Quality Control of Heterogeneous IMS Stations #336

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Introduction

Motivation: Detecting infrasonic or seismic events such as nuclear detonations is heavily dependent on data quality (DQ), and Station Operators are responsible for monitoring waveform data for completeness, transient noise, spikes, and changing or anomalous instrument response *(Marty, 2010)*

- The Wilson Alaska Technical Center (WATC) has long used an array of DQ tools to monitor state of health and completeness, but this project augments existing DQ procedures by adding a metric-based waveform data quality control (QC) scheme

Challenges: The diverse station-types monitored by WATC, which include infrasound and seismic arrays, broadband seismic, short-period seismic, and meteorological channels, are challenging for existing QC tools such as IRIS MUSTANG/ISPAQ *(Caset, et al., 2018)*

Approach: The new WATC QC system leverages existing tools, but has been built-out and customized to accommodate diverse channel types. We make heavy use of ObsPy to customize the system (*Beyreuther et al., 2010*)

Metric-based QC: Doctrine and Terminology

Metrics

a measurement (or algorithm to generate a measurement) that is indicative of some aspect of data quality

- facts
- observations
- raw data

dead_channel_lin = 1.8

Thresholds

a metric or combination of metrics combined with a cut-off value

- organize metrics
- identify and alert to potential data defects
- reduce analyst workload

num_gap/percent_availability > .12

dead_channel_lin < 2.0

Analysis

a human must investigate potential issues flagged by thresholds

- review issues
- inspect waveforms
- develop an interpretation
- provide actionable intelligence

Dead sensor at KDAK

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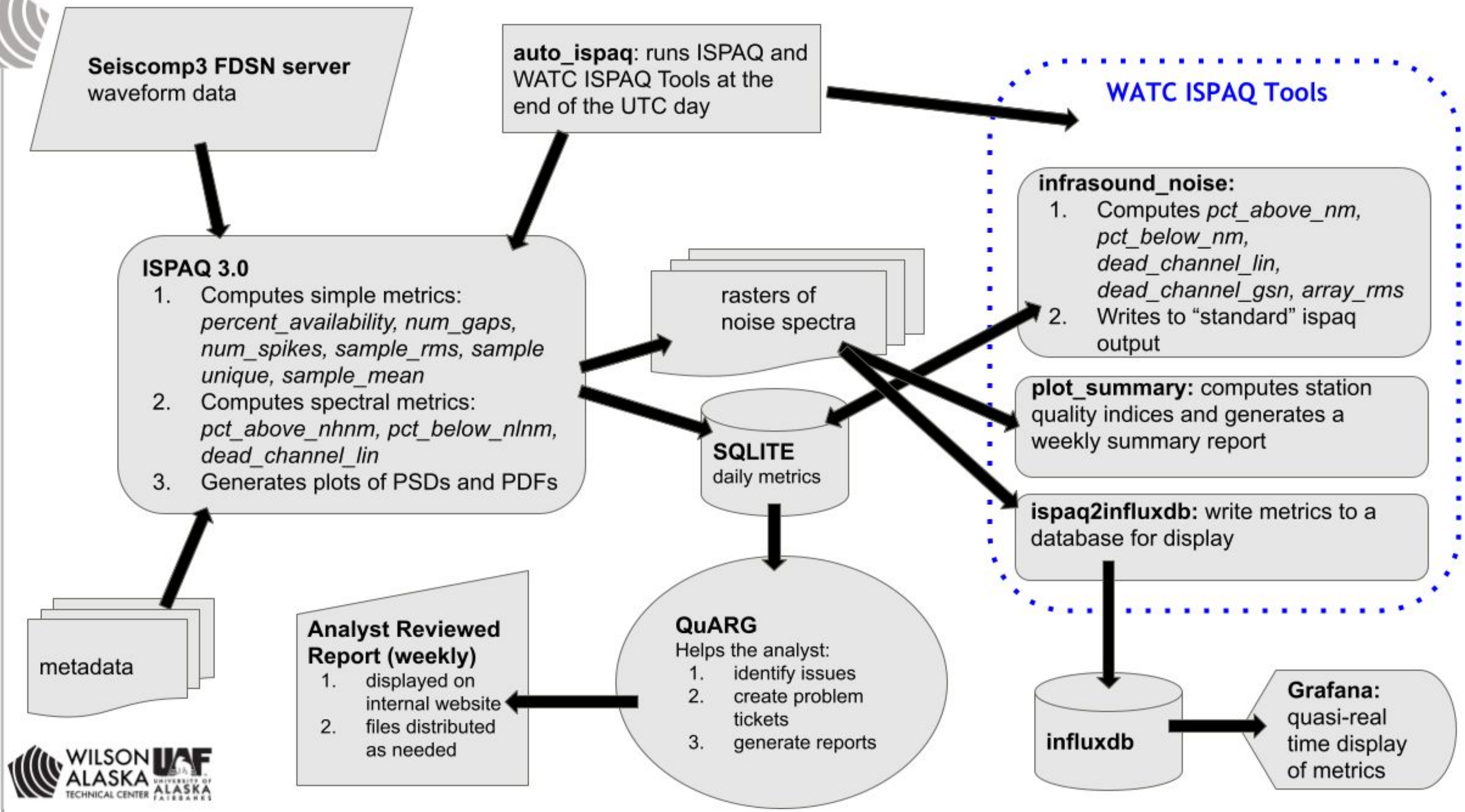
Core Software

