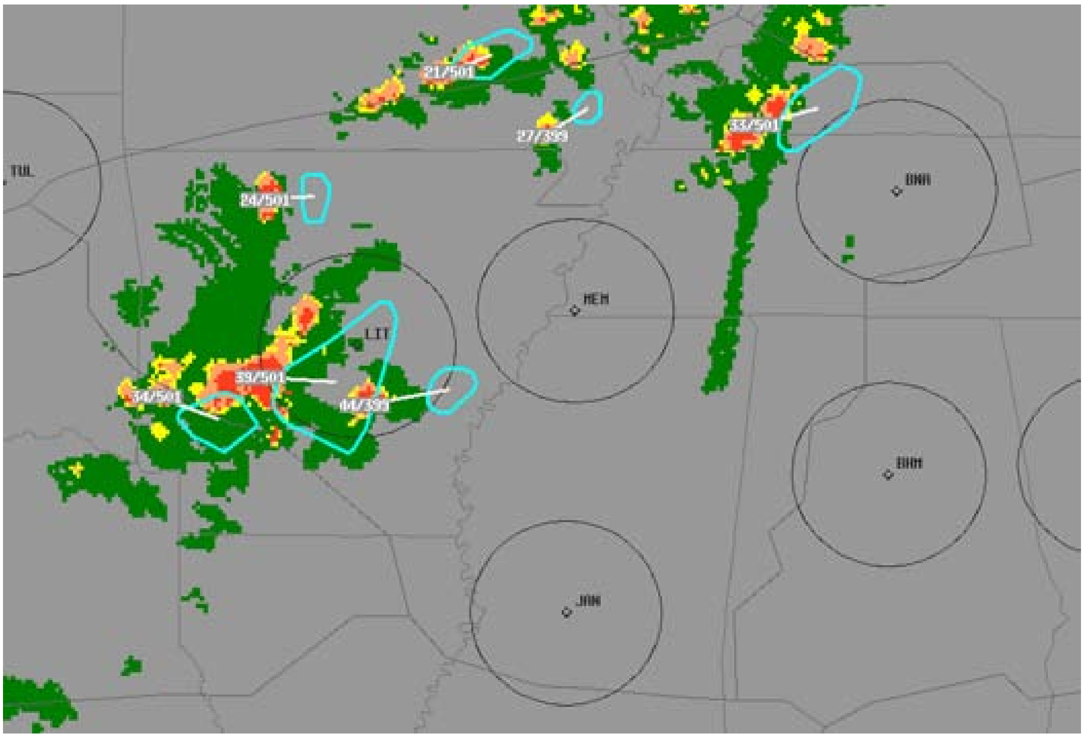
Graphic 18: Forecast fog risk



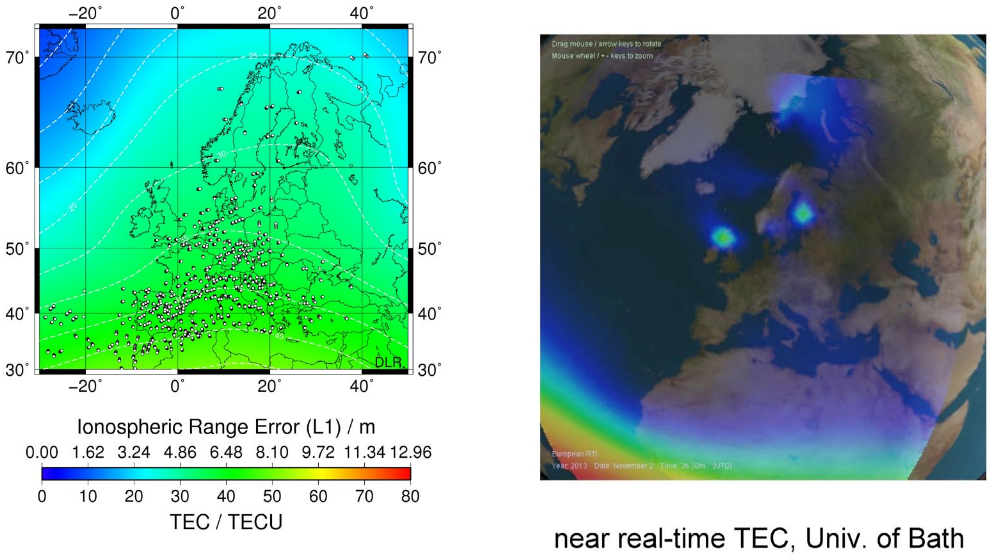
Graphic 19: Real-time radar picture, including height of tops, movement of cells



