T-FORS

Travelling Ionospheric Disturbances Forecasting System

WP3: MSTIDs climatology and probabilistic forecasting

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Meeting with the External Expert Advisory Board, 06 July 2023

Outline

- Objectives
- Collaboration partners
- Tasks & responsibilities
- Timeline and major achievements
- Ongoing and future plans

Objectives

- Develop new methodologies and statistical models
- Provide the probabilistic forecast of MSTIDs
- Issue alerts for extreme MSTIDs
- An inventory of potential indicators of MSTID

Collaboration partners

- National Observatory of Athens (NOA) [5]
- Istituto Nazionale di Geofisica e Vulcanologia (INGV) [1]
- Observatorio del Ebro Fundacion (OE) [4]
- Institut Royal Meteorolgique de Belgique (RMI) [3]
- Borealis Global Designs EOOD. (BGD) [3]
- Ustav Fyziky Atmosfery AV CR (IAP-P) [8.5]
- **Leibniz-Institut für Atmosphärenphysik e.V. an der Universität Rostock[9]**
- Institute of Earth Physics and Space Science (FI) [7]

Tasks & responsibilities

- Task 3.1: Design the MSTIDs forecasting methodology
  - [**Lead: IAP-L,** Main Contributors: IAP-P, FI, NOA]
  - Review: available data collections, data interfaces, data analysis methods
  - Compile a list of sporadic dynamic events that triggered MSTIDs and available data for analysis and validation.
- Task 3.2: MSTIDs climatological model
  - [**Lead: IAP-L,** Main Contributors: IAP-P, INGV, OE, RMI, NOA]
  - Estimation of day and Nighttime MSTIDs characteristics and extract climatology.
  - Derive an empirical model with uncertainty limits.
  - The model will have as attributes at least the solar flux indices, the geographic coordinates, the season and the local time.

Tasks & responsibilities

- Task 3.3: MSTID alert

  ➢ [**Lead: IAP-P,** Main Contributors: IAP-L, INGV, OE, RMI, NOA]

  ➢ Dynamic events that theoretically can trigger MSTIDs will be analysed.

  ➢ Based on the T-FORS methodologies extract the propagation pattern for these events and compared with the results of the climatological model. This comparison should support the definition of alerts criteria.

  ➢ Physical conditions that triggered enhanced MSTIDs will be analysed to compile an inventory of parameters

Tasks & responsibilities

➢Task 3.4 Validation and compilation of an inventory of activity indicators

- [**Lead: FI**, Main Contributors: BGD, OE, IAP-L, IAP-P]

- The climatological model will be validated following the multi-stage validation plan (section 1.2.1.c) for non-probabilistic continuous predictions.
- The alerts will be validated following the methodology for probabilistic predictions

Task 3.5: Release of functional algorithms

- [**Lead: NOA**, Main Contributors: IAP-L, IAP-P]

