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AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

D3.3.1
Quality Control of the observations and validation of the modelling systems

PP12 – ISPRA

Public

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1. Introduction

1.1. International framework

The Global Climate Observing System (GCOS), a joint activity between WMO and Unesco-IOC, is dedicated to defining and set standards for climate monitoring. Here we are referring especially to physical meteo-marine parameters such as sea level and waves, water temperature and salinity, wind speed and direction, atmospheric pressure.
In the framework of AdriaCLIM project we are asked to identify and collect the more detailed available information on data treatment and validation, in order to obtain a shared, as complete as possible, set of procedures to apply to meteo-marine time series.

1.2. Objectives of this deliverable

The quality control (QC) procedures for observations collected in A3.1 will be improved and applied. A procedure for the validation and elaboration of the GPS data will be implemented and an integrated analysis with the tide gauge data (WP 3.1) will be proposed.Validation procedures will be reviewed and applied to historical time series related to meteo-marine parameters (WMO manuals and Directive 2007/2/EC (INSPIRE)) and a new homogeneous sea level data base will be build up.
This document is aimed at the definition of a catalogue referred to quality control procedures applied to in situ data, especially oceanographic parameters (such as sea level, waves, atmospheric pressure, wind intensity and direction, water temperature and salinity). Each partner could add the physical parameters he is planning to validate or to share in a validated way in the framework of ADRIACLIM project.
Each partner should provide an extended description of actual quality control procedures applied to historical time series and implemented, and fill in the table (attached in the email) summarizing the available information. It is important to highlight the need of compiling the table referring to the actual procedures applied to historical time series (in Chapter 2) in order to reach as objective of the project, a common, complete and shared QC procedure.
The main objective of this deliverable is:
D.3.3.1 Report on upgraded meteo-marine validation and QC procedures as required by WMO standard and indications.

2. Existing Quality Control Procedures for in situ data for marine time series

2.1. Sea level

2.1.1. Synthesis of sea level procedures listed by partners

Partners providing information (tot 6): CNR-ISMAR, ISPRA-RMN, ISPRA-RMLV, IOF, Molise Region, ARPAE

Regarding real time automatic procedures, some (3) partners implement some automatic procedures in the datalogger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

One partner implements a system of flags at the data logger level. No partner implements near real time automatic procedures. One partner implements near real time manual procedure (daily check of the data flow and meaning of sea level data according to a protocol). All partners implement periodic procedures (automatic or manual) with the aim of validating the data. Among the automatic procedures, most partners implement checks on the formatting of the date, the homogenization of the time series to include gaps for missing values. One partner performs all validation procedures automatically, including the identification of gaps (missing record), the identification of missing values (no recorded sea level) the check for the physical meaning of the data (e.g. sequences of constant values), and for data with physical meaning but out of scale. Additionally, also the daily, monthly, and yearly mean sea level is computed automatically. All other partners implement periodic manual procedures with similar purposes.

Additional periodic manual procedures are the visual check of the data (monthly, yearly), the analysis of sea level gradients (difference filter) to detect spikes or other deviations from the expected sub daily sea level trends, the analysis of daily, decadal, and monthly means, and the analysis of the residuals (i.e. storm surge calculated after harmonic analysis to remove the tidal component). Some partners reported periodic visits to the gauge with manual measurement of the sea level, and the correction of the sea level data accordingly.

Three partners report a periodic check of the gauge benchmark stability, also performed with the comparison with recorded in situ sea level values. Three partners report the comparison of data from different neighboring tide gauges.

Procedures listed by the partners

Real time (datalogger)

- Signal to noise ratio (1)
- Removal of out of scale values (2)

Near real time

- Daily sea level data flow check (1)

Periodic automatic

- Date time check homogenization (4)
- Daily/monthly/annual mean analyses (3)
- Identification of gaps (1)
- Check for out of scale values (1)
- Interpolation (1)

Periodic manual

- Date time check homogenization (1)
- Daily/monthly/annual/multiannual mean analyses (3)
- Identification of gaps (1)
- Check for out of scale values (1)
- Interpolation (1)
- Check tide gauge benchmark (2)
- Residual analysis (1)
- Buddy check (1)

2.1.2. Description of sea level QC procedures from ISPRA-RMLV

Authors: Morucci S., Crosato F., Baldan D., Bonometto A., Coraci E.

ISPRA developed and applies many different procedures for sea level in situ data quality control, with different specification in different locations.
It especially refers to the manuals and guidelines 77/2012, ISPRA (2012) “Manual and guidelines of quality control and validation procedures related to Italian sea level data”, (http://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida/manuale-di-mareografia-e-linee-guida-per-i-processi-di-validazione-dei-dati-mareografici), “Manual of quality control procedures for validation of oceanographic data”, UNESCO (1993) Manual and guides 26. (http://unesdoc.unesco.org/images/0013/001388/138825eo.pdf)
Real time data are automatically checked and clean from instrumental errors, including:

a. gaps, due to lack of registration or transmission of data: in this case gap will be identified with a flag;
b. data with no physical meaning: a range of physical significativity of sea level is settled (ex. -150 cm / +250 cm). If data are out of range they will be identified with a flag;
c. spikes: the difference between two consecutive data has to range in a defined interval (depending on the location and the sampling frequency). For example into the Venice lagoon the difference is defined as 5 cm for data with time step of 5 minutes;
d. block of repeated value due to a block of the tide gauge at a fixed value (ex. fixed tide level for 60 minutes);
e. quick decreasing value due to a derailing of tide gauge: it could be seen a difference of 20 cm between two consecutive observations (20 cm corresponds to half a circumference of a pulley).

