The state of thermosphere, using ionosonde and Swarm C observations, during the storm of February 3, 2022 resulted in the loss of 38 SpaceX Starlink satellites.

L. Perrone[(1)] and A. Mikhailov[(2)]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Italia
(E-mail: loredana.perrone@ingv.it)
[2]Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russia

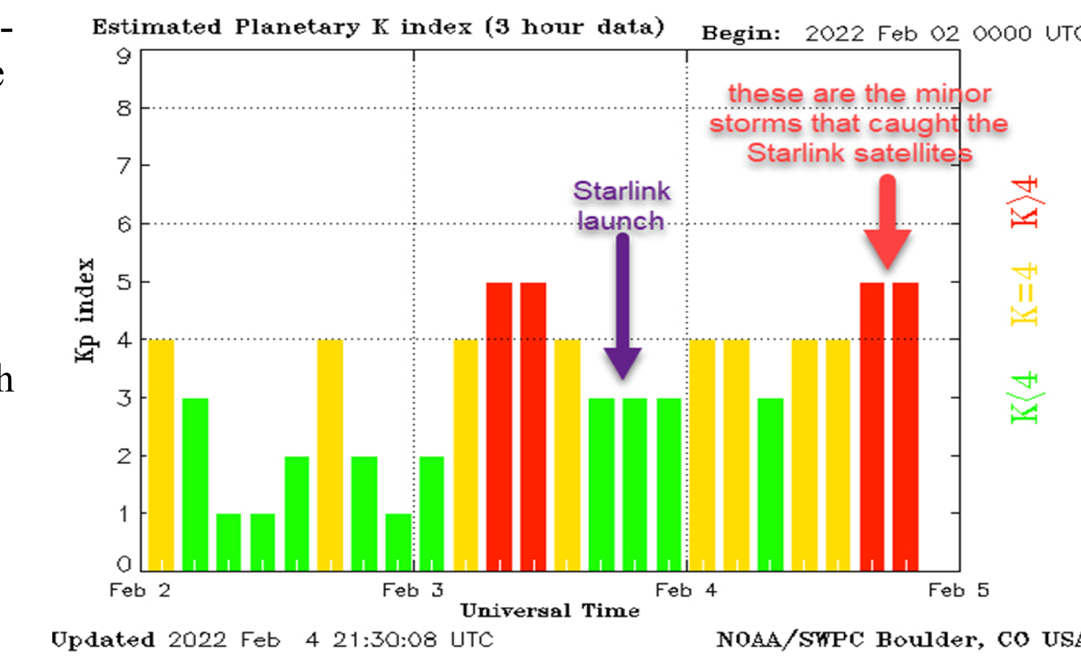
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