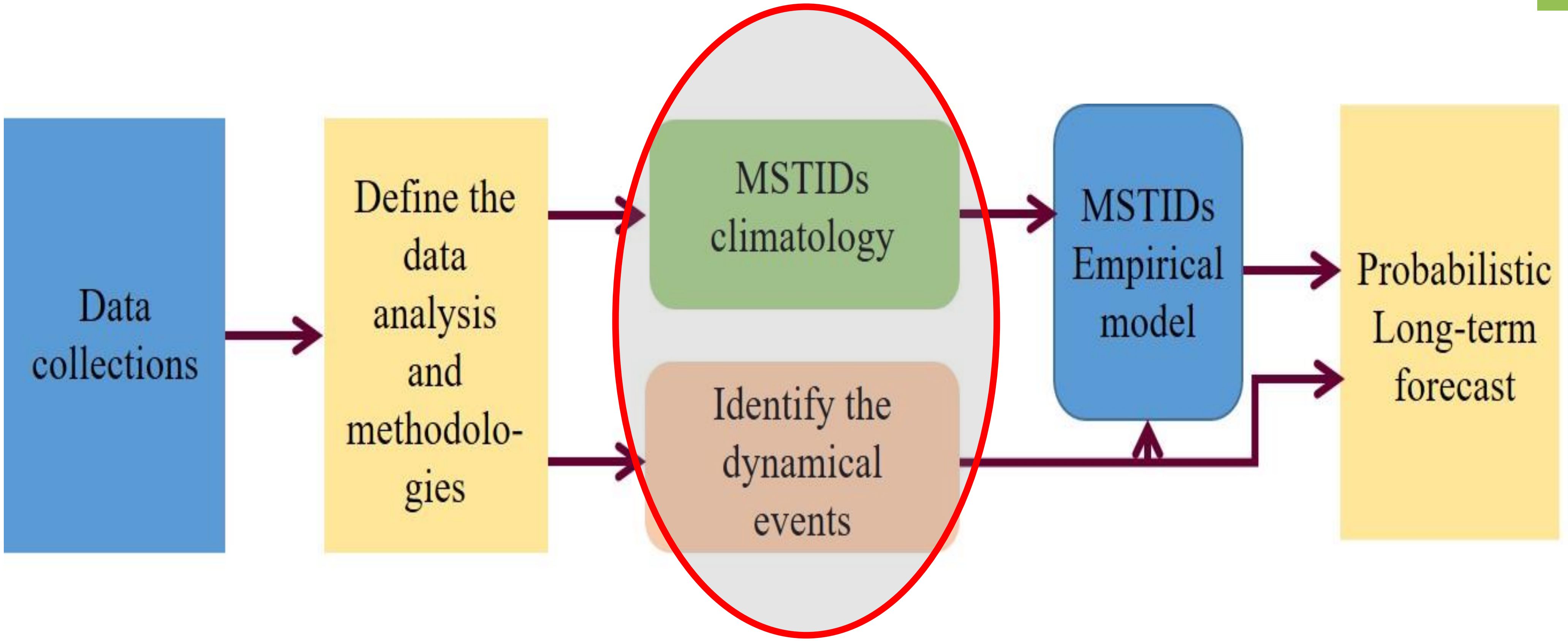
- Based on the results of Task3.2 and Task3.3, the MSTID climatological model and the criteria for the MSTID alerts will be transformed to software codes
- All software codes will be provided with open access.

Timeline & major achievements

ID	Title	Assignee	Due time
D3.1	Report on the MSTID climatological model	IAP-L	Nov 2023
D3.2	Report on the MSTID alerts issuing system	IAP-P	Feb 2024
D3.3	Inventory of early indicators for MSTIDs	FI	Mar 2024
D3.4	MSTID forecasting software codes	NOA	May 2024