- ISPAQ: IRIS System for Portable Assessment of Quality
    - Python/R code for station operators to generate MUSTANG metrics locally
    - 40 metrics available
    - ISPAQ 3.0 writes metrics to a SQLite database
- QuARG: Quality Assurance Report Generator
    - Uses thresholds to identify potential issues and alert the analyst
    - Generates QC report
    - Employs a ticketing system
- ObsPy: Python toolbox for seismology
    - Flexible through pull requests
    - Used to compute metrics for channels not currently handled by ISPAQ

WATC Metric-based Waveform QC System



Noise Spectra for Infrasound

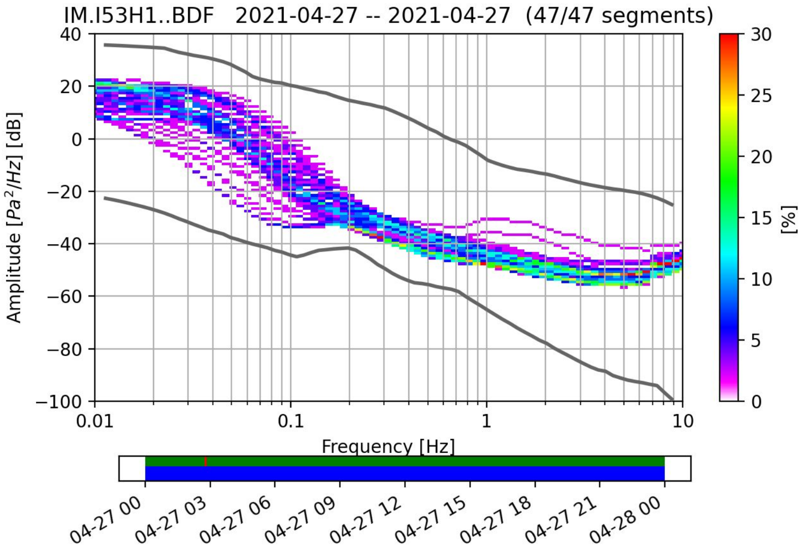
- ISPAQ and ObsPy use the Mcnamara and Buland (2004) method of computing power spectral densities (PSD)
- This method differentiates seismic data to acceleration in the response removal stage, which is not required for infrasound
- We modified the ObsPy Signal library to correctly handle PSD/PDFs for infrasound
- Also added ambient acoustic noise models from Brown (2012)

```
# Create a psd object for infrasound chan
tr = st[0]

ppsd = PPSD(tr.stats, metadata = inv,
      special_handling = 'infrasound',
      db_bins = (-100, 40, 1.))

ppsd.add(st)
ppsd.plot(xaxis_frequency = True,
      period_lim = (0.01, 10),
      cmap=pqlx)
```

