Ensemble Prediction Systems Applied to Aeronautics

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THE GOAL!

The aim of this project is to develop a new product with the purpose of making probabilistic interpretation of forecasts from the **Ensemble Prediction System** for specific grid points (**epsgram**).

In particular, the application focuses on a new tool to help forecasters to elaborate the very short range airport forecasts (**TAF**).

OUTLINE

Goal

1. Motivation
2. Features
3. Methodology
4. Results
5. Searching the best method (ongoing work)
6. Conclusions

Acknowledgements

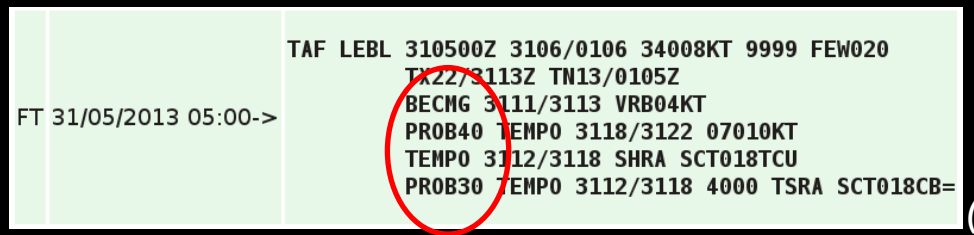
References

1. Motivation

Terminal Aerodrome Forecasts (TAF)

A concise statement of the expected meteorological conditions at an airport during a specified period (24 hours) *(Aviation Weather Center)*

Apply to approximately 8 km radius from the centre of the airport runway complex



(Ogimet)

Meteorological Elements in TAFs
Surface Wind
Visibility
Weather Phenomena (moderate/heavy precipitation, thunderstorm, etc.)
Cloud
Temperature

Use of Probability Groups
PROB30
PROB40

Use of Change Groups
BECMG
TEMPO

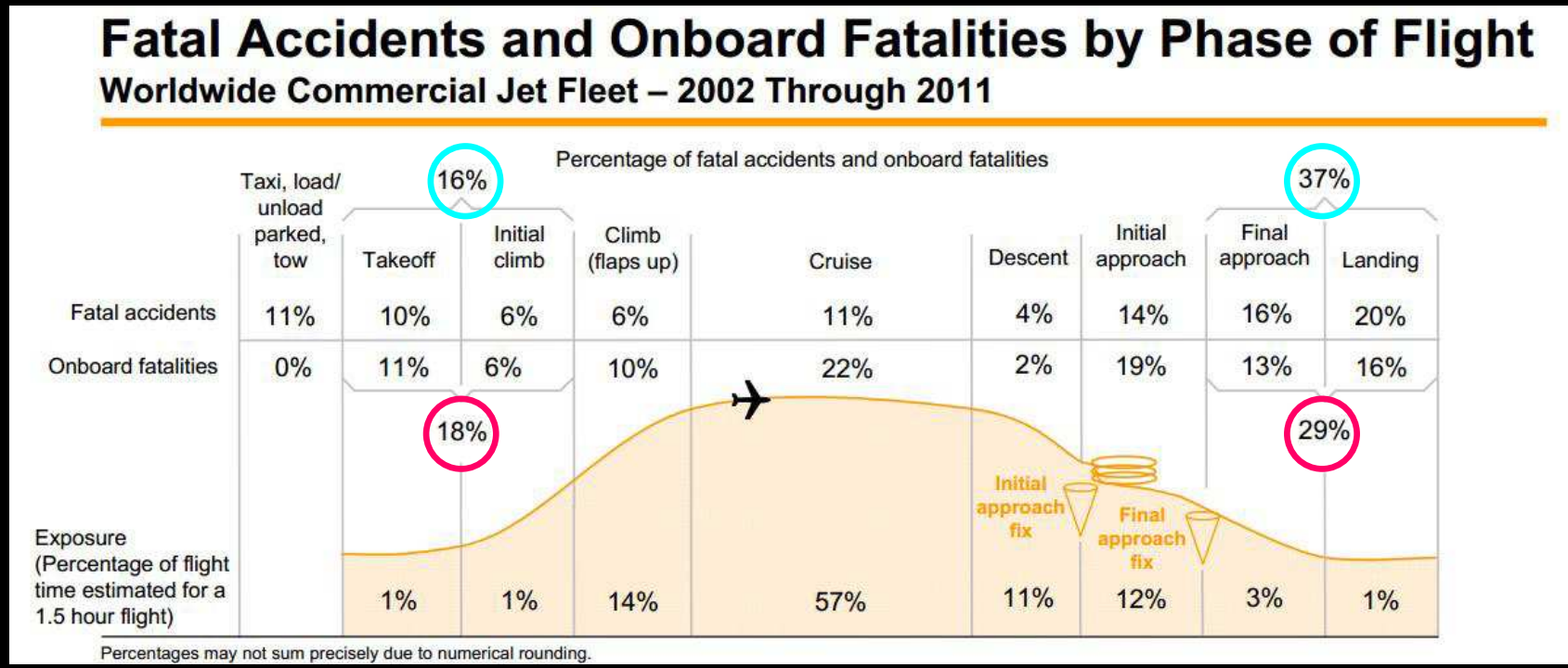
Prepared by the meteorological office designated by the meteorological authority concerned *(Meteorological Service for International Air Navigation, WMO)*

"La Agencia Estatal de Meteorología… condición de autoridad meteorológica aeronáutica…" (B.O.E. número 39, 14 de febrero de 2008)

Aeronautical Meteorology

Aviation Weather Hazards: turbulence, aircraft icing, reduced visibility, volcanic ash clouds

Accidents:

