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The ARISE project: dynamics of the atmosphere and climate

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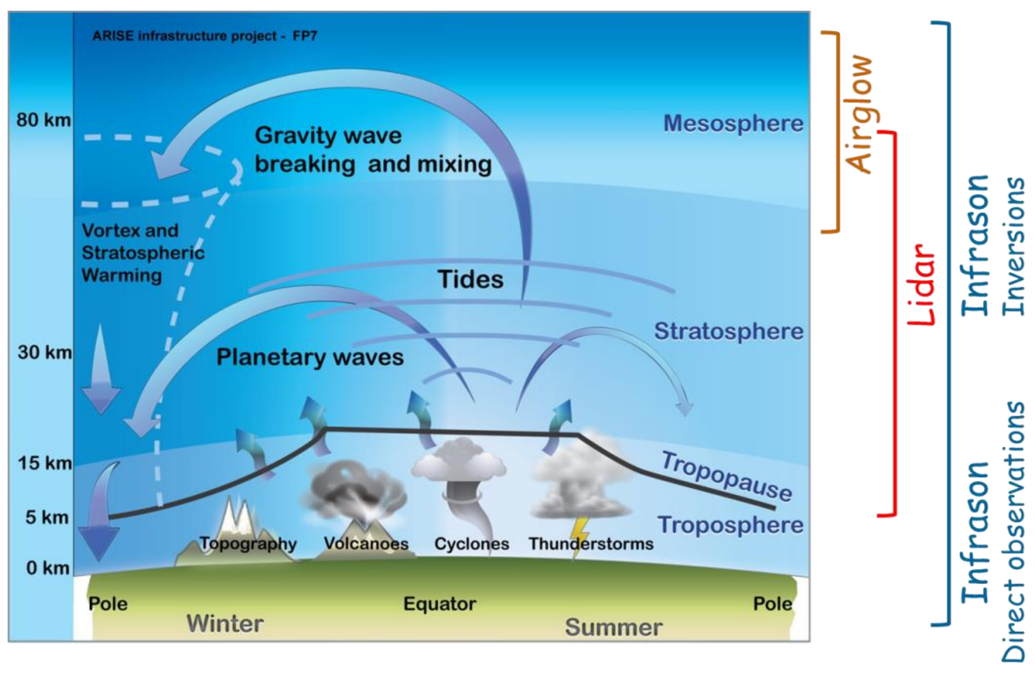
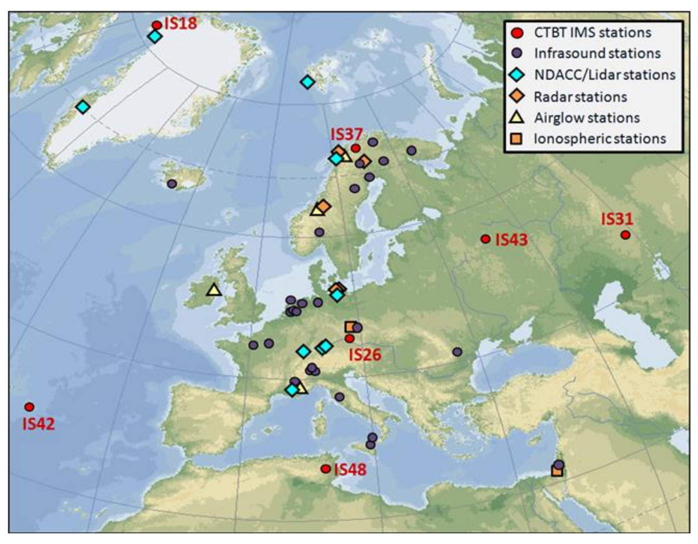
The ARISE (Atmospheric dynamics Research InfraStructure in Europe) project is funded by European Commission under the FP7 (2012-2014) and H2020 (2015-2018) European Research infrastructure program. The poster highlights the project issues associated to weather and climate.

ARISE contributes to an improved understanding of the dynamics of the troposphere-stratosphere-mesosphere exchanges and related processes.

