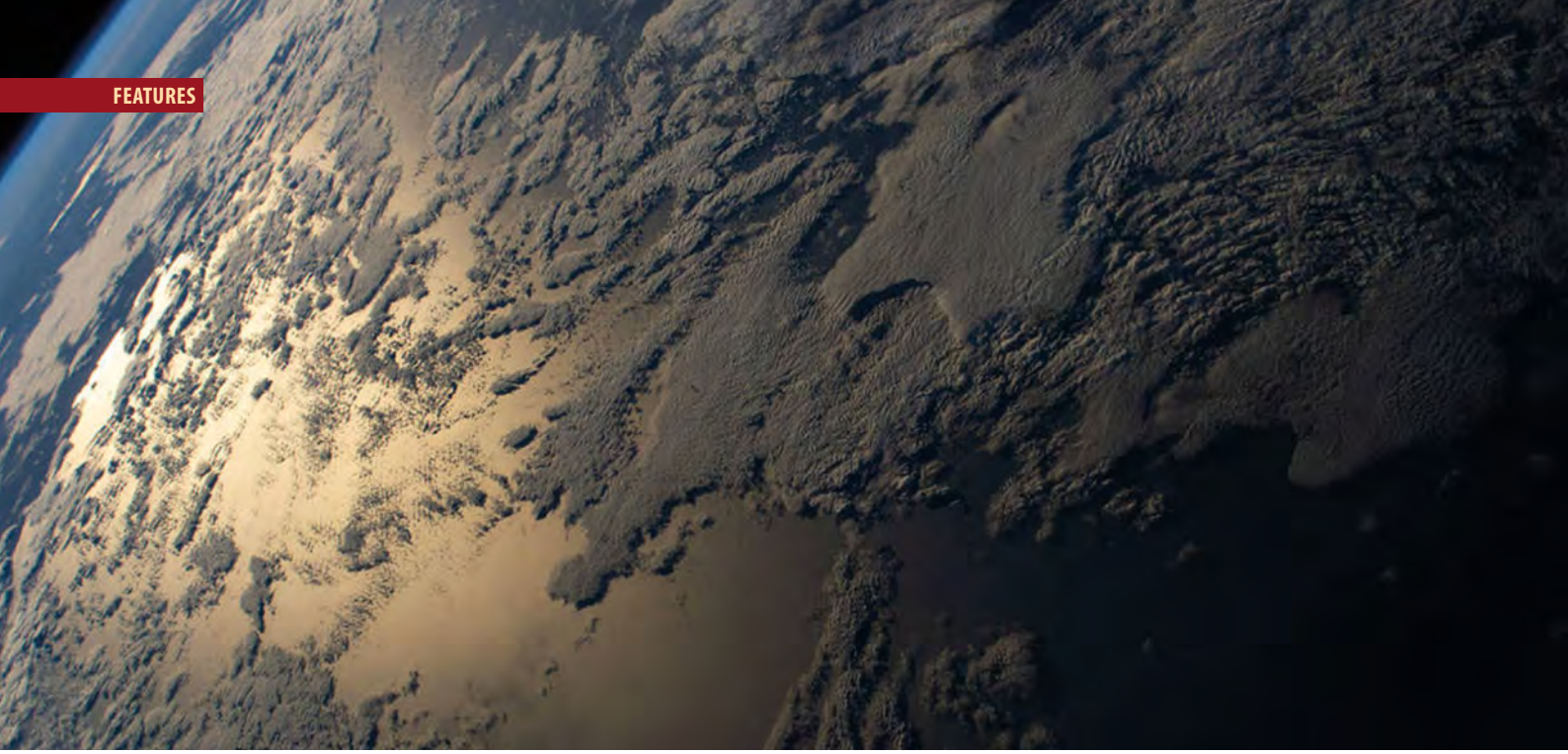

PHYSICS FOR ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

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One of the most crucial and challenging development of the last decades has been the discovery that environment is fragile. Read about it in Chapter 5 of the EPS Challenges for Physics.

▲ Sunlight glints above the Indian Ocean as the ISS orbited about 270 miles above the Earth near western Australia. Credit: NASA.

A discovery that shows that we cannot afford to delay the implementation of actions to tackle climate change if the long-term objective is to try limiting the increase in the global temperature of the planet at an affordable cost. Although the environment problem is too complex to admit simple solutions, recent developments illustrate how basic science, together with social awareness and political actions, can be successfully pulled together to avert an environmental tragedy. The contributions in chapter 5 of the EDP Grand Challenges present work done in a wide range of research areas illustrating how humanity not only has the responsibility to preserve our delicate planet but also the power to affect its environment. Together, they highlight the strength of fully interdisciplinary effort among physicists, mathematicians and chemists as well as multilateral science to address global challenges that affect societies at their core.

