

# **Topical and Geographical Focus of Chinese Oceanographic Research -A Study of Trends in Publication-**

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Since the economic boom started in the early 1990s, China has expanded its educational and scientific programs. Funds increase rapidly for education and scientific research. From 1993 to 2006, enrollment of full time students in universities and colleges grew from 924,000 to 5,400,000, total number of students (including part-time) increased from 5,000,000 to 25,000,000, and the percentage of the enrolled full-time students in the age (18-22) group jumped from 5% to 22% (Table 1); and research funds for ocean sciences from the National Natural Science Foundation of China (NSFC) increased from 12.33 million CNY supporting 58 projects to 40.05 million supporting 141 projects. Similarly, NSFC funds for the geosciences increased from 105.31 to 351.38 CNY and the number of projects more than doubled (Figs. 1 and 2). Universities, research institutes, and laboratories have been expanded or re-organized. Small colleges have been combined and upgraded into big universities. Along with these changes, the oceanographic community has been growing rapidly and new Chinese language journals have been created. To inform foreign ocean scientists about the Chinese oceanographic community and its priorities for future collaboration, we will introduce the research institutes and universities where oceanography is studied and study trends in 38 Chinese language oceanography journals.

## **RESEARCH INSTITUTES AND UNIVERSITIES**

Oceanographic research in China is usually conducted in research institutes and universities (Table 2). These institutes belong to three major government divisions: (1) the State Oceanic Administration (SOA), which strongly parallels the oceanic component of NOAA; (2) the Chinese Academy of Sciences (CAS), which appears to parallel the

Russian Academy of Science in that it has operational arms, institutes, ships, laboratories, etc; and (3) the Chinese Academy of Fishery Science (CAFS), which belongs directly to the Ministry of Agriculture. All of these institutes are located in coastal cities of China (Table 2).

The SOA is an administrative agency for the supervision and management of sea area uses and marine environmental protection, safeguarding national maritime rights and interests according to laws and regulations, and organizing and carrying out marine scientific and technical research ([http://english.gov.cn/2005-10/01/content\\_73182.htm](http://english.gov.cn/2005-10/01/content_73182.htm)). It has four research institutes: the First Institute of Oceanography (FIO) focusing on the Bohai Sea and Yellow Sea, the Second Institute of Oceanography (SIO) focusing on the East China Sea, the Third Institute of Oceanography (TIO) focusing on the South China Sea, and the Polar Research Institute of China (PRIC) focusing on the Arctic and Antarctic. The SOA also has several research/operational centers such as the National Marine Data and Information Service, the National Center for Marine Environment Forecast, and the National Ocean Technology Center. The CAS has two institutes: the Institute of Oceanology focusing on frontiers of world ocean sciences, and the South China Sea Institute of Oceanology focusing on various processes in the South China Sea. The CAFS, headquartered in Beijing, has 21 related institutions of oceanography and fishery related research spreading over coastal regions.

China has 11 universities offering undergraduate and graduate oceanographic curricula (Table 3). Among them, the Ocean University of China located in Qingdao is the largest one, with more than 10 colleges and schools, and especially renowned for its

oceanography and fisheries programs. It is a comprehensive university with science, engineering, agronomy (fishery), medical science (pharmacology), liberal arts, philosophy and economics. The other universities, spread out among coastal cities, have their own strengths and focus areas. Readers can find useful information about them from the websites listed in Tables 2 and 3.

### **CHINESE-LANGUAGE OCEANOGRAPHIC JOURNALS**

Almost all of these institutes and universities in China publish oceanographic journals in the Chinese language. Among 38 Chinese language journals (Table 4), very few are published by professional societies such as “Acta Oceanologica Sinica” by the Chinese Oceanographic Society and “Oceologia et Limnologia Sinica” by the Chinese Society of Oceanography and Limnology, “Progress in Earth Sciences” and “Progress in Natural Sciences” by NSFC, “China Sciences” and “Chinese Science Bulletin” by CAS. Such a feature is very different from the western world especially the U.S., where the oceanographic journals are all published by professional societies such as the American Meteorological Society, the American Geophysical Union, the Oceanography Society, and the Marine Technological Society.

Some Chinese language journals have an evident geographical focus such as “East China Sea Marine Science” for the East China Sea, and “Research and Development in the South China Sea” for the South China Sea. Some journals have an evident topic focus such as “Marine Forecasts” for prediction only.

### **BIBLIOGRAPHIC STUDIES**

Some of these journals have relatively long histories of publication such as “Oceologia et Limnologia Sinica” created in 1957. Some of them have relatively short

histories of publication such as “Chinese Journal of Polar Research” created in 1988. To investigate the development during the last two decades, we searched all the papers published in the 38 journals listed in Table 4 since 1990 to find topic and geographic focus, and tendencies in the Chinese oceanographic research. The purpose is to provide useful information for future collaboration between U.S. and Chinese oceanographers. The total number of papers is 16224. Since the Chinese journals don’t have subject indices at the end of a year, a bibliographic study is tedious, requiring each paper should be read. The number of published papers is quite steady from 1990 to 1999 with around 820 papers per year, and afterwards increases to 1343 papers in 2006 (Fig. 3). During the bibliographic study, we classified articles by 34 geographical focus areas (e.g., Bohai Sea, East China Sea, South China Sea, Yellow Sea, Indian Ocean, western Pacific, etc.) and 180 topics (e.g., acoustic detection, current system, numerical simulation, ocean environment, etc.) for all 38 journals. Each paper may have more than one topic focus.

