

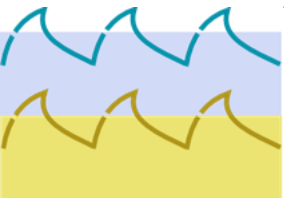
Optical communications

UNWiS - Padova (Italy)

30th of January – 3rd of February 2023

**Filippo Campagnaro, Roberto Francescon,
Angela Soldà, Antonio Montanari, Michele Zorzi**

filippo.campagnaro@unipd.it



Optical communication



Optical communication

- Optical transmission depends mainly on
 - Alignment
 - Ambient light noise
 - Attenuation coefficient **c**
 - Sum of absorption (**a**) and scattering (**b**) coefficients
- | Water type | $a[m^{-1}]$ | $b[m^{-1}]$ | $c[m^{-1}]$ |
|-----------------|-------------|-------------|-------------|
| • Clear ocean | 0.10 | 0.05 | 0.15 |
| • Coastal ocean | 0.20 | 0.20 | 0.40 |
| • Turbid harbor | 0.50 | 1.69 | 2.19 |

R. Diamant, F. Campagnaro, M. De Filippo De Grazia, P. Casari, A. Testolin, V. Sanjuan Calzado, M. Zorzi, "On the Relationship between the Underwater Acoustic and Optical Channels", IEEE Transaction on Wireless Communications 2017

Sea campaign: ALOMEX'15



Scenario 1: November 9



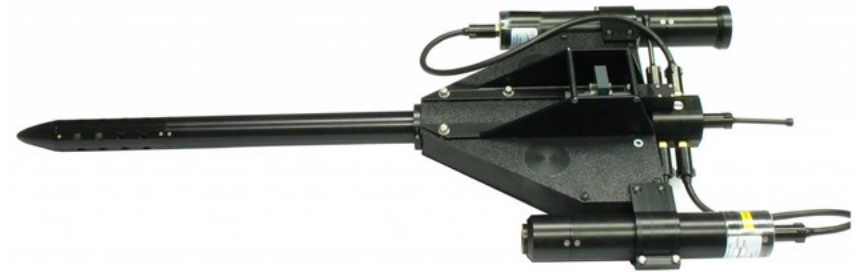
Shallow turbid Atlantic water Location:
Western Sahara



Scenario 2: November 2



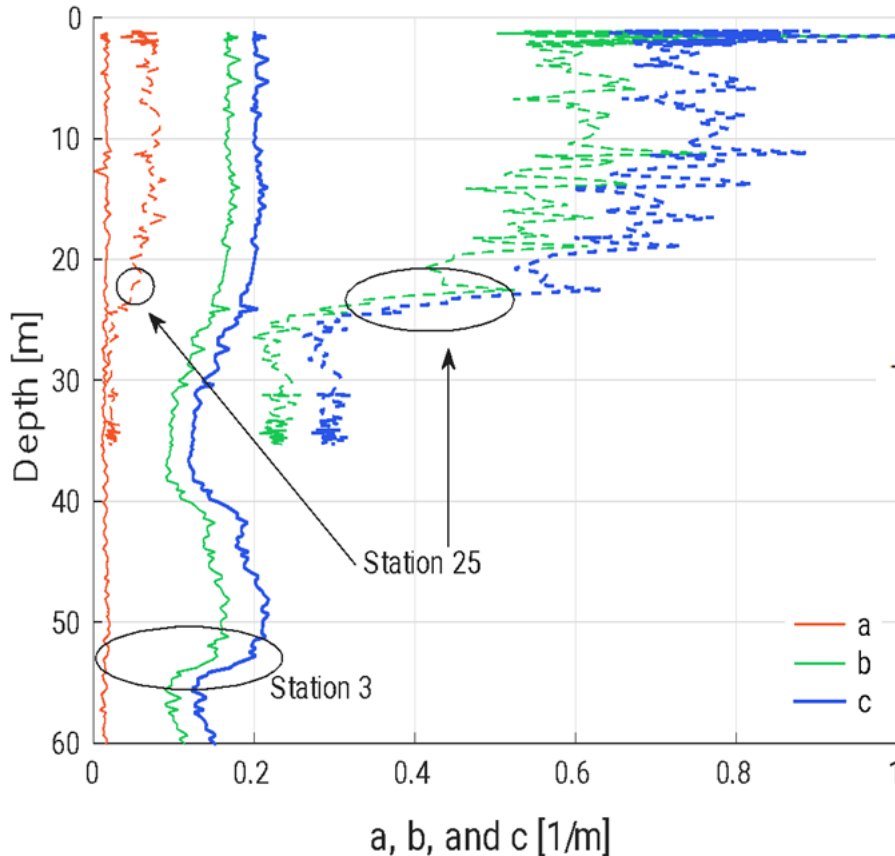
Optics Facilities



Attenuation and received power

$$c(\lambda) = a(\lambda) + b(\lambda)$$

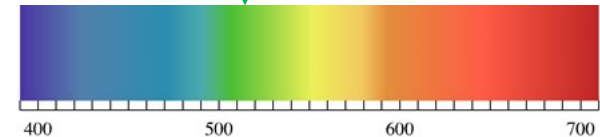
a: absorption
b: scattering
c: attenuation



