Spanish Meteorological Agency (Territorial Delegation in Catalonia, BARCELONA)

ENSEMBLE PREDICTION SYSTEMS APPLIED TO AERONAUTICS

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ABSTRACT

Meteorology plays a fundamental role in aviation. Spanish Meteorological Agency (AEMET), as aeronautical meteorological authority in application of the Convention on International Civil Aviation, provides Terminal Aerodrome Forecast (TAFs) and Airport Weather Warnings (AWWs) for the Spanish airports. A new project focused on graphical representation of probabilistic forecasting from Ensemble Prediction Systems (EPSs) for specific locations (airports) is being developed at the Territorial Delegation in Catalonia (DTCAT-AEMET). With the aim of supporting a 24-hour TAF, the probabilistic product, known as EPS meteogram or epsgram, is being produced showing the time evolution of predicted probabilities of wind (intensity and direction), temperature and dew point on the same epsgram (as indicator of visibility and fog), precipitation and low cloud cover. Epsgrams hold valuable information about forecast uncertainty and therefore a measure of its predictability.

Meteorological Variables Plotted in the Epsgrams
10m Wind Intensity
10m Wind Direction
10m Wind Gust
2m Temperature
2m Dew Point
Precipitation
Low, Medium, High Cloud Cover

Currently, the European Centre for Medium-Range Weather Forecasts (ECMWF) EPS, which takes into account uncertainties both in the initial conditions and in the Numerical Weather Prediction (NWP) model, is being used. The use of probability groups included in TAFs, the issue of AWWs as well as high unpredictability of extreme weather can make this kind of prediction system very useful.

The application is characterized, among other things, by its adaptability to any EPS and dynamism (percentiles to show, number of steps and so on). Apart from that, land-sea mask, height correction for temperature and information about the nearest grid points are being considered. Verification, calibration and feedback comments from aeronautic forecasters are the next steps to try to improve product quality.

GOAL

Forecasts at specific points (or areas) based on very high spatial and temporal resolution EPSs, such as γ-SREPS (~2.5 km), so taking into account forecast uncertainties

Terminal Aerodrome Forecast (TAF)

An aerodrome forecast consists of a concise statement of the expected meteorological conditions at an aerodrome for a specified period. They are made by the meteorological office designated by the Meteorological Authority concerned (Appendix 5, WMO-No. 49) and cover a period of 24 hours.

Inclusion of Meteorological Elements in TAF	Epsgrams Used to Forecast
Surface Wind	Wind Intensity, Direction and Gust
Visibility	Temperature and Dew Point
Weather	Precipitation
Cloud	Low, Medium and High Cloud Cover
Temperature	Temperature

Change Groups
- BECMG - TEMPO

Probability Groups
- PROB30 - PROB40

If probability < 30% should not be considered sufficiently significant to be indicated.

If probability > 50% should not be considered a probability (for aviation purposes)

Example - Barcelona Airport (February 12, 2013)

```
LEBL 121100Z 1212/1312 32012KT 9999 FEW020
     TX13/1214Z TN06/1306Z
PROB40 TEMPO 1306/1309 32012G22KT
TEMPO 1212/1216 23012KT=
```

Ensemble Prediction System (EPS)

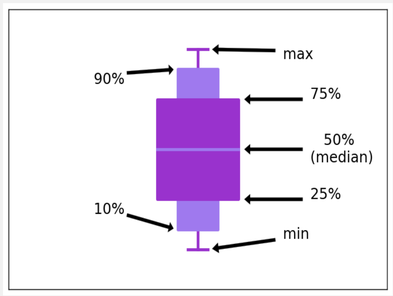
From the point of view of the primitive equations, the atmosphere is considered as a chaotic non-linear system (Lorenz, 1963). The loss of atmospheric predictability is due to the non-linear amplification, as the forecast period lengthens, of small errors and/or uncertainties in both the initial conditions and in the numerical weather prediction (NWP) models formulation (García-Moya et al., 2010; Callado et al.,2013).

