ECSS 2009 Abstracts by session

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List of the abstract accepted for presentation at the conference:
O – Oral presentation
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Session 08: (Extra-)tropical cyclones: embedded thunderstorms and large-scale wind fields

A STUDY OF GENERATION OF AVAILABLE POTENTIAL ENERGY IN SOUTH CYCLONES AND HAZARD EVENTS OVER THE URAL

A.Vetrov[1], N. Kalinin[1]

[1]*Perm State University, Bukirev str. 15, Russia, vetrov@psu.ru*

(Dated: 15 September 2009)

I. INTRODUCTION

The concept of available potential energy (APE) clarifies the role of baroclinicity in specifying the atmospheric state which is capable of generating kinetic energy. Lorenz (1955) formalized the concept of available potential energy, which has proved to be very useful in energetic analyses of the atmospheric general circulations as the appropriate companion to kinetic energy (Lorenz 1967; Huang 1998). APE has also been shown to be a useful quantity for smaller-scale stratified flows (Winters et al. 1995).

This study represents analyses of south extratropical cyclones that produced heavy precipitation and large-scale wind fields in the Ural region. In this paper, influence diabatic generation APE due latent heat release on hazard events is presented.

II. PRESENTATION OF RESEARCH

The Eta model is a hydrostatic mesoscale weather forecast model with an accurate treatment of complex topography using eta (η) vertical coordinate system and step-like mountains, which eliminates errors in computation of pressure gradient force over steeply sloped terrain present in sigma (σ) coordinate system. The model version used here follows that described by Black and Mesinger. The model employs a semi-staggered Arakawa E-grid in which wind points are adjacent to the mass points, configured in rotated spherical coordinates. The mesoscale Eta model is run operationally with a horizontal grid spacing of 48 km and 38 vertical levels, with layer depths that range from 20 m in the planetary boundary layer to 2 km at 50 mb. The model top is at 25 hPa. Split explicit time differencing is used with a time step of 120 s. Spatial differencing is done with a conserving Arakawa type scheme. The model's step mountains are derived using the official United States Geological Survey (USGS) topographical data.

Initial and lateral boundary conditions is following. Hydrometcentre global (T40L15) analysis and 6 hourly global model forecasts are used for initial and lateral boundary conditions. Wind, temperature, relative humidity and geopotential height interpolated to 26 pressure levels are used.

Results of numerical modelling were used for compute APE and generation of APE due latent heat release. Parameterization scheme are used to estimate diabatic heating due latent heat release. A research project, focused on case studies of severe convective events, has been running since 1961.

III. RESULTS AND CONCLUSIONS

Selected cases of severe convective events are discussed below. Diagnostic calculations reveal that generation available potential energy due to sensible heating influence on development heavy precipitation. Latent heat release is generally in good agreement with observed weather features and cyclone development. During the development of the extratropical cyclone, the generation APE within the region under investigation is increased. In addition, convective instability and low-tropospheric water vapour flux convergence are significant over the Ural, and therefore the environment is highly supportive for convection development. On the other hand, there is an overall tendency of the simulations to favour cyclone development leeward of the Ural mountain range. APE generation primarily results from the convective latent heat release ahead of the cold front in the warm sector. The diabatic heating fields in the cyclone vicinity and convection area contribute more effectively to increasing or maintaining the baroclinicity of the cyclone system than of the sub-regions themselves. The results exhibit a clear dependence heavy precipitation and of low-tropospheric warm air advection on the characteristics of the generation APE. Therefore, spatial details of the regional simulation are shown to be highly sensitive to the structure-scale wind fields of the generation of APE.

It is established, that in southern cyclones the APE are concentrated in the field of fronts. The minimal APE is observed in rear parts investigated baric formations.

It is established, that in southern cyclones generation of APE due to phase transformations of water (on the average 10 W/m^2 in a layer from a terrestrial surface up to 300 hPa) prevails. Areas of generation are dated for warm sector of a cyclone. In a rear part of a cyclone prevails dissipation of APE. It is necessary to note, that the areas borrowed by generation APE in southern cyclones, as a rule (in 60 % of cases), get range structure focused along a face-to-face surface. During research seasonal dependence of generation APE has been revealed. As one would expect, the greatest values of generation are observed in a cold season (from October till March).

The model of an atmosphere has allowed to reveal influence of geographical conditions on formation water generation APE. Influence of large lakes (Aral sea) on development of the southern cyclones displaced on territory of Central Asia, expressed in strengthening generation APE Is revealed. Besides it is possible to note influence of orography (mountain of Southern Urals Mountains) on development of cyclones. On the western slopes of Urals Mountains the strengthening of generation APE caused by additional development of ascending streams of air also is precisely shown.

The joint analysis temperatures, humidity and speed of a wind with power characteristics of an atmosphere have been lead water atmospheric pressure. It is established, that with pressure drop in a cyclone, the size of APE decreases.

On the other hand change of generation of the APE caused by phase transitions of water, has more complex dependence. From the moment of formation before achievement of a stage of a young cyclone generation APE decreases. It is connected by that occurrence of southern cyclones occurs, as a rule, above a warm water table of the Mediterranean, Black and Caspian seas. At an output of a cyclone inflow water the pair from a terrestrial surface is sharply reduced to a land, in a cyclone drier and cold air acts, and it leads to some reduction of generation APE. At a stage of the maximal development pressure in a cyclone continues to fall, and speeds of ascending movements reach the maximum, and it again leads to growth of generation APE. Further to a stage of filling there is a reduction of generation down to values close to zero. During the analysis of vertical structure of generation APE presence of a maximum (on the average 6 W/m^2) at all stages of evolution in average troposphere (700-400 hPa) is revealed. The important result of research is the revealed law, that in 90 % of cases in a place of occurrence of initial cyclonic circulation, there is an area with the raised values of generation of APE.

Differential characteristics of a field of speed of a wind (a vertical component of a whirlwind of speed and horizontal divergence velocity of a wind) have been in addition calculated. It is established, that these characteristics also test essential changes in time and can be level with power characteristics indicators of evolution of a cyclone. Research has shown, that presence of greater positive values vorticity in a free atmosphere defines development sever convection at sufficient instability of an atmosphere. Above a boundary layer it is possible to divide precisely enough a cyclone into areas with convergence (northeast part of a cyclone) and divergence (southeast part of a cyclone). Since height of an isobaric surface 500 hPa the situation in distribution of a sign, as a rule, varies.

IV. AKNOWLEDGMENTS

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LIGHTNING ACTIVITY IN HURRICANES

Colin Price[1], Yoav Yair[2], Mustafa Asfur[2]

[1]*Tel Aviv University, Ramat Aviv, Israel (cprice@flash.tau.ac.il)*
[2]*The Open University of Israel, Ra'anana, Israel*
(Dated: 15 September 2009)

I. INTRODUCTION

Hurricanes are the most deadly storms on the Earth, with evidence that the strength and number of intense hurricanes (category 4 and 5 of the Saffir-Simpson scale) may have increased in recent decades (Emanuel, 2005; Webster et al., 2005). While the prediction of the trajectory of these storms is now quite accurate (Shen et al., 2006), the forecast of the future storm intensity is more difficult to predict. One way of looking within storms from great distances is to monitor the electrical activity within hurricanes. It has been known for many years that lightning activity is closely related to the microphysics and dynamics of convective storms. In this study we investigate the relationship between lightning activity in hurricanes, and the storm intensity.

