The Abdus Salam International Centre for Theoretical Physics

IAEA

International Space Weather Initiative Workshop
ICTP, Trieste, Italy, 2019

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2019/05/04 14:20:01.000   46.090271173   16.080110759   233.6381   5   7   3.6104   2.6017   9.0103   0.9158   1.4778   3.9621   0.00    0.0
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```

Challenges in space weather and GNSS data aggregation and consolidation for research

Renato Filjar[1,2]

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- Content

- Introduction and motivation
- Problem statement
- Overview of data sources
- Overview of data content and formats
- Methodology proposal
- Methodology demonstration
- Recommendations

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- Introduction and motivation
- '*Data is merely a raw material of knowledge.*'
- (New York Times)
- Science is hungry for data.
- Aggregation – a process for compilation of a data set from different trusted data sources
- Consolidation – a process for assemblage of a structured data set using the aggregated data
- Space weather (incl. ionospheric and geomagnetic) data aggregation and consolidation for multi-disciplinary research

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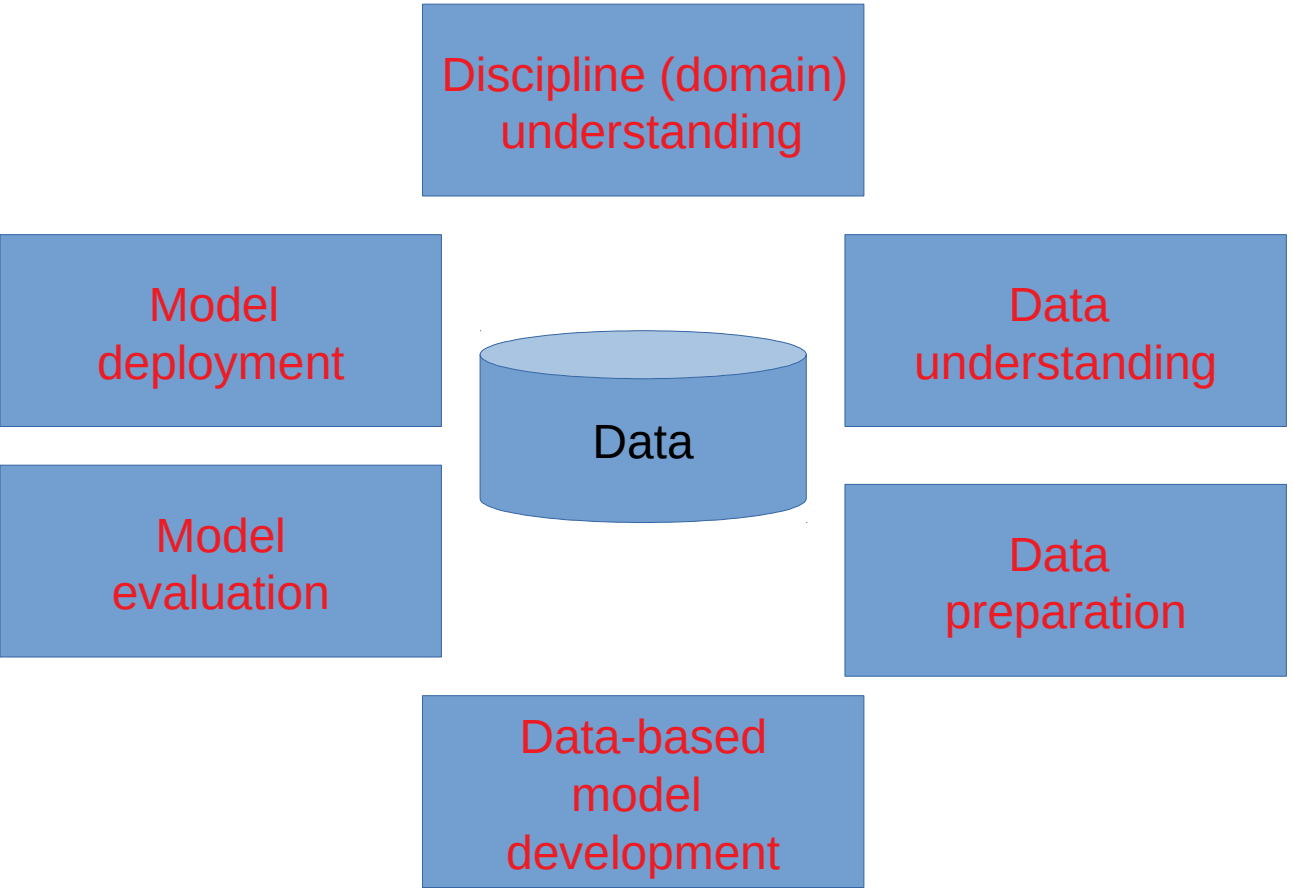
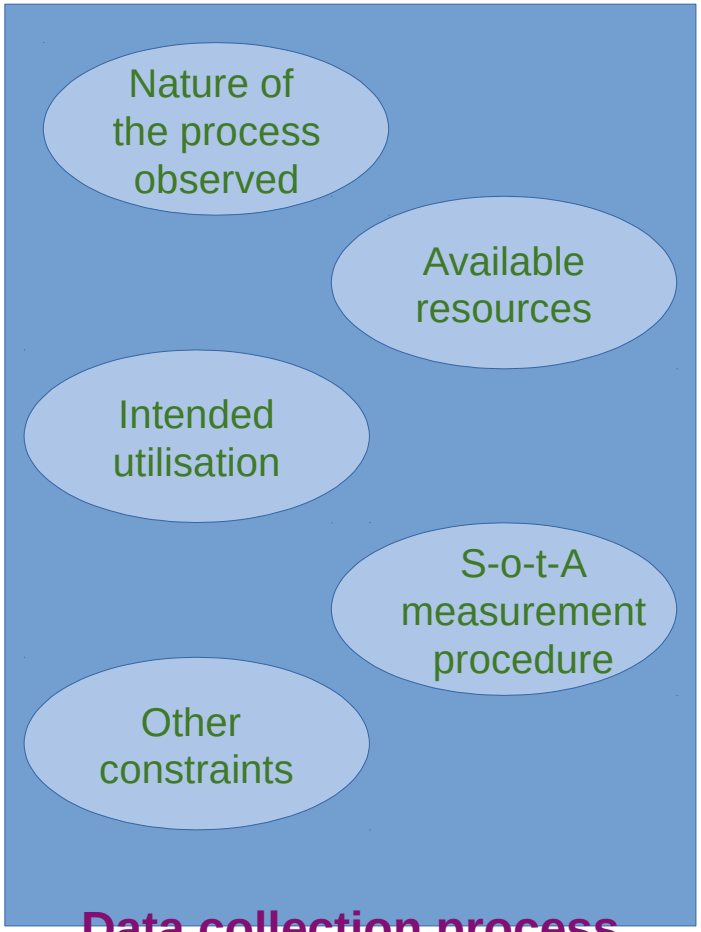
- Problem statement
- Data sets are mostly collected with best intentions, resulting with unexpected consequences.