Graphic 20: Radar, including forecast of where highly active cells will move

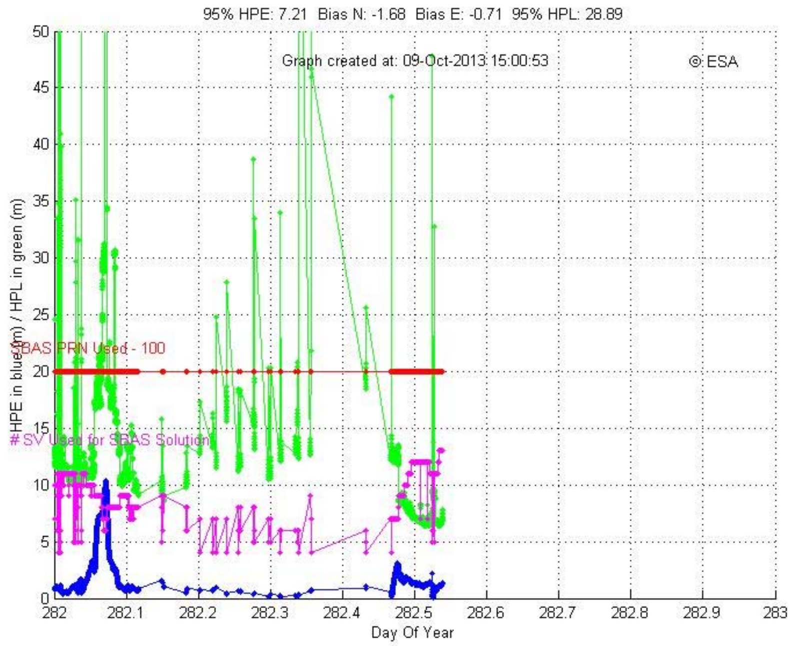


Graphic 21: Blue shapes represent future cell positions



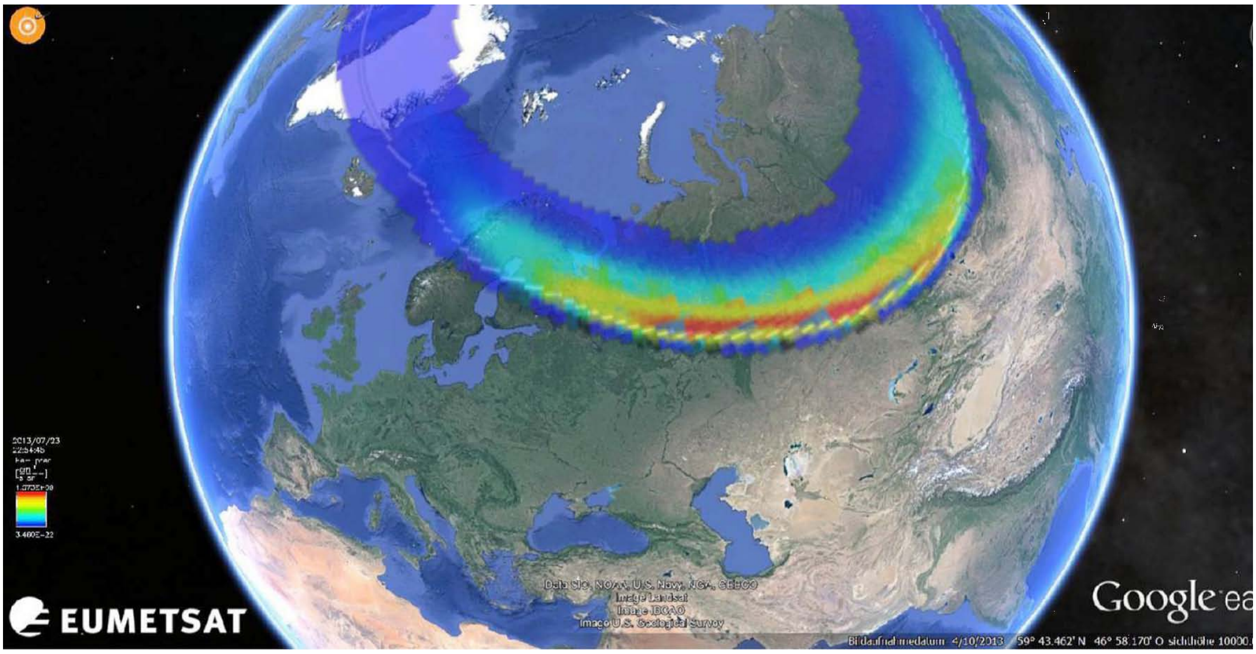
near real-time TEC, Univ. of Bath

Graphic 22: Space weather for navigation

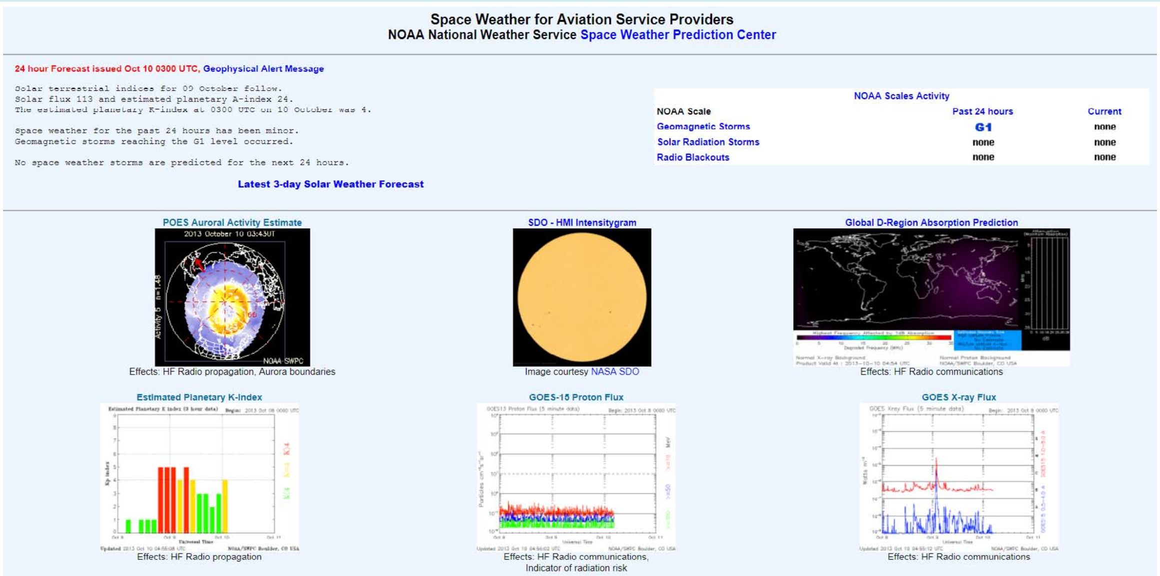


Graphic 23: Forecast and actual total electron content , for different days.

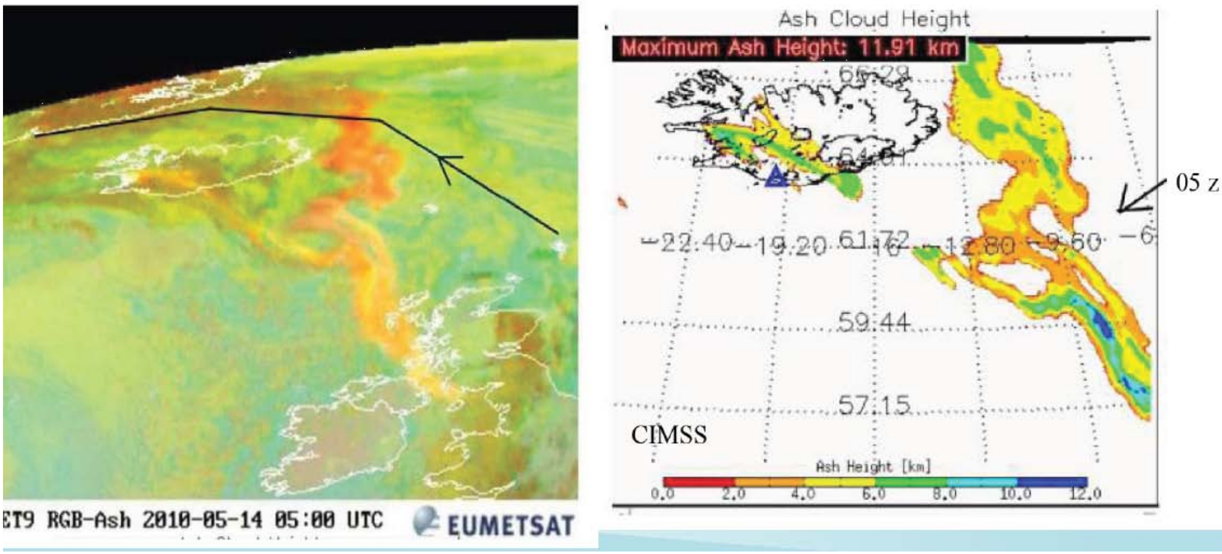
Note: these products would need further refinement, explanation. It should clearly show where GNSS approaches are possible, and where restrictions apply. Forecasts should be available. Source: ESA, EGNOS



