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Option: FLIGHT OPERATIONS

Master report theme

CLIMATOLOGICAL STUDIES AND THUNDERSTORMS FORECASTING IN TAMANRASSET

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Abstract:

Aviation in Algeria has to deal with numerous meteorological phenomena, particularly at Tamanrasset, due to the influence of the tropics. For this reason, it has become necessary to carry out a study to prevent summer thunderstorms that could threaten air safety.

The study of the climate in this region will include the following phenomena: thunderstorms, orographic turbulence, sand and dust storms, cumulonimbus clouds, showers, sand fog and low visibility.

All of these elements will be necessary in order to obtain statistically reliable results for a good numerical weather forecast.

Keywords: Thunderstorms, Tamanrasset, prediction, AROME.

ملخص:

الطيران في الجزائر يواجه العديد من الظواهر الجوية، وخاصة في تامنراست، نظرًا لتأثير مناخ المناطق الاستوائية. ولهذا السبب، أصبح من الضروري إجراء دراسة لمنع العواصف الرعدية في فصل الصيف التي قد تهدد سلامة الطيران.

ستتضمن الدراسة للمناخ في هذه المنطقة الظواهر التالية: العواصف الرعدية، والاضطرابات الجبلية، وعواصف الرمال والغبار، وسحب الكيومولونيمبوس، والزخات المطرية، وضباب الرمال وضعف الرؤية.

سيكون من الضروري استخدام جميع هذه العناصر للحصول على نتائج موثوقة إحصائيًا من أجل توقعات جوية دقيقة رقمية.

كلمات مفتاحية:

عواصف رعدية, تمنراست, توقعات,AROME

Résumé:

L'aviation en Algérie est confrontée à de nombreux phénomènes météorologiques, notamment à Tamanrasset, en raison de l'influence des tropiques. C'est pourquoi il est devenu nécessaire de réaliser une étude pour prévenir les orages d'été qui pourraient menacer la sécurité aérienne.

L'étude du climat de cette région portera sur les phénomènes suivants : orages, turbulences orographiques, tempêtes de sable et de poussière, cumulonimbus, averses, brouillard de sable et faible visibilité.

Tous ces éléments seront nécessaires afin d'obtenir des résultats statistiquement fiables pour une bonne prévision numérique du temps.

Les mots clés : Orage, Tamanrasset, prévisibilité, AROME.

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Dedication

First and foremost, praises and thanks to God, the Almighty, for his blessings that allowed us to successfully complete this work.

This thesis is dedicated to my my dear parents, who have always been there for me, no matter where I am, for all their prayers, patience and unconditional support throughout my educational journey.

I can't go further with this special occasion without thanking both of my brothers who were there for me whenever I needed them no matter what.

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MEZOUI ABIR

Dedication

In the name of Allah, The Most Gracious, The Most Merciful

All praise is due to Allah alone, the Sustainer of the entire world

I dedicate this work: To my dear parents,

You have been my guiding lights, and my biggest cheerleaders. Your belief in my abilities and your constant encouragement have given me the confidence to pursue my dreams and overcome any obstacles that came my way. Thank you for being my source of inspiration and my biggest supporters. This achievement is as much yours as it is mine.

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To my brothers

my allies, and my best friends. Your love and support have been my anchor in times of doubt and difficulty.

To my beloved grandparent,

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To my late grandparent,

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To my incredible friends,

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HADJOU KHAOULA

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ALADIN	Air Limitée Adaptation dynamique Développement International
ARPEGE	Action de Recherche Petite Echelle Grande Echelle
AROME	Application of Research to Operations at MEsoscale
ATC	Air traffic control
ATS	Air traffic service
AUTO	Automated observations
BKN	Broken
BLSA	Blowing sand
CAPE	Convective Available Potential Energy
CAT	Clear Air Turbulence
CAVOK	Ceiling and visibility OK
CB	Cumulonimbus
COR	Correction
CT	Cross Totals
DME	Distance measuring equipment
DRSA	Drifting sand
DZ	Drizzle
ECMWF	European Center for Medium-Range Weather Forecasts
FEW	Few
G	Gust
HZ	Haze
ILS	Instrument landing system
K	George index
Meso-NH	Non-hydrostatic mesoscale
METAR	Meteorological Aerodrome Report
NCD	No cloud detected
Nil	None
NMO	National Meteorological Office
NSC	No significant cloud
OVC	Overcasted
NWP	Numerical Weather Prediction
PO	Dust devils

PW	Precipitable Water
QNH	Nautical height
RA	Rain
RE	Recent
RERA	Recent rain
RH	Relative humidity
RWY	Runway
RVR	Runway Visual Range
SA	Sand
SCT	Scattered
SHRA	Shower rain
SPECI	Aviation special weather report
SQ	Squall
T	**Temperature**
TAF	Terminal Aerodrome Forecast
TCU	Cumulus congestus
Td	**Due point temperature**
TSGR	Thunderstorm and hail
TSRA	Thunderstorm and rain
TSRASN	Thunderstorm, rain and snow
TT	Total Totals
VRB	Variable
VT	Vertical Totals
WMO	World Meteorological Organization
WS	Wind shear

GENERAL INTRODUCTION

Historically, weather has been a major factor in aviation safety. Despite significant improvements over the years in such aspects as aircraft design, navigation equipment, communication facilities and pilot training, weather hazards remain a leading cause of aircraft accidents.

Tamanrasset is the largest city in Algeria, located in the south and characterized by a subtropical desertic climate. Moreover, meteorological changes in this region may vary and depend on a range of factors, involving global emissions, regional climate regimes and local environmental conditions.

The main known weather hazards include wind shear and turbulence, atmospheric electricity and lightning, visibility, ceiling, and fog. However, these individual hazards are often associated to varying degrees with thunderstorms. This phenomenon is very common during summer in the southern part of Algeria, especially in the aforementioned region, as the overheating of the continent causes the expansion of low equatorial pressure on the desert, leading to Saharan depressions. It is therefore very difficult to predict its exact location, intensity and duration.

Accordingly, it was necessary to provide computer-based models that account for a variety of atmospheric variables. Weather prediction are created by gathering objective data about the actual conditions of the atmosphere at a certain location, and treating them with forecasting models (ALADIN, AROME, ARPEGE…) in order to predict what the weather will be like in the future.

AROME is a small-scale numerical weather prediction model and the most recent to be operated at the National Meteorological Office, designed to improve short-range forecasts of severe events such as intense Mediterranean precipitation, severe thunderstorms, fog...

This research defines at first, the regional climate in Tamanrasset, then it treats one of the most hazardous phenomena in aviation starting with its formation and dissipation, then the manifestations following, and finally the dangers resulted.

Moreover, it proposes the previsibility of summer thunderstorms in Tamanrasset by means of AROME model. It consists of analyzing meteorological parameters and instability indicators including (K index, CAPE and TT) planned by

AROME. And then evaluating the forecast results of a particular summer thunderstorm case (the situation of 25/07/2020).

Objectives of this thesis:

- Assessing the reliability of the AROME model for summer thunderstorm prediction;
- Enhancements to the analysis of storm and instability indicators, leading to better identification and avoidance of their risks;
- Recognizing the importance of expanding the area covered by AROME.

CHAPTER 1
GENERALITIES

CHAPTER 1: GENERALITIES

1.1 INTRODUCTION :

Meteorology is the scientific study of the Earth's atmosphere and its phenomena, including weather patterns, climate, and atmospheric composition. It involves analyzing, predicting, and understanding weather and climate systems through the use of physics, mathematics, and computer modeling. Meteorologists study the interactions between the atmosphere, the Earth's surface, and the oceans to develop accurate weather forecasts, climate models, and to understand the causes of severe weather events such as turbulence, icing, thunderstorms. The knowledge gained from meteorology is of great importance, especially in aviation.

1.2 The importance of meteorology in aviation:

Meteorology is a scientific discipline that focuses on the study of Earth's atmosphere and its various phenomena, encompassing weather patterns, climate, and atmospheric composition. Through the application of physics, mathematics, and computer modeling, meteorologists analyze, predict, and comprehend weather and climate systems. They investigate the interactions between the atmosphere, the Earth's surface, and the oceans, aiming to develop precise weather forecasts, climate models, and an understanding of the causes behind severe weather events such as turbulence, icing, and thunderstorms. The insights gained from meteorology are particularly crucial in the field of aviation.

According to the World Meteorological Organization (2003), the primary objective of meteorological services for aviation is to provide operational meteorological information necessary for safe, efficient, and regular air navigation. These services also extend to providing near-real-time meteorological support to the aviation industry. Information regarding current and forecasted meteorological conditions at airports, specified areas surrounding airports, and during the cruising phase of flights originating from airports is furnished to air traffic service (ATS) units and other aeronautical users. In the realm of Air Traffic Control (ATC), aviation meteorology directly and significantly impacts operations, influencing every aspect of the work performed. This encompasses handling deviations, microbursts, wind shear, thunderstorms, hail, icing, contaminated runways, turbulence, and numerous other factors.

According to the World Meteorological Organisation (2003), the primary objective of aviation meteorological services is to provide operational meteorological information necessary for safe, efficient and regular air navigation. These services extend to the provision of real-time weather support to the aviation industry. Information on current and forecast meteorological conditions at airports, in defined areas around airports and during the cruise phase of flights departing from airports is provided to Air Traffic Services (ATS) units and other aviation users. In the field of Air Traffic Control (ATC), aviation meteorology has a direct and significant impact on operations, influencing every aspect of the work performed. This includes handling deviations, microbursts, wind shear, thunderstorms, hail, icing, contaminated runways, turbulence and many other factors.

1.3 The atmosphere:

The atmosphere is a mixture of gases that surrounds the Earth. They also trap heat to keep the earth warm and prevent extremes in temperature between day and night.

1.3.1 Composition of the atmosphere:

The density of the atmosphere decreases with altitude. This does not affect the composition up to
an altitude of at least 60 km. Ozone and some trace elements are affected by the chemical reactions in the upper reaches towards 60 km.
Above 70 km the lower force of gravity causes the atmospheric composition to vary with height.
The following percentages show the composition of dry air in the lower levels:

- Nitrogen: 78.09%;
- Oxygen: 20.95%;
- Argon: 0.93%;
- Carbon Dioxide: 0.03%.

The graph below represents this composition:

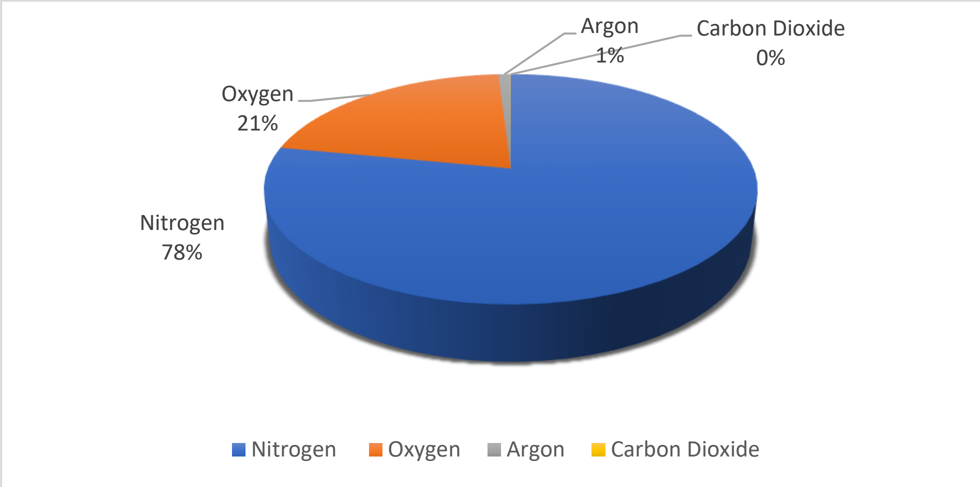


Figure 1–1 : Composition of the atmosphere -gas

1.4 Weather parameters:

1.4.1 Temperature:

In aeronautical meteorology, temperature is defined as the measure of the average kinetic energy of the molecules in the air. It is typically measured in degrees Celsius (°C) or Fahrenheit (°F). Temperature is an important parameter in aviation as it affects the density of the air, which in turn affects the performance of aircraft engines and wings.

It is often measured at various altitudes using instruments such as radiosondes, which are carried into the atmosphere by balloons. This allows for the calculation of temperature gradients, which are important for predicting weather patterns and turbulence.

Temperature is also important for determining the type of icing that may occur on aircraft during flight. For example, if the temperature is above freezing, but there is a presence of supercooled water droplets, clear ice may form on the aircraft. On the other hand, if the temperature is below freezing, and there is a presence of liquid water, rime ice may form.

1.4.2 Wind:

Wind is defined as the horizontal movement of air relative to the earth's surface. It is caused by differences in atmospheric pressure and temperature that create areas of high and low pressure from which air flows.

Wind direction is the direction from which the wind blows, while wind speed is the speed at which air moves in that direction.

It may be a critical factor that pilots must take into account when planning and executing flights. The direction and speed of the wind can affect the performance of the aircraft, particularly during takeoff and landing. Crosswinds, or winds blowing perpendicular to the runway, can create challenging conditions for pilots and require specialized techniques to maintain control of the aircraft.

1.4.3 Humidity:

In general meteorology, humidity refers to the amount of water vapor present in the air, usually expressed as a percentage of the maximum amount the air could hold at its current temperature, known as relative humidity (RH).

It is an important factor in determining weather conditions that can affect flight operations. High humidity can contribute to the formation of fog, which may reduce visibility and cause flight delays or cancellations. Humidity can also affect the formation of thunderstorms, which can be hazardous to aircraft.

Meteorologists use a variety of instruments and models to measure and forecast humidity, including hygrometers, weather balloons, and computer models.

1.4.4 Nebulosity:

is a term used in meteorology and aviation to describe the amount and type of cloud cover present in the sky. It refers to the overall cloudiness of the sky.
It is indicated by FEW (1 to 2 oktas), SCT (3 to 4 oktas), BKN (5 to 7 oktas) and OVC (8 oktas).

If there are no clouds below 1500 meters and the abbreviation CAVOK is not suitable, the abbreviation NSC is used.
The selection of the layers or cloud masses is made according to the following criteria:

- 1st group: the lowest layer regardless of amount;
- 2nd group: the next layer covering more than 2 oktas of the sky;
- 3rd group: the next higher layer covering more than 4 oktas of the sky.

Extra groups: for cumulonimbus and/or towering cumulus clouds, whenever observed and not reported in any of the above.

Cloud amount is described using the codes in the table below:

Code	**Cloud amount**
FEW	Few (1 to 2 octas)
SCT	Scattered (3 to 4 octas)
BKN	Broken (5 to 7 octas)
OVC	Overcast (8 octas)
NSC	Nil significant cloud
NCD*	Nil cloud detected

Table 1-1 : cloud description codes

Note:

NCD* is only reported in fully automated reports when a cloud sensor detects nil cloud.

Nebulosity is measured using instruments such as ceilometers, which use laser beams to determine the height of clouds, and weather satellites, which can provide information about cloud cover over large areas.

1.4.5 Visibility:

Is one of the most important elements concerning take-off and landing. It is often reduced in the lower layers of the atmosphere, especially by the presence of meteors, which in most cases belong to the group of hydrometeors and lithometeors. Horizontal visibility is defined as the maximum distance at which an object can be identified.

In weather observations and forecasts, however, it is the dominant visibility that is measured and predicted.

The main weather factors affecting visibility are:

- Haze and fog;
- Precipitation;
- Dust and sand;
- Wind-blown spray;
- Smoke;
- Salt.

1.5 Weather phenomena:

1.5.1 Precipitation:

Clouds can consist of a combination of water droplets, supercooled water droplets, and ice crystals. Individual water droplets and ice crystals are *very* small and light, and due to up currents in the clouds, they do not fall as precipitation on their own. If they combine with other water droplets or ice crystals, they become progressively heavier. If the up currents in the cloud are not strong enough to support their weight they fall as precipitation.

It follows that the stronger the up currents are, the heavier the droplet or crystal has to be in order for precipitation to occur. So, the largest droplets fall from convective clouds such as cumulus and cumulonimbus.

1.5.2 Haze:

It is defined as an atmospheric phenomenon that reduces horizontal visibility to between 5 and 10 kilometers (3-6 miles) due to the presence of fine dust, smoke, or other particles in the air. Haze is a type of meteorological condition that can affect the safety and efficiency of air transportation, especially during takeoff and landing operations.