$$P(r) = P_0 \cdot e^{-c(d) \cdot r}$$

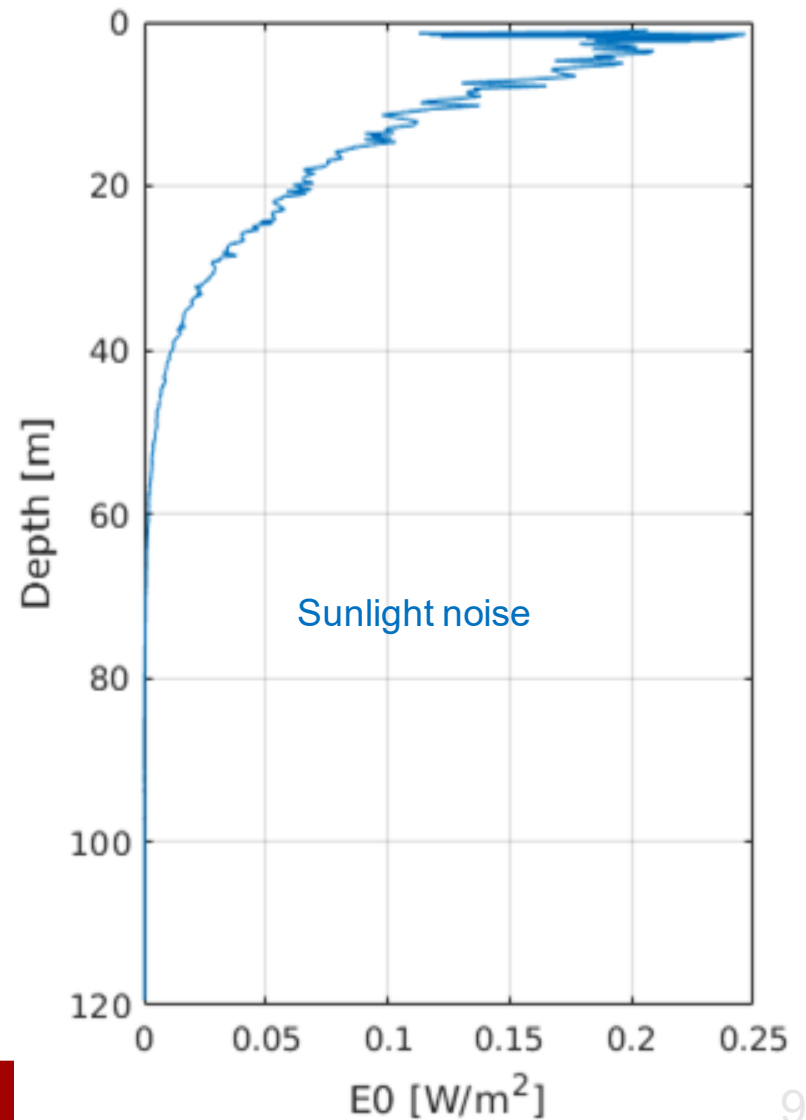
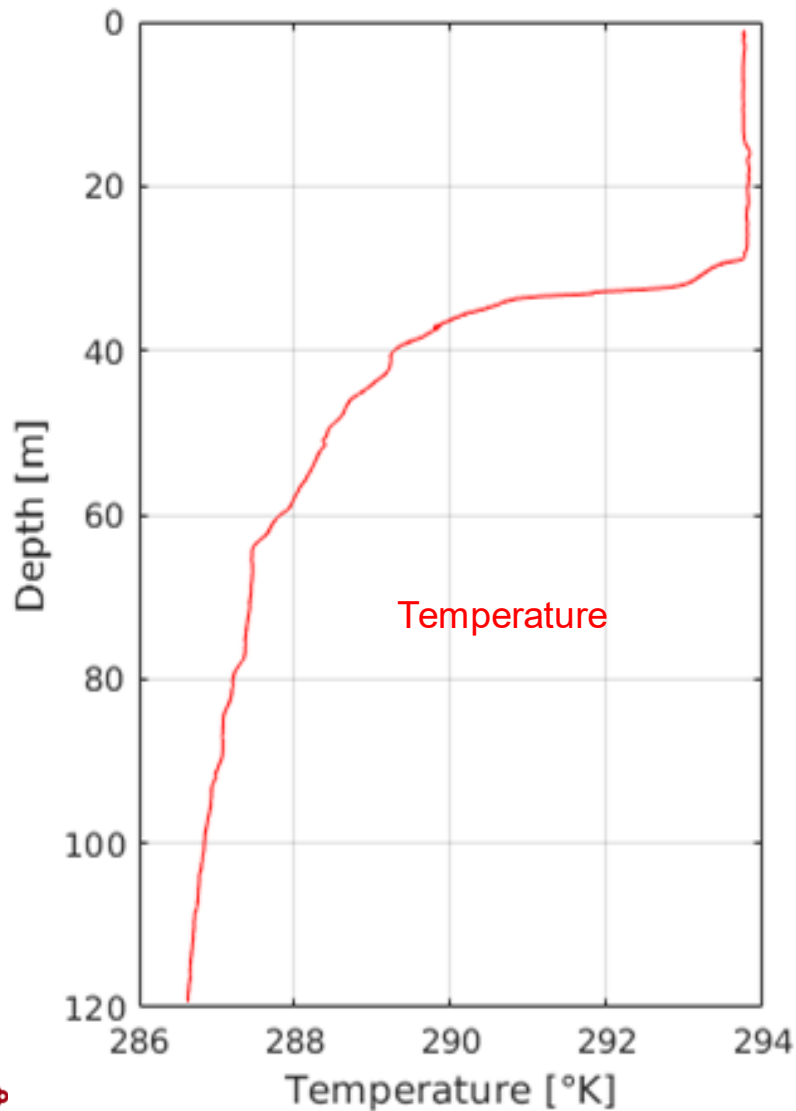
$$P(r) = P_0 \cdot \prod_{k=K_0}^{K_N} e^{-c(d_k) \cdot \Delta_r(d_k)}$$

$\lambda = 532 \text{ nm}$



F. Campagnaro, M. Calore, P. Casari, V. Sanjuan Calzado, G. Cupertino, C. Moriconi, M. Zorzi,
"Measurement-based Simulation of Underwater Optical Networks", IEEE OES Oceans 2017 Aberdeen

Optical measurements



Signal to Noise Ratio

$$SNR = \frac{P_{signal}}{P_{noise}} = \frac{i_{signal}^2}{i_{noise}^2} =$$

$$(SP)^2$$

$$= \frac{2q(I_D + I_{Ltot})BW}{\boxed{\frac{4KTBW}{R}} + \boxed{(N_A)^2}}$$

Shot noise
(dark current +
incident light)

