IOOS QARTOD software (ioos_qc)

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Materials available at https://github.com/MathewBiddle/WIO_workshop.

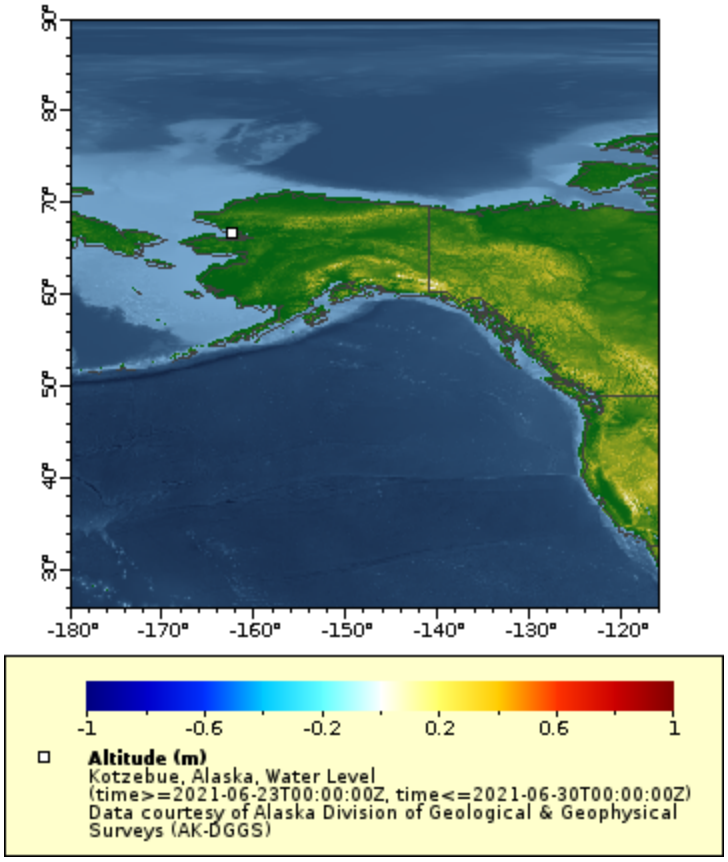
This presentation will demonstrate how to run `ioos_qc` on a time-series dataset. `ioos_qc` implements the Quality Assurance / Quality Control of Real Time Oceanographic Data (QARTOD).

Key Objectives of QARTOD

- Establish authoritative QA/QC procedures for the U.S. IOOS core variables, as necessary, including detailed information about the sensors and procedures used to measure the variables.
- Produce written manuals for these QA/QC procedures
- From the list of individual QA/QC procedures and guidelines developed, define a baseline set of QA/QC procedures that can be used for certification of RCOOS data providers
- Facilitate QA/QC integration with Global Ocean Observing System (GOOS) and other international ocean observation efforts
- Engage the Federal Agencies and IOOS Regions that are part of, or contribute to, US IOOS who will use the established QA/QC procedure
- Work efficiently, without duplication of effort, to facilitate the implementation of common QA/QC procedures amongst US IOOS Partners.

Let's go get these data

We will be using the water level data from a fixed station in Kotzebue, AK.



We will get the data from the AOOS ERDDAP server.

In [1]:
```
from erddapy import ERDDAP

e = ERDDAP(
    server="http://erddap.aoos.org/erddap/",
    protocol="tabledap"
)

e.dataset_id = "kotzebue-alaska-water-level"

e.constraints = {
    "time>=": "2018-09-05T21:00:00Z",
    "time<=": "2019-07-10T19:00:00Z",
}
```

Return data and metadata

In [2]:
```
import json
import warnings
warnings.filterwarnings('ignore')

def nice_print(indict):
    return print(json.dumps(indict, indent=2, default=str))
```

In [3]:
```
import cf_xarray

data = e.to_xarray()

data
```

Out[3]: xarray.Dataset

► Dimensions: (timeseries: 1, obs: 7241)

▼ Coordinates:

latitude	(timeseries)	float64	...
longitude	(timeseries)	float64	...
time	(obs)	datetime64[ns]	...

