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Network-enabled rapid environmental assessment: Architectures for near-real-time data collection and fusion

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ABSTRACT

Advanced communication and information processing techniques can be applied to underwater research to enable new ways of enhancing real-time experimental outcome. This paper presents solutions developed to support the Dynamics of the Adriatic in Real Time (DART) sea trials, conducted between NURC and 26 international partners in 2006, which were characterized by large shore–ship–shore data exchange requirements, in excess of 1 GB/day. The three-pillar approach adopted (based on network infrastructure, information infrastructure, context-based data management) involves the seamless combination of different commercial-off-the shelf components (369 kb/s 2-way satellite link, 1 Mb/s unidirectional satellite link, molecular sequence reduction compression and caching) and required the development of quality of service tools and policies, to translate scientific needs from natural language to configuration files. Results showed the possibility of transferring, over a 27-day period, more than 40 GB of data, meeting experimental requirements with minimal expense: the variable cost associated to the transmission of 1 MB of data was in the order of 10 Eurocents using a two-way Very Small Aperture Terminal (VSAT) system and of 40 Eurocents using Digital Video Broadcasting Satellite (DVB-S) unidirectional service. Although the solution presented refers to a specific Rapid Environmental Assessment (REA) trial, its application is not constrained to REA only. The flexible combination of technological components and well-proven data management methodologies allows its application to a broader range of scientific problems associated with near-real-time exchange of large datasets.

1. Introduction

In this paper we will use the DART06 sea trials, conducted in the Adriatic Sea between NURC and 26 international partners, as a test case to present NURC networking and information infrastructures and the benefits they introduce in terms of increased collaboration and interoperability with external research partners. Such trials were performed in 2006 as part of a multi-institutional program addressing observational and modelling methodologies on small-scale instabilities in a marginal sea, producing as a secondary product a comprehensive data-model set of ocean and atmosphere properties.

From a scientific perspective, the Adriatic Sea provides an interesting natural laboratory because of its wide range of environmentally-driven processes (e.g. as the result of bathymetric and coastline structures, wind forcing, water masses and currents, river outflows and plumes) and the conspicuous accumulation of knowledge available on this area.

The methodology chosen for the sea trials was to evaluate and combine different observational and modelling capabilities in a network-enabled concept of operations, comparing in near-real-time operational data produced by partners connected via the Internet (meteorological, wave and ocean models, at variable resolution) with local data observations (buoys, drifters, moorings, ship and satellite-based). This required the exploitation of existing NURC data communication architectures, as well as the implementation of ad-hoc configurations and data exchange methodologies capable of meeting demanding scientific requirements within the given technological constraints.

The following Table 1 provides a selected overview of experiment participants and their respective contribution.

1.1. Observational and modelling requirements

Requirements for near-real-time communications have been derived from the quantity and quality of observational and modelling tasks planned during experimental activities.

As an initial step, all activities that required network communications were categorized in seven broad categories, each with its own peculiarities in terms of data volume and time sensitivity.

In more general terms, three major “information domains” were identified, corresponding to logical areas where information was produced and processed, and from which information was exchanged

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Table 1
Overview of some trial participants and contributions.

In-situ observational tasks	Bottom-mounted ADCP	NURC, NRL-SSC, Univ. CO (USA), IOF, HHI, AMGI, and CMHS (HRV),
	SEPTR	OGS, CNR-ISMAR, ARPA, ICRAM, Air Force Met Service, Marche Poly.
	Meteo stations	Univ., and Univ. Bari (ITA)
	Wave riders	
	CTDs	
	Optical surveys	
	Drifters	
Remote sensing observational tasks	SeaWIFS real-time ocean colour	NURC
	AVHRR radiometry	
	RADARSAT Synthetic Aperture Radar	
	MODIS	NURC and NRL-SSC (USA)
Atmospheric modelling	Real-time COAMPS model	NURC
	2 real-time ALADIN models	EPSHOM (FRA) and CMHS (HRV)
	Real-time LAMI model	ARPA (ITA)
Ocean modelling	Real-time and hindcast NCOM	NRL-SSC (USA)
	HOPS	Harvard Univ. (USA), Marche Poly. Univ., and INGV (ITA)
	Real-time and hindcast ROMS	CNR-ISMAR and ARPA (ITA)
	Real-time POM and OPA	INGV (ITA)
	GOTM 1D vertical model	CNR-ISMAR (ITA) and Univ. CO (USA)
	Multi-model super ensemble	NURC and Univ. of Liège (BEL)
Wave modelling	2 real-time SWAN models	NRL-SSC (USA) and ARPA (ITA)
	2 real-time WAM models	CNR-ISMAR (ITA) and Univ. of Athens (GRC)
Surface drift modelling	Finite-size Lyapunov exponents and synthetic drifters from NCOM simulations	RSMAS, City Univ. of New York, NRL-SSC (USA), CNR-ISMAR (ITA), and Univ. Toulon (FRA)
Tidal modelling	NCOM	NRL-SSC (USA)

