Fostering cloud community relationships

Canada's Research Chair of Radar Applications in Weather and Climate, **Professor Pavlos Kollias** is focused on building stronger links between the science communities involved in cloud and precipitation research

To begin, what led to your interest in radar applications and sensors for use in meteorology?

Since first used in meteorology in the 1950s, radar has been the centerpiece for cloud and precipitation observations, offering a wide spectrum of applications that range from severe weather warning to global cloud climatology.

Today, we are entering the golden age of ground-based radar observations, propelled by continuous technological innovations that led to the development of sophisticated radar systems and the use of distributed collaborative adaptive observing networks. This can help us to evolve beyond past observational constraints that view only parts of the atmosphere, and provide a new holistic view of the atmosphere in action. At the radar system level, state-of-the-art scanning cloud radars capable of detecting the 3D structure and monitoring the entire lifetime of small cloud entities and layers are now available. At the same time, short-range weather radar networks and prototype phased-array systems that can provide rapid temporal updates of large portions of the atmosphere, especially near the surface, are becoming affordable.

Integrating all these concepts has led to the design of heterogeneous (multi-frequency) networks of radars with adaptive sampling strategies that provide a holistic view of cloud systems as coherent 4D entities with large dynamic range, rather than 2D or 3D projections of parts of their lifetime, thus overcoming artificial separations that do not exist in nature.

Can you explain the 'mind the gap' problem in severe weather detection?

The cornerstone of today's weather observation and warning system is a nationwide network of physically large, high-power Doppler radars. These long-range radars are effective in mapping the middle and upper regions of the atmosphere, but they are blocked from observing the weather near ground level due to the Earth's curvature. This results in an observational gap that significantly limits the accuracy of current forecasts and warnings. As evidenced by the series of deadly tornado outbreaks across the southeastern and central US in 2011, action needs to be taken to reduce the number of fatalities associated with these hazardous weather events.

What are the lessons learned that can benefit this research community?

A concept that has already gained traction and influences the way we conduct radar observations in weather and climate research is the use of adaptive scan strategies. Identifying regions in the sky where atmospheric features of interest are located, and subsequently sampled, can lead to an increase of temporal sampling and better quality observations in rapidly evolving phenomena, such as tornados. In parallel, the cloud community uses the same concept to optimise their radar resources to sample clouds through their entire lifetime. Another area of interaction is the development of multi-scale observing facilities that need to combine technologies and concepts from both the weather and climate community to be able to sample a wide range of cloud and precipitation conditions, and at the same time serve multiple users with different needs.

What do you believe are the most important next steps for the weather and climate research fields?

The recent advancements in radar technology constitute a giant step forward in our ability to observe the 3D structure of clouds and precipitation. However, this revolutionary radar infrastructure needs to be accompanied by the highest data quality, innovative operating strategies and a broad range of data products that address a variety of scientific applications. Dr Warren Wiscombe, Atmospheric Radiation Measurements Program (ARM) Chief Scientist between 2005-09, has played a key role in advancing some of the innovations this field. Moreover, Dr David McLaughlin of the University of Massachusetts, Amherst and Collaborative Adaptive Sensing of the Atmosphere (CASA) National Science Foundation's Engineering Research Center Director from 2002-12, has been instrumental in challenging the way we observe weather and influencing how state-of-the-art climate research facilities operate. There is much work to still be done and a new generation of the best and brightest graduate students in the area of radar applications in weather and climate research are needed. The complexity of the new multi-scale observations, and of the research problems they try to address, require fresh, clever methodologies on how to best use this information to evaluate numerical models. Our research group at McGill University aims to become such an education and training locus for undergraduate and graduate students interested in cloud research and innovative remote sensing.

Bridging gaps in **climate knowledge**

By uniting emerging, innovative radar technologies and building global radar networks, a team of cloud scientists based at **McGill University** is creating new frontiers in weather and climate research

CLOUDS PRESENT ONE of the greatest challenges facing scientists who are attempting to model short-term climate change. They are complex, unstable, occur over vast spatial and temporal scales, and are difficult to validate by using remote sensing. There are significant gaps in our understanding of cloud formation, processes and climatology and how these are represented in numerical models, including cloud coverage, phase, concentration of particles, and water content levels. In an effort to close these gaps, the Radar Applications in Weather and Climate Research Group based at McGill University is on a mission to support a greater understanding of weather and climate science through the optimised use of radar systems and networks. Led by Associate Professor Pavlos Kollias of the University's Department of Atmospheric and Oceanic Sciences, this group of highly talented experts firmly believe that the recent advancements in radar technology provide the observational power to take this research field soaring into the future.

FIGURE 1. ARM SCANNING CLOUD RADAR

A DECADE OF RADAR ADVANCEMENTS

Over the last 10 years there have been two major research programmes undertaken in the US that have significantly advanced radar technologies and observational approaches: the Collaborative Adaptive Sensing of the Atmosphere programme (CASA) and the Department of Energy (DOE) Atmospheric Radiation Measurements (ARM) programme. These have supported the development of technologies such as scanning cloud radar, which are now being blended with the more traditional weather radars to offer a unique holistic observation of precipitation and clouds. CASA is a US National Science Foundation's Engineering Research Center. Working with Professor David McLaughlin, CASA Director, the McGill University group has been collaboratively developing revolutionary radar systems that deliver a comprehensive understanding of the cloudy atmosphere over a long time period. As Kollias explains, this has required the creation of a distributed network which covers the entire dynamic scale of clouds through multi-scale observing facilities: "Such observations will provide the critical data upon which a virtual laboratory can be built for testing models and for improving parameterisations of clouds and precipitation in climate models".