### **GEOGRAPHICAL FOCUS AREAS**

Table 5 lists the focus areas with an associated number of published papers ( $n$ ) during 1990-2006. It is not surprising that the Chinese coastal seas fall into the highest interest geographical focus with the East China Sea having 1749 papers, followed by the South China Sea, the Yellow Sea, and the Bohai Sea. Fig. 4 shows the yearly number of papers published for the Pacific Ocean, Atlantic Ocean, Indian Ocean, Arctic Ocean, South Ocean/Antarctic, global ocean. For the whole period (1990-2006), the two areas (Indian Ocean and Arctic Ocean) have very evident upward trends with the Indian Ocean from 3 papers in 1990 to 26 papers in 2006, and the Arctic Ocean from 3 papers in 1990 to 27 papers in 2005 and 2006. For the recent years (1999 to 2006), two focus areas

(Pacific, Atlantic) has upward trends with the Pacific Ocean from 24 papers in 1998 to 64 papers in 2006, and the Atlantic Ocean from 1 paper in 1993 to 15 papers in 2006. For the global ocean, a maximum number of papers (36) were published in 1997. Disregarding this spike, a weak upward trend was found from 14 papers in 1990 to 32 papers in 2006.

Fig. 5 shows the yearly number of papers published for various coastal regions near China. For the whole period (1990-2006), two areas (East China Sea and Luzon Strait) have evident upward trends, the East China Sea being the most significant from 71 papers in 1990 to 152 papers in 2006. In the past decade (1997 to 2006), two areas (Bohai Sea and Yellow Sea) have yielded increased publications. This is possibly due to the fast economic growth in the coastal areas, which makes coastal oceanography of the China Seas a high priority.

### **TOPICAL FOCUS**

Fig. 6 shows the yearly (1990-2006) number of papers published for some topical areas with evident upward trend such as “acoustic detection” from 1 paper in 1994 to 23 papers in 2006, “data assimilation” for 0 paper in 1990-1993 to 11 papers in 2005, “inverse method” from 4 papers in 1990 to 53 papers in 2006, “numerical simulation” from 72 papers in 1990 to 155 papers in 2005 and 2006. However, some priorities have diminished in recent years (Fig. 5) with “El Nino” declining from 26 papers in 1998 to 10 papers in 2006, “sea-level change” from 14 papers in 1996 to 4 papers in 2006, “current system” from 30 papers in 2002 to 13 papers in 2006, and “storm surge” from 32 papers in 2002 to 10 papers in 2006.

This database, which is still under development, will be made available through the Naval Ocean Analysis and Prediction Laboratory's (at the Naval Postgraduate School) website (<http://www.oc.nps.edu/~chu/noap.html>). We will augment it with simple search capabilities. This bibliographic study points out the priorities and focus areas of the Chinese oceanic research, and we hope it inspires collaboration between the U.S. and China's oceanic research communities.

#### **ACKNOWLEDGMENTS.**

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**Table 1. Comparison of student enrollments between 1993 and 2006**

(from the website:

[http://www.albertachina.com/upload/IB\\_BEJING-123071-v1-China\\_Higher\\_education](http://www.albertachina.com/upload/IB_BEJING-123071-v1-China_Higher_education))

|                                                                      | <b>1993</b> | <b>2006</b> | <b>Increase</b> |
|----------------------------------------------------------------------|-------------|-------------|-----------------|
| Enrollment of full time students in national/provincial universities | 924,000     | 5.4 million | 4.8 times       |
| Total number of students (including part-time)                       | 5 million   | 25 million  | 4 times         |
| Percentage of enrolled students in the age group (18-22)             | 5%          | 22%         | 17%             |

