Differences between Marine Aerosol Backscatter and size-distribution in Upwind and Downwind conditions with respect of the Ship

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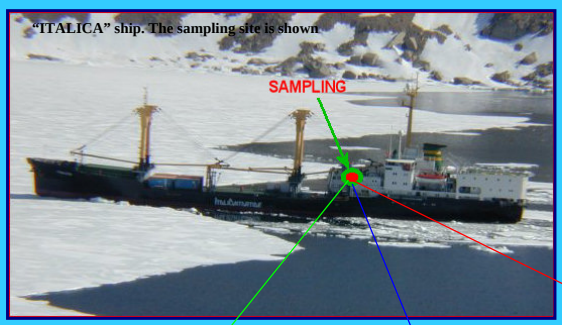
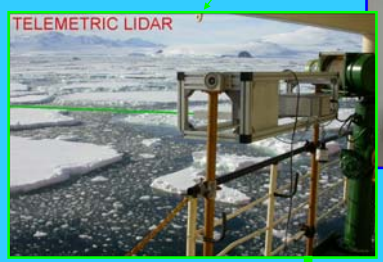
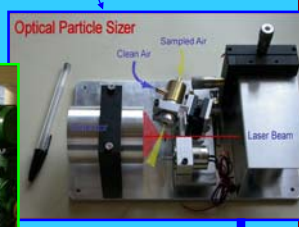


"ITALICA" ship. The sampling site is shown

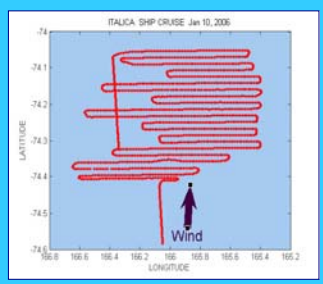
Within the framework of the Italian Antarctic Research Program (PNRA), an aerosol experiment was carried out on board the cargo ship ITALICA (Length 130 m, beam 17 m, Tonnage 6.000) in the Ross Sea (Antarctica) during the 2005-2006 winter. The experiment included three instruments developed at IFAC CNR: a backscatter PBL aerosol LIDAR, a telemetric-LIDAR, and an Optical Particle Sizer (OPS). A commercial DMA aerosol sizer (Grimm) was also used. A Gill sonic anemometer and ordinary meteo sensors completed the station. During the experiment, using an original remote-sensing instrument (telemetric-LIDAR), we continuously monitored the aerosol backscatter (5 m above sea level, 10-12 meters far from the ship left side. By means of in-situ sampling (DMA,OPS, also performed on the left side of the ship, 5 meters a.s.l.), we derived the size distribution of aerosols in the 15 nm - 10 µm range. The instruments operated in (almost…) all weather conditions. Results for January 10, 2006 are shown.



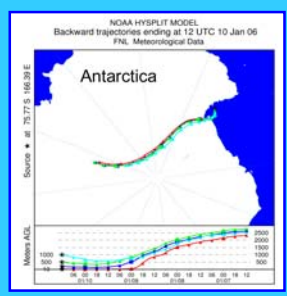
The IFAC Telemetric LIDAR on its anti-rolly mounting. The instrument measured aerosol backscatter (532 nm) at a distance of 10-12 m from the lab



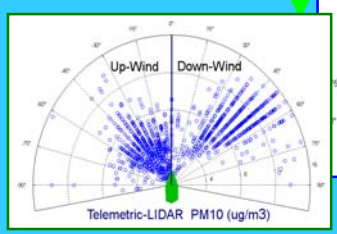
The core of the IFAC OPS

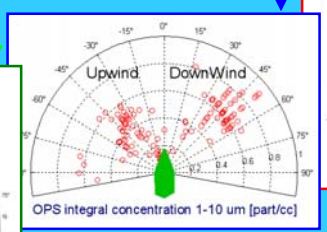


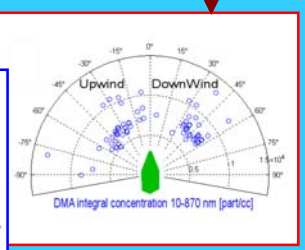
The zig-zag cruise of the ship on Jan 10, 2006. The aerosol sampling lab resulted alternatively Up-Wind and Down-Wind with respect the ship