▼ Data variables:

station	(timeseries)	object	...
rowSize	(timeseries)	int32	...
z	(obs)	float64	...
sea_surface_heig...	(obs)	float64	...
sea_surface_heig...	(obs)	float64	...
sea_surface_heig...	(obs)	float64	...

► Attributes: (54)

In [4]:
```
data.cf
```

Out[4]:
```
Coordinates:
- CF Axes:   X: ['longitude']
             Y: ['latitude']
             T: ['time']
             Z: n/a

- CF Coordinates:   longitude: ['longitude']
                    latitude: ['latitude']
                    time: ['time']
                    vertical: n/a

- Cell Measures:   area, volume: n/a

- Standard Names:   latitude: ['latitude']
                    longitude: ['longitude']
                    time: ['time']

- Bounds:   n/a

Data Variables:
- Cell Measures:   area, volume: n/a

- Standard Names:   aggregate_quality_flag: ['sea_surface_height_above_sea_level_geoid_m
hhw_qc_agg']
                    altitude: ['z']
                    sea_surface_height_above_sea_level: ['sea_surface_height_above_sea_l
evel_geoid_mhhw']
                    sea_surface_height_above_sea_level quality_flag: ['sea_surface_heigh
t_above_sea_level_geoid_mhhw_qc_tests']

- Bounds:   n/a
```

In [5]:
```
data.cf.axes
```

Out[5]:
```
{'X': ['longitude'], 'Y': ['latitude'], 'T': ['time']}
```

In [6]:
```
data.cf.coordinates
```

Out[6]:
```
{'longitude': ['longitude'], 'latitude': ['latitude'], 'time': ['time']}
```

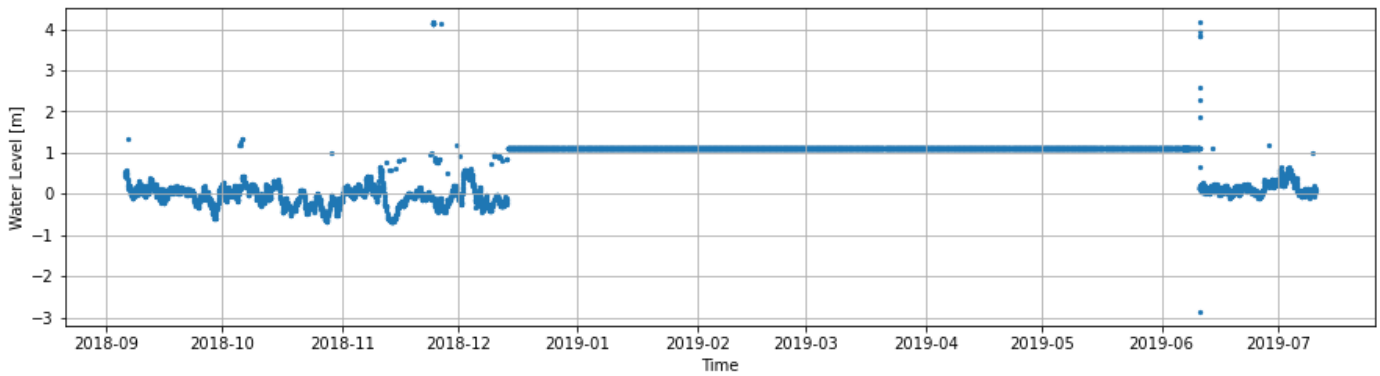
```
data.cf.standard_names
```

In [7]:

Out[7]:
```
{'latitude': ['latitude'],
 'longitude': ['longitude'],
 'time': ['time'],
 'altitude': ['z'],
 'sea_surface_height_above_sea_level': ['sea_surface_height_above_sea_level_geoid_mhh
w'],
 'aggregate_quality_flag': ['sea_surface_height_above_sea_level_geoid_mhhw_qc_agg'],
 'sea_surface_height_above_sea_level quality_flag': ['sea_surface_height_above_sea_level
_geoid_mhhw_qc_tests']}
```

