FESTER: a propagation experiment, overview and first results

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ABSTRACT

A long term field trial called FESTER (First European South African Transmission Experiment) has been conducted by an international collaboration of research organizations during the course of almost one year at False Bay, South Africa. Main objectives of the experiment are a better insight into atmospherical effects on propagation of optical radiation, a deeper understanding of the effects of (marine) aerosols on transmission, and the connection of the mentioned effects to the general meteorological and oceanographic conditions/parameters. Modelling of wakes and possible infrared-radar synergy effects are further points of interest. The duration of one year ensures the coverage of most of the relevant meteorological conditions during the different seasons. While some measurements have been performed by permanent installations, others have been performed during intensive observation periods (IOP). These IOPs took place every two to three months to ensure seasonal changes. The IOPs lasted two weeks. We will give an overview of the general layout of the experiment and report on first results. An outlook on the planned analysis of the acquired data, which includes linkage to the Weather Research and Forecasting model (WRF), will be given.

Keywords: turbulence, atmospheric propagation, aerosols, infrared, refraction, transmission, dynamic signatures

1. INTRODUCTION

Since the end of the cold war era mission scenarios for deployed troops and security forces have become more and more complex. Not only has the number of 'military' parties involved into conflicts increased compared to the bipolar cold war world, but as well the number of peace-keeping, humanitarian aid and law enforcement missions (e.g. anti-piracy missions) with potential danger for the security of the personnel has increased significantly.

To ensure success of the mission and safety of the personnel, there is a need for the ability to achieve reliable operational situational awareness, regardless of the geographical location or environmental influences. Apart from intelligence operations by secret services beforehand, most information about the current situation is gained by the deployment of sensor systems surveying the surrounding (e.g. cameras, radar systems and microphones). For an efficient and reliable use of these systems information regarding their potential performance is required.

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In theater the performance of the sensor systems is often not limited by the design of the sensor, but by the environment in which it is used. Extreme examples of such effects are the limitation of the view with cameras due to heavy fog, or strong wind causing a lot of noise on microphones. However, the environment can as well facilitate a better performance, e.g. an increased detection range for radar due to ducting channels, or for camera systems due to refraction effects in the atmosphere. For an efficient planning of the sensor deployment it is important to know how which system is affected by the environment. A Tactical Decision Aid (TDA) can assist the operator and give information on the system performance to be expected. The Electro-Optical System Transmission And Ranging (EOSTAR) model [2] is an example for such a TDA.

Regarding the naval domain, the main area of operations has shifted towards coastal zones. The protection of harbors or shipping routes[ii] and the interception of drug traffickers and weapon dealers are in focus. For these operations there is a need for information with a high spatial resolution to be able to identify potential threats. However, the environmental conditions along the coast are more complex than in open waters. They show a high variability (temporal and spatial) and are often influenced by the coast line (hills, bays, etc.) leading to small-scale disturbances. While for an open sea scenario the propagation path is usually quite homogeneous, huge inhomogeneities along the path can occur close to the coast due to varying water and air temperatures, sea breezes [3] and varying aerosol loading of the atmosphere.

To develop models for the physical processes determining the content of a scene and the propagation characteristics of the atmosphere, and to validate TDAs like e.g. EOSTAR, extensive field trials have to be performed. The simultaneous acquisition of sensor data and the proper characterization of the environmental conditions influencing the performance of these sensors require a big amount of instrumentation and a suitable infrastructure at the test site to ensure safe and reliable operation. This infrastructure has been found at False Bay on the premises of the Institute for Maritime Technologies (IMT) in Simons Town, South Africa (see Figure 1).

During a previous collaboration of the IMT and The Netherlands Organisation for applied scientific research (TNO) in the framework of the FATMOSE [1] experiment (FAlse-bay ATMOSpheric Experiment, 2009-2010), scientists from TNO and IMT already acquired some experience regarding the propagation conditions at False Bay, which served as solid basis for the planning of the “First European South-African Transmission ExpeRiment” (FESTER). FESTER was a joint organizational effort of the Institute of Maritime Technology (IMT) (Simon’s Town, South Africa), the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB (Ettlingen, Germany) and Netherlands Organization for applied scientific research TNO (The Hague). Further partners in the project were the South African Council for Scientific and Industrial Research (CSIR), department Defence, Peace, Safety and Security (DPSS), the Norwegian Defense Research Establishment (FFI) and the German Wehrtechnische Dienststelle für Waffen und Munition (WTD91).