II. DATA

To check the connection between hurricane intensification and electrical activity, we have collected pressure and wind data from all 58 category 4 and 5 (Saffir-Simpson scale) hurricanes around the globe over a three year period (2005-2007). The hurricane data giving the location, time, maximum sustained wind speeds, and minimum central pressure were obtained from the 6-hour "best track" estimations provided by the National Hurricane Center (NHC) (http://www.aoml.noaa.gov/hrd/hurdat/), and the Joint Typhoon Warning Center (JWTC) (http://metocph.nmci.navy.mil/jtwc/best_tracks/index.html).

Lightning activity around the globe can be continuously monitored from great distances using low frequency (LF) or very low frequency (VLF) electromagnetic networks on the ground. Recently efforts have been made to develop global networks, such as the World Wide Lightning Location Network (WWLLN) (Lay et al., 2007).

III. RESULTS AND CONCLUSIONS

An example of our analysis for each of the hurricanes is shown in Figure 1 for Hurricane Dennis in 2005. Figure 1a shows the trajectory of the center (eye) of the hurricane from 5-14 July 2005, with the location of the hurricane eye at 12 UTC shown by the open circles. The central pressure and the maximum sustained winds are shown in Figure 1b. As expected, there is a strong negative correlation between minimum pressure within the hurricane and the

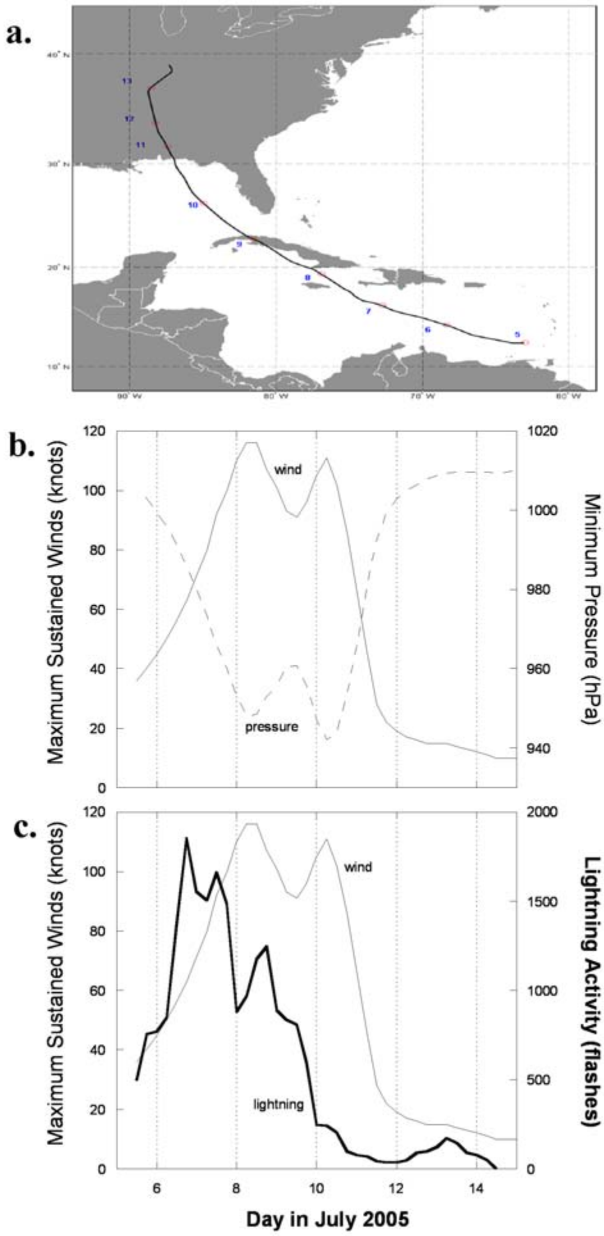

Figure 1. Hurricane Dennis 5-14 July 2005*. a) The path of Hurricane Dennis, showing the location at 1200UT every day; b) The minimum pressure (dashed curve) together with the maximum sustained winds (solid curve); c) The maximum sustained winds (solid thin curve) and the observed lightning frequencies within a 10x10 degree gridbox centered on the eye of the storm (solid bold curve).*

maximum wind speeds (Figure 1b). The horizontal winds are a result of the intense pressure gradients between the eye of the storm and the surrounding regions. The bold curve in Figure 1c represents the lightning activity detected by the WWLLN within a 10 degree box centered on the eye of the storm, while the thin curve showing the maximum sustained winds is the same as that in Figure 1b. From Figure 1c it can be clearly seen that the lightning activity follows the same pattern as the maximum winds speeds (or minimum pressures), with an approximate one day lag between the peak lightning activity and the peak intensity of the hurricane.

Hurricane Dennis had two periods of peak winds, both of which were preceded by maxima in lightning activity one day before the peak in the maximum sustained winds. The linear correlation between the lightning activity curve and the maximum sustained winds curve, taking into account the one day lag, is 0.95, implying that lightning activity can explain 90% of the day-to-day variability of the maximum sustained winds in this hurricane. The correlation with the pressure curve (Figure 1b) is -0.94.

The same analysis was carried out for all 58 category 4 and 5 hurricanes that occurred during the years 2005-2007. Of these storms, 56 showed statistically significant positive correlations between lightning activity and maximum sustained winds. More than 70% of the hurricanes analyzed have the lightning activity peaking *before* the peak wind intensities, with the most common lag being 30 hours (both the mean and median).

What could be the physical mechanism relating lightning activity to hurricane intensity? This is a topic for future research, although it has been suggested that the development of tropical cyclones is sensitive to the distribution and magnitude of moistening of the lower troposphere by convection (Emanuel, 1995). The horizontal maximum sustained winds are very sensitive to changes in vertical convection that influences the rate of moistening of the lower troposphere. In addition, it has been shown that the time to maximum intensification in hurricanes depends on the intensity of the convection (Emanuel, 1995). It has also been demonstrated that convection can generate potential vorticity anomalies that can lead to vortex intensification (Montgomery and Enagonio, 1998). Since lightning is an indicator of this convection, it follows that the lightning activity should precede the hurricane intensification.

This study shows the promise in using lightning data for understanding the processes related to hurricane intensification. If lightning can predict the intensification of hurricanes in advance, this provides a powerful tool for forecasters, especially in regions susceptible to considerable damage, and which lack proper early warning capabilities. Furthermore, since lightning is directly related to thermodynamic processes that result in the release of latent heat in convective clouds, using lightning locations and intensities for data assimilation in atmospheric models may dramatically improve future hurricane intensity forecasts.

The results of this research are published in the Price et al. (2009) paper in Nature Geoscience.

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COLD-SEASON MESOSCALE CONVECTIVE SYSTEMS IN GERMANY

Gatzen, C.[1], T. Púčik[2]

[1]*Meteogroup Deutschland, Berlin, Germany, gatzen@estofex.org*
[2]*Faculty of Science, Masaryk University, Brno, Czech Republic*

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I. INTRODUCTION

In the winter months, warm air spreading into central Europe is mostly dominated by stable lapse rates as the low level air tends to cool over the land due to weak diurnal heating. However, deep and intense moist convection can also occur along of cold fronts in the winter season. For example, large and long-lived severe mesoscale convective systems (MCS) evolved during the winter storms "Kyrill" and "Emma" in 2007 and 2008. These systems were capable of producing frequent lightning, flash floods, severe wind gusts, and strong tornadoes. Using an ingredients-based methodology, forecasting of this type of cold-season convection can be a problem as latent instability is often not detectable before the event and seems to develop immediately before it is destroyed by the convection due to the strong forcing (Van Den Broeke et al., 2005). As a consequence, lapse rates and low-level moisture may not indicate clearly where and when deep moist convection will be likely.

