

PACKMAN-Net: A Distributed, Open-Access and Scalable, Network of User-Friendly Space Weather Stations.

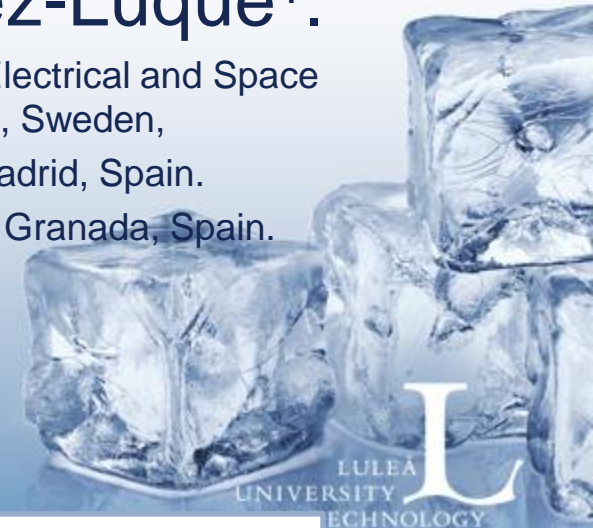
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Ramachandran¹ and J.-A. Ramirez-Luque¹.

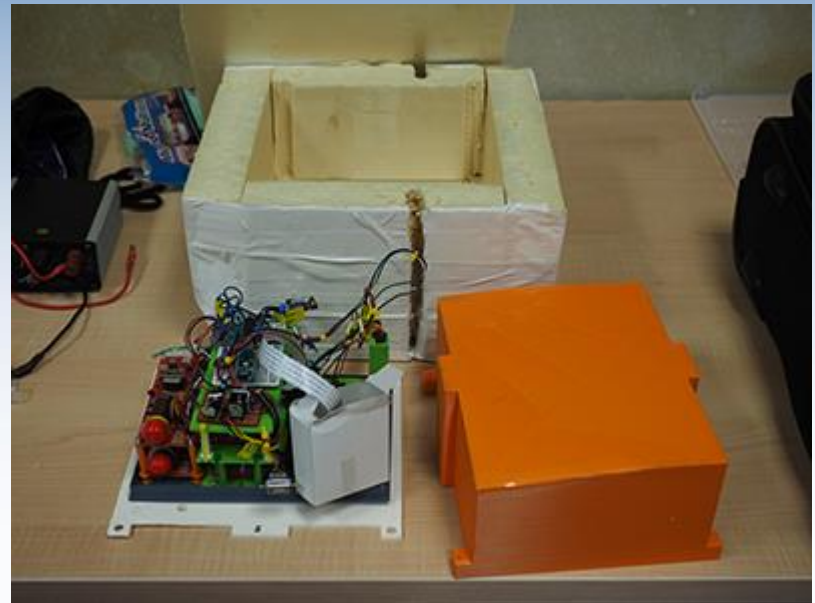
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²Centro de Astrobiología (INTA-CSIC), Torrejón de Ardoz, Madrid, Spain.

³ Instituto Andaluz de Ciencias de la Tierra (CSIC-UGR), Armilla, Granada, Spain.



