



The International Meridian Circles Project

A major opportunity for science, space weather
monitoring and international collaboration
Perspectives in Europe and Africa

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On behalf of the IMCP international team

U.N. International Workshop on the International Space Weather Initiative (ISWI): The Way Forward
Vienna, June 26-29, 2023

Main references on the IMCP project

Chinese Meridian Project (CMP)

Wang C, Xu J, Liu L, Xue X, Zhang Q, Hao Y, Chen G, Li H, Li G, Luo B, Zhu Y, Wang J. 2023. Contribution of the Chinese Meridian Project to space environment research: Highlights and perspectives. Science China Earth Sciences, 66, <https://doi.org/10.1007/s11430-022-1043-3>

International Meridian Circle Project (IMCP)

Liu W., M. Blanc, E. Donavan, J. Foster, M. Lester, H. Opgenoorth, L. Ren (2021), Science Objectives and Observation System for the International Meridian Circle, Science China, 2021. <https://doi.org/10.1007/s11430-021-9841-8>

Liu W., M. Blanc and 34 co-authors, Science Objectives and Observation System for the International Meridian Circle, Taikong #19, ISSI-Beijing, May 2020. http://www.issibj.ac.cn/Publications/Forum_Reports/201404/W020201105365405876299.pdf

Liu W., C. Wang, X. Shen, J. Wu J., M. Blanc, Y. Yan, S. Fu, X. Yue, J. Lei, W. Gong, S. Zhang., Q. Zhang, X. Wang, J. Yang, X. Zhang, J. Gao, J. Xu, G. Yang, H. Li, L. Ren, F. Yang, International Meridian Circle Program. Chin. J. Space Sci. (2020), 40(5): 723-725. DOI:10.11728/cjss2020.05.723

I- FROM SCIENCE OBJECTIVES TO OBSERVATION SYSTEM

The Ionosphere and Middle-Upper Atmosphere (IMUA), or Lower-Thermosphere-Ionosphere (LTI) is the Boundary Layer separating Plasma Earth from Fluid Earth

**Maximum deposition of energy
from above and from below:
Vertical heat conduction
Photon, particle and Joule heating
Atmospheric waves breaking**

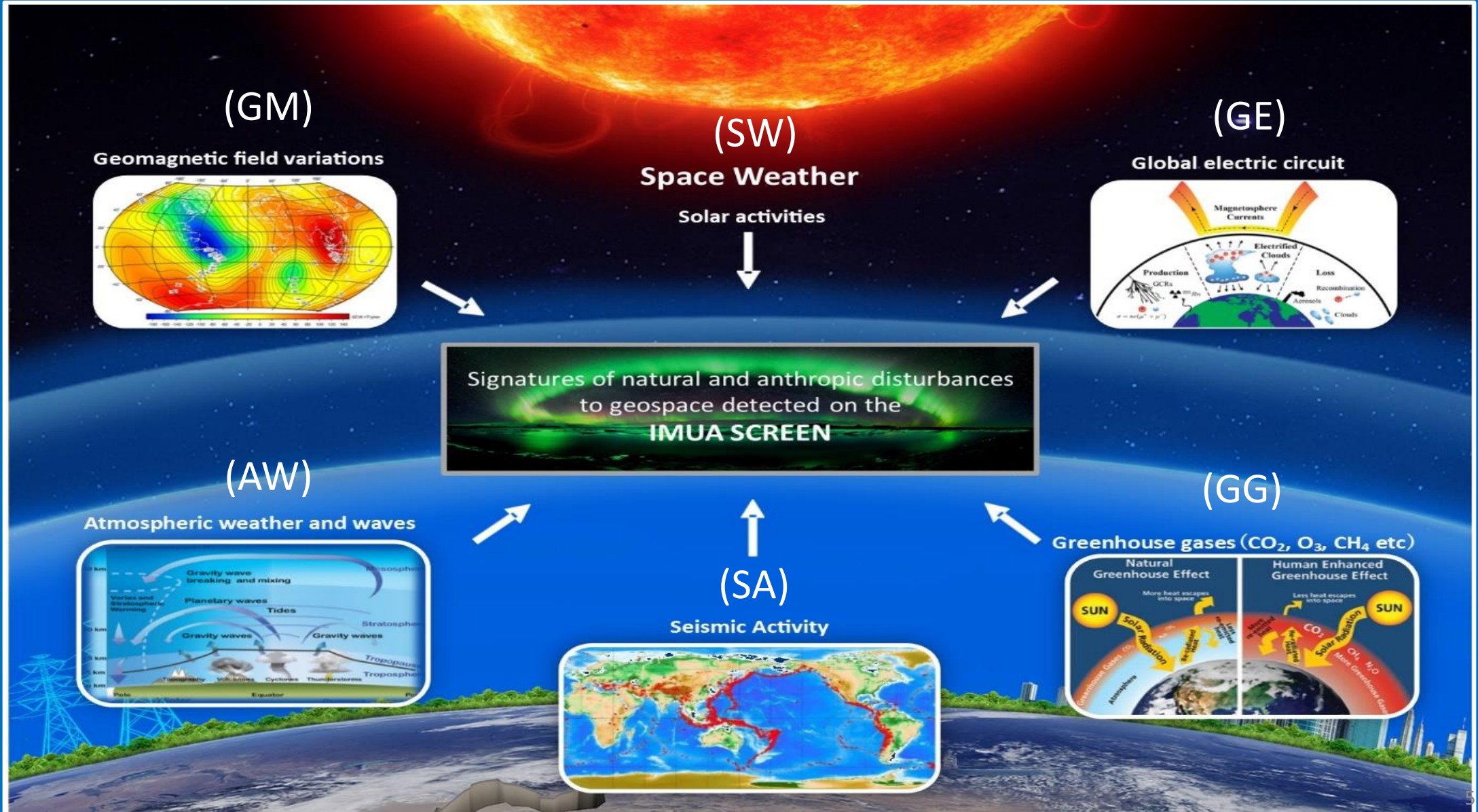
**IMUA= Live "TV screen" detecting disturbances
propagating from above and from below**



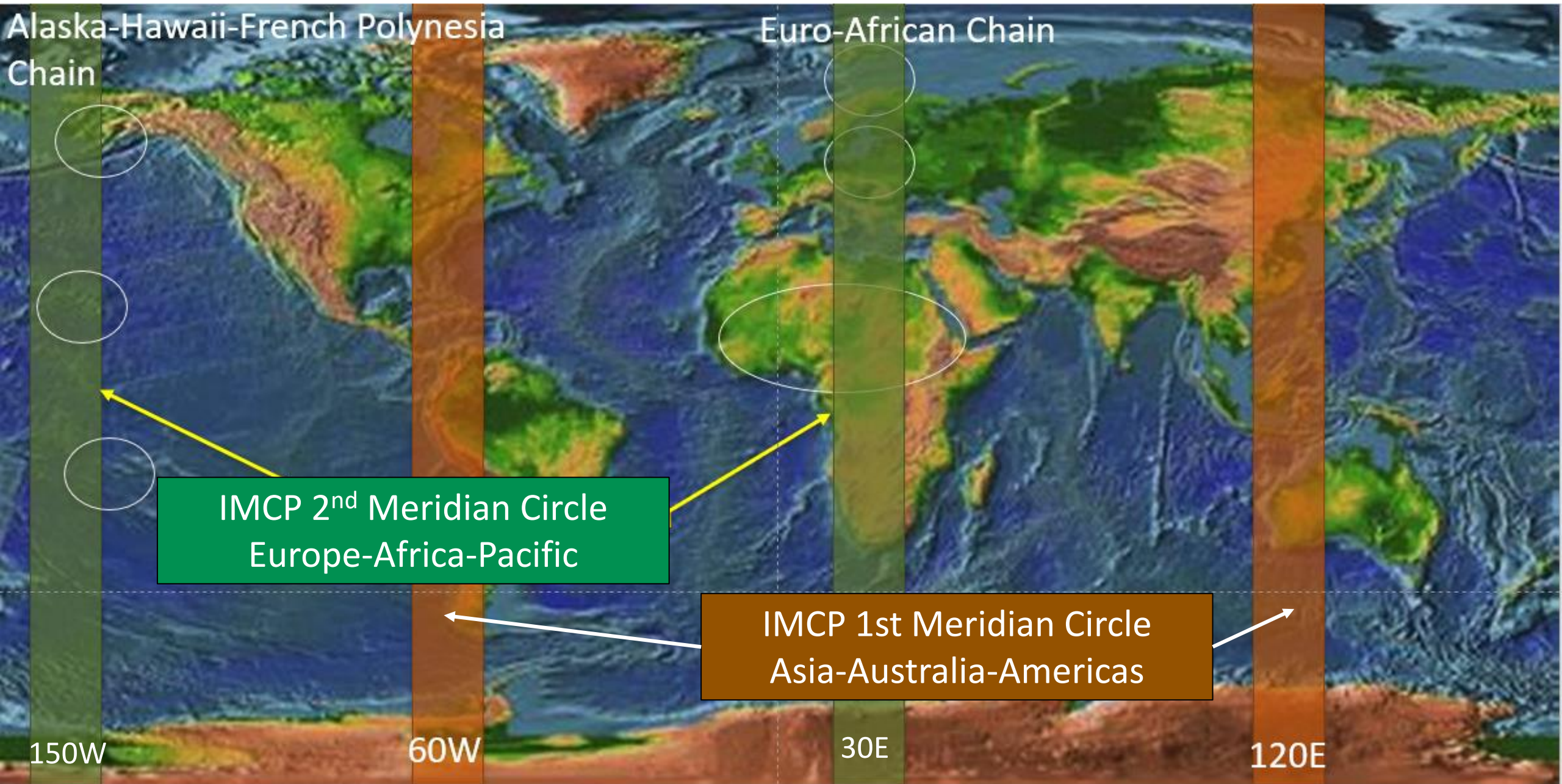
IMCP

OVERARCHING GOAL

BUILD A GLOBAL LTI SCREEN ON WHICH TO DETECT, STUDY AND MONITOR THE IMAGES OF THE DIFFERENT NATURAL AND ANTHROPIC DISTURBANCES