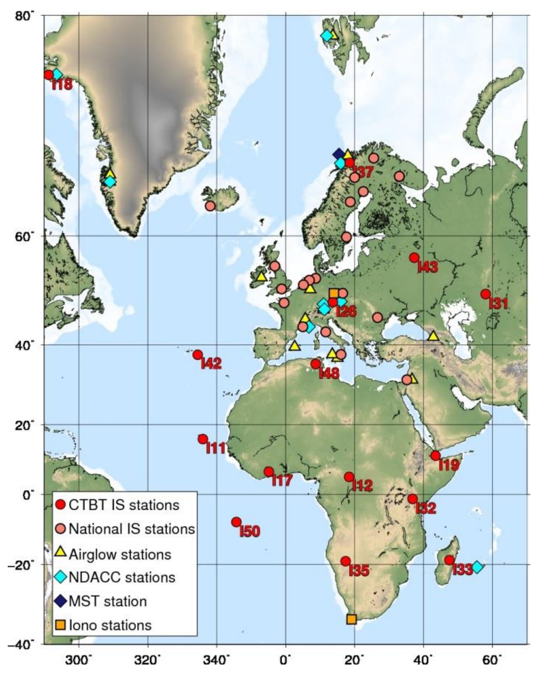
The ARISE project



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 waves and gravity waves.
Limited observations of the middle atmosphere and these waves in particular hamper our ability to faithfully reproduce the dynamics of the middle atmosphere in numerical weather prediction and climate models.



http://arise-project.eu

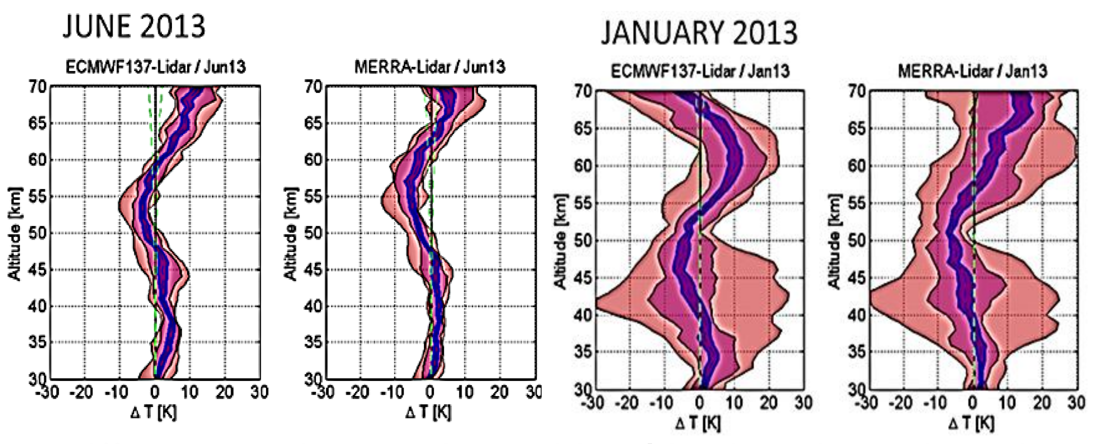


ARISE combines existing national and international station networks including:

- the International infrasound network developed for the CTBT (Comprehensive nuclear-Test-Ban Treaty) verification completed by national European infrasound stations,
- the NDACC (Network for the Detection of Atmospheric Composition Changes) providing lidar observations,
- European infrastructures at mid latitudes (Observatoire de Haute Provence: OHP), tropics (Maïdo observatory) and high latitudes (ALOMAR and EISCAT), ionospheric stations and satellite measurements.

This joint network provides advanced data products to assemble upper atmospheric wind and temperatures parameters into Numerical Weather Prediction Models.
Additional objectives are related to remote monitoring of extreme event such as volcanoes, cyclones, thunderstorms, sudden stratospheric warming events.
Applications include atmosphere monitoring in relation with climate change and future middle atmosphere data assimilation for improvement of weather forecasts on weekly timescales.

