What sparked your interest in space science and weather?

When I was little, I was always extremely excited when watching space shuttle launches on television. As I grew older, I saw spectacular solar and aurora images and videos, and wondered how these space phenomena are formed. Later I learnt about space weather and its impact on satellite operations, radio communication, power systems and radiation explosions, and this ignited my curiosity for a lifelong career in this field.

What are the principal aims of the Community Coordinated Modeling Center (CCMC)?

The CCMC is a multi-agency partnership situated at the NASA Goddard Space Flight Center. The principal aims of the CCMC are to enable, support and perform R&D for next-generation space science and space weather models. It provides access to modern space science simulations for the international research community, and supports the transition of these space research models to space weather operations.

Why are multi-point remote observations important for accurate data collection?

Such observations are necessary to capture the Sun’s temporal changes across a wider longitudinal range. This is also the idea behind NASA’s Solar Terrestrial RELations Observatory (STEREO) mission. Unfortunately the twin STEREO spacecraft cannot measure the Sun’s photospheric magnetic field. All solar magnetograms are essentially obtained from one point – the Earth – in an astronomical scale. Ultraviolet images of solar corona observed by STEREO have added two points to test coronal models.

For the solar wind coming out from the Sun, there is a group of spacecraft in the inner Solar System monitoring it, but they only count as four points in an astronomical scale (at most) at any one time – the Earth, STEREO A, STEREO B and Ulysses. As the Ulysses mission ended in 2009, we now only have three points left and they are all in the ecliptic plane.

Planetary missions, such as MESSENGER, Venus Express, can measure the magnetic field in interplanetary space, but solar wind plasma measurements are scarce. In short, the observations points are far from sufficient for such vast space. Observations closer to the Sun than the Earth are critically required for better model assessment.

Coronal mass ejections (CMEs) and solar energetic particles (SEPs) often interfere with communications. Will being better able to predict these events improve digital services technologies?

It may not improve technologies per se, but it will surely improve the quality of services. If we can successfully predict the arrival, duration and magnitude of space weather events, we can provide advanced warning to space-borne and ground-based technological systems in order to limit and even prevent damage.

At what stage is your current investigation? Are you pleased by the results obtained thus far?

We are starting the final year of this investigation and are happy with the results obtained so far. We have published a comparison study of Wang-Sheeley-Arge (WSA)/Enlil and Magnetohydrodynamics-Around-A-Sphere (MAS)/Enlil models with observations from the Advanced Composition Explorer (ACE) and Ulysses spacecraft, which were at Earth and Jupiter orbits, respectively.

We also evaluated multiple models focusing on the 2007 Ulysses perihelion.
**Next-generation space science**

Space weather events can interfere with technology that is important for modern life on Earth. Research taking place at the Community Coordinated Modeling Center in the US is assessing space weather models to advance space science and improve space weather predictions.

**SPACE WEATHER** – changing environmental conditions between the Earth and Sun – originates from disruptive solar properties, such as magnetic fields and radiation. Although occurring at an incredible distance, these disturbances are transported across the vast space by solar winds and can reach Earth, and other planets, having significant implications for modern human life. Substantial disturbances can influence space-borne and ground-based technological systems, and even endanger human health. Particularly important are the eruptive aspects of space weather – coronal mass ejections (CMEs) and solar energetic particles (SEPs).

CMEs can lead to destructive solar storms. Such storms radiate into the cosmos at speeds of over 8 million km/h, and can reach Earth in less than 24 hours, where they couple with the planet’s magnetic field. Power grids, radio communications, satellites and a range of other technological systems are all open to disruption. In fact, any communications signal that travels through or bounces off the ionosphere is affected by space weather.

**TECHNOLOGY’S ACHILLES HEEL**

Modern-day reliance on technology makes space weather modelling increasingly important as a prediction tool. When properly harnessed, forecasting space weather has the potential to mitigate potentially devastating events. However, a rigorous assessment has not been conducted for the most up-to-date models. Future model evaluation will be needed, along with the development of new models and the implementation of new solar input.

**Speaking more broadly, what are you hopes for the future of space science?**

Space science and space weather modelling have a bright future. As our society is more heavily dependent on space-borne and ground-based techniques, we require better space weather prediction, especially if we want to explore the Moon, asteroid bodies and other planetary systems. In addition to space weather, long-term space climate modelling is needed for mission planning.

Space weather prediction needs to offer accurate forecasting of space weather events, hence greater statistical model assessment is needed. As space weather modelling becomes more and more sophisticated, we also require a benchmark to compare models. With the continuing exploration of space science and the acceleration of numerical simulation, hopefully one day we will be able to predict a CME before it occurs and outrun the travel time of SEPs.