The field trial had multiple objectives:

I. Collection of data sets for the validation/enhancement of TDAs in the electrooptical domain, e.g. EOSTAR
II. Collection of data sets for the development and testing of models for dynamic signature behavior in the electrooptical domain, primarily in the infrared (target signatures, wakes, etc.)
III. Characterization of optical turbulence effects (scintillation, beam wander/angle of arrival fluctuations, image blurring) and their dependence on height above ground/sea
IV. Detailed characterization of the atmospherical conditions and the scales of spatial and temporal variations/inhomogeneities. This includes aerosol concentrations, different meteorological/oceanographic parameters and turbulence
V. Collection of datasets for an analysis of differences in the propagation behavior of electro-optical and RF signals, and potential synergy effects of combined systems.

[ii] e.g. the operation Atalanta of the European Naval Forces close to the coast of Somalia

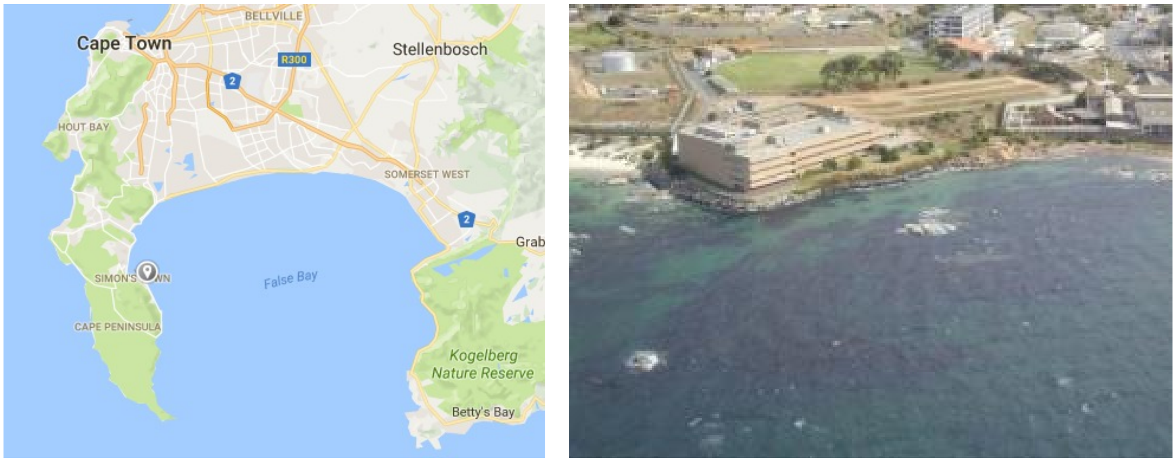

Figure 1: False Bay (left, Google Maps). IMT (right) is located in Simon'sTown (grey marker in left image)

2. LAYOUT OF THE FIELD TRIAL

The FESTER field trial was conducted from April 2015 to March 2016. The location of the experiment was at False Bay (see left image in Figure 1), South Africa. The Institute for Maritime Technology (IMT, see right image in Figure 1) at Simon's Town offered a perfect base for the experiment directly on the shore at the western edge of the bay. The experiments were performed primarily in the northern and northwestern part of False Bay.

The experiment was conducted in two different ways. The characterization of the atmosphere was primarily performed continuously by automated permanent installations like weather stations, boundary layer scintillometers and aerosol probes. Furthermore a permanent installation recorded sequences of halogen lights to investigate atmospheric refraction effects.

Measurements of dynamic signature behavior of metal targets (solar loading, etc.) and additional measurements of atmospheric transmission effects were primarily performed during four intensive observation periods (IOPs), during which the measurement teams of the different institutions worked together at IMT. These IOPs were typically of two weeks duration with a period of approximately two to three months between them. This ensured that environmental conditions during all seasons were covered by our measurements. The primary asset for the measurements during the IOPs was the Sea Lab, a small research vessel owned and operated by IMT (compare Figure 5).

2.1 PERMANENT INSTALLATIONS

For the characterization of the environmental conditions at False Bay over the period of a complete year permanent installations had been set up at multiple locations along the bay. For an overview of the instruments deployed see Table 1 (turbulence measurements) and Table 2 (meteorological and oceanographic measurements, aerosol probes). The local distribution of the instruments and used propagation paths are sketched in Figure 2. The IMT building in Simon's Town served as the center of operations and most of the instruments for permanent measurements were installed here.

