



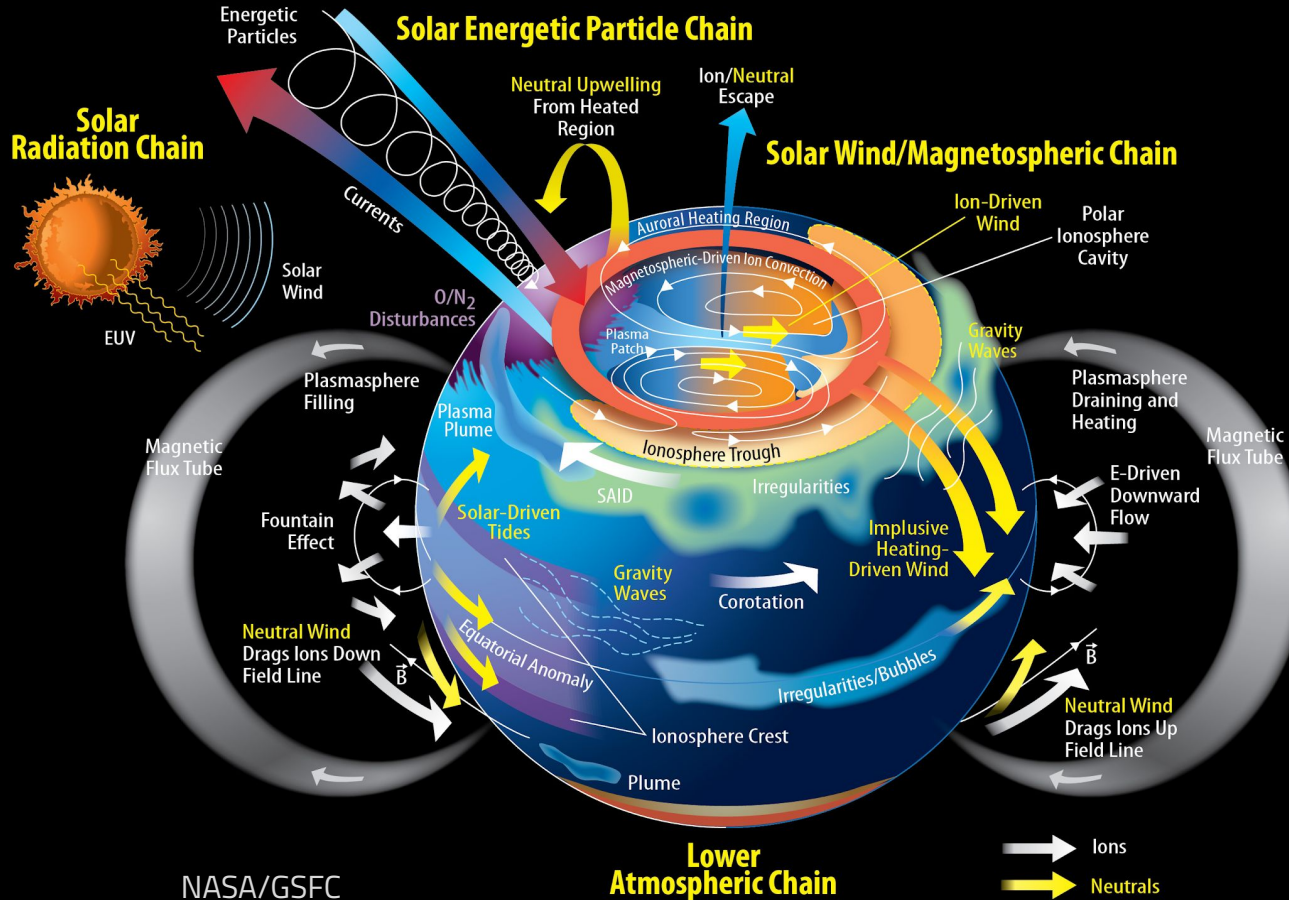
Multi-instrument detections of ionospheric disturbances

