INTERNATIONAL COOPERATION IN EARTH SYSTEM SCIENCE AND SERVICES*

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Summary

International cooperation in meteorology was one of the great success stories of the 20th Century. It provided humanity with an efficient global infrastructure for monitoring weather and climate, comprehensive scientific understanding of many of the most complex phenomena of the natural world and an extraordinary array of essential services in support of human safety and welfare and the social and economic development of nations. It was the model for greatly increased international cooperation in oceanography and hydrology and it provides the foundation for the integrated global earth observation, research and service system that has emerged as a global imperative for the 21st Century, The achievements of international cooperation in atmospheric, oceanic and related science and services reflect the globally connected nature of the atmosphere and ocean, the strongly public good characteristics of most environmental information and services, the robust and far-sighted institutional arrangements inherited from the 19th Century and the deeply ingrained traditions of trust, mutual support and cooperation within the international scientific community. The institutions of international meteorology, oceanography, and hydrology provide as good a model as the world has yet devised of nations, organisations and scientific disciplines working together for the common good. The emerging discipline of earth system science now faces unprecedented opportunities to build on the achievements of international cooperation in the atmospheric and related sciences through the 19th and 20th Centuries to provide even greater benefits to humanity in the century ahead.

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Introduction

The American Meteorological Society (AMS) has taken a bold, appropriate and timely step in launching a new series of conferences on 'International Cooperation in Earth System Science and Services' with the first conference in 2008 focussed on the atmospheric and oceanic sciences and services as a symposium honoring Richard E Hallgren.

I am grateful for the opportunity so provided to applaud the past and exalt the future of international cooperation in earth system science and services. I am especially happy to do so in honor of Dr Richard E Hallgren because, more than anyone else in our field in my professional lifetime, Dick Hallgren has championed the cause and enhanced the spirit of international cooperation in the atmospheric, oceanic and related sciences and services around the world.

This is the 'International Year of Planet Earth' and hence an especially appropriate time to take stock of the benefits of international cooperation in earth system science. I regard 'earth system science' as embracing the physics, chemistry and biology of the entire earth system including, especially, the atmosphere, ocean and inland waters, and their behaviour on all time and space scales. I regard 'science', in its broadest sense, as encompassing observation, research and service provision but, to underscore the importance of beneficial application of the products of observation and research to societal needs, I will mostly follow the lead of the conference title and speak in terms of international cooperation in science <u>and</u> services.

For the purposes of the first in this new series of conferences I have taken it as my task to provide a simple overview of the origin, rationale, mechanisms, scope and achievements of international cooperation in meteorology and oceanography by way of a general introduction to the individual expert presentations on the past, present and future of the atmospheric and oceanic sciences at the Hallgren Symposium and as a point of departure for consideration of the broader fields of earth science that will be addressed at future conferences.

But, lest my essential conclusions not emerge sufficiently clearly from the more detailed observations that follow, I will begin with four basic assertions with which, I believe, Dr Hallgren would broadly agree:

- First, there is no field of science or human endeavour that is more inherently international or more necessarily cooperative than meteorology. There is no aspect of meteorology that has been more central to the enormous benefits that it has delivered to humanity than international cooperation;

- Second, as a field of science, as a profession and as a service to society, meteorology represents both the prototype and the foundation for the integrated atmosphere-ocean-land surface observation, research and service system that has emerged as a global imperative for the early decades of the 21st Century;

- Third, as an already well established force for good in the world, international cooperation in earth system science and services has much to contribute to human progress and stewardship of the planet in a 21st Century environment of competition and economic and technological globalisation; and

- Fourth, while the societal benefits of earth system science and services in the 21st Century will be strongly influenced by the international institutional arrangements that are put in place over the next few decades they will depend, more than on any other factor, on the mutual trust, friendship and shared commitment among the people from every corner of the globe whose privilege it will be to be drawn together in international fora to make those arrangements work.

And, to the extent that we have already learned in meteorology that our skill in looking forward is a function of our perceptiveness and thoroughness in looking back, I will err on the side of drawing on the wisdom of the many great internationalists who have graced our field over the past 150 years. There is much wisdom to be drawn on and, for sheer insight and inspiration, I could not too strongly commend the two remarkable volumes (Figure 1), published by the World Meteorological Organization (WMO, 1988; 1997), of interviews by Dr Hessam Taba with sixty-five of the outstanding figures of 20th Century meteorology, oceanography and hydrology beginning, appropriately, with Dr Robert M White and concluding, equally appropriately, with Dr Richard E Hallgren.

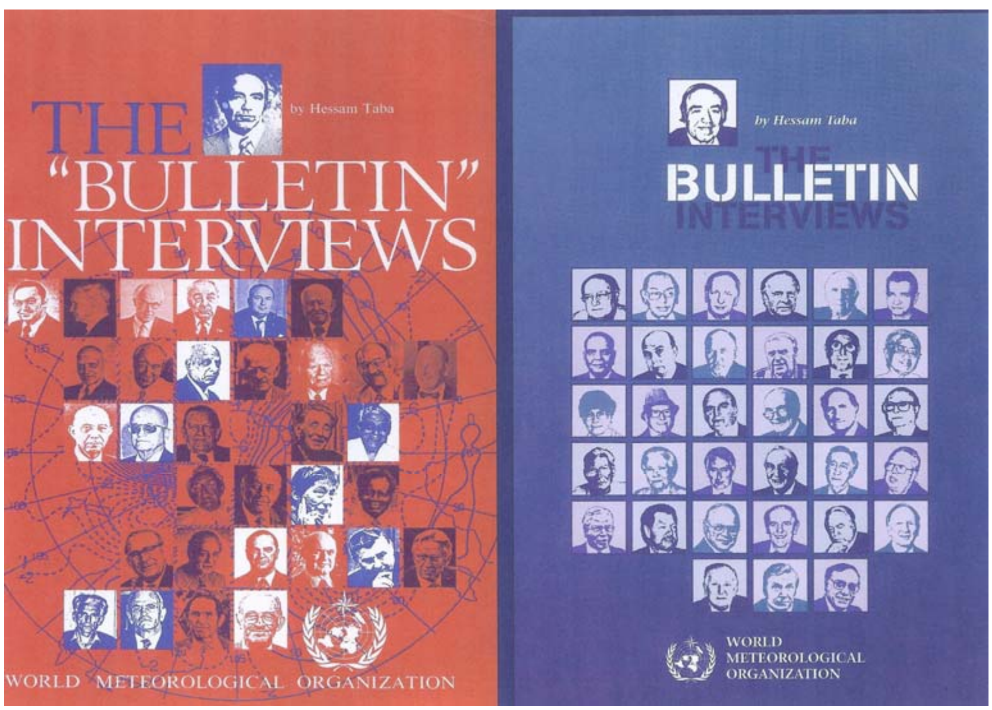

Figure 1 *The covers of the two volumes of WMO Bulletin Interviews by Dr Hessam Taba between 1981 and 1997. Dr Robert White is at the top left, Dr Richard Hallgren at the bottom right.*

The Concept of International Cooperation

Though, in many ways, unique in its achievements thus far, and arguably a model for unity and collaboration in the wider world (Zillman, 2006), international cooperation in meteorology and oceanography must clearly be viewed as part of a much broader system of international cooperation in scientific, social, economic, environmental, legal and political affairs and, thus, in turn, as an important component of the even broader field of international relations generally (Evans and Newnham, 1998).
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Theories of international relations focus on the balance between conflict and cooperation in the world (Henderson, 1998) and are based heavily, though not exclusively, on the concept of the nation state which emerged from the Peace of Westphalia in 1648 (Cooper, 2003). The state itself is an ancient human institution dating back thousands of years but the modern nation state with taxing powers, armies and authority over peoples and territory is based essentially on the concept of the social contract developed by Grotius (1625), Hobbes (1651), Rousseau (1762), Kant (1795) and the other great philosophers of the Enlightenment (Blackburn, 2005). Its role in international law is defined by the Montevideo Convention on the Rights and Duties of States (Triggs, 2006). While some, such as Ohmae (1995), have declared the end of the nation state in response to the triumph of liberal democracy and the momentous geopolitical events of the second half of the 20th Century, others, such as Fukuyama (2004), in fact, now see an even more important role for the state and state building in the era of globalisation.

