New challenges of the ARISE project

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ARISE (Atmospheric dynamics Research InfraStructure in Europe)

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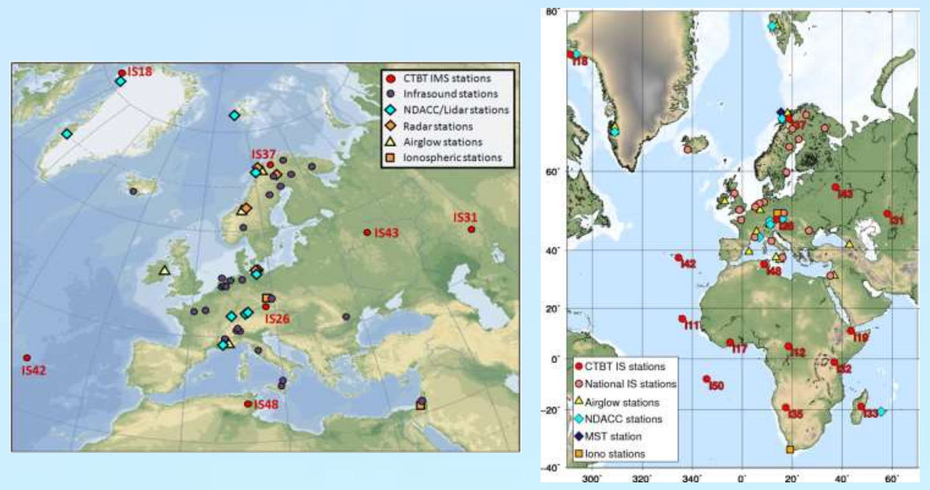
ARISE station network

ARISE infrastructure composed of:

- the **infrasound network** of the International Monitoring System (IMS) for the verification of the Comprehensive Nuclear Test Ban Treaty (CTBT - http://www.ctbto.org/),
- the Network for the Detection of Atmospheric Composition Change (**NDACC** - http://ndacc-lidar.org), using **lidar for stratospheric temperature and wind measurements**,
- complementary infrasound stations, **MST and meteor radars, airglow measurements,**
- **ionospheric arrays** and **EISCAT** radar
- **OHP** (Observatoire de haute Provence), **Observatoire Maido** (Reunion Island), **ALOMAR** infrastructure (Andoya Space Center),
- **satellite** measurements