GEOGRAPHIC DEPLOYMENT



GEOGRAPHIC DEPLOYMENT

Alaska-Hawaii-French Polynesia
Chain

Chinese Meridian Project



IMCP 2nd Meridian Circle
Europe-Africa-Pacific

150W

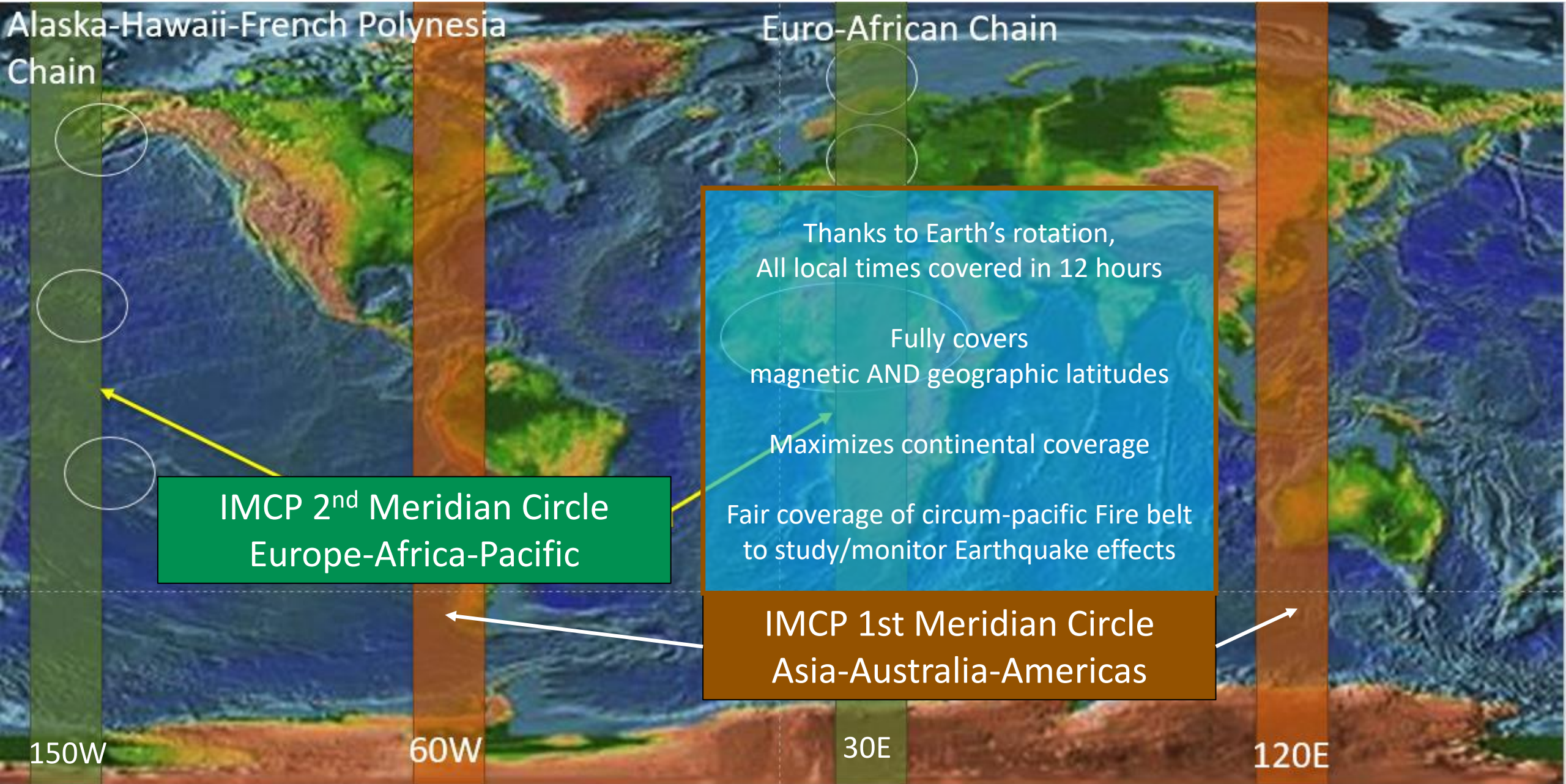
60W

30E

120E

审图号: GS京(2023)0229号

COVERAGE OF MONITORING OBJECTIVES



COVERAGE OF MONITORING OBJECTIVES

Alaska-Hawaii-French Polynesia
Chain

Euro-African Chain

In complement to first meridian
All local times covered in 6 hours

Captures land-ocean contrasts
and world maximum
of thunderstorm activity

Longest continental traverse of
equatorial electrojet

Specific coverage of "Ocean
Hemisphere"

IMCP 2nd Meridian Circle
Europe-Africa-Pacific

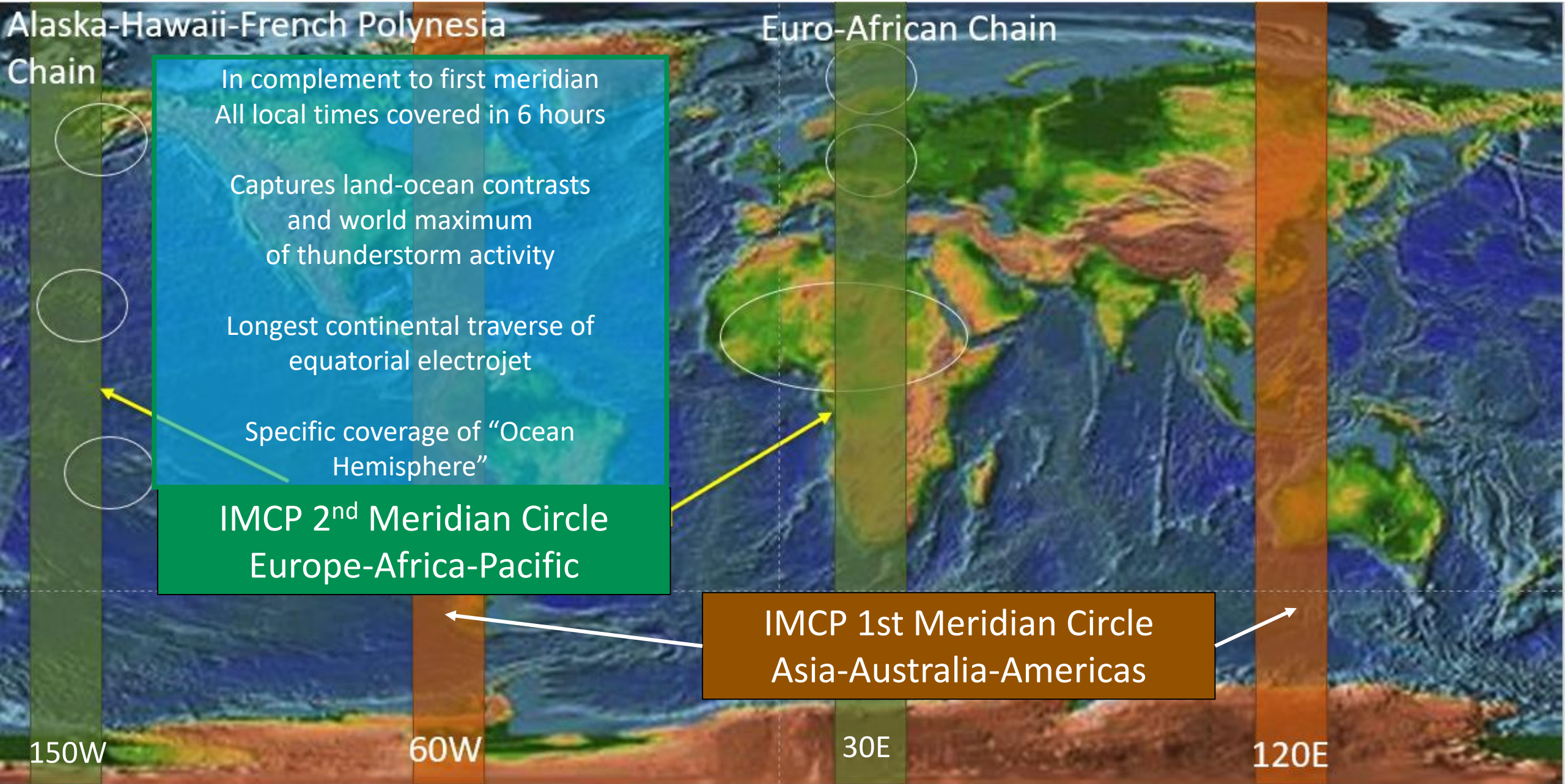
IMCP 1st Meridian Circle
Asia-Australia-Americas

150W

60W

30E

120E



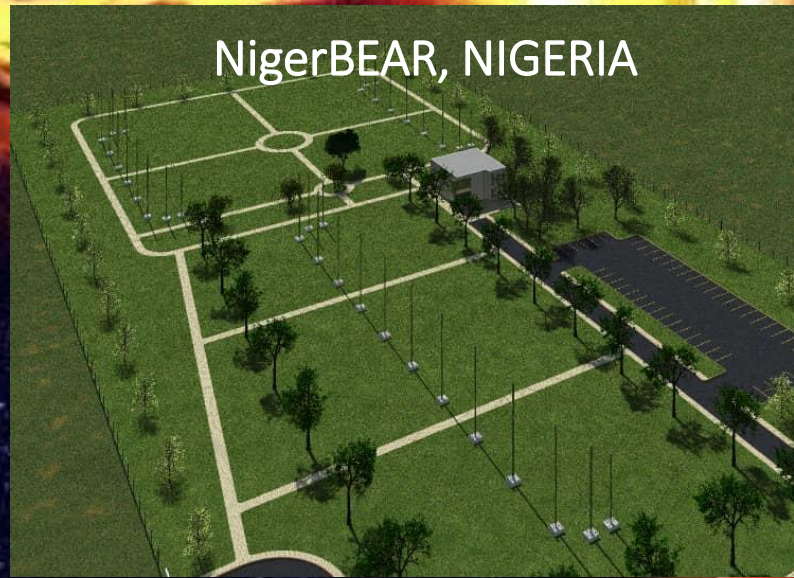
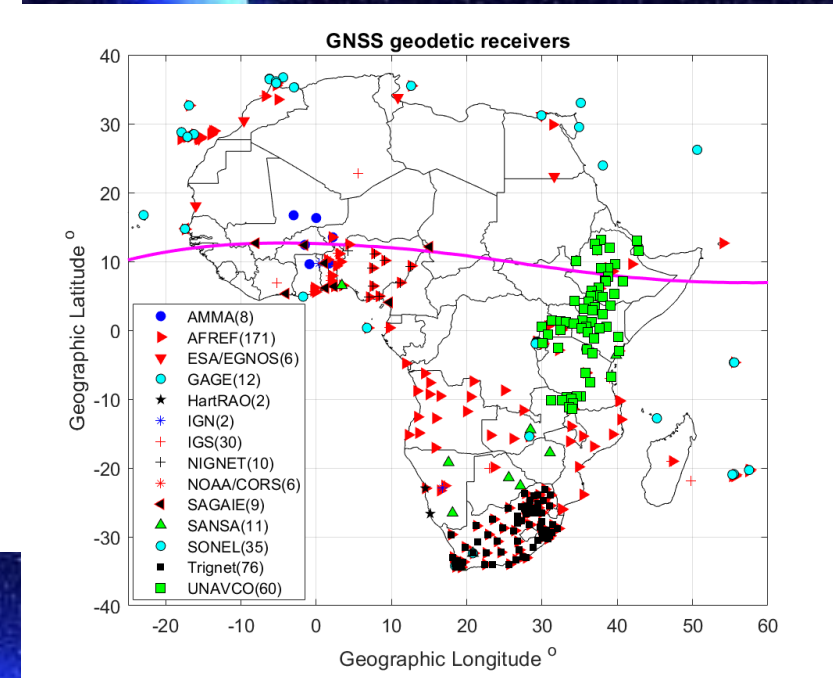
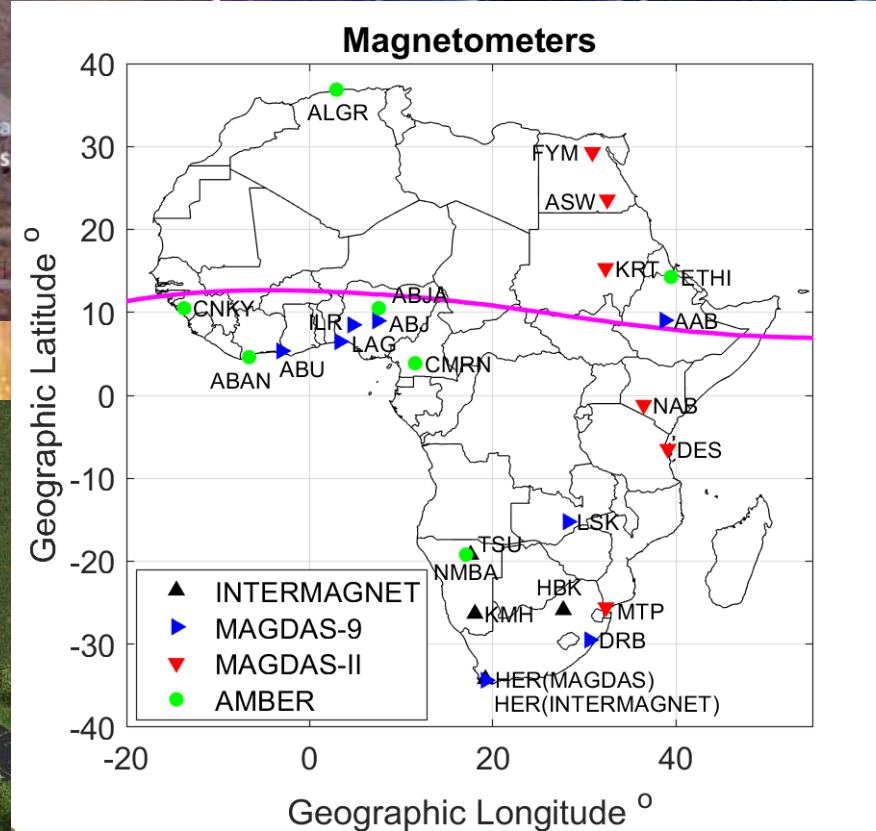
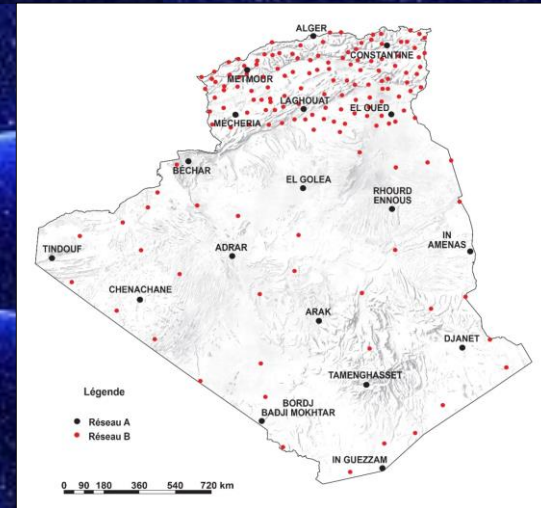
II- FOCUS ON THE UNIQUE POTENTIAL OF AFRICA

GNSS NETWORK, ALGERIA

OUKAIMEDEN OBSERVATORY, MOROCCO



CRITICAL NEED TO MAINTAIN AND OPERATE EXISTING EQUIPMENTS, TO SHARE THEIR DATA...