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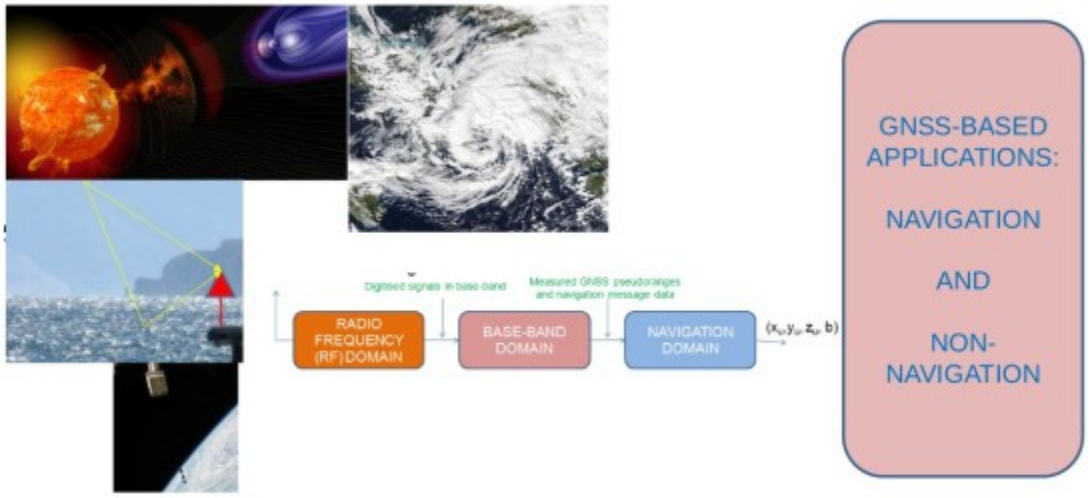
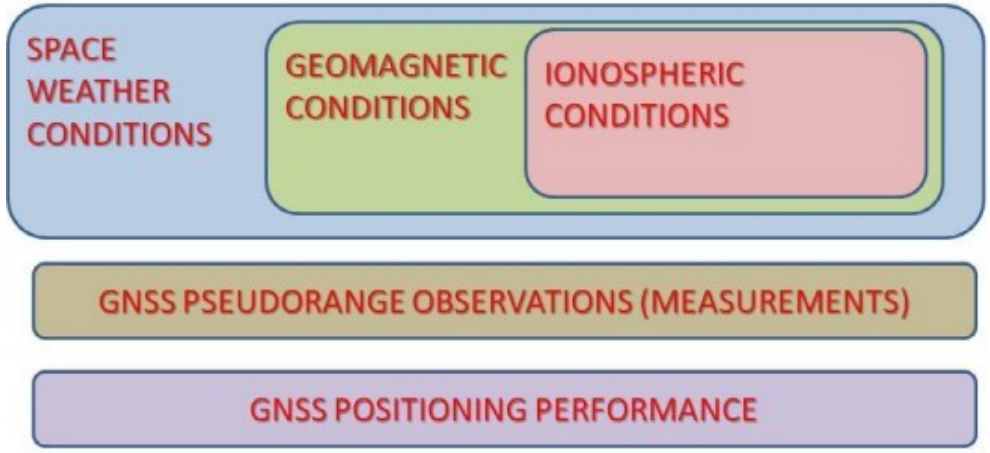
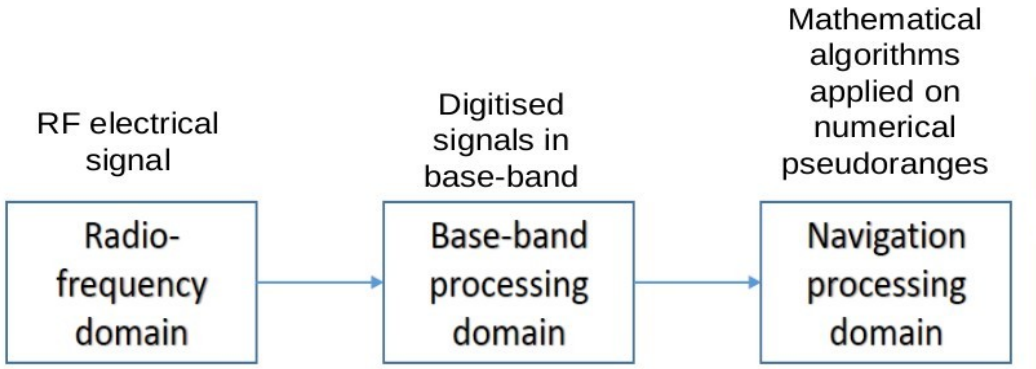
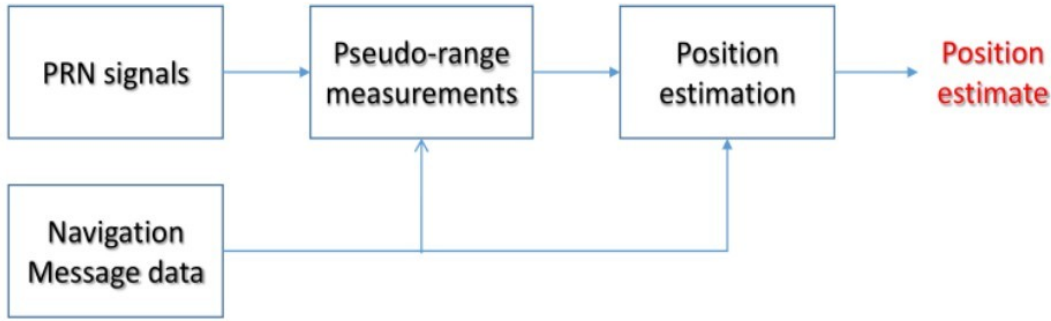
- Problem statement: development of a forecasting model of GNSS positioning performance deterioration caused by space weather and ionsopheric conditions