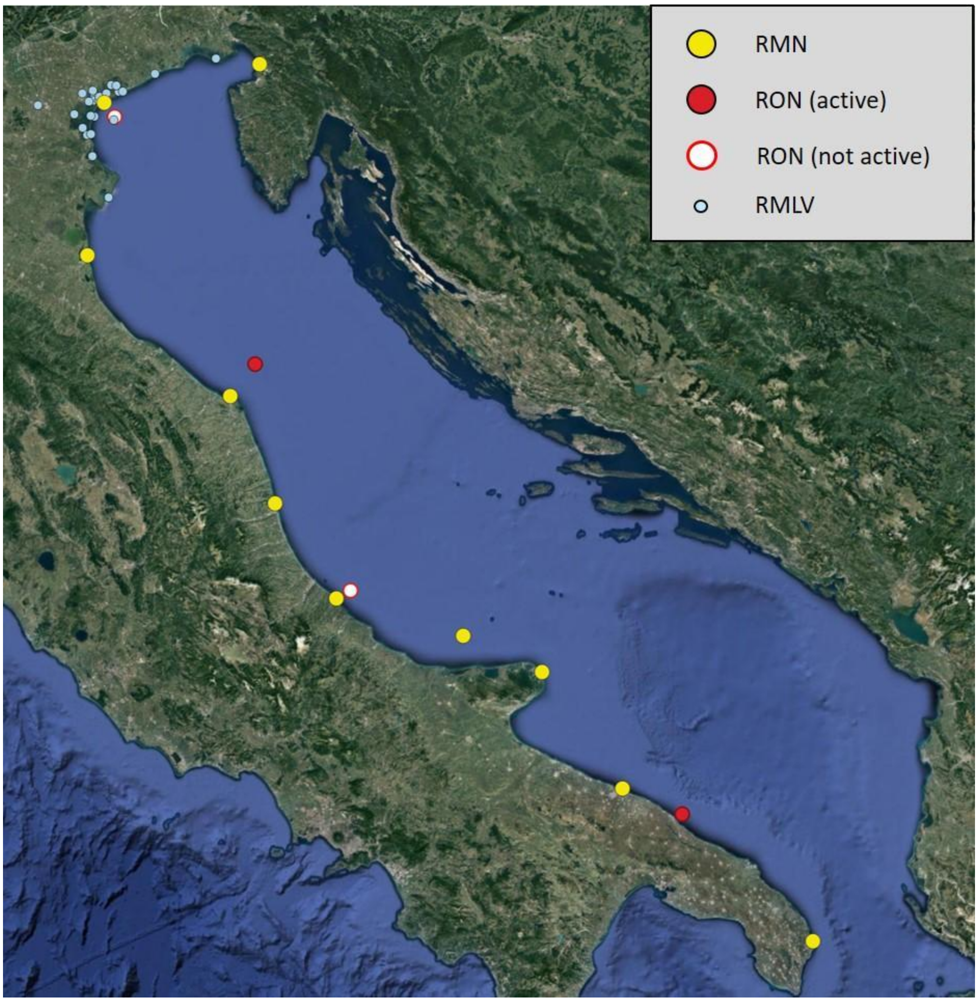

Figure 2-1. RMN, RMLV, RON stations on the Adriatic coasts

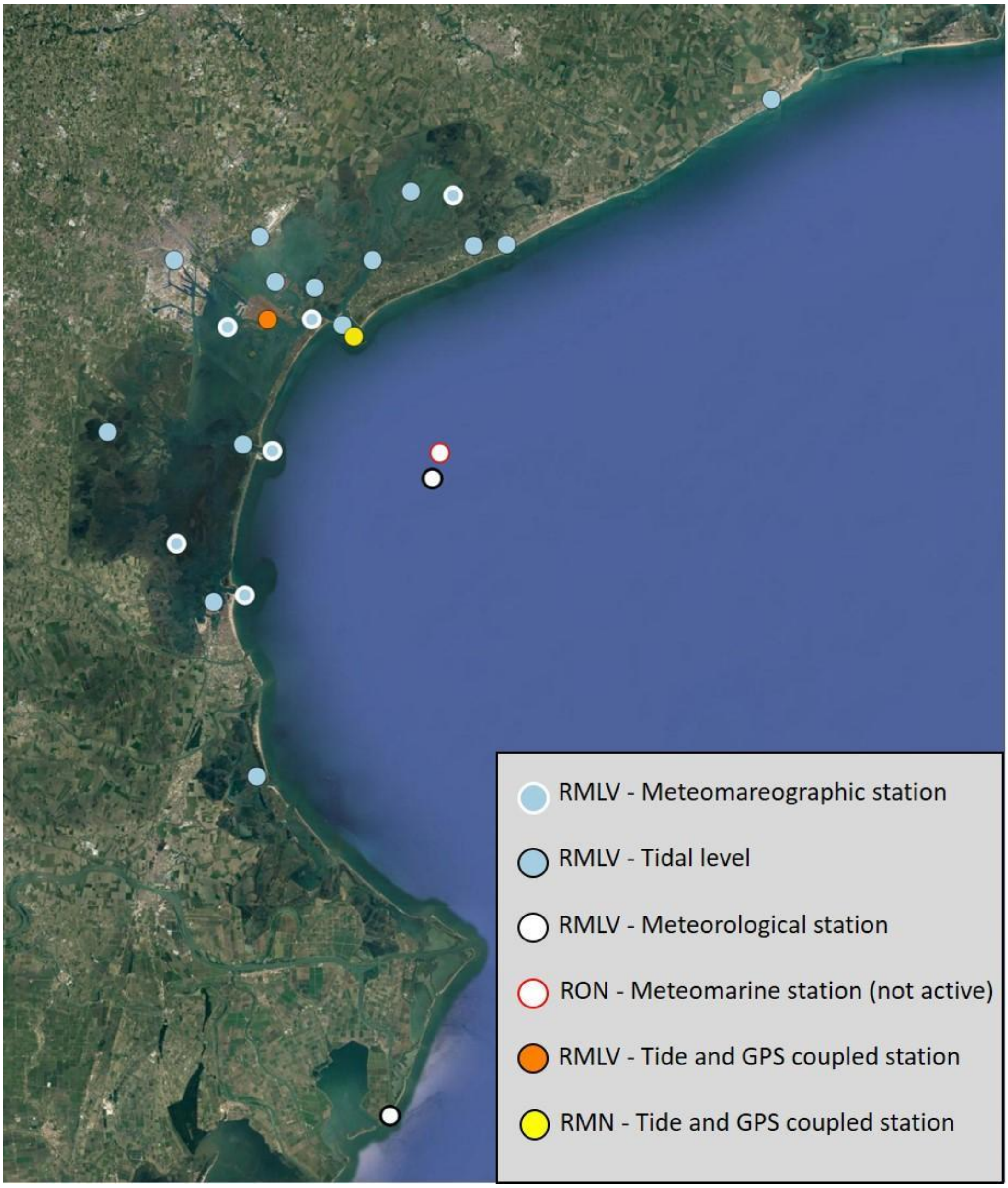

Figure 2-2. RMLV stations in the North Adriatic Sea and the Venice lagoon

2.1.3. Description of sea level QC procedures from CNR-ISMAR-TS (Trieste)

Author: Raicich F.

The tide gauge (TG) station at Molo Sartorio (nº. 340 of the GLOSS Core Network) is mainly devoted to Sea Level (SL) measurement for research purposes, namely to study the SL variability on time scales from sub-hourly to centennial. Real-time (RT) and near-real-time (NRT) data provision is not implemented.

There are currently two digital TGs, one of which serves as a backup, and one analogue TG, whose chart is changed on a weekly basis.

Hourly mean SL data are delivered to GLOSS in Delayed-Mode, which is one per month. Monthly and annual mean SL is provided once per year to the Permanent Service for Mean Sea Level (PSMSL).

Because RT and NRT modes are not implemented, no automatic QC procedures are applied.

When the chart of the analogue TG is changed, direct SL measurements are made relative to the TG benchmark and the instrumentation is checked to detect malfunctions, including record interruptions. The TG clock is checked by means of a radio-controlled clock.

Whenever data are to be delivered to GLOSS or the PSMSL, a thorough visual inspection is made and evident erroneous data and gaps are recognized and can be corrected thanks to the availability of three instruments. The direct SL measurements allow for checking the instrument stability, particularly in the long-term.

1.1.1. Description of sea level QC procedures from IOF

Authors: Jelinčić A., Mihanović H.

Automatic real time quality control includes signal-to-noise ratio identification and status flags on the datalogger.

The results of this control are planned to be used as automatic near real time quality control to eliminate data with a signal-to-noise ratio greater than predefined value. So far, there are no near real time quality control procedures, and signal to noise ratio is used in manual periodic quality control.

As for periodic quality control/validation, following procedures are used:

a. analysis of gradient of sea level
b. analysis of signal to noise ratio and out of scale values from datalogger
c. comparative analysis among near tide gauges

d. monthly mean time series analysis
e. date, time and gap format homogenization
f. visual inspection

There is also a plan to implement analysis of residuals and identification of timing failure as manual periodic quality control procedure, which could be possible after data is collected within some time.

1.2. Sea Waves

1.2.1. Synthesis of sea waves procedures listed by partners

Partners providing information (tot 2): ARPAE, Molise

Comment:

Different variables can be measured on sea waves: mean sea height, significant wave height, period of not significant wave, maximum wave height, maximum wave period, wave direction.

One partner implements a plausibility analysis as automatic procedure. No near real time procedures were listed. Date and time homogenization were listed among the automatic periodic procedures. One partner validates the data via manual comparison with other data. One partner performs manual quality checks via identification of gaps in the data, removal of out of scale values (e.g. spikes), and an analysis of sea waves gradients. Comparisons between annual and monthly statistics (mean and maxima) are also performed.

Procedures listed by the partners

Real time (datalogger)

- Plausibility analysis (1)

Near real time

- -

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Date time check homogenization (1)
- Plausibility check (1)
- Monthly/annual checks (1)

1.3. Sea Temperature

1.3.1. Synthesis of sea temperature procedures listed by partners

Partners providing information (tot 6): CNR ISMAR, IOF, CMCC, Molise region, ARPA FVG, ARPAE

Comment:

Regarding real time automatic procedures, some (4) partners implement some automatic procedures in the datalogger to remove a) data without physical meaning, and b) data with physical meaning but out of scale. One partner implements a system of flags at the data logger level.

One partner implements near real time procedures for cruise temperature data. No near real time procedures are reported for other types of data.

Among periodic procedures for validation, one partner performs the date and time format and homogenization automatically. Other manual procedures listed include: periodical comparison between nearby stations or among different stations, checks for data with physical values but out of scale (spikes), comparisons with other data (other parameters, e.g. salinity, or climatological information) to check for inconsistencies, checks on monthly and annual statistics (mean values), and data correction (e.g. surface layer correction). Consistency of temperature profiles is also checked. CTD instruments are regularly maintained as part of the validation.

Procedures listed by the partners

Real time (datalogger)

- Removal of out of scale values (2)
- Data without physical meaning (2)

Near real time automatic

- Check parameters ranges (1)

Near real time manual

- Plausibility analysis (1)

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Date time check homogenization (1)
- Plausibility check (2)
- Monthly/annual checks (1)
- Buddy check (1)
- Gradient analysis (2)
- Calibration (1)

1.3.2. Description of temperature QC procedures from CMCC

CMCC applies standard procedures for temperature and conductivity in situ data quality control referring to SeaDataNet, 2010. Data Quality Control Procedures. Version 2.0 May 2010. Available at https://www.seadatanet.org. and Reverdin, G., Thierry, V., Utiz, J., d'Ortenzio, F., Bradshaw, E., & Pfeil, B. (2016). QC Report. AtlantOS project.

Near Real Time data are automatically checked and clean from instrumental errors, including:

a. aps, due to lack of registration or transmission of data;
b. data with no physical meaning: a range of physical significativity of temperature;
c. data with no physical meaning: a range of physical significativity of conductivity;
d. check for spikes.

Periodic QC procedures include:

- Analysis of temperature gradient
- Analysis of conductivity gradient
- Sensor drift
- Comparative analysis among different sensors
- Plot temperature vs Salinity

1.3.3. Description of temperature QC procedures from IOF

Authors: Jelinčić A., Mihanović H.

IOF applies many quality control procedures for CTD data which are different from quality procedures applied to continuous measurements from autonomous sensors for sea temperature and salinity.

Real time data with no physical meaning and data out of range are automatically checked with a flag.

Automatic control of near real time data is performed using the following procedures:

1. removing data identified with a flag and data with no physical values
2. inspecting if pressures from the profile are monotonically increasing
3. checking if the deepest pressure is not higher than the highest value expected for a probe.

After automatic real time quality control, further data control is based on expert evaluation of data, using the following procedures:

1. analysis of density inversion (comparing calculated densities of adjacent pressure values in profile)
2. identification and removal of spikes (comparing temperature and salinity adjacent values in profile with median filtering)
3. analysis of digit rollover (visual inspection of temperature and salinity values and elimination of values which exceed a probe storage capacity)
4. visual detection of frozen profile.

Automatic periodic quality control controls ship speed and date/time between stations to detect potential incorrect position while inserting cruise data in IOF oceanographic referal database. It is assured that location of stations is not on land because positions are predefined.

Periodic quality control is performed by:

1. calibration and maintenance of instrument (every 1-2 year)
2. climatology analysis
3. visual vertical profile inspection (increasing density, range of temperature and salinity, climatology validation, surface layer correction, spike removal validation).

