Travelling Ionospheric Disturbances (TID) and practical analysis possibilities in the operation of direction finding systems

PITHIA-NRF Third Innovation Day

Warsaw, Poland 12 June 2024

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Outline

- Technical description HF-Direction Finder
- Location HF-Direction Finder
- Using NCDXF/IARU International Beacon Project
- Measurements
- Results
- On Ground operation in the project T-FORS
- Acknowledgments

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HF Direction Finding Technical details

The German Federal Police (GFP) Direction Finding system consists of a highly sensitive antenna system for electromagnetic sky and ground waves with high bearing accuracy for the frequency range from 1 to 30 MHz, which is a set of rod antennas, installed in two 16/8 elements concentric circles and the additional computer equipment to evaluate the signals received by the antennas. It is optimized for the HF frequency range from 1 to 30 MHz. GFP's direction finder is typically used as a directional antenna and in order to analyze the azimuth of arriving HF signals.

Photo: GFP

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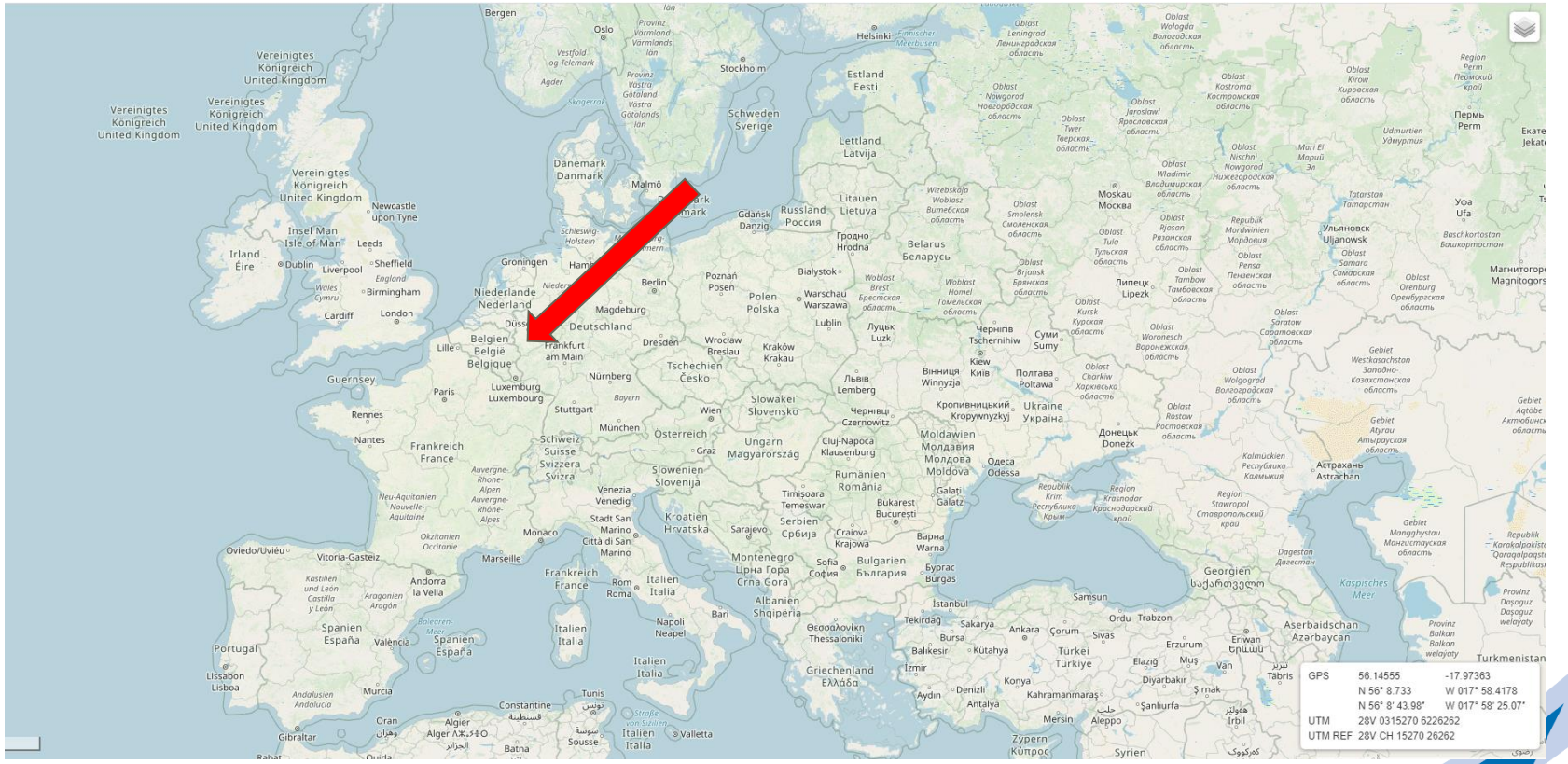
HF Direction Finding Location