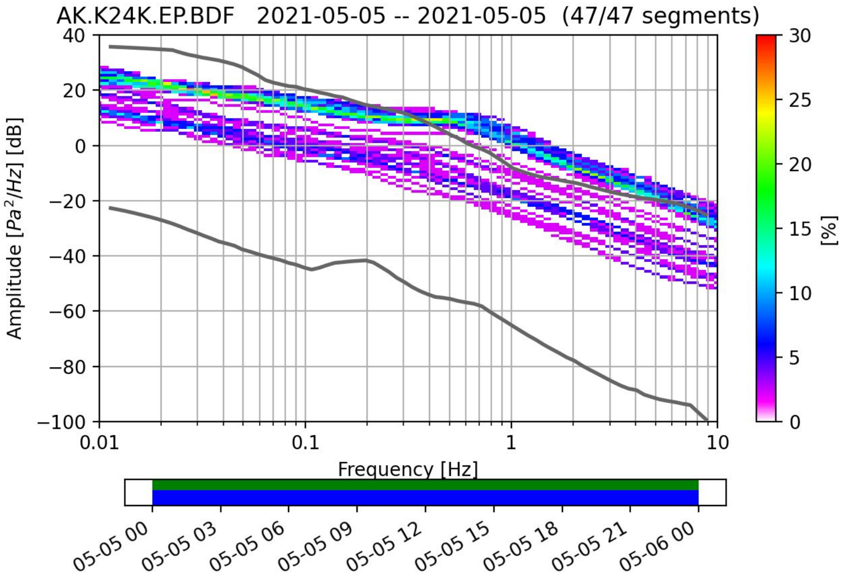
New feature!



Noise Spectra for Infrasound

- We also added MUSTANG-like spectral metrics to the ObsPy PPSD object
  - get_pct_above_nm(): percentage of spectra above IDC high noise model
  - get_pct_below_nm(): percentage of spectra below IDC low noise model
  - get_dead_channel_lin(): residual from fitting a line to spectra
  - get_dead_channel_gsn(): spectra more than 5 dB below low model near the microbarom

```
In [8]: ppsd.get_pct_above_nm()
Out[8]: 26.786688488816147
In [9]: ppsd.get_pct_below_nm()
Out[9]: 0.0
In [10]: ppsd.get_dead_channel_lin()
Out[10]: 3.6031948727904397
In [11]: ppsd.get_dead_channel_gsn()
Out[11]: 0
```



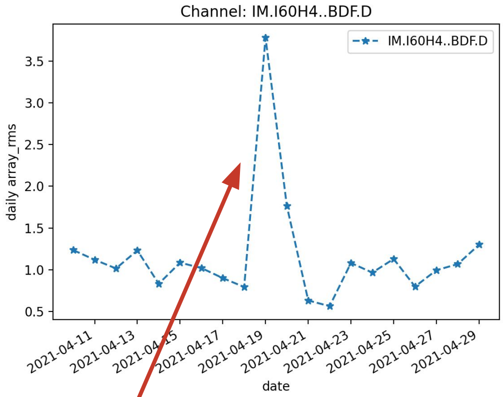
Custom Metrics

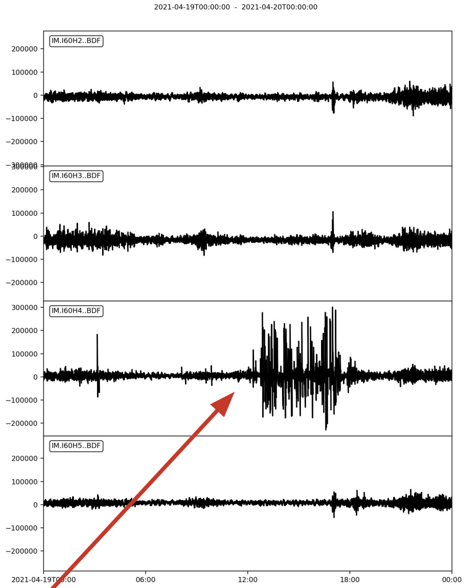
- The system is extensible and allows adding custom metrics
- ***array_rms:*** metric designed to detect transients on single element of an infrasound array
  - Grab 24 hours of data for all elements
  - Find the standard deviation of each element for the day
  - Find the mean of the standard deviation for all other elements
  - The metric is the ratio of the element standard deviation to the array average
  - If ratio is large, there is likely transient noise on a single element