MS4- MSTID forecasting methodology and data inventory→ reached June 2023

General approach

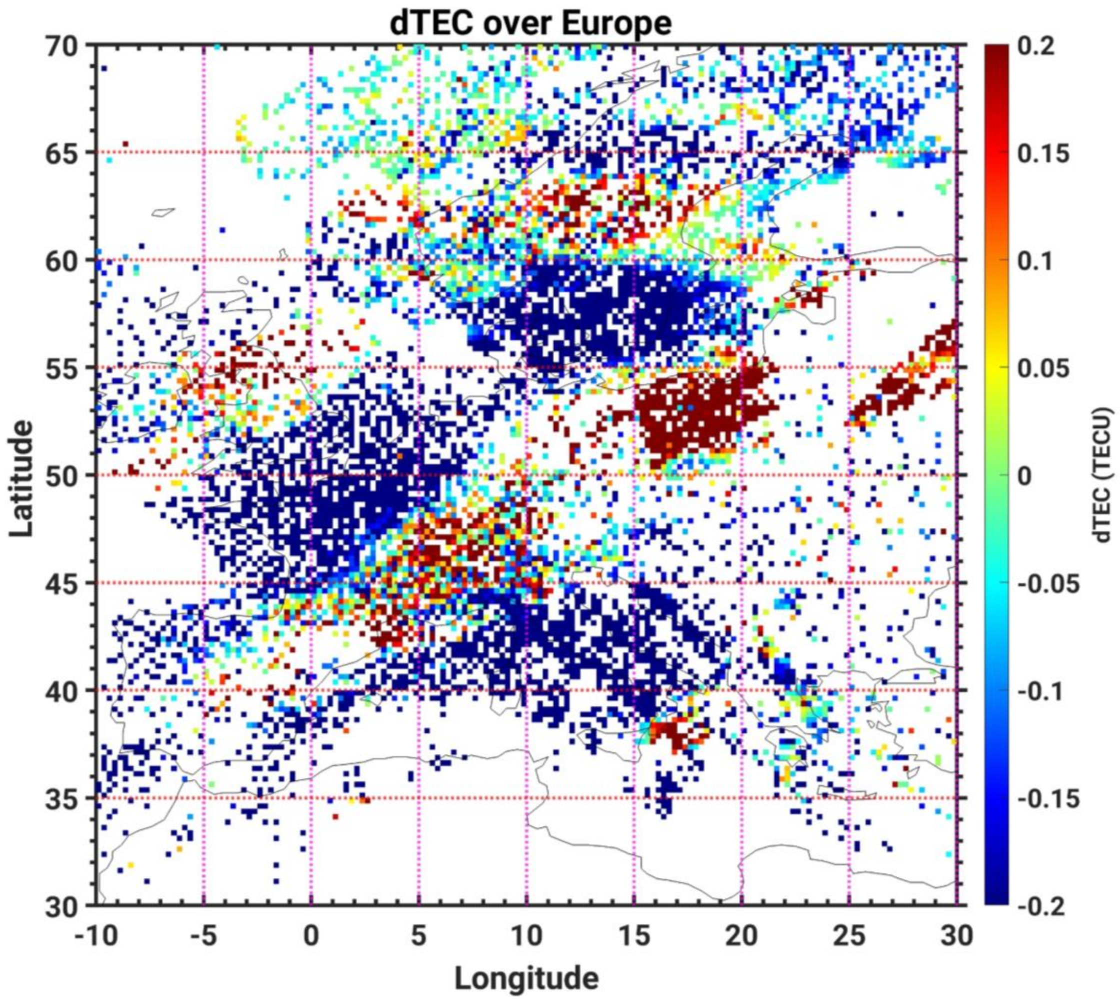


Schematic diagram for the general approach to implement our plans

Data analysis and methodologies: GNSS-TEC

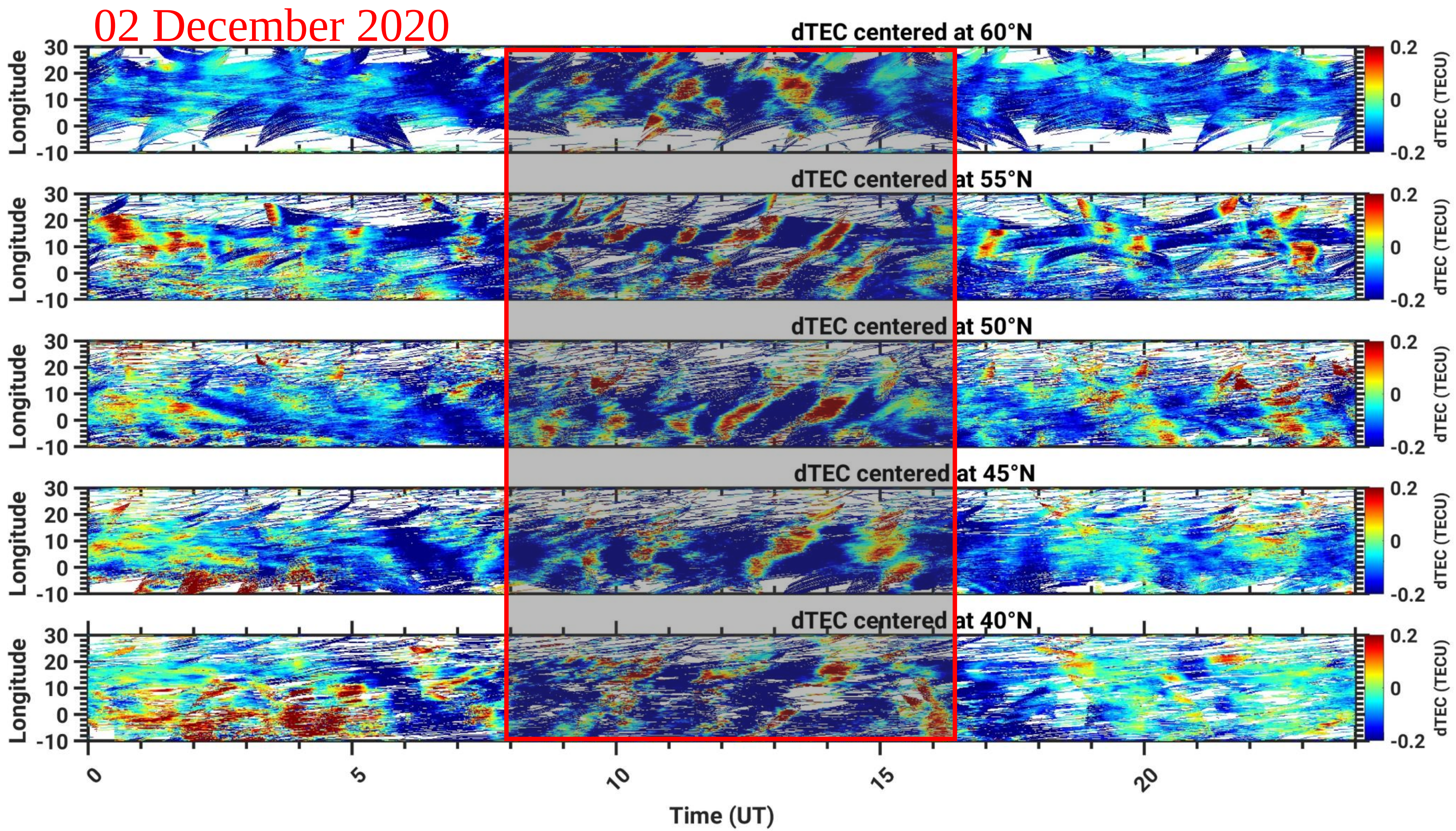
- ✓ To obtain perturbation component of TEC, which could be caused by MSTIDs, 1-hour running average of TEC was subtracted from the original TEC time series for each pair of satellites and receivers, and converted the slant to vertical TEC.

- ✓ Temporal resolution is 30 seconds, and the spatial resolution is 0.25×0.25 latitude and longitude.



