PIONEER: open wireless sensor network for smart environmental monitoring of remote areas

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EGU General Assembly 2020

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04 May 2020 08:30–10:15

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PIONEER
OPen WIreless OzoNe SEnsor NEtworRk
for smart environmental monitoring of remote areas

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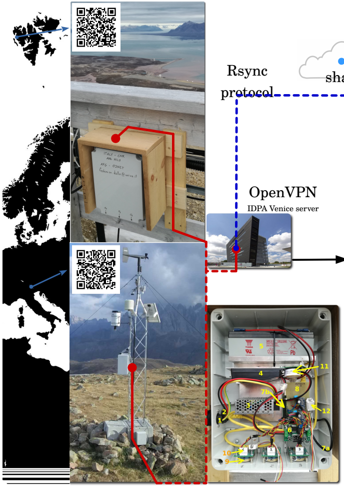
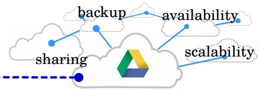
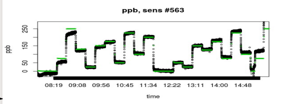




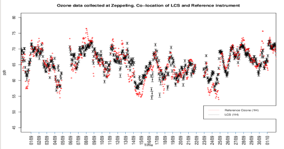
Rsync protocol

OpenVPN
IDPA Venice server

Laboratory calibration



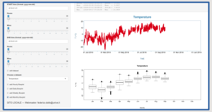
Field calibration



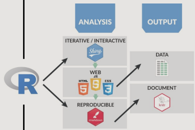
Acknowledgement

The project O3NET (RIS-ID 10940) was nanced by the Svalbard Science Forum (SSF) through an Arctic Field Grant (AFG)

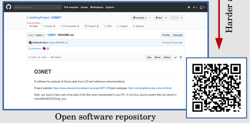
Development of a real-time air quality validation protocol and guidelines for near-surface ozone measurement in remote areas with low-cost sensors.



Interactive web page



Automatic routines for data processing



Open software repository

Easier and user friendly

Harder and low level

PIONEER: open wireless sensor network for smart environmental monitoring of remote areas

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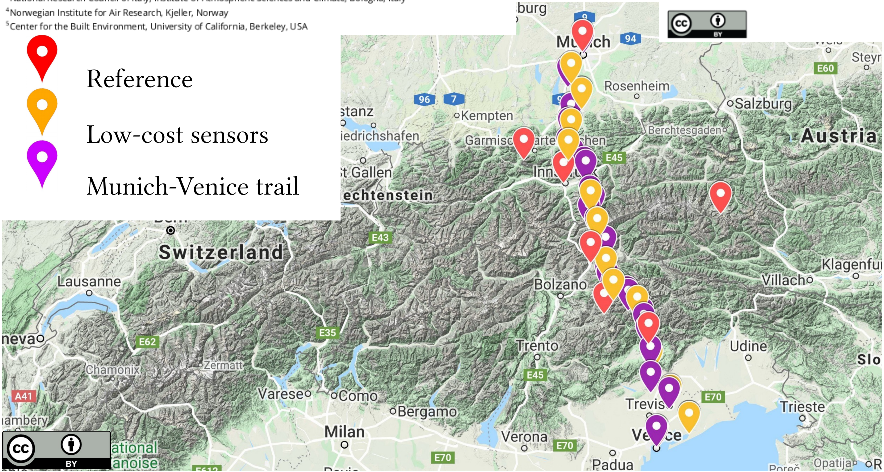

Summary part 1/3

The adoption of air quality low-cost sensors network is of a great interest for citizen society and scientific community. Many studies have been conducted in recent years to address some of the critical aspects of such networks, such as data quality, but while most of these study are conducted in the built environment, there is a lack of studies in remote regions of the Earth.

Monitoring remote areas of the planet such as the Alps and Polar regions is of critical importance as these are the most affected by Climate Change and the development of autonomous, rugged low-cost wireless sensor network (WSN) could be of a great help in the support of well known international programs such as the Global Atmospheric Watch (GAW) network.

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Summary part 2/3

In the following are summarized the results (papers in preparation) obtained using a low-cost sensing system developed for evaluating tropospheric Ozone in co-location with reference-grade instrumentation present at the Zeppelin Observatory in Svalbard and the Col Margherita Observatory in the Italian Eastern Alps.

The sensing system mounts four equivalent commercial electrochemical sensors (Alphasense OX-B431) that have been calibrated in a GAW reference laboratory prior to field deployment.