NigerBEAR, NIGERIA

AND TO DEVELOP NEW ONES!

ARCHITECTURE OF IMCP OBSERVATION SYSTEM

ON-SITE INSTRUMENTS

Large facilities

ISRs

LIDARs

Radioheliographs

...

Medium-scale

HF radars

Digisondes

FP spectrometers

Airglow imagers

...

Network instruments

Ionosondes

Magnetometers

GNSS stations

...

NETWORKS

Regional

Latitudinal

Longitudinal

World-wide



Each instrument brings a piece of the puzzle

of upper atmosphere forcing from above and from below!

Each contribution welcome!

More effective monitoring of natural hazards achieved through data sharing and collaborative research

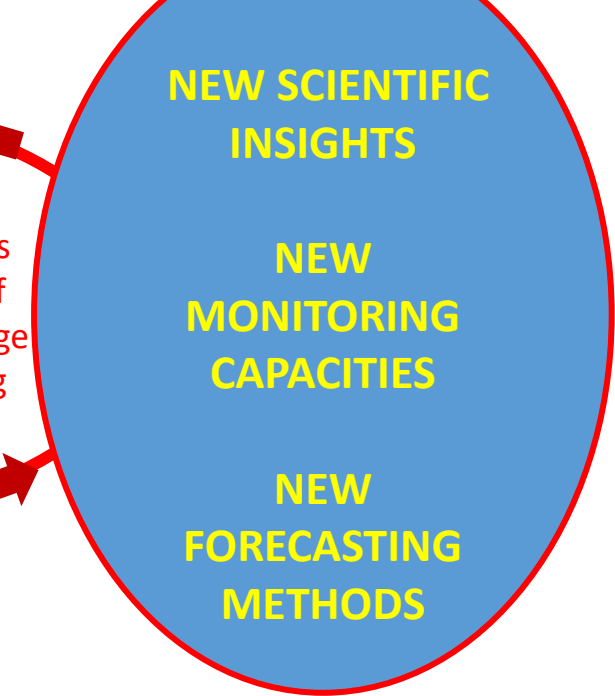
A collaboration between all nations that will benefit to all nations.

IMCP PROJECT ELEMENTS AND OVERALL LOGIC

SCIENTIFIC AND SOCIETAL BENEFITS

MONITORING NETWORK OF IMUA DISTURBANCES
Network of instruments and facilities producing complementary parameters of the IMUA

USERS COMMUNITY SCIENTIFIC QUESTION
Detect, monitor, understand, predict
A certain type of disturbance of the IMUA (the "screen")



DATA REPOSITORIES
On-line access to IMCP instruments data

COLLABORATIVE RESEARCH
Shared on-line tools
International research teams
Advanced Study institute

**OTHER G/B DATA
SPACE DATA**

**THEORY
MODELLING**

AI TOOLS

THE WAY FORWARD: Europe-Africa chain

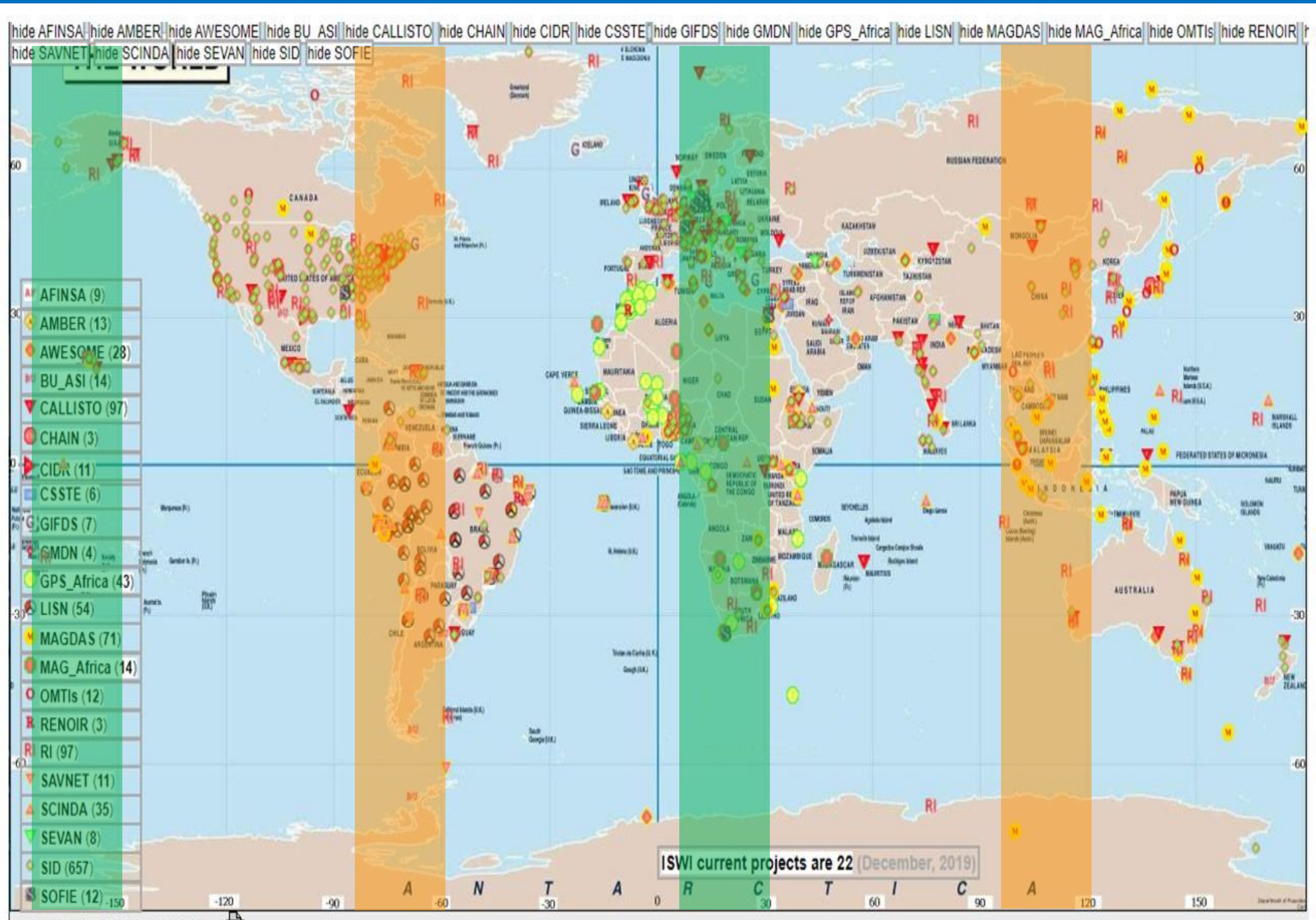
- Set-up of an “IMCP Europe-Africa-Pacific Working Group”: Summer 2023
- IMCP workshop and School: Beijing, September 13-24, 2023
- European Space Weather Week 2023 (Toulouse, France, octobre 2023):
Topical Discussion Meeting (t.b.c.) + Science contributions on IMCP
- IMCP Europe-Africa-Pacific Circle Workshop #1 in 2024

Comments, interests and participations welcome!

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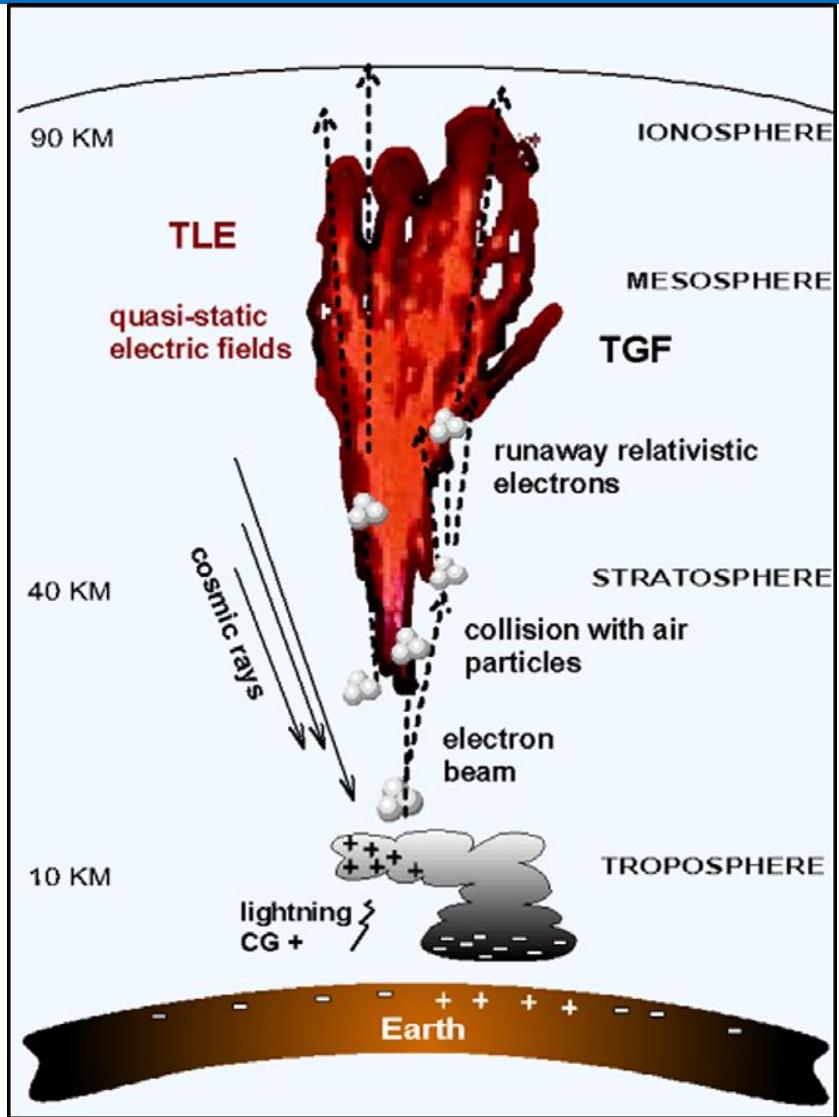
IMCP within ISWI

To stimulate cooperation between all interested countries, continued dialogue on the development of the IMCP project under the umbrella of ISWI and of UNOOSA will be particularly important !



