Project thesis - Some Results

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1 Forces' impact on the AutoNaut in open waters

After analyzing all external forces affecting the AutoNaut, these are the results that were gathered. The data in this section are gathered from Mausund missions for analysis for open waters.

1.1 Waves

When it comes to waves it seems like the frequency and size of the waves is what contributes the most to the speed of the AutoNaut.

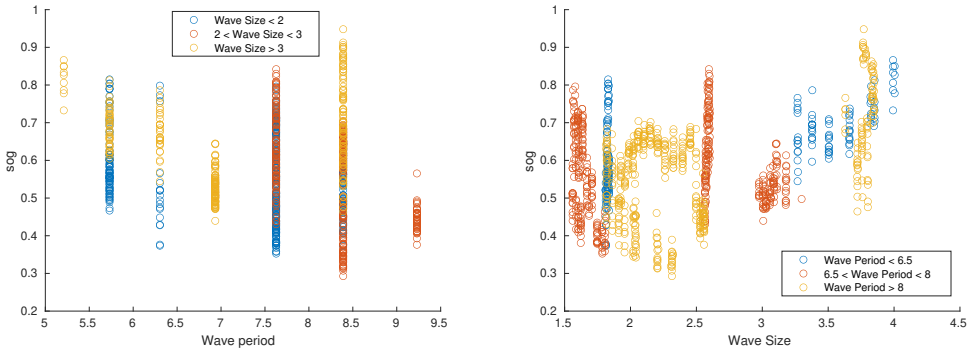


Figure 1: Lower period between waves and larger waves seem to yield higher speed over ground

From the figures above, it seems like lower period, or higher frequency of the waves together with larger waves contributes to more speed for the vessel. But there is a large spread in the data.

When it comes to the direction of the wave relative to the vessel, it does not seem to have a significant impact. The relative wave direction is calculated as

$$\gamma_{wave} = \beta_{V_{wave}} - \psi - \pi \tag{1}$$

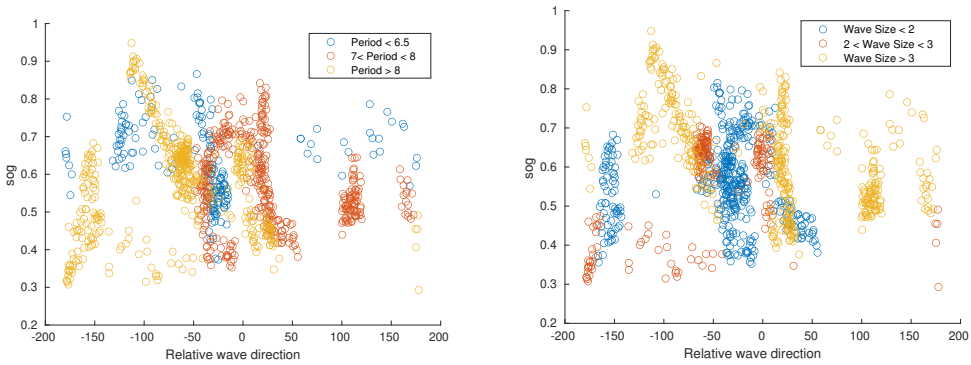


Figure 2: Relative direction to heading vs wave frequency and wave size

To check if the waves have a different affect when looking at the relative direction between the waves and course, the relative angle is calculated as