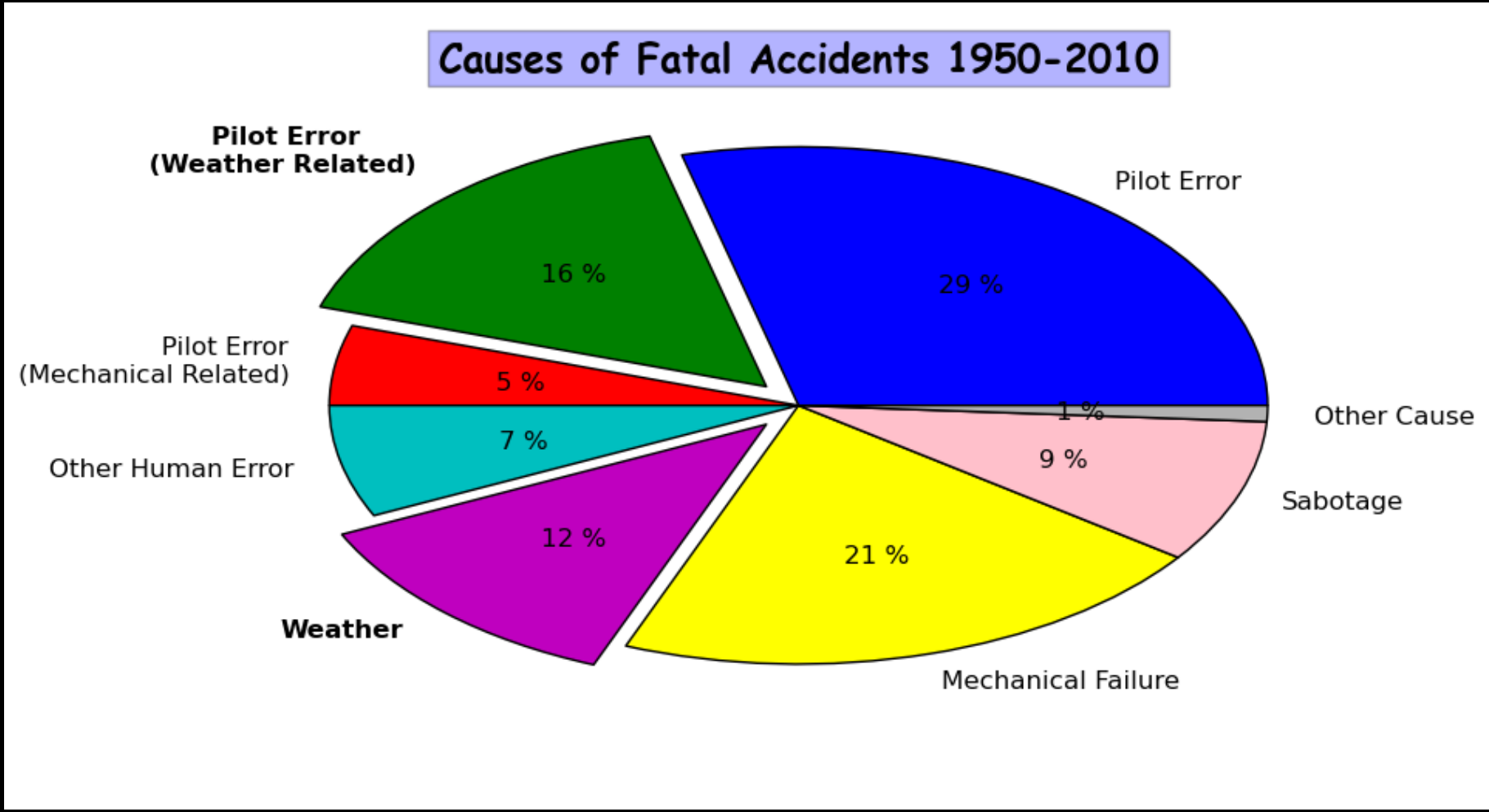


Worldwide Commercial Jet Fleet, 2002-2011

16% + 37% = **53%** of fatal accidents in the vicinity of airports

18% + 29% = **47%** of onboard fatalities in the vicinity of airports

1. Motivation



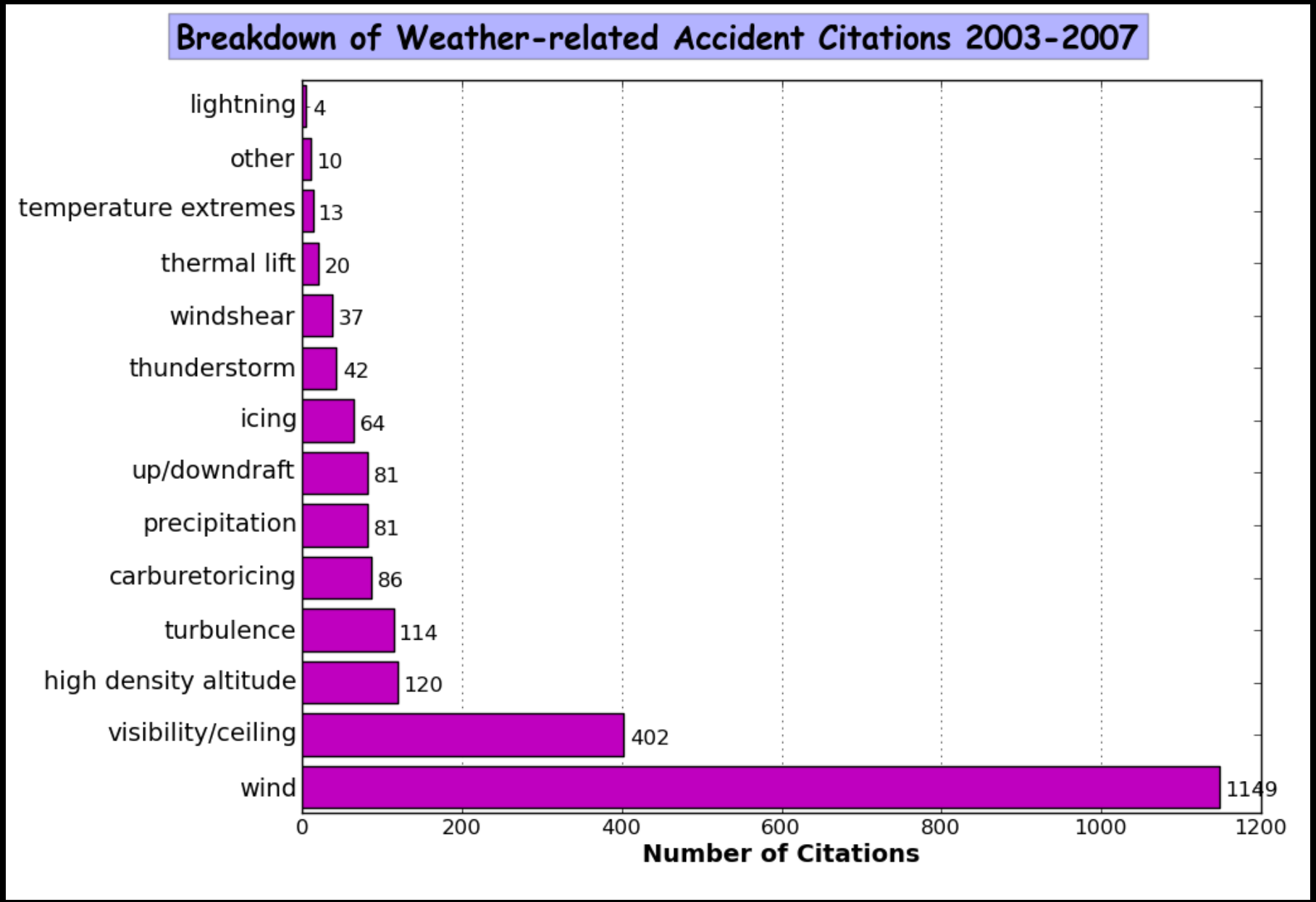
Data: Plane Crash Info

12 % + **16 %** = **28 %** of accidents in which WEATHER was the cause

1. Motivation

Ensemble Prediction Systems Applied to Aeronautics

Data: NTSB Aviation Accident and Incident Database



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Ensemble Prediction Systems Applied to Aeronautics

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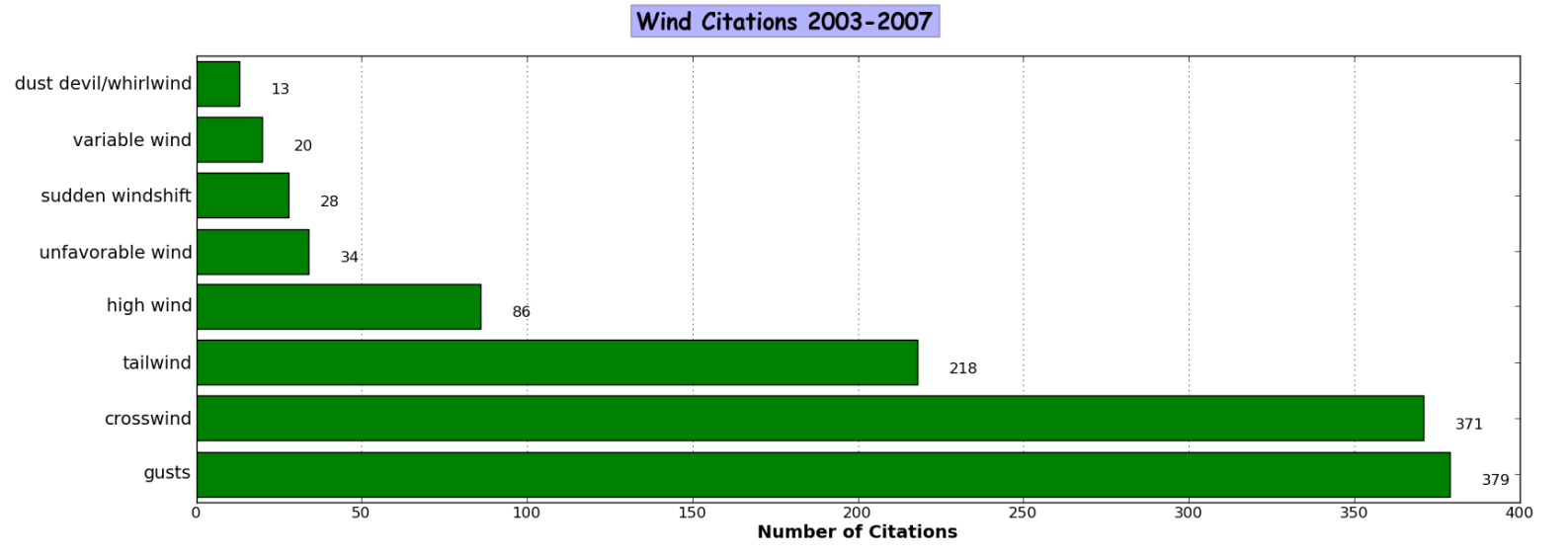
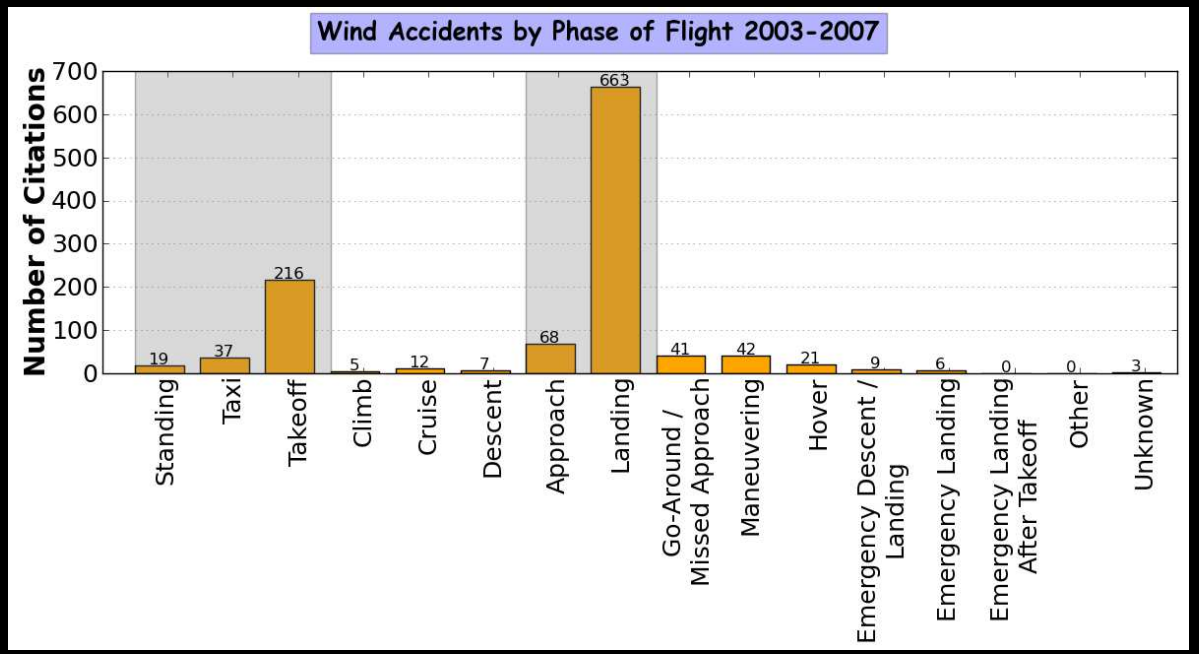
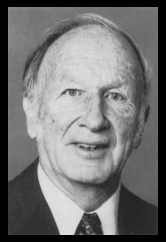




Ensemble Prediction System (EPS)

From the point of view of the primitive equations, the atmosphere is considered as a chaotic non-linear system *(Lorenz, 1963)*



Eduard Lorenz
(1917-2008)

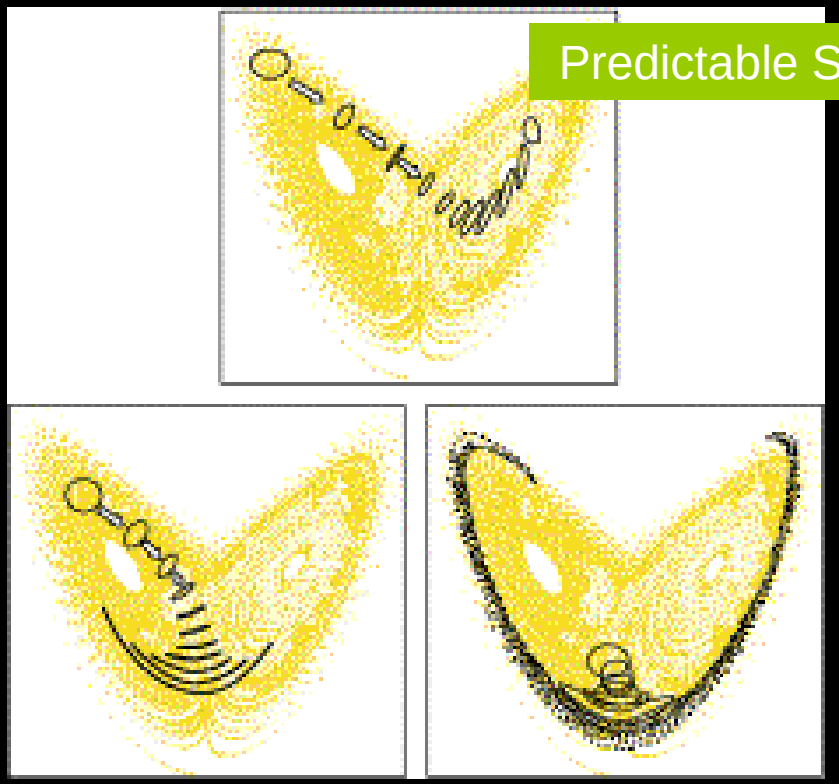
Errors and/or incertainties in:

- Initial Conditions
- Numerical Weather Prediction

Loss of Atmospheric Predictability

(García-Moya et al., 2010; Callado et al., 2013)

The Lorenz “butterfly” Attractor



(ECMWF)

Predictable State

Less Predictable State

Unpredictable State

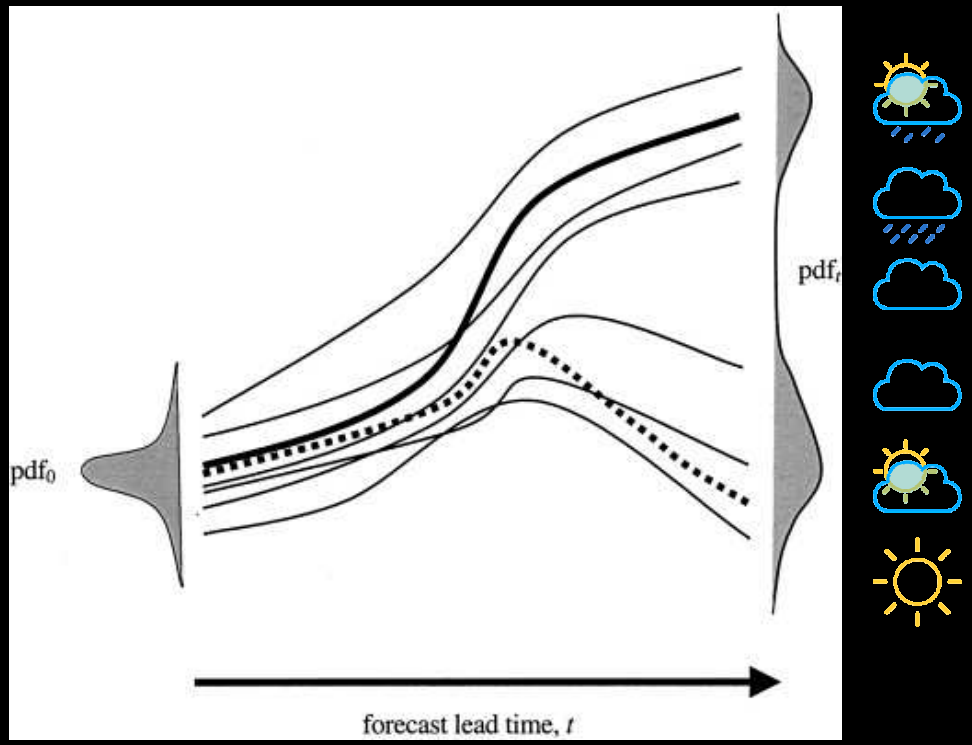
1. Motivation

Ensemble Prediction Systems Applied to Aeronautics

Deterministic Modelling Techniques ➡ single forecast

EPS ➡ suite/ensemble of predictions (estimate the probability distribution function of forecast states)

(Buizza et al., 2005)



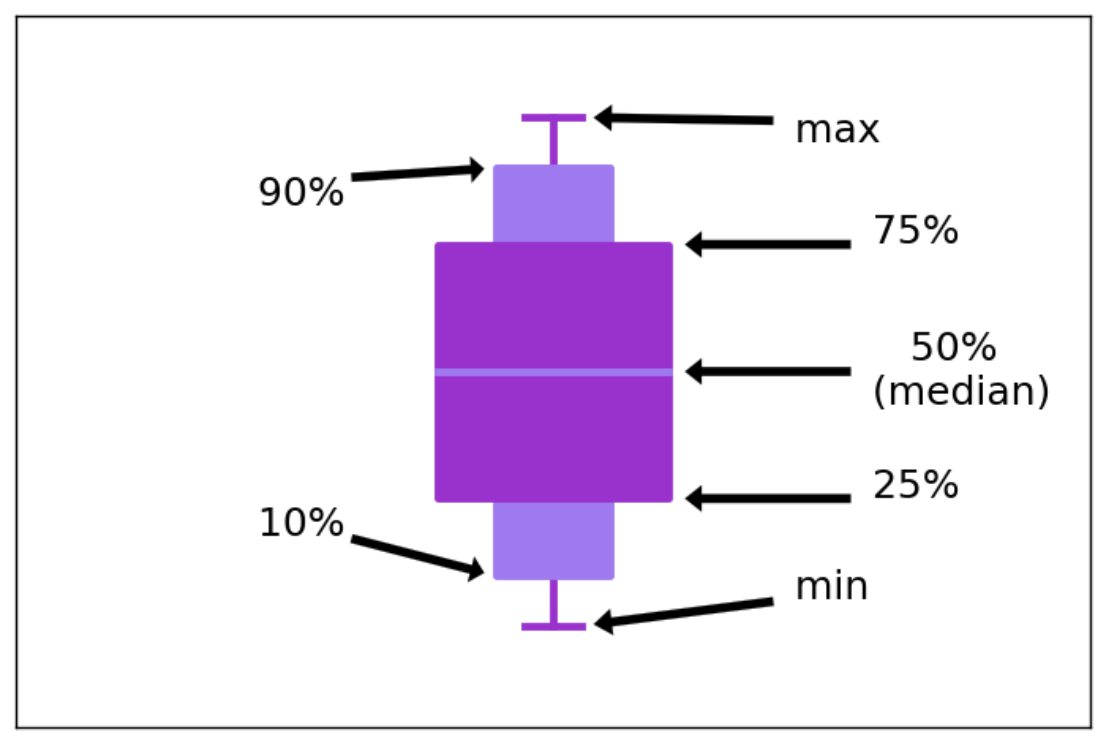
pdf_0	initial uncertainties
———	single forecast
·····	future state
_____	ensemble of perturbed forecasts
pdf_t	estimated pdf

SREPS: Short-Range EPS

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

EPS meteogram = epsgrams

Probabilistic interpretation of forecasts from the EPS for specific locations, describing the probabilistic distribution of each step *(Persson, 2011)*



Epsgrams are considered as a measure of uncertainty and predictability of the forecast *(Callado, Escribà, García-Moya, Montero, Santos, Santos-Muñoz, Simarro, 2013)*

2. Features

Epsgrams for all airports in Spain

- ❑ Generated every 6 hours
- ❑ Showing parameters in TAF

Meteorological Elements in TAF	Epsgrams Used to (Aeronautical) Forecast
Surface Wind	10m Wind Velocity, Direction and Gust
Visibility	2m Temperature, Dew Point and Visibility
Weather	Precipitation
Cloud	Low, Medium and High Cloud Cover
Temperature	2m Temperature

Adaptability

- ❑ To any EPS (GRIB1 & GRIB2 format)

Dinamism

- ❑ Percentiles to show
- ❑ Number of steps

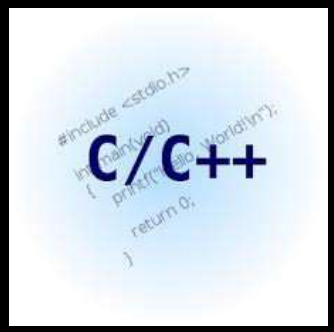
2. Features

Operational

- ❑ Feedback comments from aeronautical forecasters
- ❑ Optimal use for aeronautical forecasters

Programming Languages

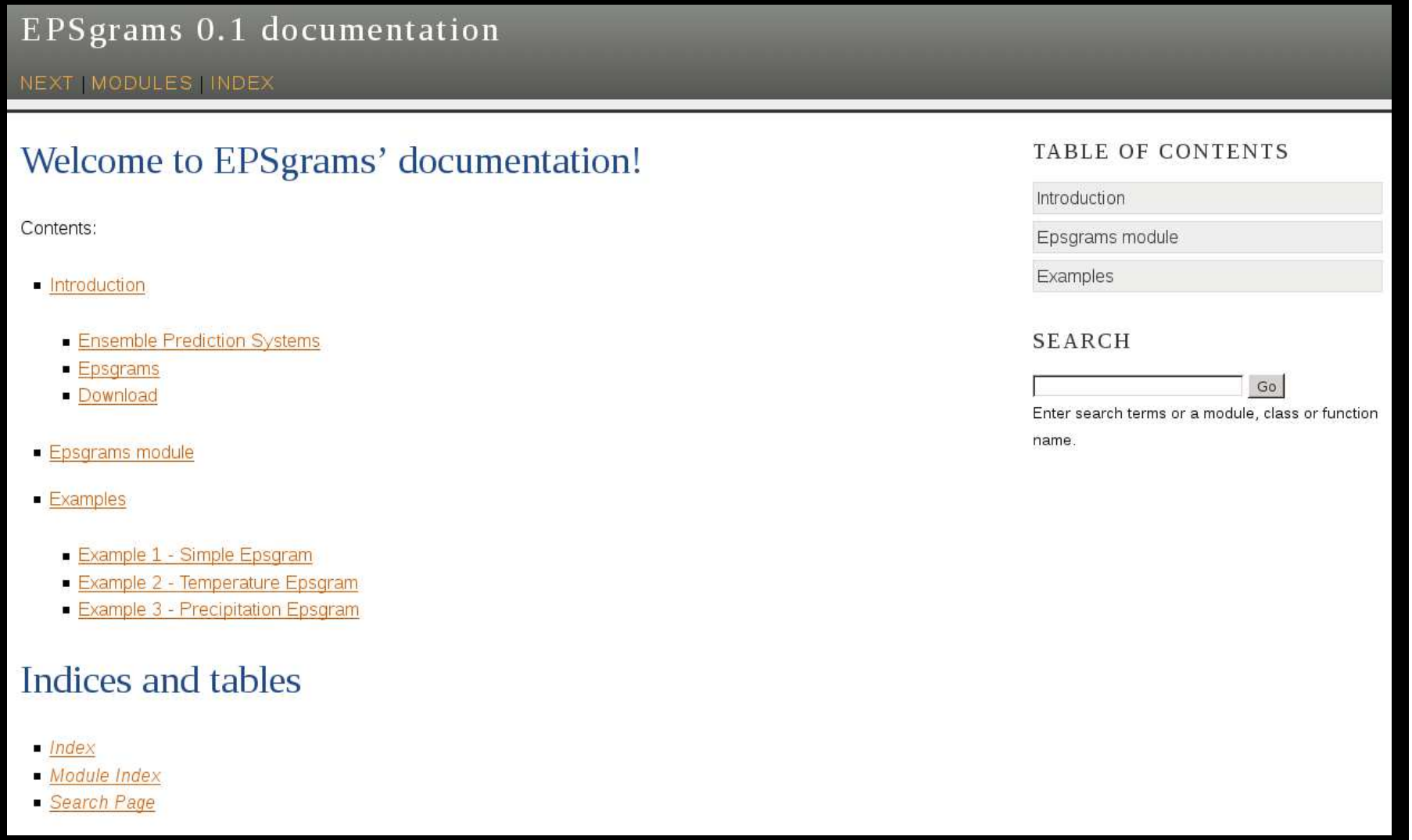
- ❑ Use of classes (in Python)