Ensemble prediction methods were developed by meteorologists to overcome the problem of deterministic weather forecasting in the face of uncertainty and chaos. In contrast to traditional deterministic modelling techniques which produce a single forecast, an EPS generates a suite, or ensemble, of predictions (Buizza et al., 2005). Therefore, such methods provide a feasible way to estimate the probability distribution function of forecast states.

EPS	Resolution	Main Characteristics
AEMET-γ-SREPS	~2.5 km	Based on HARMONIE non hydrostatic model (testing phase)
AEMET-SREPS	~25 km	Multi-model multi-boundaries (20 members)
ECMWF-EPS	~30 km	50 members + control (non-perturbed analysis)

SREPS = Short-Range Ensemble Prediction System

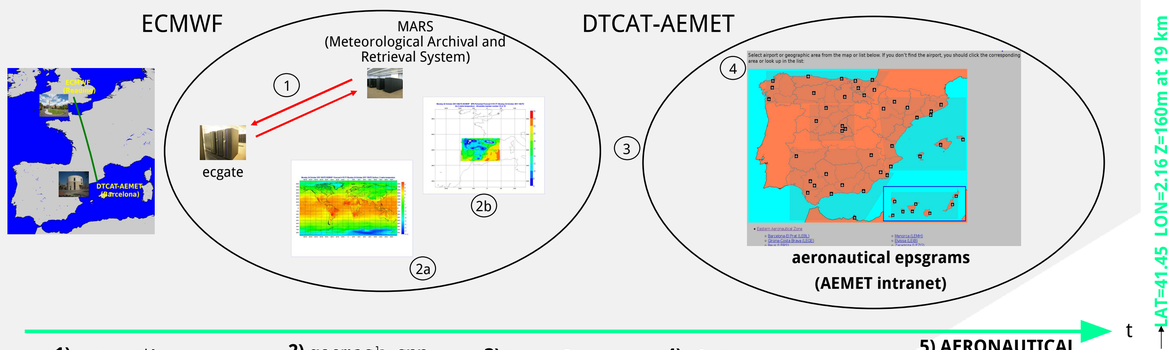
Epsgram



The EPS meteogram (epsgram) is a probabilistic interpretation of forecasts from the EPS for specific locations, describing the probabilistic distribution of each step. It displays the time evolution of the probability of several meteorological parameters from the ensemble at each forecast range by a box and whisker plot (Persson, 2011).

Moreover, epsgrams are considered as a measure of uncertainty and predictability of the forecast (Callado et al., 2013).

Methodology (example ECMWF-EPS)



1) `get_grib.scr`
Members = 51
Steps = 12, 18, 24, 30, 36
Parameters = 2t, 2d, 10u, 10v, lsp, acpcp, lcc, 10fg

2) `geomask.cpp`

	2a. Without GeoMask	2b. With GeoMask
edition	1	2
packing type	grid_simple	grid_jpeg
file size	414.1 MB	3.7 MB (> 110 times smaller!)

3) `transfer.scr` from ECMWF to DTCAT-AEMET

4) `plot_epsgrams.py` Epsgrams for all Spanish airports available on the AEMET intranet

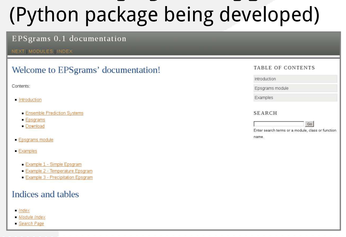
5) AERONAUTICAL FORECASTER Elaboration of TAFs

Nearest Grid Point at Barcelona Airport, ICAO code: LEBL LAT=41.45 LON=2.16 Z=160m at 19 km

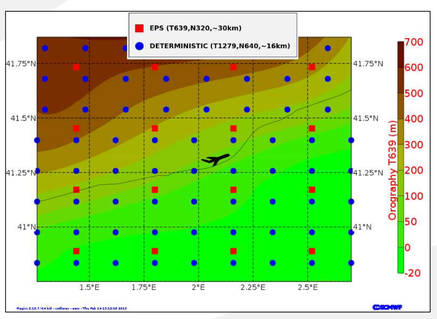
PROGRAMMING LANGUAGES AND MAIN PACKAGES USED:

matplotlib, C++, python, SPHINX Python Documentation Generator, GRIB-API, Jinja

epsgrams.py
(Python package being developed)