This work tries to analyze some environmental conditions that enable MCS development in the range of initially stable air masses. Many of these thunderstorms seem to evolve from narrow convective lines that are frequently detected by radar along of cold fronts in mostly saturated air masses. Suggesting that this initial forcing is essential in most of the cases with deep moist convection in warm air masses during the winter season, their thermodynamic environment may show some favourable conditions that allow the shallow convection to become deep.

II. DATA

For this work, radar images of the German radar network operated by the German Weather Service (DWD) were analyzed to detect narrow convective lines. The terminus "narrow" is used in this work for convective lines that have a very large line-parallel extension relative to the line-normal extension. Narrow lines that were likely related to gust fronts of convection rather than synoptic-scale cold fronts were not taken into account. Additionally, convective lines with very weak reflectivity were difficult to detect and therefore had a weaker chance to be taken into account.

Radar images were taken from the winter seasons of 1998/99 until 2008/09 between 1st of November and 10th of March. Within this dataset, about 120 narrow convective lines were analyzed across Germany. Data of the EUCLID lightning network were used to identify electrified lines. WMO wind gust observations and the ESWD data set were used to search for severe weather related to the convection. Reanalysis data of the GFS global model were analyzed to characterize the large scale flow, especially the position of mid-level and low-level jets relative to the convective line. Furthermore, proximity soundings were searched for every convective line that was detected. Soundings were stated to be proximity when they were placed about 100 km or less in front of a convective line crossing the location during the next hour or less. Low-level parameters of the soundings were compared with the environment to check that it was really launched ahead of the narrow lines.

III. RESULTS AND CONCLUSIONS

In 10 years, about 120 narrow convective lines were detected in the radar images. Most of them (90 percent) had a line-parallel extension of at least 200 km; about 50 percent had a length of at least 400 km. The lines occurred in clusters: In the winter season of 2002/03, only 2 cases were found, while 8 lines were detected in only 12 days during the winter of 2007. Although on average most narrow lines occurred in January, a significant trend was not observable. Furthermore, the lines did not indicate to follow a diurnal cycle. Regarding the regional distribution of the narrow lines, they occur rather often in the north-western portions of Germany near the North Sea. The south-eastern quadrant of the country showed to lowest number of events. The propagation direction was from the north-west to the south-east for about 90 percent of the cases. Lines that moved to the north were not detected.

From the lightning network data, about 50 percent of the lines were counted as electrified. 20 percent of the all narrow lines were accompanied by severe wind gust and/or tornadoes. Large hail was not observed, while excessive rain was not taken into account. With respect to the position of the mid-level jet, about two thirds of all narrow lines occurred in the range of the cyclonic flank. These lines did produce more thunder (66 percent) and severe weather (25 percent) compared to narrow lines that were located in the range of the anticyclonic flank of the mid-level jet, where remarkable few lines produced thunder (9 percent) and severe weather was not reported. A strong low-level jet was found for most of the narrow lines (84 percent), and intense convective lines were all associated with strong or very strong (25 m/s) low-level jets.

More than 50 proximity soundings were found. Around ten of them were located near to severe weather reports along the narrow lines. Almost every of these sounding was characterized by at least moist neutral lapse rates, 60 percent showed CAPE, while the average CAPE value was 13 J/kg. The equilibrium temperature was about -6.1°C on average, with -9.3 for electrified lines and -7.6 for severe events. The equilibrium temperature does likely have a significant influence on the electrification process in the convective line (Van Den Broeke et al., 2005). The boundary-layer air was nearly saturated in 24 percent of the cases, while mixed boundary-layers were measured for 20 percent of the events. Severe weather seems predominantly occur with well-mixed low-levels. Low-level vertical wind shear was strong in most of the cases, with the average exceeding 15 m/s in the lowest kilometre.

This work shows that narrow convective lines do occur frequently over Germany. It indicates that the development of these lines is closely related to strong forcing in the range of mid-level jet streaks, while lightning and severe weather may correlate with the position of the cyclonic flank of the mid-level jet. Based on the analysis of proximity soundings, it seems that CAPE is present ahead of these lines. The depth of the unstable layer seems to increase underneath the cyclonic flank of the mid-level jet where more lightning was detected. Future work will discuss these results including international studies on cold-season mesoscale convective systems.

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COMPARISON OF TWO COLD-SEASON MESOSCALE CONVECTIVE SYSTEMS

Gatzen, C.[1], T. Púčik[2], and D. Ryva[3]

[1]*Meteogroup Deutschland, Berlin, Germany, gatzen@estofex.org*
[2]*Faculty of Science, Masaryk University, Brno, Czech Republic.*
[3]*Skywarn CzechoSlovakia, Kolin, Czech Republic*

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I. INTRODUCTION

Mesoscale convective systems (MCS) are known to occur within a large variety of thermodynamic environments (e.g. Evans and Doswell, 2001). While MCS have been observed in association with both strong and weak vertical shear profiles, most of them seem to develop with rather high instability. As a consequence, only a few severe mesoscale convective systems forming in association with weak instability have been described (e.g. Van Den Broeke et al., 2005; Kruzdlo and Cope, 2005).

In January 2007 and March 2008, two mesoscale convective systems moved across portions of Central Europe. Both MCS were embedded in winter storms named "Kyrill" and "Emma" and associated with widespread severe weather. However, the influence of organized convection on the severity of the large-scale storms is not easy to estimate as damage reports and wind measurements often cannot be related to the convective process alone. Doing a comparison of the two MCS, we try to analyse the environmental conditions that enabled deep moist convection and effect the occurrence of severe weather.

II. THE MESOSCALE CONVECTIVE SYSTEMS

Regarding their size and lifetime, the MCS seem to be comparable as they moved along a 1500 km long path in approximately 14 hours as indicated by detected lightning. They were characterized by a narrow, around 700 km long convective line that showed several large bowing segments during its lifetime (FIG. 1). The both showed a "parallel stratiform structure" (Parker, 2006).

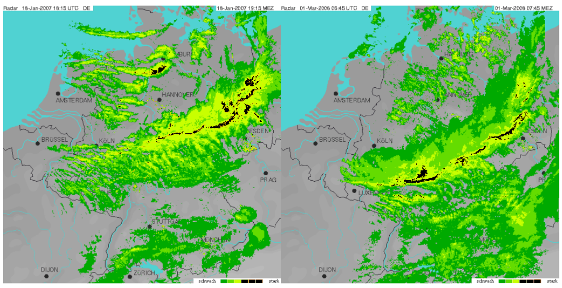

FIG. 1: Radar images of the Kyrill (left) and Emma (right) MCS.