Three receivers of boundary layer scintillometers (BLS 900) at different heights (approx. 7 m, 13 m and 19 m above mean sea level) determined the path-integrated turbulence along the 1.8 km long propagation path from the IMT building to Roman Rock (compare Figure 2). The three systems used the signal of a single transmitter installed at Roman Rock (approx. 6 m above sea level) for the measurements. Additionally an ultrasonic anemometer was installed at the top of

Figure 2: Positions of installations during the FESTER field trial. White lines indicate paths for propagation measurements during the trial (Image produced with Google Earth).

Table 1: Turbulence package deployed for continuous observations.

Name	**Equipment**	**Output**	**Location**	**Operator**
Scintec BLS900	Scintillometer	C_n^2, C_T^2	1st Floor IMT ↔ RR	IMT
Scintec BLS900	Scintillometer	C_n^2, C_T^2	2nd Floor IMT ↔ RR	IOSB
Scintec BLS900	Scintillometer	C_n^2, C_T^2	Upper roof IMT ↔ RR	DPSS
Scintec BLS2000	Scintillometer	C_n^2, C_T^2	Lower roof IMT ↔ Kalk Bay	IOSB
Gill HS-90	Ultrasonic anemometer	C_n^2, C_T^2	Roman Rock (RR)	IOSB
MSRT	Transmissometer	TRA, SI	2nd Floor IMT ↔ Kalk Bay	TNO
Telescope	Imaging MWIR &VIS	N, blur, SI	Upper roof IMT ↔ SF	IOSB

Symbols/Abbreviations: U = Wind; Q: Humidity; T = Air temperature; TRA = Transmission; SI = Scintillation index; N = Refractive index; C_n^2 and C_T^2 denote the structure constant for refractive index and temperature, respectively.

Roman Rock lighthouse as an in-situ probe of the turbulence (compare Figure 3). A BLS 2000 system was used along the 8.7 km long path from the IMT building to a sea-facing apartment in Kalk Bay. In addition to the transmitter of the BLS 2000 the source of a Multi-Spectral Radiometer Transmissometer (MSRT, TNO) and a halogen light were installed at the apartment. While the MSRT yields information about the transmission in different spectral bands from the visual to the IR and can be used to derive information about the aerosol content of the atmosphere, the halogen light was used for turbulence characterization with the Angle of Arrival method as described e.g. in [5]. Therefore the light signal was recorded repeatedly during the day with a high speed camera at the IMT building. These measurements have only been performed during IOPs.

For the characterization of refraction effects three halogen lights had been installed at different heights (1x 8 m, 2x 10 m) above mean sea level on a rescue station of the *National Sea Rescue Institute* (*NSRI*) at Strandfontein. These were continuously observed over a distance of approximately 16 km using a telescope (focal length 4 m, see left image in Figure 4) at the IMT building. At the beginning of the experiment recordings were performed using a MWIR camera. However, the aggressive sea atmosphere destroyed the system and a monochrome daylight camera had to be used later on. Every 10 seconds an image of the scene was recorded (compare right image in Figure 4).

Figure 3: Permanent installation on Roman Rock Lighthouse (left side: total view). Meteorological sensors have been installed on top of the lighthouse (right side), while a BLS 900 emitter was installed at the base of it.

Table 2: Additional sensors deployed for continuous observations.

Name	**Equipment**	**Output**	**Location**	**Operator**
PMS CSASP-100HV	Optical particle counter	Aerosol size distr.	In front of IMT	TNO
PMS CSASP-200	Optical particle counter	Aerosol size distr.	In front of IMT	TNO
Vaisala CL-51	Lidar ceilometer	Aerosol profile, cloud height	Upper roof IMT	DPSS
Cimel	Sun photometer	Aerosol column, solar/sky irradiance	Upper roof IMT	DPSS
MSRT	Transmissometer	Pat-integr. Aerosol	2nd Floor IMT ↔ KB	TNO
Name	**Equipment**	**Output**	**Location**	**Operator**
Aimar 200WX	Weather station	P, U, Q, T	Roman Rock (RR)	IMT
Gill HS-90	Ultrasonic anemometer	P, U, Q, T	Roman Rock (RR)	IOSB
Davis Vantage Pro2	Weather station	P, U, Q, T, rain, irr	Upper roof IMT	IMT
Campbell	Weather station	P, U, Q, T, rain	Lower IMT roof	IOSB
Aimar 200WX	Weather station	P, U, Q, T	Sea Lab	IMT
SPAR Buoy	Weather station on buoy	P, U, T	Middle of path IMT ↔ KB	IMT
Name	**Equipment**	**Output**	**Location**	**Operator**
Sentinel ADCP	Current profiler	Current, Tsea	1.7 km along IMT ↔ KB	IMT
Nortek AWAC	Wave and current sensor	Current, Waves	4.3 km along IMT ↔ KB	IMT
Nortek Aquadopp	Current profiler	Current, Tsea	7.2 km along IMT ↔ KB	IMT

