Capturing the atmosphere

Dr Elisabeth Blanc describes the ARISE collaborative project, which integrates observation technologies to reveal activities in all layers of the atmosphere from ground to mesosphere, with unprecedented resolution

Could you briefly outline why there is a requirement to provide a new 3D image of all atmospheric layers?

The atmosphere has been long considered as stratified, with negligible interaction between its layers, mainly because of limited observations. However, recent research has shown that the dynamics and mixing of the layers driven by large-scale gravity and planetary waves, play an important role in both weather and climate.

ARISE will create a new infrastructure, integrating three networks that provide measurements from the different atmospheric layers with satellite observations. The data will be optimised for estimation of the evolving states of the atmospheric layers. This will help to constrain the parameterisation of gravity waves, better represent the atmosphere for weather and climate modelling and support better description of extreme events.

How does this work improve on the present state of the art?

Until now, atmospheric dynamics was studied through microbarometers measuring waves at the ground level, lidars in the stratosphere, cameras in the mesospheric airglow layer and satellites. Observations were recorded independently and without comprehensive, long-term analysis of atmospheric disturbances and energy exchanges.

A renaissance of infrasound technology took place in development of the IMS infrasound network for verification of the Comprehensive nuclear Test Ban Treaty. When completed, the IMS network will comprise 60 stations; today approximately 75 per cent are operational. The IMS network provides observations with unprecedented precision, thanks to the use of a large number of arrays of sensors uniformly distributed throughout the world.

The integration of the European part of the IMS network with the NDAAC lidar and NDMC airglow observation networks will allow 3D monitoring of all atmospheric disturbances from infrasound to planetary waves, offering new perspectives.

What are the potential benefits of efforts to integrate these networks?

We expect better description of the atmosphere and improved accuracy of short- and medium-range weather forecasts. We also anticipate improved representation of gravity waves in stratosphere-resolving climate models, crucial for estimating the impact of a range of stratospheric climate forces on the troposphere. In the long term, the data will be used for monitoring the middle atmosphere climate, its long-term mean trends and changes in extreme events.

ARISE will also support civil applications for monitoring natural hazards such as thunderstorms and volcanic eruptions.

How do you plan to develop the atmospheric data centre?

Design will start with identifying advanced data products and validating them using simultaneous observations from the different networks. Observations will include archived data on specific events and new data from observation campaigns which will be performed over a year near the Mount Etna volcano in Italy, which is very active this year, and at the Observatoire de Haute Provence in France.

The project is highly multidisciplinary. Can you outline the contributions of the team?

The consortium first gathered the main European research teams in the field of infrasound sources from extreme events: Atomic Energy and Alternative Energies Commission (CEA) from France, the Federal Institute for Geosciences and Natural Resources (BGR) from Germany, the Royal Netherlands Meteorological Institute (KNMI), NORSAR from Norway, the Swedish Institute of Space Physics (IRF) from Sweden and Florence University (UNIFI). This community is already united by previous common work on infrasound.

Studies of gravity waves are more recent. The infrasound community shows real enthusiasm for this new field of research as such waves

High rise

The EU-funded **ARISE** project has assembled scientists from across Europe to collaborate in the building of a consolidated data centre that will substantially extend knowledge of the dynamics of the Earth's atmosphere

strongly impact infrasound propagation. The Detection of Atmospheric Composition Change network, represented by the Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), provides support, motivating a new community previously mostly involved in stratospheric studies.

The Network for the Detection of Mesopause Change community has started a new field of research concerning the mesosphere and coupling with the upper atmosphere. The German Aerospace Centre (DLR) manages this part of the project and will produce the demonstration data centre.

The Institute of Atmospheric Physics contributes infrasound stations collocated with ionospheric sounding stations to study the possible impacts of space weather, whilst the University of Reading expertise in weather forecasting is well complemented by KNMI expertise in atmospheric modelling. The Institut d'Aeronomie Spatiale de Belgique and Ecole Centrale de Lyon are involved in outreach and in some aspects of the infrastructure optimisation, respectively.