Observations and rawinsonde data as well as numerical models indicate weak instability in the warm air mass. Low-level warm air advection due to an indirect thermal flow my have contributed to the weakly capped instability ahead of the cold front. The structure of the convective systems is comparable to simulations by Weisman and Davis (1998) for MCS development affected by strong and deep vertical wind shear. Bowing segments are frequently observed along the leading edge of MCS due to the development of convective cold pools (e.g. Weisman and Davis, 1998). Such cold pools in the wake of the leading convective line developed in both cases. For the winter season, the cold pool was quite well-developed, with a temperature difference up to 13 K along the leading convective line of the Kyrill event. Furthermore, the intense and persistent leading convection indicates that the cold pool was balanced by the environmental vertical wind shear. The horizontal vorticity of environmental vertical wind shear can balance the horizontal vorticity generated by the cold pool, leading to more upright and persisting convection (Weisman and Davis, 1998).

Both lines developed quite different during the following hours. During the Kyrill storm, the convective line stalled across central Germany. The passage of the bowing lines over south-eastern Germany was associated with frequent lightning and strong precipitation, but decreasing winds that did only slightly turn to the west. It seems that the cold pool of the MCS increased the low-level stability and reduced the vertical impulse transport. As the rear inflow jet was likely directed to the east, it did not produce the strongest gusts at the ground along the flow-parallel portions of the convective line. In contrast, this was observed along a narrow path along the northern bowing segments. It is suggested that this was closely related to the mid-level jet streak that was spreading eastward across central Germany, leading to strong forcing especially at the cyclonic flank of its nose. Accordingly, lightning was detected only along a narrow path just to the north of the jet streak's nose. This may indicate the influence of larger-scale circulations on the mature MCS as suggested by Coniglio (2003).

The Emma MCS had a larger line-normal propagation and crossed southern Germany. Lightning was detected across most of the convective line. In contrast to the Kyrill case, the gust front clearly produced the strongest wind gusts and was accompanied by a strong turn of the wind direction to the north-west. This was likely related to the mid-level jet streak that was spreading southward across Germany as the mid-level trough was amplifying. As a consequence, the rear inflow jet did likely contribute on the wind gusts at the leading edge of the convective system.

III. RESULTS AND CONCLUSIONS

The development of the two MCS seems to indicate that their propagation and severity is closely related to the lift associated with the synoptic-scale flow. We suggest that instability is generated by the thermal indirect circulation underneath the mid-level jet streak. The ageostrophic winds at low levels may lead to differential temperature advection within a saturated, moist-neutral stratified air mass in the warm sector of the low pressure system. The instability becomes deeper for situations with strong lift due to strong mid-level quasi-geostrophic forcing.

Severe wind gusts along the leading line of the convection seem to be related to the large scale forcing as well. When the forcing mechanism disables the convection to move on, the cold pool may lead to low-level stabilization and therefore weakening winds as observed for the Kyrill case.

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KLAUS OVER BASQUE COUNTRY: LOCAL CHARACTERISTICS AND EUSKALMET OPERATIONAL ASPECTS.

S. Gaztelumendi[1 2] and J. Egaña [1 2]

[1] *Basque Meteorology Agency (EUSKALMET). Parque tecnológico de Álava. Avda. Einstein 44 Ed. 6 Of. 303, 01510 Miñano, Álava, Spain*

[2] *European Virtual Engineering Technological Centre (EUVE), Meteorology Division. Avda de los Huetos 79, Edificio Azucarera, 01010 Vitoria-Gasteiz, Álava, Spain.*

I. INTRODUCTION

Winter storm Klaus was a mid-latitude cyclone that formed on January the 22nd of 2009 in the subtropical North Atlantic, west of the Azores Islands. The system moved from west to east over the Cantabric Sea with a trajectory parallel to the Cantabric coast, affecting Basque Country area on late 23rd early 24th January (see more details in Egana J., 2009). In Basque country, wind gusts higher than 150 kilometers per hour were recorded in various locations across the region. A 200 kilometers per hour gust was recorded in a mountainous area in the interior. These are some of the strongest winds observed in Basque Country. On the other hand, waves as high as 21 meters were recorded in Matxitxako buoy (8 miles from Basque coast).

In this work, we present some aspects of this event, focusing on Basque Country local characteristics and operational aspects related with this severe weather episode. We present a detailed study based on data collected in more than 80 Automatic Weather Station (AWS) from the Basque Country AWS mesonetwork (Gaztelumendi S. et al 2003) and other data available in the area including buoy data. We also present some available numerical models results (Gaztelumendi S. et al 2008, Egaña J. et al 2008, Gaztelumendi S. et al 2007) and Basque Meteorology Agency operational aspects related with forecast and severe weather warning issues during the episode. Finally, damages and some conclusions are pointed out.

II. LOCAL CHARACTERISTICS

Klaus track, Basque Country orographic characteristics and coastal configuration makes that first effects are produced in interior part of territory with SW winds followed by increasing W and NW winds affecting all the country and particularly coastal and high places (exposed areas). Mesoscale features shown that before the wind draft, W and SW affect the interior part of Basque Country, specially in Alava and mountainous areas, during the afternoon on day 23. After wind draft, during late night and morning on day 24 W and NW wind affects coastal areas and higher parts of Gipuzkoa and Bizkaia (see FIG 1).

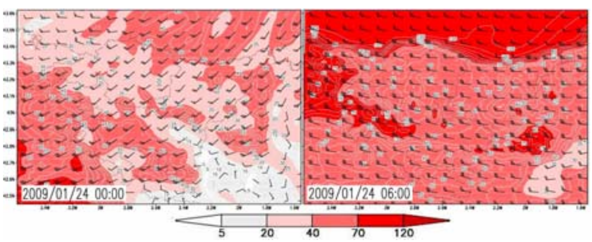

FIG. 1: Wind speed mesoscale forecast for Basque Country area for day 24 at 00:00 and 06:00 UTC.

Usually, ordinary-generated deep Atlantic depressions cause gusts values superior to 120 km/h in exposed areas (Egaña J. et al, 2006) . But in this case, Klaus, explosive cyclogenesis generated very deep depression, causes generalized gust values larger than 120 km/h and wind gusts far exceeding 150 km/h in some places. Historic data were registered in wind time series at some AWS. In more than ten stations wind gust values over 120km/h are observed, including no-exposed and exposed areas (see table I), and gusts greater than 100 km/h are measured in nearly all stations along the Country. The wind gusts intensities registered are 50-70 km/h superior to the mean wind velocities measured. In Cerroja AWS, the highest wind speeds where recorded with wind speed over 130 km/h at 05:10 GMT and wind gusts over 200 km/h at 04:30 GMT (see FIG 2).

AWS	Max gust (km/h)	AWS	Max gust (km/h)
Cerroja	203,6	Pasaia Harbour	134,3
La Garbea	164,2	Treviño	132,3
Jaizkibel	157,7	Iurreta	131,4
Oiz	157,7	Ordizia	127
Bilbao Harbour	155,5	Mungia	126,7
Bermeo	154,4	Zambrana	126
Orduña	154,1	Zegama	118,9
Zarautz	150,5	Vitoria-Gasteiz	118,1
Arboleda	137,5	Bidania	115,2
Zaldiaran	136,2	Deusto	111,6

TABLE I: Most significant wind gust data registered on Basque Country Automatic Weather Stations Network

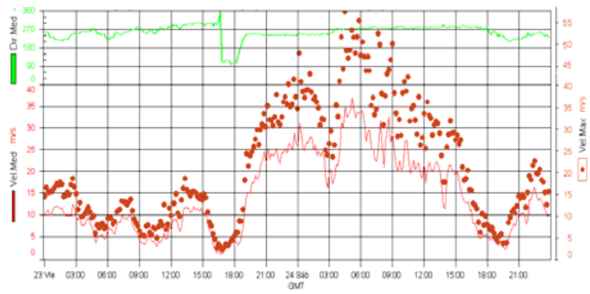

FIG. 2: Cerroja wind speed and direction during the episode.

