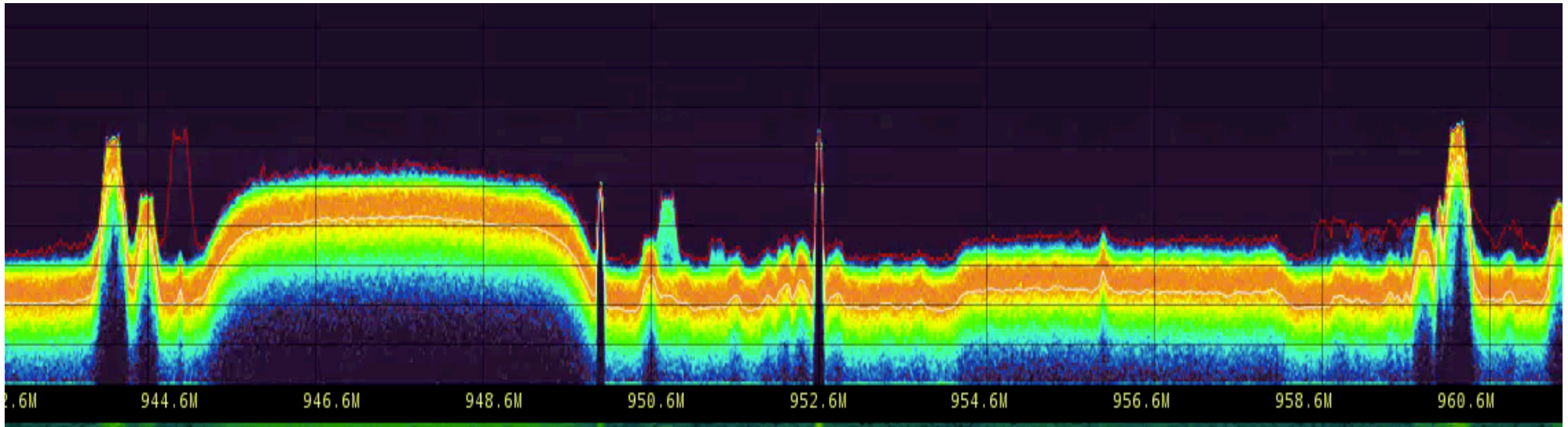


A 4G/5G cell detection & monitoring setup for MRO

To answer “but where is it all coming from!?”

Dr Balthasar Indermühle

6 March 2020

Spectrum Management School, Stellenbosch, SA

CSIRO Astronomy and Space Science

Introduction

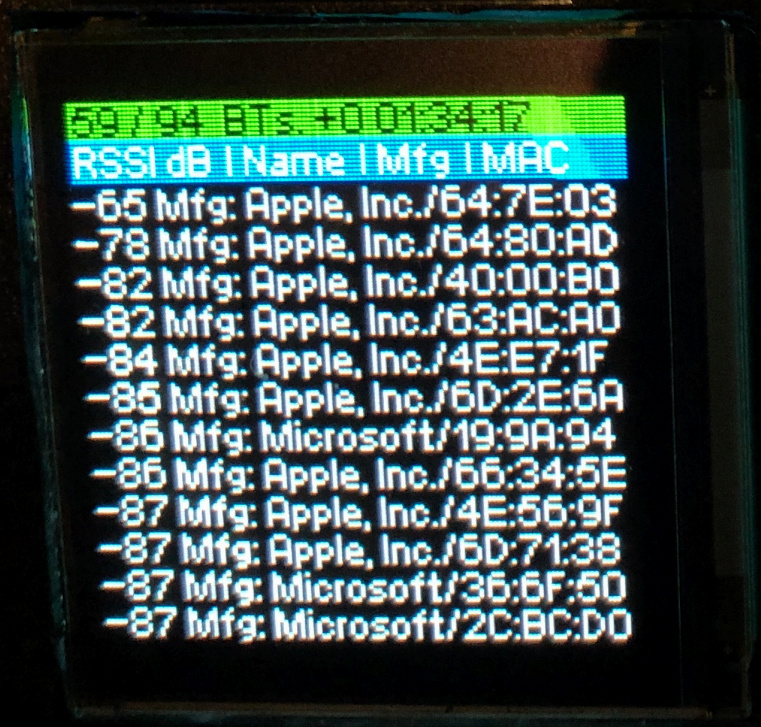
- Time scales
  - For astronomers, blindingly quick. i.e. << Gyr
  - Events take place in minutes/hours
  - Or seconds c.f. Greg's talk on NGSO RFI
- Some RFI of natural origin e.g. sun
- But most RFI of artificial origin: anthropogenic, so far
- RFI mitigation techniques are under development, but not mature yet, c.f. work by Greg Hellbourg et al
- But: Avoidance is the best form of mitigation
- "A visceral experience": Animations / videos!

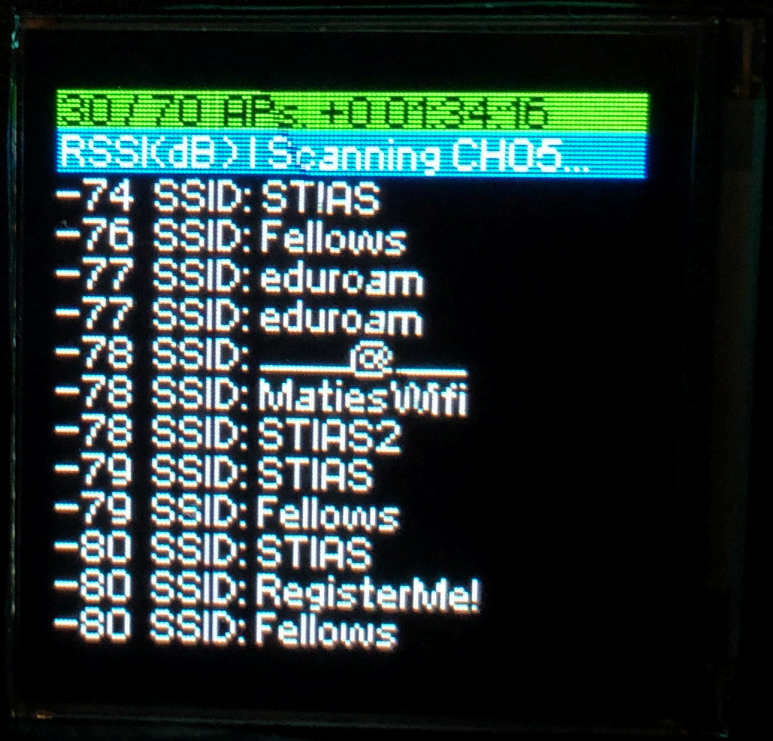
Why decode things?

- Because we can gain knowledge:
  - What is it?
  - Where is it?
- ADS-B:
  - Aircraft position and state vectors
  - Identification
- AIS
  - Ship position and state vectors
  - Identification
- GSM/3G/4G/5G
  - End user equipment (whodunit!)
  - Base station identification
    - Database lookup -> location

Why decode things?

- WiFi
  - Identify hardware based on SSID and/or mac address
- BLE/BT
  - Identify hardware based on name, mac address and/or BT manufacturer ID