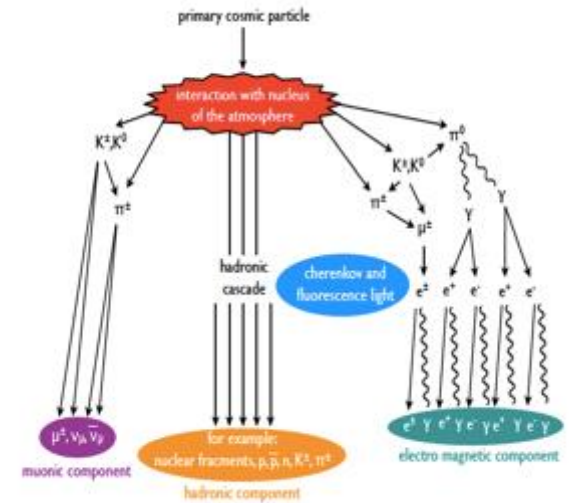
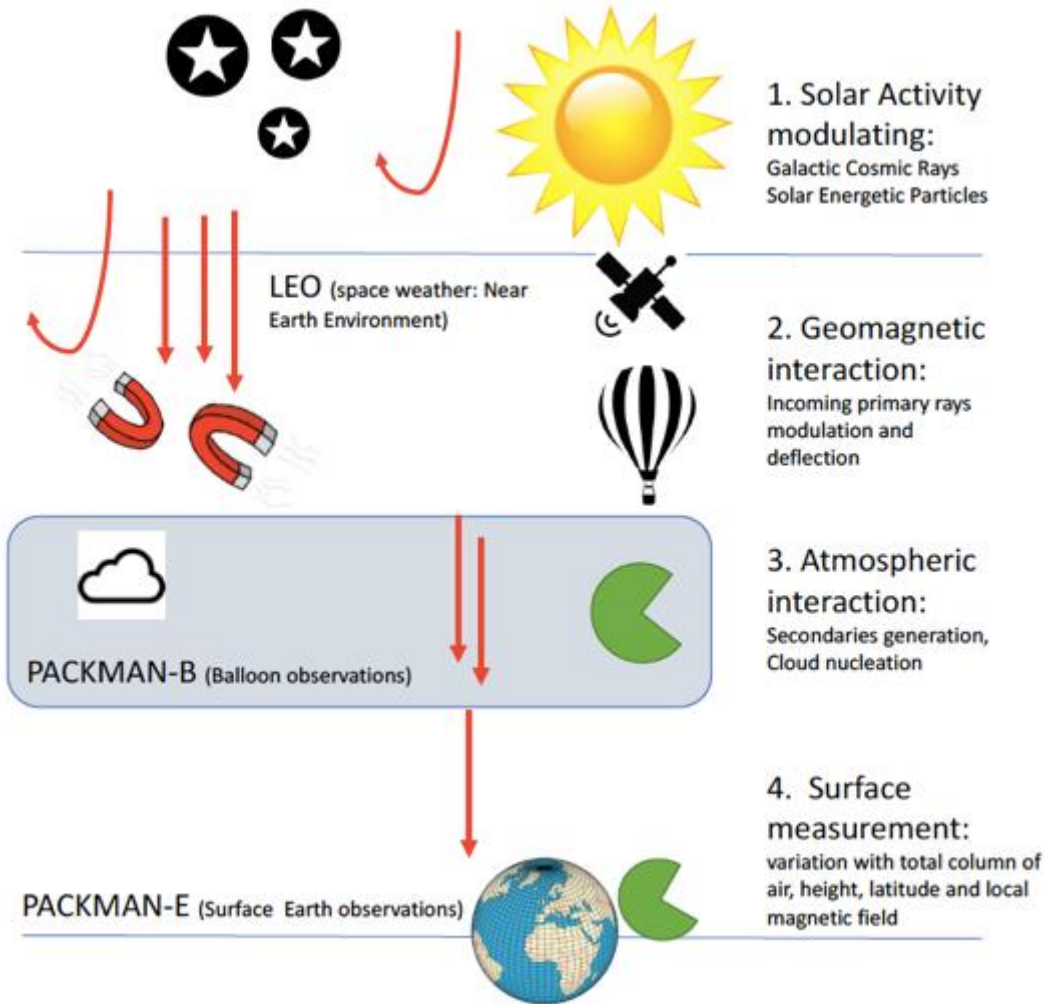
THE PACKMAN (Particle
Counter K-index Magnetic
Anomaly)
Instrument
Space Weather on Earth



The observations acquired by PACKMAN will be used to provide **open access, real time information**, for:

- 1) education and public awareness of space weather phenomena;
- 2) to compare with Earth climate observations;
- 3) to provide real-time information of space weather variability for potential damage to infrastructures (telecommunications, power generation facilities, aviation, transport, etc.);
- 4) to monitor natural radiation sources at multiple environments;
- 5) to monitor the variability of the Pfozter maximum height during different stages of solar activity and seasons and
- 6) This project may **serve as a reference for future scalable networks where multiple instruments are deployed at different sites or conditions and with different initiation times, and where the informational value increases by adhering to a common PDS4 format and analysing the data in a concurrent way.**

PACKMAN monitoring approach



Arctic balloon campaigns to monitor the variability of space radiation between 10 km and 40 km height. Complemented with surface measurements at multiple latitudes.

Atmospheric and surface observations

Atmosphere

- Orbiter based observations are available on-line, in almost real time (graphical).
- Ionosphere monitoring is available on-line (graphical)
- There is a lack of measurements of systematic radiation profiles in the lower layers of the atmosphere in the Arctic.

Surface

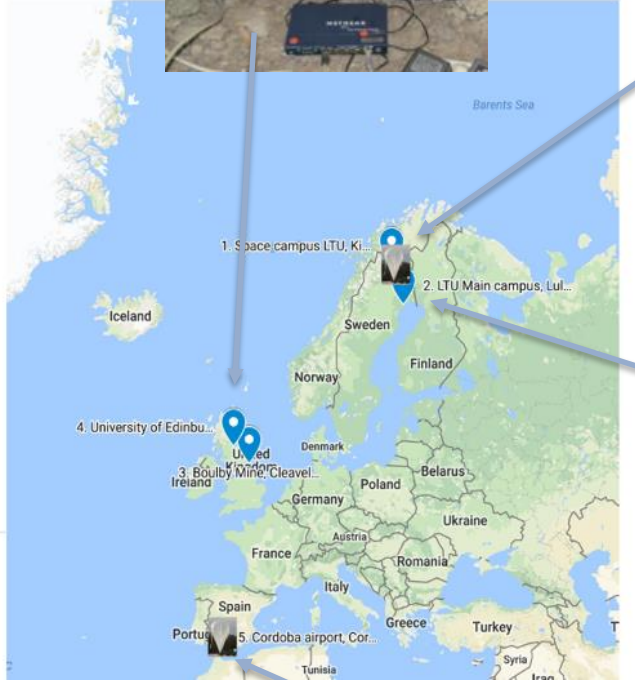
- Only neutron counters (from galactic cosmic rays) are available on-line (graphical).
- K-index (geomagnetic variability) is monitored as a proxy for solar activity at multiple latitudes.
- **It is more complex to have access to crude data in real time. These instruments are operated by scientific institutions.**

Purpose: deploy network of PACKMAN with real time on-line data access, deploy equivalent instrument on balloon campaign with access on-line to the data. Compare time-variability sequence from satellite to surface, and weather/climate records.

