**Union Lecture**

**UL1 - UL1 Union Lectures 1**

**IUGG-5771**

# Transformation of human society for sustainable future

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The train of human development is going in the wrong direction, driven chiefly by rising global population and their relentless pursuit of faster growth and more consumption. From here on, the emerging regions led by Asia will be the main drivers. How they choose to develop will largely determine the fate of our world. We must work closely with them to steer in a far more sustainable direction, by fundamentally transforming the way we think about, and go about, human development. Otherwise, what lie ahead will not be prosperity, but catastrophe.

**Union Lecture**

**UL1 - UL1 Union Lectures 1**

**IUGG-5772**

**The whole-system approach to extreme space weather**

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The whole-system investigation of extreme events has emerged as an important research area in a variety of scientific disciplines. A need to understand extreme space weather motivates a similar approach. A space storm involves all major components of the Sun-Earth system - the Sun, heliosphere, magnetosphere, ionosphere and upper atmosphere, and each is a system in its own right. The storm starts when eruptions on the Sun eject clouds of electrically charged gas and strong magnetic fields into space. Some of these clouds are harmless while others can penetrate into and disrupt the space environment around Earth, resulting at times in damage to satellites in space and power grids on Earth. In principle, the whole-system approach makes it possible to start with an extreme feature and then track back through the Sun-Earth system to identify the environmental conditions and interacting physical processes that produced it. This presentation addresses the following question. What new information (if any) is actually added by a whole-system approach to the study of space storms as opposed to the study of individual components and smaller sub-systems? To carry out this major study requires combining all available satellite observations in regions from Sun to Earth with linked global models and enlisting a large group of interested collaborators with expertise covering all system components, data sets, and global models. The subject selected for this interdisciplinary study was an anomalous space storm on 21 January 2005 that in some ways resembled a super-storm and in others a moderate event. Features associated with each of the Sun-Earth system components were studied during this event and results published in the literature. Despite this, the whole-system approach expanded on these more focused studies revealing new details of the event, in particular, that rare dense solar filament material significantly modified the magnetic cloud structure on its way to Earth, and entered the magnetosphere. The presence of this material and the compression of the magnetosphere by the associated high dynamic pressure were linked to unusual (and at times extreme) features throughout the system. This global view complemented the information from the more focused studies,

completing them by showing how the individual components interacted within the system, and feeding back with new questions generated as a direct result of the different perspective this view offered.

**Union Lecture**

**UL1 - UL1 Union Lectures 1**

**IUGG-5780**

**Challenges of Educating hydrologists for the Global South, the case of southern Africa**

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The southern Africa region has limited trained personnel in almost all fields including hydrology. Due to the limited number of hydrologists in each country, a singly hydrologist is often expected to contribute towards the solution of a diverse range of hydrological problems. These problems range from the assessment of the available water resources in both gauged and ungauged river basins, estimation of design floods for various purposes (e.g. stormwater drainage, spillways, floodlines for land use planning), river flow forecasting and prediction, assessment of environmental flow requirements, determination of appropriate water allocation, reservoir yield analysis, formulation of policies and guidelines for water resources management. Water resources management in southern Africa is either done by a central national agency or a river basin authority. For most countries, the national agency will not have more than 5-10 trained hydrologists, while river basin authorities may have 1-2 trained hydrologists who are expected to assist in solving diverse water resources management problems. The problem of the limited number of trained hydrologists is worsened by the rapid staff turnover resulting in limited mentoring of young hydrologists. It is not uncommon to find a newly graduated hydrologist being required to undertake hydrological assessments that elsewhere would require considerable years of mentoring. The need to have trained hydrologists capable of solving diverse problems in a rapidly changing environment and with limited resources, raises the questions regarding whether the hydrology education offered in southern Africa adequately prepares hydrologists for the challenges they will encounter. Most of the practising hydrologists with undergraduate degrees obtained their training as part of their civil/irrigation engineering, geography, geology and environmental science degree programmes. During the last 10 years, few undergraduate hydrology and water resources management programmes have been started. Very few universities offer postgraduate university programmes in hydrology in southern Africa. A

considerable number of hydrologists obtained qualifications in Europe and the USA. The curriculum of the hydrology education in southern Africa tends to mirror that in Europe and the USA, and using the same textbooks. Water resources management agencies in the developed countries have matured over the years, and each agency will have several hydrologists trained in the various sub-disciplines of hydrology. Since a southern African hydrologist is expected to solve diverse problems in a rapidly changing environment and with limited resources, the adoption of a curriculum that mirrors that in developed countries is questionable. Exercises used to teach various aspects of hydrology often assume stationarity, yet the hydrological landscape in southern Africa is changing. There has been a significant increase in research activity during the last 20 years in southern Africa as is evident from the number of papers published. However, the lack of national funding in most of the countries results in most of the research being based on research priorities of the external funding agencies. Thus considerable knowledge gaps exist and constrain effective water resources management. The limited research being done in parts of southern Africa has not impacted on practice in hydrology. Significant problems in the transfer and translation of knowledge exist. Consequently, practising hydrologists continue to use empirical methods developed over 40 years ago for different environmental conditions. This raises the issue of the role of hydrology education in translating research results into practice. The presentation will examine the above challenges in the education of hydrologists in southern Africa. The presentation will examine whether hydrology education in southern Africa is developing the knowledge and skills required to solve the diverse water resources management problems in the region. Suggestions for improving hydrology education in this region will also be presented.