DTU

esa

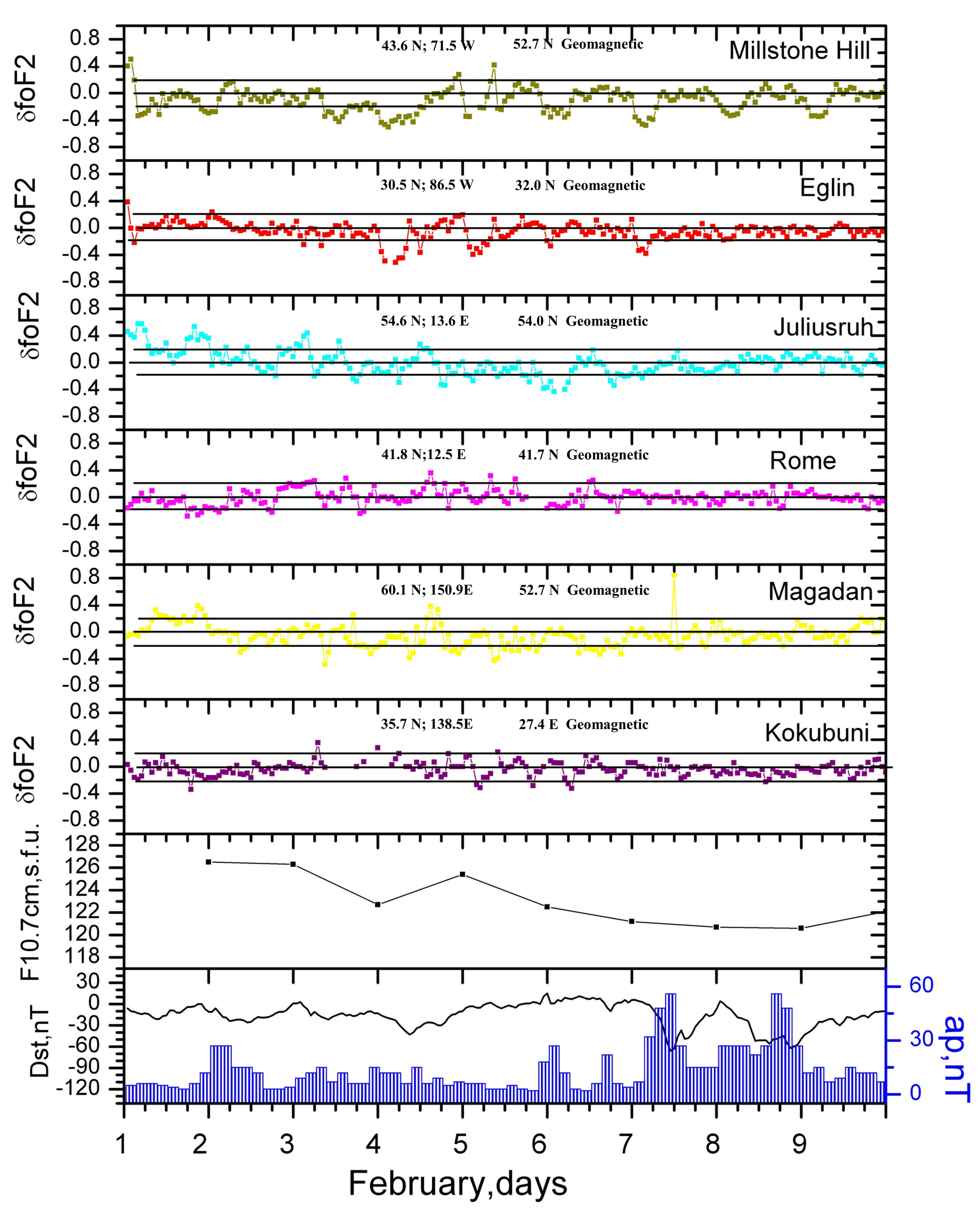
On 3 February 2022, SpaceX Starlink launching 49 satellites 38 have been lost due to enhanced neutral density associated with two moderate geomagnetic storms. It should be underlined that the ionosphere-thermosphere system was disturbed before the arrival of 03 February storm due to an increase of geomagnetic activity occurred at 31 January 2022 that determined an increase of neutral density at 250 km. After the occurremce of the first storm storm at 18:13 UTC of 3 February SpaceX has launched 49 satellites into the initial orbit around 210 km altitude. The 7th of February is the date on which the failed Starlink satellites burned up on re-entry.

The aim of our analysis may be formulated as follows:
To analyze the reaction of ionospheric (foF$_2$) and thermospheric (neutral composition, temperature, winds) parameters at mid-latitudes of both Hemispheres , to specify the role of retrieved thermospheric parameters in the formation of enhanced neutral density during the storms and to compare the retrieved parameters with modern empirical thermospheric models of neutral composition calculated for the period under study