2. Features

epsgrams.py

- Python package being developed



2. Features

EPSgrams 0.1 documentation

PREVIOUS | NEXT | MODULES | INDEX

Introduction

Release: 0.1
Date: February 07, 2013
Welcome!

I welcome you to `Epsgrams` module web page.

The Ensemble Prediction Systems and Epsgrams sections provide a brief description about this type of forecasts and their intepretation respectively. Download section contains the file you need to apply this module written in Python. *Epsgrams module* contains both classes and methods (with their arguments) which are part of this module.

Ensemble Prediction Systems

An ensemble forecast is simply a collection of two or more forecasts verifying at the same time. Because of chaotic behaviour of the atmosphere, small errors in the initial conditions of a NWP model can lead to large errors in the forecast. Apart from that, a NWP model itself is not perfect and observations are uncertain and incomplete. Ensemble systems provide a possible way to estimate the probability distribution function of forecast states. If you are not familiar with these concepts I encourage you to visit these websites:

- User guide to ECMWF forecast products (**Anders Persson**, 2011)
- The Ensemble Prediction System - Recent and Ongoing Developments (**T N.Palmer, R.Buizza, M. Leutbecher** et al., 2007)
- Predictability and ensemble forecasting (**ECMWF**)
- Predictability of short-range forecasting: a multimodel approach (**J.A. García-Moya, A. Callado, P. Escribà, C. Santos** et al., 2010)

Epsgrams

The EPS meteogram (EPSgram) is a probabilistic interpretation of forecasts from the EPS for specific grid points. It displays the time evolution of the distribution of several meteorological parameters from the ensemble at each range by boxes and whiskers plot (Anders Persson, 2011). It gives an explicit

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SEARCH

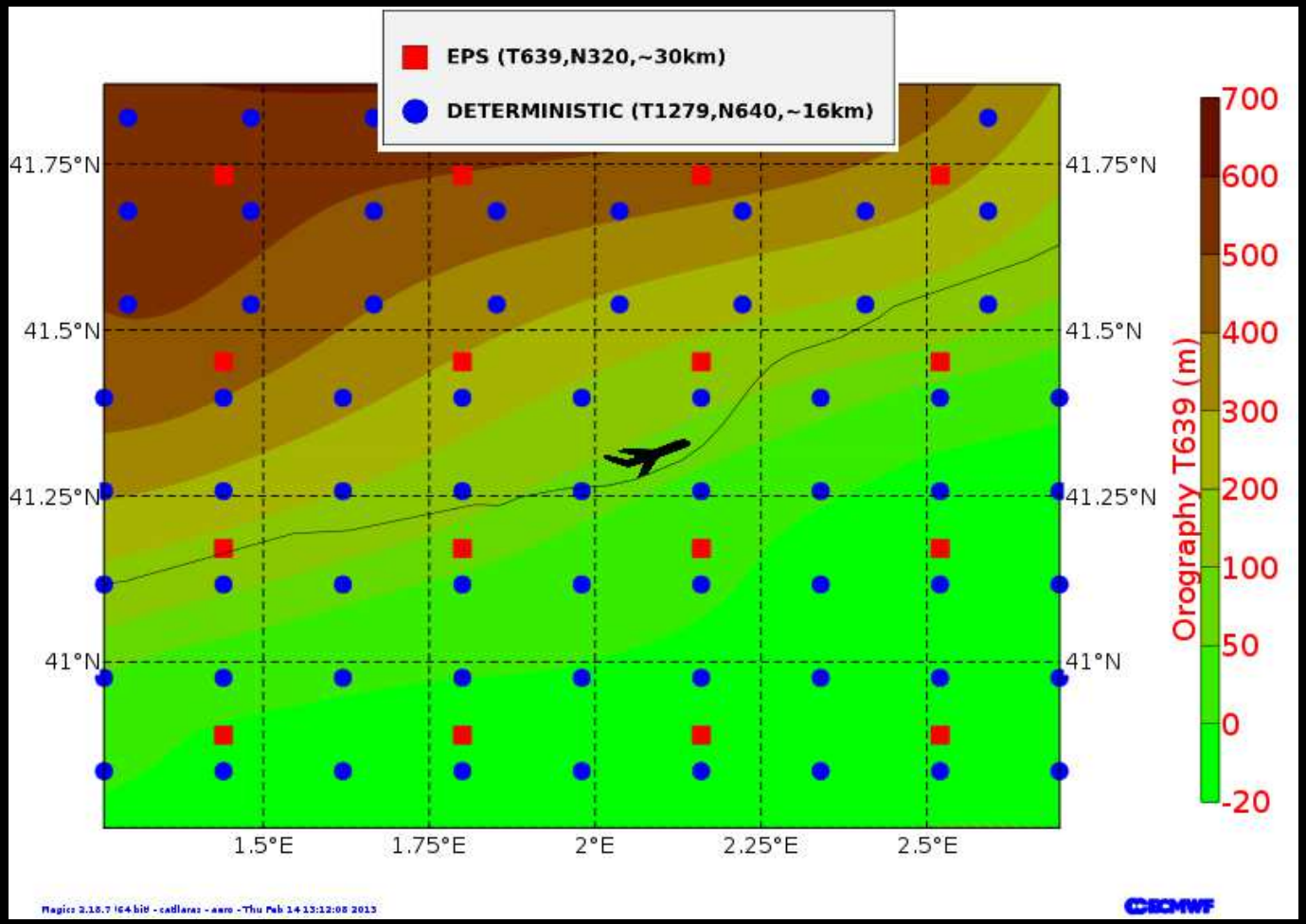
Go

Enter search terms or a module, class or function name.

2. Features

Land-Sea Mask

- Distinguish between ocean-land grid points.



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

Correction of T2m

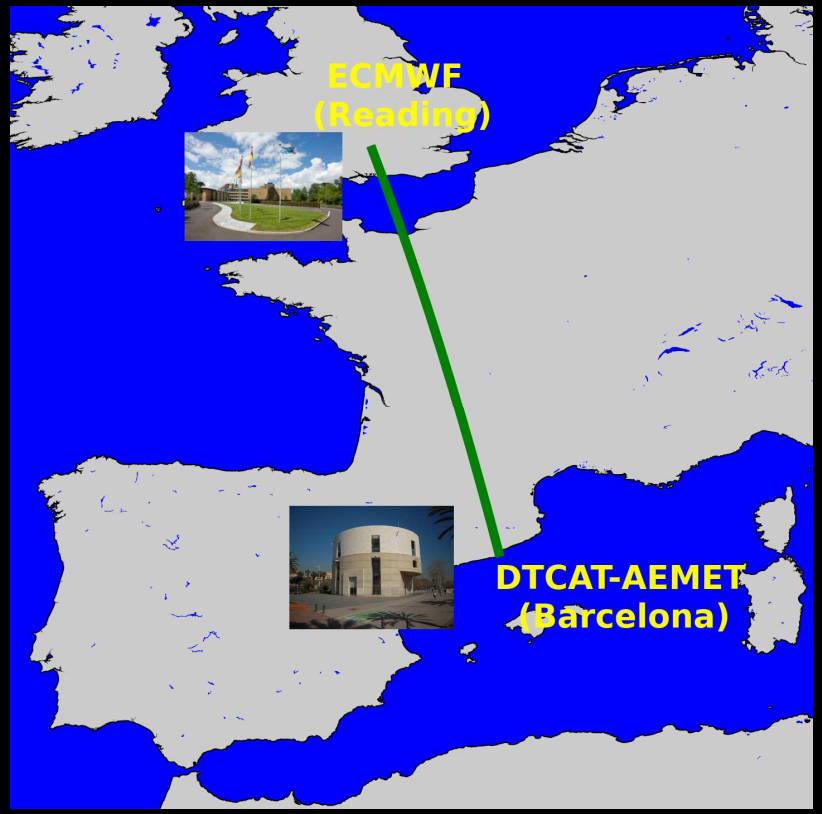
- Altitude correction (reduction) of variables (specially temperature)
  1. The whole vertical profile (u,v,T,q,ps) at the model surface is vertically interpolated to the airport height -> ETAETA subroutine
  2. The new surface temperature is evaluated preserving surface layer lapse rate, i.e., keeping the potential temperature increment between the lowest model level and the earth surface constant.
  3. The screen level (**T2m, Q2m, U10m, V10m**) are rediagnosed in the new surface layer by formulae proposed by Geleyn (1987) based on the Monin Obukhov similarity theory -> TQUV subroutine

  (Navascués, 1997)

- A Python interface has been developed by using this scheme.

