Space Weather and Conventional Weather for Civil Aviation in Low Latitude

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AGENDA

I. INTRODUCTION

II. ICAO CONCEPT FOR GNSS

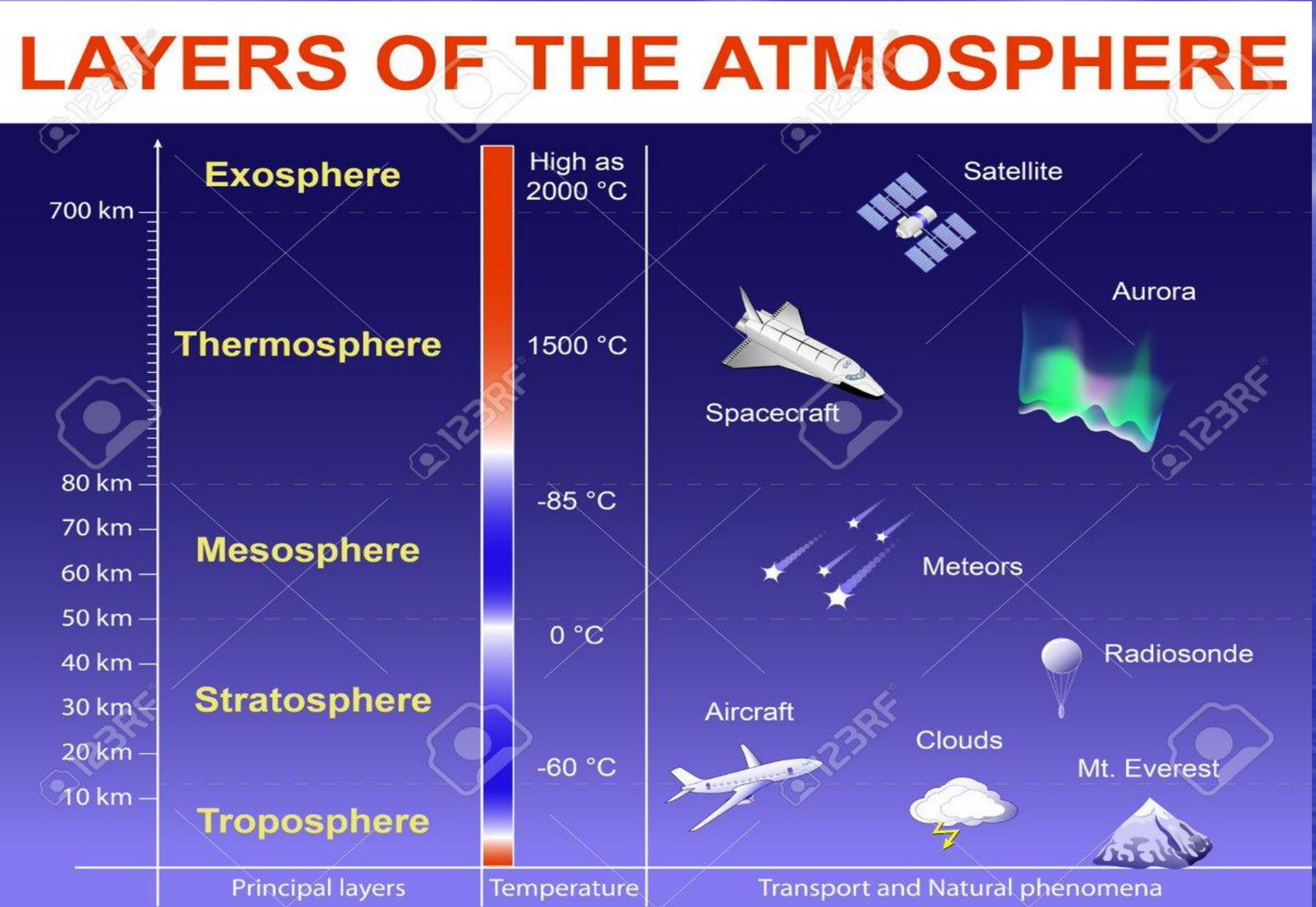
III. SPACE WEATHER

IV. IONOSPHERE EFFECTS OVER GNSS IN LOW LATITUDE (PROPOSALS)

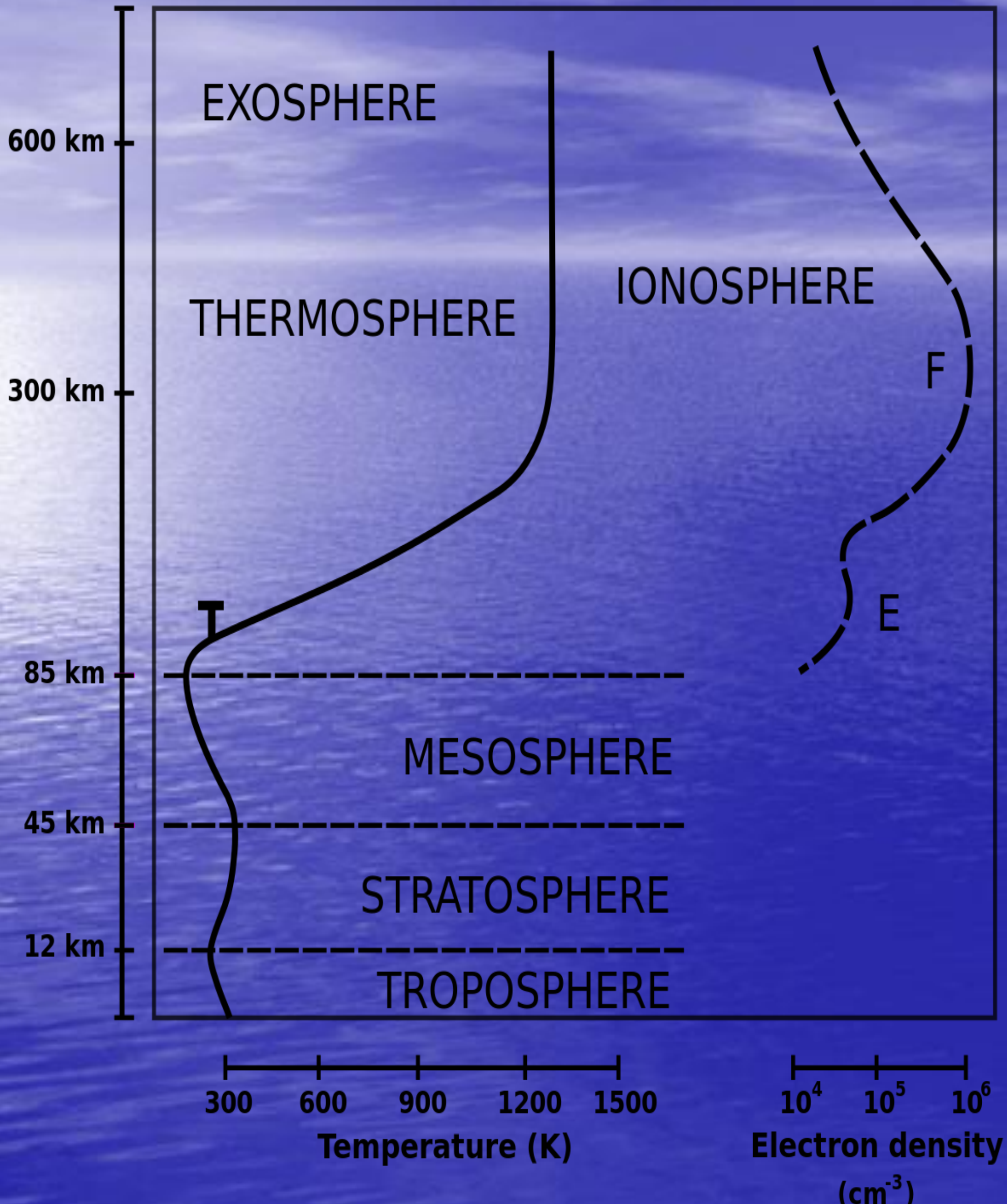
V. CONVENTIONAL WEATHER AND ITS EFFECTS

VI. REMARKS

I. INTRODUCTION



IONOSPHERE

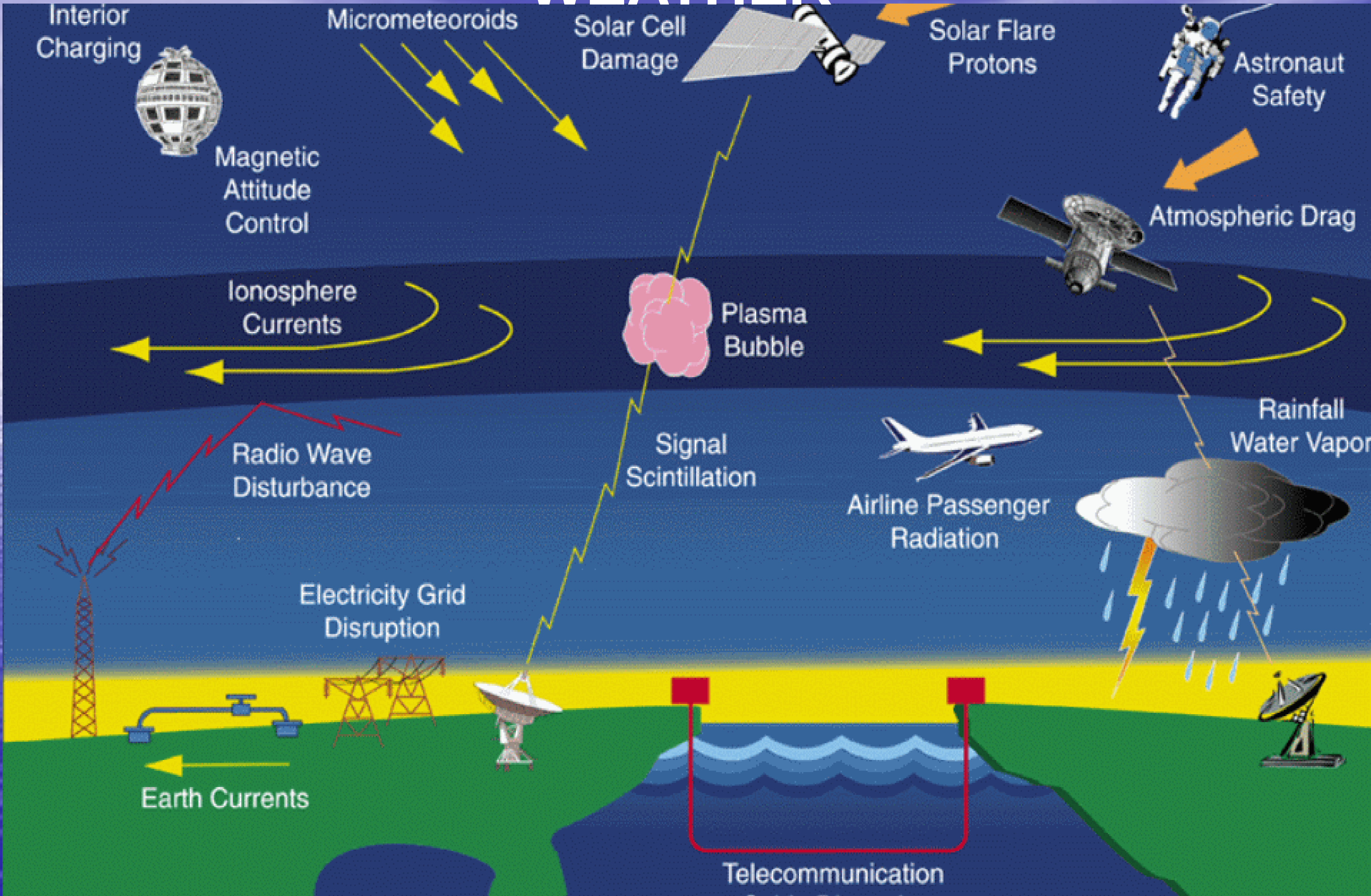


The Ionosphere is defined as the layer of the Earth's Atmosphere that is ionized by solar and cosmic radiation. It lies 80-600 km aprox.

Main characteristics of the Ionosphere:

a) electron density profile
b) TEC (Total electron content) Variability
c) Solar Cycle
d) Solar storms
e) Equatorial anomalies and scintillations

EFFECTS OF IONOSPHERE AND SPACE WEATHER



II. ICAO CONCEPT FOR GNSS

A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation. (Ref. ICAO Annex 10, Vol. I).

