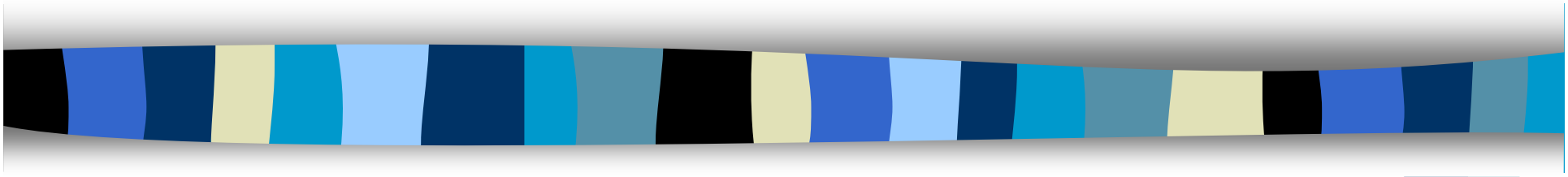
Extreme Tropo Propagation on 144 MHz and up



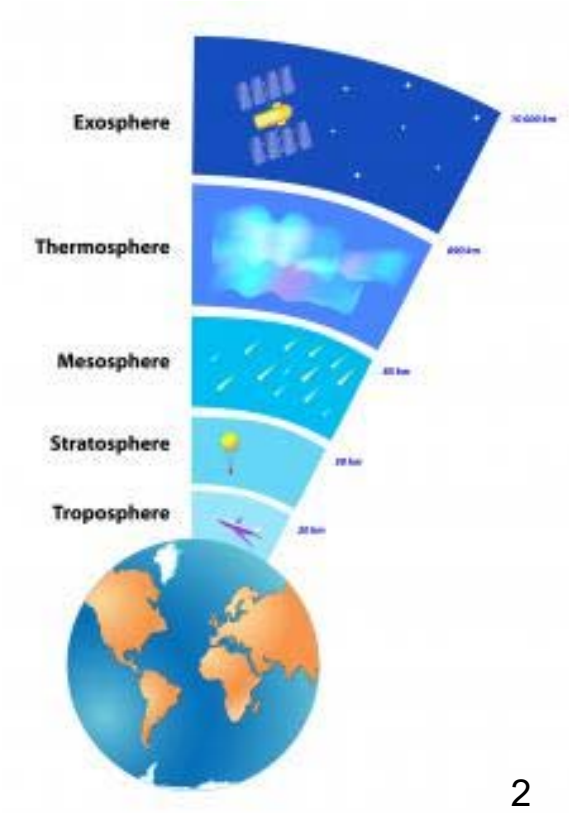
VHF-UHF contacts over distances beyond what most would consider possible.

Stefan Heck - LA0BY

(e-mail: la0by@nrrl.net)

Overview

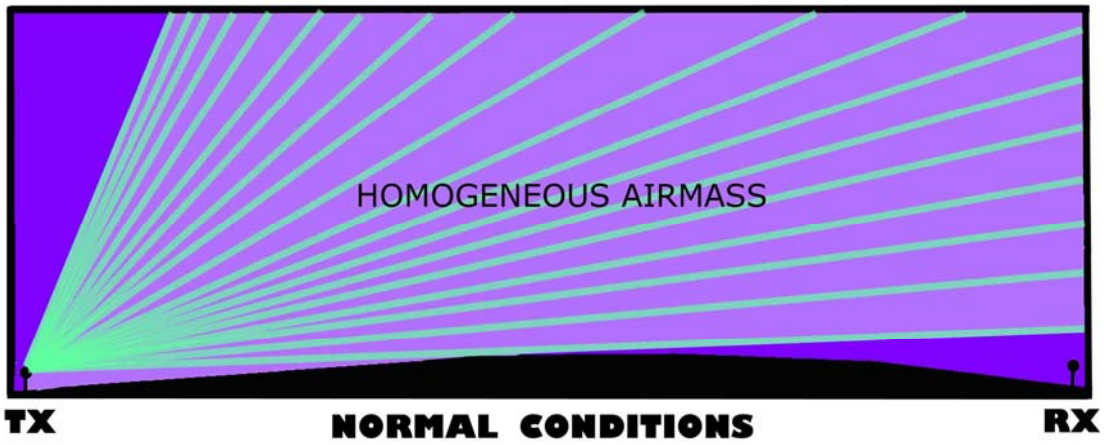
- Introduction to Tropo DX
  - What, where, why, when …
- Working 2000 km and beyond
  - Observations vs predictions
  - Equipment requirements
  - Operational considerations
  - Where is the limit?
- Summary and conclusions
  - Preparations



Troposheric propagation modes

Normal (Groundwave, Line-of-Sight)

- Most common type of propagation for radio; works for all frequency bands
- Communication path follows a (more or less) straight line
- Propagation loss depends on distance & frequency
- High altitude gives larger radio horizon

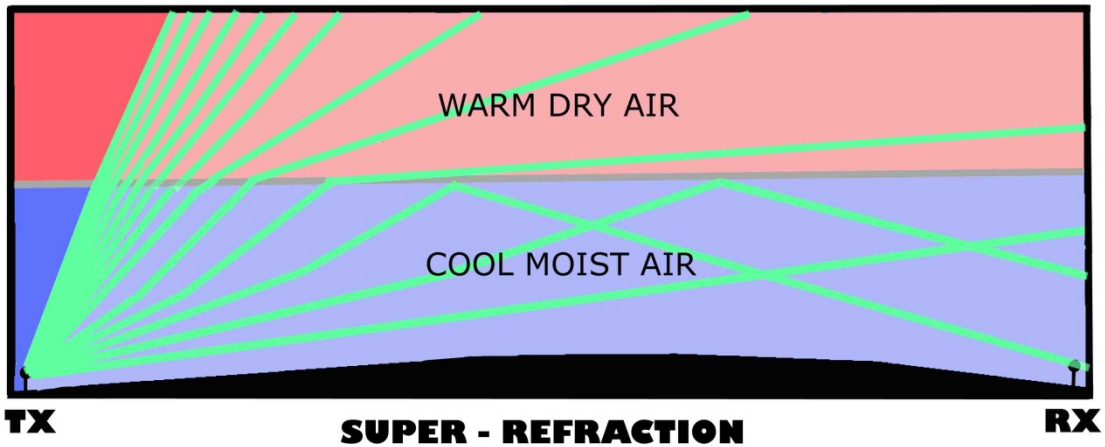


RX has no reception - TX is below the horizon.

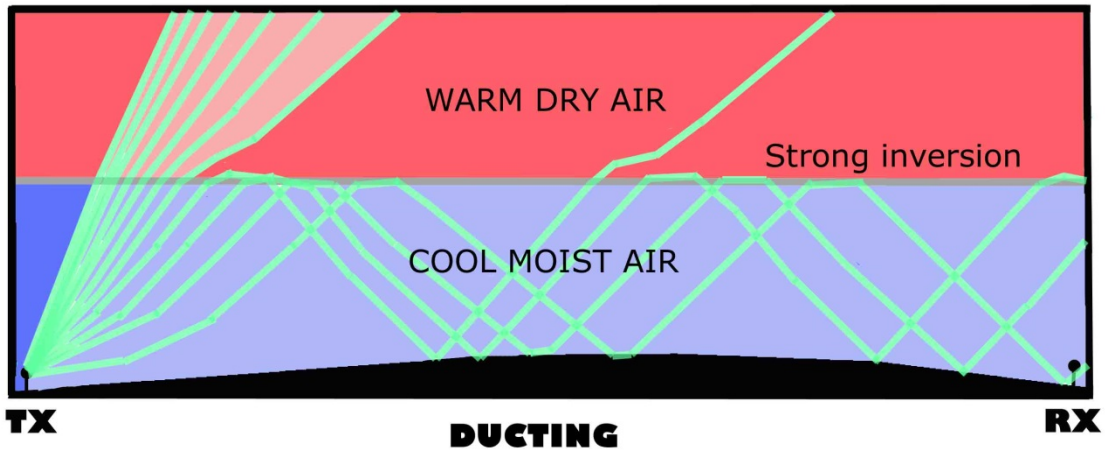
W. HEPBURN

Troposheric propagation modes

Tropospheric enhancement (TrE)



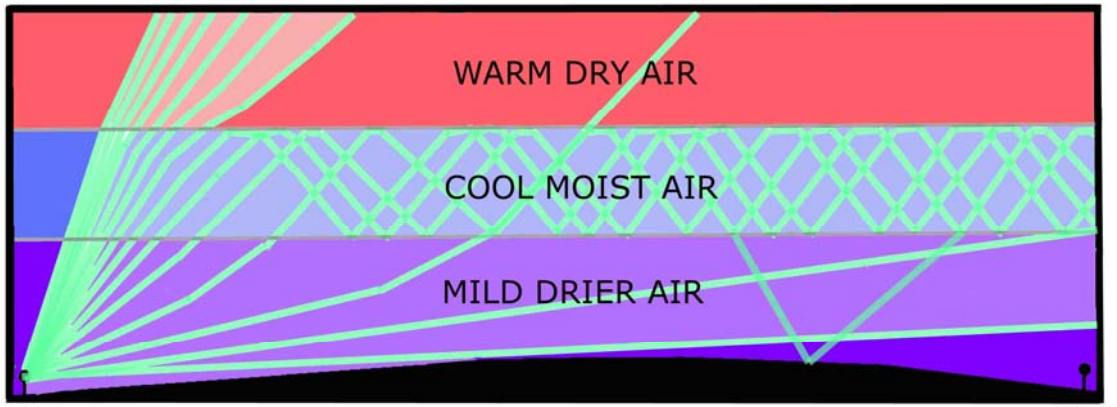
Tropospheric ducting (TrD)



Troposheric propagation modes

Elevated tropospheric ducting

- Top of inversion is very high above ground
- Receiver must be in the layer for maximum signal
- May support very long distance communications



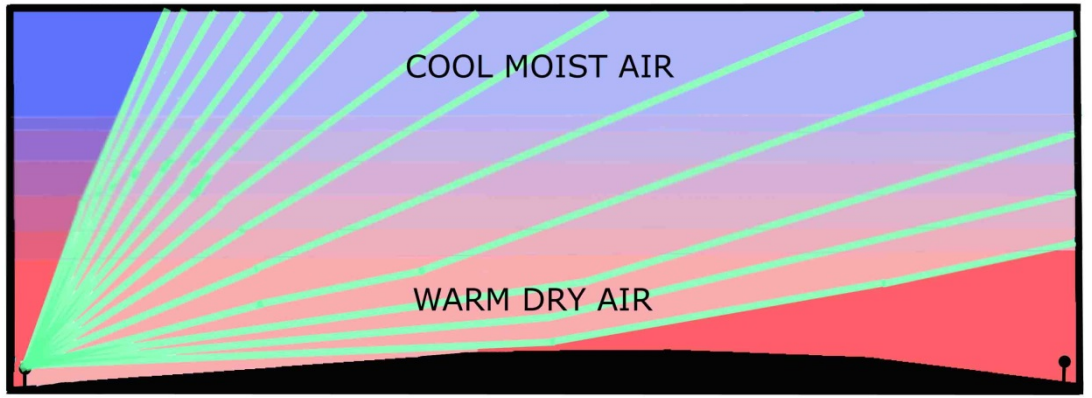
Troposheric propagation modes

Tropospheric scattering

- Refraction from minor irregularities – needs high power

Tropospheric sub-refraction

- Generated by unstable troposphere where temperature gradient drops-off with altitude faster than normal
- «anti-Tropo» condition that is worse than normal



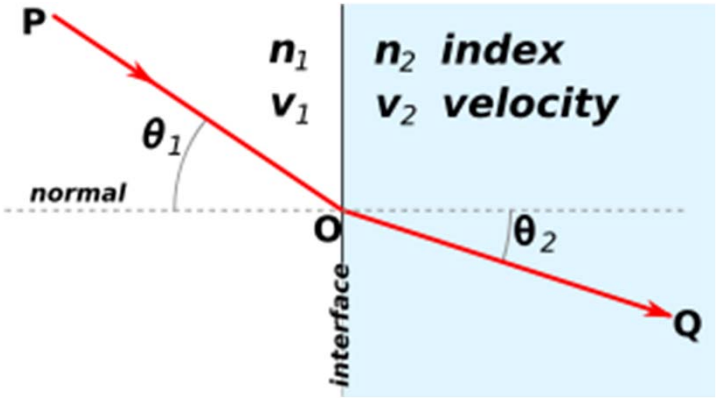
SUB - REFRACTION

Signal bends up. Range is reduced.
RX has no reception.

W. HEPBURN

Why does ray bending occur?

- Bending is called refraction = change in wave direction
- Refraction follows Snell's law: $n_1 \times \sin(\Theta_1) = n_2 \times \sin(\Theta_2)$

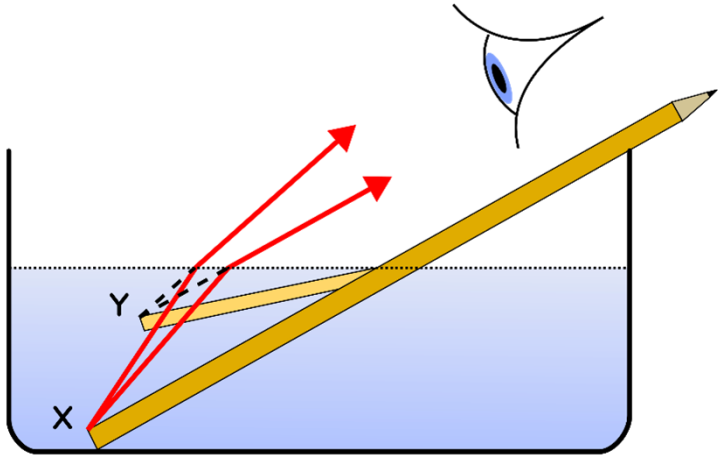


- Moving between media of different optical density
  - Crossing from lower to higher density bends towards normal
  - Crossing from higher to lower density bends away from normal

Examples of bending / refraction

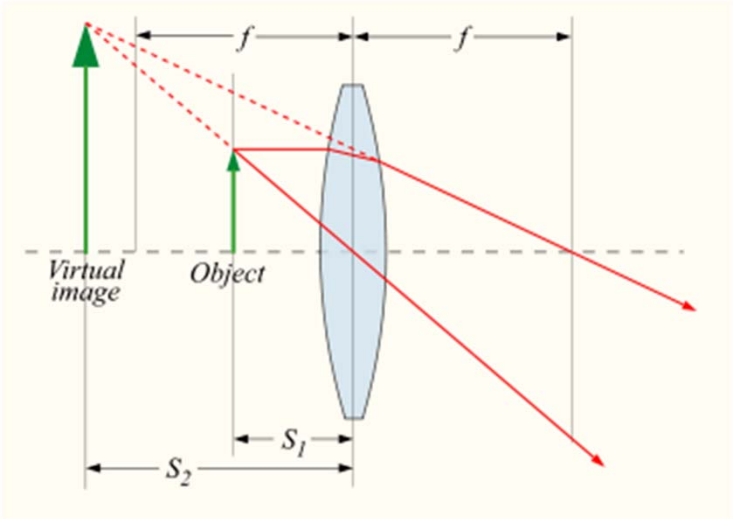
Looking into the water

- Tip appears closer to surface
- Fish look bigger than they are
- Remember when spear fishing!