3. Methodology

Ensemble Prediction Systems Applied to Aeronautics



MARS

Meteorological Achival and Retrieval System

1) get_grib.scr

Members = 51

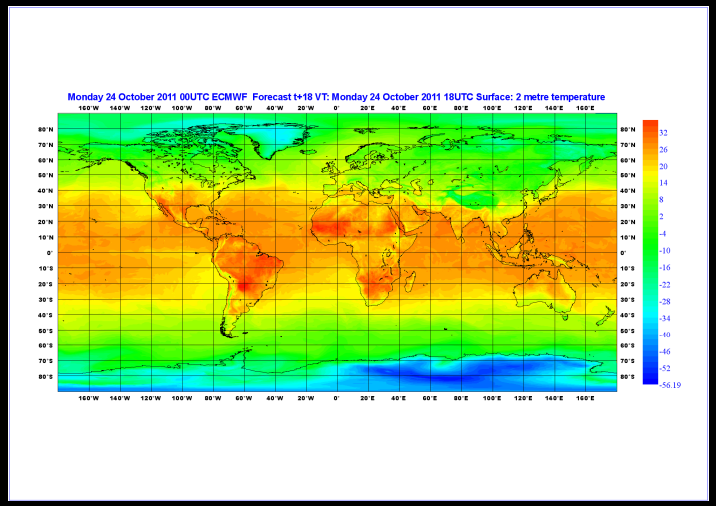
Steps = 12,18, 24, 30, 36

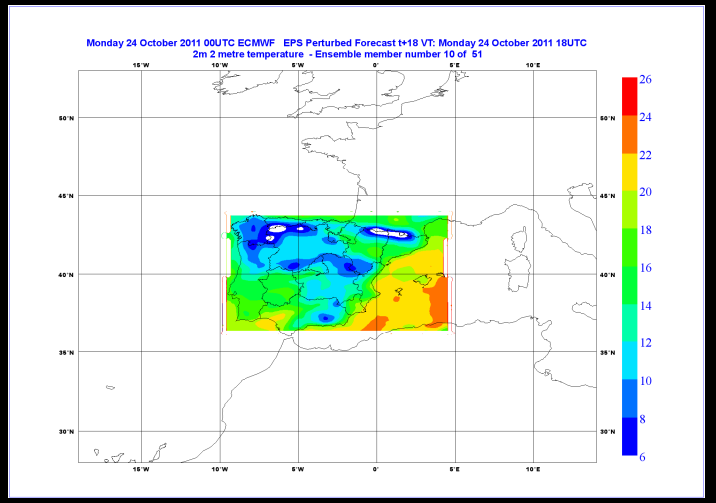
Parameters = 2t, 2d, 10u, 10v, lsp, acpcp, lcc, 10fg

ecgate

3. Methodology

2) GeoMask.cpp





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

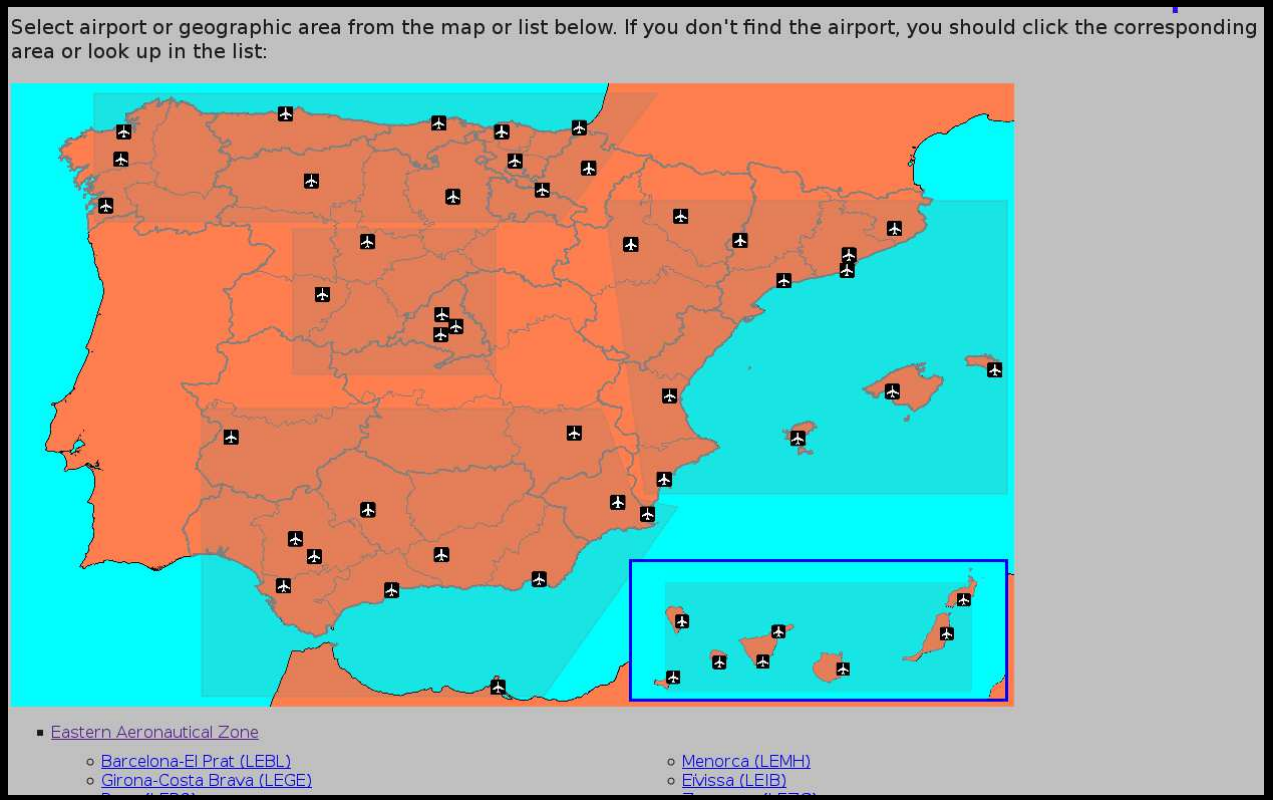
3. Methodology

3) `transfer.scr`

From ECMWF to AEMET

4) `plot_epsgrams.py`

Epsgrams for all Spanish airports available on the AEMET intranet (very soon!)



