Observations for NWP

Eoin Whelan
Irish Meteorological Service

Outline

- Background
- System aspects

Background

- Observations in NWP
- Global observing system
  - Conventional observations (GTS)
  - Satellite observations (EUMETCast)
  - Radar observations (OPERA/ODYSSEY)
  - Other observations

Acknowlegments

- Previous ECMWF DA training courses
  - https://confluence.ecmwf.int/display/OPTR/Our+training+resources

- 2014 HIRLAM training course
  - https://hirlam.org/trac/wiki/HarmonieSystemTraining2014/Programme

- The internet!

Observations in NWP

The observing system

- 1700s: Short lived networks (GB, FR, RUS, …)
- 1800s: Better instrumentation and telegraph
- 1854: Storm destroys French fleet at Balaklava
- 1855: France set up observing network
- 1873: International Meteorological Conference of Vienna placed cooperation on a formal diplomatic basis. (Permanent international committee established soon after)
- 1950: Good upper-air network over land (NH)
- 1963: WMO World Weather Watch
- 1979: Global Weather Experiment

Observations in NWP

- Initial value problem
- Minimise a cost function (3D-Var):

$$J(x) = (x - x_b)\boldsymbol{B}^{-1}(x - x_b) + (\boldsymbol{y} - \boldsymbol{H}[\boldsymbol{x}])\boldsymbol{R}^{-1}(\boldsymbol{y} - \boldsymbol{H}[\boldsymbol{x}])$$

- Fill observation vector, $\boldsymbol{y}$, with good-quality observations of atmosphere

Global observing system

# Global Observing System

- WMO programme
  - https://public.wmo.int/en/programmes/global-observing-system
- Surface, Upper-air, Marine, Aircraft, Satellite, Radar, Other

Offering operationally reliable, surface-based and space-based subsystems with observing facilities on land, at sea, in the air and in outer space in support of the World Weather Watch and climate applications.

Global Observing System

POLAR ORBITING SATELLITE

GEOSTATIONARY SATELLITE

SATELLITE IMAGES

AIRCRAFT

OCEAN DATA BUOY

SATELLITE SOUNDINGS

SATELLITE GROUND STATION

WEATHER RADAR

WEATHER SHIP

SURFACE STATION

UPPER-AIR STATION

AUTOMATIC STATION

NMS

Credit: WMO, https://public.wmo.int/en/programmes/global-observing-system

Global Observing System

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Credit: WMO, https://public.wmo.int/en/programmes/global-observing-system

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Global Observing System

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SURFACE STATION

AUTOMATIC STATION

NMS

Credit: WMO, https://public.wmo.int/en/programmes/global-observing-system

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https://www.ecmwf.int/en/forecasts/charts/monitoring/dcover

Data Coverage: SYNOP-SHIP-METAR
2019-01-28: 12 UTC +/- 90min
Total number of observations: 14589

- SYNOP-Land TAC: 2040
- METAR: 3947
- SHIP TAC: 678
- METAR-AUTO: 0
- SYNOP-Ship BUFR: 0
- SYNOP-Land BUFR: 7924

SYNOP: Z/Ps
SHIP: Z/Ps, U10m

Met Éireann, The Irish Meteorological Service
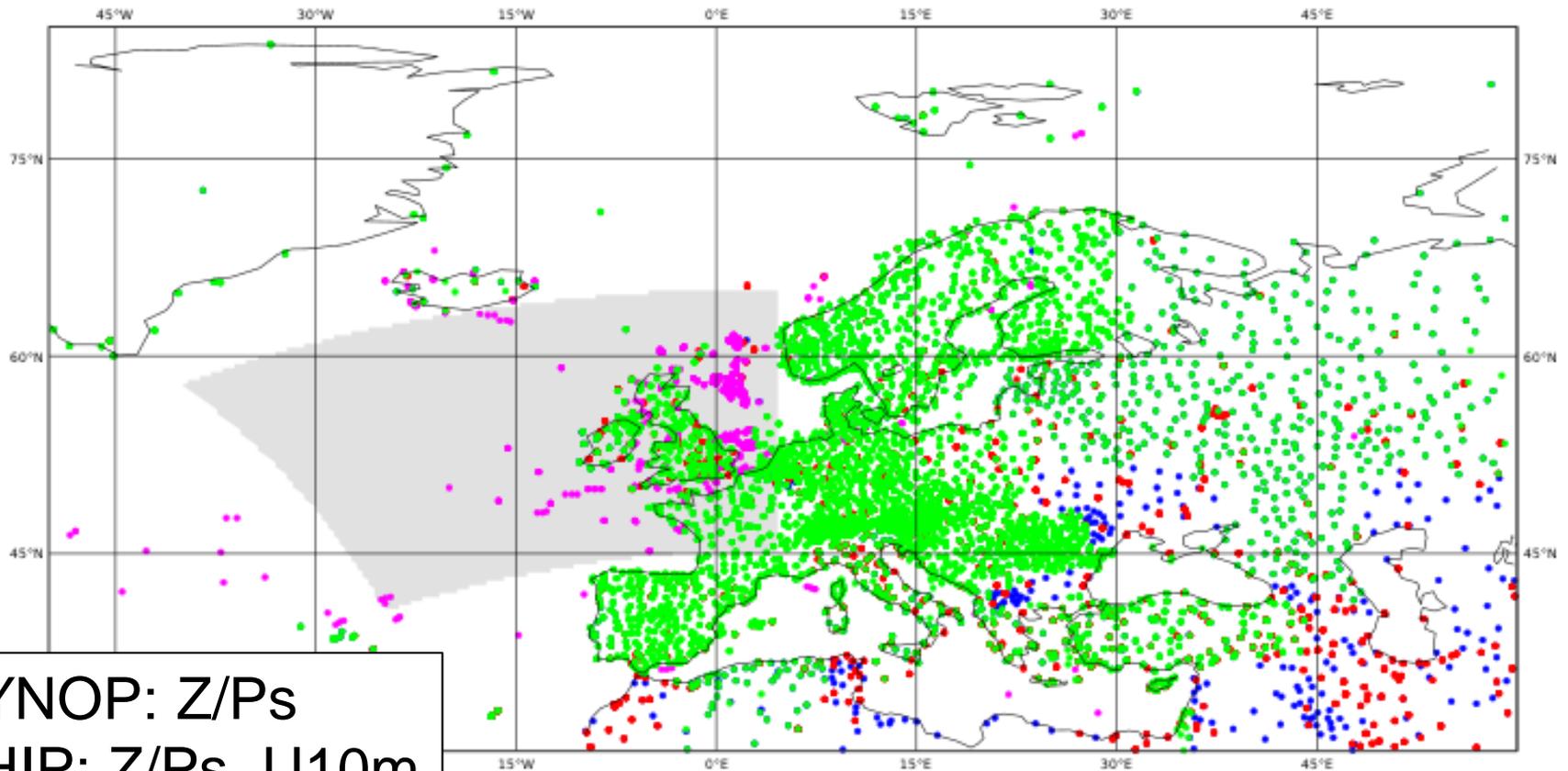
Data Coverage: BUOY
2019-01-28: 12 UTC +/- 90min
Total number of observations: 46