Pressure data registered in the AWS network shows values dropped by more than 20 hPa in the space of only eight hours.

Klaus passage over Cantabric Sea also produces an exceptional worsening in the maritime conditions. The significant wave height surpasses the 8 meters in the early morning of the 24th, registering occasionally 13 m in the coast. At 8-mile from coast, in Matxitxako buoy, maximum wave heights superior to 20 m are registered (see FIG 3).

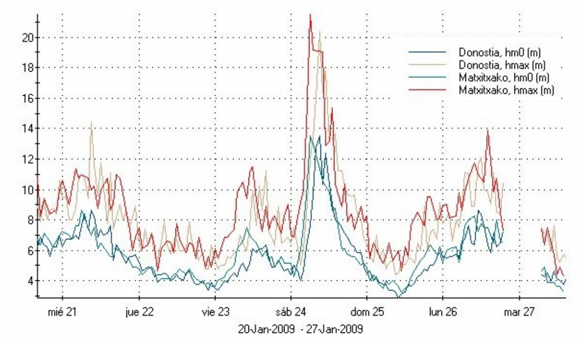

FIG. 3: The maximum and significant height evolution in Matxitxako and Donostia buoys (6-8 miles from coast).

III. EUSKALMET OPERATIONAL ASPECTS

On January 21st, EUSKALMET prognosis products shown the possible formation of a deep depression in the Atlantic west of the Azores Island on day 22nd, with a probable evolution and trajectory from west to east that can affect North Coast of Iberian Peninsula. Euskalmet mesoscalar numerical models and others available tools shown potential risk of local severe weather related with wind gust and swell. On January 22nd, morning, forecast products confirm explosive clycogenesis phenomenon and shows depression trajectory parallel to Cantabric Coast. Mesoscale numerical available products shows probability of wind gust higher that 120 km/h for exposed areas and higher than 80 km/h for non-exposed areas in Basque Country, with significant wave high higher than 7 m. During the afternoon new data available, confirm the severe weather situation event, showing even high generalized wind gust that before. On 23rd morning forecast products for D and D+ 1 show that wind gust higher than 150 km/h and waves higher than 8 m can affect Basque Country.

On day 22nd severity and exceptionality of this event is clear for us, so especial reinforcement on severe weather usual procedure is applied. Routine operative staff is reinforced with additional surveillance and forecast personnel for 23rd afternoon and 24th nigh and morning, and special severe weather briefing is planed for 23rd early morning.

In those situations, it is important to consider that small perturbations at synoptical level, specially related with final track and final pressure values are critical in final local situation. Even at mesoscalar level, an increment in wind speed during frontal passage, especially in coastal areas, must be considered due to relevant thermal difference between air masses in the frontal system associated with the cyclone. Finally not special mesoscalar forcing was observed. Situation could have been even worse specially if final track would have been somewhat further south, or mesoscalar forcing finally would have increased locally wind values.

According with operational warnings procedure awareness reports was delivered for 23rd afternoon and 24th morning during previous days. On day 21st a yellow warning level (V>100km/h for exposed and hs>6 m). On 22nd with orange level (V>140km/h in non exposed and V>90km/h for rest of the areas, hs>8m). On 23rd red level warning (first time since Basque Meteorology Agency is created on 2003) is established for coastal and higer areas due to wind gust higher than 150 km/h and for sea area due to significant waves higher than 8 m, and an orange one for any other part of Basque Country where wind gust higher than 100km/h is highly probable.

IV. CONCLUSIONS

During days and hours before Klaus passage, special effort is made in order to explain risk and the unusual of situation. Basque Government applies civil protection plan and summon “crisis table” for coordination of actions among different agents (civil protection, police, firemen, municipalities, etc.) In EUSKALMET the pursuit of the situation was continuous, providing forecast, analysis and data reports for authorities and public before, during and after the episode.

Some preventive actions, never before applied, are considered, as population transfer far from the most affected areas. Some sea-side roads are closed, fishing fleet stay on harbor and even Bermeo fleet and other from minor ports goes to Bilbao during 23rd morning. Authorities make calls to population in order to stay at home during night and if possible not to take the car.

Finally thousands of trees were flattened all over the area, causing power outages and travel disruptions across all Basque Country and especially along the coast region. Uproot trees and flying objects cause many damages on properties and buildings. Over 200.000 population without electricity, because of damage to the overhead line network and power stations. Public transport canceled or disrupted with stoppages in Bilbao, Donostia and other cities. Airports temporarily closed and telecommunications networks disrupted.

Unless material losses are very important, no fatalities are produced. It is important to consider exceptional safety measures applied by authorities, to notice that this severe windstorm affects Basque Country mainly during night hours. Even, the fact that some newspapers and TV channels talk non-properly about deep low passage as if a hurricane was, makes that at the end people stay alert and very concern with potential risk of situation.

V. AKNOWLEDGMENTS

The authors would like to thank Basque Government and specially Meteorology and Climatology Directorate staff for public provision of data from Basque Country Automatic Weather Station Network and for operational service economic support. We would like also to thank all our EUSKALMET colleagues for daily effort in promoting valuable service for Basque community.

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North Atlantic extra-tropical cyclone intensity, wind field, and CAPE: a case study

A. Schneidereit[1], K. Riemann-Campe[12], R. Blender[1], K. Fraedrich[1], F. Lunkeit [1]

[1]*Meteorologisches Institut, Universität Hamburg, KlimaCampus, Grindelberg 5, Germany, andrea.schneidereit@zmaw.de*

[2]*International Max Planck Research School on Earth System Modelling (IMPRS-ESM), Bundesstraße 53, 21046 Hamburg, Germany*

(Dated: 15 September 2009)

I. INTRODUCTION

Extratropical cyclones cause severe weather in the mid-latitudes, in part accompanied by heavy precipitation and strong winds. Most of the precipitation is produced within the fronts, especially along the cold front (Browning and Harrold, 1970). Nevertheless convection is an important contributor to the total precipitation involved in a mid-latitude cyclone. In an occluded front, part of the precipitation is caused by convective instability, while the post-frontal precipitation is exclusively triggered by this mechanism. In this study, convective precipitation in an intense mid-latitude cyclone is analysed by CAPE (Convective Available Potential Energy) and the antagonist CIN (Convective INhibition).

II. DATA AND METHODOLOGY

The data set used is given by the re-analysis ERA-40 of the European Centre of Medium-Range Weather Forecasts (ECMWF) with 6-hour resolution. The data is interpolated to T63 spectral trunction. An intense cyclone is investigated 920 hPa pressure minimum starting at January 10, 1993, and a total life time of 5 days. This cyclone has been determined in the course of an extreme value analysis of the most intense cyclones in ERA-40 and ECHAM5 model simulations (Sienz et al., 2009).
CAPE is given by the potential energy available which can be transformed to kinetic energy to develop cumulus clouds. It is calculated as the difference of virtual temperature between an idealized rising air parcel and that of its environment, computed pseudo adiabatically from a mixed layer parcel. The mixed layer extends from the surface over the lowest 100 hPa. In the ERA-40 reanalysis CAPE is used in parametrization of convective precipitation. CIN works as the counterpart of CAPE and describes the convective energy needed by the rising parcel to overcome the usually stable boundary layer to reach the level of free convection.

