Station Quality Monitoring for the Pacific Northwest Seismic Network and Shakealert

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Abstract

The Pacific Northwest Seismic Network is responsible for monitoring seismic activity in Cascadia and is also part of the USGS ShakeAlert earthquake early warning system. Fulfilling our role effectively requires monitoring station state of health metrics, those related to waveform quality such as power spectral density estimates, and those specific to ShakeAlert. We currently monitor station quality in near-real time at all PNSN stations as well as all stations contributing to ShakeAlert. Using our large database of metrics spanning many months and in collaboration with the ShakeAlert regional coordinators, we have established acceptance criteria for adding new stations to the ShakeAlert system. These include measures of latency, data completeness and number of potential earthquake triggers among others. We are also mining our database as well as logfiles from Earthquake Point-source Integrated Code (EPIC), one of two algorithms used by ShakeAlert, to identify parameters that can be modified and additional waveform checks that can be added to reduce the number of false triggers while not negatively impacting EPIC's performance. To test out ideas, we run test instances of EPIC as well as replay past earthquakes to assess any suggested changes. Finally we are exploring ways to establish thresholds for various metrics to be used to grey/black-list problematic stations in ShakeAlert. These are assessed using a map-based tool of theoretical alert time. To better visualize and comprehend the mountain of information that we collect and generate, we have begun work on an API which will be able to digest any properly formatted JSON message sent to the API and thus can ingest metrics from databases, AQMS messages, other APIs, upload via wget, etc. The API will be web-serviceable that utilizes Tableau visualization tools.

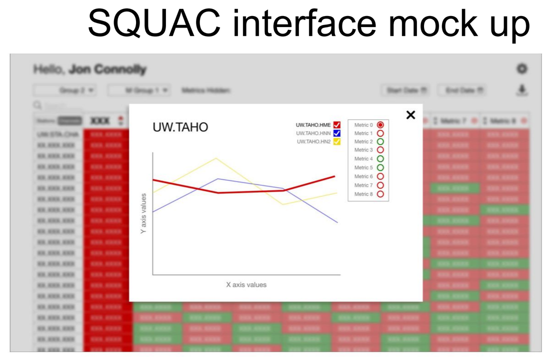
SQUAC
Seismic Quality Assessment Console

PNSN is currently developing the Seismic Quality Assessment Console (SQUAC) as a tool for monitoring "data quality", a term whose definition varies from user to usder. While currently a few similar tools exist such as MUSTANG (IRIS), SeisNetWatch (ISTI) and Data Quality Analyzer (ASL), none meet the needs of the PNSN as an ANSS regional seismic network and as a participant in ShakeAlert. Many of these overlap.

The needs include:

- Traditional PSD/PDF noise plots
- Tracking of instrument metrics: state of health, mean, min, max etc.
- Data latency
- Incidences of false triggers
- Near-real time