$$\gamma_{wave} = \beta_{V_{wave}} - \chi - \pi \tag{2}$$

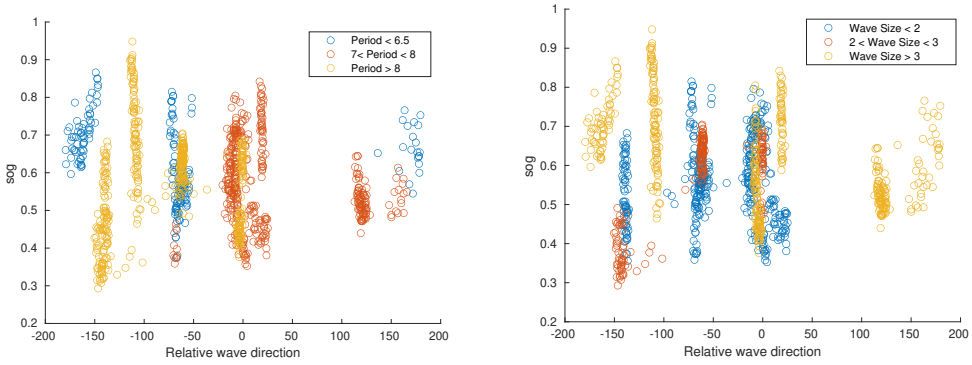


Figure 3: Relative direction to course vs wave frequency and wave size

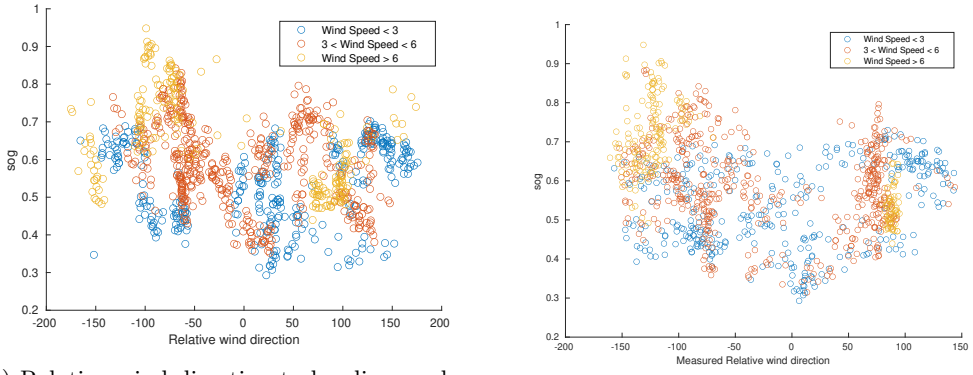
Again it is hard to conclude any specific trends when it comes to relative direction to waves.

1.2 Wind

When it comes to wind it seems like with high wind-speed, there is some impact but does not have the same impact as waves. The relative wind direction is calculated as

$$\gamma_{wind} = \beta_{V_{wind}} - \psi - \pi \tag{3}$$

I cannot see a significant relationship in the plots when looking relative to the forecast data, only that wind from the front is not desired. When looking at the measured wind-data from the AutoNaut it seems like higher winds in the direction of travel is desired.



(a) Relative wind direction to heading angle vs wind speed

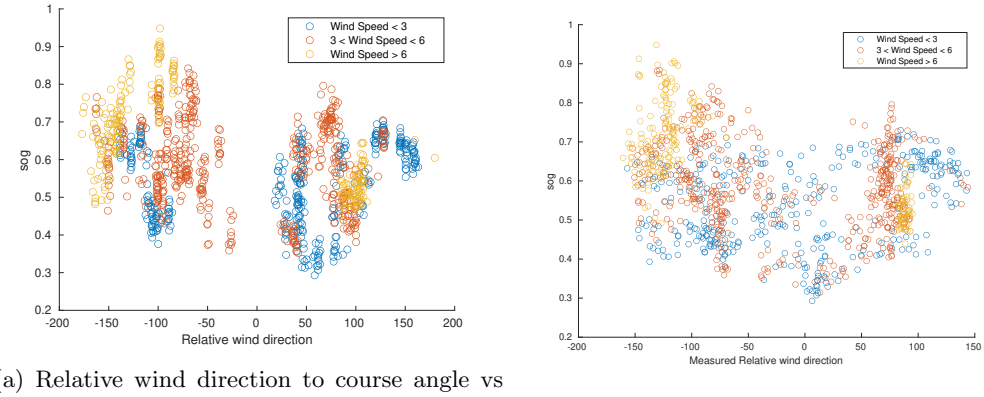
(b) measured wind and direction on the vessel

Figure 4: Relative wind direction to heading angle vs wind speed, compared to the measured wind and direction on the vessel

When looking at the forecast wind relative the course angle of the AutoNaut, the equation becomes

$$\gamma_{wind} = \beta_{V_{wind}} - \chi - \pi \tag{4}$$

The results form this is a bit more similar to the measured data and it seems that stronger winds from behind is desired, which can be seen in the plots below.