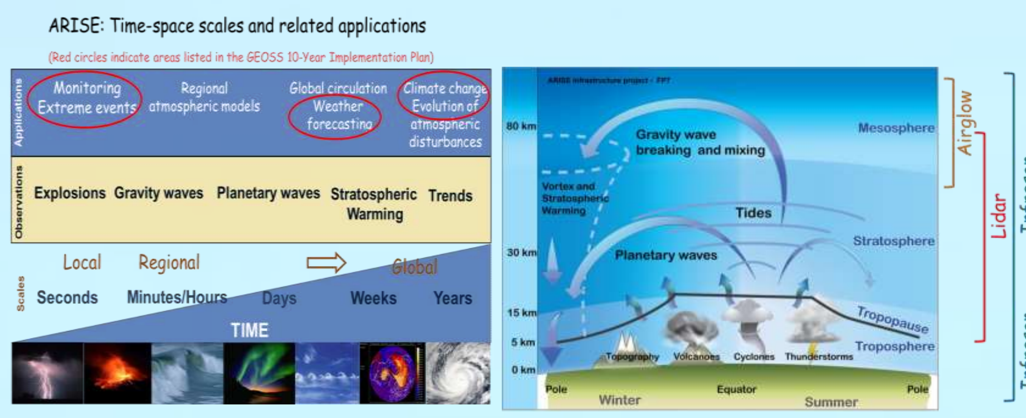


ARISE objectives

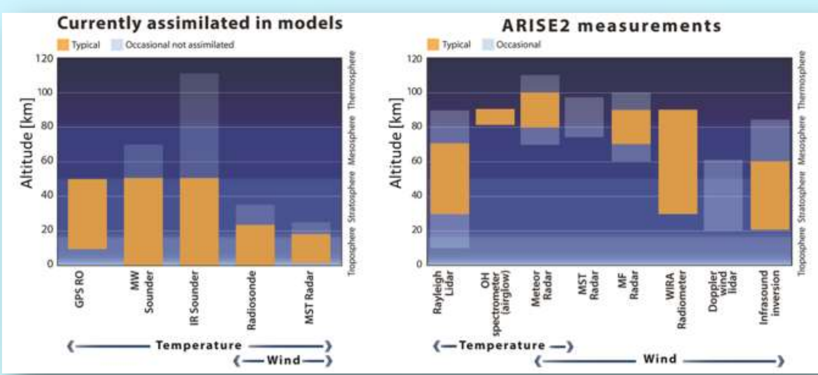
The ARISE project aims at establishing a unique atmospheric research and data platform in Europe which combines observations with theoretical and modeling studies to elucidate the dynamics of the middle and upper atmosphere.

Expected benefits:

- improved accuracy in **short- and medium-range weather forecasts,**
- better representation of **stratospheric climate forcing on the troposphere**
- **monitoring of extreme events**
- **monitoring of middle atmosphere climate** and its long-term mean trends..



ARISE observation challenges



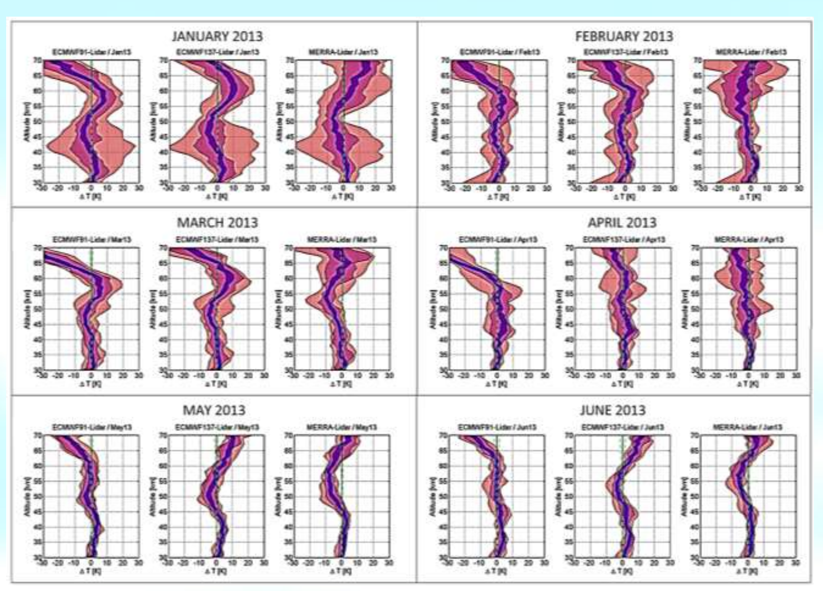
Instrumentation currently assimilated in the ECMWF(**E**uropean **C**entre for **M**edium-range **W**eather **F**orecasts) model and instrumentation proposed in the framework of the ARISE project.

Optimization of the observation network:

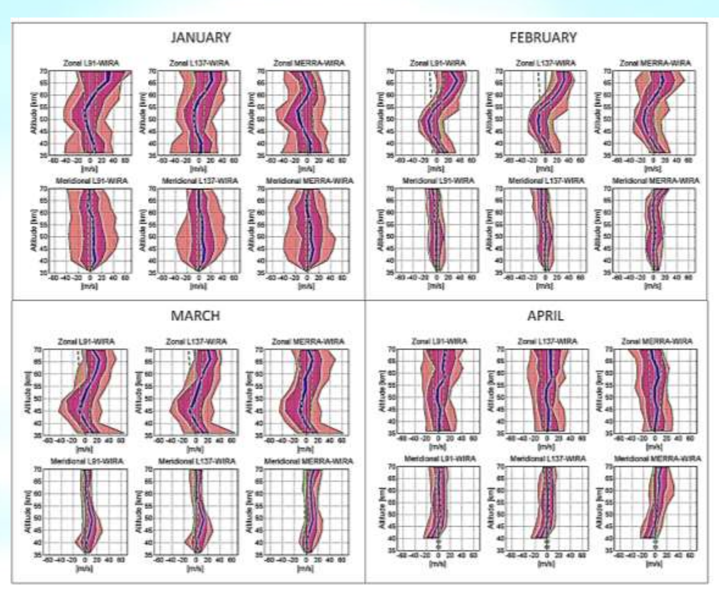
- **network coverage to low and high latitude regions** (using existing complementary infrastructures),
- **accuracy, time resolution and range of altitude** of the measurements (new instruments),
- **routine observation modes for continuous observations** (survey mode),
- **open access to advanced data products** for many applications (weather forecasting, climate, ash plumes, atmospheric extreme events) through a prototype data centre.

The project focuses especially on the challenging objective of linking observations with models

Comparison between observations and models



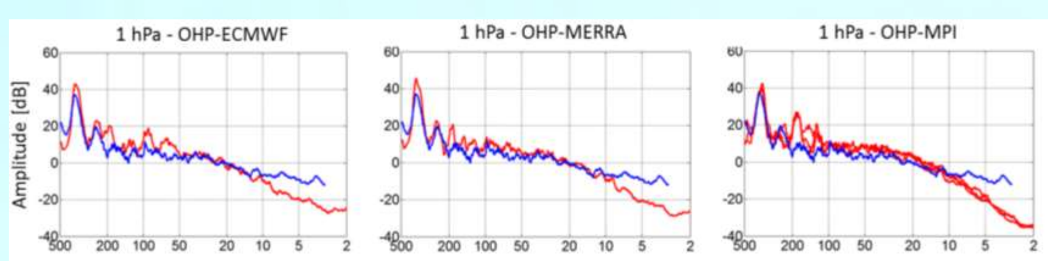
Distribution of the monthly difference between ECMWF (L91 and L137) and MERRA (**M**odern-**E**RA **R**etrospective **A**nalysis for **R**esearch and **A**pplications**)** temperature models at 0h UTC and nightly averaged lidar measurements versus altitude at OHP from January to June 2013.



Distribution of the monthly difference between ECMWF wind model at 12h UTC and daily averaged WIRA measurements versus altitude at OHP from January to April 2013.

Blue lines: standard error of the mean. Green dashed lines: instrumental error bars. The differences are significant when the blue lines fall outside of the green dashed lines. Purple and pink regions: 66% and 95% confidence intervals of the difference profiles (Le Pichon et al., JGR, 2015).

The largest deviations noted in winter at 40-45 km altitude and correspond to the time of the major Sudden Stratospheric Warming (SSW) that occurred early January 2013. This deviation might be due to the lack of short time-scale variability in the models. After the vernal equinox, the deviation of the mean and 95% intervals reduce by about a factor 2 due to the lack of stratospheric and mesospheric variability in this season.



Comparison between lidar (blue) and model (red) periodograms at 1 hPa (~47 km) over OHP. (a): ECMWF (2003-2013). (b): MERRA (2003-2013). (c): MPI-ESM-LR (1991-2005), each line corresponds to one ensemble member (Le Pichon et al., 2015).

A reasonable agreement in spectral amplitude is found down to 15-20 days for all models.

Compared to the observations, the variability at shorter time-scales is lacking in both weather and climate models.