**Union Lecture**

**UL2 - UL2 Union Lectures 2**

**IUGG-5773**

# Sea level change in the anthropocene

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The rate of global mean sea level rise (GMSLR) has accelerated during the last two centuries, from the order of magnitude of 0.1 mm yr-1 during the late Holocene, to about 1.5 mm yr-1 for 1901-1990, with ocean thermal expansion and glacier mass loss being probably the dominant contributors. During the last couple of decades the rate of rise has been larger, at around about 3 mm yr-1, because of increased radiative forcing of climate change, and increased ice-sheet outflow induced by warming of the immediately adjacent ocean. Ocean thermal expansion is the largest contributor to projections of GMSLR during the 21st century. For a given scenario, the range of projections for this component relates to uncertainty in simulating the processes of heat uptake into the ocean interior. Climate models also exhibit substantial disagreement in the geographical pattern of sea level change due to ocean density and circulation change. Larger uncertainty in projections of GMSLR comes from the land-ice contributions, especially ice-sheet dynamical change. These contributions also lead to substantial uncertainty in regional sea-level projections, through their effect on gravity and the solid Earth. Until the middle of the 21st century, projections of GMSLR under various scenarios of greenhouse-gas emissions have a small spread, because of the time-integrating characteristic of GMSLR. However by 2100 the rate of GMSLR for a scenario of high emissions could approach the average rates that occurred during the last deglaciation, whereas for a strong emissions mitigation scenario it could stabilise at rates similar to those of the early 21st century. In either case, GMSLR will continue for many subsequent centuries, because of the long timescales of ice-sheet change and deep-ocean warming, and could be partly irreversible.

**Union Lecture**

**UL2 - UL2 Union Lectures 2**

**IUGG-5774**

# Earthquake dynamics and seismic radiation

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In the 1960s, kinematic models of earthquakes were proposed based on observations of seismic radiation and directivity. Almost simultaneously Kostrov and others developed earthquake models based on fracture mechanics and the state of stress on faults. The synthesis of both approaches is the radiation model proposed by Brune in 1970, which showed that far field spectra had several universal properties. The low and high frequency properties of Brune's model were well explained by the properties of seismic radiation from fracture dynamic. An equivalent model does not exist for near field records. These are most often modelled as kinematic ruptures that do not satisfy mechanical constraints like conservation of energy, finite stress drops, etc. An alternative approach to properly model near field records is to model them with dynamic fracture models that are simple and robust. Fitting observations with dynamic models is a very non-linear problem that can only be solved with advanced inversion techniques. These are expensive but quite accessible for modern parallel computers. As it is well known dynamic inversion is not unique, but extreme models can be inverted from a set of observed seismograms. These inversions show that events of different origins: intermediate depth, shallow strike slip and subduction zones share many common features and that as proposed by Aki, they statistically satisfy rather simple scaling laws. The most important from the point of view of dynamics is that energy release rate scales with earthquake size. A similar model may explain some slow earthquakes, events whose rupture velocity has not reached speeds comparable to that of seismic waves. Comparing the spectra of observed and modelled spectra we find the central part of the synthetic spectra reproduce very well the observed ones with many characteristics that recall Brune's spectra. Corner frequency varies from station to station depending on the ratio of available to fracture energy (kappa)., The challenge now is to produce dynamic models that satisfy observations in the high frequency range where waves present significant complexity. To be presented to the 2015 IUGG meeting in Prague.

**Union Lecture**

**UL2 - UL2 Union Lectures 2**

**IUGG-5775**

**Volcanic ash and aviation safety**

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Since the early 1980s, jet-powered aircraft have experienced more than 140 damaging encounters while flying through clouds of volcanic ash from explosively erupting volcanoes. Each year, from 6 to 12 volcanic eruptions inject volcanic ash and associated gases into the upper atmosphere (>30,000 feet) where jet-powered aircraft fly. More than a dozen of these encounters have involved temporary in-flight loss of engine power. Total damage costs to aircraft from more than 30 years of encounters have totaled more than $200 million US dollars. In addition to in-flight damages, economic losses due to flight delays and cancellations, re-routing of flights, and airport closures from volcanic ash has exceeded $2 billion dollars, most of which was due to the April-May 2010 eruptions of Eyjafjallajokull volcano, Iceland. To mitigate the hazard presented by volcanic ash the international volcanological, aeronautical, and meteorological communities have worked together to ensure continued safety of flight. Since the late 1980s, several international coordination bodies including the International Civil Aviation Organization, the World Meteorological Organization, the World Organization of Volcano Observatories, the Airline Pilots Association, and the International Air Transport Association, as well as a large number of regional and national aviation organizations have worked together to improve the detection, tracking, and coordination of information about volcanic eruptions to minimize the effects of explosive volcanic eruptions to air traffic on a global scale. In addition to the improved coordination and communication about volcanic activity, there has been increased training of pilots and air traffic coordinating bodies to make them aware of the ash hazard and how to react in the event of an encounter. The global aeronautical and volcanological communities continue to look at multiple efforts to improve air safety and minimize the effects of volcanic ash on safe air travel. Following the eruption of Eyjafjallajokull volcano in April-May 2010, there has been increased effort to determine the dosage (concentration and exposure time) of volcanic ash which can damage aircraft. These efforts also include the development and installation of on-board, in-flight