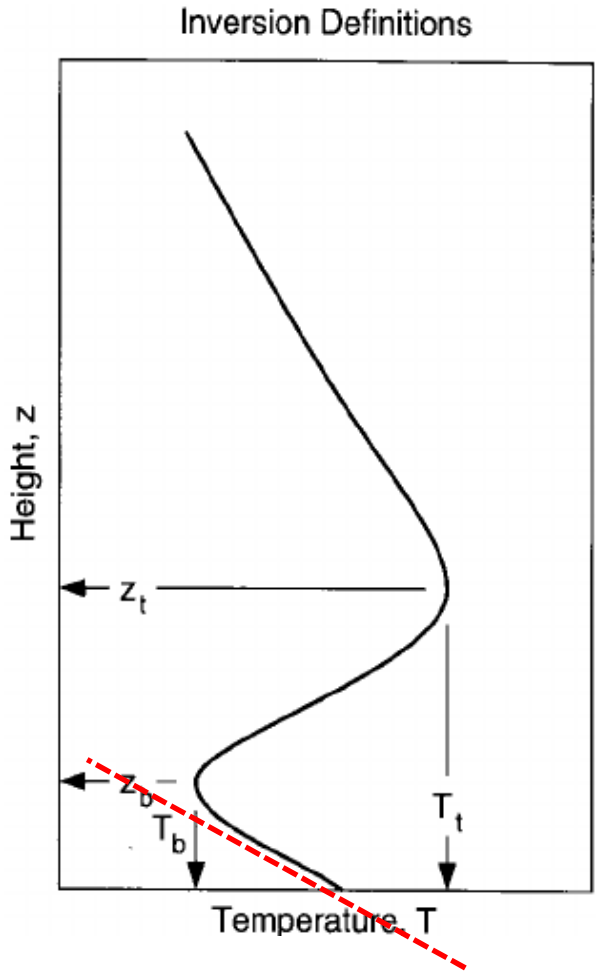
Lenses

- Make use of double bending
- This has magnifying effect

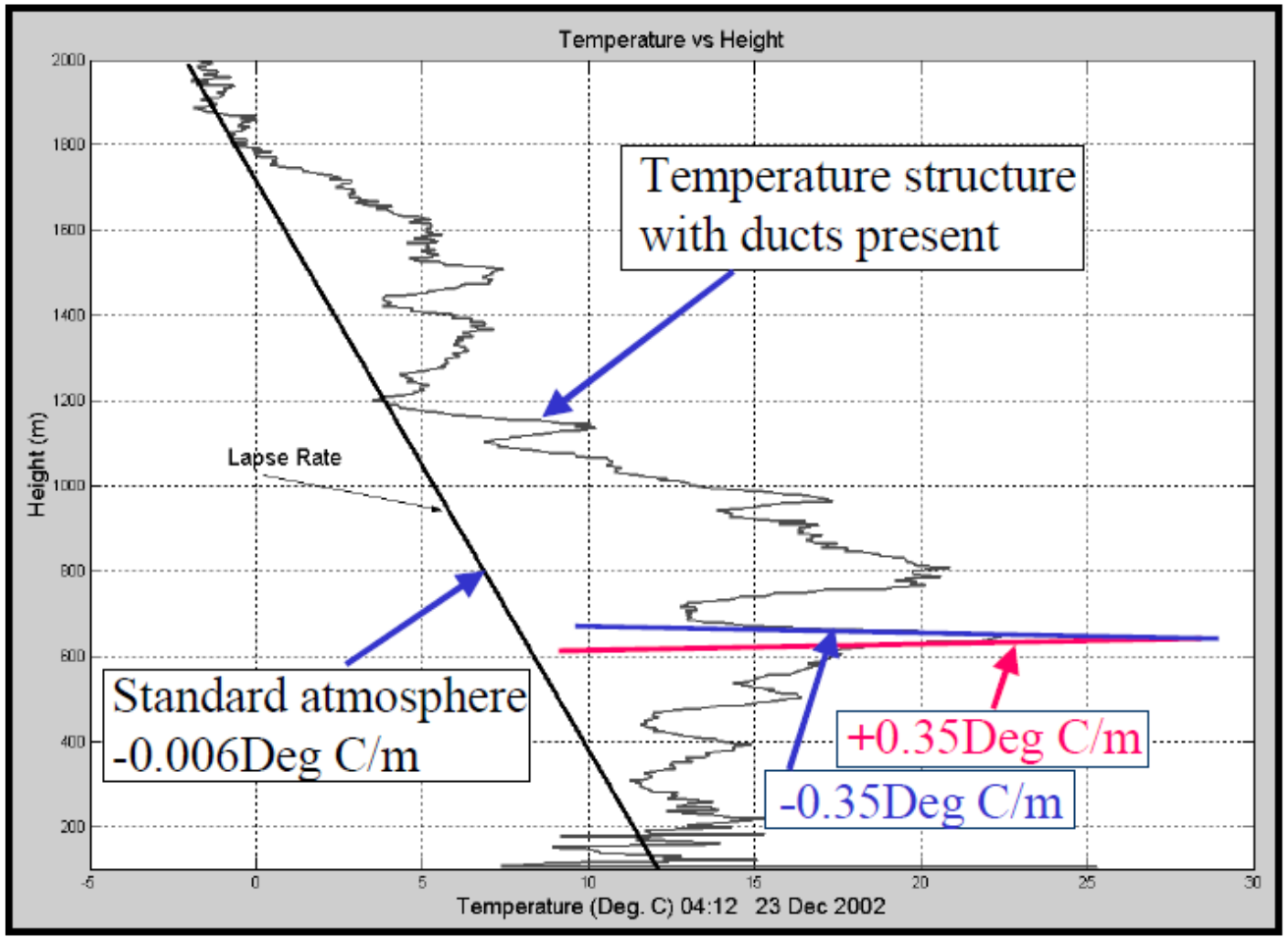


Troposheric propagation summary

- Refraction index depends on pressure, temperature, humidity
- Enhanced modes require some kind of temperature inversion
  - Temperature in lower atmosphere normally lapses by 6,5°C/km
  - Inverted profile up to 10-15°C/km
- Bending effect is frequency dependent (inversion altitude and layer thickness)
- Long paths may involve portions of different propagation modes



Real life signature of inversion



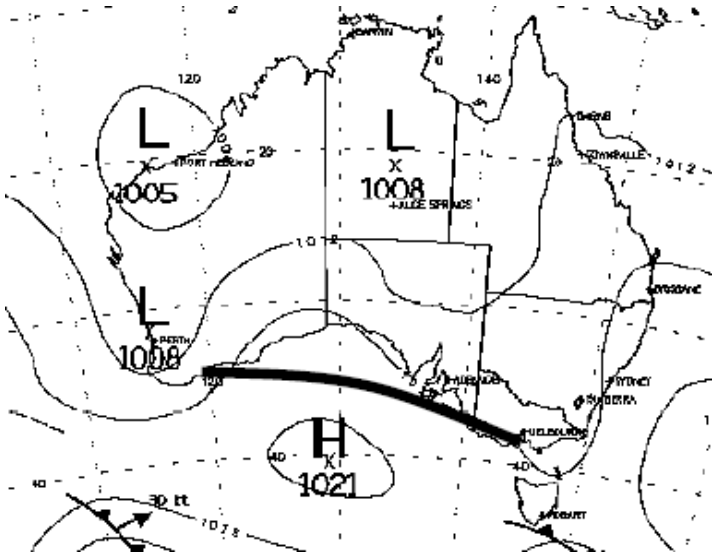
- Source: VK3KAQ – Characteristics of Ducts
- 7° C change over just 20 m in altitude

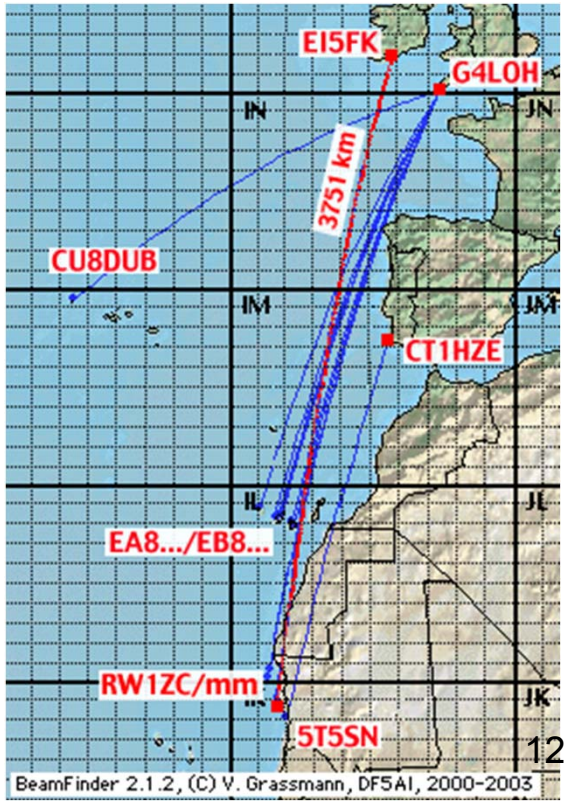
How to discover tropo ducting?

- Watch and interpret weather forecast
  - Look out for stable high pressure areas
- Monitor tropo propagation forecasts
  - Hepburn (since 2000), F5LEN
- Listen on the radio (beacons, repeaters)
- Monitor DX-Maps
- Observe nature
  - Fog in lowlands
  - Hilltops in the clear
  - Little wind, wet ground
- Webcams on hilltops …

The ultimate experience: Extreme long-distance Tropo

- Typical path across calm waters
- Coastal regions are favoured
- Distances >> 2000 km





Tropo Records – World & IARU R1

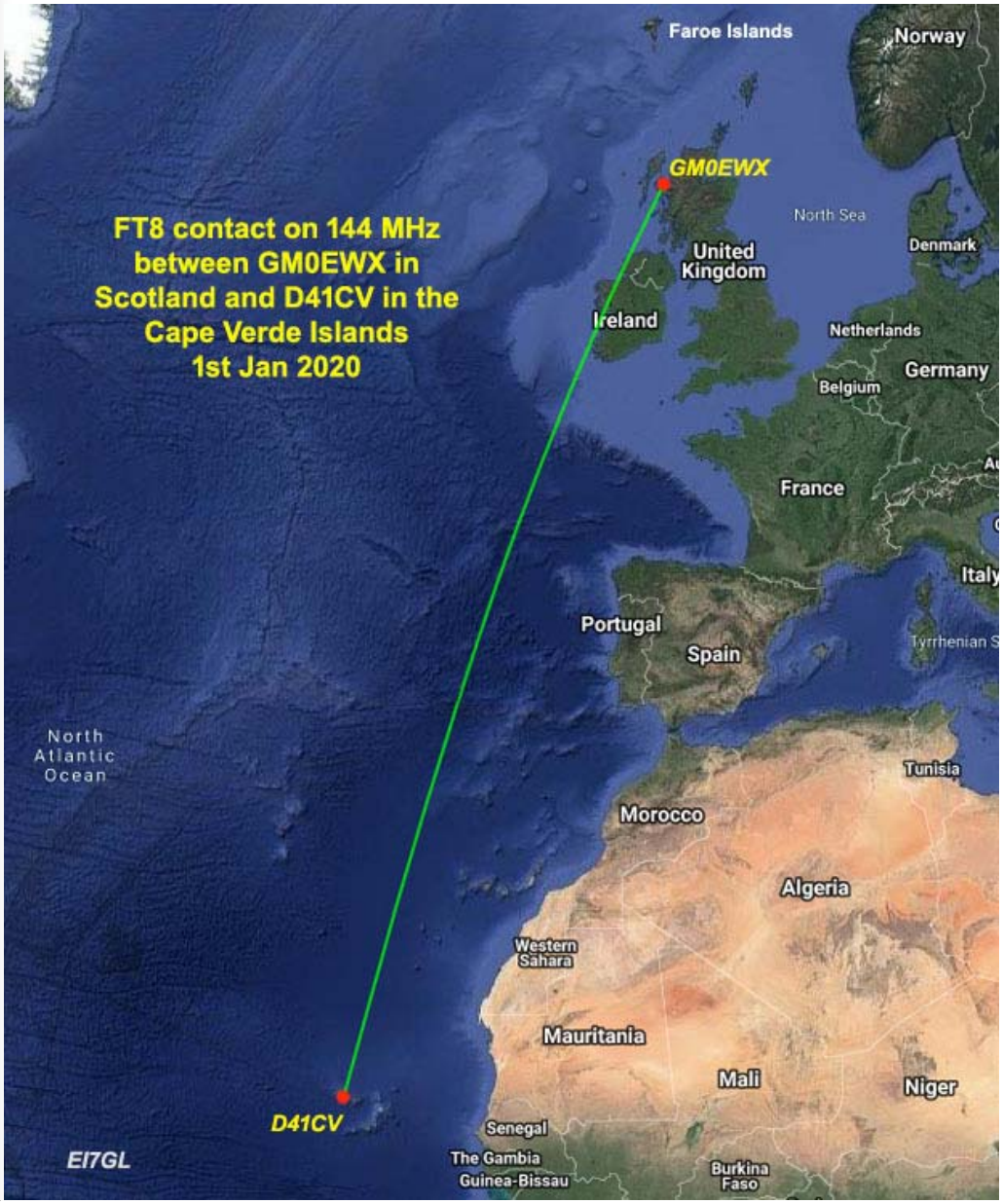
Status 2019

Band	Type	Station 1	Loc 1	Station 2	Loc 2	km
144 MHz	World	KH6EME	BK29GO	W1LP/mm	DL51CE	4755
144 MHz	R1	G				
432 MHz	World	K				
432 MHz	R1	G4LOH	IO70JC	D44TS	HK77KE	4064
1296 MHz	World	KH6EME	BK29GO	XE2/N6XQ	DL29CX	4151
1296 MHz	R1	M0VRL	IO70PO	EA8AVI	IL28FC	2660

World Records for 144 & 432 MHz were brought to Europe on 1.1.2020

- Source: http://www.ok2kkw.com/dxrecords.htm
- Reception of VK6 beacon by FR1GZ over > 6000 km ?