- DRIFTER: 6
- MOORED BUOY BUFR: 9
- DRIFTER BUOY BUFR: 31
- BATHY: 0
- TESAC: 0
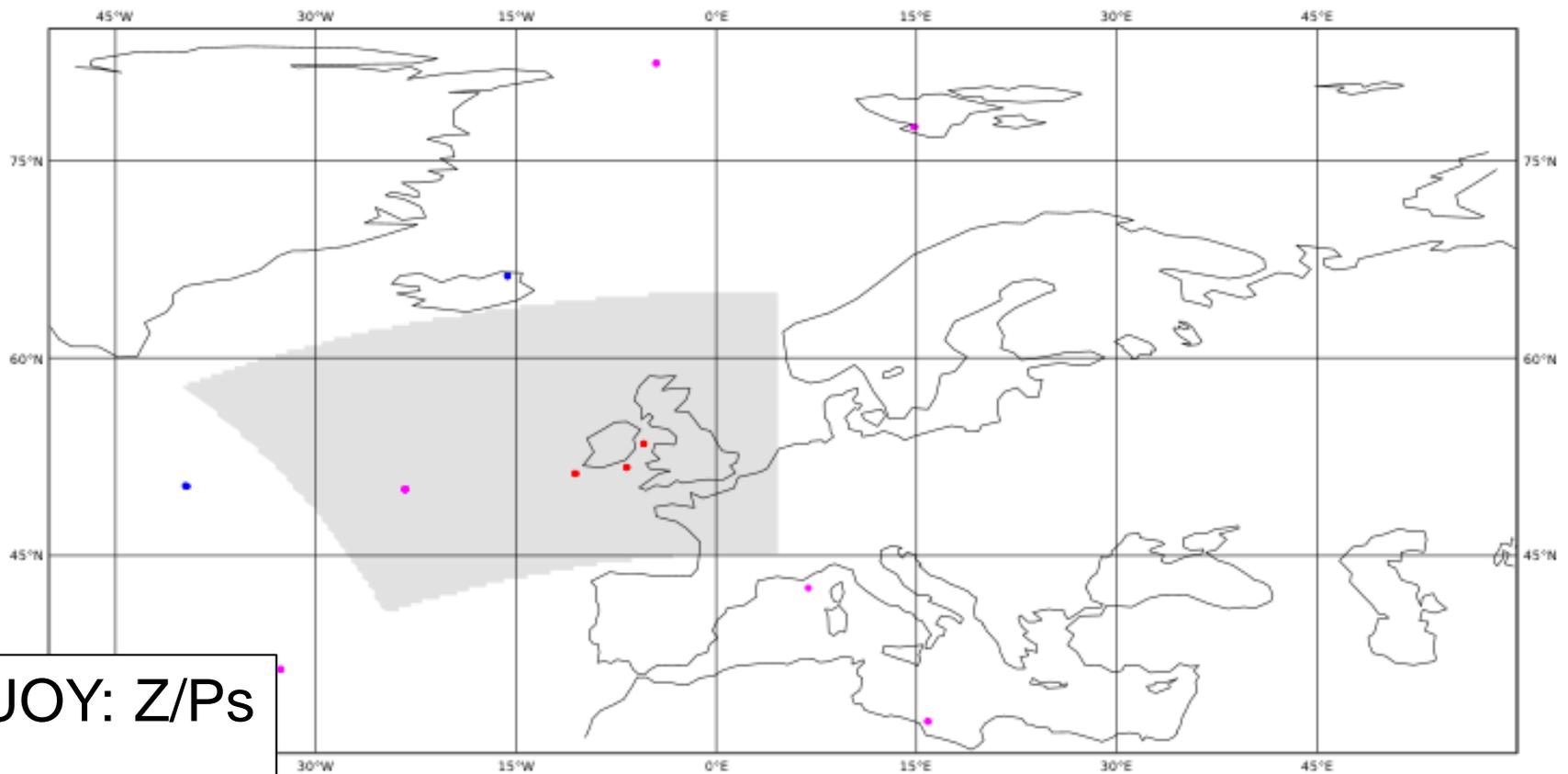
BUOY: Z/Ps

Data Coverage: AIRCRAFT
2019-01-28: 12 UTC +/- 90min
Total number of observations: 8617

- AIREP: 457
- AMDAR: 0
- WIGOS AMDAR: 8160

AIRCRAFT: T/U/Q

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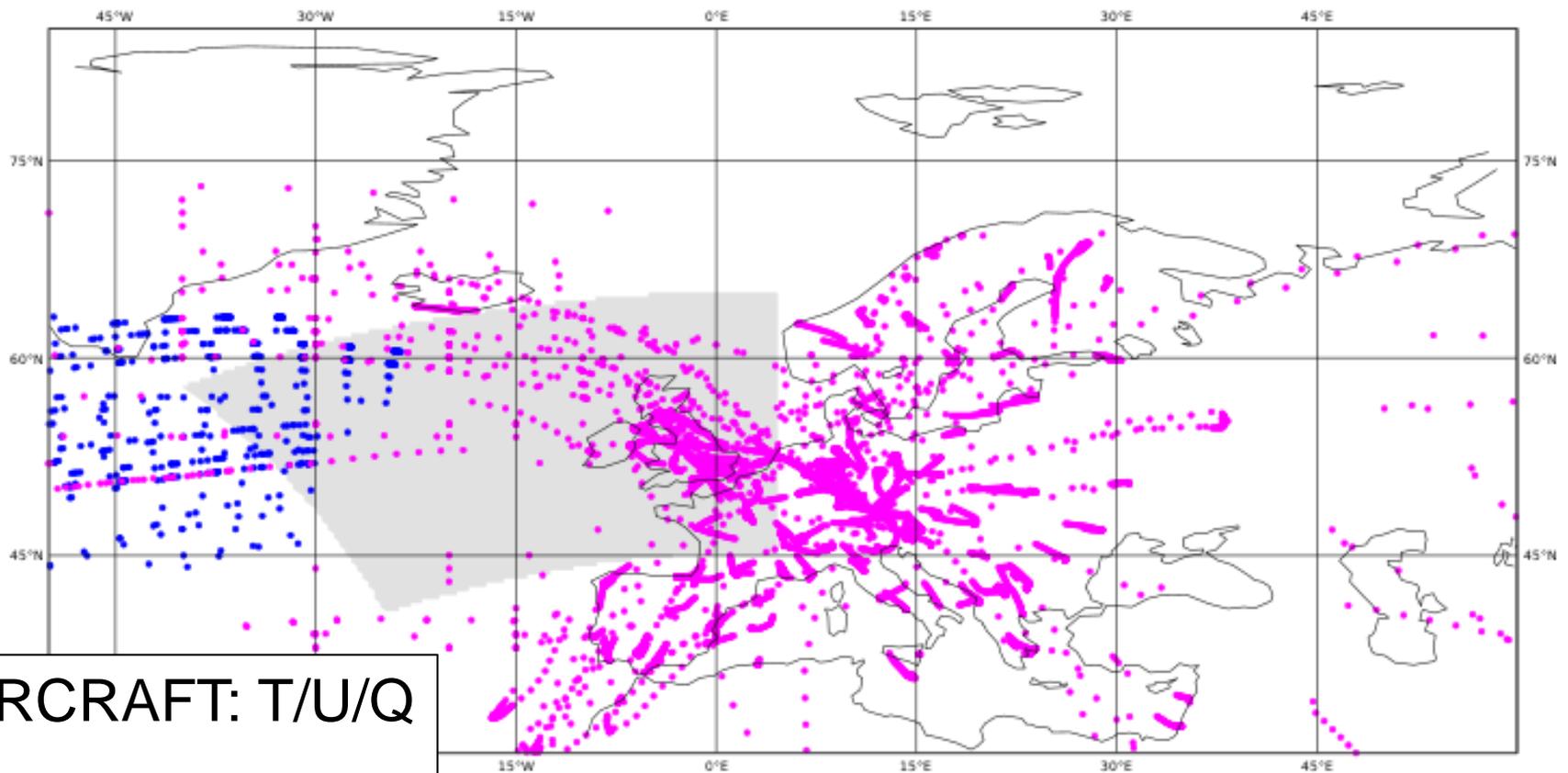
Data Coverage: RADIOSONDE
2019-01-28: 12 UTC +/- 90min
Total number of observations: 232

- TEMP-Land TAC: 104   • TEMP-Ship TAC: 0   • TEMP-Drop: 0   • TEMP-Mobile: 0
- BUFR TEMP-Land: 125   • BUFR TEMP-Ship: 3