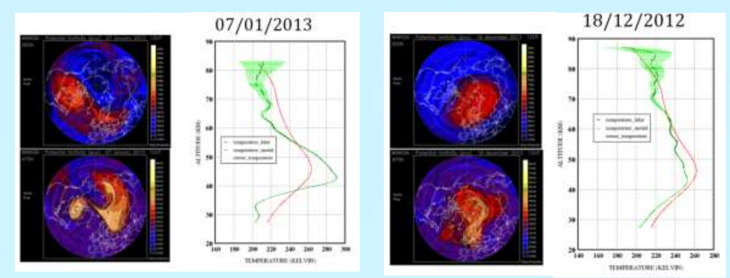
Abstract

- It has been robustly demonstrated that variations in the circulation of the middle atmosphere influence weather and climate throughout the troposphere all the way to the Earth's surface. A key part of the coupling between the troposphere and stratosphere occurs through the propagation and breaking of planetary-scale Rossby waves and gravity waves. Limited observation of the middle atmosphere and these waves in particular limits the ability to faithfully reproduce the dynamics of the middle atmosphere in numerical weather prediction and climate models.
- The ARISE project combines for the first time international networks with complementary technologies such as infrasound, lidar, radar and satellites. This joint network provided advanced data products that started to be used as benchmarks for weather forecast models. The ARISE network also allows enhanced and detailed monitoring of other extreme events in the Earth system such as erupting volcanoes, magnetic storms, tornadoes and tropical thunderstorms.
- In order to improve the ability of the network to monitor atmospheric dynamics, ARISE proposes to extend
  - the existing network coverage in Africa and the high latitudes,
  - the altitude range in the stratosphere and mesosphere,
  - the observation duration using routine observation modes, and to use complementary existing infrastructures and innovative instrumentations.

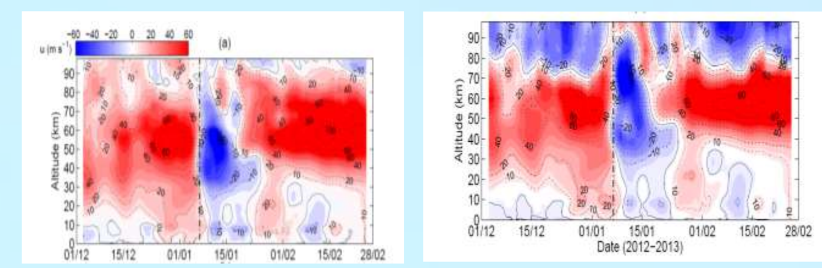
Data will be collected over the long term to improve weather forecasting to monthly or seasonal timescales, to monitor atmospheric extreme events and climate change.

- ARISE focuses on the link between models and observations for future assimilation of data by operational weather forecasting models. Among the applications, ARISE2 proposes infrasound remote volcano monitoring to provide notifications to civil aviation.

Sudden Stratospheric Warming Events



SSW observed in January 2013 by lidar at OHP (Hauchecorne, 2024).



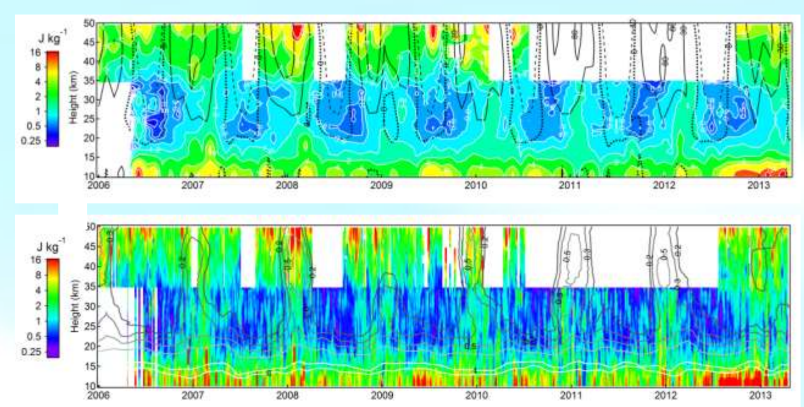
Meteor radar-MERRA @ TRD WACCM-SD @ TR D (Espy, 2014)

WACCM (Whole Atmosphere Community Climate Model)

During SSW significant differences are observed between observations and models. WACCM-SD overestimates wind shear above constraint region (60 km) and has wrong direction above 70 km. Between 40 and 50 km, differences in temperature reach 30K.