Haze is often classified according to its density, using a scale that ranges from "light" to "moderate" to "heavy." Pilots and air traffic controllers use information about the density of haze and its location to plan flight paths and make decisions about the safety of aircraft operations.

1.5.3 Gust:

A wind gust is a sudden, brusque and brief increase in wind speed and direction. The phenomenon is immediately followed by a lull.

Gusts last less than 20 seconds and are often caused by either frictional turbulence, wind shear or solar heating of the ground.

They are considered gusts when the difference between the slowest and fastest wind speed is 8.6 knots (16 km/h).

In the case of friction, a gust occurs when the wind blows around natural obstacles such as trees and mountains, tall buildings, tunnels or other man-made barriers.

Changes in wind speed and direction over a short distance - wind shear - can also cause gusts, for example over water.

Finally, on hot days, as the ground heats up and warm air rises, cooler air rises above, causing wind gusts.

1.5.4 Squall:

Squalls are extremely frequent wind events with unpredictable consequences.

A squall is a sudden, sharp and violent increase in wind speed, usually associated with torrential rain, snow or thunderstorms.

Squalls are accompanied by drastic and significant changes in cloud patterns, cold fronts and severe weather events. They can last for several minutes.

These turbulent high winds are easy to spot because of the distinctive shape of the clouds that precede them.

Once the squalls have passed, rainbows and sunny skies take over and the average wind speed drops rapidly.

Squalls are most likely to form in areas of strong mid-level fall. According to the World Meteorological Organisation (WMO), a squall is a wind increase of at least 8 m/s, with a maximum speed of at least 11 m/s, lasting for at least one minute.

1.5.5 Blowing and drifting sand:

Blowing and drifting sand refers to the transportation of sand particles by wind, often resulting in the formation of sand dunes or sandstorms.

Figure 1–2 : Drifting sand

Blowing sand occurs when the wind moves loose sand particles from one location to another, while drifting sand occurs when sand is already in motion and continues to move in the direction of the wind. Both blowing and drifting sand can have significant impacts on aviation activities. Sand particles in the air can reduce visibility, create turbulence, and cause damage to aircraft engines and other components.

Figure 1–3: Blowing sand

1.6 Aviation weather reports:

1.6.1 METAR, SPECI, TAF and COR:

METAR: is a format for reporting weather information

SPECI: is a special report of meteorological conditions issued when one or more elements meet specified criteria relevant to aviation.

elements meet specified criteria of importance to aviation. SPECI is also used to identify reports of observations recorded ten minutes after an improvement (in visibility, weather or cloud cover) to conditions above SPECI.

TAF: is a report for an aerodrome forecasting.

COR: is a code used when the METAR or SPECI is corrected.

Each of them has the following:

Location:

The location is indicated by either the ICAO (International Civil Aviation Organization) location indicator or another approved abbreviation.

Date/Time:

The day of month and the time of the report is given in UTC (Coordinated Universal Time) using six figures followed by the letter Z. The first two digits are the day of the month; the following 4 digits are the time in hours and minutes, e.g., 291741Z (time of report is 1741 on the 29th of the month UTC).

AUTO:

The abbreviation AUTO will be included when the report contains only automated observations.

Surface Wind:

The wind direction, given in degrees true rounded to the nearest 10 degrees, is the mean value over the sampling period which is normally ten minutes. A variable wind direction is given as VRB.
The wind speed, given in knots (KT), is the mean value over the sampling period. The maximum gust during the sampling period is reported when it exceeds the mean speed by 10 knots or more. It is indicated by the letter G which is followed by the gust value.
At selected aerodromes, an additional wind group will be given when the direction varies by 60 degrees or more during the sampling period. The group gives the extreme range of directions in clockwise order, e.g., 360V090.

Visibility:

The visibility is given in meters up to 9000 meters, with 9999 being used to indicate 10 kilometers or greater. When the visibility is estimated manually, two groups (the prevailing - the greatest visibility reached in at least half the horizon circle - and the minimum) will be reported when: the visibility is not the same in different directions and is not fluctuation rapidly; and the minimum visibility is not the prevailing visibility; and the minimum visibility is less than 1500 meters, or is between 1500 and 5000 meters and less than 50% of the prevailing visibility. In these cases, the prevailing visibility will be given first, followed by the minimum visibility with its direction (using one of the eight points of the compass) from the observing station e.g., 9000 2000N.
When visibility is given by an automated sensor (in fully **Auto**mated reports), only

one group will be reported, i.e., any variation in visibility that may exist will not be given.

Runway Visual Range (RVR):

RVR will be reported from aerodromes with RVR instrumentation whenever the RVR or the visibility are less than 1500 meters. It will be reported in the format RDD[r]/[n] V1 V1V1V1 [V[n]V2V2V2V2] [i]. The elements in [] are included only when applicable.

CODE	DESCRIPTION
R	A fixed indicator, denoting that RVR information follows.
DD	Designates runway threshold for which RVR is being reported.
r	Parallel runways will be distinguished by the letter L, C or R indicating the left, center or right runway, respectively.
/	A fixed separator.
n	will only be reported when the RVR is assessed to be one of the following: • greater than 2000 meters, in which case n will be reported as P, and the group will be reported as P2000; • greater than the maximum value which can be assessed by the system, and this maximum value is 2000 meters or less, in which case n will be reported as P, and VVVV will report the maximum value, e.g., P1700; • less than 50 meters, in which case n will be reported as M, and the group will be reported as M0050; less than the minimum value which can be assessed by the system, and this minimum value is 50 meters or more, in which case n will be reported as M, and VVVV will report the minimum value, e.g., M0100.
V1V1V1V1	Gives the last 10-minute average RVR value, except when the RVR has

	varied significantly during the 10 minutes in which case it gives the minimum 1-minute average value during this period (and is followed by V[n]V2V2V2V2).
V	A conditional indicator, included only when RVR has varied significantly during the last 10 minutes.
V2V2V2V2	Gives the maximum one-minute average value during the last ten minutes. Only included when RVR has varied significantly during the ten minutes
i	Gives any distinct RVR tendency over the sampling period – either U (upward), D (downward) or N (nil). Is not reported if tendency not available

Table 1-2: codes & description

Weather:

phenomena are reported using the codes listed in the tables on the left. Intensity is indicated for precipitation, dust storms, sandstorms and funnel clouds by appending:

- the prefix - for light, e.g. -DZ;
- the prefix + for heavy, e.g., +RA;
- no prefix for moderate, e.g., SHRA;
- When precipitation is reported with TS, the intensity indicator refers to the precipitation, e.g. -TSRA = thunderstorm with light rain;
- One or more codes may be grouped, e.g., +TSGR, -TSRASN.

Cloud:

Cloud height is given as a three-figure group in hundreds of feet above the aerodrome elevation, e.g., cloud at 700 feet is shown as 007.Cloud type is identified only for cumulonimbus and towering cumulus, e.g., FEW030CB, SCT045TCU. When an individual layer is composed of cumulonimbus and towering cumulus with a common base, the cloud is reported as CB only.

CAVOK:

The abbreviation CAVOK (Cloud And Visibility OK) is used when the following conditions are observed simultaneously:

- Visibility is 10 kilometers or more;
- No cloud below 5000 feet or below the highest 25NM minimum sector altitude, which-ever is the higher, and no cumulonimbus and no towering cumulus; and
- No weather of significance to aviation, i.e., none of the weather phenomena listed in the weather table.

Temperature:

Air temperature and dew point values are rounded to the nearest whole degree. Negative values are indicated by M (minus) before the numeral, e.g., 34/M04.

Pressure (QNH):

The QNH value is rounded down to the next whole hectopascal and is given using four figures prefixed by Q, e.g., 999.9 is given as Q0999.

Supplementary Information:

Supplementary information is used to report:

- Recent Weather – significant weather observed since the last report but not at the time of observation is given after the prefix RE, e.g., RERA;
- Wind Shear – reports of wind shear experienced on take-off or landing are given after the indicator WS, e.g., WS R16.

Remarks (RMK):

Indicator that marks the beginning of a section that contains information that is inserted by national decision and that is not disseminated at the international level.

Data Not Available:

Where a data group is not available, solidi will be reported in lieu of the missing group, e.g., //// for visibility, // for weather and ////// for cloud.

Element	Criterion
Wind Direction	Changes of 30° or more, the mean speed before or after the change being 20KT or more.
Wind Speed	Changes of 10KT or more, the mean speed before or after the change being 30KT or more
Wind Gust	•Gusts of 10KT or more above a mean speed of 15KT or more • Gust exceeds the last reported gust by 10KT or more
Visibility	When the prevailing visibility is below the aerodrome's highest alternate minimum visibility or 5000M, whichever is greater*
Weather	When any of the following begins, ends, changes in intensity, or is occurring at a routine reporting time: • thunderstorm • fog (including shallow fog, fog patches and fog at a distance) • hailstorm • dust storm • mixed snow and rain •sandstorm • freezing precipitation • funnel cloud • drifting snow •moderate or heavy precipitation • squall

Cloud	When there is BKN or OVC cloud below the aerodrome's highest alternate minimum cloud base or 1500FT whichever is greater*
Temperature	When the temperature changes by 5°C or more since last report
Pressure	When the QNH changes by 2hPa or more since last report
Other	• Upon receipt of advice of the existence of wind shear • The incidence of any other phenomenon likely to be significant

Table 1-3 : elements & criterions

Note:

Where no descent procedure is established for an aerodrome, the aerodrome's alternate ceiling and visibility are 1500 feet and 8 kilometers respectively.

1.7 Environmental parameters and indicators of instability:

1.7.1 Total Totals Index:

The Total Totals Index consists of two components, the Vertical Totals (VT) and the Cross Totals (CT). [1]

The VT represents static stability or the lapse rate between 850 and 500 mb. The CT includes the 850 mb dew point. As a result, TT accounts for both static stability and 850 mb moisture, but would be unrepresentative in situations where the low-level moisture resides below the 850 mb level. In addition, convection may be inhibited despite a high TT value if a significant capping inversion is present. [1]

Equation 1 : Total Totals Index

$$TT = VT + CT \qquad \textbf{(1)}$$

Equation 2 : static stability

$$VT = T(850mb) - T(500mb) \qquad \textbf{(2)}$$

Equation 3 : static stability includes the dew point

$$CT = Td(850mb) - T(500mb) \quad \textbf{(3)}$$

In degrees C, where T represents temperature at the indicated level and Td represents, dew point temperature. VT = 40 is close to dry adiabatic for the 850-500 mb layer. However, VT generally will be much less, with values around 26 or more representing sufficient static instability (without regard to moisture) for thunderstorm occurrence. CT > 18 often is necessary for convection, but it is the combined Total Totals Index that is most important. [6]

Equation 4 : Total Totals Index

$$TT = T\,(850\ mb) + Td\,(850\ mb) - 2[T(500\ mb)] \quad (4)$$

1.7.2 K Index:

The K index is a measure of thunderstorm potential based on the vertical temperature lapse rate, and the amount and vertical extent of low-level moisture in the atmosphere. [6]

Equation 5 : k Index

$$K = T\,(850\ mb) + Td(850\ mb) - T(500\ mb) - DD(700\ mb) \quad .$$

In degrees C, where T represents temperature, Td represents dew point temperature, and DD represents dew point depression at the indicated level.

In general, the higher the ambient or inflow K index value, the greater the potential for heavy rain. However, beware of low (less than 30) values of K.

Since the K index includes the dew point depression (i.e., difference between the temperature and dew point temperature) at 700 mb, dry air at this level will cause a low K value.

However, given moisture below 700 mb, unstable air, and a lifting mechanism, strong or severe organized thunderstorms, and even heavy rain, can still occur. Scattered diurnal convection occurring in an environment containing high K (and PW) values can cause a quick burst of very heavy rain. [1]

1.7.3 Convective Available Potential Energy (CAPE):

CAPE assumes Parcel Theory, in that a rising parcel exhibits no environmental entrainment, the parcel rises (moist) adiabatically, all precipitation falls out of the parcel (no water loading), the parcel pressure is equal to the environmental pressure at each level.

Parcel Theory can have significant errors, especially for large parcel displacements, at cloud edges, and for significant water loading. However, the method often works quite well in the undiluted core of a thunderstorm updraft.

CAPE represents the amount of buoyant energy available to accelerate a parcel vertically, or the amount of work a parcel does on the environment.

CAPE is the positive area on a sounding between the parcel's assumed ascent along a moist adiabat and the environmental temperature curve from the level of free convection (LFC) to the equilibrium level (EL).

The greater the temperature difference between the warmer parcel and the cooler environment, the greater the CAPE and updraft acceleration to produce strong convection. [1]

Equation 6 : Convective Available Potential Energy

$$CAPE =_{LFC}{}^{EL}\ g\{T_{parcel} - T_{envir} | T_{envir}\}\ dz\ . \qquad (6)$$

In Joules/kg. The "**{**" symbol here represents a vertical integration between the LFC (level of free convection, above which the parcel is warmer than the environment, i.e., the parcel is positively buoyant and will rise) and the EL (equilibrium level, below which the parcel is warmer than the environment). [1]

1.8 Conclusion:

This chapter introduced and defined meteorology in aviation, including meteorological parameters and conditions, observation and forecast reports... and basically everything related to the topic covered in the following ones.

CHAPTER 2 REGIONAL CLIMATE

2.1 Introduction :

The aim of this chapter is to define the climate of Tamanrasset using the average meteorological parameters observed over a given period. For the determination of these averages, it is necessary to have a large amount of observation data. This chapter summarize all information that had been given from the National Office of Meteorology also discuss the observed data that is represented on graphs.

2.2 Regional climate:

The Wilaya of Tamanrasset, by its geographical position in the middle of the central Sahara, is a desert area. Located, on average, between latitudes 19°N and 28.5°N, the wilaya of Tamanrasset only benefits from low annual rainfall ranging from 10 mm (extreme south) to 115 mm (heights of Assekrem).

Figure 2–1 : the position of Tamanrasset

Temperatures under the effect of the high altitude, the region has a mountainous climate with very mild temperatures in summer with average highs around +35°c at Tamanrasset and +25°c at Assekrem. The winters are particularly colder at Assekrem where the average minimums are from +2°c to +3°c.

The thermal regime (temperatures) is also very contrasting across the wilaya due to the large extent of the region and the significant variation in its topography (from 250 m to 2700 m).

In the Hoggar region, the temperatures are very mild and very bearable in summer when they are around 35°C. In the extreme southern zone, In-guezzam region, temperatures are excessively high and exceed 40°C for 5 months of the year (April to September); in the northern part of the wilaya, region of In-salah, temperatures are very high between May and August. The absolute minimum at Assekrem is -13 °c and at Tamanrasset of - 4 °c.

Temperatures under the effect of the high altitude, the region has a mountainous climate with very mild temperatures in summer with average highs around +35°c at Tamanrasset and +25°c at Assekrem. The winters are particularly colder at Assekrem where the average minimums are from +2°c to +3°c.

The rainfall regime in this area is very contrasted in time and space due to the nature of the precipitation. The northern part of the wilaya, beyond 25°N, benefits much more from the precipitation of the temperate regime (which comes from the North) and the majority of the rains occur in Winter (October to March), they represent 75% of the annual total (the annual average is 15 mm).

Some years, the total annual rainfall in this northern part of the wilaya can be zero (year 1970 and 1983 in In-Salah).

In the central part (the Hoggar) and the extreme south of the wilaya, rainfall generally occurs during the summer period (May to September).

In the Hoggar massif, rainfall varies significantly from one place to another due to the influence of the mountain range: in Tamanrasset the annual average is 52 mm and in Assekrem (50 km to the north) 116mm.

2.3 Climatological averages of airport station:

The station is located in a desert rock (Hoggar) region between the equator and mid-latitudes and represent the arid climate. In summer, the climate of Tamanrasset is influenced by monsoon flux.

The first Surface meteorological observation started in 1925 (at Tamanrasset Town).

The NMO's statical documents, shows the following climatological information:

2.3.1 The temperatures:

The monthly average of temperatures varies from 12.7°C in January to 29.5°C in June/July, these last two months have practically the same average. During the summer period, from May to September, the averages are very close to within 2°C, from October they drop steadily until December with an average of 14.0°C. The average annual temperature in Tamanrasset is 22.2 °C.

