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WIND INTENSITY RECONSTRUCTION OVER ITALY THROUGH LAMPINET LIGHTNING DATA.

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ABSTRACT

Italian Air Force Meteorological Service set up a lightning network and put it in operation during 2004: LAMPINET, based on VAISALA technology with 15 IMPACT ESP sensors. During the first 6 years of life LAMPINET data flow has offered an incomparable capacity in detecting and monitoring atmospheric electrical activity. At Centro Nazionale di Meteorologia e Climatologia Aeronautica (C.N.M.C.A.), the operational Centre of Italian Air Force Meteorological Service, several tools have been developed to integrate lightning information with other weather data systems, such as satellite images and post-processing products, and several studies have been carried on regarding the reconstruction of weather parameters from LAMPINET data.

In this paper an analysis on the reconstruction of wind intensity field from LAMPINET data is presented, for an estimation of turbulence close to the ground up to few hundreds meters, for aeronautical safety purpose in areas where strokes are detected. The statistical analysis is based on 8 month of LAMPINET stroke records (around 3.500.000) together with METAR bulletins from 30 italian aeronautical stations (around 150.000), to correlate lightning rate with horizontal wind intensity and gusts presence.

The study is part of a fellowship sponsored by Galileo Avionica, a Finmeccanica company builder of space-based instrument, and hosted by Centro Nazionale di Meteorologia e Climatologia Aeronautica. Goal of the fellowship is to develop a methodology for the use of real time lightning data not only as an information par se but as a proxy for other meteorological parameters connected with convection. This activity is programmed with the aim to fully prepare operational environments for the Meteosat Third Generation Lightning Imager, that together with state of the art lightning ground network, as LAMPINET, will provide a unique integrated system with the capacity of continuously detecting and monitoring total lightning.

INTRODUCTION

Object of this paper is to present one of the results obtained during studies developed at the Centro Nazionale di Meteorologia e Climatologia Aeronautica, Pratica di Mare, Italy, in a fellowship sponsored by Galileo Avionica, Firenze, Italy. This activity is programmed with the aim to fully prepare operational environments for the Meteosat Third Generation Lightning Imager, that together with state of the art lightning ground network, as LAMPINET, will provide a unique integrated system with the capacity of detect and monitoring total lightning.

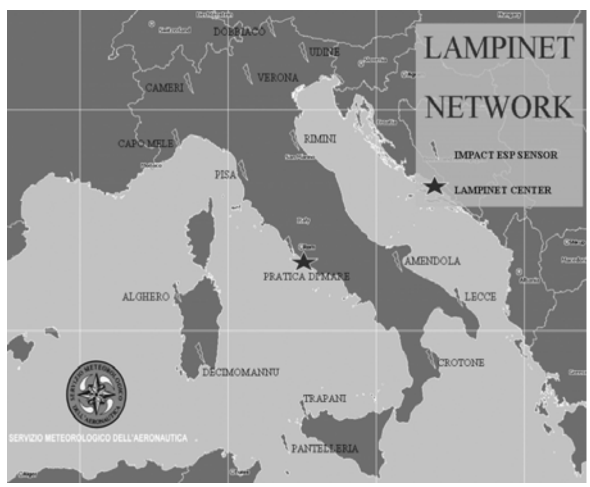

Fig.1- LAMPINET lightning location network.

For the next generation of earth observation geostationary satellites, major space operational agencies are planning to insert an optical imaging mission that continuously observes lightning pulses in the atmosphere; EUMETSAT, the european organization for the exploitation of

operational meteorological and environmental satellites, has decided recently that one of the observing mission to be flown on MTG will be LI, a Lightning Imager.
Italy, as country participating EUMETSAT, developed studies by means of its actual lightning detection capability, with the goal of define specific meteorological requirements, given from the potential use in meteorology of lightning final information for convection prediction, for estimation of a selection of weather parameters and numerical cloud modeling (Ref.1).
A study carried on during the cited fellowship is the one presented in this paper, that tries to establishes a connection between lightning rate and wind intensity measured for aeronautical purposes, especially regarding estimation of low level turbulence (up to few hundreds meters). During the 2008 2nd International Lightning Meteorology Conference (ILMC), held in Tucson, Arizona, same group of authors presented the exercise in reconstructing convective rainfall rate from lightning information (Ref.2).