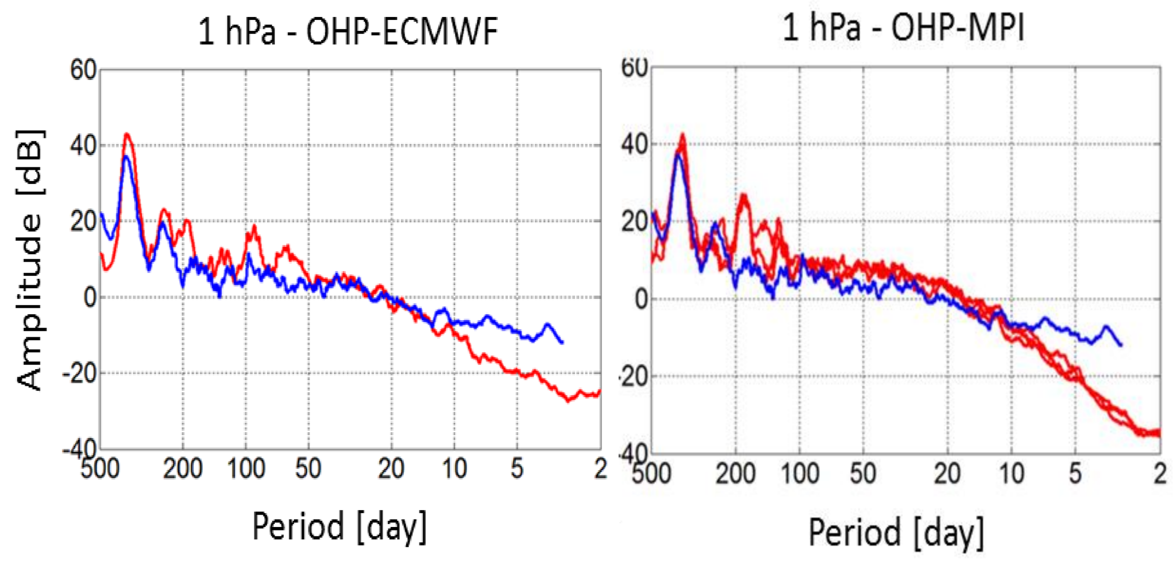
Evaluation of uncertainties in models



Distribution of the monthly differences between temperature models (ECMWF and MERRA) and lidar profiles at OHP

Blue lines: standard error of the mean. Green dashed lines: instrumental error bars. Purple and pink regions: 66% and 95% confidence intervals.

- Differences increasing with altitude when the observations assimilated in the models become sparser.
- Largest deviations observed in winter when the variability from large scale planetary waves dominates over the general circulation.



Comparison of periodograms from OHP lidar (blue) and Weather (ECMWF) or climate (MPI-ESM-LR) models (red) at 1 hPa (~47 km)

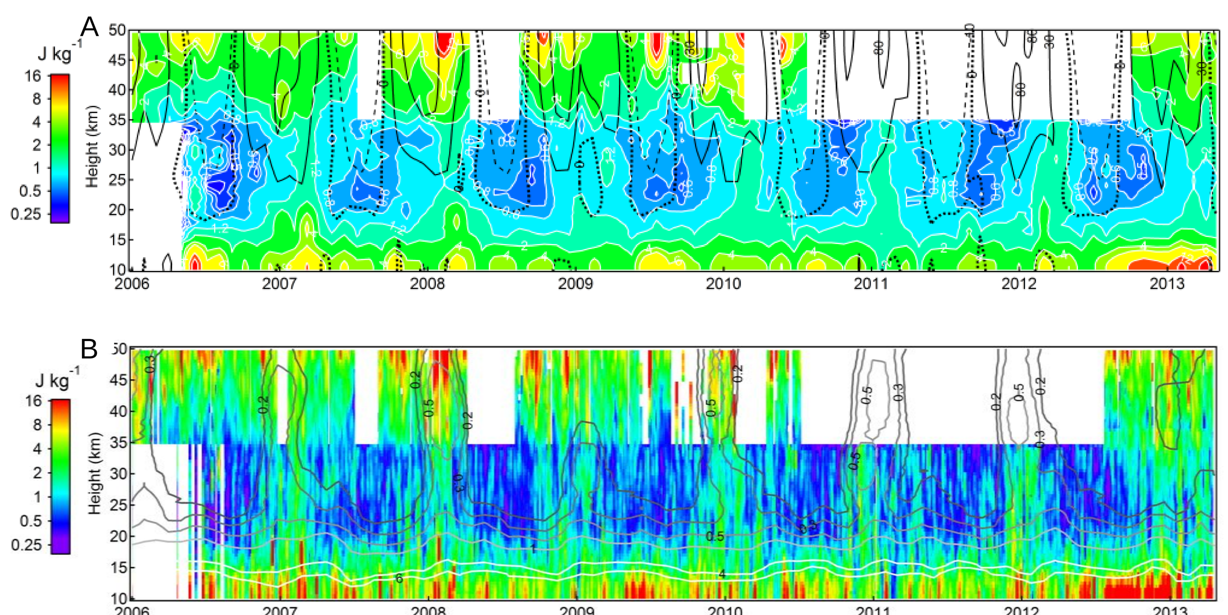
European Centre for Medium-Range Weather Forecast (ECMWF High resolution analysis 2003-2013)
NASA's Modern Era Retrospective analysis for Research and Applications (MERRA)
Free running Max Planck Institute Earth System Model (MPI-ESM-LR) 1991-2005.