Šimon Mackovjak

Slovak Academy of Sciences

Second PITHIA-NRF TNA Users Meeting, Brussels (BE), 3 June 2025

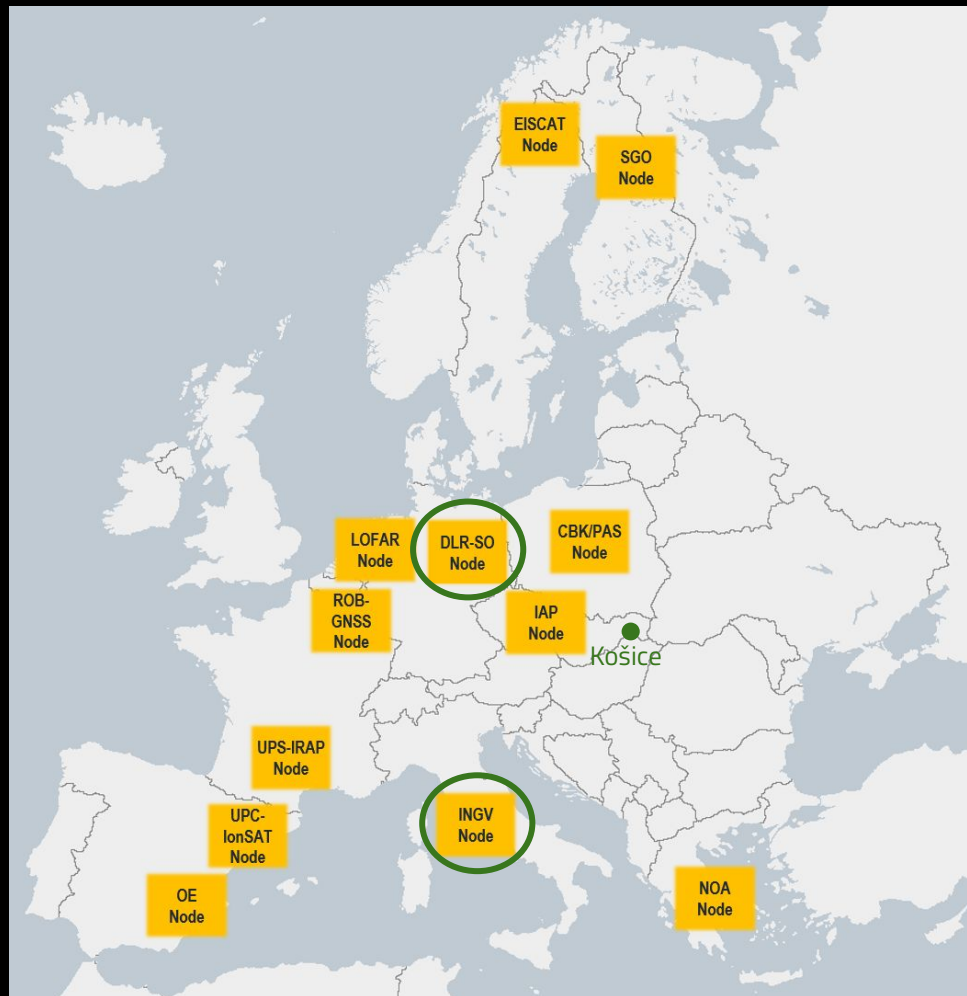
Terrestrial Atmospheric ITM Processes



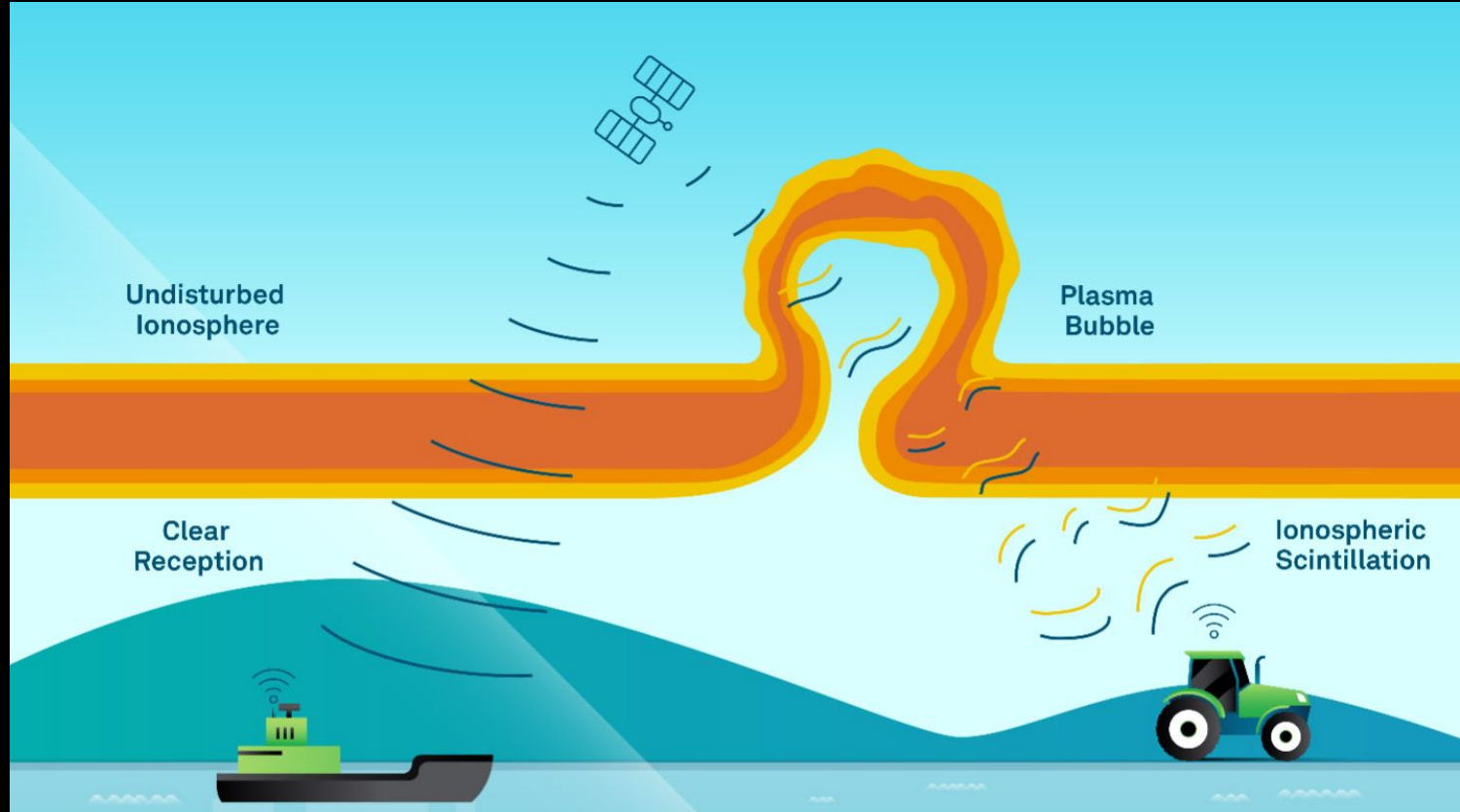
TNA activities



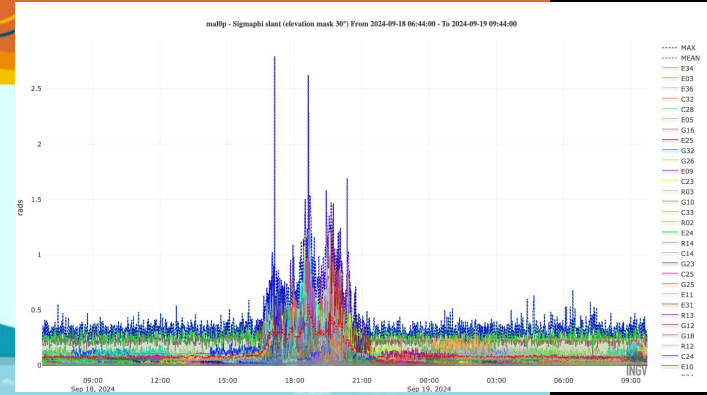
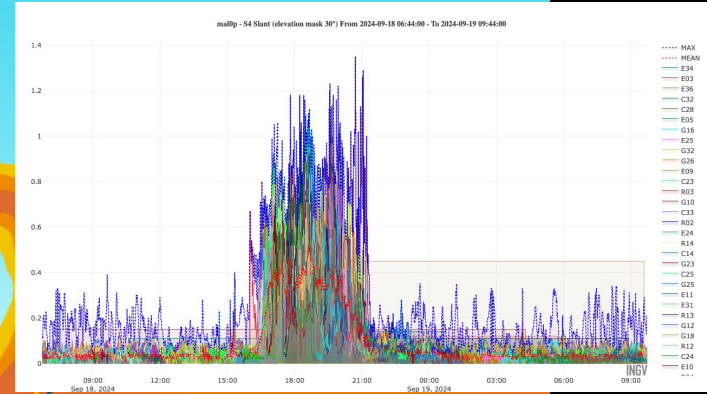
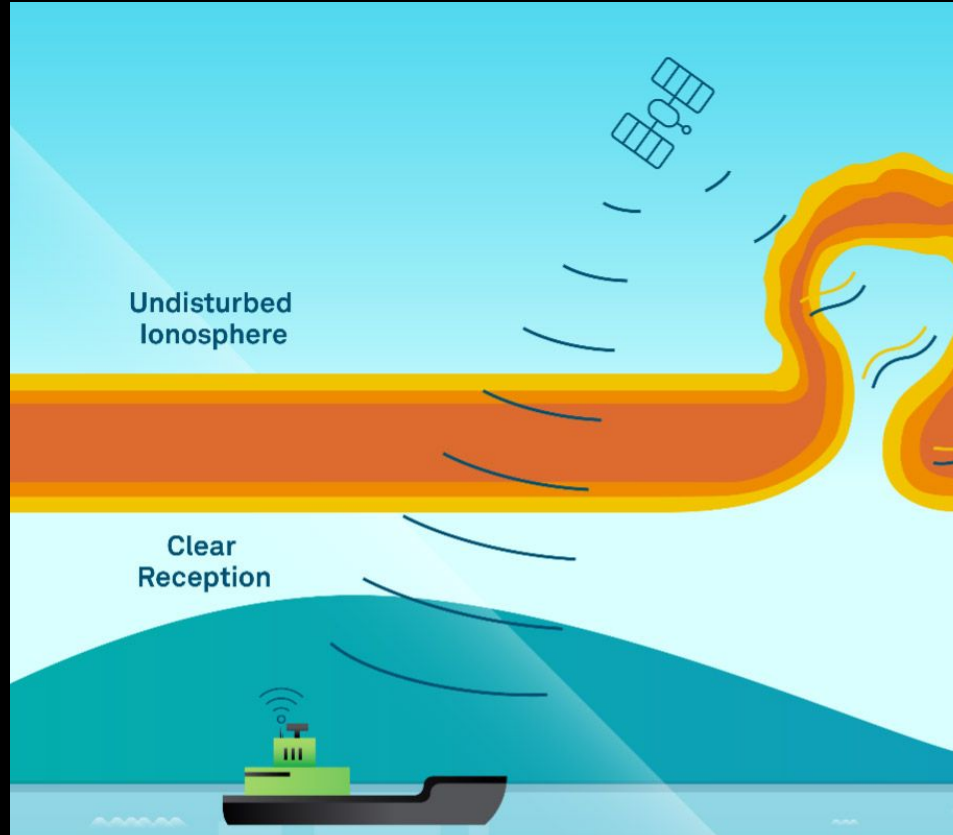
ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA



Ionospheric scintillations

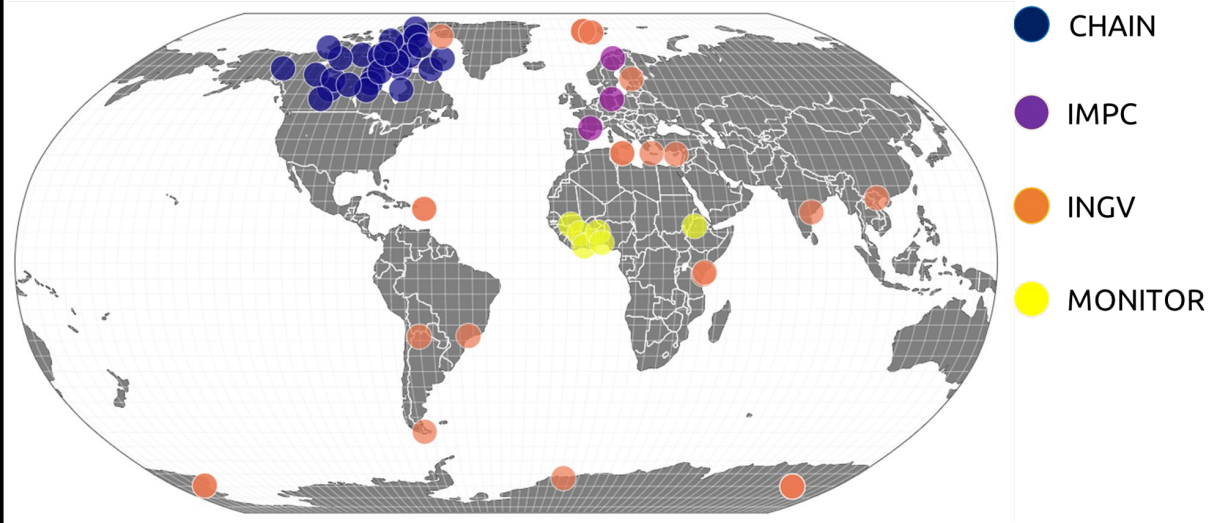


Ionospheric scintillations



Acronym	Name	Nr. of stations	Region
CHAIN	Canadian High Arctic Ionospheric Network	11	Canada
IMPC	Ionosphere Monitoring and Prediction Center, DLR	4	Europe
INGV	National Institute of Geophysics and Volcanology	28	Europe, South America, Antarctica, Asia
NMA	Norwegian Mapping Authority	8	North Europe
MONITOR	Network of scintillation receivers by ESA	12	Europe, Africa