The average maximum temperatures present the same form (pace) as the average temperatures with an increase from January (20.2°c) to 35.0°c in June/July, they vary little until September and then decrease rapidly from October. The average annual maximum temperature is 28.5°C. The absolute maximum reaches 40.0°C.

The average minimum temperatures range from 5.1°C in January to 22.8°C in July. The annual average is 14.9°C. The absolute minimum reaches -03.0°C.

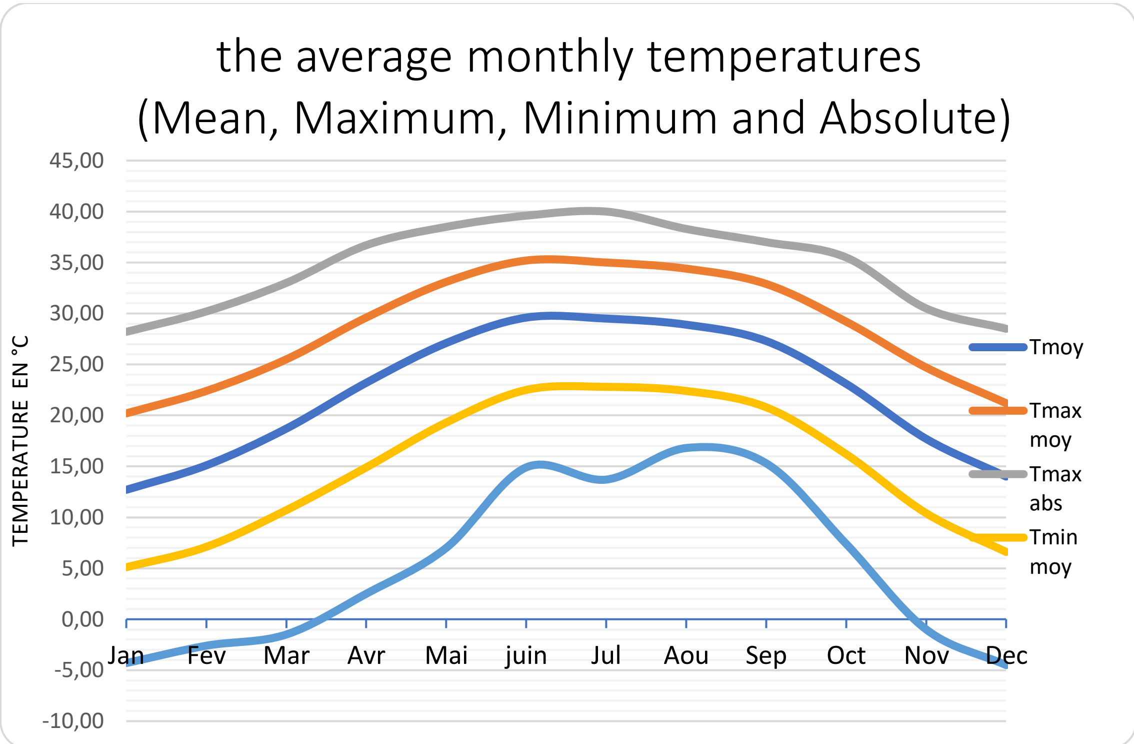


Figure 2–2 : the average monthly temperatures [2]

T_{moy}: mean monthly temperature;

$T_{max\ moy}$: average maximum temperature;

$T_{max\ abs}$: absolute maximum temperature of the month;

$T_{min\ moy}$: average minimum temperature;

$T_{min\ abs}$: absolute minimum temperature of the month.

2.3.2 The Wind:

The winds are not too strong in this region with an annual average of 4 m/s (14 km/h). The strong wind values are observed only during the period of passage of rain clouds in the summer period.

2.3.3 The Evaporation:

They are closely related to temperatures and wind speeds. The annual total of evaporation is 4354 mm (more than 4 m). The maximums are observed in the summer period with high temperatures.

2.3.4 The Insolation:

The insolation represents the number of hours of appearance of the sun per day. It has an annual total of 3363 hours (out of 4380 theoretical hours) or 77% sunshine. This shows that more than ¾ of the time, the sun is visible in the sky.

The daily averages are around 9 hours. In summer, sunshine is lower due to heavy cloud cover associated with rain.

2.3.5 The Humidity

Humidity is very low in this Saharan region far from water sources such as seas and rivers. The annual humidity is 21%, it decreases below 20% in the summer period due to the drying effect of high temperatures. Humidity increases only during rainy periods.

2.4 Meteorological phenomena of Tamanrasset:

According to the local meteorological station the most characteristic meteorological phenomena of the Tamanrasset climate are sand mist and thunderstorms. These two phenomena mainly occur in the summer period from May to September following the rise of the African monsoon in the Sahel region.

2.4.1 The haze:

It is characterized by a suspension of fine dust particles in the lower layers up to the middle atmosphere depending on the intensity of the phenomenon. The sand mist is transported from the source areas; it is lifted by the phenomenon of thermal or dynamic convection up to high altitude and then transported by strong wind currents.

Following the general circulation and the subsidence zones (downward movement), the sand is transported in the lower layers to constitute the sand mist.

In the majority of situations observed, sand mist forms during the night when the weather conditions are more stable with a very light to calm wind, it dissipates during the afternoon when the wind picks up.

Figure 2–3 : Haze

In Tamanrasset, this phenomenon observed from the month of April, the visibilities reduced very significantly after the good winter period, which extends from November to February when the visibilities are excellent.

Frequencies (in %) of low and good visibilities:

It is assumed that low visibilities are those less than or equal to 15 km (VV≤15km) and good visibilities greater than or equal to 40 km (VV≥ 40 km).

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
VV ≤15 km	04	07	20	35	38	38	25	29	23	06	04	02
VV ≥40 km	87	79	49	24	19	20	32	29	28	56	78	87

Table 2-1 : visibilities per months [2]

According to this table, we see that low visibilities (VV≤ 15 km) become very frequent from the month of April with an occurrence of 35% (11 days in the month) and is accentuated during the months of May and June with 38% each.

The average frequency of low visibilities between April and September is 31%, i.e., almost 1/3 for each month (01 day out of 3) and around 84 days in the year.

Note: The Very low visibility: VV < 5 km.

In meteorology, the visibility threshold of 5 km is very important to note because it determines the landing conditions of aircraft at airports, particularly in very rugged areas with significant relief such as Tamanrasset. In the summer period, visibilities below this threshold have the following frequencies:

	May	June	July	August	September
VV< 5km	07	12	08	12	05

Table 2-2: visibilities per summer period [2]

On an annual average, we have a total of 16 days (out of 365) of VV < 5 km. On some days, the haze reduces visibility to less than 1 km, which causes breathing difficulties for some people allergic to dust.

2.4.2 Thunderstorms:

Storms, such as haze, occur in the summer period, particularly in the afternoons with maximum thermal convection. During the afternoon, the cumuliform clouds develop very quickly above the mountains and cause very violent thunderstorms to burst and which can cause lightning strikes.

On an annual average, the number of stormy days is 18 with a significant variation from one year to another.

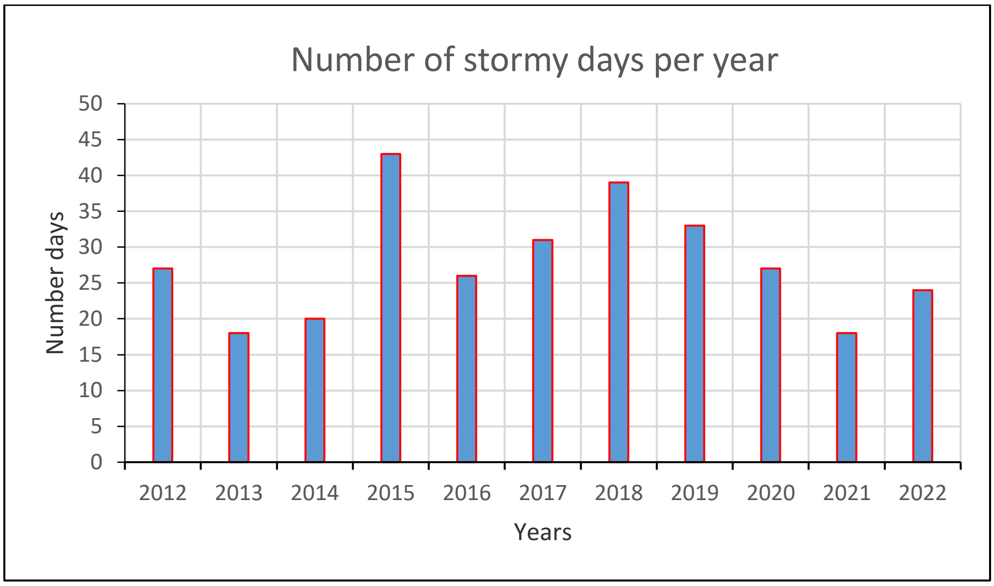


Figure 2–4 : Number of stormy days per year [2]

2.4.3 Precipitations:

Rainfall in the Hoggar region generally occurs between May and September, in connection with the African summer monsoon. The rainiest months are August and September with monthly averages of 9 to 10 mm.

Although rainfall is relatively rare in winter, but it can occur during certain years when the disturbances from the north of the country descend towards these regions as in March 1988 (52 mm) and March 2015 (47 mm).

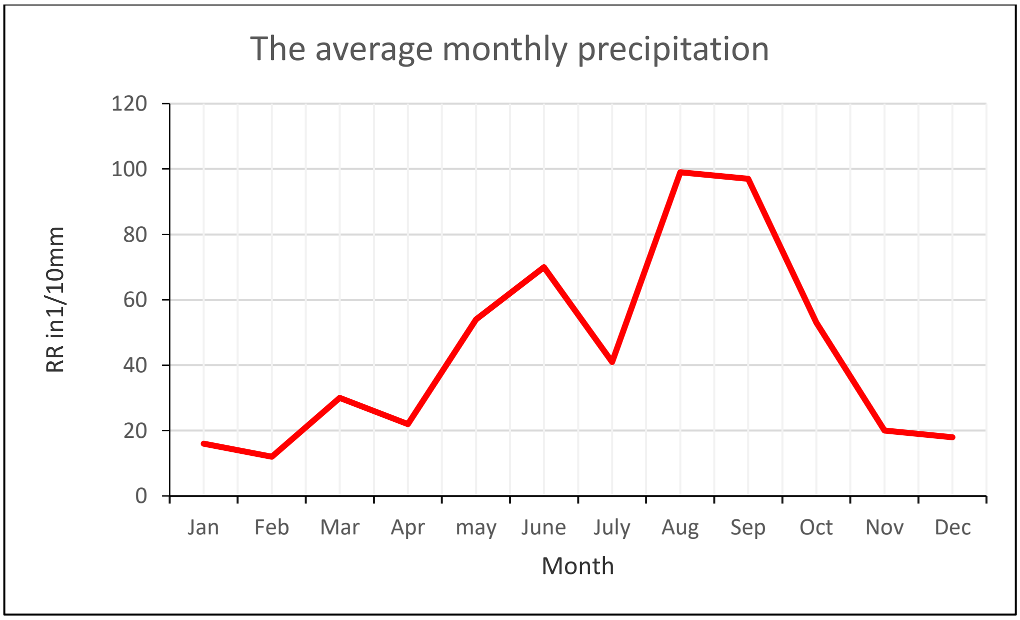


Figure 2–5 : the average monthly precipitation [2]

RR: average monthly precipitation

2.4.4 Annual totals and number of rainy days:

The rains in the Hoggar occur mainly in the summer period from May to September following the rise of the monsoon in the region (in relationship with the rise of the FIT (Inter Tropical Front) over the Sahel region).

The annual totals for this phase of the year show approximately 65% of the year-to-date. The rainiest months are August and September with monthly averages of 7 mm. summer precipitation is all in stormy form, it occurs in the afternoons in a very short time and often causes significant runoff from the wadis in the region.

The flows from these wadis are often very dangerous and can disrupt road traffic when they cross the national road. The average annual rainfall varies around 50 mm/year, but it is highly variable from one year to another. The wettest years are 2005, 1979 and 2002 where the totals exceed 100 mm and the driest are 1973, 1977 and 2001 with less than 10 mm.

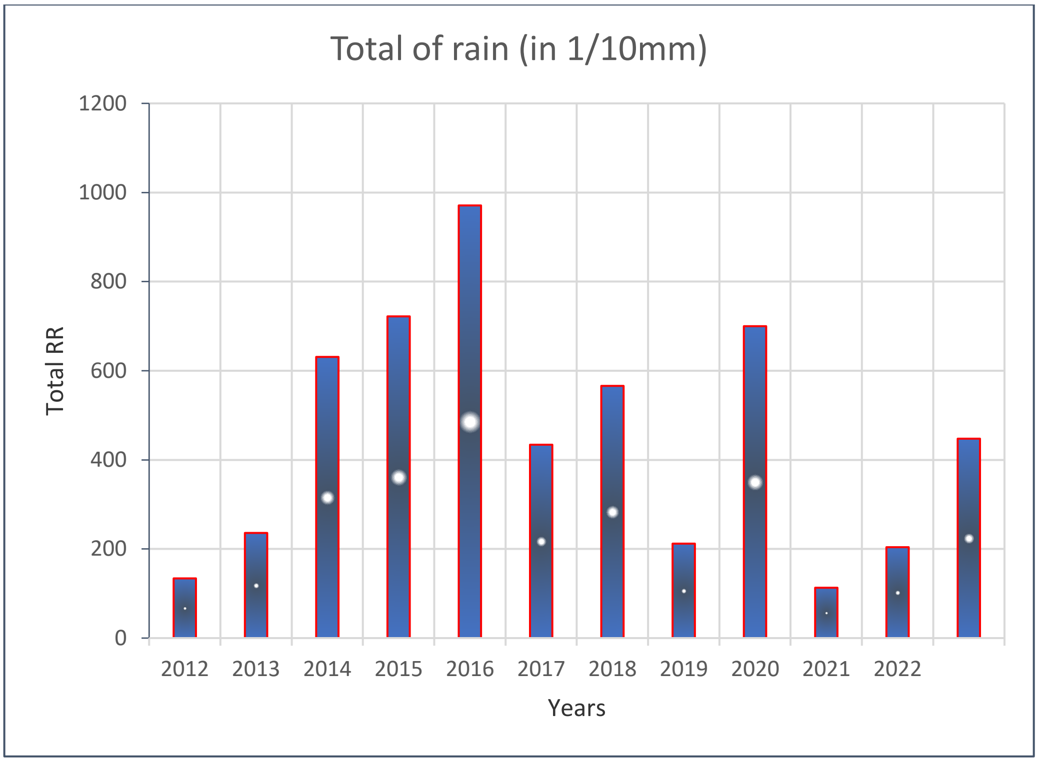


Figure 2–6 : Total of rain (in 1/10mm) [2]

2.5 Conclusion:

In conclusion, the Hoggar region has a mountainous climate, with phenomena such as rain, sand fog and thunderstorms happening mainly in the summer. They occur mainly after the onset of the African monsoon in the Sahel.

CHAPTER 3
DATA ANALYSIS

3.1 Introduction:

The study of the second chapter will mainly be about analyzing series of meteorological data (clouds and thunderstorms), their types, stage of formation, dissipation and their danger threatening aviation in Tamanrasset aerodrome.

The aerodrome of Tamanrasset (Aguenar Hadj-Bey Akhamok) is located 3.6 NM north-west of the town on the Hoggar with coordinates 22 48 40N;005 27 03E, at an altitude of 1377 m and a reference temperature of 29°C, surrounded by mountains; on the north side there is a high mountain range with the highest peak in Algeria at 3003m. It has two intersecting runways, IFR and VFR traffic allowed, it has a DVOR/DME, an ILS RWY 20 CAT 1, a DME co-located with glide path RWY20, an ILS RWY 08 CAT 1 and a DME co-located with glide path RWY08.

The aerodrome meteorological station is located near the airport, next to runway 20/02; it has three automatic stations (one at the intersection of runways (20/02) and (26/08), the second next to runway (20/02) and the third is at the station), which give accurate data, the station broadcasts METARs every 30 minutes.

3.2 Process of cumuliform clouds formation:

There are many processes involved in the formation of various clouds (convection, pornographic rise of air, frontal rise of air ... etc.).