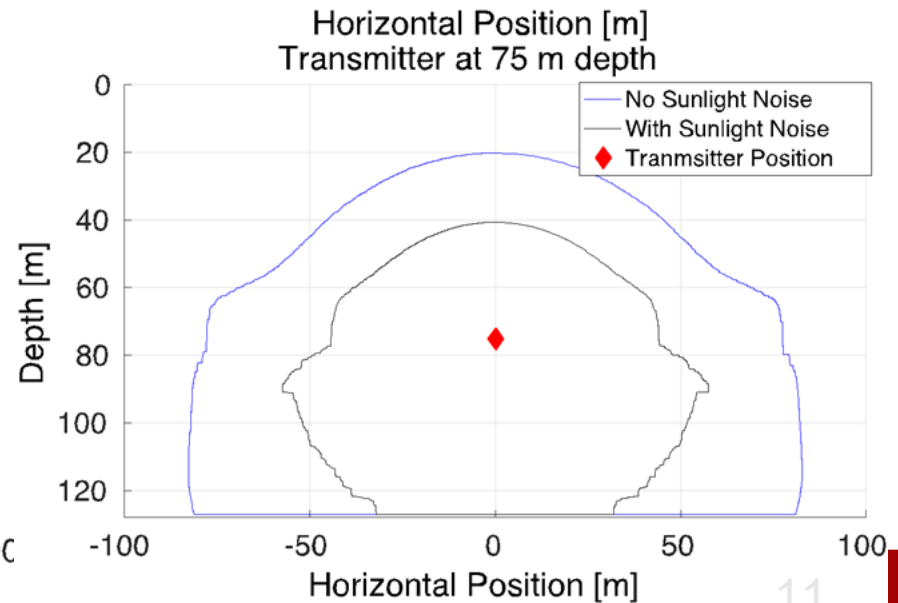
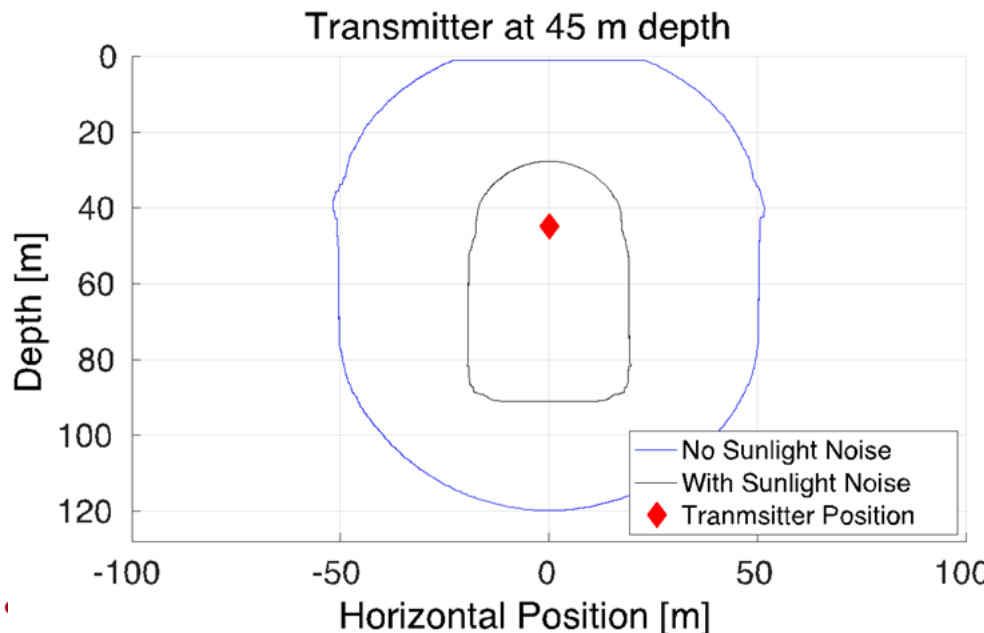
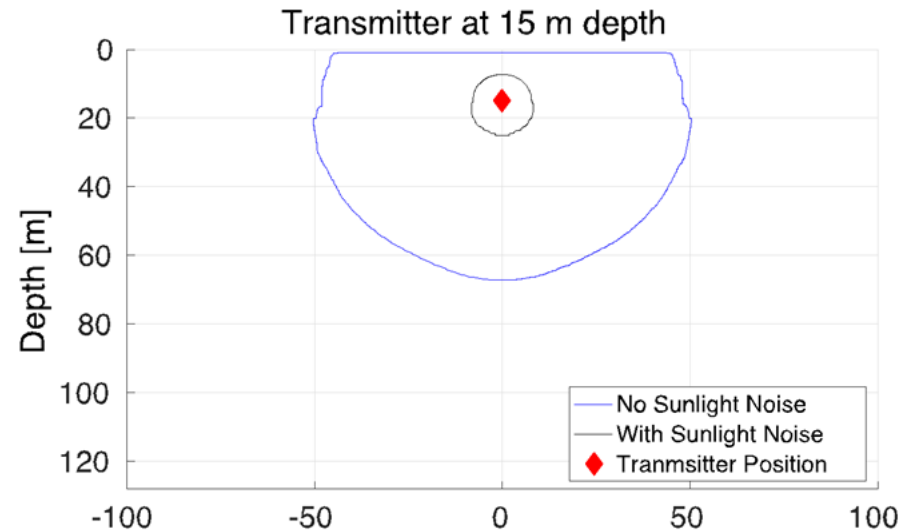
Johnson noise
(thermal noise)