LAMPINET

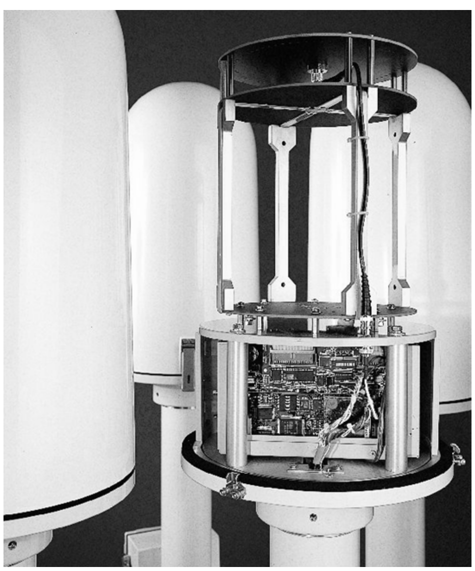

Fig.2- Vaisala IMPACT ESP sensor.

The Italian lightning network, LAMPINET, is based on Vaisala technology, with 15 IMPACT ESP sensors uniformly distributed over the national territory, and started operations during 2004. It's based both on MDF (Magnetic Direction Finding) and TOA (Time Of Arrival) technique (Fig.2). LAMPINET network can reach a detection efficiency of 90% for I > 50 kA and location accuracy of 500 meters over all Italian and surrounding area. Basic requirements, fixed in the concept development phase, were highest reliability, redundancy, scalability, integrability (Ref.3, 4, 5).
Vaisala IMPACT ESP, detect E-B field signature of lightning discharge and frequency features of waveforms for CG-CC discrimination; radio frequencies from CG and IC discharges in a bandwidth 1-350 kHz; measures azimuth angle of the discharge location, the time of signal arrival, the peak signal strength, the rise time and width of the discharge.
The network was adopted primarily for nowcast of strong electrical activity connected with atmospheric instability, to prevent risks both in air operation and ground activities, such as refueling, power plants protection, human life in the open. LAMPINET data are used by the Italian Air Force (Fig.3), Army and Navy, Civil Protection Agency and other governmental institutions, like National Research Council (ISAC-CNR), while some users pay for dataset, in real time or offline.

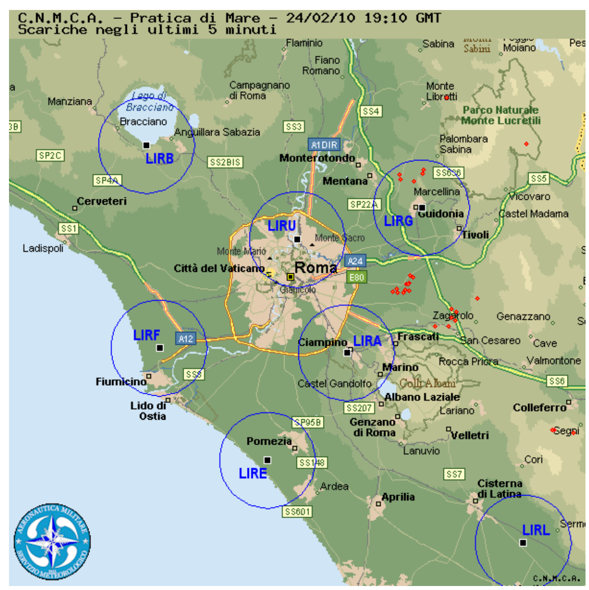

Fig.3- LAMPINET lightning location 5 minute plot; this products delivered to users on the ground within 1 minute from nominal hour is fundamental for air operations, such as maneuvering, refueling ect.