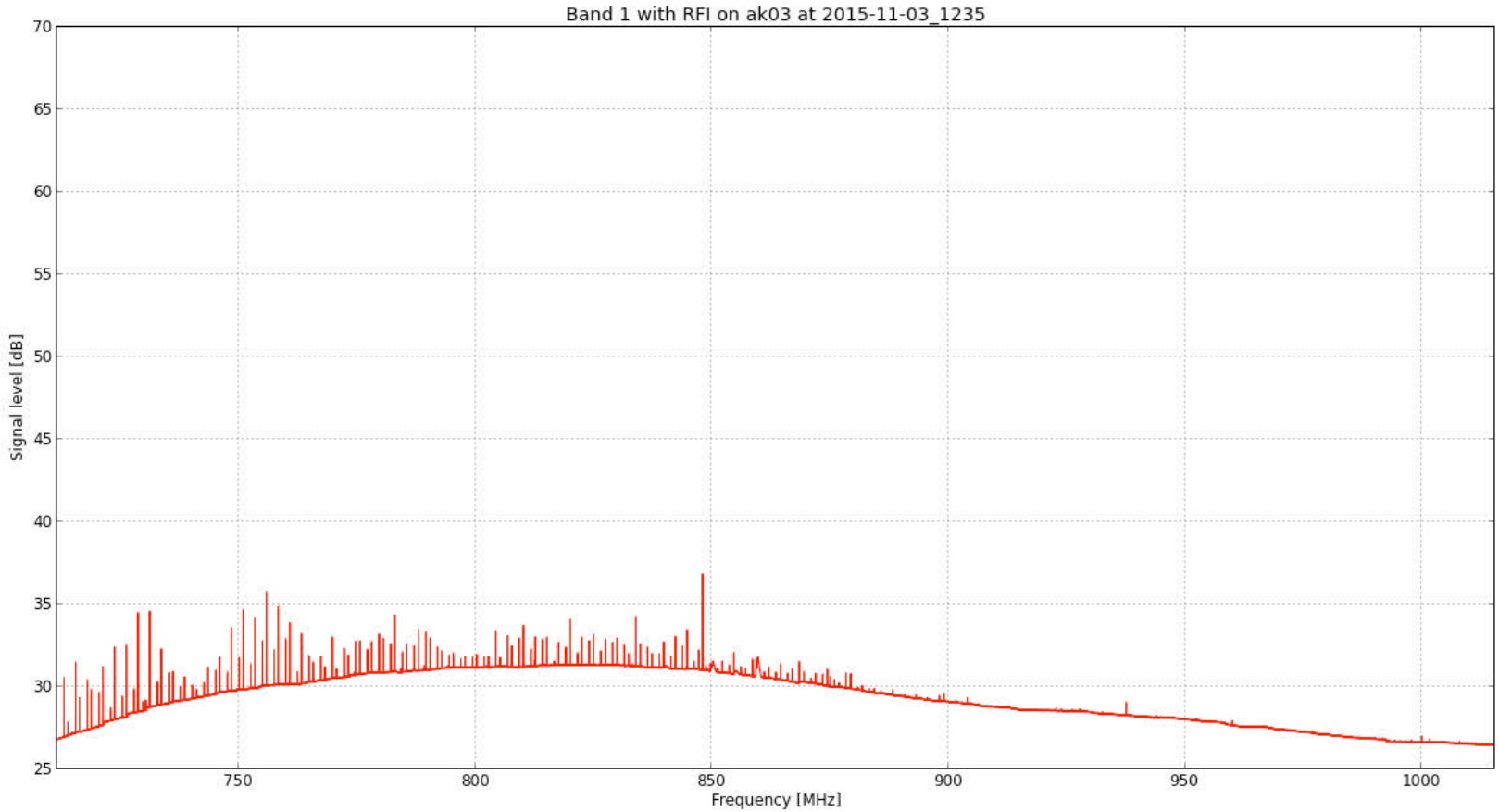


Why decode things?

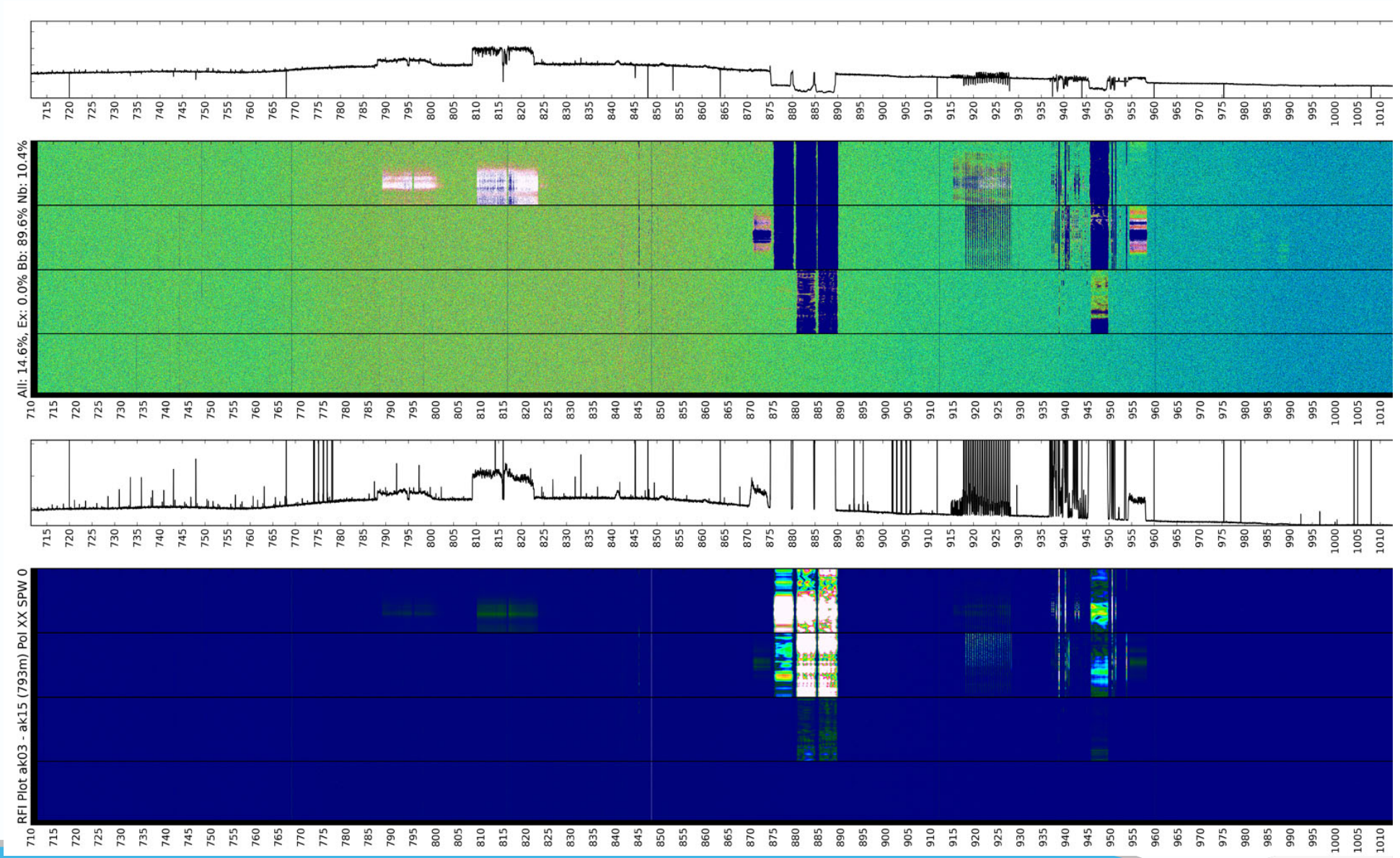
- SITUATION AWARENESS
  - If you want to know what has changed you have to know what was there first.
  - Long term monitoring
- RFI = Information
  - Use it to decipher information about your site

So we're in this low RFI environment…

- And then this happens:



The Complete Spectrum 700 – 1000 MHz

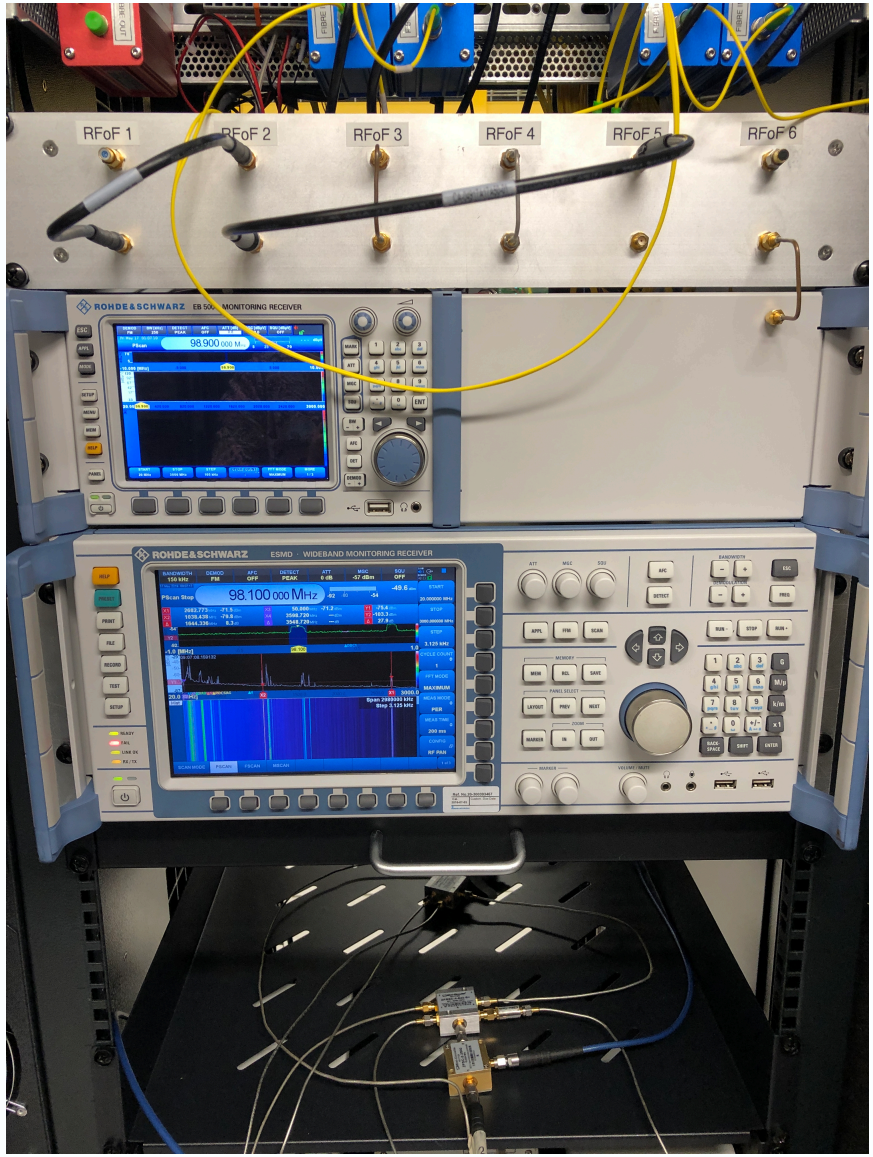


Characterisation Strategy

- 25m RFI tower near center of the ASKAP dishes
- R&S HE600 active antenna
- Coax to RFoF links
- 2km to control building