Mapsource: GFP

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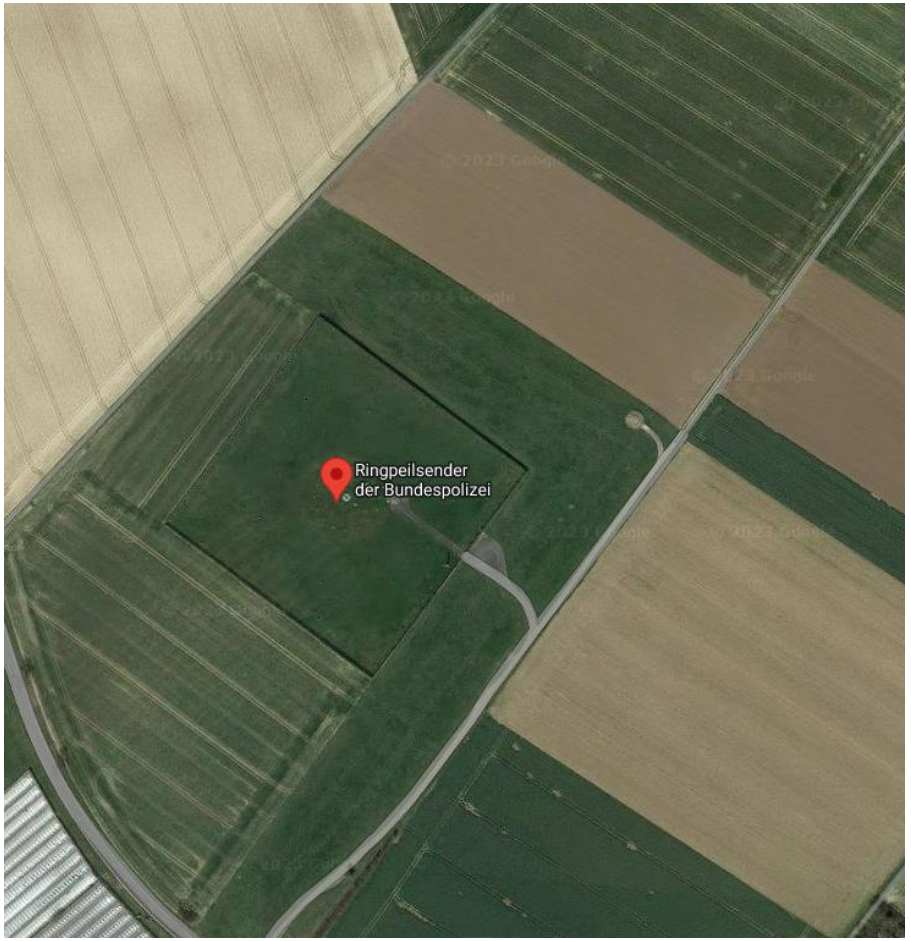
HF Direction Finding Location



Mapsource: GFP; image source: Google.com

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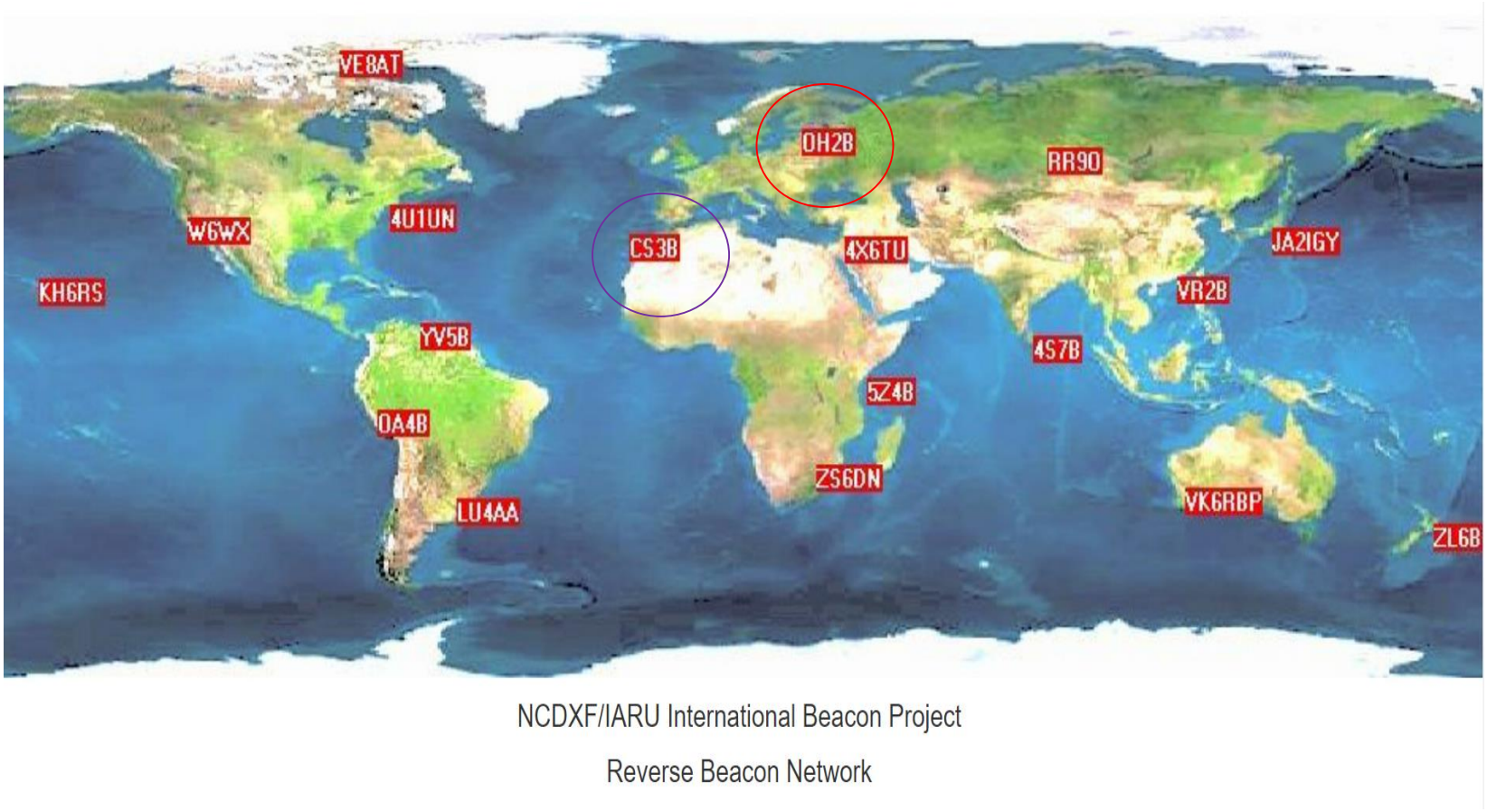
HF Direction Finding using NCDXF/IARU International Beacon Project