(a) Relative wind direction to course angle vs wind speed

(b) measured wind and direction on the vessel

Figure 5: Relative wind direction to course angle vs wind speed, compared to the measured wind and direction on the vessel

Again there is a large spread in the data, but there is some tendency that wind from behind is preferable.

1.3 Current

I thought currents would have a large impact on the AutoNaut but from what I gathered the results seem to not have as big effect on the vessel as I thought. The current is downloaded on vector form with north and east directions. Then I find the direction of the current is calculated as

$$\alpha_{V_{current}} = \text{atan2}(u_{east}, v_{north}) \tag{5}$$

And the angle between the current vector and vessel's heading is

$$\gamma_{V_{current}} = \alpha_{V_{current}} - \psi \tag{6}$$

and the speed of the current is found by taking the norm of the vector. I also looked at the current relative to the course and was calculated as

$$\gamma_{V_{current}} = \alpha_{V_{current}} - \chi \tag{7}$$

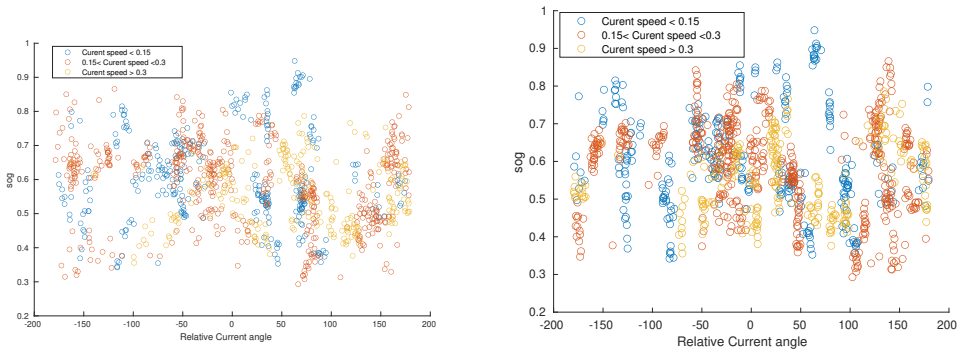
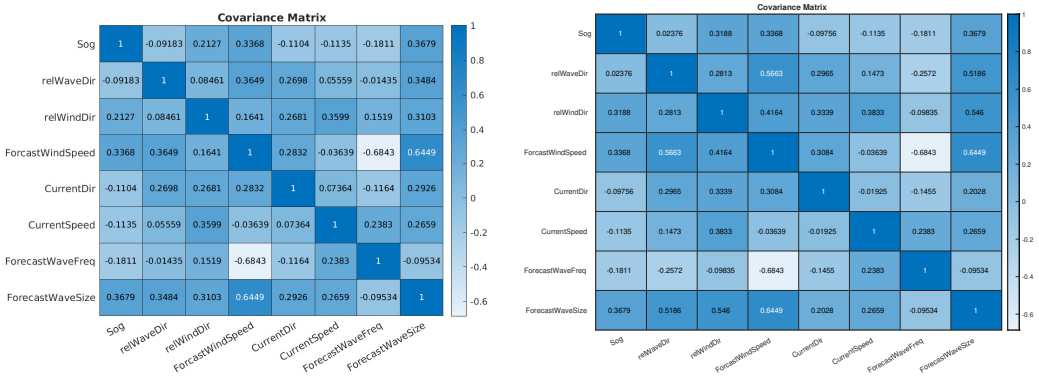


Figure 6: Relative wind direction to heading angle vs wind speed

It seems like the speed of the current has more effect than the direction. From what I gathered high speed from the front contributes to lower speeds for the vessel, while low current speed in general yields the higher speed for the AutoNaut, even higher than higher current speeds in the same direction. But again there is a large spread in the data and hard to conclude any strong relationship.

1.4 Conclusion

So as a conclusion from what I gathered it seems like the wave size is the most significant together with the frequency of the waves. When looking at the covariance matrix, we can see that speed is most correlated with the wave size.