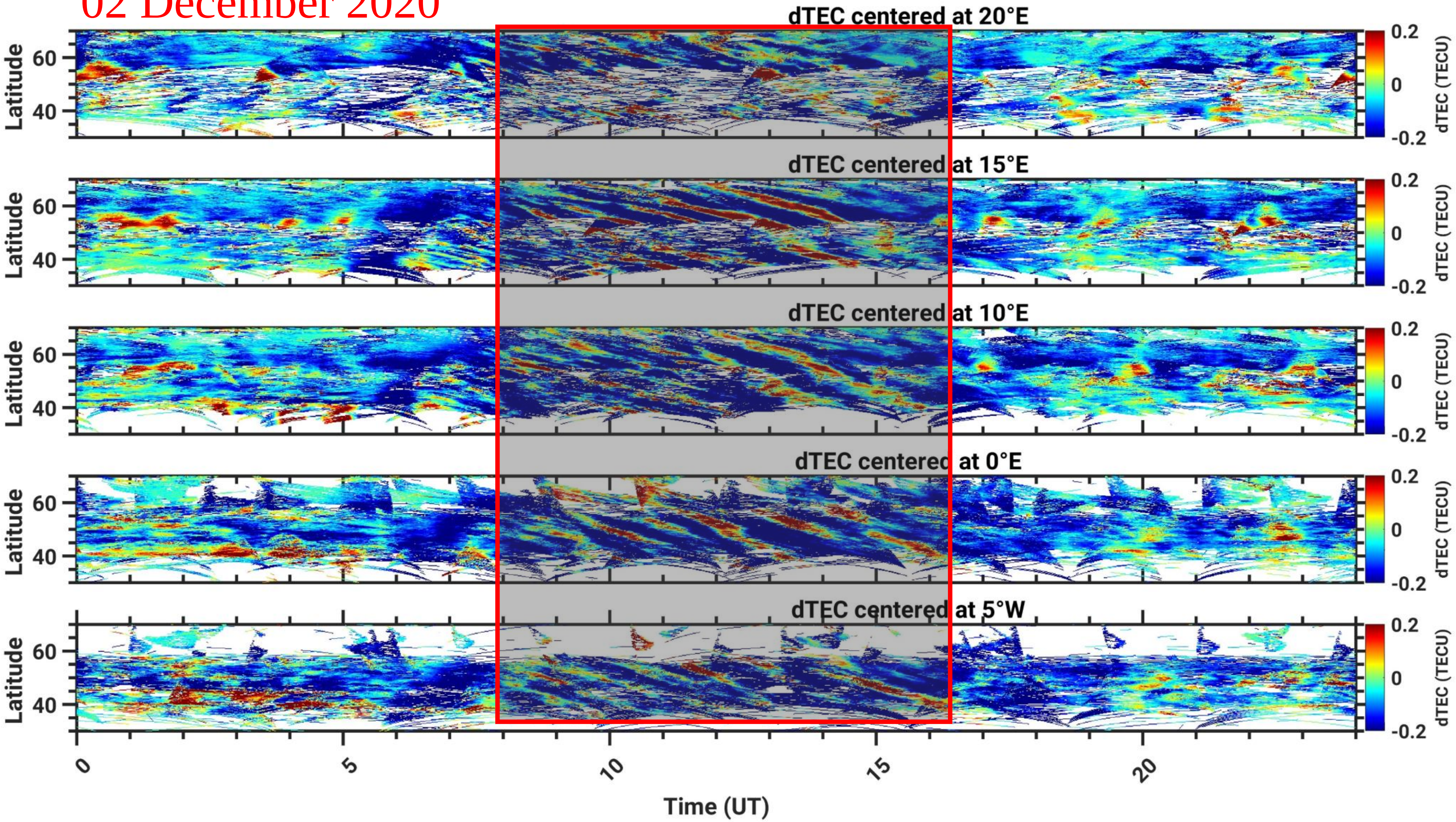
02 December 2020 at 13:00 UT

East-West Keogram



North-South Keogram

02 December 2020



Identification of MSTD propagation direction

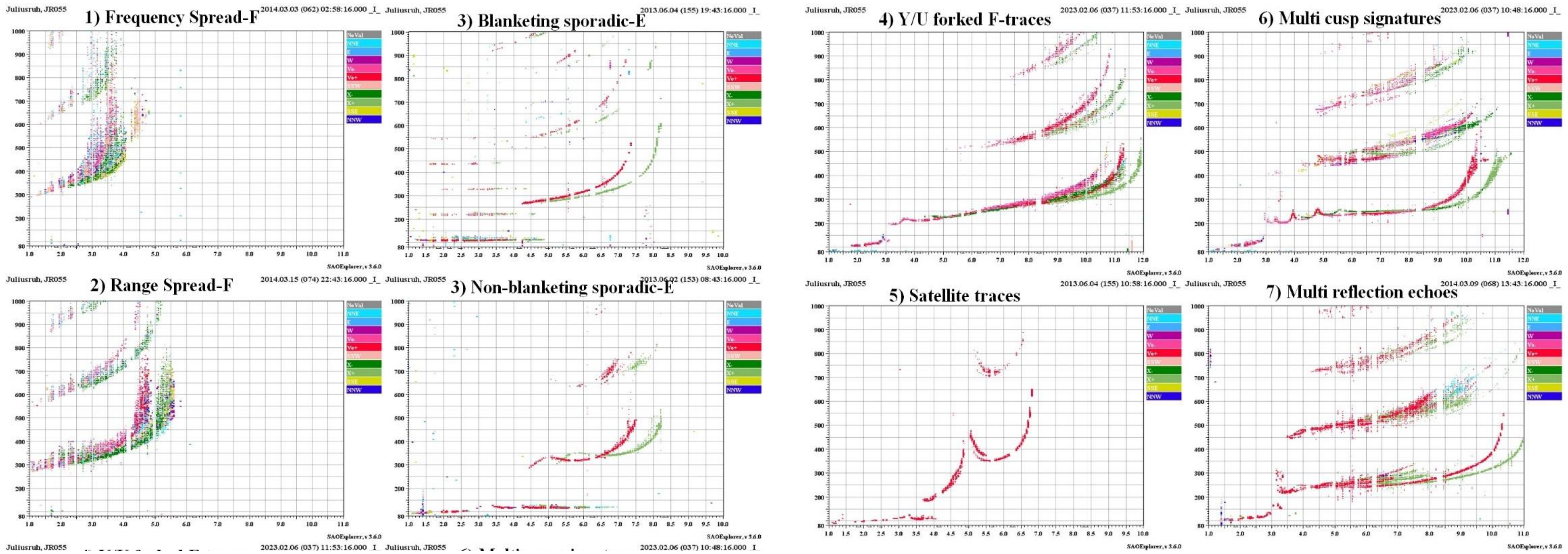
Label	Direction	Characteristics of phase front in EW and NS keogram
1	North	EWK-aligned; NSK-progression towards north
2	East	EWK-progression towards east; NSK-aligned
3	South	EWK-aligned; NSK-progression towards south
4	West	EWK-progression towards west; NSK-aligned
5	Northeast	EWK-progression towards east; NSK-progression towards north
6	Southeast	EWK-progression towards east; NSK-progression towards south
7	Southwest	EWK-progression towards west; NSK-progression towards south
8	Northwest	EWK-progression towards west; NSK-progression towards north

We analyzed three years (2014, 2016, 2020) of data for the four seasons i.e. two equinoxes (March and September) and two solstices (June and December)

Data analysis and methodologies: Ionosonde

URSI-code	Name	Latitude	Longitude	Ionosonde type
JR055	Juliusruh	54.60	13.40	DPS-4D
FF051	Fairford	51.70	358.50	DPS-4D
RL052	Chilton	51.50	359.40	DPS-1
DB049	Dourbes	50.10	4.60	DPS-4D
PQ052	Pruhonice	50.00	14.60	DPS-4D
SO148	Sopron	47.63	16-72	DPS-4D
RO041	Rome	41.90	12.50	DPS-4
EB040	Roquetes	40.80	0.50	DPS-4D
VT139	San Vito	40.60	17.80	DPS-4D
AT138	Athens	38.00	23.50	DPS-4D
EA036	El Arenosillo	37.10	353.30	DPS-4D
NI135	Nicosia	35.03	33.16	DPS-4D

Data analysis and methodologies: Ionosonde



- We analyzed three years (2014, 2016, 2020) of data for the four seasons i.e. two equinoxes (March and September) and two solstices (June and December)

- Only hourly ionograms are considered for the analysis: 24*365=8760 ionograms per station

Ionosonde: Methodology

- The parameters which will be considered for the MSITDs climatology.