Let's plot the raw data

In [8]:
```
import matplotlib.pyplot as plt

fig, ax = plt.subplots(figsize=(15, 3.75))

data.cf.plot.scatter('time','sea_surface_height_above_sea_level', ax=ax, s=5)

ax.grid(True)
```



Build the QC configuration

Below we create a simple Quality Assurance/Quality Control (QA/QC) configuration that will be used as input for `ioos_qc`. All the interval values are in the same units as the data.

For more information on the tests and recommended values for QA/QC check the documentation of each test and its inputs: https://ioos.github.io/ioos_qc/api/ioos_qc.html#module-ioos_qc.qartod

Manual for Real-Time Quality Control of Water Level Data

In [9]:
```
qc_config = {
    "qartod": {

      "gross_range_test": {
            "suspect_span": [ -2,  3],
            "fail_span":    [-10, 10]
      },

      "flat_line_test": {
            "tolerance":         0.001,
            "suspect_threshold": 10800,
            "fail_threshold":    21600
      },

      "spike_test": {
```

```
            "suspect_threshold": 0.8,
            "fail_threshold":      3,
        }
    }
}
```

In [10]:
```
nice_print(qc_config)
```

```
{
  "qartod": {
    "gross_range_test": {
      "suspect_span": [
        -2,
        3
      ],
      "fail_span": [
        -10,
        10
      ]
    },
    "flat_line_test": {
      "tolerance": 0.001,
      "suspect_threshold": 10800,
      "fail_threshold": 21600
    },
    "spike_test": {
      "suspect_threshold": 0.8,
      "fail_threshold": 3
    }
  }
}
```

For `flat_line_test`:

- 10800 seconds = 3 hours
- 21600 seconds = 6 hours

Run the QC tests with the supplied configuration

In [11]:
```
from ioos_qc.config import QcConfig

qc = QcConfig(qc_config)

variable_name = data.cf.standard_names["sea_surface_height_above_sea_level"][0]

qc_results =  qc.run(
    inp=data[variable_name],
    tinp=data.cf["time"],
)

nice_print(qc_results['qartod'])
```

```
{
  "gross_range_test": "[1 1 1 ... 1 1 1]",
  "flat_line_test": "[1 1 1 ... 1 1 1]",
  "spike_test": "[2 1 1 ... 1 1 2]"
}
```

The results are returned in a dictionary format, similar to the input configuration, with a mask for each test. The results range from 1 to 4 meaning:

flag	meaning

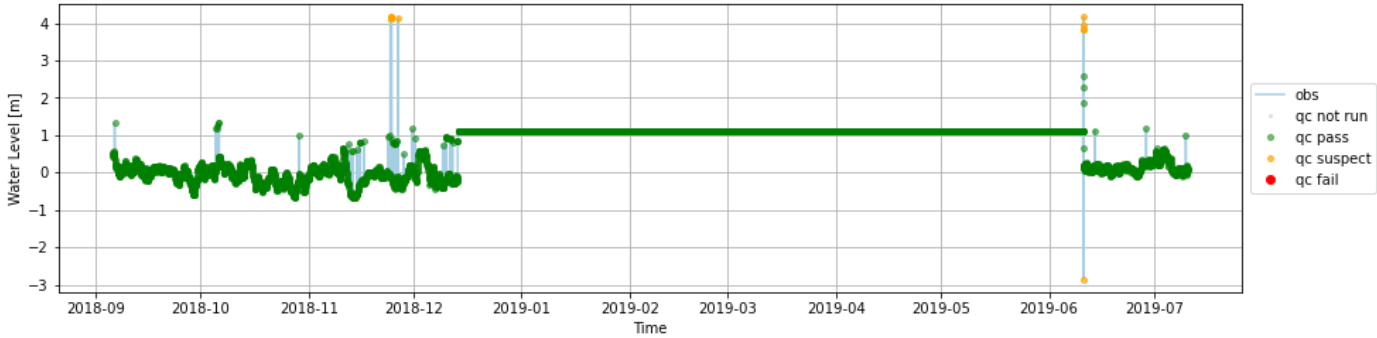
1	data passed the QA/QC
2	did not run on this data point
3	flag as suspect
4	flag as failed

