SPARC regional workshop on the

"Role of the stratosphere in climate variability and prediction"

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Abstract book

Session 1:

Climate-chemistry interactions

O1.1 (invited) *Monday 12th January, 9:15 – 9:45*

Chemistry-Climate interactions: How much model complexity do we need to understand observed signals?

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It is well established that the response of the middle atmosphere to several types of forcing is strongly mediated by atmospheric chemistry, and in particular stratospheric ozone. This is the case for forcing from solar irradiance that directly affects ozone e.g. in the upper stratosphere; volcanic aerosols and anthropogenic halogens have an influence on ozone in large parts of the stratosphere but in particular at polar latitudes; this is the region where also energetic particle precipitation can have a strong impact. For all these cases the changes in ozone contribute to dynamical responses of the middle atmosphere which are supposed to have an effect on tropospheric weather and climate. The latter, of course, is influenced by coupling with the oceans. In the recent decades, the notion of the complexity of these processes has motivated the use of more and more complex numerical models. General circulation models (GCMs) of the atmosphere have been coupled to chemistry models, and more recently, the resulting so-called chemistry climate models have been coupled to ocean GCMs. The behavior of complex models is, however, in general not easy to understand. In this presentation, I will give examples for simulation results concerning the above mentioned forcings and try to discuss the question which degree of model complexity may be needed to improve our understanding of observed signals.

O1.2 (invited) *Monday 12th January, 9:45 – 10:15*

Impact of GHGs on Stratospheric Ozone Recovery over Antarctica.

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Studies of future projections show the potencial impact of ozone recovery on carbon uptake in the Southern Hemisphere ocean, the Antartic ice sheets and sea ice, or precipitation. However, the effects of increasing greenhouse gases in the future will opposite those of decreasing ozone depleting substances. Thus, to quantify the tropospheric impact of ozone recovery, future Antarctic ozone changes in the lower stratosphere region need to be investigated together with the role (if any) of increasing greenhouse gases on ozone recovery in this region. To do so, we use the National Center for Atmospheric Research´s Community Earth System Model, CESM, with the high-top atmospheric component, CESM (WACCM), which is a fully coupled chemistry climate model. Three climate change scenarios (RCP2.6, RCP4.5 and RCP8.5) of 3 simulations each, from 2005 to 2065, are analyzed.
Our results show that ozone recovery in the lower stratosphere is quite similar under scenarios RCP2.6 and RCP4.5, being the largest in October and November at 50hPa. Compared to RCP2.6 and RCP4.5, scenario RCP8.5 shows significantly stronger ozone recovery, particularly in November and December at 70hPa. These differences are not related to differences across scenarios in advection of ozone from the source region in the tropical stratosphere, but to larger amounts of methane in RCP8.5 compared to the other two scenarios, which reduces catalytic ozone loss locally.

O1.3 *Monday 12th January, 10:15 – 10:30*

Modelling stratospheric injection of biogenic very short-lived bromocarbons and their breakdown products

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Very short-lived (VSL) bromocarbons produced by ocean biology, together with their degradation inorganic products, affect the oxidation capacity of the global atmosphere. The partitioning between the source gas (SG) and product gas (PG) species within the tropical atmosphere affect the total bromine injection to the stratosphere, which further depends on the interaction of several processes such as the geographical distribution of sources, the strength of convection and the photochemical lifetime of each species. We combine recent airborne observations in the Eastern and Western Pacific with the CAMChem global chemistry-climate model to evaluate the stratospheric injection of biogenically produced brominated VSL and their PG species. CAM-Chem incorporates a state-of-the-art tropospheric and stratospheric halogen chemistry scheme considering physically-based heterogeneous processes over sea-salt aerosols and ice-particles, as well as an individual efficiency of washout/ice-uptake removal for each bromine species. The role of tropospheric processing of VSL bromocarbons on the resulting bromine injection to the stratosphere is also investigated.

O1.4 *Monday 12th January, 10:30 – 10:45*

Polar Stratospheric Clouds observations over the Antarctic Belgrano II station based on Polarized-Micro Pulse Lidar (P-MPL) measurements

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Polar Stratospheric Clouds (PSCs) usually formed in wintertime have been identified as determinant elements on ozone depletion processes occurring at high latitudes during springtime. PSCs are classified in three main groups depending on their composition, and then on their temperature formation threshold (i.e., see the review on PSC microphysics and chemistry by Lowe and MacKenzie, 2008, and references therein): type Ia (PSC-Ia) are nitric acid trihydrate (NAT) clouds formed above the frost point (TNAT = 194K at 30 hPa), type Ib (PSC-Ib) are supercooled ternary (H2SO4, HNO3, H2O) solution (STS, liquid particles) clouds, and type II (PSC-II) are water ice clouds (Tice = 185K at 30 hPa). In addition, mixtures of them are also observed. However, despite the role of ice clouds on chlorine activation for ozone reduction is enhanced as compared to that for PSC-I clouds (e.g., Lowe and MacKenzie, 2008), their occurrence is lower than that for PSC-I (e.g., Adriani et al., 2004; Maturilli et al., 2005; Pitts et al., 2013). Hence, a more relevant role on ozone depletion is actually linked to liquid STS and NAT PSCs, which can be the most important PSCs for chlorine activation and denitrification processes, respectively, involved in ozone destruction. Nevertheless, the extent of occurrence of both PSC categories in the Arctic and the Antarctica is different. Therefore, long-term PSC field monitoring together with PSC-type identification is critical in polar ozone depletion research, and hence directly linked to stratospheric temperature variability. Lidar measurements have been usually used for PSC monitoring and classification, based on two lidar parameters: the backscattering ratio (R) and either the volume linear depolarization ratio (δ), as used in ground-based lidar measurements (e.g., Adriani et al., 2004; Maturilli et al., 2005), or the perpendicular backscattering coefficient (βs), as used in the space-borne CALIOP/CALIPSO (Cloud-Aerosol Lidar with Orthogonal Polarization/Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) observations (Pitts et al., 2013). In general, rather higher R and δ or βs values are obtained for PSC-II than for PSC-I.

