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# ARISE project: multi-instrument observations in the middle atmosphere for improving the description of gravity waves and other middle atmospheric disturbances


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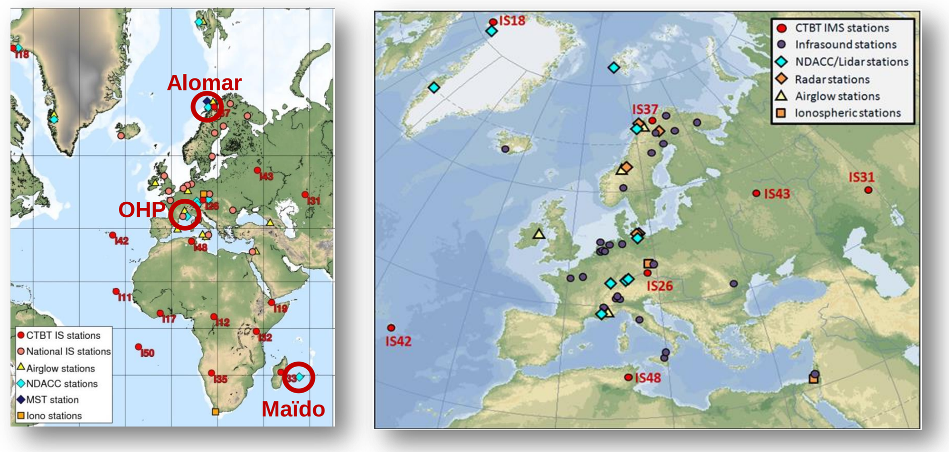
http://arise-project.eu


## Abstract

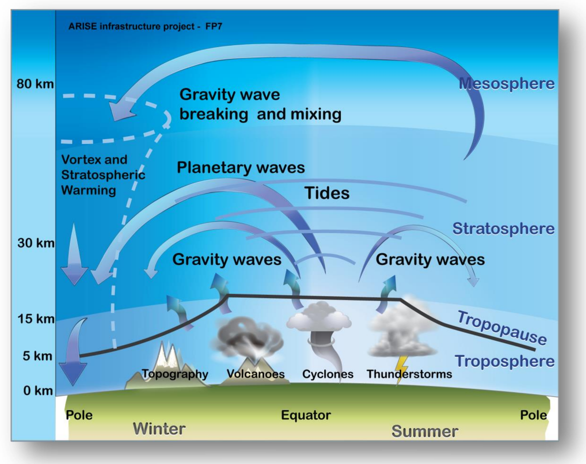
The ARISE project integrates different station networks providing observations from ground to the lower thermosphere, including:

- the International infrasound Monitoring System (IMS) developed for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification regime (http://www.ctbto.org/),
- the European infrasound network developed at national levels,
- the Network for the Detection of Atmospheric Composition Changes (NDACC) providing Lidar measurements (dynamics) (NDACC - http://ndacc-lidar.org),
- complementary Mesosphere-Stratosphere-Troposphere (MST) radars, meteor radars, wind radiometers, airglow cameras, ionospheric sounders and satellites.

Multi instrument observations are performed in reference ARISE stations such as ALOMAR (Andoya Space Center), OHP (Observatoire de haute Provence), Maïdo at Reunion Island.

*ARISE observation network*



*Atmospheric dynamic processes*

The middle atmospheric dynamics is controlled by the atmospheric waves mainly originating from the troposphere at low altitudes. The wave activity is stronger in the winter hemisphere. Large scale sudden stratospheric warming events strongly disturb the high latitude regions

As high resolution operational measurements are missing, the lack of knowledge of disturbances leads to uncertainties in Numerical Weather Prediction (NWP) models such as ECMWF (European Centre of Medium range Weather Forecasting) analyses and infrasound propagation simulations.

The project objective is to develop new multi-instrument routine and measurement campaigns to monitor the dynamics of the middle atmosphere and large scale disturbances such as gravity waves, planetary waves, stratospheric warming events.

The ARISE main objective is to better describe atmospheric disturbances to quantify uncertainties for operational infrasound monitoring and weather medium range forecasting.