PACKMAN Locations

Untitled layer

- 1. Space campus LTU, Kiruna, Sweden
- 2. LTU Main campus, Luleå, Sweden
- 3. Boulby Mine, Cleaveland, United Kingdom
- 4. University of Edinburgh, United Kingdom
- 5. Cordoba airport, Cordoba, Spain
- 6. Esrange Space Center, Kiruna, Sweden



Initial deployment:

Through the initial deployment and testing phase, PACKMAN has demonstrated its operability at multiple latitudes and atmospheric heights:

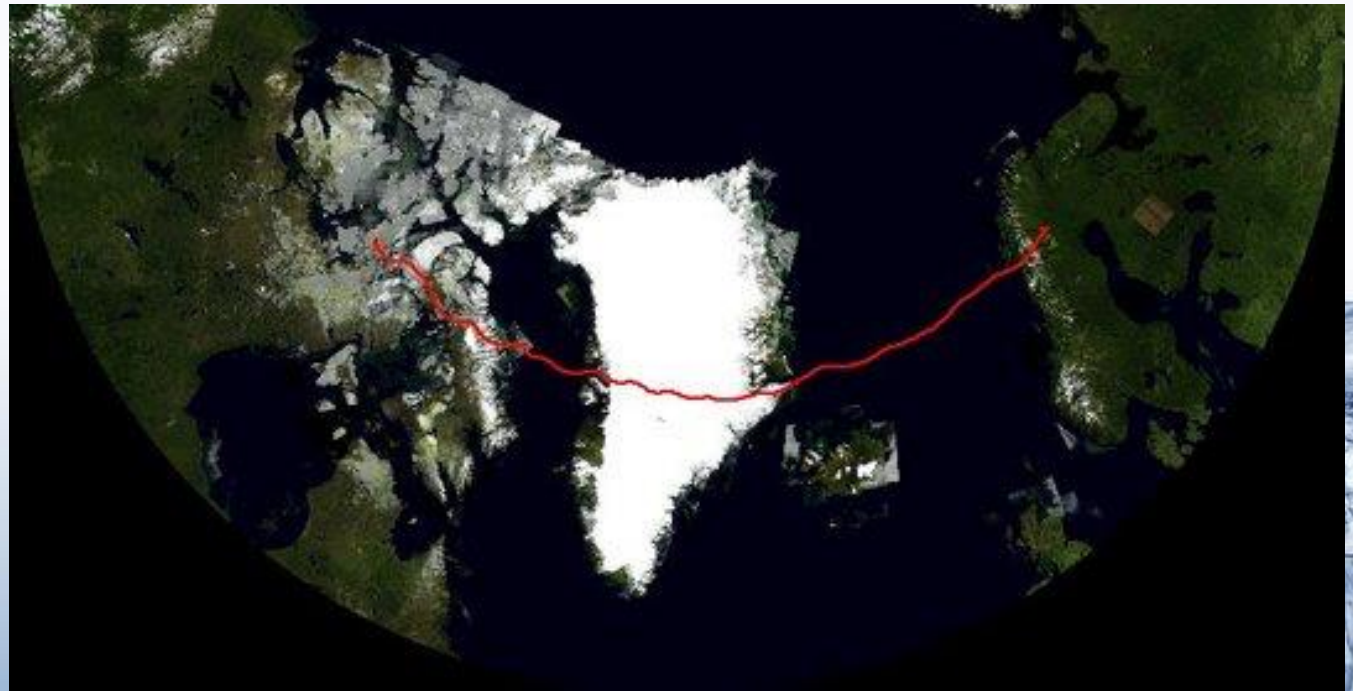
1. Space campus LTU, Kiruna, Sweden (67.84°N, 20.41°E, 390 m)
2. LTU Main campus, Luleå, Sweden (65.62°N, 22.14°E, 15 m)
3. Boulby Mine, Cleaveland, United Kingdom (54.56°N, 0.82°W, 93 m and -1.1 km)
4. University of Edinburgh, United Kingdom (55.94°N, 3.19°W, 98 m)
5. Cordoba airport, Córdoba, Spain (37.84°N, 4.84°W, 90 m to 27 km)
6. Esrange Space Center, Kiruna, Sweden (67.88°N, 21.12°E, 328 m to 27 km)



**Circumpolar long
duration
stratospheric
balloon campaigns**

**1 week duration
space weather
stratospheric
measurements.**

**Started from
ESRANGE
(Sweden) operated
by SSC.
HEMERA European
call for
instruments.**



User community

Space Weather Impacts on Earth

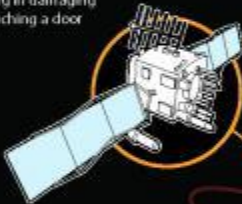
Global Positioning System (GPS)

Geomagnetic storms can impact the accuracy and availability of GPS by changing the ionosphere, the electrically charged layer of the atmosphere. A GPS signal must pass through from satellite to ground receiver. The ionosphere is the largest source of error in GPS positioning and navigation. These ionospheric disturbances are ever-present but can become severe during geomagnetic storms, resulting in range errors in excess of 100 feet, or even resulting in loss of lock on the GPS signal entirely. These errors can have significant impacts on precision uses of GPS such as navigation, agriculture, oil drilling, surveying, and timing.