Space weather – GNSS positioning performance coupling model







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- Overview of data sources
- Issues: (i) bespoke scenario-related data access, (ii) systematic provision of data

Data sub-set	Indices (originally measured variables)	Source(s)
Solar activity data	SSN, SFD	NOAA (https://www.ngdc.noaa.gov/stp/spaceweather.html)
Geomagnetic condition data	Bx, By, Bz	INTERMAGNET (http://www.intermagnet.org/data-donnee/data-eng.php)
	Kp, Ap, Dst	NOAA (https://www.ngdc.noaa.gov/stp/spaceweather.html)
Ionospheric condition data	f0Es, f0F2	NOAA (https://www.ngdc.noaa.gov/stp/spaceweather.html))
	TEC, dTEC	derived from IGS RINEX observations (ftp://cddis.gsfc.nasa.gov/gnss/data/daily/)
	SID	Stanford University SID database (http://sid.stanford.edu/database-browser/)
GNSS positioning performance indices	GNSS northing, easting, vertical positioning errors	Derived from stationary IGS RINEX observations (ftp://cddis.gsfc.nasa.gov/gnss/data/daily/) or our won observations taken at Baška, Krk Island, Croatia

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- Overview of data content and formats
- Issues: (iii) numerous formats, (iv) different sampling rates, (v) various expressions of a time-stamp as sample's ID

```
     3.03           OBSERVATION DATA    M: Mixed            RINEX VERSION / TYPE
rinex ON            NSL                 20190511 201855 UTC PGM / RUN BY / DATE
                                                            MARKER NAME
                                                            MARKER TYPE
rinex ON User                                               OBSERVER / AGENCY
  4239788.0544  1305636.9814  4567459.9458                  APPROX POSITION XYZ
XXXXXXXX            HUAWEI              VTR-L09             REC # / TYPE / VERS
XXXXXXXX            VTR-L09                                 ANT
        0.0000        0.0000        0.0000                  APP
        0.0000        0.0000        0.0000                  ANT
G    4 C1C L1C D1C S1C                                      SYS
R    4 C1C L1C D1C S1C                                      SYS
E    4 C1C L1C D1C S1C                                      SYS
C    4 C1C L1C D1C S1C                                      SYS
  2019    05    11    18    19   13.9998285     GPS         TIM
                                                            END

> 2019 05 11 18 19 13.9998285  0 11
G01  24194485.606     -218815.425        3347.816          20.291
G08  20805905.371     -105873.542        1512.176          19.012
G10  20822259.650       75520.082       -1082.790          16.341
G11  23484184.637     -254866.483        3621.784          25.537
G14  24362694.358     -205237.942        3407.453          20.032
G16  24143319.1
G18  21885896.3
G22  24852718.3
G27  20477078.6
G32  23301588.5
R15  22823772.1
```

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# Longitude = 45.33
# Latitude = 17.68
#
# UTC_Offset = -23
# TimeZone = CET
#
# UTC_StartTime = 2015-03-17 00:00:00
```

```
DST0801Q01  000-012-011-008-007-005-003-005-006-005-005-007-007-006-007-006-008-008-007-006-004-005-003-003-003-006
DST0801Q02  000-001 000-001 001 004 003 003 004 004 007 005 004 004 003 003 002 000 004 005 006 006 005 001-007 003
DST0801Q03  000-007-007-005-005-004-003-002-002 001 002 002 001 001-001 001 000 001 004 004 004 004 004 003 003-000
DST0801Q04  000 004 006 009 008 006 006 004 004 004 004 005 007 008 006 007 013 013 014 013 013 016 016 021 037 010
DST0801Q05  000 031 021 020 010 011 011 015 016 002-017-008-001-006-014-015-020-017-012-006-013-016-025-025-014-003
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```

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1 18010125152133372323271010131 77 18 22  9  9 12  4  4  5 100.63---066.80
2 18010225152217 7 3 717102010 90  6  3  2  3  6  4  7  4  40.21---067.20
3 180103251523 0 710 7 310 3 0 40  0  3  4  3  2  4  2  0  20.00---068.30
4 180104251524 7 010 0 7 31310 50  3  0  4  0  3  2  5  4  30.00---067.20
5 180105251525 71713 7 7131020 93  3  6  5  3  3  5  4  7  40.21---067.00
6 18010625152613 0 7 0 3 0 3 3 30  5  0  3  0  2  0  2  2  20.00---067.10
7 18010725152710 0 0 0 3 7 7 3 30  4  0  0  0  2  3  3  2  20.00---067.60
8 1801082516 1 3 7231737302017153  2  3  9  6 22 15  7  6  90.52---068.00
9 1801092516 23723201320201717167 22  9  7  5  7  7  6  6  90.52---068.50
10 1801102516 313171010 310 3 0 67  5  6  4  4  2  4  2  0  30.10---068.10
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```