In this work, a NASA/Micro Pulse Lidar with depolarization capabilities (P-MPL, mplnet.gsfc.nasa.gov) deployed in the coastal Antarctic Belgrano II station (Argentina, 77.9ºS 34.6ºW) for PSC observations is used to obtain these two parameters for PSC-type discrimination purposes. In particular, a good performance of this kind of micro-pulse lidars in terms of the δ-parameter was achieved in comparison with CALIPSO PSC depolarization retrievals (Córdoba- Jabonero et al., 2013). A generalized PSC occurrence over the Belgrano II station during 2009-2011 winter periods will be shown. In addition, a few case studies focused on PSC discrimination will be also shown. Radiosounding profiles were also examined for determining their link with the stratospheric temperature variability. This work is supported by the Spanish Ministry for Research and Innovation (MICINN) under grant CGL2010-20353 (VIOLIN project). Authors thank the DNA/IAA team at Belgrano II station for their valuable assistance and support in lidar and radiosounding measurements.

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DOAS and ozonesondes observations for Antarctic Stratospheric Monitoring

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The Antarctic polar vortex creates a quasi-circumpolar belt of strong meridional gradient of potential vorticity and temperature during the winter months. As a result the vortex acts as a closed vessel maintaining the isolation of the contained stratospheric air masses where the chemical species interacts with the Polar Stratospheric Clouds (PSC) formed in very low temperature conditions. Seasonal monitoring of BrO, OClO, NO_2 and O_3 inside, outside, and in the edge of the vortex during the formation, developing and collapsing periods is a useful way to study the effects of temporal evolution and meridional transport of these species.
We show here results from a long term monitoring program for NO_2 and O_3 total column by visible spectroscopy in the Antarctic region that was initiated in February 1994 by an Agreement between INTA (Spain) and DNA (Argentina). At that time two unattended scanning spectrometers were deployed at Marambio station (Antarctic Peninsula, 64ºS, 56ºW) and Ushuaia (Tierra del Fuego, 55ºS, 68ºW). A third one was installed in Belgrano station (Continental Antarctica, 78ºS, 35ºW) in January 1995. The stations are separated by 10º in latitude and very close in longitude providing meridional cross-sections across the vortex. The observations were extended in 2011 by MAX-DOAS spectrometers to measures chlorine and bromine compounds at Begrano with the aim of separating the stratospheric and tropospheric column. Additional information on ozone profiles is provided by the routine ozonesondes program established in 1999 at Belgrano, in the core of the polar vortex. Long series are now available and particular attention has been paid to provide homogeneous sets of data, taking into account instrumental and spectral analysis changes. We report here the BrO, OClO, NO_2 and O_3 vertical column seasonal wave, interannual variability, diurnal variation and dependence with the light available.

Session 2:

Observed and modeled changes of the middle atmosphere

O2.1 (invited) *Monday 12th January, 11:15 – 11:45*

Investigating the impact of pollution on the composition of the upper troposphere / lower stratosphere using 10 years of Aura Microwave Limb Sounder measurements

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Launched in July 2004, the Microwave Limb Sounder (MLS) onboard NASA's Aura mission makes daily global simultaneous co-located measurements of an extensive suite of trace gases and cloud ice. Here we use the 10-year data record from MLS to investigate the transport of pollution to the upper troposphere / lower stratosphere (UTLS). In particular, we analyze MLS observations of biomass burning products, such as CO, CH_3Cl, and CH_3CN, together with cloud ice water content (IWC) as a proxy for deep convective activity. Substantial seasonal and interannual variability in the observed abundances of the fire-generated species largely reflects variability in the intensity and location of biomass burning and the deep convection that rapidly lofts surface emissions to the UTLS. We also investigate the provenance of pollution in the Asian summer monsoon (ASM) by characterizing the climatology of and quantifying the spatial, seasonal, and interannual variations in multiple species of both tropospheric and stratospheric origin in the ASM region. The observed trace gas behavior is related to various meteorological quantities, such as the size and strength of the ASM anticyclone, the extent and intensity of deep convection, and variations in the tropopause and the upper tropospheric jets in that region. The spatial and temporal variability observed by MLS is compared to that in preliminary simulations from the specified dynamics (SD) version of the Whole Atmosphere Chemistry Climate Model (WACCM) nudged to wind fields from the Modern-Era Retrospective analysis for Research and Applications (MERRA).