There are four essential criteria: i) Accuracy, ii) Integrity, iii) Continuity, and iv) Availability, in correspondence with the new PBN (RNAV/RNP) procedure which permits flying direct routings, precise navigation capability and permits efficient operations in terrain constrained or congested airspace.

GNSS Segments:

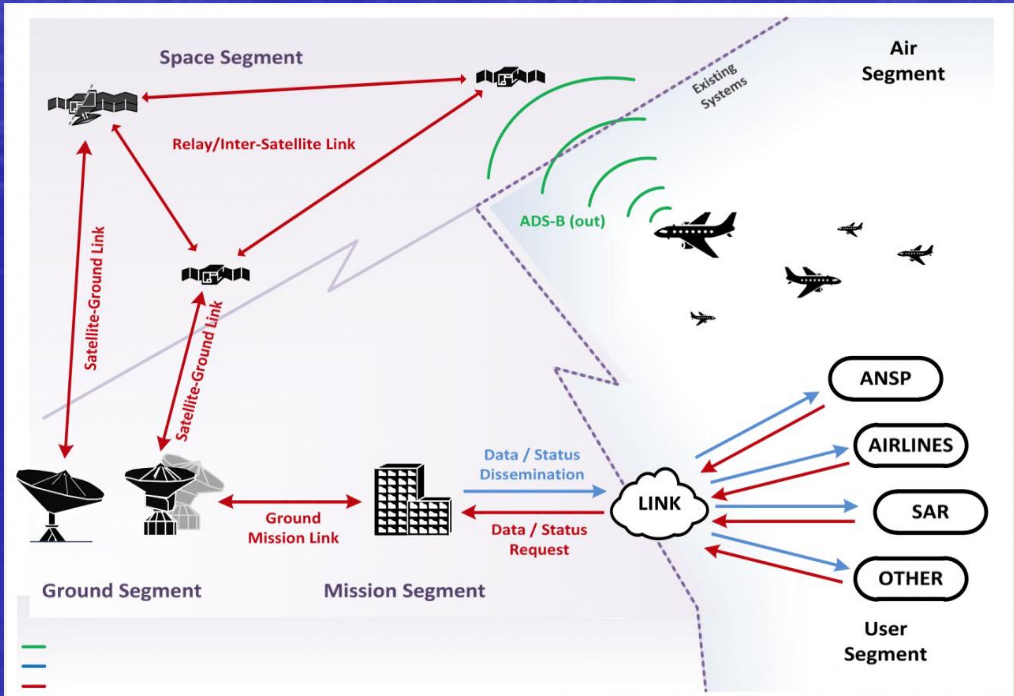
1) Space: satellite constellations

(GPS, GLONASS, GALILEO, BEIDOU)

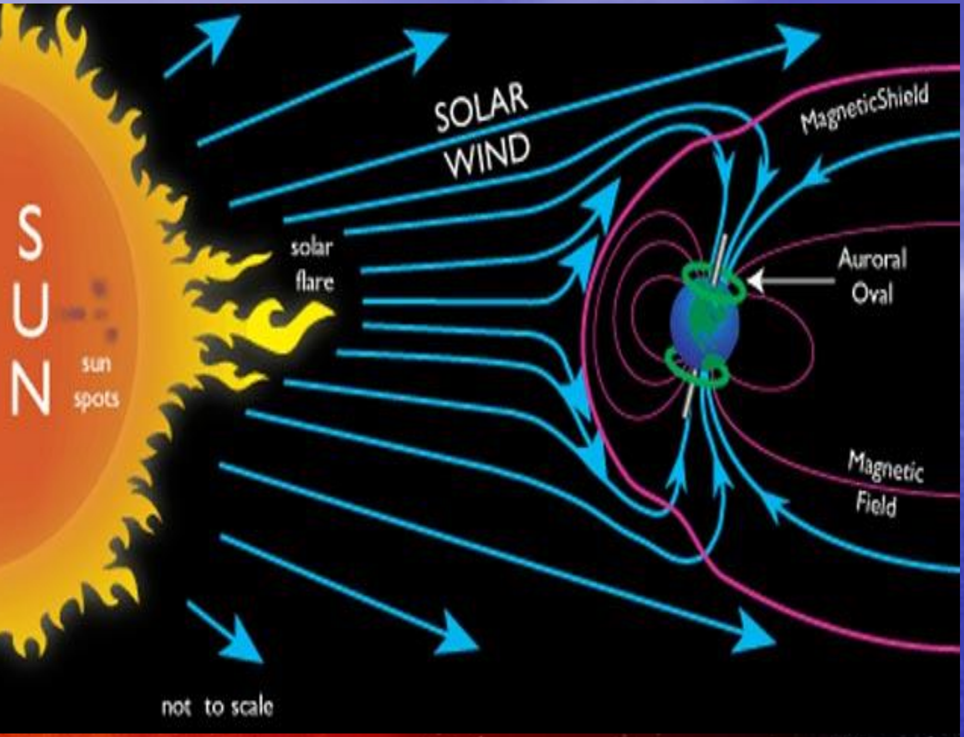
2) Control: monitor, control and syncronization of satellites

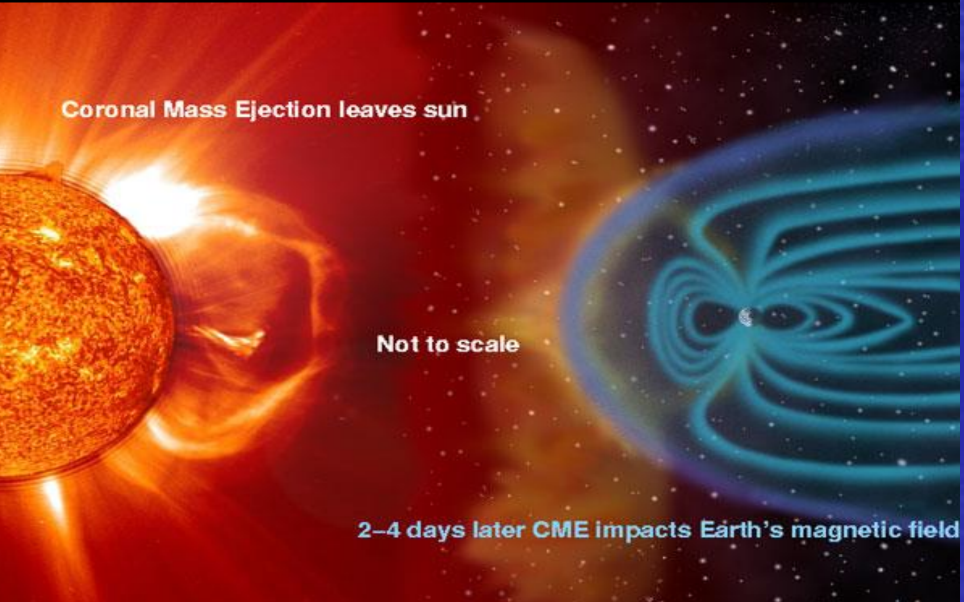
3) Users: receivers, aircraft

There are Augmentation Systems like SBAS (Satellite) and GBAS (Ground), to improve performance of GNSS systems



