An Integrated Meteorological System for the Belgium Air Traffic Control Agency

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Abstract

PS MeteoStar, Inc (IPSM) implemented an aviation meteorology decision support system for Belgocontrol under the METAFOR system modernization program. Belgocontrol is the Belgium national air traffic control agency and is headquartered in near-proximity to the Brussels airport. Belgocontrol meteorological staff provide weather analysis and forecast services for aviation within Belgium and some surrounding airspace. Key services include low level significant weather products, a variety of text forecast bulletins, and an interactive webpage. IPSM provided the Leading Environmental Analysis and Display System (LEADS®) workstations and servers to support Belgocontrol's critical operational workflow, web presence, training, and general weather environmental situational awareness. The LEADS® solution integrates weather observation and forecast data from the United States, United Kingdom, France, Germany, Czech Republic, and Belgium national forecast centers as well as European Union Meteorological Satellite (EUMETSAT) direct data. With a single data processing, storage, visualization, and publishing system Belgocontrol is able to more efficiently and reliably provide for the safety of their responsible airspace and resources. The delivered LEADS® systems includes advanced data visualization, web services, system monitoring, high-availability redundancy, and data archiving. IPSM looks forward to the continuous improvement of the METAFOR system to meet emerging requirements and the further expansion of LEADS® systems into the European market.

1. Introduction

This document will provide readers with a detailed overview of the recent IPSM LEADS® solution, which was installed as the foundational core of Belgocontrol's Project METAFOR. A brief background on IPSM and Belgocontrol will be discussed, as well as the details of Project METAFOR, the IPSM solution provided, the challenges involved with the project, how said challenges were overcome, and the current state of the project. This manuscript will include slightly more detail then the accompanying PowerPoint® presentation, as a few major milestones have passed since the presentation was given in mid January 2010.

2. IPSM Background

IPSM is an international leader in the business of meteorological and environmental data integration, processing and visualization. With over 40 customers world-wide, IPSM has a quality reputation for the delivery of high performance systems for forecasting and data monitoring operations. Beginning as a Lockheed Martin project in the mid 1990's, the LEADS® solution was initially developed for the United States (US) Navy. It has since expanded to a global customer base, with a key focus on aviation weather applications.

IPSM's LEADS® product line is the standard used by all branches of the US Military for Aviation Operations. LEADS® is also the backbone of meteorological decision toolkits for numerous other domestic and international aviation-focused agencies, such as the US Automated Flight Service Stations, Federal Express, NASA-

Wallops Island, United Airlines, KLM Airlines, Malaysia Airlines, Qantas Airlines, Aerocivil (Colombia), the Taiwan Air Force, the Colombian Air Force, the Brazilian Space Agency, and many others.

3. Project METAFOR

Project METAFOR (**Met**eorological **A**nalysis and **For**ecasting) was an undertaking by Belgocontrol to completely revamp and modernize their meteorological decision support system. A brief background of Belgocontrol, Project METAFOR, as well the overarching goals of the project, are detailed below.

a. Belgocontrol Background

Headquartered at Brussels National Airport, Belgocontrol, was founded in 1998 as an autonomous public company in charge of the safety of air navigation in the controlled civil airspace above Belgium and the Grand Duchy of Luxembourg for which Belgium is responsible (Fig. 1). This includes:

- The airspace above Belgium: from ground level to flight level 245 (24,500 feet = 8,000 meters altitude).
- The airspace above the Grand Duchy of Luxembourg from flight level 135 (13,500 feet) to flight level 245.
- The airports of Antwerp, Brussels Airport, Charleroi, Liège (during civil flight hours, at night and in weekends) and Ostend.

Besides air traffic management and control, Belgocontrol provides many other services to civil aviation: pre-flight information, flight plan assistance, aeronautical and meteorological information, communication, navigation and surveillance services, as well as training of air traffic controllers. More than 900 persons among whom 400 air traffic controllers work on 7 sites, day and night, 365 days a year (Belgocontrol 2007).

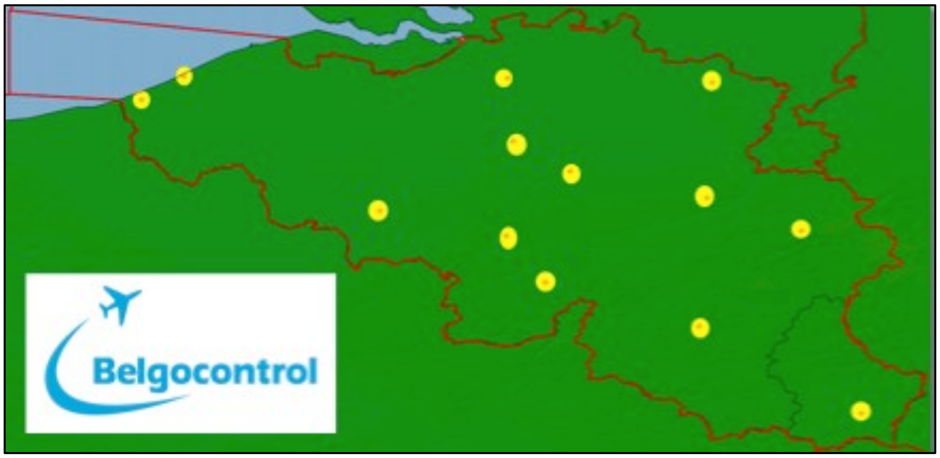

FIG. 1. Belgocontrol area of responsibility (outlined in red) and airports of responsibility (yellow dots).

The Meteorological Department within Belgocontrol (Meteo) provides a full spectrum of weather services to Belgocontrol's customer base. This includes flight planning information, real-time radar, satellite, and lightning imagery, International Civilian Aviation Organization (ICAO) standard weather charts, and numerous ICAO /World Meteorological Organization (WMO) weather bulletins, to include Significant Meteorological Information (SIGMET) messages, Airmen's Meteorological Information (AIRMET) messages, Terminal Aerodrome Forecasts (TAFs), and Aerodrome Routine Meteorological Reports (METARs).

b. Project METAFOR Background

Prior to Project METAFOR, Meteo performed its mission of generating and disseminating the items listed above via numerous, disconnected components. In essence, a Meteo forecaster was required to understand, use, and move between up to six different meteorological systems. This hindered workflow and product quality. It also presented a maintenance challenge to Meteo, as each system had unique components and different service/support contracts with the numerous vendors that provided the disconnected systems.

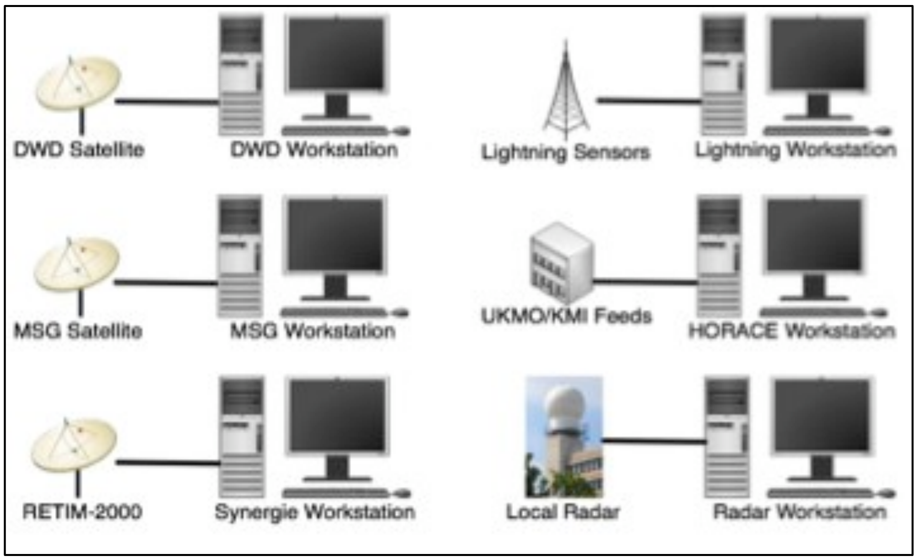

FIG. 2. High-level overview of the legacy Meteo systems. Note that every different data type was fed to a different, stand-alone system, requiring forecasters to constantly change from system to system to perform basic, daily operations.