Symbols/Abbreviations: P = Pressure, U = Wind; Q: Humidity; T = Air temperature; irr = solar irradiance

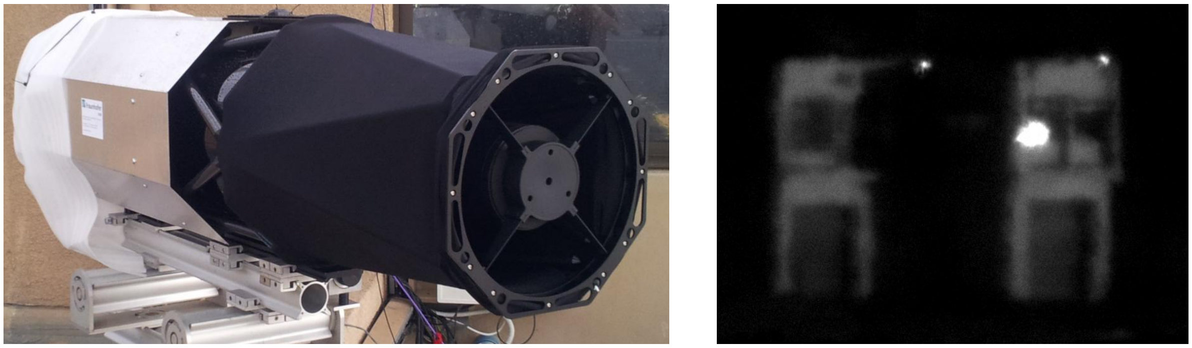

Figure 4: The four meter focal length telescope installed on the roof of the IMT building at Simon's Town (left), and the three halogen lights installed at the rescue station at Strandfontein (right) as seen with the telescope. Difference in apparent brightness is due to formation of a salt crust on the reflectors of the upper lights.

Several instruments at the IMT building were used to gather information about the aerosol content of the atmosphere. On the roof of IMT a LIDAR ceilometer and a sun photometer had been installed to collect data about the aerosol column extinction, the vertical profile, cloud height and the solar/sky irradiance during the measurements. The particle size distribution of the aerosols close to the ground was determined using two optical particle counters (OPC). These were installed close to the shoreline facing southeast towards the open water approximately 3 m above sea level and are able to classify the particle size using 91 channels ranging from 0.21 to 45 µm.

To be able to properly model the propagation conditions over sea, information about the sea state is crucial. Three oceanographic sondes moored to the sea floor at regular distances along the path to the apartment at Kalk Bay were used for oceanographic observations. They provided water current profiles from the bottom up to the surface, two of them as well the in-situ sea water temperature. The sonde in the middle of the path allowed the determination of the full directional wave field that was summarized in terms of wave height and wave period.

2.2 INTENSIVE OBSERVATION PERIODS (IOPS)

During the intensive observation periods additional equipment has been installed for experiments on dynamic signature behavior, and for further experiments on transmission/detection ranges. The main asset during the IOPs was the research vessel Sea Lab 1 (see Figure 5), which was equipped with different targets for the measurements, and with sensors recording the radiometric and meteorological conditions on the vessel. For an overview of the installations on Sea Lab 1 see Table 3.

Main objective for measurements during IOPs was the evaluation of sensor performance as a function of the environmental conditions. The IOPs were the main source of data for the validation and further development of tactical decision aids, one main objective of FESTER. Table 4 list all the sensors (cameras and radar) deployed during the IOPs. They cover the spectral range from approx. 400 nm to about 12 µm wavelength: visible (VIS), near-infrared (NIR), shortwave infrared (SWIR), mid-wave infrared (MWIR) and long-wave infrared (LWIR). Additionally during IOP 3 a radar system operating at 9.4 GHz was available.