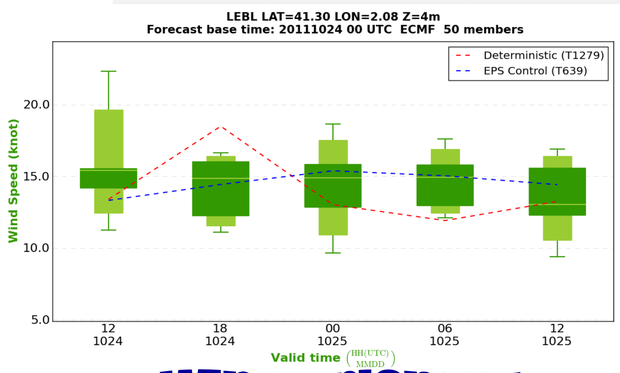


Website Available Soon!

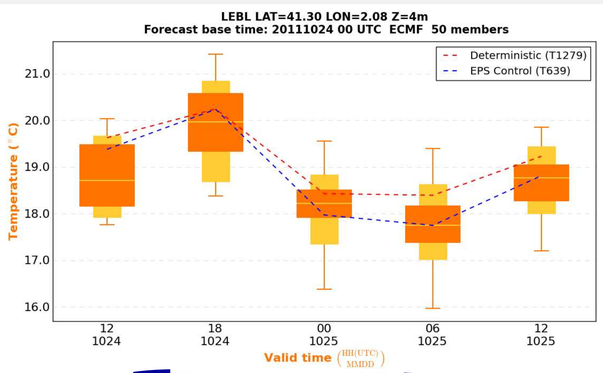


Grid spacing and Orography fields over Barcelona airport surrounding area for the N320 and N640 Gaussian grids

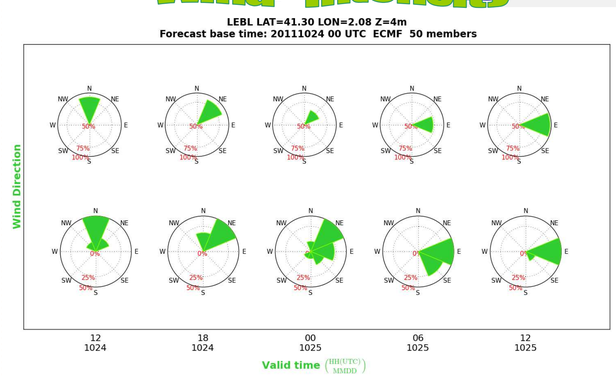
Results



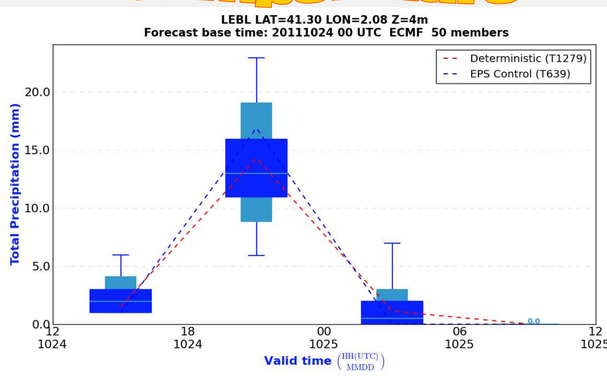
Wind intensity



Temperature



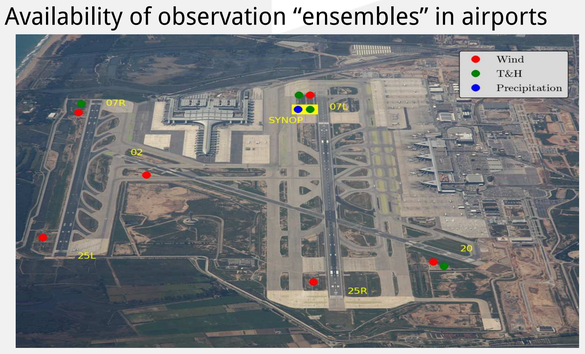
Wind Direction



Precipitation

Verification (ongoing work)