The success of ARISE is already apparent from the increasing list of associated members, including African countries interested in training and use of their stations and scientists interested in the database. We have links with groups like the Comprehensive Test Ban Treaty Organization, the International Civil Aviation Organization, the World Meteorological Organization and the European Centre for Medium-Range Weather Forecasts. Recently, we have opened up collaborations with US groups involved in infrasound studies using large arrays and Russian groups interested in the new theoretical challenges.

WHEN A LITTLE-KNOWN Icelandic volcano erupted in 2010, it became notorious as plumes of ash spread across the atmosphere, disrupting communications and air travel, and blotting out sunlight in Iceland for days.

To forecast weather and monitor events that cause warming of the stratosphere and disasters, scientists observe atmospheric disturbances caused by natural forces such as volcanic eruptions, earthquakes, meteorites, avalanches and also manmade disturbances such as explosions, supersonic aircrafts, as well as, at larger scales, wind over mountains and thunderstorms, using state-of-the-art technology. Large scale sources are at the origin of gravity waves and planetary waves which can impact on the stratosphere and mesosphere and generate stratospheric warming in Polar Regions, and have to be taken into account in weather forecasting models.

One such tool is infrasound, as Dr Elisabeth Blanc, the coordinator of the Atmospheric dynamics InfraStructure in Europe (ARISE) Design Study project, explains: "After the last Eyjafjallajökull volcanic eruption was observed by many European countries, infrasound stations were installed near active European volcanoes".

ARISE, funded by the EU Seventh Framework Programme (FP7), started in January 2012 and is due to complete in December 2014. The project draws together scientists from 12 organisations across Europe in a collaborative effort to design a common platform for studying large scale waves and atmospheric dynamics, to improve weather forecasting and climate studies and provide information for civil applications, such as aviation management systems, after extreme events.

THE SCOPE OF ARISE

The ARISE project will design and trial a new observation infrastructure that integrates three existing international atmospheric observation networks, making it possible to view the different layers of the Earth's atmosphere in greater temporal-spatial detail than ever before, for Europe and outlying regions including polar and equatorial regions.

The key networks for integration are: (i) the European parts of the International Monitoring System (IMS) infrasound network developed for verification of compliance with the Comprehensive nuclear Test Ban Treaty (CTBT) which provide localisation and characterisation of a large number of geophysical and man-made sources in a broad range of scales, (ii) the Network for the Detection of Atmospheric Composition Changes which measures temperature and ozone and aerosol concentrations in the stratosphere and mesosphere, using LIght Detection and Ranging (LIDAR), and takes wind measurements for the study of atmospheric dynamics such as planetary and gravity waves and sudden stratospheric warming events (iii) the Network for the Detection of Mesopause Changes, which performs optical measurements of atmospheric changes and atmospheric disturbances in the airglow layer in the mesosphere.

Data will also be collected from the infrasound stations near active volcanoes, the IMS infrasound stations located in low-latitude regions in Africa, ionospheric arrays that detect atmospheric disturbances in near-Earth space, and satellites.

The scope of ARISE has increased since its inception, with some geographical regions beyond Europe now involved: "The infrastructure has now been extended to tropical and equatorial regions where many IMS infrasound stations are located, a LIDAR station is operational on La Reunion Island and stations are also in operation in Greenland and Spitzberg in northern polar regions," Blanc explains.

COORDINATING ARISE

The organisations involved in ARISE include major institutions that are leaders in their technological fields or in the application of technology for monitoring extreme events, modelling climate changes and forecasting weather. There are many more associate partners, including some from outside Europe, whose data will be integrated into the ARISE infrastructure in the future: "European values such as multidisciplinarity, innovation and societal benefit are pivotal ideas for ARISE," Blanc states.