LIGHTNING DATASET

The lightning dataset considered in the study is the complete strokes detection archive recorded by LAMPINET in the 8 month period from the 1st April to 30th November 2009. In Fig.4 the strokes density for the studied dataset, suggesting where to select ground meteorological observing stations, in order to increase the population of correlated lightning - horizontal wind events (Fig.5). For example we choose the majority of stations in the central and North part of the Peninsula due to high density (Fig.6), while we select only Cagliari in Sardinia Island because a severe failure afflicted Alghero sensor (in the north of the island) during the summer 2009, reducing drastically LAMPINET detection efficiency in that area.

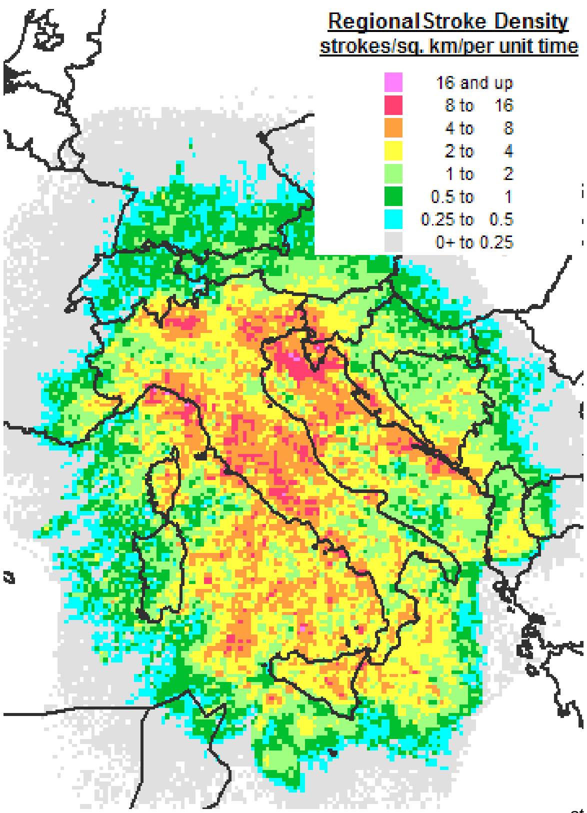

Fig.4- Stroke density over all study period (1st April – 30th November 2009).

In Fig.5 strokes time trend with bins equal to a week over all study period (1st April – 30th November 2009), it is appreciable that nearly all lightning activity used for the statistics belongs to around 10 severely active weeks.

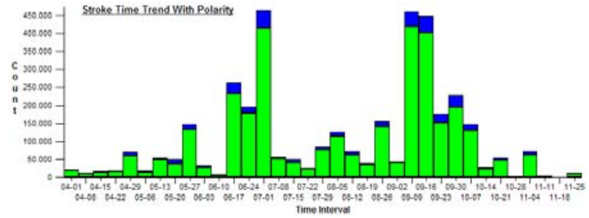

Fig.5- Strokes time trend with bins of weeks over all study period (1st April – 30th November 2009).

WIND DATASET

Fig.6- Display of the 30 aeronautical meteorological station of the study.

The wind intensity records come out from aeronautical meteorological bulletins produced by stations in Table .1. Bulletins are coded in World Meteorological Organization - METAR and SPECI format, as for example the observations of Pratica di Mare airport in early morning of 23 October 2009 (underlined the observed value of mean wind intensity in Knots and Gusts velocity, if present):

```
1.   METAR LIRE 230455Z 11020KT 4000
  TSRA BR FEW010 SCT016CB BKN030
  15/13 Q0996 RMK OVC VIS MIN 4000
  WIND THR31 12022KT GRN=
```

2. **SPECI LIRE 230520Z 16023G33KT 3000 TSRA BR FEW010 SCT016CB BKN030 15/13 Q0996 RMK OVC VIS MIN 3000 WIND THR31 17022G32KT YLO=**

METAR are emitted usually hourly or half-hourly. In the first case SPECI bulletins are emitted by meteorological stations every time a weather parameter varies exceeding codified thresholds, while in the second variation are reported in the subsequent bulletin. Wind values are representative of means calculated in the 10 minutes before UTC time of METAR emission (in the bulletin after station indicator with the format DDHHMMZ), unless marked discontinuity where are reported only value means closer bulletin emission.