This work demonstrate the methodology that can be implemented to obtain useful data from a low-cost sensory system and the strategy to scale the project into a wide sensory network to be used in remote harsh environment.

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Summary part 3/3

PIONEER will exploit the existing open source technologies and commercial low-cost sensors to provide a LCS-WSN systems for long term climate data collection, a cloud-assisted database for time series collection and management, a web portal for uploading, displaying, performing statistical analysis and downloading records and metadata in a fully open access fashion, acomprehensive open source repository with tools, guidelines and application developed. The software will be open-source and released under copyleft license, thus allowing the complete reproducibility of all the developed devices and tools.

https://www.facebook.com/pioneerBerkeleyUnive/

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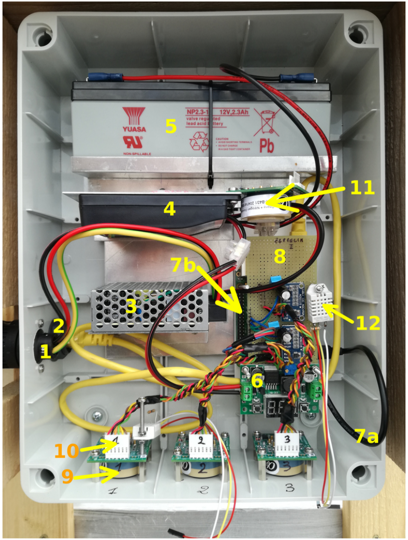
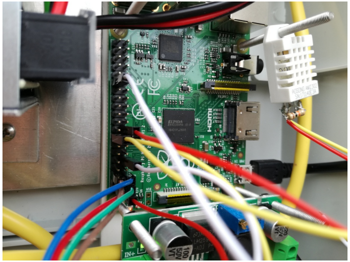


1. AC power wires
2. ethernet wire
3. power supply
4. charge regulator
5. 12 V, 2.3 Ah battery
6. DC/DC. 12 to 5 VDC
7. a) USB power wire for the b) **Raspberry Pi**
8. DAQ - **Data acquisition**
9. **Alphasense Ozone Low-Cost Sensors (LCSs)**
10. sensor plug
11. **“blank” sensor**
12. **T&RH sensors**

Raspberry Pi



Raspberry Pi is a low-cost small single-board computer

+ Linux OS
+ many free software libreries available
+ easy to replace
+ you can buy online
+ $\approx$ 40 EU
– not optimized (multi-purpose)
– “high” consumption
  (80 mA (0.4 W) up to 950 mA (5.0 W)!)

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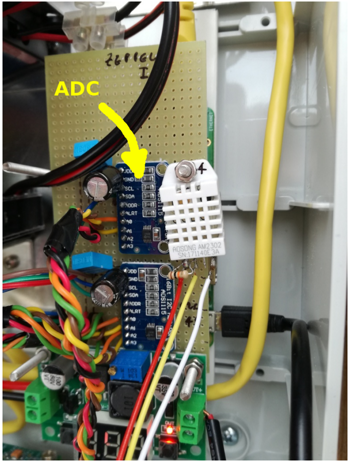
ADS1115 16-Bit analog-to-digital converter(ADC)



- wide supply range: 2.0V to 5.5V
- low current consumption: 150μA
- programmable data rate: 8-860 Hz
- internal low-drift voltage reference
- internal oscillator and PGA
- I2C interface: pin-selectable addresses
- four single-ended or two differential inputs
- you can buy online
- free software libreries available for RPi
- $\approx$ 15 EU

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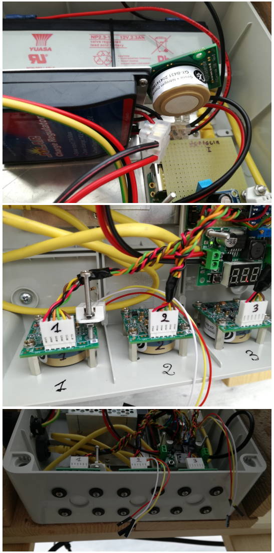
Alphasense Ozone Sensors



- \+ easy to replace
- \+ you can buy online
- \+ $\approx$ 150 EU
- ? reliable? Here some results from the **laboratory calibration**, from **field tests** and from **literature**.
- * a "blank" sensor is leaved inside the system with the aim of evaluating the stability of the calibration in time.

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Temperature and Relative Humidity

+ easy to replace
+ easy to buy online
+ 0-100% $\pm$ 2-5% RH
+ -40 to 80 ^{o}C $\pm$0.5 ^{o}C
+ $\approx$ 10 EU

*There are plenty of LCSs that can be found on-line. E.g. https://www.adafruit.com/.