World Records 144 & 432 MHz



Tropo Records – World & IARU R1

Status 2020

Band	Type	Station 1	Loc 1	Station 2	Loc 2	km
144 MHz	World	GM0EWX	IO67UL	D41CV	HK76MU	4770
144 MHz	R1	GM0EWX	IO67UL	D41CV	HK76MU	4770
432 MHz	World	G4KUX	IO94BP	D41CV	HK76MU	4638
432 MHz	R1	G4KUX	IO94BP	D41CV	HK76MU	4638
1296 MHz	World	KH6EME	BK29GO	XE2/N6XQ	DL29CX	4151
1296 MHz	R1	M0VRL	IO70PO	EA8AVI	IL28FC	2660

- Question of time when D41CV gets record on higher bands

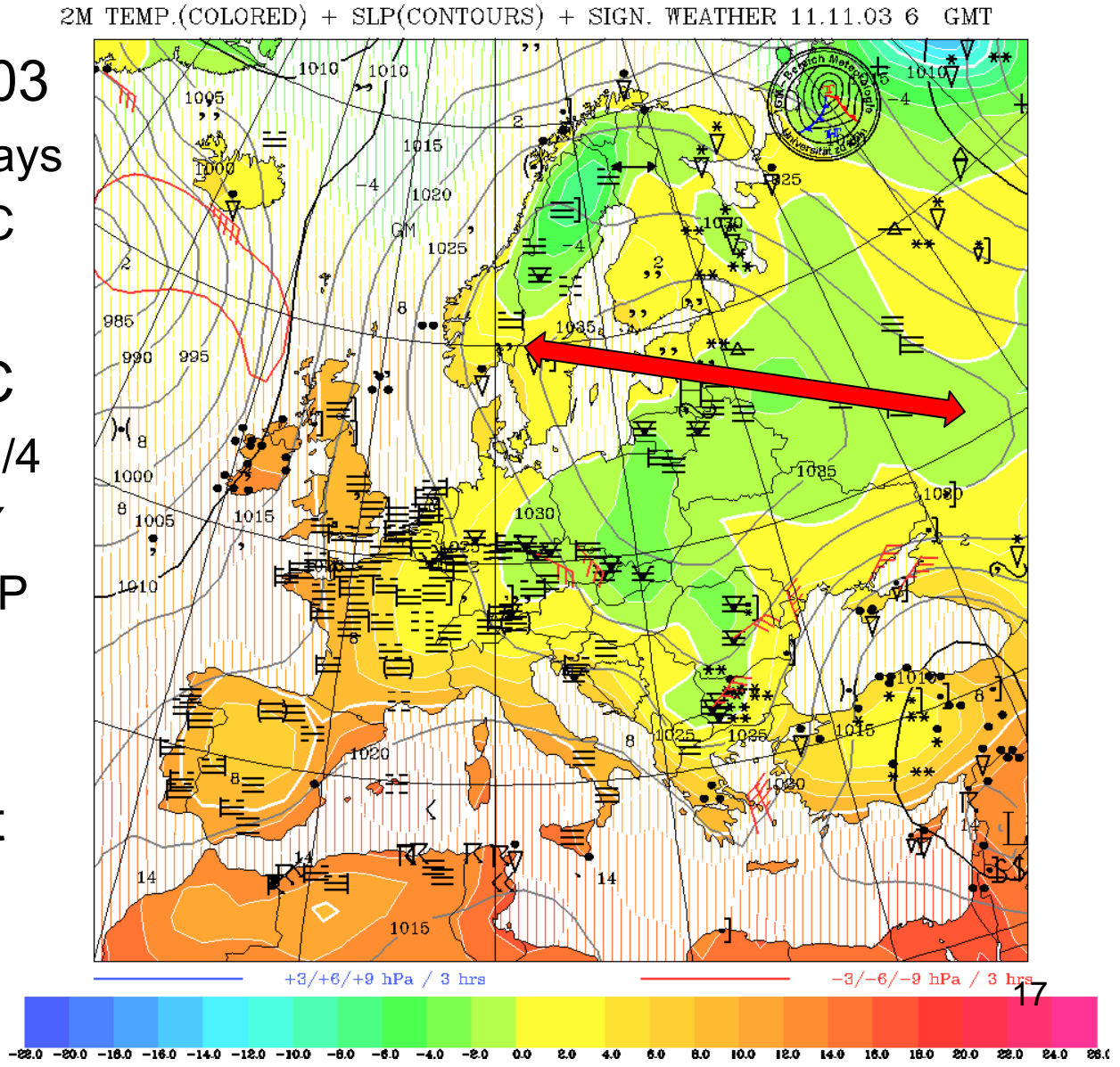
But what is possible from LA?

LA0BY in JO59IX

- Hilltop near Oslo: Tryvann, 500 m asl
- Radio horizon (flat)
  - 800 km on 2 m
  - 700 km on 70 cm
  - 600 km on 23 cm
- Limited observation options from home
- Need 45-60 min for drive and setup

The great Tropo to East

- 6.-11.11.2003
  - lasting 6 days
  - 70 cm NAC
- Many DXCC
  - OH, UA1/3/4
  - ES, YL, LY
  - EW, UT, SP
  - DL, PA, G
- Best to East



The great Tropo to East

LA0BY in JO59IX - 144 MHz

UA4UK	**LO14MA**	**2050 km***
RW3TJ	LO16XG	1980 km*
RW3TI	LO16WG	1975 km*
RW3PF	KO93CD	1837 km*
RU3ACE	KO95KG	1742 km
RA3PG	KO84TD	1737 km
RX3PR	KO84TE	1734 km
RU3FA	KO84RU	1686 km
RA3DCI	KO96CB	1664 km
RA3AQ	KO85SP	1648 km

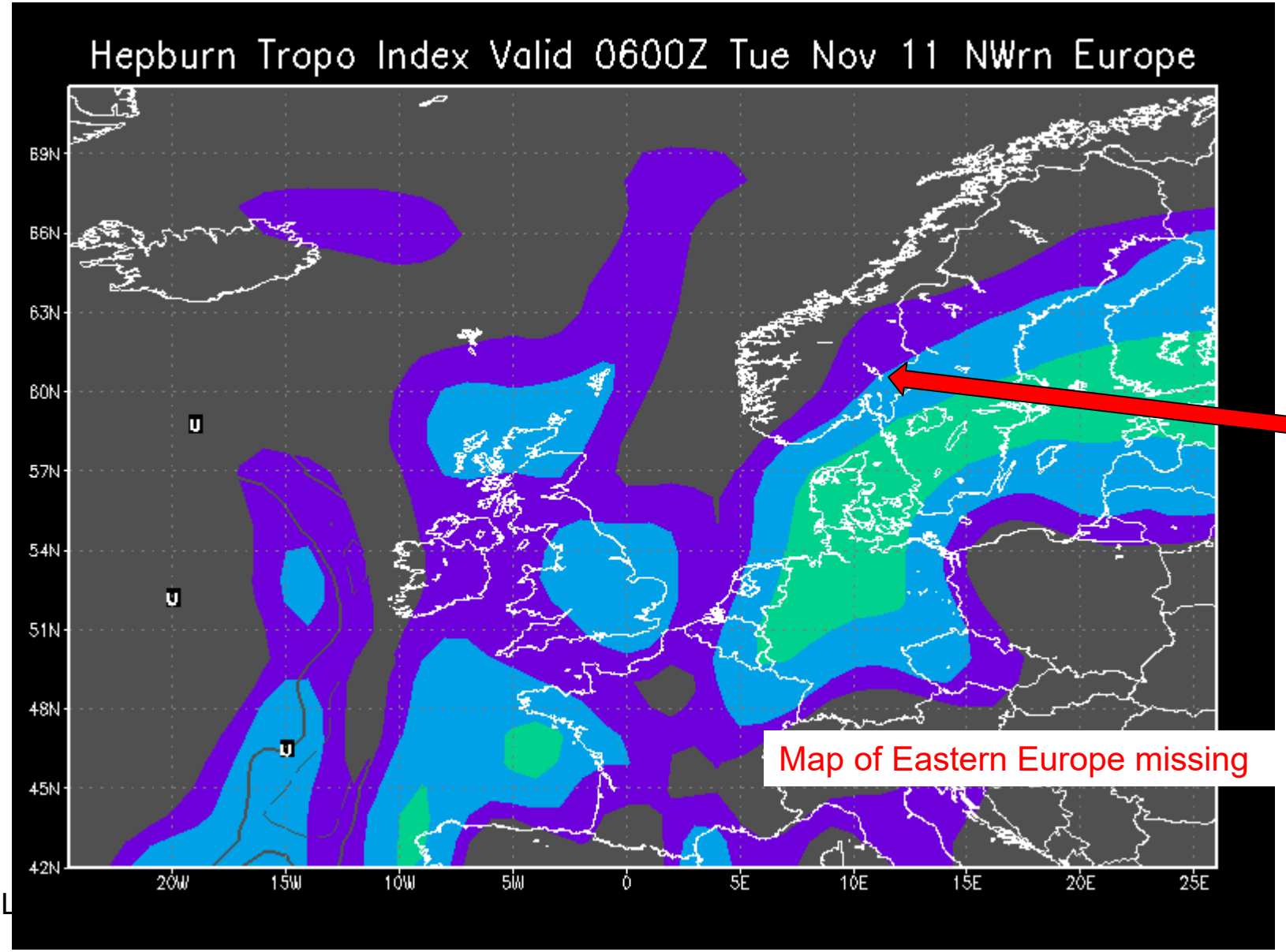
LA0BY in JO59IX - 432 MHz

RW3PF	KO93CD	1837 km*
UA3PTW	KO93BS	1787 km
UA3ARC	KO85SO	1650 km
RA3AQ	KO85SP	1648 km
RA3LE	KO64AR	1398 km
RA3LW	KO54MQ	1347 km
SP9APC	JN99QU	1252 km
SP7EXY	KO00QW	1206 km
RX1AX	KO59EW	1091 km
SP7CNL	JO91QQ	1067 km

- QRV 2 bands, total > 300 QSO, first time > 2000 km on 2 m
- Strong signals, some QSO even in FM (to EW)
- Contacts over the head of SM stations (elevated duct?)

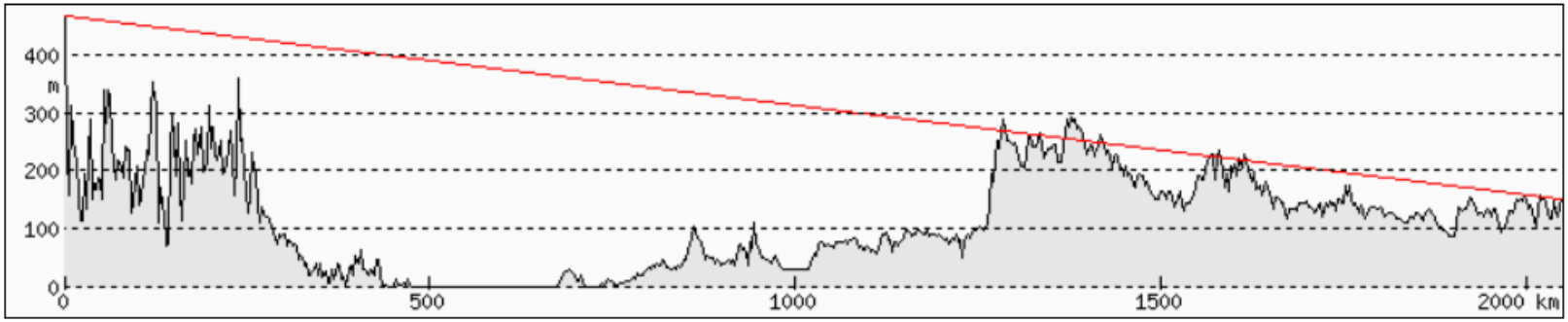
(*) Distance calculated in WGS84 fore more km