The recent literature of international relations has, in general, focussed more on confrontation, conflict and competition (eg Huntington, 1996; Porter, 1998; Hoffmann, 1999) than it has on cooperation (eg Baudot, 2001). The basic human concept of cooperation is complex and multi-facetted (Axelrod, 1984) and the modern understanding of cooperation is based heavily on game theory (Sen, 2002; Miller, 2003) especially the so-called Prisoners Dilemma (Barrett, 2003) which shows that, in the absence of the necessary ingredients for cooperation, the independent pursuit of self interest by two individuals will leave both worse off. The benefits of cooperation derive from many sources including the division of labour and increasing returns to scale and are essentially the product of non-zero-sum games. According to Beinhocker (2006), evolution has steered us in the direction whereby we are naturally inclined to be cooperative to capture the riches of non-zero-sum games. But, while fundamental human norms such as trust, loyalty and shared purpose (O'Hara, 2004) play an important part and, in certain circumstances, altruism can become a dominant consideration (Fehr and Rockenbach, 2003), in general, for people to cooperate, they must feel confident that some mechanism will be operating to ensure that they will receive some of the benefits and that the benefits will be equitably shared. Gintis et al (2005) point out that humans are 'conditional co-operators' who will behave generously as long as others are doing so and 'altruistic punishers' who will strike back at those perceived to behave unfairly. A small amount of 'free riding' can be tolerated but, if it becomes widespread, the system of cooperation breaks down.

International cooperation is usually framed in terms of cooperation between sovereign nation states but it also embraces major roles for non-governmental bodies, business firms and individuals (Henderson, 1998). Its fundamental purpose is to enable states and non-state entities to serve optimally the interests of their members by working together to deliver better outcomes for all than could be achieved by each working separately. Its understanding is based on a complex mix of concepts from philosophy, psychology, politics, economics, sociology, law, management and other disciplines and the literature provides case studies of the operation of most of these in the success or failure of the various grand experiments in international cooperation such as the League of Nations (Evans and Newnham, 1998), the Bretton Woods Institutions (Singer, 1995; Stiglitz, 2002) and the Marshal Plan (Kunz, 1997; Reynolds, 1997).

The theory of international cooperation made a big leap forward by accepting the assumption that, like individuals, states and international organisations are self-interested and have conflicts of interest with one another (Martin, 1999; Boehmer-Christiansen and Kellow, 2002). The theory provides a basis for identifying conditions under which self-interested states and organisations, even in the absence of genuine altruism, find it beneficial and possible to cooperate with one another. And the most important emerging framework within which to identify these conditions and formulate cooperative strategy is provided by the concept of global public goods (Kaul et al, 1999).

In the language of economics (Heilbroner and Thurow, 1994), public goods are goods or services that are non-rivalrous in use (such as a navigation map or a weather observation) and non-excludable (such as the light from a light-house or weather information broadcast over public radio). They are the opposite of private goods which are both rival and excludable and are normally provided through the operation of competitive markets. Almost by definition, markets do not operate for the provision of public goods and, if they are to be provided at socially optimum levels, the responsibility for their provision falls mainly to governments and voluntary organisations (Bailey, 1995). Two important categories of public goods are of special relevance to earth system science and services:

- Merit goods (Stiglitz, 2000): those goods and services which governments feel bound to ensure that people use even though they may not choose to do so on their own – basic education, seat belts in cars, retirement insurance, disaster warnings; and
- Club goods(Cornes and Sandler, 1996): those which, though non-rival, are sufficiently excludable that their benefits may be restricted to the members of a particular group or 'club' who agree on a basis on which to cooperate for their provision and use by members of the club.

Global public goods are public goods whose benefits are strongly universal in terms of countries (covering more than one group of countries), people (accruing to several, preferably all, population groups) and generations (extending to both current and future generations, or at least meeting the needs of current generations without foreclosing development options for future generations) (Kaul et al, 1999). To a significant extent, the challenge of international cooperation is that of providing global public goods and, indeed, the international regime of cooperation through which they are provided is itself an important class of global public good.

The costs to nations from under-provision of global public goods include those resulting from the lack of the necessary legal regimes for international trade and commerce, the additional expenditures which individual governments must incur through duplication of essential information gathering, defence or other infrastructure, and the ‘tragedy of the commons’ - the depletion of an essential common resource (eg the global fish-stock or a clean atmosphere) through lack of accepted mechanisms for apportioning or regulating its use (Friedman, 2005; Stiglitz, 2006). The impediments to the provision of adequate levels of global public goods include insufficient understanding of the non-zero-sum-game benefits of international cooperation and the free-rider problem – the temptation to enjoy the benefits without contributing to the costs – albeit in well-established international communities such as meteorology, where shared values are strong, benefits clear and trust levels high, individual members are usually extremely reluctant to be seen as free riders by their colleagues. The enlightened self-interest consideration emerges strongly in the case of development assistance where it is in the interests of the international community to assist developing countries not only because they are poor but also to enable them to make their contribution to the provision of essential global public goods (Kaul et al, 1999).

It may be coincidental, but it is still rather nice, that one of the outstanding figures of 20th Century public sector economics, within which the theory of global public goods has been built, the 1972 Nobel Prize winner Kenneth Arrow, started his career as a meteorologist (Fuller, 1990; Arrow, 2008).

The major mechanisms of international cooperation and the principal providers of global public goods are the various types of international organisation. While some form of international cooperation among sovereign entities is traceable to the Greek city states of more than two thousand years ago, the real history of the modern international organisation begins in the nineteenth century (Henderson, 1998), interestingly with bodies concerned with river management, marine communication and meteorological data collection such as the Danube River Commission of 1856, the International Telegraph Union (ITU) of 1865 and the International Meteorological Organization (IMO) of 1873.

The international organisations which now provide the main framework for international cooperation fall into several different categories based on:

- Coverage – global or regional;
- Membership – universal, limited multilateral or bilateral;
- Nature – intergovernmental, non-governmental or business;
- Scope – multifunctional or uni-functional; and
- Character – political or technical.

The two pre-eminent global international organisations of the 20th Century were the League of Nations established in 1920 and its successor, the United Nations (UN) established in 1945 (Evans and Newnham, 1998). Importantly, Article 13 of the UN Charter (Triggs, 2006) charges its General Assembly with initiating studies and making recommendations for the purposes of ‘promoting international cooperation in the economic, social, cultural, education and health fields …..’ and provides for other specialised intergovernmental organisations to be brought into relation with the UN, by formal agreement, as part of what is now referred to as the ‘UN System’, with the designation of UN Specialised Agencies. It is important to note, however, that the UN and its Specialised Agencies are made up of legally equal sovereign states with little or no coercive power and they fall far short of the concept of 'world government' envisaged in Alfred Lord Tennyson's famous reference to 'the Parliament of man, the Federation of the world' (Kennedy, 2006).

While the UN, its Organs, Programmes, Subsidiary Bodies and Specialised Agencies dominate the global agenda for international cooperation, there is also a host (many hundreds) of global non-UN treaty-level multilateral Intergovernmental Organisations (IGOs) and a much larger (many thousands) set of International Non-Governmental Organisations (INGOs). The most important of the regional intergovernmental organisations is the European Community/European Union (EC/EU) and its Secretariat known as the European Commission.

The most important of the international non-governmental organisations, for present purposes, is the International Council for Science (ICSU), formerly the International Council of Scientific Unions, which, since 1931, has provided the overall framework for global cooperation within the various specialist fields of science. ICSU is one of the oldest international non-governmental organisations in the world. It arose out of the evolution of two earlier bodies known as the International Association of Academies (1899-1914) and the International Research Council (1919-1931). With its small Secretariat in Paris, it operates with a global membership of more than 100 National Scientific Bodies (usually the national Academies of Science) and some thirty Scientific Unions many of whom, in turn, operate through a sub-structure of specialised Associations, Commissions and Committees. ICSU also operates through a set of Interdisciplinary Bodies. Its mission is to strengthen international science for the benefit of society (ICSU, 2006).

The International Architecture of Earth System Science

The description and understanding of the natural systems of the planet have long been seen as one of the great challenges for science and the provision of essential environmental information in support of community safety and welfare as one of the basic responsibilities of government for the supply of public goods (Malone, 1993; Zillman, 1999a). Because of the global interdependence of atmospheric processes and the pervasive influence of weather and climate on almost every aspect of human society and economy, meteorology historically led the way, among the earth sciences, in establishing world-wide observing networks, mounting international research programs, developing global prediction models and providing coordinated information, forecast and warning services to the community (Anthes, 1993; Zillman, 1999b, Obasi, 2003).

But, increasingly through the second half of the 20th Century, as community needs for information, understanding and prediction of the state and behaviour of the atmosphere, oceans, lakes and rivers, and terrestrial and marine ecosystems (collectively, the atmosphere, geosphere and biosphere) (Figure 2) as well as the near-earth space environment became more urgent and realisation grew that none of the components of the earth system can be properly observed, understood or modelled in isolation (White, 1981; Smagorinsky, 1983; Dooge, 1986; Spengler, 1987; Bolin, 1988; Stommel, 1991; Malone, 1992; Bruce, 1995; Izrael, 1996), it became necessary to dismantle the formerly rigid walls between the traditional domains of meteorology, oceanography and hydrology and the various sub-domains of physics, chemistry and biology on which they were built. We now tend to see all of these as part of an increasingly integrated field of earth system science (Lawton, 2001; Asrar et al, 2001) and we continue to search for the most appropriate institutional frameworks for achieving the necessary international, interdisciplinary and inter-functional cooperation, coordination and overall interoperability for meeting the contemporary needs and expectations of society including especially for reducing the impact of human activities on the environment in order to ensure sustainable development (World Commission on Environment and Development, 1987; McBean and Qin, 2007).

