Marine Climate Change Impacts Partnership

Topic
Shipping

Author(s)
Dr Paul G Wright

Organisation(s) represented
Associate Director University of Plymouth Marine Institute, Drake Circus, Plymouth, PL4 8AA

Executive Summary

Shipping and the ports industry are involved in the most international of industries. Over 90% of world trade, by mass, is carried by shipping.

Understanding of climate change impacts on shipping is very limited with little in the traditional scientific literature. Here we present evidence drawn from a wider body of information (including non-scientific literature, speeches technical documents and news articles) to discuss the wide range of issues facing this sector.

At a national level the UK Department for Transport states that *"no specific research has been done into the impact of climate change on shipping. However discussions with the Maritime and Coastguard Agency suggest that increased storminess and sea levels / reduction in polar ice are probably the most important factors."* The major impacts of climate change on ports are likely to be floods, infrastructural damage, and operational disruption. Ports will need to consider climate change in light of new infrastructure which may have a life span into the next century.

Shipping is an international service industry which responds to the derived demand. Its major assets operate in the global economy and are subject to economic cycles. As such one of the main impacts of climate change upon shipping is the need for shipping to contribute to the mitigation of climate change, along with the ongoing impacts of climate change on the global economy. The role of the regulator, the responsible ship owner and the market interact to make progress, where technological advances and uptake will be key.

Full review

What role has shipping in the world ?

Shipping and the ports industry are involved in the most international of industries. Over 90% of world trade, by mass, is carried by shipping. During the last twenty years, demand for shipping capacity has risen by 135% from 13,000 Billion tonne – miles in 1986 to 30,600 Billion tonne – miles in 2006[1]. World fleet growth is set to continue. In August 2007 seven thousand ships were on order worldwide[2]. It is estimated that the new buildings will lead to an increase in the global fleet of 20%. A ship built today will have a physical life of between 25 and 35 years. Many will still be operating in 2040. Worldwide there are in excess of 50,000 cargo carrying ships greater than 100 gross tons engaged in international trading. In addition a further 45,000 ships are involved in a range of miscellaneous activities including offshore work, research and dredging[3]. Growth in world trade associated with an increasing world population will put pressure on the development of both the fleet size and port's infrastructure over the short to long term. Increase in ship numbers and size will enable growth to be absorbed, but will impact heavily on port provision.

How will climate change impact on the movement of shipping and development of ports?

At a national level The United Kingdom's Department for Transport states that *"no specific research has been done into the impact of climate change on shipping. However discussions with the Maritime and Coastguard Agency suggest that* ***increased storminess*** *and* ***sea levels / reduction in polar ice*** *are probably the most important factors.[4]"* The same report notes that Associated British Ports, a provider of port facilities and services to shippers and cargo owners has commissioned research into the risks of climate change. The major impacts of climate change on ports are likely to be floods, infrastructural damage, and operational disruption. Ports will need to consider climate change in light of new infrastructure which may have a life span into the next century.

Shipping of water and food.
It is anticipated that in the long term and beyond, the present sources of water and food which provides for human life will be disrupted.[5] Climate change will lead to regional water shortages and to reductions in agricultural yields. Distribution of water by large ocean going water tankers, the towing of ice from glaciers (or granulation of polar ice for transportation) may provide opportunities for shipping.[6] Regional changes in agricultural yields and demand for agricultural products, which already provide shipping with opportunity for trade, will create new opportunities in the medium to long term.

New Shipping Routes.
Observations over the past 50 years have indicated a marked decline in the extent of Arctic sea ice. The Northern Route across Russia's North coast and the North West Passage will provide reduced sea distances between

America, Europe and Northern Asia. By 2080 it has been predicted that the navigation season for the Northern Sea Route (NSR) from Eurasia to the Bering Sea will increase from the current 20-30 days per year to 90-100 days by 2080[7a]. Ice locked states will gain access for the exploration and distribution of primary materials which are known to exist in the Artic including natural gas and oil.[7b] Risk of degradation to a pristine environment due to the possibility of oil spills from ships is a concern, particularly as clean up will take longer, due to less wave action and breakdown is slower in colder temperatures. In addition ballasting/de-ballasting required for safe ship operations will have to be undertaken in full recognition of the potential transfer of alien and invasive biological species.