Satellite Operations

There are thousands of satellites in orbit around Earth with applications in television and radio communications, meteorology, national defense, and much more. Space weather can affect these satellites in many ways. Solar radiation storms can cause spacecraft orientation problems by interfering with star trackers and by causing errors or damage in electronic devices. Geomagnetic storms can create a hazardous charging environment for satellites resulting in damaging electrostatic discharge, much like touching a door knob and getting that spark on a dry winter day. Geomagnetic storms also cause heating of the atmosphere, essentially causing it to expand, which results in more drag or slowing down of an orbiting satellite. In a worst case, space weather can cause the satellite to fail.



Space Operations

Astronauts and their equipment in space are bombarded with charged particle radiation. This radiation causes tissue or cell damage in humans. Space weather and solar radiation storms are of particular concern for activities outside the protection of Earth's atmosphere and magnetic field.



Electrons accelerated in the tail of the magnetosphere travel down the magnetic field lines.

Electrons collide with the upper atmosphere 50 to 300 miles above Earth.

Electrons exchange energy with the atmosphere causing the atmospheric atoms and molecules to higher energy levels. When the atoms and molecules relax back to lower energy levels, they release their energy in the form of light.

Aurora

The Aurora Borealis (Northern Lights) and Aurora Australis (Southern Lights) are the result of electrons colliding with Earth's upper atmosphere. The electrons are energized through acceleration processes in the downwind tail (nightside) of the magnetosphere. The accelerated electrons follow the magnetic field of Earth down to the polar regions where they collide with oxygen and nitrogen atoms and molecules in Earth's upper atmosphere. In these collisions, the electrons transfer their energy to the atmosphere, thus exciting the atoms and molecules to higher energy states. When they relax back to lower energy states, they release their energy in the form of light. The aurora typically forms 50 to 300 miles above the ground. Earth's magnetic field guides the electrons such that the aurora forms two ovals approximately centered at each magnetic pole.

THE COLORS OF THE AURORA

- Deep red from high altitude atomic oxygen
- Magenta from high altitude molecular nitrogen in sunlight
- Greenish yellow from lower altitude atomic oxygen
- Magenta from low altitude molecular nitrogen (not shown in the picture)



Aviation

Aircraft use High Frequency (HF) radio communication to stay in touch with ground controllers in remote areas such as over the oceans or over the poles. Solar flares can "black out" the use of HF on the dayside of earth and solar radiation storms can "black out" use of HF near the poles, impacting the aircraft's ability to stay in touch with the ground. Impacts to GPS systems can also significantly affect airline operations.

Power Grids

Geomagnetic storms result in electric currents in the magnetosphere and ionosphere as the area shaped by Earth's magnetic field is compressed and disturbed. The disturbed conditions create additional currents in long conductors on the ground such as overhead transmission lines or long pipelines. In the most extreme cases, these currents can cause voltage instability or damage to power system components, potentially resulting in temporary service disruptions, or even a widespread power outage.