O2.2 (invited) *Monday 12th January, 11:45 – 12:15*

Long-term Monitoring of Atmospheric Trace Gases by using ground-based FTIR spectrometry at the Izaña Atmospheric Observatory

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Continuous monitoring of the atmospheric composition is crucial for improving our knowledge on the Earth-atmosphere system and, thus, for predicting its changes. Among the current measurement techniques, the ground-based Fourier Transform Spectrometry (FTS) has a special status since, by recording very high resolution infrared solar absorption spectra, the FTS experiments can provide total column amounts and vertical profiles of many different atmospheric trace gases with high precision. As a consequence, the FTS systems have been successfully used for atmospheric composition monitoring since the 1990s. Currently, there are about 25-30 instruments distributed worldwide operating into two international networks, TCCON (Total Carbon Column Observation Network) and NDACC (Network for the Detection of Atmospheric Composition Change).

The FTS operated at the Izaña Atmospheric Observatory, IZO (Izaña Atmospheric Research Centre, IARC-AEMET) is until now the sole FTS instrument in Spain dedicated to climate research. This is the result of a close collaboration between the IARC-AEMET and the IMK-ASF (Institute of Meteorology and Climate Research-Atmospheric Trace Gases and Remote Sensing) since 1999. The IZO FTS's activities have been contributing to the networks NDACC and TCCON since 1999 and 2007, respectively.

In this contribution we give an overview of the FTS's activities at the IARC, focused on the long-term monitoring of atmospheric gas composition (ozone related species and greenhouse gases) and the validation of satellite remote sensing measurements and climate models. In particular, we show the large potential of the FTS observations for monitoring and investigating the troposphere, the stratosphere and their interchange processes.

Evolution of the Brewer-Dobson circulation for 1979-2012 in three reanalyses

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The trends in the stratospheric Brewer-Dobson circulation predicted by chemistry-climate models remain to be confirmed in observational data. We evaluate and compare the evolution of the BDC for the period 1979-2012 in three modern reanalyses (ERA-Interim, MERRA and JRA-55). Three different estimates of the BDC are computed for each reanalysis, the residual circulation based on the reanalysis velocity field and two indirect estimates derived from momentum and thermodynamic balance. The comparison among the nine computed estimates of the BDC highlights significant common variability on monthly-to-interannual timescales throughout the layer 100-10 hPa. Despite the large uncertainties, the results suggest an overall acceleration of annual mean tropical upwelling. Consistently, the spatial structure of the BDC trends shows increasing downwelling in both hemispheres, with qualitative agreement among the estimates.

O2.4 *Monday 12th January, 12:30 – 12:45*

Changes in the characteristics of the stratospheric vortex during stratospheric sudden warmings

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The strastospheric polar vortex is detected using a method based on regions of interest. Data from ERA-Interim reanalysis and WACCM are used to follow the vortex from the lowermost stratosphere to the mesosphere. The changes associated to stratospheric sudden warmings are studied from the point of view of the vortex: what happens inside, in the border and in the outside. Variables such as temperature, horizontal wind, ozone or the Brewer-Dobson Circulation are analized.

O2.5 *Monday 12th January, 12:45 – 13:00*

Stratospheric NOy: Global budget and variability in 2002-2012 from MIPAS observations

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The MIPAS Fourier transform spectrometer on board Envisat has been measuring limb emission spectra in the mid-IR during 2002 - 2012. We have employed the scientific MIPAS level 2 processor developed and operated by the Institute of Meteorology and Climate Research (IMK) together with the Instituto de Astrofısica de Andalucıa (IAA) to derive vertically resolved distributions of 6 principal reactive nitrogen (NOy) compounds (HNO_3, NO_2, NO, N_2O_5, $ClONO_2$, and HNO_4) with global coverage and independent on illumination (i.e., including the polar night). The obtained data set provides a unique climatological record of NOy in the middle atmosphere for a close-to-10 years period. Here, we discuss the MIPAS-derived spatial distributions of NOy and their seasonal and inter-annual variability. Responsible chemical and dynamical mechanisms are identified and an estimation of the global middle atmosphere NOy budget is presented, including a quantitative analysis of individual sources and sinks.

O2.6 *Monday 12th January, 13:00 – 13:15*

IMK/IAA water vapor global distributions in the middle atmosphere from MIPAS

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Water vapor is a key constituent in the middle atmosphere. It is is an infrared cooler in the stratosphere, it is involved in the ozone chemistry, and it is the precursor of polar stratospheric and mesospheric clouds. Additionally, it is an very good dynamical tracer. Envisat's Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) observed water vapor's infrared emissions with high resolution up to the lower thermosphere. We have derived wáter vapor abundance from MIPAS spectra using the Institut für Meteorologie und Klimaforschung and Instituto de Astrofísica de Andalucía (IMK/IAA) data processor. This scientific processor is able to deal with atmospheric emissions affected by non-LTE because it includes the GRANADA non-Local Thermodynamic Equilibrium algorithm, that is particularly important above 50km in the case of H2O retrievals. We will present global comparisons of our results with other measurements made in the frame of the SPARC-WAVAS-II activities. We will run our eyes over MIPAS pole-to-pole distributions and time series retrieved from the stratosphere to the upper mesosphere, discussing the seasonal variations and their interhemispheric assymetries. We will finally focus our attention on the water vapor behavior over the poles, where the summer polar mesospheric clouds and the winter sudden stratospheric warmings may significantly perturb its usual vertical distribution.