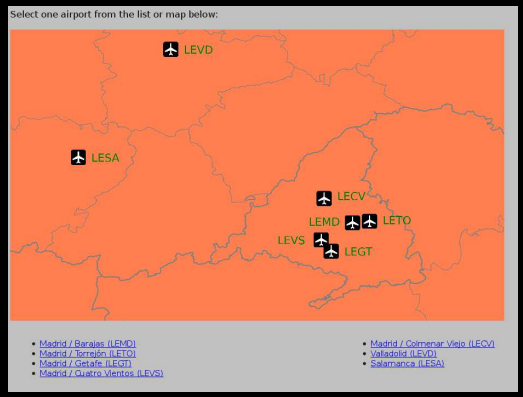
3. Methodology

Ensemble Prediction Systems Applied to Aeronautics

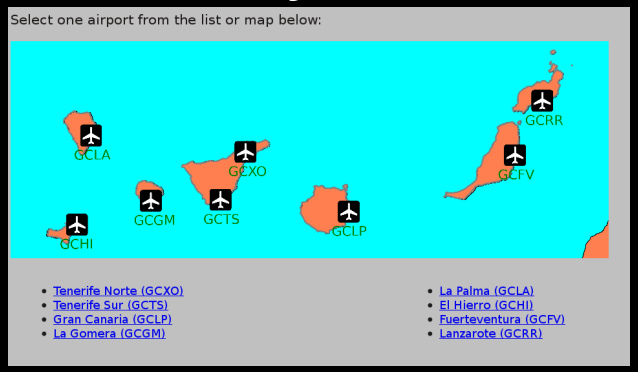
East

North

Centre



Canary Islands

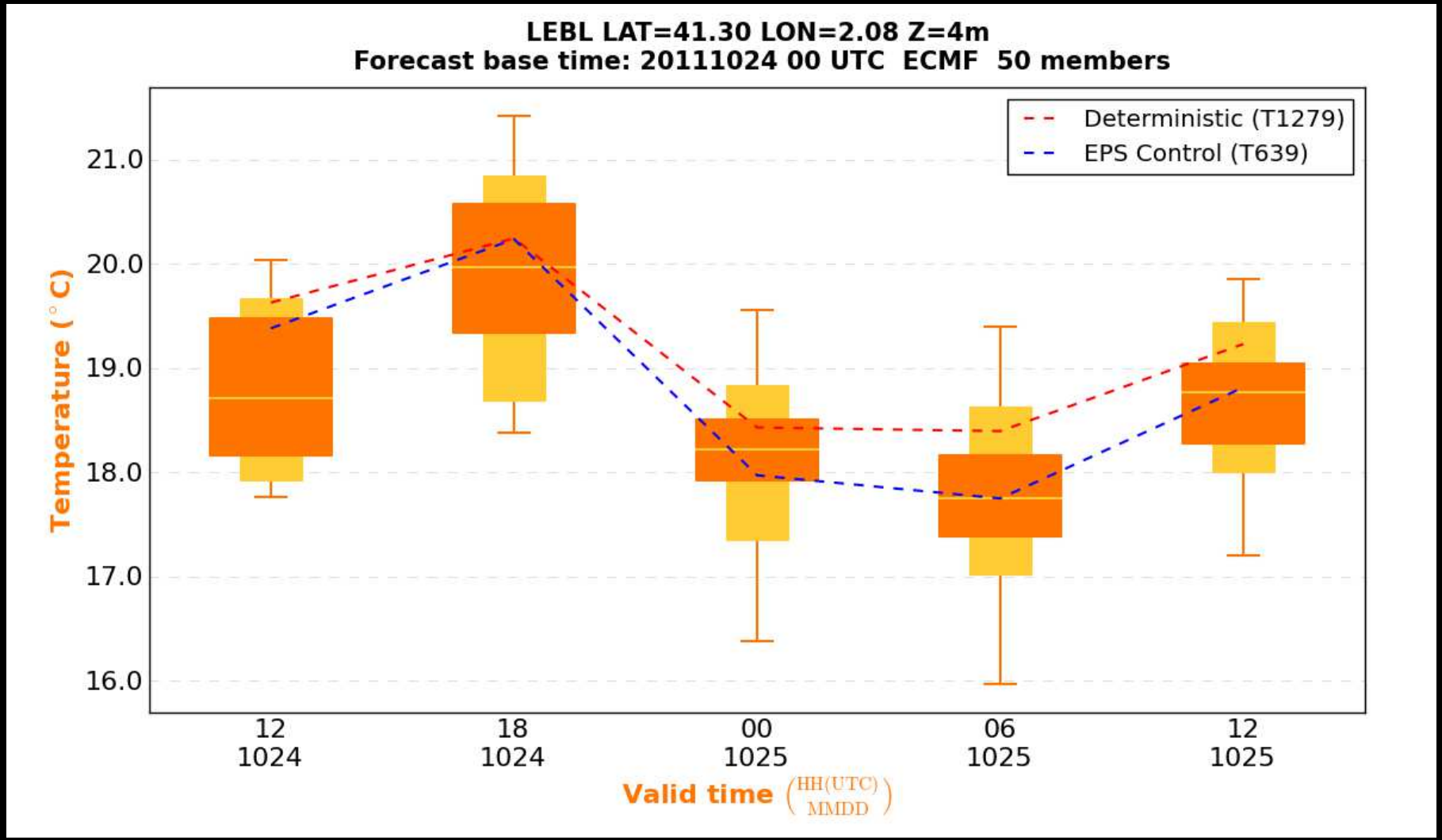


South

4. Results

Nearest Grid Point at Barcelona Airport, ICAO code: LEBL

LAT = 41.15 LON = 2.16 Z = 160 m at 19 km



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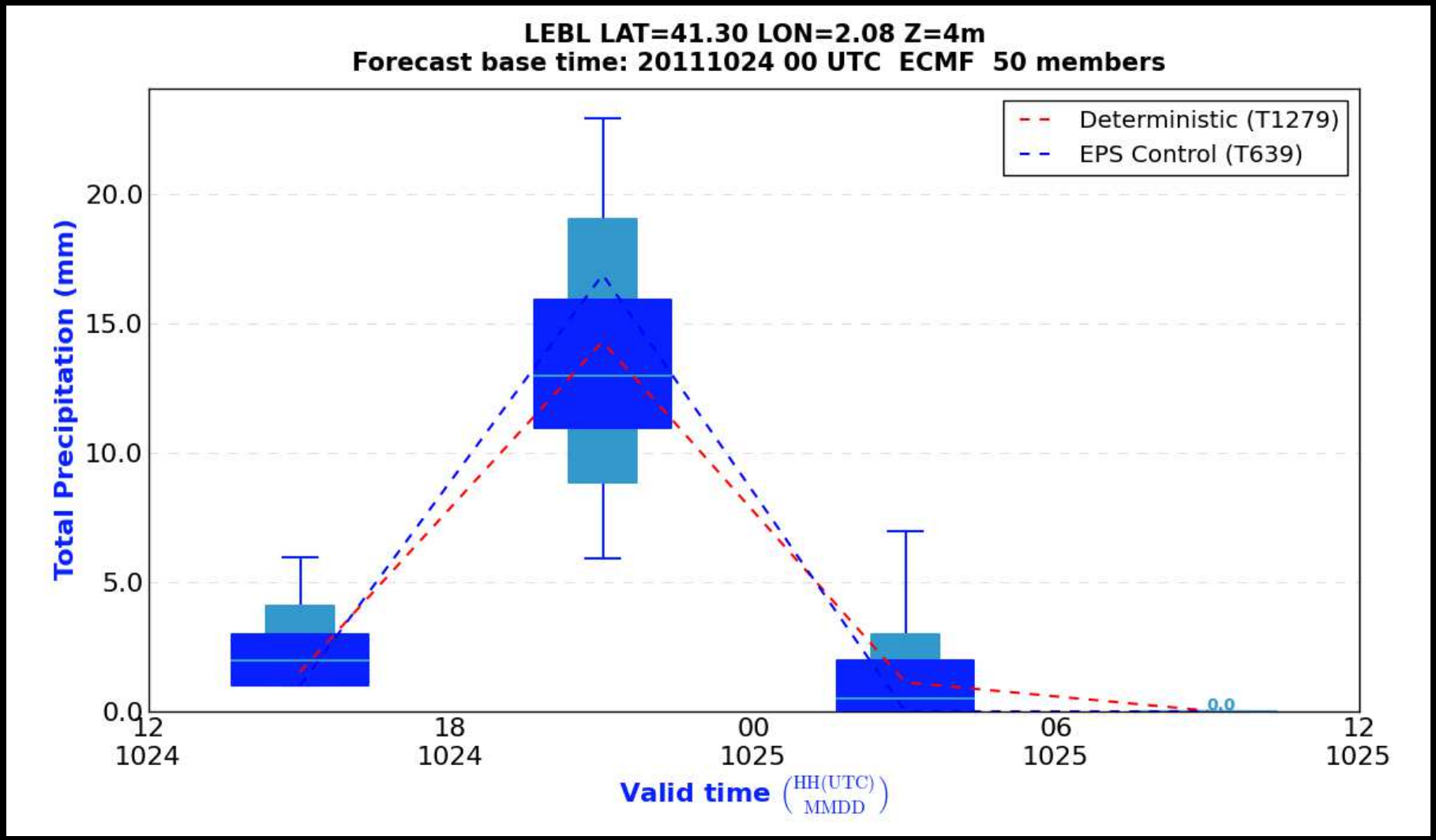

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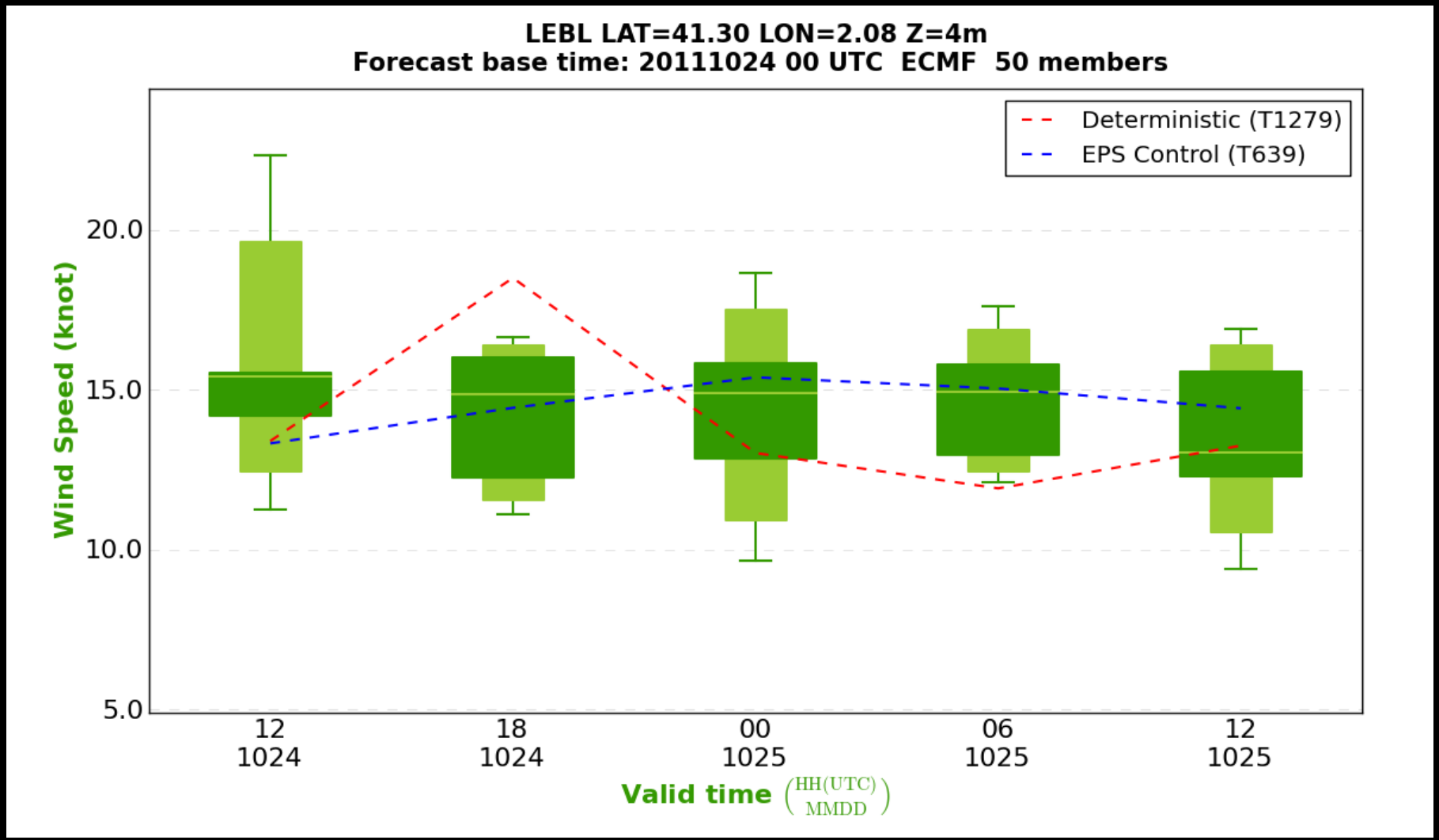