- Overall agreement in spectral amplitude down to 15-20 days.
- Differences at shorter time-scales partly explained by a coarser resolution and the lack of assimilated data.

(*Le Pichon et al., JGR, 2015*)

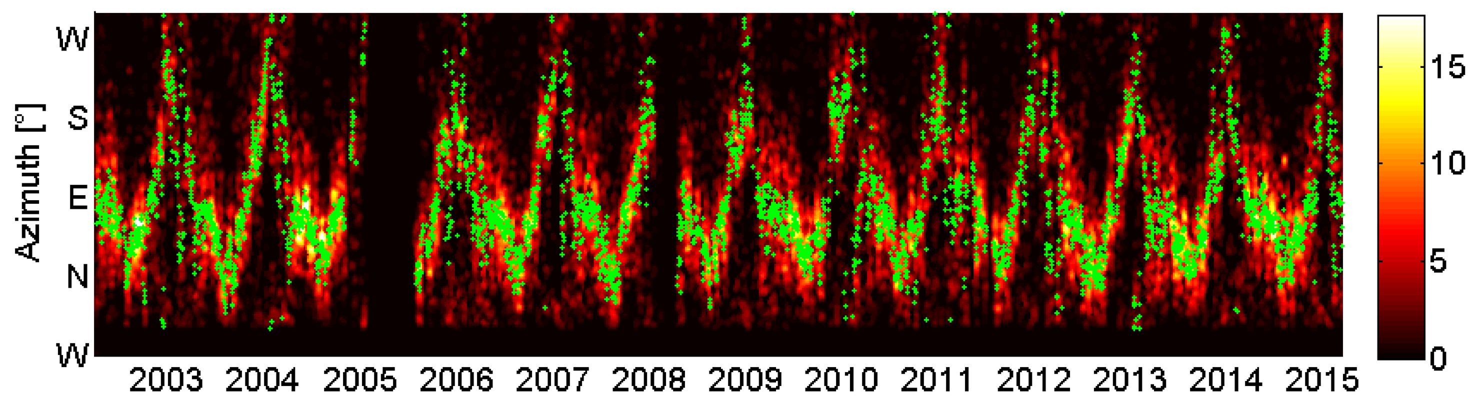
Gravity waves (GW) and the dynamics of the atmosphere

GW 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, Rev Geophys, 1995, Baldwin et al., Science, 2003)*.They are generated by topography, jet stream instabilities or convection and constitute an important component of the global circulation system.



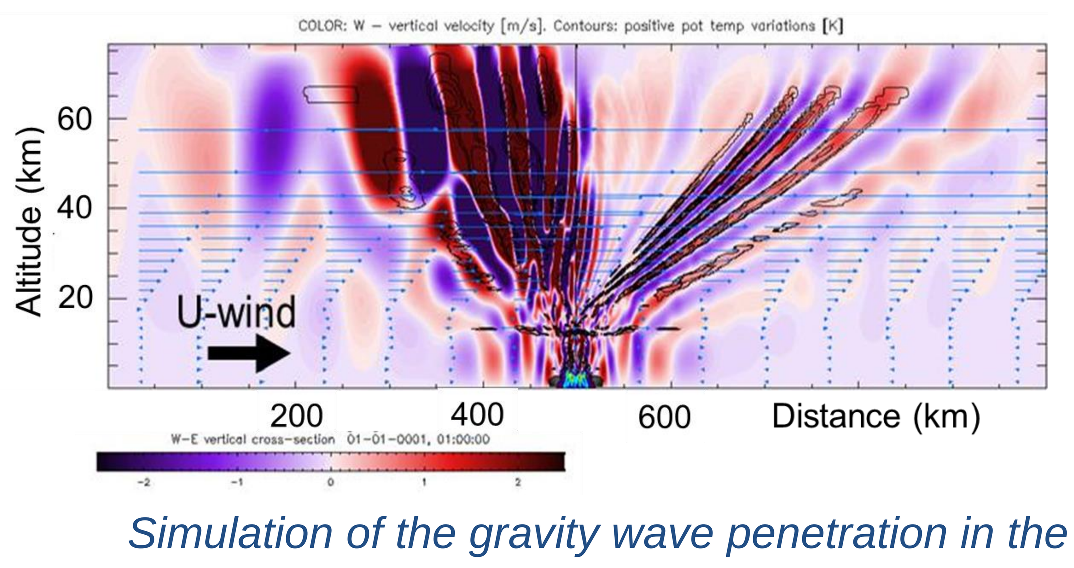
Time series of GW Ep from the OHP lidar and COSMIC GPS Radio Occultation data