SQUAC interface mock up



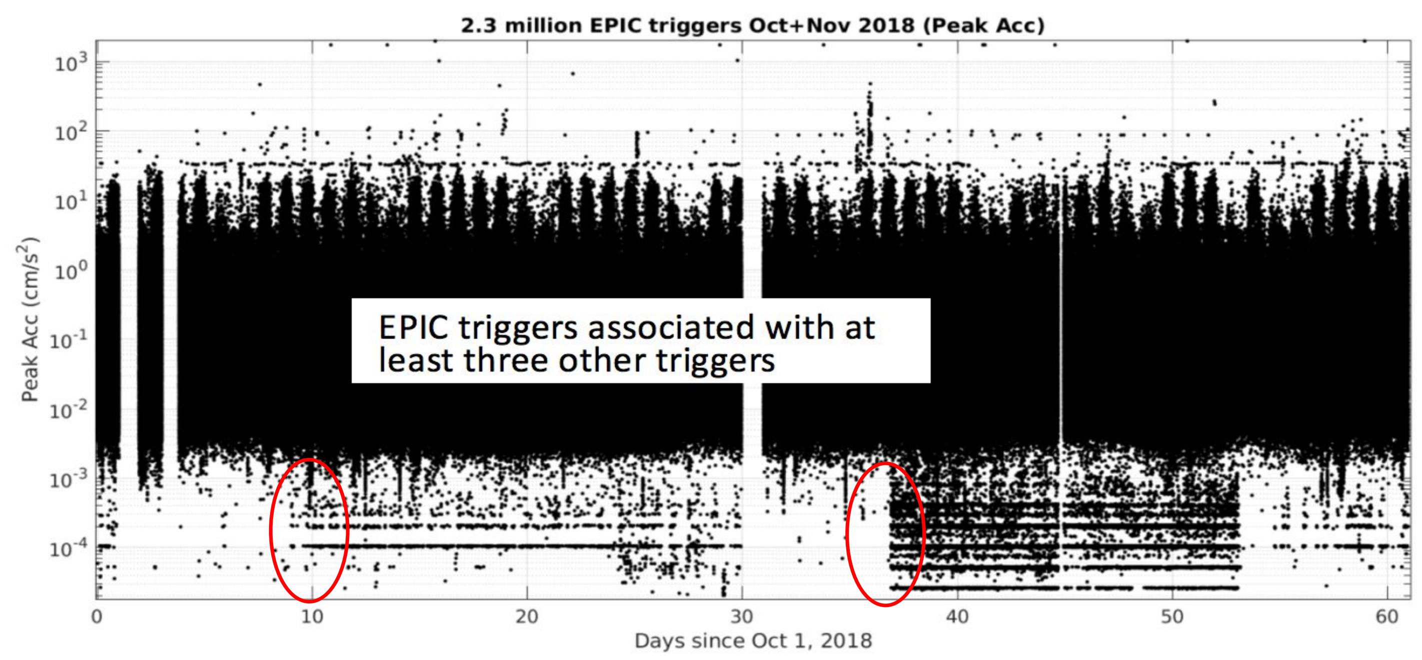
Features being baked in include:

- A centrally managed postgres database under the hood
- User configurable alarms
- Ability of any authorized user to contribute, e.g. ASQM messages, a metric in another database via JSON wget, etc.
- Simple web service based interface for use by techs in the field as well as research seismologists:
  - group by net, stat, or chan
  - Configurable parameters & thresholds for "one-gance" network SOH

In the database of metrics:

- Updated every hour, about two hours behind realtime.
- Over 1600 PNSN and ShakeAlert (vertical) channels being monitored
- Over 50 metrics currently being calcualted
  - Metrics of completeness: gaps, shortest/logest gap…
  - Simple metrics: max, mean, min…
  - Metrics of noise: estimates of noise floor, power at discrete frequencies…
  - Counts of EPIC triggers or simple amplitude exceedance (FinDer/PLUM)

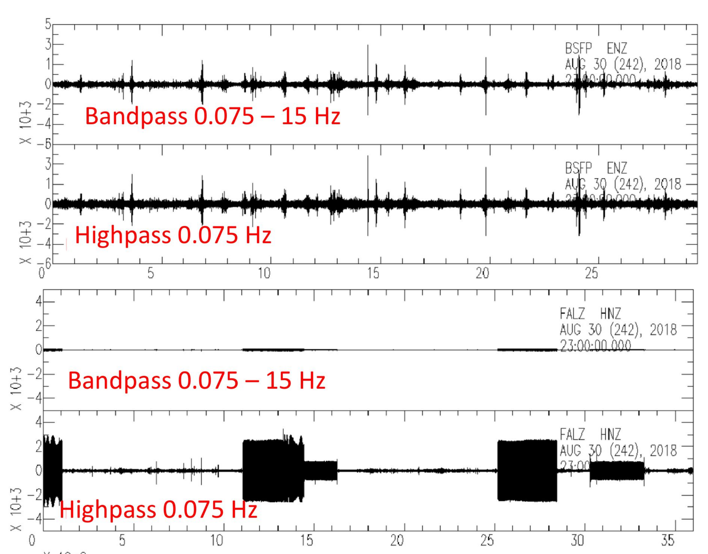
Visualization of log files (metrics) is worth a thousand lines of code?



Shown are two months of triggers in EPIC associated with at least three other triggers; four stations triggering are required to create a candidate event. Routine collection of metrics and comparison with thresholds, in this case number of associated triggers at a constant value or below, e.g. 99th percentile, could have flagged this issue earlier. The issues persisted for about 20 days.