III. RESULTS AND CONCLUSIONS

The life cycle in this case study is determined by the central geopotential height, and the area averaged thermodynamic variables mixed layer temperature and specific humidity, CAPE, and CIN, which are compared to the development of total and convective precipitation (Fig. 1). The mixed layer temperature and humidity are averaged in the lowest 100 hPa. The horizontal extension is given by the radius determined by a fit of a Gaussian function to the 1000 hPa geopotential height (Schneidereit et al., 2009). The radius is marked for a specific time step in Fig. 2.

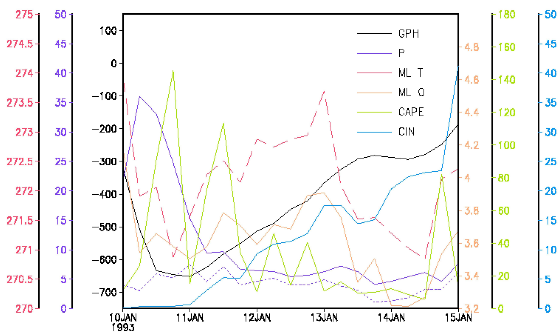

FIG. 1: Area averaged life cycle of a cyclone case study, with 1000 hPa geopotential height GPH, total precipitation (*P*, solid), convective precipitation (dashed, [mm/day],) mixed layer temperature (ML-T, [K]), and specific humidity (ML-Q, [g/kg]), CAPE, and CIN [J/kg]. The scales are given on the left and the right axes with the same colours.

During the life cycle, the central geopotential height reaches the minimum after the first day and increases to the environmental value after 6 days. The asymmetry of the life cycle characterizes intense cyclones while weak cyclones show a symmetric growth and decay (Schneidereit al., 2009). CAPE shows a rapid development during the first day and a successive slow decay superimposed by a distinct diurnal cycle determined by the near surface temperature. The initial increase of CAPE goes along with the rapid deepening of the central geopotential height. CIN starts with a negligible amount and grows with a nearly constant increase. Mixed layer temperature and humidity follow the intensity life cycle, however with symmetric growth and decay. Total precipitation which is mainly based on stratiform convection, attains its maximum during the first day. Thereafter one day total and convective precipitation remain approximately constant throughout the life cycle. During the second half of the last day high values of temperature, humidity, CAPE, and CIN are obtained.

At the CAPE maximum the distributions of total and convective precipitation are compared to CAPE (Fig. 2). At this time the cyclone is occluded and its frontal area extending from Iceland towards the North Sea. Remnants of the warm front occur near Denmark while the cold front follows the British Channel.

Intense total precipitation (left panel) is concentrated along a narrow rainbandof the occluded front. A second, minor (occluded) depression produces precipitation in the Norwegian/Barents Sea. Post-frontal rainfall west of Ireland is embedded in a north-westerly flow. Convective precipitation (middle) demonstrates the stratiform origin of frontal rainfall. Only in the centres of both cyclones convection contributes to rainfall. In the post-frontal areas of both cyclones, convective precipitation accounts for at least half of total precipitation.

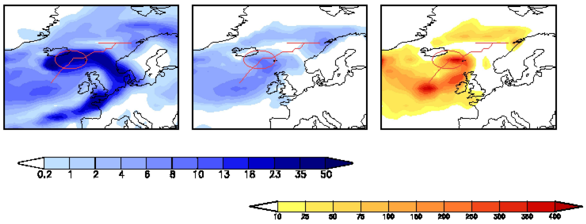

FIG. 1: Precipitation and CAPE at the maximum of CAPE (January 10, 1993, 18UTC). Left panel: total precipitation, middle convective precipitation, right CAPE. The red line is the trajectory and the marked area shows the cyclone position at the maximum, the extension indicating the width of the averages in Fig. 1.

CAPE (right panel) is closely related to convective precipitation, caused by cold Arctic air advected to the warm North Atlantic. Along the cold front CAPE vanishes and convective precipitation is absent.

The benefit of the present analysis is hampered by the fact that the parameterization of convective precipitation is based on CAPE. Therefore, the present study needs to be extended to the analysis of observed precipitation.

IV. AKNOWLEDGMENTS

Thanks to Frank Sielmann for his support in CAPE calculations, and to DKRZ, DWD, and ECMWF for the data. AS acknowledges the Sonderforschungsbereich 512 (Tiefdruckgebiete und Klimasystem des Nordatlantiks) and KRC acknowledges the support by IMPRS-ESM.

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KLAUS OVERVIEW AND COMPARISON WITH OTHER CASES AFFECTING BASQUE COUNTRY AREA

J. Egaña[1 2] and S. Gaztelumendi [1 2]

[1] *European Virtual Engineering Technological Centre (EUVE), Meteorology Division. Avda de los Huetos 79, Edificio Azucarera, 01010 Vitoria-Gasteiz, Álava, Spain.*

[2] *Basque Meteorology Agency (EUSKALMET). Parque tecnológico de Álava. Avda. Einstein 44 Ed. 6 Of. 303, 01510 Miñano, Álava, Spain*

I. INTRODUCTION

Strong extratropical cyclone (ETC) that forms in the North Atlantic often exhibits a period of very rapid strengthening known as explosive cyclogenesis. Those severe cyclonic storms can generate hurricane-force winds and when track across land, the results can be devastating. Usually strong ETC tracks over the north part of Europe, but in very few cases, can veer more to the south and affects south France and north Spain.

Explosive cyclogenesis generally happens when a surface cyclone deepens at a rate greater than 1hPa/hr over 24 hours. Is an extreme phenomena that consist on the deepening and intensification of a surface cyclone in a few hours period caused by its interaction with a perturbation in height consistent with baroclinic instability conditions. These phenomena can be characterized with the following criteria (Sanders and Gyakum 1980):

$$\Delta P \geq 24\left(\frac{sen\alpha}{sen60}\right)$$

with α the mean latitude along the low pressure trajectory. In our latitudes the pressure fall must be equal or superior to 19-20 hPa in 24 hours.

In this work we focus on those cases in which the Basque Country area is affected by extreme wind episodes during past years. Available wind data for the area are used, and synoptic situations considered in order to analyze different events. Finally we focus on Martin and Klaus cases making a comparison from Basque Country registered wind data.

II. WIND STORMS OVER BASQUE COUNTRY

The most severe wind storm in the Iberian Peninsula happened in the 1941 February 15^{th}-16^{th}, is in synoptic scale the most violent on XX century. This phenomena is originated, after the deepening of a strong depression in the northwest of Iberian Peninsula, with pressure central values lower than 960 mb. During this episode gusts over 200 km/h was registered in Basque Country area. At west, Santander city suffer worst fire in history.

In the last years the most singular episodes are Hortensia, Martin and Klaus cases:

October, 1984. Basque country is affected by the remains of Hortensia hurricane, that moves eastwards over the Cantabric Sea. Is a singular event that affects infrequently Basque Country. Cyclone are formed in the Caribbean Sea (hurricanes) moves towards higher latitudes and are absorbed by zonal circulation turn into deep extratropical cyclones (hurricane remains), Sometimes, the depressions get stronger by interaction with medium latitude perturbations. Previously, the cyclones had lost strength due to arriving colder waters.