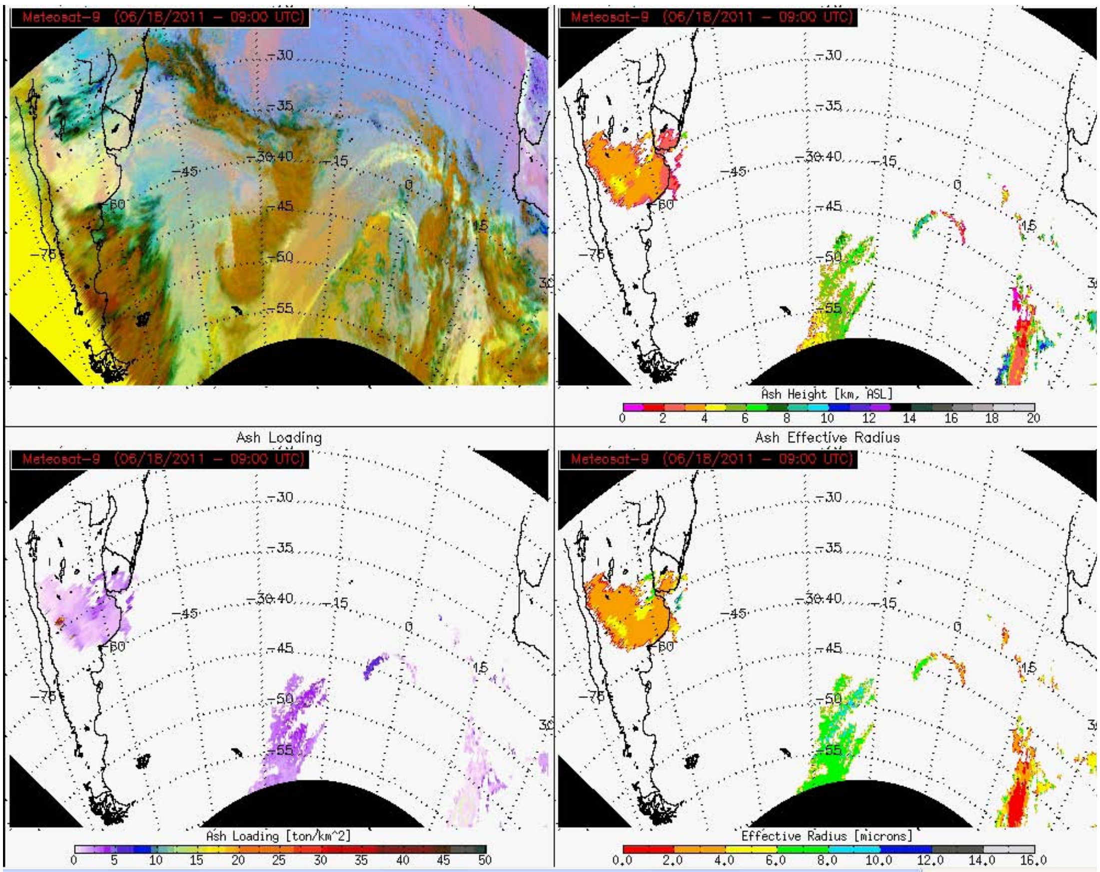
Graphic 24: Display of aurora - location. This could also show where HF communication might be disturbed or ionospheric conditions



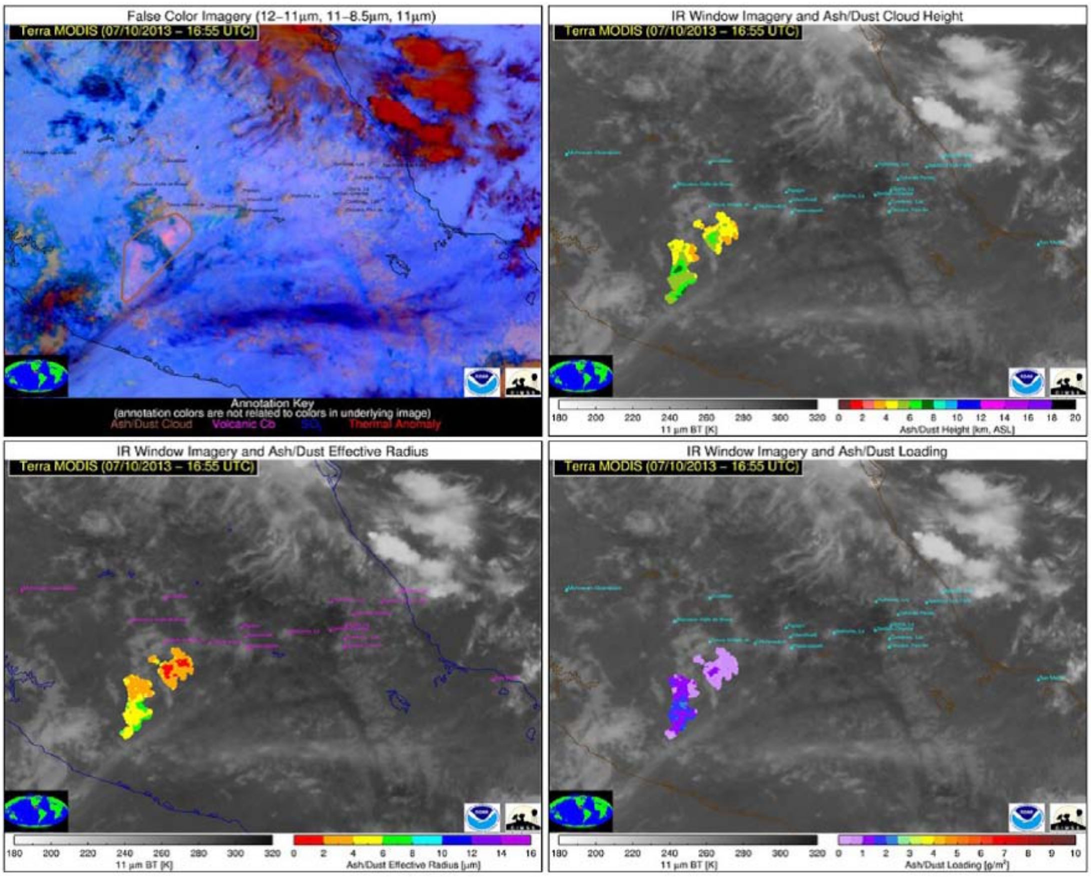
Graphic 25: Integrated display of space-weather for aviation, covering communication, navigation and health effects. Source NOAA Space Weather Prediction Centre



