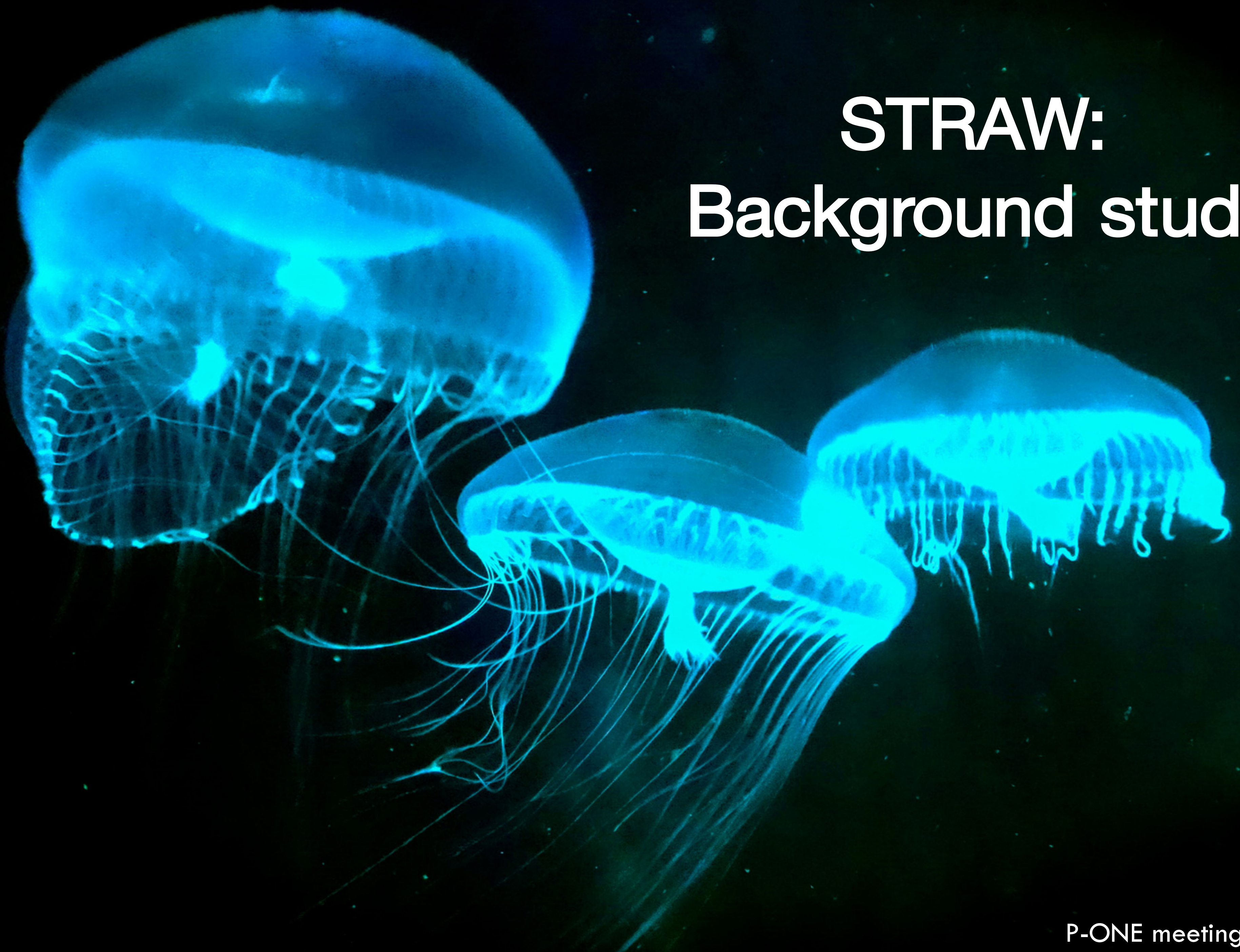
STRAW: Background study



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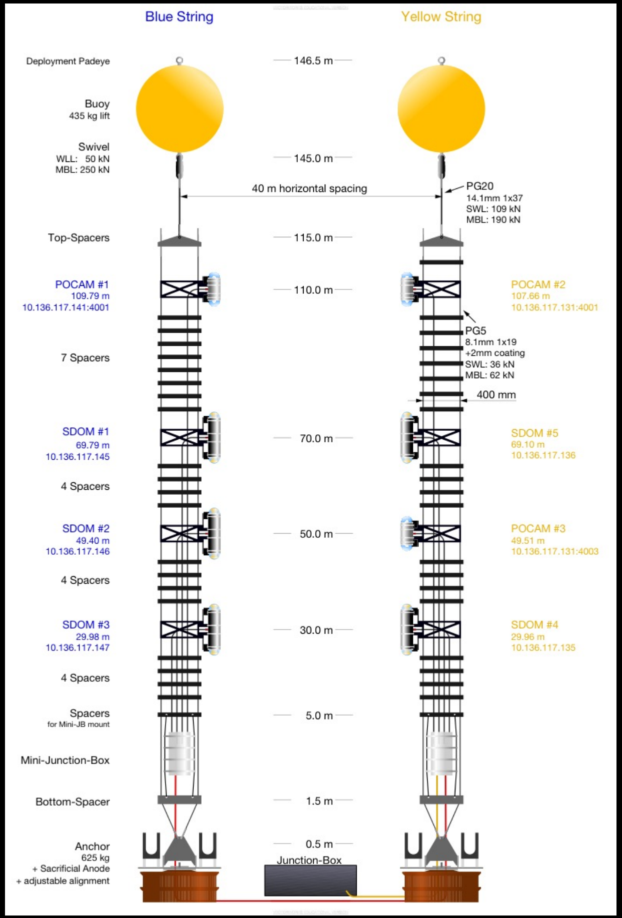
P-ONE meeting December 2020

Scientific goal

GOAL

Understand the behaviour of light background and water optical properties of the chosen site over a long timescale → define design constraints for the P-ONE moorings



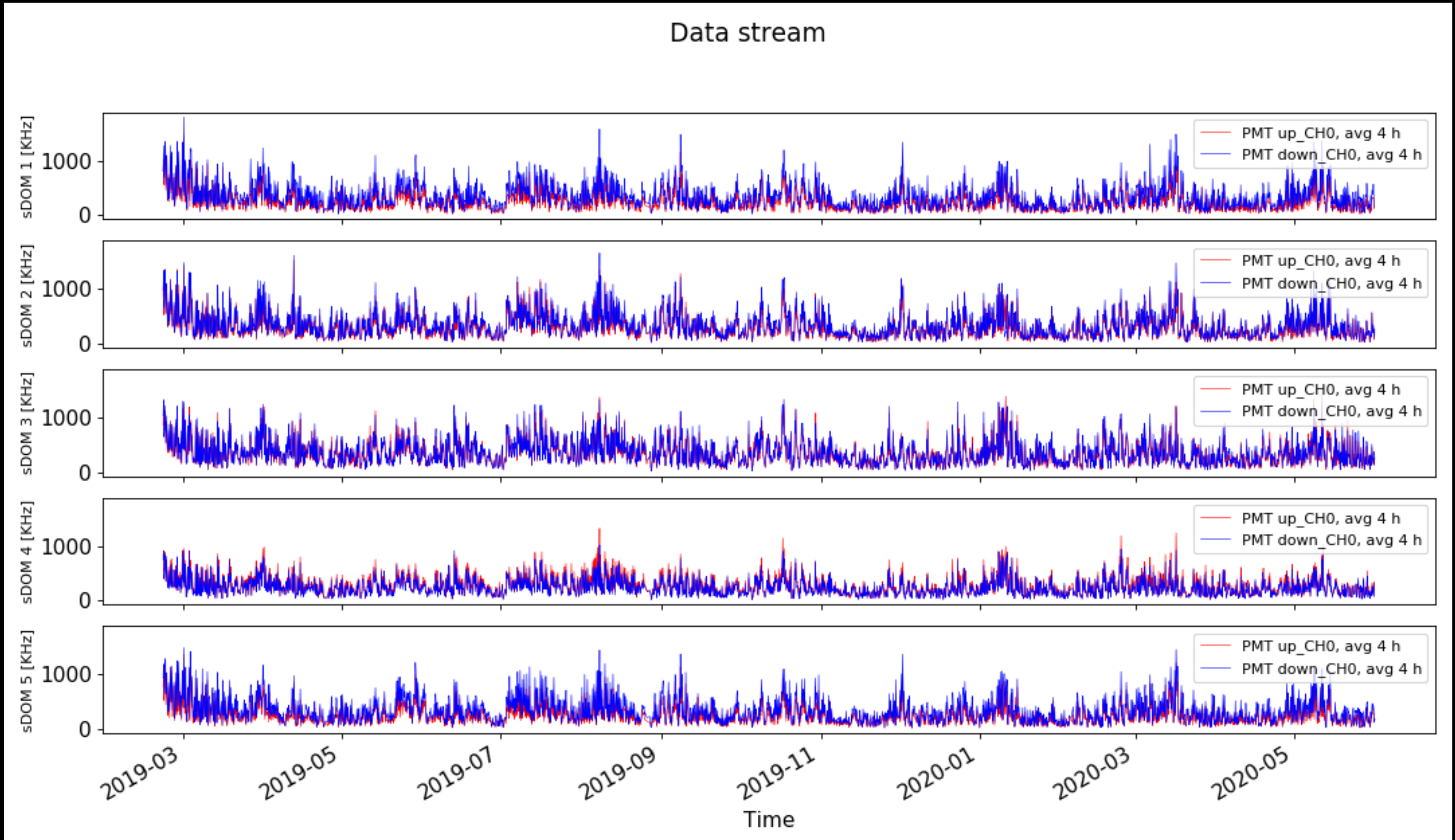
In order to reach the goal, several deliverables need to be provided:

1. Evaluate the variation range of the rates
2. Evaluate different components of the rates: baselines, bursts
3. Correlation of baseline and bursts with water current
4. Sedimentation and biofouling
5. Periodicity
6. Considerations for the future

1. Evaluate the variation range of rates

The first focus has been to analyse the data stream from the 5 sDOMs of STRAW for the entire period of activity

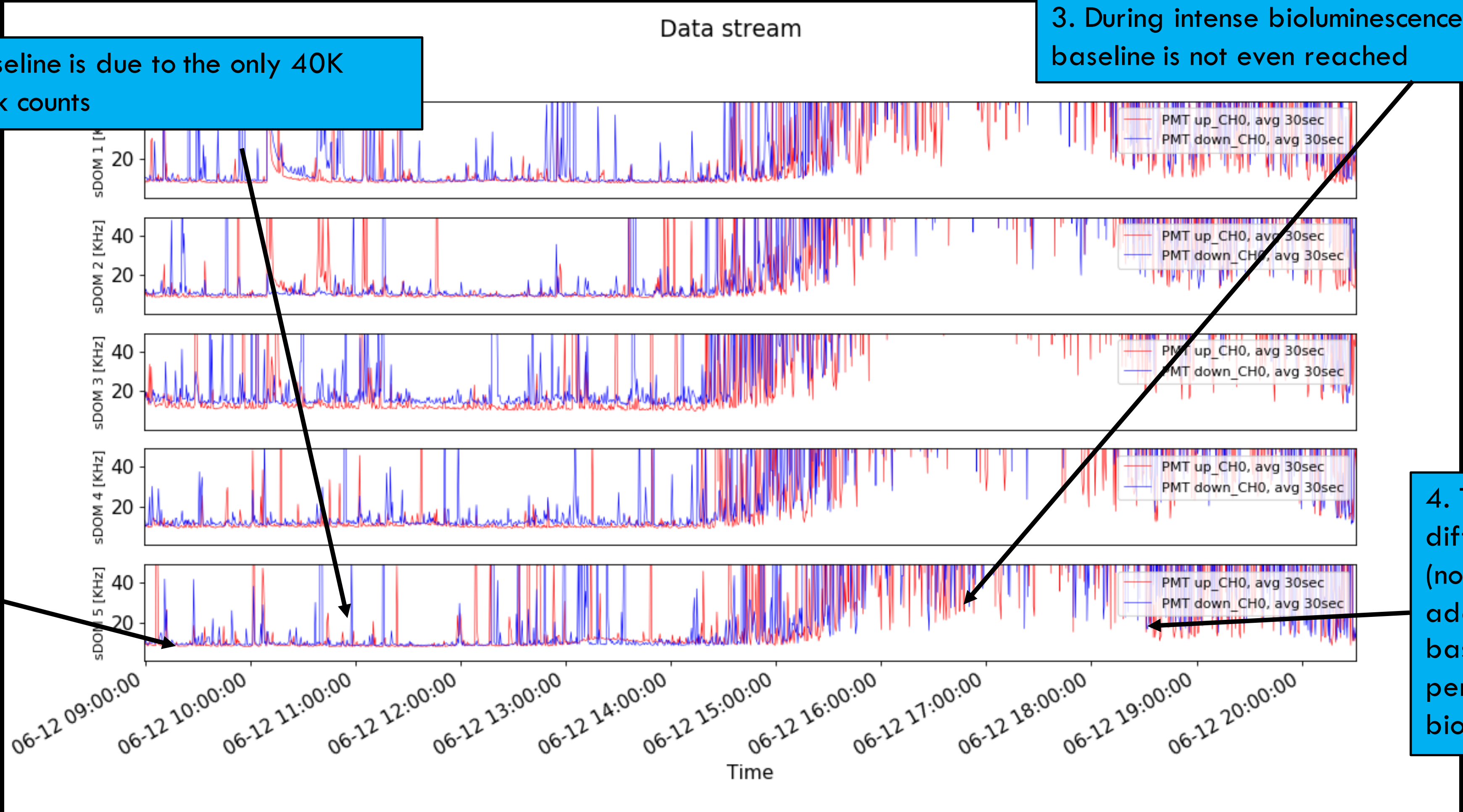
End of February 2019 to the end of May 2020: several periods of higher background level due to a combination of bioluminescence bursts on top of a diffuse bioluminescence baseline have been registered



2.[1] Can we understand the different levels of BKG with STRAW?

2. Contribution to the baseline is due to the only 40K decays plus the PMT dark counts

3. During intense bioluminescence bursting periods, the baseline is not even reached



1. The lowest value of the continuous data stream measured by the optical modules is defined as *baseline*

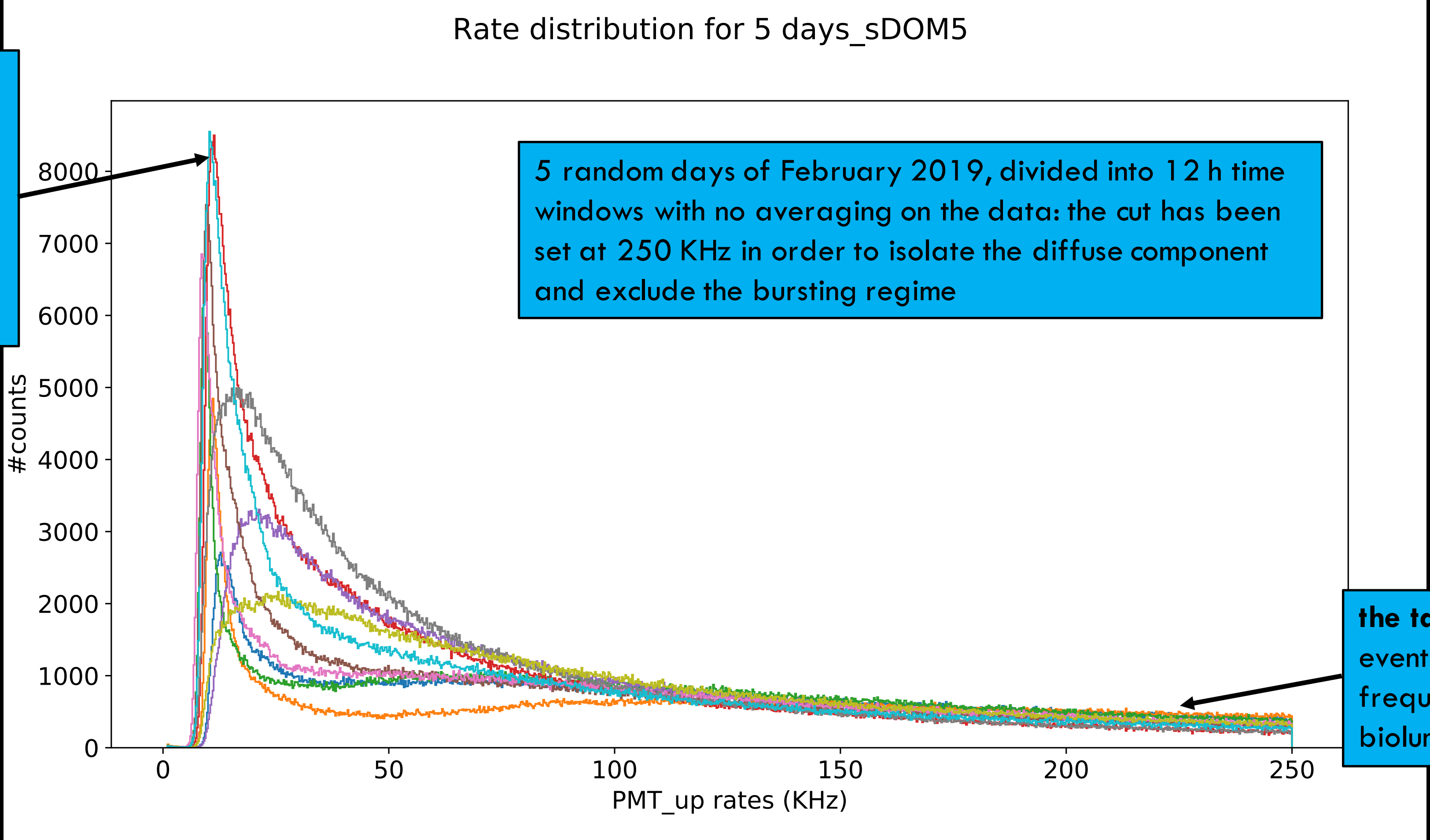
4. The contribution of diffuse bioluminescence (not necessarily bursts) can add an extra offset to the baseline during some periods of major bioluminescence activity.

AVG 30 sec, time window ~12 hours (6 June 2019): the baseline value, that is around 10 KHz at the beginning of the time window, increases as the bioluminescence activity (diffuse and bursts, whose contributions are not distinguishable for the moment) increases.

2.[2] Baselines trend

The goal of this study has been to estimate the minimum and the maximum baseline value during the monitoring period.

the peak: is representing the most frequent value of the baseline, whose contributions are 40K and diffuse bioluminescence activity (also bursts in same cases).

