

# Advancing atmospheric imaging

ARISE

As the head of an important pan-European collaboration, **Dr Elisabeth Blanc** discusses her work investigating opportunities for integrating different atmospheric stations. As she explains, their findings will ultimately support cutting-edge research infrastructure



## How was your curiosity in the dynamics of the atmosphere first sparked?

My interest developed during my first studies of the infrasound propagation in the atmosphere a long time ago. Infrasound is produced by volcanic eruptions, severe weather, hurricanes, exploding meteoroids, earthquakes and ocean swelling. It can't be heard but propagates over very large distances. The waves are ducted in the atmospheric wave guide formed by the ground and temperature increases of the stratosphere and lower thermosphere, and propagation is strongly affected by the intense stratospheric winds.

Simultaneously, we measured strong travelling waves in the ionosphere at more than 200 km altitude originating from the lower atmosphere. Rocket measurements of up to 70 km altitude also showed that gravity waves modulate the wind profiles, inducing changes of 20 per cent or more. It was demonstrated that the lack of knowledge of these waves constituted the main limitation in infrasound propagation

predictions. Such waves are very frequent in the atmosphere and transport energy momentum from a region of the atmosphere to another. This sparked my curiosity in the origin and global possible effect of these waves.

## You lead the 'Atmospheric dynamics Research Infrastructure in Europe' (ARISE) project. What are the key phases of the project and what stage are you currently working on?

ARISE has now reached its midway point. The beginning of the project was dedicated to the assessment of networks and data processing methodologies. This work was managed by the Federal Institute for Geosciences and Natural Resources (BGR). A catalogue of reference infrasound events was edited by NORSAR. The ARISE observation campaigns started in July 2012. The first campaign, managed by the Laboratory of Atmosphere, Environment, Space Observation (LATMOS), was located in Southern France at the Observatoire de Haute Provence (OHP) and the second, managed by the University of Firenze, was installed near the Mount Etna volcano in Italy. Different ARISE technologies were collocated to start the collaborative work by comparing complementary data.

Systematic comparisons between atmospheric models and lidar showed that the temperature appears to be overestimated by an average of ~5 K in the stratospheric models and underestimated by ~10 K in the mesospheric models. Differences can be larger during strong disturbances such as sudden stratospheric events.

This collaborative work was stimulated by the common analysis of the campaign datasets, several of which were made available to the consortium through the ARISE website in April 2013. The infrasound

data will be gathered in the infrasound portal hosted by the Alternative Energies and Atomic Energy Commission (CEA) in September to further provide data to the ARISE data centre developed by the German Aerospace Center (DLR) next year and the prototype will be open at the end of the project in December 2014.

The OHP campaign proved attractive to other teams, and additional instrumentation was installed to complement the observations. Although the campaigns were planned for one year, they are still running – the quality of the results motivated the different teams to continue recording measurements up to the end of the project in December 2014 and maybe beyond.

## How important is a holistic approach to your research?

The ARISE project aims to develop collaborations among European scientists while, for the first time, supporting and integrating a large set of complementary topics such as infrasound, gravity and planetary waves, stratosphere and mesosphere disturbances, satellite atmospheric studies and modelling of the atmosphere and atmospheric dynamics. Working together across these issues can reinforce knowledge of the processes in broad time and spatial scales both horizontally and vertically. This was the only way to extend the prediction timescales of weather forecasting to several weeks. This also reinforces the project issues related to extreme event and climate monitoring. The team is a strong representation of the different science communities and the partners are assigned to lead different project work packages based on their experience and expertise.

# The future of atmospheric research

The rapid international growth and exposure of the **ARISE** network is testament to the continued progress the European consortium is making in building a new and improved knowledge base in atmospheric dynamics

## Has ARISE seen success in coordinating scientific communities that have not previously worked together?

ARISE integrates different communities involved in multifarious topics, such as observations in different atmospheric layers, climate modelling and weather forecasting. It was difficult to link the different observations, including direct pressure measurements, light detection and ranging lidar remote sensing and camera mesospheric measurements providing different results and submitted to different constraints. Advanced parameters to be assimilated in the models have to be defined but the modelling needs have yet to be clearly established. The ARISE observation campaigns were dedicated to resolving these difficulties.