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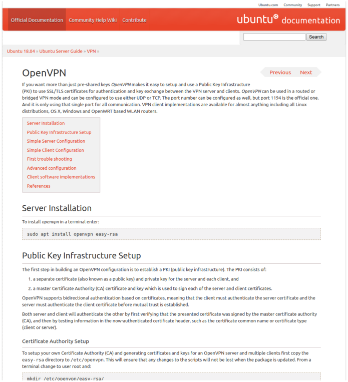
Using OpenVPN to build a network



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OpenVPN

Previous Next

If you want more than just pre-shared keys *OpenVPN* makes it easy to setup and use a Public Key Infrastructure (PKI) to use SSL/TLS certificates for authentication and key exchange between the VPN server and clients. *OpenVPN* can be used in a routed or bridged VPN mode and can be configured to use either UDP or TCP. The port number can be configured as well, but port 1194 is the official one. And it is only using that single port for all communication. VPN client implementations are available for almost anything including all Linux distributions, OS X, Windows and OpenWRT based WLAN routers.

- Server Installation
- Public Key Infrastructure Setup
- Simple Server Configuration
- Simple Client Configuration
- First trouble shooting
- Advanced configuration
- Client software implementations
- References

Server Installation

To install *openvpn* in a terminal enter:

```
sudo apt install openvpn easy-rsa
```

Public Key Infrastructure Setup

The first step in building an OpenVPN configuration is to establish a PKI (public key infrastructure). The PKI consists of:

1. a separate certificate (also known as a public key) and private key for the server and each client, and
2. a master Certificate Authority (CA) certificate and key which is used to sign each of the server and client certificates.

OpenVPN supports bidirectional authentication based on certificates, meaning that the client must authenticate the server certificate and the server must authenticate the client certificate before mutual trust is established.

Both server and client will authenticate the other by first verifying that the presented certificate was signed by the master certificate authority (CA), and then by testing information in the now-authenticated certificate header, such as the certificate common name or certificate type (client or server).

Certificate Authority Setup

To setup your own Certificate Authority (CA) and generating certificates and keys for an OpenVPN server and multiple clients first copy the `easy-rsa` directory to `/etc/openvpn`. This will ensure that any changes to the scripts will not be lost when the package is updated. From a terminal change to user root and:

```
mkdir /etc/openvpn/easy-rsa/
```

- "OpenVPN provides flexible VPN solutions to secure your data communications, whether it's for Internet privacy, remote access for employees, securing IoT, or for networking Cloud data centers."
- Each station is provided with a certificate to join a secured network where data can be shared
- There is no need to know the gateway with which the station is connected to the Internet

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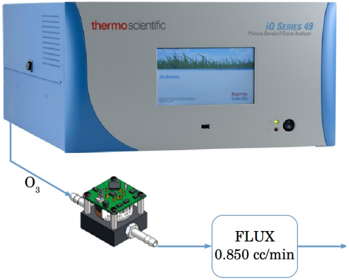
LCSs Calibration part 1/2

LCSs have been calibrated at ISAC-CNR headquarters comparing mV output from LCSs with reference Ozone concentration produced with the Thermo Scientific Model 49i-PS Ozone Primary Standard.



→ Calibration procedure used for reference-grade instruments used in the WMO network

- precision of 1 ppb
- zero noise of 0.25 ppb
- O_3 span from 0-250 ppb
- ≈23 °C
- ≈50% RH
- 21 step of random concentration
- each step last for 20 min
- total calibration time = $\frac{7hr}{LCS}$

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LCSs Calibration part 2/2

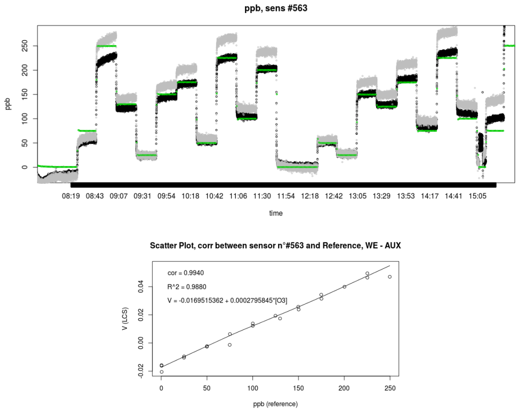

Figure: Voltage data of the low-cost sensor (#563) are calculated as concentration (black) and plotted against the reference (green). Concentration obtained by using intercept and regression coefficient provided by Alphasense are also shown (grey).