Characterisation Strategy

- RFI Rack:
  - RFoF converters
  - R&S EB500
    - 70-3000 MHz
  - R&S ESMD
    - 70-3000 MHz 2s
  - 5 x B200 SDRs
    - MIB/SIB
    - Iridium
    - SOPS
  - DVB-T dongles
    - ADS-B
    - AIS

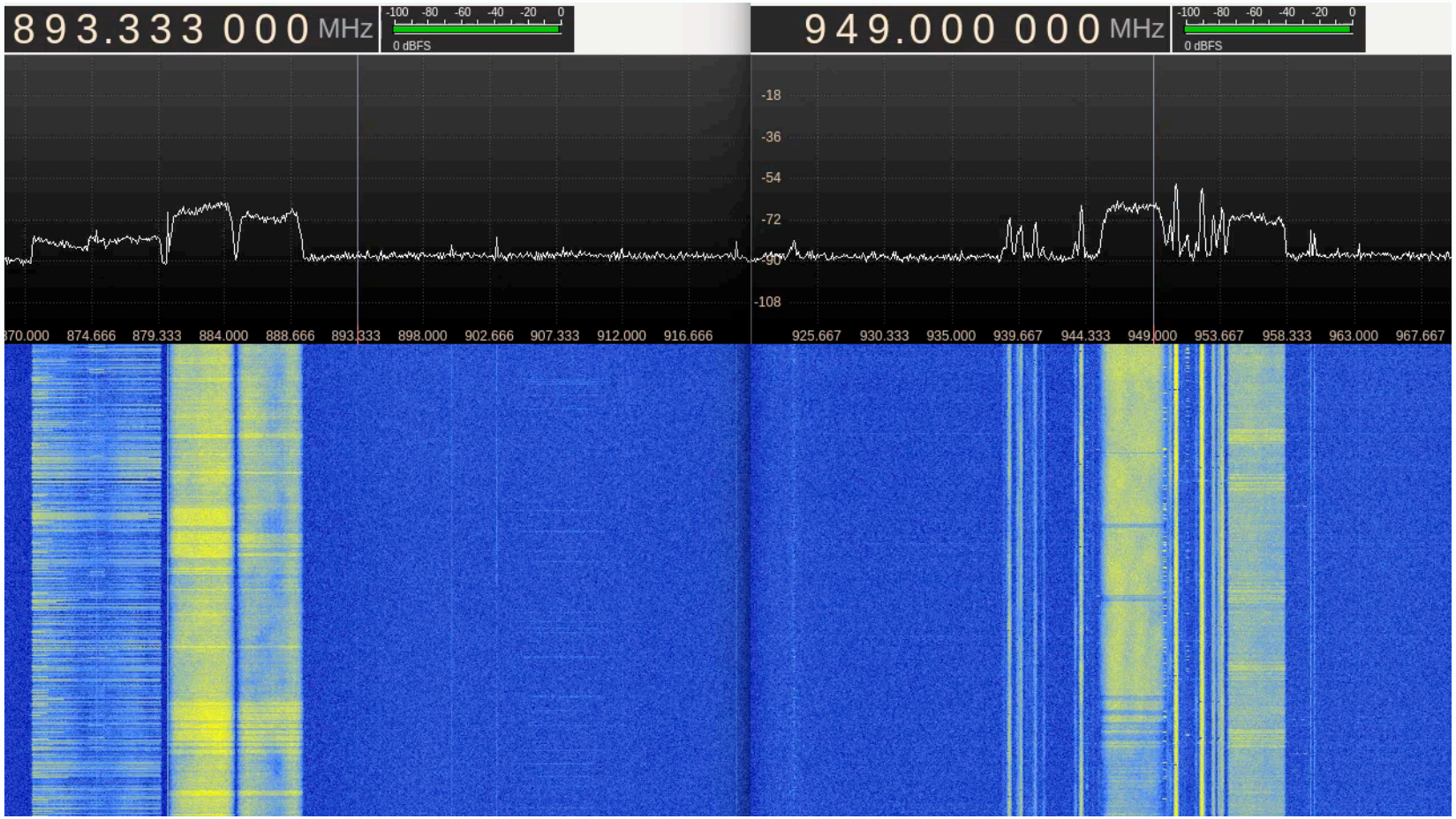


Telecommunications

- Base station receive (BR) frequencies
  - = handset transmit frequency
- Base station transmit (BT) frequencies
- Frequencies give hints on protocols:
  - 2G
    - 920 - 960 MHz
  - 3G/UMTS
    - 830 - 890 MHz (HSPA/WCDMA)
    - 920 - 960 MHz
  - 4G/LTE
    - 703 - 788 MHz
    - 1710 - 1850 MHz
    - 1920 - 2170 MHz

Telecommunications

- Handset transmit independent of base station transmit



Telecommunications

- GMSK and HSDPA Base Transmit signature (GSM and 3G)

Why explore these details?

- We’re in ultra low RFI environment that every little bit we see is interesting.
- Knowing where the signals are coming from, we can (in theory) selectively create nulls in the formed beams
- Find out when, why, and how it comes that we see signals in the RQZ
- If we can predict when RFI will be present, we can
  - Adaptively schedule observations
  - Avoid RFI altogether