Nonlinear physics - Key concepts from nonlinear physics enable us to treat challenging problems of Earth sciences and climate projections. A reliable understanding of the Earth system is essential for the quality of life in a modern society. Natural hazards are the cause of most life and resource losses. The ability to define the conditions for a sustainable development of humankind to keep the Earth system within the boundaries of habitable states or to predict critical transitions and events in the dynamics of the Earth system are crucial to mitigate and adapt to Earth system related events and changes and to avert the disastrous consequences of natural hazards. Modelling climate requires the development of methods to simulate the interactions of the important drivers of climate, including atmosphere, oceans and land surface (Fig.1). *Read more: Earth system analysis from a nonlinear physics perspective, Juergen Kurths, Ankit Agarwal, Ugur Ozturk, Shubham Sharma, Norbert Marwan and Deniz Eroglu.*

Energy - Energy is the blood that moves today's society and is one of the factors that has decisively contributed to improving humanity's quality of life. The debate about the connection between energy sources and climate change has profound political and ethical consequences. It addresses the further development of energy storing

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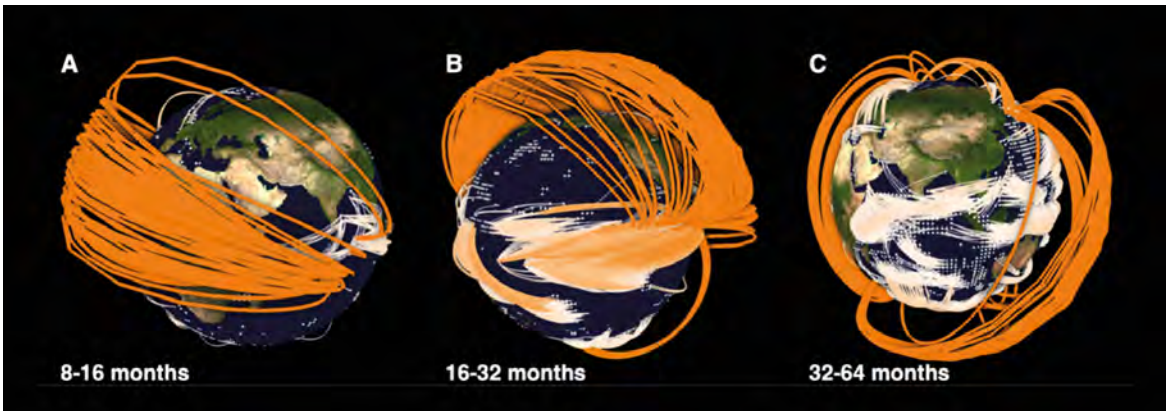
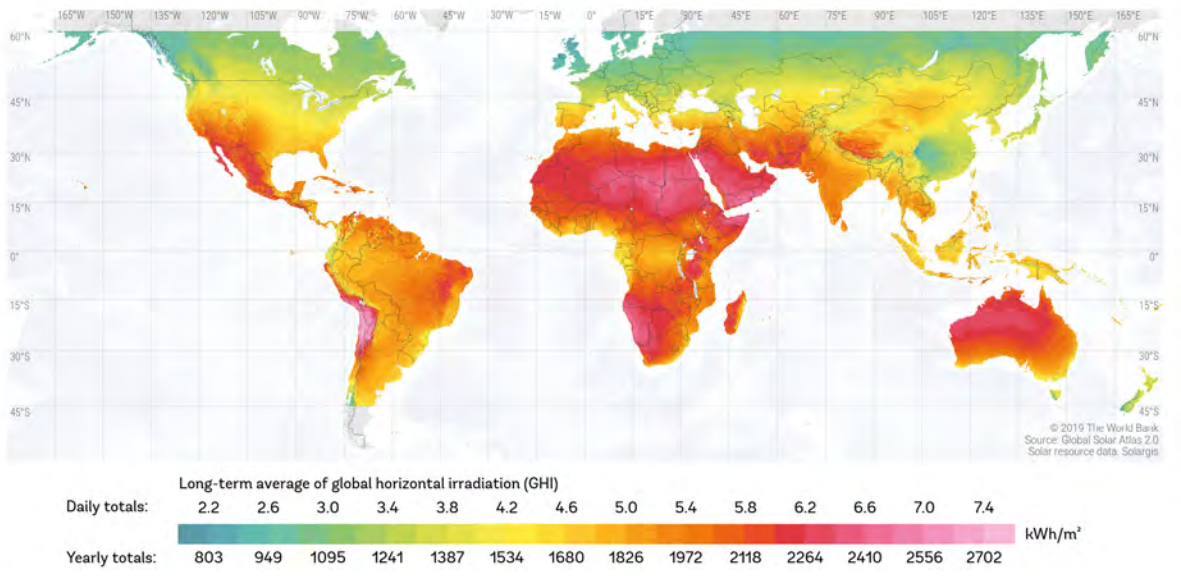


▸ FIG. 1: Spherical three-dimensional globe representation of the long-range teleconnections at different timescales in sea surface temperature network.