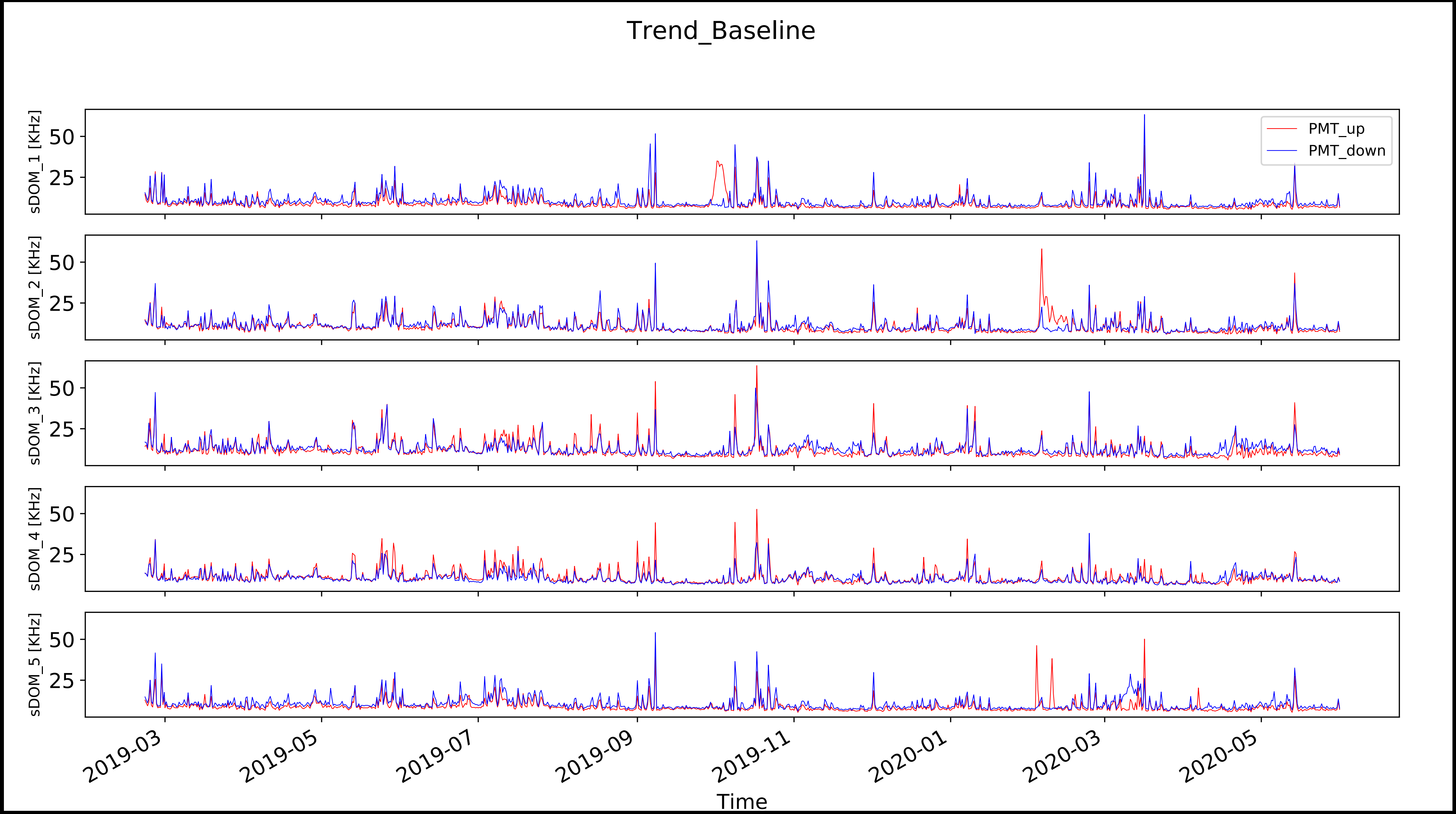


5 random days of February 2019, divided into 12 h time windows with no averaging on the data: the cut has been set at 250 KHz in order to isolate the diffuse component and exclude the bursting regime

the tail: is representing the light events that happen less frequently, like bursts of bioluminescence.

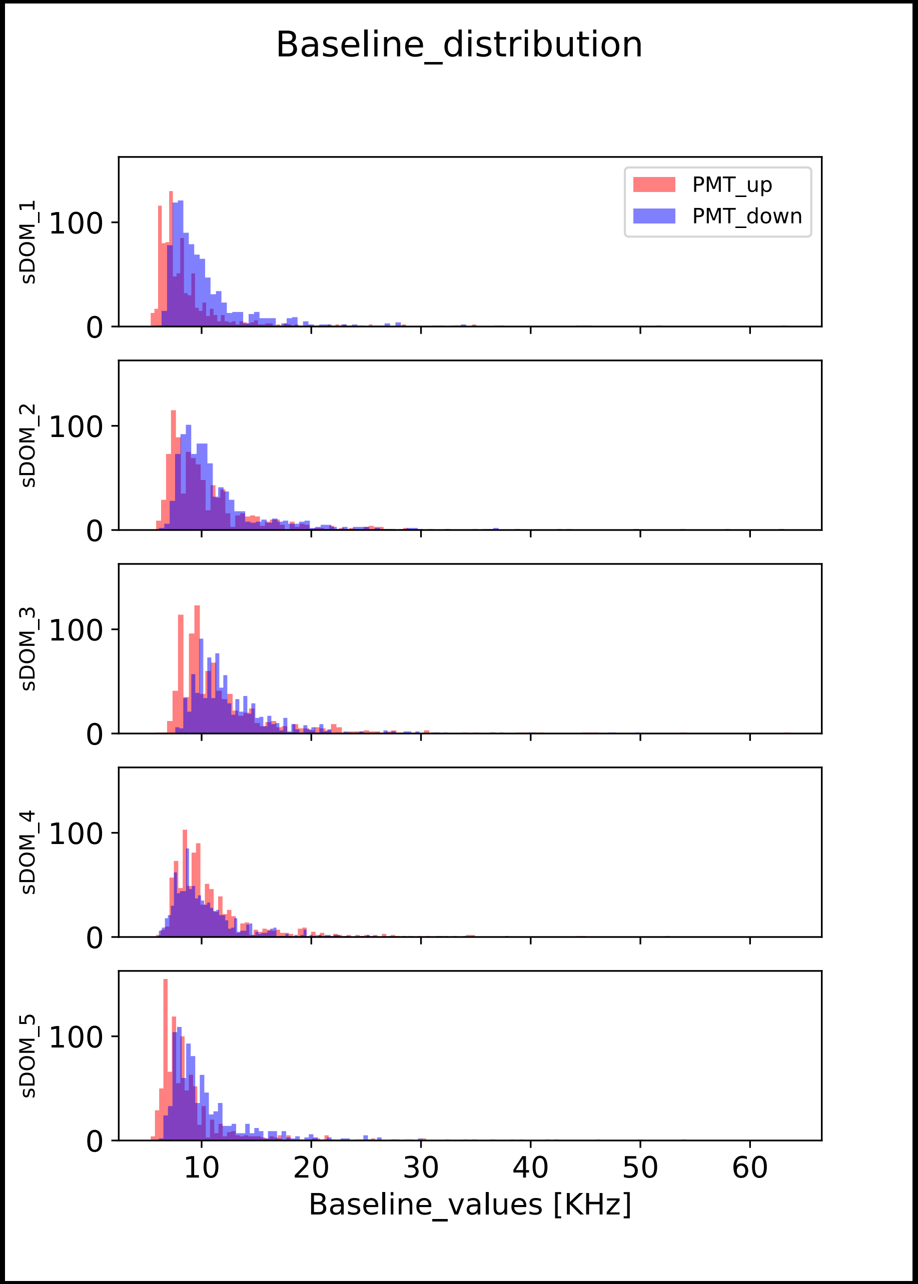
Some distributions are very different from the others, highlighting how variable can be the diffuse bioluminescence activity.

2.3 Baselines trend



The baseline varies between a minimum of ~5 KHz and a maximum of ~63 KHz. The minimum detected value corresponds to the light background due to 40K (water + optical module glass) and PMTs dark noise.

2.4 Baselines distribution



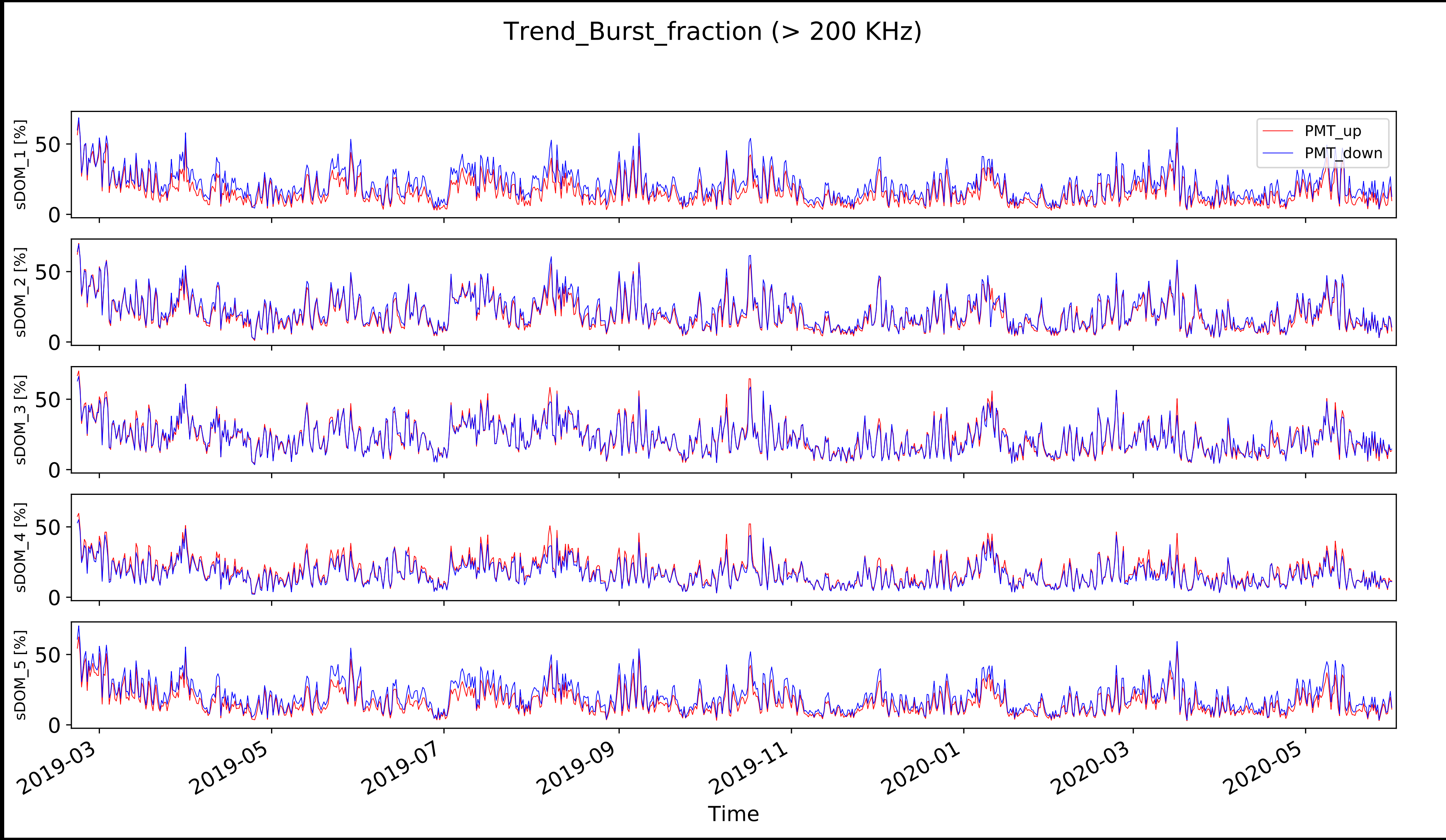
Around which values the baselines are distributing?