<http://chain.physics.unb.ca/chain/>
via PITHIA-NRF TNA

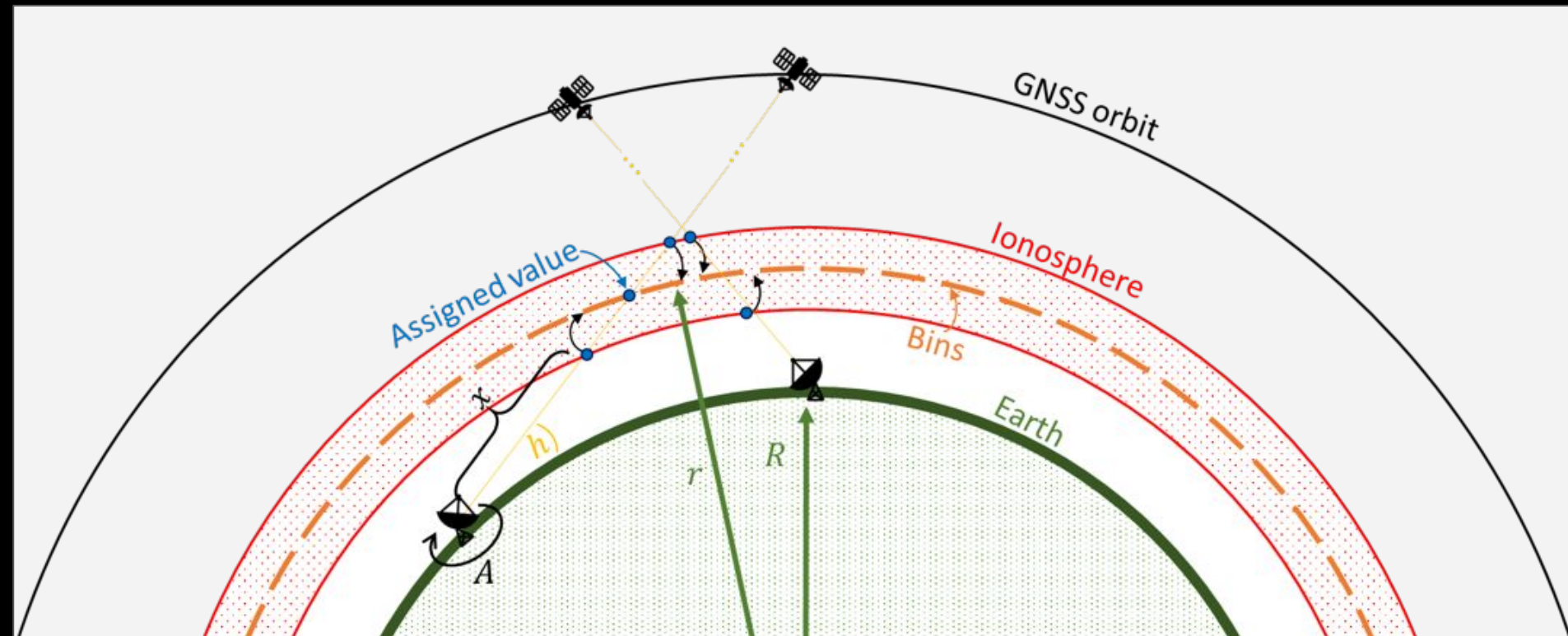


Focus on Phase scintillations:

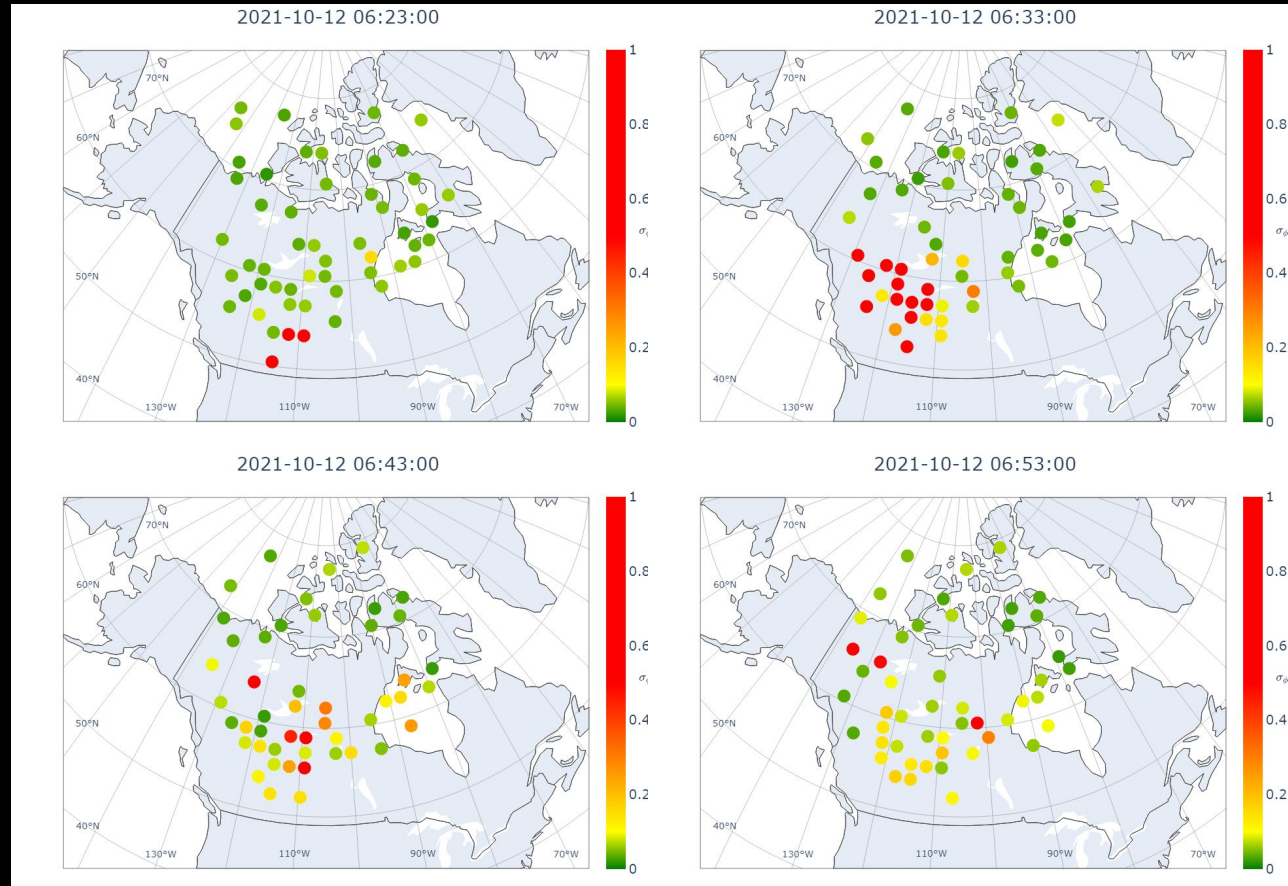
$$\sigma_{\phi} = \sqrt{\langle \phi^2 \rangle - \langle \phi \rangle^2},$$

Φ - detrended carrier phase

Sketch of considered geometry



Example of ionospheric scintillation in 2D space and time

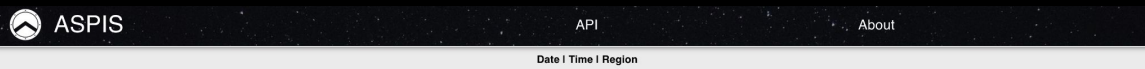
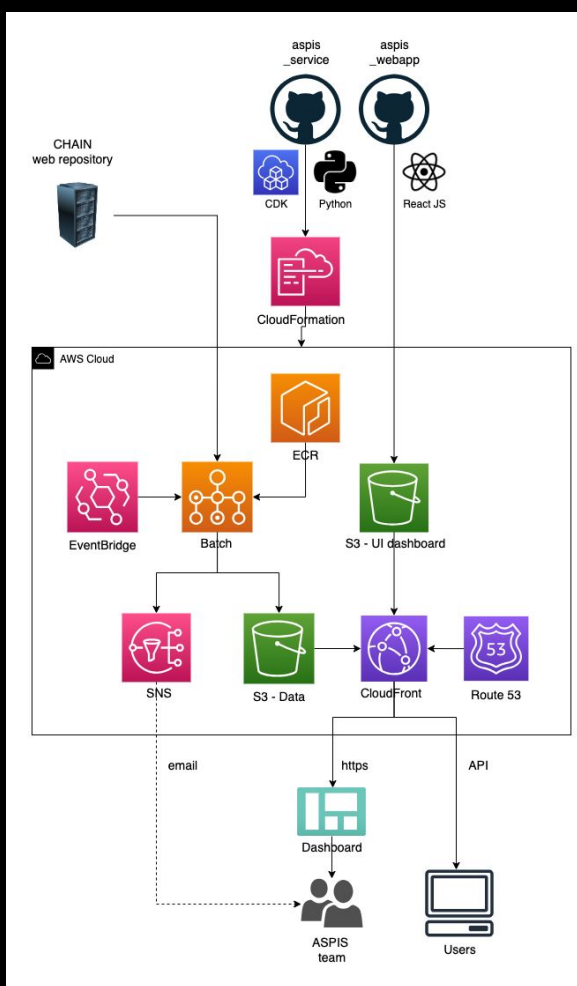


Ionospheric scintillations (σ_{ϕ})