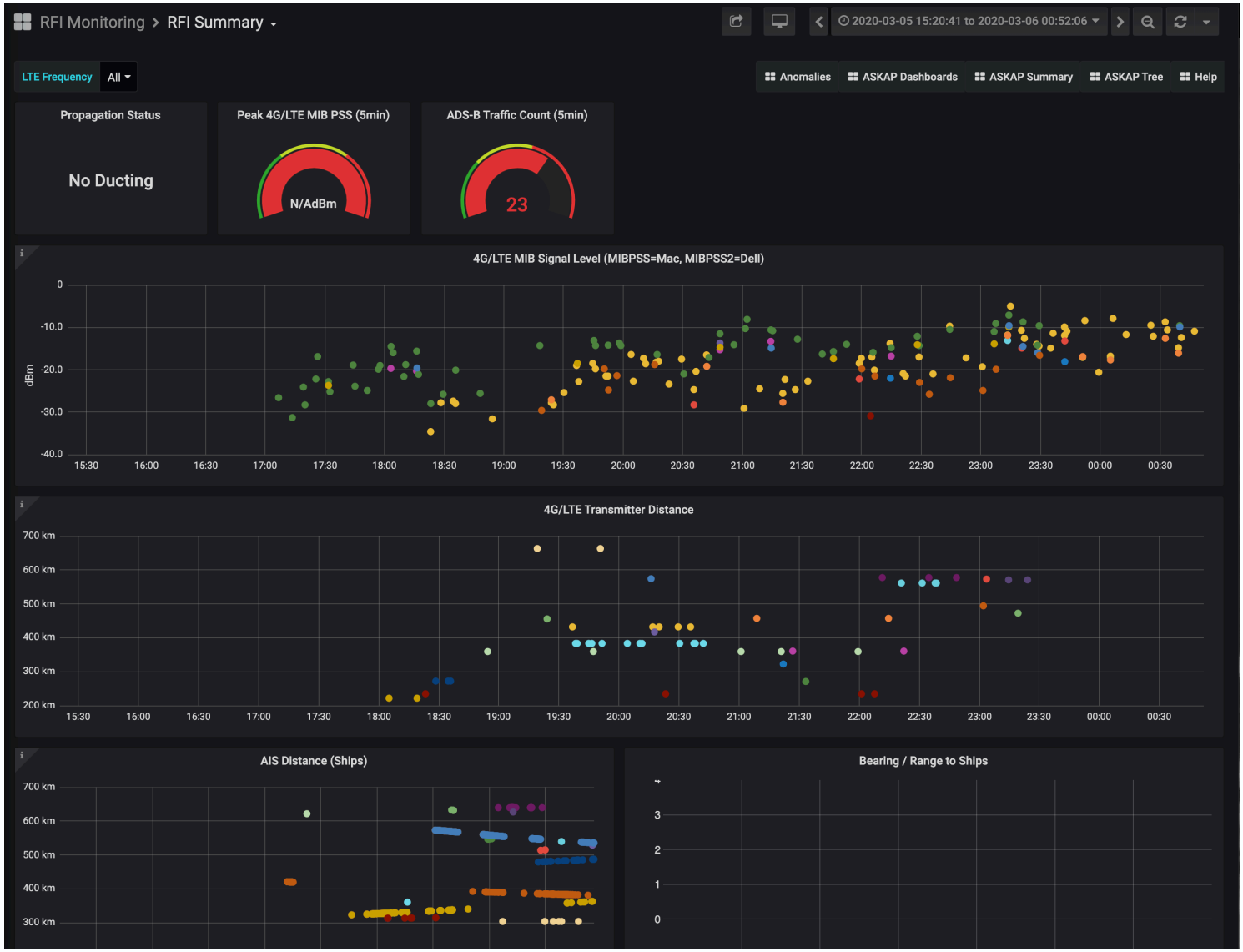
4G scanner details

- Bands 1,3,5,28
  - 2100/1800/850/700 MHz
- MIB scanner
  - Scans each EARFCN in each band
  - Decodes management information block (MIB)
  - If one is found, makes DB entry with details and moves on
- SIB scanner
  - Scans DB for new EARFCN entries
  - Listens for system information block 1 (SIB1) message
  - Decode SIB1, and look up cell ID
  - Store result in DB

4G scanner details

- Customised version of srsLTE
  - https://github.com/srsLTE/srsLTE
- srsUE
  - Simulates a handset – receive only
- Ingest data in Influx DB with Grafana frontend for easy live and history access

4G scanner details



Tropospheric Ducting

- Refractive index of air n = 1.0003 ± 0.0001 depending on conditions: Pressure, Temp, WVPP
- Because so close to 1, refractivity N defined as:

$$N = (n-1) \times 1.0^6$$

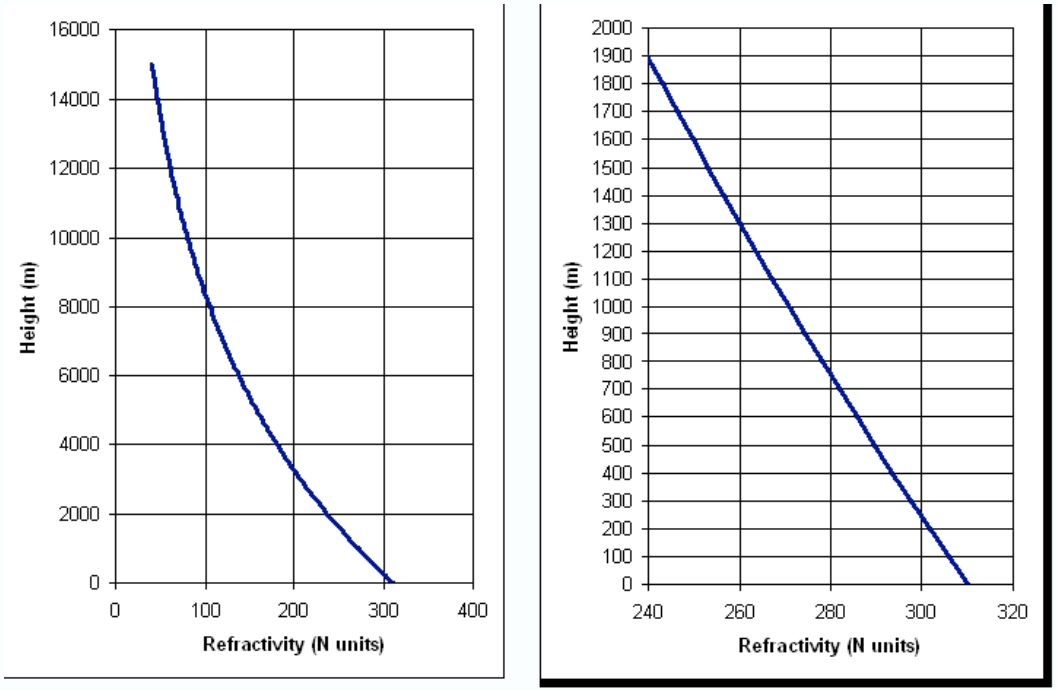
so N becomes:

$$N = \frac{P}{T} + 3.73 \times 10^5 \frac{e}{T^2}$$

Dry term | Wet term

Tropospheric Ducting

- Dry term scale height (1/e) pressure ~ 8km
- Lowest ~2km approximately linear
- Slope ~ -40N/km



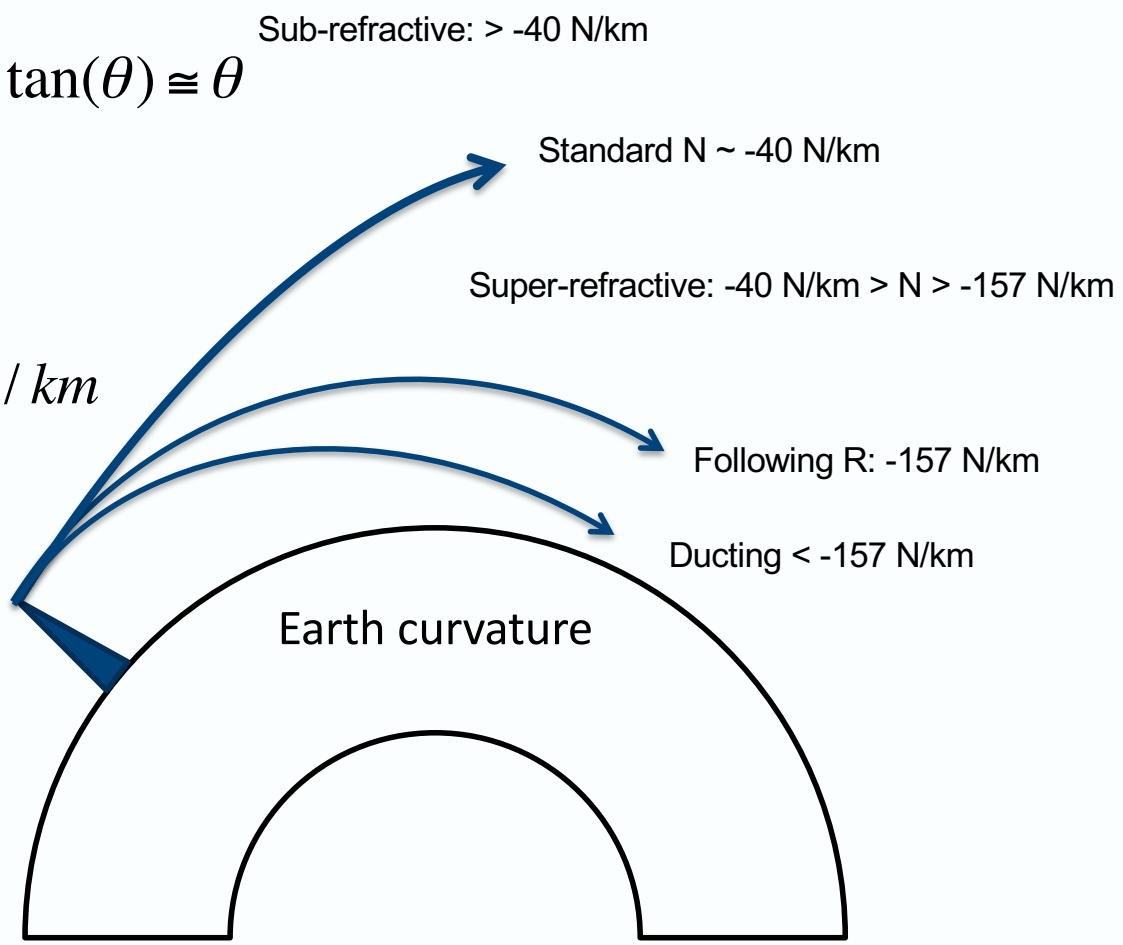
From: Principles of Radio Wave Propagation, Dr Mike Willis