Gravity waves and the dynamics of the atmosphere

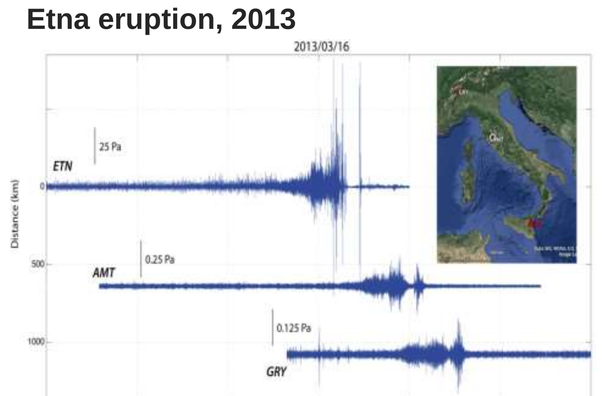
Gravity wave at low and middle latitudes produce a forcing of the stratosphere. This induces long-lived changes in the stratospheric circulation, leading to fluctuations in the strength of the polar vortex. These fluctuations move down to the lower stratosphere in high latitude regions with possible effects on the troposphere *(Holton, 1995, Baldwin et al., 2003).* They are generated by by topography, jet stream instabilities or convection. Mainly produced at low and mid latitudes they constitute an important component of the global circulation system.



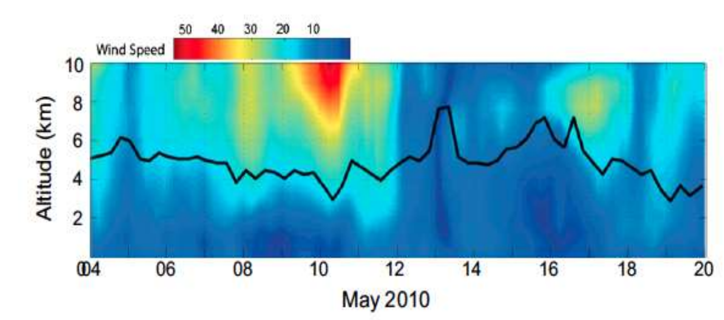
Combined time series of GW Ep from Rayleigh lidar at OHP and COSMIC GPS Radio Occultation data (5° × 5° domain centered at OHP). a) Monthly-mean Ep (color map) and zonal wind (solid contours - westerly winds of 30 and 80 m/s, dotted contour - zero wind, dashed contour - easterly wind of 10 m/s). b) Weekly means of E_p from COSMIC and lidar (color map) and monthly means of MERRA Ep (Khaykin et al., 2015).

Monitoring of distant volcanoes by infrasound technology

Etna eruption, 2013

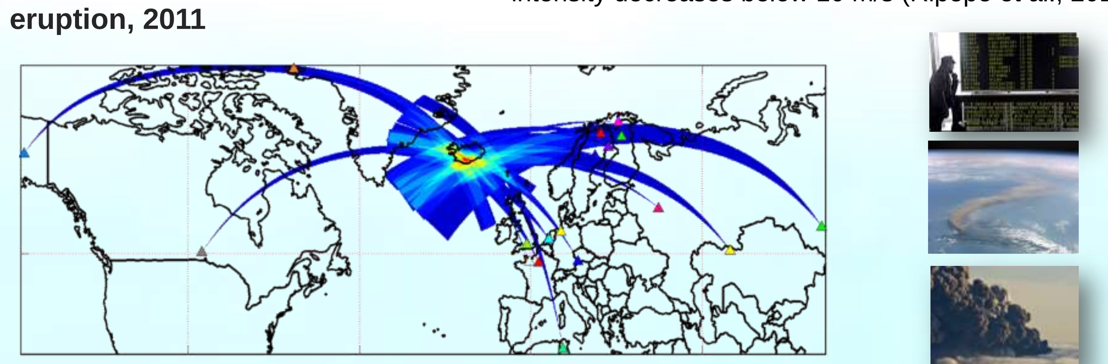


Infrasonic signals from Etna at ETN (~5 km) at AMT (~630 km) and at GRY (~1080 km) (Marchetti, 2014).