Present shipping routes.
The *Panama Canal* depends for its operation on regular, high rainfall. Reduction of rainfall due to climate change will lead to less than optimal use of the canal and limit the draft of ships using the lock system. There will be inevitable consequences for quantities of cargo which move through the system. Likewise climate change could impact on the *Great Lakes and St Lawrence Seaway*, where water depths are reducing affecting the operation of the entire system. Slow filling of locks and reduced draft available for shipping will reduce its value to the international community.[8]

Extreme weather
Any changes to extreme weather conditions in the form of **tropical revolving storms** (including hurricanes and typhoons) and **storm surges** will have to be faced by shipping. **Freak waves,** which it is claimed may have lead to the loss of 200 containerships and tankers over the last two decades, are expected to become more common. These are events which shipping already faces. Improvements and reliability of **weather forecasting** methods, developments in **ship design** and a review of the **construction rules** of ships can accommodate potential problems.

Ports
Ports provide the necessary intermodal link in the shipping process. Port terminals are vulnerable to **sea level rise**, flooding and extreme weather conditions. Flooding may cause serious operational disruption within the port and port hinterland. Defences against sea level change and flooding are possible and may be incorporated into terminal design. The use of barriers and gates is common but will cause some restriction in the layout and terminal efficiency. In the United Kingdom east coast ports are most vulnerable to flooding. **Extreme weather** conditions are experienced by ports and are difficult to defend against. Major disruption to both land and sea port users can be caused. **Storm surges** created by a combination of low pressure, high tides and strong winds can create exceptional conditions. Around the eastern coast of the UK sea level can be raised by 2 metres. It is anticipated that climate change will increase the frequency and height of storm surges.[9] Strong winds are a further example of extreme weather which will impact on ports and port operation and are expected to be more intense in some parts of the world. The potential type of damage to port infrastructure is illustrated by Typhoon *Maemi* which in 2003 developed over the Pacific Ocean and

produced winds of 135 miles per hour which toppled eleven gantry cranes in the southern port city of Busan, Korea.[10]

New opportunities for shipping due to climate change
The pressures caused by the threat of climate change will provide new opportunities for shipping. Access to previously **untapped oil and gas fields of the Arctic** will call for innovative ship design to work in harsh weather and ice conditions. The development of **renewable energy** using offshore wind, current or wave energy will require specialist construction and service ships. Technology will be refined to produce **greater engine and hull efficiency** with the consequent reduction of maritime created Green House Gases (GHG) per tonne of cargo moved. It is possible that the cruise ship industry will exploit hitherto inaccessible cruising areas. Cargo carrying ships will continue to meet demand, but **trade patterns** and the quantities moved will change as the climatic pattern changes and using climate friendly fuels there is reduced need for fossil fuels. With climate change creating a different pattern of supply and demand of fresh water, international distribution will become of increasing importance. New shipping trades may be developed using water tankers to satisfy the world's demand for fresh water.

Impacts of climate change mitigation on shipping

One of the impacts of climate change on shipping is the need for shipping to mitigate its own contribution to the issues associated with climate change. The role of the regulator, the responsible ship owner and the market interact to make progress.

Governance of International Shipping
The need for international governance of world shipping was recognised by the United Nations, who in 1948 set up the International Maritime Consultative Committee now the International Maritime Organisation (IMO). The responsibilities of the IMO are stated in its strap line "Safe, Secure and Efficient Shipping on Clean Oceans". The effectiveness of IMO as a regulator is dependent on its member governments and their ability to implement and enforce through flag and port state control, agreed actions.[11] The IMO is concerned with setting a regulatory regime which reduces the environmental impact of shipping through the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). However international conventions take time to ratify, implement and when necessary amend. Uniform international enforcement is also difficult to achieve. The UK Government is a government member of the IMO.

Fuel Used by Shipping
Ships first used diesel engines in 1912. Whilst the diesel engine can be run on many fuel types, the slow speed diesel engines used by the majority of today's ships run on cheap low grade heavy fuel. Heavy fuels are the residue (dregs) of the crude oil distillation process, their use being encouraged by a relatively low cost per tonne and wide availability.[12] The largest marine diesel engine in service today produces 108,000 brake horse power (bhp) at 102

revoutions per minute (rpm). It uses 300 tonnes of Heavy Fuel Oil (HFO) each day at cruising speed.[13] The cost of heavy fuel varies depending on demand and availability. In July 2007 the cost of Heavy Fuel Oil was $377 per tonne at Rotterdam.[14] Fuel costs are a significant feature in ship operation. Economics and practical issues confirm that HFO and Diesel Oil will continue to be used by shipping into the long term future. Effective altermative fuels are being sought, but continuing growth makes it unlikely that fossil fuels will be displaced. In a recent speech to the UK Chamber of Shipping, the Secretary of State for Shipping emphasised the direction that shipping should take:- *"it is important that shipping becomes more fuel efficient, takes full advantage of greener technologies and better manages the adverse consequences of fuel use to help fight climate change."*[15].