O2.7 *Monday 12th January, 13:15 – 13:30*

Solar cycle and seasonal variability of CO and CO2 in the middle atmosphere

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In this paper we compare the distributions of CO and CO2 in the mesosphere and lower thermosphere (MLT) measured by the ACE-FTS and MIPAS satellite-borne instruments with calculations obtained by the Whole Atmosphere Community Climate Model (WACCM). The comparison spans almost one solar cycle, covering solar minimun and solar maximum conditions. We also show the sensitivity of the CO and CO2 distributions simulated by WACCM to the parameterization of the gravity waves. In addition, we will show an analysis of the solar cycle and trends in the CO and CO2 distributions.

P2.1 *Poster session: Monday 12th January, 16:45 – 18:30*

The SAGE III's mission aboard the International Space Station

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The Stratospheric Aerosol and Gas Experiment (SAGE III) is being prepared for a flight on the International Space Station (ISS) beginning in 2015. Since the instrument was constructed in the early 2000s, the instrument undergoing extensive testing and refurbishment prior to deliver to ISS. In addition, the project will also refurbish the ESA-provided Hexapod which is a high-accuracy pointing system developed to support ISS external payloads particularly SAGE III. SAGE III refurbishment also includes the replacement of the neutral density filter that has been associated with some instrument performance degradation during the SAGE III mission aboard METEOR/3M mission (2002-2005). In this presentation, we will discuss SAGE III - ISS refurbishment including results from Sun-look testing, revisions to the science measurements, and discuss expected measurement accuracies in part by examining SAGE III - METEOR/3M measurement data quality. We will also discuss potential mission science goals enabled by the mid-inclination ISS orbit. No dedicated field campaign for SAGE III validation is anticipated. Instead, validation will most rely on a collaborative effort with international groups making in situ and ground-based measurements of aerosol, ozone, and other SAGE III data products. A limited balloon-based effort with a yet-to-be-determined validation partner will is also in the planning stages.

Composition changes at northern high latitudes as observed by MIPAS and MLS in February 2009

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Profiles of different minor atmospheric compounds from Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) aboard ENVISAT and Microwave Limb Sounder (MLS) on Aura have been used to study composition changes in the upper stratosphere/lower mesosphere (USLM) region at northern high latitudes in February 2009. After the strong January 2009 sudden stratospheric warming (SSW) event, the observed low temperatures and high O3 VMRs in February resulted to be associated with an evident partitioning in the chlorine family. In particular, an HCl decrease by about 0.4 ppbv was coupled with an increase in both ClO and ClONO2. This has been mostly due to the low temperatures that favored the O3 production and increased the O3/O ratio. Therefore ClOx was repartitioned towards ClO. ClONO2 increased mostly at the northernmost latitudes, where the still prevailing nighttime conditions preserved it from the solar photolysis. Comparable ClONO2 changes at similar altitudes have been reported only after solar proton event (SPE) occurrence. The expected negative correlation between O3 and temperature is evident mostly at long time scales. Air mixing, characterized by evident changes in CH4, has been identified during and soon after the SSW. During such time the sum of VMRs of the investigated chlorine compounds resulted to be about 0.2 ppbv lower than the values of February while it remained at levels analogous to the other years in February/March. The descent of mesospheric NOx starting after the January 2009 SSW, which could potentially affect O3, did not reach the investigated altitudes and region in February. When comparing such variations with respect to 2005-2013 we note that similar atypical chemical conditions occurred also in February 2006 but 2009 still stands out for the persistence of its effects, remaining perturbed until late March.

Ground-based lidar stratospheric aerosols measurements: Rescuing and maintaining an important complement of space-borne measurements

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Currently stratospheric aerosols measurements primarily rely on space-based instruments including lidar and various passive techniques, but still ground-based lidar measurements play an important role as a complement of space-borne instruments. Among the demonstrated capabilities of surface lidar measurements of stratospheric aerosols are the validation of satellite instruments and filling gaps between missions as wells as filling gaps where the stratospheric burden exceeds the dynamic range of the measurement approach. Such roles are likely to remain important for the foreseeable future. Accessibility of these data records from the middle of the XX century to the present is a significant issue. For instance, an effort to account for missing SAGE II data during the Pinatubo period, conducted for the 1st SPARC Stratospheric Aerosols Assessment, was limited to data sets readily available to that group and a number of viable sites were not included in the analysis. There are also significant stratospheric aerosols measurements with lidar and searchlights that predate the satellite era and could provide valuable information for the reconstruction of the earlier stratospheric aerosol record and future data assimilation projects. Therefore, it remains important to build and maintain a global dataset of stratospheric aerosols measurements by ground-based lidars. This effort should compile as many existing datasets as feasible effectively rescuing currently lost original measurements. Some of this may be recovered from archived versions of the original measurements while others may only be able to be reconstructed from scientific literature and/or technical reports. The particular cases of lidar dataset from the volcanic eruptions of El Chichón in 1982 and Mount Pinatubo are shown. This presentation describes an approach to address the former issues and promote future efforts to conduct the building and maintenance of a global dataset of stratospheric aerosols measurements by ground-based lidars.