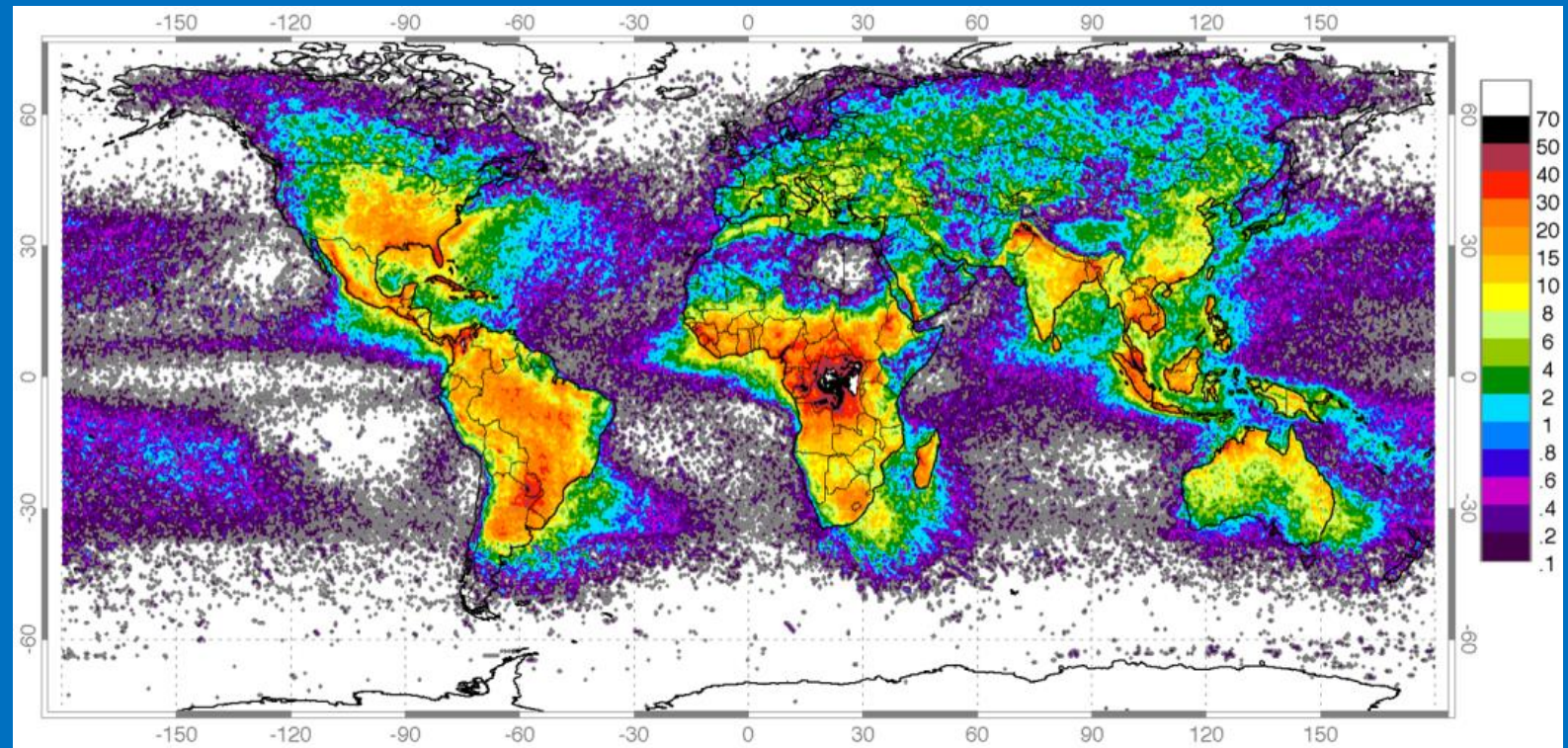
Additional slides

(AW) + (GE) Vertical coupling in the atmosphere: World maximum of thunderstorm activity in Africa

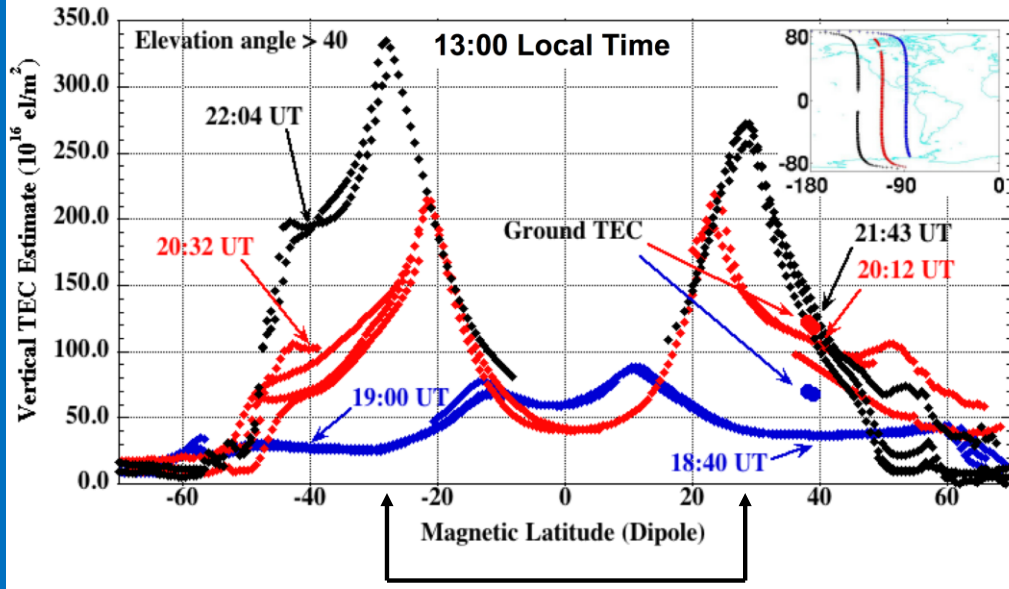


Upward electric discharges from top of clouds to ionosphere close the global ionospheric circuit

Identify how discharges are triggered, associated EM and ES generation mechanisms , charged particle acceleration mechanisms



Oct 30, 2003: CHAMP Buildup of TEC on the Dayside



(SW) LOW-LATITUDE PHENOMENA Longest land traverse of equatorial electrojet in Africa

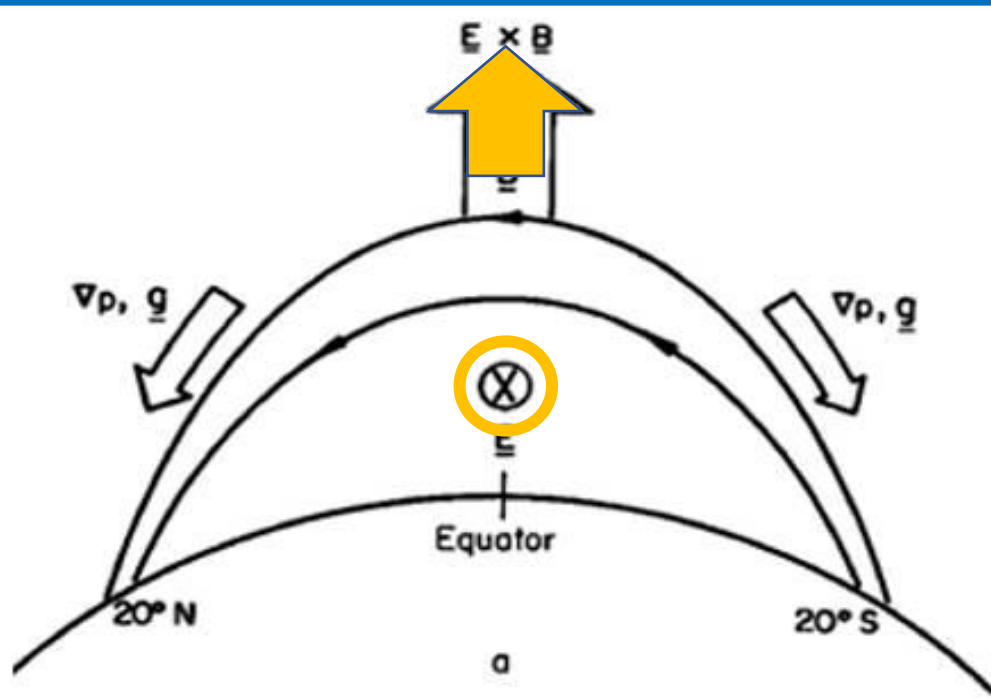
Equatorial electrojet and fountain are driven by :

- Variations of the **zonal ionospheric electric field**
- Travelling atmospheric/ionospheric disturbances
- Cross-equatorial winds

Need to quantify the time response of:

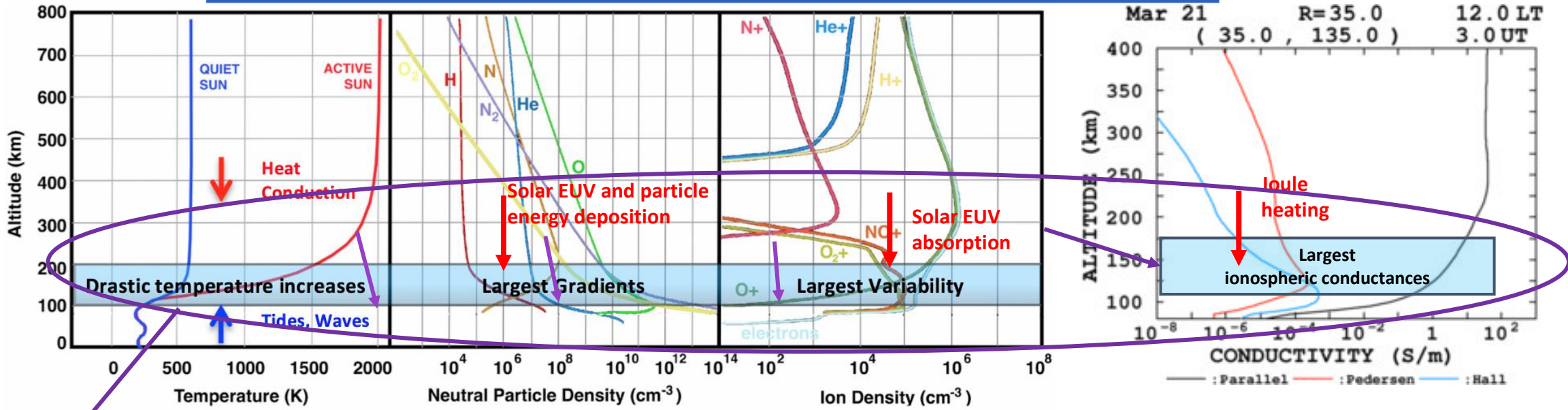
- equatorial electrojet
- vertical plasma drifts
- sub-tropical crests
- equatorial irregularities
- spread-F

through the **diversity of magnetic storms**

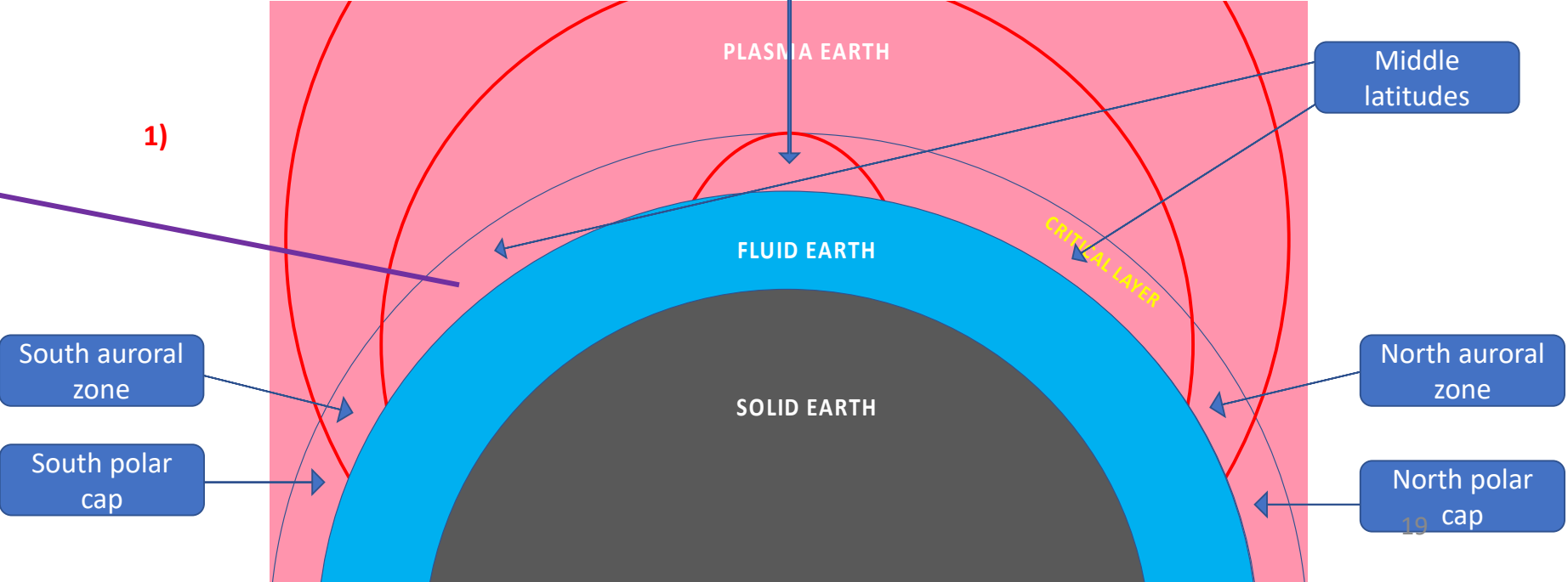


Ionosphere and Middle-Upper Atmosphere (IMUA)