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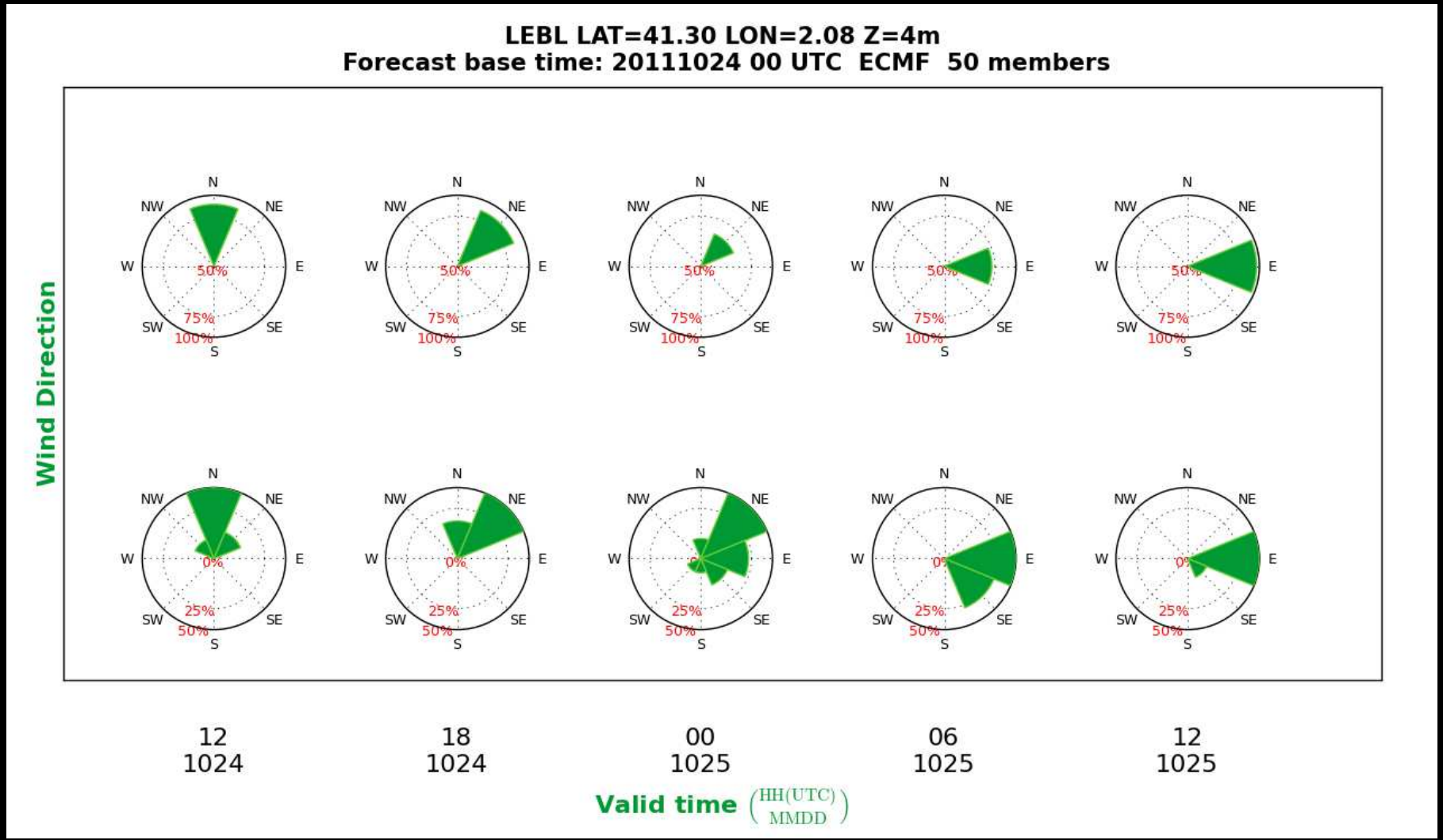
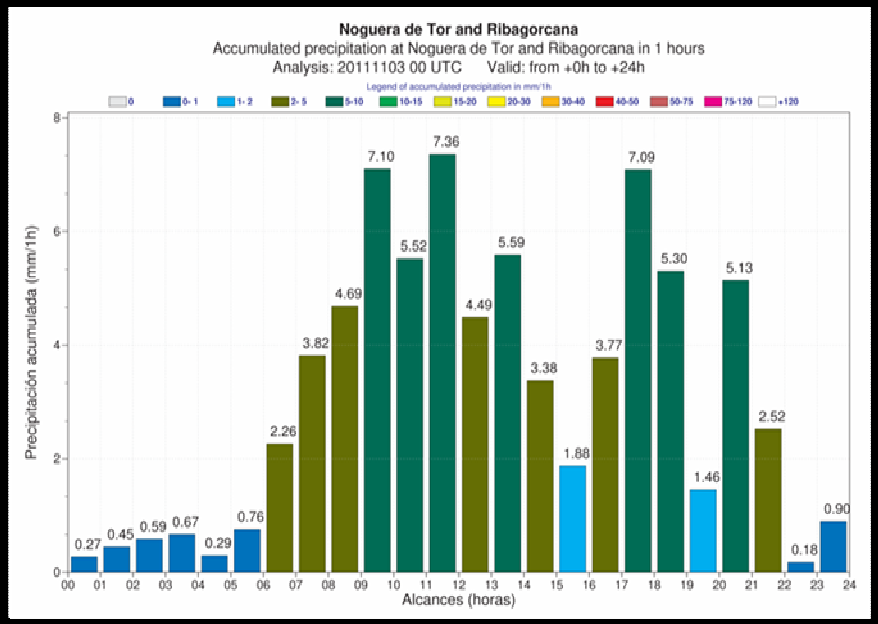
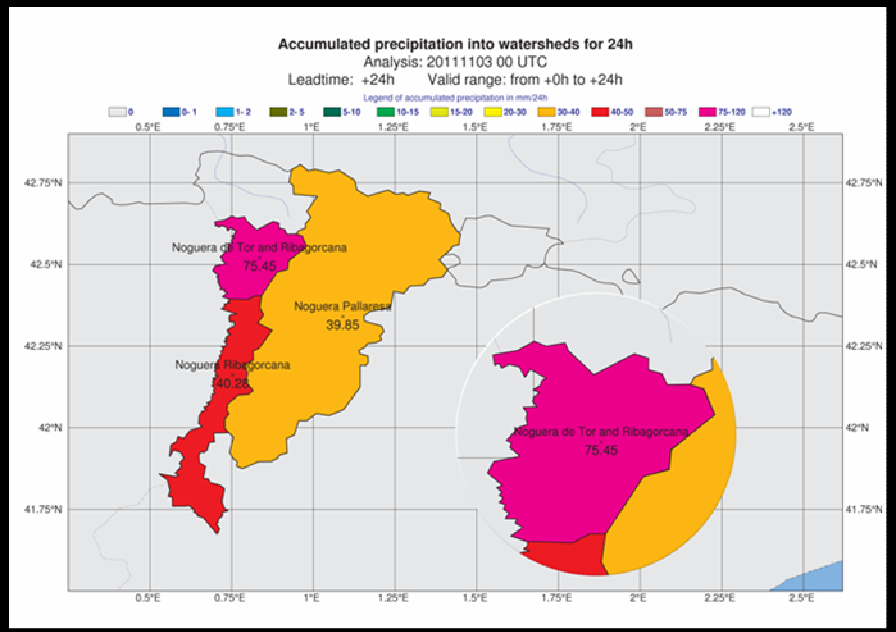


4. Results

Continuous Epsgrams (in very high resolution EPS)

Epsgrams for Polygons: drainage basins

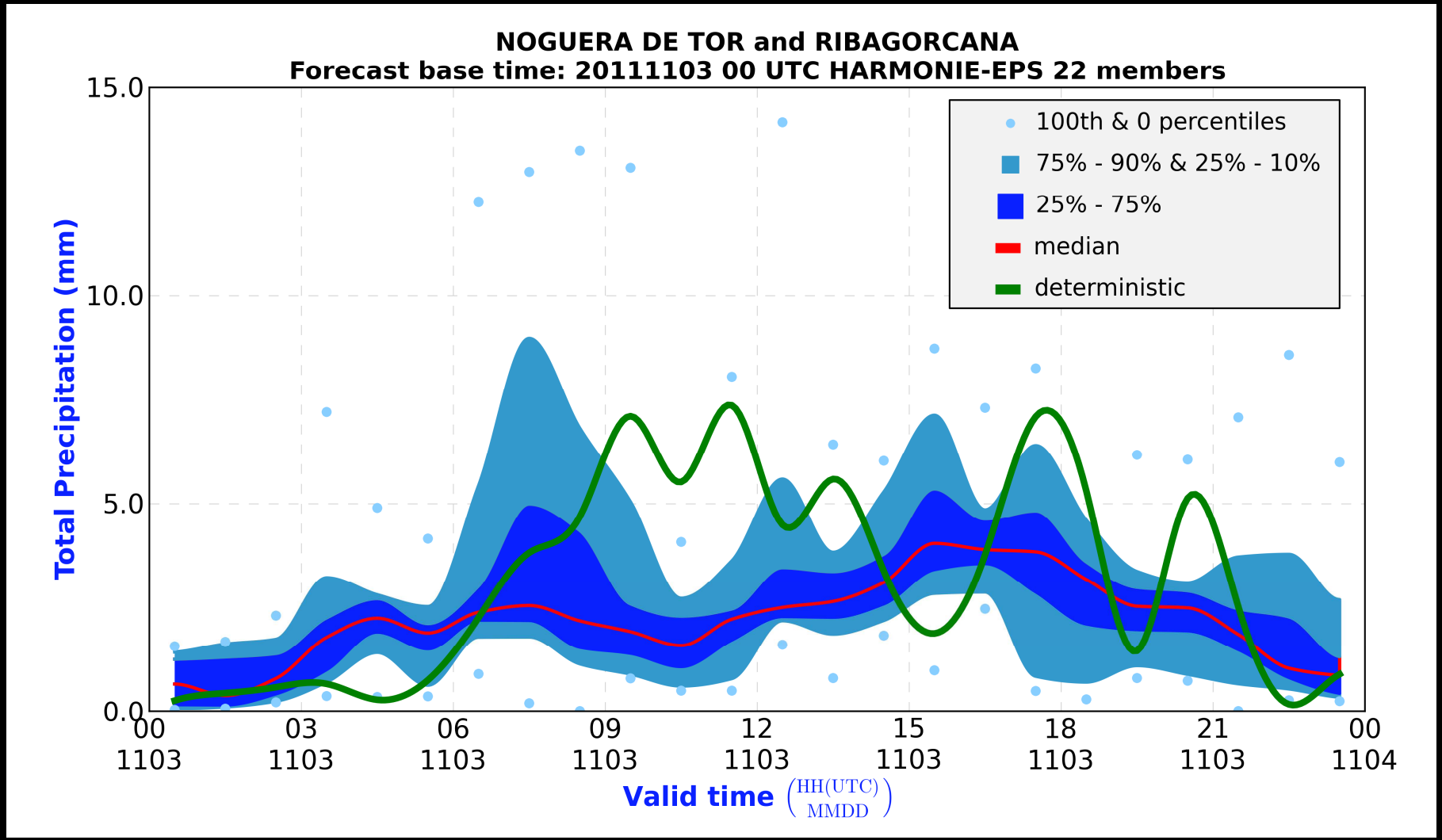




(A. Callado)