*Blanc et al., Surveys in geophysics, https://link.springer.com/journal/10712 2017*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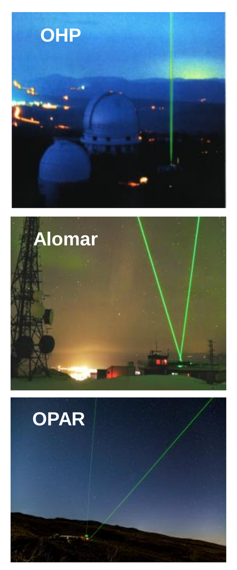
## Gravity waves at the origin of uncertainties in models

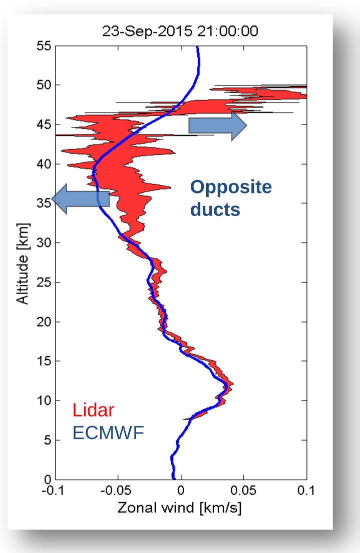
The ARISE multi-observation campaigns focused on the estimation of the differences between observations and European Centre for Medium-Range Weather Forecast (ECMWF) analyses up to 70 km altitude to assess model uncertainties .

*The models are well adapted to describe the atmosphere at time scales larger than several days. However, gravity waves and other disturbances are poorly represented in models. The ARISE new measurements provide description of these disturbances. ARISE data are currently used as benchmark by ECMWF. In future, ARISE data will be improved (additional stations, prototype developments) for improving the ARISE data base for future assimilation in models.*