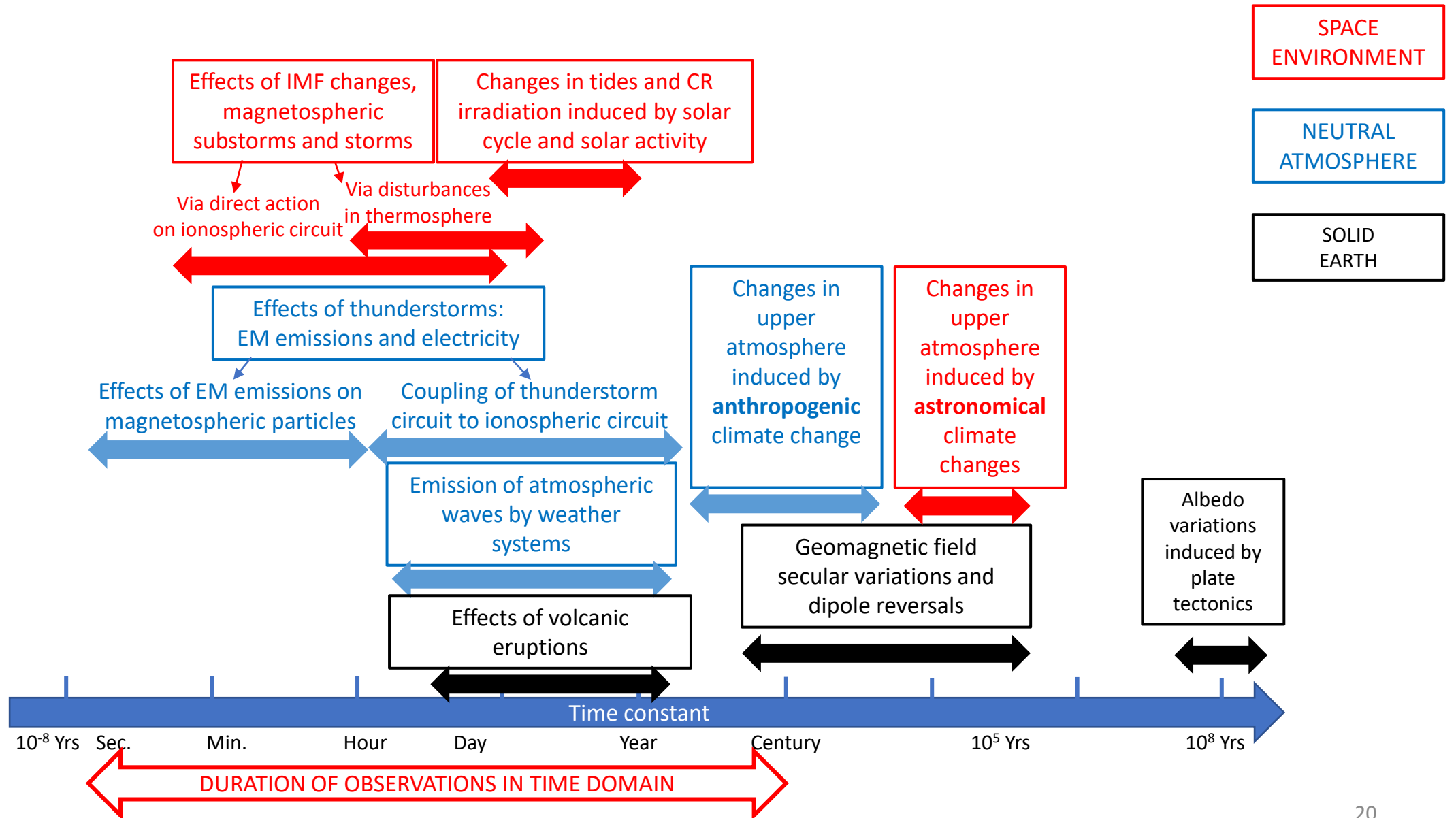
A critical interface layer in Geospace



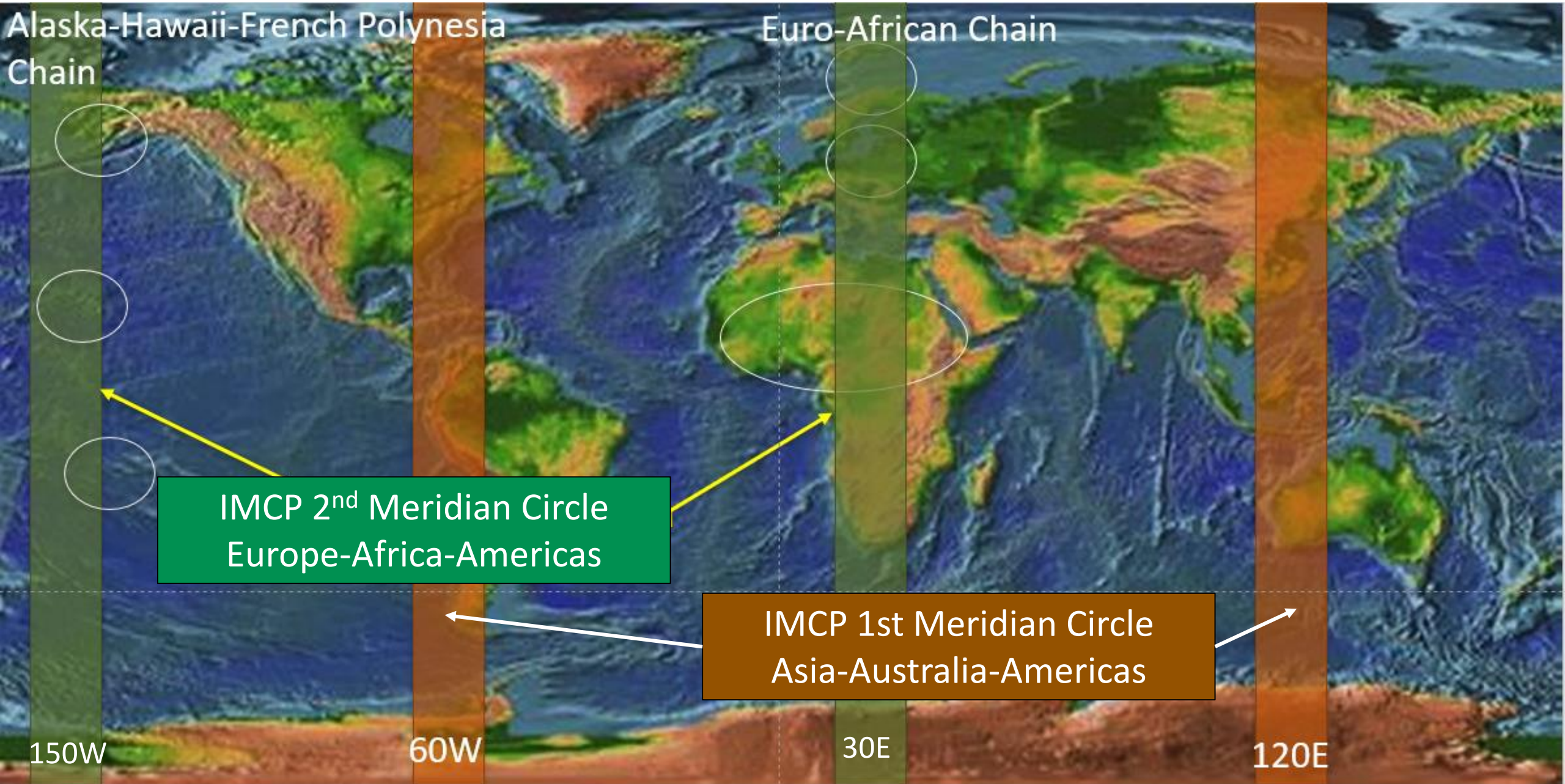
Need to identify a set of « Key Parameters » whose measurements can characterize the average state of this critical layer and the disturbances induced on it both from above and from below