For the validation of the TDAs it was necessary to intensify the characterization of the environment during the IOPs. Special care has been taken to characterize spatial and temporal inhomogeneities in the air and the water. During the measurements the Sea Lab was either sailing along one of two radials away from IMT or it was performing small manoeuvers in an area approximately 500 m southeast of the IMT building (signature area). One of the radials was performed in north eastern direction along the lower line in Figure 2, which passes Seal Island on the southern side. This long range radial was used for the evaluation of sensor performance in terms of contrast, resolution and detection ranges in different spectral bands. The second radial was performed along the path from IMT to the apartment at Kalk Bay.

Figure 5: Research vessel 'Sea Lab 1', owned and operated by IMT (left). It served as primary asset during the intense observation periods. Middle: Steel plates used for dynamic signature/solar loading measurements. Right: Surfboard used for temperature profiles along the propagation path to Kalk Bay.

Table 3: Equipment installed on Sea Lab 1 during IOPs.

Name	**Equipment**	**Output**	**Operator**
Bar target	Standard black-white bar pattern	Contrast as function spatial frequency	IMT
LED lights (2x)	High-intensity, narrow beam light	Resolved target separation distance	IMT
Heat sources (2x)	High-temperature blackbody	Point source intensity	IOSB
Vaisala WXT520	Weather station	P, U, Q, T, rain	IMT
Aimar 200WX	Weather station	P, U, T	IMT
GPS, AIS	Positioning and location tools	Position, trajectory	IMT
Metal plates (6x)	3 and 6 mm steel with insulation	Dynamic IR signature	IMT
Pyrgeometer (2x)	Irradiance measurement	Incident sky radiance on metal plates	TNO
Pyranometer (2x)	Irradiance measurement	Incident solar radiance on metal plates	TNO
iButtons (12x)	Temperature sensors and loggers	Plate and hull temperatures	TNO
Helitronics	LWIR radiometer	Sea surface temperature	IMT
Alisop Helikite	Kite with weather sensors	Vertical profiles of P, U, Q, T	IMT
CTD Probe	Underwater characterization	Sea water temperature	IMT
Surfboard	Towed sensor platform	Air-sea interchange temperatures	IMT

Symbols/Abbreviations: P = Pressure, U = Wind; Q: Humidity; T = Air temperature;

In addition to the sensor performance evaluation, this radial served for dynamic signature measurements and the characterization of upper air (up to 200 m) and oceanographic conditions.

For the oceanographic measurements a small surfboard equipped with sea and air temperature sensors (see right image in Figure 5) was dragged alongside Sea Lab 1 to determine temperature profiles along the propagation path from IMT to Kalk Bay. Furthermore at five points along the radial Sea Lab 1 stopped to acquire vertical profiles with a CTD probe, measuring Current, Temperature and water Depth. The surface temperature was separately determined using a longwave infrared (LWIR) radiometer.

A helikite connected to a winch on Sea Lab 1 was used to determine vertical profiles of air temperature, pressure, humidity and wind up to a height of 200 m. These measurements were performed at the middle of the propagation path from IMT to Kalk Bay and will allow for a test of the validity of meteorological theories, which in turn are used in the calculations of turbulence quantities. During the fourth IOP weather balloons with radio sondes have been used by WTD 91 to acquire such profiles for heights up to 15 km three times a day. These profiles have a lower height resolution than the helikite measurements, but allow for a bigger scale picture of the meteorological situation in the bay.

The primary task of Sea Lab 1 was to serve as a target for experiments on solar loading and dynamic signatures. To mimic behavior of bigger vessels, 1 x 1 m big steel plates of different thicknesses (6 mm and 3 mm), painted with a navy grey color, were mounted on both sides of Sea Lab 1 (see middle image in Figure 5). Insulation material was attached on the back of the plates to avoid cooling from this side. A smaller third plate (3 mm thickness) was used to mount pyranometers and pyrgeometers on both sides of the vessel to monitor radiation fluxes onto the steel plates. The temperatures of the steel plates were measured with multiple iButtons® (Maxim Integrated) on each plate.

The variation of the signature of Sea Lab with time and with different solar and sky irradiance conditions was recorded with all the camera systems listed in Table 4. Typically, the dynamic aspect was forced by changing the orientation of the vessel with respect to the sensors, and the sun, and thus by changing the irradiant flux on the steel plates. First, in a preparation phase, Sea Lab kept its position and orientation until the plates were in an equilibrium state. Then the vessel turned to point the steel plates to the sensors, which recorded the following changes in the signature of the plates (and Sea Lab). When the plates reached equilibrium again, either having cooled down or heated up depending on the time of the day, the vessel turned by 180° to expose the other set of steel plates.