Green House Gas Emissions

Atmospheric pollution by shipping has been considered since the development of MARPOL 73. Agreement to look at the impact of gas emissions on climate change commenced in 1990 when a series of papers were presented to the IMO. They concerned the six main GHGs (namely CO2, SOx, NOx, Methane, Hydrofluorcarbon and Perfluorocarbons). Initial focus was on the Hydrofluorocarbons and then Sulphur Oxides (SOx) and Nitrogen Oxides (NOx). In December 2003 the IMO adopted an Assembly resolution on **IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships.**[16] The IMO has looked at developing an Indexing Scheme for ships, through which shipowner's can evaluate the performance of their fleet with regard to GHG emissions and provide information regarding fuel efficiency. The Marine Environmental Protection Committee (MEPC) of IMO is presently involved in a workplan and timetable to reduce GHG. Agreement has been made through the MEPC, that unilateral action by global, regional or national bodies on the development of GHG strategies for shipping should be avoided and that the IMO, in cooperation with other UN bodies should take the lead**.**[13] A maximum sulphur content of any marine fuel is required by MARPOL Annex 6 and control areas initially encompassing the entire Baltic Sea and extended to the North Sea in 2007 have been established. The North Sea **SOx Emission Control Area** (SECA) requires ships within that area to burn fuel with a sulphur content no greater than 1.5% m/m. There are concerns regarding the provision of adequate stocks of compliant fuel and the monitoring of compliance by coastal states. Stricter rules concerning the amount of sulphur in marine fuels are being considered for future implementation.

Fuel Efficiency

When compared to other modes of transport, shipping is very efficient. The energy required by sea to move one tonne of cargo one kilometre using a 1200 TEU containership has been calculated to be 0.12 Megajoules. The energy required to move the same weight a similar distance by road vehicle vaies between 0.7 and 1.2 Megajoules.[18] Increasing demand for cargo and passenger transport by sea will cause an overall increase in the amount of fuel burned. The total GHG created by shipping is not well understood though arguably small. Stern reports that total international CO2 emissions from shipping account for less than 1.5% of all GHG emissions.[19] Other studies suggest that shipping emitted around 800 Tg (Terragrams) of CO_2 and contributed around 2.7% to all anthropogenic CO_2 emissions in 2000. [20] The overall growth of GHG produced by shipping is expected to rise due to an expanding shipping sector. The short and medium term challenge is for shipping to minimise overall GHG emissions whilst meeting the increasing demand for economical transport. In the short term this can be done by creating more efficient engines, developing performance enhancement devices, using new technology eg the use of flue gas scrubbers and connecting ships to shore power whilst alonside (“cold ironing”). In the longer term the development of economical ships primary power systems which are self sustaining and do not require the use of fossil fuels must be the ultimate aim.

Primary Power Plant

It is accepted that in the medium to long term the diesel engine will remain the primary power system for shipping. Whilst diesel manufacturers undertake continuous research in engine development, further encouragement is provided from quasi governmental sources. In 2007 a European Project known as HERCULES was launched to further encourage the development of marine diesel engines and improve their efficiency.[21]

Improved Operation

It may be in the shipowner’s own interest to improve the environmental efficiency of their shipping fleet, often ahead of regulation. An example of good practice is provided by the Ever Green Corporation’s, Greenship project. Among environmental features incoporated in the 2006/07 build of the Evergreen “S-Type” - 7,000 TEU containerships, are a low sulphur fuel system, an Alternative Maritime Power (AMP) plant (allowing connection to shore power supplies during loading / unloading operations) and a hull design which improves fuel consumption. Dr Chang, Vice Group Chairman of Ever Green, believes “that all shipowners have a duty to minimise the impact of their operations on the global environment” [22] The cost of providing environmental features can be significant. It is estimated that the features incorporated into the design of the “S-Type” ships cost $5 million per ship, plus an ongoing costs of $400,000 per year. Based on a 20 year economic life of a contanership, the total additional cost set against each vessel is $13 Million.[23] In the short term such features could be incorporated into all new ship builds.