4. Results

HARMONIE (Hirlam Aladin Regional / Meso-scale Operational NWP In Europe



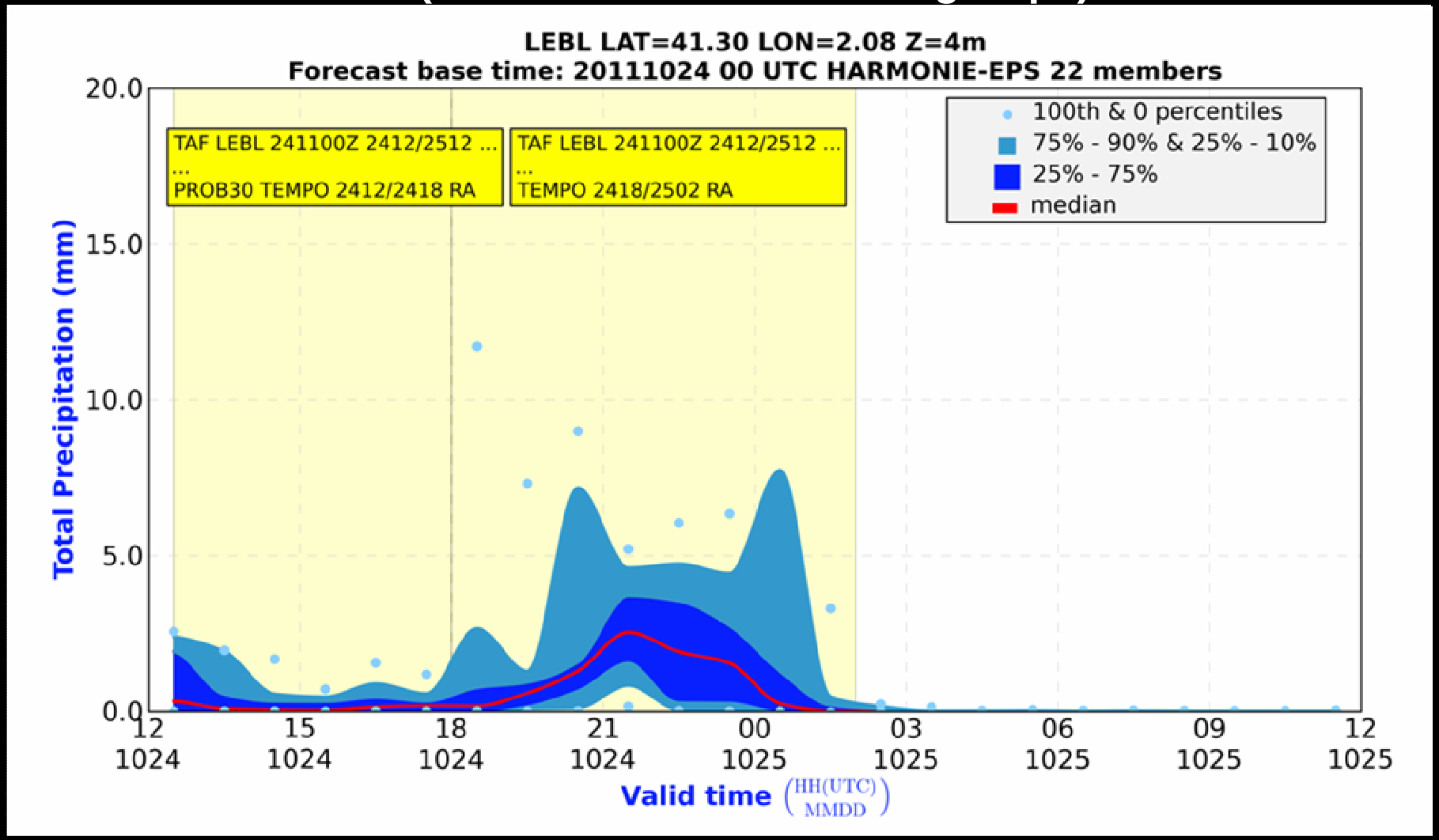
4. Results

Ensemble Prediction Systems Applied to Aeronautics

Suggestions for forecasters in epsgrams

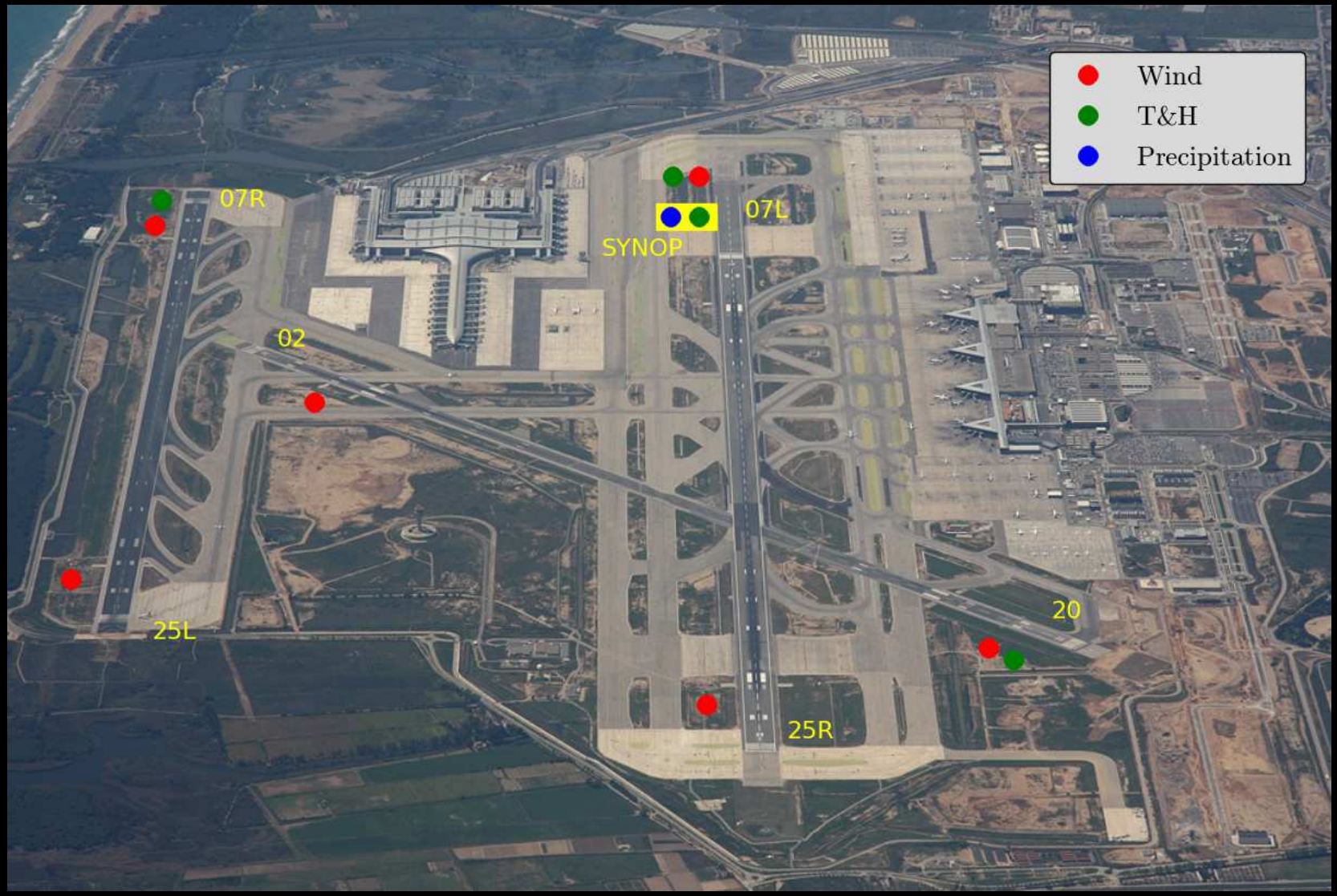
Automatic Detection of Significant Weather Changes

(TAF's TEMPO & BECMG groups)



5. Searching the best method

Availability of observation “ensembles” in airports*



(*) J.L. Casado. DTCAT looking for East airport observations

5. Searching the best method

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 Velocity
10m Wind Direction
2m Temperature
Precipitation
2m Dew Point Temperature
Low Cloud Cover

Verification will be applied to **50** airports

5. Searching the best method

ensemble prediction VS. "ensemble" observation

For us, verification as a tool to find the best method!

Experiment	Description
Nearest Point	Closest NWP grid point to the airport
Nearest Land Point	Closest NWP grid point to the airport over land
Bilineal Interpolation	▪ 4-point interpolation of the four closest NWP grid points ▪ Anywhere / over land
Bicubic Interpolation	▪ 16-point interpolation of the sixteen closest NWP grid points ▪ Anywhere / over land
4-point EPS	▪ 4-point "subensemble" ▪ Weight / non-weight with distance
16-point EPS	▪ 16-point "subensemble" ▪ Weight / non-weight with distance
Polygon-points EPS	NWP grid points "subensemble" inside airport "climatological" coherent area

6. Conclusions

- ✓ **Strong relationship between probabilistic forecasts and TAF reports.**
- ✓ **At the moment, epsgrams plotted from ECMWF EPS data. In the future, AEMET-SREPS and AEMET-γ-SREPS too.**
- ✓ **Feasible applications in aeronautics, such as Airport Weather Warnings (AWWs), or in drainage basins.**
- ✓ **Is 'correction for 2m temperature' really worth?**
- ✓ **Verification process will depend on, among other things, airport database.**

Acknowledgements

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Rest of Predictability Group: ***C. Santos, A. Amo, J.Sancho, J. Simarro and J.A. García-Moya***

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Climatology: B. Téllez

Forecasters Group: ***J. Arús, J.C. Bullón, G. Cuevas, J. Fernández, S. González, A. Pladevall, S. Viana and E. Werner***

B. Orfila, E. Terradellas, J. L. Casado

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- http://www.ecmwf.int/research/predictability/
- http://planecrashinfo.com/cause.htm

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