**Ambient light
noise**
 $N_A = E_0 A_r S$

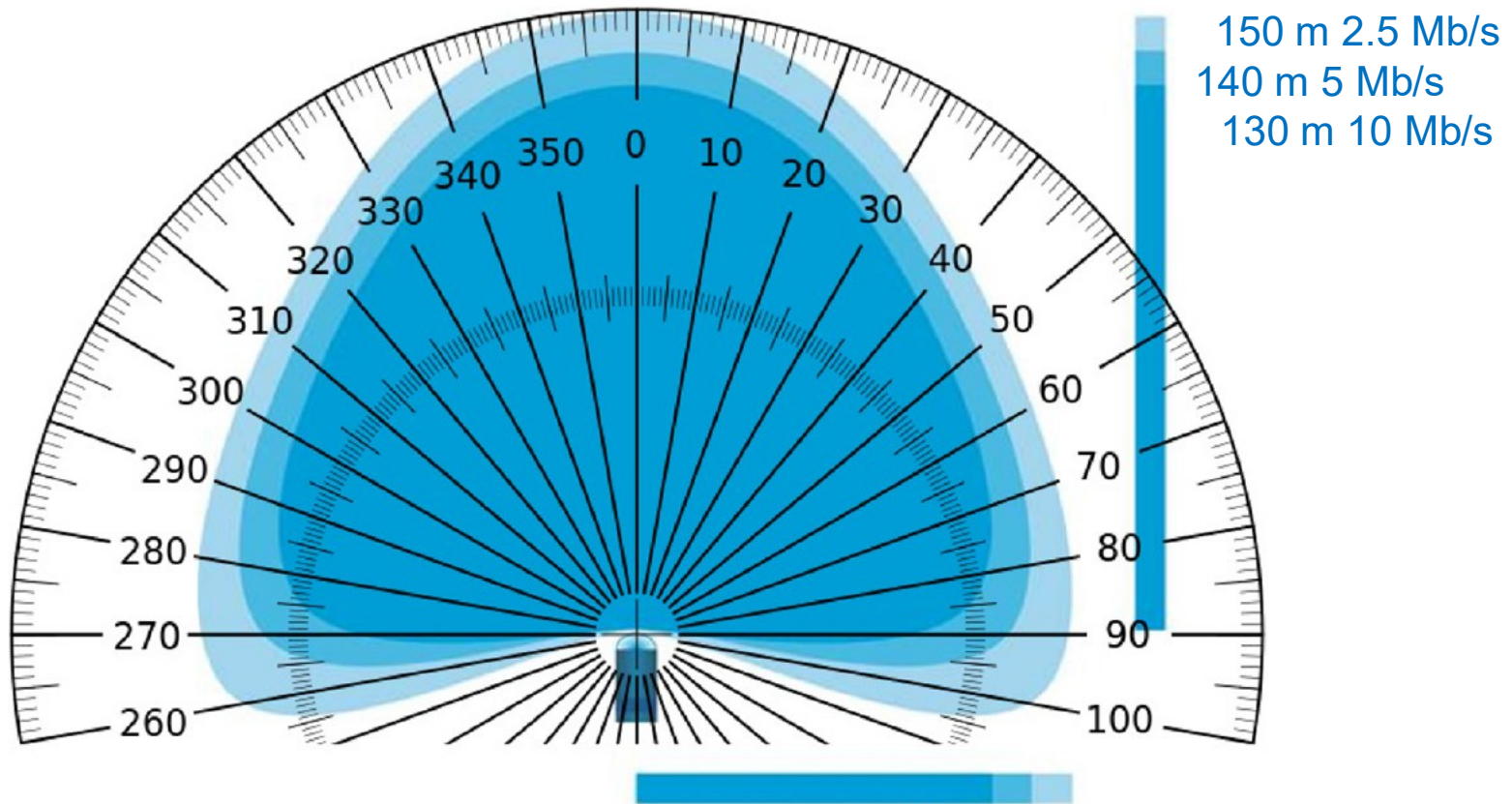


Optical coverage area from model

- Perfect alignment
 - LED-based transmitter
 - Si PIN Hamamatsu receiver



Real modem beam pattern

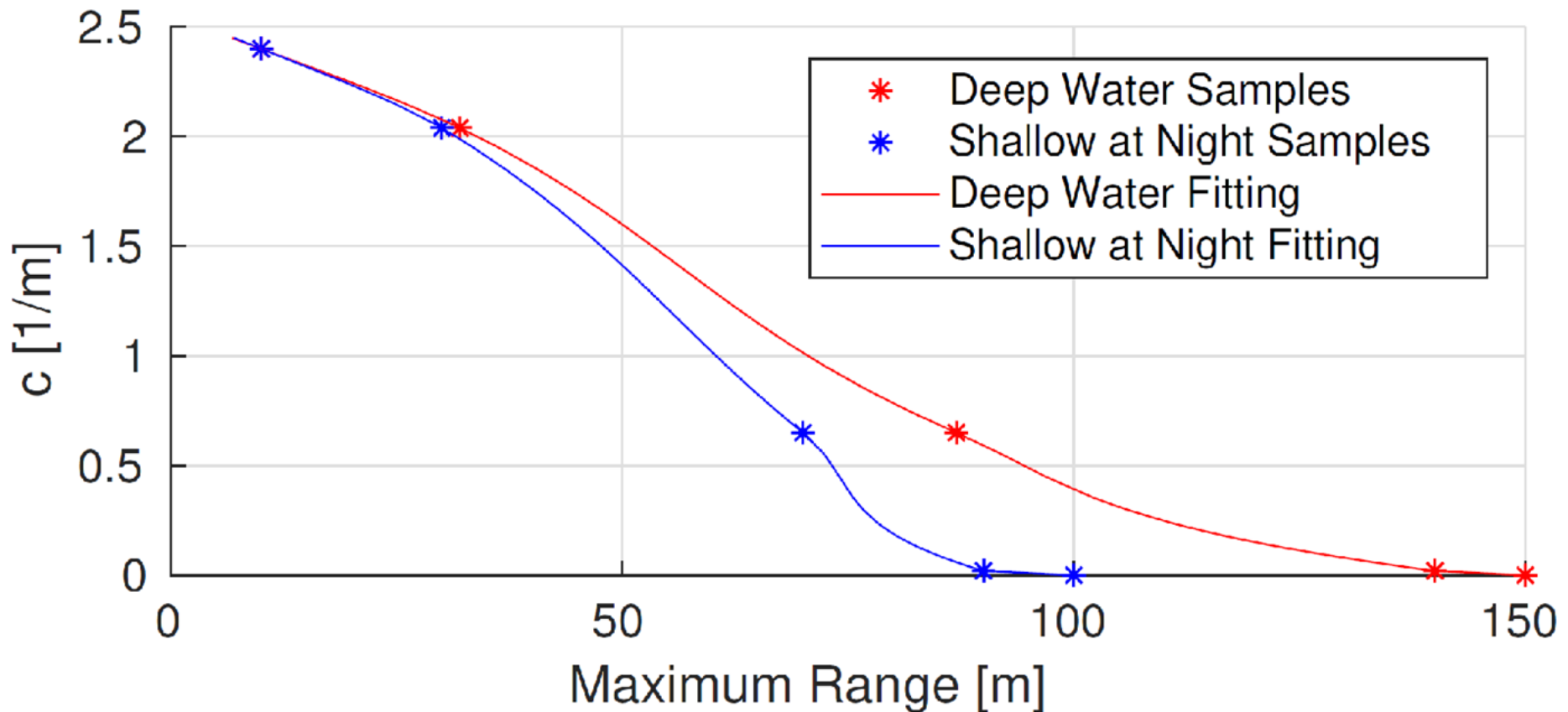


A. Signori, F. Campagnaro, M. Zorzi, "Modeling the Performance of Optical Modems in the DESERT Underwater Network Simulator", IEEE Ucomms 2018