In 2007, Meteo decided to undertake a project to integrate all their systems capabilities, as well as associated data types into one, redundant solution. This solution would provide Meteo forecasters with a single interface to perform all their daily tasks, streamlining workflow and reducing time lost in transferring from system to system in the legacy setup (Fig. 2). A Request for Proposal for an integrated weather solution was let in the fall of 2008, and IPSM was awarded the contract in January of 2009.

c. Goals - Belgocontrol

Although the general goal of Project METAFOR is described above, Belgocontrol and Meteo had numerous other goals associated with the focus of integrating all their tools and datasets into one system. The goals presented to IPSM by Belgocontrol upon contract award were as follows:

- Integrate all disconnected system, functionalities, and data (as previously stated).
- Develop a robust, web-based solution for WMO/ICAO text bulletin generation and publishing/Global Telecommunications System (GTS) dissemination.
- Provide for redundant, high-availability (HA), fault-tolerant hardware (three threads of identical hardware components; 1 for training/testing, 2 for operations). This would allow for no single points of failure.
- Provide for a completely integrated system monitoring and alerting solution, which will monitor all aspects of the system (hardware and software) and alert administrators when certain user-defined thresholds are exceeded.
- Allow for ease of system expansion/growth in the future (mainly in terms of hardware).

Many other sub-goals were laid out in the contract/Statement of Work, but the items above consisted of the primary focus, in Belgocontrol's eyes, of what the system needed to do and provide to be successful. As much as Belgocontrol had their goals for this project, so did IPSM.

d. Goals - IPSM

IPSM's goals were more business oriented, but still encompassed an overall focus on technological advancement. IPSM's goals for the project were as follows:

- First and foremost, deliver the purchased system, meeting or exceeding all Belgocontrol requirements.
- Further advance the LEADS® / LEADS® On-Line product line by developing new tools and processing new data sets within the software.
- Continue to grow business and solidify IPSM's reputation in the European market.

As simplistic as these goals may appear, they represented a new chapter in IPSM's history and product line. IPSM's strongest markets have historically been in the Americas. With a large company like Belgocontrol, centrally located in Europe, partnering with IPSM, the focus was to provide a solid solution, which would intrigue others in the region.

e. Overall Program Challenges

As with any undertaking of this size and scope, many challenges readily presented themselves upon onset of the project. The main challenges were:

- Developing a web-based WMO/ICAO text bulletin tool. The challenge here was to make it flexible and configurable for the user, while still ensuring it was functional.
- Creating and installing a system monitoring and alerting capability that could span all three threads of hardware/software to be delivered.
- Implementing a HA/failover solution that could span all three threads of hardware/software, and allow for monitoring and seamless transition if failover occurs.
- Automatic system synchronization to ensure all three systems always have the same configuration and setup, preventing any discontinuities during a failover.
- Cross-continent testing and system delivery.

These were indeed difficult challenges, but none that could not be overcome when the final system was delivered.

4. Delivered System Solution

In September – October 2009, IPSM successfully delivered and Site Acceptance Tested the Project METAFOR system. As shown below (Fig. 3), the system consisted of 3 identical hardware threads, running identical versions of the IPSM LEADS® / LEADS® On-Line software. IPSM successfully integrated with all required data types/sources, and also provided a web-based forecaster and administrator toolkit. HA and failover mechanisms were embedded in the system, which used all Hewlett-Packard (HP) enterprise hardware. Highlights of the key functionalities and capabilities delivered to Belgocontrol are described below.

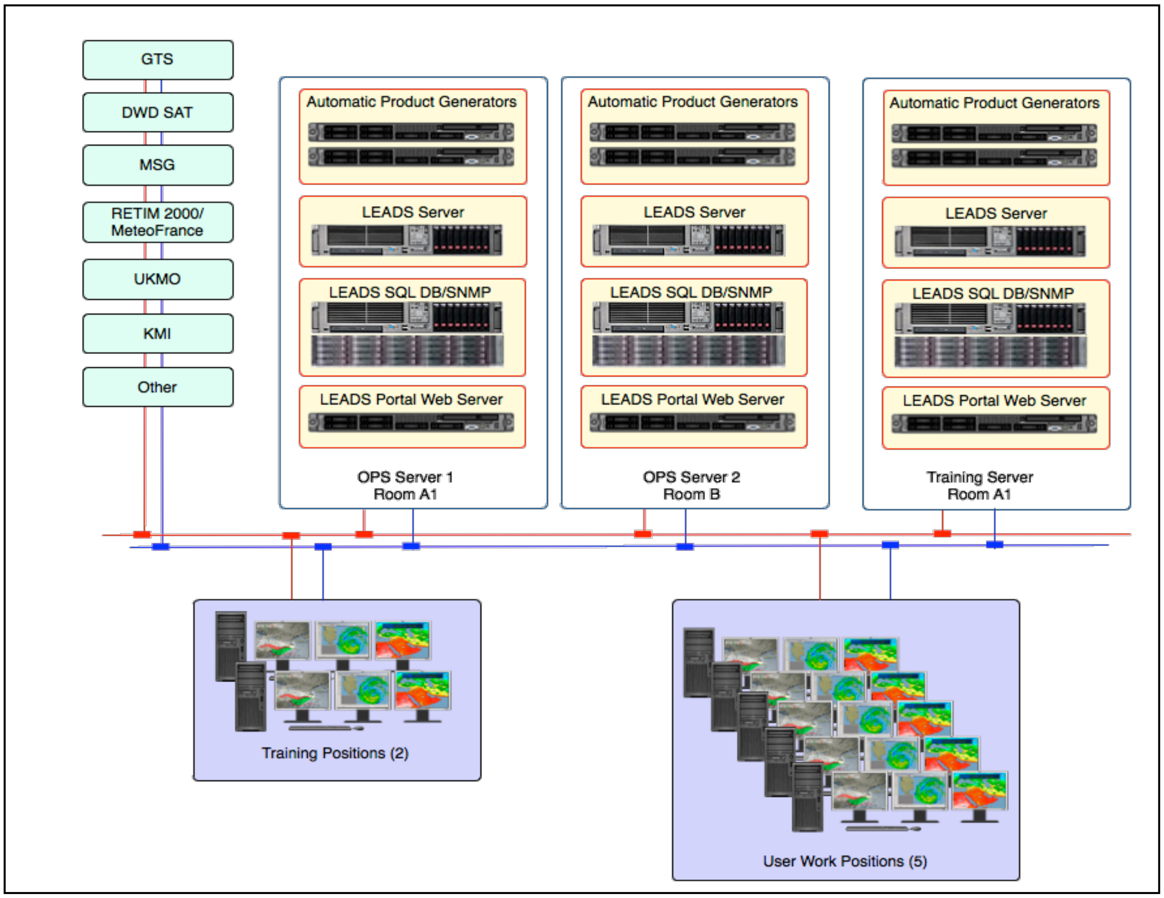

FIG. 3. Project METAFOR delivered architecture, showing 3 identical hardware threads, all fed by the same data feeds.

a. Key Functionalities/Capabilities – LEADS® On-Line

LEADS® On-Line is a web-based user back end for viewing and querying data and products that are processed by the LEADS® system. The LEADS® On-Line component of Project METAFOR is the primary tool used by Meteo forecasters for visualizing numerous data types, interacting with the data, and generating and publishing WMO/ICAO bulletins. LEADS® On-Line is fully customizable all the way down to the pull-down menus, and supports user roles and permissions for controlling access to data/functionalities. LEADS® On-Line can also be exposed to external agencies, which Belgocontrol is taking advantage of by allowing regional airport forecasters to access products and capabilities on the Project METAFOR LEADS® On-Line system. The figures below (Fig. 4-9) depict some of the pages on the current Project METAFOR LEADS® On-Line system that forecasters can access.