Timescales of the different sources



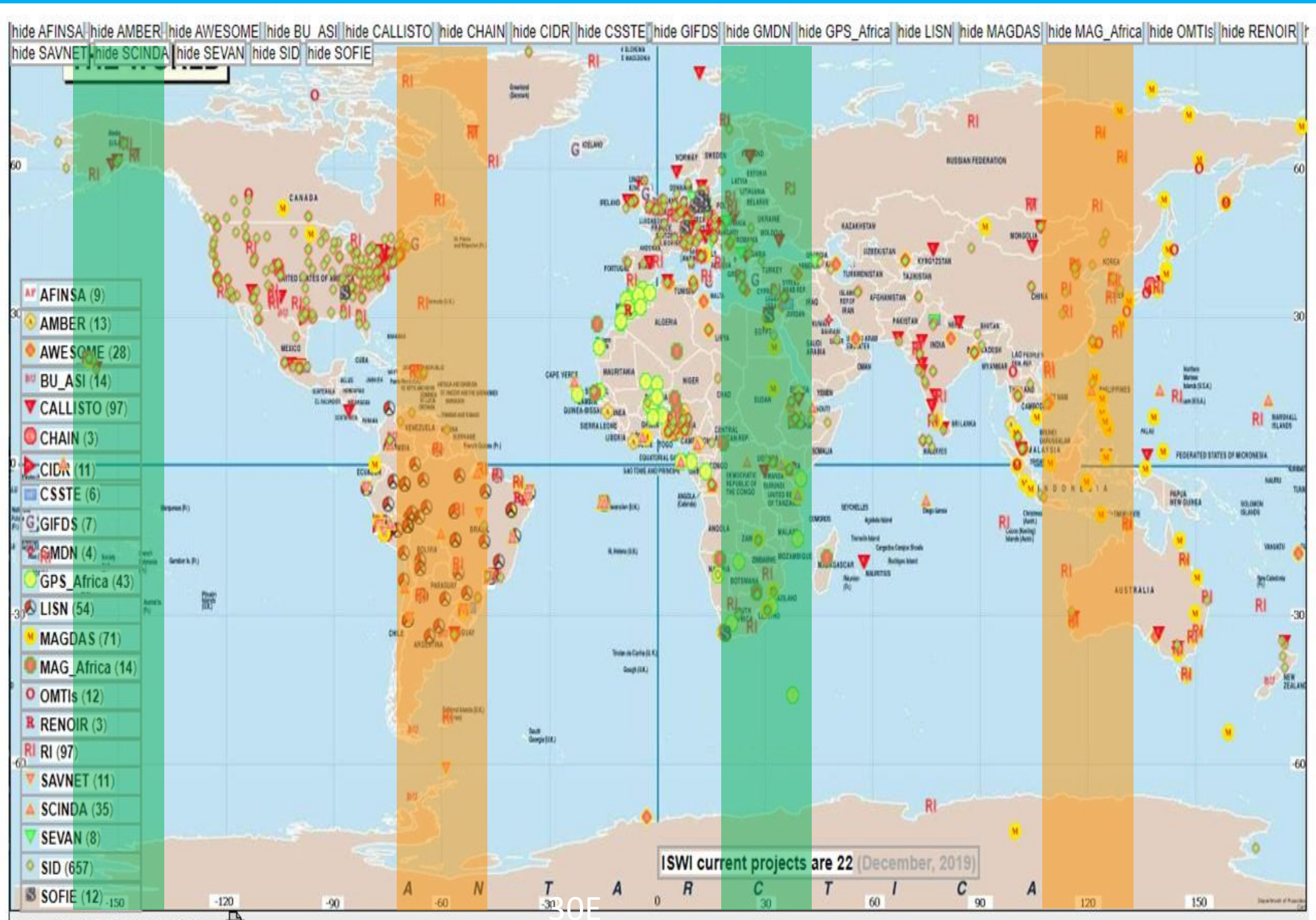
GEOGRAPHIC DEPLOYMENT



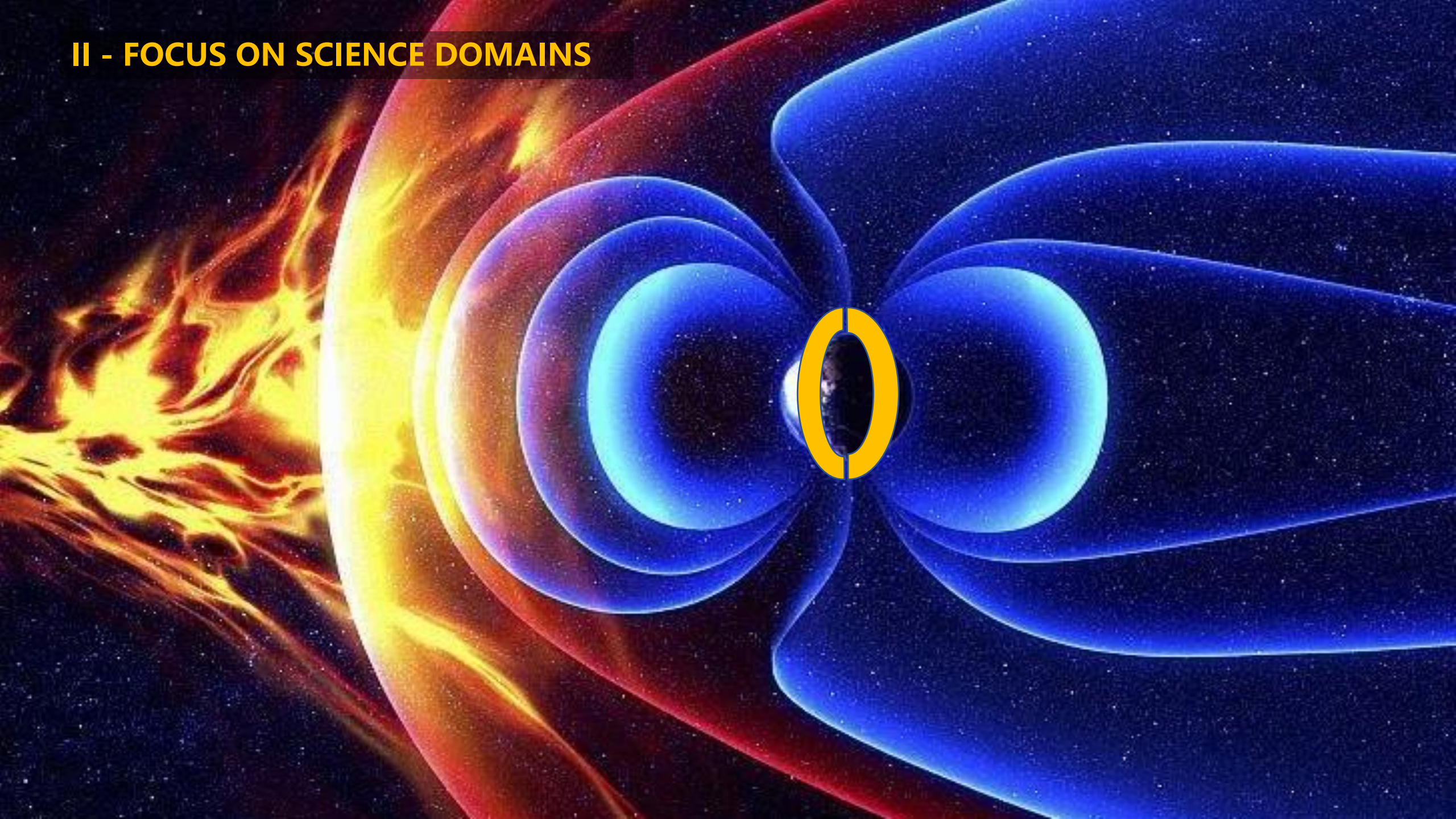
IMCP within ISWI

To facilitate cooperation between all interested countries, continuation of dialogue on the development of the IMCP project with its two Great Circles (and more...), continuation under the umbrella of ISWI and of UNOOSA will be particularly welcome

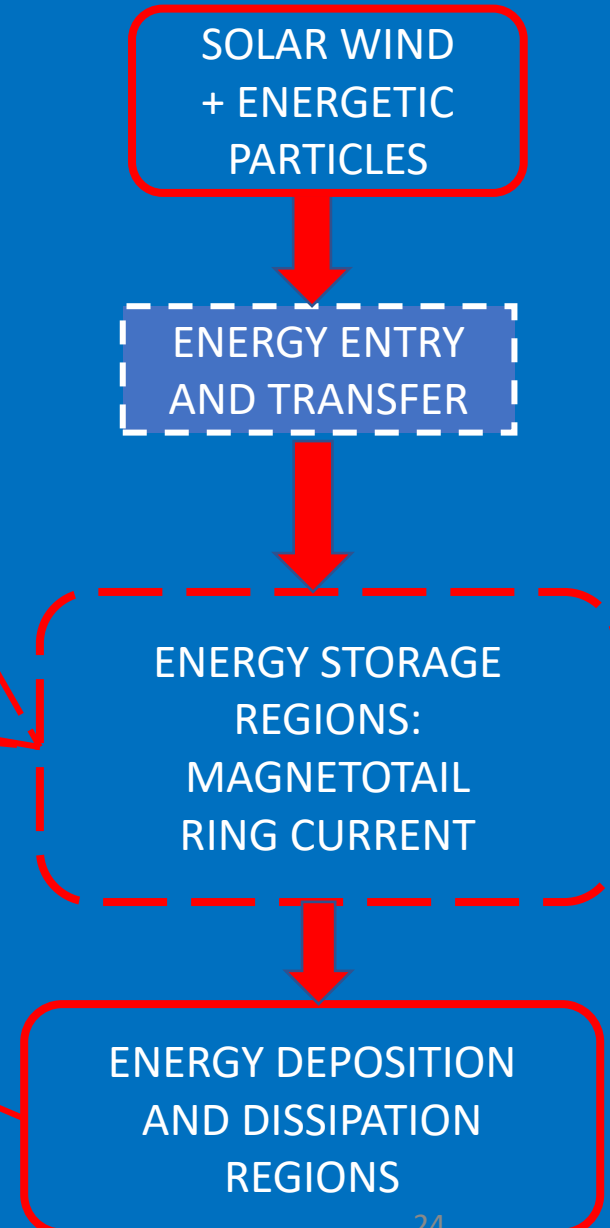
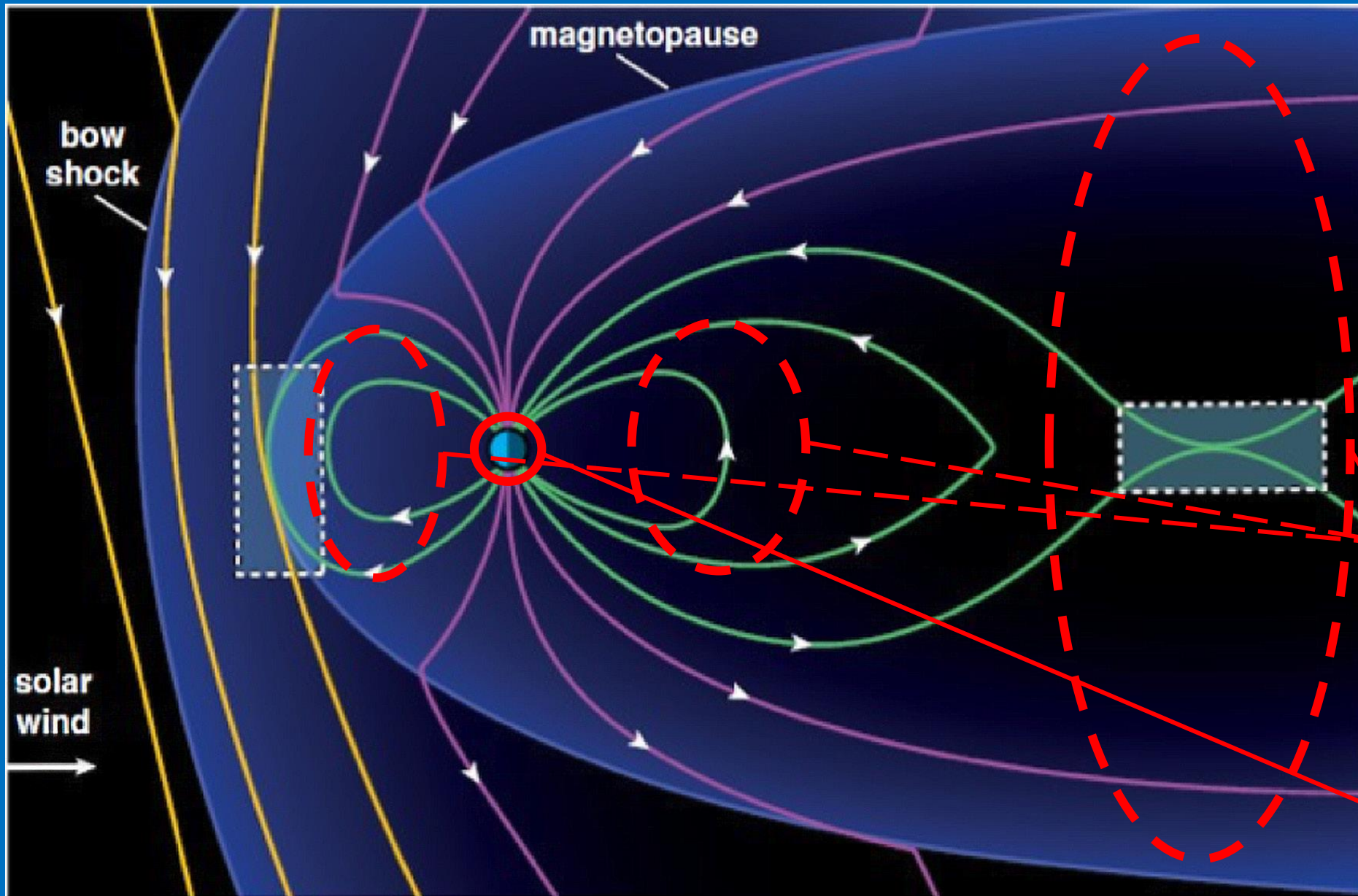
150W