**PHOTOSPHERIC MAGNETOGRAMS**

The Sun has an activity cycle, which peaks around every 11 years. The 2007–09 solar minimum (between solar cycles 23 and 24) was uncharacteristically long and deep, and therefore provides a challenging but extremely favourable backdrop on which to test the models.

Coronal models evaluated in the project use photospheric synoptic magnetograms from a range of observatories, including the Mount Wilson Observatory in California, the Global Oscillation Network Group (GONG), the Synoptic Optical Long-term Investigation of the Sun (SOLIS) of the National Solar Observatory, and the Solar and Heliospheric Observatory. However, magnetograms derived from these sources are not necessarily the same: "Sometimes the magnitude of the magnetic field can differ by a factor of two," Jian explains. "Efforts have been made to inter-compare the results from various observatories, but the standard is debatable and no consolidated products have been obtained." Taking such measures should allow her to obtain data on the effect of the different magnetogram sources on the individual models; findings which will be especially important to help model developers better complement magnetogram data.

**CONTROLLED COMPARISONS**

Comparing the output of the models with real-world observations, Jian and her team are testing more than 200 model runs, each of which is for a solar Carrington rotation (a system to compare locations on the Sun over time), and are mapping the results to actual data obtained by spacecraft tasked with constantly monitoring the Sun and/or solar wind.

An assessment based on over 20 criteria is being made for each model. These controlled comparisons allow comprehensive understanding of the differences caused by changes in the solar boundary conditions measured by different observatories versus changes seen by different coronal models.
INTELLIGENCE

SHINE: SYSTEMATIC EVALUATION OF THE CORONAL AND HELIOSPHERIC MODELS INSTALLED AT THE COMMUNITY COORDINATED MODELING CENTER

OBJECTIVES

• To evaluate the success of coronal and heliospheric models now being hosted at the Community Coordinated Modeling Center, NASA Goddard Space Flight Center. Because it is not involved in developing any of these models, the project acts as an unbiased broker in making intercomparisons.

• To provide additional validation information to model developers and users, and help increase the capability of these models to predict space weather.

KEY COLLABORATORS

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RECIPROCAL BENEFITS

Collaboration is at the core of the project, and even within the team there are a number of important partnerships. Co-Principal Investigator Dr Christopher Russell is involved in several elements of the project, and also provides validated spacecraft data. Furthermore, Russell will incorporate the results into his teaching at the University of California, Los Angeles, passing on this knowledge to the next generation of space science researchers. Dr Peter MacNeice is another important collaborator. He works at the CCMC and has crucial experience in coordinating model runs and model development. “Collaboration is essential for our project,” Jian comments. “We have been working closely with CCMC staff and model developers.”

Because team members are not involved with the development of any specific model, they can be entirely unbiased in their comparisons. Furthermore, model providers have adopted suggestions made by the project team to validate and improve their models, as Jian evidences: “We found consistently slower solar wind than observed in one of the models. We reported this to the model developers, and they improved their models based on this information”. In a cycle of innovation, these newer versions are being incorporated by the team in their evaluations.

IMPROVING PREDICTIONS

Currently in the last year of the project, the team has published comparisons of a number of models. They hope to soon publish their evaluation of models focusing on the 2007 Ulysses perihielion pass, which will improve simulation of solar wind at high latitude.

Jian’s efforts look set to have a number of important outcomes, permitting more accurate simulations of solar wind evolution in the inner heliosphere, improving the ability to predict solar wind structure and allowing scientists to connect phenomena occurring on the Sun with solar wind structures.

Through comparing observational data, and understanding key differences, it will be possible to determine where the physics and parameterisations assumed in the models work most effectively. By extension, the findings will provide information on how to improve existing models and develop new ones, as well as draw conclusions on the benefits and drawbacks of each. Ultimately, the team’s comprehensive evaluation of the CCMC-hosted corona and solar wind models will advance scientific understanding of the origin of solar wind and its evolution in the inner heliosphere. Findings from this pioneering research will open the door to further advances in space science and space weather forecasting.

THE IMPORTANCE OF SPACE WEATHER

US $4 billion in satellite losses can be traced back to space weather damage

The last major space storm caused an electrical blackout in Quebec, Canada, affecting 5 million people at a cost of over $2 billion

Environment – cosmic rays from the Sun change the way clouds, rain and snow are formed, with important consequences for weather and climate

Health – astronauts are affected by radiation from solar flares and have an increased long-term risk of cancer. This can also affect airline pilots, crew members and frequent flyers

Electricity – although electrical outages are common, those caused by solar storms are more severe and can cover entire continents

Technology – there are currently over 900 operating satellites in space, and almost every class is vulnerable to space weather, which may lead to damage or failure

(Source: www.solarstorms.org)