NCDXF/IARU International Beacon Project

Reverse Beacon Network

Source picture and table:
https://www.ncdxf.org/beacon/RBN.html

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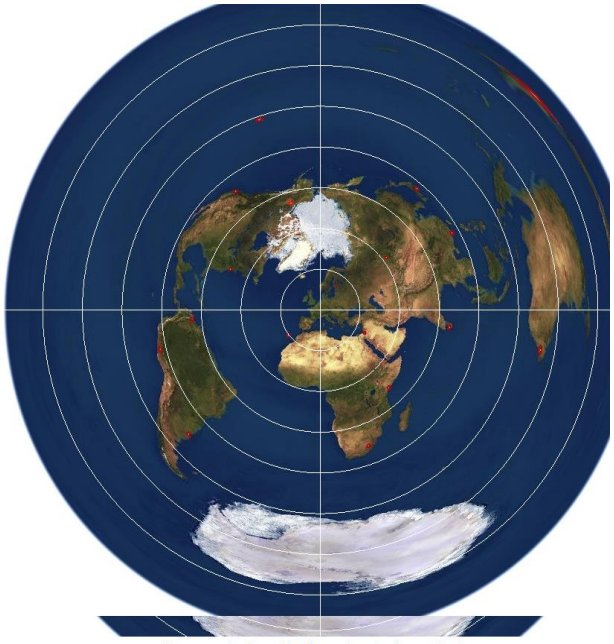
HF Direction Finding using NCDXF/IARU

International Beacon Project



Beacon	Beam Heading	Distance	Propagation
4U1UN	295°	6132 km	14 18 21 24 28
VE8AT	344°	6645 km	14 18 21 24 28
W6WX	321°	9237 km	14 18 21 24 LP
KH6RS	343°	12151 km	14 18 21 24 28
ZL6B	51°	18861 km	14 18 21 24 28
VK6RBP	100°	14005 km	14 18 21 24 28
JA2IGY	39°	9599 km	14 18 21 24 28
RR9O	51°	5078 km	14 18 21 24 28
VR2B	62°	9415 km	14 18 21 24 28
4S7B	98°	8220 km	14 18 21 24 LP
ZS6DN	160°	8592 km	14 18 21 24 28
5Z4B	142°	6218 km	14 18 21 24 28
4X6TU	116°	2980 km	14 18 21 24 28
OH2B	34°	1781 km	14 18 21 24 28
CS3B	238°	2600 km	14 18 21 24 28
LU4AA	229°	11213 km	14 18 21 24 28
OA4B	257°	10519 km	14 18 21 24 28
YV5B	264°	8080 km	14 18 21 24 28

Source picture and table:
https://www.ncdxf.org/beacon/AzMap/index.html

Distance and azimuth relative to Ollheim (GFP)

Propagation forecasts courtesy of OH6BG.

Signal strength color code: s0 s? s1 s2 s3 s4 s5 s6 s7 s8 s9

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HF Direction Finding Results

Analysis of LSTID events detected by the HF-INT method are compared with DF data provided by GFP.

As example the table with values of the average squared deviation for the beacon of interest located in Helsinki,OH2B Finland.

TID-Event	$AvSQD_{NO\ TID}$	$AZIM_{HF-B}$	$AVSQD_{TID}$	$AZIM_{TID}$	ΔAZIM	Degraded
03/10/2021	8.13	39.5	14.7	267	227.5	YES
06/10/2021	8.13	39.5	0.56	255	215.5	NO
06/10/2021	8.13	39.5	1.67	186	146.5	NO
07/10/2021	8.13	39.5	3.12	220	180.5	NO
08/10/2021	8.13	39.5	9.38	258	218.5	YES
10/10/2021	8.13	39.5	1.63	274	234.5	NO

As JR055 is located in the GFP-Helsinki path, we focused on the azimuth detected over JR055.

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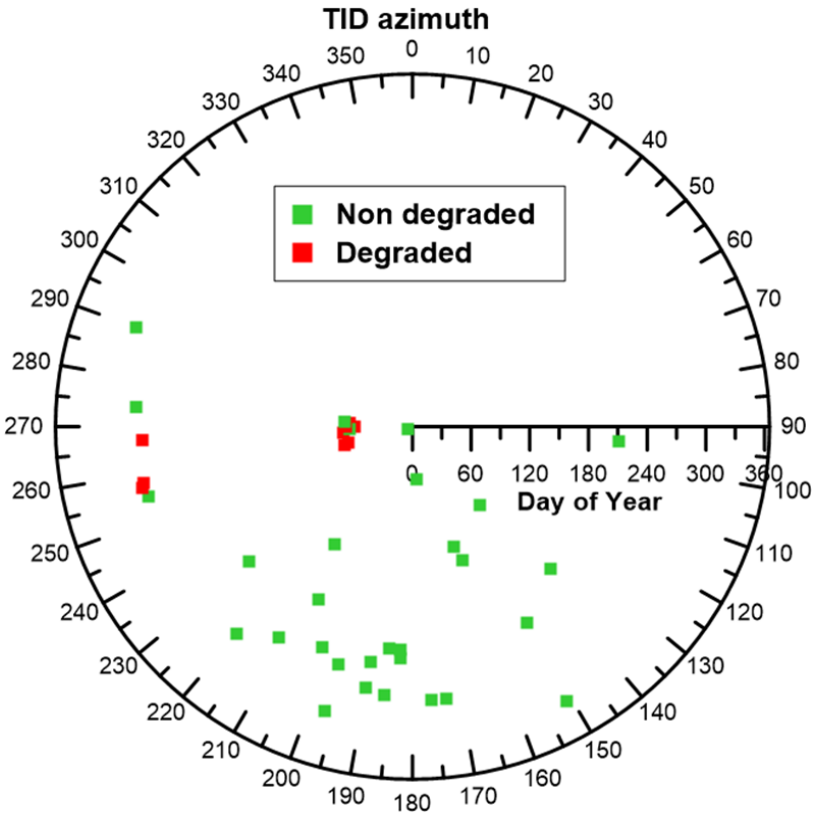
HF Direction Finding Results

- All degraded events are concentrated **between 260º and 280º of TID azimuth, at 45º respect the line of sight**