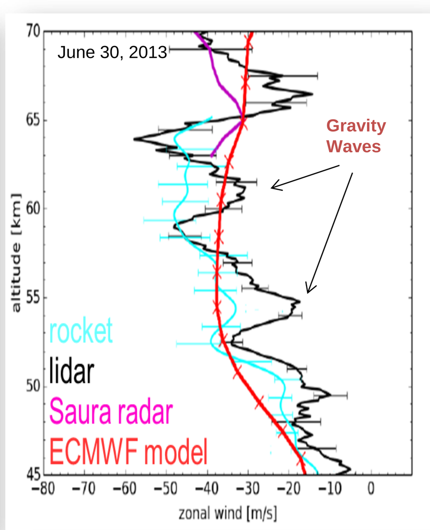
Maïdo wind profile





*Hauchecorne, 2016*

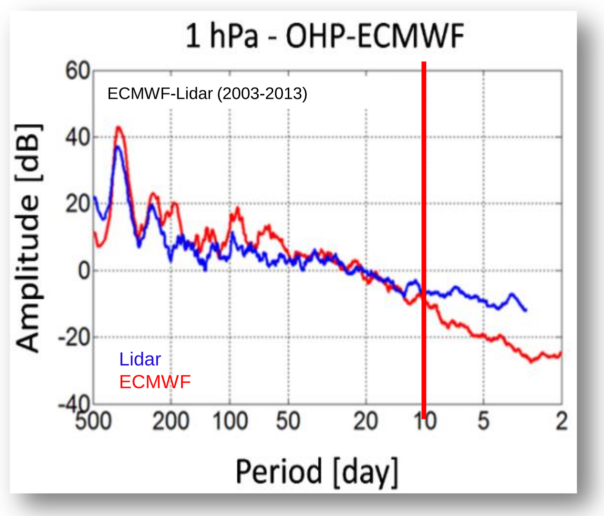
Alomar wind profile





*Baumgarten, 2014*

Observatoire de Haute Provence OHP lidar spectra

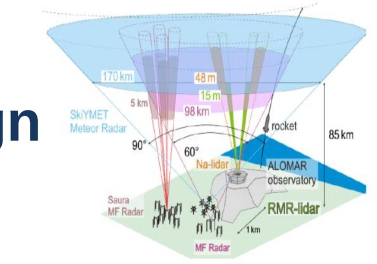


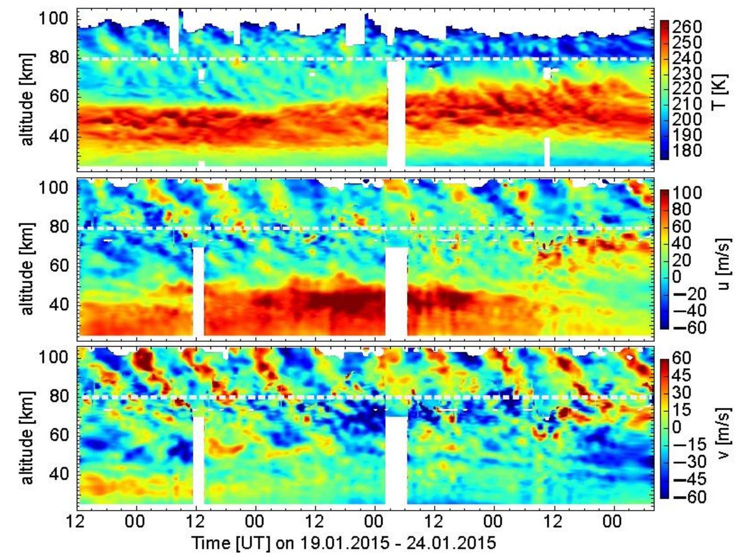


*Keckhut, 2014; Le Pichon et al, 2015*

- ❑ *Wind lidar and ECMWF present large differences in the presence of **gravity waves** which are generally not integrated in models*
- ❑ *They also present differences above 30 km during the equinox period when **opposite ducts** are expected*

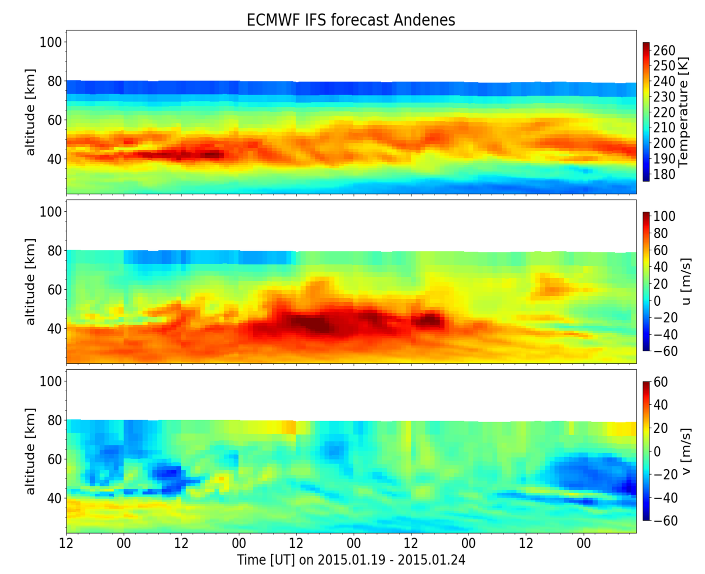
## Continuous high resolution lidar and radar intercomparisons during a five days campaign







*Lidar and radar observations at ALOMAR: - temperature (top panel), - zonal (middle panel) and meridional wind (lower panel). Measurements below 80 km altitude were performed by the RMR lidar. Temperature and wind measurements above 80 km altitude were performed with the Fe lidar and the meteor radar respectively.*





*ECMWF IFS forecast data extracted for ALOMAR with a temporal resolution of 1 hour. The data were extracted on model levels.*