Aerosol particles in the UT-LS from the summer 2011 Nabro's eruption over Spain and Portugal

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During the night of 12 June 2011 the Nabro volcano (13.37ºN, 41.70ºE) in the state of Eritrea (Horn of Africa) started its eruption generating large amounts of ashes, water vapour and sulphur dioxide gas that intermittently blocked the air traffic over Eastern Africa. Besides the human and economic factors, the Nabro episode was relevant from the climate point of view by injecting a layer of sulphur aerosol particles in the lower stratosphere. The stratospheric aerosols generated from the Nabro's eruption were detected at several locations over the planet in the upper troposphere and lower stratosphere (UT-LS) [Sawamura et al., 2012; He et al., 2014], five SPALINET (the Spanish and Portuguese Aerosol LIdar NETwork, www.lidar.es/spalinet/en) stations in southern Europe. This study is focused on geometrical, optical and microphysical properties of the volcanic particles. On the one hand, the zero-crossing method is used to determine the layer's minimum and maximum heights and geometrical thickness. On the other hand, the transmittance method is applied to pre-processed elastic lidar signals for deriving the aerosol optical depth (AOD) in those isolated volcanic layers. Finally, LIRIC (LIdar and Radiometer Inversion Code) [Chaikovsky et al., 2012] is used for profiling particle microphysical properties.

The first volcanic aerosol particles from the Nabro volcano could be detected over Spain and Portugal after a relatively short time (within the first two weeks after the eruption). All the stations considered in this study observed the first layers on 26 to 27 June and a few of them detected the volcanic layer until the middle of July. Mean daily layer-AOD values during these days ranged from 0.021 in Sta. Cruz de Tenerife (28.47ºN, 16.25ºW, 52 m) to 0.057 in Barcelona (41.39ºN, 2.11ºE, 115 m). A predominance of fine mode particles was detected in the volcanic layers monitored over Granada (37.16ºN, 3.58ºW, 680 m) and Évora (38.57ºN, 7.91ºW, 290 m). Besides the stratospheric volcanic layer, another coupled layer was detected over several stations in the uppermost troposphere during some periods.

This work was supported by the University of Granada through the contract “Plan Propio. Programa 9. Convocatoria 2013”; by the Andalusia Regional Government through projects P12-RNM-2409 and P10-RNM-6299; by the Spanish Ministry of Science and Technology through projects CGL2010-18782, and CGL2013-45410-R and CSD2007-00067; by the Spanish Ministry of Science and Innovation and FEDER funds under the Complementary Action CGL2011-13580-E/CLI; by the Spanish Ministry of Economy and Competitiveness (MINECO) under grant CGL2011-24891 (AMISOC project); by FCT under grant SFRH/BPD/81132/2011 and in the framework of the projects FCOMP-01-0124-FEDER-029212 (PDTC/CEO-MET/4222/2012); and by EU through ACTRIS project (EU INFRA-2010-1.1.16-262254).

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First detection of stratospheric particles by lidar at the LALINET Medellín-Colombia station

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Keywords: LALINET, active remote sensing, stratospheric particles.
Session 2: Observed and modeled changes of the middle atmosphere
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The northernmost LALINET station (Latin American Lidar Network) [Guerrero-Rascado et al., 2014], located at Medellín (6.26ºN, 75.58ºW, 1471 a.s.l.) is routinely operated since December 2012. The system me-LOA-UNAL is configured in a monostatic coaxial alignment arrangement based on a Nd:YAG laser source with fundamental wavelength at 1064 nm, however the radiation is transmitted into the atmosphere simultaneously at 1064, 532 y 355 nm due to is equipped with second and third harmonic generator. The backscattered radiation is collected by a receiving telescope based on a 200 mm-diameter Newtonian configuration. The collected radiation is split into two channels by dichroic mirrors and interferential filters are used in order to select the elastic backscattered radiation at 532 and 355 nm. Detection is carried out by photomultiplier tubes acquiring signals in analog and photon counting modes.
During the period of 2014 (June-August) the number of lidar measurements at Medellín increased due to the presence of unusual atmospheric scenarios such as Saharan dust outbreak at the end of June. This work is devoted to the characterization of the first detection of stratospheric particles over Medellín by active remote sensing. The system me-LOA-UNAL monitored stratospheric particles from 16 June to 11 August 2014 as a fairly homogeneous layer extended from 18km m to30km m above lidar system. Figure 1 shows an example of quick look for lidar range corrected signal at 532 nm on 14 July 2014. Such kind of stratospheric features was also detected by CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) on board CALIPSO satellite (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) indicating the presence of stratospheric layers over a wider area.

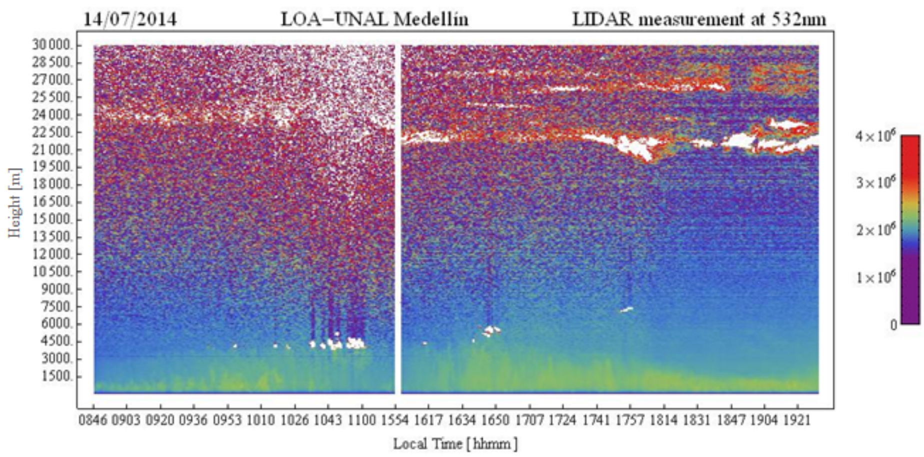

Figure 1. Lidar quick look for range corrected signal at 532 nm on 14 July 2014 over Medellín-Colombia.