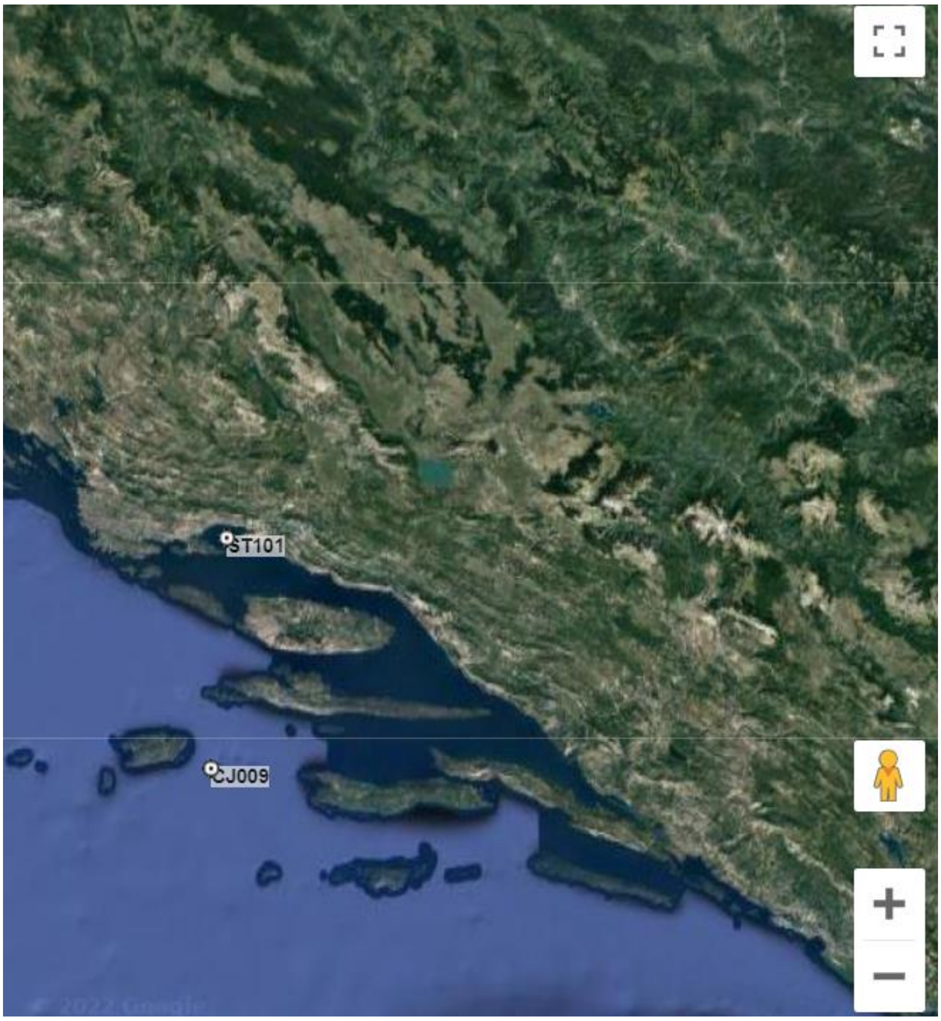

Figure 2-3. Stations Stončica (CJ009) and ST101 where CTD data are collected (IOF)

1.4. Salinity

1.4.1. Synthesis of salinity procedures listed by partners

Partners providing information (tot 2): IOF, ARPA FVG

Comment:

Regarding real time automatic procedures, all partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

One partner implements near real time procedures for cruise salinity data. No near real time procedures are reported for other types of data.

No partner reported periodic automatic validation procedures. Other manual procedures listed include: checks for data with physical values but out of scale (spikes), comparisons with other data (e.g. climatological information) to check for inconsistencies, checks on monthly and annual statistics (mean values), and data correction (e.g. surface layer correction). Consistency of salinity profiles is also checked. CTD instruments are regularly maintained as part of the validation.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (3)
- Spike detection (1)

Near real time automatic

- Check parameters ranges (1)

Near real time manual

- Plausibility analysis (1)
- Data logger check (1)

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Date time check homogenization (1)
- Plausibility check (2)
- Gradient analysis (2)
- Calibration (2)
- Validation with other data (1)

1.4.2. Description of salinity QC procedures from IOF

Authors: Jelinčić A., Mihanović H.

IOF applies many quality control procedures for CTD data which are different from quality procedures applied to continuous measurements from autonomous sensors for sea temperature and salinity.
Real time data with no physical meaning and data out of range are automatically checked with a flag.
Automatic control of near real time data is performed using the following procedures:

4. removing data identified with a flag and data with no physical values
5. inspecting if pressures from the profile are monotonically increasing
6. checking if the deepest pressure is not higher than the highest value expected for a probe.

After automatic real time quality control, further data control is based on expert evaluation of data, using the following procedures:

5. analysis of density inversion (comparing calculated densities of adjacent pressure values in profile)
6. identification and removal of spikes (comparing temperature and salinity adjacent values in profile with median filtering)
7. analysis of digit rollover (visual inspection of temperature and salinity values and elimination of values which exceed a probe storage capacity)
8. visual detection of frozen profile.

Automatic periodic quality control controls ship speed and date/time between stations to detect potential incorrect position while inserting cruise data in IOF oceanographic referal database. It is assured that location of stations is not on land because positions are predefined.

Periodic quality control is performed by:

4. calibration and maintenance of instrument (every 1-2 year)
5. climatology analysis
6. visual vertical profile inspection (increasing density, range of temperature and salinity, climatology validation, surface layer correction, spike removal validation).

1.5. Dissolved Oxygen

1.5.1. Synthesis of dissolved oxygen procedures listed by partners

Partners providing information (tot 3): IOF, Molise Region, ARPA FVG

Comment:

Regarding real time automatic procedures, all partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

No parthner directly implements near real time procedures for dissolved oxygen data.

Among periodic procedures for validation, one partner performs the date and time format and homogenization automatically. Other manual procedures listed include: checks for data with physical values but out of scale (spikes), and comparisons with other data. Consistency of salinity profiles is also checked. CTD instruments are regularly maintained as part of the validataion.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (2)
- Spike detection (1)

Near real time automatic

- -

Near real time manual

- -

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Check spikes (1)
- Sensor calibration (1)

1.6. Conductivity

1.6.1. Synthesis of conductivity procedures listed by partners

Partners providing information (tot 2): CMCC, Molise Region

Comment:

Regarding real time automatic procedures, all partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

No parthner directly implements near real time procedures for dissolved oxygen data.

Among periodic procedures for validation, one partner performs the date and time format and homogenization automatically. Other manual procedures listed include: checks for data with physical values but out of scale (spikes), and comparisons with other data, or data from different sensors, and checks for sensor drifts.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (1)

Near real time automatic

- -

Near real time manual

- -

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Sensor calibration (1)
- Check with other data (1)

1.6.2. Description of conductivity QC procedures from CMCC

CMCC applies standard procedures for temperature and conductivity in situ data quality control referring to SeaDataNet, 2010. Data Quality Control Procedures. Version 2.0 May 2010. Available at https://www.seadatanet.org. and Reverdin, G., Thierry, V., Utiz, J., d'Ortenzio, F., Bradshaw, E., & Pfeil, B. (2016). QC Report. AtlantOS project.

Near Real Time data are automatically checked and clean from instrumental errors, including:

e. aps, due to lack of registration or transmission of data;
f. data with no physical meaning: a range of physical significativity of temperature;

g. data with no physical meaning: a range of physical significativity of conductivity;
h. check for spikes.

Periodic QC procedures include:

- Analysis of temperature gradient
- Analysis of conductivity gradient
- Sensor drift
- Comparative analysis among different sensors
- Plot temperature vs Salinity

1.7. Generic parameters for marine data

1.7.1. Description of marine (water temperature, salinity, pressure, dissolved oxygen, turbidity and chlorophyll-a) QC procedures from ARPA-FVG

(Authors: Alessandro Acquavita, Dario Giaiotti, Elena Gianesini, Denis Guiatti, Eddio Marini, Alessandro Minigher and Alex Pividori)

ARPA FVG performs monthly measurement campaigns of the main physical and biogeochemical water parameters, both in the open sea and the lagoon on the pilot area; see figures 2.1.1 (a) and 2.1.1 (b) for the spatial distribution of the measurement points.

For each point, all the water properties are measured by means of a device which probes the water column, from the bottom to the sea surface. The resulting measurements represent the vertical profile of the water at the measurement time.

The probes are regularly calibrated in standard environments allowing ranges of the parameters; that calibration is conducted in certified and specialized institutes where the devices are sent for the purpose.

Since the data acquisition is automatically performed by means of the calibrated probe, a first quality check is done by the software managing the response of the device transducer. In this first check, data with physical meaning but out of scale are set to missing data, furthermore instrumental spikes are identified and replaced with the missing data flag.

In addition to the automatic measurement in progress data check, a manual analysis of the water data profiles is carried on by an expert operator, who compares all the set of measures for spatial and climatological consistency. This second step is carried on at the end of the monthly measurement campaign.