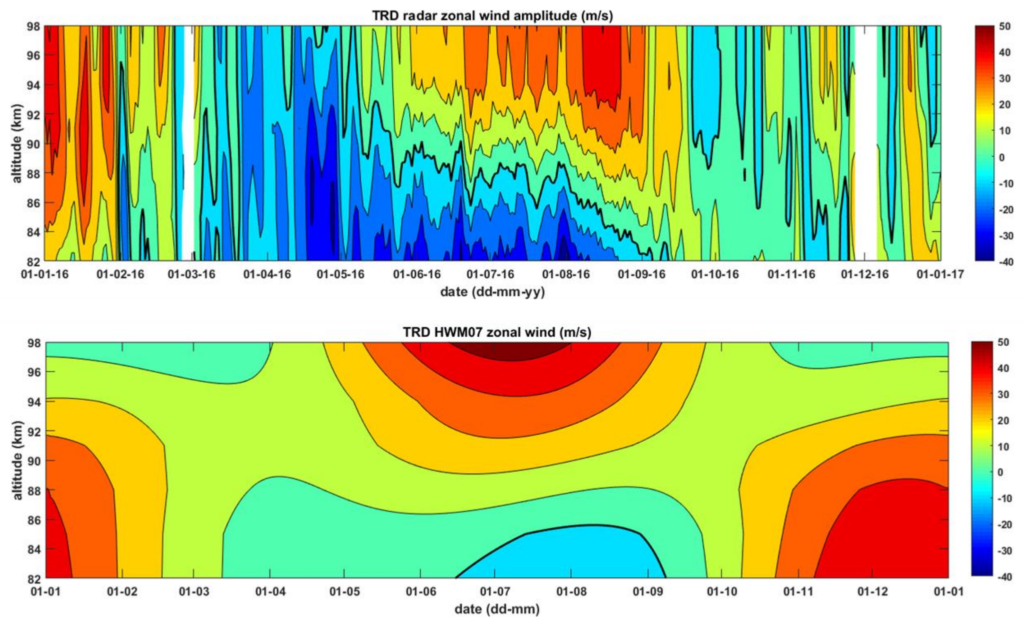
*Baumgarten, Hoffner, Stober, 2016*
*Hildebrand et al., 2016*

We notice remarkable agreements but also large differences, especially in the GW-induced structures. For example, the increase in the stratopause altitude is partially captured; the same observation applies to the increase / decrease in zonal wind. But, GW and tidal observations are not reproduced in the ECMWF estimates, neither in temperature nor in winds. Detailed comparisons of the wave activity in January (Hildebrand et al., 2017) shows that the GW amplitudes in temperature and wind fluctuations are underestimated in ECMWF by more than a factor of 3 above 50 km.

## Uncertainties determined by lidar and meteor radar routine observations

### Trondheim meteor radar (NO)

All-sky SKiYMET system





*(Top) 4-day running mean zonal wind (82-98 km) during 2016. (Bottom) 4-day running mean zonal wind derived from the quiet time HWM07 model at 63.5°N, 10°E. Contours are at 10 m/s intervals.*

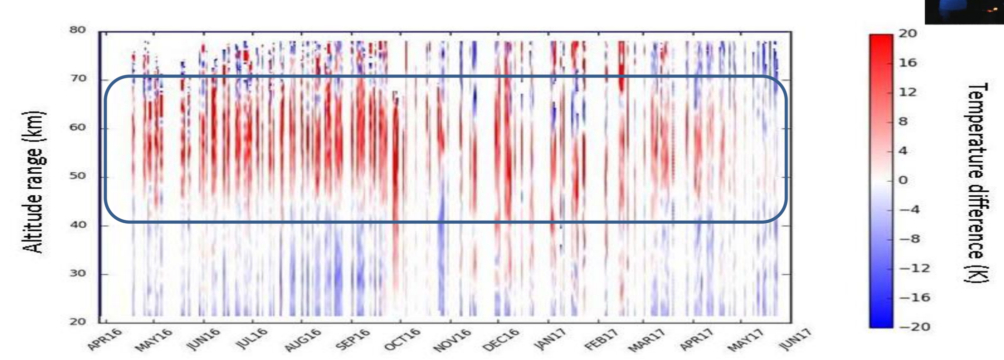
During the summer months, a strong positive zonal wind shear is observed, as the stratospheric and lower mesospheric westward flow is dragged eastwards by gravity wave breaking . Outside the summer months, the wind field is much more variable because of planetary waves activity.