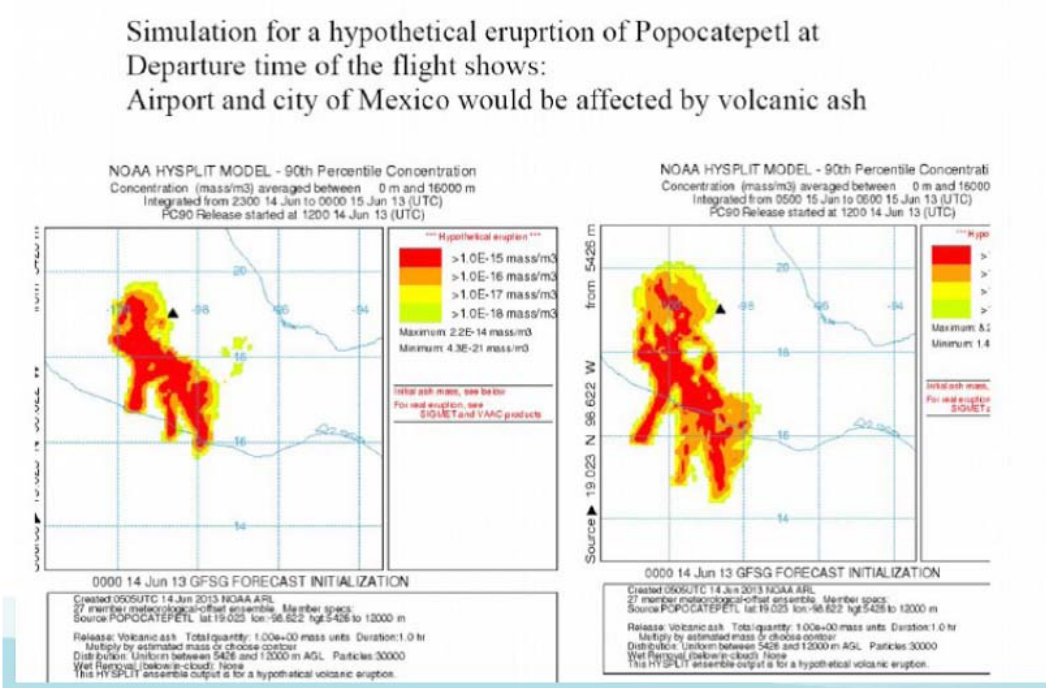
Graphic 26: If volcanic acitivity is present, near-real time images of ash position, height and amount need to be provided in addition to the forecast charts from VAAC



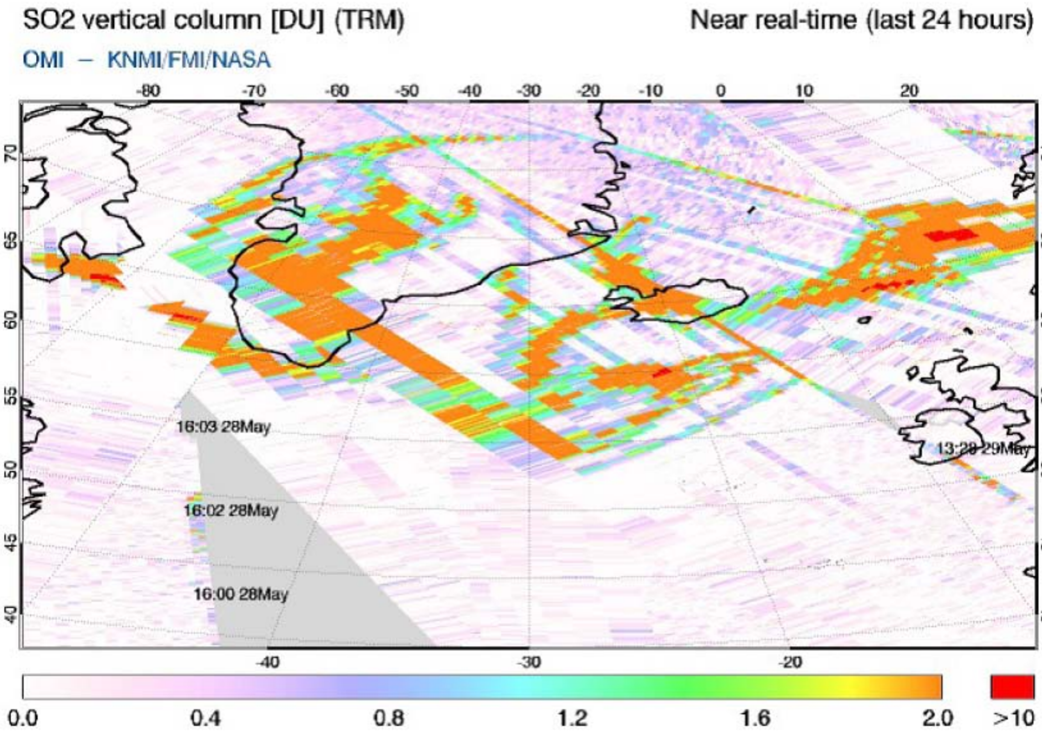
Graphic 27: Note that these pictures were freely available already 2010. The whole Eumetsat-Area is covered. These are pictures from the eruption of Puyehue, 2011.



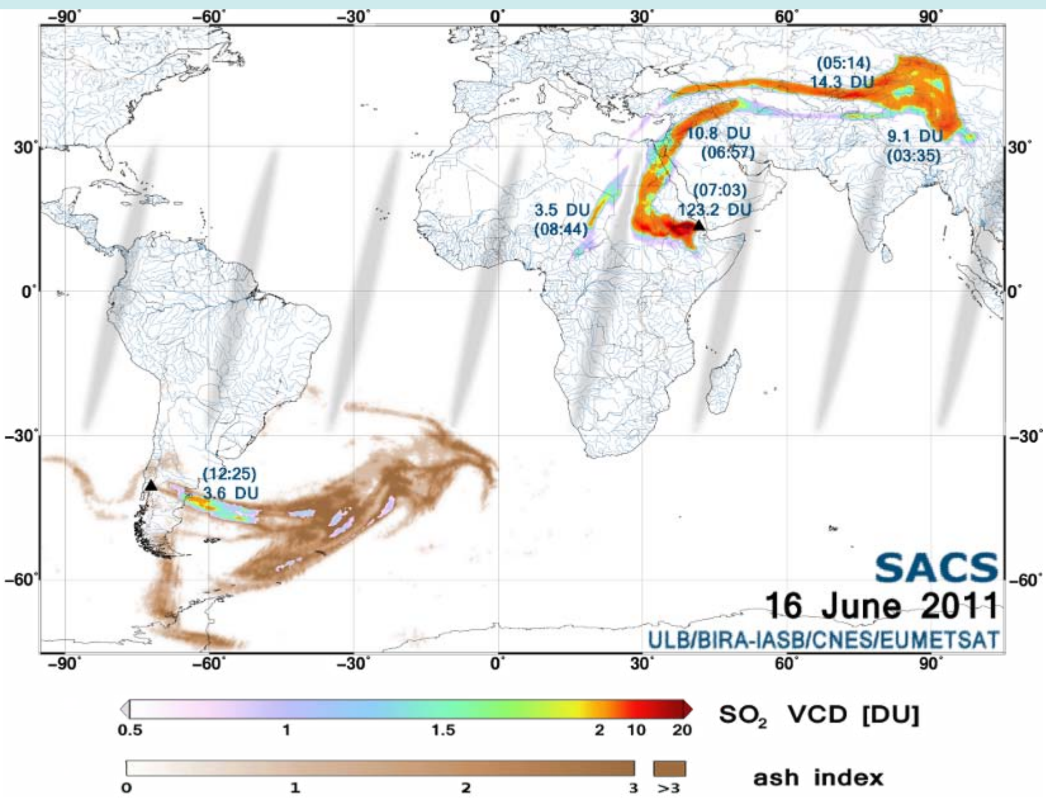
Graphic 28: If available, low-earth orbit satellites can deliver a more precise satellite analysis of volcanic ash cloud, showing clearly the measured hight and amount of ash - MODIS satellite, over Mexico, 2013. Source: CIMSS