This work was supported by the Air Quality Laboratory-CALAIRE, NASA-AERONET, LALINET, and the University of Granada through the contract “Plan Propio. Programa 9. Convocatoria 2013”. Furthermore the authors would also like to acknowledge benefits arising from the membership in LALINET.

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Variability of the Brewer-Dobson circulation during Stratospheric Sudden Warmings

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In this work we look for changes in the latitudinal distribution and intensity of the vertical branch of the Brewer-Dobson Circulation during the formation and development of the Stratospheric Sudden Warmings. Therefore we analyze the vertical component of the Transformed EulerianMean residual circulation (w*) from the lowermost stratosphere to the mesosphere. We use daily data from the ERAInterim reanalysis and simulations with high vertical resolution performed with the Whole Atmosphere Community Climate Model (WACCM). Preliminary results show that, in the stratosphere, strong negative anomalies apppear at high latitudes around 20 days before the wind reversal. Thereafter, they shift to lower latitudes following the vortex, giving way to strong positive anomalies at high latitudes. In the lowermost stratosphere and in the mesosphere corresponding anomalies are also found. Associated to the positive anomalies at high latitudes, a weakening of the equatorial ascending branch of the Brewer-Dobson Circulation is found in the stratosphere. This equatorial signal is not so clear in the model as it is in the reanalysis.

P2.7 *Poster session: Monday 12th January, 16:45 – 18:30*

Non-LTE retrievals of CO2 collisional rates and VMRs using limb emission high resolution spectra from MIPAS/ENVISAT

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The MIPAS insrument on Envisat has a large spectral coverage (15-4.3 μm), measuring the most important IR emission of CO2, i.e., the 15 μm, 10 μm and 4.3 μm bands. Additionally, it has a very high spectral resolution (0.0625 cm^{-1}). These characteristics make it an ideal instrument for studying the non-LTE processes of CO2 emissions and measuring the CO2 VMR. In this paper we focus on the retrieval of non-LTE collisional rates and CO2 VMR using emission spectra at 10 and 4.3 μm in the mesosphere and lower themosphere (MLT). The unprecedented spectral coverage and spectral resolution of MIPAS allow us to study in depth the non-LTE emission of CO2 in the 4.3 μm, discerning the individual contributions to the limb emission of several tens of bands, including optically thick and thin bands in this altitude range. These measurements thus allow us to acquire unique information of the non-LTE processes driving the populations of the CO2 vibrational levels. We present here new information about the non-LTE collisional processes derived from MIPAS spectra. Studies of the non-LTE populations and preliminary results on the inverted CO2 VMR profiles from the daytime spectra in the MLT region are also presented.

TEMPERA, a new ground-based microwave radiometer to provide continuous stratospheric temperature profiles

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The importance of the knowledge of the temperature structure in the atmosphere has been widely recognized. Temperature is a key parameter for dynamical, chemical and radiative processes in the atmosphere. The cooling of the stratosphere is an indicator for climate change as it provides evidence of natural and anthropogenic climate forcing just like surface warming ([1] and references therein). However, our understanding of the observed stratospheric temperature trend and our ability to test simulations of the stratospheric response to emissions of greenhouse gases and ozone depleting substances remains limited. Stratospheric long-term datasets are sparse and obtained trends differ from one another [1]. Therefore it is important that in the future such datasets are generated.

Different techniques allow to measure stratospheric temperature profiles as radiosonde, FTIR, LIDAR or satellite. The main advantage of microwave radiometers against these other instruments is a high temporal resolution with a reasonable good spatial resolution. Moreover, the measurement at a fixed location allows to observe local atmospheric dynamics over a long time period, which is crucial for climate research.

TEMPERA (TEMPERature RAdiometer) is a newly developed ground-based microwave radiometer designed, built and operated at the University of Bern. The instrument and the retrieval of temperature profiles has been described in detail in [2]. TEMPERA is measuring two pressure broadened oxigen lines at 52.5 GHz and 53.1 GHz, respectively in order to determine stratospheric temperature profiles. The retrieved profiles of TEMPERA cover an altitude range of approximately 20 to 45 km with a vertical resolution in the order of 15 km. The lower limit is given by the instrumental baseline and the bandwidth of the measured spectrum. The upper limit is given by the fact that above 50 km the oxygen lines are splitted by the Zeeman effect in the terrestrial magnetic field.

In this study a first dataset of stratospheric temperature measurements from microwave radiometer is presented. These measurements have been validated and compared with radiosonde and satellite data. The results evidence the capability of TEMPERA radiometer to monitor the temperature in the stratosphere for a long-term. Moreover, the detection of some singular sudden stratospheric warming (SSW) shows the necessity of these continuous monitoring in order to measure and understand some important processes which could happen on a short time scale.