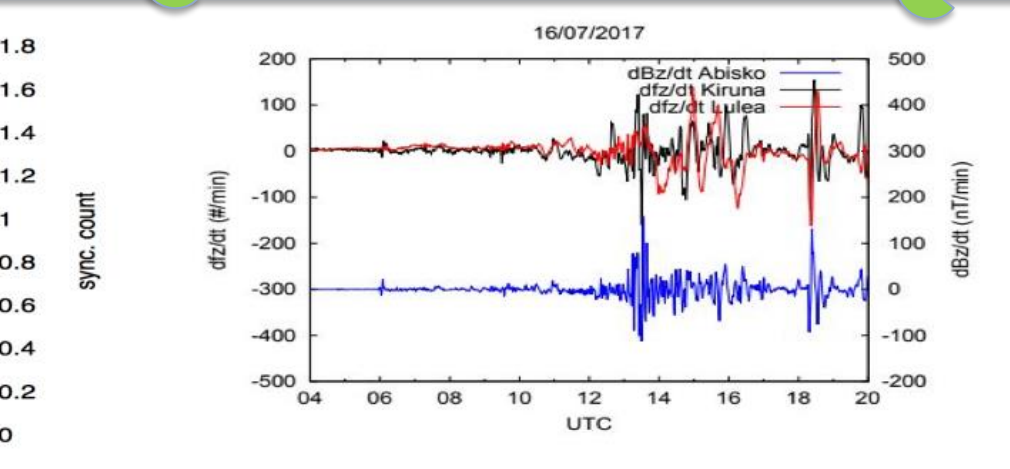
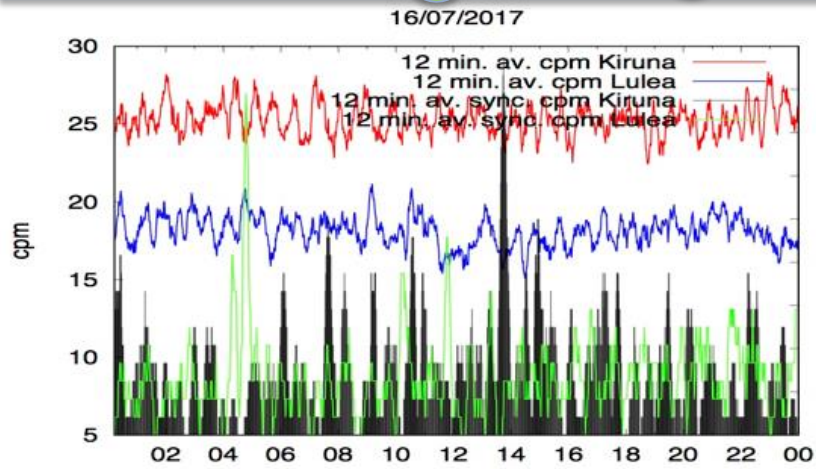
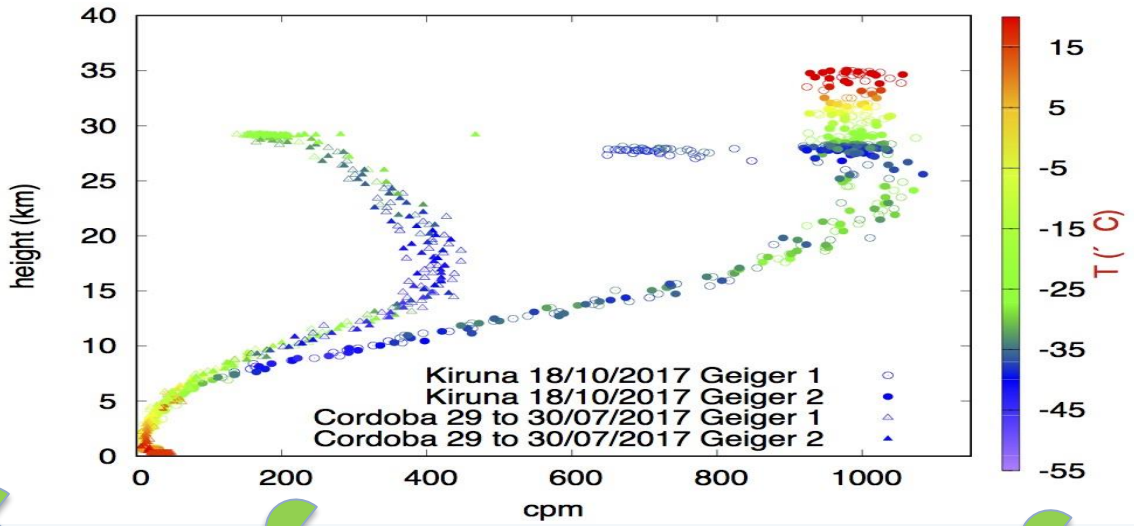


*Image source: Aurora Borealis taken from the International Space Station in April of 2012.

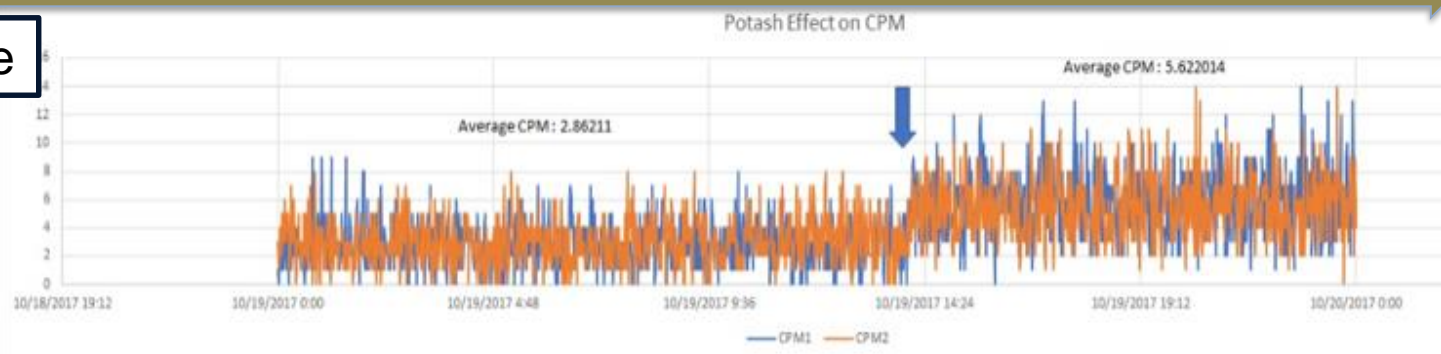


Planet atmosphere and orbit

Planet Surface



Planet sub-surface



Open access to planetary data

- Because of our heritage from the and the **REMS Mars Science Laboratory (NASA)** and the **HABIT ExoMars mission (ESA)**: the PACKMAN data will have a similar structure as the PDS4 protocol that is used by NASA/ESA for planetary data distribution.

Mars Science Laboratory (MSL)

August 1, 2014. MSL Release 6 includes new raw and derived data acquired on sols 450 through 583, along with revised versions of some previously released data.

August 7, 2014. Products from sols 450-583 have been added to the safed SAM EDR data set.

August 1, 2014. MSL Release 6 includes new raw and derived data acquired on sols 450 through 583, along with revised versions of some previously released data.

April 23, 2014. Products from sols 360-449 have been added to the safed SAM EDR data set.