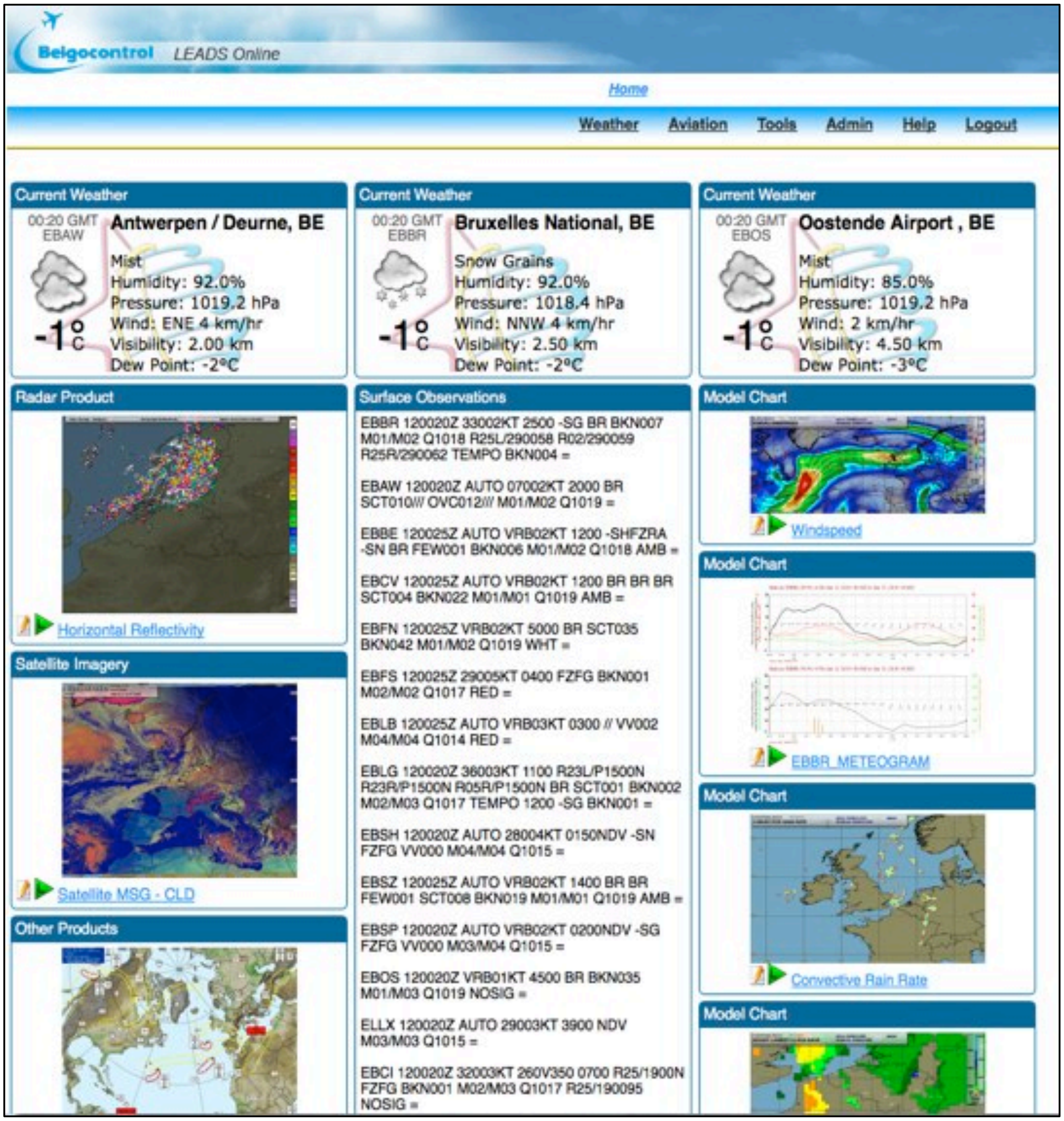

FIG. 4. A sample LEADS® On-Line custom page, where various different data types and products can be displayed. Custom pages are fully customizable by each user and tied to user accounts.

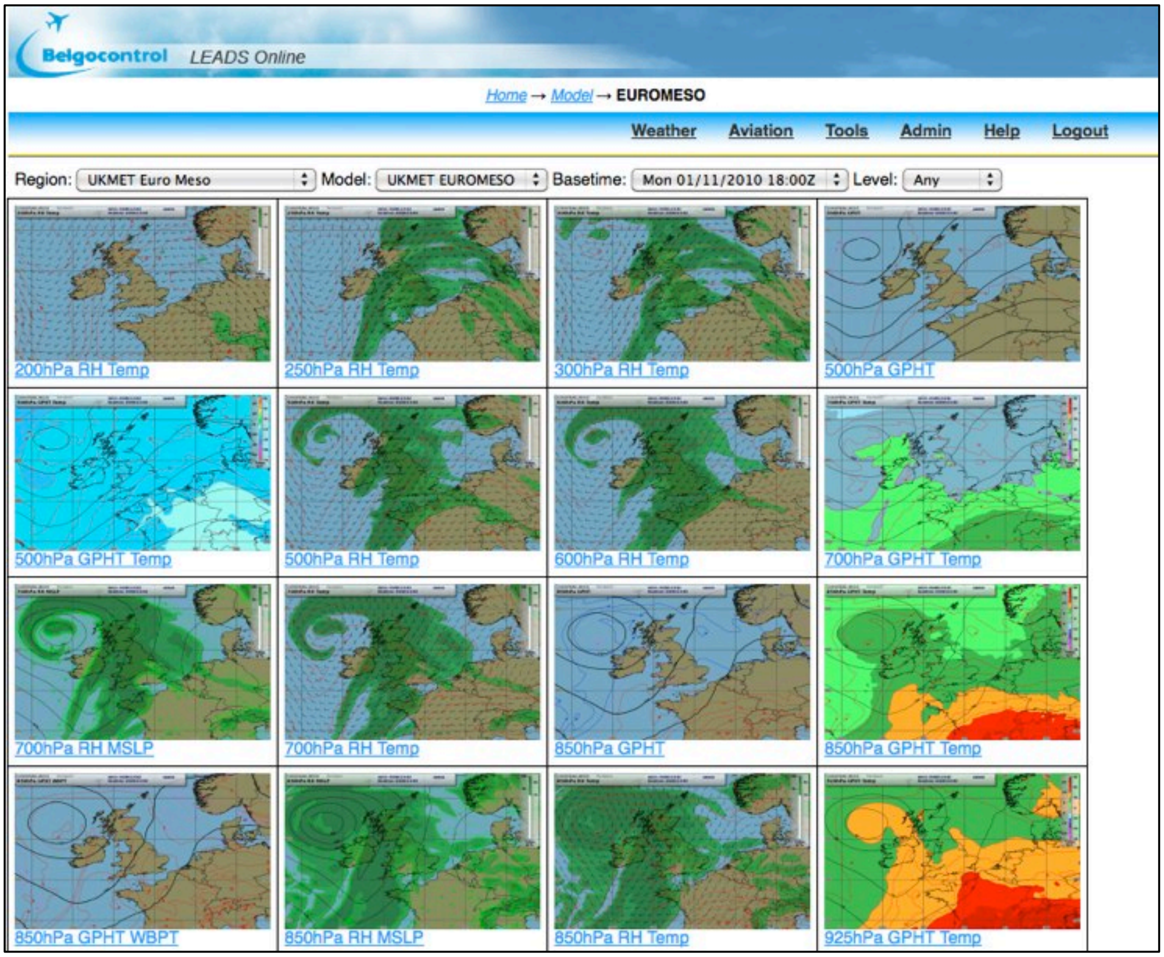

FIG. 5. LEADS® On-Line model product page. Thumbnails can all be clicked and larger, looped images can be displayed.