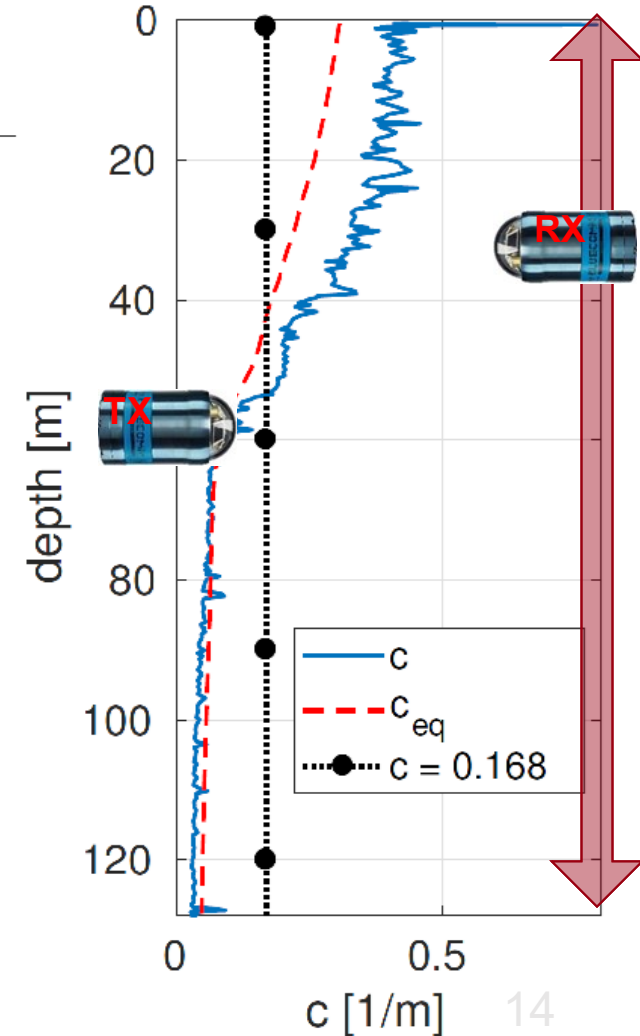
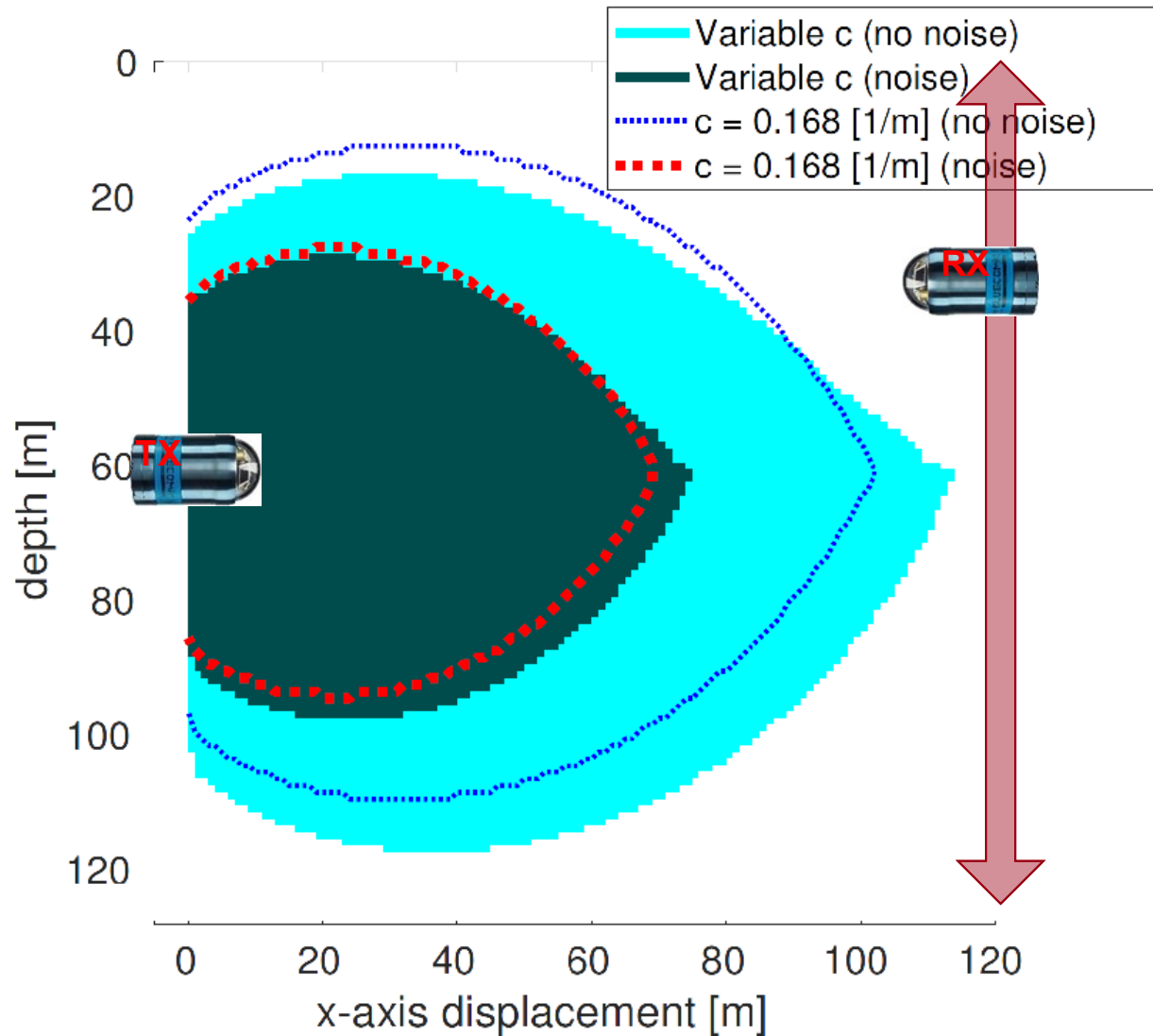
80 m 10 Mb/s
90 m 5 Mb/s
100 m 2.5 Mb/s

Real modem max range

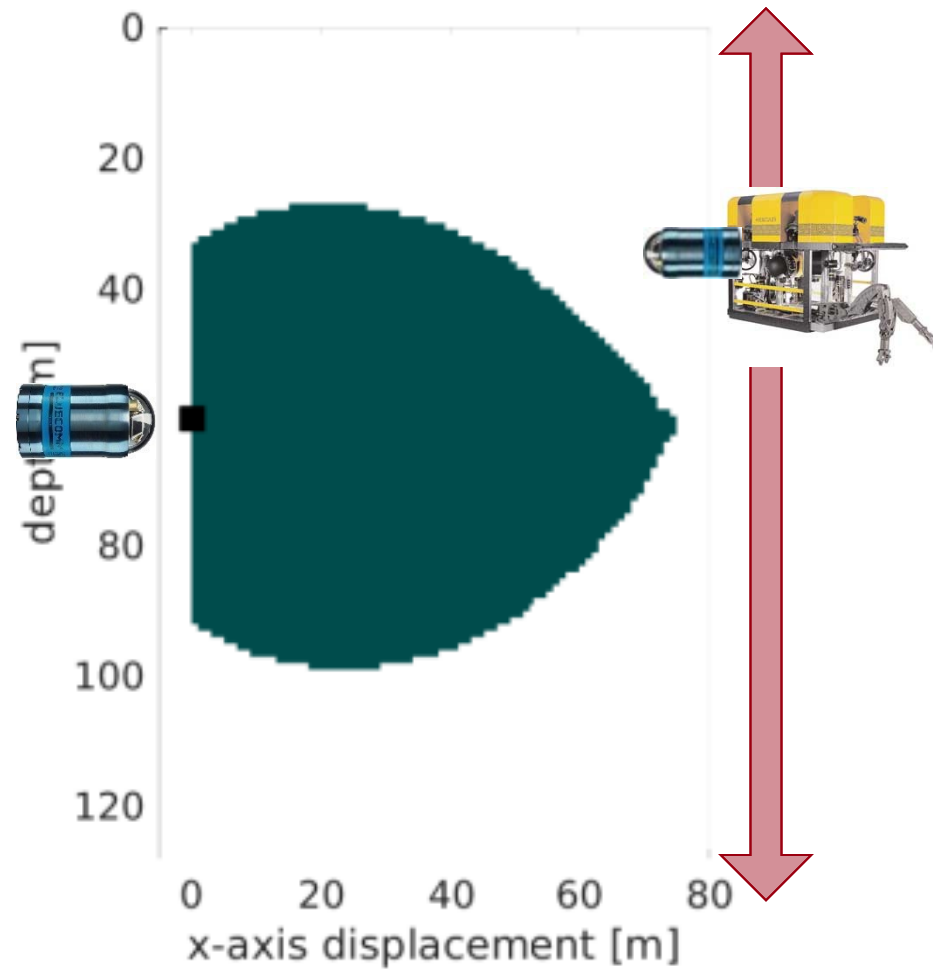
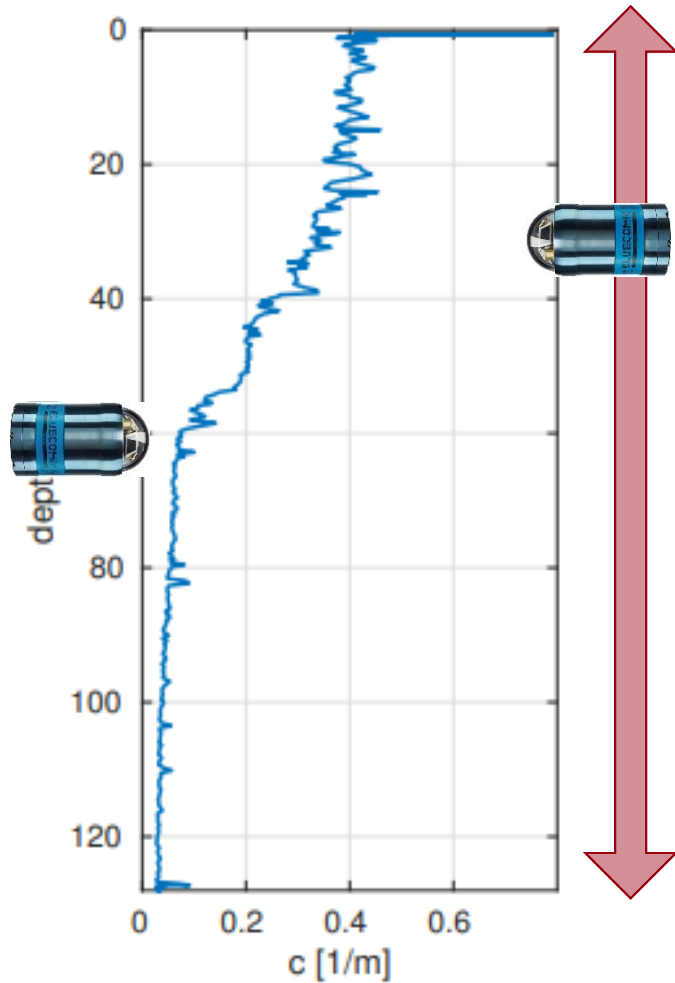
- BlueComm 200 max range in different conditions