Clouds form when warm, moist air rises and cools, causing water vapor to condense into visible droplets or ice crystals. Once they've formed, they can take on a variety of shapes and sizes, depending on the conditions in the atmosphere. However, cumulonimbus clouds are the only type of cloud under consideration in this study.

3.3 Cumulonimbus cloud:

Cumulonimbus is a dense, towering vertical cloud, typically forming from water vapor condensing in the lower troposphere. These clouds are capable of producing lightning and other dangerous severe weather, such as tornadoes, hazardous winds, and large hailstones.

The base of the cloud is often flat, with a very dark wall-like feature hanging below and may be only a few hundred meters above the surface.

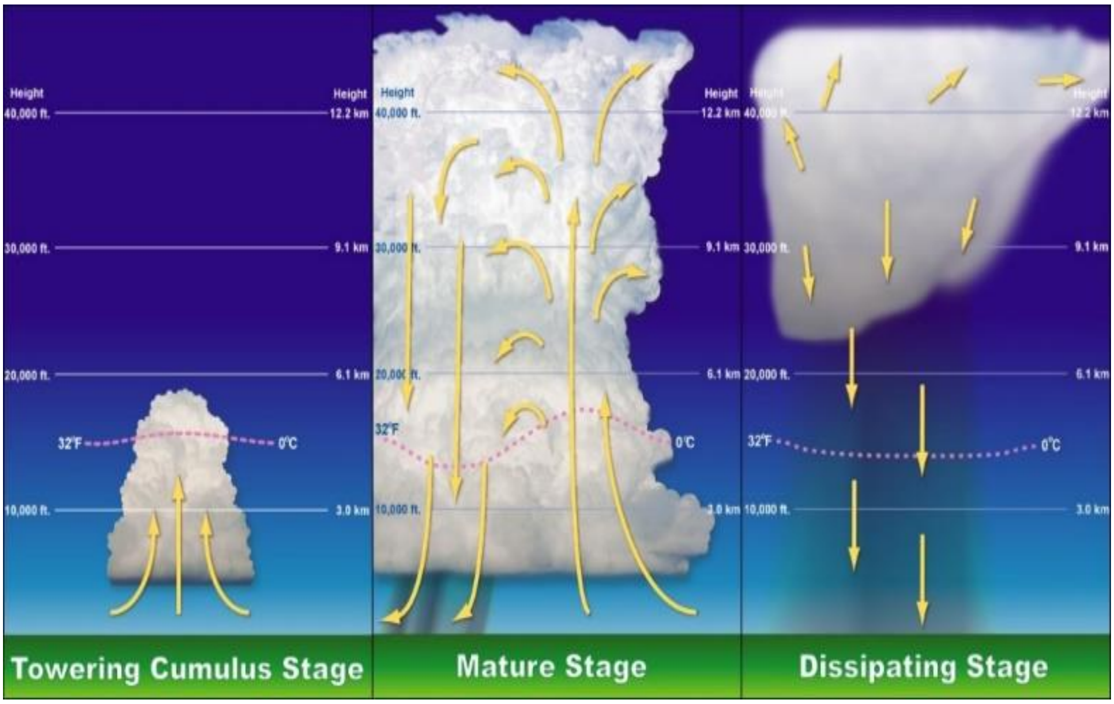


Figure 3–1 : diffrent stages of cumulonimbus cloud

The base of the cumulonimbus in the region is at an average height of 1200 m with a quite considerable extension that reaches 14000 m. Several dangerous phenomena accompany the formation and displacement of the cumulonimbus (wind in the form of gusts, thunderstorms, heavy rain in the form of showers, hail, lightning, squalls, sand sandstorms…

Their formation is a complex process influenced by many factors, the main ones being hot air masses, high levels of humidity …etc. Overall, cumuliform clouds in the site of Tamanrasset formed generally when:

3.3.1 Haze and sand mist:

are present to consisted support of clouds formation, it is a phenomenon where the air contains particles of dust and sand in suspension in the atmosphere coming from the Sahel region in Africa. If the conditions are favorable, it's more likely for a cumulonimbus to appear and it's very difficult to identify clouds in this situation, because the visibility is very low, the sky is dark and as soon as the calm wind turns into a gust, the cumulonimbus will be embedded in the suspended dust.

Figure 3–2 : Tamanrasset in June 6th, 2020

Figure 3–3 :Tamanrasset MTO station in the northern sector, northeast march20th,2023

3.3.2 Orographic clouds:

Form when air is forced to rise over an obstacle, such as high ground. This can happen in a stable or unstable environment. If the air is sufficiently warm and moist and the atmospheric conditions are unstable, the cloud can continue to grow vertically, leading to the formation of cumuliform clouds. These develop into cumulus humulus, cumulus mediocris, cumulus congestus, then cumulonimbus and sometimes thunderstorms and other phenomena.

Figure 3–4 : Formation of orographic cloud -cumulus humilis-

Figure 3–5 : development of orographic clouds - Cumulus-

Figure 3–6 : development of orographic clouds - Cumulonimbus-

3.3.3 Movement of the cloud system coming from another region:

-Coming mostly from the southern regions-

In some cases, cumulonimbus clouds can form outside the region and due to meteorological factors, that may result clouds movement.

in Tamanrasset the displacement of cumulonimbus is generally from southern area.

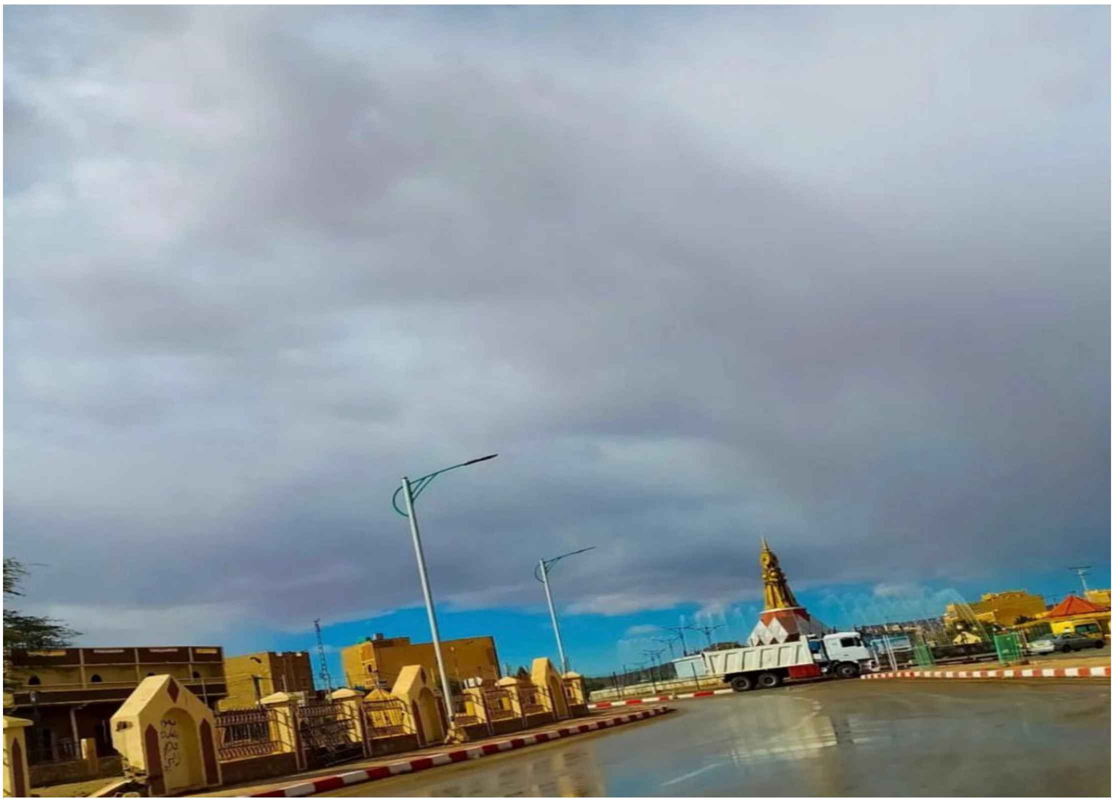


Figure 3–7 : cumulonimbus clouds coming from another region -TMR 2022-

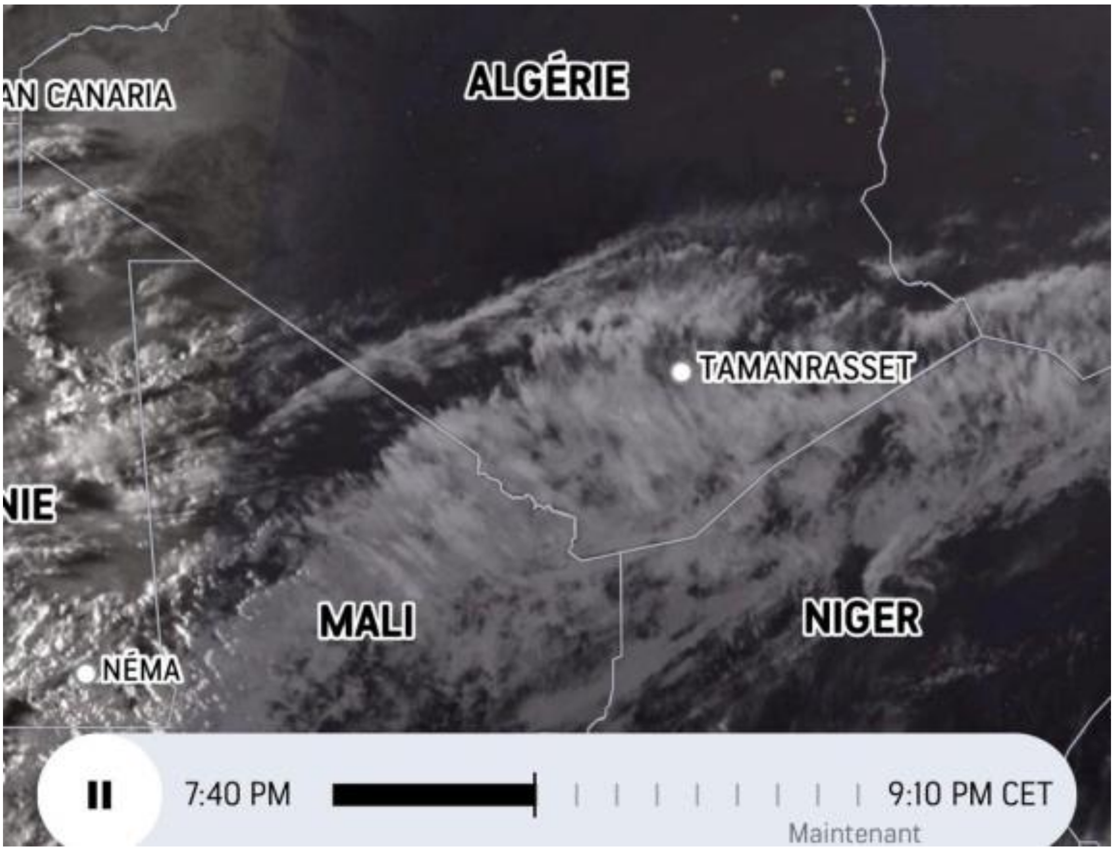


Figure 3–8 : clouds coming from south west regions

As an example, the following analysis illustrate how the cloud begins to form in region of Tamanrasset, from METARs sent on 25 July 2014:

- **Part one:**

25/07/2020 02:00	METAR DAAT 250200Z 14011KT 5000 SCT046 28/15 Q1017=
25/07/2020 02:30	METAR DAAT 250230Z 15013KT 2000 HZ SCT046 27/15 Q1017=
25/07/2020 03:00	METAR DAAT 250300Z 13008KT 2000 HZ SCT046 27/15 Q1017=
25/07/2020 03:30	METAR DAAT 250330Z 15009KT 1000 HZ SCT046 26/15 Q1017=
25/07/2020 04:00	METAR DAAT 250400Z 14012KT 0800 HZ SCT046 26/16 Q1017=
25/07/2020 04:30	METAR DAAT 250430Z 14011KT 0800 HZ SCT046 26/15 Q1018=
25/07/2020 05:00	METAR DAAT 250500Z 14009KT 0800 HZ SCT046 26/15 Q1018=
25/07/2020 05:30	METAR DAAT 250530Z 15007KT 0800 HZ SCT046 25/14 Q1018=
25/07/2020 06:00	METAR DAAT 250600Z 14008KT 0800 HZ SCT046 25/14 Q1018=

Table 3-1 : METAR

The situation was good before 2am, then visibility dropped sharply (5000m) by 3000m in 30min.

In this part, the only risk is reduced visibility.

- **Part two:**

25/07/2020 11:30	METAR DAAT 251130Z 26011KT 220V310 1000 HZ NSC 33/11 Q1019=
25/07/2020 12:00	METAR COR DAAT 251200Z 27013KT 0800 SA VV/// 33/12 Q1018=
25/07/2020 12:30	METAR DAAT 251230Z 27014KT 0800 SA VV/// 33/13 Q1018=
25/07/2020 13:00	METAR DAAT 251300Z 28014KT 0800 SA VV/// 34/13 Q1018=

Table 3-2 : -METAR-

The temperature is constantly rising, the wind is variable between 220° and 310°, the vertical visibility is not recognizable, and the horizontal visibility is always low. Eventually the haze turns into cloud.

Figure 3–9 : haze, march20th,2023

Figure 3–10 : appearance of cumulonimbus after haze, march20th,2023

- **Part three**

25/07/2020 13:30	METAR DAAT 251330Z 26013KT 230V290 1000 SA FEW040CB SCT046TCU 34/12 Q1017=
25/07/2020 14:00	METAR DAAT 251400Z 27016KT 240V300 2000 HZ FEW040CB SCT046TCU 34/12 Q1017=
25/07/2020 15:00	METAR DAAT 251500Z 26015KT 230V310 3000 HZ FEW040CB SCT046TCU 34/11 Q1016=
25/07/2020 15:30	METAR DAAT 251530Z 10029G43KT 080V140 0600 TSSQ BLSA FEW040CB SCT046TCU 29/13 Q1016=
25/07/2020 16:00	METAR DAAT 251600Z 10028G39KT 3000 TS DRSA SCT040CB SCT046TCU 26/15 Q1017=
25/07/2020 16:30	METAR DAAT 251630Z 07019KT 3000 TS DRSA SCT040CB SCT046TCU 26/14 Q1018=
25/07/2020 18:30	METAR DAAT 251830Z 08014KT 2500 TS FEW040CB SCT046TCU 24/17 Q1017 RERA=

25/07/2020 19:30	METAR DAAT 251930Z 17007KT 3000 TS FEW040CB SCT046TCU 24/16 Q1018=
25/07/2020 20:00	METAR DAAT 252000Z 18010KT 3000 HZ FEW040CB SCT046TCU 24/16 Q1018 RETS=

Table 3-3 : METAR

After 30 minutes, the sand haze (SA) began to dissipate and become haze (HZ), with the appearance of a cumulonimbus at 1200 m and a cumulus congestus at 1400 m. The associated phenomena were gusty wind, thunderstorm, squall, then high sand drifts becoming low sand drifts.

- Wind: The wind was initially moderate and variable around 230-310°; Nebulosity: of 4/8 Cumulus congestus cover at 1400 m and a cumulonimbus at 1200 m.

25/07/2020 13:30	METAR DAAT 251330Z 26013KT 230V290 1000 SA FEW040CB SCT046TCU 34/12 Q1017=
25/07/2020 14:00	METAR DAAT 251400Z 27016KT 240V300 2000 HZ FEW040CB SCT046TCU 34/12 Q1017=
25/07/2020 15:00	METAR DAAT 251500Z 26015KT 230V310 3000 HZ FEW040CB SCT046TCU 34/11 Q1016=

Table 3-4 : METAR *Wind & nebulosity

- Thunderstorms have begun.
  Gust: variable between 80° and 140°.
  Squall: the presence of that phenomenon affects pressure, temperature, humidity (tick in parameters) also the blowing sand is appeared.

