Monitoring Sea Surface Salinity in the Global Ocean from Ships of Opportunity: the French SSS Observation Service

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Abstract. Sea Surface Salinity (SSS) observations are needed to improve our understanding of the earth's water cycle and climate variability, as reminded during the Oceanobs99 and Oceanobs09 meetings. This paper presents the French SSS Observation Service (http://www.legos.obs-mip.fr/observations/sss/), providing SSS data from merchant ships.

Background. Sea Surface Salinity (SSS) data have been collected by oceanographers for over a century. It is presently one of the fundamental variables for which global sustained observations are needed for CLIVAR (http://www.clivar.org) and GOOS (http://www.ioc-goos.org/), as it is required to improve the monitoring, understanding and predictive capabilities of the earth's water cycle and climate variability. The analysis of in situ SSS observations has already proven to be valuable for describing and understanding climate variability at seasonal to decadal time scales (from equatorial to polar latitudes), improving estimates of long-term trends in the context of climate change, testing physical processes, assessing numerical model performances, improving mixed layer representation via assimilation technics in operational oceanography, quantifying the relative role of salinity on sea level change, improving El Niño prediction lead time, calibrating paleo-salinity time series, and improving estimates of CO_2 flux at the ocean-atmosphere interface. The importance of SSS in the climate system has further motivated the development by European and USA/Argentina space agencies of dedicated satellite missions (SMOS and Aquarius) which will soon enhance global observations (see the Oceanobs09 Community White Paper by Lagerloef et al.).

Objectives of the SSS Observation Service. Recognizing the importance of SSS observations, whose routine monitoring was hampered by the previously poorly-coordinated efforts by different Institutes, the French SSS Observation Service (http://www.legos.obs-mip.fr/observations/sss/) was created in 2002, for the benefit of climate research and operational ocenanography. It is now a nationally certified 'Observatory for Research in Environment', and it represents an important contribution to the international Global Ocean Surface Underway Data program (GOSUD; http://www.gosud.org, see the Oceanobs09 extended abstract by Petit de la Villéon et al.). The main objectives of the French SSS Observation Service are to collect, validate, archive and make available in situ SSS measurements, as derived from thermosalinograph (TSG) instruments installed on Voluntary Observing Ships (VOS).

The monitoring system. The SSS measurements are mainly based on SeaBird SBE-21 TSG instruments located as close as possible to ship's engine water intake (Fig. 1). The TSG are connected to a laptop located on the bridge and to a GPS receiver.

Figure 1. A TSG installed on board a merchant ship.

On average, our contributing ships provide one to three SSS sections per season along a regular track (Fig. 2). Most of the SSS measurements are collected every 15 s, and a 5 min median filter is applied to reduce small scale signal and/or noise. The 5 min resolution data are recorded on a laptop, and collected later during ship calls; a 5 min median value is additionally transmitted every hour via email by Inmarsat C (or Irridium) to the LEGOS laboratory in Toulouse, France.

The one-hour resolution *real time data* are used to detect any instrument failure from the laboratory (Fig.3). Automated controls are applied when decoding emails received at LEGOS: received data are checked for realistic ship name, date, location, ship speed, and climatic limits with regards to climatology (i.e., the World Ocean Atlas 2005). In case of dubious measurements, alert messages are automatically sent to designate operators in laboratories, so that they can ask for the help of ship officers to correct potential errors. After external validation procedures, *real time* salinity data are assimilated in operational models.

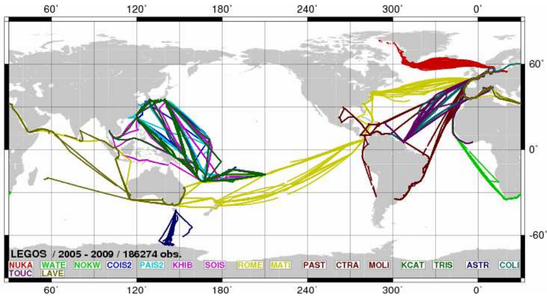

Figure 2. Spatial distribution of real time SSS collected from January 2005 to July 2009, with one color code by voluntary observing ship

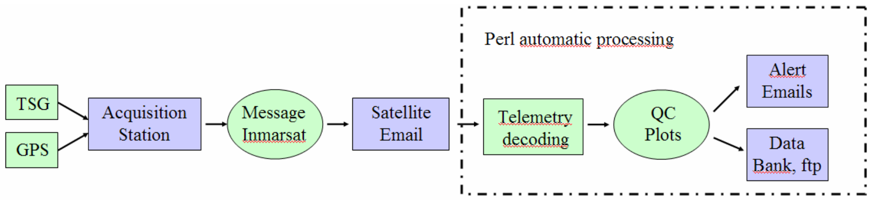

Figure 3. Schematic of the real time SSS data acquisition, transmission, and processing

The 5-min resolution *delayed mode* data are processed in laboratories via procedures that check for internal consistency, realistic geographic positions, and deviations from the climatological mean. Simultaneous water samples (one/day, on average), collocated ARGO floats and/or CTD measurements, pre/post calibration of the TSG sensors, and remarks from scientific users are further considered to flag the data (with ARGO-type flags). This is performed with the help of dedicated Matlab software.

Data distribution, scientific products, and climatic indices. The *real time* SSS data received and roughly checked at LEGOS are collected daily via ftp by CORIOLIS which is the Global Data Acquisition Center for GOSUD. The *delayed mode* data are made available from our web site. So far, we provide validated SSS data for the three tropical oceans (30°N-30°S; 1950-2003) and the Northern Atlantic Ocean (up to 50°N; 1970-2002). The 2003-2009 data and the Southern Ocean data are being processed and will soon be available on line. Research products derived by scientists addressing specific scientific questions in referred publications are also made available on our web site. These products include along-track mean monthly year and climatology, as well as 2D and 3D gridded files. Climatic indices are also derived, as in Figure 4 (see also the Oceanobs09 extended abstract by Cravatte et al.).

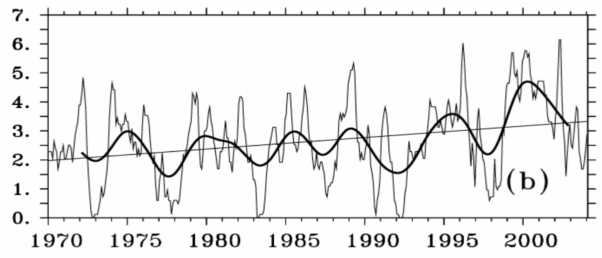

Figure 3. Monthly time series of the surface covered by SSS lower than 35.0 in the SPCZ (24°S-10°S, 140°E-140°W). Units are 10^6 km2. Note the El Niño signature, e.g., in 1976-77, 1982-83 and 1997-98. The straight line represents a linear fit, showing an increase of low-salinity water surface in the area, in relation to global change. Adapted from Delcroix et al. (JGR, 2007).

Being a key variable for climate changes, the existence of sustained and permanent SSS observational systems, including the key VOS-derived measurements, providing long time series is thus vital to infer the impacts of climate change on the salinity field, and the possible feedbacks of salinity changes on the climate system. This has been fully recognized and endorsed in the Oceanobs09 statements.