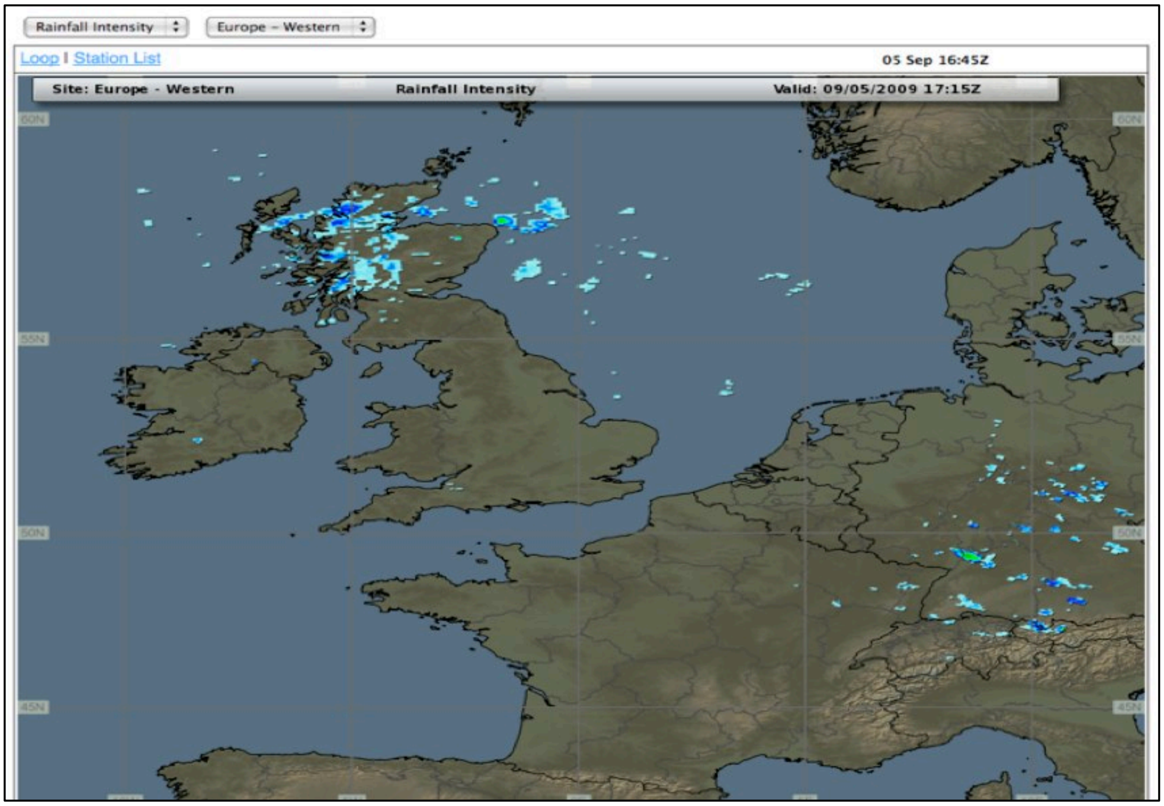

FIG. 6. Western Europe composite radar imagery as seen in LEADS® On-Line.

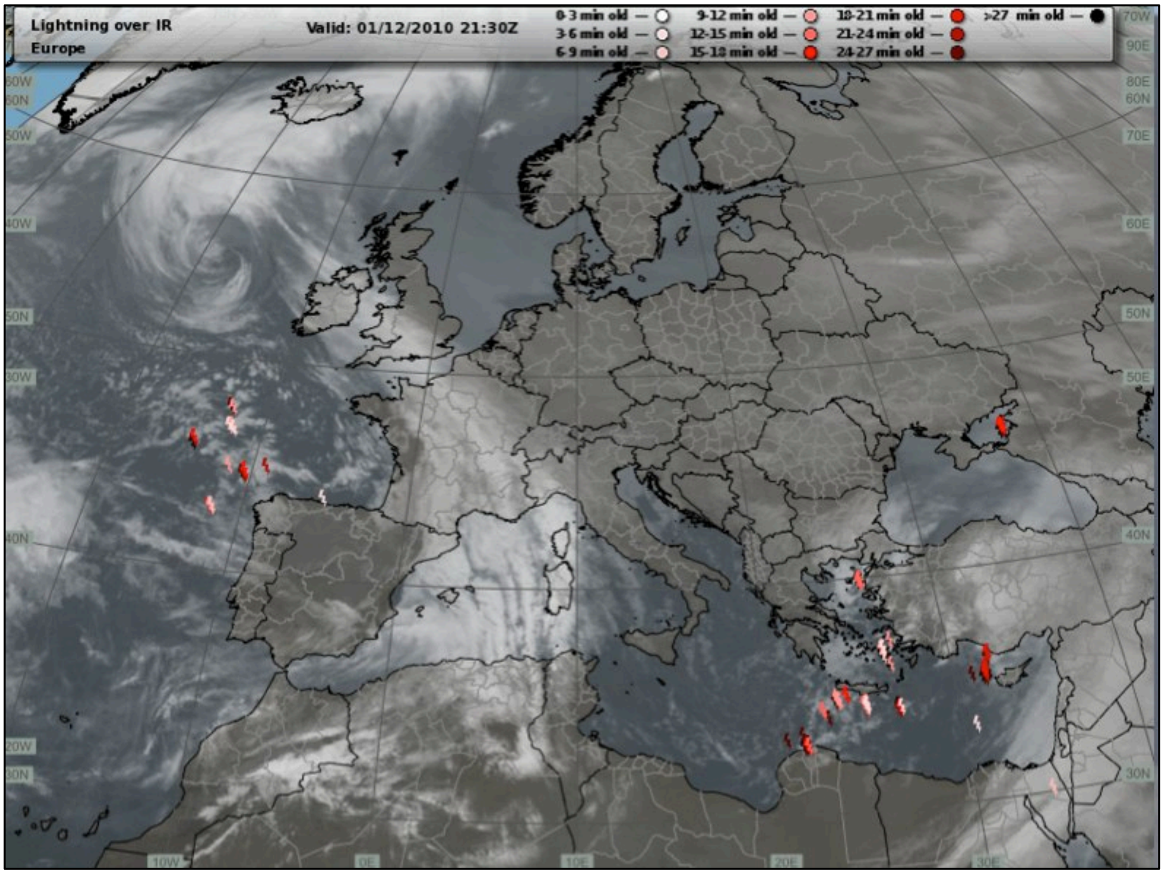

FIG. 7. MSG IR satellite imagery, overlaid with regional lighting data, as seen in LEADS® On-Line.