25/07/2020 15:30	METAR DAAT 251530Z 10029G43KT 080V140 0600 TS SQBLSA FEW040CB SCT046TCU 29/13 Q1016=

Table 3-5 : METAR *TS SQ BLSA GUST

- The blowing sand became a Low drifting sand

25/07/2020 16:30	METAR DAAT 251630Z 07019KT 3000 TSDRSA SCT040CB SCT046TCU 26/14 Q1018=

Table 3-6 : METAR *DRSA

❖ In the evening Rain started with thunderstorms till night

25/07/2020 18:00	METAR DAAT 251800Z 08014KT 2500 TSRAFEW040CB SCT046TCU 24/17 Q1017=

Table 3-7 : METAR *RAIN

➢ **Final part:**

25/07/2020 22:00	METAR DAAT 252200Z 11004KT 3000 HZ FEW040CB SCT046TCU 23/18 Q1019=
25/07/2020 22:30	METAR DAAT 252230Z 11004KT 4000 HZ FEW046 SCT100 23/17 Q1019=

Table 3-8 : METAR

The cumulonimbus began to dissipate around 10pm, and visibility improved.

Hypotheses:

25/07/2020 15:30	METAR DAAT 251530Z 10029G43KT 080V140 0600 TSSQ BLSA FEW040CB SCT046TCU 29/13 Q1016=

Table 3-9 : METAR Hypotheses

In that case, it's assumed that:

- a scattered cumulonimbus and TCUs located in the east;

Figure 3–11 : the hypothesis represented on a geographical map

- Strong gust with variable squall between 80° and 140°;
- Relief located 15km from the runway (26.08);

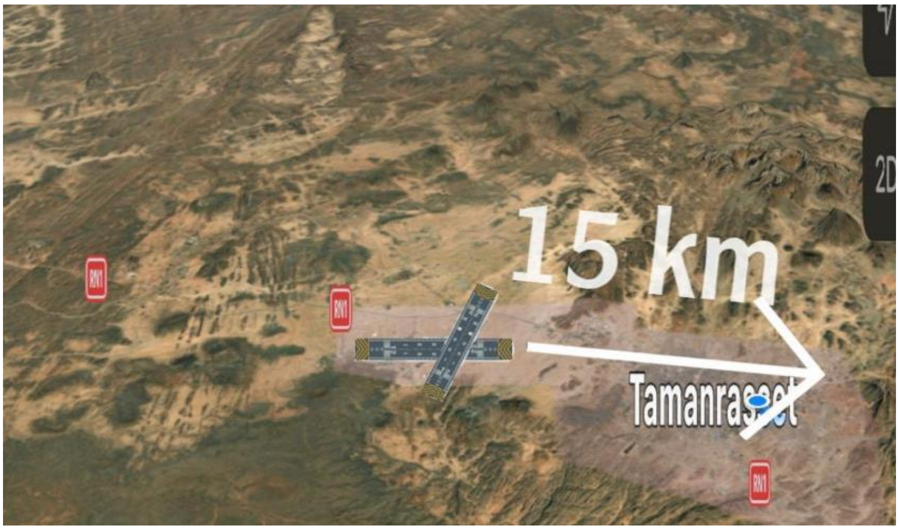


Figure 3–12 : illustration on maps

- Low visibility of 600m;
- Possibility of wind shear (due to the relief around the aerodrome);
- Presence of thunderstorms with high sand drift.

Note:

The airport of Tamanrasset is surrounded by high mountains in the north to the east, and the orientation of the runway threshold makes take-offs difficult and dangerous. In addition, cumulonimbus clouds tend to form in the evening and are characterized by fast moving clouds with a base of around 1000m.

Question 01: Is it possible to land on the 08 runway? And how serious is the situation?

- There is possibility to land on this runway however safety is not guaranteed.
- The case becomes serious when performing a go-around due to the existence of the relief located about 15km from the runway26/08 as shows the figure (3-12).

Question 02: Is it possible to use the runway (20/02)?

- The crosses wind is strong that make runway (20/02) not operational.

Question 03: What can we do if there is an emergency or a critical situation?

- Pilot should wait till the weather becomes good enough for any operation; or
- Manipulate a quite return flight.

3.4 Thunderstorms:

Thunderstorm is one or more sudden electrical discharges, manifested by a flash of light (lightning) and a sharp or rumbling sound (thunder), for their formation, three ingredients are needed: moisture, atmospheric instability, and usually an additional lifting mechanism.

They're associated with Cumulonimbus clouds, and are most often accompanied by turbulence, icing, lightning strikes, wind shear/wind gradient and precipitation that, when it reaches the ground, is in the form of a shower of rain, small hail or hail.

They have major impact on aviation, especially during the most critical flight phases: take-off and landing. Moreover, they reduce both terminal and in route airspace capacity.

Lightning is a luminous phenomenon that is accompanied by a sudden discharge of electricity from the atmosphere.

Figure 3–13 :thunderstorm in Tamanrasset

The dry noise or rumble that accompanies lightning is called thunder. This noise is due to the accumulation of clattering caused by the heating and sudden expansion of the air along the high-intensity electrical discharge. Lightning and thunder therefore occur simultaneously, but the observer perceives the lightning almost instantaneously due to the high speed of light (almost 300.000 km/s). Sound, on the other hand, travels at about 330 m/s and the sound of thunder reaches the observer after a time that depends on the observer's distance from the lightning's impact point.

Thunderstorm is therefore the result of several phenomena:

- A mature convective cell (cumulonimbus) ;
- Very rapid upward and downward movements, which cause very strong ionization of the air by friction, resulting in a very strong electric field;
- An electrical discharge: lightning;
- A dry noise or a dull roll: thunder.

These phenomena may be accompanied by other phenomena such as:

- Sudden precipitation in the form of intense showers (rain, snow, sleet, hail);
- Turbulence, which can be severe, both in and around the cumulonimbus;
- The ejection of cold air, which can result in strong wind gradients that are extremely dangerous for aviation.

Note:

A thunderstorm is always caused by existing of cumulonimbus cloud, but a cumulonimbus cloud does not always cause a thunderstorm.

Note:

For security of persons and materials, the meteorological station sends regulars messages METREPORTs, METARs every 30 minutes to the control service and SPECIs, issued when one or more elements meet specified criteria significant to aviation.

3.4.1 Thunderstorms in the region:

On an average based on 10 years of meteorological data analyzed, thunderstorms are more likely to occur in Tamanrasset during the summer months, from June to September. They can appear at any time of day but are more likely to be seen in the afternoon and evening, when the sun heats the ground, causing the air to rise and form storms.

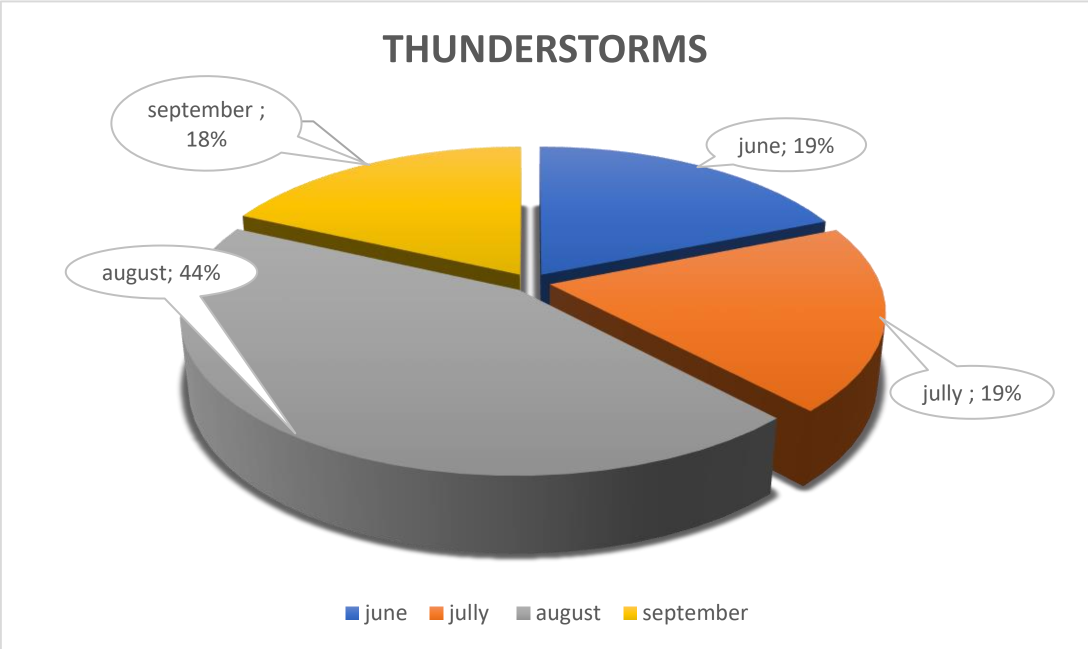


Figure 3–14 : thunderstorms graphical circle [2]

3.4.2 Danger of thunderstorms:

Flying through a thunderstorm can be hazardous due to several reasons. Thunderstorms can produce severe turbulence, low-level wind shear, low ceilings and visibilities, hail, lightning, and icing, which can be difficult to cope with, and if all these conditions arrive at once, it can be disastrous.

Lightning strikes can damage the aircraft's electrical systems, and hail can damage the engines. Icing can form on the aircraft's wings, which can reduce lift and increase drag, making it difficult to control the aircraft.

Thunderstorms with numerous lightning strikes indicate extreme updrafts and downdrafts inside it, which can cause friction and result in lightning strikes. Therefore, pilots should avoid flying through thunderstorms and take appropriate precautions to avoid them.

3.5 Real example of a critical situation and possibility of taking off or landing:

In the day of 31st august, 2014 the situation was considered critical. The meteorological parameters on that day were: a variable wind and temperature between 23°C and 33°C, a gust reached 40kt and a high humidity of 68%.

The meteorological station of Tamanrasset transmitted the following METARs:

31/08/2014 00:00	METAR DAAT 310000Z 10006KT 9999 FEW050 27/05 Q1018=
31/08/2014 01:30	METAR DAAT 310130Z 17017KT 0500 HZ FEW050 26/12 Q1018=
31/08/2014 03:30	METAR DAAT 310330Z 15007KT 120V180 0200 HZ FEW050 25/13 Q1019=
31/08/2014 05:30	METAR DAAT 310530Z 10004KT 0150HZ SKC 24/13 Q1019=
	Low visibility 150m
31/08/2014 07:30	METAR DAAT 310730Z 10004KT 070V140 0200 HZ SCT053 27/13 Q1021=
31/08/2014 10:00	METAR DAAT 311000Z 21008KT 180V250 0800 HZ SCT050TCU 30/14 Q1022=
31/08/2014 11:30	METAR DAAT 311130Z 20009KT 160V240 1000 HZ SCT053 31/14 Q1021=
31/08/2014 12:00	METAR DAAT 311200Z 22008KT 180V270 1200 HZ FEW053 32/13 Q1021=
31/08/2014 14:30	METAR DAAT 311430Z VRB09G29KT 1200 TSSQ HZ FEW040CB SCT050TCU 32/11 Q1020=
31/08/2014 15:00	METAR COR DAAT 311500Z 04026G40KT 2000 –TSRA PO SCT033CB SCT046 26/15 Q1020=
31/08/2014 15:30	METAR DAAT 311530Z 01023KT 7000 -TSRA SCT033CB SCT046TCU 23/14 Q1022=

31/08/2014 16:00	METAR DAAT 311600Z 04021G33KT 7000 TSRA SCT033CB SCT046TCU 25/14 Q1022=
31/08/2014 16:30	METAR DAAT 311630Z 33009KT 9999 TS SCT040CB SCT050 27/13 Q1020=
31/08/2014 17:00	METAR DAAT 311700Z 08006KT 060V160 9999 FEW040CB SCT050 26/16 Q1019=
31/08/2014 17:30	METAR DAAT 311730Z 04007KT 9999 FEW040CB SCT050 26/17 Q1019=
31/08/2014 20:00	METAR DAAT 312000Z 02010KT 8000 FEW040CB BKN050 23/15 Q1020=
31/08/2014 20:30	METAR DAAT 312030Z 04010KT 8000 BKN050 SCT100 24/14 Q1021=

Table 3-10 : METAR DAAT

In this case, the analysis of the circumstances is as follows:

- The visibility is variable, it decreases sharply when the fog appears, accompanied by cumulonimbus clouds;
- The presence of several phenomena that pose a risk to aviation and they include: thunderstorms, Squalls, whirlwinds, gusts and rain...In this situation, the pilot may decide to divert to one of the following alternate airports: Bordj-Badji Mokhtar (DATM), Ain Salah (DAUI) or Djanet (DAAJ).

Figure 3–15 : reouteing airports

It's important to check that the runway, at the aerodrome where landing is planned, is accessible and suitable for the aircraft, and that the weather conditions are not critical.

It was noted that the situation in the rerouting airports was:

- **METAR/SPECI from station of Bordj-Badji Mokhtar;**

31/08/2014 06:00	METAR DATM 310600Z 19018KT 3500 DRSA NSC 31/08 Q1008=
31/08/2014 08:10	*SPECI DATM 310810Z 19024KT 2500 DRSA NSC 34/13 Q1009=*
31/08/2014 09:00	*METAR DATM 310900Z 19030KT 0500 BLSA VV/// 36/17 Q1010=*
31/08/2014 10:00	METAR DATM 311000Z 20030KT 0700 DRSA VV/// 37/17 Q1010=
31/08/2014 11:04	*SPECI DATM 311104Z 21028KT 1500 BLSA VV/// 40/17 Q1009=*
31/08/2014 12:00	METAR DATM 311200Z 22022KT 3000 DRSA NSC 42/17 Q1009=
31/08/2014 18:00	METAR DATM 311800Z 21016KT 4000 DRSA FEW046TCU SCT100 41/20 Q1007=

Table 3-11 : METAR -DATM-

Presence of drifting and blowing sand leading to reduced visibility.

- **METAR from station of In Salah;**

31/08/2014 05:00	METAR DAUI 310500Z 06017KT CAVOK 32/01 Q1010=
31/08/2014 07:00	METAR DAUI 310700Z 06024KT 9000 DRSA NSC 34/00 Q1011=
31/08/2014 08:00	METAR DAUI 310800Z 05024KT 7000 DRSA NSC 36/01 Q1012=
31/08/2014 09:00	METAR COR DAUI 310900Z 06024KT 6000 DRSA NSC 38/04 Q1012=
31/08/2014 10:00	METAR DAUI 311000Z 06022KT 7000 DRSA NSC 41/06 Q1012=
31/08/2014 13:00	METAR DAUI 311300Z 07016KT CAVOK 44/07 Q1010=

Table 3-12 : METAR -DAUI-

Presence of drifting sand. In general, the visibility was good with a clear sky. However, this aerodrome may not be suitable for some aircraft such as the B737.

- **METAR from station of Djanet;**

31/08/2014 00 :00	METAR DAAJ 310000Z 08010KT CAVOK 28/10 Q1016=
31/08/2014 06 :00	METAR DAAJ 310600Z 00000KT CAVOK 24/09 Q1018=
31/08/2014 07 :00	METAR DAAJ 310700Z 00000KT CAVOK 27/11 Q1018=
31/08/2014 08 :00	METAR DAAJ 310800Z VRB02KT CAVOK 29/12 Q1019=
31/08/2014 09 :00	METAR DAAJ 310900Z 15010KT CAVOK 34/13 Q1020=
31/08/2014 10 :00	METAR DAAJ 311000Z 16012KT CAVOK 36/12 Q1020=

31/08/2014 12 :00	METAR DAAJ 311200Z 18010KT CAVOK 37/09 Q1019=
31/08/2014 15 :00	METAR DAAJ 311500Z 15008KT CAVOK 37/08 Q1016=
31/08/2014 16 :00	METAR DAAJ 311600Z 15006KT CAVOK 37/08 Q1016=
31/08/2014 17 :00	METAR DAAJ 311700Z VRB03KT 9999 FEW046 36/07 Q1016=
31/08/2014 18 :00	METAR DAAJ 311800Z 00000KT 9999 FEW046 34/06 Q1016=

Table 3-13 : METAR -DAAJ-

Clear sky and good visibility with no significant hazards. However, it could be dangerous for certain aircraft due to the mountainous nature of the region.

3.6 Conclusion:

In conclusion, according to the data, thunderstorms in the city of Tamanrasset are very active in summer and they are usually accompanied by haze, blowing sand or low drift. In this case, cumulonimbus clouds are not identified due to low visibility. They are also accompanied by dangerous phenomena that can affect aviation safety.