The great Tropo to East

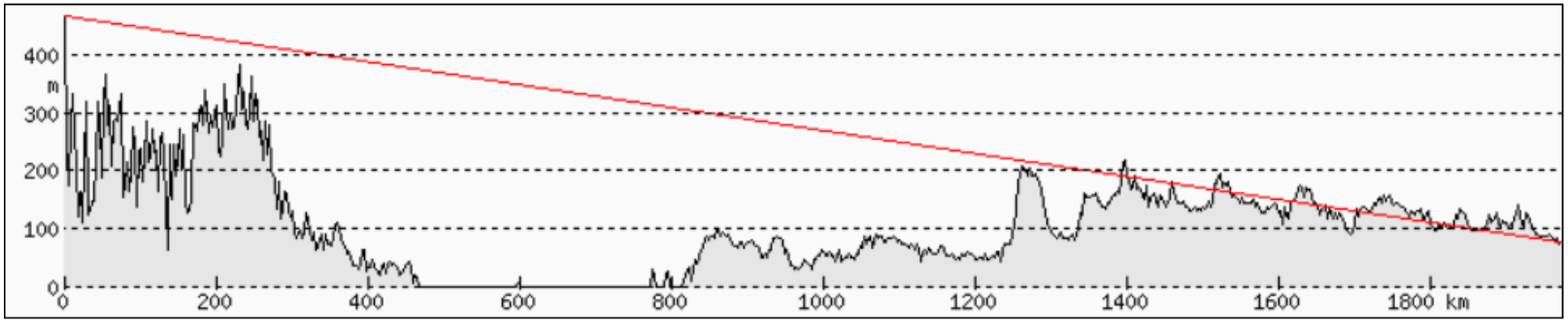


The great Tropo to East

UA4UK, LO14MA, path almost clear, 2050 km

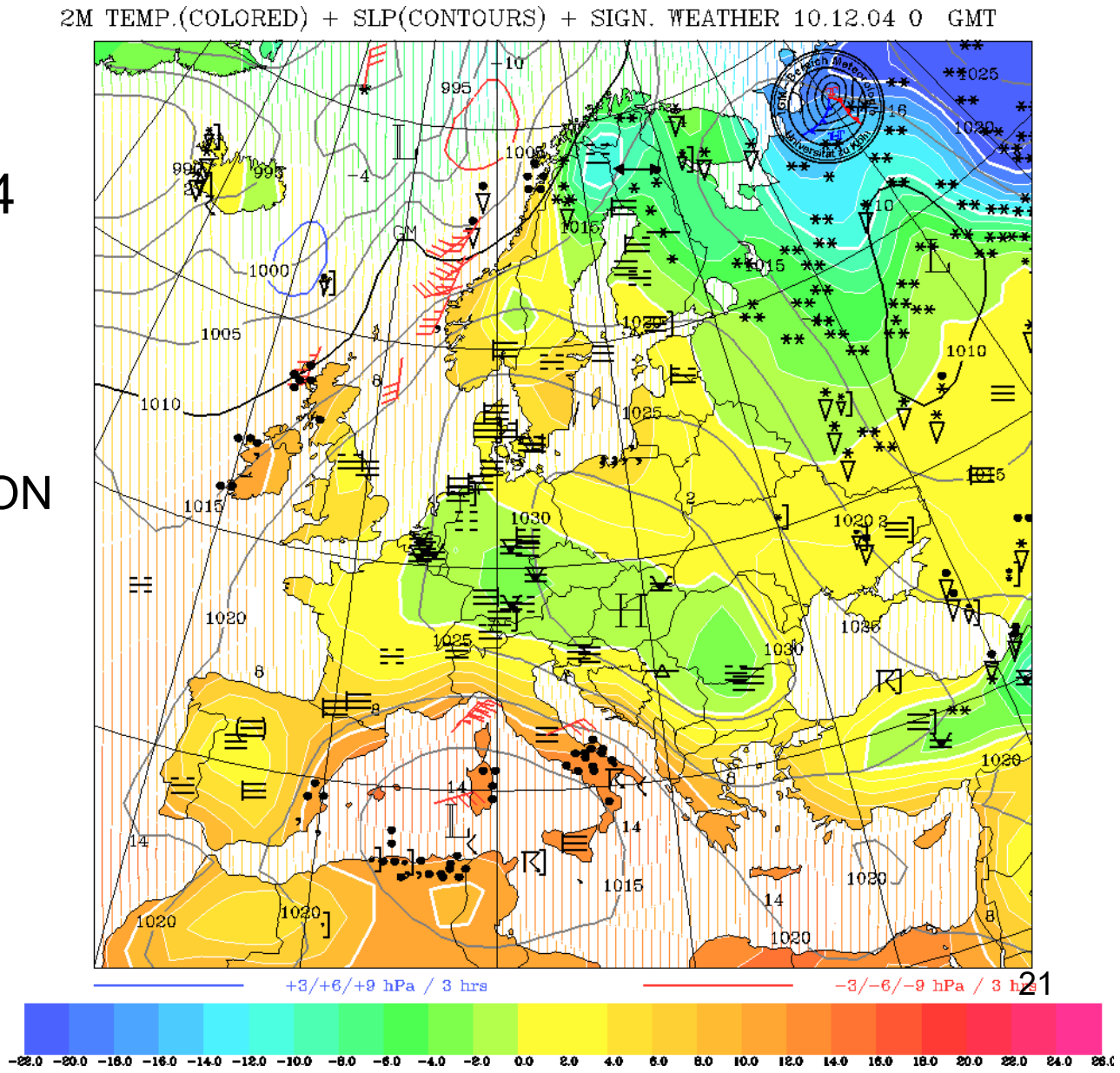


RW3TI, LO16WG, path quite clear, 1975 km, 40 W, 2 x 16-ele



Winter Tropo to France

- 10.12.2004
- DXCC
  - SP6, OK
  - DL, PA, ON
  - G, F
- Best to F



Winter Tropo to France

LA0BY in JO59IX - 144 MHz

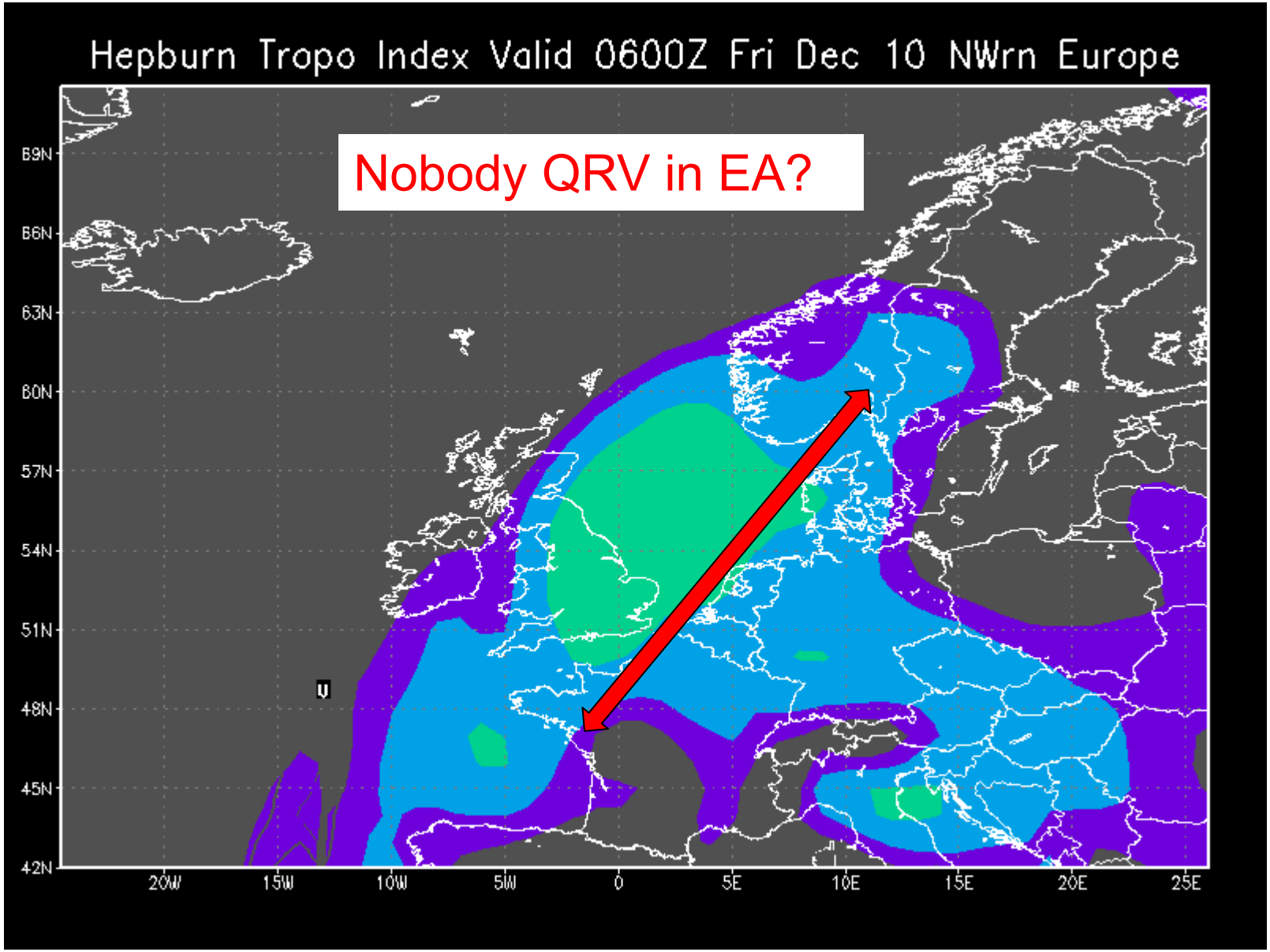
F6AQI	IN96DW	1661 km
F6DZF	JN16GB	1638 km
F4DXX	IN97LH	1602 km
F6APE	IN97QI	1585 km
F5NXU	IN97MR	1557 km
F2GL	IN97ST	1533 km
F2GL	IN97ST	1533 km
F1CIA	IN97XW	1508 km
F/ON5KO/P	IN98QL	1471 km
F6DKW	JN18CS	1360 km

LA0BY in JO59IX - 432 MHz

F6DZF	JN16GB	1638 km
F4DXX	IN97LH	1602 km
F6APE	IN97QI	1585 km
F5NXU	IN97MR	1557 km
F6DKW	JN18CS	1360 km
F8BRK	IN99VF	1338 km
F6CBH	JN19BH	1308 km
OK2POI	JN99AJ	1266 km
F5PEJ	JN09XT	1259 km
F4EMG	JO00WU	1155 km

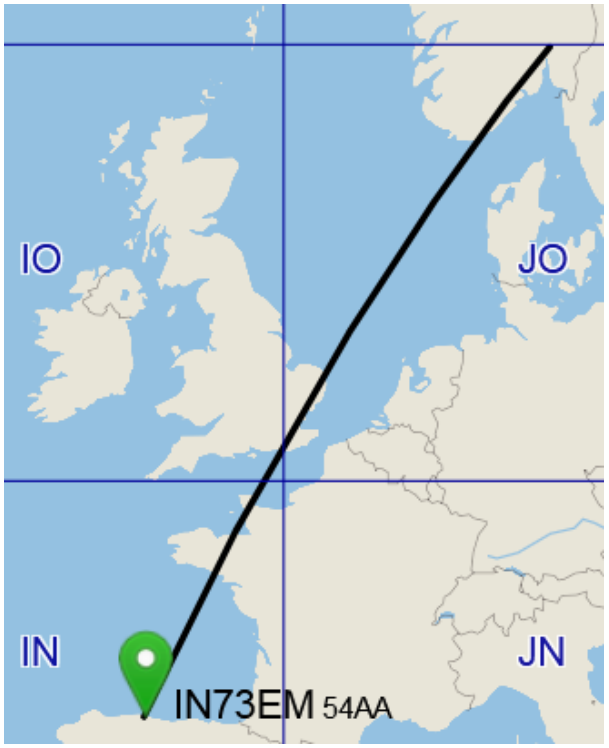
- Widespread tropo, strong signals
- QRV 2 bands, total > 160 QSO, 70 cm almost like 2 m

Winter Tropo to France

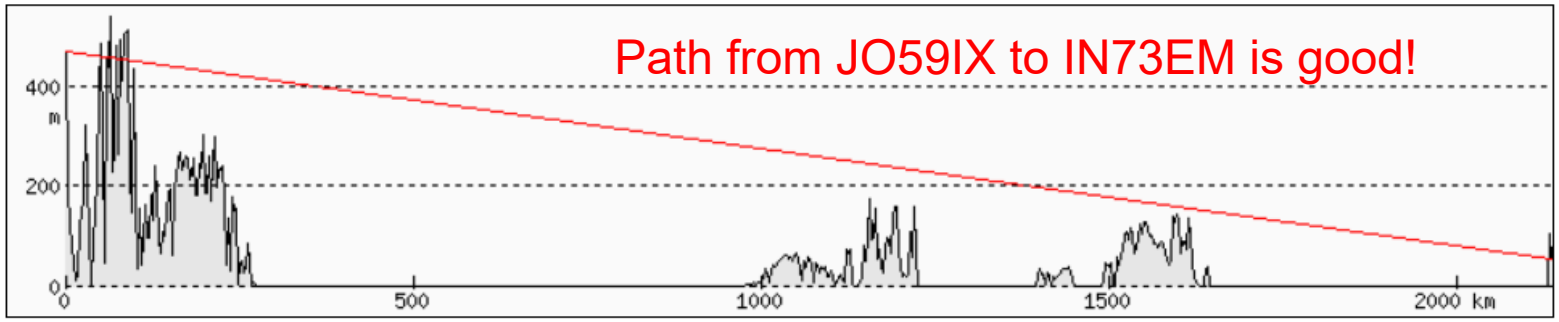


EA1 on 144 MHz Tropo - new ODX

- 15.10.2011, 20:45 UTC: QSO between LA0BY (JO59IX) and EA1DDU (IN73EM), CW/SSB, 2135 km
- Result of > 10 year of attention and observation of propagation forecasts, weather maps & attempts
- Challenges
  - Simultaneous ducting over 3 sea- and 3 land areas needed
  - Breaking the wall of ON/PA
  - No other stations QRV from hill-top locations at both ends
- Mode was elevated duct
- Few QSO - F/G/ON/PA/DL

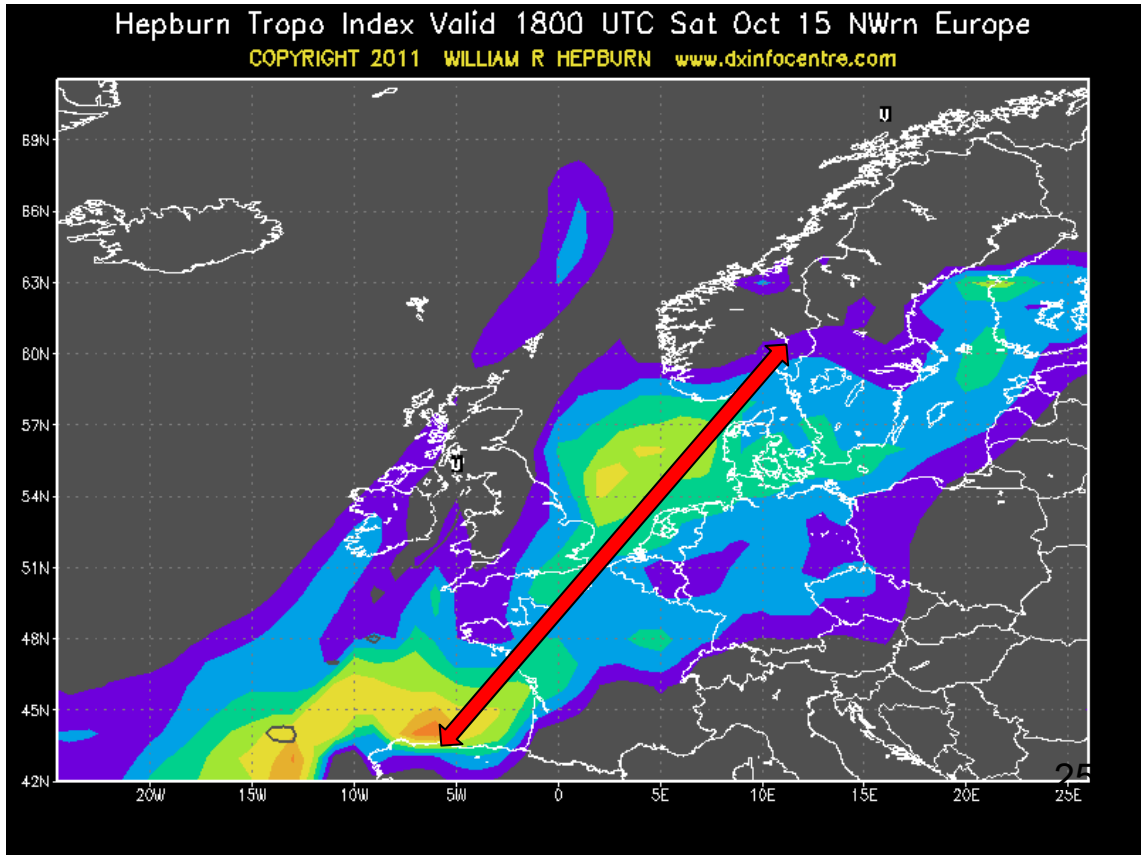


EA1 on 144 MHz Tropo



Equipment

- LA0BY:
  - 180W
  - 2 x 9-ele-yagi
- EA1DDU
  - 100 W
  - 12-ele-yagi



Crossing mountains: LA to 9A/S5

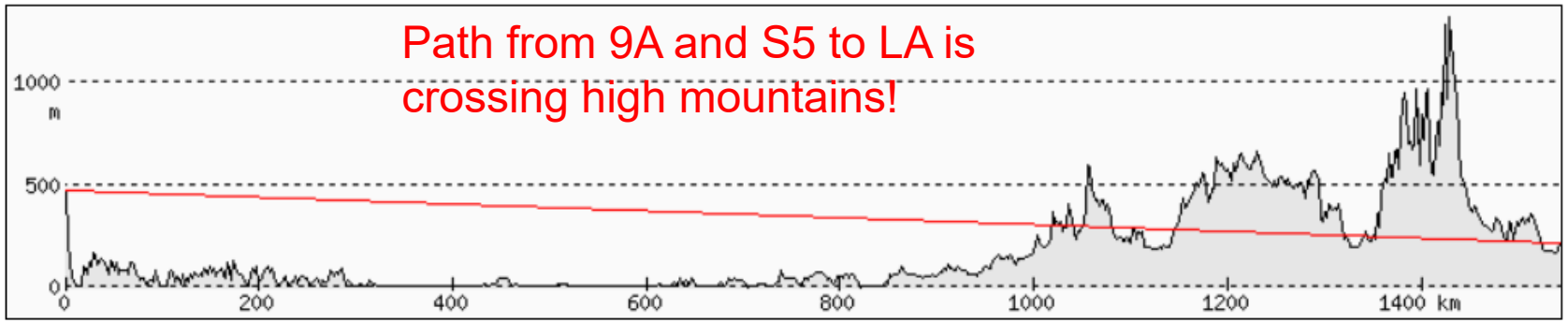
LA0BY in JO59IX - 144 MHz

9A1CAL	JN86DM	1541 km
S51ZO	JN86DR	1518 km
OM2RC	JN88OL	1345 km
DL6MFK	JN67JX	1341 km
OE5KE	JN78EG	1323 km
DL8NP	JN58SC	1318 km
OK2BRD	JN99ET	1230 km