For an *n* element array, the *array_rms* for the *ith* element is given by

$$array\_rms_i = \frac{\sigma_i}{\bar{\sigma}_{[1,n]\setminus i}}$$

Where the numerator is the standard deviation of the *ith* element and the denominator is the mean standard deviation of the array excluding the *ith* element



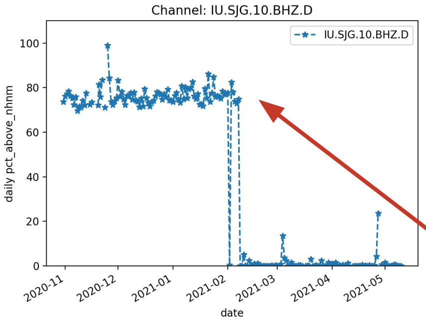


Spike in *array_rms*

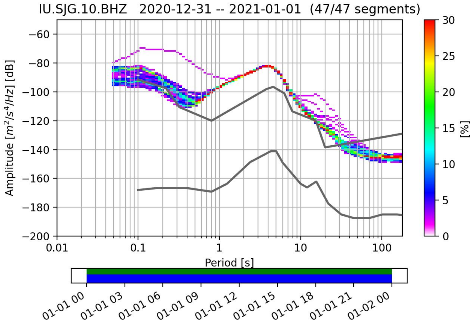
Transient!