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Session 3:
Stratosphere-troposphere coupling

O3.1 (invited) *Monday 12th January, 15:30 – 16:00*

A Conceptual Framework for Stratosphere–Troposphere Coupling

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Little progress has been made in the past decade on understanding the dynamics of stratosphere troposphere coupling. I believe that we, as a community, are being imprecise about 1) what we are trying to explain, and 2) what constitutes a dynamical explanation. I suggest that we should be trying to explain the largest, most robust relationships — e.g., Why is the surface NAM linearly related to the strength of the polar vortex? We are also limiting our enquiries by using traditional labels such as "PV inversion" and "downward control". I will suggest a path forward that is focused on explaining the observations, and physical explanations that can be tested in simple models and even observations.

Onset of circulation anomalies during stratospheric vortex weakening events: the role of planetary-scale waves

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While mounting evidence links weak polar vortex events in the stratosphere to the upward propagation of planetary-scale Rossby waves from the troposphere to the stratosphere, the causes of the accompanying tropospheric circulation anomalies remain uncertain. To highlight the details of stratosphere-troposphere dynamical coupling during the onset of events of strong vortex variability, this study identifies Stratospheric Vortex Weakening (SVW) events using rapid deceleration of polar vortex and performs composite budget analyses of the zonal wind tendency in the Transformed Eulerian Mean (TEM) framework on daily time scales.

Consistent with previous work on the variability of the Northern Annular Mode (NAM), the time evolution of zonal wind anomalies during SVW events shows a near-instantaneous vertical coupling in a time scale of only a few days which results from an anomalous upward and poleward propagation of planetary-scale waves. This coupling differs from the extended stratosphere-troposphere coupling that results from synoptic scale eddy feedbacks. Decomposition of the eddy fields into individual wavenumber components reveals that while stratospheric deceleration is due to zonal wavenumber one and two waves, tropospheric change is dominated by the latter. It is also found that wavenumber-one disturbances in the troposphere have less geographical preference during the onset of the SVW events, whereas wavenumber-two disturbances Project strongly onto the climatological pattern of planetary-scale waves in most cases. This indicates the presence of a constructive linear interference of wavenumber-two disturbances that systematically modulates vertically propagating planetary-scale waves.
These results are largely insensitive to the stratospheric background flow conditions, whether events occur under strong or weak vortex regimes.

Diagnostics of finite amplitude wave activity suggest that SVW events are caused to a large extent by the growth of planetary-scale waves rather than by wave breaking. Overall results are also compared with vertical coupling associated with weak polar vortex events such as stratospheric sudden warming events.

A Study on the Structure of Barotropic/Baroclinic Instability in the Mesosphere Using a Gravity-wave Resolving General Circulation Model

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In general, atmospheric motions are categorized into two: One is the quasi-geostrophic (QG) flows including planetary waves (PWs), and the other is gravity waves (GWs). The GWs are largely affected by the QG flows in their generation, propagation, and dissipation, but GWs can modify the QG flows such as the weak wind layer in the upper mesosphere by their ability of momentum transport. In the winter mesosphere, a necessary condition of barotropic and/or baroclinic instability for the QG flow, i.e., negative latitudinal gradient of potential vorticity (PV), is often satisfied. This study examines dynamical mechanism of the formation of such instability condition in boreal winter and discusses the significant role of the GW forcing. We used simulation data from a GW-resolving general circulation model (GCM). As this GCM does not include any GW parameterizations, all waves including GWs are resolved, which allows us to analyze the role of GWs in the momentum budget in the middle atmosphere explicitly.

First, a two-dimensional (2-d) analysis using the transformed Eulerian-mean equations was made. It is seen that the negative PV gradient is regarded as an enhanced PV maximum. This maximum is due to the poleward shift of the westerly jet in association with strong EP-flux divergence caused by PWs from the troposphere. Strong GW drag slightly above the westerly jet shifts poleward as well, which can be understood by a selective GW-filtering mechanism. It seems that this GW-drag shift induces strong upwelling in the middle latitudes and adiabatically cools the middle mesosphere. Resultant enhanced static stability is the main cause of the PV maximum in the upper mesosphere. Because of the dominance of PWs during this event, this process may not be zonally uniform.

Thus, second, a 3-d analysis was made using a recently derived 3-d transformed Eulerian-mean theory (Kinoshita and Sato, 2013; Sato et al., 2013). As expected, the GW drag is distributed depending on the longitude. The zonal structure of PV maximum is consistent with the GW drag distribution. An interesting fact is that the spatial distribution of GW drag is not largely correlated with that of the zonal wind at the same level but highly correlated with that in the stratosphere where PWs are dominant. This result indicates significant coupling between the stratosphere and mesosphere via the selective GW filtering.

O3.4 *Monday 12th January, 16:30 – 16:45*

Intraseasonal variability of the wave activity associated with polar vortex extremes in the boreal stratosphere

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In recent years the study of the troposphere-stratosphere coupling has had a growing interest due to the importance on the seasonal prediction of the tropospheric climate. Several studies have analyzed this coupling in the Northern hemisphere by the study of tropospheric planetary wave activity considering an unique winter season, either the whole extended winter or December-January-February months. In this work, we focus on analyzing the intraseasonal variability of the tropospheric wave activity prior to stratospheric polar vortex extremes. To accomplish this aim, we divide the Winter season in three subperiods: early winter (October-December), mid-winter (January- February) and late winter (March-April). Eliassen-Palm flux through the 1000-1 hPa column and 100-hPa meridional eddy heat flux preceding weak and strong vortex events are analyzed from daily ERA-Interim data. The study period is 1979-2011.