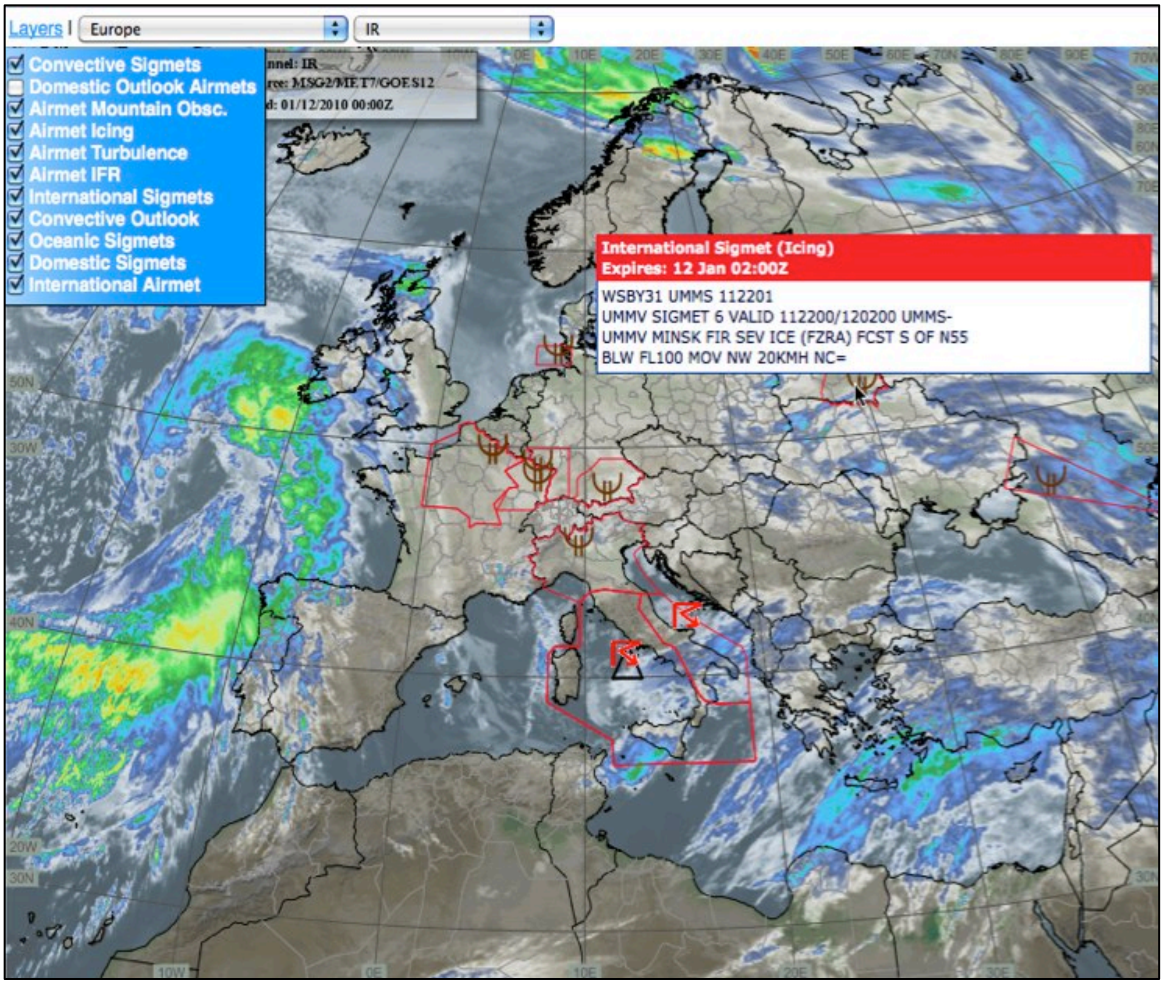

FIG. 8. LEADS® On-Line SIGMET/AIRMET page. Forecasters can see SIGMET/AIRMET polygons overlaid onto any image/product type, as well as mouse-over the polygons to view the textual message. Different SIGMET/AIRMET message types can be toggled on/off via the layers menu.

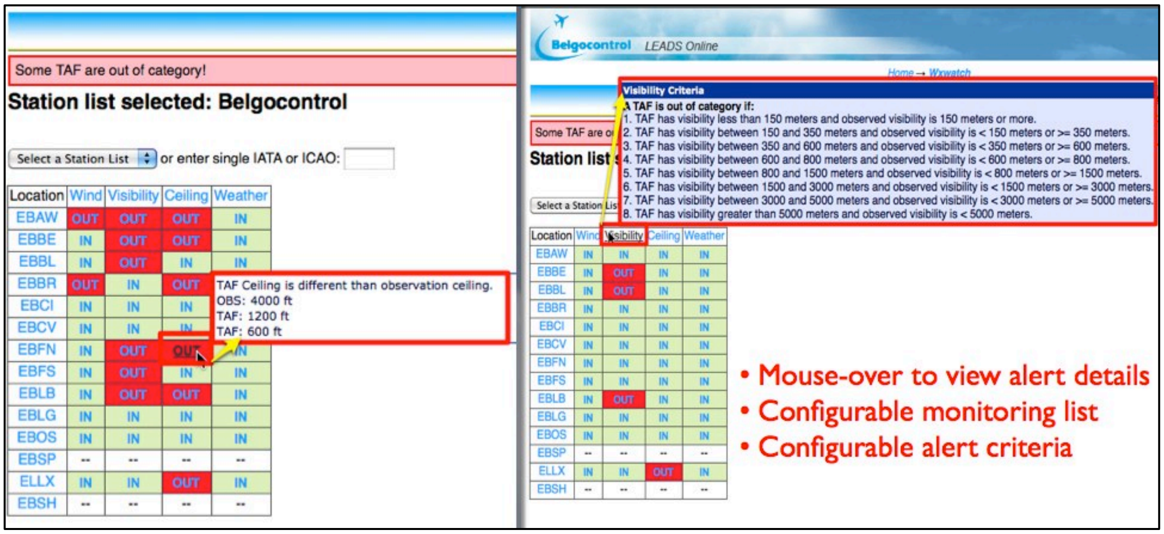

FIG. 9. LEADS On-Line TAF monitoring/alerting page. Forecasters are alerted (visually and audibly) when TAFs are out of specification based on user-configured amendment criteria.

WMO/ICAO BULLETIN GENERATOR

One of the key LEADS® On-Line components delivered to Belgocontrol was the WMO/ICAO Bulletin Generator. This tool allows Meteo forecasters to create, edit, and disseminate 100% WMO/ICAO compliant text bulletins, which portray key aviation weather information to the Belgocontrol customer base. The delivered editor, shown in the screenshots below (Fig. 10-13), also pre-populates key bulletin fields with observed data, model output, and/or text from previously published bulletins. This allows for massive time savings in bulletin generation and allows forecasters to focus on the key meteorological challenges of the day. The bulletin generator also provides for a wide variety of automatic validation and error checking, to ensure messages are encoded to all standards. Finally, the tool allows for seamless integration with a GTS socket, so that messages can be easily and quickly disseminated to the rest of the world.