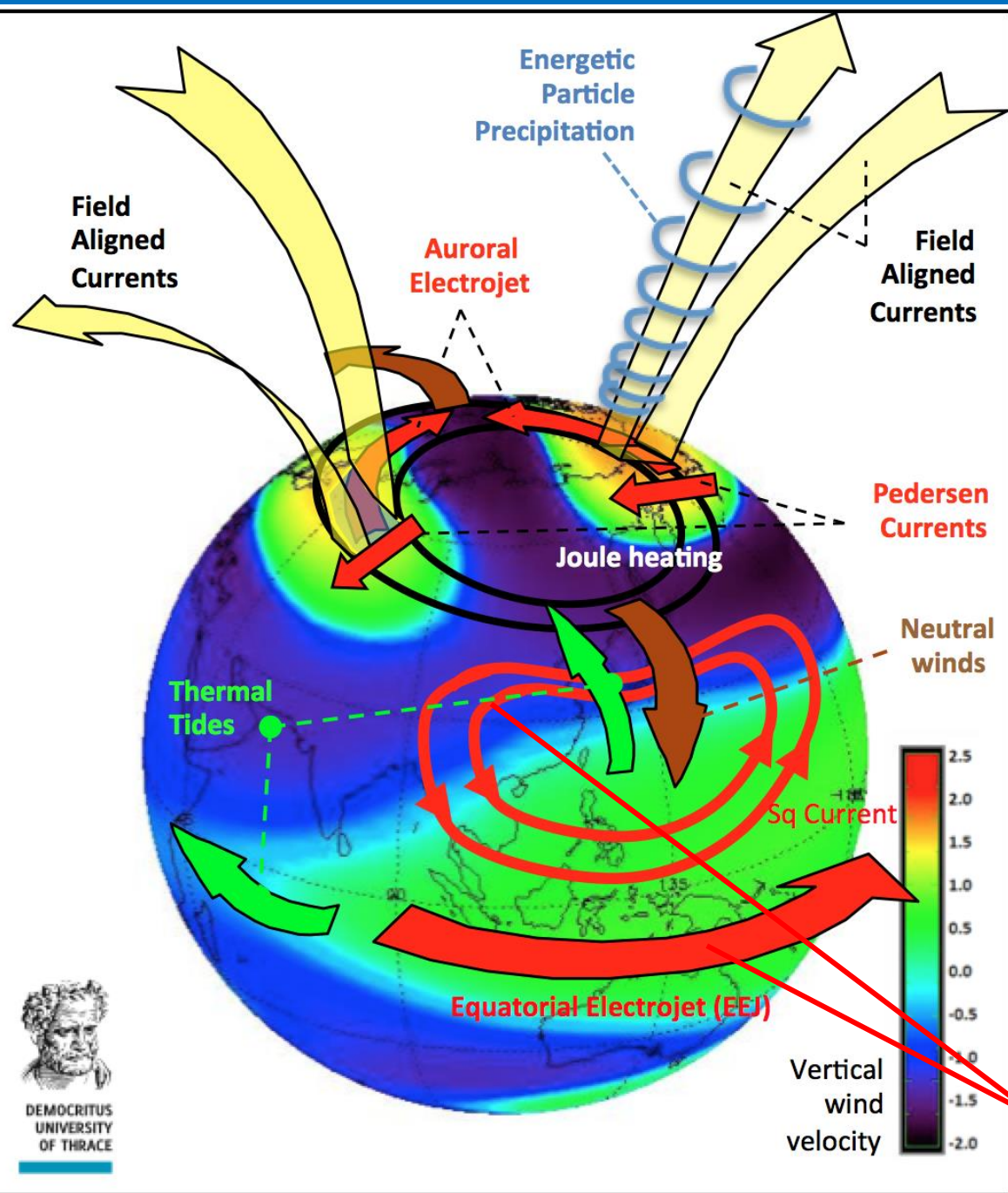
II - FOCUS ON SCIENCE DOMAINS



(SW1) Geospace coupling to Solar wind and Interplanetary Space



(SW2) MIT and cross-latitude coupling processes

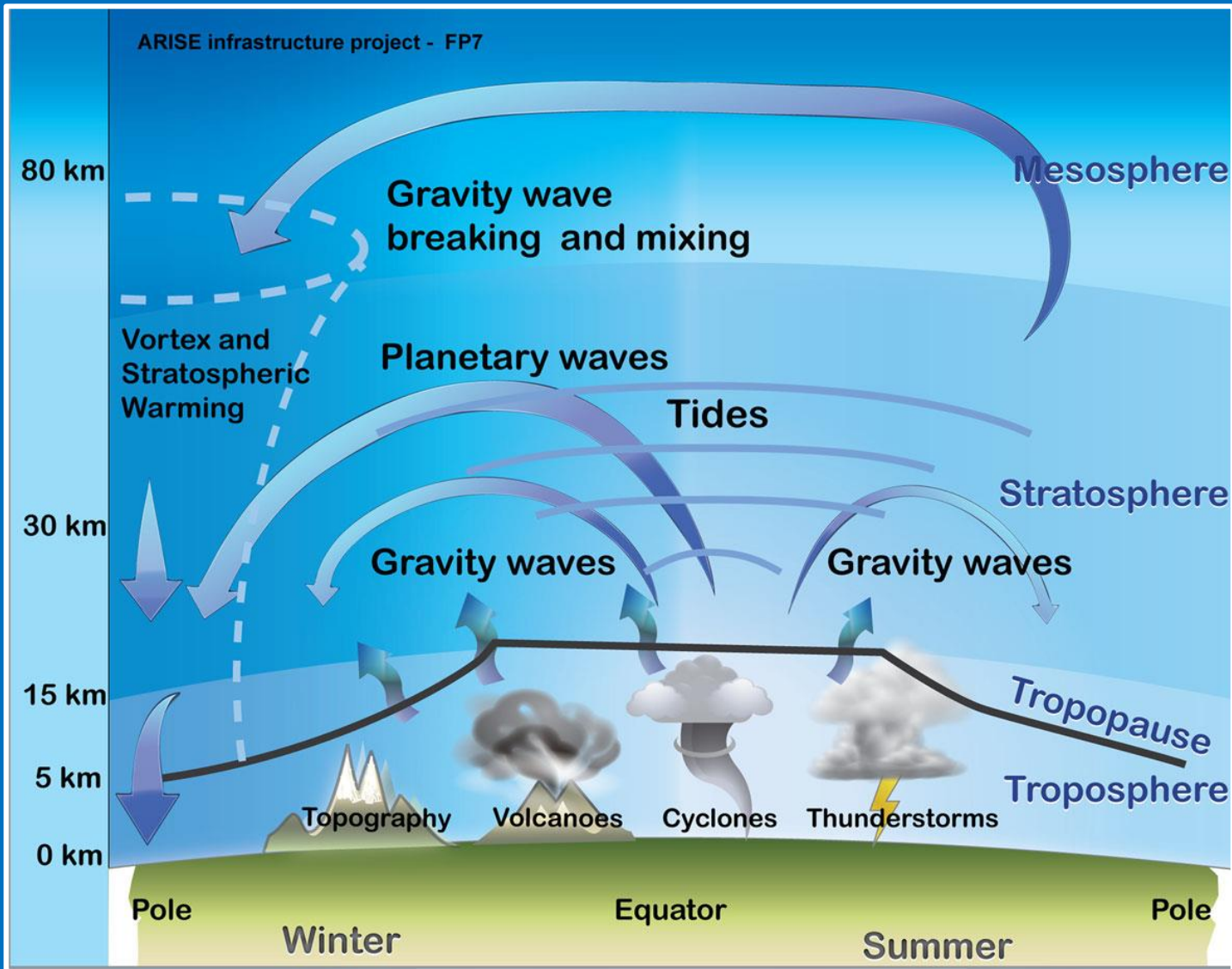


1. Penetration to middle and low latitudes of electric fields produced by the ionospheric closure of field-aligned currents
2. Partial and time-dependent shielding of these electric fields by the polarization of the inner edge of the ring current
3. Generation of latitudinal Hadley cells by auroral heating, latitude redistribution of angular momentum in thermosphere, production of westward flows in the middle latitude thermosphere
4. Transmission of these westward flows to the ionosphere and plasmasphere by the "ionosphere disturbance dynamo" mechanism

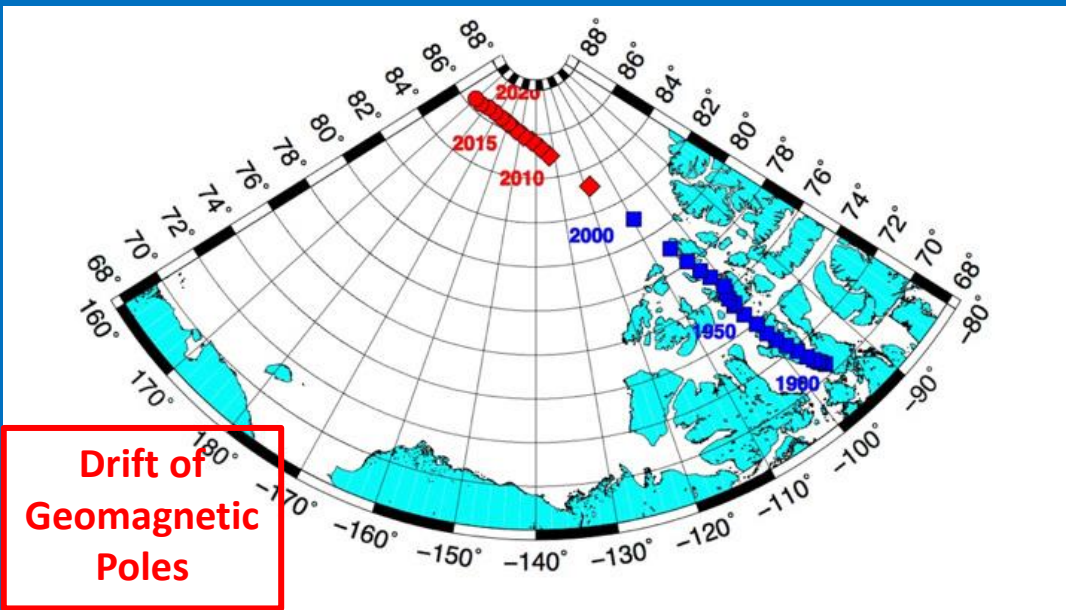
"Red" : regular currents driven by tides (upward-propagating and in situ) generated via the Ionospheric Dynamo



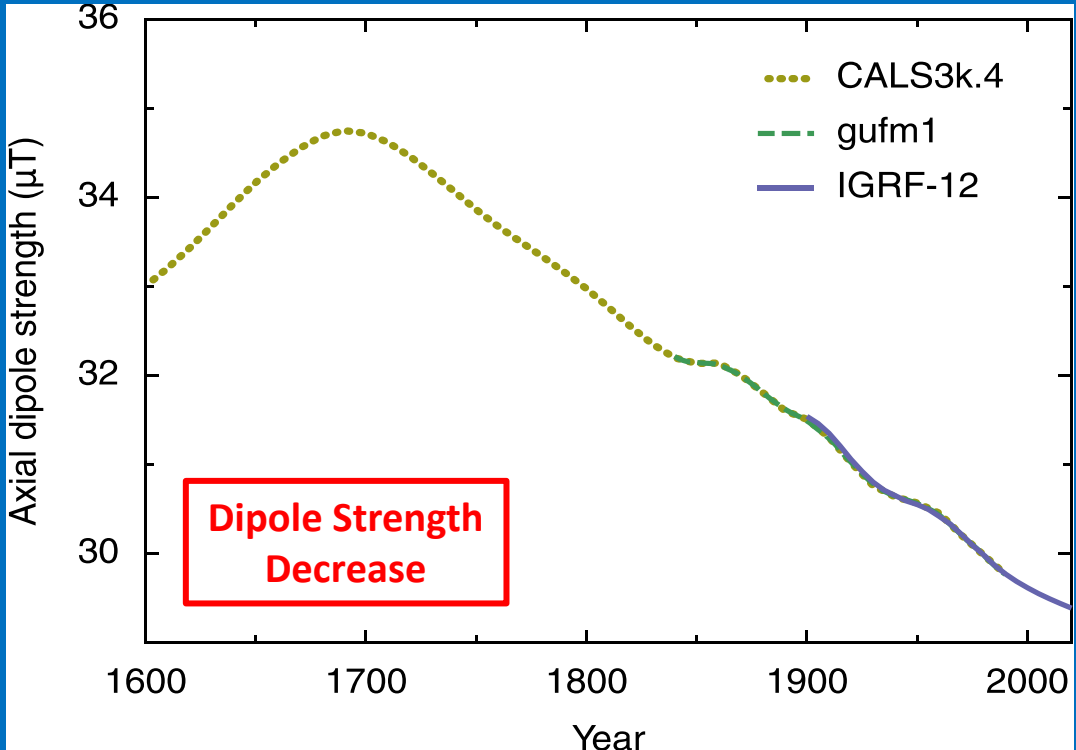
(AW) Vertical coupling in the atmosphere: Atmospheric waves