**Table 2. Major oceanographic research institutions in China.**

| Name                                                 | Location                                   | Focus Area                               | Year of Establishment | Website or Contact Information                                                                                                  |
|------------------------------------------------------|--------------------------------------------|------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------|
| First Institute of Oceanography SOA                  | Qingdao Shandong Province                  | Bohai Sea Yellow Sea                     | 1962                  | <a href="http://www.fio.org.cn/english/index.asp">http://www.fio.org.cn/english/index.asp</a>                                   |
| Second Institute of Oceanography SOA                 | Hanzhou Zhejiang Province                  | East China Sea                           | 1966                  | <a href="http://www.sio.org.cn/english/index.asp">http://www.sio.org.cn/english/index.asp</a>                                   |
| Third Institute of Oceanography SOA                  | Xiamen Fujian Province                     | South China Sea                          | 1959                  | <a href="http://jcomm.coi.gov.cn/english/eoverview/e3s/thr_jj.htm">http://jcomm.coi.gov.cn/english/eoverview/e3s/thr_jj.htm</a> |
| Polar Research Institute of China SOA                | Shanghai                                   | Arctic Antarctic                         | 1989                  | <a href="http://www.pric.gov.cn/enindex.asp">http://www.pric.gov.cn/enindex.asp</a>                                             |
| National Marine Data and Information Service, SOA    | Tianjin                                    | Ocean Data                               | 1958                  | <a href="http://www.nmdis.gov.cn/">http://www.nmdis.gov.cn/</a>                                                                 |
| National Center for Marine Environment Forecast, SOA | Beijing                                    | Prediction for all coastal seas of China |                       | 8 Dahuisi Road, Haidian District Beijing 100081 China<br>Email: <a href="mailto:wlz@nmefc.gov.cn">wlz@nmefc.gov.cn</a>          |
| National Ocean Technology Center, SOA                | Tianjin                                    | Ocean Engineering /Technology            |                       | <a href="http://www.notc.gov.cn/">http://www.notc.gov.cn/</a>                                                                   |
| Institute of Oceanology CAS                          | Qingdao Shandong Province                  | Frontiers of world ocean sciences        | 1959                  | <a href="http://www.qdio.ac.cn/English/index.asp">http://www.qdio.ac.cn/English/index.asp</a>                                   |
| South China Sea Institute of Oceanology CAS          | Guangzhou Guangdong Province               | South China Sea                          | 1959                  | <a href="http://www.scsio.ac.cn/scsio/default.htm">http://www.scsio.ac.cn/scsio/default.htm</a>                                 |
| Chinese Academy of Fishery Science                   | 21 Institutes over China's coastal regions | Coastal Seas of China                    | 1978                  | <a href="http://www.lib.noaa.gov/china/archi/headquaters.htm">http://www.lib.noaa.gov/china/archi/headquaters.htm</a>           |

**Table 3. Major universities in China offering oceanographic curriculum.**

| Name                                                                          | Website                                                                               | Year of Major Reorganization & Expansion |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------|
| Dalian Fishery University (Liaonin Province)                                  | <a href="http://www.dlfu.edu.cn/">http://www.dlfu.edu.cn/</a>                         | 1978                                     |
| Dalian Maritime University (Liaonin Province)                                 | <a href="http://english.dlmu.edu.cn/">http://english.dlmu.edu.cn/</a>                 | 1953                                     |
| East China Normal University (Shanghai)                                       | <a href="http://www.ecnu.edu.cn/">http://www.ecnu.edu.cn/</a>                         | 1951                                     |
| Guangdong Ocean University (Guangdong Province)                               | <a href="http://www.gdou.edu.cn/">http://www.gdou.edu.cn/</a>                         | 1997                                     |
| Hainan University, Ocean College (Hainan Province)                            | <a href="http://www.hainu.edu.cn/xy_haiyang/">http://www.hainu.edu.cn/xy_haiyang/</a> | 2002                                     |
| Hohai University (Nanjing)                                                    | <a href="http://en.hhu.edu.cn/">http://en.hhu.edu.cn/</a>                             | 1952                                     |
| Nanjing University, School of Geographic and Oceanographic Sciences (Nanjing) | <a href="http://sgos.nju.edu.cn/Index.asp">http://sgos.nju.edu.cn/Index.asp</a>       | 2006                                     |
| Ocean University of China (Shandong Province)                                 | <a href="http://www.ouc.edu.cn/english/">http://www.ouc.edu.cn/english/</a>           | 1988                                     |
| Shanghai Ocean University (Shanghai)                                          | <a href="http://www.shfu.edu.cn/">http://www.shfu.edu.cn/</a>                         | 1985                                     |
| Xiamen University, College of Oceanography (Fujian Province)                  | <a href="http://coe.xmu.edu.cn/1/">http://coe.xmu.edu.cn/1/</a>                       | 1996                                     |
| Zhejiang Ocean University (Zhejiang Province)                                 | <a href="http://www.zjou.net.cn/">http://www.zjou.net.cn/</a>                         | 2005                                     |