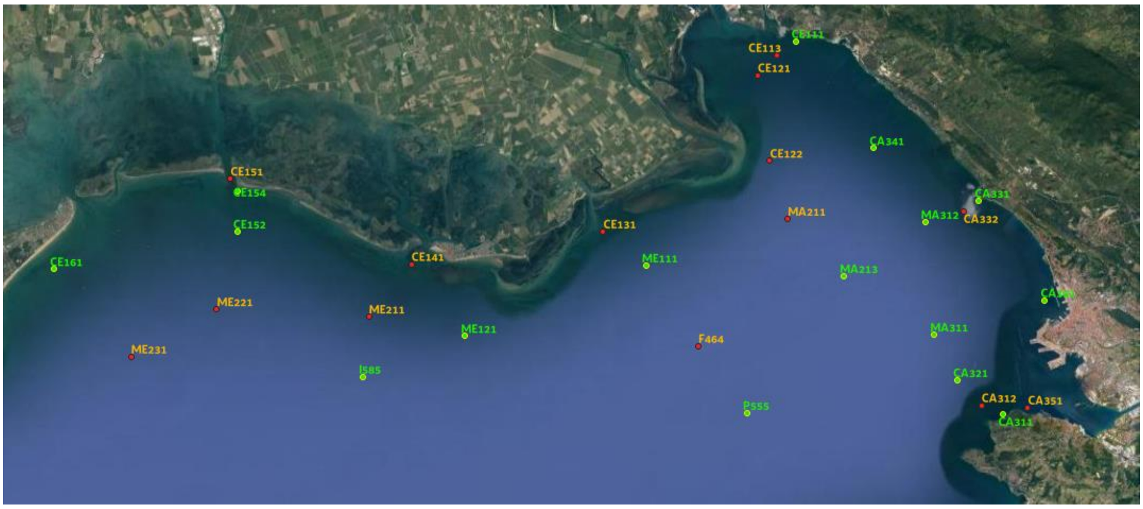

Figure 2-4. Monitoring network for the quality of coastal and marine waters ARPA-FVG.

Figure 2-5. Monitoring network for the quality of transitional waters in Grado and Marano Lagoon (ARPA-FVG)

2. Existing Quality Control Procedures for in situ data for meteorological time series

2.1. Atmospheric pressure

2.1.1. Synthesis of atmospheric pressure procedures listed by partners

Partners providing information (tot 6): CNR-ISMAR, Molise Region, IOF, ISPRA, ARPA FVG, ARPAE

Comment:

Regarding real time procedures, three partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

Three partners implement near real time manual procedures to check daily the data, e.g. for extreme values and consistencies with local climatology.

Among automatic periodic procedures for validation, two partners implemented checks for date and time homogenization. Among manual periodic procedures for validation (4 partners) are listed: visual inspections of data to check for consistencies, comparisons between data from neighboring stations, and comparisons of decadal and monthly means. One partner performs correction of pressure based on sensor altitude, and comparison with pressure measured from different instruments during field inspections.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (4)

Near real time automatic

- -

Near real time manual

- Check data consistency (2)

Periodic automatic

- Date time check homogenization (2)

Periodic manual

- Check monthly/annual means (3)
- Comparison with other stations (2)
- Correction for sensor elevation (1)

2.2. Wind

2.2.1. Synthesis of wind intensity and speed procedures listed by partners

Partners providing information (tot 7): CNR-ISMAR, Molise Region, IOF, ISPRA, ARPA FVG, ARPAE, ARPAV

Comment:

Regarding real time procedures, three partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

One partner implements automatic near real time procedures to check for: maximum daily value within prescribed range compared to values at sampling frequency, same value for more than 1 hour (6 measurements), Instrumental spike identification and flagging at sampling frequency, value above a high threshold (warning), same value for more than 1 hour (6 measurements).

Three partners implement near real time manual procedures to check daily the data, e.g. for extreme values, consistencies with local climatology, and consistencies between neighboring stations.

Among automatic periodic procedures for validation, one partner implements checks for date and time homogenization.

Among manual periodic procedures for validation (4 partners) are listed: visual inspections of data to check for consistencies, comparisons between data from neighboring stations (annual and long-term statistics), checks for inconsistencies in the data (spikes, drifts), and comparisons of monthly means. Sensors are periodically checked.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (6)

Near real time automatic

- Data plausibility (1)

Near real time manual

- Buddy check (1)
- Data plausibility (1)
- Check daily values (1)

Periodic automatic

- Date time check homogenization (1)

Periodic manual

- Buddy check (1)
- Plausibility check (1)
- Check monthly/annual means (3)

2.3. Air temperature

2.3.1. Synthesis of air temperature procedures listed by partners

Partners providing information (tot 7): CNR-ISMAR, Molise Region, IOF, ISPRA, ARPA FVG, ARPAE, ARPAV

Comment:

Regarding real time procedures, three partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

One partner implements automatic near real time procedures to: compare daily means with neighboring stations, for replicated values and for spikes. Four partners implement near real time manual procedures to: check the consistency with other measured parameters (humidity, radiation, and precipitation), check for outliers, check for the consistency of the time series (e.g. temperature measured the previous day).

Among periodic procedures for validations were listed: check of data statistics (mean, 10th and 90th percentiles), weekly, monthly, annual comparisons with neighboring stations. The sensor is regularly calibrated.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (5)

Near real time automatic

- Data plausibility (1)
- Buddy check (1)

Near real time manual

- Buddy check (1)
- Consistency check (1)

Periodic automatic

- Date time check homogenization (1)

Periodic manual

- Buddy check (1)
- Plausibility check (2)
- Check daily/monthly/annual means (4)

2.4. Air humidity

2.4.1. Synthesis of air humidity procedures listed by partners

Partners providing information (tot 6): IOF, Molise Region, ARPAV, ARPA FVG, ARPAE

Comment:

Regarding real time procedures, three partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.

One partner implements automatic near real time procedures to: compare daily means with neighboring stations, for replicated values and for spikes. Four partners implement near real time manual procedures to: check the consistency with other measured parameters (radiation, air temperature, and precipitation), check for outliers, and check for the consistency of the time series (e.g. temperature measured the previous day).

Among periodic procedures for validations were listed: check of data statistics (mean, 10th and 90th percentiles), weekly, monthly, annual comparisons with neighboring stations. The sensor is regularly calibrated.

Procedures listed by the partners

Real time (datalogger)

- Identification of data without physical meaning (4)

Near real time automatic

- Data plausibility (1)
- Buddy check (1)

Near real time manual

- Buddy check (1)
- Consistency check (1)

Periodic automatic

- Plausibility check (1)

Periodic manual

- Buddy check (1)
- Plausibility check (2)
- Check daily/monthly/annual means (4)

2.5. Precipitation

2.5.1. Synthesis of precipitation procedures listed by partners

Partners providing information (tot 5): ISPRA, Molise Region, ARPAV, ARPA FVG, ARPAE
Comment:
Regarding real time procedures, three partners implement some automatic procedures in the data logger to remove a) data without physical meaning, and b) data with physical meaning but out of scale.
One partner implements automatic near real time procedures to: compare values higher than a precipitation threshold with neighboring stations, for replicated values and for spikes. Four partners implement near real time manual procedures to: check the consistency with other measured parameters (radiation, air temperature, and precipitation), check for outliers, and check for the consistency of the time series (e.g. temperature measured the previous day).
Among periodic procedures for validations were listed: check of data statistics (mean, 10^{th} and 90^{th} percentiles), weekly, monthly, annual comparisons with neighboring stations. The sensor is regularly calibrated.

Real time (datalogger)
- Identification of data without physical meaning (4)

Near real time automatic
- Data plausibility (1)
- Buddy check (1)

Near real time manual
- Buddy check (1)
- Consistency check (1)

Periodic automatic
- Plausibility check (1)

Periodic manual
- Buddy check (1)
- Plausibility check (2)
- Check daily/monthly/annual means (4)

2.6. Generic meteorological procedures

2.6.1. Synthesis of meteorological (wind direction and speed, atmospheric pressure) procedures listed by ISPRA-RMLV

Authors: Morucci S., Crosato F., Bonometto A., Coraci E.

As for sea level, ISPRA developed and applies many different procedures for meteorological parameters especially referring to "Manual of quality control procedures for validation of oceanographic data", UNESCO (1993) Manual and guides 26 (Annex D2 "Meteorological data" – Quality control of meteorological data (2.1.1 (Raw data timing), 2.1.2 (Gross error limits), 2.1.4 (Stationary tests and 2.2.3 (Data limit tests)).

2.6.2. Synthesis of meteorological procedures listed by IOF

Authors: Jelinčić A., Mihanović H.

Station with continuous measurements from autonomous sensors is soon to be set at Neretva River estuary. Quality control procedures planned to be implemented are:

a. flagging data with values exceeding defined ranges for each parameter
b. elimination of data with no physical value
c. gaps due to lack of transmission of data

2.6.3. Synthesis of meteorological procedures (air temperature, wind and atmospheric pressure) listed by CNR-ISMAR-TS

Author: Raicich F.

Similarly to the TG station, the meteorological-marine stations are mainly devoted to measurement for research purposes, namely to study the meteorological variability on time scales from hourly to multidecadal. Real-time (RT) and near-real-time (NRT) data provision is not implemented. As a consequence, no automatic QC procedures are applied.
The station at Molo Fratelli Bandiera measures air temperature, wind speed and direction at 10 m, and sea temperature at 0.4, 2 and 6 m depth. All sensors are calibrated with irregular frequency.

The atmospheric pressure at 2.5 m above mean sea level is measured at the TG station of Molo Sartorio, by means of one digital and one analogue barometer.
Data are collected and quality-controlled with irregular frequency, as needed, but at least every year, when they are collected and archived.
The QC is mainly based on a thorough visual inspection and the comparison with the data from the nearby station operated by Protezione Civile (Civil Protection) of Regione Autonoma Friuli Venezia Giulia.