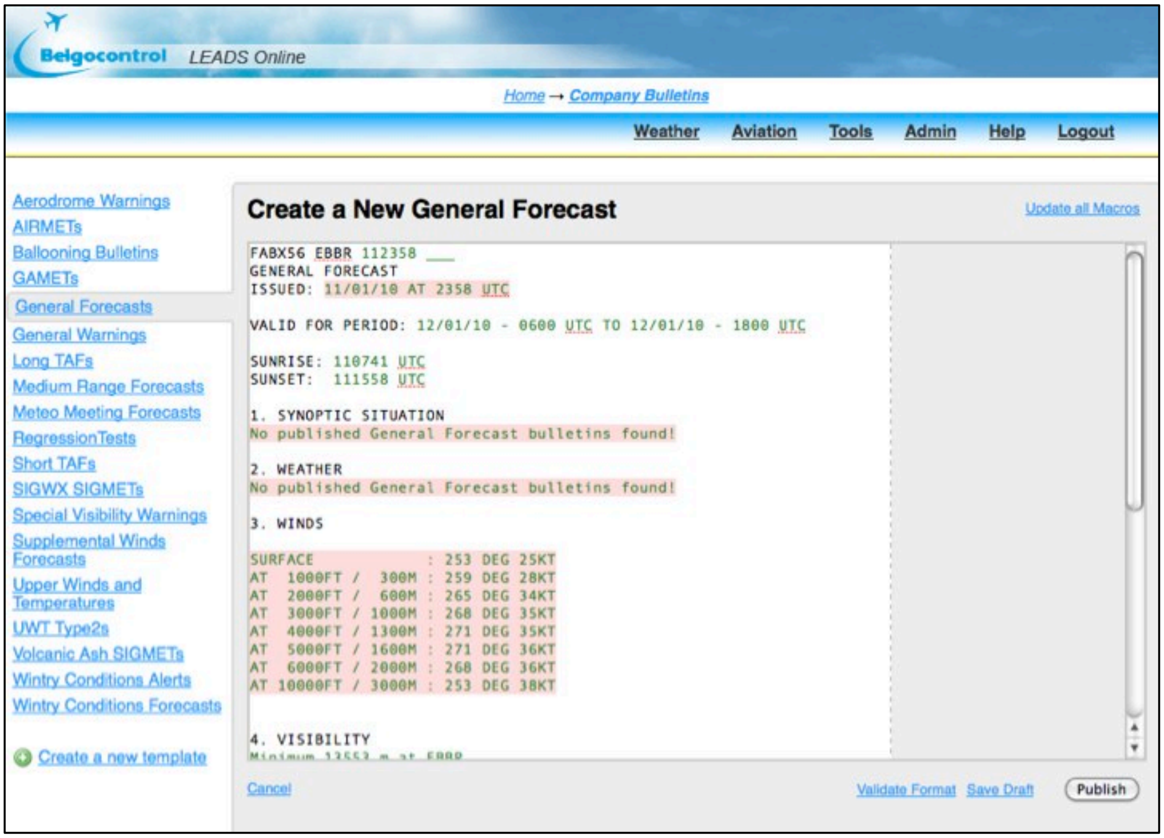

FIG. 10. A Belgocontrol General Forecast Bulletin, as seen in the LEADS® On-Line Bulletin Generator. All fields, including the WMO header, are pre-populated based on the macros that operate in the background. Green areas are key time parameters, which are auto-populated based on the system clock and can be manually refreshed prior to bulletin issuance. Pink and green fields are pre-populated from observed data, model data, and/or text from previously issued bulletins. These fields can also be manually refreshed prior to publishing.

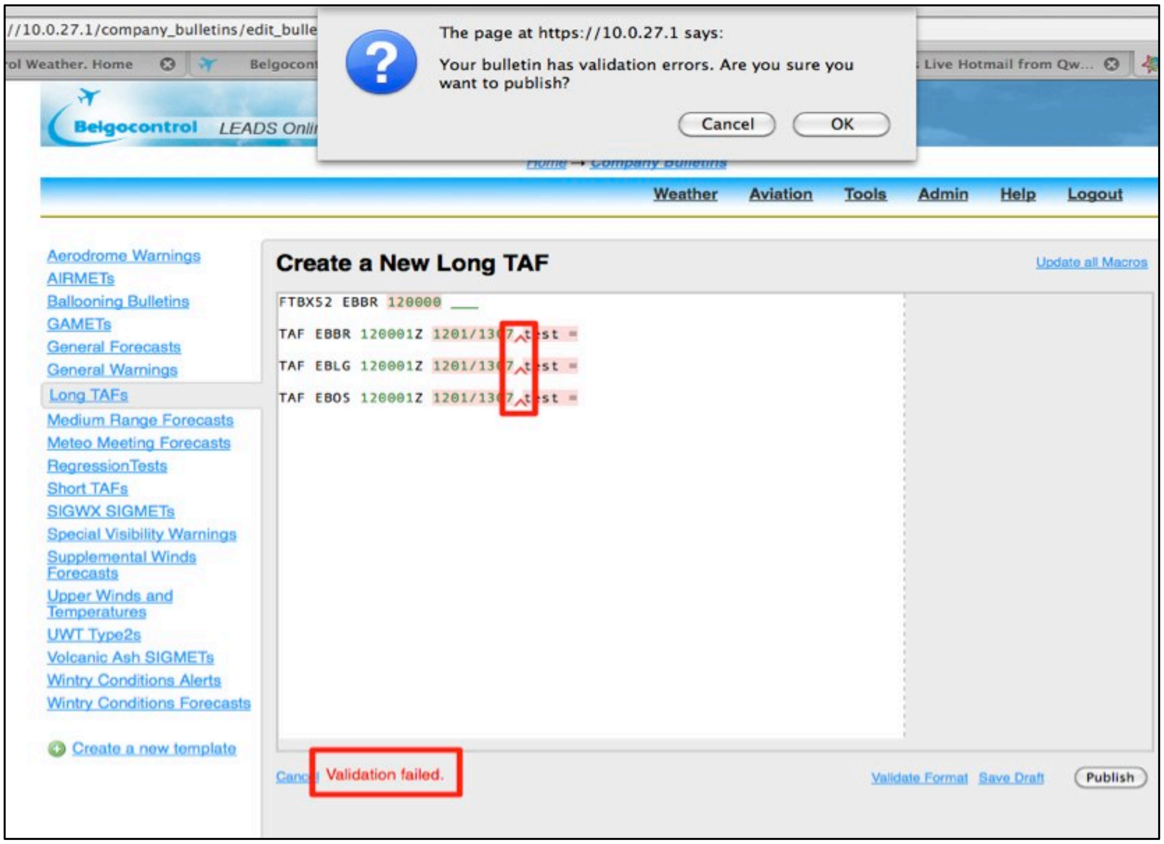

FIG. 11. A sample TAF message, with automatic validation/error checking turned on. In this example, the forecaster failed to enter valid forecasted weather parameters and numerous alerts notify the forecaster of this discrepancy.

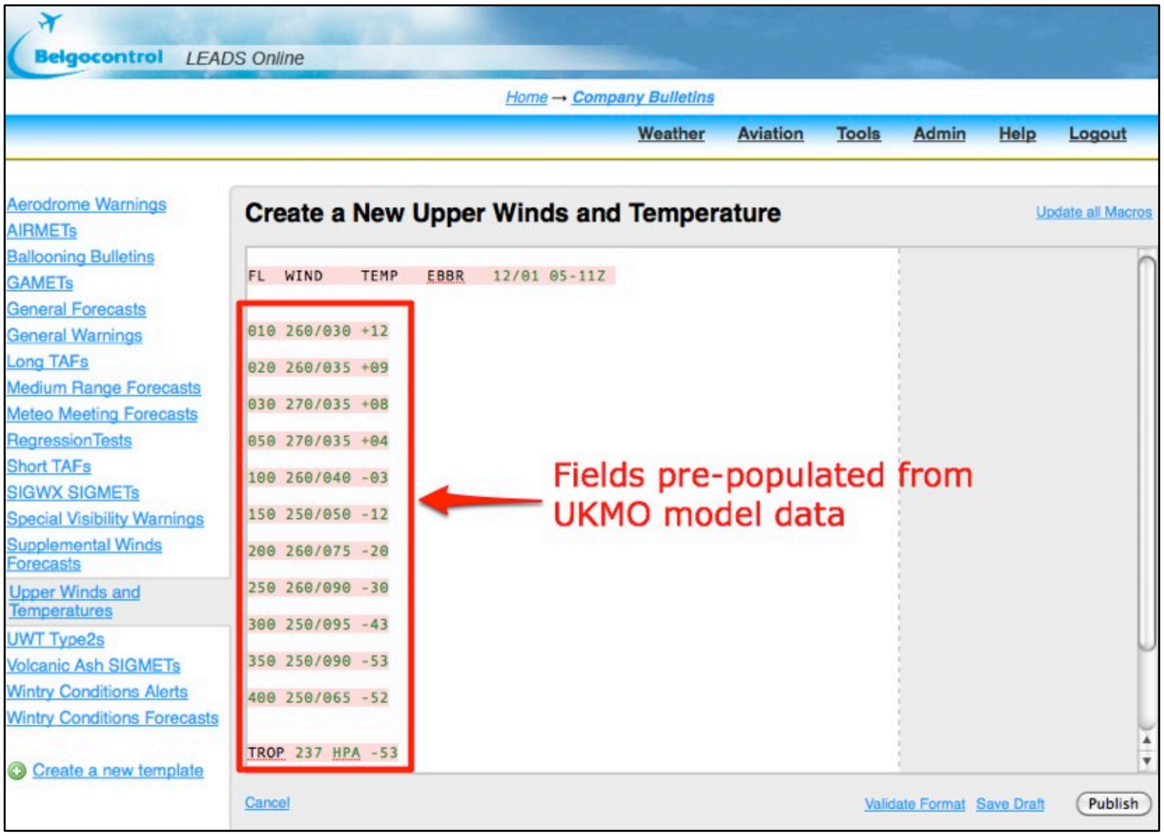

FIG. 12. A Belgocontrol Upper Winds and Temperature bulletin, where the pre-determined flight levels have data pre-populated into them from the United Kingdom Meteorological Office (UKMO) Mesoscale Model.