TECHNICAL UNIVERSITY
OF KOSICE

2184, 194460, 12,	628, 381, 14, 38.6,	0.393,	0.117,	0.056,	0.063,	0.069,	0.071,	0.072,	-1.197,	0.572,	18.435,	0.026,	24.632,	-0.062,	20.158,	-0.035,
2184, 194460, 22,	628, 80, 36, 42.2,	0.128,	0.078,	0.036,	0.039,	0.040,	0.040,	0.040,	-1.989,	0.241,	14.603,	-0.033,	13.832,	0.001,	14.060,	0.009,
2184, 194460, 19,	628, 218, 58, 47.2,	0.046,	0.044,	0.020,	0.028,	0.031,	0.032,	0.032,	-3.824,	0.076,	8.584,	-0.029,	10.412,	0.004,	14.238,	-0.024,
2184, 194460, 14,	628, 156, 27, 42.6,	0.110,	0.074,	0.028,	0.035,	0.039,	0.039,	0.039,	-5.340,	0.179,	7.333,	0.228,	3.373,	0.447,	6.534,	0.212,
2184, 194460, 24,	628, 277, 36, 43.3,	0.082,	0.069,	0.032,	0.034,	0.036,	0.037,	0.037,	-3.521,	0.175,	12.113,	0.009,	14.940,	0.009,	16.026,	-0.020,
2184, 194460, 21,	628, 56, 21, 39.9,	0.143,	0.101,	0.038,	0.043,	0.047,	0.047,	0.047,	-3.599,	0.245,	11.442,	0.021,	13.888,	0.017,	12.917,	0.011,
2184, 194460, 32,	628, 5, 25, 42.8,	0.138,	0.072,	0.032,	0.038,	0.044,	0.044,	0.044,	-1.319,	0.262,	15.800,	-0.023,	17.551,	0.001,	16.847,	0.010,
2184, 194460, 3,	628, 107, 27, 41.6,	0.127,	0.083,	0.036,	0.047,	0.050,	0.051,	0.051,	-2.703,	0.289,	21.540,	-0.021,	15.124,	0.011,	12.316,	0.009,
2184, 194460, 17,	628, 156, 67, 48.0,	0.042,	0.040,	0.019,	0.026,	0.029,	0.029,	0.029,	-3.400,	0.082,	14.551,	0.007,	14.189,	0.029,	13.133,	0.012,
2184, 194460, 1,	628, 69, 41, 44.3,	0.181,	0.061,	0.033,	0.039,	0.042,	0.043,	0.044,	-2.244,	0.175,	9.649,	0.036,	13.809,	0.041,	12.838,	-0.042,
2184, 194460, 6,	628, 198, 15, 37.3,	0.427,	0.137,	0.077,	0.132,	0.143,	0.149,	0.156,	-1.020,	0.665,	27.580,	-0.040,	22.744,	-0.077,	15.204,	-0.109,
2184, 194520, 12,	628, 381, 15, 38.3,	0.481,	0.122,	0.052,	0.056,	0.061,	0.062,	0.063,	-1.673,	0.637,	32.609,	-0.007,	25.793,	0.018,	8.848,	0.042,
2184, 194520, 22,	628, 80, 36, 43.0,	0.105,	0.070,	0.033,	0.036,	0.038,	0.038,	0.038,	-1.758,	0.208,	15.421,	-0.024,	12.442,	0.003,	13.822,	-0.018,
2184, 194520, 19,	628, 217, 58, 46.9,	0.050,	0.045,	0.021,	0.026,	0.028,	0.028,	0.028,	-3.790,	0.109,	17.637,	0.054,	20.122,	-0.010,	21.540,	-0.042,
2184, 194520, 14,	628, 156, 27, 42.7,	0.146,	0.074,	0.030,	0.034,	0.037,	0.037,	0.037,	-4.798,	0.250,	9.380,	0.117,	7.191,	0.097,	8.914,	0.507,
2184, 194520, 24,	628, 277, 35, 42.8,	0.086,	0.073,	0.033,	0.037,	0.038,	0.039,	0.039,	-3.428,	0.175,	15.416,	0.022,	16.502,	0.017,	14.179,	0.036,
2184, 194520, 21,	628, 56, 21, 40.0,	0.140,	0.100,	0.038,	0.043,	0.048,	0.049,	0.049,	-3.563,	0.246,	14.507,	-0.013,	13.622,	0.042,	10.023,	-0.033,
2184, 194520, 32,	628, 5, 25, 43.1,	0.151,	0.070,	0.030,	0.035,	0.041,	0.042,	0.042,	-1.374,	0.332,	25.119,	0.006,	14.048,	0.020,	14.724,	0.011,
2184, 194520, 3,	628, 106, 27, 40.7,	0.135,	0.092,	0.040,	0.050,	0.055,	0.056,	0.056,	-2.764,	0.293,	10.859,	-0.015,	14.829,	0.011,	19.979,	-0.022,
2184, 194520, 17,	628, 155, 67, 48.2,	0.048,	0.039,	0.019,	0.023,	0.025,	0.026,	0.026,	-3.337,	0.087,	13.771,	0.098,	14.751,	0.053,	12.847,	-0.043,