**Table 4. Chinese language journals publishing oceanographic papers**

|                                                                                                                                                                                   |                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 海洋学报 (Acta Oceanologica Sinica)<br><a href="http://www.ilib.cn/P-hyxb.html">http://www.ilib.cn/P-hyxb.html</a>                                                                    | 沉积学报 (Acta Sedimentologica Sinica)<br><a href="http://www.ilib.cn/P-cjxb.html">http://www.ilib.cn/P-cjxb.html</a>                                               |
| 地球科学进展 (Advances in Earth Sciences)<br><a href="http://www.ilib.cn/P-dqkxjz.html">http://www.ilib.cn/P-dqkxjz.html</a>                                                            | 海洋科学进展 (Advances in Marine Science)<br><a href="http://www.ilib.cn/P-hbhhhy.html">http://www.ilib.cn/P-hbhhhy.html</a>                                          |
| 中国科学 (China Sciences) (D)<br><a href="http://www.scichina.com/new_web_Fa/index.asp">http://www.scichina.com/new_web_Fa/index.asp</a>                                              | 大气科学 (Chinese Journal of Atmospheric Sciences)<br><a href="http://www.ilib.cn/P-daikx.html">http://www.ilib.cn/P-daikx.html</a>                                 |
| 地球物理学报 (Chinese Journal of Geophysics)<br><a href="http://www.geophy.cn/cn/dqml.asp">http://www.geophy.cn/cn/dqml.asp</a>                                                         | 极地研究 (Chinese Journal of Polar Research)<br><a href="http://www.lunwentianxia.com/qikan_detail_314/">http://www.lunwentianxia.com/qikan_detail_314/</a>         |
| 科学通报 (Chinese Science Bulletin)<br><a href="http://www.ilib.cn/P-kxtb.html">http://www.ilib.cn/P-kxtb.html</a>                                                                    | 海岸工程 (Coastal Engineering)<br><a href="http://www.cqvip.com/qk/95947X/200004/index.shtml">http://www.cqvip.com/qk/95947X/200004/index.shtml</a>                 |
| 海洋学研究 (East China Sea Marine Science)<br><a href="http://www.cqvip.com/qk/96340X/199301/">http://www.cqvip.com/qk/96340X/199301/</a>                                              | 海洋测绘 (Hydrographic Surveying and Charting)<br><a href="http://www.ilib.cn/P-hych.html">http://www.ilib.cn/P-hych.html</a>                                       |
| 大连水产学院学报<br>(Journal of Dalian Fishery University)<br><a href="http://www.ilib.cn/P-dlscxyxb.html">http://www.ilib.cn/P-dlscxyxb.html</a>                                         | 华东师范大学学报 (自然科学版)<br>Journal of East China Normal University (Natural Sciences)<br><a href="http://www.cqvip.com/qk/90014X/">http://www.cqvip.com/qk/90014X/</a> |
| 水产学报 (Journal of Fisheries of China)<br><a href="http://www.ilib.cn/P-scxzb.html">http://www.ilib.cn/P-scxzb.html</a>                                                             | 湛江海洋大学学报 (Journal of Guangdong Ocean University)<br><a href="http://www.cqvip.com/qk/93246A/200604/">http://www.cqvip.com/qk/93246A/200604/</a>                 |
| 河海大学学报 (Journal of Hohai University)<br><a href="http://www.ilib.cn/P-hhdxxb.html">http://www.ilib.cn/P-hhdxxb.html</a>                                                           | 水动力研究与进展<br>(Journal of Hydrodynamics)<br><a href="http://scholar.ilib.cn/Periodical.aspx?P=sdlxyjyz">http://scholar.ilib.cn/Periodical.aspx?P=sdlxyjyz</a>     |
| 中国海洋大学学报<br>(Journal of Ocean University of China)<br><a href="http://www.cqvip.com/qk/92605A/200601/index.shtml">http://www.cqvip.com/qk/92605A/200601/index.shtml</a>           | 台湾海峡<br>Journal of Oceanography in Taiwan Strait<br><a href="http://www.cqvip.com/qk/90949X/index.shtml">http://www.cqvip.com/qk/90949X/index.shtml</a>         |
| 上海水产大学学报<br>(Journal of Shanghai Fishery University)<br><a href="http://www.ilib.cn/P-shscdxxb.html">http://www.ilib.cn/P-shscdxxb.html</a>                                       | 热带海洋学报<br>(Journal of Tropical Oceanography) <a href="http://www.ilib.cn/P-rdhy.html">http://www.ilib.cn/P-rdhy.html</a>                                        |
| 厦门大学学报 (Journal of Xiamen University)<br><a href="http://www.ilib.cn/P-xmdxxb.html">http://www.ilib.cn/P-xmdxxb.html</a>                                                          | 浙江海洋学院学报<br>(Journal of Zhe-Jian Ocean University)<br><a href="http://dx2.cqvip.com/qk/97875A/200604/">http://dx2.cqvip.com/qk/97875A/200604/</a>               |
| 海洋预报 (Marine Forecasts)<br><a href="http://www.ilib.cn/P-hyyb.html">http://www.ilib.cn/P-hyyb.html</a>                                                                            | 海洋地质 (Marine Geology)<br><a href="http://www.cqvip.com/qk/98440X/200603/index.shtml">http://www.cqvip.com/qk/98440X/200603/index.shtml</a>                      |
| 海洋通报 (Marine Science Bulletin)<br><a href="http://www.ilib.cn/P-hybt.html">http://www.ilib.cn/P-hybt.html</a>                                                                     | 海洋与海岸带开发<br>(Ocean Development and Management)<br><a href="http://www.ilib.cn/I-hykfygl.2002.04.html">http://www.ilib.cn/I-hykfygl.2002.04.html</a>             |
| 海洋工程 (Ocean Engineering)<br><a href="http://www.ilib.cn/P-hygc.html">http://www.ilib.cn/P-hygc.html</a>                                                                           | 海洋科学 (Ocean Sciences)<br><a href="http://www.ilib.cn/P-hykc.html">http://www.ilib.cn/P-hykc.html</a>                                                            |
| 海洋科学消息 (Ocean Science News)<br><a href="http://www.cqvip.com/qk/97093X/199104/index.shtml">http://www.cqvip.com/qk/97093X/199104/index.shtml</a>                                  | 海洋世界 (Ocean World)<br><a href="http://www.cqvip.com/qk/91227X/index.shtml">http://www.cqvip.com/qk/91227X/index.shtml</a>                                       |
| 海洋技术 (Ocean Technology) <a href="http://www.ilib.cn/P-hyjs.html">http://www.ilib.cn/P-hyjs.html</a>                                                                               | 海洋与湖沼 (Oceologia et Limnologia Sinica)<br><a href="http://www.cqvip.com/qk/90072X/">http://www.cqvip.com/qk/90072X/</a>                                         |
| 地球物理学进展 (Progress in Geophysics)<br><a href="http://dqwj.chinajournal.net.cn/">http://dqwj.chinajournal.net.cn/</a>                                                               | 自然科学进展 (Progress in Natural Sciences)<br><a href="http://zrkxjz.nt.n.f2us.com/index.html">http://zrkxjz.nt.n.f2us.com/index.html</a>                            |
| 南海研究与开发<br>(Research and Development in the South China Sea)<br><a href="http://www.cqvip.com/qk/94902X/199403/index.shtml">http://www.cqvip.com/qk/94902X/199403/index.shtml</a> | 海洋湖沼通报<br>(Transaction of Oceanology and Limnology)<br><a href="http://www.ilib.cn/P-hyhzbt.html">http://www.ilib.cn/P-hyhzbt.html</a>                          |