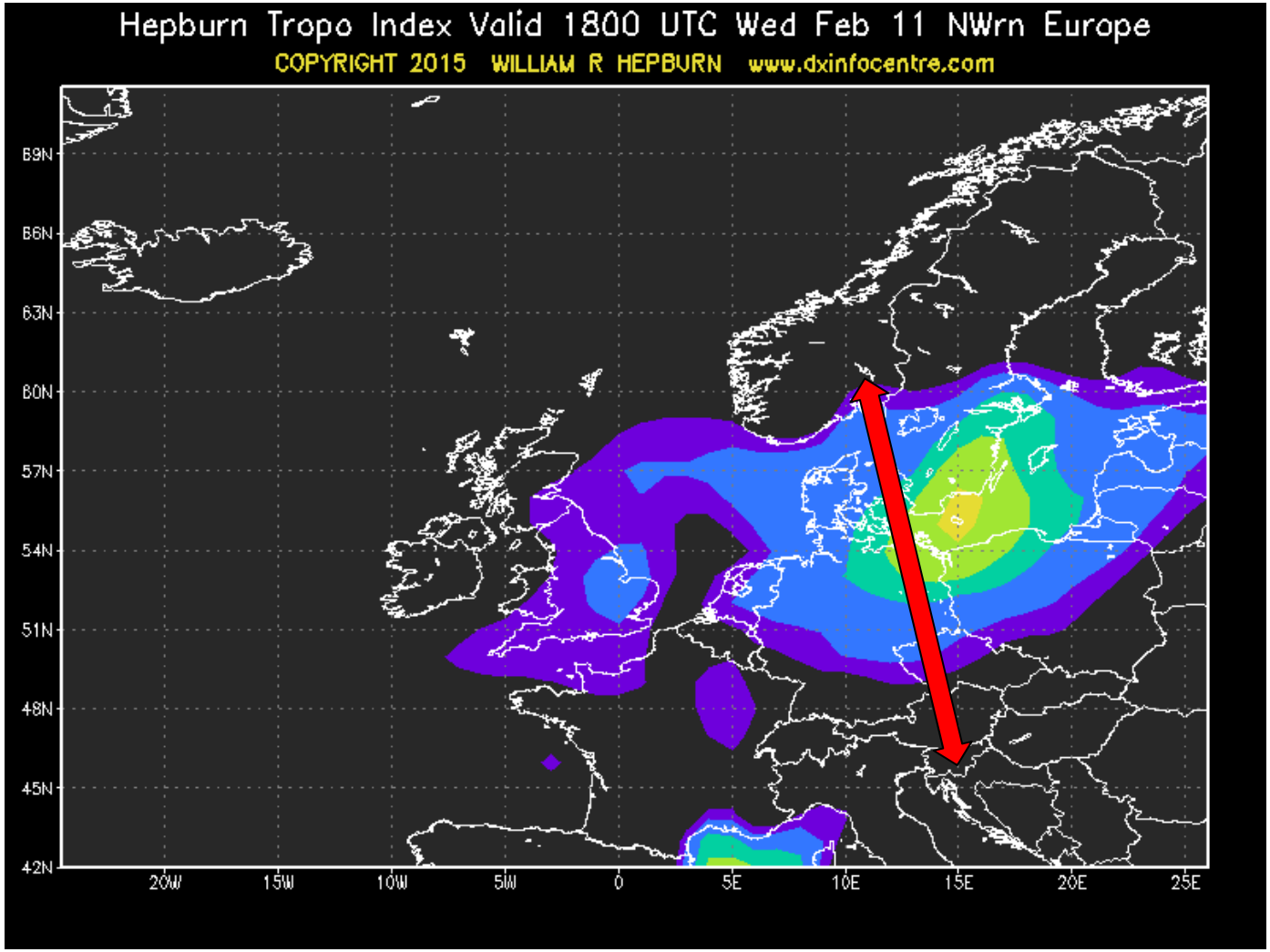
LA0BY in JO59IX - 432 MHz

9A1CAL	JN86DM	1541 km
S51ZO	JN86DR	1518 km
OE3DSB	JN78FA	1352 km
DL6MFK	JN67JX	1341 km
OM3CLS	JN99FC	1306 km
DL3RBH	JN68IK	1290 km
OK2BRD	JN99ET	1230 km

- Event on 11.2.2015, lasting for ca. 1 day - in winter
- 2 m and 70 cm worked equally well (I was not QRV on 23 cm)
- Very good activity (> 200 QSO on 2 bands), strong signals

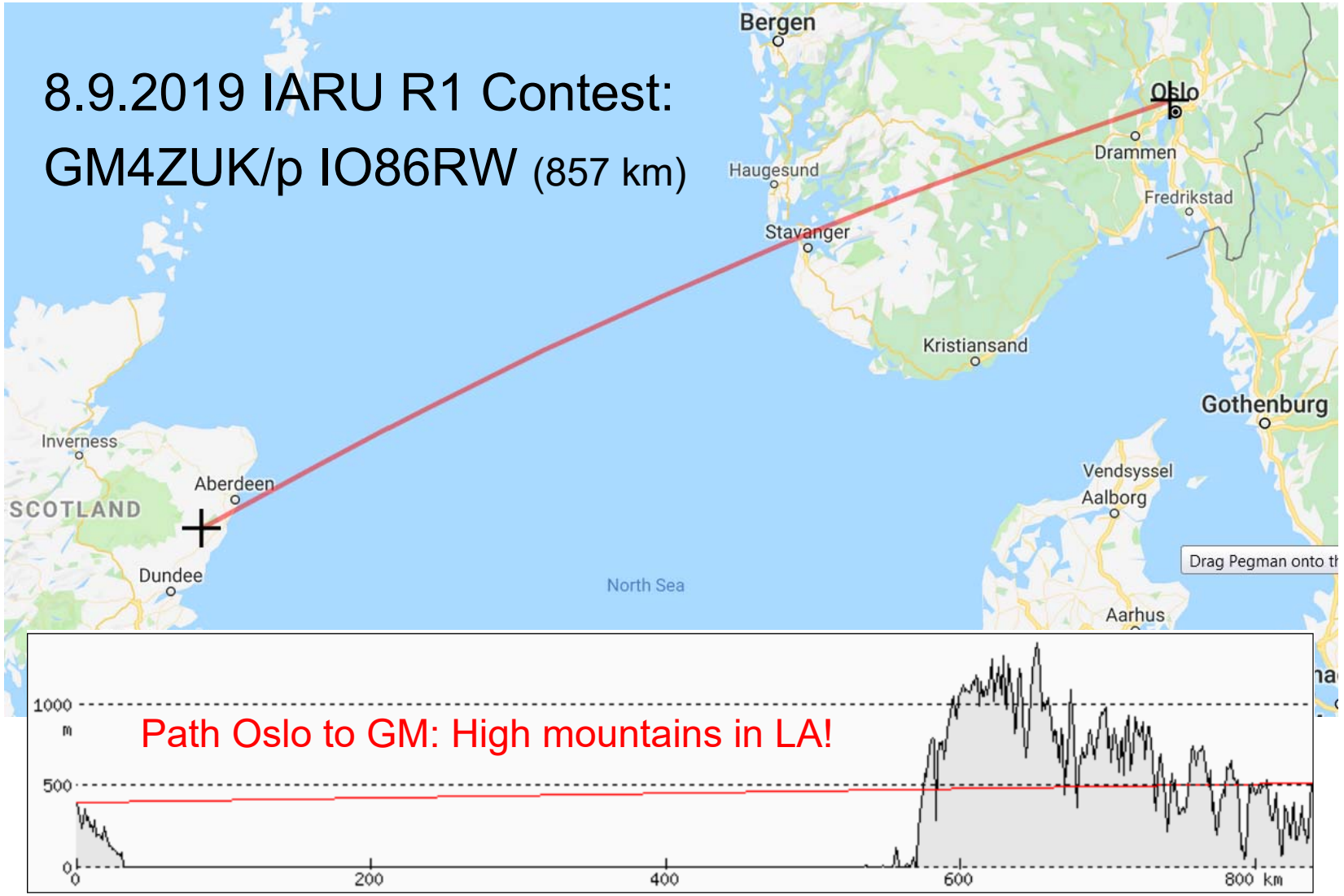


Crossing mountains: LA to 9A/S5



LA0BY 2020 Hepburn predictions did not indicate path reaching 9A/S5

Crossing mountains: Oslo to GM



LA-UA6 Unbelievable distances

- Surprise event on 22.11.2018, ca. 40 stations in CW & SSB
- Focus on 70 cm, but operational on two bands at a time (limited by antenna constraints)

LA0BY in JO59IX - 432 MHz

R6AM	**LN04NX**	**2611 km**
RZ6DD	**LN04MX**	**2606 km**
UA6AQN	**KN96VC**	**2448 km**
UR8GZ	KN66RT	2082 km
UT4LA	KN89CW	1954 km
UT8LE	KN79WW	1937 km
UR5LX	KO70WK	1899 km
UT5VD	KN68MT	1889 km
UT8AL	KO61WP	1705 km
UT6UG	KO50EI	1634 km

total 24 stations

LA0BY in JO59IX - 144 MHz

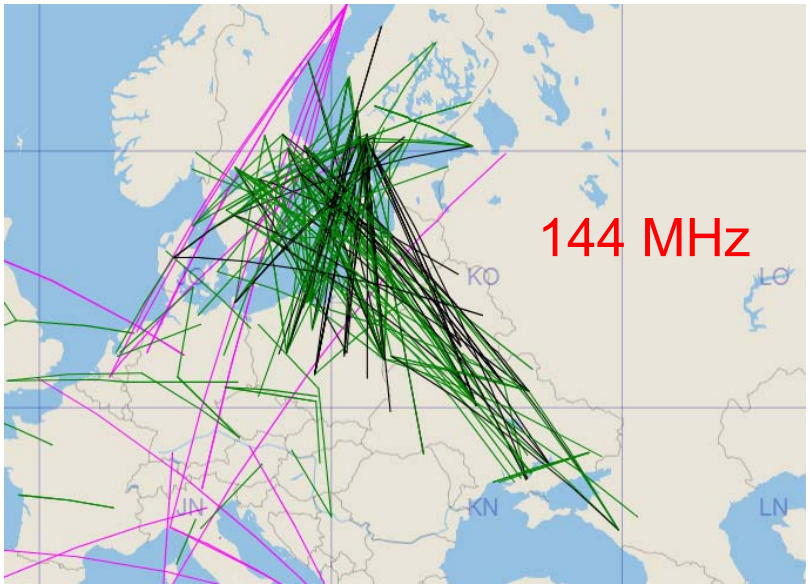
UR8GZ	KN66RT	2082 km
UY5HF	KN66HP	2059 km
UR3VKC	KN68NO	1911 km
UR5LX	KO70WK	1899 km
UT8AL	KO61WP	1705 km
US8AR	KO60AR	1683 km
UT9UR	KO40XD	1632 km

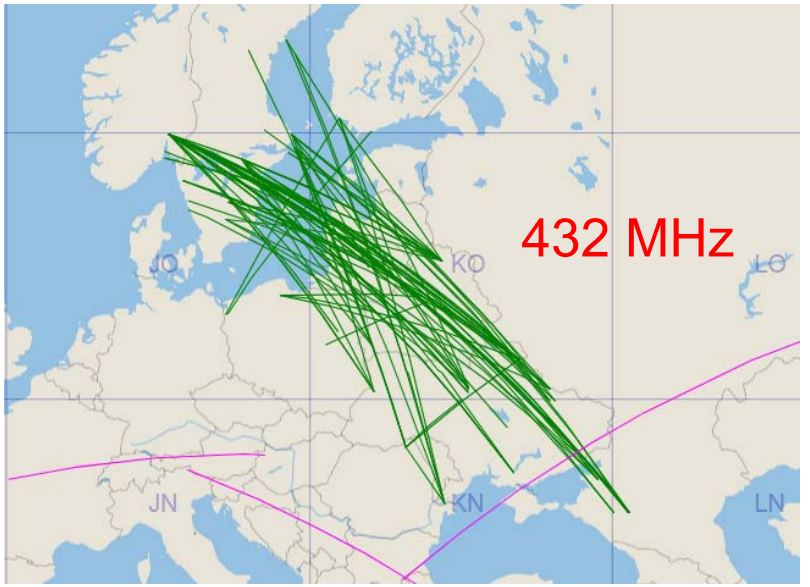
total 12 stations

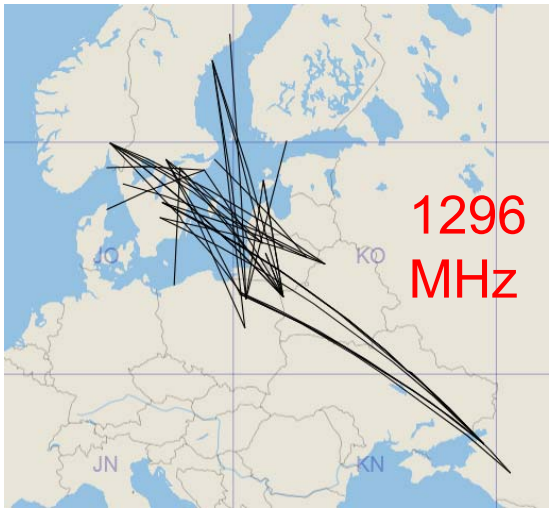
LA0BY in JO59IX - 1296 MHz

EW6FS	KO35LB	1110 km
EU4AX	KO13VP	1060 km
SP4MPB	KO03HT	911 km
LY2R	KO15VS	902 km
LY2HM	KO15CX	809 km

LA-UA6 Unbelievable distances

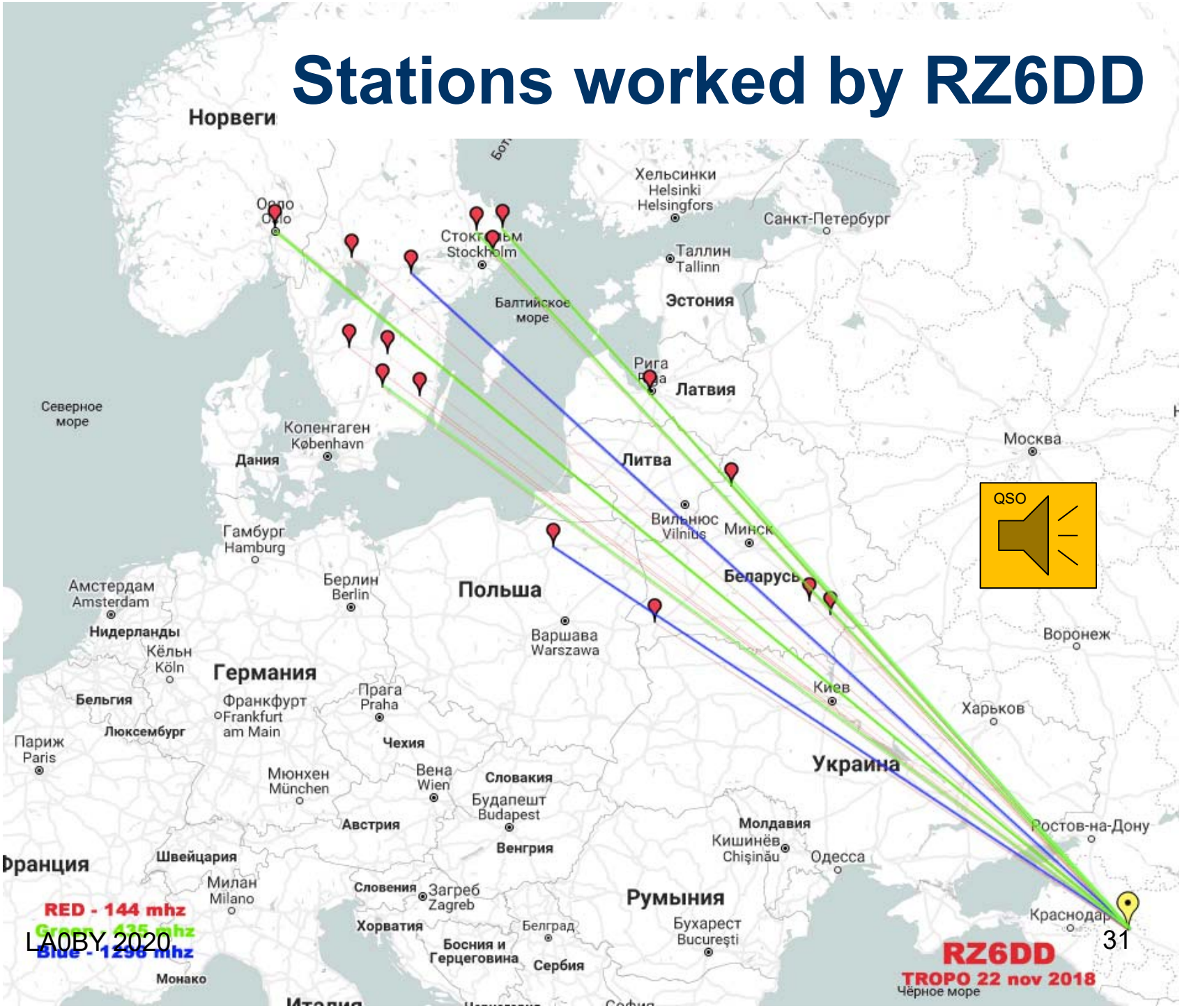






- Pictures show reported contacts on 22.11.2018 from 17-24 UTC
- Working UA6 on 2 m was possible, but I did not focus on it (hrd RA6A)
- Working UA6 on 23 cm may have been possible