2.6.4. Synthesis of meteorological procedures (10 m wind speed and direction, 2 m atmospheric pressure, temperature, relative humidity, solar radiation and precipitation) listed by ARPA-FVG

Authors: Alessandro Acquavita, Dario Giaiotti, Elena Gianesini, Denis Guiatti, Eddio Marini, Alessandro Minigher and Alex Pividori

ARPA FVG collects meteorological data from network of automatic stations which are distributed across the Friuli Venezia Giulia region. Those stations measure all the main meteorological parameters, with the hourly resolution and a subset of them has been considered to support AdriaClim project for monitoring purposes; see figure 3-1for the spatial distribution of considered stations.
Since the data acquisition is automatically performed by means of the calibrated devices, almost all the relevant quality checks are done by the software managing the response of the device transducer, directly at the station. In this first check, data with physical meaning but out of scale are set to missing data; furthermore, instrumental spikes are identified and replaced with the missing data flag.
In addition to the automatic measurement, a manual daily validation is carried on at the data collection centre, namely the meteorological observatory. A set of checks on data consistency with climatological constrains, spatial gradients and time derivatives jumps is conducted by an expert operator, who runs quality check software highlighting potential problems in the time series. This second step is repeated also on monthly base.

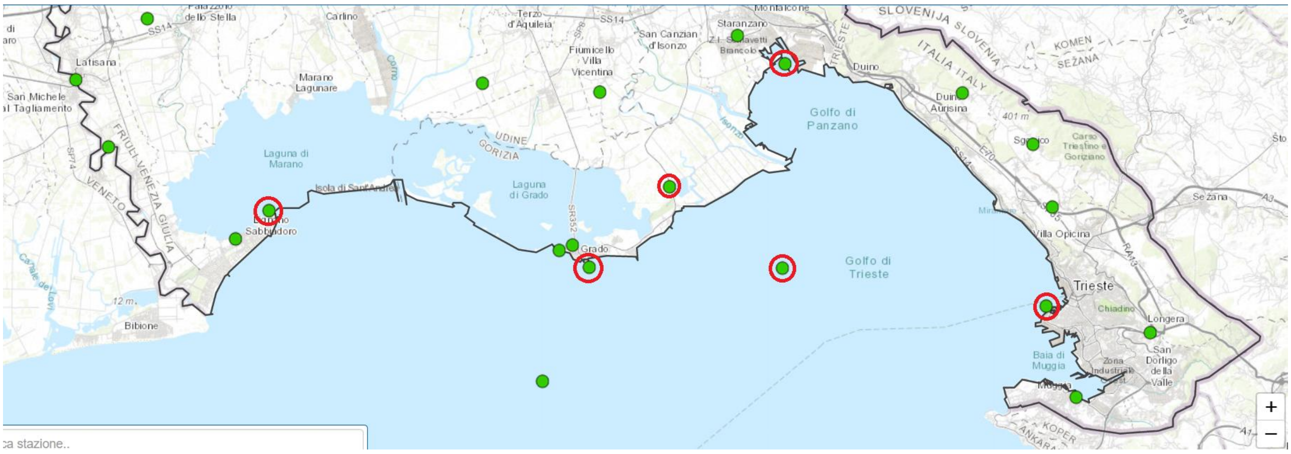

Figure 3-1. The subset of automatic meteorological stations (ARPA-FVG) that are included in the monitoring network of AdriaClim project, for the purposes of the gulf of Trieste and the Marano and Grado lagoon pilot area. Included stations are marked with a red circle

2.6.5. Synthesis of meteorological procedures listed by ARPAV

Authors: Fabio Dalan, Francesco Rech, Fabio Zecchini

ARPA Veneto measures, controls and manages data relating to the main meteorological variables through a network of automatic stations operating throughout the region. These stations transmit the data via radio in real time to the Acquisition Center in Marghera (VE) which uses a system called POLARIS. Most of ARPAV's automatic stations have been operational since March 1992. Figure 3-2 shows the subset of ARPAV meteorological stations operating in the project area
These stations measure the following variables with the related acquisition intervals: Wind direction, Wind Speed, Air Temperature, Air Relative Humidity, Soil temperatures, Atmospheric pressure, Global solar radiation (short wave), Reflected solar radiation (short wave), Precipitation (Table 1).

The data, both at the acquisition scan and as hourly and daily derived values, are stored in an ARPAV database called SIRAV (Veneto Regional Environmental Information System), which is a relational database in an ORACLE environment, accessible from the ARPA Veneto intranet.

Table 1 – Meteorological parameters measured and validated by ARPAV.

Weather variable	Acquisition time lapse	Unit of measure	Range	Resolution
Wind direction	*average every 10 minutes*	*Sexagesimal degrees °*	*0°-359°*	*3°*
Wind Speed	*average every 10 minutes*	*$m\ s^{-1}$*	*0,1-50 $m\ s^{-1}$*	*0,1 $m\ s^{-1}$*
Air Temperature	*instant data every 15 minutes*	*°C*	*-30 ÷ +50 °C*	*0,1 °C*
Air Relative Humidity	*instant data every 15 minutes*	*%*	*0-100*	*1%*
Soil temperatures	*instant data every 60 minutes*	*°C*	*-30 ÷ +50 °C*	*O,1 °C*
Atmospheric pressure	*instant data every 30 minutes*	*hPa*	*850-1050 hPa*	*0,1 hPa*
Global solar radiation (short wave)	*average every 15 minutes*	*Wm^{-2}*	*0- 1500 W/m^2*	*7 Wm^{-2}*
Reflected solar radiation (short wave)	*average every 15 minutes*	*Wm^{-2}*	*0- 1500 W/m^2*	*7 Wm^{-2}*
Precipitation	*sum every 5 minutes*	*mm*	*0-350 mm/h*	*0,2 mm*

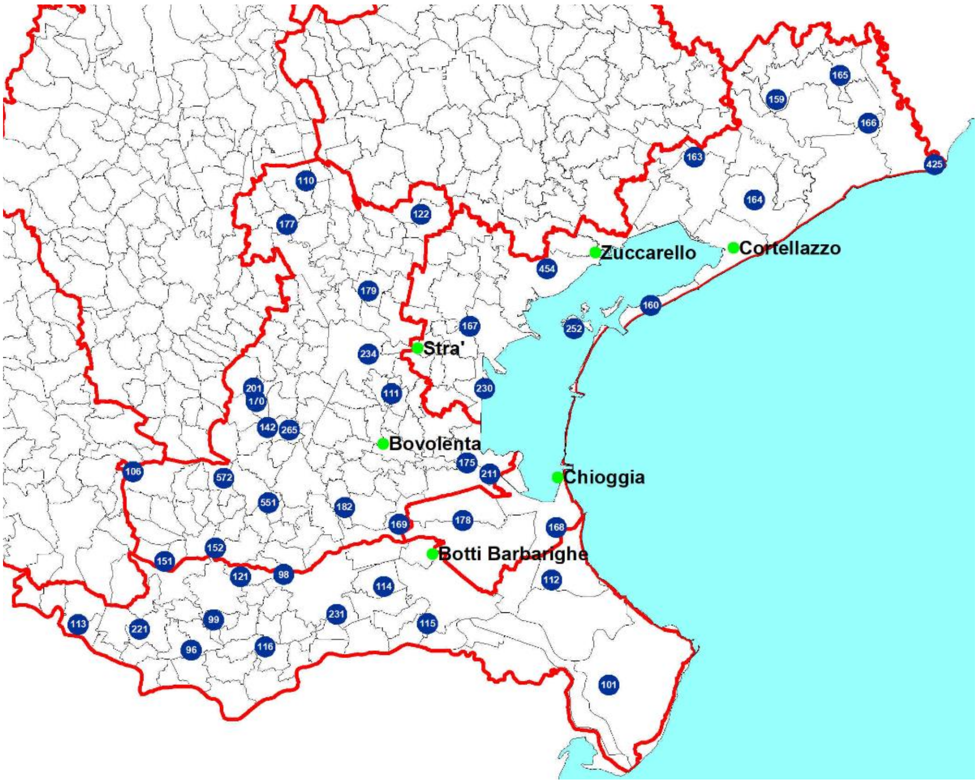

Figure 3-2. Veneto Region Provinces of Padua, Rovigo and Venice location of ARPAV automatic weather stations. The blue dots show the existing the stations. The green dots identify the 6 new automatic stations, installed in 2021 near the Adriatic coast with the RESPONSe project (Interreg Italy Croatia Program).

First level automatic controls

Data loading operations in the data base are carried out by carrying out the following checks:

- the data block of a station must allow the unambiguous recognition of the station and the reference date (the following must be recognized: station code, no. of sensors, date, hour, minute of start of monitoring);
- for each station, the acquisition start date cannot be prior to the data already present in the database (i.e. there must not be any temporal overlapping of the data even for a single scan);
- for each sensor of a given station, the mandatory elements that uniquely characterize it must be present (channel, sensor code, acquisition interval, no. of data) and at the same time the sensor must be configured in the database, i.e. the database must contain the space referenced to allocate the related data);
- the acquisition start date cannot be more than 30 days prior to the current date;
- the acquisition start date cannot be later than the current date;

- the data must actually be present and there must be congruence between the number of data expected and the number of data actually present.

The non-occurrence of these conditions determines the non-transfer of the relative data.

Subsequently, a specific application called VALIDAZIO intervenes, which carries out automatic checks highlighting macro anomalies such as discontinuity or absence of data. The program also automatically invalidates aberrant data on the basis of threshold values which are generally represented by the measurement range of the specific sensor (for example from – 30 to + 50 °C for air temperature sensors in plains, from 0.0 to 30.0 mm for the precipitation data detected in the 5 minutes).