Tropospheric Ducting

- R = 6371 km
- SAF $\sin(\theta) \cong \tan(\theta) \cong \theta$

$$\frac{d\theta}{dh} = \frac{n_2}{n_1}$$

$$= -1.57 \times 10^{-4} \, rad / km$$

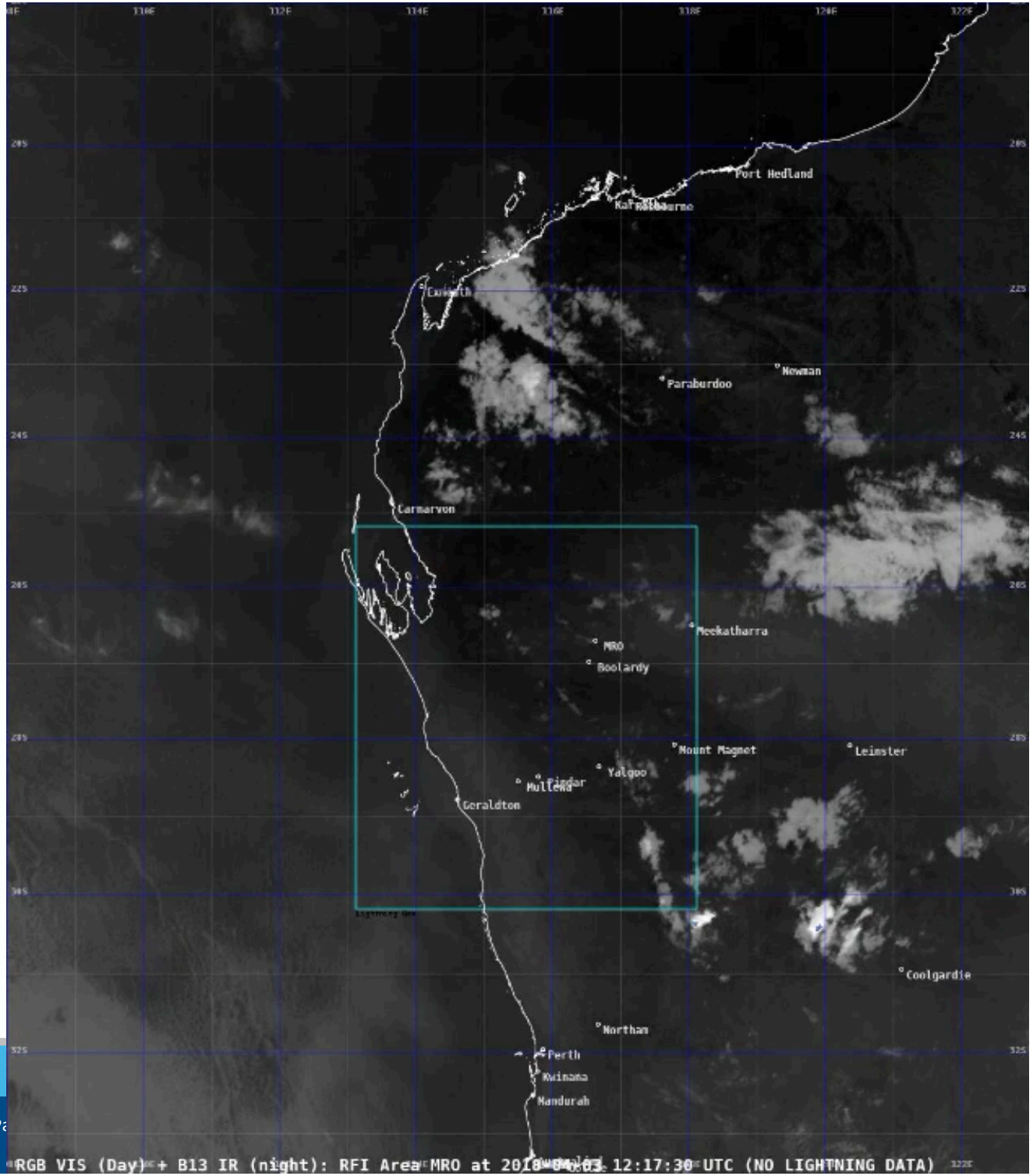


Tropospheric Ducting

- Evaporation Ducts
  - Water vapour pressure high due to evaporation.
  - 5m – 15m above surface, large bodies of water. 30m in warm waters.
- Temperature inversions
  - Radiative cooling of ground at night
  - If air is dry, T becomes dominant: super refractivity/ducting occurs
- Subsidence
  - Sinking airmass in anticyclone heats up, leads to elevated inversion (1-2km up). Elevation highest at centre, lowest at edge of anticyclone.
  - Often exists over large contintens.
- Advection
  - Movement of cooler ocean air over warm land. Coastal effect.