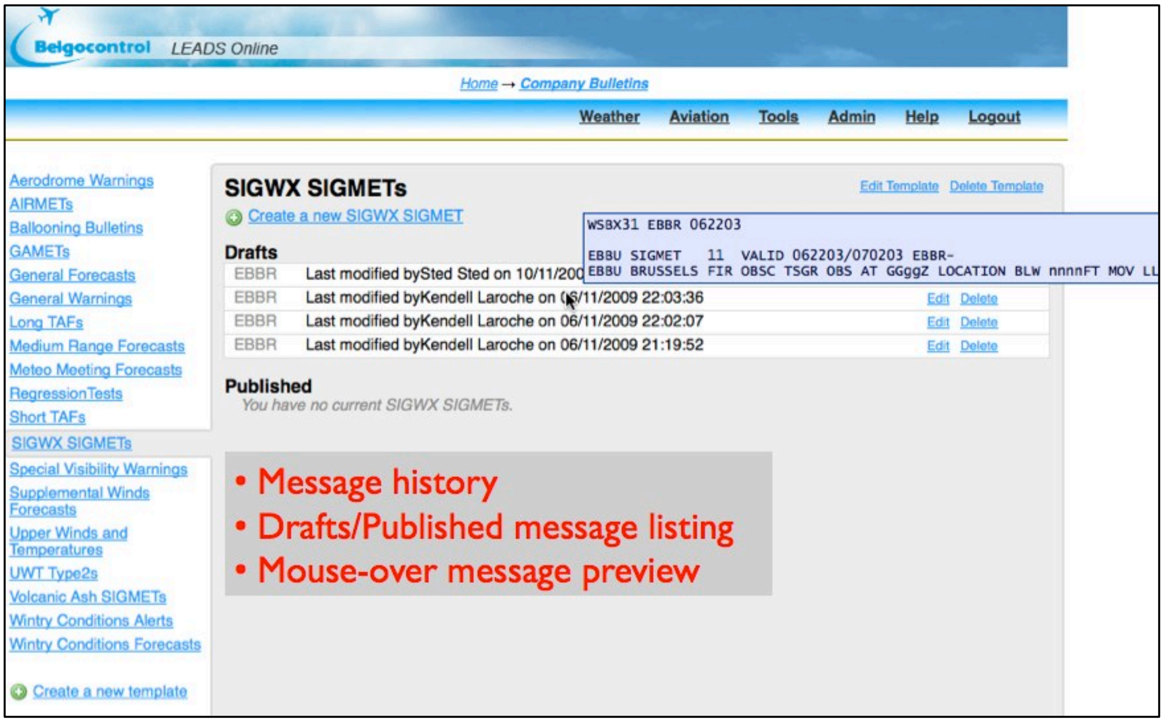

FIG. 13. Bulletin display page (in this case, for Significant Weather SIGMETs), where users can view message histories, either drafts or published, and mouse-over to see message previews.

b. Key Functionalities/Capabilities – System Monitoring and Alerting

As mentioned earlier, the delivered system also provided for a suite of system monitoring and alerting tools. These tools, installed standard as part of the entire system solution, monitor all key hardware components and software processes. IPSM used two open-source solutions, Ganglia and NAGIOS (Fig. 14-15), to meet the required monitoring and alerting needs of Project METAFOR. Ganglia was configured to received key capacity and system/network traffic data, to be displayed in trend graphs. NAGIOS, on the other hand, was configured to receive Simple Network Management Protocol (SNMP) traps distributed by both the HP hardware and the LEADS® / LEADS®

On-Line software. These SNMP traps are then validated against user-defined alert threshold configurations, and the status of processes/components was then displayed in the NAGIOS web-based interface.

FIG. 14. Ganglia display page, depicting color-coded memory, load, and other trends of system statistics for all components of a specific hardware thread. Each hardware thread has its own Ganglia instance, but Belgocontrol system administrators can monitor all instances simultaneously.

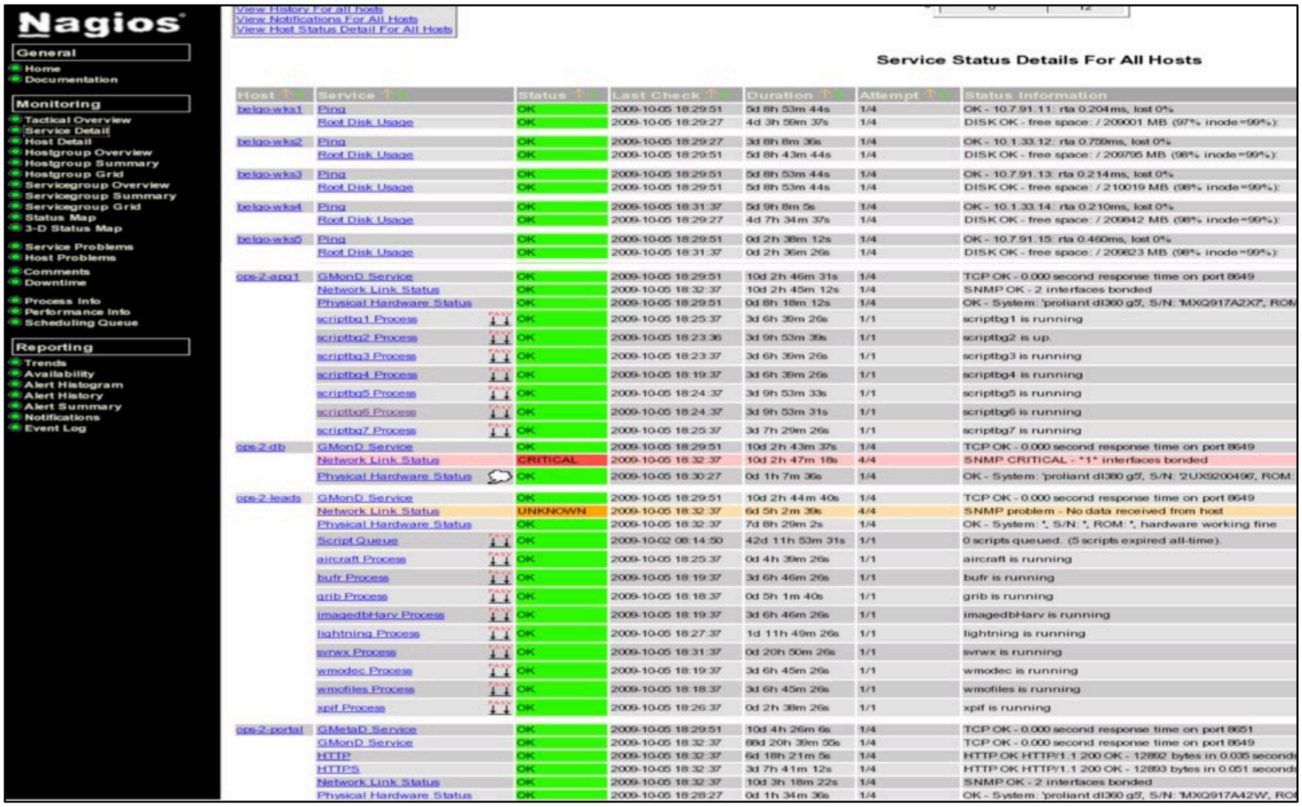

FIG. 15. NAGIOS display page, depicting color coded hardware component statuses (i.e. hard disk usage, network link status, etc.) and software process status (i.e. LEADS® decoders, LEADS® On-Line services, etc.). Alerts are fully acknowledgeable and historical alert logs are accessible.

c. Key Functionalities/Capabilities – HA/Failover

The final key capability delivered as part of the system solution was the embedded HA/failover functionality. The final solution consisted of three identical hardware threads, which constantly sync with each other via the use of rsync scripts (developed by IPSM). The three systems were installed in two physically different locations on the Belgocontrol property, allowing for an on-site disaster recovery. IPSM implemented the open source software packages Heartbeat and MON for node-level and resource level monitoring, respectively. If either of these processes detects a failure on the primary hardware thread, a seamless failover takes place, making the backup thread the new primary (Fig. 16). Belgocontrol also worked with IPSM to allow the training thread to become a tertiary operational thread in case of catastrophic failure of the main two operational threads. All status and statistics regarding the Heartbeat and MON processes were also integrated into each thread's NAGIOS instance.