*Hibbins, Espy, 2017*

The HWM-07 climatological model reproduces the wind shear seen during the summer months, although the altitude of the zero zonal wind line is not well reproduced. In spring and autumn, the model tends to overestimate the observed zonal winds; the strong low frequency (>4 days) variability seen in the zonal winds during wintertime is not captured.

### OHP lidar (FR)

RMR and Doppler lidar at the OHP

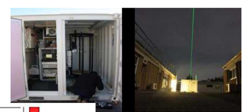




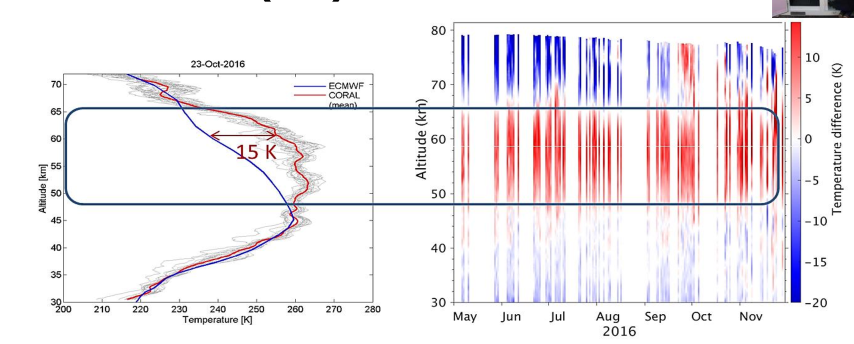
*The differences between the observed temperatures and the estimates from ECMWF HRES analysis reveals a good agreement up to 45 km*

*However, the increase observed in temperatures from September 2016 to January 2017 between altitudes from 40 to 65 km is hardly captured by the model.*

### CORAL lidar (DE)



Mobile CORAL Lidar(DLR, DE) at the IS26DE infrasound station





*The comparison between observations and model (ECMWF IFS137) reveals systematic difference between 45 and 68 km, with a maximum reaching 16 K on the 25th of October.*

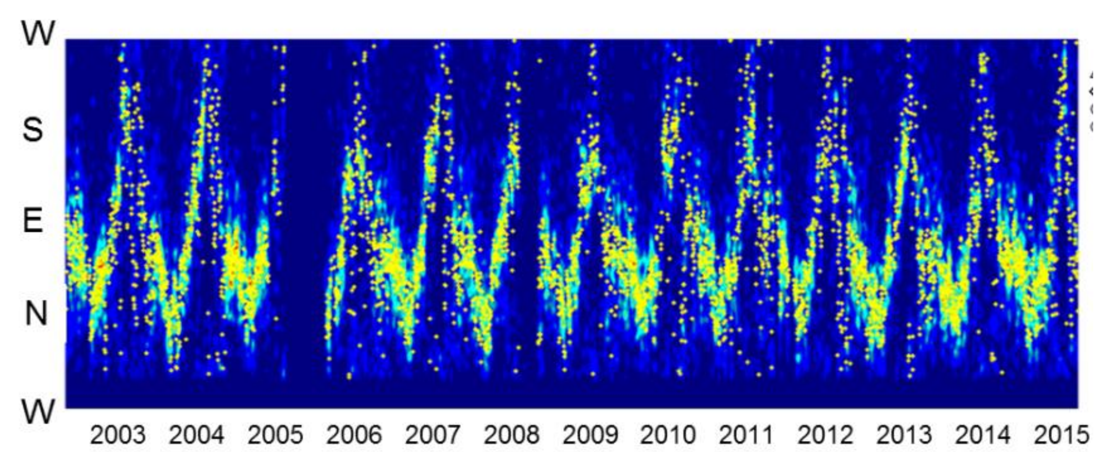
It is highly probable, that the overall observed ECMWF model under-performance in reproducing the thermal atmospheric state is explained by intense gravity wave activity, not resolved by the model.