Defect Detection Examples

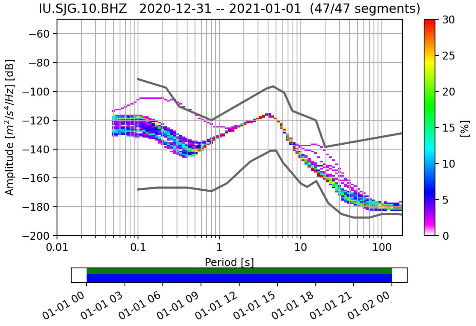
Ex. 1 Metadata problem on broadband



Consistently high noise



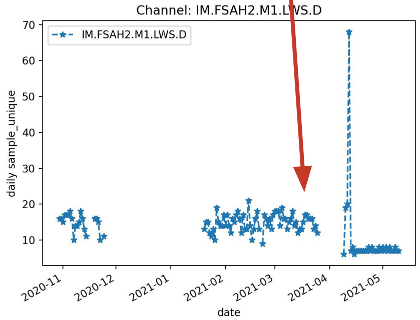
Spectra mostly above model



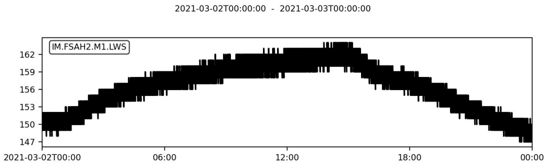
Corrected response

Ex. 2 Dead Weather Sensor

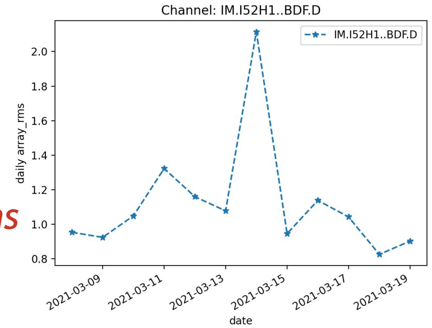
Small number of unique values each day



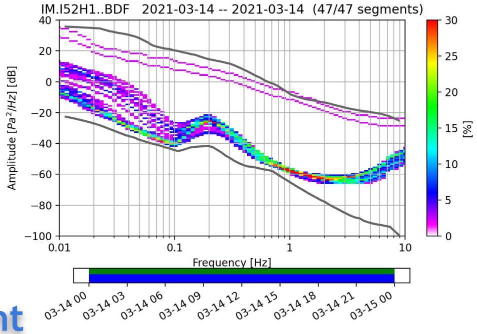
Digitizer noise



Spike in *array_rms*



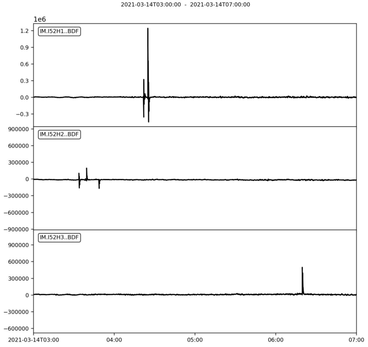
Short duration noise



Ex. 3 Transient on infrasound

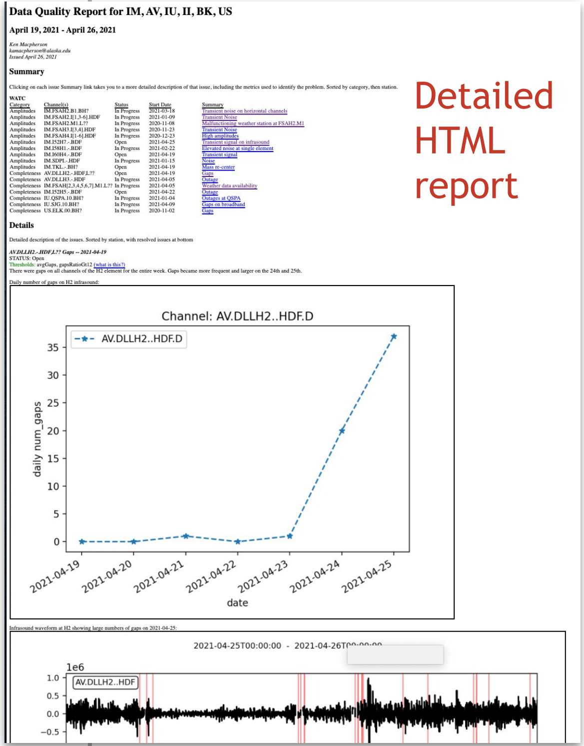
Waveform transients

cause: Site visit!



Reporting

- WATC uses QuARG to generate a detailed analyst-reviewed QC weekly report
- Also distributes a single-page summary overview



Data Quality Report for IM, AV, IU, II, BK, US

April 19, 2021 - April 26, 2021

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Issued April 26, 2021

Summary

Clicking on each issue Summary link takes you to a more detailed description of that issue, including the metrics used to identify the problem. Sorted by category, then station.

WATC

Category	Channel(s)	Status	Start Date	Summary
Amplitudes	IM.FSAH2.B1.BH?	In Progress	2021-03-18	Transient noise on horizontal channels
Amplitudes	IM.FSAH2.I[1,3-6].HDF	In Progress	2021-01-09	Transient Noise
Amplitudes	IM.FSAH2.M1.L??	In Progress	2020-11-08	Malfunctioning weather station at FSAH2.M1
Amplitudes	IM.FSAH3.I[3,4].HDF	In Progress	2020-11-23	Transient Noise
Amplitudes	IM.FSAH4.I[1-6].HDF	In Progress	2020-12-23	High amplitudes
Amplitudes	IM.I52H7.-.BDF	Open	2021-04-25	Transient signal on infrasound
Amplitudes	IM.I58H1.-.BDF	In Progress	2021-02-22	Elevated noise at single element
Amplitudes	IM.I60H4.-.BDF	Open	2021-04-19	Transient signal
Amplitudes	IM.SDPI.-.HDF	In Progress	2021-01-15	Noise
Amplitudes	IM.TKL.-.BH?	Open	2021-04-19	Mass re-center
Completeness	AV.DLLH2.-.HDF,L??	Open	2021-04-19	Gaps
Completeness	AV.DLLH3.-.HDF	In Progress	2021-04-05	Outage
Completeness	IM.FSAH[2,3,4,5,6,7].M1.L??	In Progress	2021-04-05	Weather data availability
Completeness	IM.I52H5.-.BDF	Open	2021-04-22	Outage
Completeness	IU.QSPA.10.BH?	In Progress	2021-01-04	Outages at QSPA
Completeness	IU.SJG.10.BH?	In Progress	2021-04-09	Gaps on broadband
Completeness	US.ELK.00.BH?	In Progress	2020-11-02	Gaps

Details

Detailed description of the issues. Sorted by station, with resolved issues at bottom

AV.DLLH2.-.HDF,L?? Gaps -- 2021-04-19
STATUS: Open
Thresholds: avgGaps, gapsRatioGt12 (what is this?)
There were gaps on all channels of the H2 element for the entire week. Gaps became more frequent and larger on the 24th and 25th.