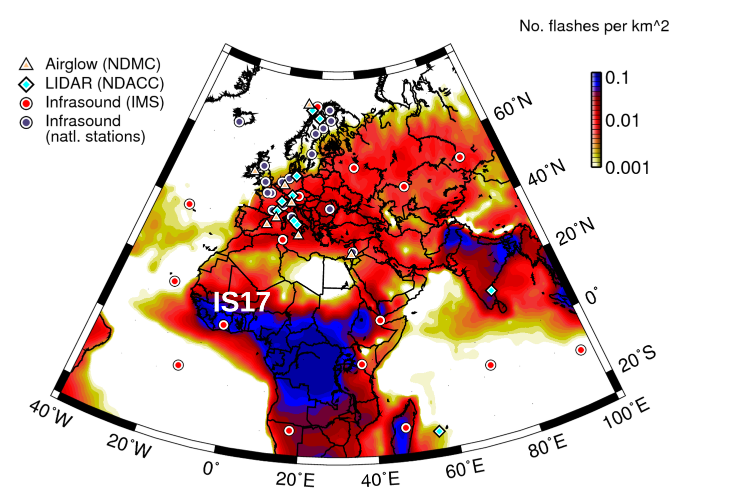
A) *Monthly-mean Ep (color) and zonal wind (solid contours - westerly winds of 30 and 80 m/s, dotted contour - zero wind, dashed contour - easterly wind of 10 m/s).*
B) *Weekly means E_p from COSMIC and lidar and monthly means of MERRA Ep (Khaykin et al., GRL, 2015).*



Gravity wave scales observed by the Ivory coast IS17 infrasound station
(*Blanc et al., JGR, 2014)*

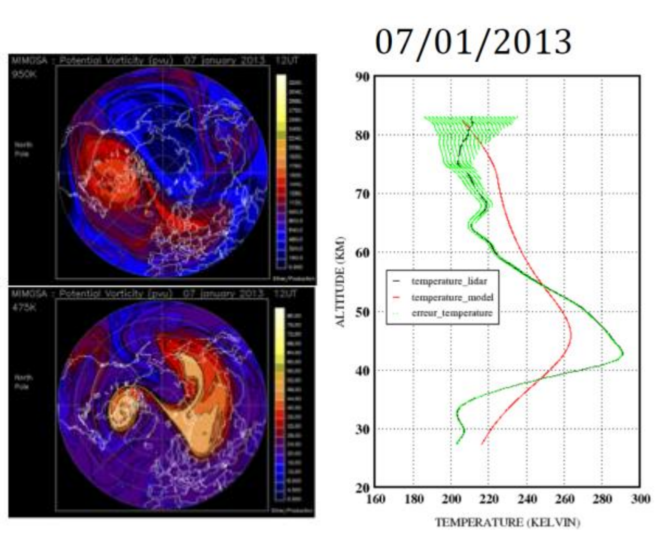
The azimuthal oscillation follows the thunderstorm motion over the station driven by the Intertropical Convergence Zone of the winds.