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#dataquality_average_v0.1=0.144428
#dataquality_max_v0.1=4.197576
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2015-03-17 00:00:05 3572599.78873
2015-03-17 00:00:10 3588448.06218
2015-03-17 00:00:15 3604296.33563
2015-03-17 00:00:20 3620144.60908
2015-03-17 00:00:25 3635992.88253
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2015-03-17 00:00:35 3667689.42943
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2015-03-17 00:00:45 3699385.97632
2015-03-17 00:00:50 3746122.73534
2015-03-17 00:00:55 3792859.49435
```

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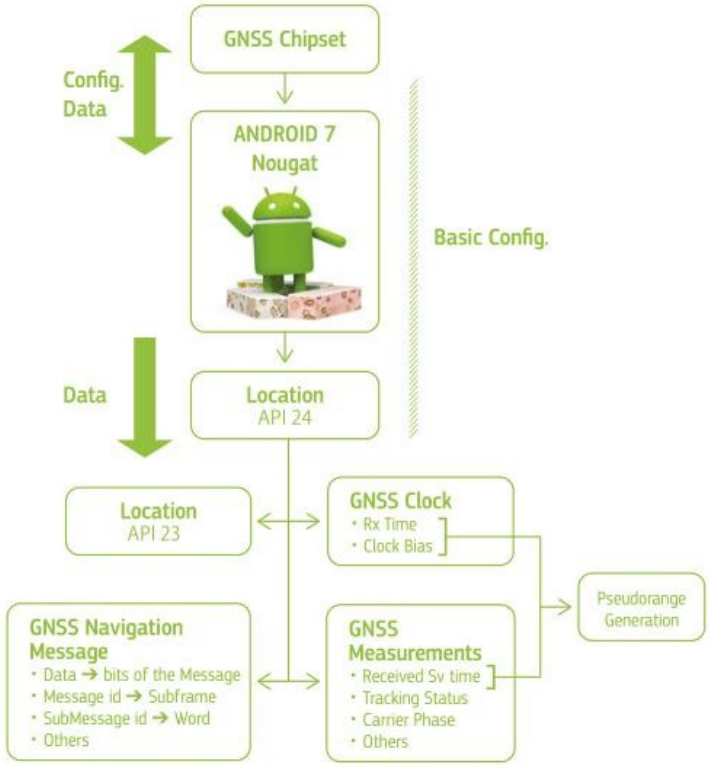
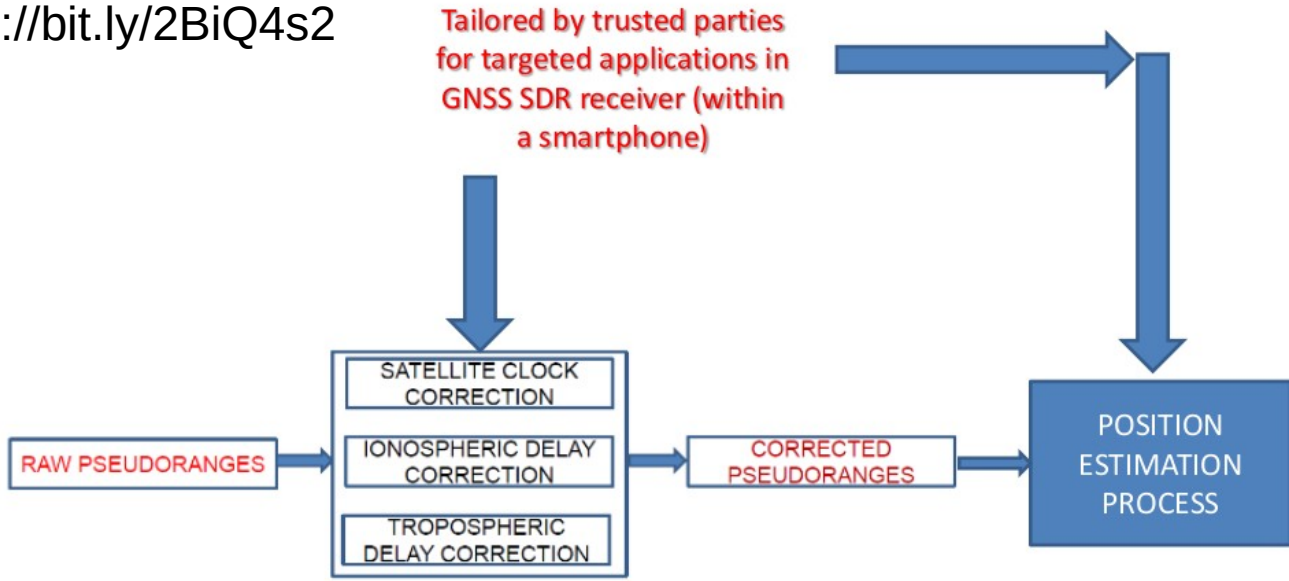
- Overview of data content and formats
- Utilisation of raw single- and dual-frequency GNSS pseudoranges provided through Android Location API (selected devices) – GSA Raw Measurement Task Force