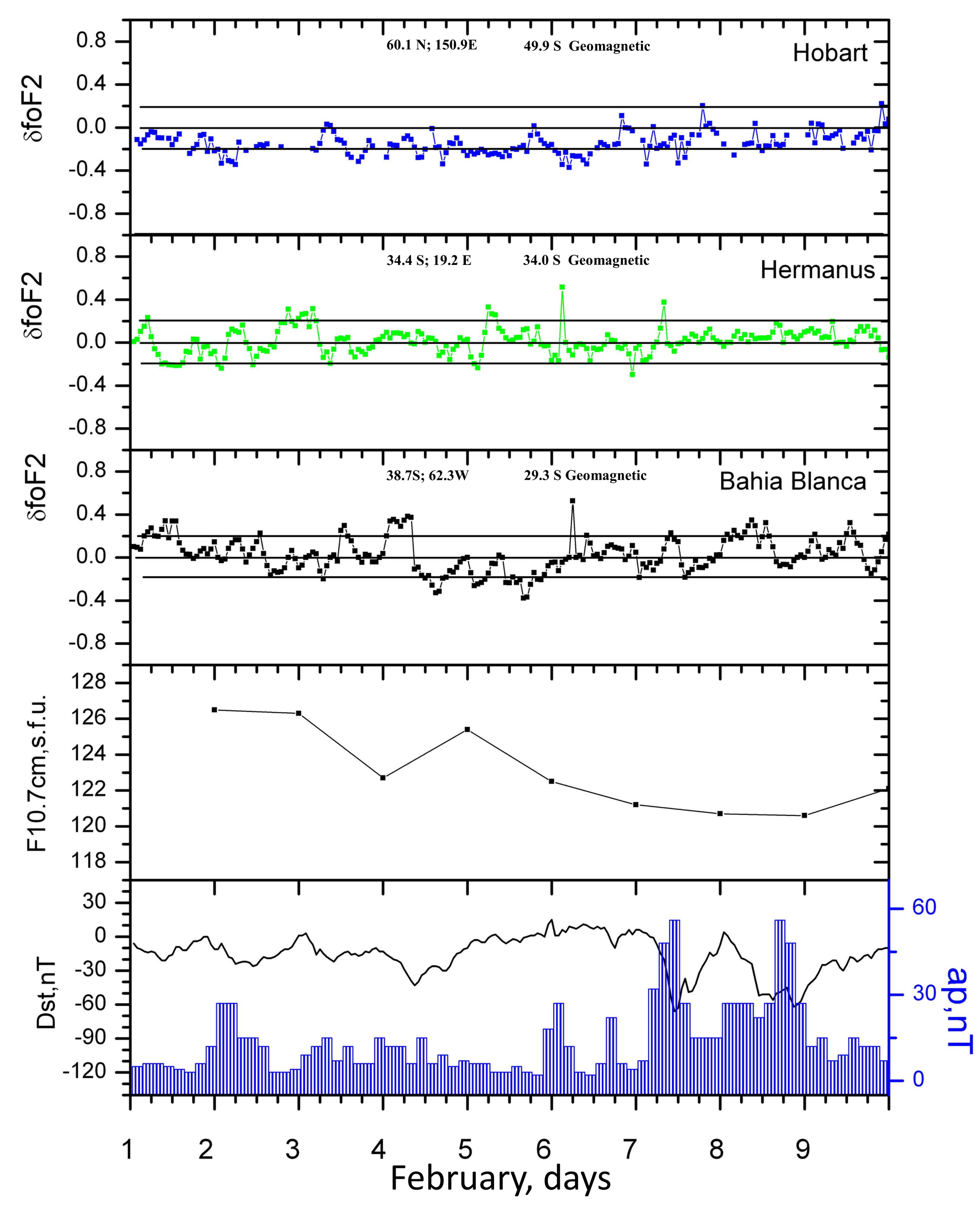


STATE OF THE IONOSPHERE

Northern Hemisphere



Southern Hemisphere

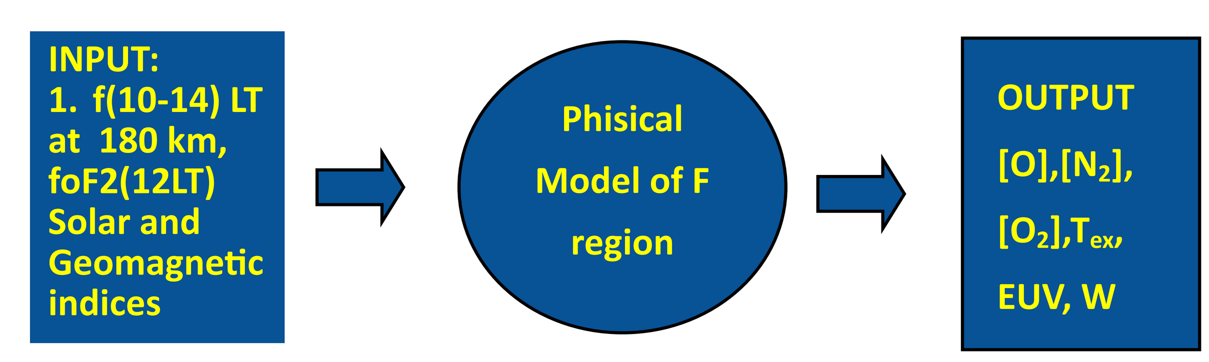


Relative variation dfoF2=foF2obs-background/background for Northern and Southern hemisphere ionosonde station,F10.7 solar flux index, geomagnetic indices :ap and Dst

Three ionosonde observatories located at middle latitudes in the American longitudinal sector. Two stations in the Northern Hemisphere Eglin and Millstone Hill and one station in the Southern Hemisphere, Bahia Blanca located in the South Atlantic Anomaly region have been selected. Three ionosonde observatories located at mid-latitudes in the Central Europe-South Africa longitudinal sector. Two stations in the Northern Hemisphere: Juliusruh, Rome and one station in the Southern hemisphere : Hermanus. Three ionosonde observatories located in the East Russia, Japan and Australia longitudinal sector. One station in East Russia: Magadan, one station at middle latitude Japan :Kokubuni, one station at middle latitudes in Australia: Hobart.