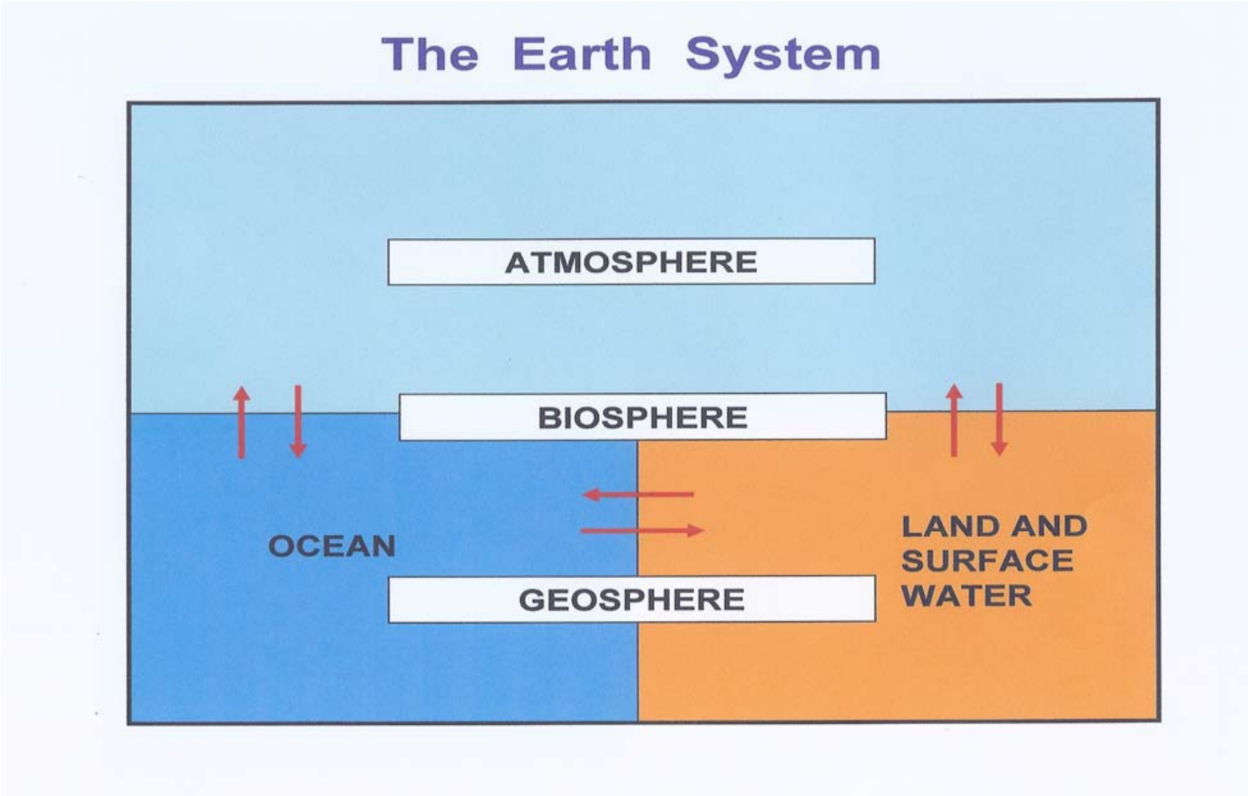

Figure 2 *The earth system consisting of the atmosphere, geosphere and biosphere. The atmosphere consists of the troposphere, stratosphere and mesosphere and the ionised layers of the ionosphere above. The geosphere is made up of the hydrosphere (oceans and fresh-water), the cryosphere (ice and snow) and the lithosphere (the earth's crust and upper mantle). The biosphere is the thin near-surface layer of air, water and land that supports life. The atmosphere, ocean and land surface are physically coupled through the exchange of mass, momentum and energy between them.*

As an essential minimum, we need a generally accepted framework which gets meteorology, oceanography and hydrology "onto the same page" and recognises the fundamentally important role of observations and data processing in underpinning the research and modelling on which the capacity for service provision in support of the wide range of applications to human needs must be built (Figure 3). And, most importantly for present purposes, we need a framework which facilitates the aggregation of the efforts of individual countries, whether carried out for reasons of self-interest or altruism, in a positive sum game to provide the essential global public goods on which the entire world community can draw. In practical terms, this means that we need international program structures and institutional frameworks which bring the contributions of individual countries together into an integrated whole and, at the same time, provide effective international support for integrated observation, research and service delivery at the national level. The next most important dimension that we must add to the simple two dimensional architecture of Figure 3, therefore, is that which aggregates the individual national observation, research and service delivery activities across the three earth system domains into an internationally coordinated whole. The essential building blocks of earth system science and services are thus, clearly, the various international programs that occupy the cells of the 3x3 matrix of Figure 3.

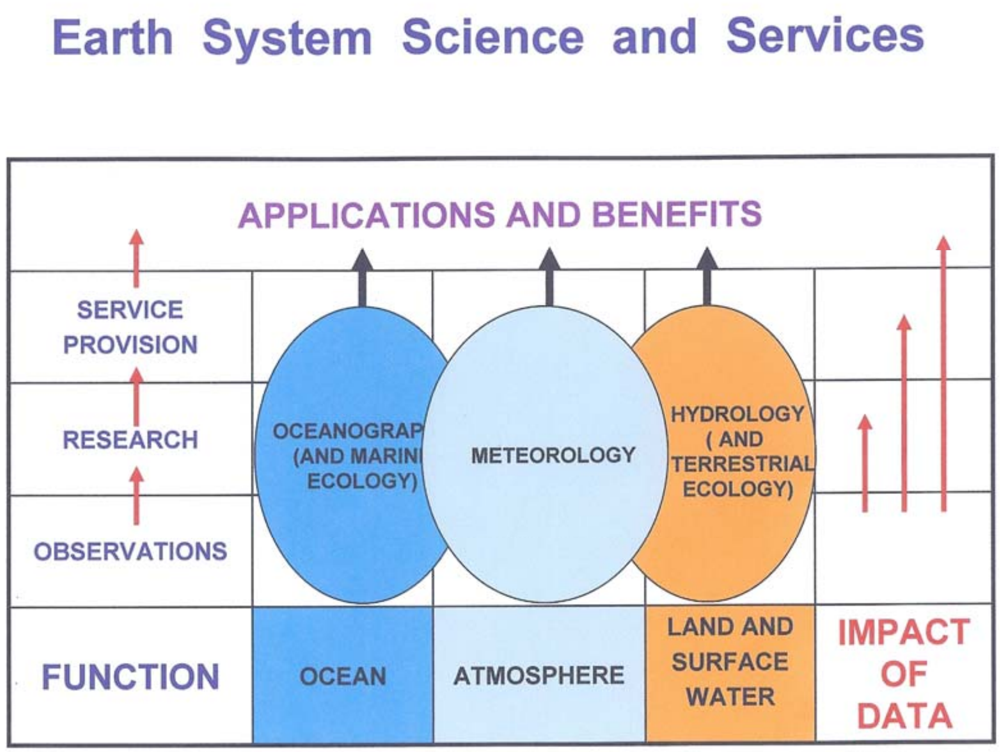

Figure 3 A *simple two-dimensional view of the architecture of earth system science in terms of the three main domains (ocean, atmosphere, land and surface water) and the three main functions (observation, research, service provision) involved in delivering benefits to society. The arrows on the right emphasise the underpinning role of observations for research, service provision and a wide range of applications and benefits for society*.

In proceeding to elaborate a few of the historical and institutional building blocks on which the future international architecture of earth system science will be built, I assume that I will be forgiven for again emphasising the extent to which meteorology has lead the way. I will draw, especially, on the meteorological application of the theory of global public goods (Gunasekera and Zillman, 2004). And I would like to use this special focus on meteorology to enable me to return, at the end, to offer as objective an assessment as I can of the validity of Sir Arthur Davies' characterisation of meteorology as 'a model of international cooperation' (Davies, 1986).