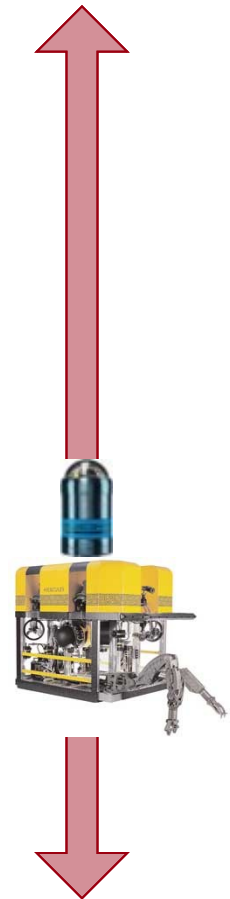
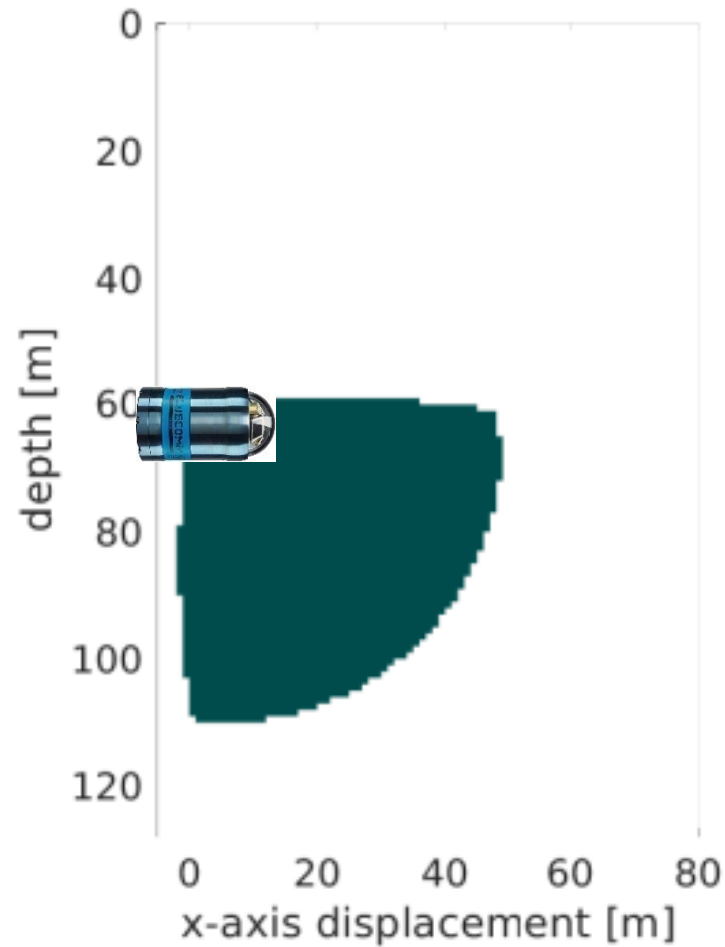
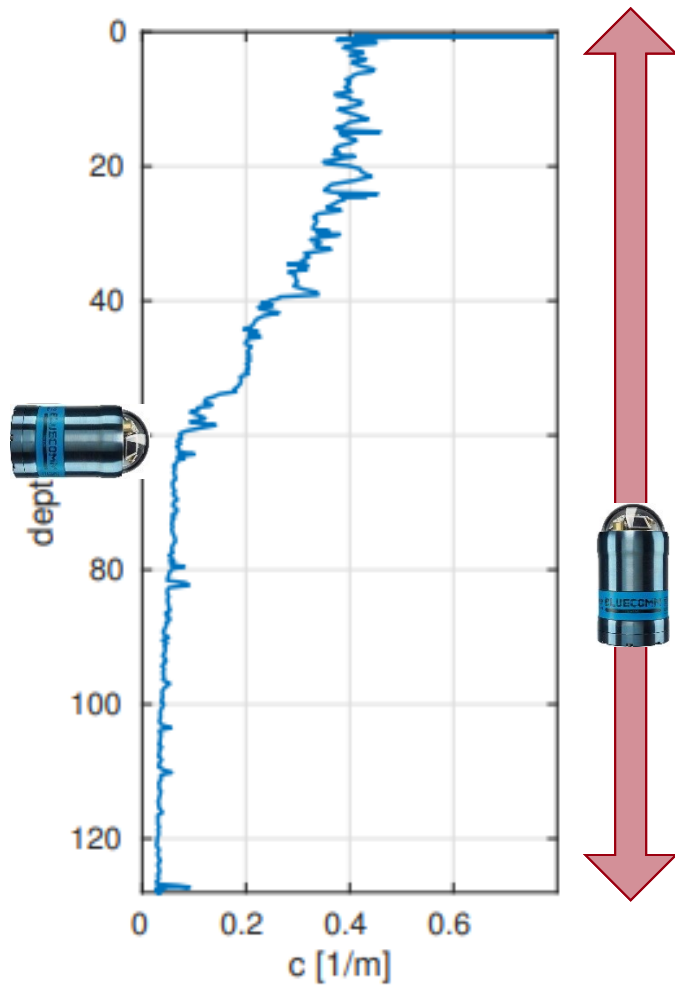
Results – Morocco