TEMP: T/U/Q

Met Éireann, The Irish Meteorological Service
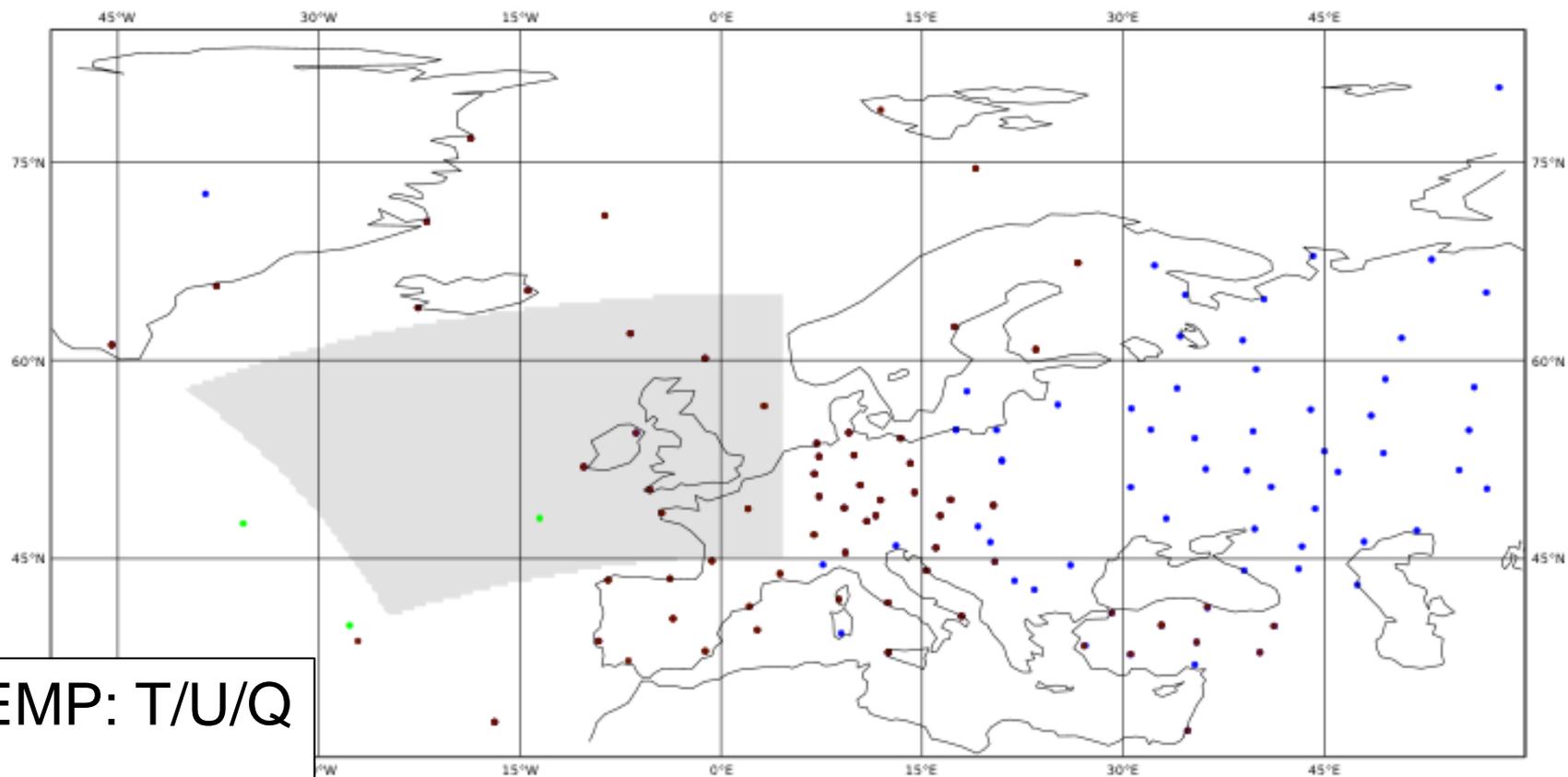
Data Coverage: PILOT-PROFILER
2019-01-28: 12 UTC +/- 90min
Total number of observations: 85

- PILOT LAND: 3   • PILOT SHIP: 0   • US WIND PROF.: 0   • EURO WIND PROF.: 80
- BUFR LAND PILOT: 2   • BUFR SHIP PILOT: 0

PILOT: U

Met Éireann, The Irish Meteorological Service
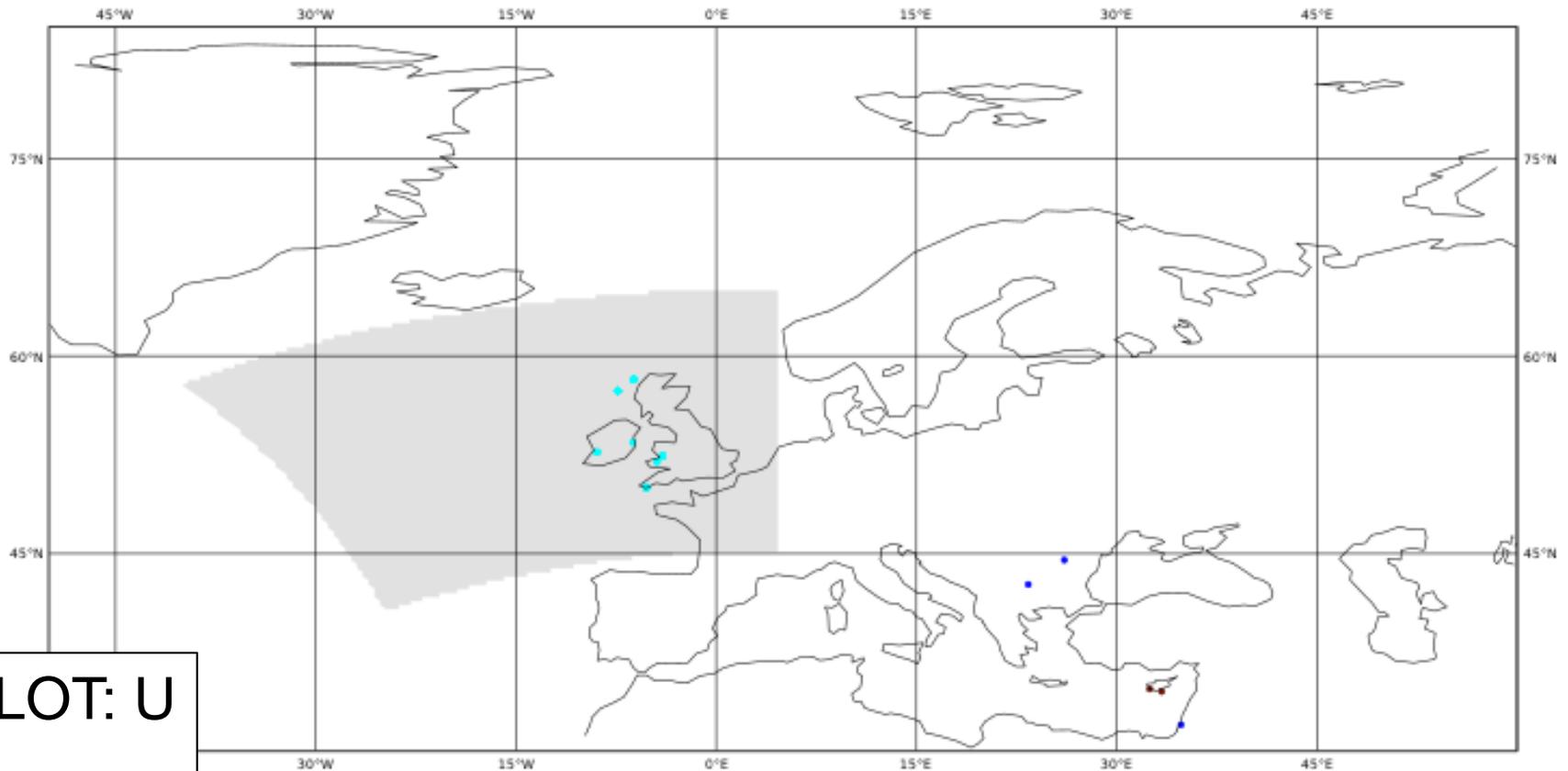
Data Coverage: GROUND-BASED GPS
2019-01-28: 12 UTC +/- 90min
Total number of observations: 42364