Nowcast

2025-06-01 11:00



Forecast

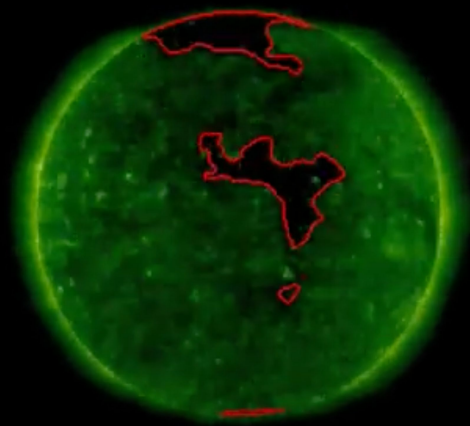
2025-06-01 12:00



<https://aspis.services>

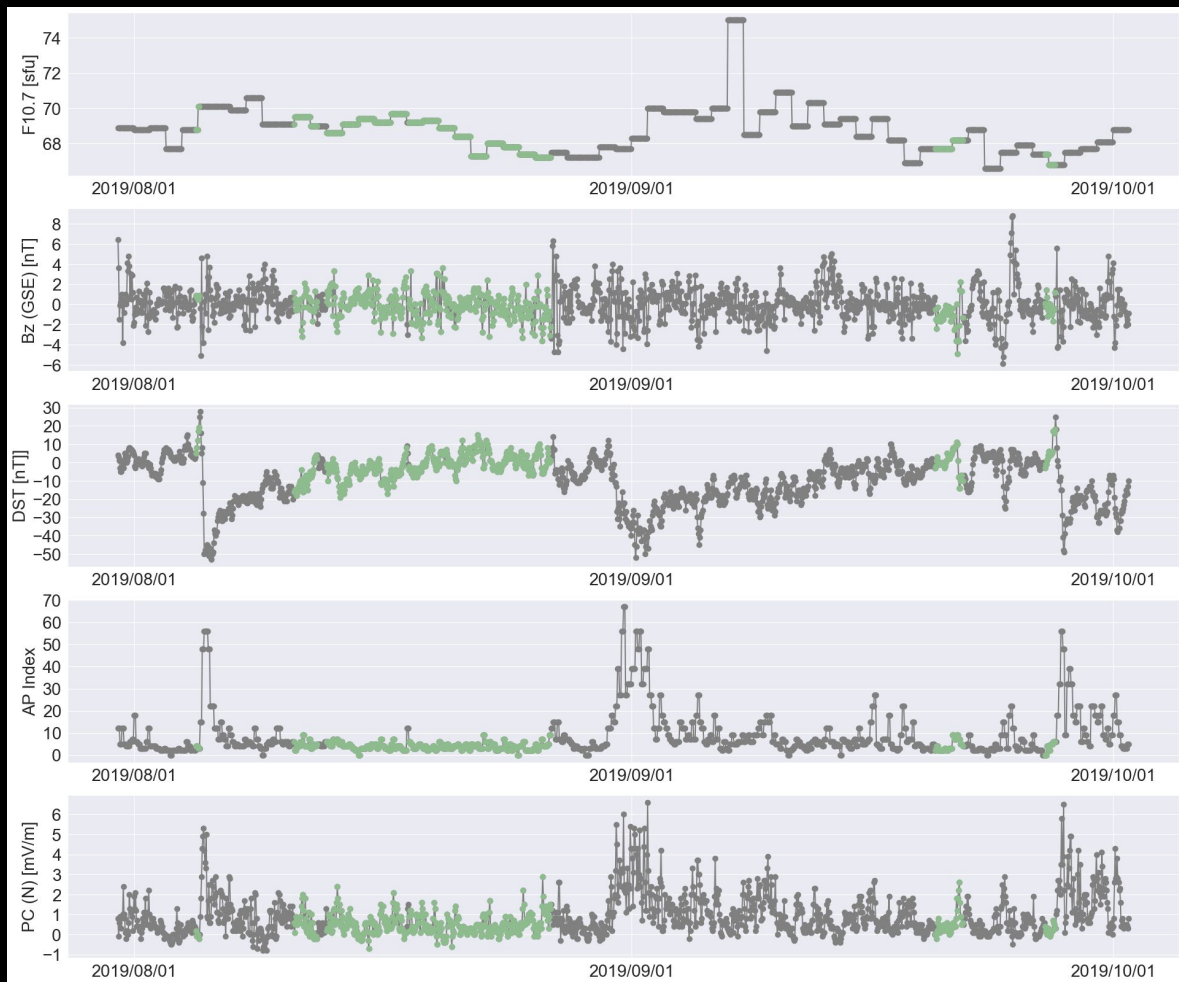
Space Weather Quiet Period

Aug - Sep 2019

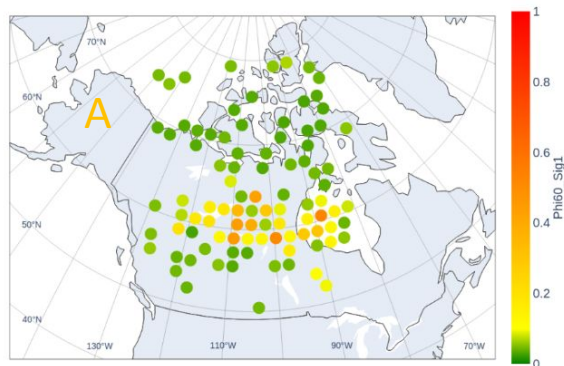


SOHO/EIT

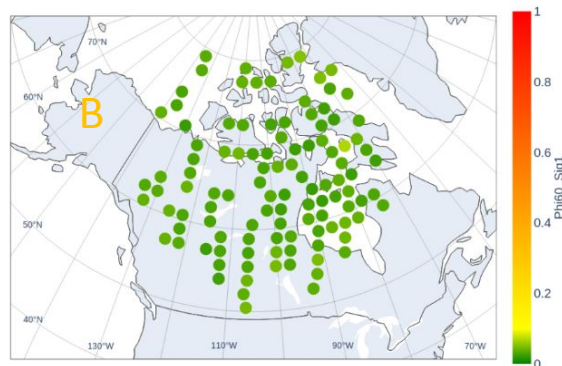
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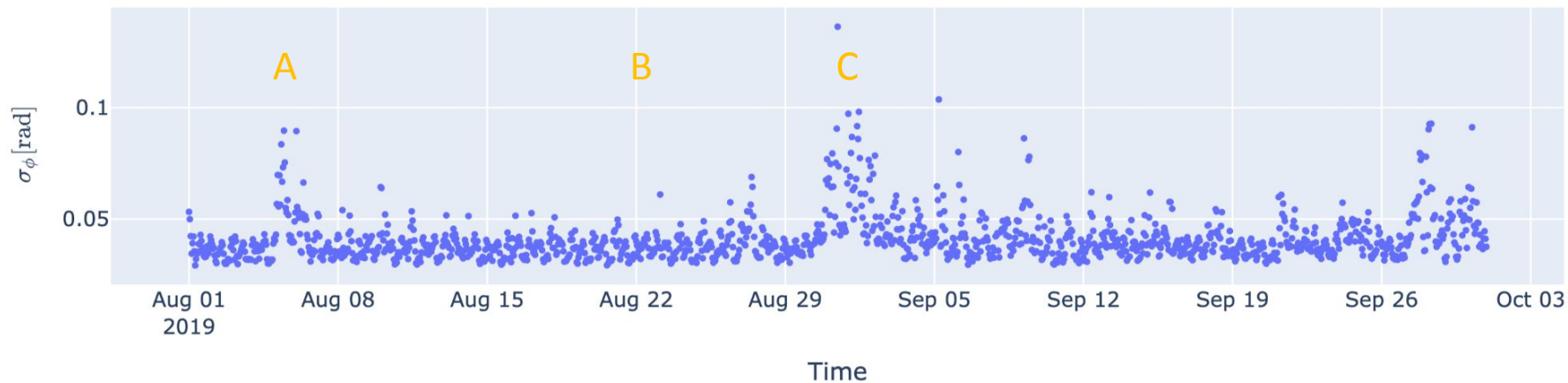
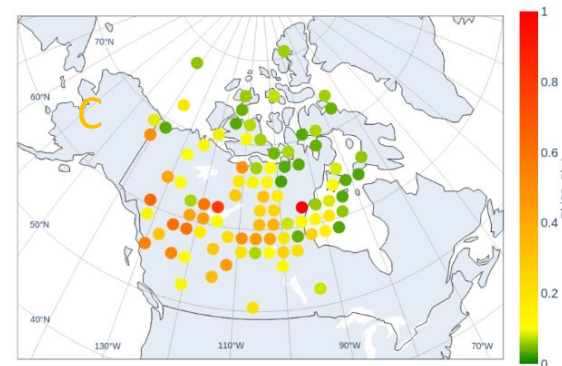
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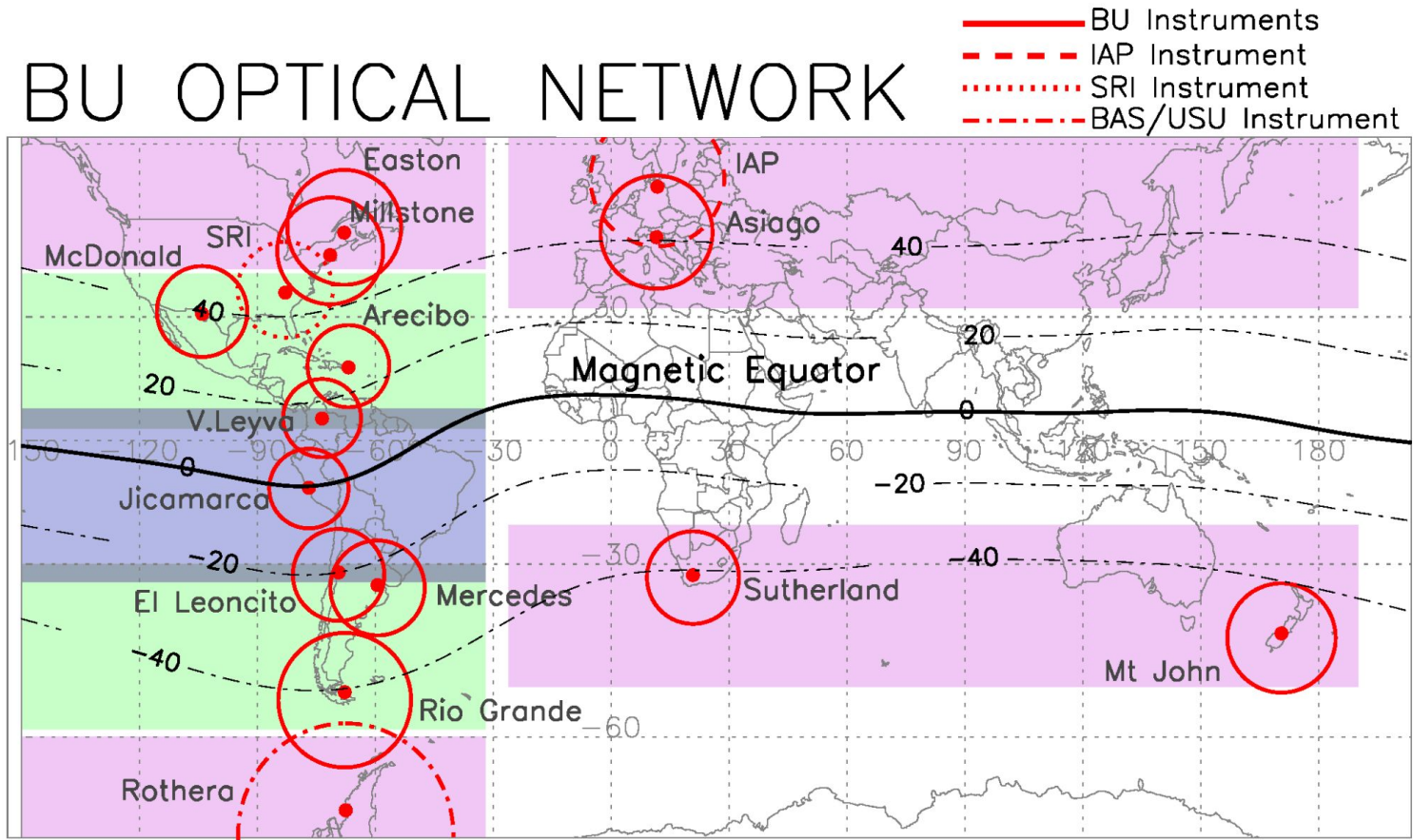
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2019-08-31 12:00:00