Availability of observation "ensembles" in airports



Several meteorological sensors at Barcelona airport

Standard Probabilistic Verification Methods
Attribute Diagrams
Spread-skill diagram
Continuous Ranked Probability Skill Score
Brier Score (BS), Brier Skill Score (BSS) and their decompositions
Relative Operating Characteristic (ROC) curve and ROC Area
Relative Value Diagrams

Variables
10m Wind intensity
10m Wind direction
2m Temperature
Precipitation
2m Dew Point Temperature
Low Cloud Cover

Verification will be applied to 52 Spanish airports

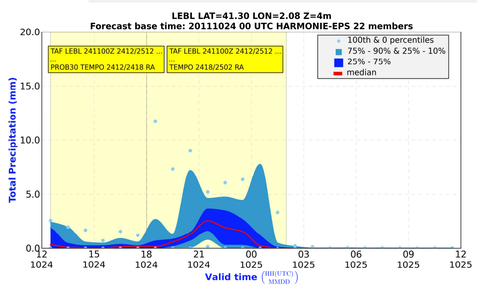
Experiment	Description
Nearest point	❑ Closest NWP model grid point to the airport
Nearest land point	❑ Closest NWP grid point to the airport over land
Bilineal interpolation	❑ 4-point interpolation of the 4-closest NWP grid points ❑ Anywhere / over land
Bicubic interpolation	❑ 16-point interpolation of the 16-closest NWP grid points ❑ Anywhere / over land
4-point EPS	❑ 4-point "sub-ensemble" ❑ Weight / non-weight with distance
16-point EPS	❑ 16-point "sub-ensemble" ❑ Weight / non-weight with distance
Polygon-points EPS	❑ NWP grid points "sub-ensemble" inside airport "climatological" coherent polygon

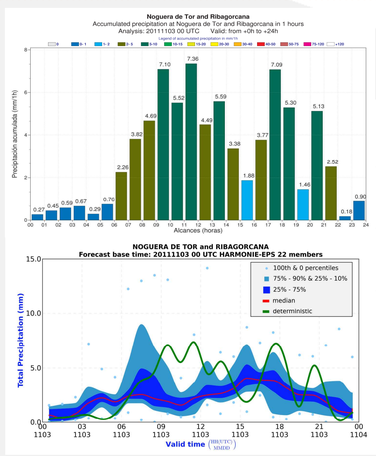
Verify each experiment probabilistic forecast with respect to observation "ensembles"

Which method will be the best?
Will it depend on each airport?

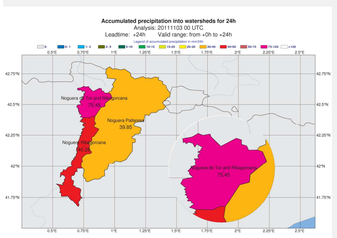
Future Work

- Continuous Epsgrams (in very high resolution EPSs)
- Automatic Detection of Significant Weather Changes (TAFs TEMPO & BECMG groups)





- Epsgrams for Polygons:
  - Drainage basins



- Calibration:
  - Extended logistic regression
  - BMA

References

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Acknowledgements

Predictability Group, Bartolomé Orfila Estrada (Head of Numerical Prediction) and José Antonio Garcia-Moya (consultant).
Basic Systems: José Manuel López Pérez, Sara Vidal Vicedo
Climatology: Beatriz Téllez Jurado
Forecasters Group: Joan Arús Dumenjo, Joan Carles Bullón, Gabriela Cuevas Tascón, Jaime Fernández Garcia-Moya, Sergi González Herrero, Agustí Pladevall Boix, Samuel Viana Jiménez, Ernest Werner Hidalgo

4th International Meeting on Meteorology and Climatology of the Mediterranean Banyuls (Roussillon, France) February 27 – March 1, 2013