In the Beginning

The meteorological historian Howard Frisinger regards the 1723 initiative by the Secretary of the Royal Society of London, James Jurin (successor to Robert Hooke, regarded by many as the 'father of modern meteorology') to assemble annual records from a network of volunteer observers across Europe, Asia and North America as the first truly international effort at collecting and comparing weather observations (Frisinger, 1977). In 1771, J H Lambert proposed a fully standardised world network of meteorological stations and, from 1780 to 1795, the Societas Meteorologica Palatina at Mannheim routinely assembled and published observations from 57 stations across Europe and North America (Frisinger, 1977; Davies, 1990). With the development of Morse Code telegraphy in 1843, it became possible to collect observations in real time and the first weather maps based on telegraphic reports from across national borders appeared in the early 1850s.

The real beginning of the modern concept of international cooperation in meteorology, however, through what would nowadays be described as a 'user-driven' approach, was due to US Navy Lieutenant Matthew Fontaine Maury. In August 1853, he convened the First International Meteorological Conference, in Brussels, of (mainly) naval representatives from nine countries to agree on a plan for standardisation, collection and analysis of meteorological data from ships' logs to assist in marine navigation around the world (Maury, 1855). Though somewhat looked down on from scientific circles (Cox, 2002) the Maury vision was bold in the extreme. In his own words "This plan contemplates the cooperation of all the states of Christendom, at least so far as the form, method, subjects of observations, time of making them, and the interchange of results are concerned. I hope that my fellow-citizens will not fail to …..….. cooperate in such a humane, wise and noble scheme" (Maury, 1855). And then, with amazing prescience of one of the most challenging issues facing international meteorological cooperation in the 21st Century, he asserted "Another beautiful feature in this system is, that it costs nothing additional".

As it turned out, the following decades brought a great upsurge of scientific and practical work on international standardisation of observation collection from land as well as at sea and, in 1873, the Government of Austria convened the First International Meteorological Congress which gave birth to the International Meteorological Organization (IMO) as the almost universally recognised framework for international cooperation in meteorology until its replacement by the World Meteorological Organization (WMO) in 1950 (Davies, 1990; Gibbs, 1994).

Through its three quarters of a century of operation, the IMO went through substantial changes in its membership and management structure which largely internalised the tensions between the governmental and non-governmental aspects of its role and between its scientific and operational functions. Although strictly a non-governmental organisation, it doubled as an intergovernmental coordination mechanism, with its peak body for most of its life consisting of a ‘Conference of Directors’ of (the, by then, mainly governmental) National Meteorological Services (NMSs), albeit serving essentially in their personal capacities. In many respects, though, the centrepiece of IMO and much of the source of scientific progress in international meteorology through the first half of the 20th Century was the IMO system of extremely active Technical Commissions (Langlo et al, 1982) responsible for such areas as:

- Terrestrial magnetism and atmospheric electricity;
- Solar radiation;
- Exploration of the upper atmosphere;
- Synoptic weather information;
- Agricultural meteorology;
- Application of meteorology to aerial navigation;
- Maritime meteorology;
- Investigation of waves of explosion;
- Study of clouds;
- Climatology; and
- Polar meteorology.

The members of the Commissions were, for the most part, experts serving in their personal capacities but, with the establishment of intergovernmental regulatory structures for civil aviation in the 1930s, the IMO Commission for Aerial Navigation was restructured as a body of governmental representatives rather than individual experts. Indeed, more generally, between World Wars I and II, the need to strengthen the intergovernmental aspects of international meteorological cooperation became increasingly apparent and work began under Dr Th Hesselberg, the Director of the Norwegian Meteorological Service and the sixth President of IMO, on the draft of a new intergovernmental World Meteorological Convention (Davies, 1990).

Through the IMO years and especially following the establishment of ICSU in 1931, an important complementary role in international cooperation continued to be played by bodies such as the Royal Society of London and the various national Academies of Science. But the tensions between the disciplines of science and the demands of service were never far from the surface following the early clashes between the Royal Society and Admiral Robert Fitzroy of the UK Meteorological Office (Gribbin and Gribbin, 2003) and similar confrontations in other countries. In 1939, Sir Napier Shaw asserted that “The stress of service has hampered the progress of the science”, not a position that, I believe, would be taken so strongly today (Zillman, 2003).

But it is, perhaps, not surprising, given the attitudes of the times, that the Royal Society and the international scientific establishment were only cautiously receptive to the visionary proposal from the Australian polar explorer-scientist Sir Hubert Wilkins (Nasht, 2005) in the 1930’s for a coordinated global weather monitoring system and an international meteorological bureau on a scale that, three decades later, following the advent of meteorological satellites and computers, was to become the WMO World Weather Watch.

The World Meteorological Organization

With the Hesselberg draft as its foundation, and following a final meeting in Toronto of all the IMO Technical Commissions, the Convention of the World Meteorological Organization (WMO) was negotiated to finality, signed on behalf of governments by the representatives of 31 countries in Washington DC in October 1947 and came into force on 23 March 1950. The First World Meteorological Congress in Paris in March-April 1951 established the basic operating structure of WMO and approved its entering into agreement with the United Nations (UN) to become a Specialised Agency of the UN. The first President of WMO was Dr Francis Reichelderfer of the United States who, on his retirement after 25 years as Chief of the US Weather Bureau in 1963, received a letter from President Kennedy commending, in particular, his leadership in "international scientific cooperation"(Reichelderfer, 1982).

With essentially universal Membership, now totalling 188 States and Territories, WMO has provided the global framework for intergovernmental cooperation in 'world meteorological activities' since 1950. The working of WMO inherited many of the features of the IMO but the supreme body of WMO, the quadrennially meeting World Meteorological Congress, its Regional Associations and its Technical Commissions are fully intergovernmental, albeit the Commissions are comprised of governmentally designated technical experts in the field of coverage of the Commissions which deal with basic systems, research and the various applications of meteorology and related fields. The two unique features of WMO, also largely inherited from IMO, which, in my assessment (Zillman, 2006), have been primarily responsible for its extraordinary success as a mechanism for international cooperation over the past fifty years, are:

- The provision that the 'Permanent Representatives' of countries with WMO, while normally the Directors of their NMSs, should draw on, and look to the interests of, their entire national communities, governmental and non-governmental, in planning and carrying out the work of the Organization; and
- The fact that the President and Vice-Presidents of WMO and the members of its annually meeting Executive Council, while elected from the ranks of the governmental Principal Delegates to its Congress, are elected in their personal capacities to serve the interests of the entire Organization without influence from their own governments when fulfilling their duties as officers of the Organization.

The WMO is comprised of its Members, its Constituent Bodies and its Geneva-based Secretariat of several hundred headed by the full-time Secretary General appointed by the Congress and responsible to the President of the Organization. The Major Programmes of WMO, especially its core Programme, the World Weather Watch, consist of the integrated activities of all its Members carried out within a framework of General and Technical Regulations and Congress-determined policies and plans. The so-called Regular Budget of WMO is administered by the Secretary General in providing Secretariat support for the work of the Members in implementing the agreed WMO Programmes and Plans.

Though one of the smaller and least political of the global intergovernmental organisations (Henderson, 1988), the existence of WMO makes meteorology the only individual field of science with its own Specialised Agency of the United Nations (Davies, 1990; Obasi, 2003).

Even in its early years, however, there was considerable debate as to how broadly 'world meteorological activities' should be interpreted and especially what should be encompassed under the WMO mandate to facilitate world-wide cooperation in the establishment of networks of stations for the making of 'meteorological observations or other geophysical observations related to meteorology'. There was particular uncertainty over the extent of the WMO role in hydrology reflecting the differing allocations of responsibility for hydrology at the national level in Member countries. And, even from the beginning, there were proposals from some of the visionaries of the time to recast WMO as a 'World Geophysical Organization' (Fedorov, 1981). As it turned out, the boundaries between meteorology and both oceanography and hydrology evolved pragmatically, helped, in the case of hydrology, by the useful, if somewhat arbitrary, distinction between operational (WMO) and scientific (UNESCO) hydrology built into the joint activities of the International Hydrological Decade (1965-74). Then, after lengthy consultations, the 1975 Congress amended the Convention to give WMO coverage of 'world meteorological and related activities' and expand its facilitation role to 'meteorological observations as well as hydrological and other geophysical observations related to meteorology'. The Congress, however, stopped just short of explicit mention of oceanography.

UNESCO and the Intergovernmental Oceanographic Commission

International oceanography has many similarities to international meteorology and solution of the many outstanding problems in oceanography requires the same kind of international cooperation as in meteorology (White, 1981; Holland, 1998). But, while meteorology, including especially marine meteorology, has always had a strong operational and service dimension and the WMO had almost a century of institutionalised international cooperation on which to build, oceanography, historically, tended to be more regionally focussed and research oriented. So, when Roger Revelle, Warren Wooster and other eminent oceanographers of the time met under the auspices of UNESCO in Copenhagen in July 1960 to discuss the need for a world organisation dealing with ocean science, their recommendation was for the establishment of an Intergovernmental Oceanographic Commission (IOC) within UNESCO, itself a big sister Specialised Agency to WMO (Holland, 1998). The IOC was thus established by the immediately following 1960 General Conference of UNESCO. In line with the overall charter of UNESCO (Mayor, 1997), its initial mission was focussed specifically on international collaboration in oceanographic research (White, 1981).