**Table 5. Number of papers published for various focus areas from 1990 to 2006. Here, the integer in parenthesis indicates the number of papers published for the corresponding focus area.**

|                                         |                           |                                           |                         |
|-----------------------------------------|---------------------------|-------------------------------------------|-------------------------|
| East China Sea<br>(1749)                | South China Sea<br>(1700) | Yellow Sea<br>(1282)                      | Bohai Sea<br>(1164)     |
| Antarctic<br>(881)                      | Pacific Ocean<br>(662)    | Yangtze River<br>Delta/Estuarine<br>(434) | Global<br>Oceans (417)  |
| Taiwan Strait<br>(408)                  | Western Pacific<br>(296)  | Yellow River<br>Delta/Estuarine<br>(278)  | Arctic (254)            |
| Pearl River<br>Delta/Estuarine<br>(239) | Spratly Islands<br>(219)  | Indian Ocean<br>(149)                     | Okinawa<br>(141)        |
| Atlantic Ocean<br>(140)                 | Gulf of Tonkin<br>(134)   | Gulf of Daya<br>(120)                     | Paracel<br>Islands (56) |
| Sea of Japan<br>(43)                    | Philippine Sea<br>(29)    | Luzon Strait<br>(23)                      | Mariana<br>Trench (23)  |
| Pratas Islands<br>(14)                  | Sea of Okhotsk<br>(6)     | Huai River<br>Delta/Estuarine<br>(3)      | Gulf of<br>Thailand (2) |
| Tsushima/Korean<br>Strait (1)           | Strait of Malacca (1)     | Guan (1)                                  |                         |

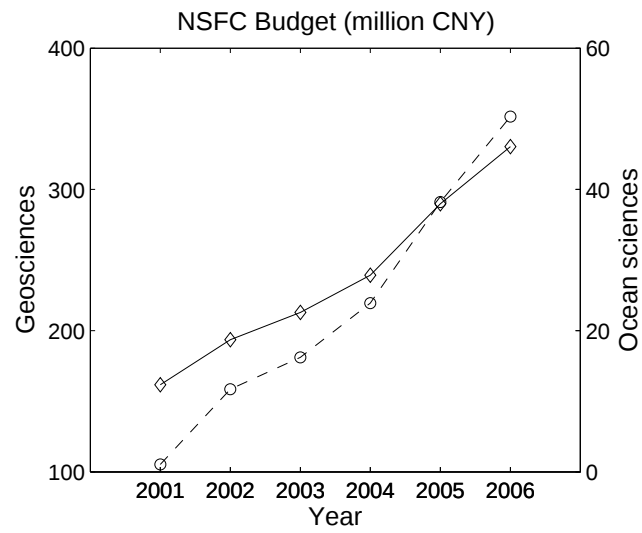


Fig. 1. Annual NSFC budget (unit: million CNY) for ocean sciences (solid) and geosciences (dashed). Note different scales are used (from the website: <http://www.nsfc.gov.cn/nsfc2008/index.htm>).

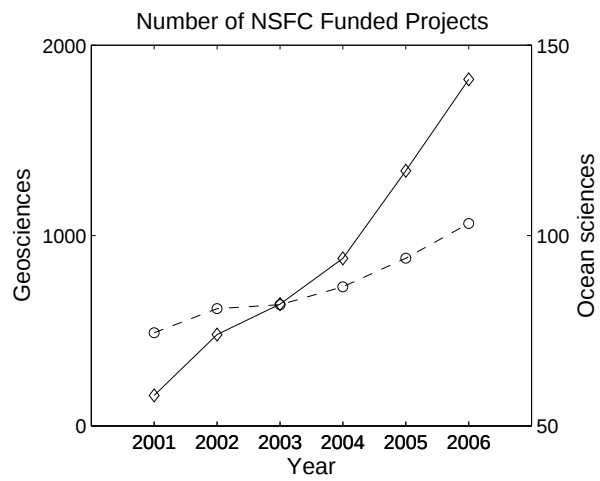


Fig. 2. Annual number of NSFC sponsored projects for ocean sciences (solid) and geosciences (dashed) (from the website: <http://www.nsfc.gov.cn/nsfc2008/index.htm>).