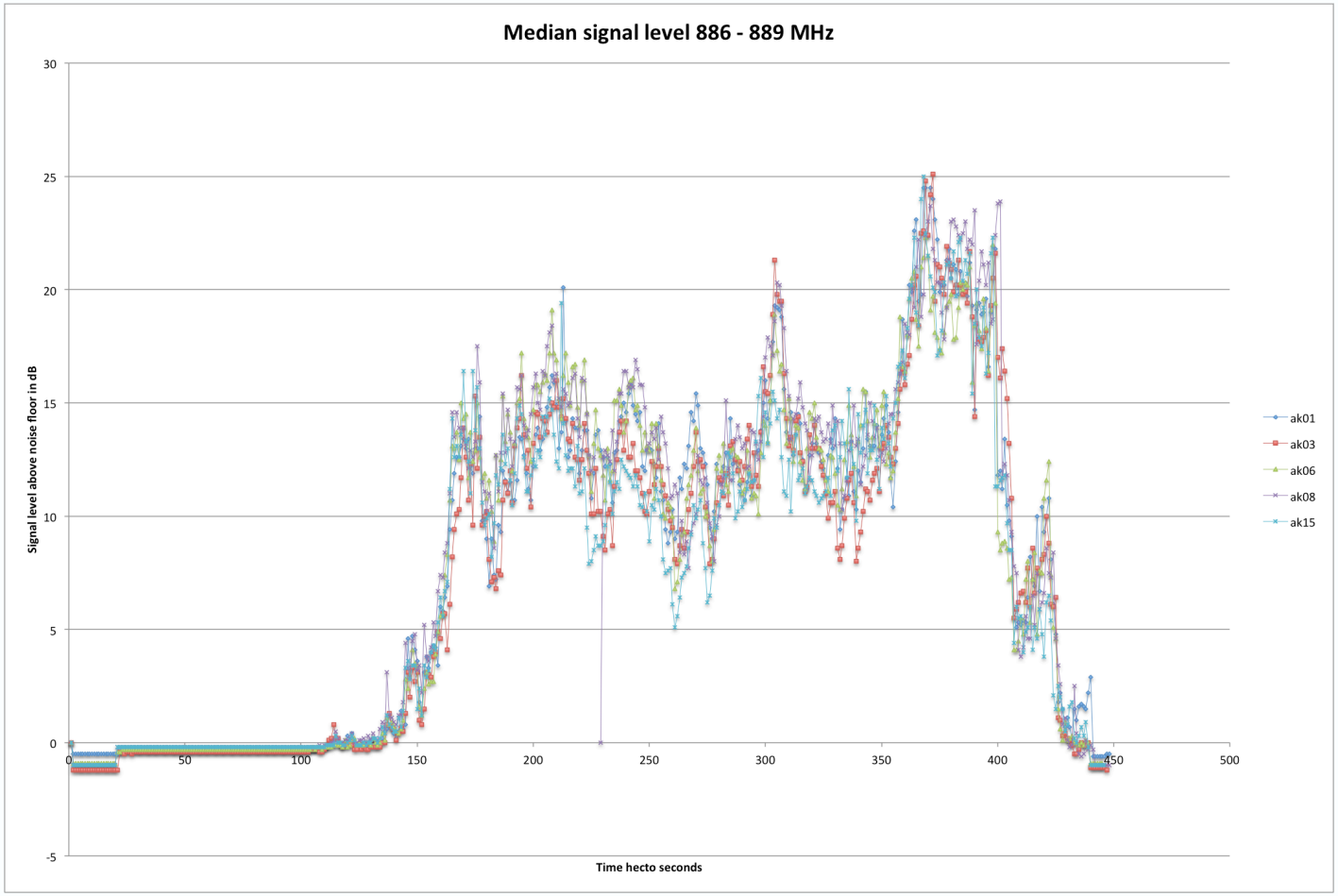
Tropospheric Ducting

- Decoding AIS and 4G



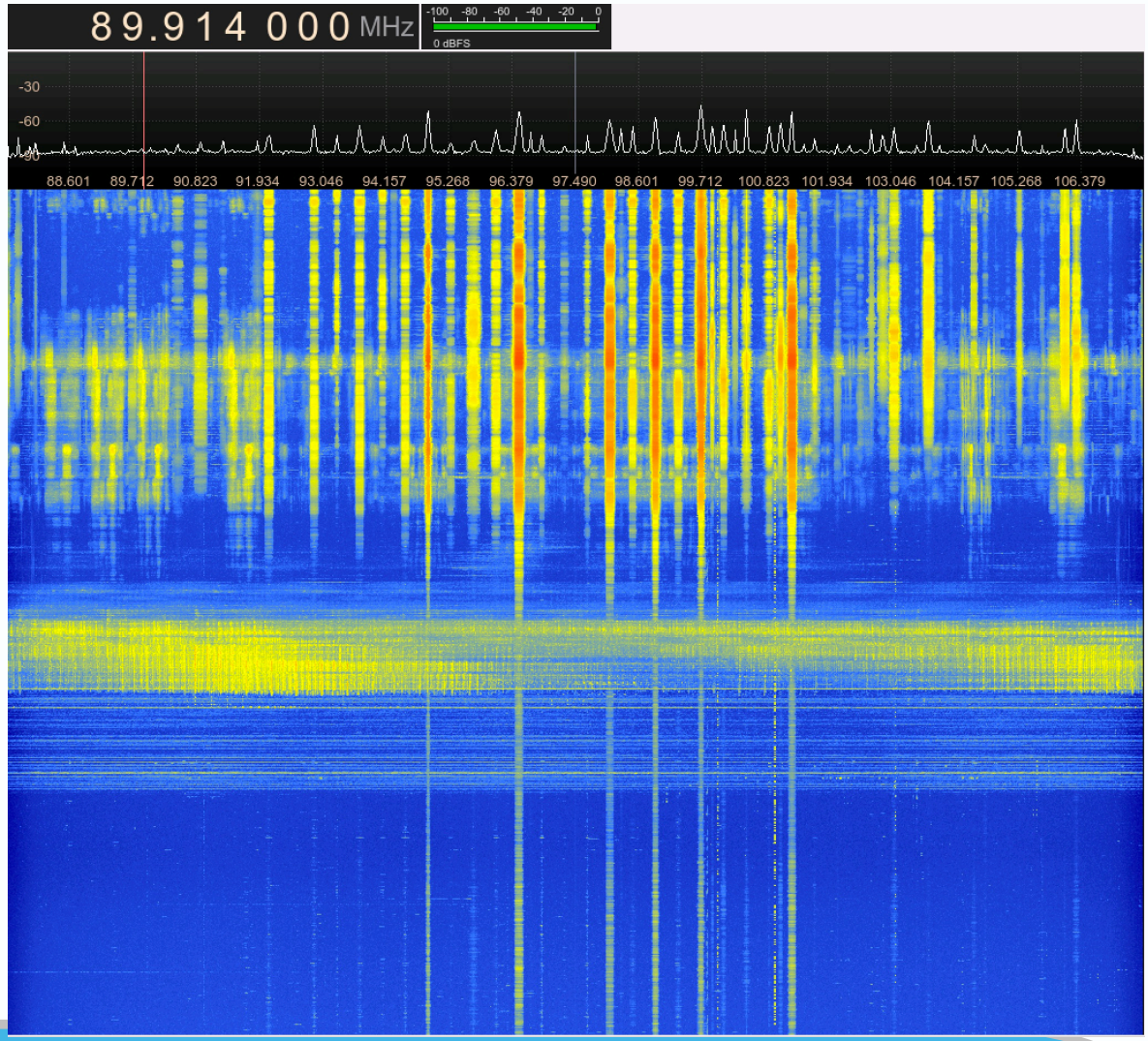
Tropospheric Ducting

- Onset of ducting



Tropospheric Ducting

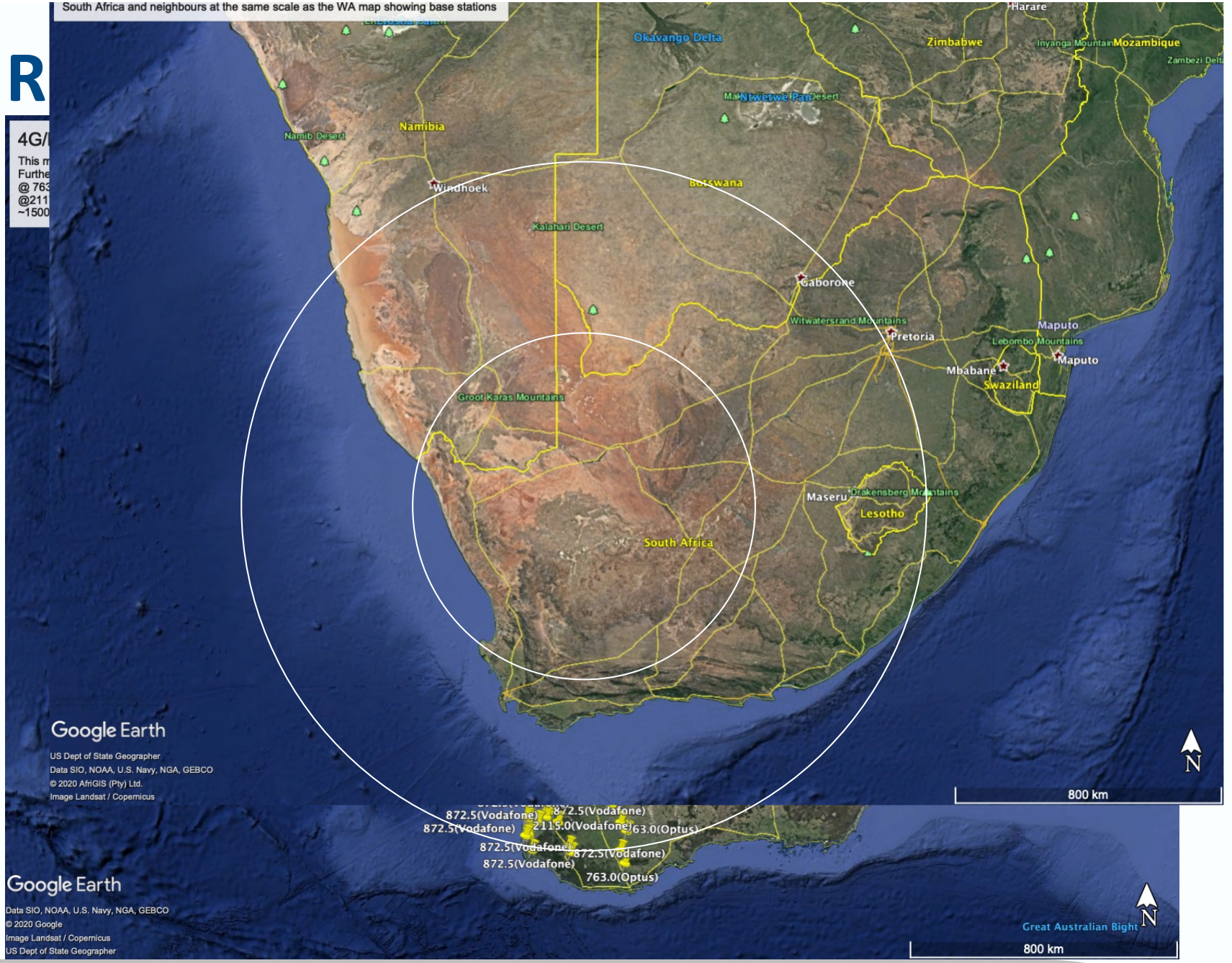
- FM Stations