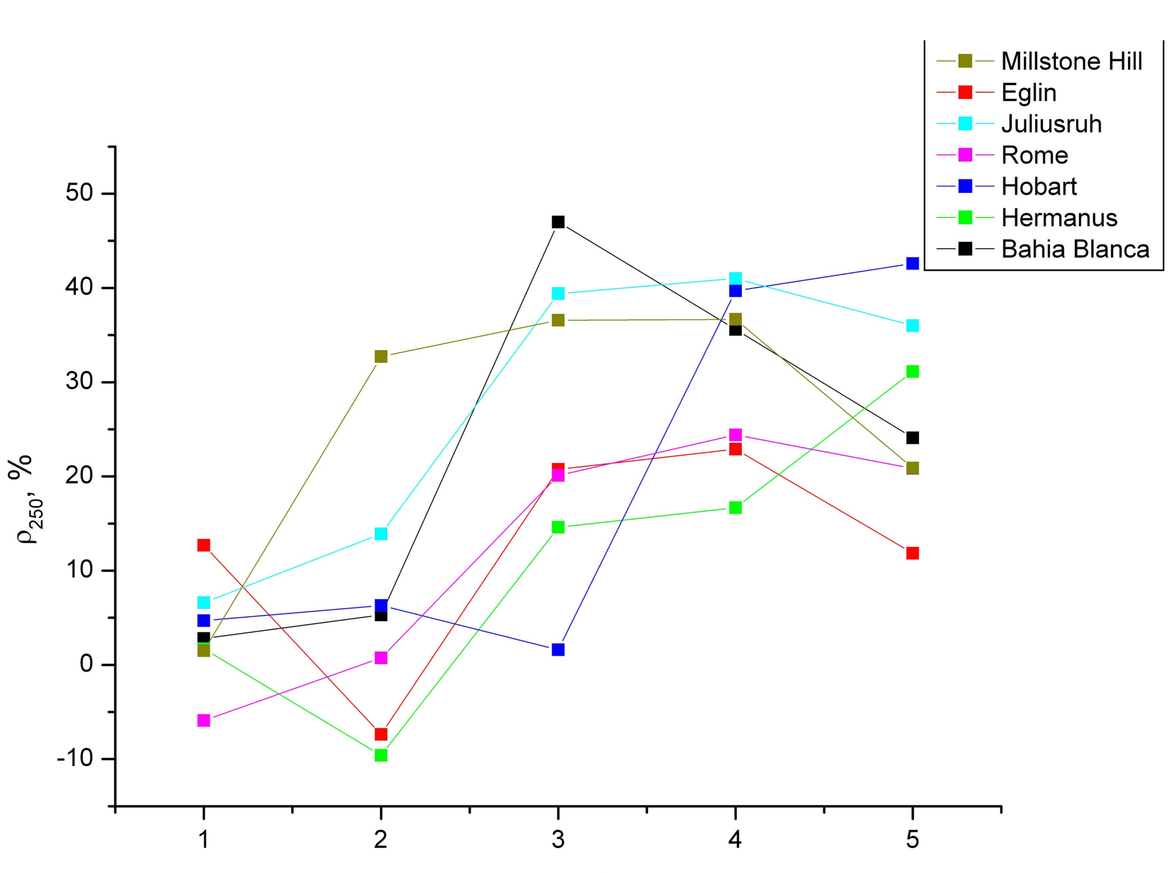
After the occurrence of two geomagnetic storms a strong and prolonged negative ionospheric storm was observed in South Hemisphere (Hobart and Hermanus) and in North America (Millstone Hill).