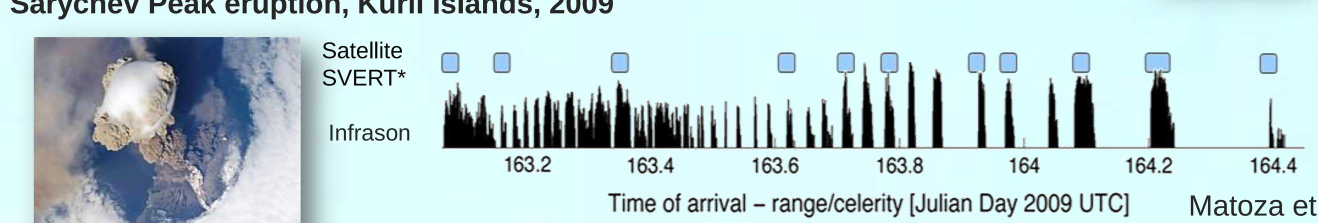


Plume height (black line) reflects the wind profile (ECMWF), reaching the maximum heights of 8 km only when the wind intensity decreases below 10 m/s (Ripepe et al., 2013).

Eyjafjallajökull eruption, 2011

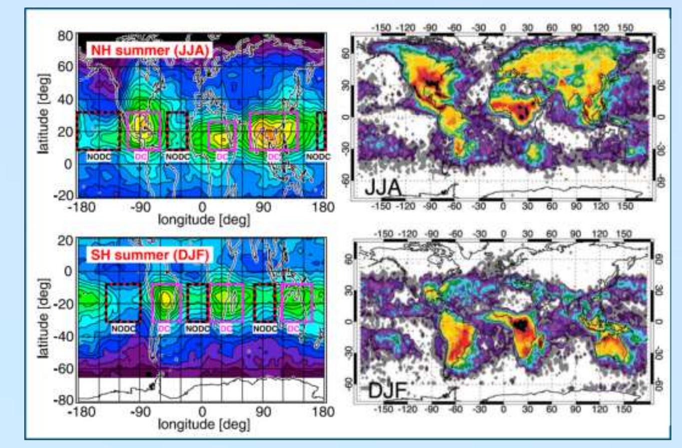


Sarychev Peak eruption, Kuril Islands, 2009



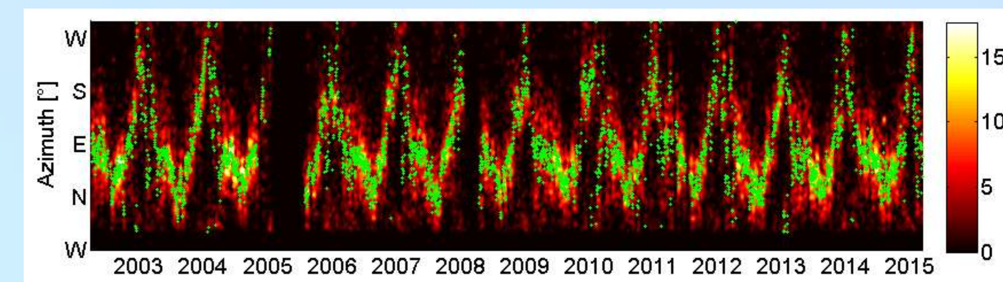
Matoza et al., 2011; 2012

Observations of gravity waves using the IMS infrasound network

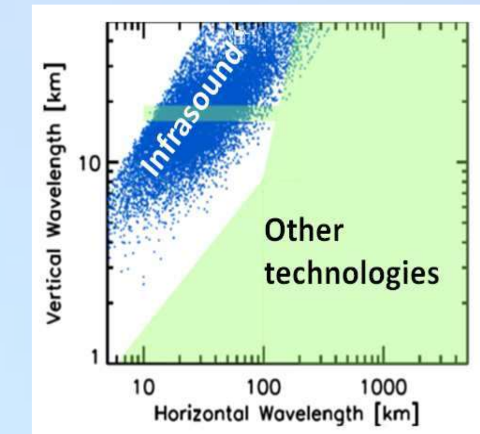


One of the experimentally least studied GW sources is the generation of waves by convection which appears to be responsible for the strong near-equatorial gravity wave activity in the Summer Hemisphere seen in various satellite data sets (Christian et al. 2003).