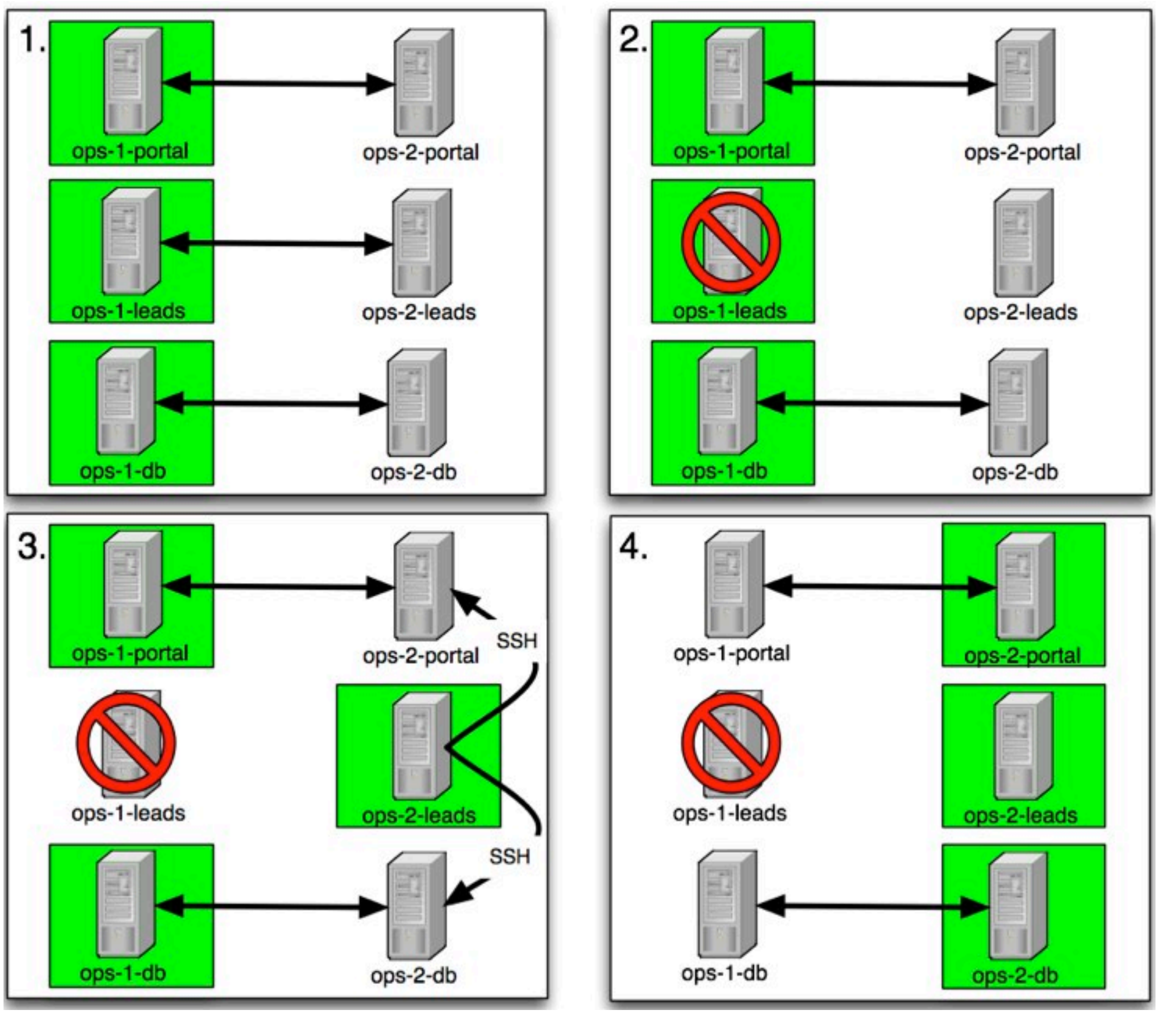

FIG. 16. A simplistic overview of the Project METAFOR HA/failover architecture. In this example, the primary thread (ops-1) experiences a failure of the LEADS® server. Heartbeat and MON detect this failure, send an secure shell (SSH) message to the secondary (ops-2) threads and instruct them to take over as the new primary. This process happens within a number of seconds and is seamless to a user.

d. Integrated Data Types/Sources

The primary, overarching goal of Project METAFOR was to integrate all of the existing Belgocontrol meteorological data, from different sources, into the LEADS® solution. The table below (Table 1) provides the reader with a simplistic view of all the numerous data types and sources, which were integrated into the LEADS® solution.

TABLE 1. Data sources and types integrated into the Project METAFOR LEADS® solution.

Data Source	**Data Types Integrated**	**Comments**
Royal Meteorological Institute of Belgium (KMI)	Belgian Aladin model, Belgian Ensemble Prediction Forecasts, and MeteoWing (Belgian Army) text bulletins/discussions.	
Belgocontrol	Local Aeronautical Information Services (AIS)	GTS feed allows for pulling in of large

	data, local radar data, and a complete WMO GTS feed.	volumes of meteorological data, as well as transmission of text bulletins out to the world.
UKMO	Mesoscale model, North Atlantic model, European Lighting Composite, and European Radar Composite (regional & local).	UKPP (Nowcast Model Output) added in February 2010.
Deutscher Wetterdienst (DWD)	GME Model, and LME Model	
MeteoFrance (MF)	Aladin model, Arpege model, ECMWF model, regional radar imagery, and a full RETIM-2000 feed.	RETIM-2000 feed filtered down to remove any duplicate data already provided via GTS feed.
EUMetSat Direct Receive System	MeteoSat primary sensor channels and derived products.	Derived products include FOG, CLOUD, DUST, and AIR.
Czech Republic Hydrometeorological Institute	Binary Universal Form for the Representation of meteorological data (BUFR)	Surface synoptic observations (SYNOP) only at this time.

	surface observations.	
United States National Centers for Environmental Prediction (NCEP)	Global Forecasting System (GFS) model data.	As of 22 Feb 2010, the LEADS system can easily process the GFS data, but Belgocontrol is not receiving the data due to bandwidth concerns.

5. Current Project Status

To date, Project METAFOR has been an overwhelming success. The numerous challenges listed earlier were all overcome, and the system was successfully delivered on-time and within budget. All project goals, as expressed by both parties, were met, and as of February 15, 2010, the system was deemed approved for operational use by Belgocontrol. Since this time, it is now the primary weather toolkit for the Meteo forecasters. Project METAFOR catapulted a fundamental shift in Belgocontrol meteorological operations, as well as IPSM's solution offerings. IPSM looks forward to continuing a close, cooperative working relationship with Belgocontrol for years to come.

Acknowledgments.

Special thanks to the entire Project METAFOR team at Belgocontrol, with specific acknowledgement being given to Alexandre Allard, Françios Bouvy, Wim Demol, Dany Mariën, Michel Vangeel, Dirk Vandenbergh, and Raf Windmolders. Also, thanks to

Matthew Taylor and David Vanden Heuvel at IPSM for providing guidance with crafting this presentation.

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