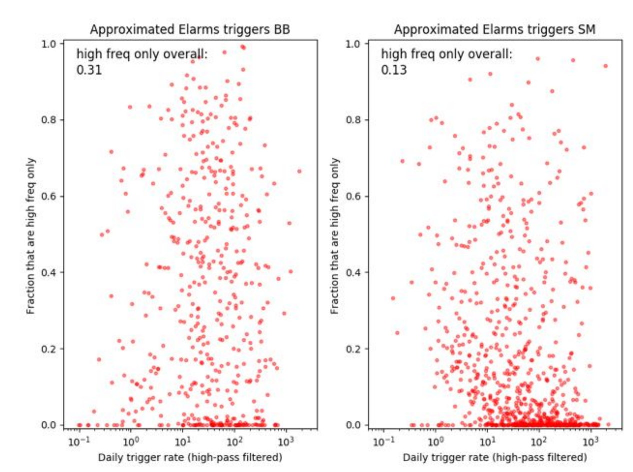
Guiding ShakeAlert algorithm parameters with a database of metrics

On quite a few ShakeAlert channels where the trigger rate wsa alarmingly high, a good portion of those came only from higher frequencies as shown here. The bumps at UW.BSFP (Boeing Field) appear uniform across both frequency bands, while at UO.FALZ the high amplitude noise features dramatically get reduced when a frequency corner of 15 Hz is applied in filtering.



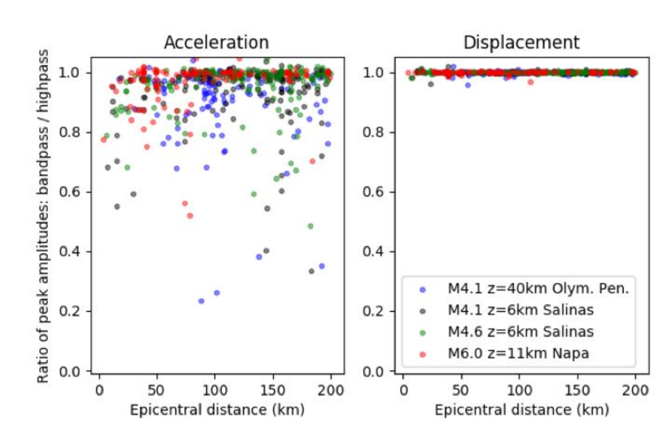
How frequent of a problem is this?

Over a 6 month span across all of ShakeAlert there were 22 million triggers. About 4 million were only present at high frequencies, i.e. with a bandpass instead of highpass filter, the amplitude threshold criteria for triggering would not have been met.



Would bandstop filtering at 15Hz significantly impact estimated EPIC's performance?

Likely not, because:
1) triggering criteria are mostly using acceleration while magnitude estimates are made using displacement which acts as a lowpas filter.
2) As magnitude of event increases, the corner frequency decreases reducing the usefulness of information at very high frequencies.



Next steps:

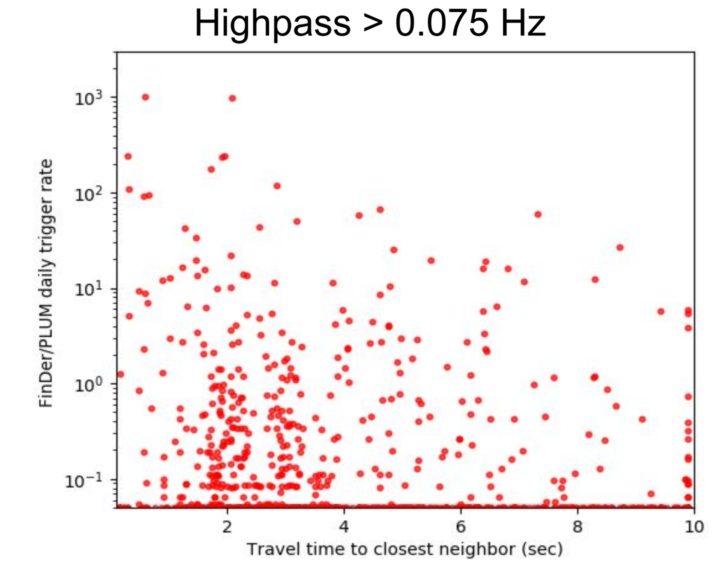
We have been running parallel instances of EPIC, one with a highpass and another with a 15Hz bandpass filter and will do an apples-to-apples comparison of both false and true triggers and EPIC's overall performance.