CHAPTER 4
MODELLING

4.1 Introduction:

This chapter will be treating Numerical weather forecast models leaded to predict what the atmosphere will be like at a specific time, by using historical data and known observations token from the NMO. The last part of this chapter was done on NMO in prediction department that is mainly about analyzing a group of meteorological maps, created by NWP models, concerning a crucial situation

4.2 Numerical weather prediction (NWP):

Numerical weather prediction utilises computer algorithms to provide a forecast based on current weather conditions by solving a large system of nonlinear mathematical equations, which are based on specific mathematical models. More specifically, these models define a coordinate system, which divides the earth into a 3-dimensional grid. The weather parameters such as winds, solar radiation, the phase change of water, heat transfer, relative humidity, and surface hydrology are measured within each grid and their interaction with neighbouring grids to predict atmospheric properties for the future.[3]

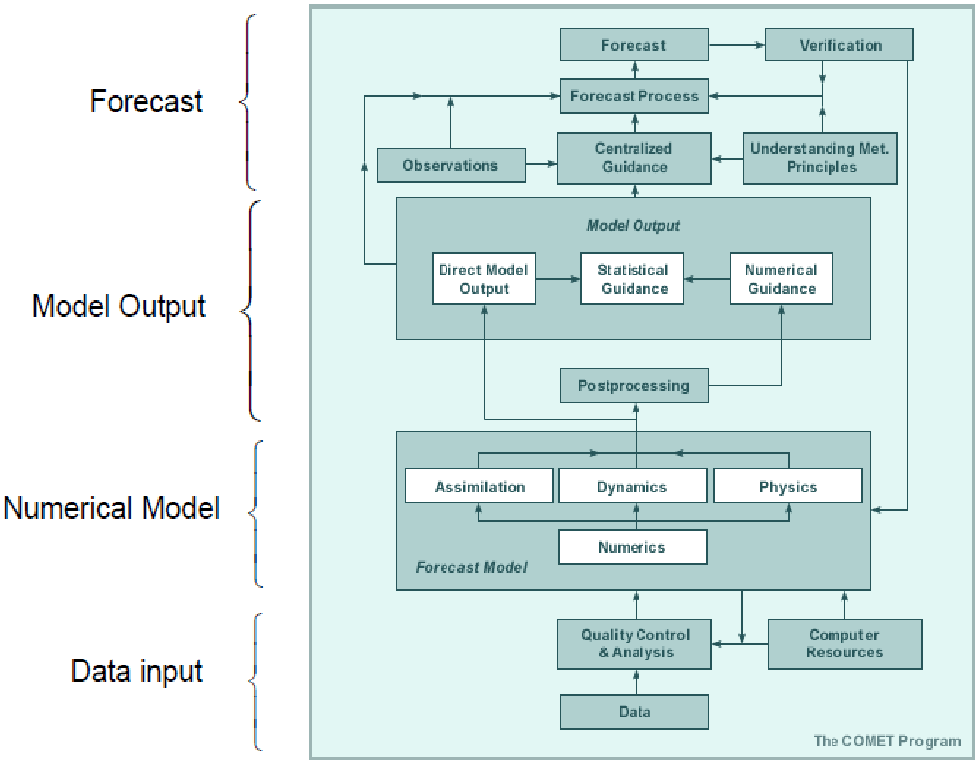


Figure 4–1 : NWP process

Forecasters have always understood the value of examining multiple numerical weather prediction (NWP) forecasts to help produce a more reliable forecast. One way they have done this is by comparing several different NWP forecasts. They may have compared regional to global model forecasts, or compared forecasts from the models used at different NWP centers.

They have also done this by comparing different model runs from the same model, looking at how new observations change model forecast outcomes over time.

Ensemble prediction is a relatively new tool for operational forecasting that allows for more rapid and scientifically based comparisons of multiple model forecasts.

Ensemble products, like the spaghetti diagrams below, use various statistical and graphical methods to combine multiple models runs, each based on slightly different initial conditions or using slightly different model configurations and/or parameterizations. By doing so, they can include information about the level of

uncertainty, the most likely forecast outcomes, and probabilities of those outcomes. With ensemble prediction products added to their NWP toolkit, forecasters now have another level of information that will help them make intelligent use of NWP guidance in their forecast process. [4]

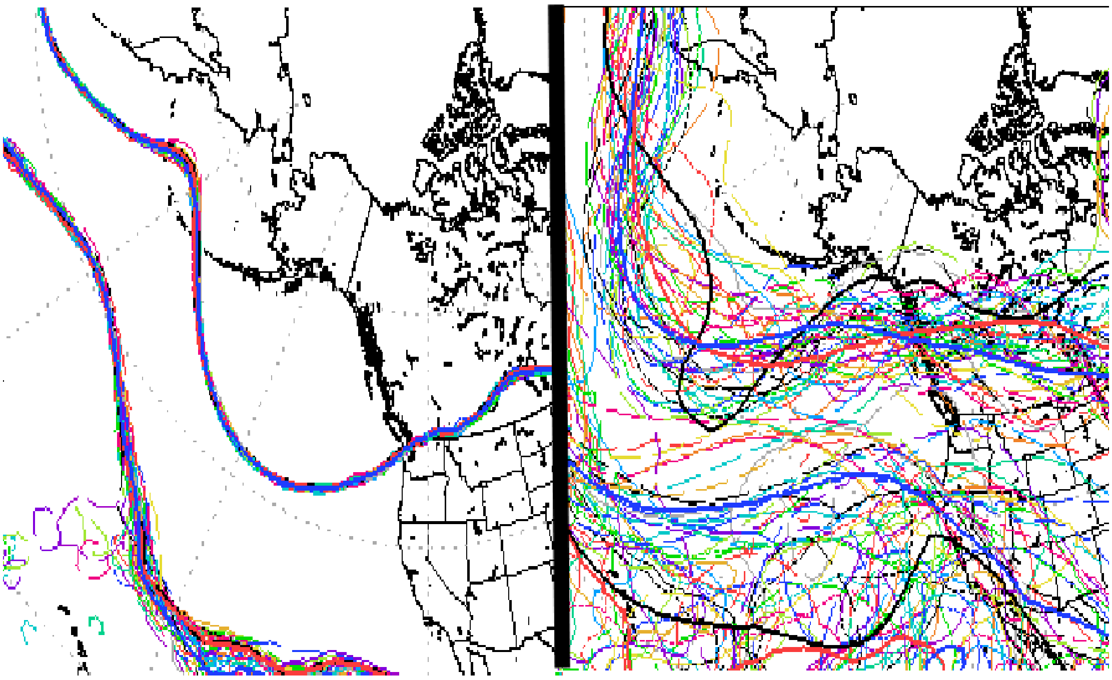


Figure 4–2 : spaghetti plot

4.3 Numerical prediction models used in the NMO:

Numerical models are currently considered essential elements in the environmental sciences especially in the weather and climate forecasting. It's divided on two basic types of weather models: Global and Local or Regional. Global models are used for the whole world, however local models are used for particular country or region of the world.

4.3.1 The ARPEGE model:

The ARPEGE (Action de Recherche Petite Echelle Grande Echelle) numerical planetary prediction model is an essential element for operational weather forecasting at Météo-France. It is an integrated part of the ARPEGE - IFS software, designed, developed and maintained in collaboration with ECMWF (European Center for Medium-Range Weather Forecasts).

This program includes most of the needed applications for operational numerical forecasting and ensures a strict consistency of the calculations in the analysis, the model and the post-processing. With a new release every 9 months or so, this code is constantly evolving to take advantage of the performance of supercomputers, to incorporate data from new observing systems, and to improve the components of the forecast model. The ARPEGE model has a much longer lifetime than any of its predecessors.

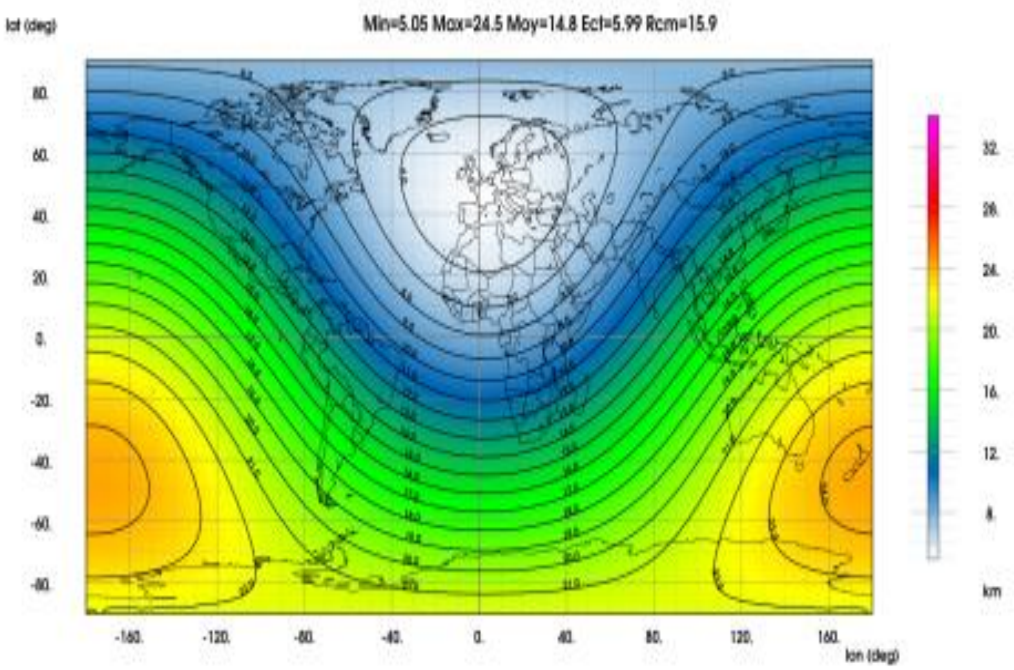


Figure 4–3 : ARPEGE resolution

4.3.2 The ALADIN model:

The operational version of ALADIN-Algeria covers all of Algeria. It has a horizontal resolution of 12Km × 12Km and a vertical resolution of 70 levels.

The first level is at 17 meters and the last at 65 kilometers. It is updated every 3 hours by the ARPEGE simulations to reflect the conditions on board.[10]

ALADIN (Air Limitée Adaptation dynamique Développement International) was developed as part of an international collaboration between Météo France and partner meteorological services to better monitor the behavior of weather phenomena such as: orographic lift, convection, sea or land breezes, etc. ....

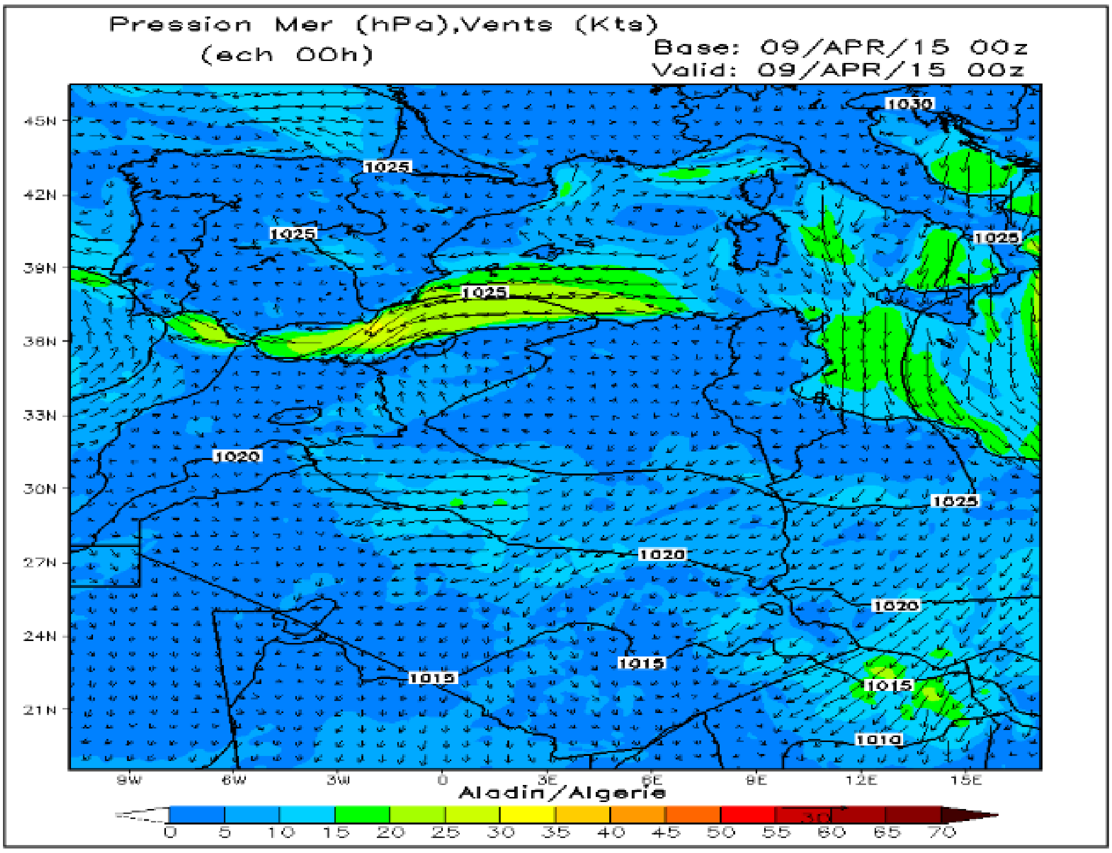


Figure 4–4 : ALADIN - pressure & Wind-

4.3.3 AROME weather model:

AROME, which stands for **A**pplication of **R**esearch to **O**perations at **ME**soscale, is a limited area numerical model operated by ONM since May 2014 for fine-scale modeling with a horizontal resolution of 3 km and a vertical resolution of 41 levels.[5]

The main feature of the model is that "it was designed to improve short range forecasts of severe events such as intense Mediterranean precipitations (Cévenole events), severe storms, fog, and urban heat during heat waves."

The AROME model is supplied by large-scale models such as ALADIN and ARPEGE. It uses non-hydrostatic (NH) dynamics of the ALADIN code and physical parameterizations of the MESO-NH research model.

In its operational configuration at NMO, AROME is coupled to the ALADIN model every hour and provides two forecasts per day, at 00 UTC and 12 UTC.

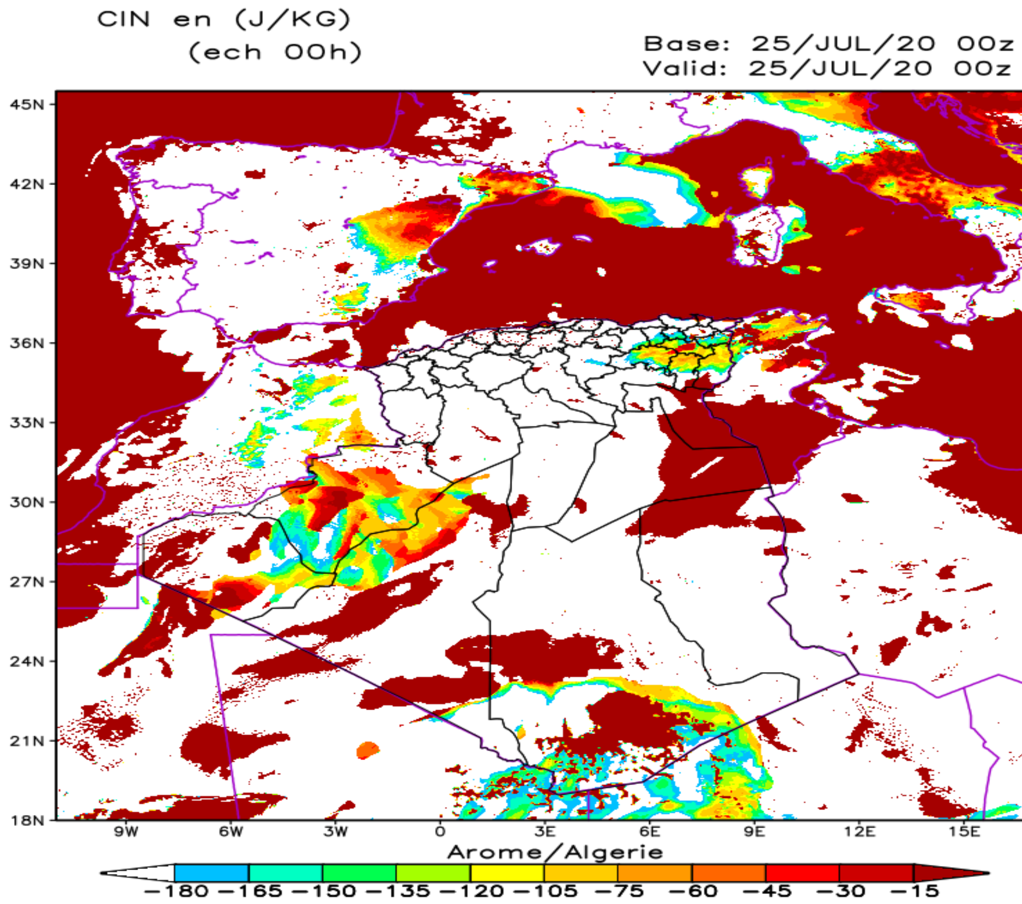


Figure 4–5 : AROME – Instability Indicator-

Note:

Tamanrasset region is not covered by the AROME weather prediction model

4.3.3.1 *Parametrization*:

Any important physical process that cannot be predicted directly requires a parameterization scheme based on reasonable physical or statistical physical or statistical representations.