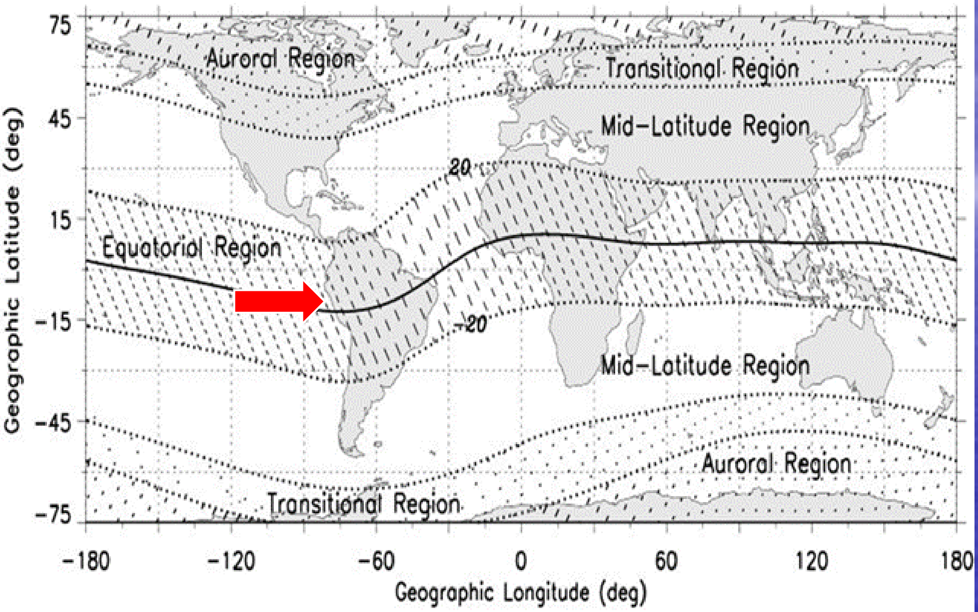
III. SPACE WEATHER (SW)



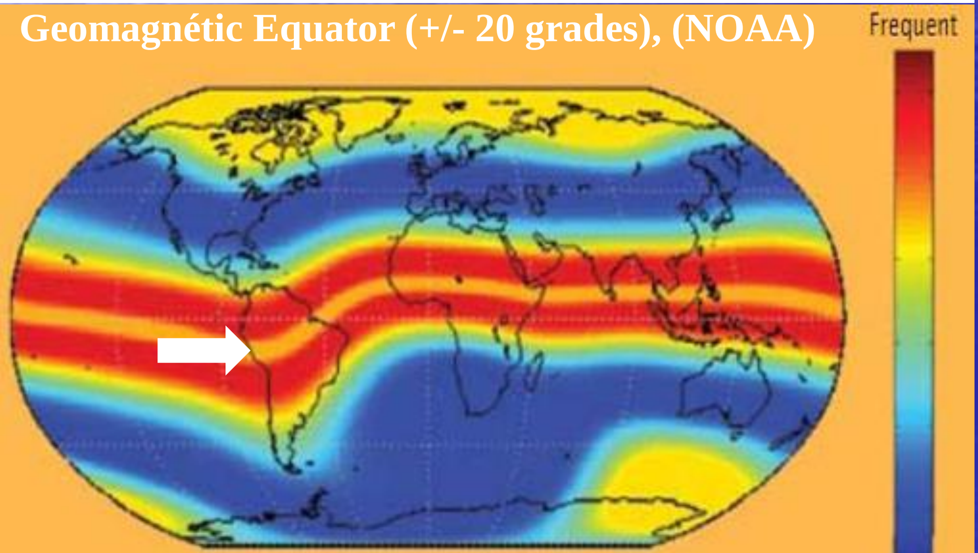


Space weather is related to the behaviour of the Sun, the nature of Earth's magnetic field and atmosphere, and our location in the solar system. The active elements of space weather are particles, electromagnetic energy and magnetic fields, rather than the more commonly known weather contributors of water, temperature and air. Magnetic fields, radiation, particles and matter which have been ejected from the Sun can interact with the Earth's magnetic field and upper atmosphere to produce a variety of effects

IV. SPACE WEATHER EFFECTS ON GNSS IN LOW LATITUDE (EQUAT. REGION) - PROPOSALS



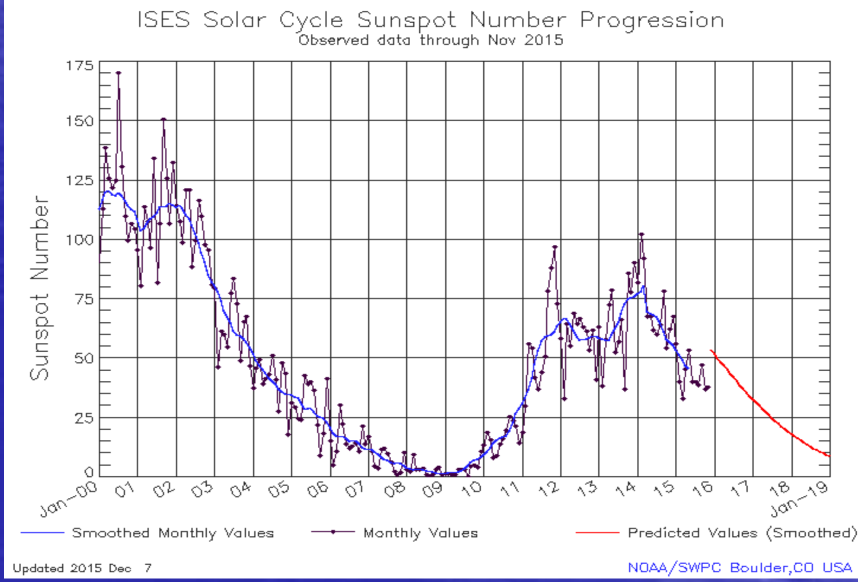
Geomagnétic Equator (+/- 20 grades), (NOAA)



Frequency of disturbances in ionosphere

Lima-Peru is the Geomagnetic Equator in Southamerica Region (low latitude), that is why the peruvian airports have an intense ionosphere activity, as well as countries located between 20° N and 20° S (aprox) from the geomagnetic Equator, especially during periods of maximum solar activity.