With the goal of improving atmospheric datasets used in the global and regional climate models, the ARM Climate Research facility programme has been allocated US $60 million to acquire and deploy both new and upgraded equipment and infrastructure. Kollias is among the scientists and engineers who advised DOE on their acquisition of radar systems valued at over $30 million, which are designed to address observational shortcomings in cloud and precipitation research. Alongside Jim Mather, the ARM Technical Director and his colleagues, who are based at the Pacific Northwest National Laboratory, Kollias is dedicated to ensuring that these new innovations in radars will help to fill gaps in our current observational approaches in studying weather and climate. He believes that with these acquisitions, the DOE and ARM is now the world leader in operating atmospheric radars over a wide range of frequency bands and in several geographical locations: "The value in these technological advancements is that all cloud partical sizes are now observed, breaking down the artificial separation between 'precipitation' and 'cloud' particles that previously resulted from limited observation power".

NEW OBSERVATIONAL POWERS OFFER A MORE HOLISTIC VIEW

Kollias illustrates how the traditional profiling mode which cloud radars have used to probe the vertical structure of clouds and precipitation is rather like a 'soda-straw' view: "Looking only vertically is like looking at cloud systems through a tiny key hole, thus hiding all the holistic connections". The group at McGill University is hoping to widen the keyhole by offering the tools to realise 3D cloud observations. They are now looking at how these new technologies can be employed in research projects, how they can influence the design of such projects, and how they can build on the operations of the ARM and CASA facilities to improve observations of clouds and precipitation. It is Kollias' vision that this innovative equipment will provide the leap in observation power needed to fill the existing knowledge gaps: "In weather research, distributed adaptive networks of short-range weather radars address the limitation of current operational weather radar networks to detect severe weather in the boundary layer and challenge the way we sample the atmosphere". This work is producing an integrated view of clouds which can then help break down the barriers that have existed between the formerly isolated research fields of cloud, aerosol and precipitation.

THE BENEFITS OF A NETWORK APPROACH

At the core of the development of these new radar tools and infrastructure is the supplementation and replacement of the present network of large radars with hundreds of smaller radars which can be easily set up on existing sites, such as rooftops and cellular towers. Kollias describes how an intelligent network will connect these small radars, which run on less power and for a lower cost than their larger counterparts, so that they can feedback data about atmospheric conditions near the Earth's surface through collaborative and adaptive sensing. One of the key elements of this network are the electronically-scanned phased array antennas, which are critical because they can be easily installed on existing infrastructure and lack moving parts that can be expensive to maintain. "The closer spacing of these radars will avoid the obstruction caused by the Earth's curvature and allow forecasters to directly view

INTELLIGENCE

RADAR APPLICATIONS IN WEATHER AND CLIMATE RESEARCH GROUP

OBJECTIVES

To innovativley use radars and other sensors in weather and climate research with the goal of improving our understanding of the atmospheric component of the hydrological cycle (eg. cloud, precipitation, radiation and thermodynamics) and to improve representation of cloud and precipitation processes in global, regional and storm scale numerical models.

PARTNERS

Brookhaven National Laboratory, USA

CASA ERC, Amherst, USA

DOE ARM program, USA

University of Massachusetts, **Amherst,** USA

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PAVLOS KOLLIAS is Associate Professor and a Canada Research Chair in Radar Applications in Weather and Climate at McGill University. His research focuses on improving our understanding of cloud-scale processes and the development of state-of-the-art ground-based facilities for weather and climate studies. Kollias is the leader of the US DOE Atmospheric Radiation Measurement programme radar science group and serves at the Mission Advisory Group of the European Space Agency Earth Clouds Aerosols Radiation Experiment (EARTHCARE) Explorer Mission that is scheduled for launch in 2015.

McGill

In weather research, distributed adaptive networks of short-range weather radars address the limitation of current operational weather radar networks to detect severe weather in the boundary layer and challenge the way the atmosphere is sampled

the lower atmosphere with high-resolution observations," observes Kollias. This adds a totally new dimension to existing weather observation by offering better forecasting of storms, resulting in improved warnings and faster response to weather-related hazards.

One of the challenges of providing such highly innovative technology to support scientific research in such a complex and dynamic field is that the aims of different organisations can often be vastly different. For example, CASA is keen to follow the development of tornados at the ground level using the radar network, and ARM wants to use the radar system to closely analyse clouds to help understand more about their lifecycles. This means that Kollias and his team are faced with the interesting task of marrying weather and climate observing resources with a range of scientific goals. Even with such significant progress made already, Kollias believes there is still plenty of work to be done to deliver the technologies that are needed to help improve our understanding of weather and climate systems: "Significant research work lies ahead in order to discover new tools and methods to maximise the scientific output of radars and make their data friendly to the user community".

FIGURE 2. After nearly a decade of R&D, a collaboration between the University of Massachusetts, Raytheon Company, and First RF Corporation of Boulder, Colorado has resulted in the FRF-166 low-power phased array antenna.