GBGPS: 42364

GBGPS: IWV

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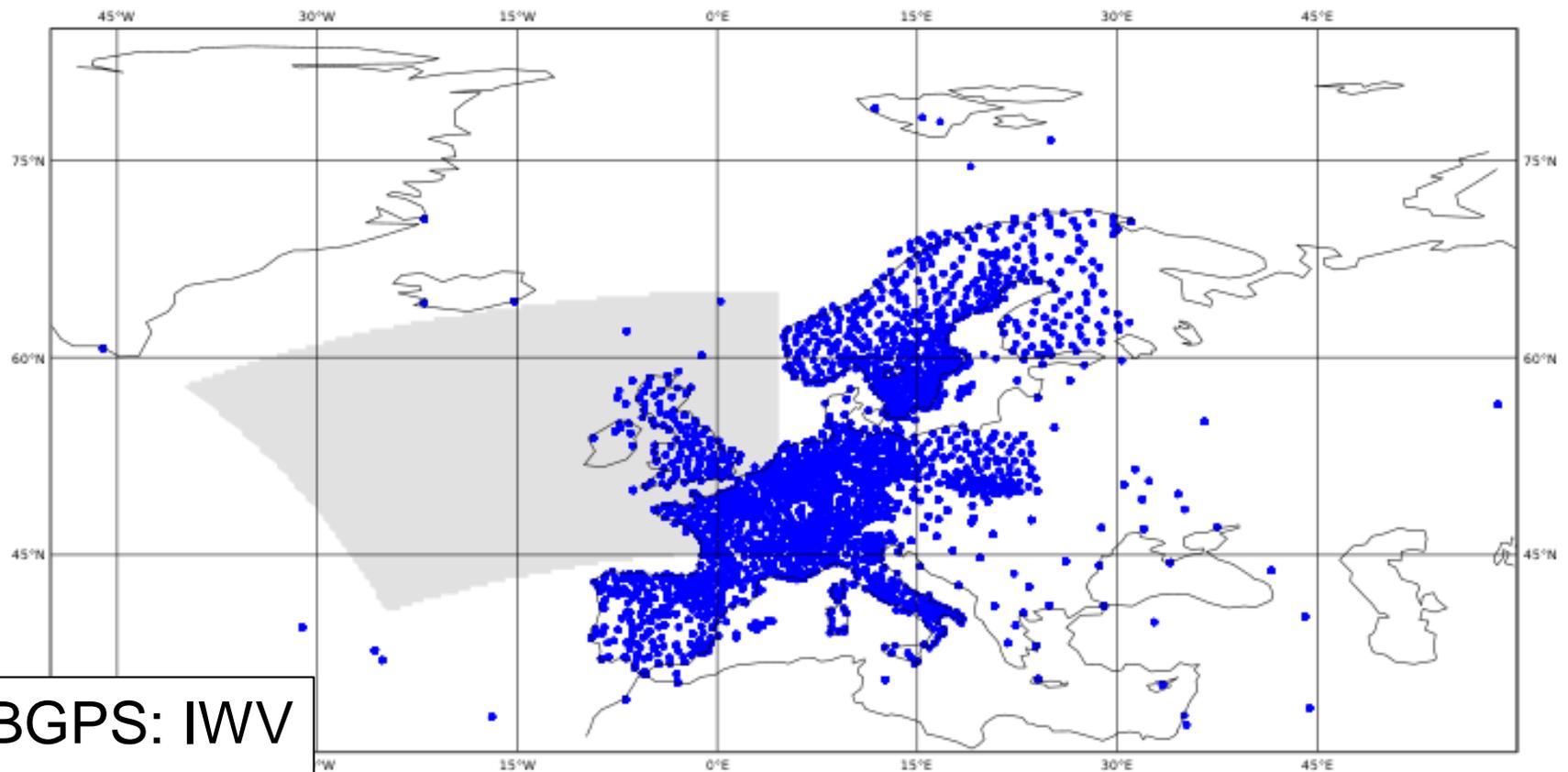
Data Coverage: AMSU-A
2019-01-24: 12UTC +/-90min
Total number of observations: 62460

METOP-A: 14850   METOP-B: 10320   NOAA-18: 17790   NOAA-19: 19500   NOAA-20: 0

AMSU-A: T_b

Met Éireann, The Irish Meteorological Service
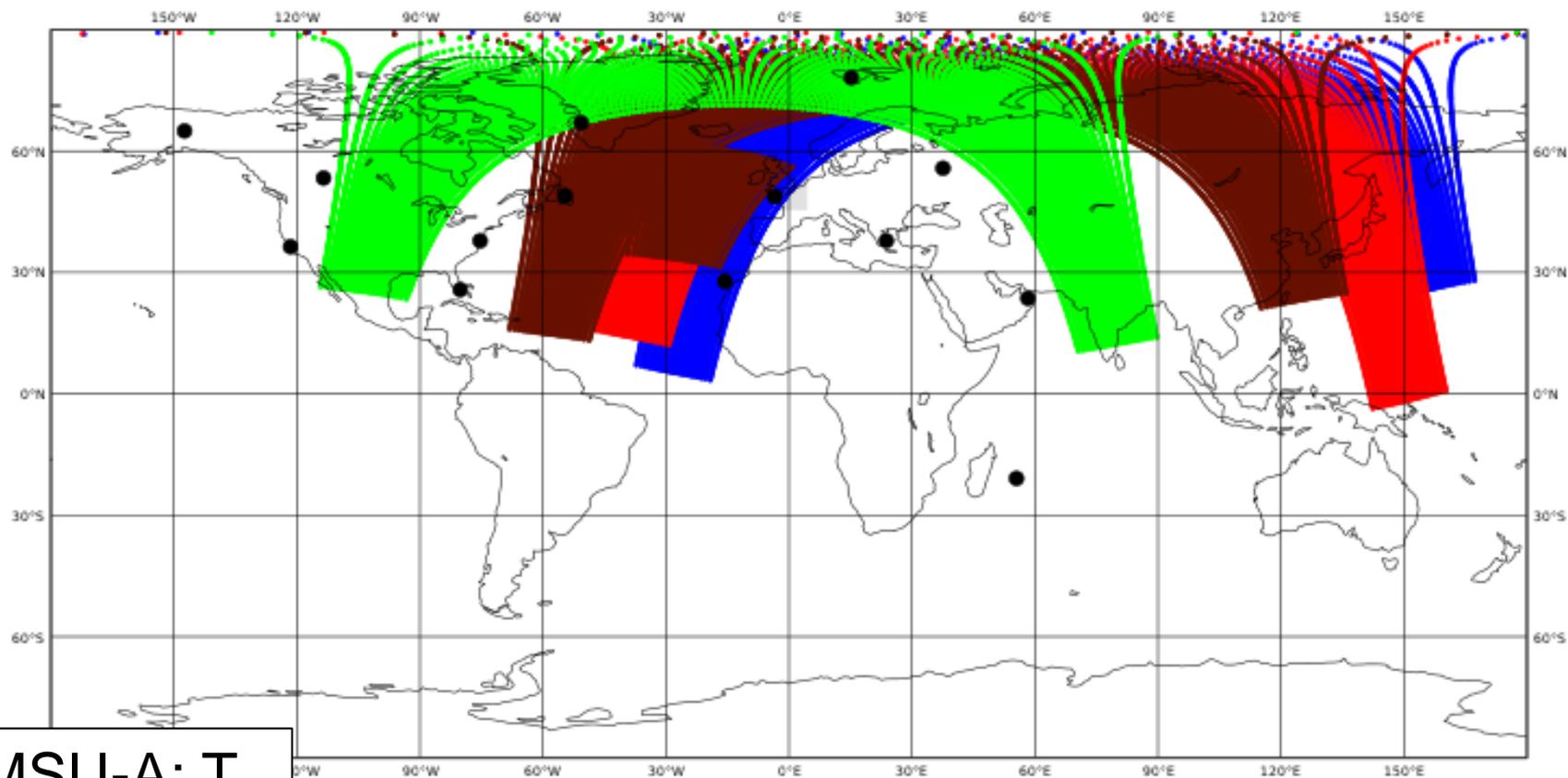
Data Coverage: AMSU-B/MHS
2019-01-24: 12UTC +/-90min
Total number of observations: 425430