Used to approximate the mass effects of physical processes that are too small, short complex or poorly understood to be represented explicitly by the governing equations and/or numerical methods.[4]

The graphic depicts some of the physical processes and parameters that are typically parameterized, both because they cannot be explicitly predicted in full detail in model forecast equations.

Figure 4–6 : Parameterization

4.3.3.2 Basic equations:

There is a complete set of seven equations with seven unknowns that governs the evolution of the atmosphere: Newton's second law or conservation of momentum (three equations for the three velocity components), the continuity equation or conservation of mass, the equation of state for ideal gases, the first law of thermodynamics or conservation of energy, and a conservation equation for water mass.[6]

In the Cartesian coordinate system, this set of equations can be written as follows:

Equation 7 : Conservation of masse

$$\frac{\partial \boldsymbol{\rho}}{\partial t} = -\vec{\nabla}.(\boldsymbol{\rho}\vec{\boldsymbol{V}}) \qquad \textbf{(7)}$$

Equation 8 : Ideal gaz law

$$P\alpha = RT \qquad \textbf{(8)}$$

Equation 9 : Energy conservation law

$$Q = C_P \frac{dT}{dt} - \alpha \frac{dP}{dt} \qquad \textbf{(9)}$$

Equation 10 : Conservation of water substance

$$\frac{\partial \boldsymbol{\rho q}}{\partial t} = -\vec{\nabla}.\left(\boldsymbol{\rho}\vec{\boldsymbol{V}}\boldsymbol{q}\right) + \boldsymbol{\rho}(\boldsymbol{E} - \boldsymbol{C}) \qquad \textbf{(10)}$$

These four equations can be written as:

Equation 11 : a vector form

$$\frac{d\vec{V}}{dt} = -\alpha\overrightarrow{\nabla_p} - \vec{\nabla}\boldsymbol{\phi} + \vec{\boldsymbol{F}} - \mathbf{2}\Omega \times \vec{\boldsymbol{V}} \qquad \textbf{(11)}$$

Where $\vec{\boldsymbol{V}} = (\boldsymbol{u}, \boldsymbol{v}, \boldsymbol{w})$ represents the velocity of air, **t** is arbitrary time, **α** is specific volume, **ρ** is density, **p** and **T** are pressure and temperature, **Φ** is geopotential height, **q** is the water vapor mixing ratio, **Q** is heating, **E** and **C** represent evaporation and condensation, respectively, **R** is the gas constant, and $\vec{\boldsymbol{F}}$ is the friction force.[6]

4.4 Case of study:

All the analysis below are made with the limited area Model (AROME), which is used by Algerian Meteorological Office

The month of July 2020 was characterized by the passage of a rainy-stormy activity over Tamanrasset, this situation of July 25 is considered among the most important meteorological situations which marked the Hoggar region, from the point of view of dangerous atmospheric phenomena for the aviation.

For the study of this situation, the AROME model in predicted fields, is chosen, given the availability of its data (archives / Grip) and also its good behavior in relation to this situation.

4.4.1 Analysis of the situation and results:

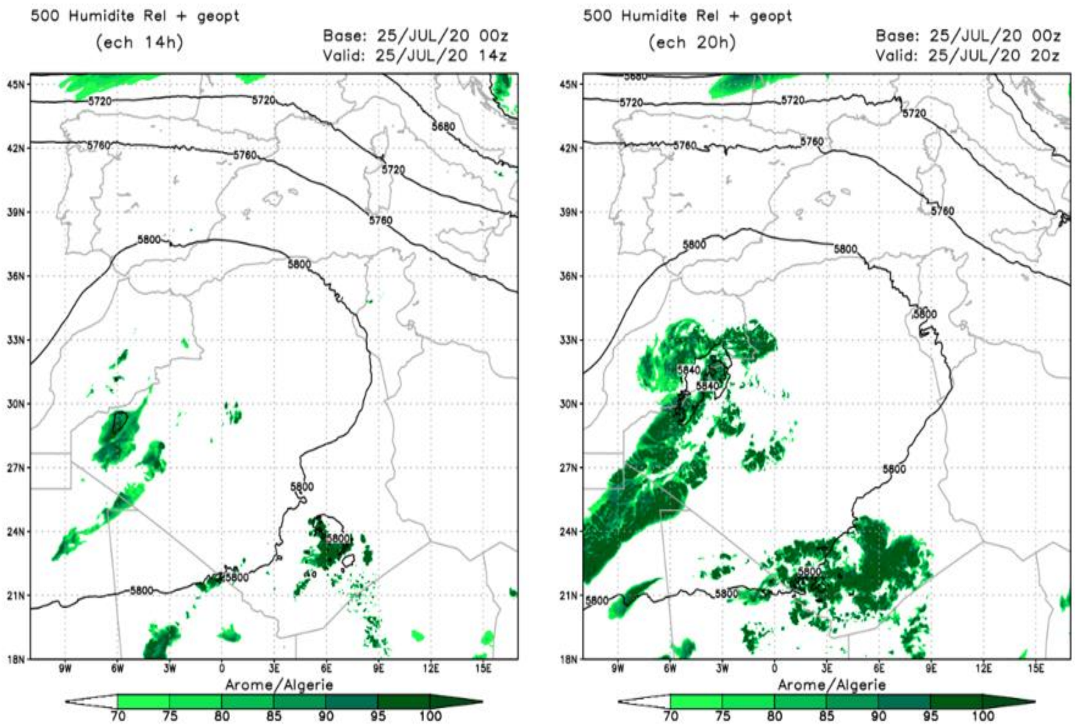


Figure 4–7 : Humidity Rel +geopt (500hPa)

At 500 hpa, a relative geo-potential minimum of around 5800 mgp deepened in the Hoggar region and persisted throughout the afternoon of July 25 with a slight south-westward trend in evening, this low was associated with cold air (-4 to -6 degrees Celsius) and fairly high humidity as -figure “4-7” shows.

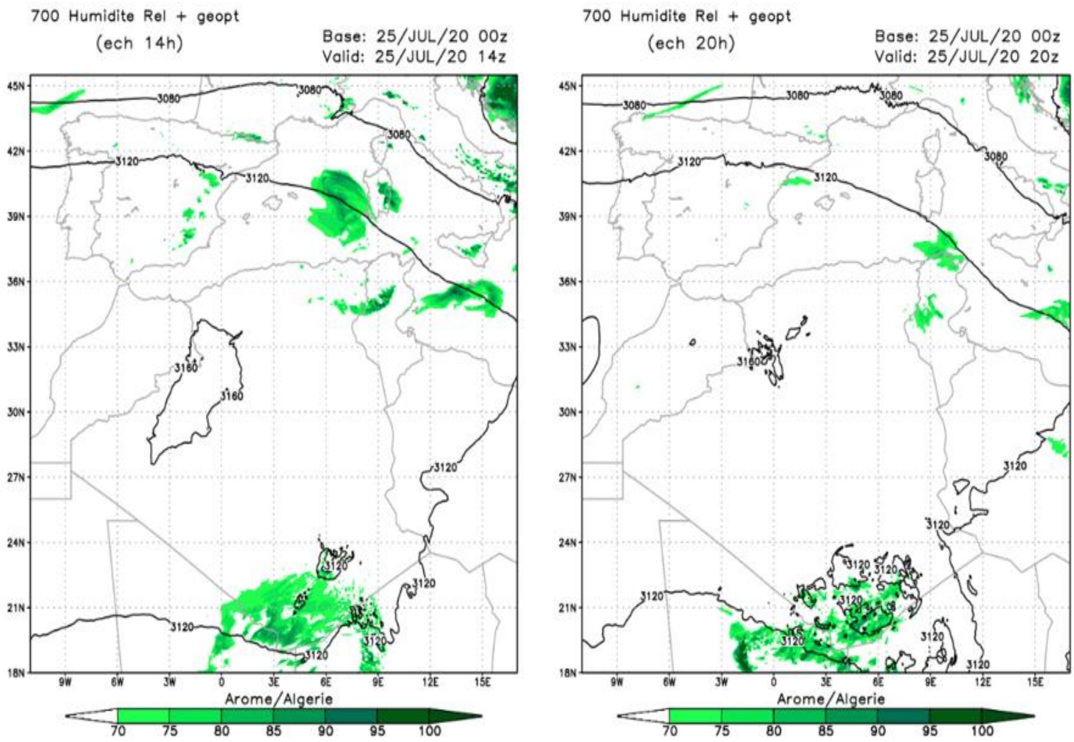


Figure 4–8 : Humidity Rel +geopt (700HPA)

The figure"4-8" shows that at the 700 hpa level of the, the system proceeded identically with that of the 500 hpa, for the digging (3120 mgp) and the movement in the evening towards the south-west of the region.

Resume:

The study of nebulosity charts, show the strong presence of humidity in all layers of the atmosphere in region of Tamanrasset, in general and especially around the airport, in the afternoon and evening of July 25th, 2020. That means that we can find trace of Cumulonimbus because it starts in the low layer and go up to high layer of atmosphere.

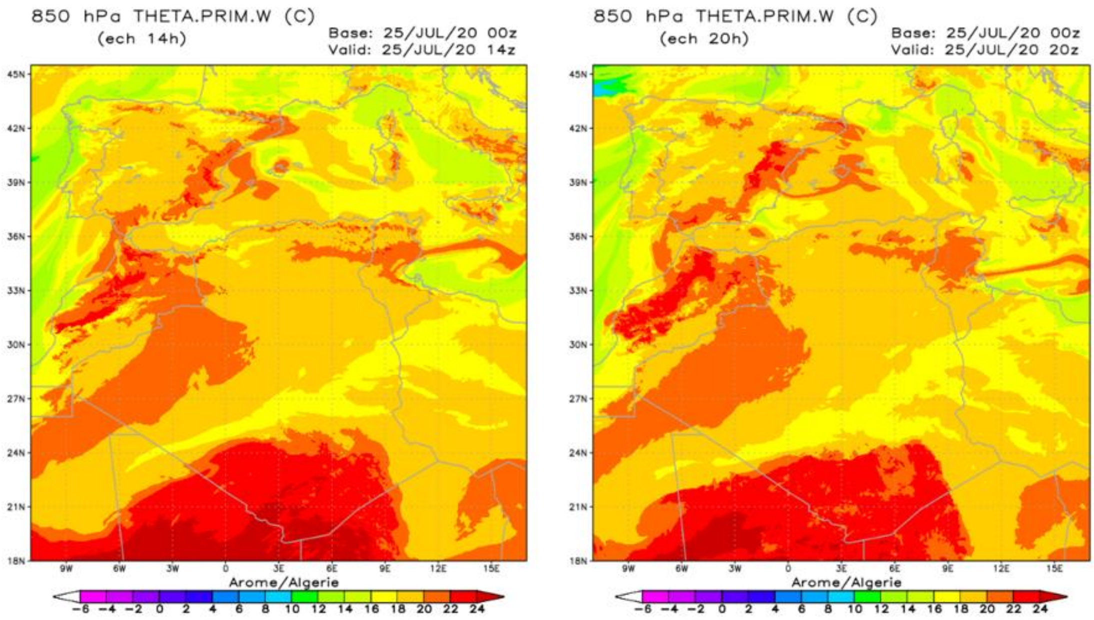


Figure 4–9 : AROME –THETA.PRIM (850HPA)

At 850 hpa, we notice from the figure4-3, a good advection of hot air (20 to 22 degrees Celsius in Theta Prime W).

Surface fields:

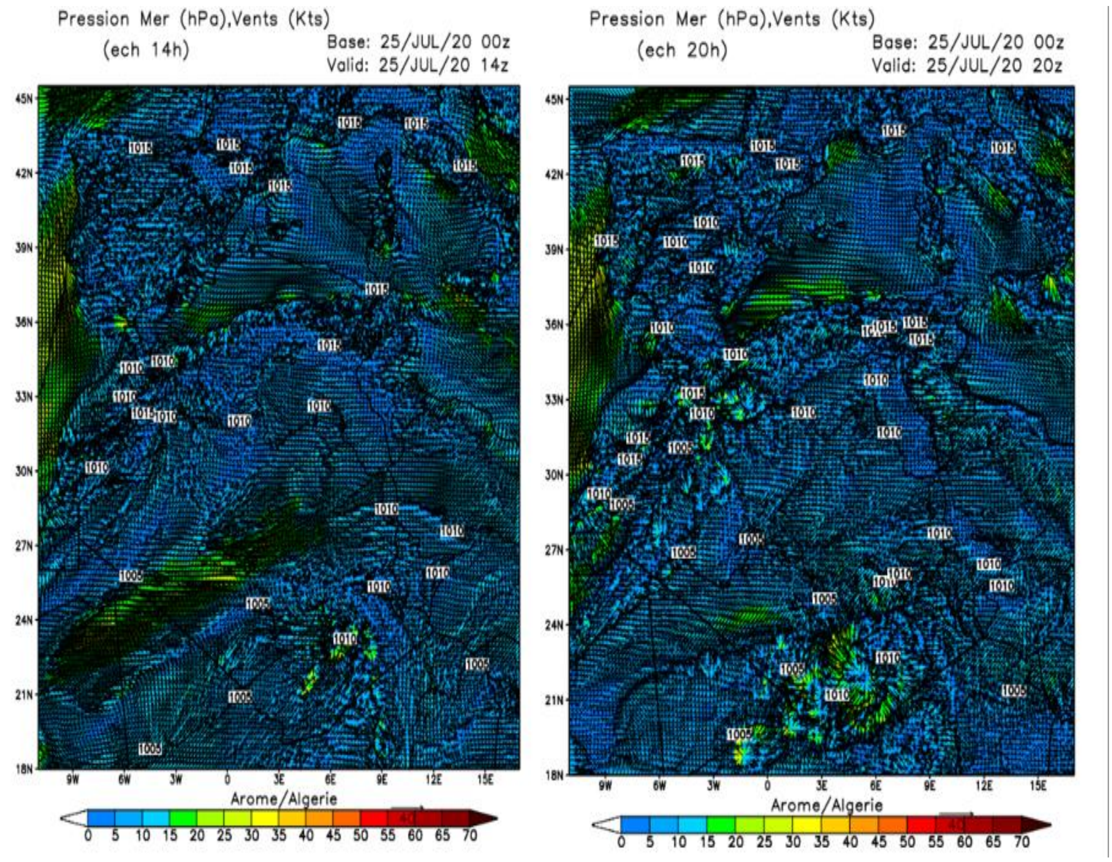


Figure 4–10 : AROME – Sea pressure (hPa). Wind (Kts)

Low pressure conditions characterized the Tamanrasset region on July 25th, 2020 with a deepening of around 1010 hpa on the Hoggar and 1005 hPa towards the extreme south, therefore a strong pressure gradient was established over the region, in generating strong gusts of wind (35 to 45 kts).

This depression was accompanied by high values of CAPE (convective potential energy available) over the region with a maximum reaching 1000 j/kg in the afternoon of July 25, the figures 4-10 & 4-11 represent the situation.