*Rapp et al. ARISE MTR, 2017 , Ceranna et al., 2017*

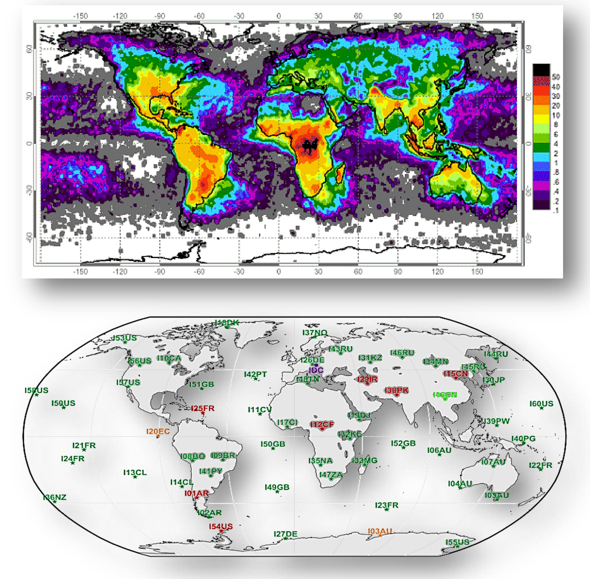
*Pol, Hauchecorne, 2017, Blanc et al., 2017*

## Infrasound technology as used to determine gravity wave characteristics

### Gravity Waves from deep convection







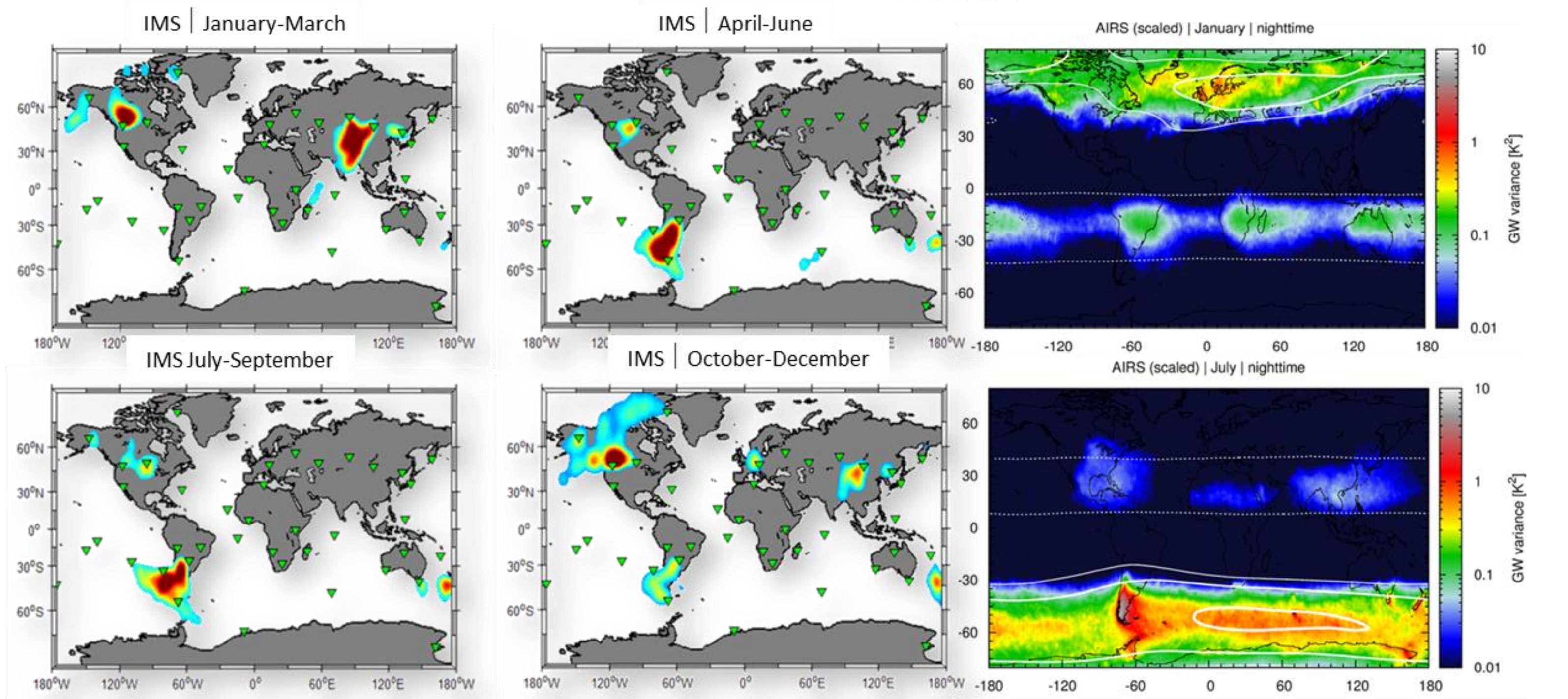
*Left: GW activity measured during 13 years in the IS17 infrasound station in Ivory Coast (6.67°N, 4.85°W) . GWs originate from deep convection. Right: map of thunderstorm activity (Christian et al., 2003) and map of the IMS CTBT infrasound stations (Marty, 2017).*