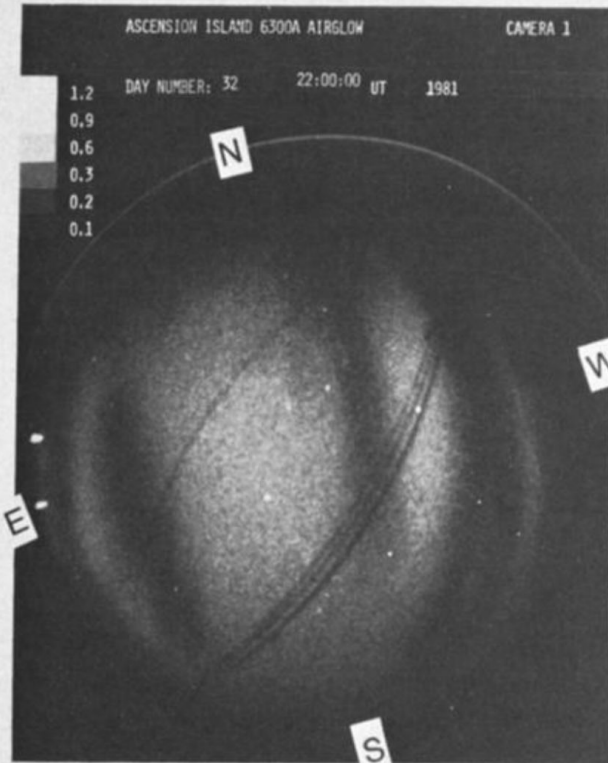


BU OPTICAL NETWORK

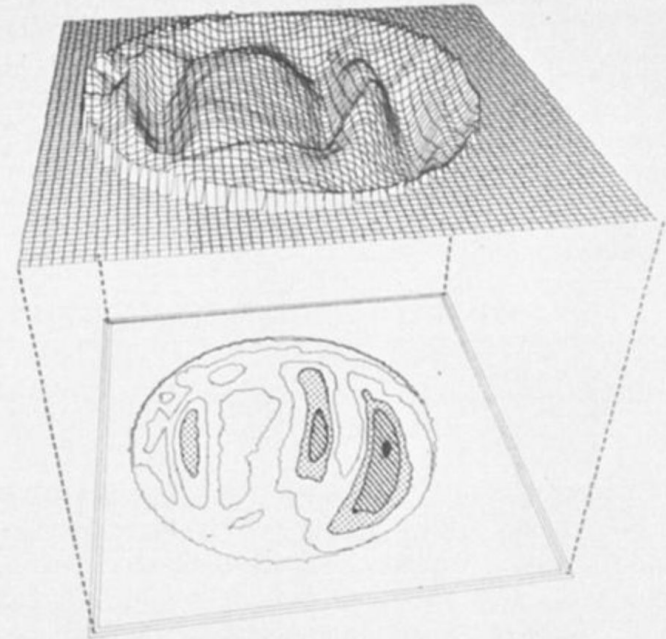


<http://sirius.bu.edu>

ASCENSION ISLAND 6300 Å AIRGLOW



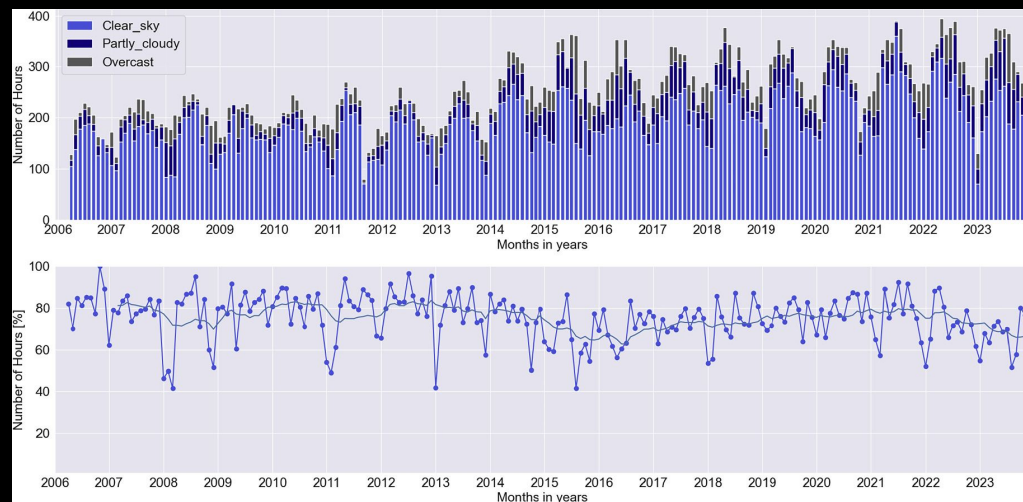
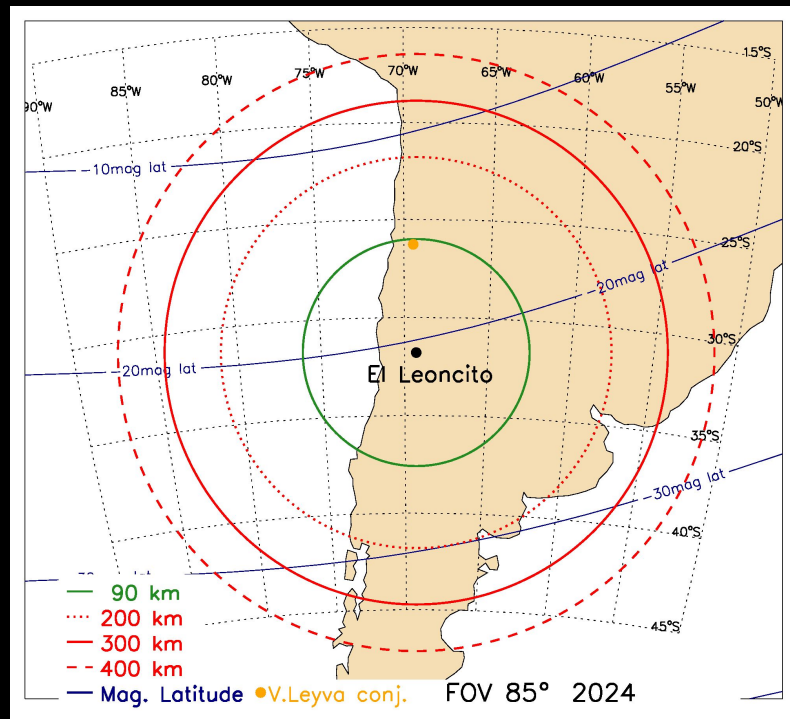
1 FEBRUARY 1981



22:00 U.T.

Mendillo & Baumgardner (1981)

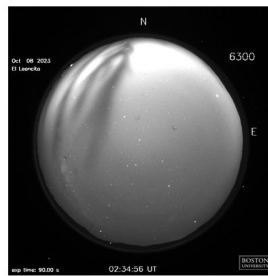
El Leoncito (Argentina)



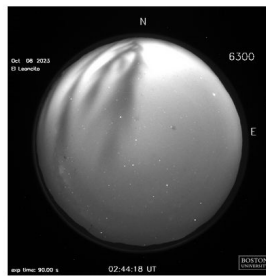
~ 40,000 clear night hours available

Mackovjak et al. (2025)

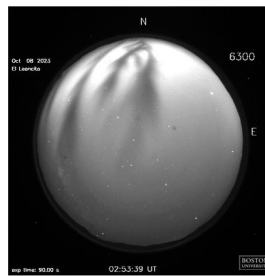
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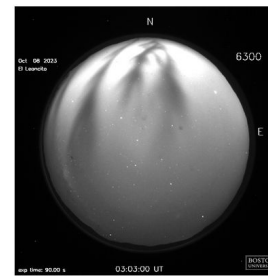
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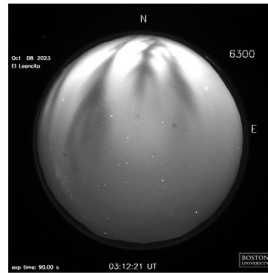
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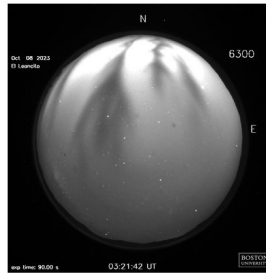
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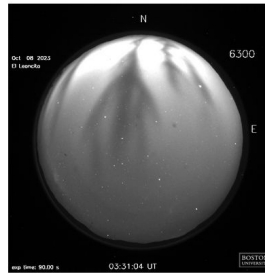
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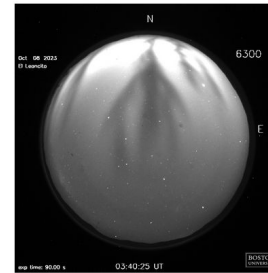
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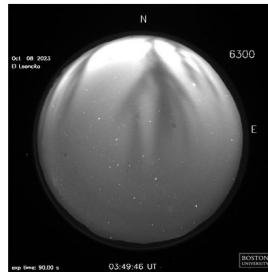
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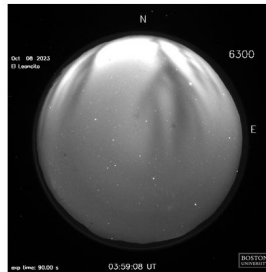
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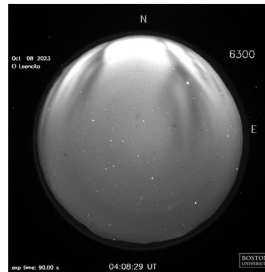
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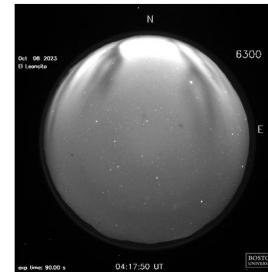
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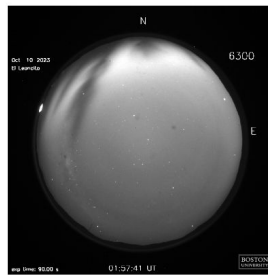


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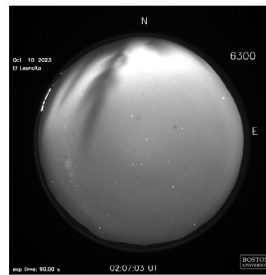