ICAO	PLACE	LAT	LON
LIBD	Bari Palese	41,13	16,75
LIBP	Pescara	42,41	14,21
LIBR	Brindisi	40,65	17,93
LIBV	Gioia del Colle	40,76	16,93
LICA	Lamezia Terme	38,90	16,23
LICC	Catania	37,46	15,05
LICJ	Palermo	38,16	13,08
LICT	Trapani Birgi	37,90	12,48
LICZ	Sigonella	37,40	14,92
LIEE	Cagliari Elmas	39,23	9,05
LIMC	Milano Malpensa	45,62	8,72
LIME	Bergamo	45,40	9,42
LIMF	Torino Caselle	45,20	7,63
LIMJ	Genova Sestri	44,40	8,83
LIML	Milano Linate	45,43	9,26
LIPC	Cervia	44,21	12,18
LIPE	Bologna	44,53	11,28
LIPH	Treviso	45,63	12,18
LIPL	Ghedi	45,42	10,27
LIPR	Rimini	44,02	12,60
LIPS	Istrana	45,68	12,08
LIPX	Villafranca	45,38	10,88
LIPY	Ancona	43,61	13,36
LIRA	Roma Ciampino	41,78	12,58
LIRB	Vigna di Valle	42,07	12,21
LIRE	Pratica di Mare	41,65	12,43
LIRF	Roma Fiumicino	41,80	12,25
LIRN	Napoli	40,88	14,28
LIRQ	Firenze	43,80	11,20
LIRS	Grosseto	42,75	11,07

Tab.1- Aeronautical stations utilized for the study.

EXERCISE

A lightning generating cloud system, mostly always a convective system, generate for the presence of strong updrafts and downbursts, a surrounding ground wind field characterized by abrupt changes of blowing direction and consistent intensity or sheer of intensity. Having an indication in the wind field intensity could be a relevant tool for estimation of low level turbulence (up to few hundreds meters), and the use of lightning information as a proxy could provide the answer in areas where lack of observation.

We collect METAR and SPECI bulletins from 30 italian aeronautical stations (around 150.000) as described in Table.1, in the 8 month period 1^{st} April – 30^{th} November 2009, scanning them 1 by 1 to find in correspondence the number of near strokes in LAMPINET dataset (around 3.500.000 stroke records).

Spatial collocation is 0.1° from meteorological station site, this means that a stroke occurrence is flagged near to the station if closer than 11,1 km (6 NM), while temporal collocation is ± 15 minutes centred on METAR emission time.

The 2 datasets are in this way collocated with software coded in Matlab.

RESULTS

In Fig.7 is depicted the statistic in the occurrence trend in % (Y) of the totality of collocated wind with a certain number of stroke (X). In particular the percentage number of events with winds collocated with up a total number strokes is:

- up to 5 strokes 70%;
- up to 10 strokes 81%;
- up to 20 strokes 90%;
- up to 30 strokes is over 95%;
- cases with more than 30 stroke represent less than 5% of the total exercise.

This suggests the fact that it will be hard to retrieve a parameterization of wind intensity simply from lightning rate.