Simulation of the gravity wave penetration in the stratosphere during a thunderstorm
(Costantino and Heinrich, Atmos. Chem. Phys. 2014).
Weather Research and Forecasting (WRF) Model

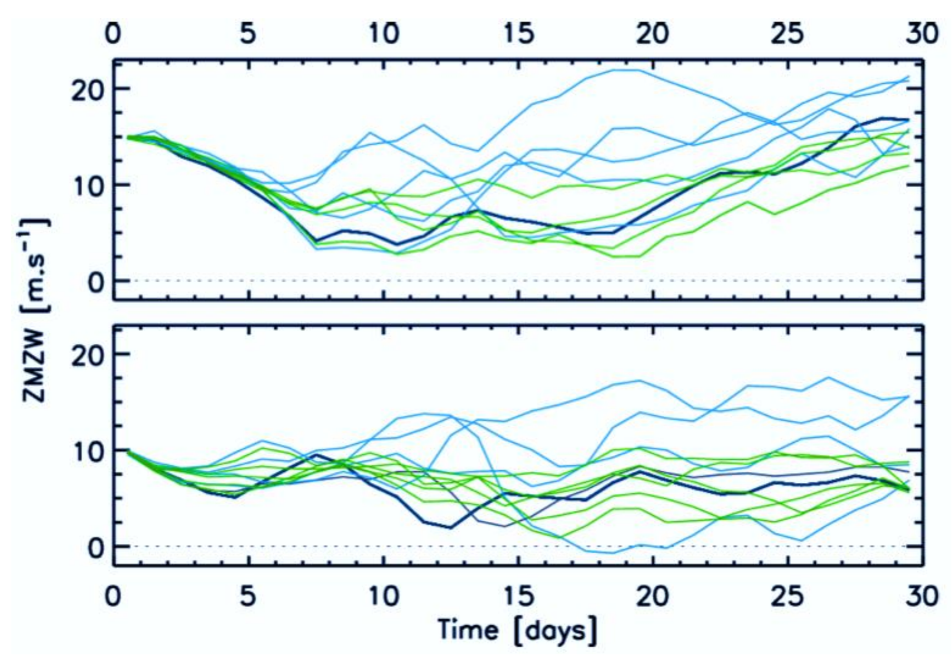
Sudden Stratospheric Warming (SSW) Events



SSW observed by lidar at OHP and MIMOSA potential vorticity maps

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

Application to weather forecasting



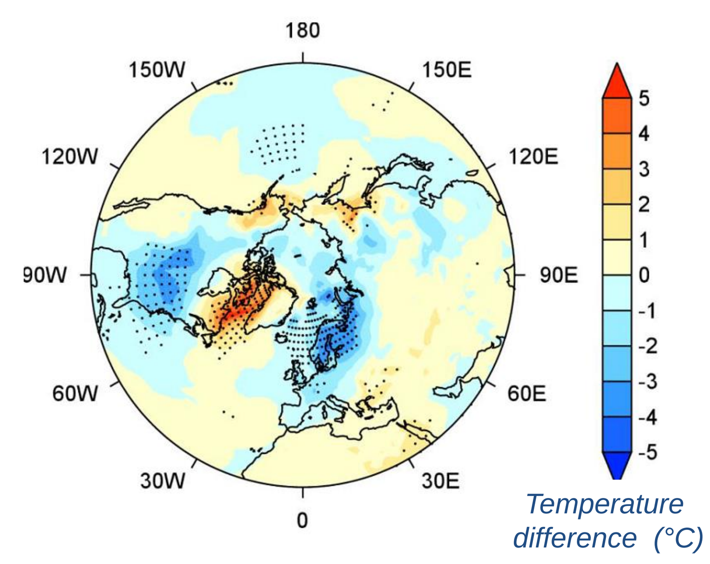
Two SSW cases from the control run (thick dark line), and their 30 day ensemble forecasts (light blue) with upper-stratosphere nudged ensemble (green lines), in the upper troposphere (100hPa)

Stratospheric nudging reduces the ensemble spread indicating enhanced predictability at these altitudes.

Major SSW events can be followed by cold weather in Northern Europe for many weeks (ex: 2010 and 2013).

Tropospheric forecasts by current Numerical Weather Prediction models are unreliable beyond a few days under these circumstances.

The expected impacts of SSW following 15 SSW events were simulated as part of the ARISE project.
(HadGEM-2 climate model)



Surface temperature anomalies averaged over forecast days 15-30 for 15 SSW

References

1- ARISE - FP7 infrastructures - http://ec.europa.eu/research/infrastructures/pdf/fp7_factsht_arise_310113.pdf
2- World Meteorological Organization (WMO bulletin 62(1) 2013): ARISE: A European research infrastructure combining three measurement techniques
3- International innovation (2012), ARISE - Capturing the atmosphere;
4- International innovation (2013), Advancing atmospheric imaging