Table 4: Imaging sensors and radar deployed during the IOPs.

Name	Band	Characteristics	Location	Operator
FLIR SC7300L	LWIR	CMT 320x256, 2.75 x 2.2° FOV, 0.15 mrad IFOV	Upper roof IMT	IMT
FLIR/CEDIP	MWIR	InSb 320x256, 2.75 x 2.2° FOV, 0.15 mrad IFOV	Upper roof IMT	IMT
CEDIP	SWIR	CMT 320x256, 2.75 x 2.2° FOV, 0.15 mrad IFOV	Upper roof IMT	IMT
JAI AG080	NIR	CCD, FOV (HxV) 0.18 x 0.14°, 3.1 μrad IFOV	Upper roof IMT	IMT
JAI CB-200GE	VIS	CCD, FOV (HxV) 0.27 x 0.20°, 2.9 μrad IFOV	Upper roof IMT	IMT
InfraTec LWIR	LWIR	CMT, 640x512, 2.8° FOV	Upper roof IMT	IOSB
InfraTec MWIR	MWIR	CMT, 640x512, 2.8° FOV	Upper roof IMT	IOSB
AIM640C	MWIR	CMT, 640x512, 1° FOV	Upper roof IMT	IOSB
FLIR SC7000	MWIR, SWIR	InSb, 640x512, 2.8° FOV	Upper roof IMT	IOSB
FLIR AC6555SC	LWIR	640x480, 5.25° FOV		TNO (1)
FLIR SC7750L	LWIR	InSb, 640x512, 2.93 x 2.35° FOV, 0.08 mrad IFOV	1st floor IMT & old Signal School	TNO (3)
FLIR SC7600	MWIR	InSb, 640x512, 2.75 x 2.2° FOV, 0.075 mrad IFOV	1st floor IMT & old Signal School	TNO (3)
	VIS		1st floor IMT & old Signal School	TNO (3)
Telops Hyper-Cam	LWIR, MWIR	320 x 256, 6.4 x 5.1° FOV	In front of IMT	FFI (3)
SimRad 4G radar	9.4 GHz	2.6 – 5.2° beam width	In front of IMT	FFI (3)

Remark: numbers between brackets in column ‘operator’ signal the specific IOP that the instrument was deployed

As a reference source two black bodies operated at a temperature of 50 ° C and 70 °C had been mounted at the stern of Sea Lab. At each turn of the boat these references have been recorded. Additionally, during the radials the black bodies served as radiation sources with known intrinsic radiant intensities. Using the known radiant intensity and the apparent radiant intensity measured with calibrated IR sensor systems allows for a range dependent analysis of the propagation conditions on the radial. By comparing these experimental results to the predictions of the Tactical Decision Aids a validation and improvement of these models can be made.

The signature measurements were completed with recording of the sea and sky backgrounds, and the wake of Sea Lab as it sailed at various speeds. The elevated sensor position at the Old Signal School was primarily chosen for this experiment. Furthermore, a side experiment consisted of tracking the Sea Lab as it sailed along, and moved in front of or behind other traffic.

3. FIRST RESULTS

The First European-South African Transmission ExpeRiment (FESTER) has yielded a huge amount of data on environmental effects on the performance of electrooptical systems. Most of the participating institutions have just started to analyze the data. Thus, only some first results on different aspects of the experiment can be presented here.

To illustrate the importance of air-sea temperature differences and potential effects of local inhomogeneities in the atmosphere, Figure 6 shows the results of C_n^2 measurements for a specific day. The bright red, blue and green curves show the path-averaged C_n^2 values retrieved from the three scintillometers on the 1.8 km long path from IMT to Roman Rock. The curves demonstrate that the turbulent intensity decreases as the propagation path is higher above the water. This is a direct consequence of the changes in air temperature with height, which can (in principle) be quantified by the information provided by the helikite. The plot also shows the in-situ C_n^2 value as retrieved from the sonic anemometer at the top of the lighthouse, and the path-averaged values obtained with the BLS2000 along the longer 8.7 path from IMT to Kalk Bay. In the afternoon all five curves show similar behavior, which suggest that the False Bay environment was rather homogeneous at that time. However, for the first part of the day the sonic and the BLS2000 show a markedly different behavior from the three BLS900 systems. This reflects the spatial inhomogeneity of the environment and suggests that a specific event took place along the path from IMT to Roman Rock, which affected the lowest air layers of the atmosphere. This has to be analyzed further. A linkage of the data to simulations using the weather research and forecasting model (WRF) may provide a deeper insight.