The peaks of these new distributions indicates that the most frequent baseline values are ranging between 7 and 10 KHz for every sDOM during the entire 16 months period.

This provides an estimation of the **diffuse bioluminescence** due to microorganisms that fluctuate constantly around the optical modules, adding count rates to the minimum detected value of 5 KHz.

2.5 Burst Fraction

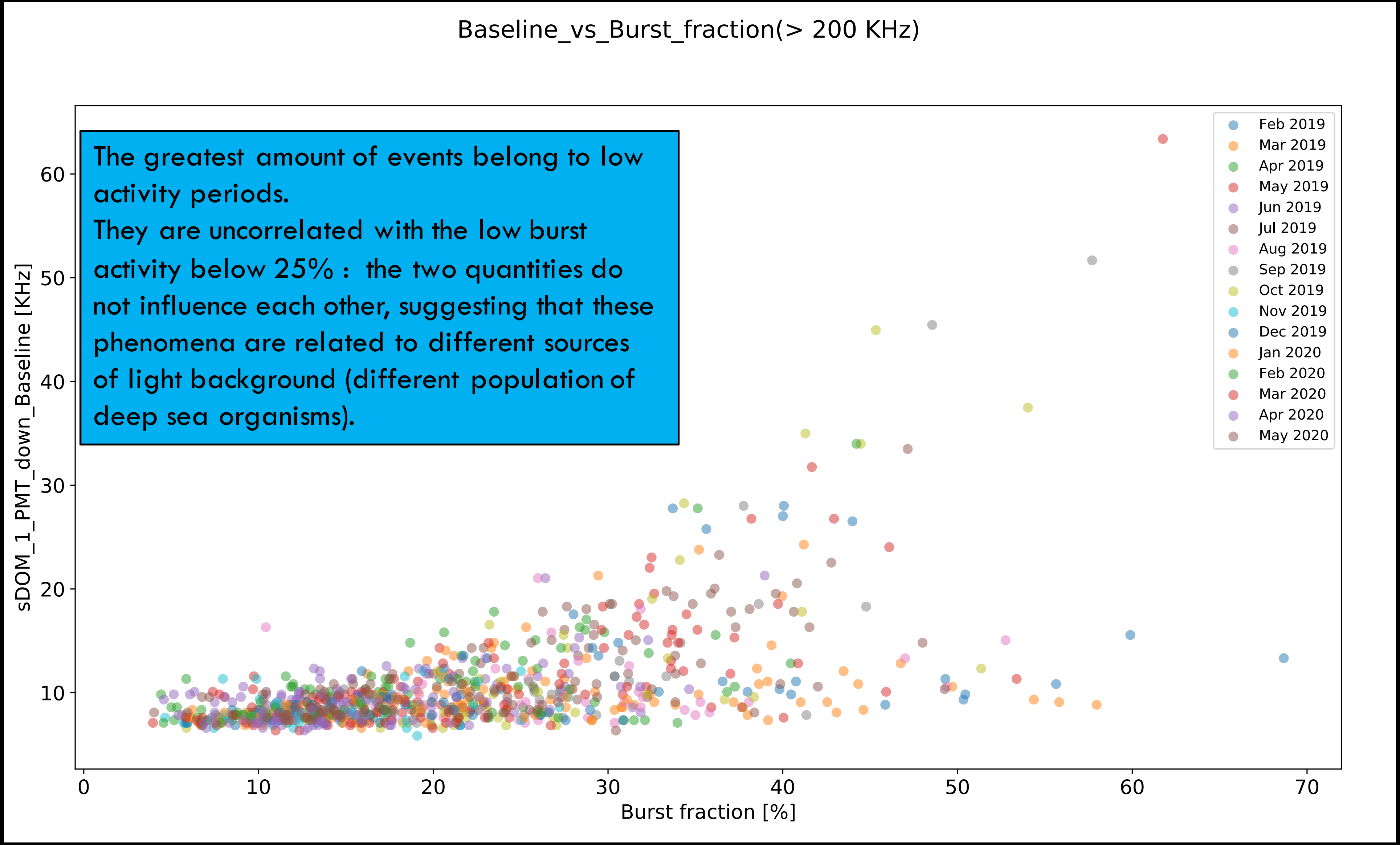
Are the baseline rates affected by an increased activity?



Burst Fraction: the number of events higher then a certain threshold (200 KHz), integrated and normalized with respect to the total amount of detected events.

The evolution in time of the B.F.: if compared with the plot of the baseline trend, it is possible to understand if (and how) the two quantities are correlated

2.6 Baseline vs. Burst Fraction



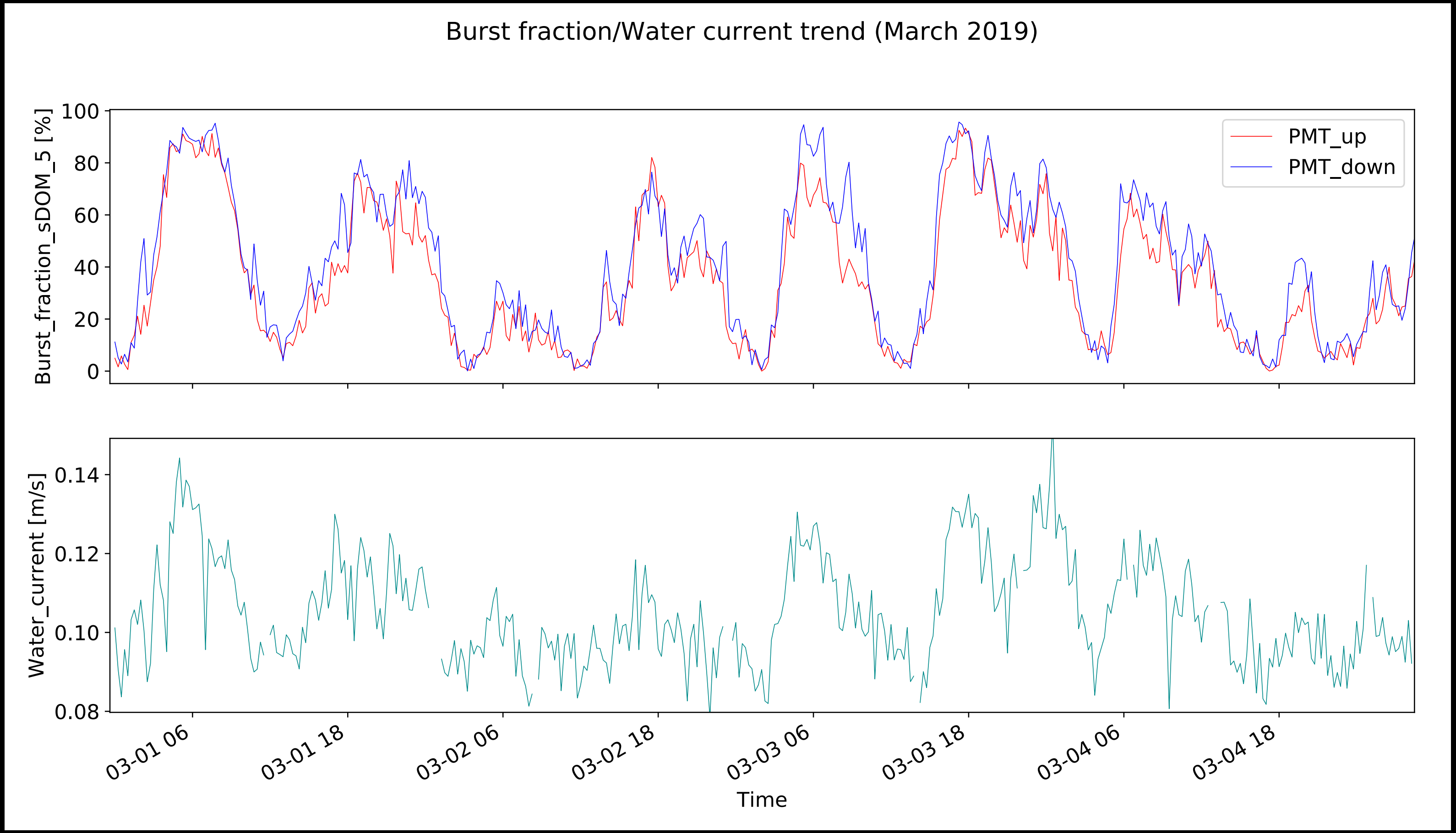
The greatest amount of events belong to low activity periods.
They are uncorrelated with the low burst activity below 25% : the two quantities do not influence each other, suggesting that these phenomena are related to different sources of light background (different population of deep sea organisms).