1999 December 27^{th}. A depression deepens in an extraordinary way in the Cantabric Sea due to an explosive cyclogenesis. Martin crosses Cantabric Sea from West to East (see FIG 1), originating intense southwest winds, with a later northwest rotation, when the maximum gusts surpassing 150-160 km/h in coastal places.

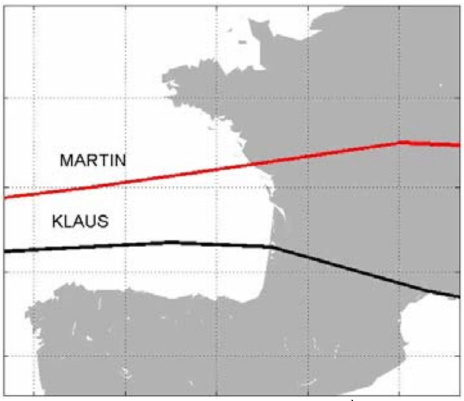

FIG. 1: Track of Martin (1999 December 27^{th}) and Klaus (2009 January 24^{th}).

During the 2009 January 23^{rd}, 24^{th} days the extratropical cyclone Klaus crosses the Cantabric Sea from West to East, affecting directly the Cantabric coast (see FIG 1, FIG 2 and FIG 3). In the Basque Country hurricane force gusts produce several material losses. The stronger winds begin the 23^{rd} in the afternoon, west-southwest winds that intensifies at the end of the day, which specially blows in the interior areas and in mountainous interior areas due to the topography and wind direction. In exposed areas 120 km/h and 100 km/h in no-exposed areas are exceeded. The 24^{th} day, when the cyclone arrives France, the wind begin to rotate towards the west-northwest in the early morning, blowing with special intensity in the coast and in mountainous areas in the north zone. The hurricane force gusts going on surpassing 150 km/h values in exposed zones. In no-exposed zones are about 100-120 km/h (see Gaztelumendi et al 2009 for more details).

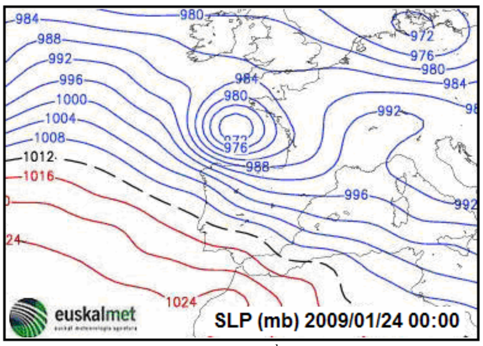

FIG. 2: Sea level presure for 00:00 24^{th} January 2009.

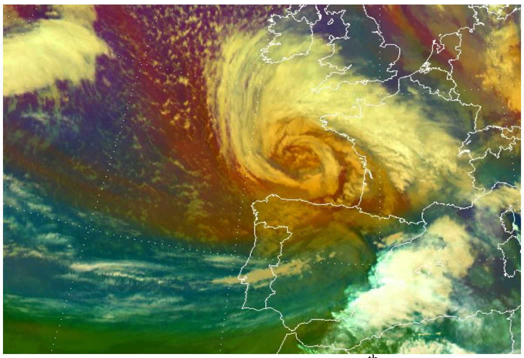

FIG. 3: MSG RGB composite for 00:00 24th January 2009.

III. KLAUS-MARTIN COMPARISON.

In Klaus and Martin episodes the necessary ingredients to produce an explosive cyclogenesis are present: strong horizontal temperature gradient, due to very different air masses meeting, strong vertical temperature gradient (instability), strong vertical shear and adequate jet stream structure. This phenomena is very frequent in North Atlantic in cold season. Normally, happen in higher latitudes than our, although in this two cases its unusual trajectory affect directly our territory.

The two events are quite similar, but we can mark some details regarding trajectory and pressure values. The Klaus trajectory is more southern arriving to the southwest of France, Martin arrives France in the south of Brittany region (see FIG 1). The pressure minimum that reach Martin cyclone is 970 mb, decreasing 23 mb in 24 hours. Klaus deepens 30 mb in 24 hours, reaching 963 mb.

In Basque Country an Automatic Weather Station Network owned by Basque Government is operational (see more details in Gaztelumendi et al 2003). This automatic network provides different meteorological measures at real time. Among others, provides wind data in different places all over the Country, each ten minutes. In Klaus and Martin events, maximum wind gusts present similar values. In southern stations the gusts are stronger that in the Klaus event (see table 1).

Stations		Maximum Gusts (km/h)	
		Martin 1999 December 27th	Klaus 2009 January 24th
South Area	Llodio	101	101
	Vitoria-Gasteiz	107	118
	Zaldiaran	127	132
	Iturrieta	94	123
	Kapildui	128	141
	Zambrana	101	126
	Navarrete	104	135
North-west Area	Pta. Galea	141	132 *
	Mungia	117	127
	Derio	106	103
	Oiz	177	158 *
	La Garbea	168	164
	Urkiola	99	96
	Barazar	125	114
	Orduña	126	154
North-east Area	Jaizkibel	167	158
	Zarautz	124	150
	Arrasate	91	105
	Bidania	123	115

TABLE I: Most significant data registered on Basque Country automatic stations (*broken during episode).

In some sense Martin is a similar event that Klaus not only considering his genesis and track but also analyzing registered maximum winds values over Basque Country area. Considering synoptic aspects Klaus is bit more violent than Martin, and at local scale very high wind gust was more generalized over the area in Klaus case.

III. RESULTS AND CONCLUSIONS

Usually, ordinary-generated deep Atlantic depressions cause gusts values superior to 120 km/h in exposed areas (specially in the mountain areas). But in this case, Klaus and Martin, explosive cyclogenesis generated very deep depressions, origin generalized values larger than 120 km/h and gust that exceeded widely the 150 km/h.

In the Klaus event in more than ten stations hurricane gust registers are observed, including no-exposed and exposed areas, in all stations gusts greater than 100 km/h are measured.

Although, in south part of Basque Country, Klaus measurements overcome Martin values due to the less deepness and the trajectory slight northern of Martin comparing with Klaus, in the north area not appreciable differences are found. In Martin case an important mesoscale factor is present, due to the relatively high temperatures before wind rotation. In Klaus case the synoptic factors are the most important.

Respect to injuries, during Martin episode 3 people died, during Klaus no injuries was produced in Basque Country area. Is important to consider that worst part of Klaus take place during night hours, meanwhile worst part of martin happens during afternoon on a Christmas day.

IV. AKNOWLEDGMENTS

The authors would like to thank Basque Government and specially Meteorology and Climatology Direction staff for public provision of data from Basque Country Automatic Weather Station Network and for Basque meteorology Agency financial support.

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A NUMERICAL STUDY OF THE WINDSTORM KLAUS: ROLE OF THE SEA SURFACE TEMPERATURE AND DOMAIN SIZE

Nazario Tartaglione, Rodrigo Caballero

School of Mathematical Sciences, University College Dublin, Ireland, nazario.tartaglione@ucd.ie

(Dated: 15 September 2009)

I. INTRODUCTION

The windstorm denominated 'Klaus' occurred between the 23rd and 24th January 2009. When it landed over the coast of France it wrecked havoc in France and Spain. Klaus belongs to those kinds of storms classified as meteorological bombs (Sanders and Gyakum, 1980). Analysing the pressure maps and satellites images it is possible to see that it was "similar" to the cyclone "Lothar" that has been the subject of several works (e.g. Wernli et al 2002). It's challenging to forecast correctly the genesis and evolution of this kind of cyclones (Sienkiewicz et al. 2004).