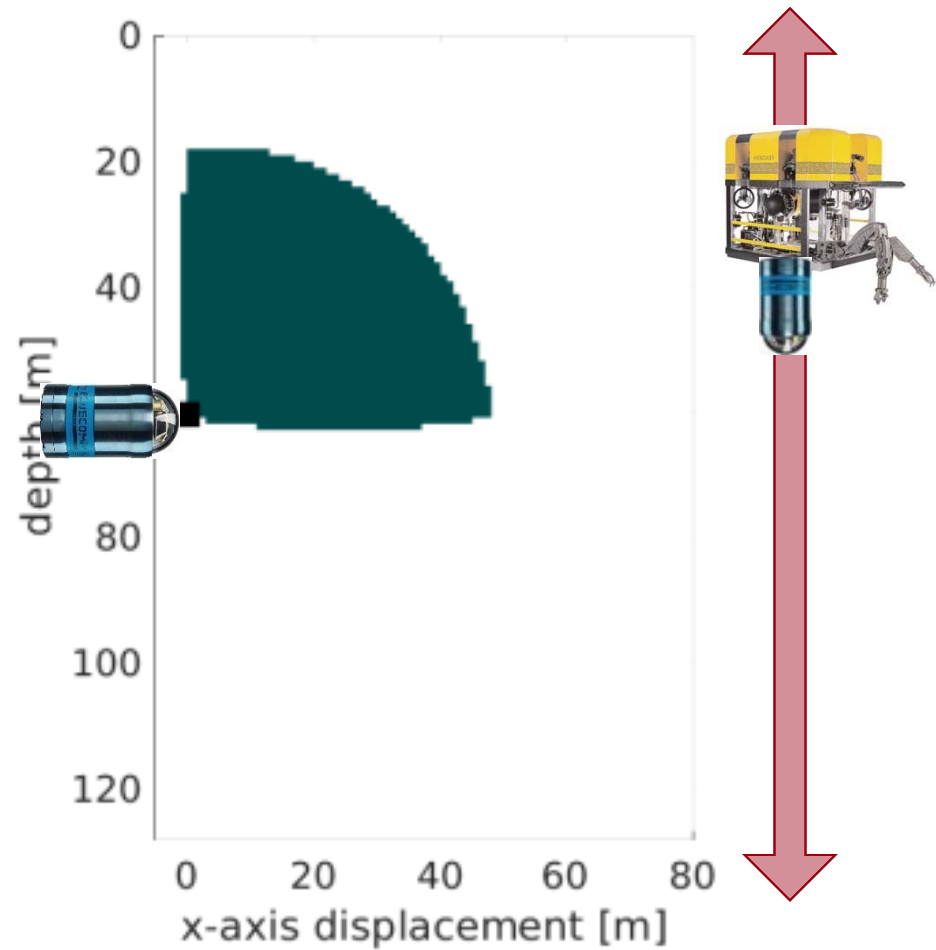
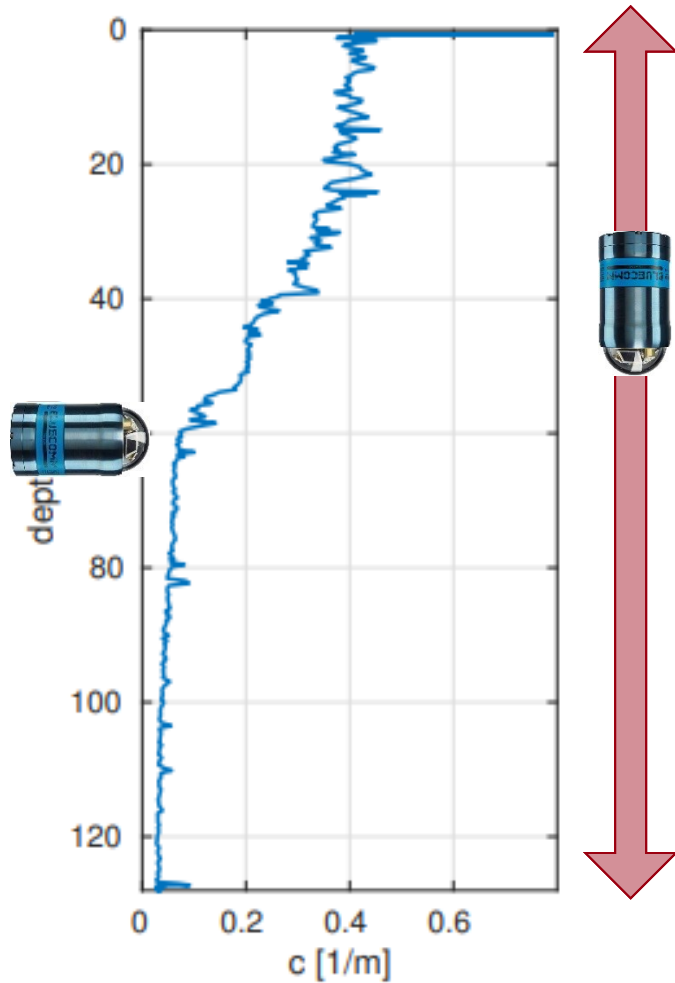
Optical modem installation 1