Daily number of gaps on H2 infrasound:

Infrasound waveform at H2 showing large numbers of gaps on 2021-04-25:

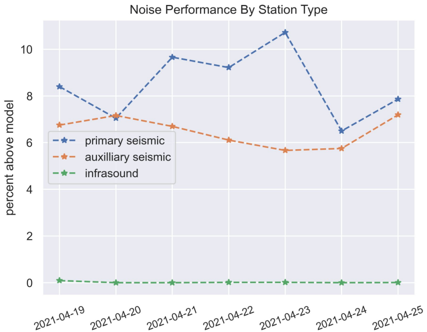
Detailed HTML report

WATC has developed a metric-based ***station quality index (Q_S)*** to rate stations. A channel that is defect-free has a score of "1", while a score of "0" would indicate an outage, digitizer noise, etc.

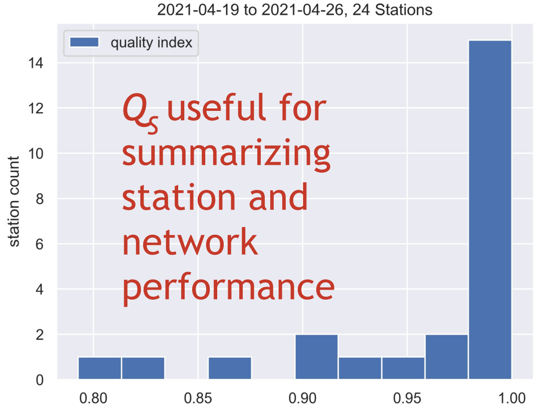
$$Q_s = \left(1 - \frac{1}{n}\sum_{1}^{n} dead\_channel\_gsn\right) \times \left(1 - \frac{\frac{1}{n}\sum_1^n pct\_above\_nm}{100}\right) \times \cdots$$

$$\left(1 - \frac{\frac{1}{n}\sum_1^n num\_spikes}{max\_num\_spikes}\right) \times \left(1 - \frac{\frac{1}{n}\sum_1^n num\_gaps}{max\_num\_gaps}\right) \times \left(\frac{\frac{1}{n}\sum_1^n percent\_availability}{100}\right)$$

where n is the number of days



Summary plots provide insight into Q_S score



Q_S useful for summarizing station and network performance

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Conclusions

- We developed a **metric-based waveform QC scheme**, augmenting existing monitoring
- The system **accommodates diverse channel types** including seismic, infrasound, and environmental
- The system is **extensible** through the use of custom metrics
- The system **generates network intelligence** including completeness, transient detection, and spectral characteristics
- The system **communicates network intelligence** to engineers and data consumers in the form of weekly detailed and summary reports

Select References:

Moritz Beyreuther, Robert Barsch, Lion Krischer, Tobias Megies, Yannik Behr, Joachim Wassermann, ObsPy: A Python Toolbox for Seismology. Seismological Research Letters 2010, 81 (3): 530–533.

Brown, D., Ceranna, L., Prior, M. et al. The IDC Seismic, Hydroacoustic and Infrasound Global Low and High Noise Models. Pure Appl. Geophys. 171, 361–375 (2014)

Robert Casey, Mary E. Templeton, Gillian Sharer, Laura Keyson, Bruce R. Weertman, Tim Ahern; Assuring the Quality of IRIS Data with MUSTANG. Seismological Research Letters 2018;; 89 (2A): 630–639.

Julien Marty (2019) The IMS Infrasound Network: Current Status and Technological Developments: Challenges in Middle Atmosphere Dynamics and Societal Benefits

Daniel E. McNamara, Raymond P. Buland; Ambient Noise Levels in the Continental United States. Bulletin of the Seismological Society of America 2004;; 94 (4): 1517–1527.

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