In general, latent heat release that is due to condensation may have a strong impact on the evolution of cyclones as shown by observational and modelling studies (Davis and Emanuel 1991, Fantini 1991). In meteorological bombs the latent heat release seems to be crucial to promote low-level vorticity (Kuo and Low Nam, 1990).

Most of the meteorological bombs in the Atlantic Basin form just north of Gulf Stream (Sanders and Gyakum 1980; Robber, 1984). The impact of the sea surface temperature on storm evolution is usually evaluated for tropical cyclones, whereas how it affects the extra-tropical cyclones has been object only of a few case studies (e.g. Giordani and Caniaux 2001). The importance of SST is critical in understanding how possible scenarios of global warming may modify the evolution and the strength of extra-tropical storms. In this study we analyzed how the sea surface temperature impacted in the numerical simulations on the evolution of the cyclone "Klaus". We analyzed contextually how the domain size is a very important for forecasting correctly the deepening of the cyclone.

II. PRESENTATION OF RESEARCH

A study of sensitivity of development of the cyclone to the sea surface temperature is presented here. The study was conducted by using the model BOLAM developed at ISAC-CNR (Buzzi and Foschini, 2000).

The study investigates the role of the SST in the evolution of the cyclone, we show also the importance of choosing the model domain in order to forecast correctly the evolution of the cyclone.

We performed the control simulation SST0 and 9 runs in which the SST was increased from 1 K (SST1) to 9 K (SST9). The model runs were performed with a horizontal resolution of 30 km. As we are not interested in studying the sensitivity of the forecast to the grid resolution, it is sufficient to simulate sufficiently well the genesis and the evolution of the cyclone. The numerical simulations started at 0000 UTC of 23 Jan 2009.

However, before analyzing the sensitivity to SST we tried a couple of domains in order to check the sensitivity of the domain size. A "good" prediction of this cyclone was obtained only when the initial perturbation was contained in the domain. With a too small domain even with a higher resolution (15 km) with respect to the simulations analyzed in this paper (all at 30 km horizontal resolution) but not including the initial perturbation, the simulated cyclone do not reach the intensity obtained with the simulation with a coarser grid step (984 hPa vs 974 hPa).)

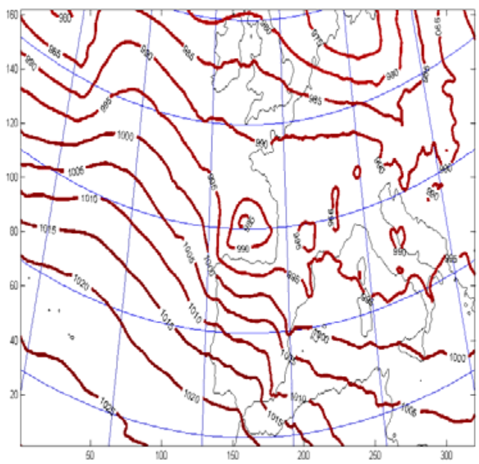

FIG. 1: MSLP at 00 00 24 Jan 2009, model resolution 0.13º was selected to simulate numerically the evolution of Klaus. Minimum Pressure 984 hPa.

III. RESULTS AND CONCLUSIONS

The results of the sensitivity of "Klaus" to SST can be resumed in Figs. 2, 3 that show the evolution of the MSLP minima and 10 m wind speed maxima for the 10 numerical simulations when the cyclone reaches its maxim intensity, i.e. at 00 00 UTC of 24th Jan 2009 (These value were obtained considering subdomain of 31x31 grid points encompassing the cyclone). The positions of MSLP minima and 10 m wind speed maxima of the sensitivity experiments were not much different from the control simulation (not shown). It worth noting as there is not a unique trend of the minimum MSLP and maximum wind speed. When the temperature is larger than 5º the trend slope increases suggesting a non-linear effect due to increasing of the water vapour and more production of rainfall (Fig. 4).

Increasing the SST implies providing furthermore a source of latent heat that seems to be fundamental in the evolution of this kind of cyclones (Tartaglione et al., 2009). The sea surface is the main source of water vapour whose condensation provides the energy to invigorate the strength of the cyclone. Tartaglione et al. (2009) showed that the cyclone is generated by "dry" baroclinic instability, but without latent heat contribution it was not able to transform itself in an exceptional windstorm.

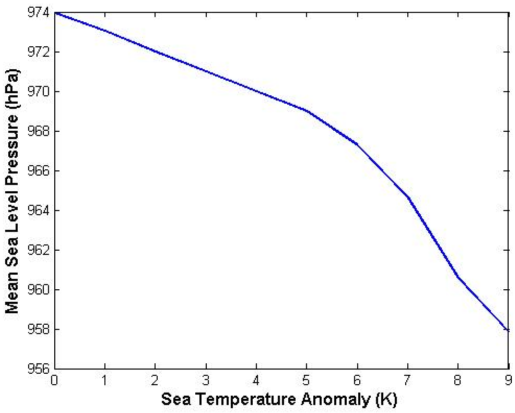

FIG. 2: 'Klaus' MSLP minimum as a function of the SST anomaly with respect to the control simulation (SST0).

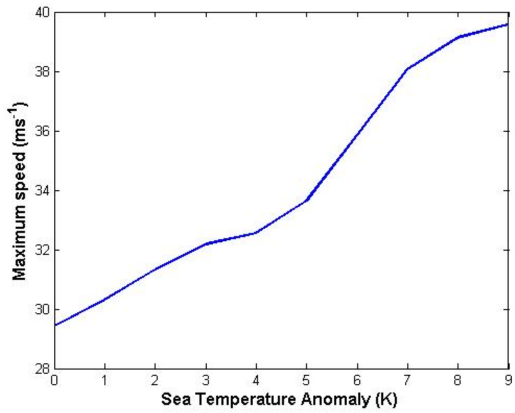

FIG. 3: As Fig 2 but for the maximum wind speed.

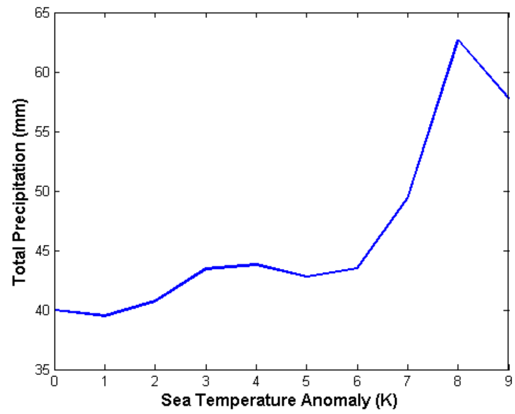

FIG. 4: As Fig. 2 but for the total precipitation (mm in 6 h)

We showed here the high sensitivity of meteorological bomb like 'Klaus' to SST. Although it represents only a case study, it seems that the SST plays a significant impact on the evolution of this kind cyclone, a result to be considered when we take in account global warming scenarios. We performed simulations of this cyclone increasing and decreasing the atmospheric temperature but keeping the same sea temperature of the control experiment and we found that the evolution of the cyclone is not as sensitive as the one obtained changing the sea temperatures.

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