Second level manual controls

A group of technicians using the VALIDAZIO application subsequently carries out the daily check of the data observed the previous day from each station. This application, thanks to automatic procedures and easy graphical representations, helps operators to identify exceeding values such as 10 and 90 percentile of the period values, excessive persistence of data with the same value, excessive variations of the data in a limited period. In addition, the VALIDAZIO program allows the technicians to make comparisons between trends of different sensors of the same station (e.g. presence of leaf wetness if rain is recorded or relationships between changes in temperature and relative humidity of the air) and between trends of the same sensor on nearby stations. For rainfall observations, comparisons are also possible between the images of the meteorological radar and the point values measured by the rain gauges.

The VALIDAZIO program carries out automatic reports (Warnings) but the final decision to validate, modify, or cancel a data rests with the technician.

The technicians carry out a monthly check of the multi-day trend of the observations in order to identify any instrumental drifts.

Doubts and functional problems identified in the data control phase activate field control processes by the maintenance teams.

General consideration

Data quality is guaranteed by:

- the suitable positioning of the sensors on the measurement site (choice of the site considering the indications of the WMO (mainly: WMO 2008, Guide to Meteorological

Instruments and Methods of Observation, WMO n. 8, Seventh edition. Secretariat of the World Meteorological Organization, Geneva – Switzerland);

- the maintenance of the measurement site conditions over time;
- from the periodic cleaning of the sensors;
- the periodic check (calibration) of the metrological characteristics of the instruments in the field and/or their replacement with calibrated instruments;
- rapid identification and replacement of faulty or uncalibrated sensors;
- rapid intervention on stations with functional and communication problems.

As regards the precipitation and temperature variables, the related maintenance, control and data validation and data dissemination procedures followed by the ARPAV Meteorological Service have been subject to quality certification according to the UNI EN ISO 9001/2015 standard.

3. A proposal for shared Quality Control procedures

3.1. A proposal for shared Quality Control procedures for sea level

Here we report a proposal of quality control (QC) procedures to validate sea level data.

These procedures are a subset of procedures implemented by ISPRA-RMLV. The procedures implemented by ISPRA-RMLV are compliant with the international quality checks standards (IOC) and are performed periodically (yearly) and manually. The application of these procedures with a specific protocol allows ISPRA to be ISO 9001 certified for the validation of RMLV sea level data.

Two procedures are reported, corresponding to two different levels of validation:

- Quality control L1. Data validated until L1 have been carefully checked for measurement errors (sensor, datalogger, transmission system, etc.). Among the QC procedures implemented, data are corrected for sensor drifts, measurement errors, and tide gauge benchmark drifts.
- Quality control L2. Data validated until L2 have been carefully checked for coherence with the expected physical behavior of the system. Among the QC procedures implemented, data are analyzed for tide and surge decomposition, and compared among neighboring stations (or stations with similar behavior) both for the whole series and using monthly and decadal means.

The objective of the procedures is to check, correct, and validate the sea level data to ensure data can be used for further processing and analyses. The procedures are implemented on annual data sets.

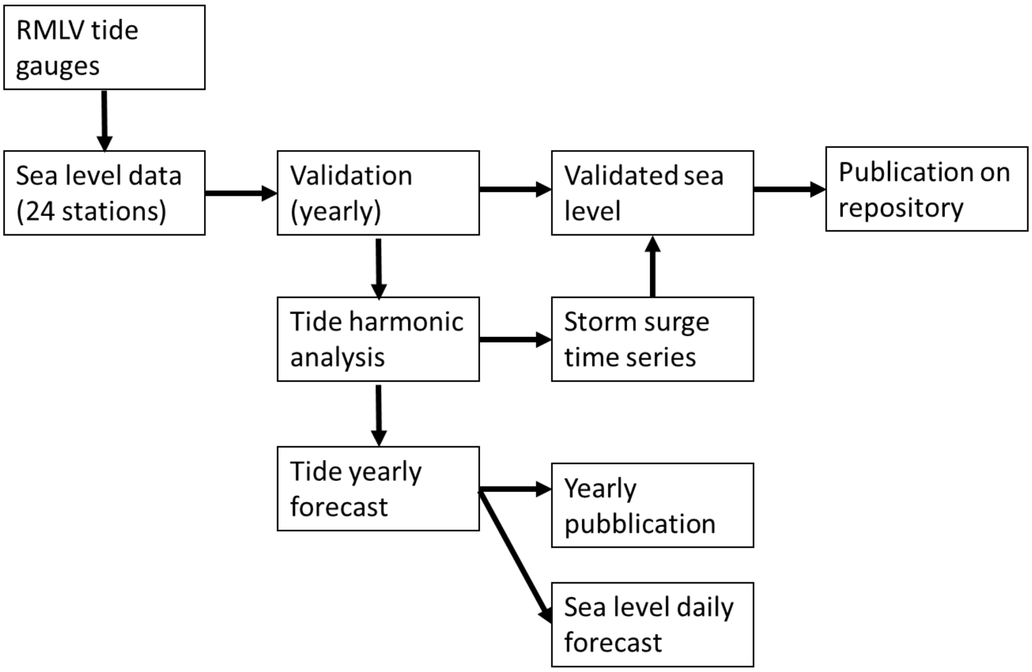

Figure 4-1. Position of validation procedures in the data flow at ISPRA-RMLV.

3.1.1. Data and metadata acquisition

Sea level measurement

Sea level is measured with float-operated tide gauge located inside a still well. The data are stored in a datalogger and sent in real time to a server via UHF radio and GPRS. The transmitted data can be considered as raw data and will be processed in the validation process.

Most dataloggers allow the user to set some real time procedures to flag issues in the data (e.g. values out of scale, values without physical meaning). The user then can obtain two data series: one with raw data, and one with filtered data which can be used in real-time applications (e.g. to display the data on a web page).

Tide gauge visit

The tide gauge stations are visited periodically (ideally every 4-6 months). During the visit, a manual measurement of the sea level is performed with a metric string. The sea level value measured manually is compared with the level recorded by the sensor to check for instrumental drifts. The level measured by the sensor is adjusted to align to the manual measurement. The manual sea level measurement and all other operations performed during the visit (e.g. sensor reading and regulation) is recorded in a report to be used in the following validation steps.

Tide gauge stability

The sea level measured values are referred to the tide gauge benchmark (TGBM). The tide gauge benchmark should be connected to a local network of benchmarks to check for its stability. This way, the relative sea level measured in the tide gauge is not only relative to the tide gauge benchmark, but is also connected to a local reference system.

Buddy check with neighboring station (or stations with similar behavior) can also be performed to check for differential settlements in the tide gauge benchmark compared to the datum. This check is usually performed during neap tide when meteorological conditions allow it (see later).

3.1.2. Quality control L1

Data validated until L1 have been carefully checked for measurement errors. The L1 level of quality control ensures that the sea level data are clean enough with respect to measurement errors, data gaps, spikes, etc.

Visual check of the time series and difference filter

The data are checked visually with the help of a difference filter. The difference filter is computed as the difference between a sea level measurement and the previous one. Since the sea level signal is usually smooth, the values of the difference filter are supposed to be within definite bounds. For instance, for ISPRA-RMLV data, values of the filter between +5 and -5 cm for 5-min data are considered normal. For different locations, different thresholds should be implemented. Values above or below these thresholds might be indicators of:

- Spikes: the sea level has a short and steep peak
- Derailments: the sea level is shifted of a fixed quantity for a long amount of time. This issue was common in stations where the float-operated sensor is connected to the measurement trough a pulley;
- Blocked sensor: when the sensor records only constant data;
- Missing data: there is a gap in the data due to the lack of measurement or transmission;

Data that are flagged as suspicious by the difference filter are manually examined; the values causing the abnormal behavior of the filter can be removed and substituted with interpolated values.