- All degraded events are concentrated during the equinox



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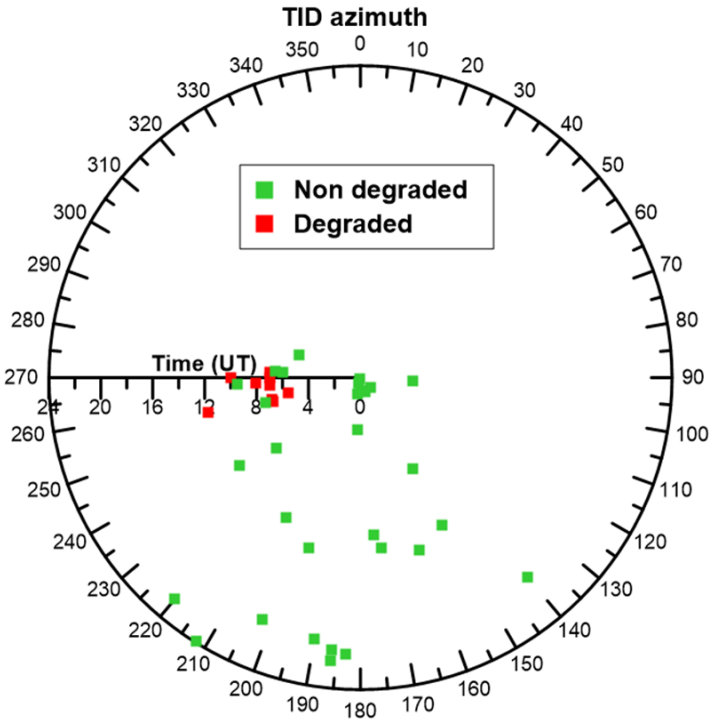
HF Direction Finding Results

- All degraded events are concentrated in the morning sector. Solar terminator influence
- As we are looking high latitude area, the ionization is too weak at night to see any effects at DF system



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On Ground operation in the project T-FORS

- **Partner in the WP 4**

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ONERA
THE FRENCH AEROSPACE LAB

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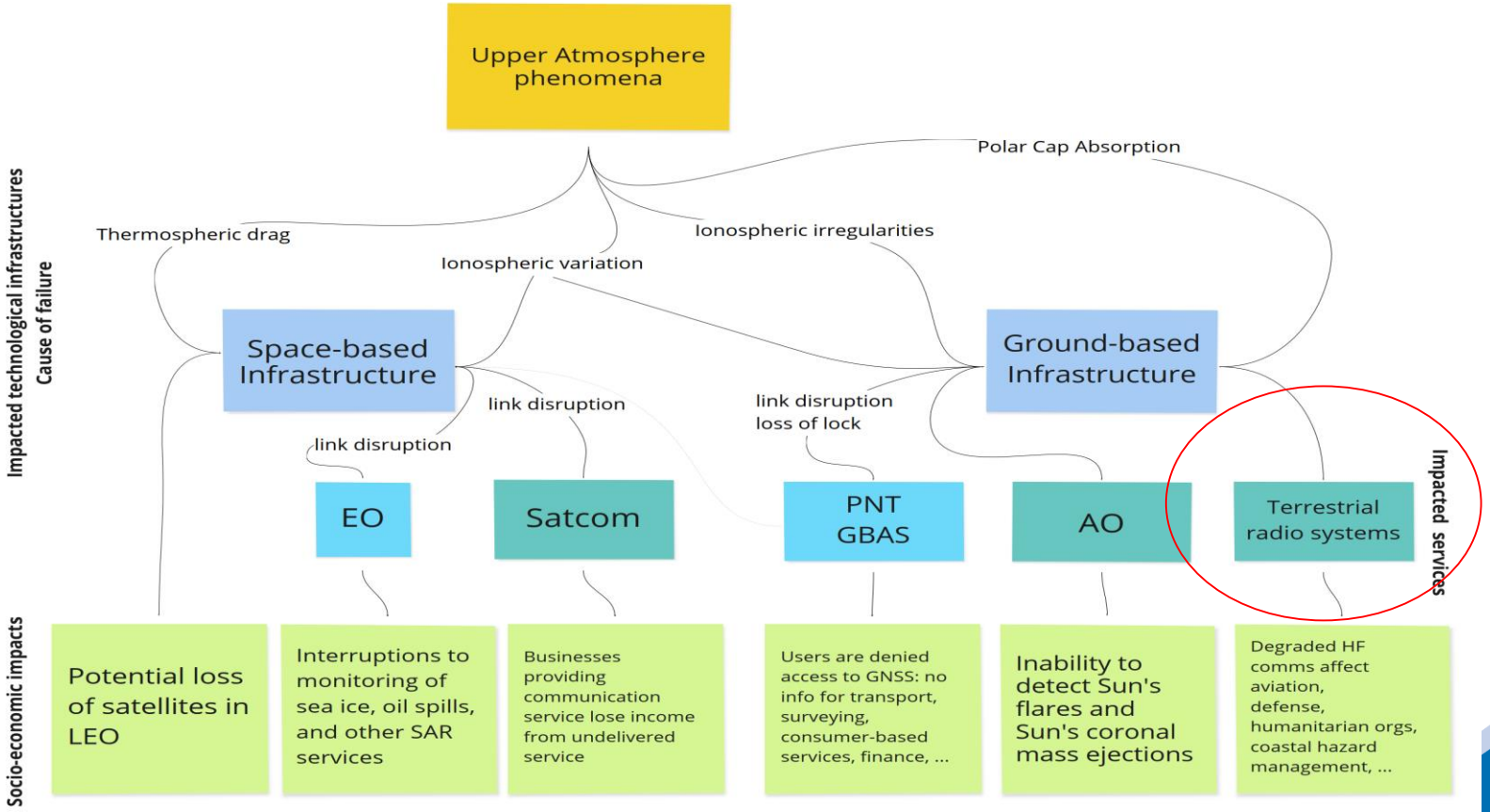