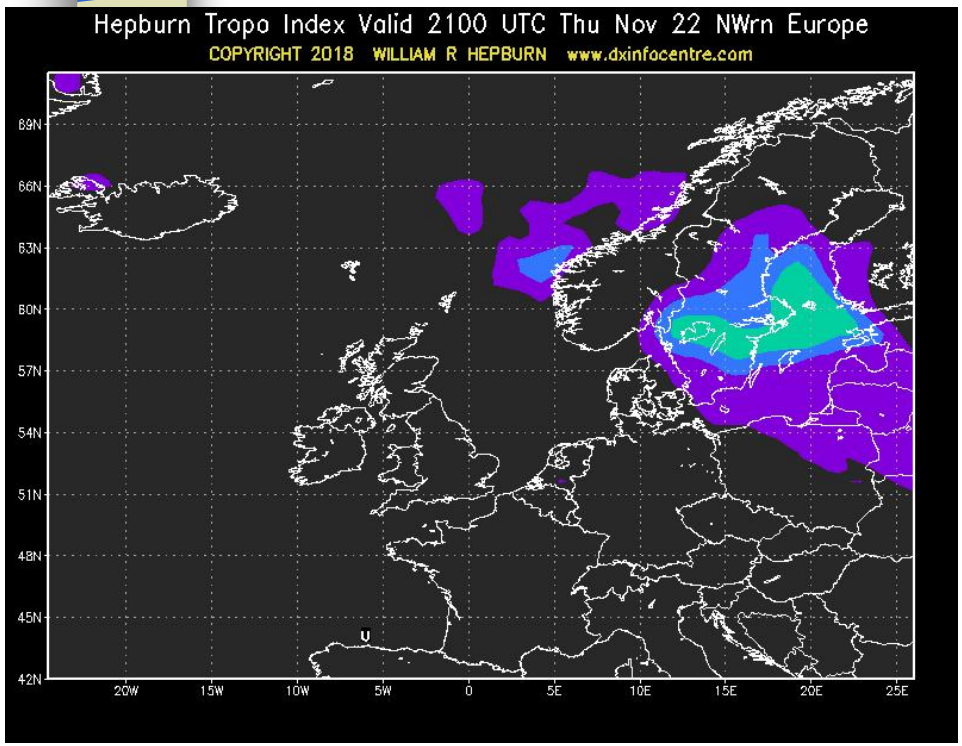
Stations worked by RZ6DD



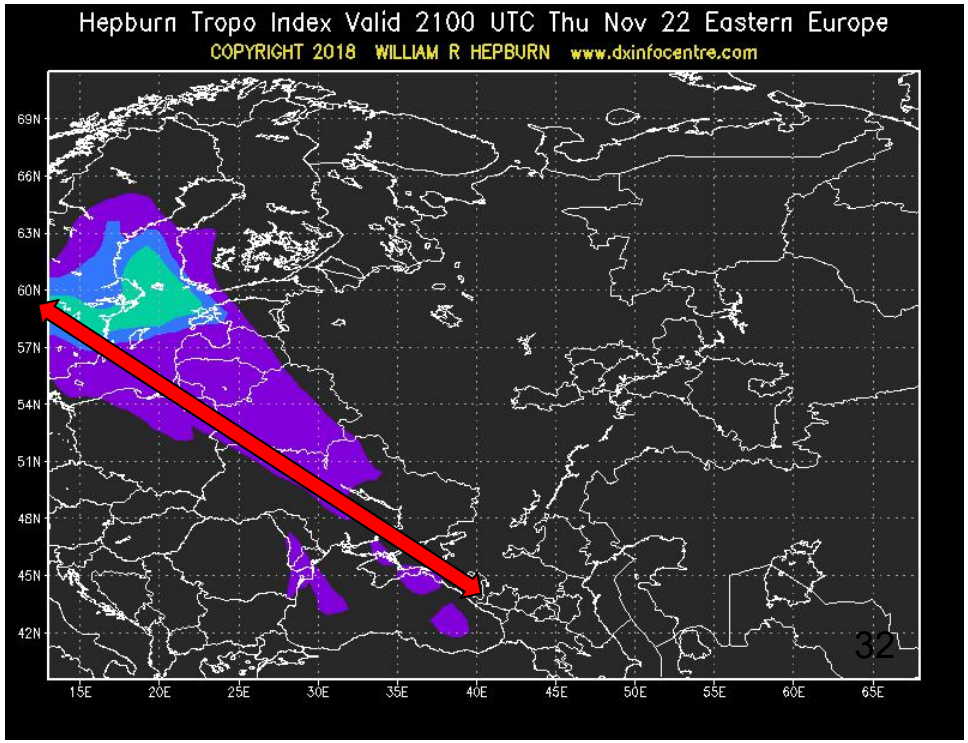
LA-UA6 Propagation predictions

- Hepburn predicted enhanced propagation from Oslo to ES, YL, YL, SP, perhaps extending to EW and UT
- The duct to UA6 was not obvious and far beyond expectations

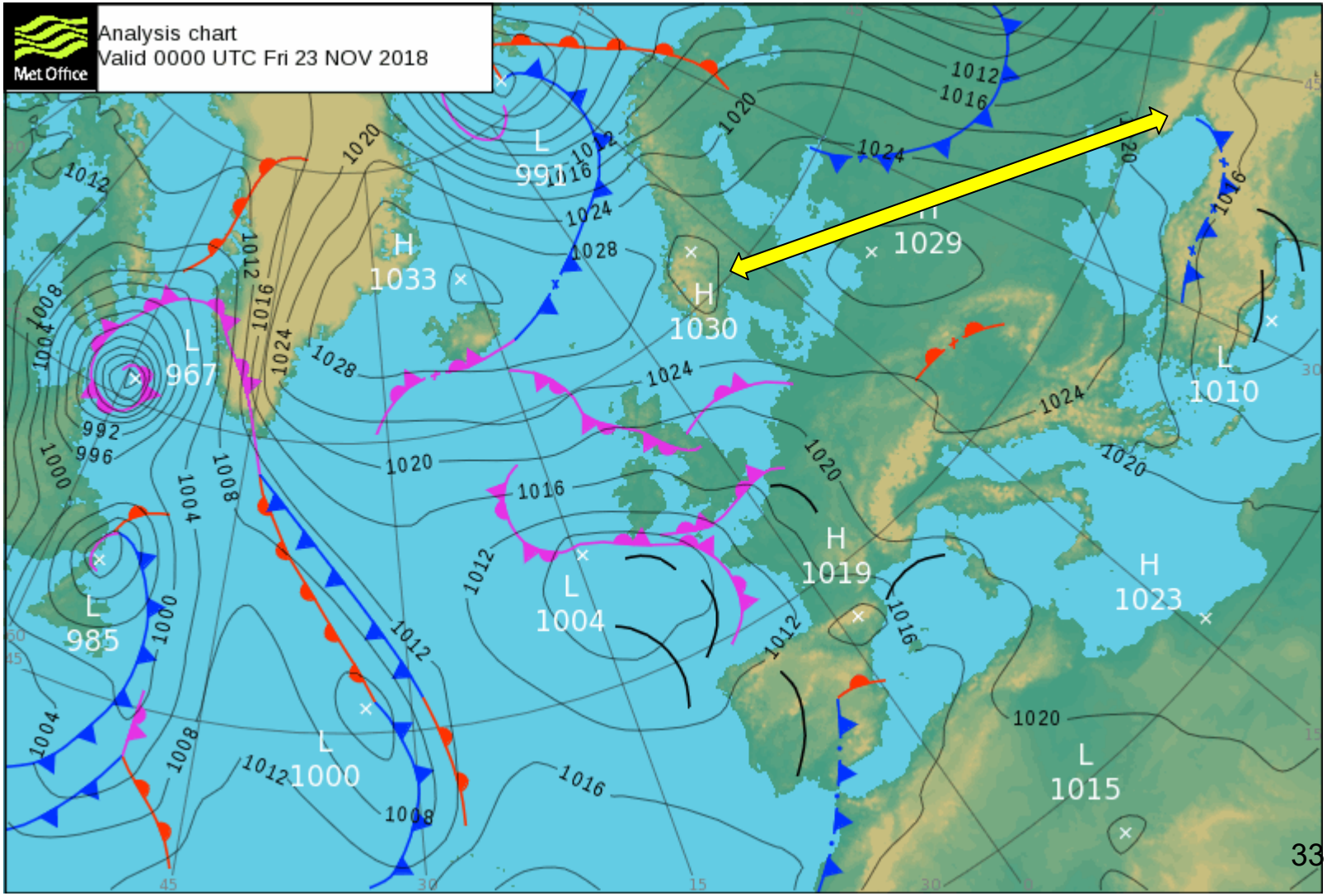
North-Western Europe



Eastern Europe



LA-UA6 Surface pressure map



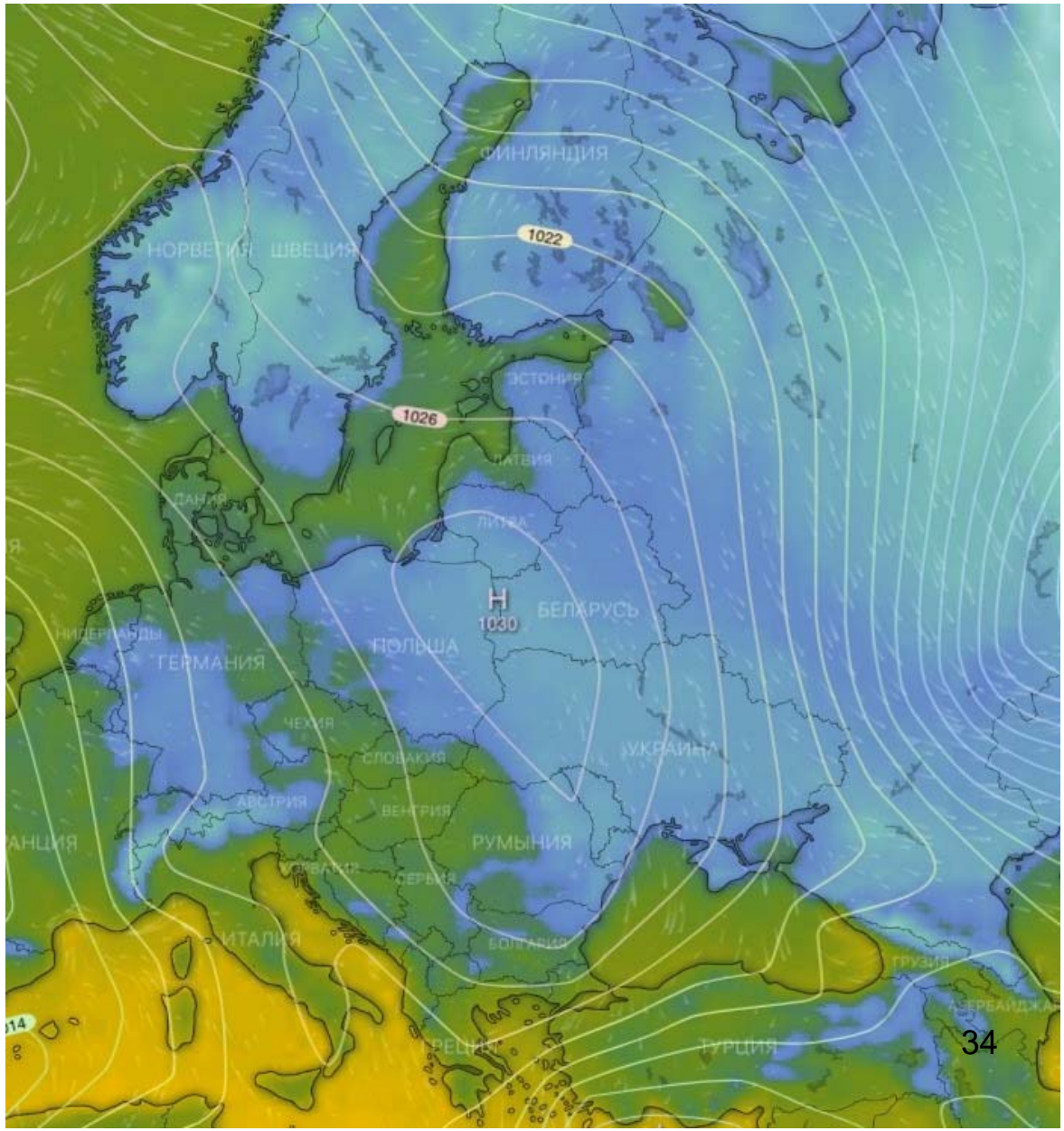
LA-UA6 Temperature vs altitude

Ground level

Windy.com

- Website with weather maps, current and predicted
- Maps display isobars and temperature
- Altitude can be selected (new!)