A starting point for Blacklisting stations using a database of metrics

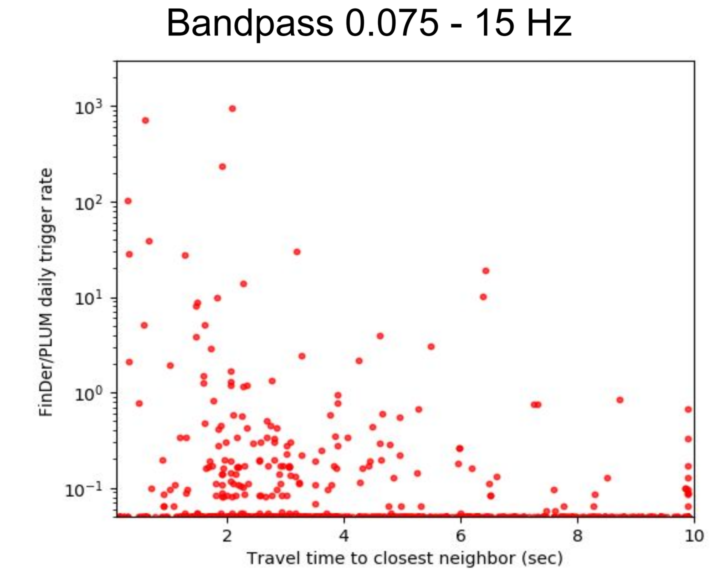
The ShakeAlert algorithm Finite Fault Rupture Detector (FinDer) triggers on high frequency (acceleration) detections that exceed a threshold of at least 2 cm/^2. Japan's PLUM algorithm also triggers on a similar threshold of acceleration. The PNSN station_metrics database has been calculating the number of times the acceleration has exceeded 2 cm/s^2 each hour. Measurements must be separated by at least 30 sec.