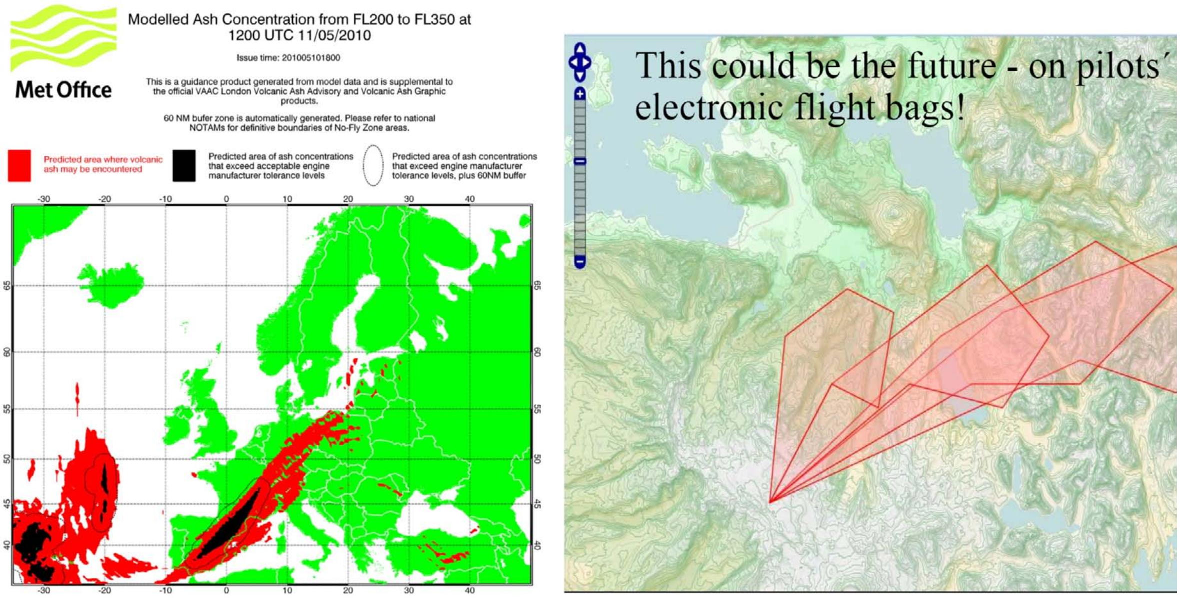
Graphic 29: Ash cloud forecast for hypothetical eruption scenarios for use during flight planning - Source: VAAC Washington



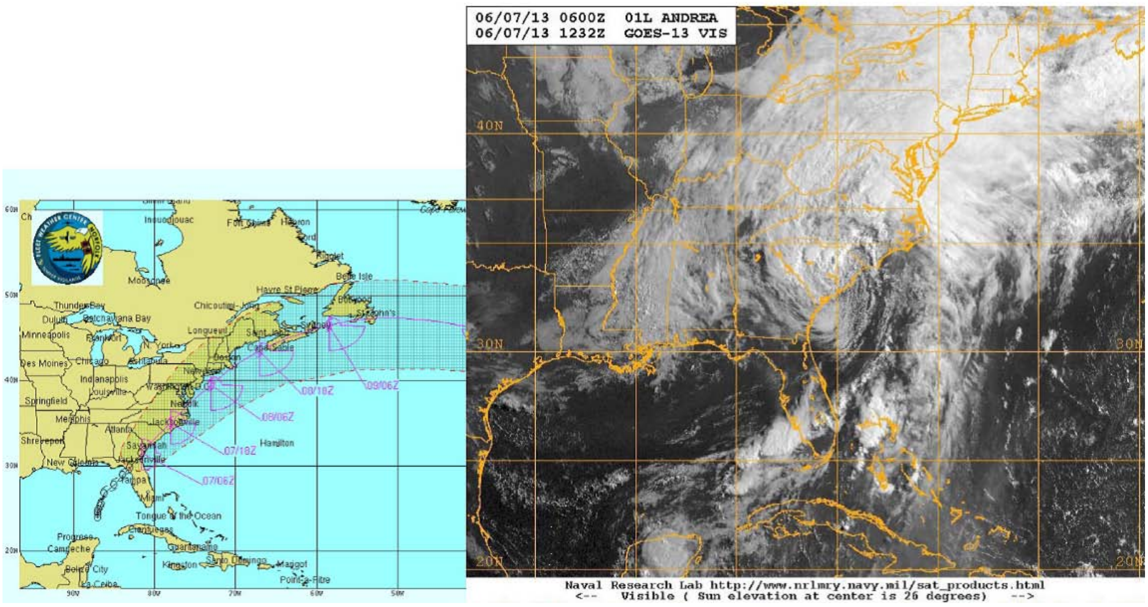
Graphic 30: Detection of volcanic SO2 Aerosol - Source: SACS, Brussels



Graphic 31: Global picture of volcanic ash and aerosol - to be provided when necessary Source: Brenot at al, SACS 2013

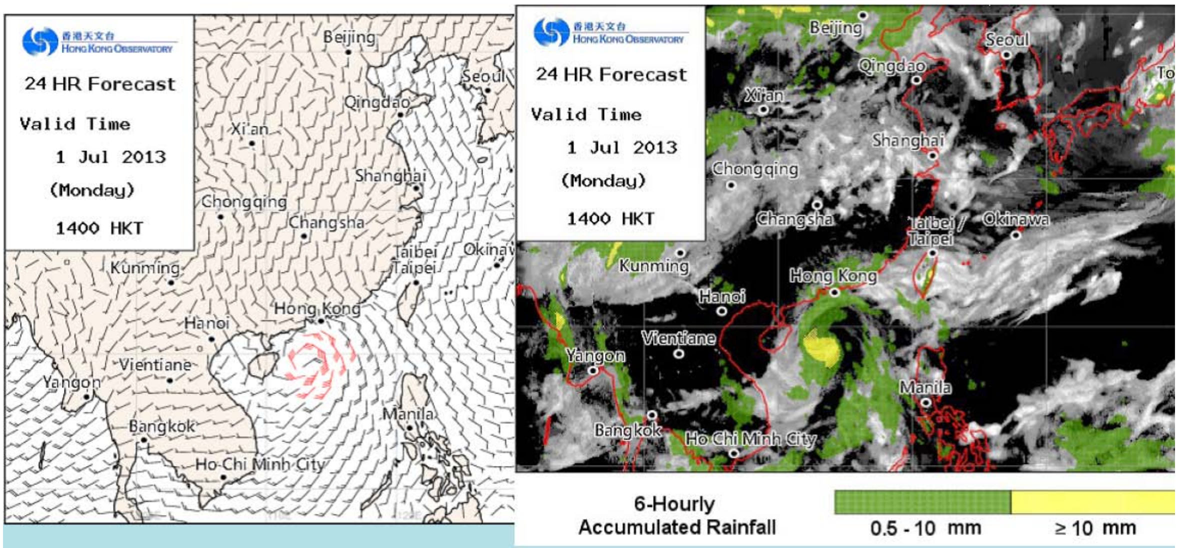


Graphic 32: Standard VA charts & modern display (Leads system).