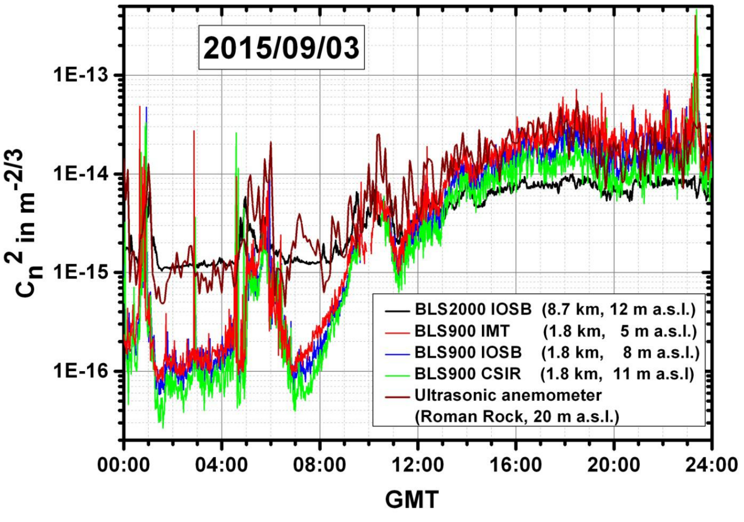

Figure 6: Variations in turbulence intensity (Cn^2) on 3 September 2015 (IOP2).

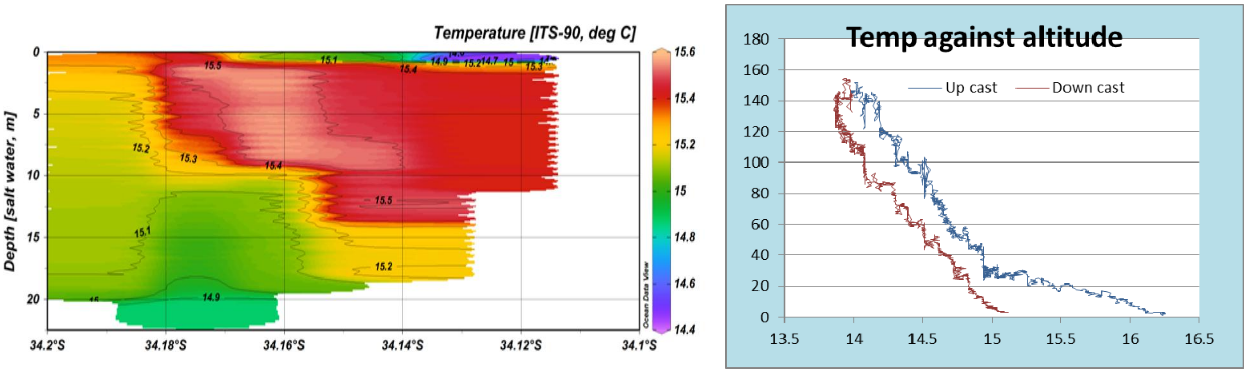

Figure 7: Left: sea water temperatures along the path from IMT to Kalk Bay. Right: Vertical profile of air temperature acquired with the helikite.

As mentioned before, big efforts have been made to characterize the inhomogeneity of the environment, especially during the IOPs. As an example, Figure 7 shows the variation in seawater temperatures along the transect IMT – Kalk Bay as observed during one particular run of Sea Lab (left image). The right image of Figure 7 shows the vertical profile of air temperature as obtained with the helikite at the midpoint of the transect.

The variability of the atmospheric conditions are additionally represented in Figure 8. It shows the change of the apparent position of the halogen spots (1x 8m, 2x 10 m AMSL) at the NSRI station in Strandfontein over the course of a day, as it was seen using the telescope on the roof of IMT. Changes in the Air Sea Surface Temperature Difference (ASTD) lead to changes in the index of refraction of the atmosphere, thus leading to the apparent movement. However, part of the movement may be caused by thermal effects on the mount of the telescope. A detailed analysis, taking into account especially the relative motion of the spots, has to be done.