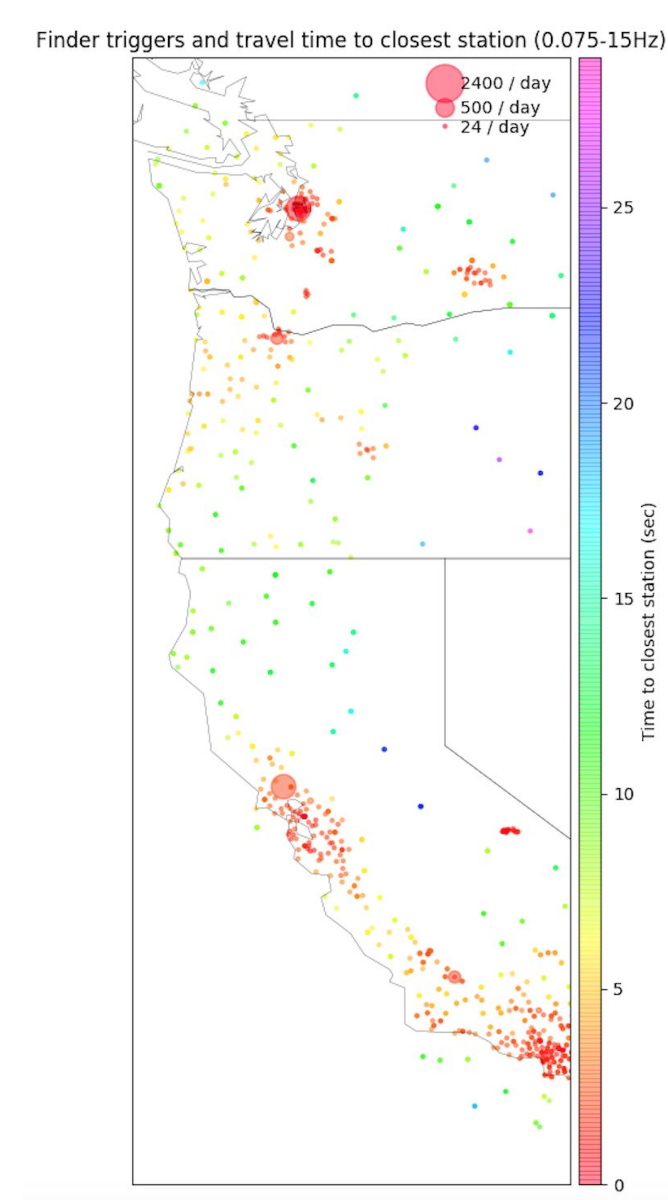
Measurements made 3/1 - 4/23 2019

Hourly rate > 2 cm/s^2
Highpass > 0.075 Hz



Hourly rate > 2 cm/s^2
Bandpass 0.075 - 15 Hz





FinDer/PLUM wall of shame

Columns
1) **SNCL**
2) **Hourly trigger rate using highpass > 0.075 Hz**
3) **Hourly trigger rate using bandpass 0.075 - 15 Hz**
4) **Difference in trigger rates (N_HP - N_Bandpass)**
5) **Distance to closest station (km)**
6) **Distance to 4th closest station (km)**

Sorted by hourly trigger rate (Highpass)

UW.PIER.--.HNZ	42.59	30.15	12.45	0.74	3.53
NC.NSM.--.HNZ	41.29	39.58	1.71	8.66	15.03
UW.TKCO.--.ENZ	10.19	4.31	5.88	0.70	2.22
NP.2172.--.HNZ	10.00	0.01	9.99	6.62	10.70
CI.CAR.--.HHZ	9.95	9.97	-0.01	5.72	13.20
CI.RCU.--.HNZ	7.42	0.12	7.30	4.64	9.37
NP.7044.--.HNZ	4.90	0.00	4.89	9.95	14.26
UW.KCAM.--.HNZ	4.50	1.17	3.33	0.82	2.43
UW.HART.--.HNZ	3.91	1.60	2.31	0.74	3.68
UW.PIE.--.HNZ	3.79	0.21	3.58	2.37	5.48
NP.5272.10.HNZ	2.83	0.17	2.67	10.62	31.26
CI.AVM.--.HNZ	2.51	0.03	2.48	31.45	38.69
NP.5056.10.HNZ	2.39	0.09	2.30	15.33	23.35
NC.NLH.--.HNZ	2.12	1.25	0.88	10.88	18.47
CI.NEN.--.HNZ	1.82	0.01	1.81	10.57	20.05
NP.5337.10.HNZ	1.78	1.14	0.63	3.98	7.20
CI.LFP.--.HNZ	1.43	0.34	1.09	2.71	10.08
UW.BOW2.--.ENN	1.12	0.04	1.08	26.42	43.76
UO.NOMA.--.HN	1.04	0.01	1.04	13.07	25.03
CI.STS.--.HNZ	0.91	0.07	0.84	10.24	10.37
UW.TILL.--.HNZ	0.82	0.13	0.69	12.01	48.14
CI.LFP.--.HHZ	0.81	0.16	0.65	2.71	10.08
CI.NBS.--.HNZ	0.81	0.81	0.00	16.33	38.68
CI.CFS.00.HNZ	0.68	0.00	0.68	3.42	10.18
NP.7043.--.HNZ	0.68	0.00	0.68	15.29	42.45
UW.REED.--.HNZ	0.67	0.42	0.24	5.08	35.94
CI.HLL.--.HNZ	0.65	0.21	0.44	2.63	8.47
CI.WCS2.--.HHZ	0.58	0.58	0.01	6.15	13.05
CE.24945.10.HNZ	0.57	0.37	0.20	6.48	8.92
CI.MOP.--.HNZ	0.56	0.05	0.51	7.71	14.33

Sorted by hourly trigger rate (Bandpass)