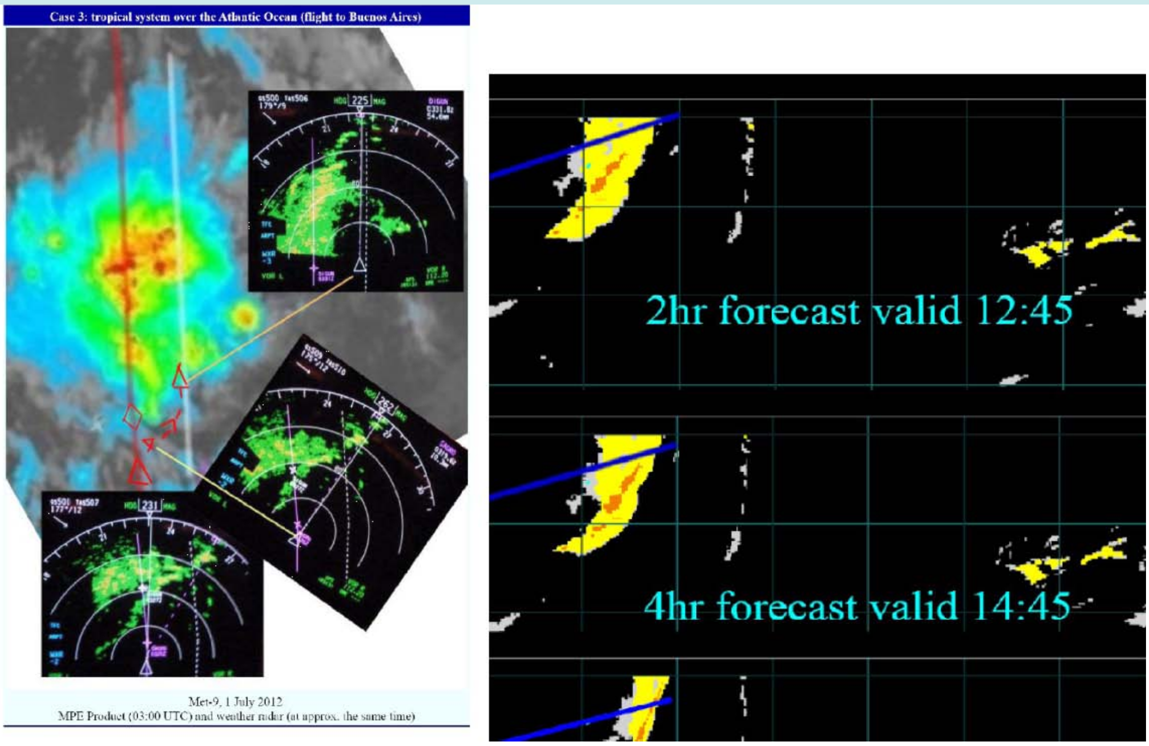


Graphic 33: Hurricane-tracking-chart that shows the forecast position clearly, plus high resolution sat image.

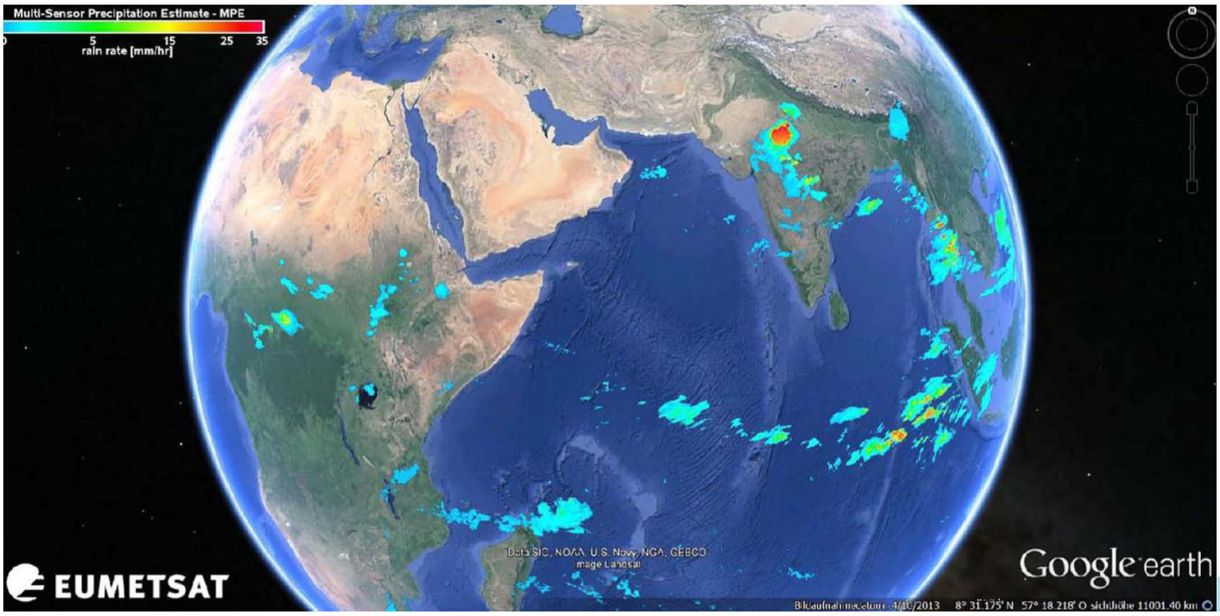
Note that hurricanes regularily affect the Azores, the Canary Islands, the NAT – tracks and many areas of the world that airplanes fly to from Europe.



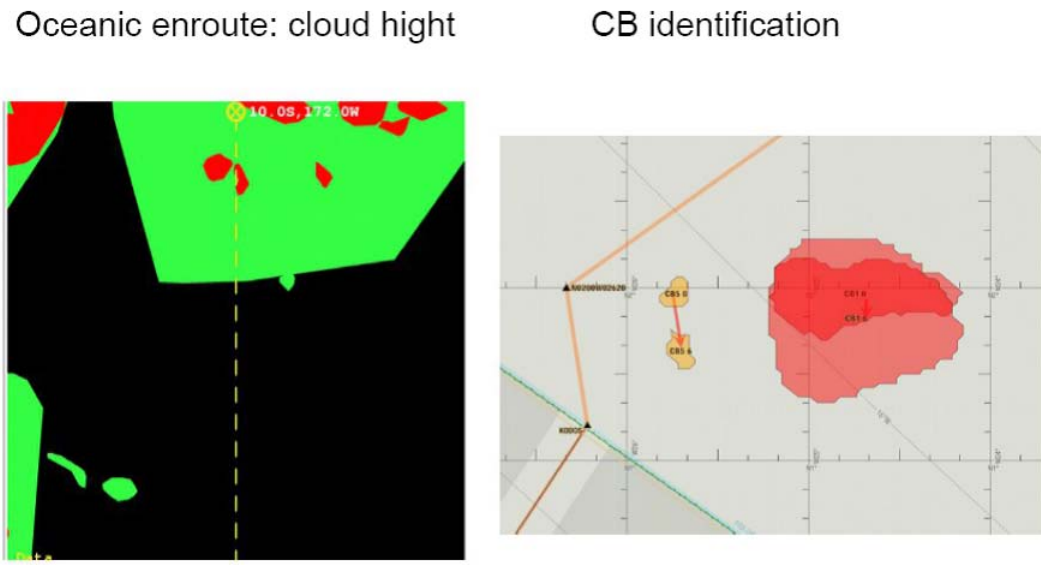
Graphic 34 : High precision forecast of wind-field & precipitation