https://pithia-nrf.eu/pithia-nrf-users/innovation/innovation-day-3

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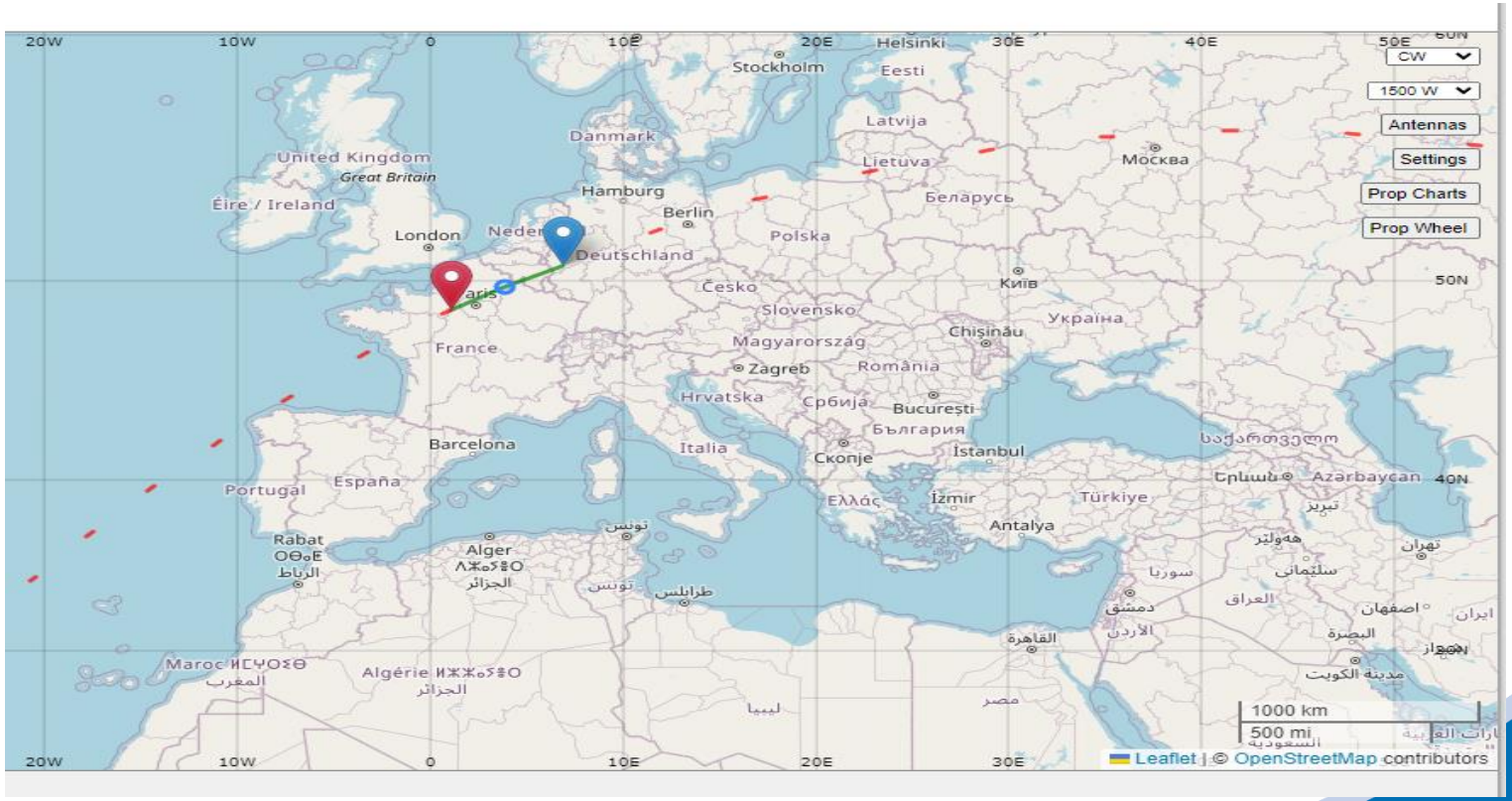
- Locations Onera (F) and GFP (D):



Mapsource: www.voacap.com

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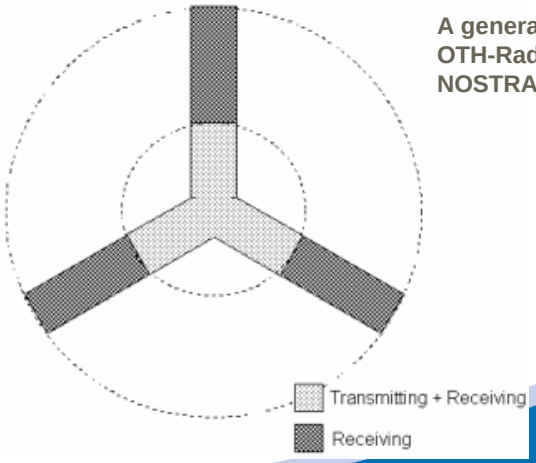
On Ground operation in the project T-FORS

- **General parameters** of the on ground test with Nostradamus OTH-System:
  - The system was developed by ONERA .
  - Nostradamus transmits on shortwave with a pulse repetition time of 30 ms.
  - The antenna array consists of 288 seven-metre-high biconical antennas, which are set up in a star-shaped structure with three rows, each approx. 400 m long and offset by 120 degrees.



A general presentation about the OTH-Radar NOSTRADAMUS

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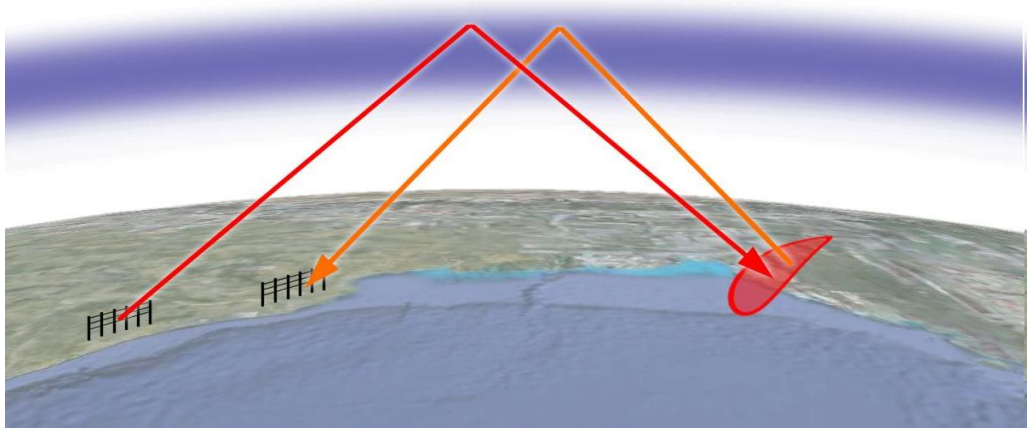
On Ground operation in the project T-FORS

- **General parameters** of the on ground test with Nostradamus OTH-System:
  - The signal azimuth from Nostradamus is 243° (QDR)
  - The distance between Nostradamus OTH and GFP DF-System is 476,1 KM (QRB)



https://de.wikipedia.org/wiki/%C3%9Cberhorizontradar#/media/Datei:OTH-B.big.jpg

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On Ground operation in the project T-FORS

- **Sequence of the on ground test:**
  1. The signal is a continuous frequency carrier (CW)
     - it is easier to see this tpye of signal with a DF
     - after the cw-signal, Nostradamus will transmit a chirp signal
     - Power. 1,2 KW ERP
  2. HF link from Nostradamus with **only one** transmitter
     - This allows to GFP to collect all the different ionospheric path from Nostradamus to the DF system
  3. HF link from Nostradamus with **all transmitter** and in focus mode in the direction of the GFP DF system.
     - This allows us to confirm the efficiency of the focus mode with Nostradamus and enable direct path detection from GFP.