## Will the work of monitoring stations continue to expand in years to come?

Following the example of the OHP instrumentations at mid latitude, there are plans to install a similar station in the tropics at La Réunion where a lidar station is already in operation. The Alomar lidar station located in a high latitude region close to the airglow and infrasound station could form a third strategic area. The collected observations offer a unique opportunity to provide detailed information on upper atmospheric processes from seasonal to daily scales to better understand atmospheric coupling processes and their influence on weather and climate. Together with the Network for the Detection of Atmospheric Composition Change (NDACC), Network for the Detection of Mesopause Change (NDMC) and International Monitoring System (IMS), developed for the verification of the Comprehensive nuclear Test Ban and Treaty (CTBT), as well as national stations, this could constitute the first step for the ARISE infrastructure.

**A CLEAR UNDERSTANDING** of the processes underway in the Earth's atmosphere is crucial to overcoming global climate challenges. However, many unanswered questions remain. Improving this knowledge is a critical factor in developing informed policy and improving decision making around adaption and climate change. A pan-European consortium of atmospheric researchers representing 12 institutes from nine countries is focusing on building the capacity of Europe's atmospheric observation infrastructure, with a particular emphasis on novel 3D imaging. The intention is that Europe and its outer lying polar and equatorial regions will be covered by the network. Known as the 'Atmospheric dynamics Research Infrastructure in Europe' (ARISE) project, the work seeks to address the lack of knowledge surrounding the interactions between the upper layers of the atmosphere and the troposphere.

The importance of these interactions to tropospheric weather and climate patterns is increasingly apparent. Project Coordinator Dr Elisabeth Blanc explains that vital descriptive information, as well as significantly more accurate forecasting, can be garnered from examining the new measurements being gathered from above the stratopause. In particular, Blanc is keen to investigate how atmospheric waves provide the mechanics for these processes. The main objectives of ARISE, along with improving knowledge of the relationship between the stratosphere and the lower atmosphere, revolve around monitoring climate-related phenomena so that it is able to better inform climate change decision making, and providing observations of natural hazards

that impact the atmosphere. ARISE's challenge is to integrate complementary measurements to provide new 3D images of the atmosphere and unresolved disturbances from the ground to the mesosphere with unprecedented spatiotemporal resolution. This covers a vast range of timescales, spanning mere seconds to a period of decades, for both extreme events and other atmospheric processes.

ARISE is aiming to integrate three networks. First, the international infrasound network developed for the verification of the Comprehensive nuclear Test Ban Treaty (CTBT) is addressing the treaty's infrasound. This network's capacity and quality for infrasound and atmospheric wave observations makes it valuable to the project. Second, is the Network for the Detection of Atmospheric Composition Changes (NDACC), using light detection and ranging (lidar) to measure stratospheric dynamics. Finally, the Network for the Detection of Mesopause Changes (NDMC) is a key component of the project. NDMC is dedicated to airglow layer measurements in the mesosphere. ARISE also includes additional complementary stations and satellite data. It is hoped that synergies across the three networks will result in improved 3D observations of atmospheric dynamics.

## DEFINING SPECIFICATIONS OF ADVANCED DATA PRODUCTS

Work on the ARISE project began in early 2012 with a number of observation campaigns. The team is now over halfway through their work plan and the researchers are beginning to sort



IMS INFRASOUND STATION (IS34, MONGOLIA)

through the immense amount of data that has been gathered to date. A large focus of the project has been on identifying and describing the advanced data products the team will use to gather measurements. They are devoting significant time and energy to integrated studies, which will be founded upon the data products gathered from the ARISE network. The advanced data products work package is being led by the Laboratory of Atmospheres, Environments, Space Observations (LATMOS) research unit in France, who also represent the NDACC lidar observation network. The German Aerospace Center (DLR) represents the NDMC airglow observation network. Reading University and the Royal Netherlands Meteorological Institute (KNMI) are managing the work package focused on data utilisation. The key to this work package is understanding and interpreting the ARISE multi-instrument measurements in the context of weather, and climate monitoring and modelling.