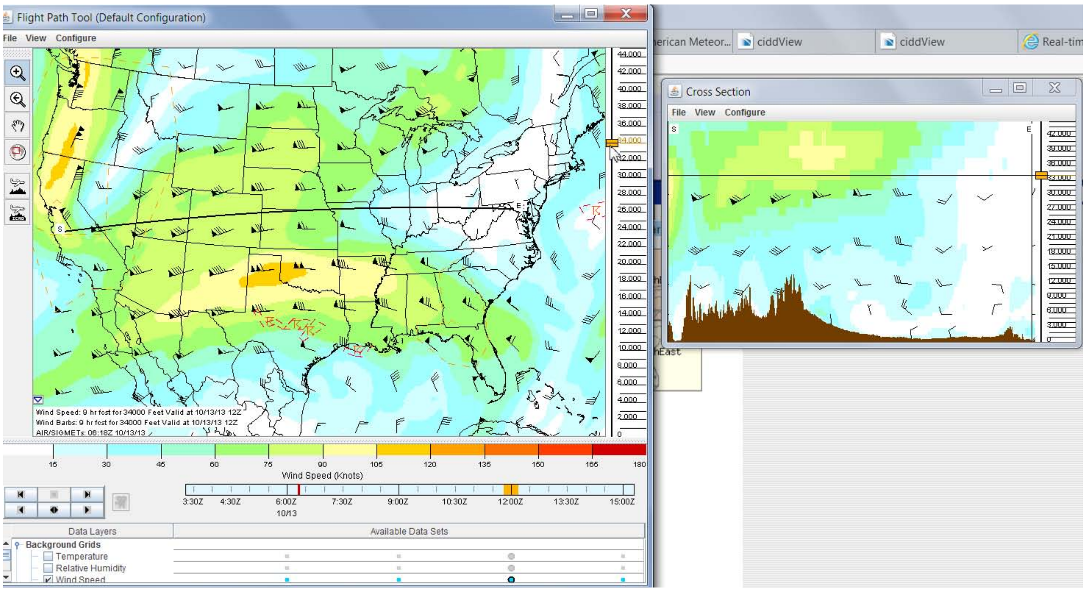
Graphic 35: Oceanic weather - real-time satellite pictures plus satellite-based forecasts



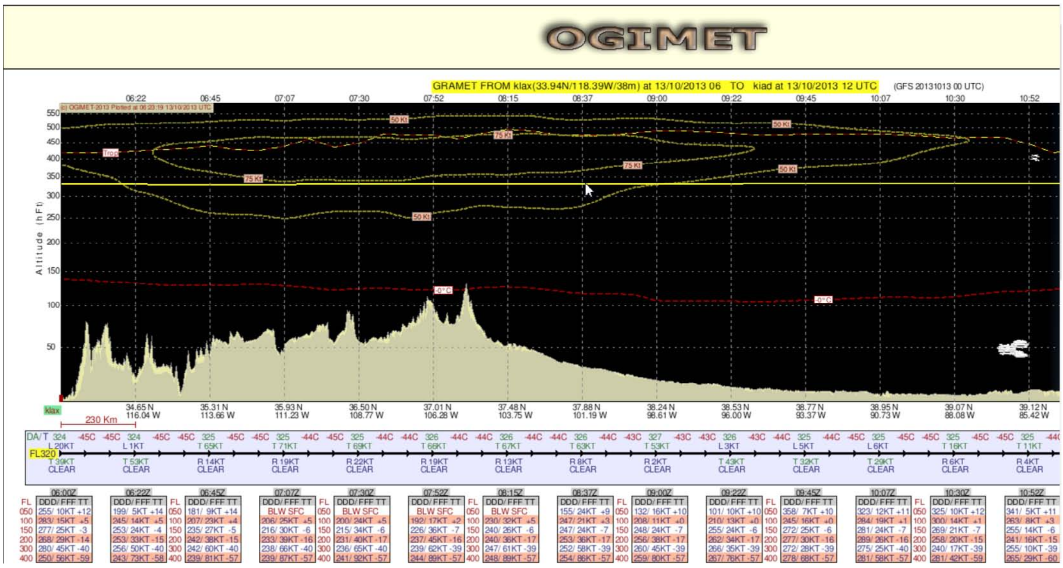
Graphic 36: Weather satellites: the tool of choice for crossing oceans. Satellite picture is showing precipitation. Colour-coding corresponds to aircraft wx radar.



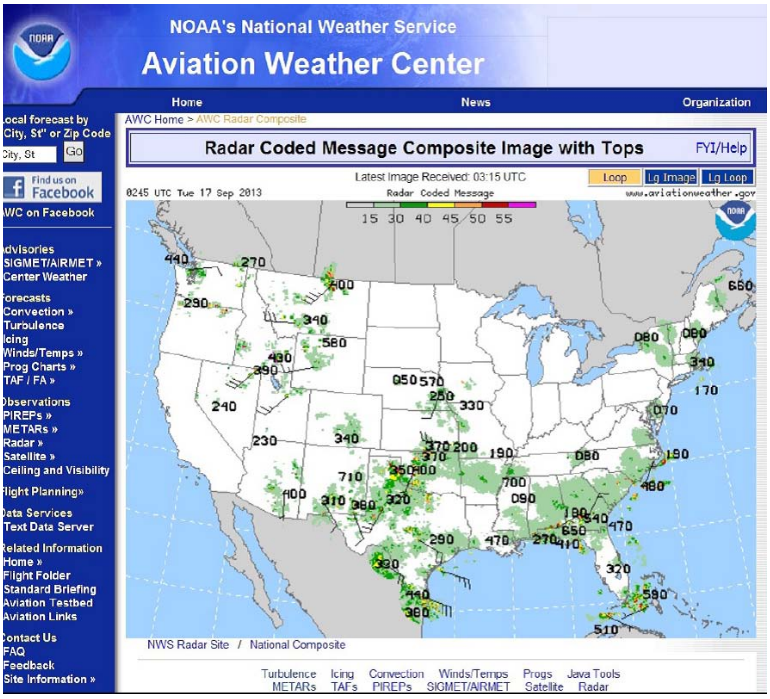
Graphic 37: If communications-bandwith is restricted, these types of information can still be uplinked to aircraft in real time. Source: The FAA AWRP Oceanic Weather Program Development Team