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On Ground operation in the project T-FORS

- **Time parameters:**
  - ONERA transmit 7 seconds, 15 seconds, 30 seconds, 60 seconds with a pause of at least one minute between the transmissions.
  - Every hour
  - Every day of the week

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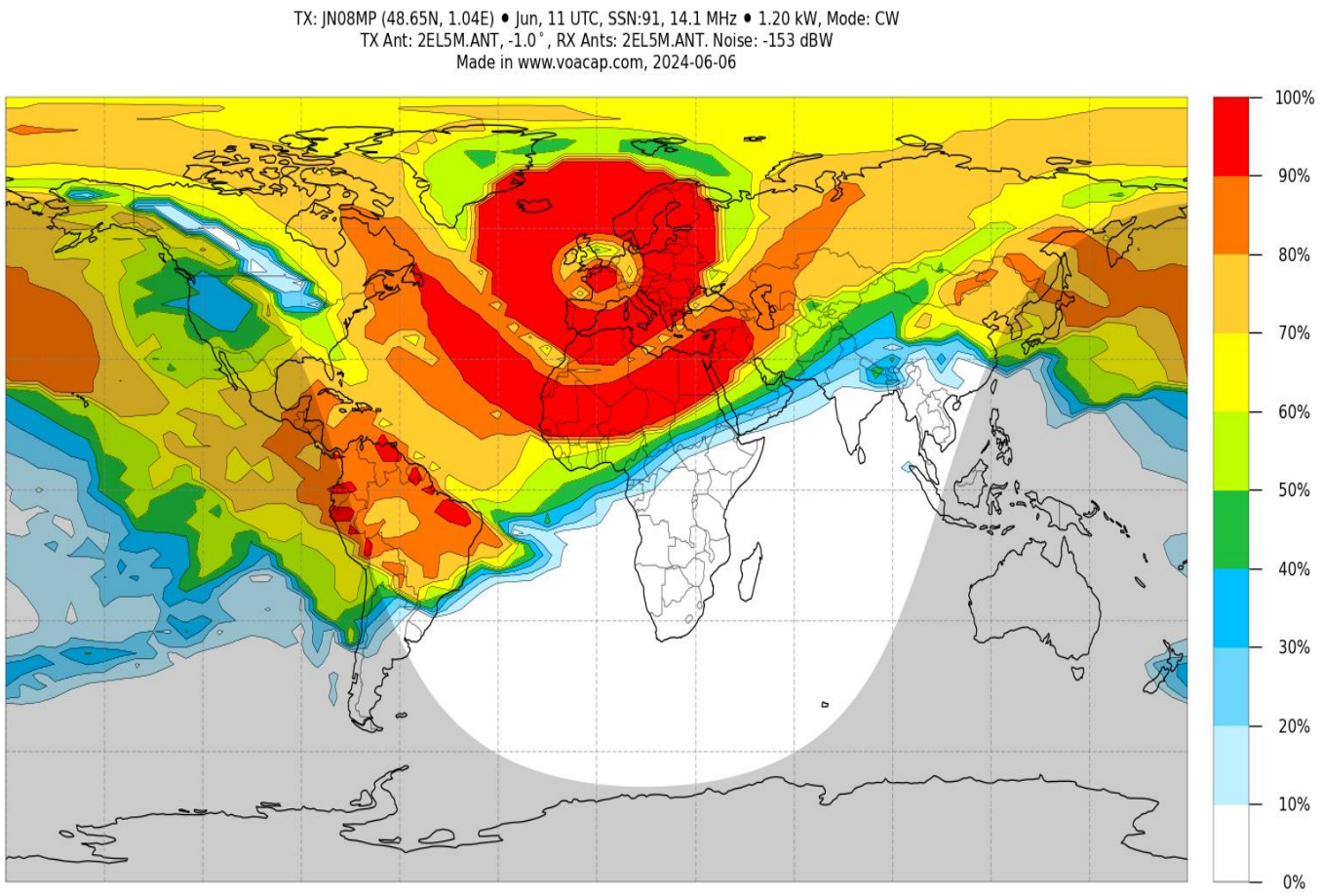
On Ground operation in the project T-FORS



Mapsource: www.voacap.com

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On Ground operation in the project T-FORS

- **Frequency parameters:**

  - The Nostradamus OTH-system transmit 7 seconds, 15, seconds, 30 seconds, 60 seconds with a pause of at least one minute between the transmissions.
  - We generated five frequency groups containers:
    - FOT
    - MUF
    - QRG 1
    - QRG 2
    - QRG 3