Within the project, the major tasks are arranged into stages comprised of interlinked 'Work Packages': "The first stage will be to determine new advanced parameters from all observations that have high added value compared with parameters previously extracted from each technology separately," Blanc outlines. The next stage will be to use observations and simulations to optimise the parameters describing gravity and planetary waves for the best use for future assimilation in atmospheric models. The third stage will comprise demonstration of the capabilities of the new infrastructure: "The main challenge is to

ARISE

ATMOSPHERIC DYNAMICS INFRASTRUCTURE IN EUROPE

OBJECTIVES

To design a new infrastructure that integrates different station networks in order to provide a new 3D image of the atmosphere from the ground to the mesosphere with unprecedented spatio-temporal resolution. In addition the network will incorporate complementary infrasound station and satellite observations.

PARTNERS

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 • **Ecole Centrale de Lyon (ECL)**, France

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ELISABETH BLANC is Research Director at CEA. Her area of expertise includes the study by different technologies of the disturbances of the Earth environment from ground up to the ionosphere. She was a scientific expert in the infrasound expert group mandated by the CTBT's international monitoring system and proposed several international projects related to atmospheric observations.

extract from three different networks, managed by three different communities who have never worked together previously, new data models able to better represent atmospheric dynamics and exchanges," she asserts.

BASELINE ANALYSIS, REQUIREMENTS DEFINITION AND DATA ARCHITECTURE

Baseline analysis of the different observation networks and optimisation of their configuration to create the technical infrastructure for ARISE is the first objective. The work will consist in assessing the data produced by sensors and stations, taking into account their home network architectures and processing procedures, and identifying the data most suited to meeting the requirements of the consolidated data centre.

In parallel, another work package will define the requirements for atmospheric parameters used in weather and climate studies, and establish the network capabilities of different possible infrastructure configurations; and another will define the requirements for extreme event monitoring, especially in terms of monitoring volcanic activity. The final work package will be production of a prototype ARISE data centre for validation purposes.

For defining ARISE data products, the working group will compare observations from the different networks during prototype experiment campaigns where the three sets of instrumentation will be used simultaneously, as well as selected archived observations. The objective is to ensure that the integrated datasets are accessible for most scientific studies. Simultaneously, the data products for extreme event monitoring will be designed and observations will be converted into numerical models of the atmosphere and its dynamics; data gathering and management, and data display via web servers will be modelled and the infrastructure will be refined.

Outreach is an important part of ARISE's activities, with workshops and a summer school planned to train new teams interested in the installation of stations in their countries and to provide information to scientists interested in the potential of the new infrastructure, thus opening up the service to new stakeholders.

THE ARISE DATA CENTRE

The demonstration of the ARISE data centre and web services is the major deliverable from the final project stage. This will highlight the project's scientific results and challenging future applications. The service will be demonstrated in Germany. It will use data from observation campaigns organised by LATMOS at the Observatoire de Haute Provence in France where the three network technologies will be used simultaneously. Other campaigns organised by UNIFI will also be performed in Italy near Etna volcano: "The demonstration will use input data from the three participating networks, obtained regularly and by campaign measurements, and additional satellite data," Blanc outlines. A platform will be developed by DLR using the integrated data and running simulations. It will provide data services to access, process and display data for users inside and outside of the project – results will be online, accessible by a website.

The working group's activities cover all disturbances of the atmosphere from infrasound to planetary waves, from ground to mesospheric altitudes, so the impact will be considerable. Interest in the study of atmospheric dynamics and climate is large, as global atmospheric circulation in the stratosphere and mesosphere involves a strong coupling between low and high latitude regions. The success of the work to date means the project looks set to spread even further afield. Expansion of ARISE into Africa will allow exceptional coverage from equatorial regions to polar regions and the inclusion of topics related to atmospheric modelling will increase its potential future use for better understanding, and parameterisation, of large scale atmospheric disturbances.