#	Temp. Outside (C)	Temp. in Circuit#	Mag-X	#Mag/Z	Mag/Y	Humidity Outside
Temp. Outside (C)	Pressure (Pa)	Pressure (bar)	CPM	microSv/Hr	Temp.	
2017/06/03	20:50:33 23,59	22,45	32,63	101416,47		
1,0141547	24,37	47387	126791	64712	22	
2017/06/03	20:51:35 23,56	22,52	32,67	101417,23		
1,0141723	24,31	47389	126791	64712	20	
2017/06/03	20:52:37 23,54	22,59	32,7	101414,06		
1,0141408	24,31	47346	126891	64828	19	
2017/06/03	20:53:39 23,53	22,88	32,74	101411,72		
1,0141172	24,31	47348	126889	64828	23	
2017/06/03	20:54:41 23,52	22,88	32,76	101412,81		
1,0141281	24,31	47349	126889	64826	19	
2017/06/03	20:55:43 23,5	22,85	32,79	101412,85		
1,0141289	24,31	47350	126889	64826	18	



#	Temp. Outside (C)	Temp. in Circuit#	Mag-X	#Mag/Z	Mag/Y	Humidity Outside
Temp. Outside (C)	Pressure (Pa)	Pressure (bar)	CPM	microSv/Hr	Temp.	
2017/06/03	20:50:33 23,3	22,7	32,63	101421,11		
1,0142111	23,62	125510	61,60	26,81	101421,11	
2017/06/03	20:51:35 23,28	21,81	32,67	101422,63		
1,0142263	23,62	125510	62760	77229	21	0,168
2017/06/03	20:52:37 23,26	21,92	32,67	101422,63		
1,0142724	23,62	125610	62666	77229	21	0,168
2017/06/03	20:53:39 23,24	22,21	32,62	101427,24		
1,0142078	23,56	125596	62669	77521	19	0,152
2017/06/03	20:54:41 23,22	22,06	32,62	101420,78		
1,0142216	23,56	125591	62670	77522	18	0,144
2017/06/03	20:54:41 23,22	22,06	32,62	101422,16		
1,0142216	23,56	125591	62670	77518	18	0,144

PACKMAN data volume

- Data storage: 132 Kilobytes/Day
- PACKMAN data have 11 columns of measurement that start with a time stamp and latitude/coordinate/elevation information.
- Every new line corresponds to a new time stamp, with measuring interval of 1 minute in UTC.
- All PACKMAN nodes provide observations with the same time stamp, and same observation cadency.
- 365 days of continuous measurements/year.
- Scalable network:
 - Internal nodes uploading daily.
 - External nodes uploading at blocks of 3 months (pre-acceptance required).



#	Temp. in Circuit# Box (C)	Temp. Outside (C)	Pressure (Pa)	Humidity Outside %	Pressure (bar)	Temp.
Magnetometer (C)	Mag-X	#Mag				
2017/05/03	20:50:33	23,5				
1,0141647	24,37	4738				
2017/05/03	20:51:35	23,5				
1,0141723	24,31	4738				
2017/05/03	20:52:37	23,5				
1,0141408	24,31	4734				
2017/05/03	20:53:39	23,5				
1,0141281	24,31	4734				
2017/05/03	20:54:41	23,5				
1,0141289	24,31	4735				

#	Temp. in Circuit# Box (C)	Temp. Outside (C)	Pressure (Pa)	Humidity Outside %	Pressure (bar)	Temp.
Magnetometer (C)	Mag-X	#Mag/Z	Mag/Y	CPM	microSv/Hr	
2017/05/03	20:50:33	23,59	22,45	32,63	101416,47	
1,0141647	24,37	47387	126791	64712	22	0,176
2017/05/03	20:51:35	23,56	22,52	32,67	101417,23	
1,0141172	24,31	47389	126791	64712	20	0,16
2017/05/03	20:52:37	23,54	22,59	32,7	101414,08	
1,0141408	24,31	47346	126891	64828	19	0,152
2017/05/03	20:53:39	23,53	22,08	32,74	101411,72	
1,0141172	24,31	47348	126889	64828	23	0,184
2017/05/03	20:54:41	23,52	22,88	32,76	101412,81	
1,0141281	24,31	47349	126889	64826	19	0,152
2017/05/03	20:55:43	23,5	22,85	32,79	101412,89	
1,0141289	24,31	47350	126889	64826	18	0,144

PACKMAN data requirements

Data uploading (Instrument)

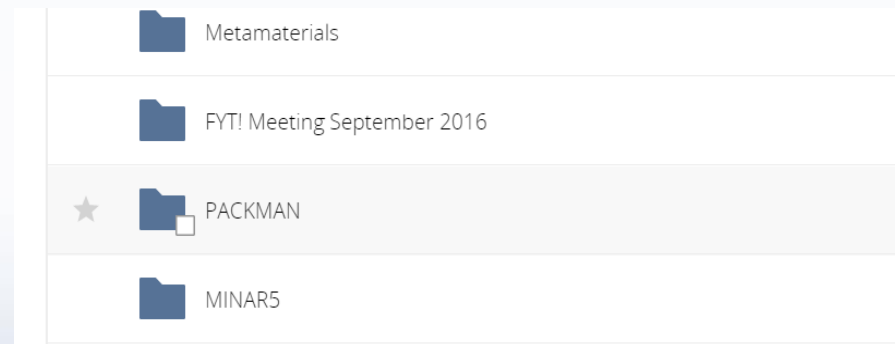
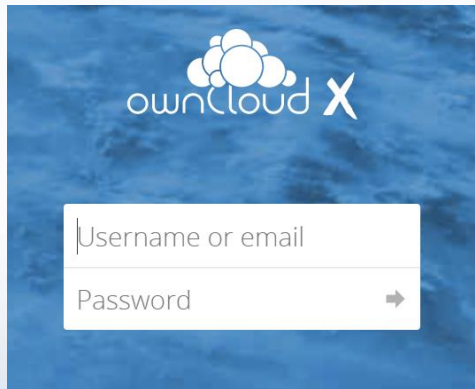
- **Open access** –“pre-authorized” users- data storage.
- Scalable (over time more nodes).
- **Automatic PDS4 labelling**