THE SOLAR CYCLE



- At the end of 2013 and 2014 it was the maximum solar cycle Nr 24. Next cycle would be in 2025

IV. (…) SCINTILLATIONS AND TEC EFFECTS OVER GNSS

Principal impacts of ionospheric scintillation on GPS performance:

- Loss of lock / outages
- Induced ranging errors

Consequences of these effects on GPS positioning accuracy depends on constellation geometry

For example, losing multiple satellites in the same region of the sky can lead to large errors

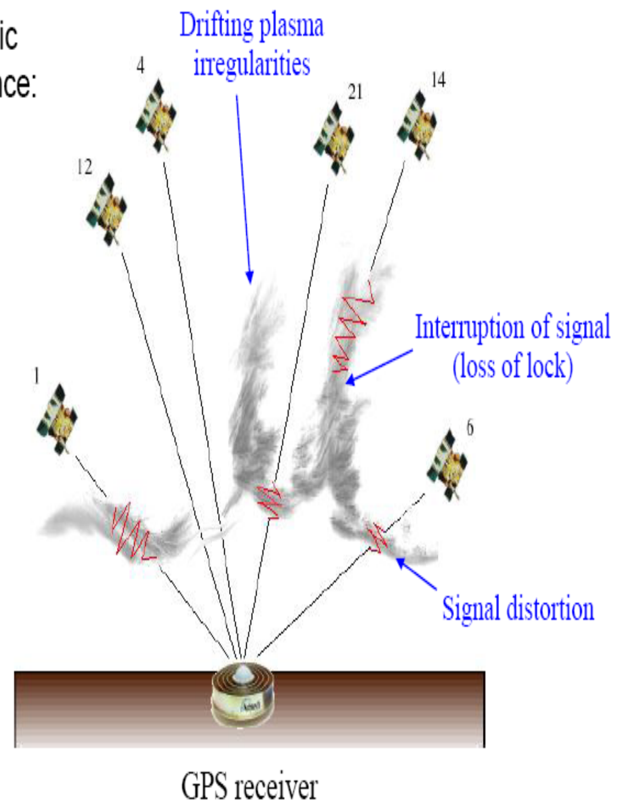
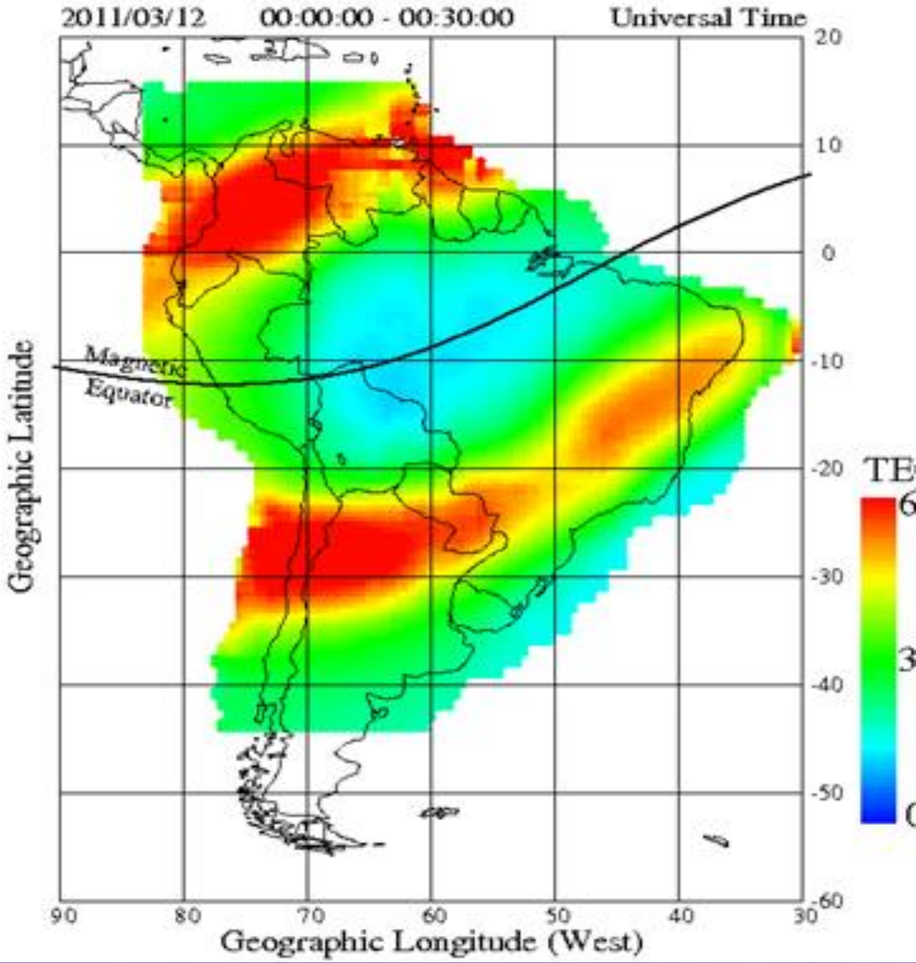


Figure Courtesy of C. Carrano, BC



Scintillations generate fading over GNSS signals

TEC generates delays, measurements made by LISN (Low-latitude Ionosphere Sensor Network) – Courtesy of Boston College

4.1 Proposals

1) Test Bed SBAS/WAAS/GPS - Regional Project RLA/00/009 (ICAO – FAA)