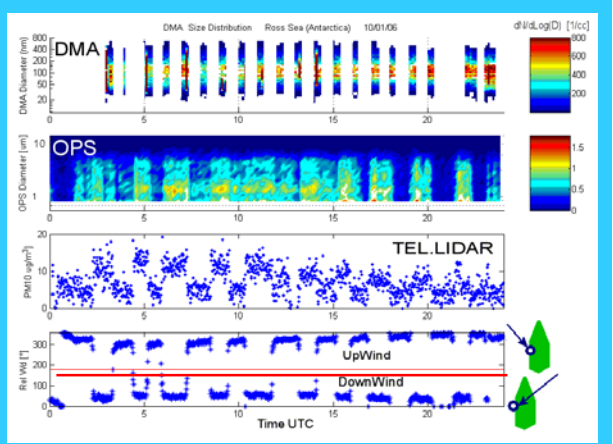


Backtrajectories: On Jan 10, 2006 the air was very clean because of its continental origin









24 hour-data from the three instruments are here compared with the direction of the wind relative to the ship axis. The red line discriminates between the cases in which the aerosol station is Down-wind and Up-wind. Wind directions close to 0° should be considered "Up-wind "

Taking advantage of a bathimetric scan of the sea bottom performed by the ship, we were able to establish the differences in aerosol backscatter and size distribution when the aerosol lab was, respectively, downwind or upwind of the ship. Due to the zig-zag course of the ship, the aerosol lab was alternatively upwind and downwind of the ship. 24 hours of LIDAR-derived PM10 is plotted vs the direction of the wind relative to the ship axis, as measured with a Gill 2-D sonic anemometer. The PM resulted larger in down-wind conditions.

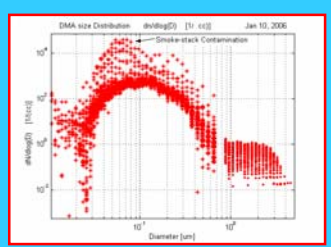
The speed of the ship was almost constant (~13 kt) during the scan, while the absolute wind speed was approximately 15 kt in the morning, and slowly decreased down to 5 kt in the evening.

The total aerosol concentration observed by the OPS (0.8-10 µm) is here plotted. A marked Downwind-Upwind pattern was evidenced in the coarse particle concentration: almost two times larger concentrations were observed in downwind conditions throughout the OPS size spectrum. This difference cannot be explained by a difference in sampling efficiencies of the OPS in different wind directions. The telemetric-LIDAR data, which was measured approx. 10 meters far from the ship wall, confirmed in fact this behaviour.

The LIDAR is very sensitive to large particles, and thus the LIDAR signal showed the same pattern as the OPS, with a similar, marked signal difference between upwind and downwind conditions.

The total aerosol concentration observed by the DMA (0.01-0.87 µm) is here plotted. The DMA size distribution was almost unaffected by the direction of the relative wind.

During the entire day, only a few events of direct contamination from the ship smokestack were observed: as the natural aerosol concentration of 50 nm particles in the Ross sea is typically low, any aerosol contamination from the ship Diesel engine due to turbulent transport can be easily detected as a sharp increase in DMA concentrations in this size range. Such an increase was considered a fingerprint of the contamination from the ship exausts.



The DMA+OPS Size Distributions overlapped for the entire day of study. The events of contamination from the Diesel engine are evidenced.

CONCLUSIONS: As a result, the ship acted as an efficient "source" of coarse-aerosols, thus spoiling the collection of natural marine aerosols when the laboratory was downwind of the ship. This effect extended for at least 10 meters away from the ship walls, as confirmed by the telemetric-LIDAR data.