Reference: GSA GNSS Raw Measurements Task Force. (2017). Using GNSS raw measurements on Android devices (white paper). European GNSS Agency. Prague, Czechia. Available at: http://bit.ly/2BiQ4s2





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- Methodology proposal

- (i-a) Structured description of space weather data applications to allow for systematic and seamless data utilisation
- (i-b) Categorisation of space weather data applications
- (i-c) Standardised terminology and onthology

- (ii) common agreement on data access procedure and methodology (incl. structures of web-addresses)

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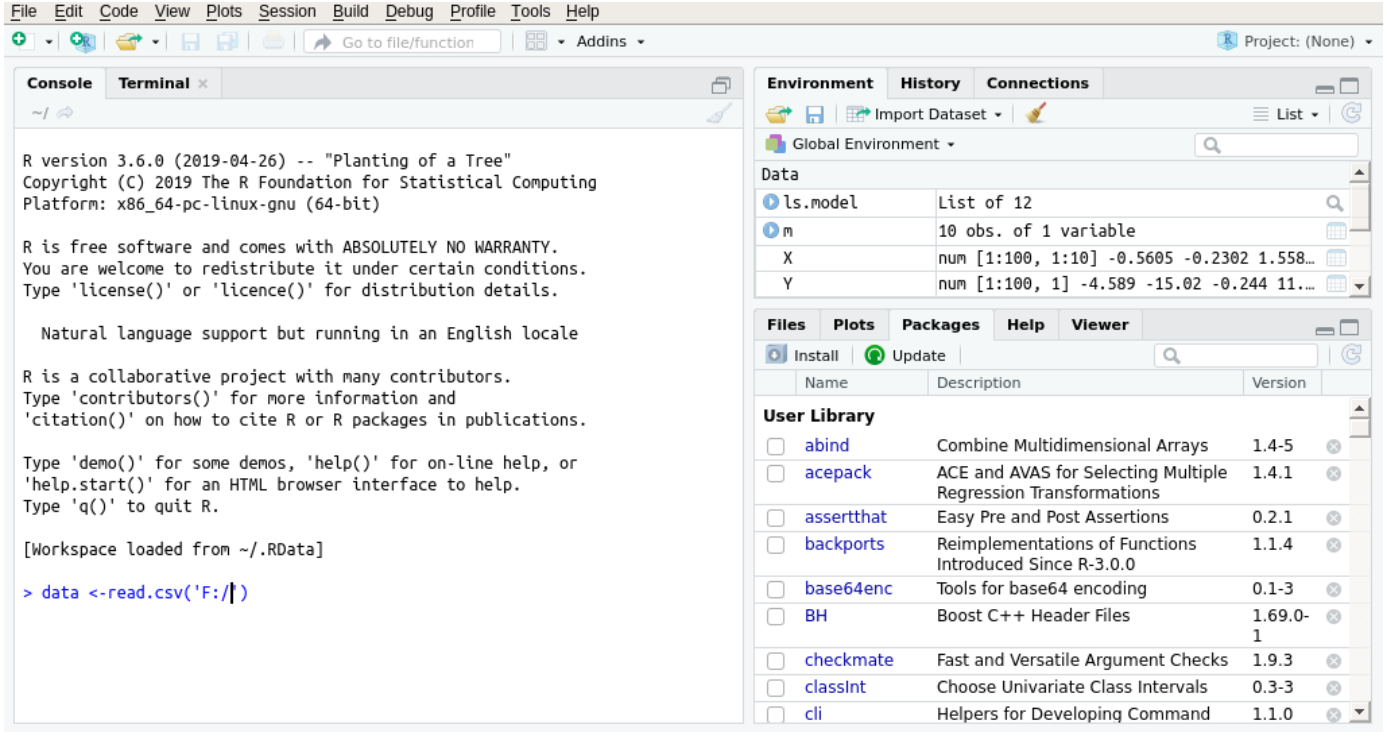
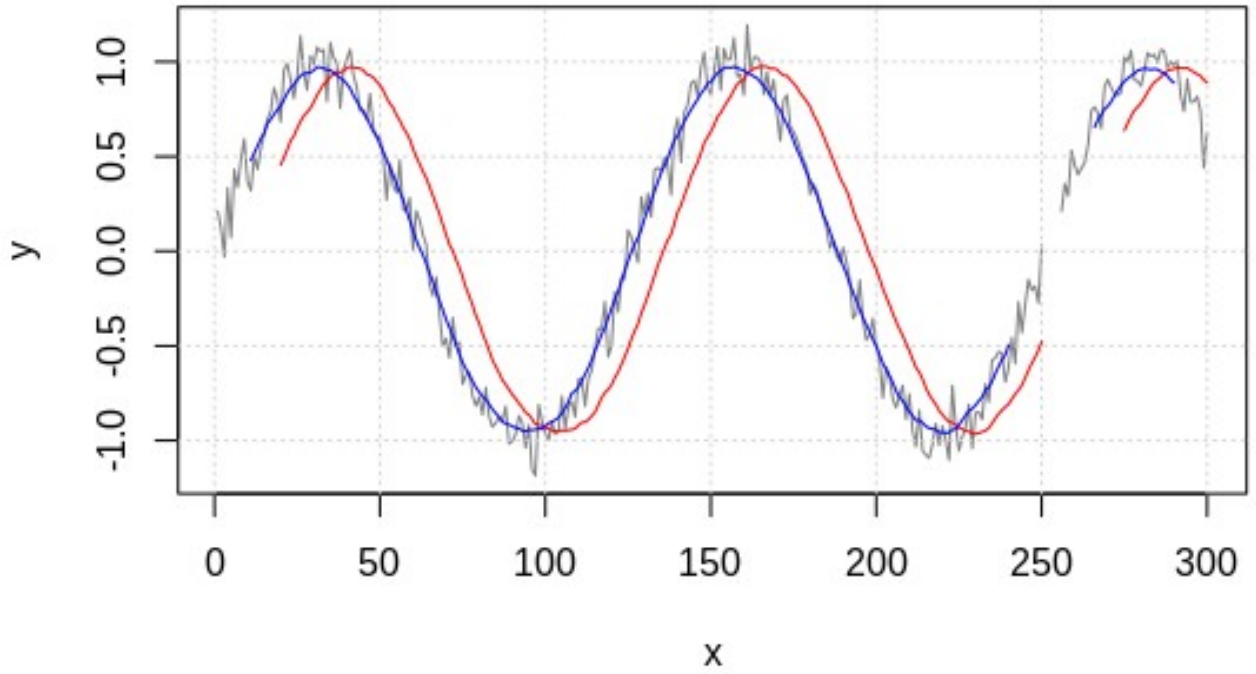
- Methodology proposal
- (iii) Set of dedicated data parsers have to be developed
- **R environment for statistical computing**
- Selection of R libraries in support of data wrangling (tidyr, tidyverse, dplyr, lubridate)

R is available as an open source software at: https://www.r-project.org/



- Methodology proposal
- (iv) Varying sampling rates should be treated with statistical methods, such as *Moving Average* (smoothing, filtering) – R package *smooth*



- (v) cross-discipline agreement on datum expression

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- Methodology demonstration

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- Recommendations

- 1. International collaboration on cross-disciplinary data format standardisation, considering environments for data processing
- 2. Description and categorisation of scenarios of space weather data utilisation
- 3. Capacity development in widely embraced and utilised computational environments
- 4. Research facilitation in the segment of efficient data preparation and data quality assessment

In appreciation of your kind attention!

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