An example of sensor's response in respect to the Ozone concentration is presented. A simple linear model

$$V_{([O_3])} = \beta_0 + \beta_1 \cdot [O_3] \quad (1)$$

where β_0 is the intercept and β_1 is the regression coefficient related to ozone concentration is sufficient to obtain a good agreement between the reference and the LCS.

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Field Calibration part 1/3

Installation of the sensing system was carried out the 25th May 2018 at the Col Margherita Observatory and at the 3rd August 2018 at the Zeppelin Observatory in collaboration with the Norwegian Polar Institute (NPI) personnel.

Figure: Col Margherita Observatory 46.36683 N, 11.79192 E, 2543 m.a.s.l.

Figure: Zeppelin Observatory 78.90806 N, 011.88139 E, 475 m.a.s.l.

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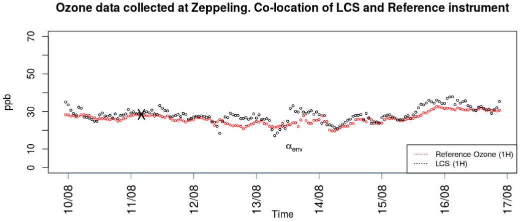
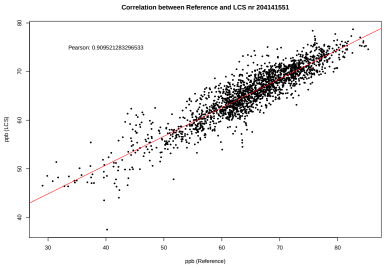
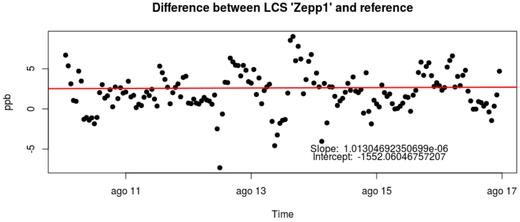
Field Calibration part 2/3, the Svalbard case study







$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \sigma_Y}$$

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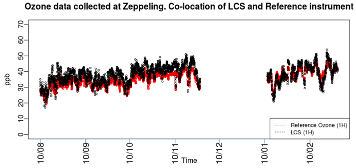
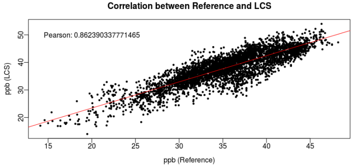
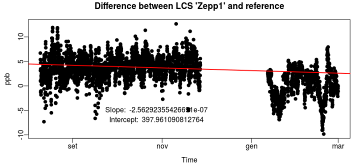
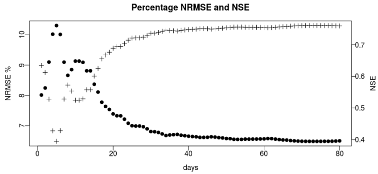
Field Calibration part 3/3, the Svalbard case study









$$NRMSE_{\%} = \sqrt{\frac{\sum_{t=1}^{T^{tot}} (x_{ref,t} - x^{c}_{lcs,t})^2}{T^{tot}}} \cdot \frac{1}{\bar{x}_{ref,T^{tot}}} \%$$

$$NSE^{tot} = 1 - \frac{\sum_{t=1}^{T^{tot}} (x_{ref,t} - x^{c}_{lcs,t})^2}{\sum_{t=1}^{T^{tot}} (x_{ref,t} - \bar{x}_{ref,t})^2}$$

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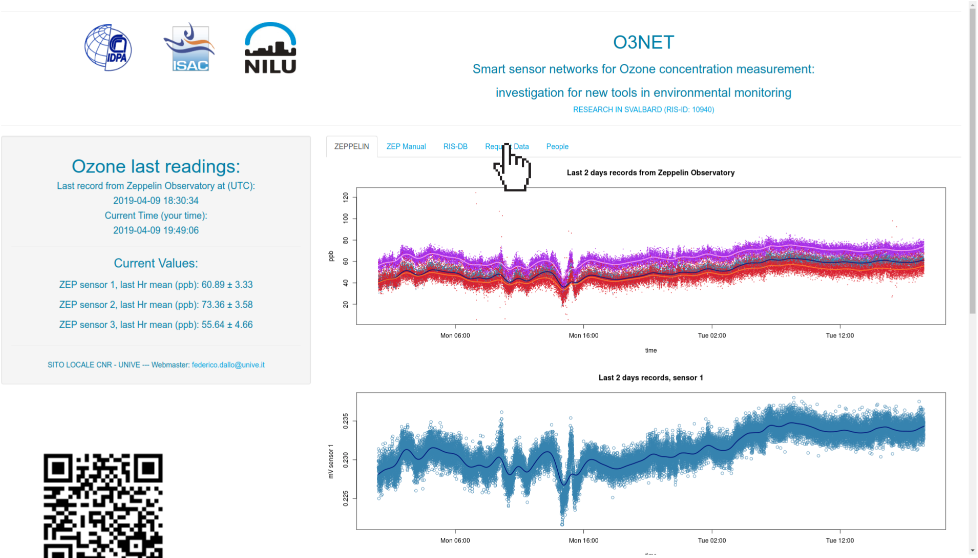
Dashboard to monitor actual raw data