- A broad spectrum of atmospheric waves are generated by the latitudinal structure of general circulation, weather events, orography and land-ocean contrasts
- They propagate upwards through the stratosphere, mesosphere and into the lower atmosphere
- Reflection at critical levels, refraction, interactions with the mean wind, dissipation determine how much momentum and energy they transfer to the region of positive temperature gradient of the thermosphere

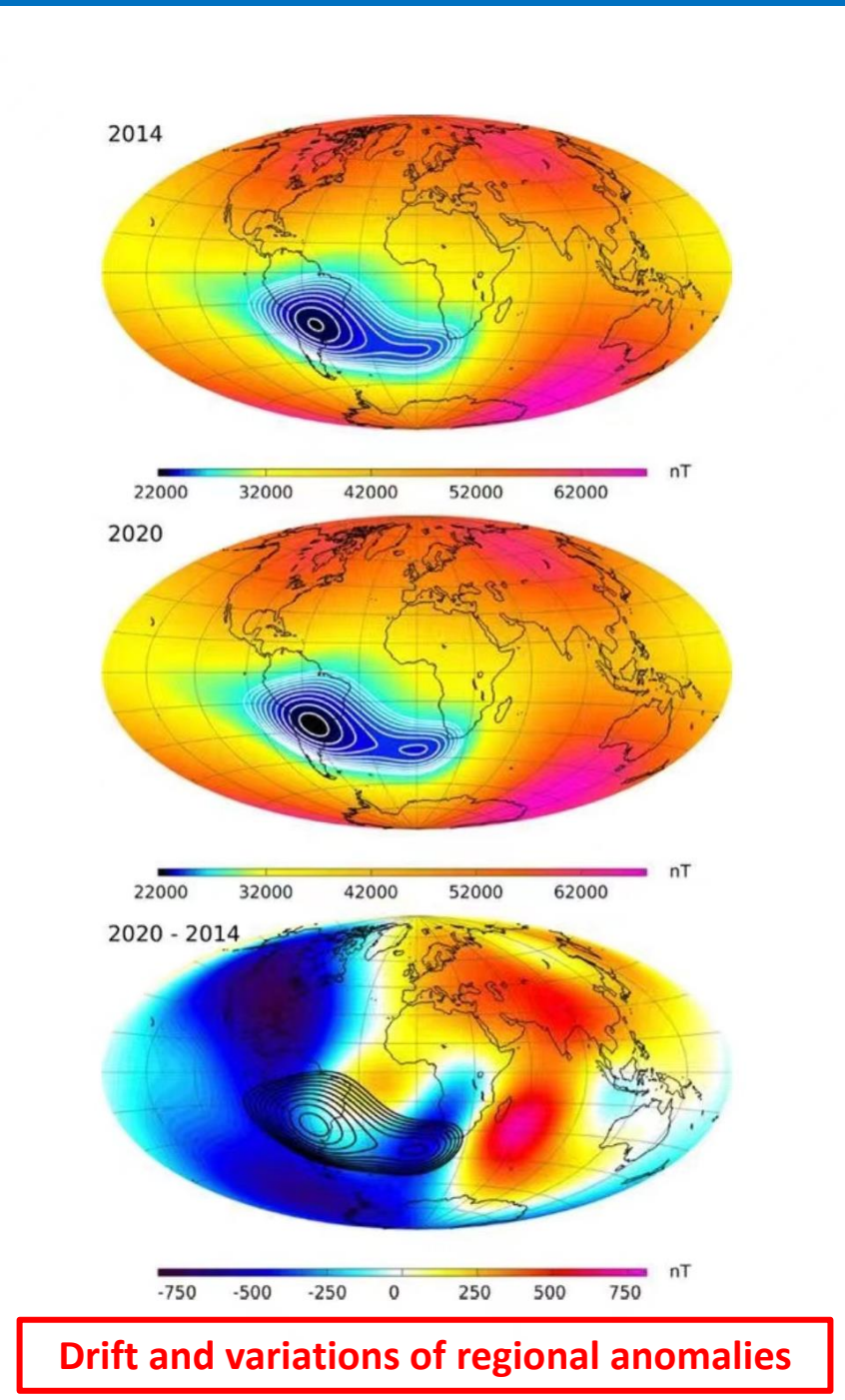


Drift of Geomagnetic Poles



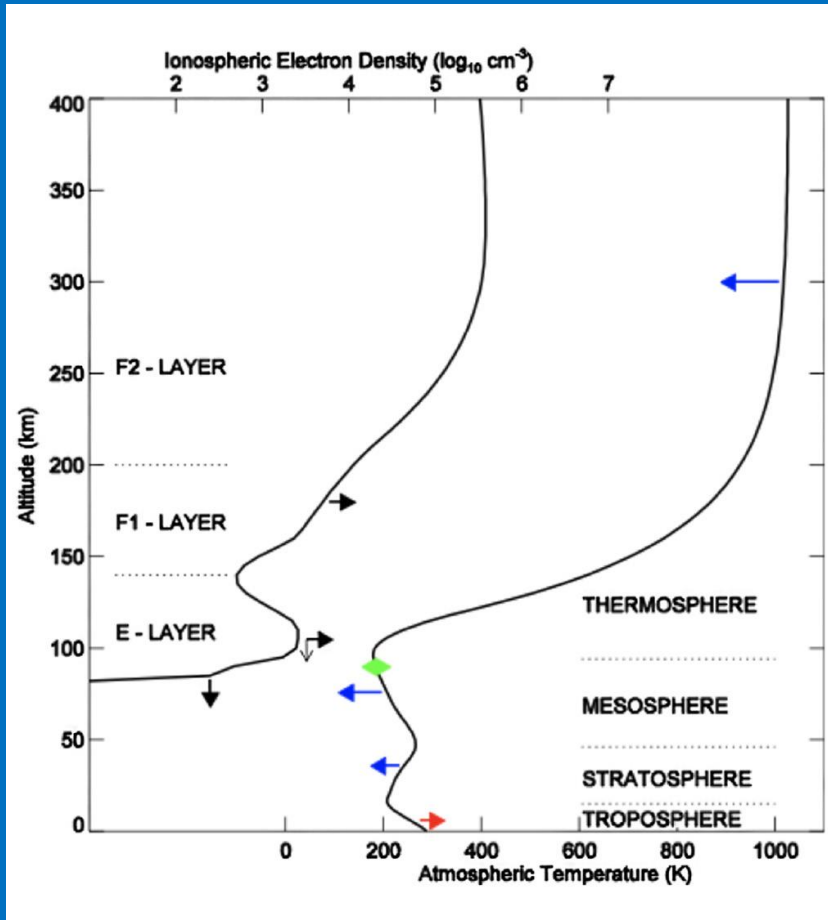
Dipole Strength Decrease

(GM) Secular variations of the geomagnetic field

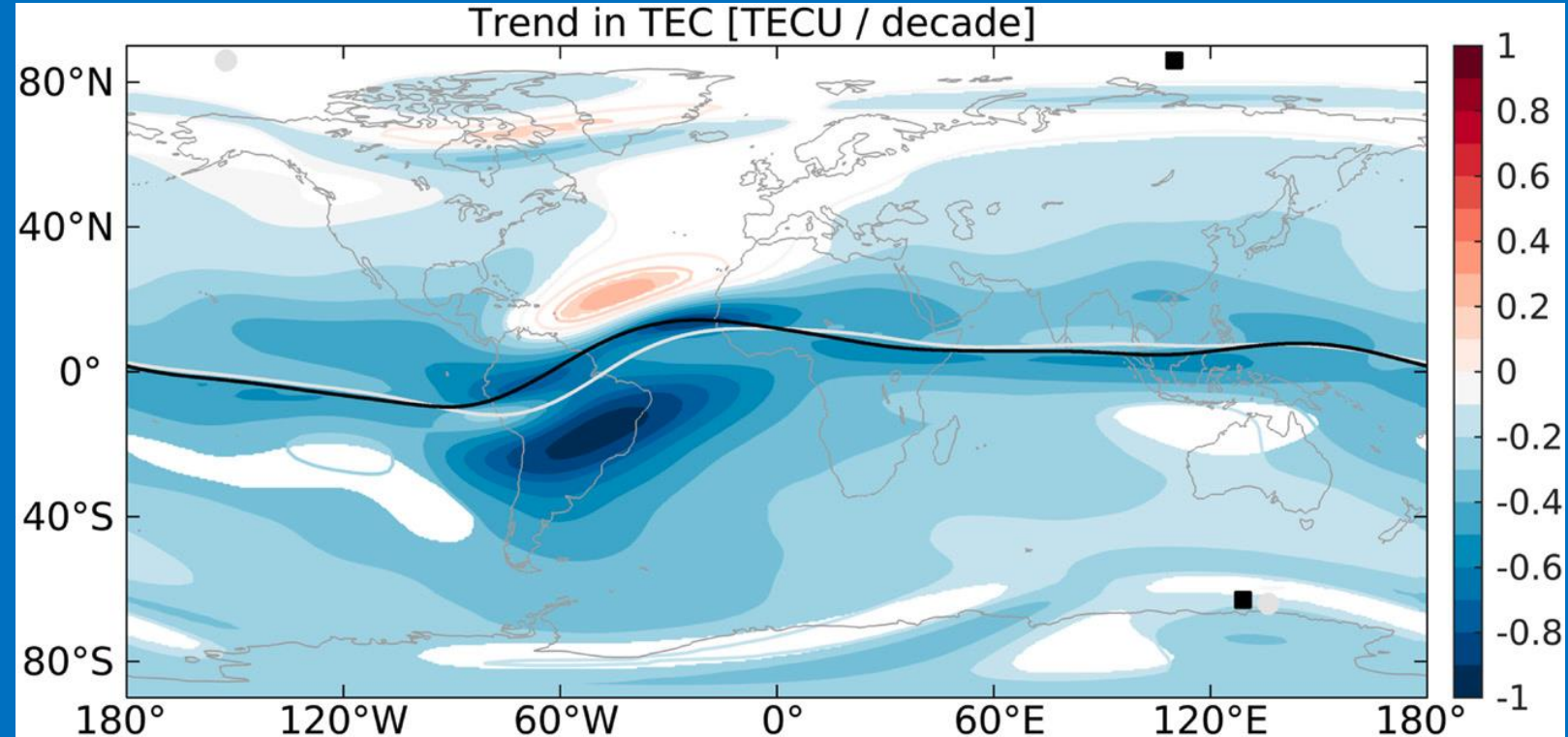


Drift and variations of regional anomalies

(GG + GM) Combined effects of climate change and geomagnetic field secular variations



Emerging pattern of global change in the thermosphere and ionosphere, according to J. Lastocicka et al. (Ann. Geophys., 26, 1255-1268, 2008)



Model prediction of change in TEC between 2015 and 2070, according to the simulations of Cnussen (2022) GRL, 49, e2022GL100693. <https://doi.org/10.1029/2022GL100693>