R

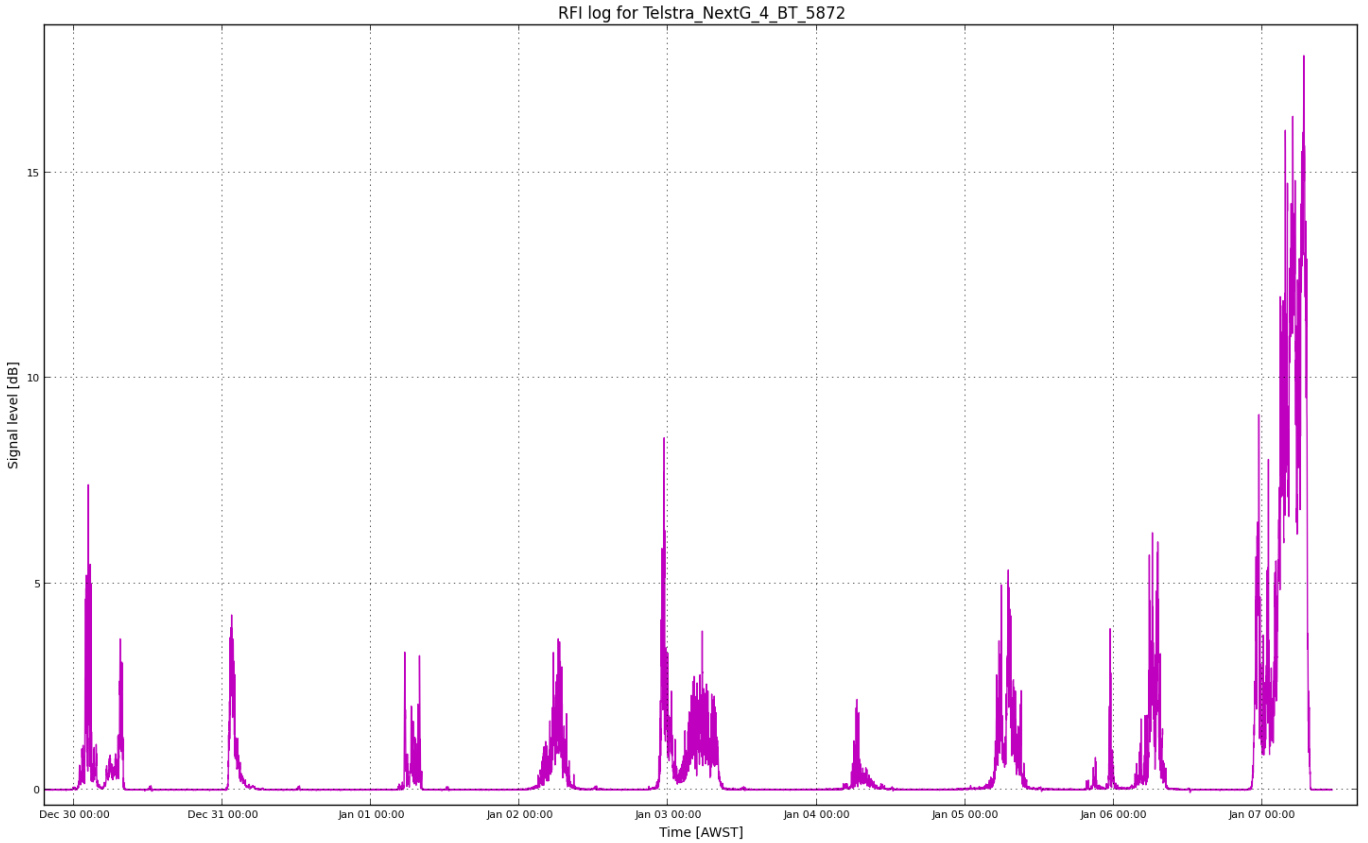
4G/

This m
Furthe
@ 763
@211
~1500

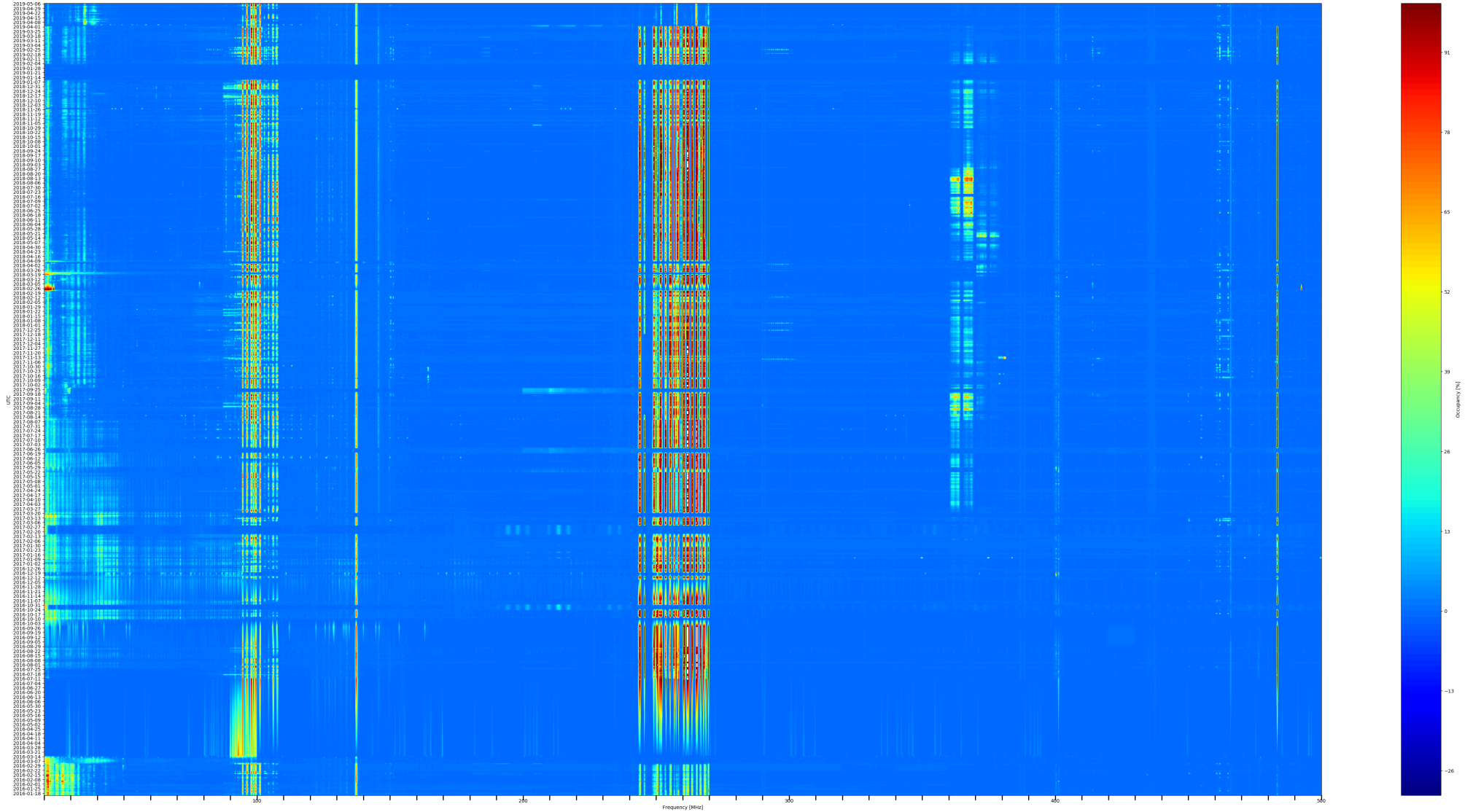


RFI Situation Awareness

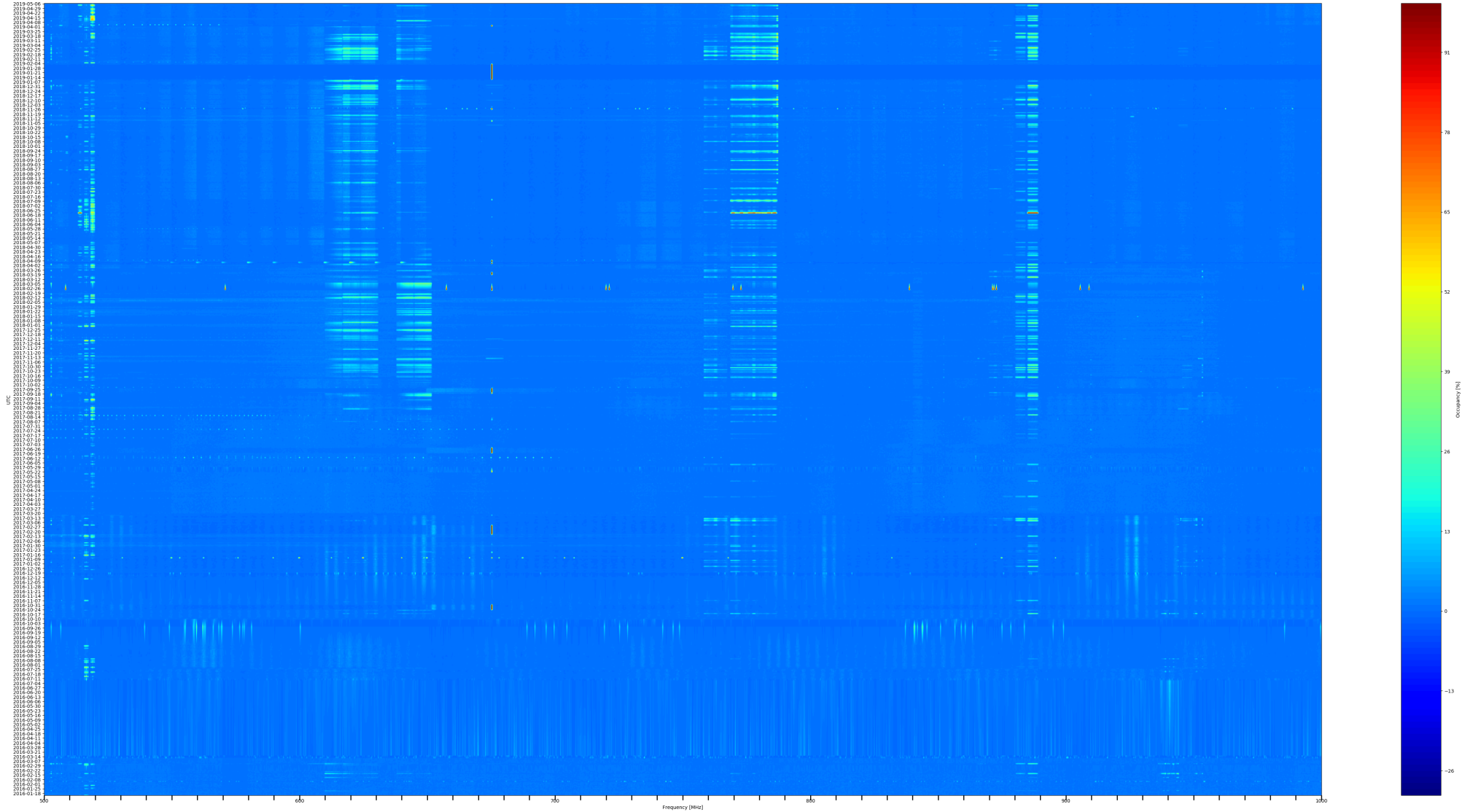
- Ducting:
  - How often?
  - Conditions?
  - Prediction?



