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.itsbn.org),
- the European infrasound network developed at national levels,
- the Network for the Detection of Atmospheric Composition Changes (NDACC) providing Lidar measurements (dynamic) (NDACC - http://ndac-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), Mado at Reunion Island.

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 modify 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 project main objective is to better describe atmospheric disturbances to quantify uncertainties for operational infrasound monitoring and weather medium range forecasting.
Blanc et al., Survey in geophysics. https://doi.org/10.1016/j.sGGF.2017

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Gravity waves at the origin of uncertainties in models
The ARISE multi-instrument observations focused on the estimation of the differences between observations and Numerical Weather Prediction (NWP) models such as ECMWF (European Centre of Medium Range Weather Forecasting) analyses and infrasound propagation simulations.
The models are well adapted to describe the atmospheric 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. ARSE data are currently used as benchmark for ECMWF. In future, ARSE data will be improved (additional stations, prototype developments) for improving the ARSE data base for future assimilation in models.

Continuous high resolution lidar and radar intercomparisons during a five days campaign
The HWM-07 climatological model reproduces the wind shear seen during the summer months, although the altitude of the zero wind line is not well reproduced. In spring and autumn, the model leads to overestimate the observed wind-shear; the strong low frequency (≥4 days) variability seen in the zonal winds during vortexime is not captured.

The HWM07 model in the upper stratosphere.

Ecudiff model

We notice remarkable agreement but also large differences, especially in the GW induced structures. For example, the increase in the stratospheric 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 ECDFM 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 2 above 60 km.

Infrasound technology as used to determine gravity wave characteristics
Gravity Waves from deep convection
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 archetypal change in the GW direction represents the movement 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 described by WRF model in the upward direction (Costantino and Heinrich, 2014).

Infrasound acoustic gravity waves
The map of mountain areas from remote observables in the infrasound frequency range compared with GW maps observed by satellite (right) from Hoffman et al., 2014. The large mountain wave activity over South America is observed by both techniques indicating that the infrasound mountain waves are indicators of the GWs observed by satellites over mountain. The infrasound technology identificies mountain waves from waves generated by other sources (connection).

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 scale distances, 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 trace of the mountain Gibbs.

Blanc et al., 2017. "Why?" 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.

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