The main objective was to develop a plan of test bed (trials) and evaluation of the technical and operational benefits of SBAS Augmentation System/GNSS based on GPS / WAAS for CAR/SAM

The GPS receivers used the L1 and L2 frequencies

Results of Project RLA/00/009:

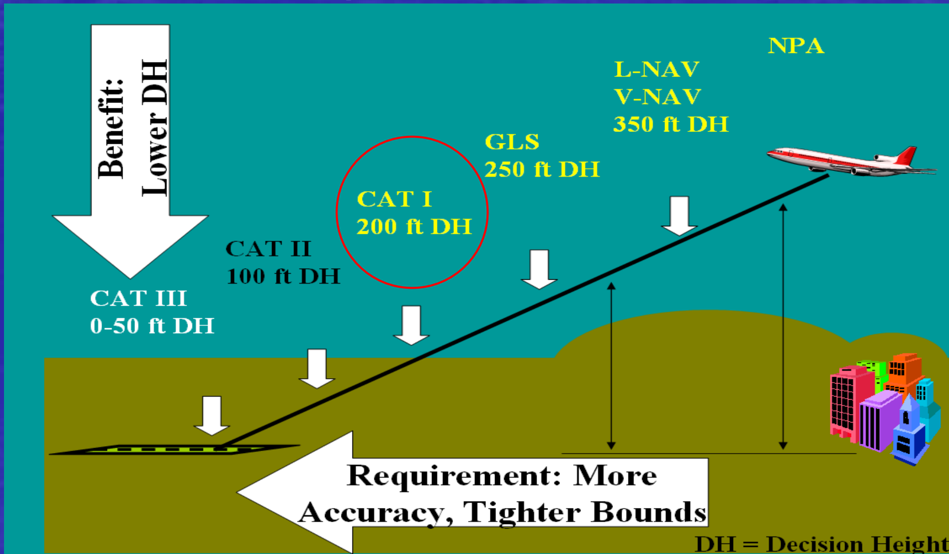
- The Scintillation generated lost of messages and data in collection stations

- Lack of an algorithm more robust to interference or ionospheric scintillation , especially in the equatorial region (low latitude)

- It may also be considered as an aspect of risk in the development of SBAS systems for procedures of accuracy or vertical guidance.

2) Reference: Results of ionosphere impact evaluation on GBAS operation in Brazil (Published in SAM/IG/15-20)

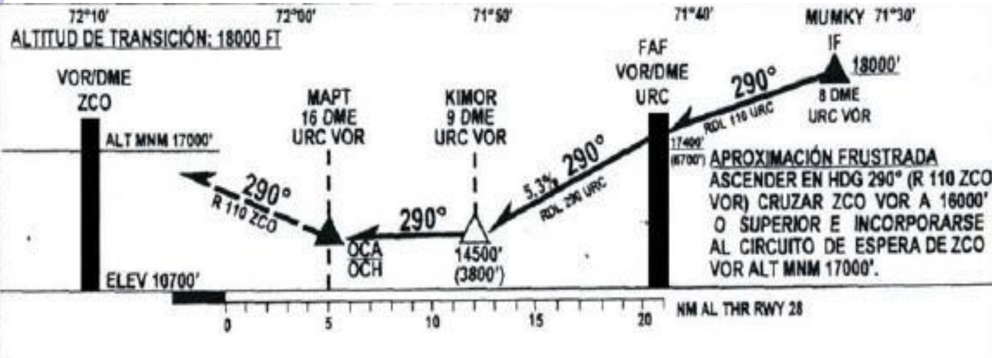
-GBAS system, in accordance with ICAO Annex 10, Volume 1, allows performing precision approach Category I with increasing values of GPS signals accuracy and integrity.
-The purpose of the evaluation was to study the impact of the ionosphere on the operation of the SLS-4000 station (Rio de Janeiro – Southamerica region) during solar cycle 24 by using a mid-latitude ionosphere threat model. Software is in process of updating/test
-As result of the ionosphere impact evaluation on GBAS (operations in Brazil) : It was concluded that the mid-latitude ionosphere threat model is not directly applicable to low latitudes like Equatorial Region
-Like the mentioned Regional Project RLA/00/009, the receivers used the L1/L2 GPS frequencies.



Using this model, the most critical situation for GBAS operation would be an aircraft on approach (landing) receiving wrong correction from the ground station caused by different ionosphere delay received by aircraft and ground station

c) PERUVIAN EXPERIENCE:

The first operational approach procedure based on GNSS and RNP Baro - VNAV information was authorized at the Cusco Airport in 2008