NC.NSM.--.HNZ	41.29	39.58	1.71	8.66	15.03
UW.PIER.--.HNZ	42.59	30.15	12.45	0.74	3.53
CI.CAR.--.HHZ	9.95	9.97	-0.01	5.72	13.20
UW.TKCO.--.ENZ	10.19	4.31	5.88	0.70	2.22
UW.HART.--.HNZ	3.91	1.60	2.31	0.74	3.68
NC.NLH.--.HNZ	2.12	1.25	0.88	10.88	18.47
UW.KCAM.--.HNZ	4.50	1.17	3.33	0.82	2.43
NP.5337.10.HNZ	1.78	1.14	0.63	3.98	7.20
CI.NBS.--.HNZ	0.81	0.81	0.00	16.33	38.68
CI.WCS2.--.HHZ	0.58	0.58	0.01	6.15	13.05
UW.REED.--.HNZ	0.67	0.42	0.24	5.08	35.94
NC.CAL.--.HNZ	0.41	0.41	-0.00	2.95	11.55
CE.24945.10.HNZ	0.57	0.37	0.20	6.48	8.92
CI.LFP.--.HNZ	1.43	0.34	1.09	2.71	10.08
CI.HLL.--.HNZ	0.65	0.21	0.44	2.63	8.47
UW.PIE.--.HNZ	3.79	0.21	3.58	2.37	5.48
NP.5272.10.HNZ	2.83	0.17	2.67	10.62	31.26
CI.LFP.--.HHZ	0.81	0.16	0.65	2.71	10.08
UW.TILL.--.HNZ	0.82	0.13	0.69	12.01	48.14
CI.RCU.--.HNZ	7.42	0.12	7.30	4.64	9.37
AZ.LVA2.--.HNZ	0.10	0.10	0.00	14.22	18.38
NP.5056.10.HNZ	2.39	0.09	2.30	15.33	23.35
UW.BSFP.--.ENZ	0.21	0.09	0.12	0.70	2.39
NC.MQ1P.--.HNZ	0.12	0.08	0.04	2.68	5.43
CI.STS.--.HNZ	0.91	0.07	0.84	10.24	10.37
CI.WLT.--.HNZ	0.11	0.06	0.05	5.84	10.91
NP.5241.10.HNZ	0.22	0.06	0.17	8.29	15.62
CI.STS.--.HHZ	0.43	0.05	0.37	10.24	10.37
CI.WLT.--.HHZ	0.09	0.05	0.03	5.84	10.91
CI.MOP.--.HNZ	0.56	0.05	0.51	7.71	14.33

Sorted by Difference in trigger rate

UW.PIER.--.HNZ	42.59	30.15	12.45	0.74	3.53
NP.2172.--.HNZ	10.00	0.01	9.99	6.62	10.70
CI.RCU.--.HNZ	7.42	0.12	7.30	4.64	9.37
UW.TKCO.--.ENZ	10.19	4.31	5.88	0.70	2.22
NP.7044.--.HNZ	4.90	0.00	4.89	9.95	14.26
UW.PIE.--.HNZ	3.79	0.21	3.58	2.37	5.48
UW.KCAM.--.HNZ	4.50	1.17	3.33	0.82	2.43
NP.5272.10.HNZ	2.83	0.17	2.67	10.62	31.26
CI.AVM.--.HNZ	2.51	0.03	2.48	31.45	38.69
UW.HART.--.HNZ	3.91	1.60	2.31	0.74	3.68
NP.5056.10.HNZ	2.39	0.09	2.30	15.33	23.35
CI.NEN.--.HNZ	1.82	0.01	1.81	10.57	20.05
NC.NSM.--.HNZ	41.29	39.58	1.71	8.66	15.03
CI.LFP.--.HNZ	1.43	0.34	1.09	2.71	10.08
UW.BOW2.--.ENN	1.12	0.04	1.08	26.42	43.76
UO.NOMA.--.HNZ	1.04	0.01	1.04	13.07	25.03
NC.NLH.--.HNZ	2.12	1.25	0.88	10.88	18.47
CI.STS.--.HNZ	0.91	0.07	0.84	10.24	10.37
UW.TILL.--.HNZ	0.82	0.13	0.69	12.01	48.14
CI.CFS.00.HNZ	0.68	0.00	0.68	3.42	10.18
NP.7043.--.HNZ	0.68	0.00	0.68	15.29	42.45
CI.LFP.--.HHZ	0.81	0.16	0.65	2.71	10.08
NP.5337.10.HNZ	1.78	1.14	0.63	3.98	7.20
UW.MRN.--.HNZ	0.54	0.00	0.53	4.22	5.64
BK.KCC.00.HNZ	0.51	0.00	0.51	40.32	43.21
CI.MOP.--.HNZ	0.56	0.05	0.51	7.71	14.33
UW.GRE.--.HNZ	0.50	0.01	0.49	2.85	5.48
UW.MAUP.--.HNZ	0.49	0.00	0.48	20.01	42.39
CI.PUT.--.HNZ	0.47	0.00	0.47	13.25	19.07
UW.SAIL.--.HNZ	0.48	0.01	0.47	5.37	19.46