• METOP-A: 132840   • METOP-B: 92880   • NOAA-18: 23760   • NOAA-19: 175950   • NOAA-20: 0

AMSUB/MHS: T_b

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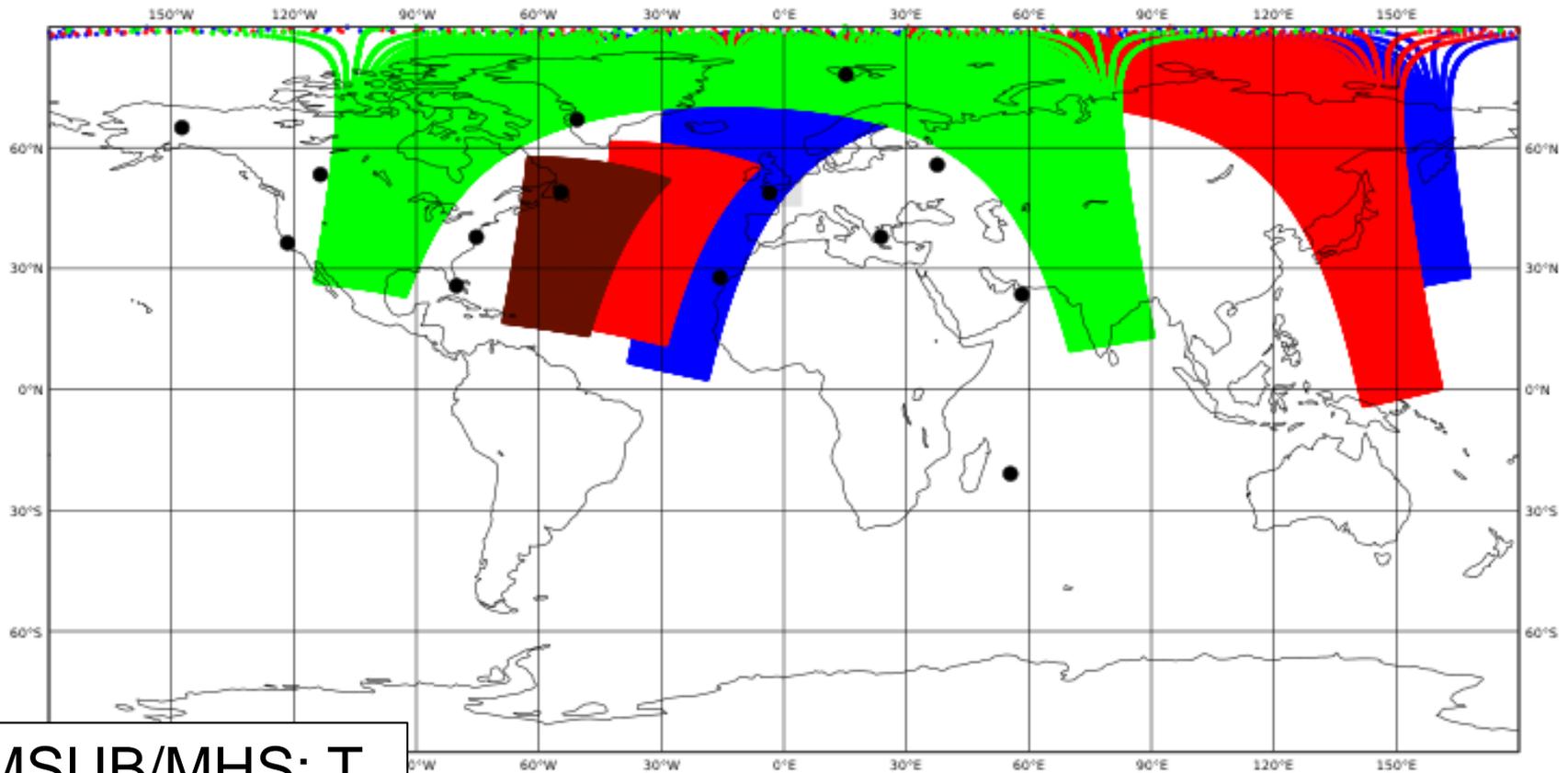
Data Coverage: IASI
2019-01-24: 12UTC +/-90min
Total number of observations: 51720

METOP-A: 10440   METOP-B: 41280

IASI: T_b

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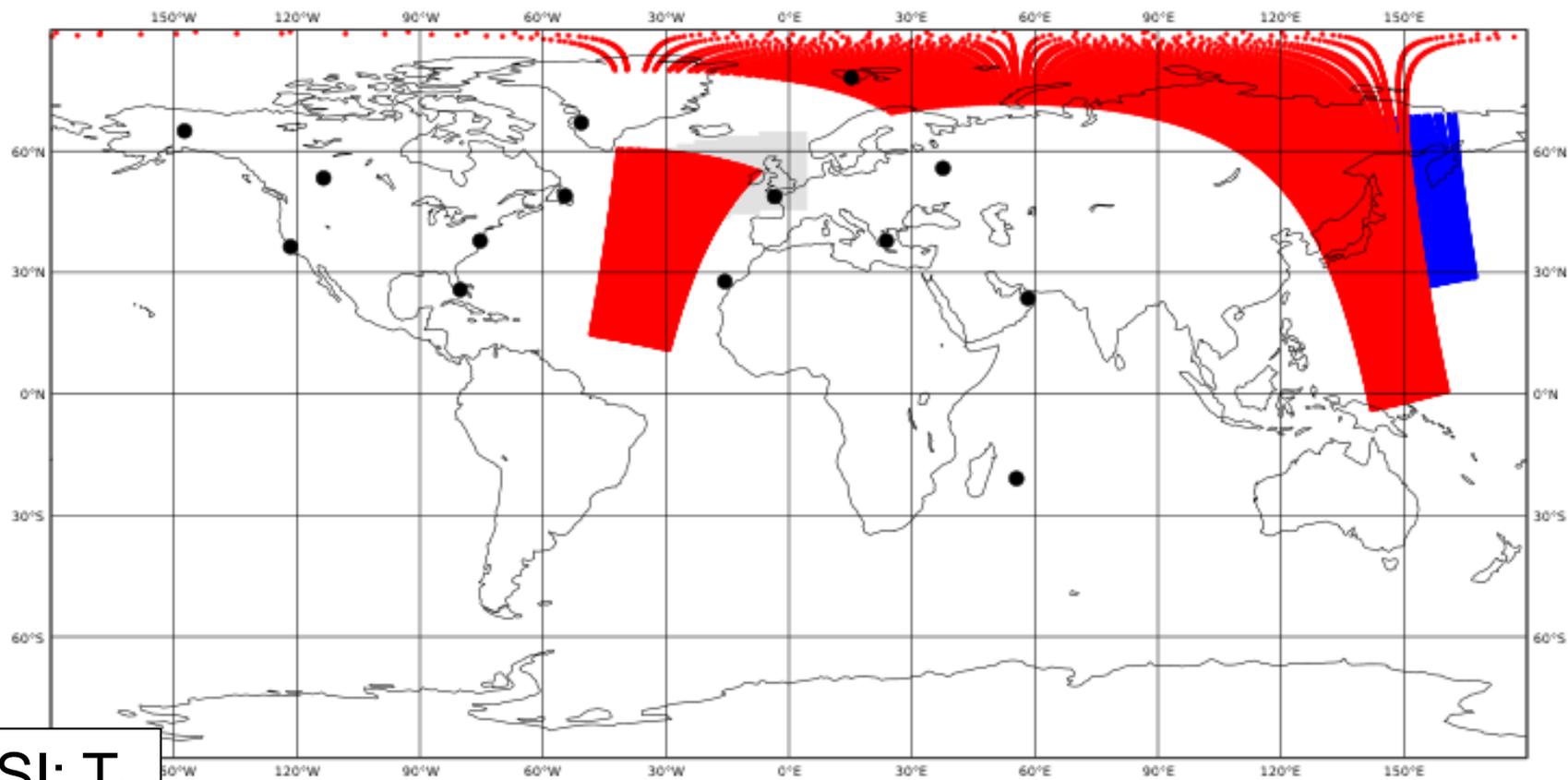
Data Coverage: SCATT
2019-01-24: 12UTC +/-90min
Total number of observations: 256496

• METOP-A: 135300   • METOP-B: 121196

ASCAT: U10m

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European Radar and Lightning
29.01.2019 14:00
INTERNAL USE ONLY