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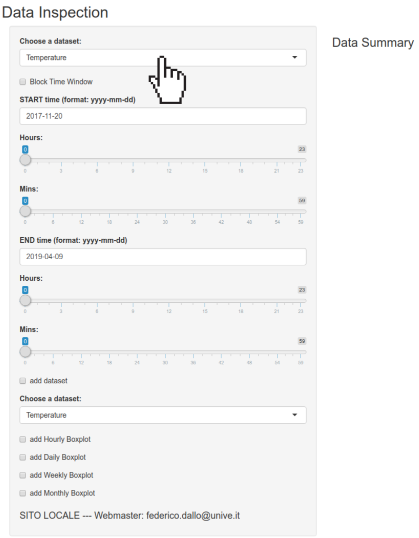
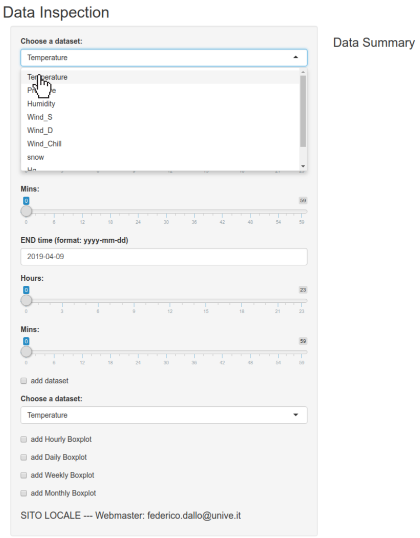
User interface: select the variable of interest



User interface: select the variable of interest



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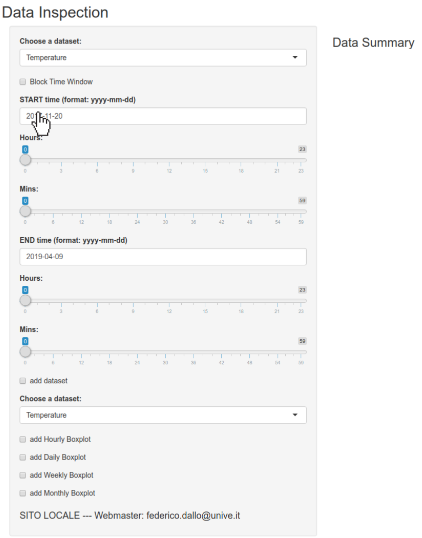
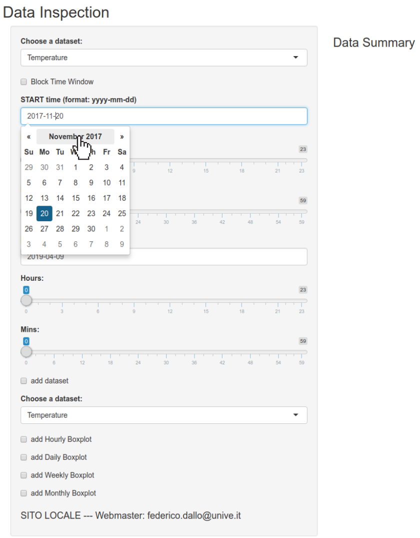
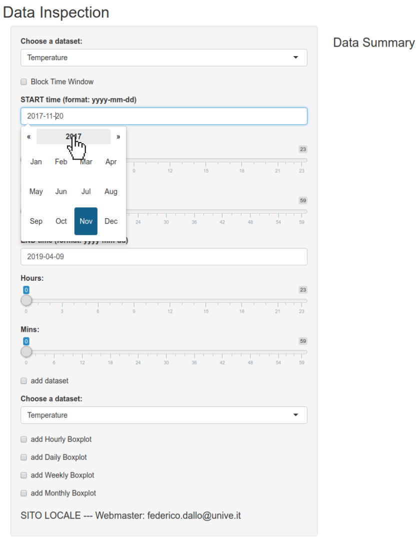
User interface: select the time interval