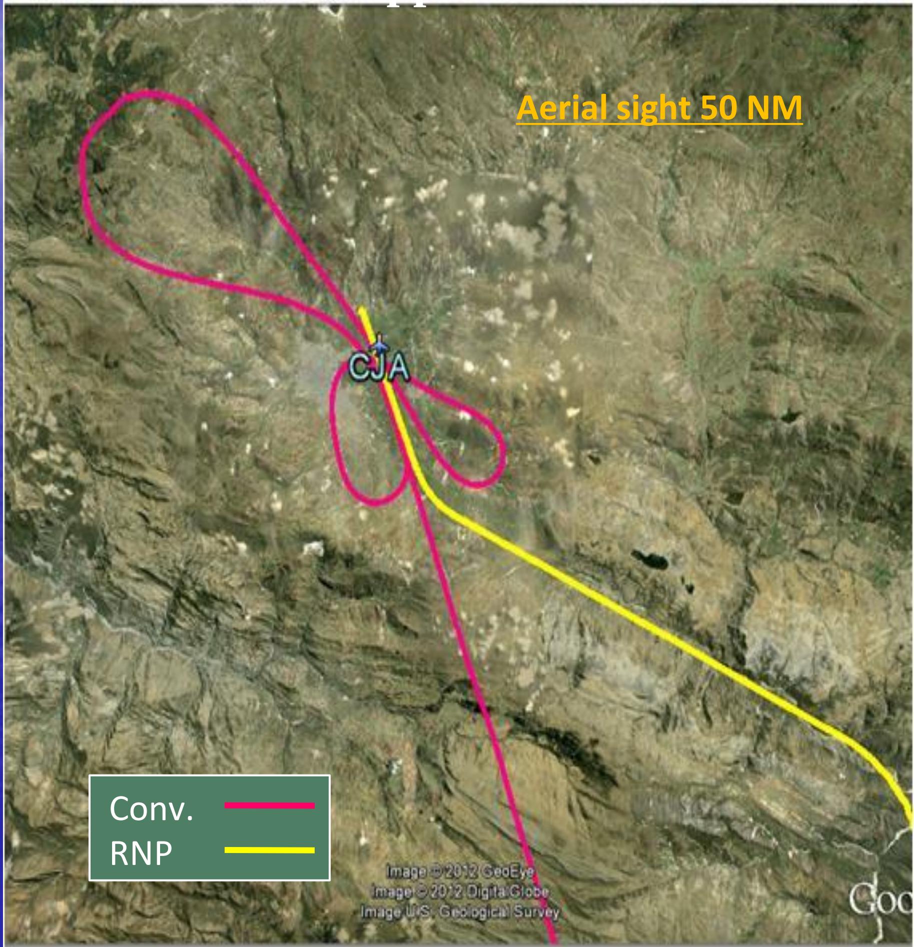


OCA / H	A - B - C - D	MÍNIMOS DE UTILIZACIÓN DEL AD
EN CIRCUITO RWY 28	14500' (3800')	TECHO DE NUBES: 1200 M VISIBILIDAD : 8 KM

Elevation: 10745 ft.
Minimum approach (DA 14500', visibility required 8Km) often higher than actual weather conditions.

Caxamarca Airport

Shorter Flight distance/Best minimum of approach

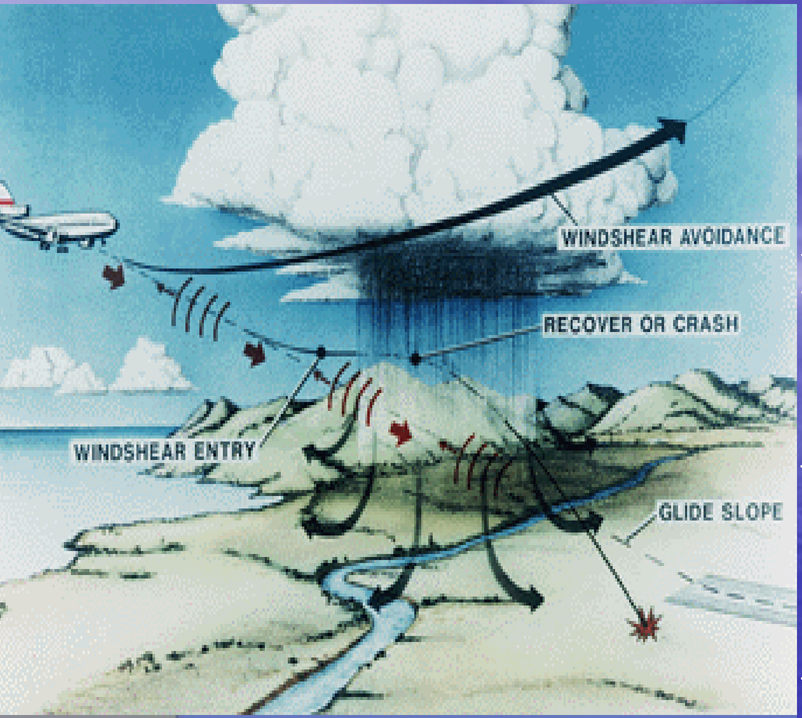


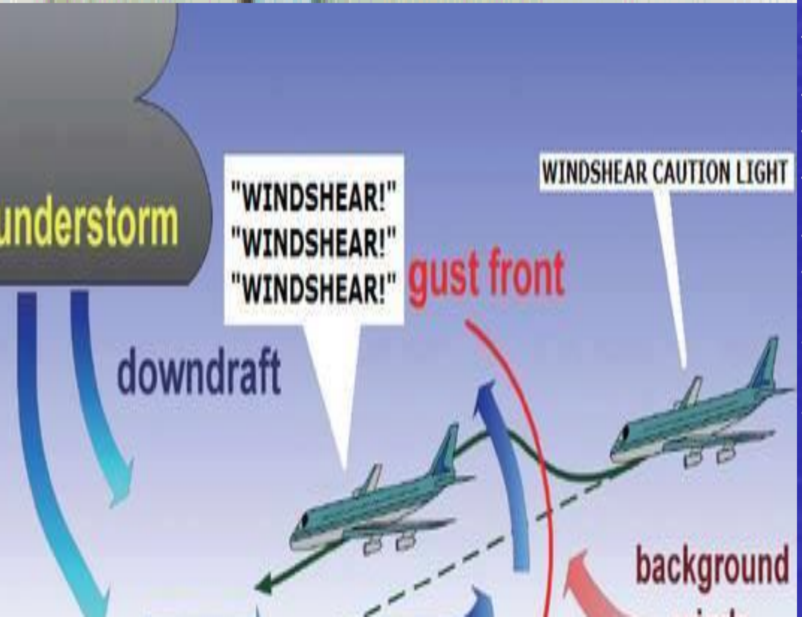
Saving per flight			
Distance	Time	Fuel	CO2
34.8 nm	11.6 min	375.9 gal	1186 kg

SBAS O GBAS SYSTEM FOR SOUTHAMERICAN REGION?

-Equatorial region (Low Latitude) is hostile for the GNSS signals, requires more investigation.
-Less air traffic in Southamerica than Northamerica (Medium Latitude) .
-Brazil is doing the study and testing of a national GBAS Augmentation system, which could be a model extended for the South America Region .
-Continuos study of the scintillation in more detail as the main constraint on the use of two frequencies (L1 and L5) for vertical guidance.
-The scintillation can seriously affect the continuity and availability of GNSS.
-Cost - benefit analysis