Alternatives to Fossil Fuels

If non fossil fuel were used, the emission of GHGs could be eliminated. There are several potetial alternative fuel and power sources for shipping including nuclear power, hydrogen cells, solar cells, biofuels and wind energy. Alternative fuels can be used as a primary, secondary or hybrid energy source. It is unlikely that in the short, medium term and even longer the alternatives will replace fossil fuels.

Hans Blix in a paper to the World Nuclear Association 2001[24] comments on the use of **nuclear power** “*some people shudder at the mere mention of the words uranium, nulclear or atomic as if they were supernatural forces -*

ionising radioation is as natural as the sun - it is rational to work for acceptance regulation and prudent use of nuclear power" In conversion terms, 1 kg of oil corresponds to 3kWh to 4kWh of electricity whereas 1 kg of plutonium corresponds to 6 Million kWh of electricity*. "To me the suggestion that wind power, solar power and commercial biomass are rational answers to thr world's needs for sustainable energy is about as implausible as suggestions that it would be rational to to handle transport on the high seas by sailing ships rather than diesel powered ships.*" Whilst experimental nuclear powered merchant ships were built in the 1960s, the present use of nuclear power sources at sea are confined to ice breakers, aircraft carriers and submarines. Mark Brownrigg, Director General of the UK Chamber of Shipping replying to a UK Select Committee Inquiry stated[25] *"nuclear ships have never worked in terms of cargo carrying .... and there are other issues (eg restricted port calls)"* Nuclear power, however, is a proven technology, used as the primary power system in present ship types, including ice breakers and submarines. It is GHG free and has certain potential for the medium and long term. Although the use of **hydrogen cells** is a possibility the present situation is that shipping is a long way from using the technology as a main power source.[26] Experiments on their for auxiliary energy sources at sea are being initiated. The use of hydrogen cells for primary marine power is a medium to long term objective. Using **solar cells** as a main power supply for shipping has potential. The craft in which it has presently been used arelimited, but the baisc technology has been proven. A 120 passenger ferry has been working in the Port of Hamburg since 2000 using solar panels alone can cruise at 5 kilometers per hour. It is more likely that solar cells will be used in hybrid power systems.[27] The use of **biofuels** is another alternative. Bioethanol is available in various countries for use in cars. Bioethanol is produced from vegetable sources. The UK Government is encouraging its use and in the short term (ie by 2010) is expecting 5% of all petroleum and diesel to contain biofuels). There is no similar requirement for shipping and as fuel quantities required by shipping are large it is unlikely that it will become a common fuel for cargo carrying ships.[28] Until the middle of the nineteenth century ships were powered by a free and environmentally sustainable source – the **wind**.[29] This source of power is still available in abundance and modern wind assisted ships can take advantage of new technologies and materials. There has been an increase in the understanding of ocean weather and climatic patterns which encourages experimentation in the use of wind as a primary power source. A "new age of sail" reducing or completely eliminating GHGs is possible. However the wind is fickle and with sophiticated worldwide supply chains demanding strict vessel timetables it is highly doubtful that it will be used as a primary power source. It is more likely that wind power will be used as a secondary source of power. In the early 1980s when there were dramatic increases in Fuel Oil prices a great deal of activity to develop wind assisted ships took place. Among successful designs was the Walker Wingsail which reached a prototype stage when fitted to the 6500 dwt MV Ashington. It showed that 15% - 20% fuel saving could be achieved. The Sea Kite**,** is a more recent idea, designed to harness the winds above sea level. An inflatable aerofoil, in kite form, is attached to the forepart of the ship and flies at a height of between 100 - 500 metres. The kite is designed to maximise thrust whatever the wind conditions and is said to have the propulsive power equivalent to a large ship's engine. The system is under experimentation but claims that savings in fuel oil usage of between 20% and 40% have been made. It is expected to be available for commercial sales within the short term. [30] In 2006 the Norwegian shipping company Wallenius Wilhelmson produced a revolutionary concept ship known as the **Hybrid E/S (Environmentally Sound) Ship.** The concept ship, based on a 10,000 pure car carrier brought together known technologies including a revolutionary hull design (the pentamaran) hydraulic sails, fuel cell technology and photovoltaic cells, to provide a ship which is possible within the medium time frame. The choice of technologies ensures there are no GHG emissions.