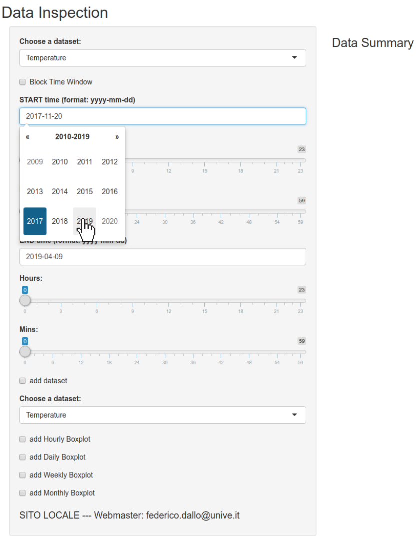
User interface: select the time interval



User interface: select the time interval



User interface: select the time interval



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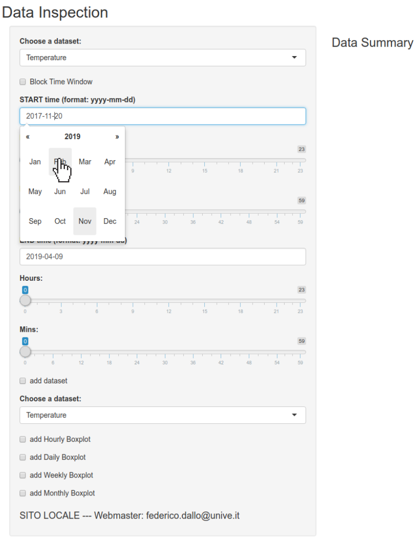
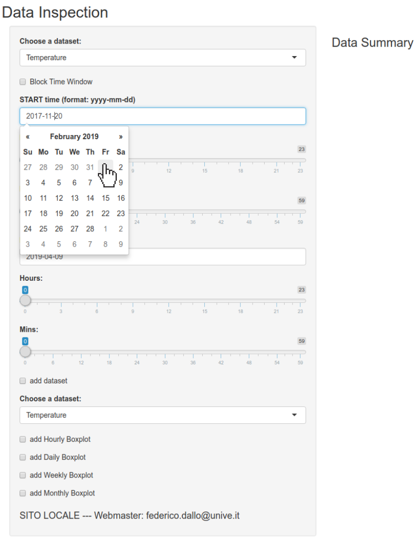


User interface: select the time interval



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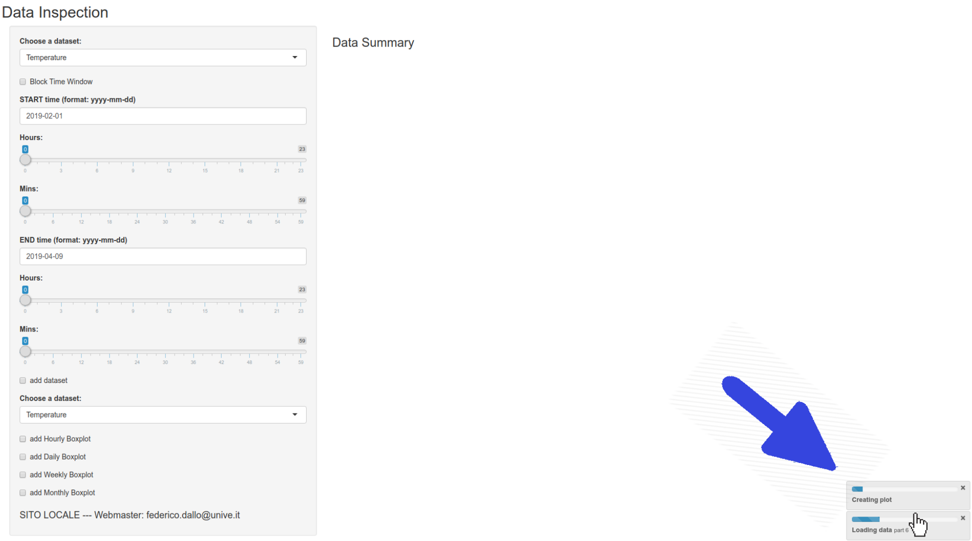
User interface: time series is loading