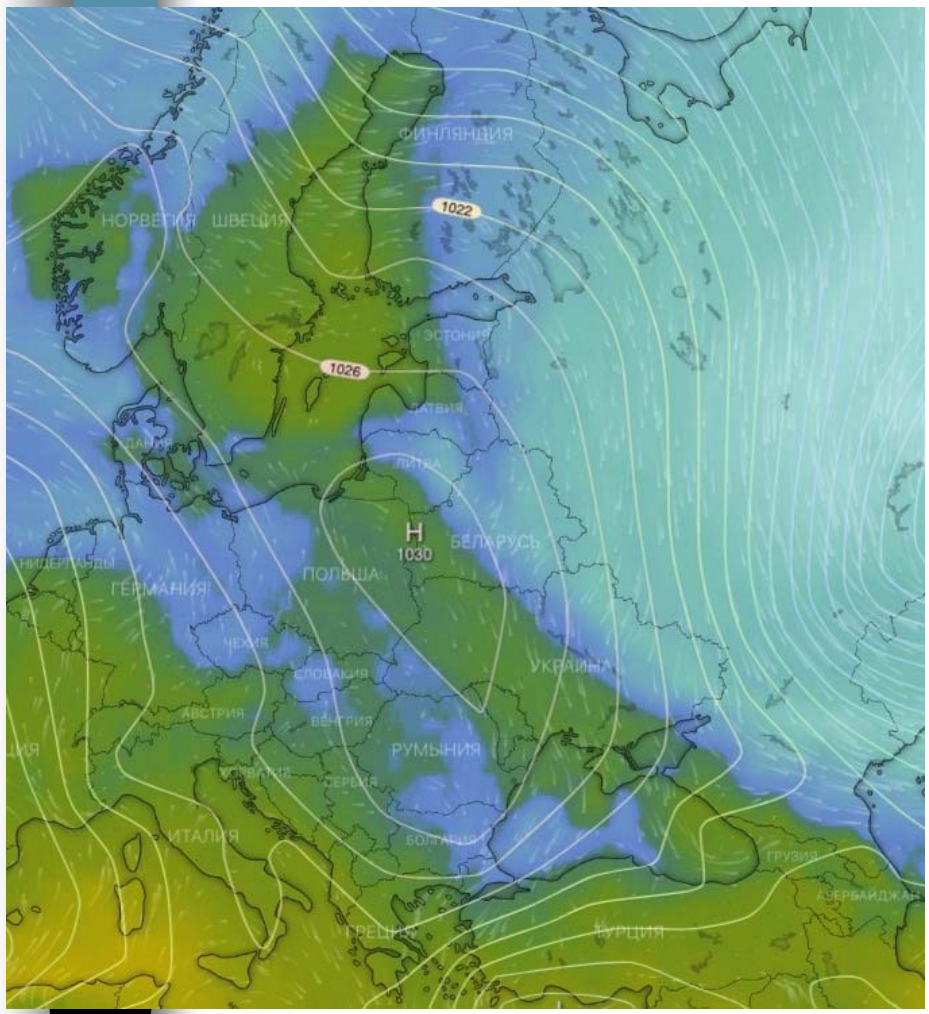
(tnx RZ6DD)



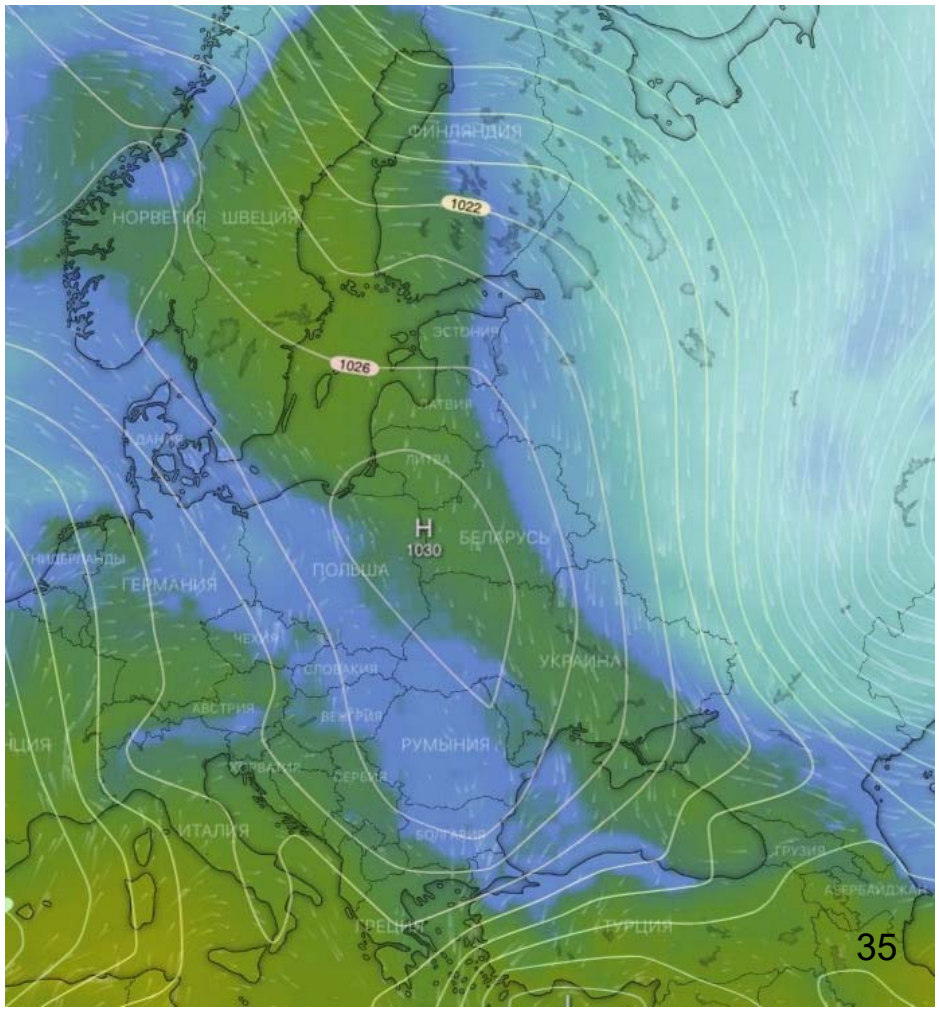
LA-UA6 Temperature vs altitude

- The duct to UA6 shows in the altitude view (even to 4L/TA?)

900 m



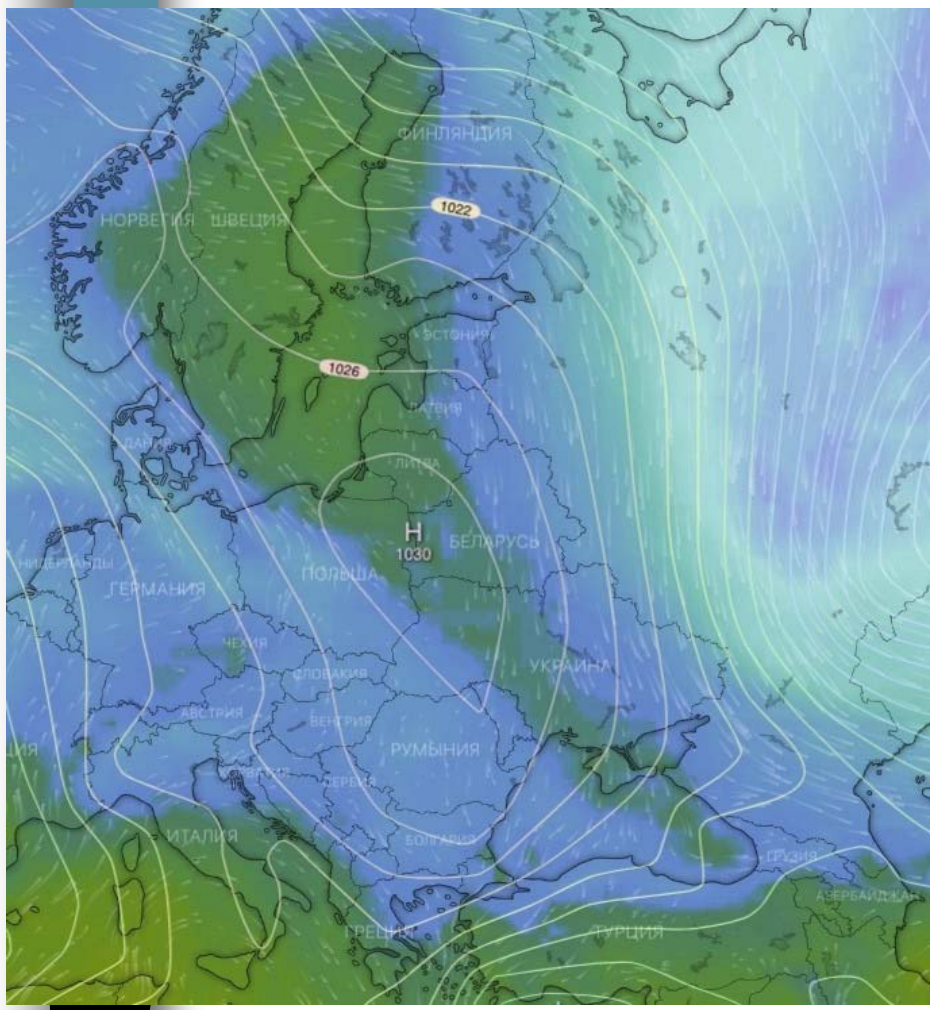
1500 m



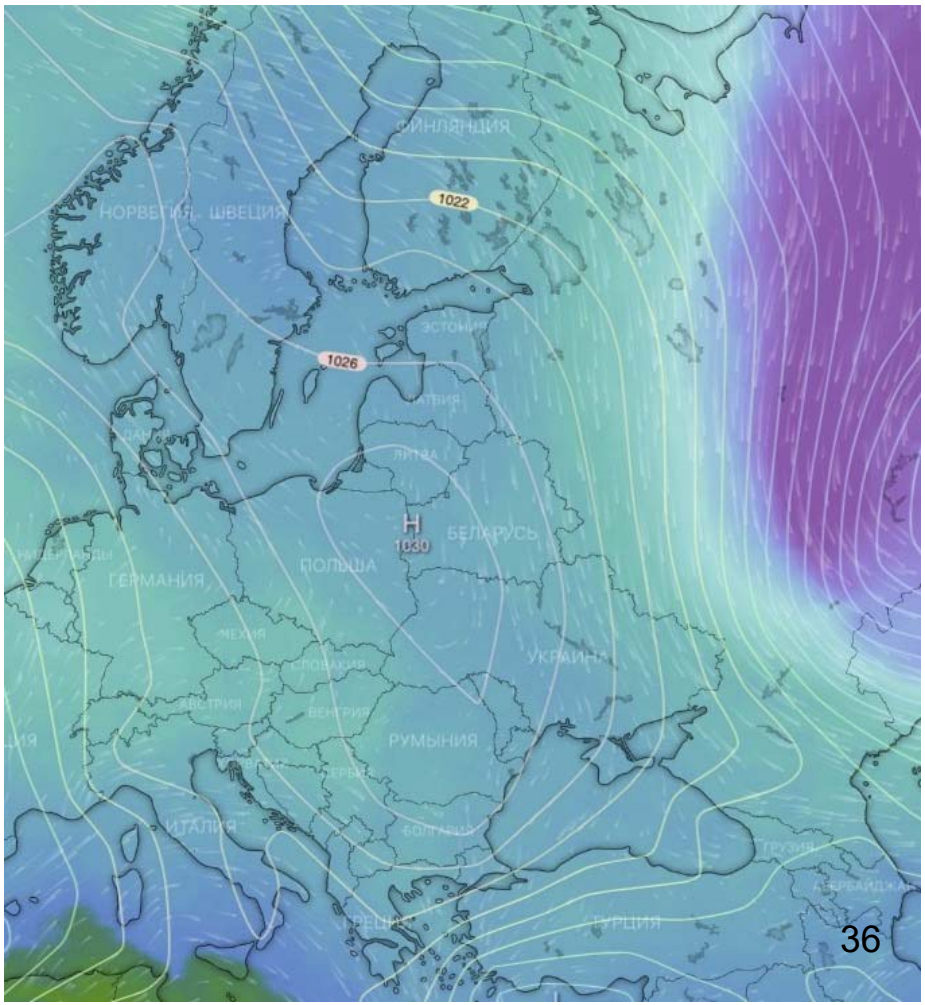
LA-UA6 Temperature vs altitude

- It seems the duct ended just above 2000 m

2000 m

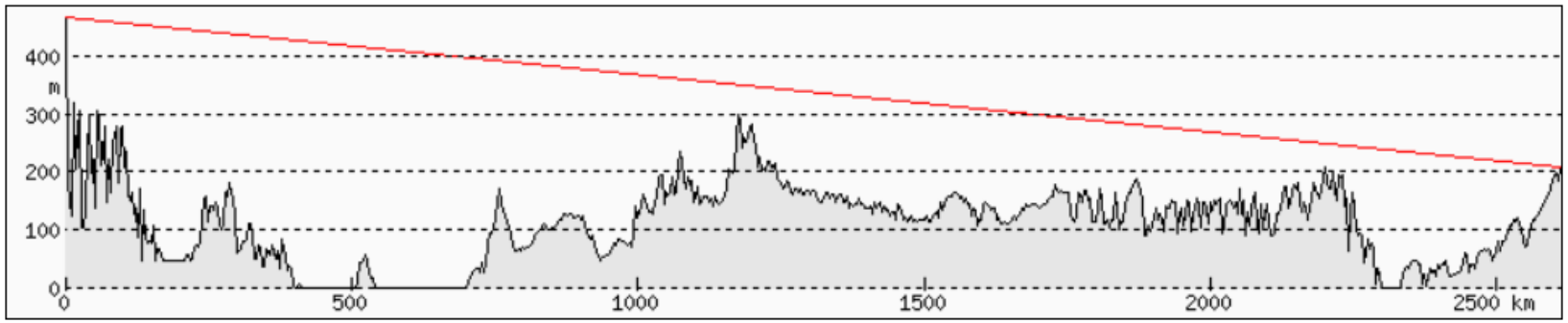


3000 m



LA-UA6 Path profile analysis

- JO59IX: Tryvann/Oslo - altitude 500 m
- LN04MX: Armavir - altitude 200 m



- Path seems unobstructed, but graph is for flat Earth

=> LA to UA6 is the perfect path for working tropo

LA-UA6 Take-aways from event

- The tropo event on 22.11.2018 was predictable with maps showing temperature over altitude
- There was a wide channel (duct) with significantly inverted temperatures between LA and UA6.
- The duct was more elevated at the LA side. This explains why only LA0BY was able to get into it.

- Looking at Hepburn/F5LEN forecast is not enough
- We should be able to predict more extreme tropo conditions with the right tools – and work more DX!

LA-UA6 More observations

- Path from LA to UA6 was quite stable for at least 6-8 hours
- Local weather not typical for standard enhanced mode (rather cold, foggy on hilltop), but perhaps indicating elevated duct.
- Moderate equipment was sufficient on both sides
  - LA0BY on 70 cm: IC-821H, PA 120 W, 17-ele yagi
  - RZ6DD on 70 cm: IC-910, 75W, 2 x 23-ele yagi
  - UA6AQN on 70 cm: IC-9100, 75 W, 2 x 32-ele yagi
  - Most UT/UR stations worked were having only 20-50 W output power into a single yagi (UT3UCP: 20W into 5-ele duoband yagi)
- Activity and total number of contacts seemed a bit low for these extraordinary condx covering a wide area
  - Other LA were alerted, but could not hear much => elevated duct?
  - Distraction from FT8 (people «stuck» on 144,174 MHz) ?

Operational considerations

- Working on multiple bands by a single operator can be quite challenging in extreme tropo condx:
  - Complex set-up, perhaps time consuming to get going
  - Hard to decide which band to favour, etc.
  - Stress and distraction from chat (in multiple rooms)
- Activity should be on radio, but raising attention through ON4KST chat and DXC spotting is useful
- SSB and CW go well together; digimode (e.g. FT8) seems to isolate different user groups
- Run beacon loop on one band while operating on another (interference permitting)?

Have I reached my limit?

- Configuration: Never ending improvements
  - Equipment RF performance: more power, better antennas
  - Technological developments: digimodes (FT8, etc)
  - Agility: shorter time to operation, band switching

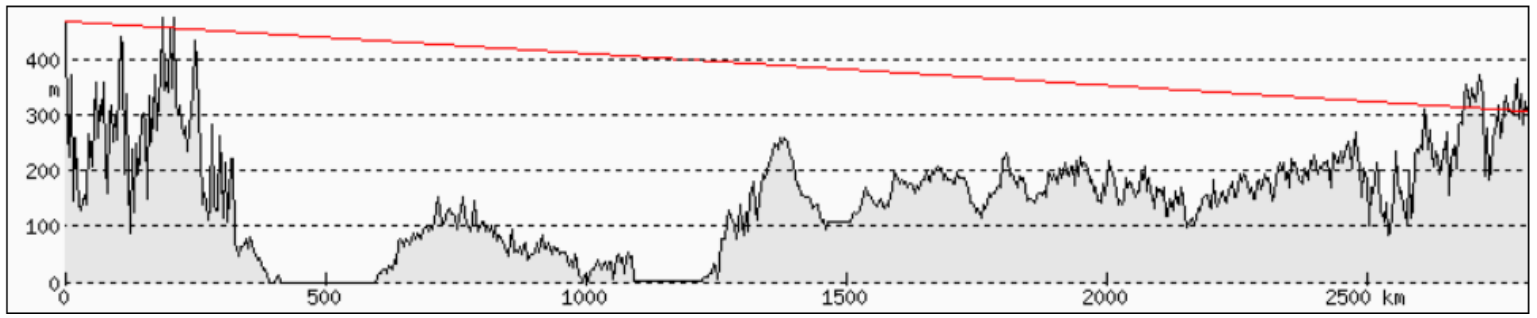
- Opportunities: Preparing for the next frontier
  - Location: Assess path limitations
  - Targets: Identify potential Tropo partners further away
  - Awareness: propagation monitoring, alert routines

=> Limit is probably not yet reached!