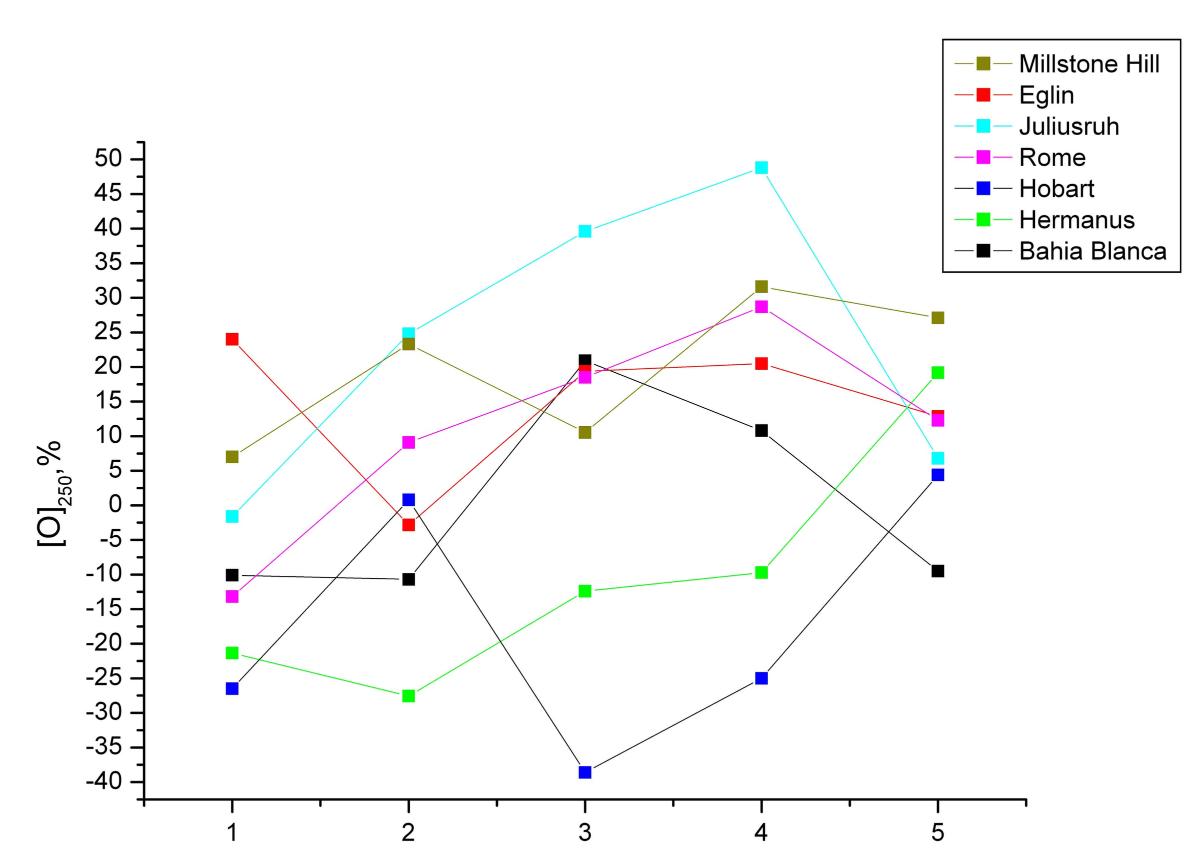
THERION:A METHOD TO RETRIVE THERMOSPHERIC PARAMETERS
(Perrone,Mikhailov, JGR, 2018)