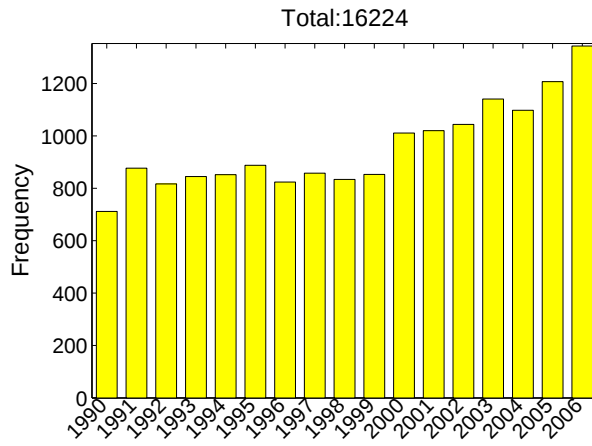


Fig. 3. Yearly (1990-2006) number of papers published in 38 Chinese language journals.

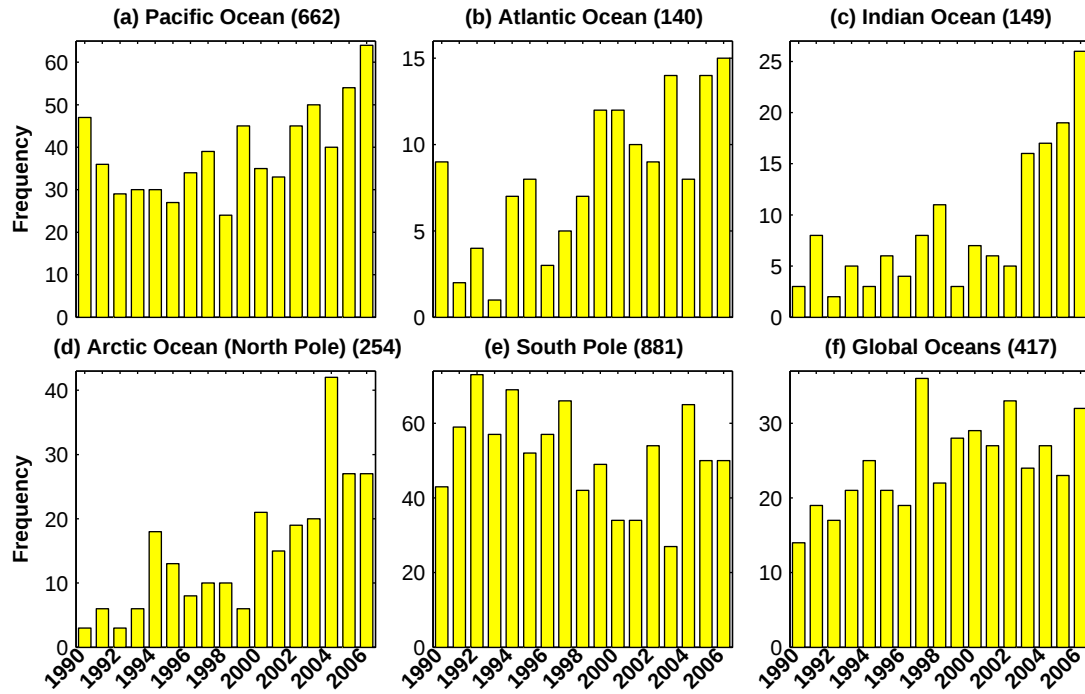


Fig. 4. Yearly (1990-2006) number of papers published for (a) Pacific Ocean, (b) Atlantic Ocean, (c) Indian Ocean, (d) Arctic Ocean, (e) Antarctic/Southern Ocean, and (f) global ocean, with evident upward trends for the Indian Ocean and Arctic Ocean.