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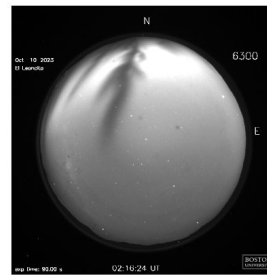
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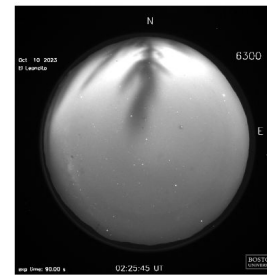
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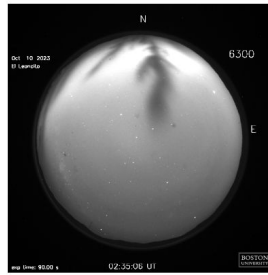
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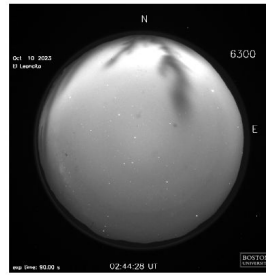
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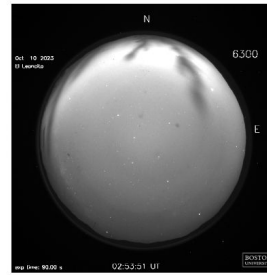
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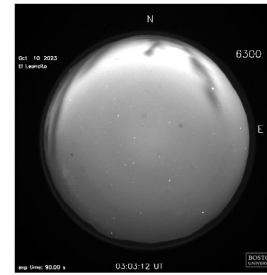
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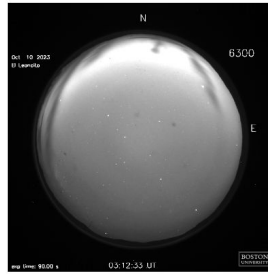
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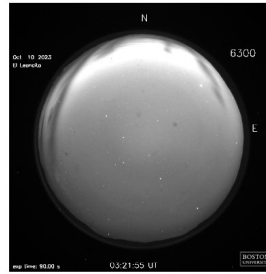
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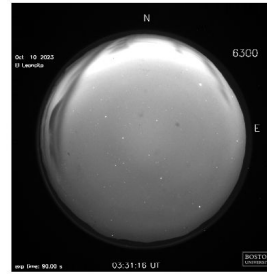
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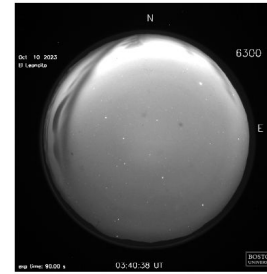
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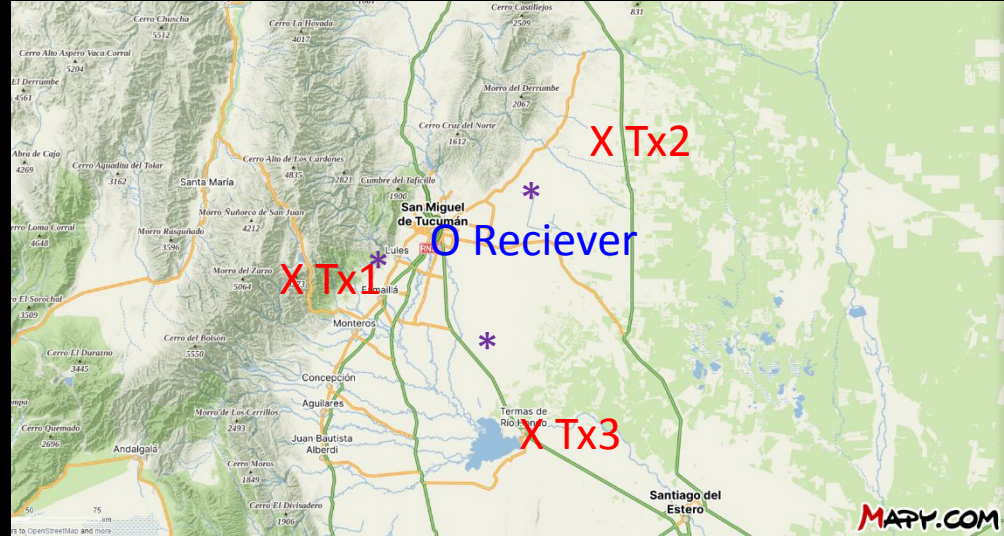
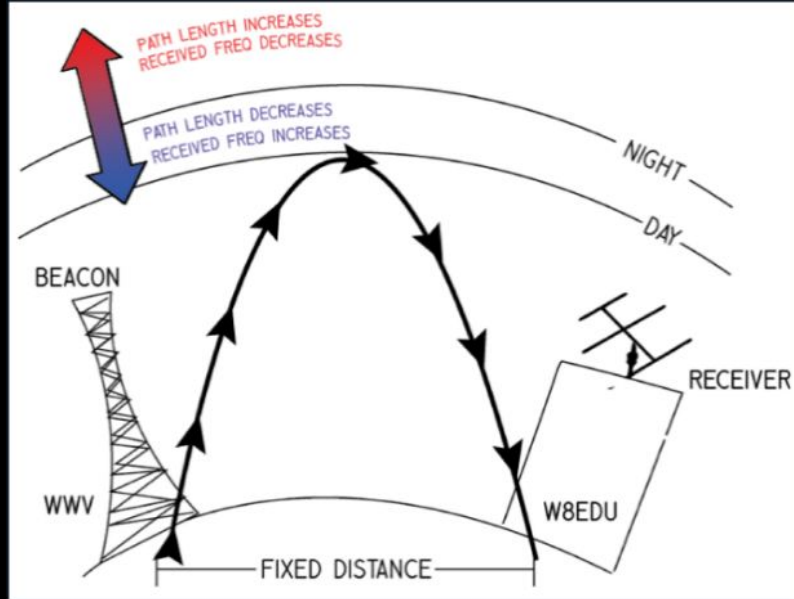


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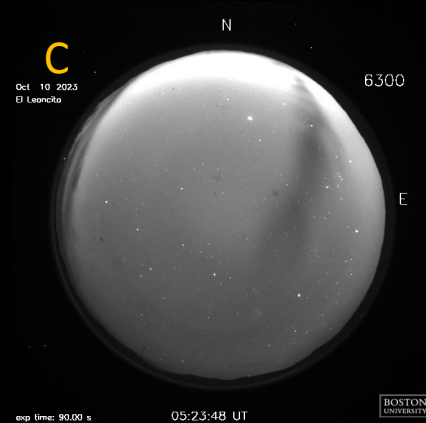
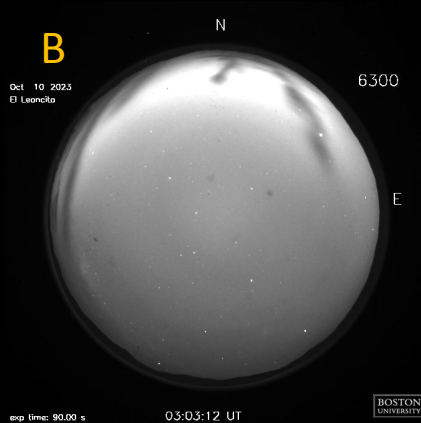
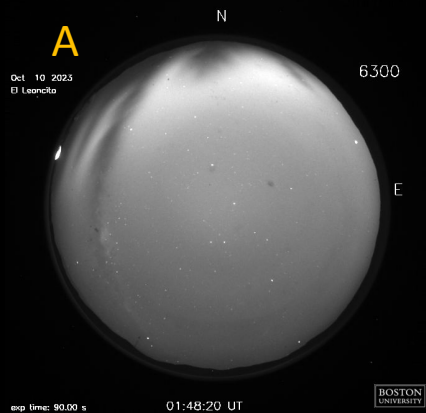


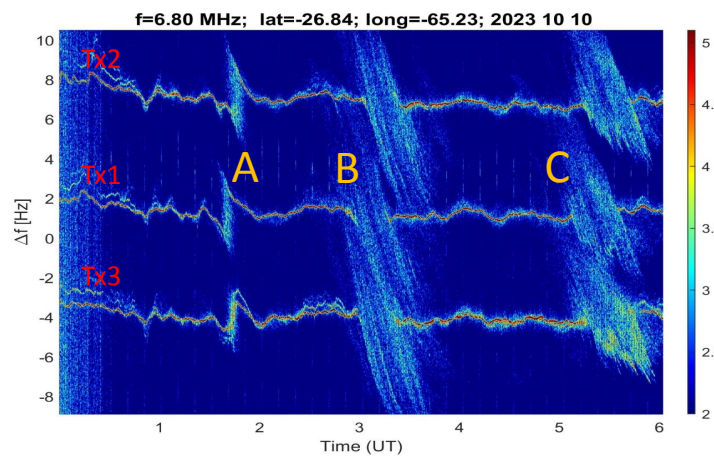
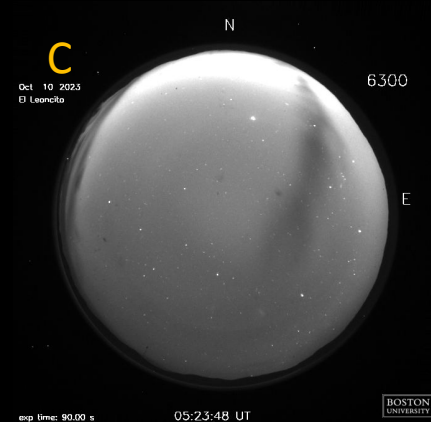
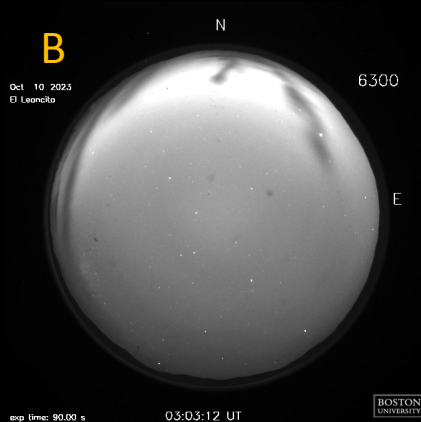
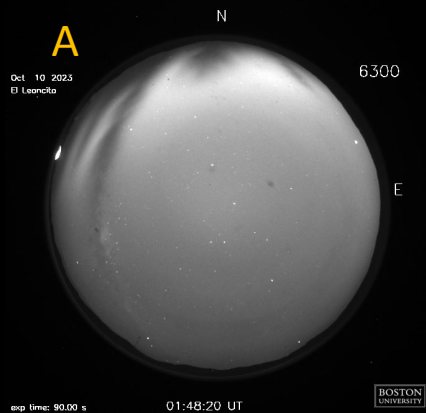
INSTITUTE OF ATMOSPHERIC PHYSICS
CAS