RFI Situation Awareness

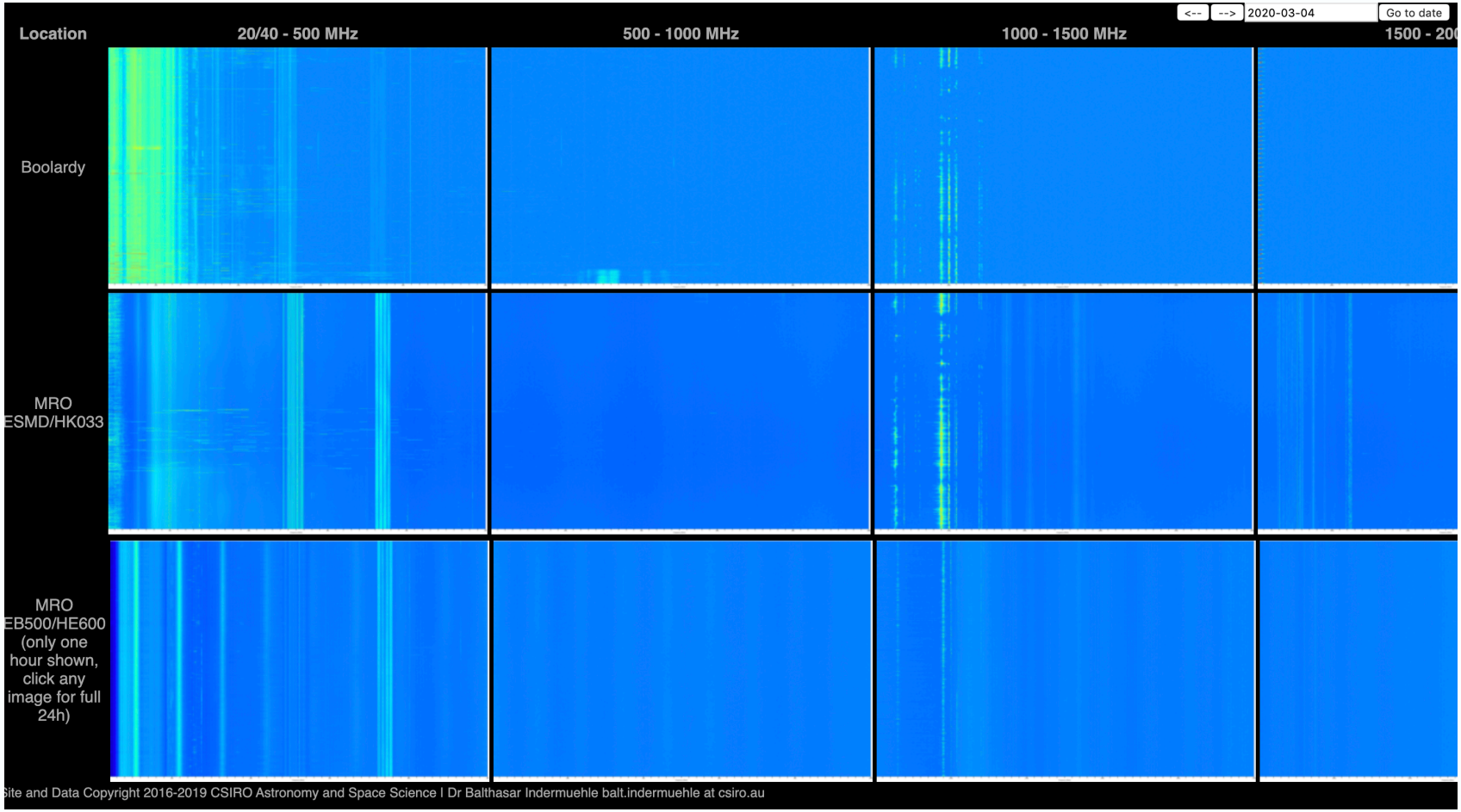


RFI Situation Awareness



RFI Situation Awareness

- https://www.atnf.csiro.au/observers/RFI/

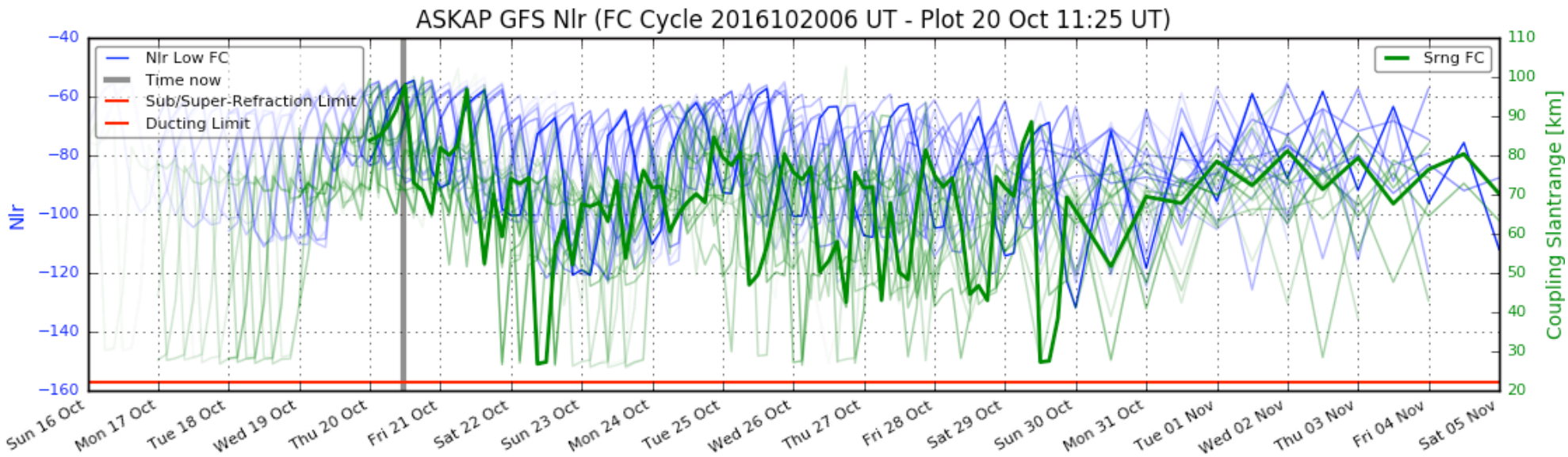


Tropospheric Ducting Forecasting

- Ducting due to temperature inversion
- T inversion caused by rapid radiative cooling of the ground
- If the humidity is low, T becomes the dominant factor
- Super refractivity occurs
- Prediction using the Himawari 8 thermal infrared (IR) sensor data
- Observe cooling gradient and match to observed ducting events for calibration
- Use GFS model

Tropospheric Ducting Forecasting - GFS

- Using the GFS model atmosphere to calculate refractivity lapse rate (Nlr):



Ongoing work:
Tropospheric Ducting Forecasting - GFS

- Shown to work occasionally
- Vertical temperature/humidity profiles insufficiently resolved (need hectometers, not km)
- Does not take low level ducts into account
- Investigations ongoing using Himawari 8 TIR band data to infer soil temperature radiative cooling rate
- => predict low level inversion forming

Thank you

CASS
Dr Balthasar Indermühle
Suum cuique

t +61 2 9375 4074
e balt.indermuehle@csiro.au
w www.atnf.csiro.au