Over the succeeding decades, the focus of the IOC moved progressively more towards the operational aspects of ocean data collection, especially following the establishment of the (initially so-entitled) Integrated Global Ocean Station System (IGOSS) , the establishment of increasingly broadly-based working relations with WMO and the subsequent development of the Global Ocean Observing System (GOOS) – as a sort of 'World Ocean Watch', an ocean counterpart to the WMO World Weather Watch (Hallgren, 1971, 1997; White, 1981); and then, further still, especially following the establishment of the IOC-WMO Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), to a strong emphasis on marine observation, data management and service provision, in addition to ocean research.

Within UNESCO, a clear distinction was maintained for many years between UNESCO activities in ocean science, carried out alongside its programs in scientific hydrology and the other natural (including biological and solid earth) sciences such as the International Hydrological Programme (IHP) and Man and the Biosphere (MAB), and those of the IOC which carries functional autonomy within UNESCO through its own intergovernmental Assembly as its supreme governing body. The IOC, in recent years, has carried a particularly important and politically visible role in international coordination of tsunami warning.

Many in the IOC and WMO communities have aspired for the IOC to grow into a fully-fledged ocean counterpart of WMO, albeit, if necessary, still within the broad overall framework of UNESCO, as a genuine UN Specialised Agency for the Oceans. That, unfortunately in my view, has still to come to pass.

The International Council for Science

The primary non-governmental framework for international cooperation in earth system science is provided by the International Council for Science (ICSU).

While several of the ICSU Unions carry responsibility for particular areas of earth science (eg the International Union of Geological Sciences (IUGS)), the main role is played by three of the Associations of the International Union of Geodesy and Geophysics (IUGG), the:

- International Association of Meteorology and Atmospheric Sciences; (IAMAS);
- International Association of Physical Sciences of the Ocean (IAPSO); and
- International Association of Hydrological Sciences (IAHS);

along with a series of ICSU interdisciplinary assessment, thematic and data coordination bodies such as the :

- Scientific Committee on Problems of the Environment (SCOPE);
- Committee on Space Research (COSPAR);
- Scientific Committee on Oceanic Research (SCOR);
- Scientific Committee on Solar-Terrestrial Physics (SCOSTEP);
- Committee on Data for Science and Technology (CODATA); and the
- Panel on World Data Ccentres (WDC).

ICSU itself and its Committees and Unions and their Associations and subsidiary specialist Commissions individually, through joint initiatives, and especially through joint activities with various parts of the UN System have mounted a wide range of international earth observation and research programs. The early manifestations of what must now be regarded as an especially close international partnership between the atmospheric and oceanic research communities emerged from the first Joint Assembly of IAMAS and IAPSO in Melbourne in 1974.

In addition to its long-standing partnership with WMO and IOC in a host of atmospheric and oceanographic observation and research programs over the years, ICSU has played a vital role in bringing together the international biological, ecological and solid earth research communities to address the many emerging issues associated with human impacts on the environment (Perry, 1996). Perhaps the two most notable such initiatives were the SCOPE 29 Report (Bolin et al, 1986), which paved the way for the establishment of the WMO-UNEP

Intergovernmental Panel on Climate Change (IPCC), and the establishment of the ICSU International Geosphere Biosphere Programme (IGBP).

Regional and Bilateral Cooperation

Regional cooperation in the atmospheric, oceanic and hydrological sciences, is focussed strongly in the regional subsidiary bodies of WMO and IOC, the WMO Regional Associations and IOC Sub-Commissions, which maintain strong collaboration in observational network operation and data collection and in such important regional applications as typhoon and hurricane warning and marine meteorological and oceanographic services.

The two outstanding meteorology-specific non-UN intergovernmental organisations are the European Centre for Medium Range Weather Forecasts (ECMWF), established in 1975 (Woods, 2006), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), established in 1986 (EUMETSAT, 2001). Both had their origins in a fascinating series of scientific and political developments within the European Community and both have emerged as major players in international meteorological cooperation, operating essentially in club mode (Cornes and Sandler, 1996) within the community of European NMSs but also taking on major responsibilities in the overall system of global cooperation provided by WMO, IOC and ICSU.

The Caribbean Meteorological Organization (CMO) has played a particularly effective role in coordinating the activities of the many small NMSs of the English-speaking countries of the Caribbean. Similar groupings exist for other regions and purposes such as, for example, the provision of aviation meteorological services in Western Africa.

Many other non-UN and non-meteorology/oceanography-specific regional bodies also play an active role in coordination of earth system science and services such as the intergovernmental South Pacific Regional Environment Programme (SPREP) and South Pacific Applied Geosciences Commission (SOPAC) and the non-governmental Pacific Sciences Association (PSA).

There are, also, of course, the various professional societies of which the American Meteorological Society (AMS) has been pre-eminent in working with other regionally focused professional societies such as the European Meteorological Society (EMS), the African Meteorological Society, the Chinese Meteorological Society, the Australian Meteorological and Oceanographic Society (AMOS) and the Canadian Meteorological and Oceanographic Society (CMOS) in organising joint conferences, establishing scientist to scientist collaboration across national borders and the like.

The work of all of the many global and regional cooperation organisations is complemented and under-pinned by hundreds of bilateral cooperation agreements in the various areas of earth system science between government agencies (eg Zou and Zillman, 1989; Qin and Zillman, 2004), national academies, universities and research institutes. The international web of research partnerships and linkages fostered by these agreements is very strong and extremely productive.

The Invisible College

Notwithstanding the effectiveness of all these formal structures for international cooperation, it is, perhaps, the invisible colleges (Ziman, 1994) of shared scientific interest and commitment, which they spawn and build on, that play the most fundamental role of all. How beautifully this is captured in George Cressman's Postscript to his AMS 75th Anniversary review (Cressman, 1996) where he reflects on the impact of communication of ideas across international boundaries in the numerical weather prediction community:

> "It was an informal club of good friends and colleagues. The leading workers in numerical weather prediction were in frequent communication through letters, telephone calls and visits, both short and extended. Nothing was secret, and there were no monetary charges to each other for data, computer time, methods or results. What benefited one benefited all. No significant advance was private for more than a very short time. It was an ideal milieu for scientific progress – a Camelot that deserves to be remembered".

I believe that this openness of communication and free exchange of information among the institutions of meteorology has been one of its greatest strengths. Indeed, in economic as well as colloquial terms, the global network of National Meteorological Services and research institutions enjoys many of the most positive features of a 'club' (Cornes and Sandler, 1996). It would not be inappropriate, here, to quote, in full, from the closing lines of the 1992 Taba interview with a person whose insights into international meteorological cooperation were probably as deep as any, the late Gordon Cartwright (Cartwright, 1992):

> "Meteorology presents unlimited challenges. In some ways it is as complex as any of the sciences. But by its very nature it inspires this sort of brotherhood among meteorologists the world over which is so deeply satisfying. Once I was walking down a long hill in Wellington with Dr Richie Simmers, then Director of the New Zealand Meteorological Service, to have lunch at his club. We were talking about our various experiences, his in the southern hemisphere and mine in the northern, and I shall never forget Dr Simmers' remark: "You know Gordon, we meteorologists belong to the best club in the whole world".

Sometimes the clubbiness of international meteorology is used as a label of criticism. Like Richie Simmers and Gordon Cartwright, I believe that meteorology is not only the best club in the world but the one that most effectively provides the whole world with some of its most essential and valuable public goods.

Education, Training, Technology Transfer and Technical Cooperation

Since the early days of WMO, IOC and ICSU, there has been a strong commitment to international cooperation in education and training (Kintanar, 1998; Zillman, 2000a) and to the sharing of technologies for observation, communication and service provision (Davies, 1990; Obasi, 2003). WMO's Voluntary Cooperation Programme (VCP) and IOC's Training, Education and Mutual Assistance (TEMA) have played a vital role in building the professional and administrative capabilities and technical infrastructure of the developing countries and enabling them to play their part in the successful operation of global programs such as the World Weather Watch and the Global Ocean Observing System.

The Great Success Stories of International Cooperation

It is hard to attend an international dinner at the annual meetings of the AMS, sit in on a planning meeting for THORPEX or read the Annual Reports of WMO and IOC without feeling great satisfaction with the totality of the rich fabric of international cooperation in the atmospheric and oceanic sciences over the past century.

But there have been some truly iconic achievements in our field since the Brussels Conference of 1853 which I think deserve special mention. If I am limited to just three, I would identify these as:

- The International Polar Years including the IPY 2007-08 now nearing completion;
- The World Weather Watch (WWW) and the Global Atmospheric Research Programme (GARP); and
- The World Climate Programme (WCP) and the Intergovernmental Panel on Climate Change (IPCC).