ARISE employs a number of different measuring methods within the International Monitoring System (IMS) to represent different characteristics of atmospheric dynamics. The IMS offers global and homogeneous coverage, as well as high quality data. "With 60 infrasound stations distributed uniformly around the planet it will be larger and much more sensitive than any previously operated infrasound network," Blanc enthuses. The IMS can provide a clear and simple

understanding of the processes involved in the atmosphere, as well as supporting and facilitating the integration of data into atmospheric models. One example is the superposition of temperature profiles given by lidar in the stratosphere, and airglow observations in the mesosphere, and how the infrasound data then provide details of the sources of the disturbances which can affect the observations.

The approach used to detect and characterise low amplitude coherent infrasound signals, along with advances in algorithm development, means the team is able to identify different coherent wave systems and distinguish them using various characteristics. In addition, novel techniques incorporating well determined repetitive infrasound sources have enabled the researchers to examine processes underway in the upper atmosphere. "The high quality of these observations was demonstrated by validation experiments and analysis of some large-scale disturbances including tides, solar eclipses and large-scale waves from thunderstorms," Blanc explains.

#### GATHERING AND INTERPRETING IMPORTANT DATA

ARISE has implemented an associate membership programme geared towards potential end-users of the infrastructure or

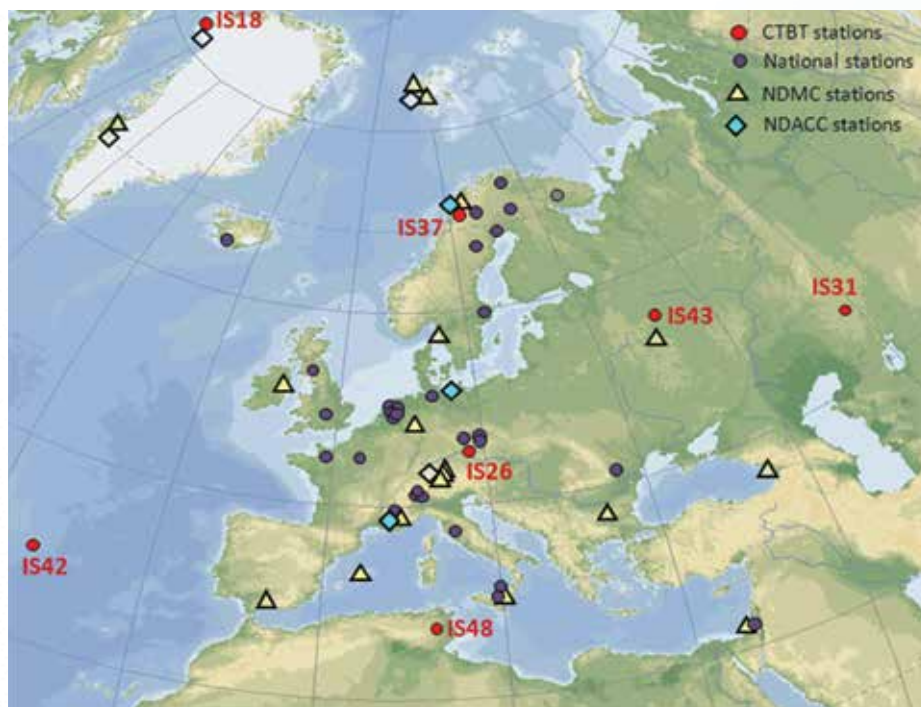
possible future project partners, which has seen much interest and success. These associated partners make significant contributions to the ARISE observations or to ongoing scientific studies. One example is in Switzerland where the University of Geneva is modelling volcanic jet dynamics and effects on infrasound observations, and the University of Bern has provided an extra groundbased sounding technique that is being used to calculate the vertical structure of the wind fields. ARISE data will be used for monitoring the long-term mean trends of the atmospheric dynamics and the evolution of extreme event characteristics with climate change. "A better knowledge of the evolution of extreme events is important to predict how their impact on environment will change in future," Blanc asserts.