Graphic 38: Vertical profile/flight information from NOAA



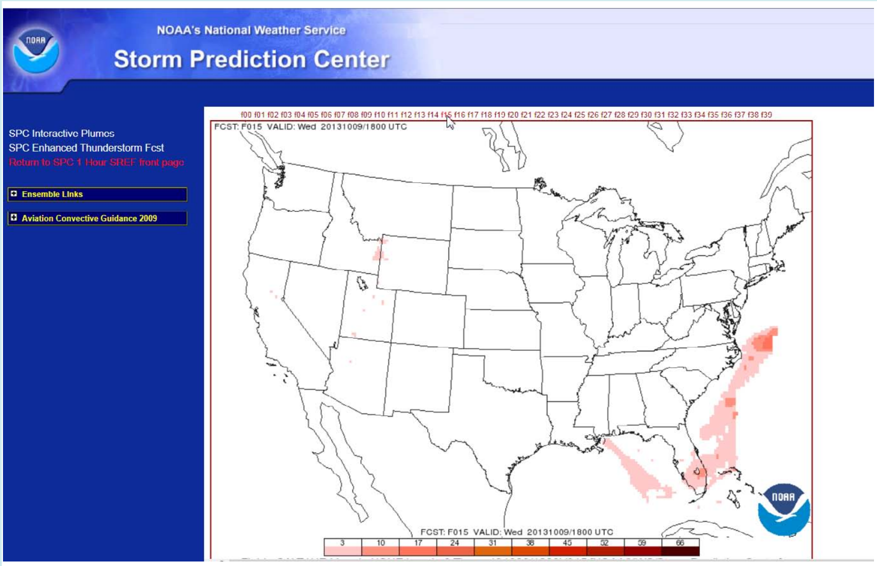
Graphic 39: Ogimet, European website



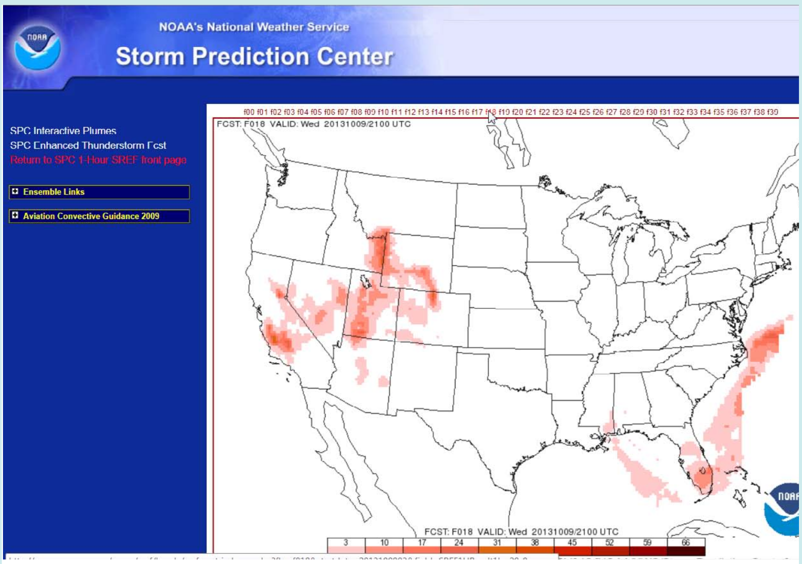
Graphic 40: One place to gather weather info...

Graphic 41: Traffic Flow Management Portal: Display and try out new weather displays, products

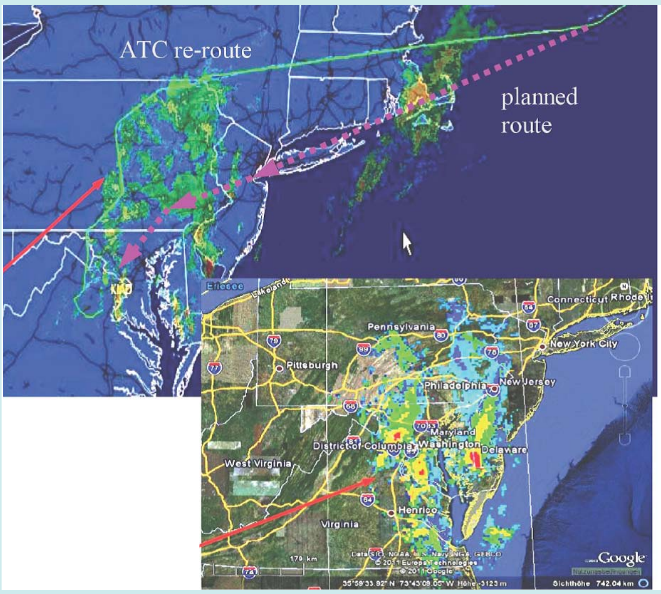
Note: EUROCONTROL NOP contains weather information



Graphic 42: Example: Thunderstorm forecasting has “enroute impact”



Graphic 43: A few hours later



Graphic 44: Traffic flow, controller position and staffing and more can be planned based on such forecasts. The graphic shows real world example.

Summary

The examples shown here are proof that weather information is available in easy to interpret, graphical form. There are clear safety and economic benefits in giving pilots continuous acces to it during all phases of flight, from flight planning to landing.

This is expressed in ECA's key messages

» Deliver relevant MET information into the pilots' hands. Do not simply store or "hide" information in computers
» Ensure that ATC/ATM works with relevant MET across borders in a coordinated way
» Build a MET-Portal for Europe such as www.aviationweather.gov
» Re-think the dependence of SESAR on the GBAS, other GNSS systems
» Halve the time between TAF from 6 hrs to 3 hrs in the Europe

ABBREVIATIONS

AAtS	Aircraft Access to SWIM
AC	Advisory Circular
ADS-B	Automatic Dependent Surveillance - Broadcast
AI	Airbus Industrie or Anti Icing System
AIRMET	Airman´s Meteorological Information (below fl 245, less severe)
ATM	Air Traffic Management
C&V	Ceiling and Visibility
CIP	Current Icing Potential
DCS	Decision Support System
DOT	Department of Transportation
ECA	European Cockpit Association
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control System
FIS	Flight Information Service
FIS-B	Flight Information Service Broadcast
FTP	File Transfer Protocol
GAMET	Area forecast for low-level flights
GTG	Graphical Turbulence Guidance
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Airline Pilot Associations
ILS	Instrument Landing System
MET	Meteorological
METAR	Meteorological Aerodrome Report
NAS	National Airspace System
NextGen	Next Generation
NWS ADDS	US National Weather Service Aviation Digital Data Service
RSMC	WMO Regional Specialized Meteorological Centre
SESAR JU	Single-European Sky Joint Undertaking
SIG WX	Significant Weather
SIGMET	standard message of Significant Meteorological Phenomena
Skybrary	Eurocontrol collection of information relevant to aviation
SPECI	Special met report, issued when conditions change rapidly
SWIM	System – Wide Information Management
TAF	Terminal Aerodrome Forecast
UAT	Universal Access Transceiver
UAV	Unmanned Aerial Vehicle
VAAC	Volcanic Ash Advisory Centre
WAFC	World Area Forecast Centre
WAFSOPSG	World Area Forecast System Operations Group
WMO	World Meteorological Organisation
WTIC	Weather Technology in Cockpit