The First Polar Year (1882-83) was one of the early major scientific and logistic achievements of the IMO (Corby, 1982). IMO members joined forces to send 13 expeditions to the Arctic and two to the Antarctic to carry out meteorological and magnetic observations for a full year with the results edited by, and published under the leadership of, the then President of IMO, Professor Heinrich Wild of the St Petersburg Academy of Science. The Second Polar Year, fifty years later in 1932-33, was a much larger undertaking by the IMO, this time with a stronger focus on the Antarctic and carried out in conjunction with the newly established ICSU. But it, in turn, was followed by the far more ambitious and scientifically and geographically comprehensive International Geophysical Year (IGY) of 1957-58 led by the IUGG with the early and strong support of the newly established WMO and in the spirit of an agreement between IUGG's (then) IAMAP (International Association of Meteorology and Atmospheric Physics) and WMO which was summarised by a key player of the time in both organisations, Dr Reg Sutcliffe (Sutcliffe, 1981), as 'assigning to WMO all the hard work of international organisation and to IAMAP the arranging of scientific meetings' (Davies, 1990). The IGY was a huge scientific and logistical undertaking that marked the dawn of the space age and triggered the negotiation of one of the great success stories of international political cooperation, the Antarctic Treaty (Triggs, 2006).

But even more ambitious and far-reaching undertakings in international meteorological and oceanographic cooperation lay just ahead – in the form of the almost twin birth of the operational World Weather Watch (WWW) and the Global Atmospheric Research Programme (GARP). Inspired by the IGY and the possibilities opened up by earth orbiting satellites and numerical weather prediction for greatly improved weather and climate forecasting and warning for the good of the entire world, and triggered by a series of US-sponsored resolutions by the UN General Assembly in 1961 and 1962, the planning and implementation of the WMO WWW and the WMO-ICSU research-operations, meteorological-oceanographic, weather-climate partnership of GARP over the following two decades (Fleagle, 2001) must be regarded as one of the finest achievements in international cooperation the world has ever seen.

Looking back on the planning of the 1979 Global Weather Experiment (Zillman, 1977), the so-called First GARP Global Experiment (FGGE), and it's implementation and use as a basis for redesign of the already immensely successful WWW, it is hard to believe that so much could have been achieved so quickly and so well. Much has been, and will be, written about the WWW and GARP (eg Davies, 1990). Suffice it here to observe that it should be a matter of great pride and satisfaction for this scientific community, as well as cause for reflection when planning for the future, that the WWW and GARP were conceived, born and grew to maturity as two of the most globally comprehensive scientific undertakings of all time, at the height of the Cold War as a product, as much as anything, of the flow-on to the entire professional meteorological and oceanographic communities of the personal trust, friendship and shared commitment to develop science for the good of the world, between a succession of leading WMO figures from West and East: Wexler-Bugaev, White-Fedorov, Hallgren-Izrael - and carried on, it should be said, by their successors Friday/Kelly/Hayes of the US and current WMO President Bedritsky of Russia.

The story of the planning and implementation of the World Climate Programme (WCP) as a joint initiative of WMO, IOC, UNEP (United Nations Environment Programme), FAO (Food and Agriculture Organization) and ICSU and especially of its research component the (now) WMO-IOC-ICSU sponsored World Climate Research Programme (WCRP) and the increasing interdisciplinarity achieved through collaboration with the ICSU International Geosphere Biosphere Programme (IGBP) and other programs to form the Earth System Science Partnership (ESSP) is one of the many other great accomplishments in international cooperation in the earth system sciences. But I cannot fail to single out for special mention the even more remarkable experiment in international scientific cooperation that is represented by the assessment work of the WMO-UNEP Intergovernmental Panel on Climate Change (IPCC). Though the pressures for a broadly-based assessment mechanism for climate change had been building for some years, the IPCC had its formal origins at the 1987 World Meteorological Congress where the head of the US Delegation, one Richard E Hallgren played a key role, behind the scenes, in building support for what turned out to be exactly the right combination of scientific independence and government authority. Though rejected by some (eg Boehmer-Christiansen and Kellow, 2002) as a source of objective scientific information and accepted, perhaps too much on faith, by others (eg Gore, 2006; Stern, 2006), I believe that the IPCC has served the world extremely well (Zillman, 2007) through its regular preparation of policy-relevant but policy-neutral assessments of climate change science as essential input to the international public policy process. And, in paying tribute to the many thousands of natural and social scientists from almost ever country in the world who have worked together on the IPCC assessments over the past 20 years, I note with sadness the recent passing of its first Chairman, who had served also as the first Chairmen of the Joint Organising Committee for GARP, the late Professor Bert Bolin of Sweden. In a letter just twelve days before his death, to his IPCC colleagues, Professor Bolin characterised the achievements of the IPCC as those of a 'great cooperative undertaking' (Parry, 2007).

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The Benefits of International Cooperation

From even a brief survey of the achievements of the Polar years, WWW, GARP, the WCP and the IPCC, it might seem reasonable to observe that the benefits of international cooperation in meteorology and its sister earth system sciences and services are so self-evident that no more need be said.

And so it was for many years. But, over recent decades, it has become increasingly necessary, in government, academic and private sector allocation of resources, to more clearly demonstrate the margin of benefits over costs, not just within each of the various areas of science and service but especially in the balance between what is done for strictly national purposes and what is done incrementally by way of investment in international cooperation – both for altruistic reasons and to help ensure the availability of essential public goods for the sake of the even greater benefit that they will deliver at the national level in every country. If the current annual global investment in meteorology and related activities is of the order of US$10B and the benefits, as they have confidently been estimated to be, at least an order of magnitude larger, it is reasonable to ask whether the 1-2% of expenditure that is currently assigned specifically to international cooperation – through national cooperation programs as well as in the form of national contributions to the budgets of WMO and other international mechanisms of cooperation – is large enough. I regard international meteorological economics (Zillman and Freebairn, 2001) as an important area for development and hope that the follow-up to the Action Plan from the March 2007 Madrid Conference on Social and Economic Benefits of Weather, Climate and Water Services (WMO, 2007a) will be helpful in this regard.

For present purposes, however, let me just allude briefly to some of the enormous societal benefits that flow, directly and indirectly, from the system of international cooperation that has been put in place over the past century (Zillman, 1997a,b). These include:

- *Natural disaster reduction*. It was the Genevoise philosopher Rousseau in 1682 who suggested in 'The Social Contract' that Providence created natural disasters to force men to cooperate (Cranston, 1968). If this is true, it has been extremely successful as evidenced by the high level of national and international cooperation that has been achieved in providing storm, hurricane, flood, fire and drought forecasting and warning systems and the loss of life and property that they have averted over the years (Hallgren, 1993; Zschau and Küppers, 2002). For anyone seeking evidence of the power of international cooperation to do good in the world, I commend the Roman Kintanar story (Kintanar, 1998) of the establishment of the ESCAP Typhoon Committee and the WMO Tropical Cyclone Programme. The international scientific and technical cooperation necessary for the effective operation of national warning systems has been greatly facilitated over the past few decades by initiatives such as the International Decade for Natural Disaster Reduction (IDNDR) and the more recent WMO (WMO, 2004) and ICSU (McBean, 2007) programs for disaster research and management.

- *Safety of Life at Sea*. From the foundation provided by the Brussels Conference of 1853, the regime of international cooperation in the collection and dissemination of ships' data and the broadcast of marine forecasts and warnings that has progressively been put in place by WMO, IOC and other international maritime organisations within the framework of the International Convention for the Safety of Life at Sea (SOLAS), remains a critical component of the international infrastructure that supports the 80% of world trade carried by ships plying the global oceans (CAETS, 2005).

- *Aviation safety and efficiency*. The original rationale for the establishment of NMSs in many countries was the provision of weather support for international civil aviation (Zillman, 1999a). At the intergovernmental level, the long-standing partnership between WMO and the International Civil Aviation Organization (ICAO) has shaped a regime of international cooperation in the provision of meteorological support for civil aviation that costs the industry and, thus the international travelling community, only a fraction of what it would cost to provide similar levels of safety assurance by other means. Although weather was a much more critical safety factor in the early years of civil aviation than it is now (Cartwright and Sprinkle, 1996), it is still true, as noted often and forcefully by Dick Hallgren in WMO fora in the 1980s, that the hundreds of thousands of people who travel each day along the skyways of the world fly much more safely because they fly with the round-the-clock support of internationally coordinated aeronautical meteorological services.