Optical modem installation 2

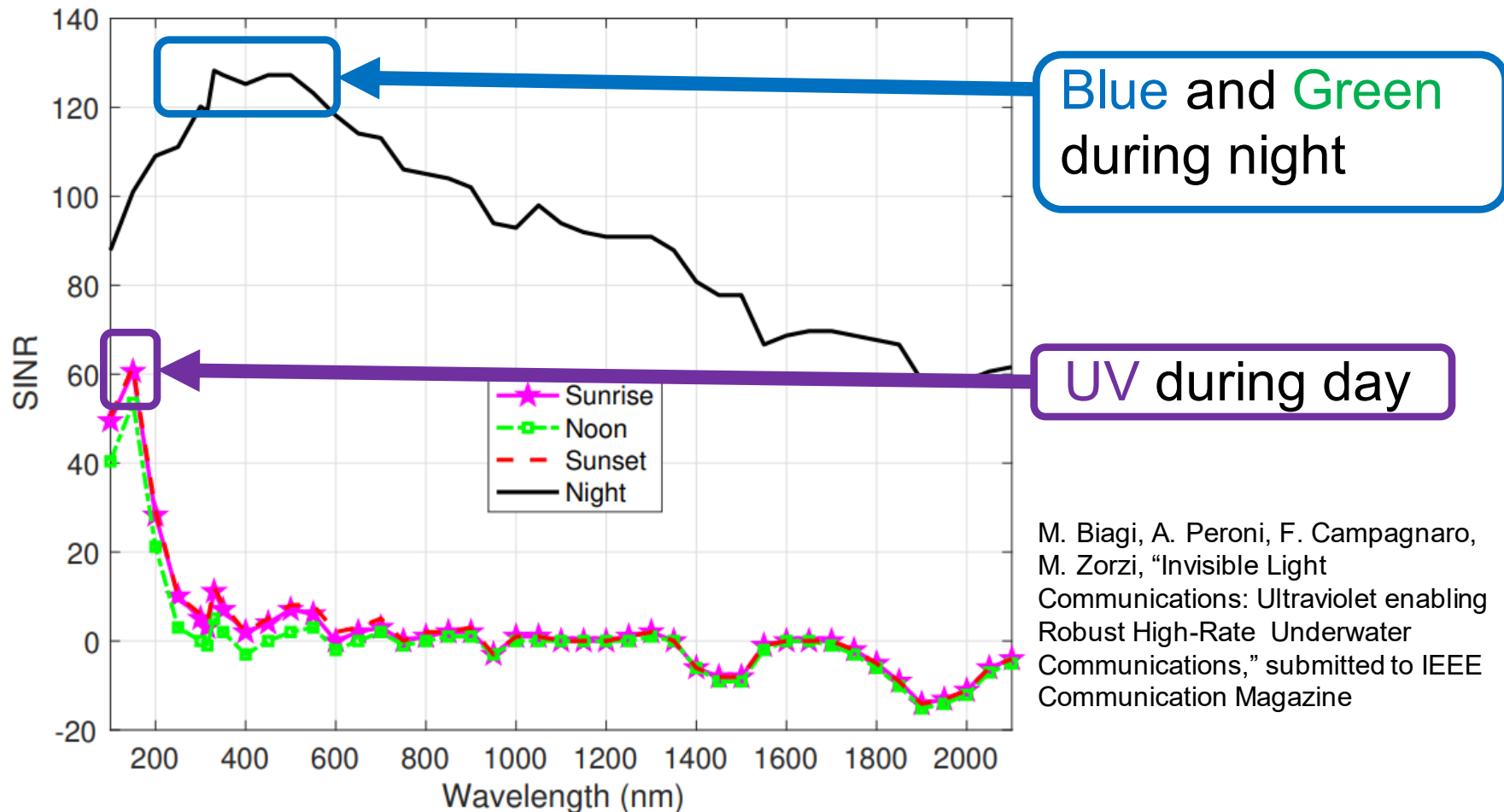


Optical modem installation 3



Optical: which is the best wavelength in shallow water?

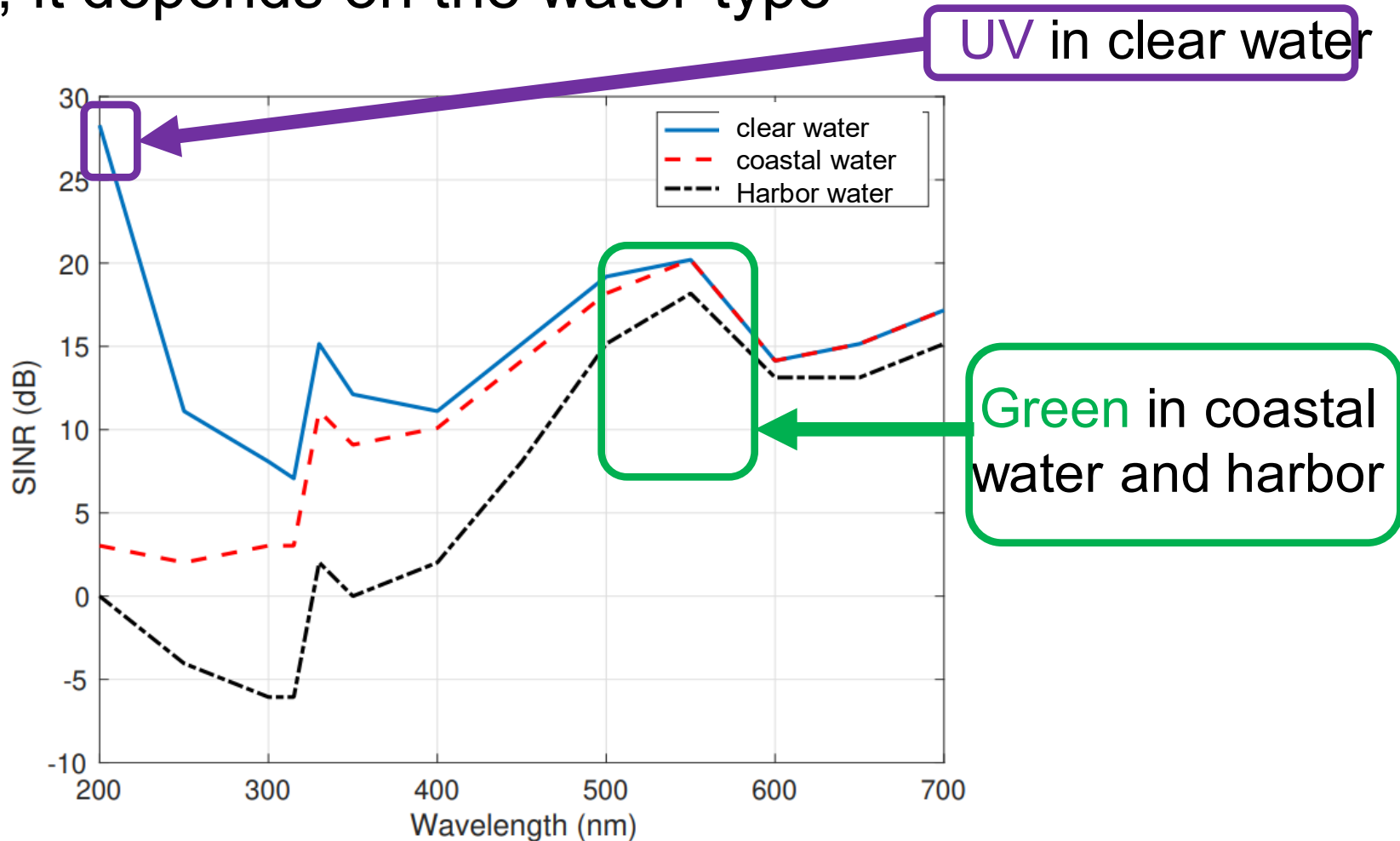
- It depends on the time of the



M. Biagi, A. Peroni, F. Campagnaro, M. Zorzi, "Invisible Light Communications: Ultraviolet enabling Robust High-Rate Underwater Communications," submitted to IEEE Communication Magazine

Shall I always use UV during day?

- No, it depends on the water type



References

- Alberto Signori, Filippo Campagnaro, Michele Zorzi, Modeling the Performance of Optical Modems in the DESERT Underwater Network Simulator, IEEE Ucomms 2018
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- Filippo Campagnaro, Federico Guerra, Paolo Casari, Roe Diamant, Michele Zorzi, Implementation of a Multi-modal Acoustic-Optical Underwater Network Protocol Stack, IEEE/OES Oceans 2016 Shanghai
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