For burst fraction values higher than the 25%, two population of points can be distinguished:

- low baseline, high burst fraction: no correlation
- high baseline, high burst fraction: correlation.

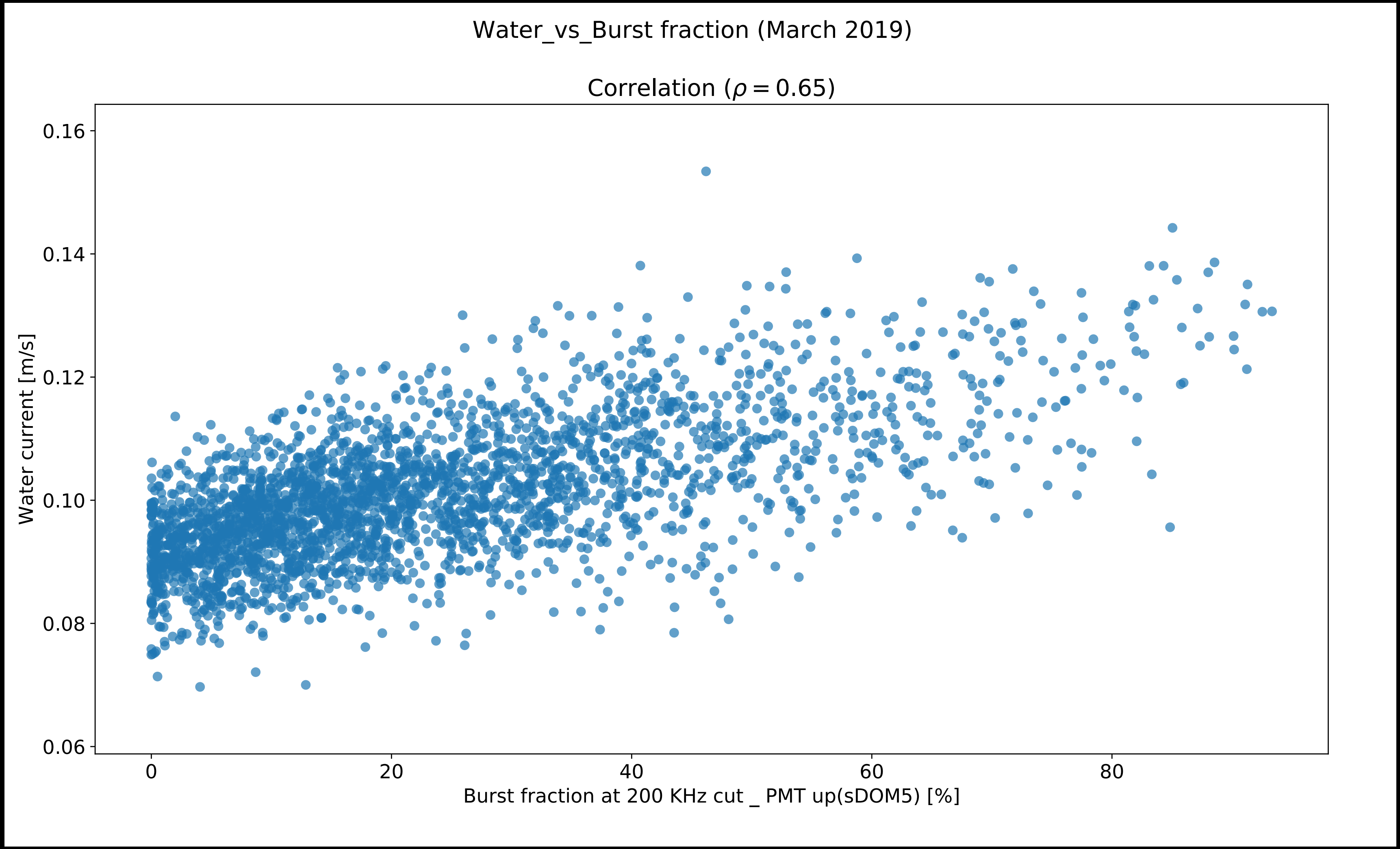
Even if the bioluminescence bursts are due to a different population of deep sea organisms with respect to the ones responsible of the diffuse bioluminescence (that influence the baselines even in low activity periods) they start to influence the baseline when their values are very high or persistent.

3.[1] Rate correlation with water current



- The deep sea organisms emit light when mechanically stimulated so the deep sea currents play an important role in making them hitting against submerged structures.
- The current speed alone cannot explain the greater bioluminescence activity that can be found in certain periods of the year: this can be related to dense water formation events.

3.2 Rate correlation with water current

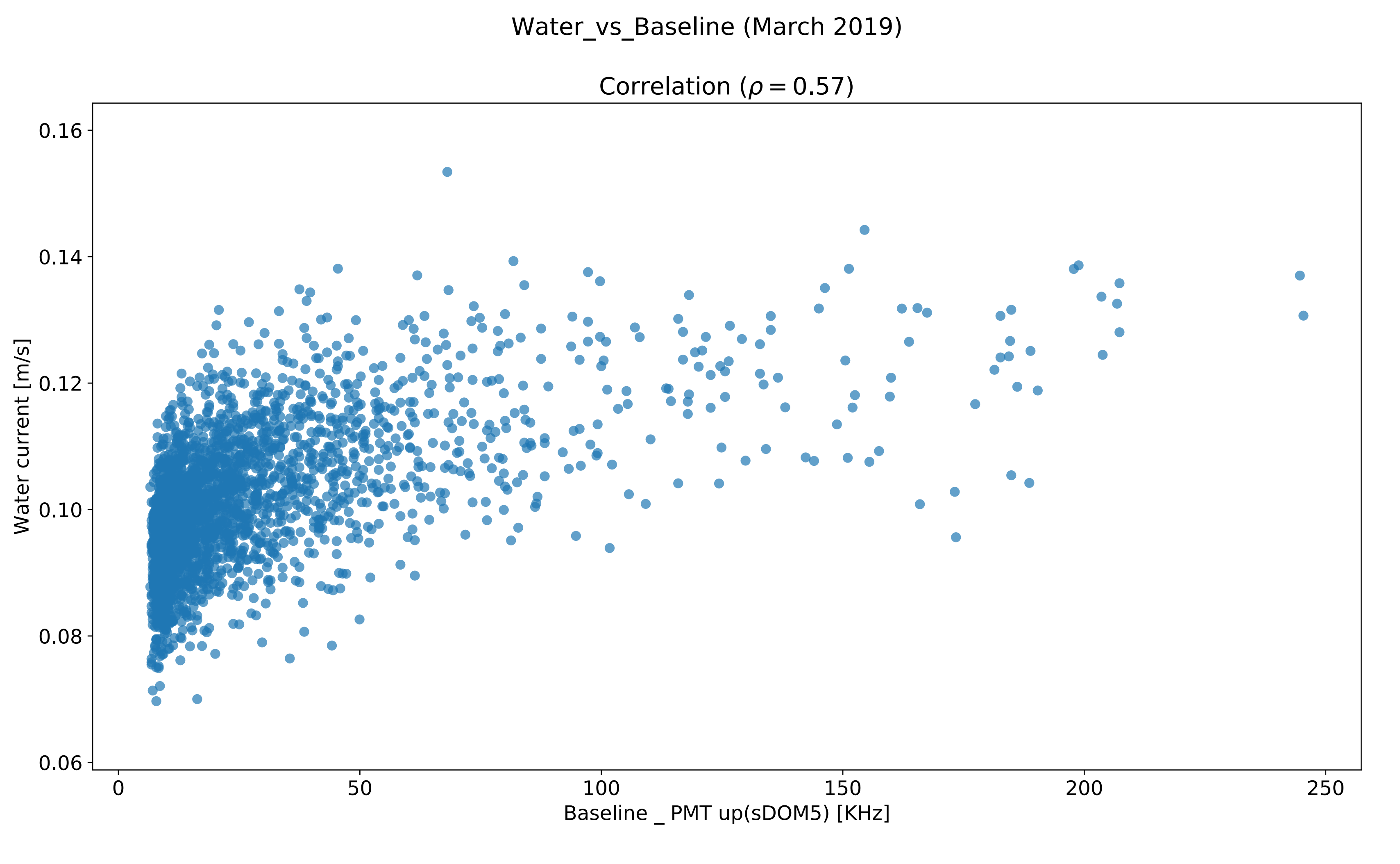


When the current is stronger, the burst fraction is higher.

This correlation could be the starting point for identifying periods of high bioluminescence activity taking into account the only monitoring of the currents, in case an ADCP or a current meter is installed next to a mooring.

possibility of installing several current meter devices next to the future P-ONE strings?