Ivory Coast is a hot spot for gravity wave momentum fluxes as shown by the GW momentum flux global distribution measured by the satellite borne instrument HIRDLS (High resolution dynamics limb sounder) on board the AURA mission spacecraft) (Ern and Preusse, 2012) .



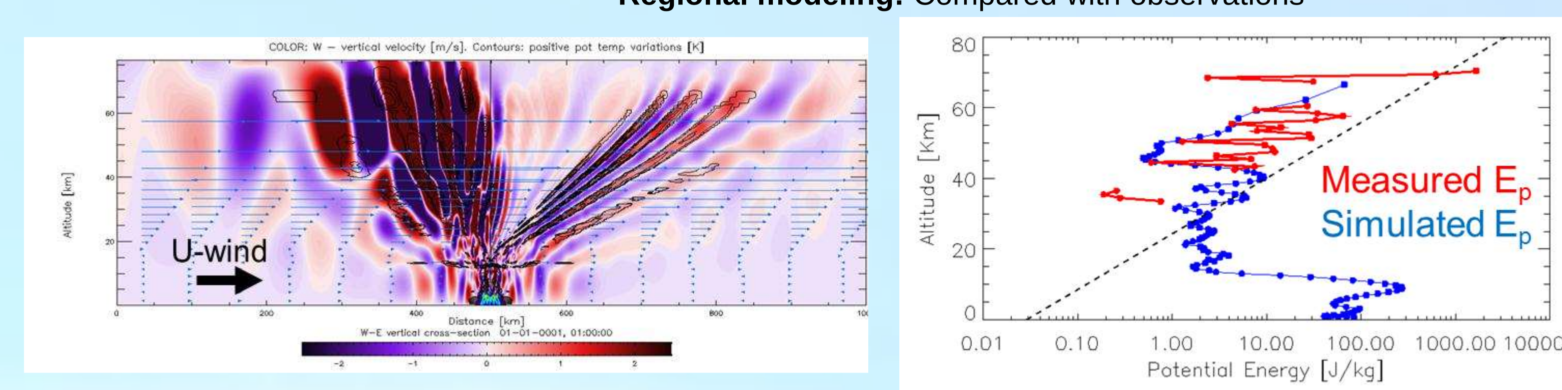
Thirteen years of gravity wave activity measured at IS17 infrasound station (Ivory Coast). The color scale indicates the logarithm of the number of detections. The seasonal variations of the wave azimuth are related to thunderstorms and to the tropical rain belt partly related to the Intertropical Convergence Zone of the winds (Blanc et al., 2014).



Gravity wave scales observed by the Ivory Coast infrasound station (blue dots), and typical observation ranges of other instruments (green shading) (Charlton Perez et al., 2014).