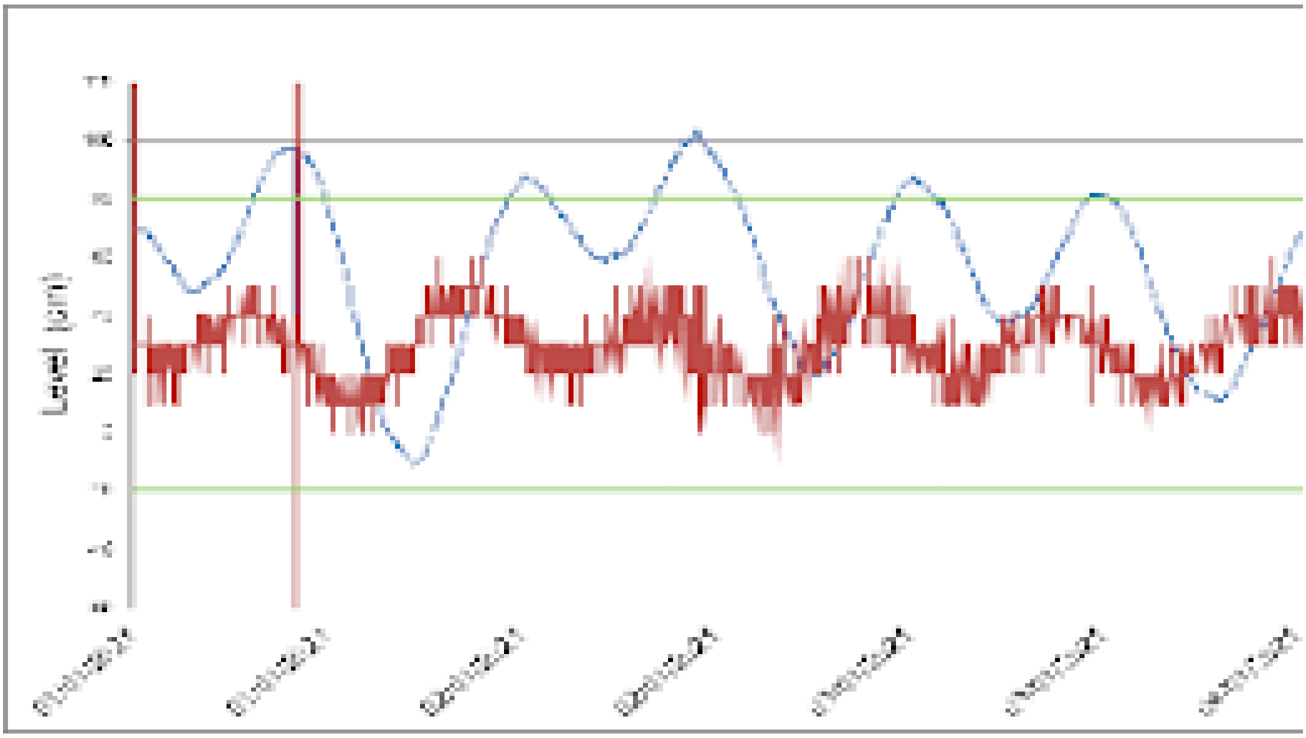

Figure 4-2. Example of difference filter. Note the filter is highlighting a spike.

After the time series has been cleaned, hourly data can be extracted. Hourly data are used in some programmes to extract the tide signal form the series. To this end, Pugh filters can be used to generate hourly data from data collected with a finer resolution by filtering out high frequency related signals. The number of the coefficients of the Pugh filter and their values depends on the resolution of the original signal and they can be found tabulated (Pugh, 1987).

3.1.3. Quality control L2

Data validated until L2 have been carefully checked for coherence with the expected physical behavior of the system: storm surges and decadal-monthly sea level variations.

Data adjustment based on metadata

The measured sea level is adjusted based on the report generated during the visit to the station. When there is not a visible step in the data, the correction is implemented gradually backwards until the previous visit.

Quality control flags

The following quality control flags have been implemented for the L2 validated data:

- 0: value missing in the raw data

- 1: value missing in the validated data
- 2: removed value: present in the raw data and missing in the validated data
- 3: corrected value: present in the raw data, and adjusted after metadata
- 4: interpolated value: missing in the raw data, interpolated

Tide analysis

The tidal component of the sea level can be obtained from the analysis of the tidal constituents. The procedure involves the fitting of a linear combination of harmonic functions (component). An amplitude and a phase coefficient, representing respectively the absolute contribution of the component to the tide amplitude, characterize each component and its lag compared to the other component. The fitted constituents constitute a tidal model. The tidal model can be then used to reconstruct the tide signal for the period the sea level measurement are available, or for a different period in time. For the Adriatic sea, a tidal model with 7 constituents is generally employed (M2, S2, N2, K2, K1, O1, P1); in the northern Adriatic sea, an additional constituent might be needed (S2), but more constituents can be used in particular situations (Tomasin, 2005).

There are several software packages that allow for the fitting and evaluation of a tide model. ISPRA-RMLV uses the software POLIFEMO; other software packages are 'oce' and 't_tide' in the R and python computing environments, respectively.

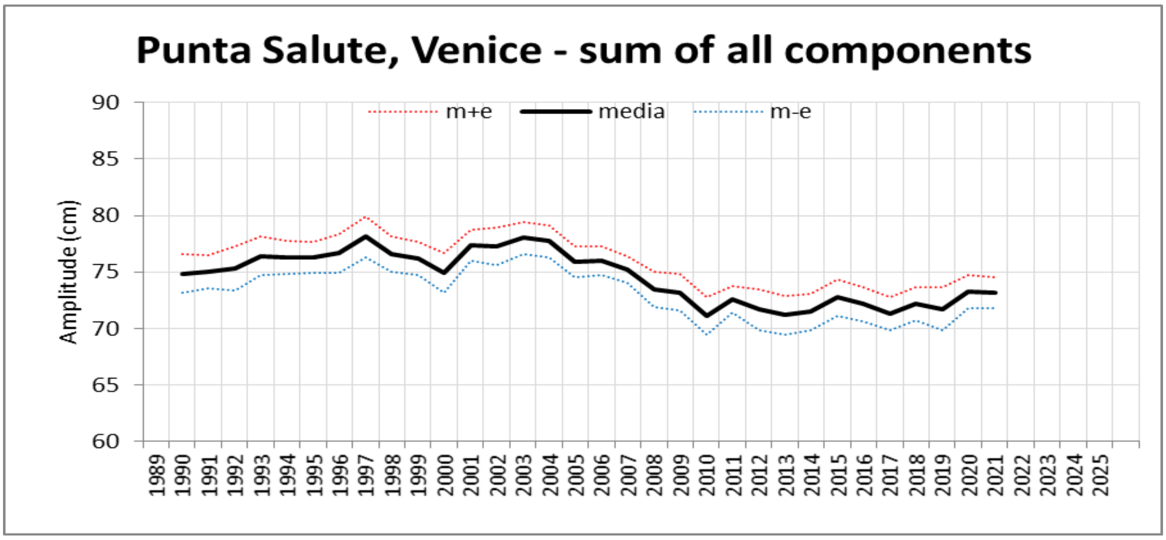

Figure 4-3. Temporal behavior of the sum of the amplitude of all tidal constituents for the Punta della Salute gauge, Venice.

The amplitude and phase coefficients of each constituent can be plotted in a time series to check for the stability over several years. Changes in the coefficients can be related with morphological changes of the cost, but also can indicate problems with the tide gauge.

Residual analysis

The meteorological contribution (residual) to the sea level can be calculated as the difference between the measured sea level and the tide (as predicted by the tidal model). The residual should fluctuate around zeroes, with large positive values in correspondence of storms or other relevant meteorological events. The residual might show some periodicity in correspondence to seiches (the periodicity is daily in the Adriatic sea). However, seiches-related periodicity has short durations (few days). A constant periodicity in the residual signal might be an indicator of a misalignment between the tide and the sea level time, which can be due to an error in the time of the original sea level data (e.g. daylight saving time instead of universal time), or an error in the fitted tidal model. Another source of error could be an obstruction in the still-well, which causes a timing error.

Residuals from different neighboring or comparable stations can be plotted together and checked. Stations that are affected by the same meteorological phenomenon should have comparable residual signal.

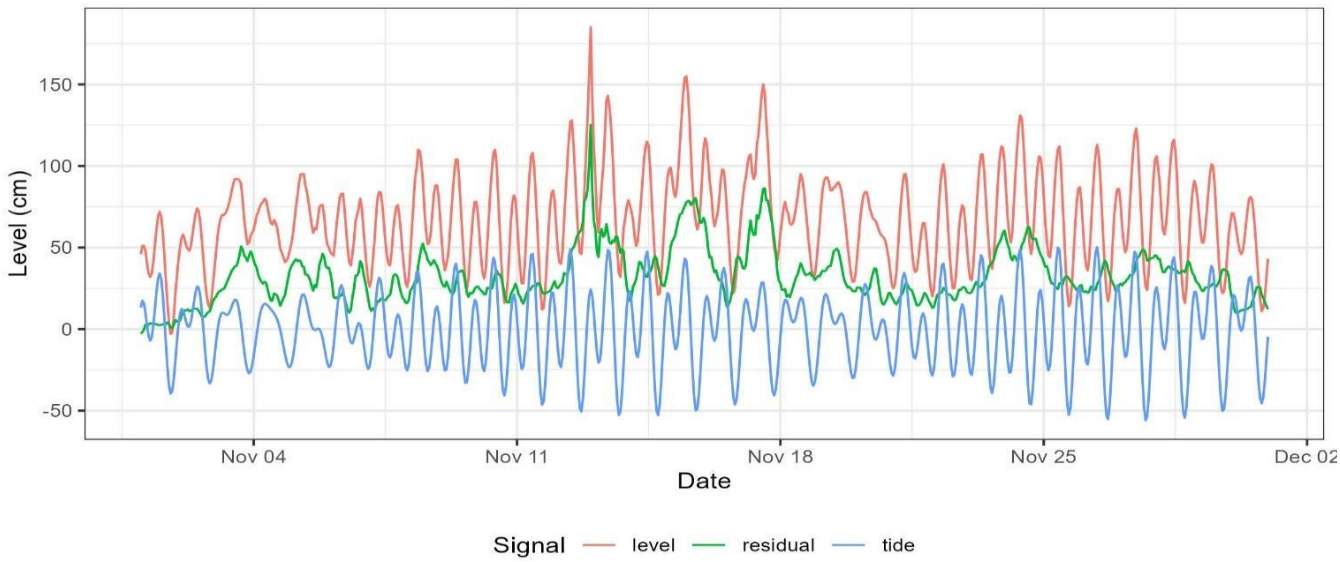

Figure 4-4. Residual calculation (green) as the difference of the sea level (red) and the tide (blue) for data from the Punta della Salute station, Venice, for November 2019.

Comparison among similar stations

The sea level signal can be compared between neighboring or similar stations (3-4 stations at a time) to check for congruency in the signal.

A sea level comparisons during neap tide can be used to check for sensor drifts, or for vertical displacements of the tide gauge bench mark. The comparison can be performed only when meteorological conditions allow for it: when the neap tide conditions persist over 4-6 hours and when the wind speed is lower than 5 m/s. Such conditions are rarely satisfied during a year.