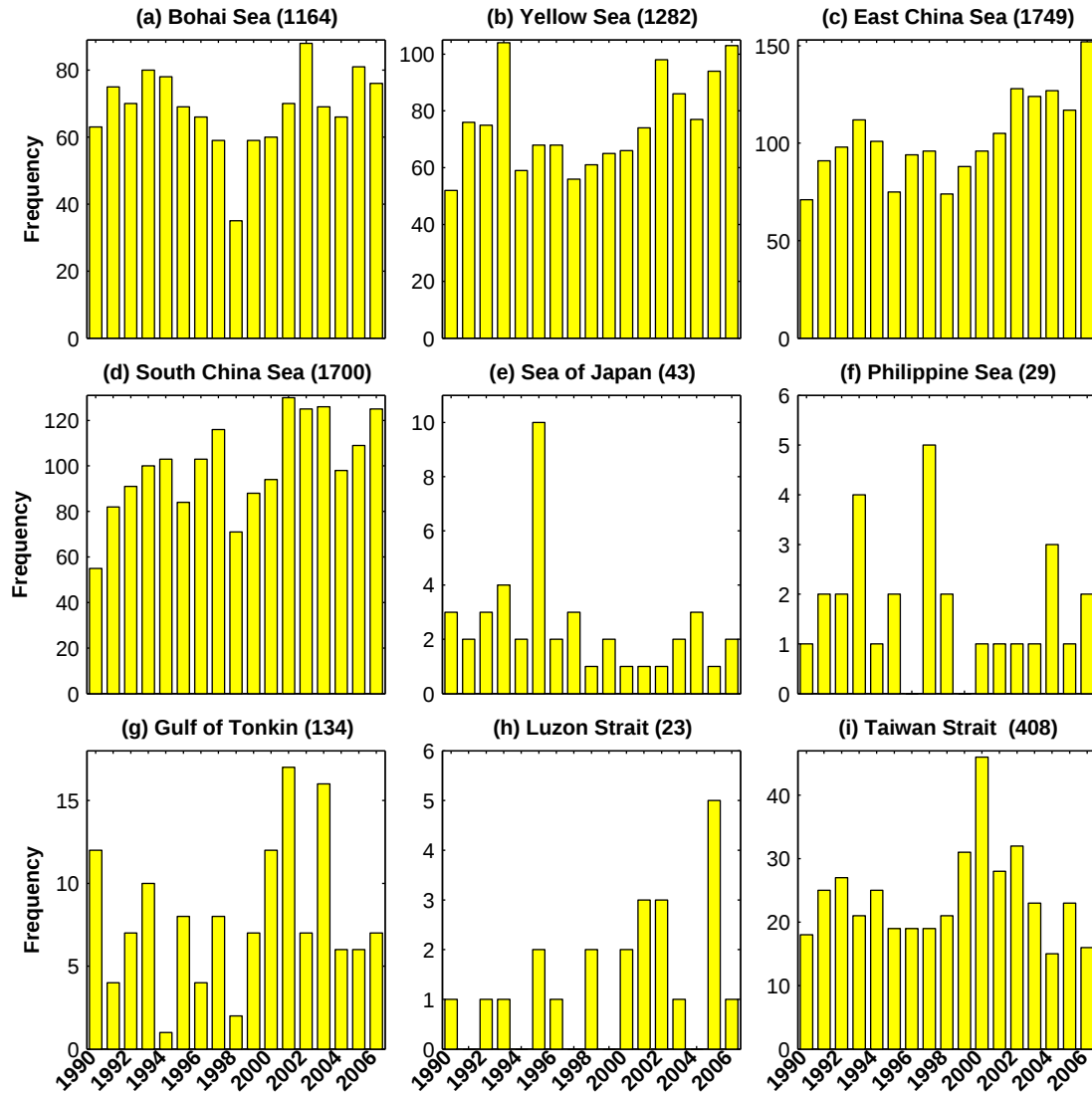


Fig. 5. Yearly (1990-2006) number of papers published for the east Asian regional seas: (a) Bohai Sea, (b) Yellow Sea, (c) East China Sea, (d) South China Sea, (e) Sea of Japan, (f) Philippine Sea, (g) Gulf of Tonkin, (h) Luzon Strait, and (i) Taiwan Strait.