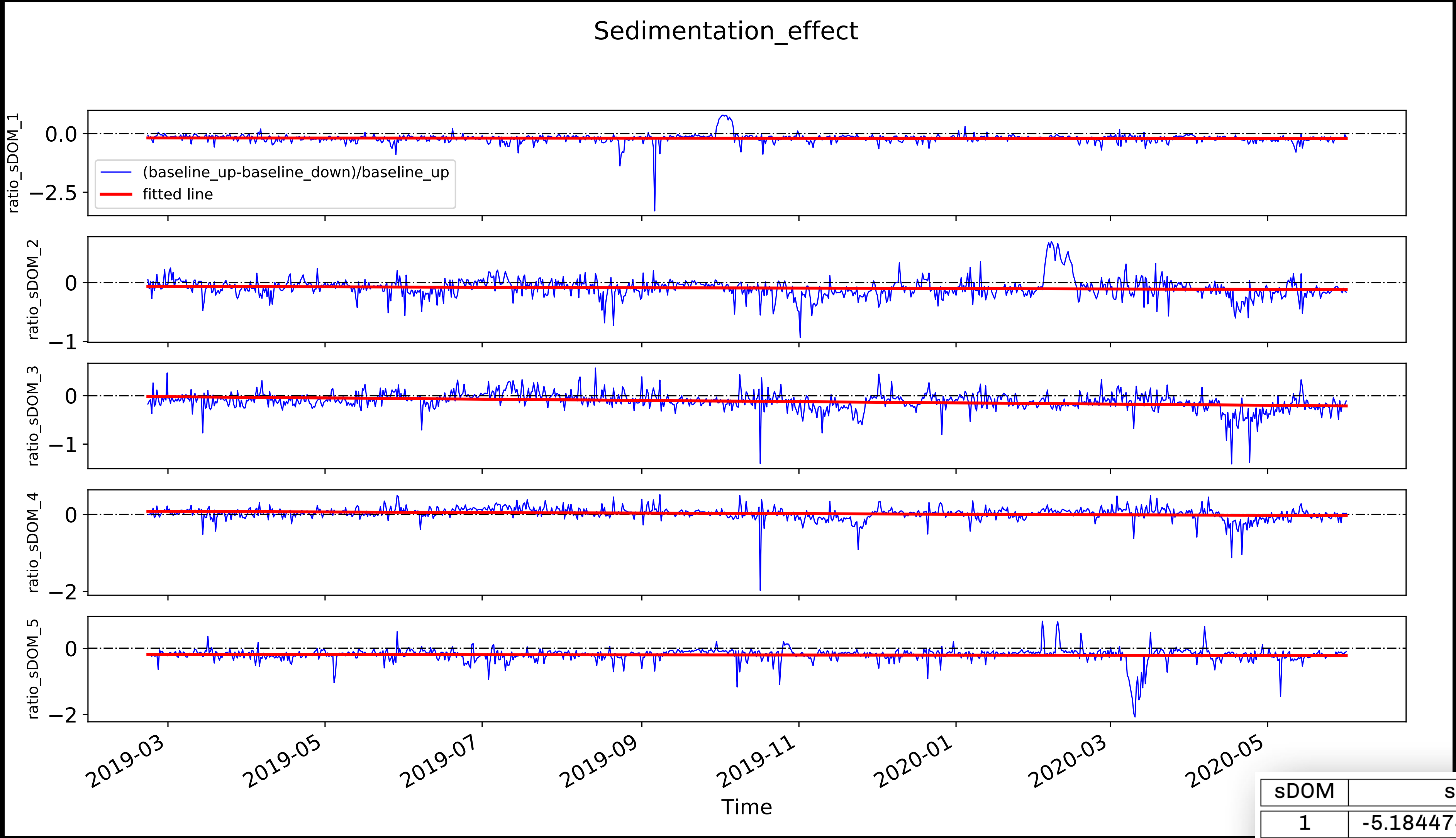
3.2 Rate correlation with water current



Even if the obtained correlation is weaker, the distribution is still indicating that one part of the baseline population tends to be higher when currents are higher, but not as much as for the burst fractions.

The accumulation in the left part of the plot: is related to the existence of the two main populations of the baseline values described in slide 9.

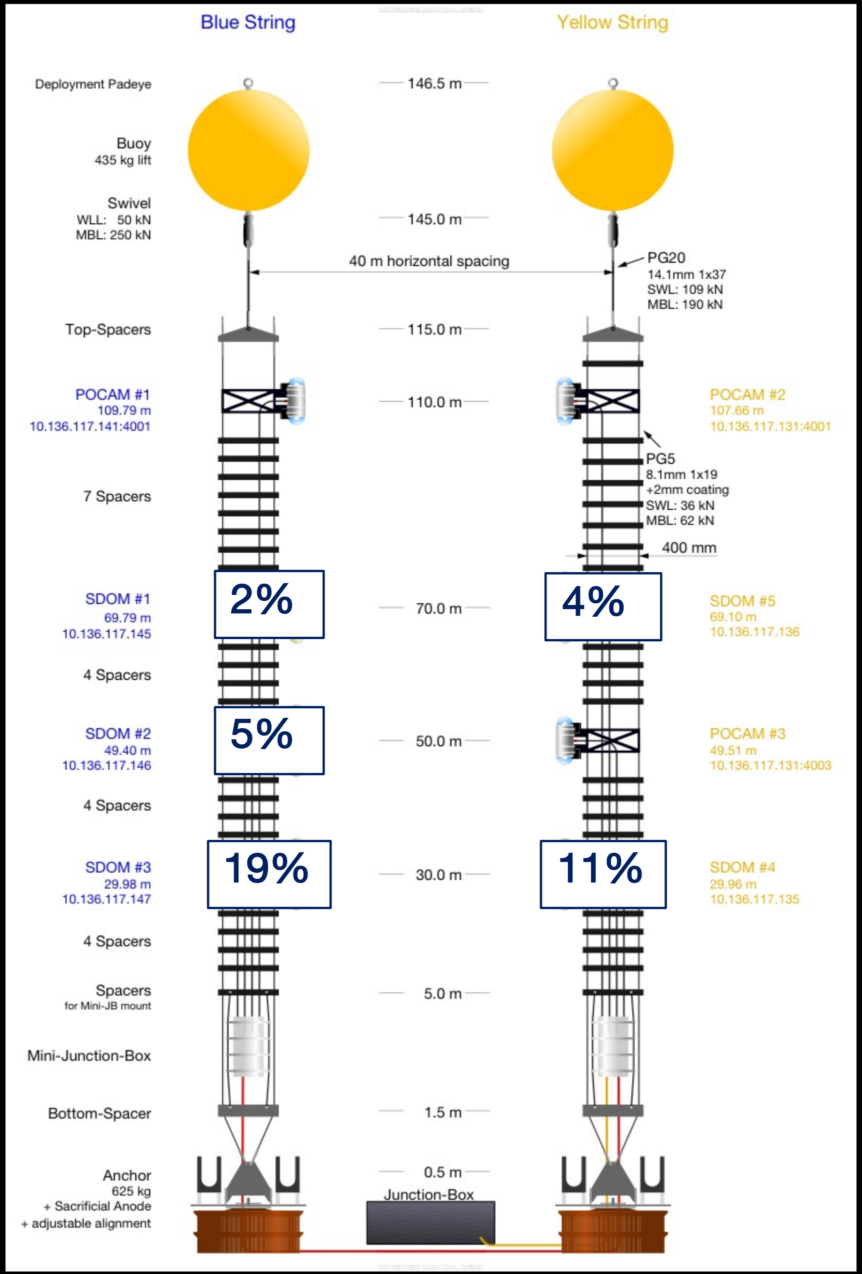
4.[1] Sedimentation and biofouling



Downward flux of sediment in the deep sea can cover submerged structures: in a neutrino telescope environment such a phenomenon can affect the transmittance of Cherenkov light through the glass of the optical modules, decreasing the detection efficiency of the detector.

sDOM	slope
1	-5.18447469591e-10
2	-1.36984405319e-09
3	-4.80249700044e-09
4	-2.77550270457e-09
5	-1.00134951253e-09