In [12]:
```
%matplotlib inline

import numpy as np

def plot_results(data, variable_name, results, title, test_name):
    time = data.cf["time"]
    obs = data[variable_name]
    qc_test = results["qartod"][test_name]

    qc_pass = np.ma.masked_where(qc_test != 1, obs)
    qc_notrun = np.ma.masked_where(qc_test != 2, obs)
    qc_suspect = np.ma.masked_where(qc_test != 3, obs)
    qc_fail = np.ma.masked_where(qc_test != 4, obs)

    fig, ax = plt.subplots(figsize=(15, 3.75))
    fig.set_title = f"{test_name}: {title}"

    ax.set_xlabel(f"{time.long_name}")
    ax.set_ylabel(f"{data[variable_name].long_name} [{data[variable_name].units}]")

    kw = {"marker": "o", "linestyle": "none"}
    ax.plot(time, obs,  label="obs", color="#A6CEE3")
    ax.plot(time, qc_notrun, markersize=2, label="qc not run", color="gray", alpha=0.2,
    ax.plot(time, qc_pass, markersize=4, label="qc pass", color="green", alpha=0.5, **kw
    ax.plot(time, qc_suspect, markersize=4, label="qc suspect", color="orange", alpha=0.
    ax.plot(time, qc_fail, markersize=6, label="qc fail", color="red", alpha=1.0, **kw)
    ax.legend(loc='best',bbox_to_anchor=(1.12,.75))
    ax.grid(True)

title = "Water Level [MHHW] [m] : Kotzebue, AK"
```

Let's look at the `gross_range` test results

The gross range test test should fail data outside the $\pm$ 10 range and suspect data below -2, and greater than 3. As one can easily see all the major spikes are flagged as expected.

In [13]:
```
plot_results(
    data,
    variable_name,
    qc_results,
    title,
    "gross_range_test"
)
```



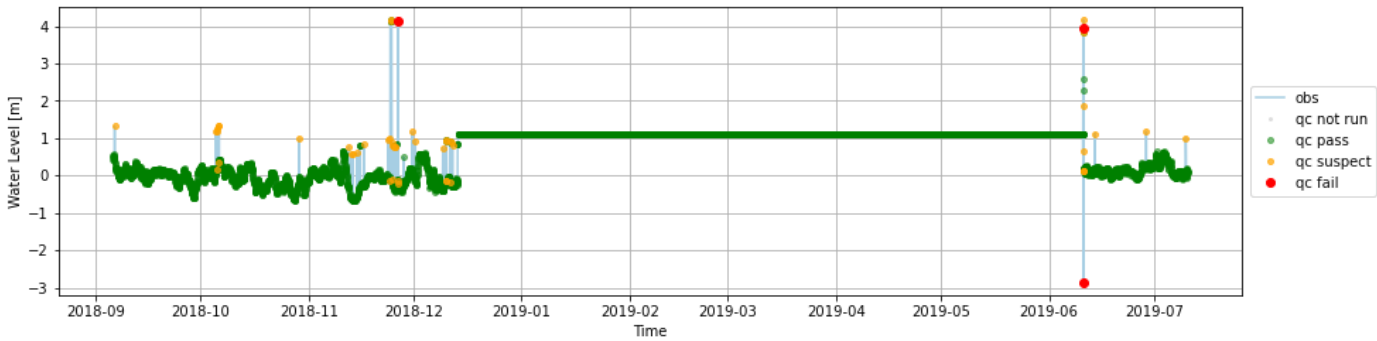
In [14]:
```
qc_config['qartod']['gross_range_test']
```

Out[14]:
```
{'suspect_span': [-2, 3], 'fail_span': [-10, 10]}
```

Let's look at the `spike` test results

An actual spike test, based on a data increase threshold, flags similar spikes to the gross range test but also indetifies other suspect unusual increases in the series.