Some of the initial results to emerge from the project partners and work packages are encouraging and indicative of a bright future for ARISE. It is hoped that through this work the project will realise a number of important applications, eg. a better representation of gravity and planetary waves in the stratosphere. These can be used for further improving the accuracy in short- and medium-range weather forecasts on time-scales up to four weeks ahead. Another is the near real-time and continuous monitoring of natural hazards such as large volcanic eruptions, cyclones, avalanches and meteorites. There is understandably a large interest in ash injections caused by volcanoes within the civil aviation industry. As such, ARISE aims to develop, in relation with the Volcanic Ash Advisory Centers (VAAC), techniques and tools to enable remote monitoring of the volcanoes using the Mount Etna eruptions data and its analysis and applying these to other volcanoes where local infrasound observations are missing or scarce. Measurement campaigns integrating co-localised instrumentation are organised at Mount Etna by the University of Firenze. The challenge is to measure volcano infrasound and volcano-induced gravity wave to better determine the ash emission and dispersal in the atmosphere. The ARISE group is also prototyping a notification system of possible volcanic activity based on infrasound observations and Mount Etna is being used for testing the procedure.

#### COMMUNICATING WIDELY

ARISE's success can be seen in increasing interest in the project from international science groups, and subsequent growth in cooperation from other institutes. The Institute for Space Aeronomy Belgium (IASB) is managing the work package relating to dissemination and exploitation of project results, including the organisation of the ARISE training school in June this year. The summer school programme has also raised awareness about the work of the collaboration. The group is undertaking a range of key dissemination activities to ensure their findings are effectively communicated to a wide audience. Involvement in international events and conferences has been essential,

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ARISE INSTRUMENTAL NETWORK



NEAR-FIELD INFRASOUND EXPERIMENT DURING YASUR ERUPTION (CREDIT: IRD, GEOHAZARDS VANUATU)

namely the presentation at the European Geophysical Union (EGU) in April 2012, as well as presentations to EGU scientific sessions this year. ARISE has also published findings in internationally peer-reviewed journals, and further publications are set to emerge. Another key tool for communicating findings is through the ARISE workshops that focus on some of the main topics for the networks. These are well attended by participants from many different countries, as are the training school events. Furthermore, information provided on the dedicated project website helps to support debate about the efforts and relevant scientific topics.

### EXPANDING ARISE'S REACH

Atmospheric processes certainly do not adhere to country boundaries, and while ARISE has initially focused on Europe, the team recognises the importance and relevance of wider regions. Disturbances that originate in one continent, such as wind over mountains, can affect the processes underway in Europe and this has led the researchers to looking both horizontally and vertically in respect to the wider atmosphere. ARISE's coverage integrates, in the same longitude sector, equatorial and tropical Africa, the European mid-latitude region, high latitude and polar Northern regions to study the latitudinal coupling of the atmosphere in the different atmospheric layers. One of the regions of particular interest to the team is Africa – the most active continent in terms of thunderstorms. However, there is a lack of information available to assist scientists in explaining many of the dynamics underway in this area.

One of the challenges presented by working in Africa is the availability of continuous high resolution measurements. To this end, ARISE has been analysing some of the very intense gravity wave activity observed by African infrasound stations. "By using 10 years of data recorded at an infrasound station on the Ivory Coast we have been able to show that this large activity was only produced by thunderstorms," Blanc outlines. The team is looking at the ways in

which such disturbances affect circulation in the stratosphere and mesosphere. Another area of focus is the study of the many active volcanoes in Africa. To disseminate their work and reach out to Africa's schools and science community, representatives from different institutions across Africa were invited to the ARISE training school in June. It is hoped that the success seen in Africa will set a solid grounding for the continued internationalisation, growth and expansion of the network as ARISE rises to the next level.

## INTELLIGENCE

# ARISE

### OBJECTIVES

To design a new infrastructure that integrates different station networks in order to provide a new 3D image of the atmospheric dynamics from the ground, up to the mesosphere, with unprecedented spatiotemporal resolution.

### KEY COLLABORATORS

Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), France • Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany • Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), France • Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Germany • University of Reading (UREAD), UK • Università Degli Studi Di Firenze (UNIFI), Italy • Koninklijk Nederlands Meteorologisch Instituut (KNMI), The Netherlands • Stiftelsen Norwegian Seismic Array (NORSAR), Norway • Ustav Fyziky Atmosfery (IAP), Czech Republic • Institutet för Rymdfysik (IRF), Sweden • Institut d'Aéronomie Spatiale de Belgique (IASB), Belgium • Laboratoire de Mécanique des Fluides et d'Acoustique (ECL), France

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