with other logical regions using bandwidth-limited communication channels.

One domain was associated to NATO's Research Vessel NRV Alliance, providing the seagoing laboratory for the execution of the DART06 trials, connected to NURC with a Very Small Aperture Terminal (VSAT) satellite connection. Conversely, another domain was associated to NURC, which acted as a central gateway for the execution of the experiment, ensuring seamless communication with NRV Alliance, with Centre scientists involved in supporting the trials and with partners participating from remote locations. The third domain referred to experiment contributors connected over the Internet.

The following Fig. 1 shows the various information domains, and the corresponding data flows. It should be noted that most traffic patterns were forced through the GEOS Data Fusion Servers installed at NURC and onboard NRV Alliance (Fig. 2). This choice proved to be essential in providing the Quality of Service (QoS) required by scientific objectives.

Communication capabilities normally available on maritime platforms cannot meet such a demanding requirement. Table 2 provides an optimistic estimation of the data volumes that can be supported by commonly available systems. The estimation is optimistic in the sense that it is based on the assumption of 100% efficiency and uptime, where the actual figure is normally lower because of protocol overheads and inefficiencies, rain attenuation, tracking problems with high sea states, interference and antenna shadowing from shipboard infrastructures. In addition, the affordability and cost-effectiveness of the various solutions may be questioned because all services listed in Table 2 are charged by time or by volume.

2. Information domains and network infrastructure

NURC has been experimenting with near-real-time communications during sea trials since 1993, first using cellular phones and then

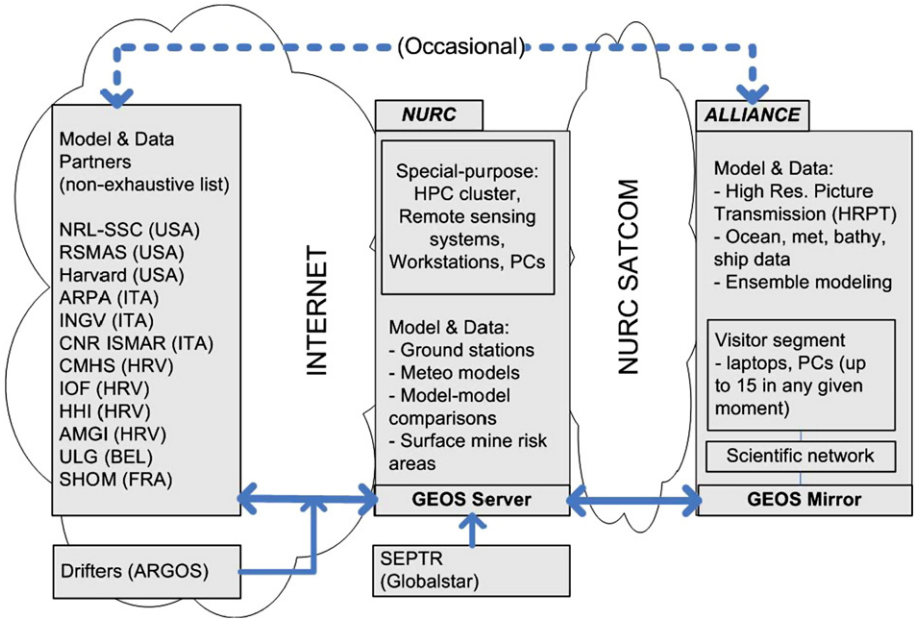

Fig. 1. Summary of DART information domains and traffic patterns.