(a) Relative directions are related to heading (b) Relative directions are related to course

Figure 7: Covariance matrix between speed and forecast data

We can also see a wind speed and wind direction has some correlation in positive direction for direction and higher speed. We also see that there is not to much difference when looking at the course or heading.

2 Forces' impact on the Autonaut in Fjords

After analyzing all external forces affecting the AutoNaut, these are the results that were gathered. The data in this section are gathered from Trondheim missions for analysis in fjords and calmer water.

2.1 Waves

From the data gathered in fjords it seems like longer wave periods and larger waves are desired.

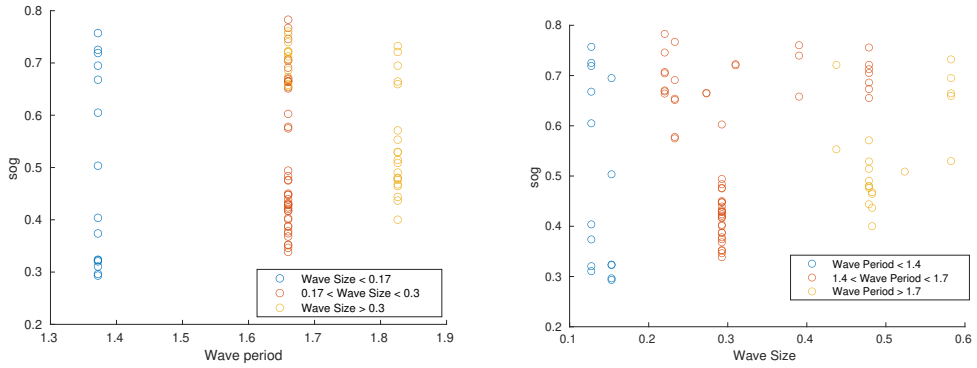
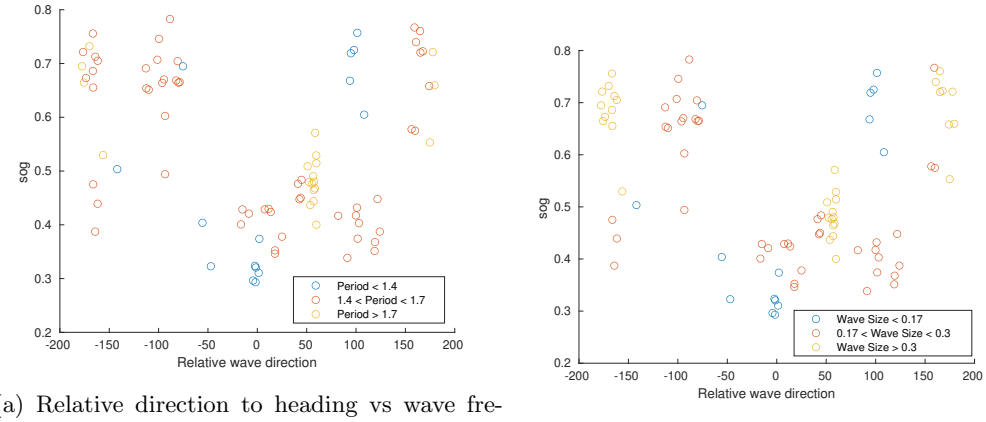


Figure 8: Lower period between waves and larger waves seem to yield higher speed over ground

When it comes to the direction of the wave relative to the vessel, it seems that the relative direction has a higher effect in calmer waters. The relative direction is calculated as