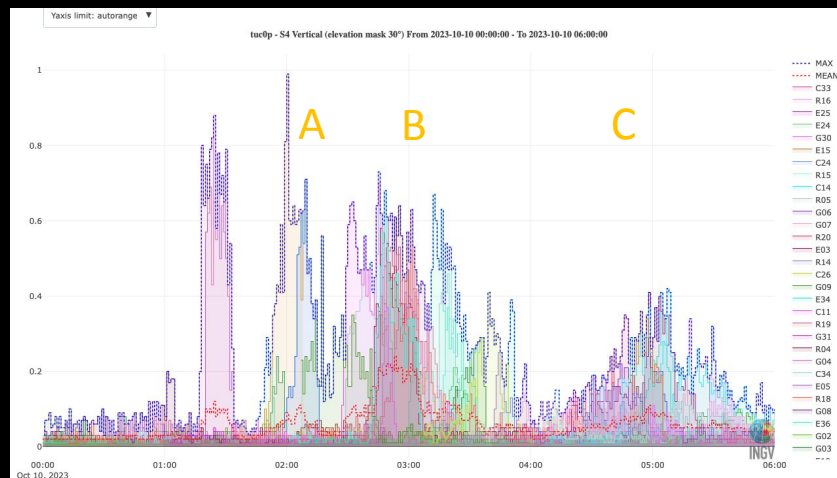
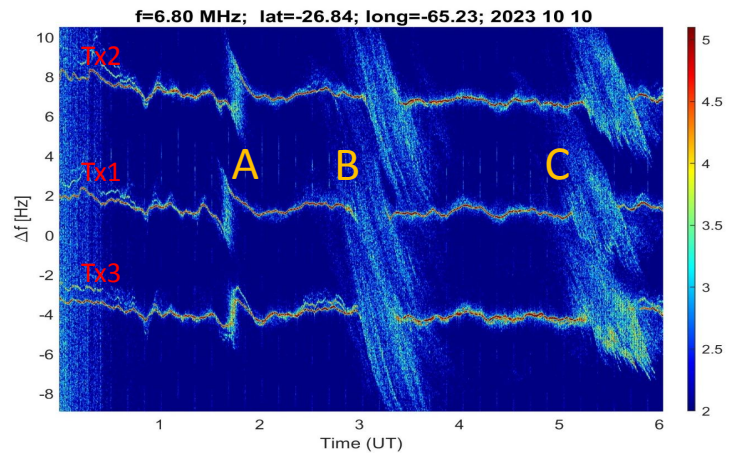
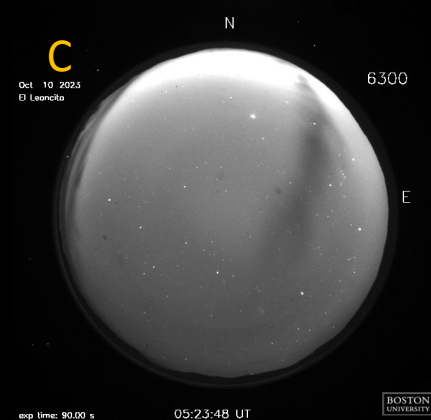
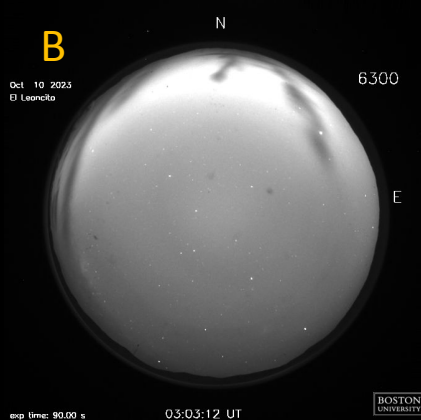
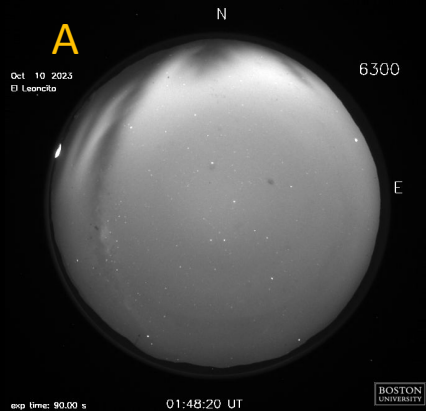
Continuous Doppler Sounding System in Argentina



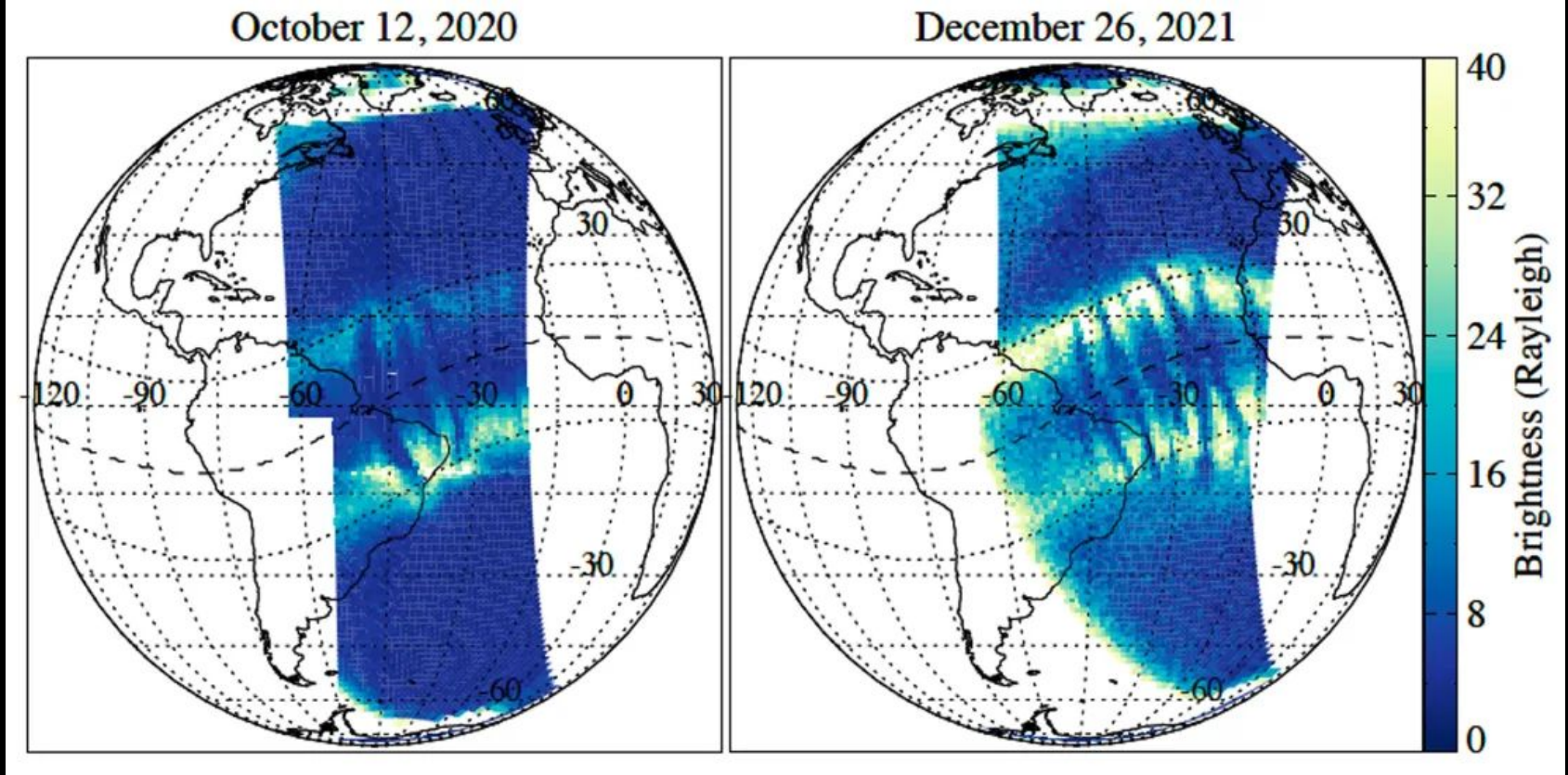
Marew et al. (2025)







Plasma Bubbles and EIA by mission GOLD



Karan et al. (2023)

Summary

- PITHIA NRF TNA significantly improve our understanding of scintillations
- Study of scintillation drivers is in progress
- Multi instruments approach is required for interpretation of causality

Summary

- PITHIA NRF TNA significantly improve our understanding of scintillations
- Study of scintillation drivers is in progress
- Multi instruments approach is required for interpretation of causality

We are open to new partnerships: mackovjak@saske.sk

Our ML work & papers:  <https://github.com/space-lab-sk>