Innovative Hull Design

Along with fuel considerations, greater efficiency leading to reduction in GHG can be achieved through improving the efficiency of hull design. New novel hull forms which provide efficiency in fuel consumption include the **Pentamaran**[31] and the **Ulstein Verft** new X Bow (the upside down bow) . Both provide lower fuel consumption and an easier ride at sea.[32] Among other novel developments leading to reduced fuel consumption is the **Slippery Ship** by which a layer of bubbles is produced along the body of the ship. The bubbles reduce the frictional drag of the ship, improving the efficiency of the hull by a factor of 20%.[33]

Shipping supports data monitoring to inform of climate change

Finally shipping has a role in supporting the role of the scientist in evaluating and gaining knowledge about climate change. Presently some 7,000 ships are involved in carrying out systematic observations of the weather data through the World Meteorological Office Voluntary Ships Scheme.[34] For more than 75 years merchant ships have used continuous plankton recorders to sample the North Sea and AtlanticOcean. More than 170,000 samples have been collected which when analysed can provode evidence of climate change. [35] The Ferry Box System uses commercial ferries to carry sophisticated monitoring devices. The devices provide scientists with information they require to support the effective management of coastal and shelf seas.[36]

<u>Confidence in the future development of the shipping sector with respect to climate change.</u>

Role of Shipping

Ships are vehicles whose design and structure using technology based on sound scientific principle have produced international transport solutions for commerce.

Shipping and port capacity has developed to meet the demands of a growing population.

There is some present mismatch and imbalance in certain trade patterns that have lead to certain inefficiencies in the ship and port industries. Inefficiencies suggest that greater resources are used than are necessary to undertake the task. Awareness of the issue and its potential impact on the environment and climate are recognised by many key players. Confidence in resolving mismatch is low.

Future projections show an increasing level of demand. Whilst it is relatively easy to meet the demand for increased ship capacity that of port and port infrastructure is less. Confidence that future ports and their respective hinterland will meet the demand suggested by the projected growth is moderate.

Impact of climate change on the movement of shipping and development of ports

There is moderate confidence that as climate change causes modification of climatic regions there will be a slow and largely subtle adjustment in general shipping routes. In the long term there is moderate confidence that the Arctic routes, which provide significant reduction in distance between major trading blocs, will be used not only for access to the development of the Arctic oil and gas fields, but also as commercial highways.

There is expectation that extreme weather will be increase causing challenges to ship design. There is moderate confidence that in the medium and long term new ship design will incorporate features which will reduce risk.

Impacts of climate change on shipping.

There is every confidence in the governance of ships through the International Maritime Organisation. However there is moderate confidence that pressure exerted by strong and influential blocs of maritime states will have increasing weight in determining issues and solutions to problems of environmental concern.

Reducing the amount and improving the efficiency of fuel used is a recognised commercial concern of ship management. There is high confidence that in the short and medium term continuing efforts will be made to ensure gains in both areas.

The precedent in developing areas where cleaner fuels are used has been established by SOx Emission Control Areas (SECA). Whilst presently limited to Europe it is considered that the idea could be developed internationally. However confidence in the long term development of SECAs outside Europe and America is low,

Confidence in a dramatic development in primary power plant technology in the medium term is low. However incremental improvements in power plant efficiency are anticipated.

There is moderate confidence that alternatives to fossil fuels will be used to supplement primary power plant within the medium term. The role of nuclear plant to power commercial ships are considered a long term possibility but with low confidence. Hybrid power systems incorporating fuel cell technology are considered feasible in the long term.

Confidence assessments

'What is already happening' – Low

'What could happen in the future' - Low

Research on the impacts of climate change on shipping is extremely limited, the evidence presented here is drawn from many sources rather than the strictly peer-reviewed literature. As such this article has not itself been peer-reviewed and MCCIP have given the confidence as ***low*** *for both present and future in the ARC to take account of this.*

Knowledge gaps

- There are many knowledge gaps. The impact of climate change on shipping is wide and tends to be speculative. The area is one which requires further study and research.

Commercial impacts

This topic is entirely concerned with commercial aspects of climate change in the marine environment.

References

1. **IMO's Response to Current Environmental Challenges** *in* IMO News No 2 2007 pp 14-27
2. **Vessel Types on Order** *in* Fairplay Solutions Issue 131 August 2007 p53.
3. **World Fleet Statistics 2006**, p10 *in* Lloyd's Register – Fairplay ISBN 978-190129093-6 2007
4. **The Changing Climate: its impact on the Department for Transport** http://www.dft.gov.uk
5. **Climate Change Around the World** http://news.bbc.co.uk/1/hi/in_depth/629/6528979.stm
6. **Water bosses plan to tow icebergs up Thames,** *by* Smith L, *in* Times online, 17th May 2006.