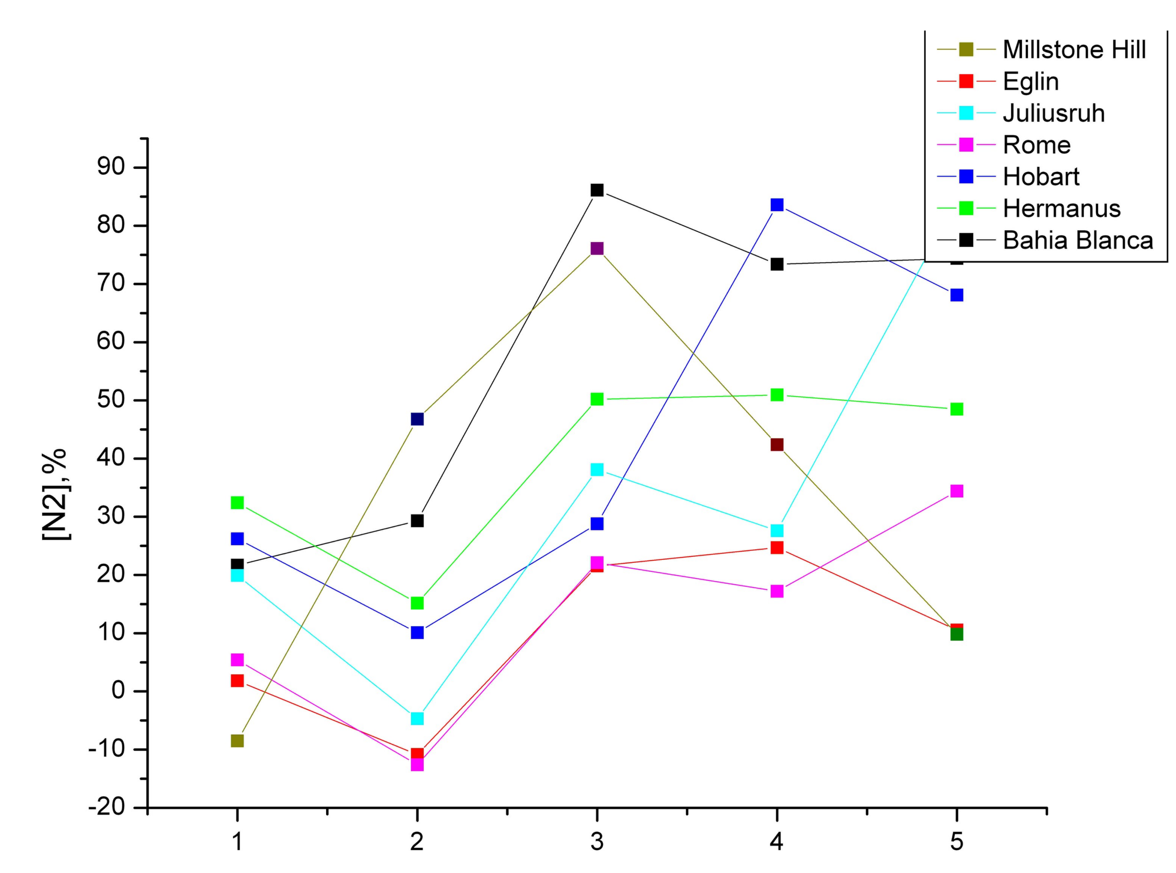


With THERION there is a possibility to follow such storm-time daily variations of thermospheric parameters in different longitudinal sectors.

STATE OF THE THERMOSPHERE







Relative variation in percentage of the neutral density at 250 km at 12 LT, relative variation in percentage of Oxygen concentration at 250km at 12LT relative variation in percentage of molecular Nitrogen concentration at 250 km at 12 LT, for all the analysed stations.

The impact on the Thermosphere of the two storms has been different in the analysed stations.
Due to the storm of 3 February the max increase of neutral density at 12LT, 47%, is seen in Bahia Blanca, in Millstone Hill 37% and in Hobart 39% while the second storm had a stronger impact in Juliusruh, 41%, Hobart 43% and Hermanus, 31%.
The increase of neutral density at 250 km during daytime in the analysed period is seen in the Northern and Southern hemisphere at mid latitude in different longitudinal sectors. The ρ increase is due for the large part to the [N$_2$] increase, in accordance with the Tex increase. This is an expected result as [N2] is a chemically inactive species whose distribution is controlled by the barometric law. The Tex increase determines the molecular nitrogen increase with a consequent increase of neutral density.
The impact of the storms on the Northern and Southern hemisphere mid latitude stations has been different . Summer season in the Southern hemisphere with the storm thermospheric wind directed in the same versus of background circulation that brings at mid-latitude the disturbed composition with low [O] explains the lower increase of neutral density in Hermanus and Hobart 3 February in comparison with the other stations.This is the result of interplay between storm-decreased atomic oxygen and storm-increased molecular nitrogen which practically compensated each other
The empirical models, MSISE00 and JB2008, underestimate the value of neutral density in all stations.
The impact on the Ionosphere Thermosphere system at the mid-latitude locations of the two moderate geomagnetic storms occurred during 2022, year of increasing solar activity (solar cycle 25), is explainable inside the present day mechanism of mid-latitude F2-layer storms and put in evidence the importance of the Thermosphere monitoring.

Aknowledgmens
The authors thank A. Malagnini for the help on the preparation of the poster; for the Ionosonde data the GIRO group **http://spase.info/SMWG/Observatory/GIRO**; European Space Agency for providing Swarm data (https://earth.esa.int/eogateway/catalog/swarm-ionosphere-magnetosphere).This research was carried within the INGV Pianeta Dinamico Project-SESAR (Space weather Effects on the South Atlantic anomaly Region) funded by MUR (law 145/2018)