No ionogram 0

- FSF 1– Frequency spread-F
- RSF 2– Range Spread-F

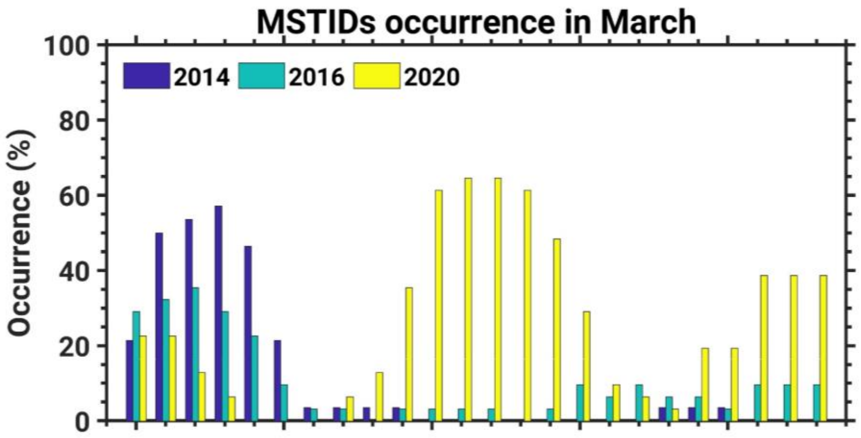
Spread-F

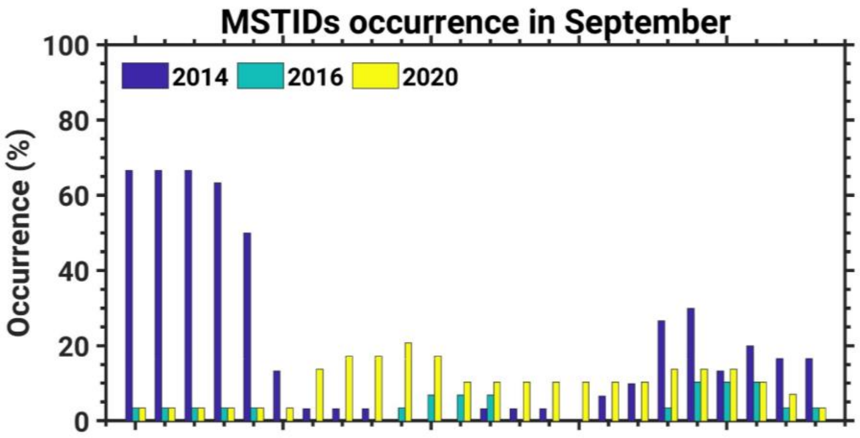
- Es 3-- Sporadic E (Es) layer –not considered for the MSTIDs climatology
- Y/U 4– Y or U shape signature
- ST 5– Satellite Traces
- MCS 6– Multiple Cusp signature
- MRE 7– Multiple reflection echoes

Trace deforming signatures

Date	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Station
02/12/2020	1	1								14	14		4		4		1							1	JR055
02/12/2020				1	1							4				4									DB049
02/12/2020									57	4		4	7	4											NI135