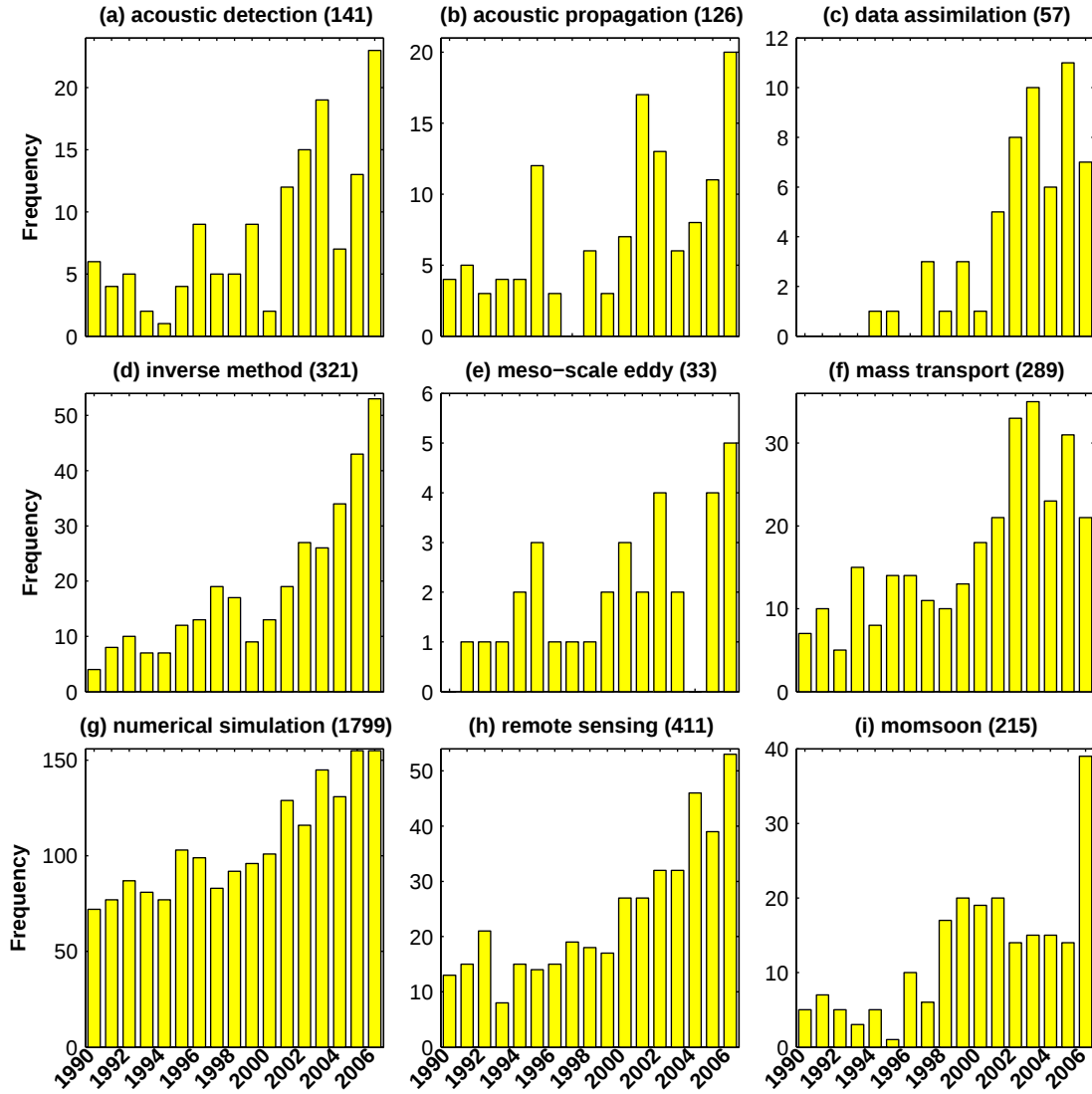


Fig. 6. Yearly (1990-2006) number of papers published for various priorities with evident upward trend: (a) acoustic detection, (b) acoustic propagation, (c) data assimilation, (d) inverse method, (e) meso-scale eddy, (f) mass transport, (g) numerical simulation, (h) remote sensing, and (i) monsoon.

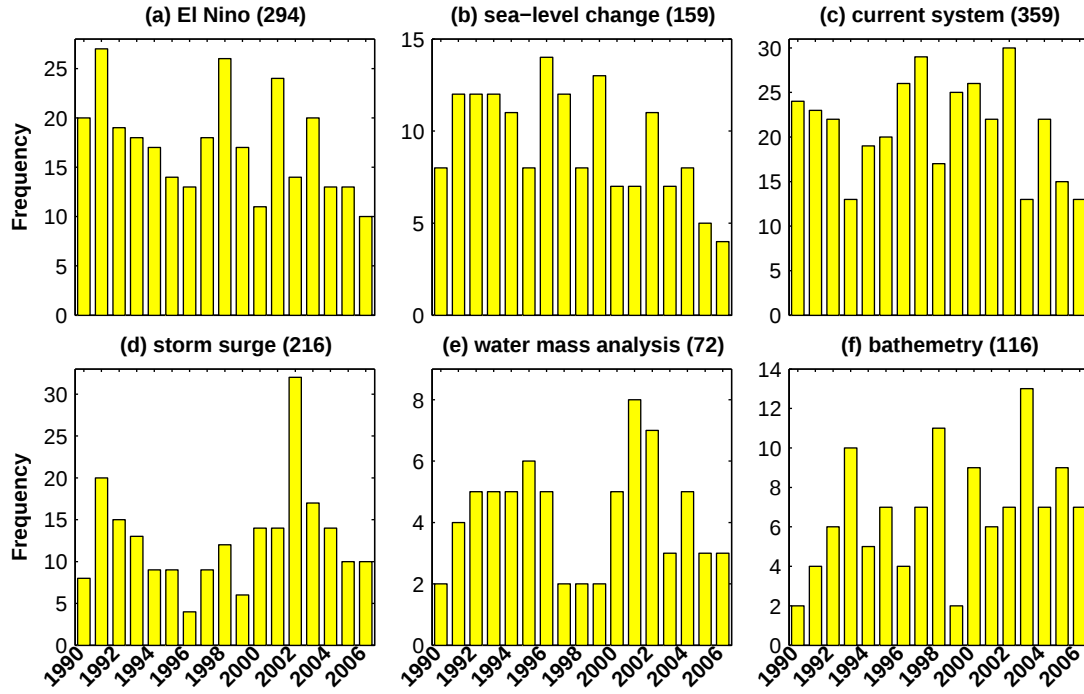


Fig. 7. Yearly (1990-2006) number of papers published for various priorities with downward trend in recent years: (a) El Nino, (b) sea-level change, (c) current system, (d) storm surge, (e) water mass analysis, and (f) bathymetry.