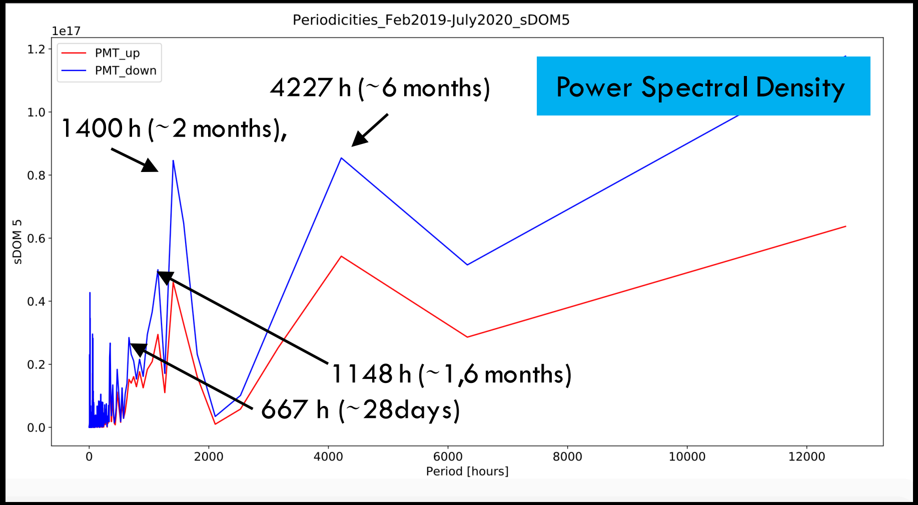
4.2 Sedimentation and biofouling

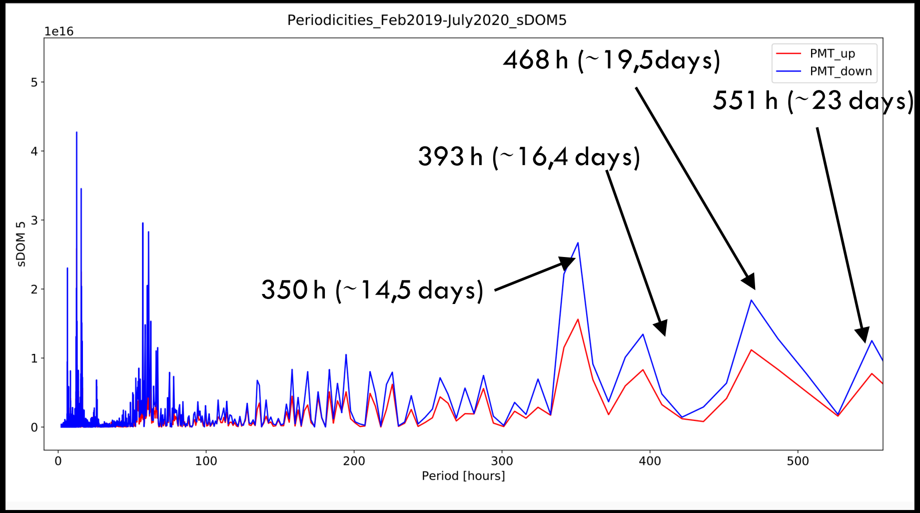


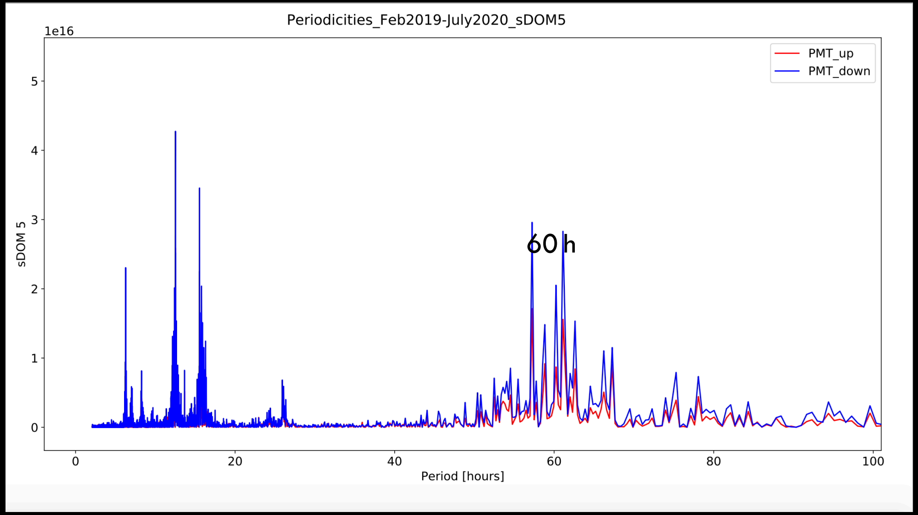
- The detection efficiency decreases with increasing depth.
- Since the depth is not the only parameter that influences the sedimentation on the modules, no conclusion can be drawn so far.
- Monitoring this effect over time is useful for P-ONE future design and detection effciency simulation.

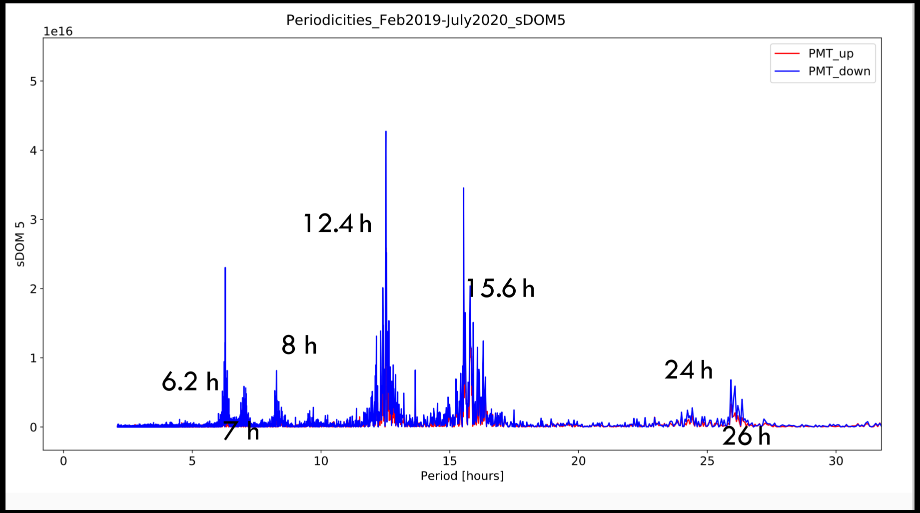
5.[1] Periodicity

An interesting aspect of the observed data is how they behave in time.
For the identification of periodicities in detected signals, it is helpful to analyse the data in their frequency domain.





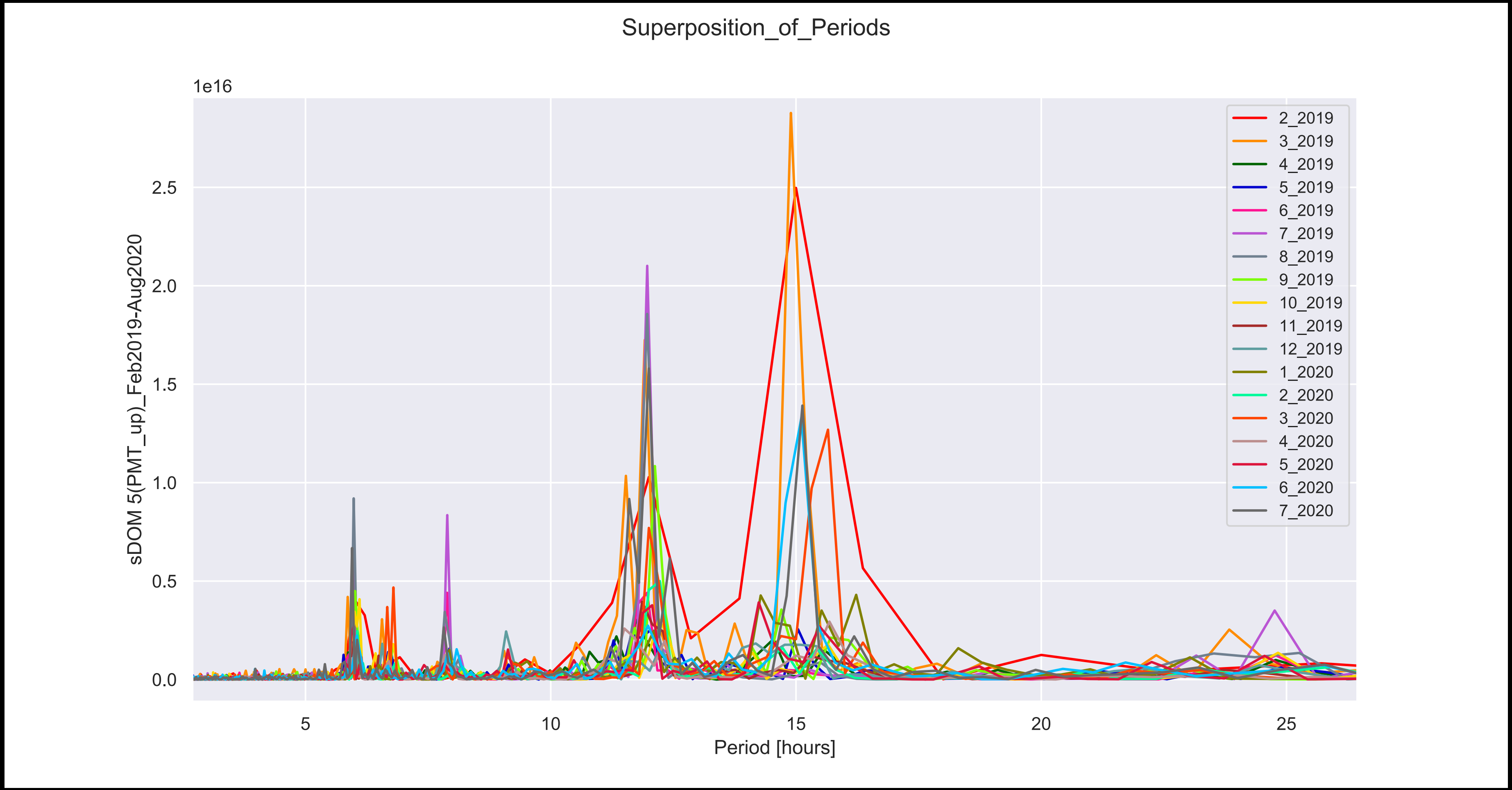




- 18 months data set
- The greatest amount of periodicities is related to well known existing tides in Cascadia Basin.
- The deep sea convection plays a major role in renewing the deep waters, increasing the biological activity.

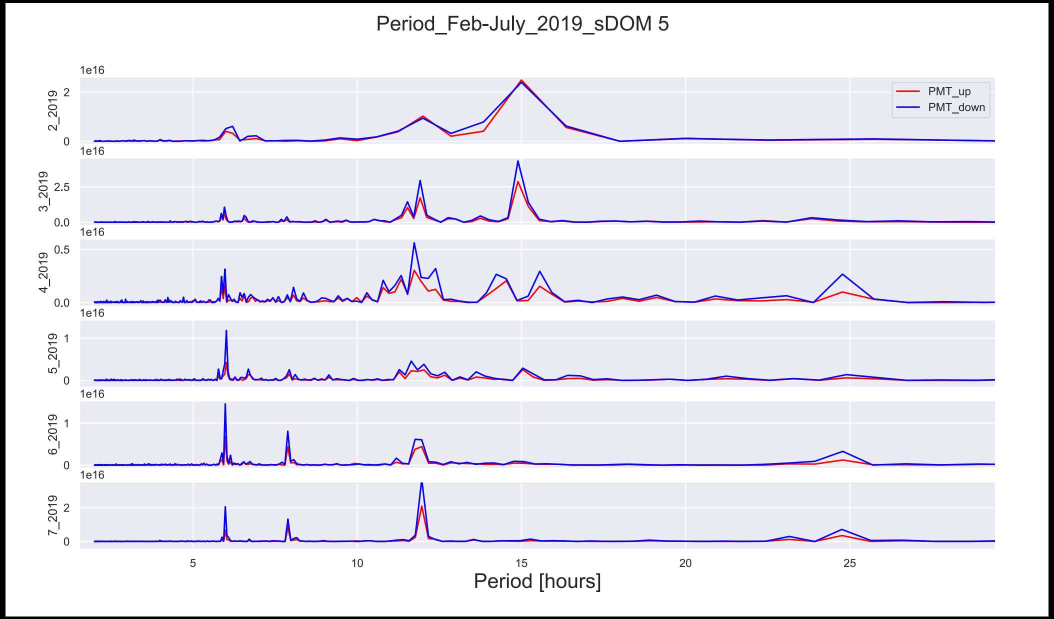
5.2 Periodicity

Each month can add a different contribution to the data periodicity



Looking closer it is possible to appreciate differences over months.