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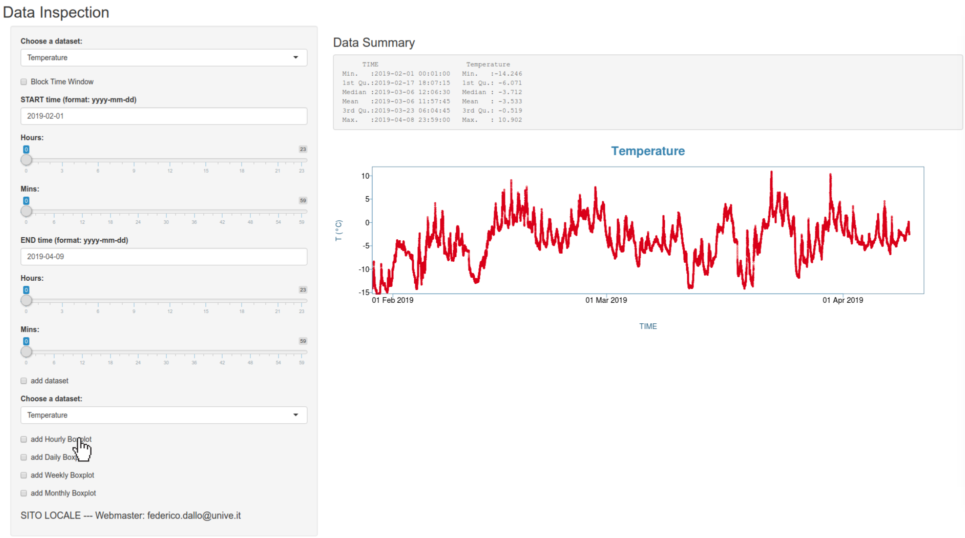
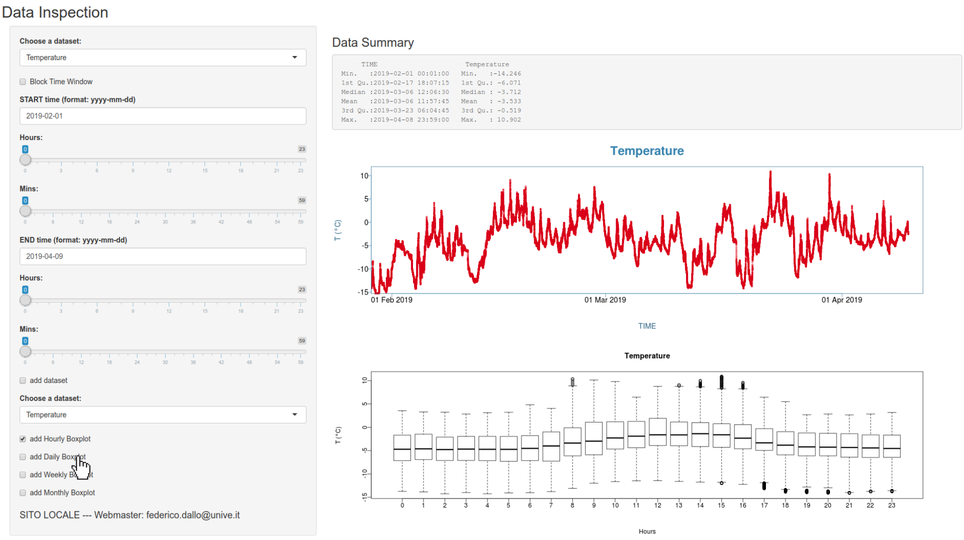
User interface: variable's time series and summary table



User interface: display hourly boxplot



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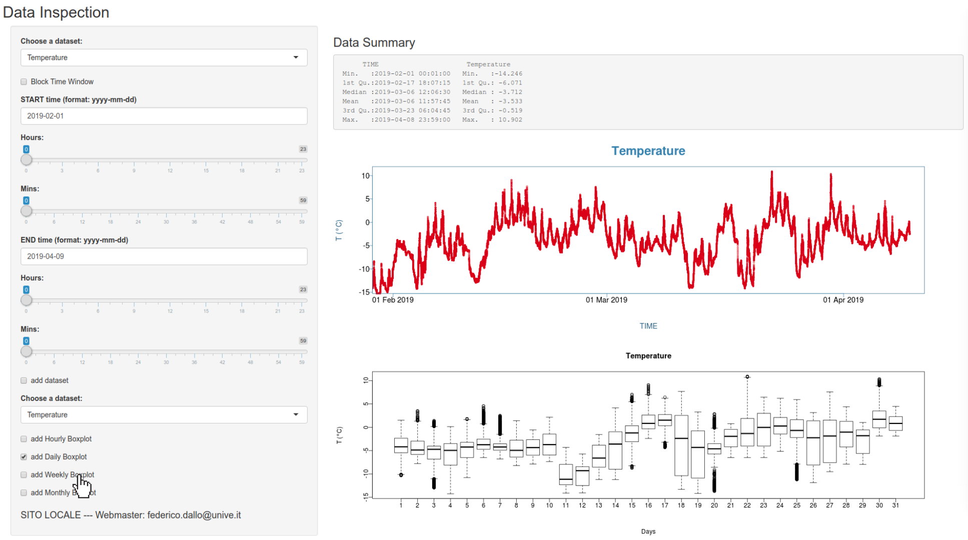
User interface: display daily boxplot