dTEC: Seasonal and diurnal variation of MSTIDs occurrence

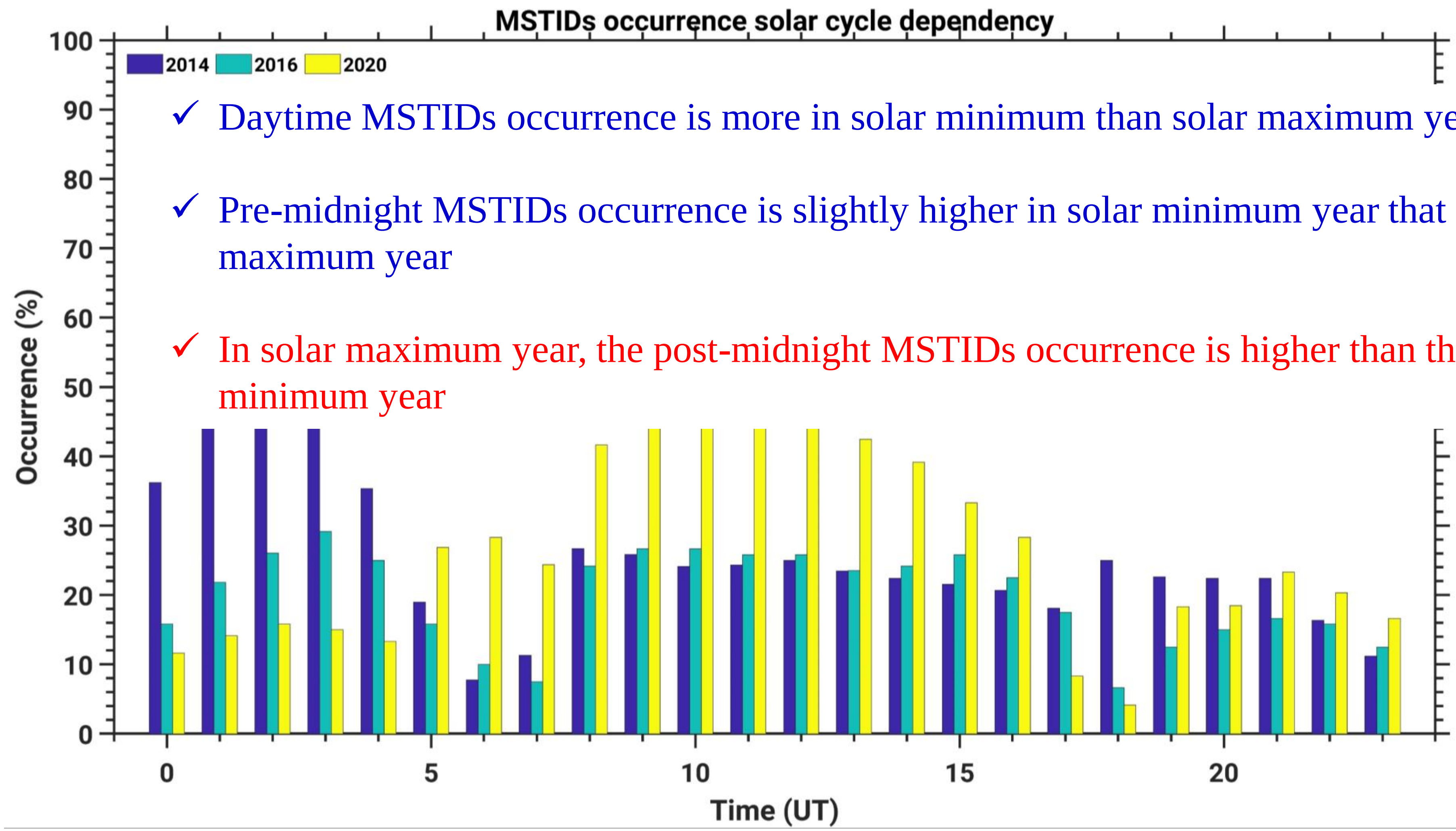




- Daytime MSTIDs occurrence is more during December than any other months
- Pre-midnight MSTIDs occurrence is high in June
- Post-midnight MSTIDs occurrence is high in equinoxial months
- Anomalous day and nighttime MSTIDs occurrence are noted in the months of March and June

Time (UT) Time (UT)

dTEC: Solar dependency of MSTIDs occurrence



- ✓ Daytime MSTIDs occurrence is more in solar minimum than solar maximum year
- ✓ Pre-midnight MSTIDs occurrence is slightly higher in solar minimum year that the solar maximum year
- ✓ In solar maximum year, the post-midnight MSTIDs occurrence is higher than the solar minimum year

Major achievements

- New data methodologies are implemented to analysis the GNSS-TEC and ionosonde data sets to explore the MSTIDs climatology over Europe.

- We found a clear seasonal and solar cycle dependency of the day and nighttime MSTIDs occurrence.
  - ✓ Daytime MSTIDs occurrence is more during December than any other months and pre-midnight MSTIDs occurrence is high in June. Surprisingly, post-midnight MSTIDs occurrence is high in equinoxial months
  - ✓ Pre-midnight MSTIDs occurrence is slightly higher in solar minimum year that the solar maximum year
  - ✓ In solar maximum year, the post-midnight MSTIDs occurrence is higher than the solar minimum year
  - ✓ In 2020, significant number of northeast and westward propagating early morning MSTIDs are noted in June and December, respectively

Ongoing and Future plans

- Focus on the empirical model development
  - ✓ Based on our climatological results, we will develop a probabilistic statistical model.

- Study the role of extreme tropospheric events on the generation of MSTIDs

- Development of MSTIDs alert issuing system

Thank you for your attention!

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