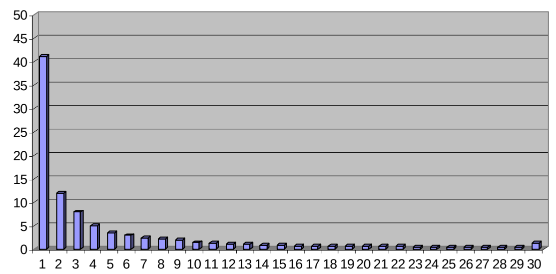

Fig.7- Occurrence trend in % (Y) of the totality of collocated wind with a certain number of stroke (X). Values 30 represents also greater values, up to the greater ever computed value of 598 strokes.

In Fig.8 are represented collocated wind velocities in X (KT) with a number of stroke (Y) in log scale. It is evident that in presence of a stroke counting up to around 10 (in half hour centred in the wind observational time) it is mainly possible to find velocities in 3-15 KT. For stroke number between 10 and 30 velocities may vary in 5-18 KT, while for higher number of strokes velocities have a mean value of 12 KT. There are also same cases (less than 0.5%) with strokes passing over a weather station that reports 0 KT winds. In only few events wind with velocity higher than 18 KT is accompanied by not more than few strokes.
From the exercise is evident that lightning presence is not usually connected to high horizontal velocity in winds in the aeronautical definition, but with the variation in direction, the shear. Analyzing the dataset emerges that during the presence of stroke over a station the direction of wind has done a marked discontinuity in more than 60% of the collocated events. A directional shear with a mean intensity of 12-14 KT may surely create moderate turbulence in low levels (up few hundreds meters).

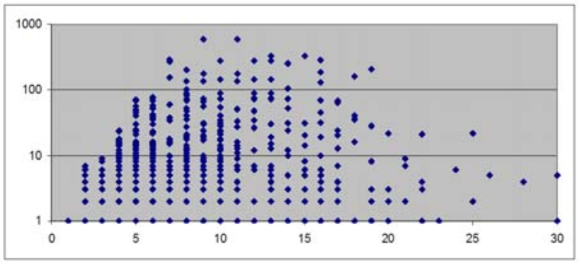

Fig.8- Collocated wind velocities in X (KT) with a number of stroke (Y) in log scale. Spatial collocation is 0.1° from meteorological station site while temporal collocation is ± 15 minutes centred on METAR emission time.

CONCLUSIONS

Italian Air Force Meteorological Service set up a lightning network and put it in operation during 2004: LAMPINET, based on VAISALA technology with 15 IMPACT ESP sensors. During the first 6 years of life LAMPINET data flow has offered an incomparable capacity in detecting and monitoring atmospheric electrical activity. At Centro Nazionale di Meteorologia e Climatologia Aeronautica (C.N.M.C.A.), the operational Centre of Italian Air Force Meteorological Service, several tools have been developed to integrate lightning information with other weather data systems, such as satellite images and post-processing products, and several studies have been carried on regarding the reconstruction of weather parameters from LAMPINET data.
In this paper an analysis on the reconstruction of wind intensity field from LAMPINET data is presented, for an estimation of turbulence close to the ground up to few hundreds meters, for aeronautical safety purpose in areas where strokes are detected.
In presence of a stroke counting up to around 10 (in half hour centred in the wind observational time) it is mainly possible to find velocities in 3-15 KT. For stroke number between 10 and 30 velocities may vary in 5-18 KT, while for higher number of strokes velocities have a mean value of 12 KT. There are also same cases (less than 0.5%) with strokes passing over a weather station that reports 0 KT winds. In only few events wind with velocity higher than 18 KT is accompanied by not more than few strokes.
From the study presented is evident that lightning presence is not usually connected to high horizontal velocity in winds in the aeronautical definition, but with the variation in direction, the shear, and that was not possible to retrieve a parameterization of wind intensity simply from lightning rate.
Analyzing results emerges that during the presence of stroke over a station the direction of wind has done a marked discontinuity in more than 60% of the collocated events. A directional

shear with a mean intensity of 12-14 KT may surely create moderate turbulence in low levels (up few hundreds meters).

References

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