    14782 rows
  - all frequency-parameter were generated by www.voacap.com

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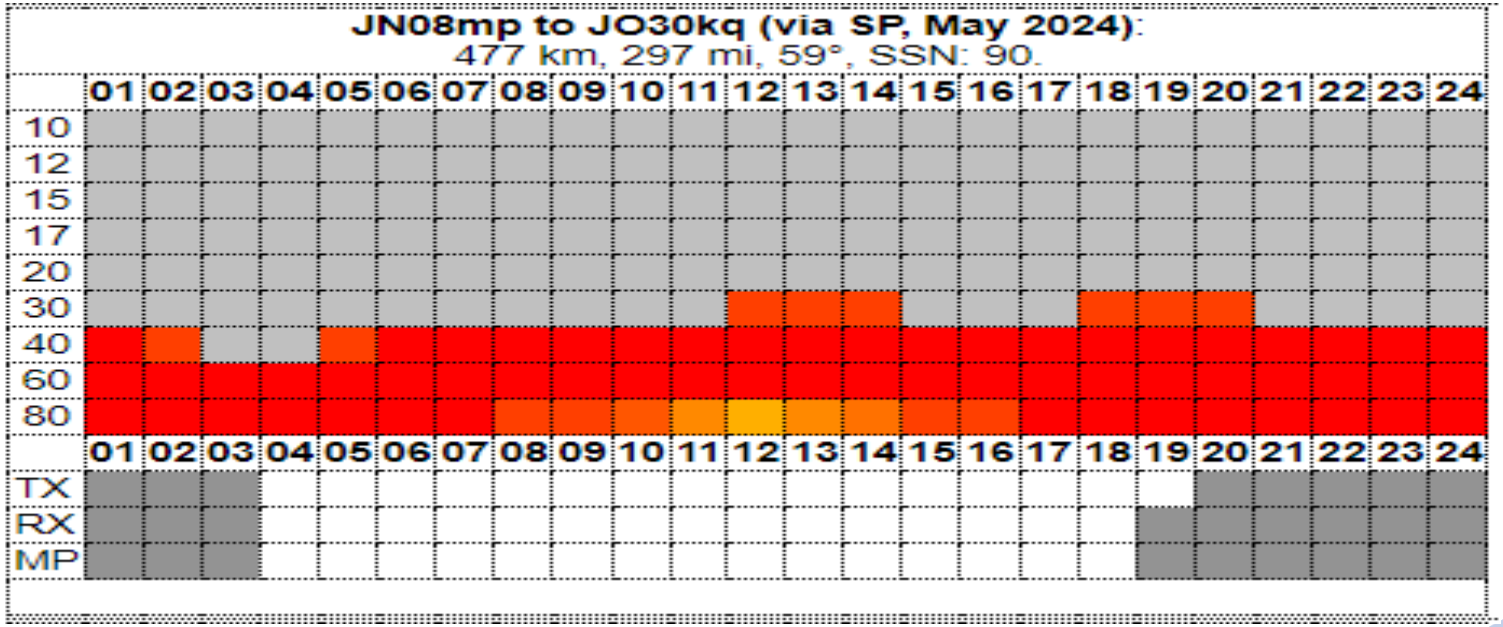
Availability and suitability of frequencies for May 2024



https://www.voacap.com/hf/all_year.html

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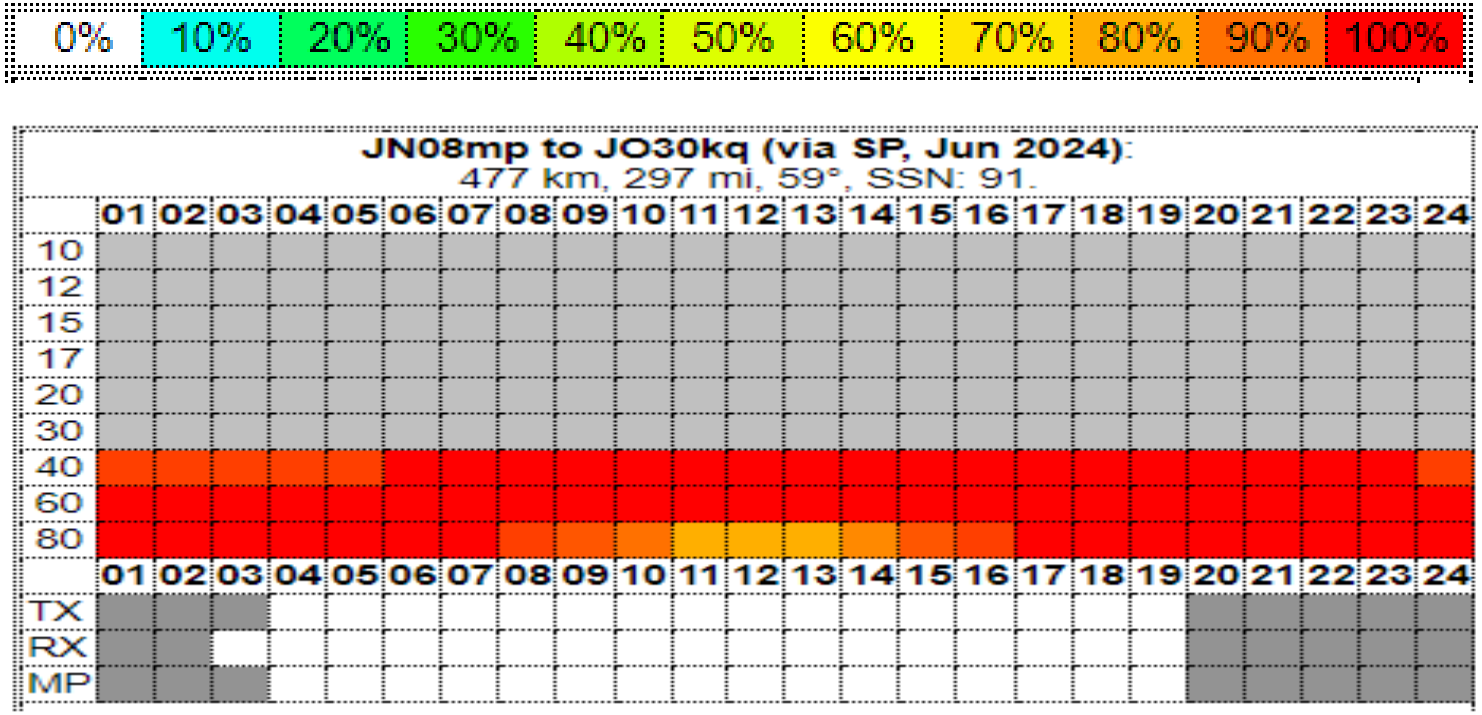
On Ground operation in the project T-FORS

Availability and suitability of frequencies for June 2024



https://www.voacap.com/hf/all_year.html

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Jun 2024 SSN = 91. Minimum Angle= 3.000 degrees
JN08mp JO30kq AZIMUTHS N. MI. KM
48.65 N 1.04 E - 50.69 N 6.88 E 59.44 243.89 257.7 477.3
REQ.SNR = 19 dB, TX POWER = 1.20 kW, SHORT-PATH