- *Economic development*. Whether it be through day by day agrometeorological support for subsistence farming in Africa, the use of El Niño based seasonal outlooks for large-scale rural planning in the developed countries or the design and operation of water resource, energy, transport and communication infrastructure in every country, the widespread availability of internationally sourced meteorological and related information and technology has become a critical success factor in national strategies for sustainable development (GCOS, 2006; WMO, 2007b).

- *Environmental policy and programs*. Meteorological, oceanographic and related science and services make a vital contribution to national and international policies and programs for environmental protection. Internationally coordinated ocean services are critical to the prevention and management of oil spills and other forms of marine and coastal pollution. The international climate monitoring, research and assessment carried out, respectively, through the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC) have been central to almost every aspect of the international effort to address the threat of human induced climate change through the negotiation and implementation of the UN Framework Convention on Climate Change (UNFCCC, 1992).

- *Public safety and welfare*. I may not be completely objective on this but I believe that the international cooperation that has been put in place through the WMO Public Weather Services Programme over the past 15 years has delivered enormous improvement in the quality and utility of public weather and climate services in many parts of the world and hence in their overall contribution to public safety and welfare in both developed and developing countries (O'Loughlan and Zillman, 2007).

- *Understanding of the natural world*. Through their ramifications into various areas of science, economics, business, law and other aspects of human affairs that go far beyond the normal reach of the meteorological and oceanographic communities, the internationally cooperative atmospheric and oceanic research programs of the past century have contributed enormously to the broader benefits that flow from increased understanding of the natural world and hence, ultimately, to the overall good of humanity (Board on Atmospheric Sciences and Climate, 1998).

The Threats to International Cooperation

The level of international cooperation in meteorology and related fields that leverages the benefits to humanity mentioned briefly above has been hard won. It would be wrong to assume that it has come easily or that it is permanently secure. General theories of international cooperation (Henderson, 1988) and the specific experience in meteorology (Bureau of Meteorology, 2000) underscore the difficulty of achieving socially optimum levels of international cooperation and the fragility of the conditions which maintain it.

It is not widely understood just how close international meteorological cooperation under WMO came to collapse in the late 1980s and early 1990s or how carefully those who went through the crisis believe it will be necessary to monitor developments in the World Intellectual Property Organization (WIPO) and the World Trade Organization (WTO) General Agreement on Trade in Services (GATS) if we are to ensure the long-term survival of the WMO system of international cooperation.

The massive swing that began in many parts of the world in the 1980s towards redefinition of the role of the public sector and the use of markets for provision of many of the services that had traditionally been provided by governments (Kelsey, 1997) forced many NMSs towards a more commercial mode of operation and the assertion of property rights in nationally collected data that they had previously exchanged freely as global public goods (Reichman and Samuelson, 1997; Zillman, 1997c, d). Many of the essential conditions for international cooperation came under stress and it was widely feared that we were on the brink of the break-down of the free and unrestricted exchange that had underpinned international meteorology for generations but had been seen as so fundamental in the IMO era that it was not even felt necessary to build it into the WMO Convention. The crisis took different forms in different parts of the world as pressures mounted to set aside the unwritten understanding that NMSs would use the freely exchanged data received from other countries only for the purposes of meeting their own domestic and internationally agreed responsibilities and would not use those data to interfere in the public good responsibilities of the originating NMSs. While the feared international data war was eventually averted through the unanimous adoption of the so-called Resolution 40 of the 1995 World Meteorological Congress, the international data exchange regime that it provides is less comprehensive and arguably less robust than what went before (Zillman, 1997c).

The other threat to international cooperation in meteorological data exchange which surfaced for a while in the late 1990s, followed from WIPO moves to conclude a *sui generus* treaty on property rights in data bases and the prospect of GATS provisions leading, directly or indirectly, to the requirement for competitive trade regimes in some or all of the services that are an integral part of the cooperative regime of international meteorology. While it appears that most of these are adequately covered by the GATS exception for 'services provided to the public in the exercise of government authority' (Gunasekera and Zillman, 2004), this remains a live, if currently dormant, issue and one where it will be in the interests of both the NMS and commercial meteorological service provider communities to establish an agreed policy basis for a united stand.

Just like individual people, the states and institutions party to the WMO Convention and similar international and inter-institutional agreements can be expected to continue to play their part only as long as they feel strong ownership of shared objectives, trust in the goodwill of others, confidence that every one else will play their part and the assurance that there are no, or few, free riders in the club (Kaul et al, 1999). Perhaps most importantly of all for the regime of international meteorological and oceanographic cooperation amongst nation states, those who command the resources, both in the national science and service agencies and in the higher levels of government, must be helped to clearly understand the scale of the benefits that flow from international cooperation and the price that would be paid by all countries if this cooperation were to collapse (Zillman, 2002; 2005a; 2006).

Strategic Planning in International Earth System Science

I think there is little doubt that the outstanding success of the big international initiatives such as the IGY, the World Weather Watch, the GARP Atlantic Tropical Experiment (GATE) and the Global Weather Experiment (Bengtsson, 1983; Zillman, 1983) owed much to the vision and thoroughness of their planning and especially to the complementarity of the scientific and logistic components of the planning. Ever since its establishment, the World Weather Watch planners have maintained a comprehensive long-range strategy for its major systems such as satellites (eg Asrar et al, 2003).

While I may not be able to be entirely objective on matters relating to WMO planning, I also believe that the considerable achievement of international cooperation in meteorology over the past quarter of a century owes much to the WMO Long Term Planning process, instituted in 1979 (Langlo et al, 1982; Zillman, 1984, 1998; WMO, 2004). I regard the principal ingredients of its success as:

- The initial ten-year time-frame which was considerably longer than was fashionable in the UN System at the time that it was originated;
- The clear structural linkages from the basic purposes of WMO, through its overall policy and strategy to the objectives of its major programs and their supporting Secretariat departments;
- The formal assignment of program planning responsibility to the WMO Technical Commissions and Programme advisory bodies rather than to the Secretariat;
- The structuring of the scientific and technical components of the WMO Regular Budget to reflect the needs of the Member-determined programs; and most importantly

- The process undertaken to achieve close alignment of the WMO Plan with the objectives and priorities of the National Meteorological and Hydrological Services of its Members.

The remarkable achievement of the First to the Sixth WMO Long-term Plans (WMO, 2004) was the extent to which they were subsequently reflected in individual national policies and plans and the cohesion that this provided in the global implementation of WMO Programmes.

Similar planning processes have proceeded in IOC, ICSU and the many other institutions for international cooperation (eg ICSU, 2006). While I cannot attempt to assess them all, I believe there is compelling evidence that the effectiveness of international cooperation in meteorology, oceanography and the related earth sciences has been strongly dependent on the extent of Member country involvement in the planning processes of the responsible international organisations.

Cooperation Within the International System

One very important ingredient of successful international cooperation which I have already touched on several times is the nature and depth of cooperation among the many and diverse international organisations that themselves provide the framework for international cooperation within their individual catchment communities.

In this respect, I think we can claim enormous progress over the past few decades (Zillman, 2006). It may be a feature of the ease of modern-day communication but, with few exceptions, the once carefully erected walls between WMO and IOC and the various other individual governmental and non-governmental organisations providing international cooperation in the earth sciences have now largely disappeared. One needs no better example than the progressive convergence of the separate IOC and WMO activities in ocean observation and marine services into the agenda of the now Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM). Perhaps even more notable is the work of the joint scientific/steering committees and joint secretariats of the various co-sponsored programs, systems and activities such as:

- The WMO-IOC-ICSU World Climate Research Programme (WCRP);
- The WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS);
- The IOC-WMO-UNEP-ICSU Global Ocean Observing System (GOOS);
- The FAO-WMO-UNESCO-UNEP-ICSU Global Terrestrial Observing System (GTOS);
- The Integrated Global Observing Strategy Partnership (IGOS-P);
- The Earth System Science Partnership (ESSP); and
- The Intergovernmental Panel on Climate Change (IPCC).

The Role of National Institutions

One of the key requirements for successful international cooperation in any field is the existence of clearly defined and empowered national counterparts, usually but not always "government entities whose mandate is to deal with the rest of the world and who are responsible for the common provision of global public goods" (Kaul et al, 1999).

This requirement is well met in the case of international cooperation through WMO and ICSU programs. Though most WMO programs extend beyond the remit of the NMSs and, for this reason, it is incumbent on the Permanent Representative (usually the NMS Director) to consult widely at the national level, the close alignment of the mission of most NMSs with the core responsibilities of WMO, especially the World Weather Watch , means that there is a large body of shared values amongst those whose commitment is essential for success of the international programs and, over time, the opportunity for build-up of shared trust and mutual support as well as increased scope for satisfaction of national self interest.