SFERIC CSV 29.01.2019 14:00

RADAR: dBz/Vr

1   1.5   2   3   4   6   8   12   16   24   32

Met Éireann, The Irish Meteorological Service
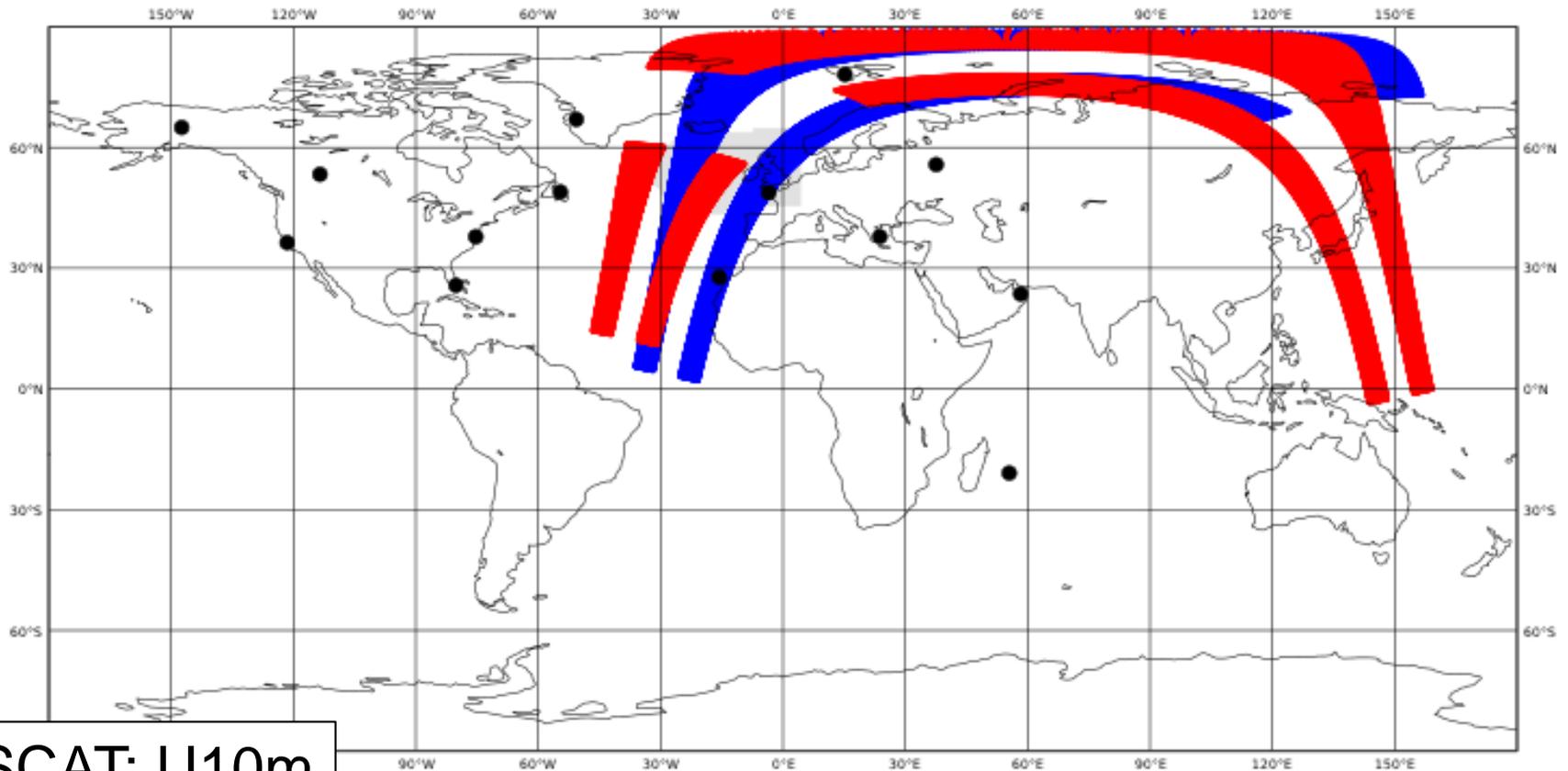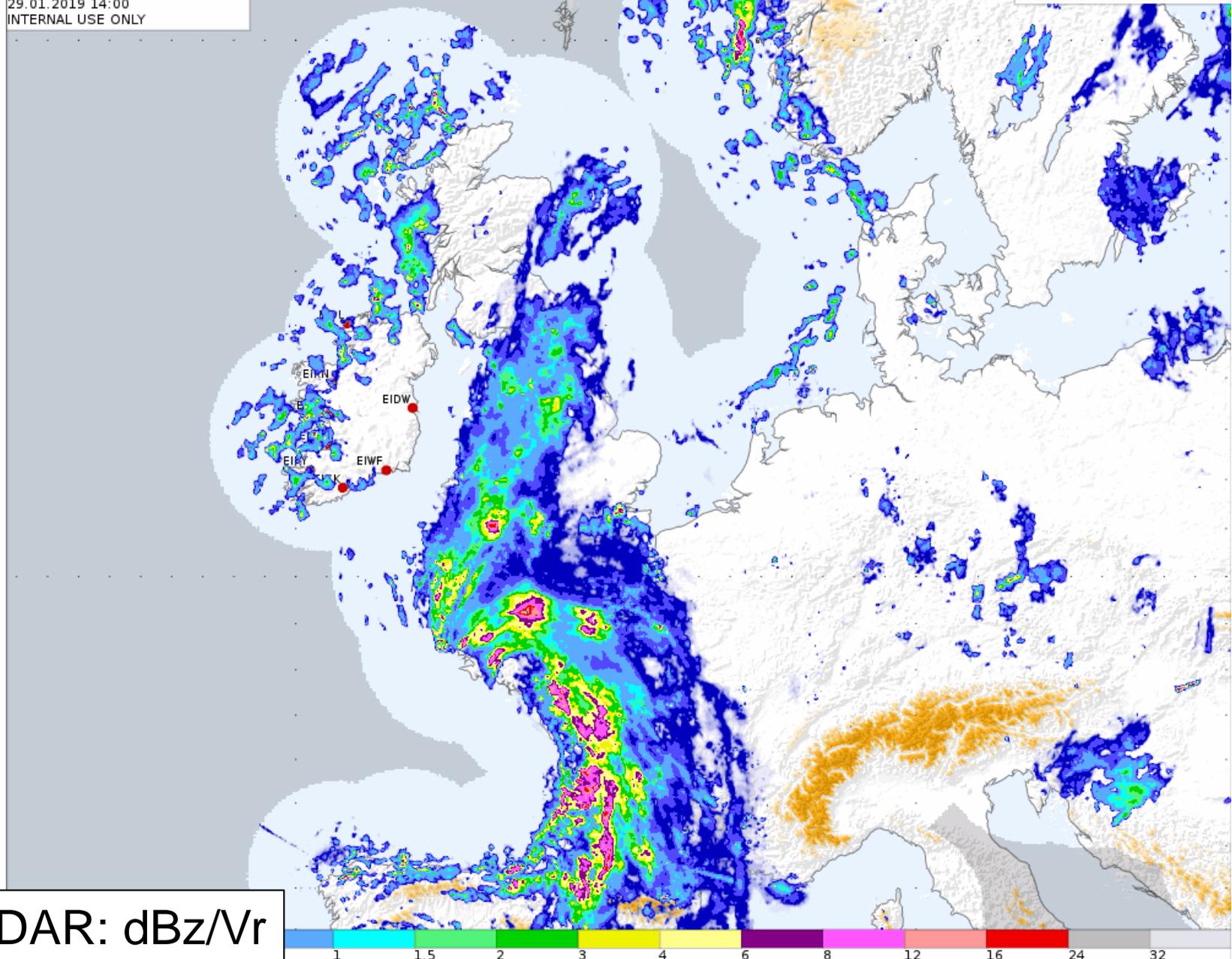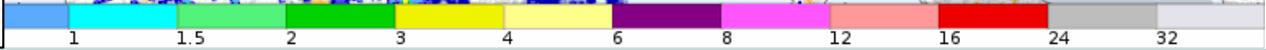
Other observations

- ## Mode-S (EHS/MRAR)
  - http://mode-s.knmi.nl/
  - https://www.umr-cnrm.fr/aladin/IMG/pdf/modes-bs.pptx.pdf
  - European Meteorological Aircraft Derived Data Center (EMADDC)

- ## Crowd-sourced
  - Many opportunities!

System aspects

- Data formats & data-handling tools

Global Telecommunication System
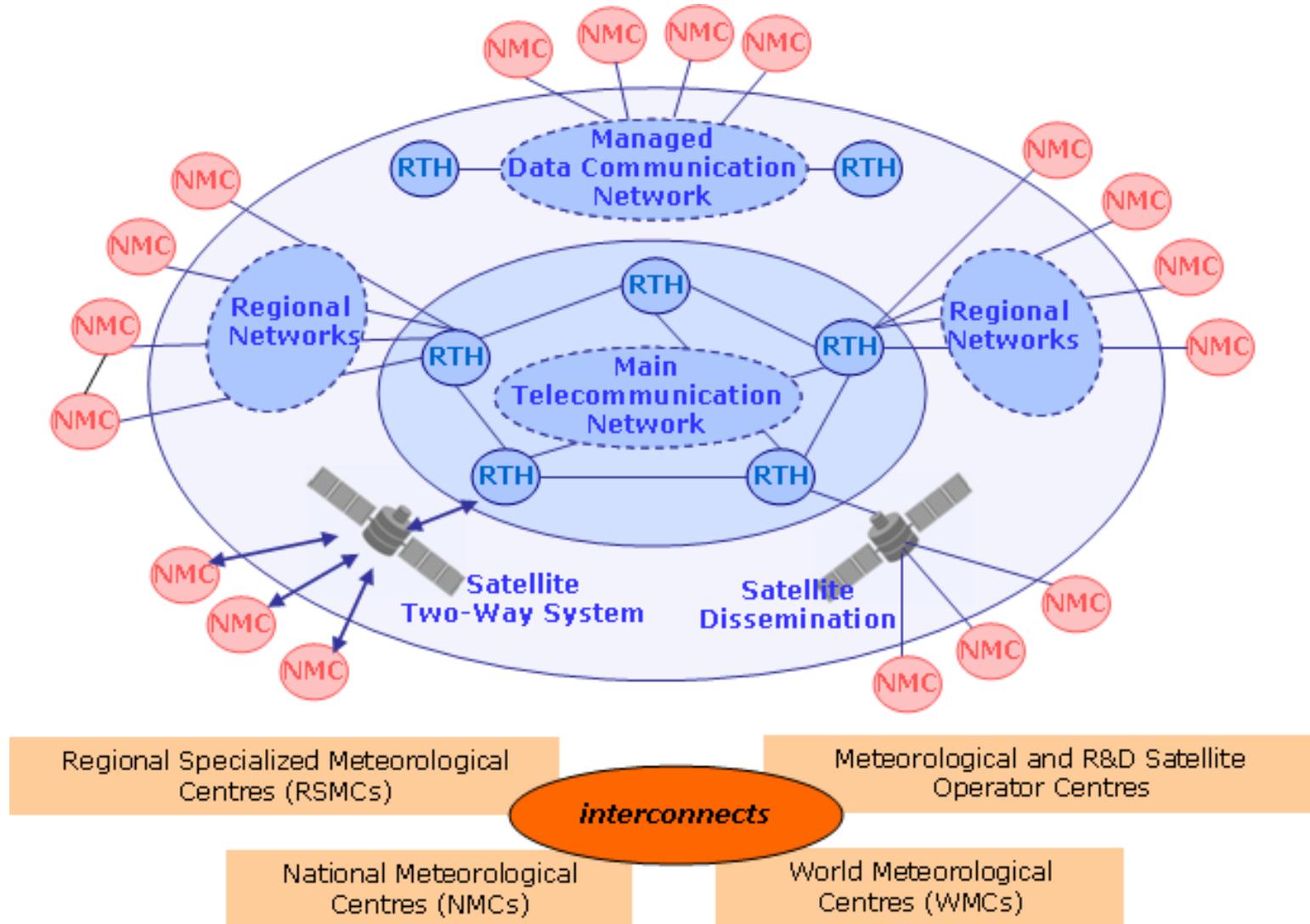
Credit: WMO, http://www.wmo.int/pages/prog/www/TEM/GTS/index_en.html