As a last example, Figure 9 depicts the dynamic signature behavior of the three steel plates, recorded with the MWIR camera of Fraunhofer IOSB. As described before, Sea Lab had been oriented first such, that the plates could heat up in the sun till they reached equilibrium. Then Sea Lab turned to expose the plates to the sensors. Receiving a lower

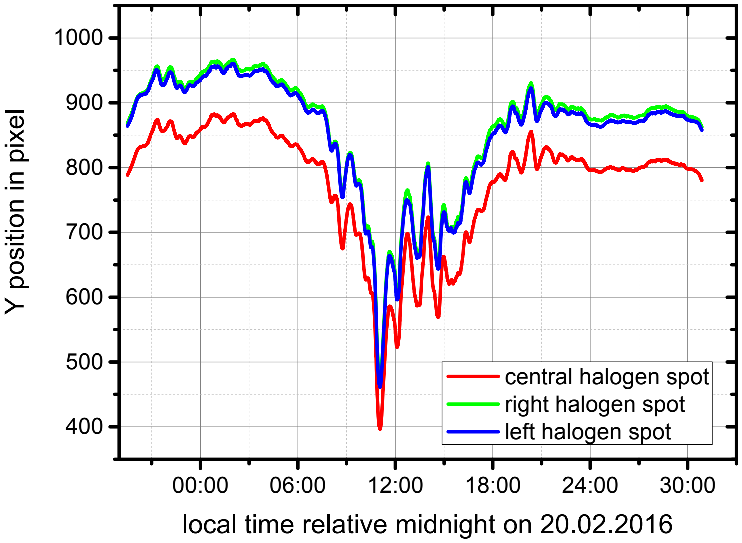

Figure 8: Apparent movement of the halogen spot positions in the recorded images. Part of the movement is caused by telescope movement.

Figure 9: Snapshots of a time series showing the variation in metal plate temperature

radiation flux in this position, the metal plates started to cool down. Although the radiant intensities have not yet been normalized, the snapshots clearly show the cooling of the metal plates, indicated by a darker grey level. The thinner plate (plate in the middle) has a smaller heat capacity and cools down more rapidly than the thicker plate. Time series like these provide time constants for the reaction of materials to changing environmental conditions, which can be induced by ship movements (turns, speed), but also by the environment itself (clouds moving in front of sun). Such information may e.g. be used as input in ship signature management systems.

4. SUMMARY AND CONCLUSIONS

The First European – South African Transmission ExpeRiment (FESTER) took place over the False Bay area at Simon's Town, South Africa, from April 2015 till March 2016. The primary objective of the field trial was the validation of Electro-Optical Tactical Decision Aids (EO-TDAs), with secondary objectives focusing on signature modeling and the characterization of the (inhomogeneous) propagation environment.

Continuous measurements of the environmental conditions, including turbulence, refraction and transmission effects, have been performed using permanent installations. This includes path-averaged turbulence along two different paths and in situ-measurements at Roman Rock lighthouse and IMT. A detailed statistical analysis of these data still has to be performed. Thanks to minimal equipment failure the dataset spans a complete year for most of the parameters and allows for the characterization of seasonal variations. Data on aerosol distribution was recorded in situ at IMT using particle counters, and over horizontal and vertical paths using a MSRT, a Lidar ceilometer and a sun photometer.

During four two-week Intensive Observation Periods (IOPs) focus was on experiments on environmental influences on sensor performance. The IOPs were spaced over the year to capture the seasonal variations over False Bay. FESTER yielded information on sensor performance in all electro-optical bands (VIS to LWIR) as well as in the X-band of the radiofrequency domain. This information was primarily gathered during outbound tracks of the research vessel Sea Lab 1 over the Bay, when sensors focused on bar targets, LED lights and black bodies. During these radials profiles of seawater and air temperatures have been recorded, which may allow for a test of standard micrometeorological approaches to characterize the propagation environment.

Experiments on dynamic signature behavior have been performed with Sea Lab 1 close to IMT (approx. 500 m). The effect of changing irradiance on the apparent radiant intensity and the temperature of metal plates has been recorded using electro-optical sensors operating in different spectral bands. Sea and sky backgrounds were recorded to allow for contrast calculations.

In conclusion, the FESTER effort has resulted in a rather unique and extensive dataset that allows evaluating the performance of EO Tactical Decision Aids and its underlying modules.

5. ACKNOWLEDGEMENTS

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