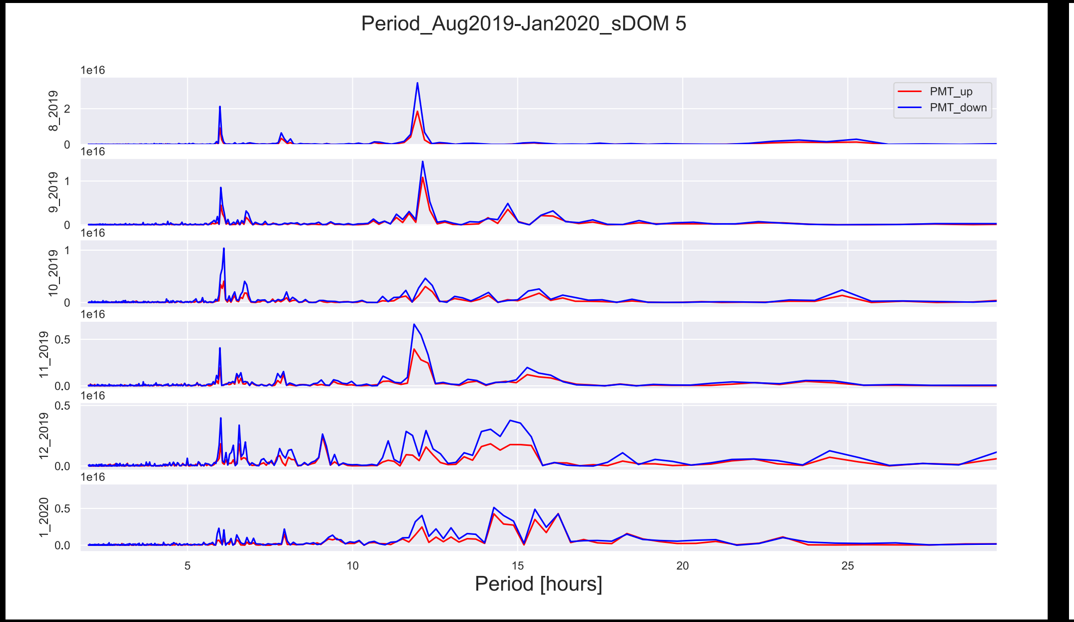
5.3 Periodicity

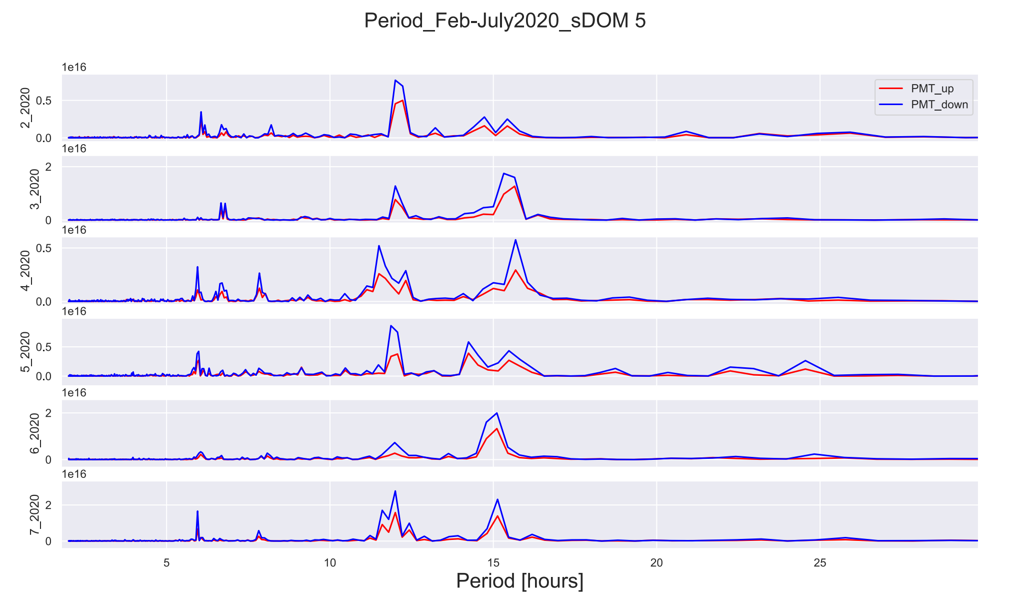


- Only two periodicities appear constantly in all months: 6 hours and 12 hours.

- The periodicity of ~16 hours seems to disappear completely during Summer 2019, even if it represents the local inertial frequency of Cascadia Basin.

- The reasons for these differences need a properly investigation, as this is a very peculiar multidisciplinary topic that involves, besides physics, oceanography and marine biology.





Monitoring the light background periodicity over time is fundamental in order to know exactly at which time of the day/month/year a higher light background in the detected events can be expected.

6.1 Considerations for the future

The Earth atmosphere is warming up, the same is happening with the oceans: waters can be impacted by persistent climate trends.

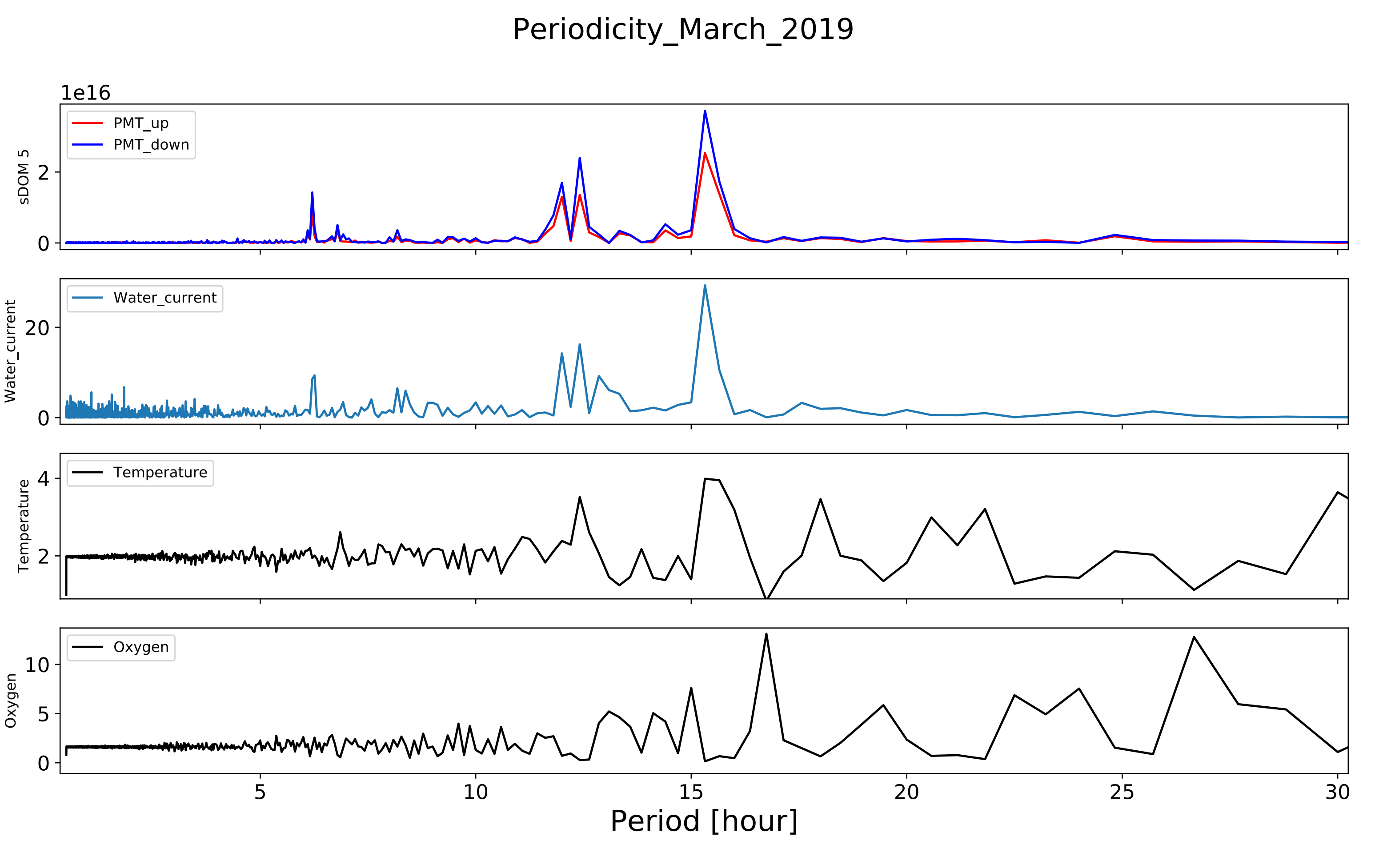
From a study of the Institute of Ocean Sciences *, it has been seen that Pacific Ocean waters up to at least 1000 m depth have been warming and losing oxygen in the last 50 years.
This process has a negative impact on marine ecosystem since life in the ocean requires oxygen to support flora and fauna metabolism.

As the oxygen levels are decreasing and the water temperature is increasing,
could the monitoring of variations in the deep sea bioluminescence background trace this signature?
How the light background could be influenced by this process?

* https://www.sciencedirect.com/science/article/abs/pii/S0079661107001516?via%3Dihub

6.[2] Considerations for the future

The idea is that since water currents can affect deep ocean temperatures, one can expect that an investigation on the deep eddies and tides periodicities, can show corresponding periodicities in the temperature trend.



Water masses movements influence the bioluminescence activity and the temperature for some periodicities.

Multidisciplinary: a deep sea neutrino telescope permanently connected to the shore can provide synergetic opportunities for continuous long-term deep-sea parameters observations, **global warming** effects and **climate change**.

thanks for the attention