What the world most needs now as we work towards even closer and more effective international cooperation across the full range of earth system science and services, is the establishment, in all countries, of clearly mandated national counterparts to the IOC and the various other international organisations and programs who make up the global earth science and service partnership at the international level. Countries need strong National Ocean Services (NOSs) and strong National Hydrological Services (NHSs) working in collaboration with their NMSs and perhaps, eventually, after the NOSs and NHSs have grown strong, some form of institutional partnership of all three, extending to the full range of environmental science services.

Meteorology as a Model for International Cooperation

I foreshadowed an attempt at a considered assessment as to whether we, in the international earth system science community, just feel especially privileged or whether meteorology really is a model of international cooperation as suggested by Sir Arthur Davies in 1986. From even this briefest of overviews, I believe it is clear that the past fifty years of international cooperation in meteorology more than meet the criteria that international relations theory would suggest for outstanding success. While it would be presumptuous to suggest that meteorology is <u>the</u> model of international cooperation, I think we can say with confidence that the world has yet to find one better. The success of international cooperation in meteorology is the product of the global nature of the atmosphere, the intellectual challenge of the science, the public good characteristics of meteorological infrastructure, research and services, the insatiable societal need for weather and climate information and the deeply ingrained traditions of trust, loyalty and shared commitment to the common good that pervade the global meteorological community.

GEO and GEOSS

For several decades, some of the visionaries in our field have been looking to the day when the entire earth system science community, including especially those working in the cross-cutting ecological and social science disciplines, would be called on to work together to implement the fully integrated global environmental science service system that was first proposed by Dick Hallgren in his AMS Address nearly 40 years ago (Hallgren, 1971), that was embraced by the 1972 Stockholm Conference on the Human Environment as the Global Environmental Monitoring System (GEMS) and which, by the 1980s, had emerged as an urgent requirement for informed stewardship of the natural systems of the planet (White, 1981; Fedorov, 1981; Baker, 1994).

The most fundamental component of such a system will clearly be an integrated earth observation system to underpin the research, modelling and service provision infrastructure needed to support the full range of socio-economic and environmental applications and needs of national communities (cf Figure 3).

The foundation and the core of such a system has now been in place for 40 years in the form of the Global Observing System (GOS) of the World Weather Watch and the ingredients of its success are well understood. Already by the early 1990s, the essential strategy for cross-domain, cross-agency and cross-discipline implementation of global observing systems was also largely in place with the initial implementation of the WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS) and the basis for its extension to a completely integrated earth observing system taking shape through the progressive implementation of the IOC-led Global Ocean Observing System (GOOS) and the FAO-led Global Terrestrial Observing System (GTOS). By the late 1990s, the various UN System and ICSU sponsors of the established systems had committed to the goal of an integrated earth observing strategy through the IGOS (Integrated Global Observing Strategy) Partnership and looked to the governments of their Members to make it happen (Zillman, 1997a).

The Global Earth Observation System of Systems (GEOSS), developed under the auspices of the initially ad hoc Intergovernmental Group on Earth Observations (GEO) set up by the First Ministerial Earth Observation Summit in Washington DC in July 2003, is thus a concept whose time has come. So, too, is the emphasis given in its Ten Year Implementation Plan (Group on Earth Observations, 2005) to its intended support for end-user benefits rather than earth observation for its own sake. I believe that the key ingredients for its successful implementation will be interdisciplinary trust and understanding, shared commitment, explicit recognition of the individual roles of its various components, a well-informed and receptive user community and the incremental resources need to strengthen its foundations and fill the gaps between its component systems (Zillman, 2005b).

The progress reported to the Fourth Ministerial Earth Observation Summit in Cape Town on 30 November 2007 (Group on Earth Observations, 2007) provides grounds for optimism that action on the GEOSS Ten Year Implementation Plan will be sufficiently advanced by 2015 to proceed with its long-term institutionalisation. I believe the three key steps will be:

- Establish national counterpart structures to GEOSS to ensure coordinated implementation and operation of its component observing systems at the national level;
- Encourage governments to move those essential components of GEOSS that are currently funded from national research budgets on to long-term operational funding; and
- Not later than the completion of the ten-year implementation phase, carefully and sensitively embed the intergovernmental GEO mechanism within the UN-ICSU System to bring the institutional ownership of GEOSS into alignment with the ownership of its main component global observing systems and so avert the otherwise

None of these steps will be easy but the international spirit of cooperation for their achievement is now in place and the benefits of success will be large.

The Future of International Cooperation in the Earth Sciences

International cooperation in the atmospheric and related sciences and services has contributed greatly to humanity over the past 100 years (Zillman, 2002) but it has the potential to contribute even more in the 21st Century. Two years ago, in response to an invitation from the Editor of the WMO Bulletin, I suggested as the five main challenges for international meteorological cooperation for the 21st Century (Zillman, 2005a):

- Ensuring that the forces of competition in an economically globalised world do not overwhelm the traditions of cooperation of the meteorologically globalised world;
- Maintaining the long-standing spirit of trust and ease of cooperation amongst the global meteorological community in an era of growing distrust, fear of terror and preoccupation with national and international security;
- Rebuilding faith in the universal mechanisms of the United Nations System and the use of WMO and its sister agencies (governmental and non-governmental) for the implementation of the essential global coordination arrangements for meteorology and related fields;
- More clearly defining the respective roles of WMO and it sister agencies and programmes in providing the framework for international cooperation in the earth system sciences; and
- Re-validating and strengthening the WMO charter to reflect the evolving role of meteorology on the global scene and to enshrine the basic principles of international cooperation and free exchange that provide the *sine qua non* for its existence.

I would now go further and suggest that, perhaps, the time is near when we should look to new international institutional arrangements which bring together the enormous strengths of the WMO model, the undoubted benefits and efficiencies of joint sponsorship by the UN System and ICSU and the new commitment to high level governmental support for earth system science and service that is promised by the GEOSS initiative.

I suggest therefore, that, once nurtured to accelerated maturity outside the established international framework for earth observation, GEOSS should be carefully and sensitively embedded within the UN-ICSU system, as suggested above, with GEO re-established as a joint (WMO-IOC-UNESCO-UNEP-FAO-WHO (World Health Organization)-ICSU,) high-level intergovernmental mechanism for its further planning and coordination; and, then, when this has been achieved, the interdisciplinary partnership of GEOSS should be extended from observations up the value-adding research, modelling and service provision chain (Figure 3) to establish an integrated Global Earth Observation, Research and Service System of Systems (GEORSSS) that provides, for the entire earth observation, research and service provision community, the international framework for cooperation that WMO, IOC and ICSU have provided so effectively in the past for the atmospheric and oceanic sciences.

The world will be well served if, by 2020, we can achieve an integrated international system, embracing all countries, spanning the full range of earth system science disciplines and serving the full range of user needs through coordinated national observation, research and service delivery systems involving the government, academic and private sectors. This will require new forms of partnership amongst more diverse scientific and service communities than have worked together in the past but all the key building blocks are now in place and the international sponsors have made clear their willingness to provide the necessary institutional framework (Jarraud, 2007). Perhaps the greatest challenge will be to reach agreement on its name!

International Cooperation, Institutions and People

Just as they have been in the past, the institutional arrangements that are put in place for future international cooperation in earth system science and service provision will be extremely important for its success. But more important, by far, will be the trust, friendship and shared commitment among the people from every corner of the globe whose role it will be to make those institutions work.

The foundations are very strong. The bonds of trust and friendship in the international meteorological and oceanographic community already bind tightly across the barriers of politics, race, religion and social and economic condition. In the words of one well-known member of our community in his response to a 1996 Taba Interview question as to what was the most unforgettable event of his professional life:

> "I have always tried to find a way to express how important international activities are to me. I would never have dreamed that I would have had the opportunities that I've had in my life, particularly internationally. To meet people from every country in the world, to have some of my closest and dearest friends from other countries, to be able to interact and learn about people from different parts of the world, different cultures, different ways of thinking, different backgrounds. It is not an event as such but, professionally this has been the most treasured component and experience"
> (Richard E Hallgren, September, 1996)

Dick Hallgren's affection for the international community was completely mutual and extraordinarily powerful as a lever for cooperation and a multiplier of goodwill.

It was the late Dr Roman Kintanar, for 36 years the Permanent Representative of the Philippines with WMO and President of WMO from 1979 to 1987 who wrote in his autobiography a decade ago (Kintanar, 1998):

> "Among the US Weather Service Directors, Dick was the one I was closest with because of his unassuming and friendly nature.
>
> While he was the representative of a super power, he championed the causes of small countries and was very well respected by the third world representatives.

Moreover, he was always casually dressed and wore his tie in his pocket".

I believe this country and this professional community should feel proud that, in the Hallgren era of international cooperation, the respect, affection and friendship felt towards the United States from the rest of the meteorological and oceanographic world was based on the certain knowledge that the US leadership in international activities was driven by the highest motives and directed at the common good.

Long may it continue.

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