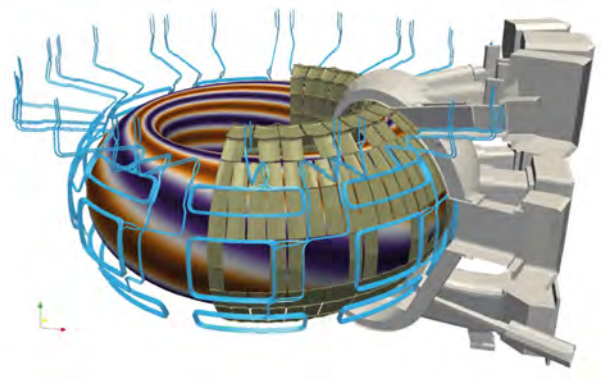
systems and of energy sources, like solar, wind, nuclear fission as well as the quest for nuclear fusion since the dominance of fossil fuels must decline (Fig. 2). It highlights the potential challenges and opportunities in the development of global energy systems, emphasising how deeply interconnected the energy and climate debates are. Now the physics and technology strands need further convergence and integration for the development of massive and sustainable energy sources. From this perspective the next few decades will be crucial to demonstrate the scientific and technical viability of fusion as an energy source by integrating the acquired knowledge in physics such as confinement and engineering optimisation, *e.g.* tritium technologies (Fig. 3).
Read more: Solar Energy, Robert Pitz-Paal and Bernd Rech.
Wind Energy. H. - J. Wagner.
Energy Storage, Søren Linderoth.
Fission Energy, Marco Ripani.
Fusion energy Development, Alberto Loarte.

Green cities and transport - The invention of the combustion engine radically transformed industrial and personal transport and, consequently, our social organisation system. Improving the performances of batteries and fuel cells cannot be based exclusively on an empirical approach; it requires a deeper understanding of the complex multi-scale phenomena occurring in batteries and fuel cells. This challenge can be achieved by making use of computational simulation in combination with advanced characterisation techniques. Therefore, significant effort must be devoted to model validation against experiments.
Read more: Green cities and transport, Natalio Mingo; Gérard Gebel; Philippe Azais; Thierry Priem; Tuan Quoc Tran; Didier Jamet; Florence Lefebvre-Joud; Simon Perraud.

Environmental safety - Hazardous wastes and materials are diverse, with compositions and properties that vary significantly between industries and related energy sources. Challenges include air quality avoiding and reducing pollutant emissions, access to safe drinking water and food, economics and scale of waste management as well as public acceptability. From a chemical perspective environmental emissions and waste disposal can be managed to meet sustainable development criteria. Technical innovation is required to handle the foreseen burst of chemicals on environmental safety and health.
Read more: Environmental Safety, Jacob de Boer



▸ FIG. 2: The solar energy distribution is quite inhomogeneous on the earth surface. As the output of solar energy converters is almost proportional to its input, the cost of solar energy for both PV and CSP is strongly related to the selected site.



▲ FIG. 3: Magnetic confinement fusion plasmas maintain equilibrium by the magnetic fields creating a force that opposes the expansion of the hot plasma and this equilibrium may become unstable. These instabilities (so-called magneto-hydrodynamic instabilities) impact directly the achievable fusion power production and therefore their control is crucial. The figure shows the set of 27 coils (in blue) to control edge instabilities in ITER.

Space weather - Space weather describes the way in which the Sun, through emergence of magnetic field into its atmosphere, flares, coronal mass emissions, high-energy particles and subsequently induced space conditions, impacts human activity and technology both in space and on the ground (Fig. 4). It causes substantial socio-economic impact on human infrastructures in space and at Earth; therefore it is a great challenge developing robust methods that allow prediction of space weather events with sufficient accuracy. With the rapid increase in computational power, new opportunities are arising to address non-linear processes where numerical experiments can guide us to the frontiers of solar and space weather physics.

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▼ FIG. 4: One of the key drivers of space weather are solar eruptions. These include both solar flares and Coronal Mass Ejection