$$\gamma_{wave} = \beta_{V_{wave}} - \psi - \pi \tag{8}$$



(a) Relative direction to heading vs wave frequency

(b) Relative direction to heading vs wave size

Figure 9: Relative direction to heading vs wave frequency and size

Also looking at the the data relative to the course, the direction is calculated

$$\gamma_{wave} = \beta_{V_{wave}} - \chi - \pi \tag{9}$$

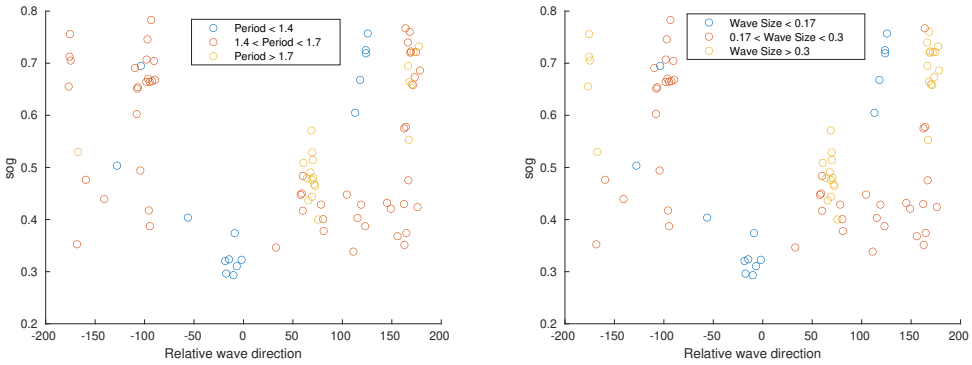


Figure 10: Relative direction to heading vs wave frequency

The plots are similar when looking at waves relative to heading and course. It seems the preferred conditions are large waves with lower frequency from behind.

2.2 Wind

When it comes to wind it seems like wind has more impact in calmer waters than in open waters. The relative wind direction is again calculated as

$$\gamma_{wind} = \beta_{V_{wind}} - \psi - \pi \tag{10}$$

We can see that more wind from behind is preferred and wind from the front yield lower speed.

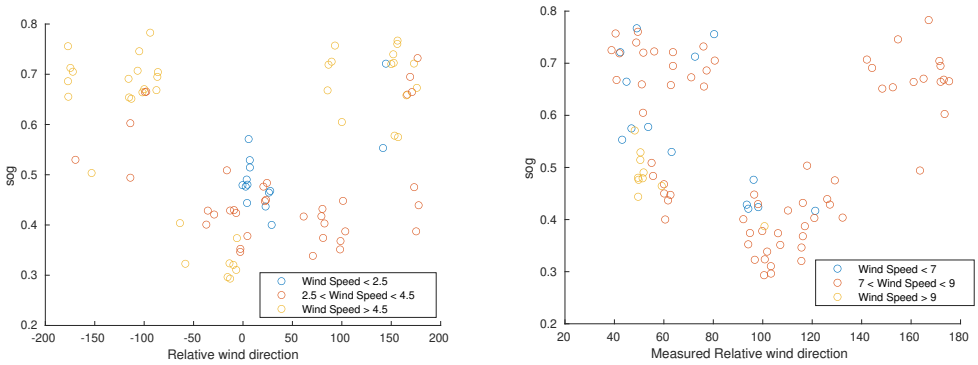


Figure 11: Relative wind direction to heading angle vs wind speed

We notice that the measured wind speeds are much higher than the forecast wind speeds, but the tendency is still the same that wind from behind is more preferred than wind from the front. The same plots can be seen when wind is calculated relative to course

$$\gamma_{wind} = \beta_{V_{wind}} - \chi - \pi \tag{11}$$

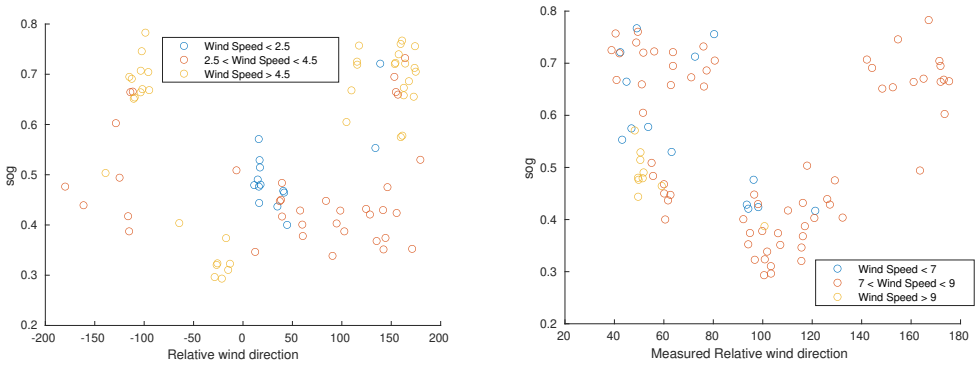


Figure 12: Relative wind direction to heading angle vs wind speed

So we can see that in calm waters more wind from behind is preferred.