The best operating frequencies (FREQ1, FREQ2, FREQ3) by hour

UTC	SDBW	ΔSIG	REL	SNR	ΔSNR	MUFday	FOT	MUF	HPF	FREQ1	FREQ2	FREQ3
01	-74 (S9+)	20.2	100%	70	24.2	99%	5.0	6.5	7.9	3.6	5.4	7.1
02	-75 (S9+)	19.9	100%	71	25.6	100%	4.8	6.2	7.5	3.6	5.4	7.1
03	-76 (S9+)	20.0	100%	72	26.2	100%	4.7	6.1	7.4	3.6	5.4	7.1
04	-78 (S9+)	25.0	100%	75	30.2	84%	4.8	6.3	7.6	5.4	3.6	7.1
05	-79 (S9+)	23.9	100%	76	30.7	91%	5.2	6.7	8.1	5.4	3.6	7.1
06	-81 (S9+)	26.0	100%	76	31.4	96%	5.5	7.2	8.7	5.4	7.1	3.6
07	-83 (S9+)	23.7	100%	75	28.0	60%	5.8	7.5	9.1	5.4	7.1	3.6
08	-85 (S9+)	20.2	100%	74	25.7	83%	6.0	7.8	9.4	5.4	7.1	10.1
09	-86 (S9+)	24.4	100%	76	28.5	69%	6.0	7.8	9.5	7.1	5.4	10.1
10	-87 (S9+)	21.8	100%	76	27.4	67%	6.2	7.8	9.4	7.1	5.4	10.1
11	-88 (S9+)	25.7	100%	75	29.4	66%	6.4	7.7	9.3	7.1	5.4	10.1
12	-88 (S9+)	26.7	100%	74	30.8	65%	6.4	7.6	9.2	7.1	5.4	10.1
13	-88 (S9+)	30.2	100%	74	34.5	63%	6.4	7.6	9.1	7.1	5.4	10.1
14	-88 (S9+)	31.7	100%	74	36.1	61%	6.2	7.5	9.1	7.1	5.4	10.1
15	-88 (S9+)	30.3	100%	73	34.5	63%	6.0	7.5	9.0	7.1	5.4	3.6
16	-87 (S9+)	25.8	100%	72	32.5	73%	5.8	7.5	9.1	5.4	7.1	3.6
17	-84 (S9+)	25.8	100%	73	32.5	98%	5.9	7.7	9.3	5.4	7.1	3.6
18	-81 (S9+)	18.4	100%	74	27.2	99%	6.2	8.0	9.7	5.4	7.1	3.6
19	-78 (S9+)	18.8	100%	72	28.1	100%	6.4	8.3	10.0	3.6	7.1	5.4
20	-77 (S9+)	16.7	100%	75	24.1	99%	6.4	8.3	10.1	5.4	3.6	7.1
21	-76 (S9+)	18.2	100%	74	22.4	99%	6.2	8.1	9.8	5.4	3.6	7.1
22	-75 (S9+)	19.9	100%	70	22.9	100%	5.9	7.7	9.3	3.6	5.4	7.1
23	-75 (S9+)	21.0	100%	70	24.1	100%	5.6	7.3	8.8	3.6	5.4	7.1
24	-75 (S9+)	21.0	100%	70	25.4	100%	5.3	6.9	8.4	3.6	5.4	7.1

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On Ground operation in the project T-FORS

Datarows are transferred to the DF-jobs table and selected every day

```
06.700|000007 |000014  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
06.700|000015  |000029  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
|06.700|000030 |000044  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
|06.700|000045 |000059  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
|06.700|000207 |000214  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
|06.700|000215 |000229  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
|06.700|000230 |000244  | |Nostradamus (OTH), (F) |   |  |OTH Onera, Frankreich, JN08mp      |    |      |    |  |1234567 |2024-06-01|2026-12-31|
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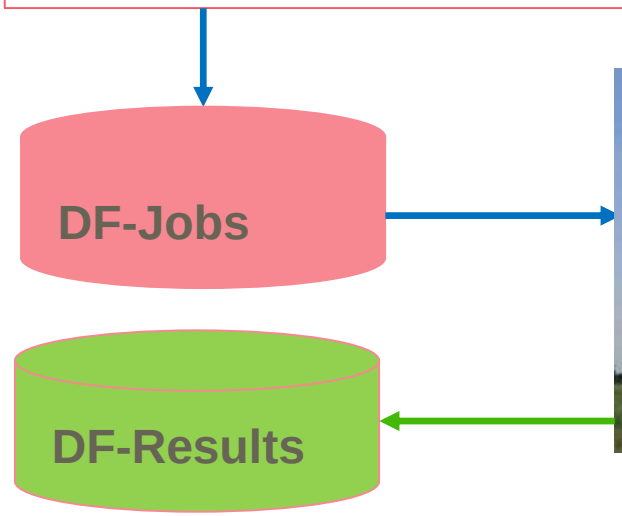

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On Ground operation in the project T-FORS

- Further steps in data processing:
  - evaluation of the forecast and prediction data for TIDE (direction, azimuth, speed, time)
  - time comparision of the TIDE prediction data with the stored DF data
  - comparison of the stored DF azimuths between default and stored bearing values during a TIDE event (azimuth differences)
  - evaluation between the prediction time (timestamp) of a TIDE and the time of the actual occurence of the TIDE (time differences)
  - checking the degree of availability for the predicted frecuency forecast (voacap)

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Acknowledgments

- Gobal Ionospheric Radio Observatory (GIRO; Prof. Dr. Bodo Reinisch and Dr. Ivan Galkin 2011) and GIRO data providers for making Digisonde data available.
- Dr. David Altadill, Observatori de l'Ebre (OE), CSIC-URL, Roquetes, Spain; Thank you very much for your support advice and many ideas
- Dipl.-Phys. Jens Mielich, Responsible Operations Manager from the Juliusruh Ionosonde which is operated by the Leibniz Institute of Atmospheric Physics Kuehlungsborn for his support.
- The Operators from the ionospheric observatory in Dourbes, owned and operated by the Royal Meteorological Institute (RMI) of Belgium.
- NCDXF/IARU International Beacon Project: To the many unknown radio amateurs working worldwide who have dedicated themselves to the worldwide beacon project (NCDXF/IARU International Beacon Project) and made this investigation possible in the first place.