ash detection devices, to improvements in remote sensing of volcanic activity and ash cloud generation and movement, to improvements in computer modeling of ash transport and dispersion.

**Union Lecture**

**UL3 - UL3 Union Lectures 3**

**IUGG-5776**

**Contributions of geodesy to monitoring natural hazards and global change**

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The definition and realization of precise and stable reference frames play an important role in modern geodesy, as they are required when we want to monitor changes on the Earth such as plate tectonics or global sea level rise. An overview of the various natural hazards and global change phenomena that can be observed by geodetic techniques will be given. Depending on the spatial scale, various types of measurements can be used, from space geodetic techniques such as GNSS (Global Navigation Satellite Systems), SLR (Satellite Laser Ranging), VLBI (Very Long Baseline Interferometry), and DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite), to local measurements by geodetic surveying instruments. All these techniques are combined in GGOS, the Global Geodetic Observing System of the IAG (International Association of Geodesy), and the concept of this integrative enterprise will be described. Case studies will be presented that document the essential role of precise geodetic data, accurate analysis methods, and realistic mathematical and physical models.

**Union Lecture**

**UL3 - UL3 Union Lectures 3**

**IUGG-5777**

## Atmospheric chemistry in the anthropocene

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he anthropocene poses new challenges to the atmospheric chemistry community. There are challenges linked to the fundamental understanding of processes, to the development and maintenance of observational instruments and systems (including models), and to the complexities of the intricate interactions among the climate system components, including human activities. For instance: how do carbonaceous aerosols evolve in the atmosphere becoming more or less absorbing or hydrophilic?; how will our warming planet alter the distribution of ozone and consequently the oxidative capacity of the atmosphere?; how important are halogens for tropospheric ozone in coastal cities?; how do we best observe the changing chemistry of the Earth's atmosphere?, etc. Such challenges may be considered "old" as they reflect the endeavor of science and research. However, they occur in a fast changing world, under increasing pressure for finding answers and solutions, which leads to stresses regarding science organization and funding. But also to opportunities to explore new perspectives, involve new people, particularly in the developing world, and finding new paradigms. In this presentation, I will illustrate these issues addressing current challenges in the over and around the South Pacific Ocean.

**Union Lecture**

**UL3 - UL3 Union Lectures 3**

**IUGG-5779**

**The global ocean carbon sink: Recent trends and variability**

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Since the onset of the industrial revolution in the late 18th century, the ocean has taken up about 30% of the total anthropogenic emissions of CO2, thereby constituting the most important sink for this CO2. While the annual rate of uptake has increased considerably over this period, largely in response to the increase in atmospheric CO2, there is considerable concern that this sink might saturate or even reverse in response to future climate change. Here, I present and discuss the most recent estimates of the oceanic sink strength for atmospheric CO2 and how this sink might have changed and varied in the recent decades. These estimates are based on two very complimentary sets of observations, i.e. (i) surface ocean observations of the partial pressure of CO2, from which monthly resolved global air-sea CO2 fluxes can be estimated for the period from 1980 onward, and (ii) ocean interior observations of dissolved inorganic carbon and ancillary properties, from which the accumulation of anthropogenic CO2 between the 1990s and the mid-2000s can be derived. The ocean interior results suggest a global increase in the anthropogenic CO2 inventory of about 25 Pg C between 1994 and 2006, while the cumulative air-sea CO2 flux over this period amounts to about 19 Pg C. Assuming a cumulative outgassing flux of ~5 Pg of “natural” carbon stemming from the carbon input by rivers, the global ocean interior and surface perspective are consistent with each other, suggesting a mean oceanic uptake flux of about 2.0 Pg C yr-1 over this period. This flux is at the lower end of most other estimates (e.g., atmospheric data and ocean inversions). If correct, the ocean sink would have been smaller than expected from the increase in atmospheric CO2. The surface ocean observations suggest that most of this lower than expected uptake stems from the Southern Ocean, whose sink strength was particularly weak in the 1990s. However, over the last decade, the Southern Ocean sink strength appears to have increased substantially, causing the global ocean uptake to increase commensurably. These substantial decadal variations and trends in the ocean carbon sink suggest that the sink strength could be more susceptible to the impact

of future climate change than currently suggested by Earth System Models.