Data downloading (Science/ Infrastructures/ Education/ Outreach)

- Global: open access
- **Online tools for quick preliminary analysis** (online representation, online fast processing) and comparison of multiple nodes-data.
- Accessibility to multiple simultaneous instrument observations.

Open-access pre-authorized data uploading

- Owncloud: Private Owncloud server for third party users to upload their PACKMAN Data automatically using the official Owncloud client.



- Automation tools: Using Python scripts to create the repositories and put the data uploaded to owncloud and check new files everyday.

Labelling PDS4

- Label creation: Use of MakeLabelsPDS4 tool created by **Dan Scholes (PDS GeoSciences Node)** using Excel to populate the PDS4 XML fields over XML Templates

A	B	C	D	E	F	G	H	I	J	K
spectrum_id	file name	create_date	lab_name	lab_desc	instr1_name	instr1_id	instr2_name	instr2_id	meas1_date	
Spectra ID	File Name	Creation Date (YYYY-MM-DD)	Laboratory Name	Laboratory Description	Instrument #1 Name	Instrument #1 ID	Instrument #2 Name	Instrument #2 ID	Measurement #1 Date (YYYY-MM-DD)	
spectra_id1	spectra1.dat	2000-01-02	Lab Name 1	University 1 laboratory	Lab 1 Bidirectional Reflectance Spectrometer	bdrs.lab1			2000-01-02	
spectra_id2	spectra2.dat	2001-01-02	Lab Name 2	University 2 laboratory	Lab 2 Bidirectional Reflectance Spectrometer	bdrs.lab2			2001-01-02	
spectra_id2	spectra3.dat	2003-01-03	Lab Name 3	University 3 laboratory	Lab 3 Bidirectional Reflectance Spectrometer	bdrs.lab3			2003-01-03	

1	2018-01-16 00:00:13	1, 4, 0	1133.07,15.69,35.69,30.69,124282.0	84606.00	86544.00
2					
3	2018-01-16 00:01:14	3, 3, 0	1132.63,15.68,35.73,30.69,124284.0	84604.00	86543.00
4					
5	2018-01-16 00:02:14	5, 4, 0	1132.95,15.66,35.75,30.69,124284.0	84607.00	86546.00
6					
7	2018-01-16 00:03:15	1, 3, 0	1132.89,15.66,35.75,30.69,124285.0	84610.00	86543.00
8					
9	2018-01-16 00:04:16	1, 2, 0	1132.88,15.63,35.75,30.75,124286.0	84614.00	86547.00
10					
11	2018-01-16 00:05:17	1, 5, 0	1132.92,15.63,35.74,30.75,124286.0	84620.00	86546.00
12					
13	2018-01-16 00:06:18	1, 3, 0	1132.76,15.65,35.76,30.75,124287.0	84621.00	86549.00
14					
15	2018-01-16 00:07:19	4, 2, 0	1132.91,15.67,35.76,30.75,124287.0	84631.00	86550.00
16					
17	2018-01-16 00:08:20	2, 3, 0	1132.89,15.62,35.79,30.75,124289.0	84634.00	86550.00
18					
19	2018-01-16 00:09:20	0, 4, 0	1132.90,15.60,35.81,30.75,124291.0	84639.00	86548.00
20					
21	2018-01-16 00:10:21	4, 0, 0	1132.88,15.60,35.80,30.75,124292.0	84640.00	86551.00