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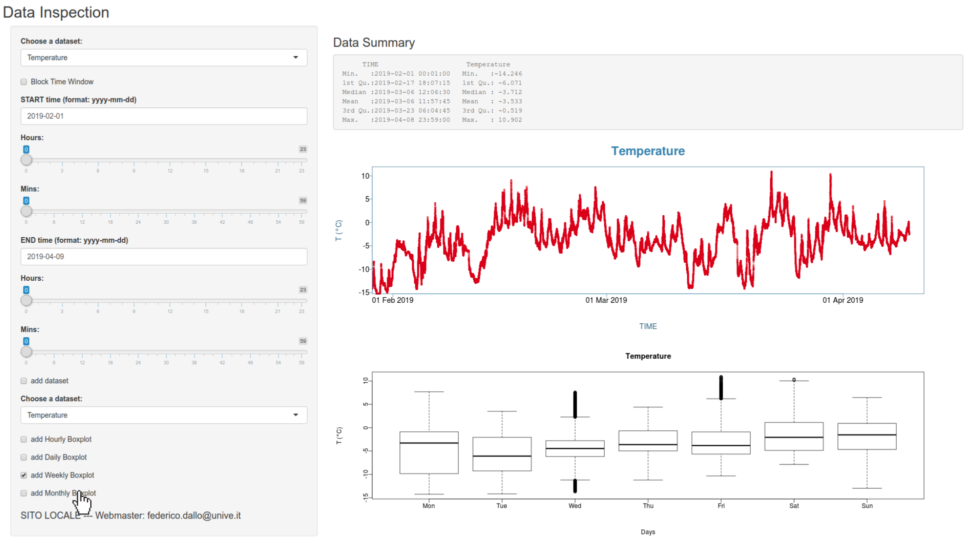
User interface: display weekly boxplot



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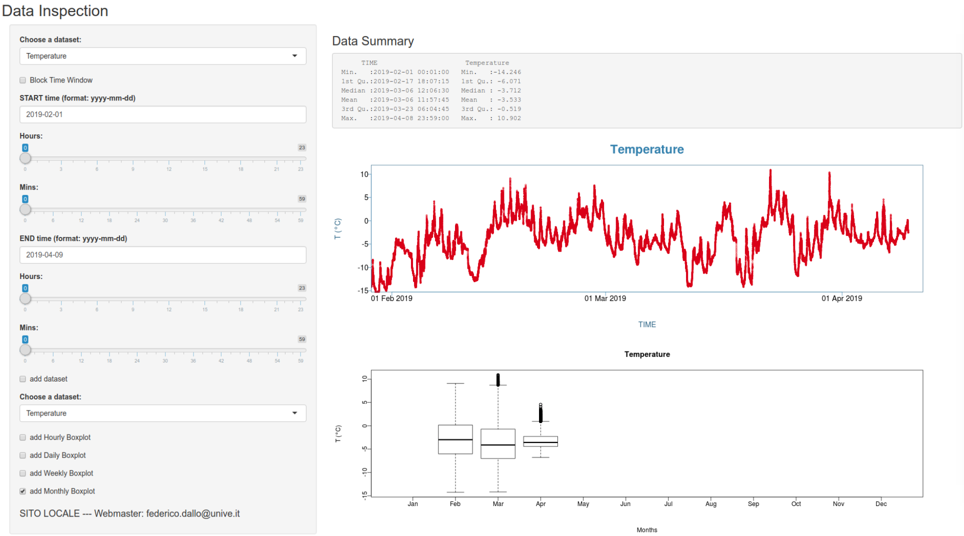
User interface: display monthly boxplot



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Thank you!

The project O3NET (RIS-ID 10940) was financed by the Svalbard Science Forum (SSF) through an Arctic Field Grant (AFG)

https://www.researchinsvalbard.no/project/8713

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