V. CONVENTIONAL WEATHER AND ITS EFFECTS

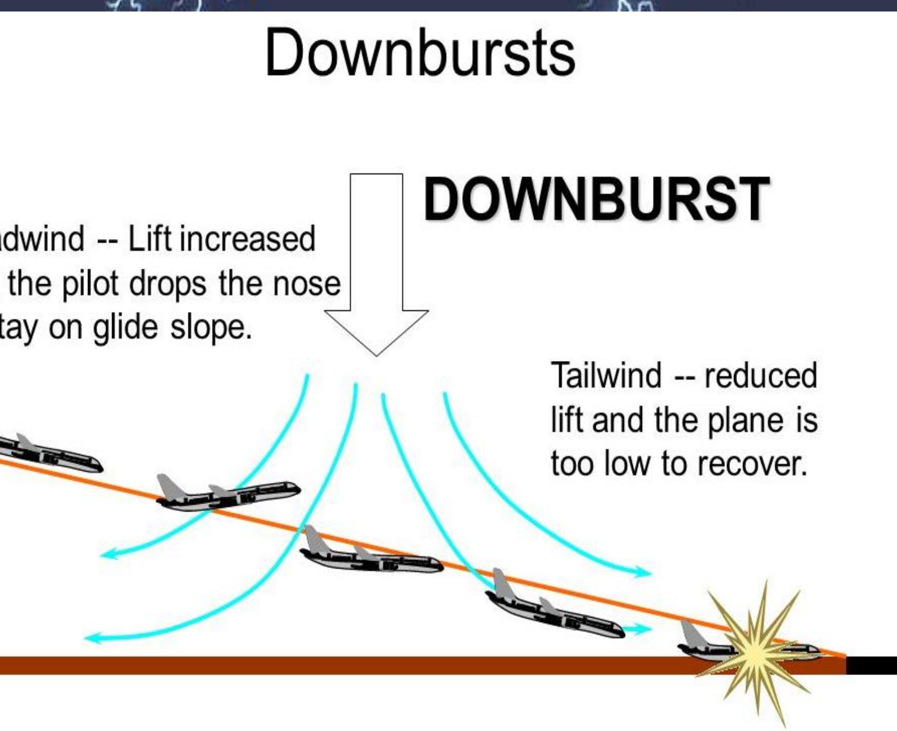




a) WIND SHEAR

Is the change in speed or direction of wind over a relatively short distance or time period. Vertical wind shear is the most commonly described shear. Wind shear is considered to be severe if the horizontal velocity changes at least 15 m/sec over distances of 1 to 4 km. In the vertical, wind speeds change at rates greater than 500 ft/min. It happens at different heights in the troposphere.

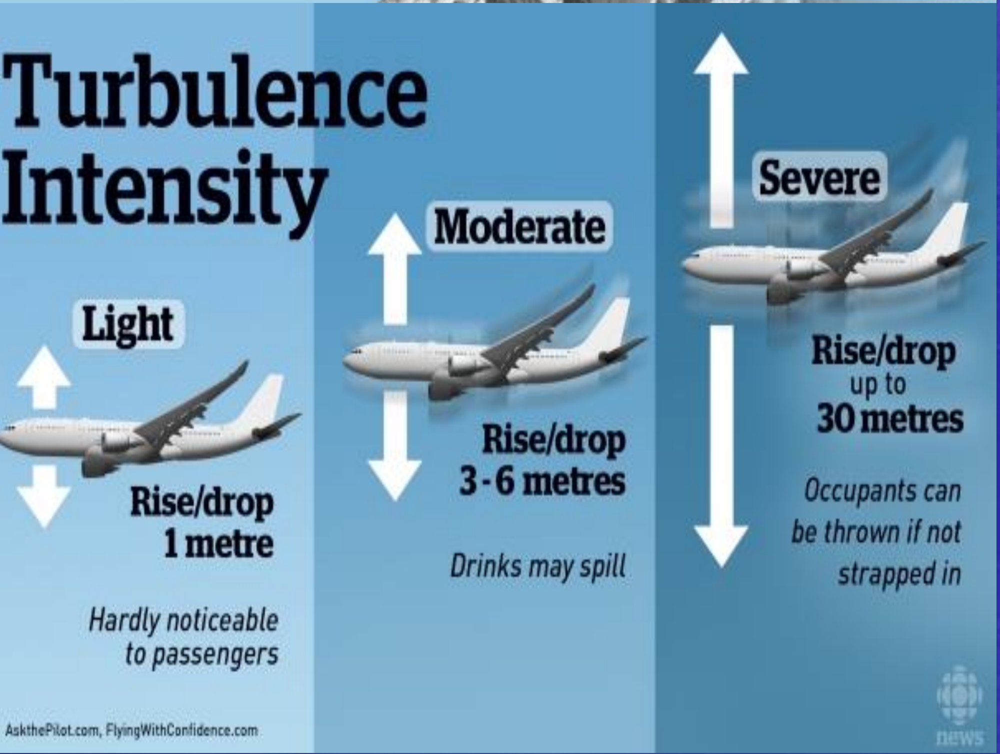
Multiple aviation accidents were attributed to wind shear phenomena. According to the NASA, about 540 fatalities and numerous injuries resulted from wind-shear crashes involving 27 civil aircraft between 1964 and 1994. These numbers do not include accidents that almost occurred.



b) DOWNBURST

Is a localized area of damaging winds caused by air rapidly flowing down and out of a thunderstorm.

To create a downburst at the ground, the downward (downdraft) speeds in the thunderstorm must be unusually high, and this downward flowing air must penetrate close to the ground. These conditions can be met when rain falls through an atmospheric layer with relatively low humidity.



c) TURBULENCE

Is a flow regime in fluid dynamics characterized by chaotic changes in pressure and flow velocity. It is in contrast to a laminar flow regime, which occurs when a fluid flows in parallel layers, with no disruption between those layers. Turbulence is commonly observed in everyday phenomena such as surf, fast flowing rivers, billowing storm clouds, or smoke from a chimney, and most fluid flows occurring in nature and created in engineering applications are turbulent.

EFFECTS ON CIVIL AVIATION

WIND SHEAR

TURBULENCE

DOWNBURST

REMARKS

- No SBAS and GBAS operation in Peru and Southamerica (SAM) Region, No infrastructure deployed in SAM Region
- Ionospheric effects over the GNSS signals (Low Latitude)
- Need of strategy analysis to identify SBAS/GBAS implementation.
- Opportunity: Aircraft would be equipped with SBAS/GBAS capability
- In Peru, use of GNSS is currently limited to supplemental navigation of “No-Precision” like GPS/RAIM on board and it is not enough. New RNP AR procedure implemented in Cusco since 2015.
- Space Weather effects happen in the Ionosphere
- Conventional Weather effects happen around 20 km Down (Troposphere)

THANK YOU!!

Note: The opinions expressed here are solely those of the author