Global Telecommunication System
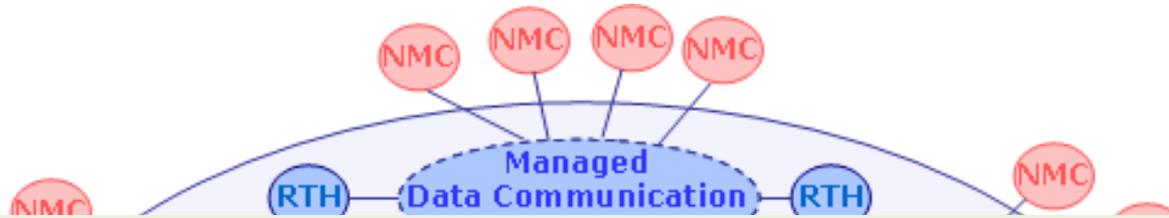
"The co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch."

Regional Specialized Meteorological Centres (RSMCs)

Meteorological and R&D Satellite Operator Centres

interconnects

National Meteorological Centres (NMCs)

World Meteorological Centres (WMCs)
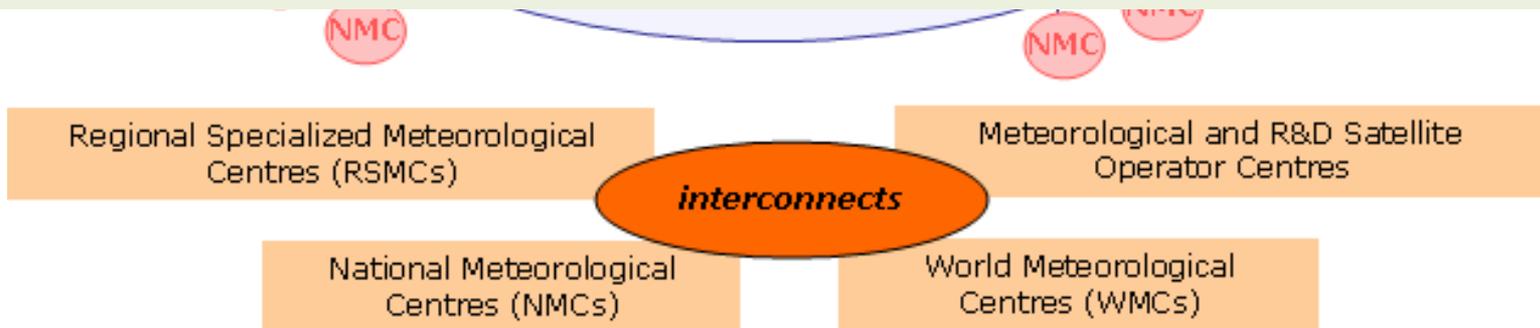
Credit: WMO, http://www.wmo.int/pages/prog/www/TEM/GTS/index_en.html

GTS messages

- ## All the information you will need!
  - http://www.wmo.int/pages/prog/www/ois/ois-home.html
  - https://wiswiki.wmo.int/tiki-index.php?page=ManualGTS
  - http://www.wmo.int/pages/prog/www/ois/Operational_Information/Publications/WMO_386/AHLsymbols/AHLsymbols_en.html

- ## All the software you will need!
  - https://confluence.ecmwf.int/display/ECC/ecCodes+Home
  - https://confluence.ecmwf.int/display/OPTR/ecCodes%3A+BUFR+data+decoding+and+encoding+software+2017 (eccodes_bufr_ecCodes_extra.pdf)
  - GTS tools: gts_ls, gts_dump, gts_filter
  - More in the practical session after lunch

GTS messages

Start of GTS message

Transmission sequence number

GTS data designators (TTAAii CCCC YYGGgg)

End of GTS message

```
^A^M^M
999^M^M
ISMA01 EIDB 171200^M^M
BUFR^@^H²^D^@^@^V^@^@Ã©^@^@^@^@^@^B^@^N^@^GÃ£^A^Q^L^@^@^@^@
^@^@^L<80>Ã‡P^@^H<82>^@^GÃ>Â©Â¤"Â©%Â¤Â§^P$Â©Â¦ Â§"^P^P^P^P^P^P^OÃ†(Âº^FÂ¾Ã-
Ã,^H<91>Â ^Ph^H9O<85>>Ã«Ã¬^_Ã¿Ã¿Ã¿Ã¿Ã¸^CÃ«i<9b>S^_Âº^L<84>~^@^T^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã
¸^OÃ¿Ã¿Ã¿^@^_Ã¾GÃ¼<9f>Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã£½)OÃ¿Ã¿ÃŸÂ£Ã¿<80>^T?Ã•^@?Ã¿Ã¿
Ã¸^CÃ¯Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¸^_D
Ã½<80>^@^AÃ·Ã¶Ã¿Ã»L^?Ã¿Ã¿Ã¿Ã½Âº?Ã¿^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Â¿GÃ¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã
¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿^GÃœÂ« Â¦"Â§*$Â <90>'Âi)Â¢Â©+
Âª'Â©,<8f>Ã†(Âº^FÃ„<8b>B^F^XÃ•^P<86>^HMOs>ÃƒÃ®^_Ã¿Ã¿Ã¿Ã¸^CÃ«hÃ»LÃŸÃº^L<86>Ã–
^@^T^?Ã¿Ã¿Ã¿Ã¿Ã±^WÃŸÃ¿Ã¸

 ÷
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^@/Ã¿Ã¿Ã¿Ã¼^AÃµÂ´UÂ¦Â¿Ã¸^FAÃ´^@
?Ã¿Ã¿Ã¿Ã¹^K/Ã¿Ã¼
QÃ¼Y,_<8b>Ã ^AÃ¿Ã¤^?Ã‰Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿2Â¿Ã"Â¾Ã¿Ã¿Ã½Âº?Ã¸^ACÃ½^@^@Ã¿Â
¿Ã¿<80>>Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿<84>=@<9f>Ã˜^T^E^_^?oÃ¿Ã¿Â´Ã‡Ã¿Ã¿Ã¿Ã¿ÃŸÂ£Ã¿Ã·Ã¿Ã¿Ã¿Ã¿Ã¿
Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã»Ã´^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Âº7777^@^@^@^M^M
^C
```

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BUFR data

- <u>B</u>inary <u>U</u>niversal <u>F</u>orm for the <u>R</u>epresentation of Meteorological Data

- Used for non-gridded data; i.e. obs!

- All the information you will need!

  - http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/VolumeI.2.html

- All the software you will need!