*Blanc et al., 2014*

The low latitude dynamical activity is mainly controlled by the thunderstorm activity. GWs observed in Ivory Coast are strongly related to convection associated with thunderstorms. The seasonal azimuth change in the GW direction represents the motion of the ITCZ (InterTropical Convergence Zone) which drive the thunderstorm activity North and South of the station every year.

GWs produced by thunderstorms propagate vertically into the stratosphere, mesosphere, and lower thermosphere as demonstrated by WRF model in the upwind direction (Costantino and Heinrich, 2014).

### Mountain acoustic gravity waves





*Left: Map of mountain waves from remote observations in the infrasound frequency range compared with GW maps observed by satellite (right) (from Hoffmann et al. 2014). The large mountain wave activity over South America is observed by both technologies indicating that the infrasound mountain waves are indicators of the GWs observed by satellites over mountains. The infrasound technology isolates mountain waves from waves generated by other sources (convection)*

Infrasound waves originating from mountain areas are identified by the IMS network. Their period is few tens of seconds and their duration can vary from hours to days with a stable azimuth directed towards mountain areas. As these waves propagate over large distances in the infrasound wave guide, they can be detected by several stations of the IMS infrasound network and their origin can be determined. Because of this possible related origin, the infrasound mountain waves are expected to be a tracer of the mountain GWs.

*Blanc et al., 2017; Hupe, 2017*

## Perspectives

ARISE provides new multi-instrument data sets associated to modelling for a better description of the middle atmospheric dynamics from polar to tropical regions in the Europe-Africa sector.

The perspectives focus on:

- Station network improvement by developing synergy between instruments, including association between lidar and infrasound technology,
- Data portal development for improving the representation of GW and other disturbances
- Applications:
  - Future assimilation in short- and medium-range weather forecasts,
  - Monitoring of atmospheric extreme events,
  - Monitoring of middle atmosphere climate and its long-term mean trends.

## The ARISE2 team

1- Commissariat à l'Energie Atomique et aux Energies Alternatives (FR)
2- Bundesanstalt für Geowissenschaften und Rohstoffe (DE)
3- Centre National de la Recherche Scientifique (FR)
4- University of Reading (GB)
5- Stiftelsen Norwegian Seismic Array (NO)
6- Universita Degli Studi Di Firenze (IT)
7- Deutsches Zentrum für Luft- und Raumfahrt (DE)
8- Koninklijk Nederlands Meteorologisch Instituut (NL)
9- Leibniz Institute of Atmospheric Physics (DE)
10- Andoya Space Center (NO)
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15- Université de la Réunion (FR)
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17- Tel Aviv University - Department of Geosciences (IL)
18- National University of Ireland Maynooth (IE)
19- Veðurstofu Íslands/Icelandic Meteorological Office (IS)
20- Institut et Observatoire de Geophysique d'Antananarivo (MG)
21- National Institute of Earth Physics (RO)
22- Universidade dos Açores - Fundação Gaspar Frutuoso (PT)
23- Centre National de la Cartographie et de la Télédétection (TN)