Mean sea level comparison

The decadal (or monthly) mean sea level can be calculated and compared among different stations to check for discordant values that are not justified by local meteorological events. Decadal means are used because they are more sensitive to single events.

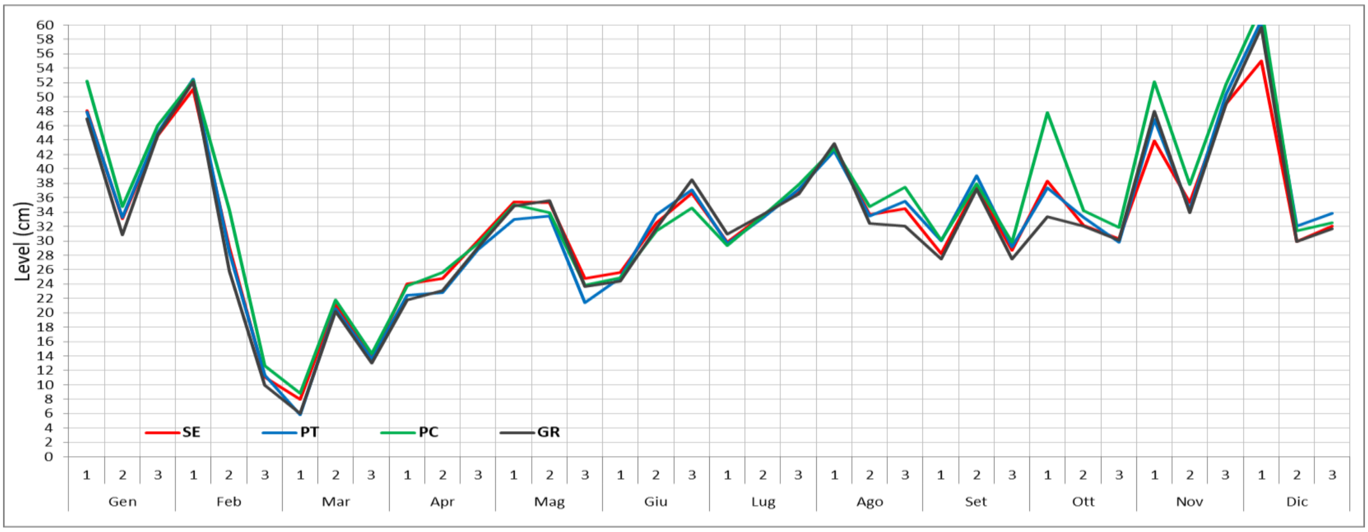

Figure 4-5. Comparison between decadal means for fata from four stations of the ISPRA.RMLV network for 2021. SE: Sant'Erasmo, PT: Piattaforma Acqua Alta, PC: Porto Caleri, GR: Grado.

3.2. A proposal for Quality Control procedures for wind waves

Here we report a proposal of quality control (QC) procedures to validate wind waves data.

The following steps are implemented:

- Date and time checks: check for missing dates in the time series;
- Identification and filling of missing data;
- Identification of values without physical meanings;
- Difference filter and identification of spikes (see below);
- Check on waves periods.

Visual check of the time series and difference filter

The data are checked visually with the help of a difference filter. The difference filter is computed as the difference between each wave measurement and the previous one. For different locations, different thresholds to flag suspicious values should be implemented. Values above or below these thresholds might be indicators of:

- Spikes
- Missing data: there is a gap in the data due to the lack of measurement or transmission;

Data that are flagged as suspicious by the difference filter are examined; the values causing the abnormal behavior of the filter are removed and flagged as missing data.

3.3. A proposal for Quality Control procedures for wind direction and speed

Here we report a proposal of quality control (QC) procedures to validate wind direction and speed data. These procedures are a subset of procedures implemented by ISPRA-RMLV.

The meteorological stations are visited periodically (ideally every 4-6 months). During the visit, a manual measurement of the wind direction and speed is performed with a calibrated anemometer. The direction and speed values measured manually are compared with the values recorded by the sensor to check that instrumental drifts are lower than a fixed threshold. When the threshold is exceeded, the sensor is substituted. The manual measurement and all other operations performed during the visit (e.g. sensor reading) are recorded in a report to be used in the following validation steps.

The data are stored in a datalogger and sent in real time to a server via UHF radio and GPRS. The transmitted data can be considered as raw data and will be processed in the validation process.

The validation process is performed yearly. Wind speed and direction are plotted for different stations that are expected to have the same behavior (max 3 stations together) and checked for inconsistencies. The comparison should focus on those periods with sustained winds (wind speed greater than 5 m/s).

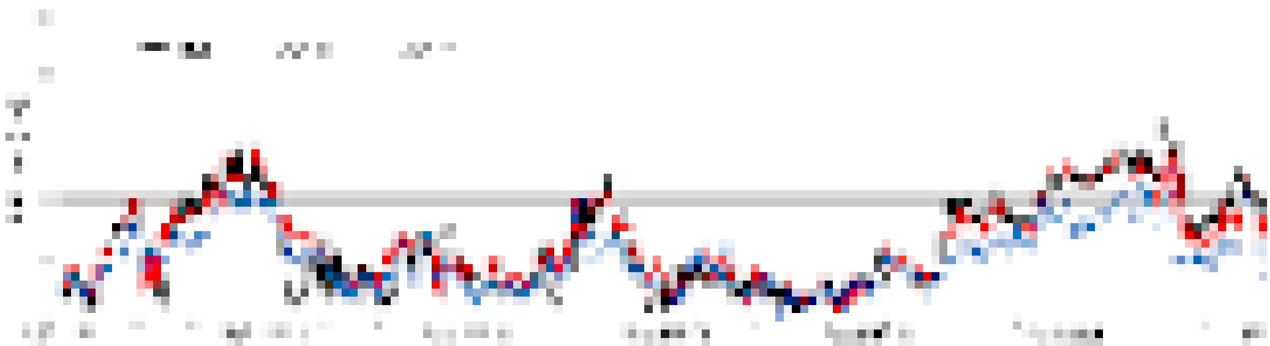

Figure 4-6. Comparison between wind speed measured at three different ISPRA-RMLV stations for the first days of January 2021. NM: Malamocco Diga Nord, SC: Chioggia Diga Sud, DS: Lido Diga Sud.

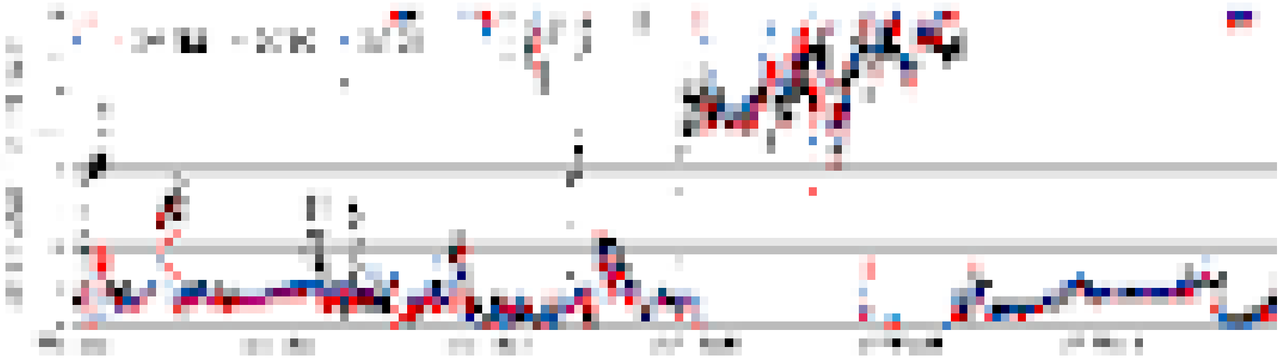

Figure 4-7. Comparison between wind direction measured at three different ISPRA-RMLV stations for the first days of January 2021. NM: Malamocco Diga Nord, SC: Chioggia Diga Sud, DS: Lido Diga Sud. Note that the wind direction is aligned for those periods where wind speed is high (e.g. Bora wind on January 1st and January 9th).

3.4. A proposal for Quality Control procedures for atmospheric pressure

Here we report a proposal of quality control (QC) procedures to validate atmospheric pressure data. These procedures are a subset of procedures implemented by ISPRA-RMLV.

The meteorological stations are visited periodically (ideally every 4-6 months). During the visit, a manual measurement of the atmospheric pressure is performed with a calibrated barometer. The atmospheric pressure values measured manually are compared with the values recorded by the sensor to check that instrumental drifts are lower than a fixed threshold. When the threshold is exceeded, the sensor is substituted. The manual measurement and all other operations performed during the visit (e.g. sensor reading) is recorded in a report to be used in the following validation steps.

The data are stored in a datalogger and sent in real time to a server via UHF radio and GPRS. The transmitted data can be considered as raw data and will be processed in the validation process.

The validation process is performed yearly. To validate the data, the full time series is plotted. A visual inspection allows for the identification of missing values, values with physical meaning but out of scale, and data without physical meaning. The values are then adjusted backwards based on the report produced during the visit to the station. Another station-specific compensation is implemented to consider the different elevation of the stations and express all the measured values with respect to mean sea level.

The atmospheric pressure yearly series then is plotted for different stations that are expected to have the same behavior (max 3 stations together) and checked for inconsistencies. The pressure signals should be aligned when the meteorological conditions are stable in the area of interest. Finally, the decadal (monthly) means are plotted and visually checked.

4. Acronyms

Quality Control (QC)
Neretva Estuary Stations (NES)
Split-Dalmatia Stations (SDS)

5. References

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