Dreaming: East beyond UA4

Asiatic Russia, UA9

> 2500 km, UA9FAD, RA9FMT, UA9CCL + many others

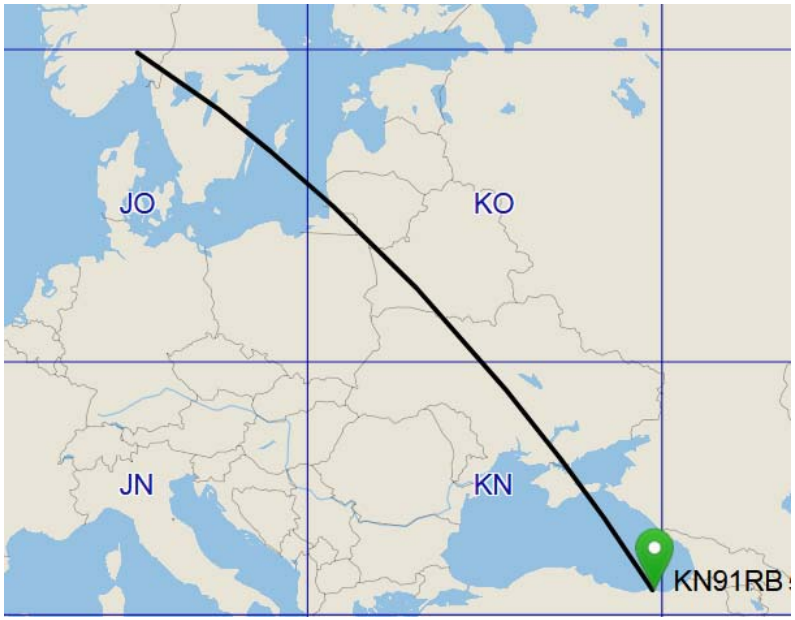


Path to LO96KE: clear (2800 km) but over land

Dreaming: SE beyond UA6

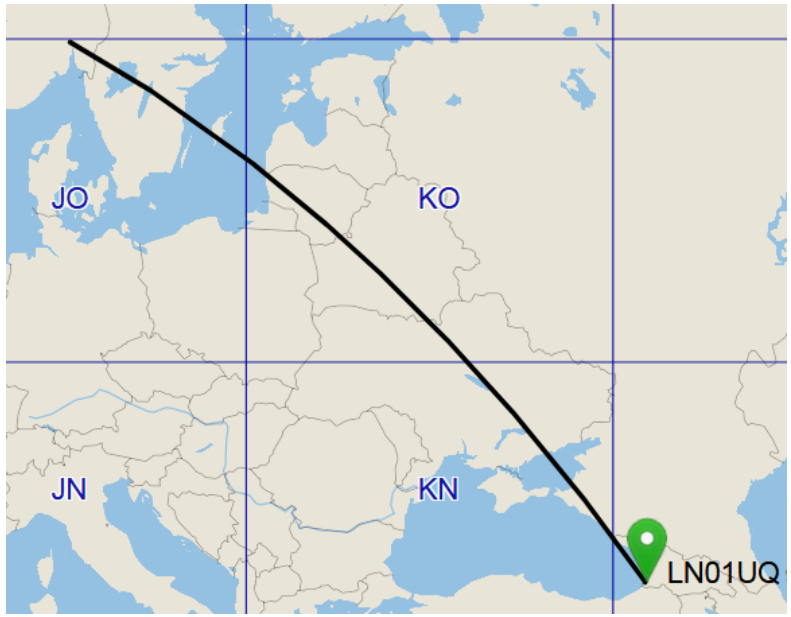
Turkey, TA

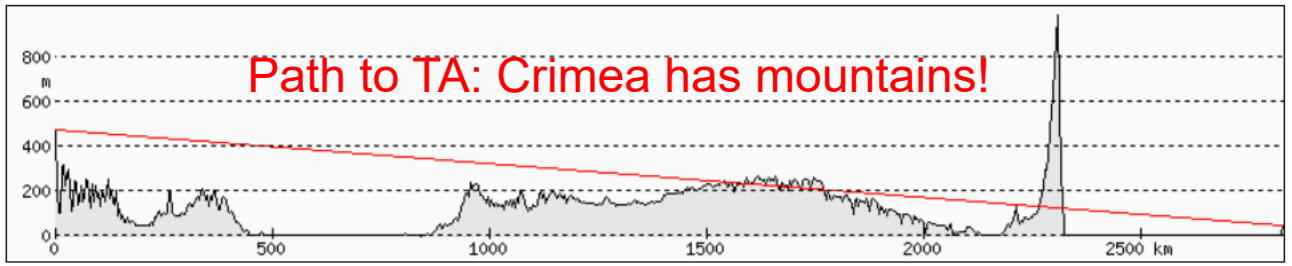
2500-2950 km, TA7OM, TA6P



Georgia, 4L

2700-2950 km, 4L1R, 4L5P

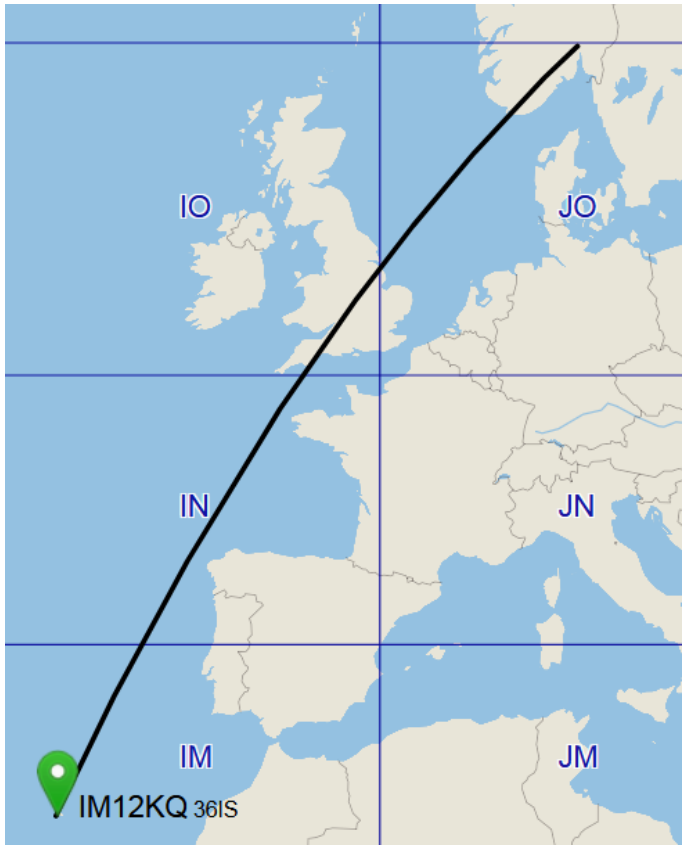




Dreaming: SW beyond EA1

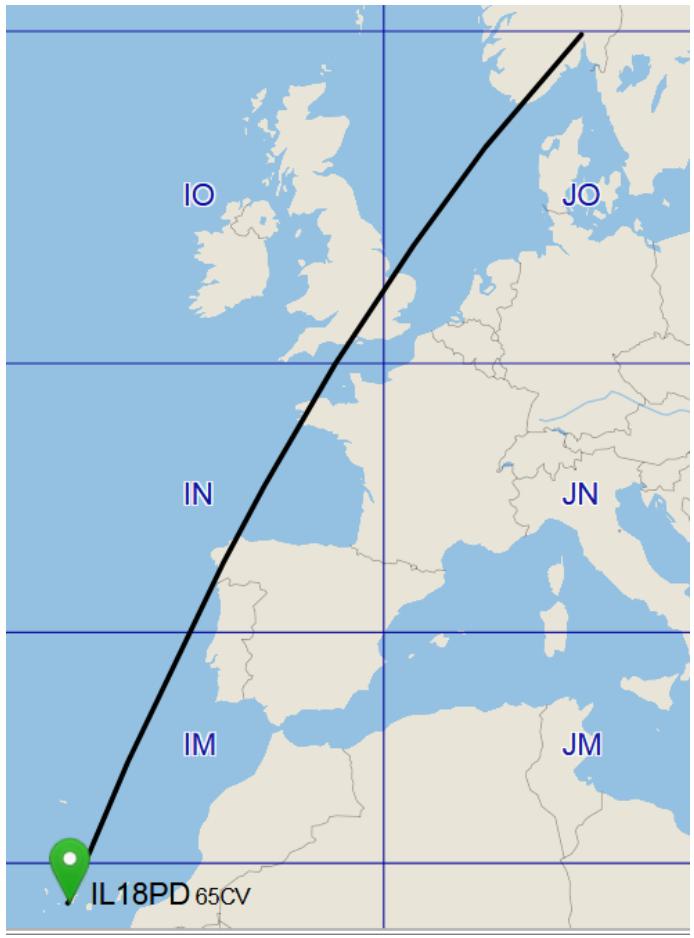
Madeira, CT3:

3600 km, CT3KN, CT3HF

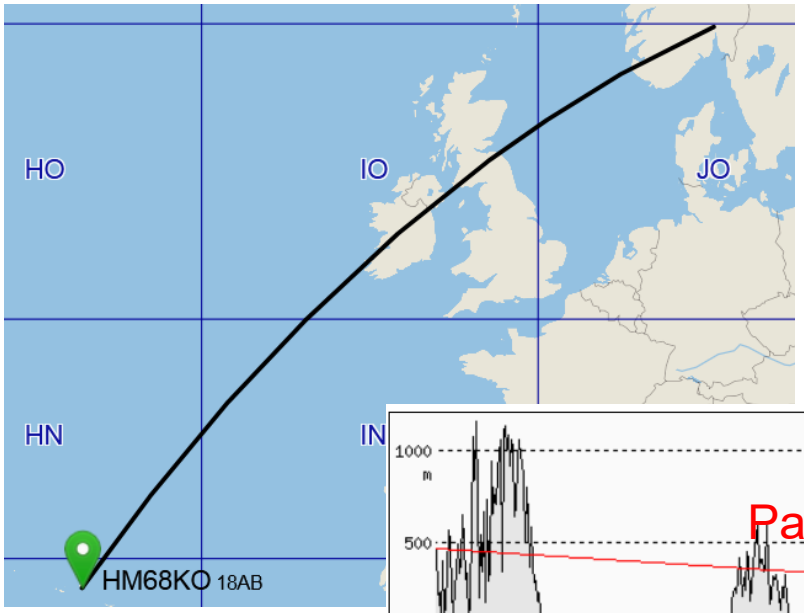


Canary Islands, EA8:

> 4000 km, EA8BDM, EA8TJ, …

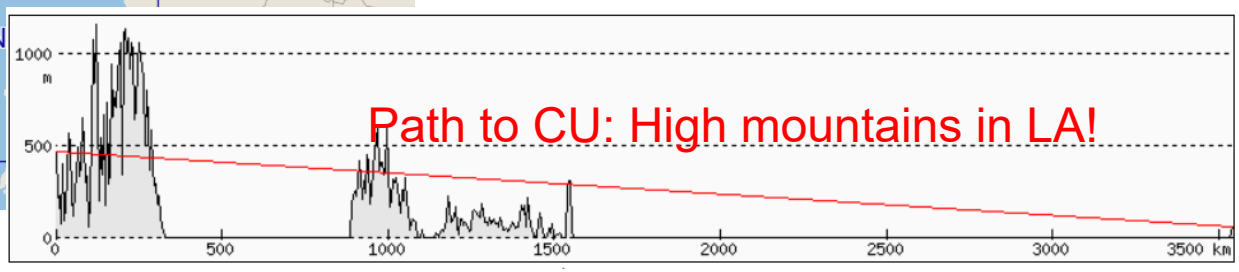


Dreaming: SW beyond EA1



Azores, CU:

3550 km, CU3EQ



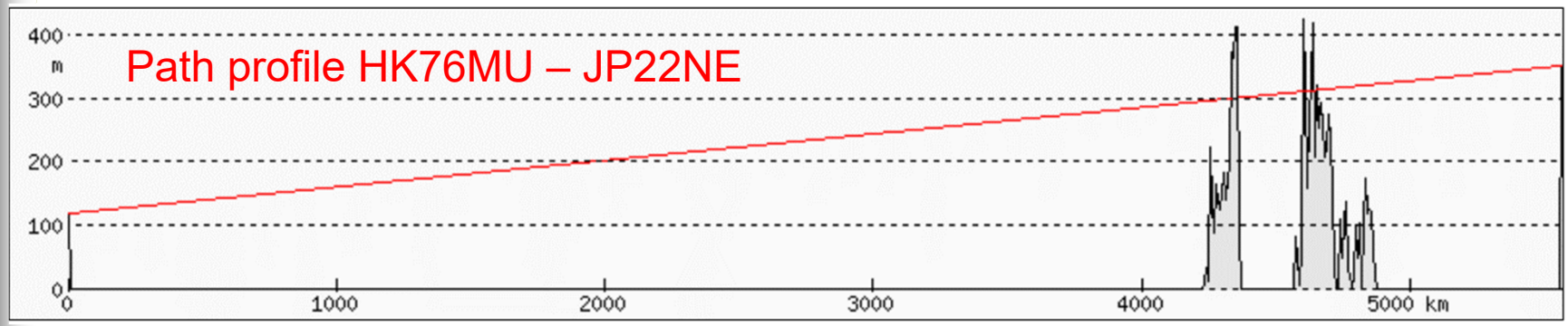
The best bet for very long tropo DX from JO59:

- Paths to UA9, TA and EA8 seem most promising
- None of them is an easy task, not even on 2 m Es

Dreaming: Working D4 from LA

- Locations with very good take-off to SW can be found in North-West Norway (e.g. JP22NE).
- Could this be an area for working D4 on 2 m and settinging a new record?
- Absolutely unbelievable and insane distance, and very unlikely to work in time-limited operation !

Dreaming: Working D4 from LA



- The path profile reveals there are only few hills of low altitude along the G/GM border in the path.
- It seems like one of the very few options to beat the current World Record, so we should be on alert.
- Consider establishing a beacon or remotely operated station in JP22?

Summary and conclusions

- Working extreme DX on VHF/UHF by tropospheric propagation can be accomplished by everybody
- Equipment requirements are low to moderate
- Operating from a location with good horizon helps
- Mountains on a path are not always a show-stopper
- Tropo ducting can be predicted days in advance

The golden rule(s)
Rule 1: Be at the right location at the right time!
Rule 2: Have your equipment ready!

Checklist vs phases

- Preparation (weeks to days ahead)
  - Equipment, ready in box for portable operations
  - Identify good paths and potential QSO partners
- Observation (days to hours ahead)
  - Hepburn and F5LEN propagation forecasts
  - Analyze promising paths in altitude (with Windy)
  - DX-Maps and/or DX-Cluster (proof of something starting)
- Own activity (when it happens)
  - Monitor beacons and activity (DXC, calling frequencies …)
  - Call in promising directions, perhaps aided by skeds
  - Spot unusual contacts and own observations on DXC
  - Determine and focus on most attractive band