7a. **Arctic Climate Impact Assessment**. Cambridge University Press, 1042pp.

7b. **The North West Passage – without ice.** http://news.bbc.co.uk/americas/918448.stm

8. **Brace Yourself for Climate Change**, *by* M Reynolds, *in* McGill Reporter 24th October 2002, vol35 No 4
9. **Climate Change Scenarios for the United Kingdom: The UKCIP02**

Scientific Report. Hulme M, JenkinsGJ, Lu X, Turnpenny JR, MitchellTD, Jones RG, Lowe J, Murphy JM, Hassell D, Boorman P, McDonald R and Hill S (2002) Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp

10. **Typhoon pounds South Korea**, news.bbc.co.uk/1/hi/world/asia-pacific/3105440 ,13th September 2003.
11. **IMO's Response to Current Environmental Challenges**, *in* IMO News No 2 2007 p27
12. **Diesel Engines** *Wikipedia, The Free Encyclopedia,* en.wikipedia.org/wiki/Diesel_engine#Modern_diesel_engines
13. **Marine Propulsion Engines – Failure in Corporate Innovation**, by Hudson RJF, www.imarest.org
14. **Bunker Prices** Fairplay – the International Shipping Weekly Issue 6441 p60 2nd August 2007
15. Alexander D. *Speech to* UK Chamber of Shipping Annual Dinner January 2007
16. **Prevention of Air Pollution from Ships: IMO Begins Work**. www.imo.org/Environment/mainframe.asp?topic-id=233
17. **IMOs Work on reduction of GHGs from ships.** www.imo.org/Newsroom/mainframe.asp?topic_id=1605
18. **Fuel Efficiency**, International Chamber of Shipping www.marisec.org/shippingfacts/environmental/efficiency.php
19. **The Stern Report -The Economics of Climate Change** HM Treasury www.hm-treasury.gov.uk
20. **Comparing Fuel Consumption, CO_2 and Other Emissions from International Shipping and Aircraft,** Eyring V & Corbett JJ, www.pa.op.dlr.de/SeaKLIM/Fuel_Emissions_International_Shipping.html
21. **Shaping the Future of Shipping** EU Hercules Project ec.europa.eu/research/star/index_en.cfm?p=52_main
22. **Creating a Better Life for the Future,** Chang Kuo-Cheng, *Speech to* Transpacific Maritime Conference 6th March 2006
23. **Your Partner in a Brighter Tomorrow.** Evergreen - www.evergreen-line.com/tbnl/images//2006EMCe01.jpg
24. **Nuclear Energy in the 21st Century**, Blix H, World Nuclear Association Annual Symposium 2001
25. **Treasury Committee on Climate Change** February 2007 Answer to Q 413
26. **Treasury Committee on Climate Change** February 2007 Answer to Q 411
27. **"Alster Sun" - World Wide Number One** www.solarserver.de/solarmagazin/anlageaugust2000-e.html
28. **An old fuel for the future: bio-ethanol offers a way forward,** *by* Brignall M *in* The Guardian, 31st March 2007
29. **The New Age of Sail,** *by* Hamer M, *in* New Scientist.com.news service

26th February 2005

30. **Close to the Wing-Sail**, *by* Walker J, *in* New Scientist, 26th March 2005
31. **Kite and Sail Power for Huge Ships** New Scientist, 2488, p44, 26th February 2005.
32. **Back to the Future,** Tisdall J, http://www.nortrade.com/index?cmd=show_article&id=165
33. **Slippery ships float on Thin Air**, *by* Thwaites T, *in* New Scientist.com.news service 18th Febuary 2006
34. **The WMO Voluntary Observing Ship (VOC) Scheme** http://www.vos.noa.gov/vos_scheme.shtml
35. **SAHFOS Continuous Plankton Recorder Survey** www.sahfos.ac.uk.
36. **Use of a Ferry-Box system to look at shelf sea and ocean margin processes**, Hydes, D.J.; Yool, A.; Campbell, J.M.; Crisp, N.A.; Dodgson, J.; Dupee, B.; Edwards, M.; Hartman, S.E.; Kelly-Gerreyn, B.A.; Lavin, A.M.; González-Pola, C.M.; Miller, P. (2003). *in*: Dahlin, H. *et al.* (Ed.) (2003). *Building the European capacity in operational oceanography: proceedings of the 3rd International Conference on EuroGOOS 3-6 December, 2002, Athens, Greece. Elsevier Oceanography Series,* 69: pp. 297-303.