PACKMAN Data File

```

1 <?xml version="1.0" encoding="UTF-8"?>
2 <!-- this is an abbreviated xml example -->
3 <Product_Observational>
4   <Identification_Area>
5     <logical_identifier urn:nasa:pds:sample:reflectance:1--><{spectrum_id}>--></logical_identifier>
6     <version_id:0/version_id>
7     <title:Example 1--><{spectrum_id}>--></title>
8     <information_model_version:1.6.0.0/information_model_version>
9     <product_class:Product_Observational/product_class>
10    <Modification_History>
11      <Modification_Detail>
12        <modification_date>1--><{CurrentDate}>--></modification_date>
13        <version_id:0/version_id>
14      </Modification_Detail>
15    </Modification_History>
16  </Identification_Area>
17  <Observation_Area>
18    <Time_Coordinates>
19      <!-- Show if: [meas1_date] equals [inapplicable|missing|unknown] -->
20      <start_date_time><{start="true" nilReason="">--><{meas1_date}>--></start_date_time>
21      <!-- End of Show if: [meas1_date] equals [inapplicable|missing|unknown] -->
22      <!-- Show if: [meas1_date] not equals [inapplicable|missing|unknown] -->
23      <start_date_time>1--><{meas1_date}>--></start_date_time>
24      <!-- End of Show if: [meas1_date] not equals [inapplicable|missing|unknown] -->
25      <!-- Show if: [meas1_date] equals [inapplicable|missing|unknown] -->
26      <stop_date_time><{start="true" nilReason="">--><{meas1_date}>--></stop_date_time>
27      <!-- End of Show if: [meas1_date] equals [inapplicable|missing|unknown] -->
28      <!-- Show if: [meas1_date] not equals [inapplicable|missing|unknown] -->
29      <stop_date_time>1--><{meas1_date}>--></stop_date_time>
30      <!-- End of Show if: [meas1_date] not equals [inapplicable|missing|unknown] -->
31    </Time_Coordinates>
32    <Observing_System>
33      <name>1--><{lab_name}>--></name>
34      <description>1--><{lab_desc}>--></description>
35    </Observing_System_Component>
36    <name>1--><{instr1_name}>--></name>
37    <type>Instrument</type>
38    <Internal_References>
39      <ltid_reference urn:nasa:pds:context:instrument:1--><{instr1_id}>--></ltid_reference>
40    </Internal_References>
41    </Observing_System_Component>
42    <!-- Hide if not populated: [instr2_id] -->
43    <Observing_System_Component>
44      <name>1--><{instr2_name}>--></name>
45      <type>Instrument</type>
46      <Internal_References>
47        <ltid_reference urn:nasa:pds:context:instrument:1--><{instr2_id}>--></ltid_reference>
48      </Internal_References>
49    </Observing_System_Component>
50  </Observation_Area>
51  <!-- End of Hide if not populated: [instr2_id] -->
52  </Observing_System>
53  </Observation_Area>
54  </File_Area_Observational>
55  <File>
56    <file_name>1--><{file_name}>--></file_name>
57    <creation_date_time>1--><{create_date}>--></creation_date_time>
58    </file>
59  </File_Area_Observational>
60 </Product_Observational>
61

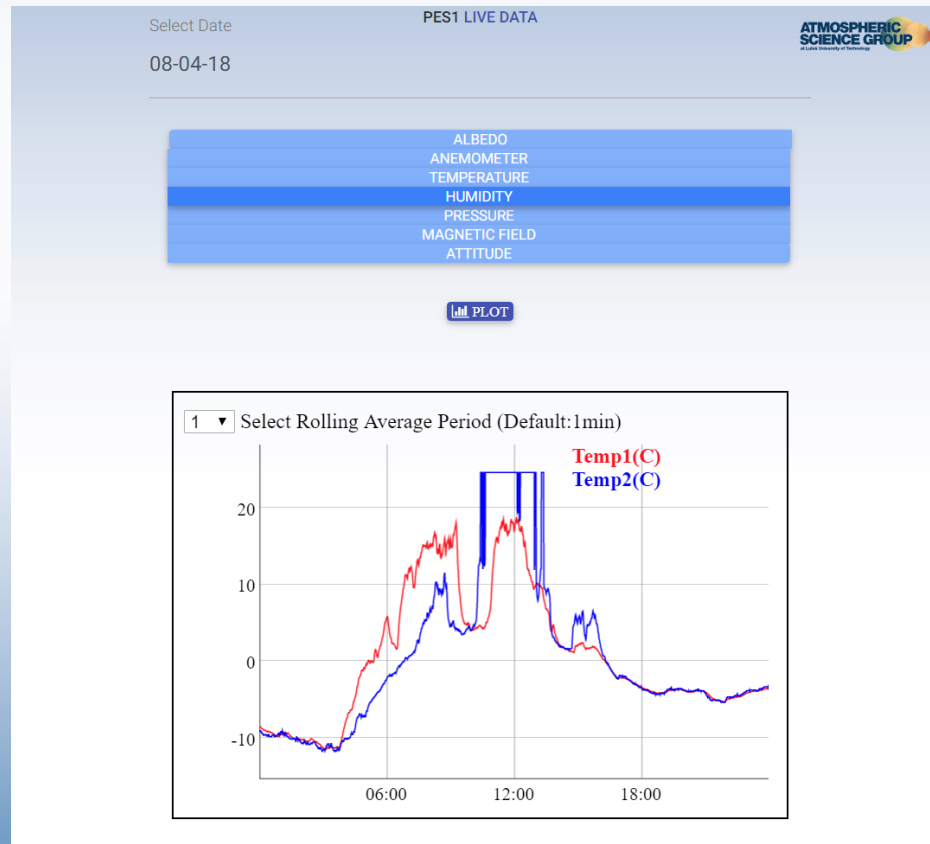
```

XML Template Example →



Online quick analysis: cross-instrument comparison (multi latitud)

- Online data visualization
- (<https://atmospheres.research.ltu.se/pes1>)



Online plotting of
different variables using →
DYGRAPHS API
(www.dygraphs.org)



Summary: PACKMAN-Net

- This is an example of **planetary instrumentation** relevant data (Space Weather) in our planet which needs a **dedicated scalable data archiving and processing architecture** that adheres to the PDS4 standard.
- Furthermore, this project may be used to **benchmark** the design of archiving, scalable, networks of future planetary instrumentation observations of the Moon or Mars or Earth orbiters.
- This project will bridge the gap between society and research, adding **new stake holders** such as teaching institutions (high schools, universities), or industry and infrastructures representatives.