In [15]:
```
plot_results(
    data,
    variable_name,
    qc_results,
    title,
    "spike_test"
)
```



In [16]:
```
qc_config['qartod']['spike_test']
```

Out[16]:
```
{'suspect_threshold': 0.8, 'fail_threshold': 3}
```

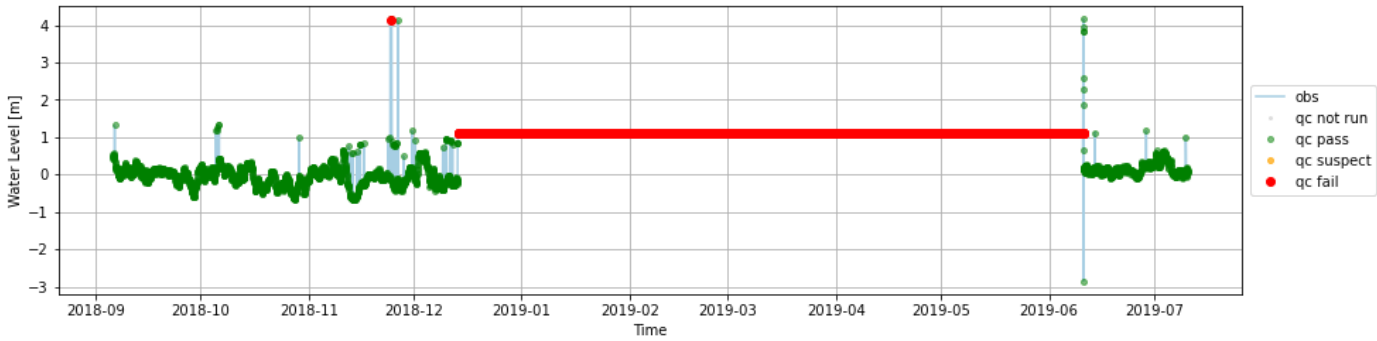
Let's look at the `flat_line` test results

The flat line test identifies issues with the data where values are "stuck."

`ioos_qc` succefully identified a huge portion of the data where that happens and flagged a smaller one as suspect. (Zoom in the red point to the left to see this one.)

In [17]:
```
plot_results(
    data,
    variable_name,
    qc_results,
    title,
```

```
    "flat_line_test"
)
```



In [18]:
```
qc_config['qartod']['flat_line_test']
```

Out[18]:
```
{'tolerance': 0.001, 'suspect_threshold': 10800, 'fail_threshold': 21600}
```

What tests are currently available in `ioos_qc` for QARTOD?

In [19]:
```
import ioos_qc

for func in dir(ioos_qc.qartod):
    if "test" in func:
        print(func)
```

```
attenuated_signal_test
climatology_test
density_inversion_test
flat_line_test
gross_range_test
location_test
rate_of_change_test
spike_test
```

Where can you find more information?

- IOOS CodeLab example: https://ioos.github.io/ioos_code_lab/content/code_gallery/data_analysis_and_visualization_notebooks/2020 02-14-QARTOD_ioos_qc_Water-Level-Example.html
- Example notebooks: https://github.com/ioos/ioos_qc/tree/master/docs/source/examples
- Source documentation: https://ioos.github.io/ioos_qc/
- QARTOD manuals: https://ioos.noaa.gov/project/qartod/

Thank you!

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Materials available at https://github.com/MathewBiddle/WIO_workshop.

This notebook was adapt from Jessica Austin and Kyle Wilcox's original ioos_qc examples. Please see the `ioos_qc` documentation for more examples.