2.3 Current

When looking at the current in calm waters there are a lot of spread in the data. The direction the direction of the current is calculated as

$$\alpha_{V_{current}} = \text{atan2}(u_{east}, v_{north}) \tag{12}$$

The angle between the current vector and vessel's heading is

$$\gamma_{V_{current}} = \alpha_{V_{current}} - \psi \tag{13}$$

and the angle between the current vector and vessel's course is

$$\gamma_{V_{current}} = \alpha_{V_{current}} - \chi \tag{14}$$

and the speed of the current is found by taking the norm of the vector.

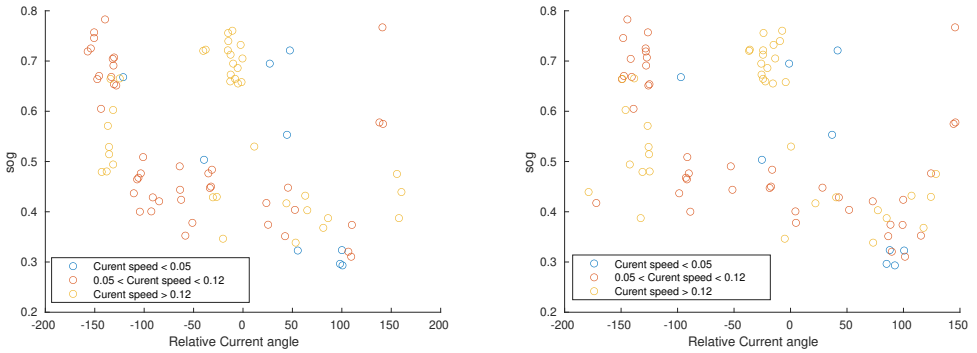
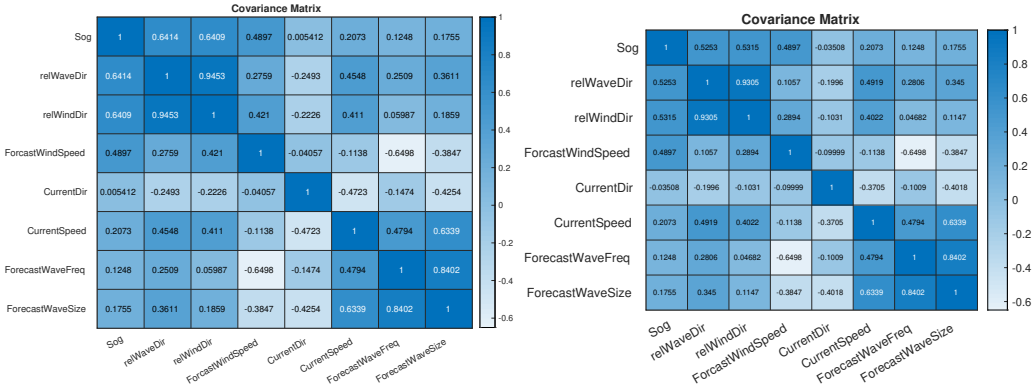


Figure 13: Relative wind direction to heading angle vs wind speed

It can look like from the data that current either in direction of travel or from behind is more preferred than current from the side. Large currents in the same direction might be preferred, but large speeds with current in opposite direction is also found. Due to large spread in the data it is hard to conclude the effect of the currents.

2.4 Conclusion

From what I gathered it seems like the direction of wave and wind is most significant factors when it comes to the speed of the AutoNaut in calmer waters. Larger, lower frequent waves in the direction of travel and more wind in the direction of travel seems like the preferred environment.



(a) Relative directions are related to heading (b) Relative directions are related to course

Figure 14: Covariance matrix between speed and forecast data

We see that speed is highly correlated to wind direction and wind direction. We also see that in calmer waters, wind and wave directions are also highly correlated, so which contributes more is hard to say. We also see that wave frequency and wave size is also highly correlated in calmer waters.