  - https://confluence.ecmwf.int/display/ECC/ecCodes+Home
  - BUFR tools: bufr_ls, bufr_dump, bufr_filter
  - https://confluence.ecmwf.int/display/METV
  - Metview: data examiner and plotting
  - More in the practical session after lunch

BUFR data

Section 0	"BUFR" + length of BUFR
Section 1	Data identification: category, BUFR table, date, time
Section 2	Local information: optional (used by ECMWF)
Section 3	Data description: # subsets, descriptors, compression on|off
Section 4	The data!
Section 5	"7777" (end of BUFR)

BUFR data

BUFR^@^HÂ^D^@^@^V^@^@Ã©^@^@^@^@^@^@^B^@^N^@^GÃ£^A^Q^L^@^@^@^@
^@^@^@^L<80>Ã‡P^@^H<82>^@^GÃ>Â©Â¤"Â©%Â¤Â§^P\$Â©Â¦ Â§"^P^P^P^P^P^P^OÃ†(Âº^FÂ¾Ã-
Ã‚^H<91>Â ^Ph^H9O<85>>Ã«Ã¬^_Ã¿Ã¿Ã¿Ã¿Ã¸^CÃ«i<9b>S^_Âº^L<84>~^@^T^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã
¸^OÃ¿Ã¿Ã¿^@^_Ã¾GÃ¼<9f>Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã£Ã½)OÃ¿Ã¿ÃŸÂ£Ã¿<80>^T?Ã•^@?Ã¿Ã¿
Ã‚¸^CÃ¯Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¸^_D
Ã½<80>^@^AÃ·Ã¶Ã¿Ã¿Ã»L^?Ã¿Ã¿Ã¿Ã½Âº?Ã¿^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã‚GÃ¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã
¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿^GÃœÂ« Â¦"Â§*\$Â <90>'Âi)Â¢Â©+
Âª'Â©,<8f>Ã†(Âº^FÃ„<8b>B^F^XÃ•^P<86>^HMOs>ÃƒÃ®^_Ã¿Ã¿Ã¿Ã¿Ã¸^CÃ«hÃ»LÃŸÃº^L<86>Ã–
^@^T^?Ã¿Ã¿Ã¿Ã¿Ã±^WÃŸÃ¿Ã¸

   ⋮
   ⋮
   ⋮

^@/Ã¿Ã¿Ã¿Ã¿Ã¼^AÃµÂ´UÂ¦Â¿Ã¸^FAÃ´^@
?Ã¿Ã¿Ã¿Ã¿Ã¹^K/Ã¿Ã¼
QÃ¼Y,_<8b>Ã ^AÃ¿Ã¤^?Ã‰Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿2Â¿Ã"Â¾Ã¿Ã¿Ã½Âº?Ã¸^ACÃ½^@^@Ã¿Â
¿Ã¿<80>>Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿<84>=@<9f>Ã˜^T^E^_^?oÃ¿Ã¿Â´Ã‡Ã¿Ã¿Ã¿Ã¿ÃŸÂ£Ã¿Ã·Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿
Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã»Ã´^?Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Ã¿Âº**7777**

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BUFR data

```
delayedDescriptorReplicationFactor= {1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0}
edition=4
masterTableNumber=0
bufrHeaderCentre=233
bufrHeaderSubCentre=0
updateSequenceNumber=0
dataCategory=0
internationalDataSubCategory=2
dataSubCategory=0
masterTablesVersionNumber=14
localTablesVersionNumber=0
typicalYear=2019
typicalMonth=1
typicalDay=17
typicalHour=12
typicalMinute=0
typicalSecond=0
numberOfSubsets=12
observedData=1
compressedData=0
unexpandedDescriptors=307080
#1#blockNumber=3
#1#stationNumber=951
#1#stationOrSiteName="SHERKIN ISLAND"
#1#stationType=0
#1#year=2019
#1#month=1
#1#day=17
#1#hour=12
#1#minute=0
#1#latitude=51.47
#1#longitude=-9.42
#1#heightOfStationGroundAboveMeanSeaLevel=20
#1#heightOfBarometerAboveMeanSeaLevel=21
#1#nonCoordinatePressure=101780
 :
 :
```

# BUFR data

metview –e BUFR file.bufr

BUFR data

metview plotting – more later!

Data Coverage: Surface data - Land
2019-01-17: 12 UTC +/- 0min
Total number of observations: 12

● Hourly SYNOP [0]: 0
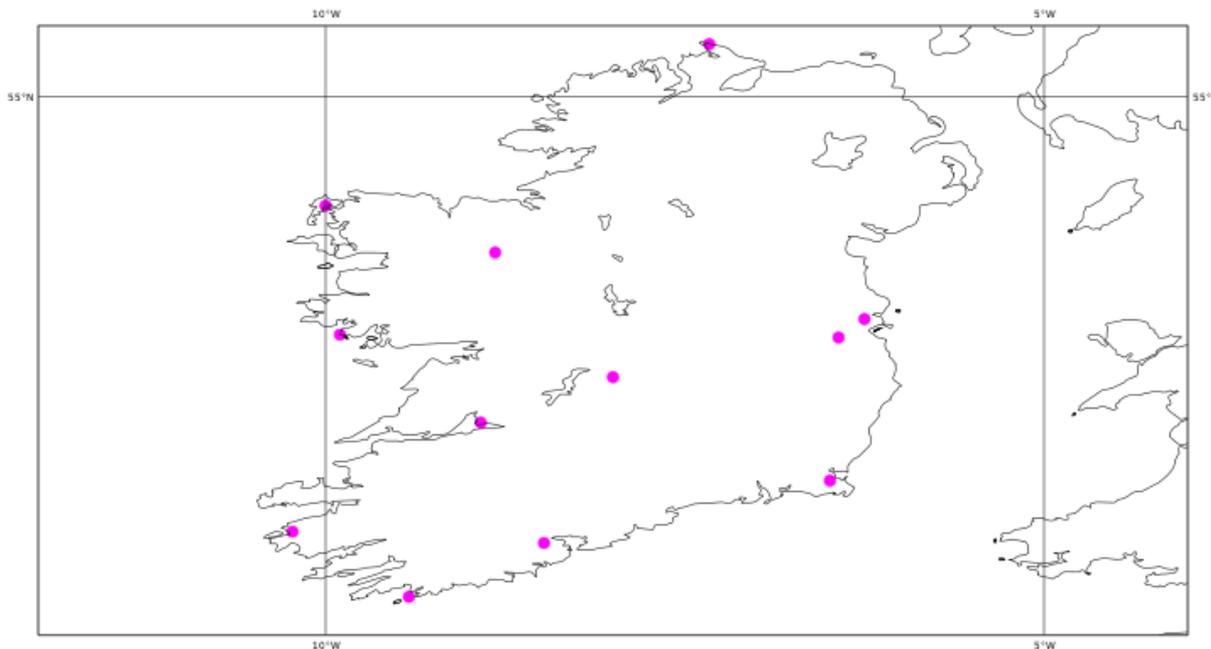
System tools: ShuffleBufr

- Simple FORTRAN program
  - util/oulan/ShuffleBufr.F90
- Splits input BUFR file by type
- Output files readable by Bator
  - More on this from Alena

System tools: ShuffleBufr

PROGRAM SHUFFLEBUFR
Split and shuffle BUFR file into specific BUFR files for OULAN

Usage: SHUFFLEBUFR -i <bufr_file> [-s1|-s2|-s3] [-a] [-r]

    -s1 : Synop ship will be extracted in <synop>
    -s2 : Synop ship will be extracted in <buoy>
    -s3 : Synop ship will be extracted in <ship>

    Nota Bene: If -s1,-s2 or -s3 are not specified
            synop_ship will not be extracted

    -a : Extracts ATOVS in files amsua and amsub

    -r : Extracts also record messages (synop)

System tools: ShuffleBufr

- Bator expects input BUFR files
- BUFR files split by observation type
- Names match Bator (BUFR) type names
  - src/odb/pandor/module/bator_init_mod.F90
- For conventional:
  - synop
  - buoy,moored,drift
  - temp,temps
  - airep/amdar
  - gpssol
  - modes

Miscellany: Local GTS processing

- Monitoring
- Decoding & re-coding (for NWP)
- Duplicate/correction handling
- Gross-error checking
- Other simple QC (consistency/integrity)

Miscellany: Local GTS processing

- ECMWF: SAPP & MARS
  - https://confluence.ecmwf.int/display/UDOC/MARS+user+documentation
  - https://www.ecmwf.int/en/elibrary/17341-sapp-new-scalable-acquisition-and-pre-processing-system-ecmwf

- Météo France: BDMO
  - http://www.umr-cnrm.fr/gmapdoc/spip.php?article226

- RC LACE: OPLACE
  - https://meetingorganizer.copernicus.org/EMS2018/EMS2018-837.pdf

- Everybody else!

Miscellany: possible developments

- SAPP
  - Scalable Acquisition and PreProcessing
  - System available as ECMWF Optional Programme

- COPE
  - Continuous Observation Preprocessing Environment
  - Flexible software to process observations for NWP
  - Reads BUFR/ODB-2
  - Writes ODB-2

- ODB-API & ODB-2
  - Software & format to handle observation and observation feedback information
  - https://confluence.ecmwf.int/display/ODBAPI