Regional modeling

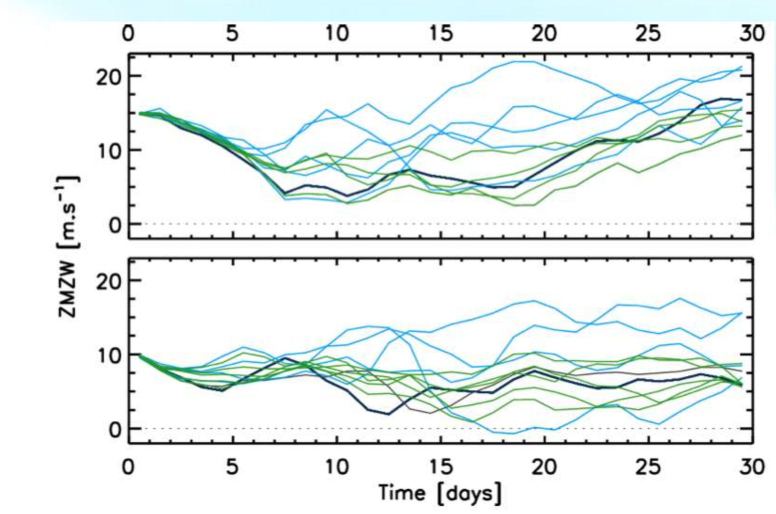
Local observations: Lidar + gravity waves at ground
Regional modeling: Compared with observations



Gravity waves generated by a thunderstorm during the ARISE OHP observation campaign in October 2012 (in blue, at the bottom of the figure) for a vertically-sheared horizontal velocity. Vertical velocity is computed from ground to an altitude of 77 km. Black contours represent strong variations of the potential temperature. Simulations were performed by a regional meteorological model and compared with lidar observations (Heinrich and Costantino, 2015).

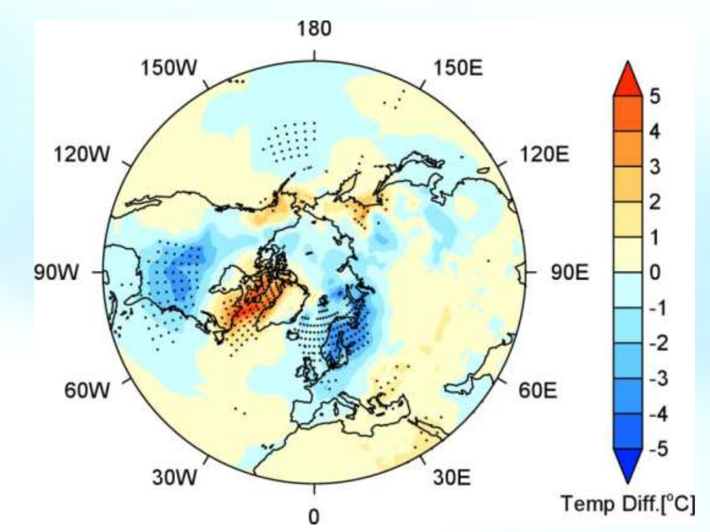
Weather predictability (30 days) : Effects of SSW

Simulation: 30 day forecasts including stratospheric effects



Two SSW cases from the control run (thick dark line), and their 30 day ensemble forecasts (light blue) with upper-stratosphere nudged ensemble (green lines), in the upper troposphere (100hPa). Stratospheric nudging reduces the ensemble spread for the nudged ensemble, indicating enhanced predictability at these altitudes.

Surface temperature anomalies for 15 SSW



The surface temperature anomalies are averaged over forecast days 15-30 for 15 SSW cases. The stippling indicates significance at the 95% confidence level.

Major SSW events can be followed by cold weather that can affect Northern Europe for many weeks (for instance in 2010 and 2013). Unfortunately, **tropospheric forecasts by Numerical Weather Prediction models are unreliable beyond a few days under these circumstances.**

ARISE2 provides relevant advanced data products for future data assimilation needed for longer-term and more precise forecasts in the past decades**.** In the shorter term, ARISE2 measurements can be used as an independent means to constrain ensemble predictions and gravity wave parameterisations

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