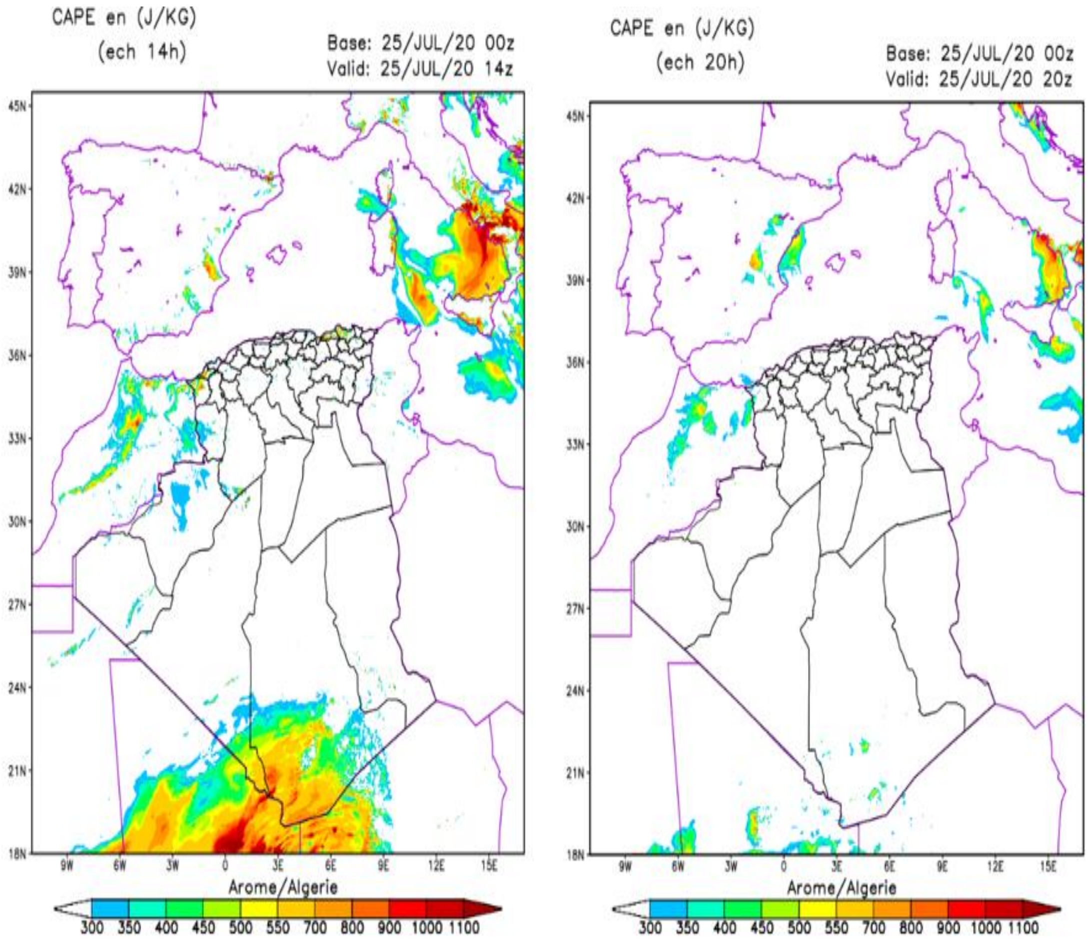


Figure 4–11 : AROME – CAPE en (J/KG)

4.4.1.1 The interaction between the upper fields, the lower layers and the surface:

The geopotential minimum at 500 hpa and the cold air associated with it was found to be coupled, i.e. the low level anomaly (advection of warm air at 850 hpa) , associated with the depression on the surface, it positioned itself downstream of the geo-potential minimum at 500 hpa during the afternoon of July 25, this positioning generated a lot of lift (strong vertical speeds), in the atmospheric column and strong convection (strong Cap), which explains the heavy stormy rains that were recorded in the area on July 25, 2020. This explains very well the amount of rain recorded at the Tamanrasset station.

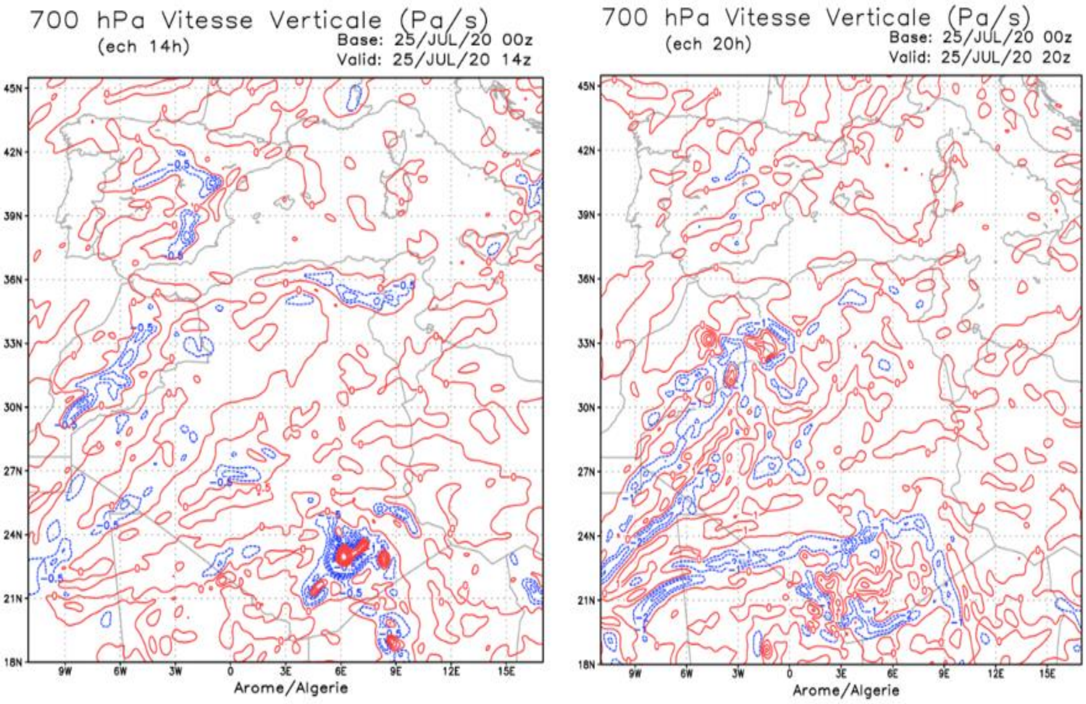


Figure 4–12: AROME – Vitesse Vertical (Pa/s) 700 hPa

From the figure “4-12” the vertical speed at 700 hPa, we have more chance to see the highest values, opposite the signal is less in the 500 hPa layer. According to this region and the period of summer where Tropopause can go up to 13 or 14 Km, we can conclude that there is strong chance to have development of Cumulonimbus because of vertical movements due to strong convection.

RESULT:

It also shows the presence of wind shear, this means that around cumulonimbus we can have strong winds gust which can influence negatively on aviation.

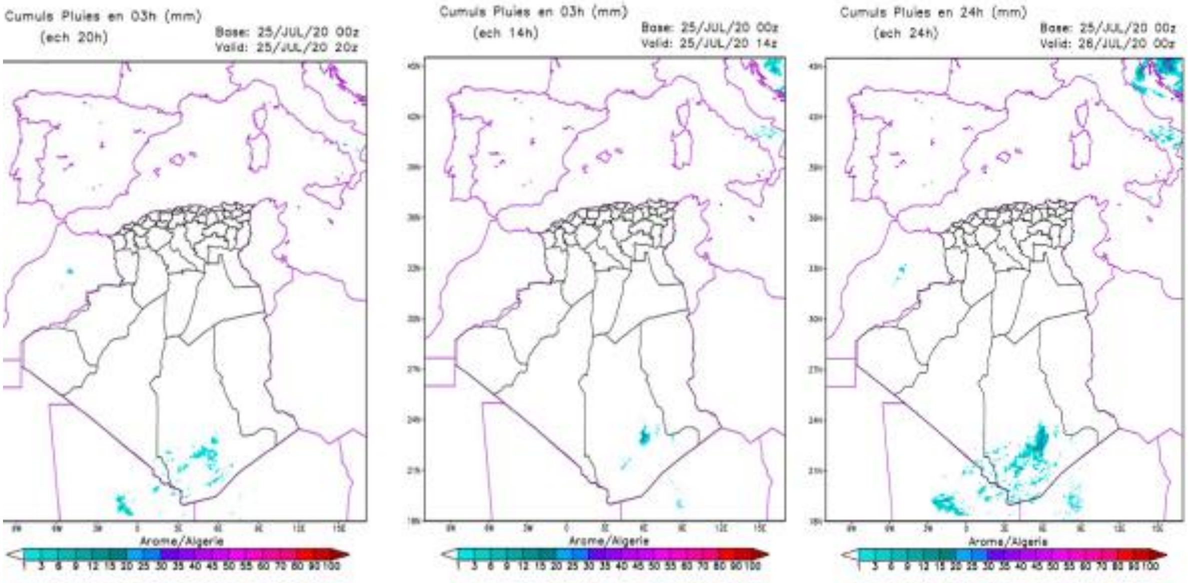


Figure 4–13: AROME – Cumuls Pluies(mm)

The figure “4-13” shows the next 24 hours, that there are chances of moderate to heavy rainfall over Tamanrasset, between 25 and 30 mm of rain are forecasted by the model, which is very significant for this region in this period of year in only 24 hours.

This situation (Wind shear” figure “4-14”, Wind gust, Thunderstorms, sandstorms and precipitation) is very usual common in this period of year at Tamanrasset, it`s due for the presence of FIT (Intertropical Front) as it’s represented by the figure “4-15”.

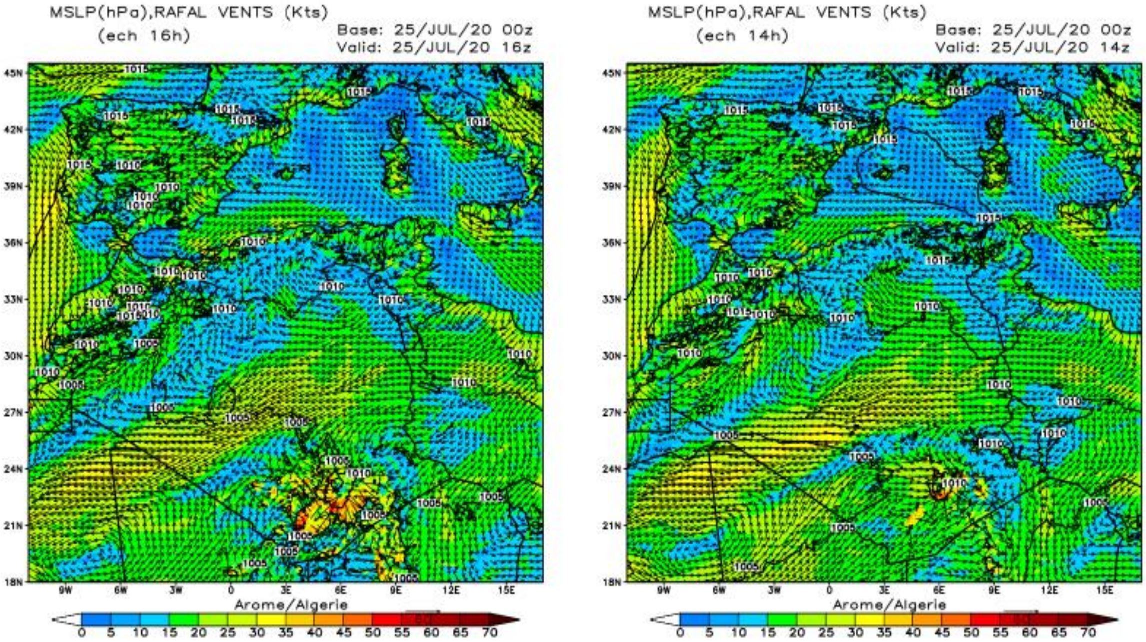
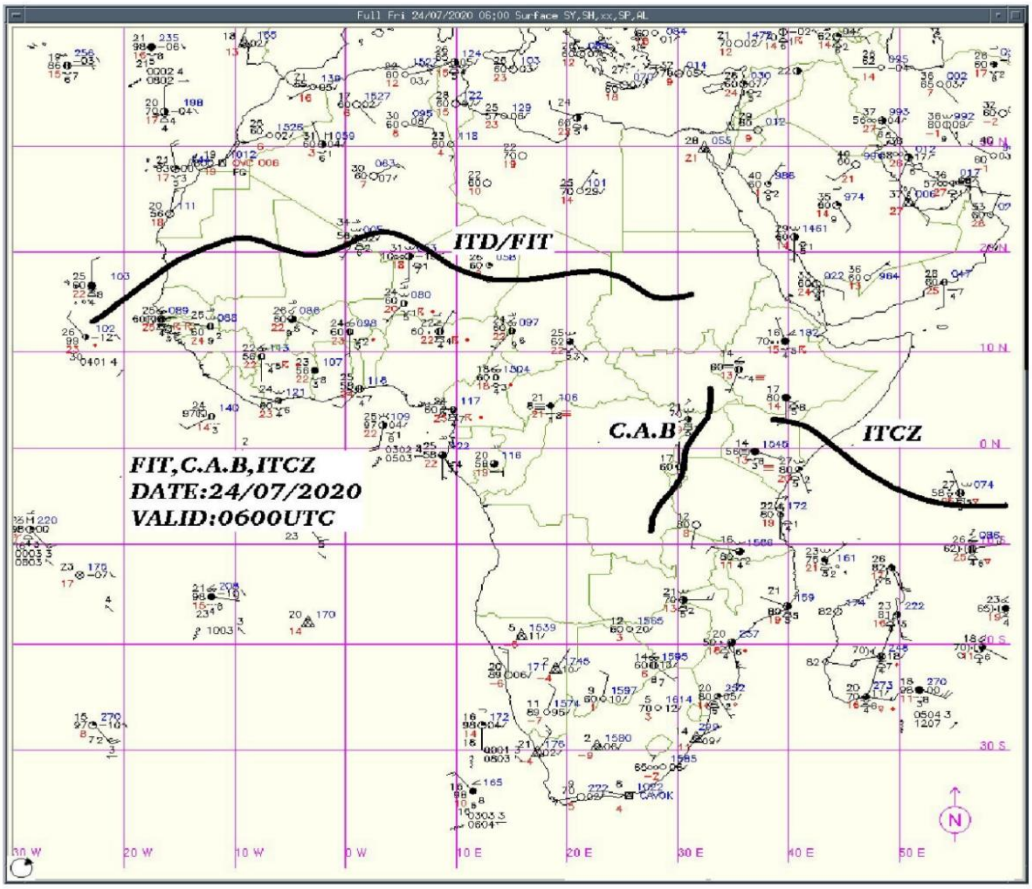


Figure 4–14 : Wind shear and MSLP

MEAN POSITION OF THE ITD ON
FRIDAY, JULY 24, 2020 AT 0600 UTC



Tabulated positions of the ITD: 24th July 2020

Date	15W	10W	5W	0	5E	10E	15E	20E	25E	30E
24/07/2020	19°04'N	21°17'N	19°54'N	20°41'N	21°48'N	18°31'N	17°18'N	17°44'N	17°23'N	15°32'N

Figure 4–15 : mean position of the ITD on 24/07/2020 at 06:00 UTC

4.5 Conclusion:

In conclusion, models can help to predict phenomena by displaying on maps a group of weather indicators in a given region. In our case, we were able to predict thunderstorms and determine the severity of the danger that could be caused by a cumulonimbus and thunderstorm cells by using the AROME model.

GENERAL CONCLUSION

The mountainous climate of Tamanrasset and the reliefs surrounding its aerodrome constitute a difficult area for an aircraft facing a critical weather case, especially thunderstorms dense activity in summer after the onset of African monsoon, which are accompanied by haze, blowing sand or low drift.

As it is known, AROME's model coverage extends only in the northern part of Algeria, and due to its importance regarding thunderstorms prediction it was one of the main factors this search is made.

This study has shown that the use of AROME model is based on performing data assimilation and known observations to forecast over a limited area. It has been also defined the instability indicators such as the K index, and the thunderstorm indicators as Convective Available Potential Energy, to better identify storms, their severity, and predict their risks. Thus ensures the safety of aircrafts and passengers.

After the research carried out, it was concluded that the strategic location of Algeria imposes to enhance the aviation security in the whole territory.

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