Among other results, the anomalous tropospheric wave propagation up to the stratosphere prior to polar vortex extremes presents notable differences among the three winter subperiods, both in intensity and location of the anomalous-divergence maximum. Furthermore, it has been observed that the significant regions of tropospheric planetary-wave injection into the stratosphere also vary depending on whether the vortex extremes occur in early winter, mid-winter or late winter.

O3.5 (invited) *Tuesday 13th January, 9:00 – 9:30*

The energetics of the polar vortex variability

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Experiments with stratosphere-only models (e.g. *Holton and Mass, JAS, 1976; Scott et al., JAS, 2008*) show that strong polar vortex vacillations may be reproduced with a time independent tropospheric forcing at the lower model boundary. It is also well known from models and observations that strong vortex anomalies progress downward from the upper stratosphere to the lowermost stratosphere and are followed by anomalous tropospheric weather regimes that persist for several weeks (e.g. *Baldwin and Dunkerton, Science, 2001*). Therefore the coupled stratosphere-troposphere variability can be understood as an interplay between the stratospheric modulation of the upward propagation of waves forced in the troposphere and, on the other hand, the change on the generation of waves in the troposphere due to a change on baroclinic instability in the upper troposphere/lower stratosphere (*Wittman et al, JAS, 2007*). The changes on baroclinic wave activity are accompanied by barotropic responses that are manifested on the annular mode variability.

The processes associated with the coupled stratosphere-troposphere variability are associated with anomalies in the energy of both barotropic and baroclinic waves, and with anomalies in the rates of energy conversions and interactions. The analysis of such anomalies may contribute for the understanding of the mechanisms associated with the coupled stratosphere-troposphere variability.
On this communication we will describe the anomalies in the energy amounts and energy flows associated with strong vortex deccelerations and with strong vortex accelerations. The analysis is based on the normal mode energetics (NME) scheme developed by *Marques and Castanheira (JAS, 2012)*, which performs an explicit evaluation of the kinetic and available potential energies, accounts for their dissipation and generation rates, respectively, along with the rates of energy conversion and interaction, each decomposed onto zonal mean and eddy components, and onto barotropic and baroclinic components. Statistical significant anomalies were found both in the energy amounts and energy flows. The physical significance of the anomalies will be discussed.

O3.6 *Tuesday 13th January, 9:30 – 9:45*

On the relationship between ENSO, Stratospheric Sudden Warmings and Blocking

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Major Stratospheric Sudden Warmings (SSWs) are foremost disruptions of the polar vortex and provide a potential source for more skilful seasonal forecasts of tropospheric winter weather in the northern extratropics. However, little attention has been paid to identify the tropospheric precursors of SSWs. In this study, we examine the influence of El Niño-Southern Oscillation (ENSO) on different aspects of Stratospheric Sudden Warmings (SSWs) and atmospheric blocking, including the blocking precursors of SSWs, for the 1958-2010 period of the ERA-40 and ERA-I reanalyses.

It is found that SSWs are preceded by blocking patterns over different regions depending on the ENSO phase. Euro-Atlantic and western Atlantic blocks tend to precede SSWs during El Niño (EN), whereas Eastern Pacific and Siberian blocks are the preferred precursors of SSWs during La Niña (LN) winters. This ENSO signal on the blocking precursors of SSWs is larger than that obtained in previous studies by stratifying the SSWs into splitting and displacement SSWs.

Our results also reveal that the regional blocking precursors of SSWs during each ENSO phase have different impacts on the upward propagation of planetary-scale wave number 1 and 2, and hence determine ENSO differences in the wave number signatures of SSWs. Thus, SSWs occurring during EN are preceded by amplification of wave number 1, whereas LN SSWs are predominantly associated to wave number 2 amplification. This leads to an unbalanced frequency of wave-1 and wave-2 SSWs between opposite ENSO phases. However, there is not a strong preference for splitting or displacement SSWs during any ENSO phase due to a lack of correspondence between wave-2 and splitting SSWs.

O3.7 *Tuesday 13th January, 9:45 – 10:00*

Stratospheric sudden warming role on Central Pacific El Niño stratospheric response

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The Northern Hemisphere polar stratospheric response to Central Pacific El Niño (CP El Niño) remains unclear. Contradictory results have been found on its resemblance with the canonical East Pacific El Niño (EP El Niño), depending on the index used to characterize these events or the number of cases. Some studies have found a stronger and colder polar vortex while others showed a weaker and warmer polar stratosphere. Results based on reanalysis data show that the CP El Niño response in the Northern Hemisphere is robust when the events are classified according to the occurrence of stratospheric sudden warmings (SSWs). CP El Niño winters without SSWs show significant cold anomalies in the Northern Hemisphere early winter polar stratosphere. In contrast, CP El Niño winters with SSW occurrence are associated with significant warm anomalies, which are in fact related to SSWs. Therefore, the polar stratospheric response to CP El Niño events is significant and opposite during winters with and without SSWs. In addition, and contrary to previous studies, CP and EP El Niño polar stratospheric responses are clearly distinguishable in early winter in the absence of SSWs. Similar results are also obtained from CMIP5 historical simulations. Hence, our results reveal that the SSW occurrence needs to be taken into account when studying the CP El Niño stratospheric response and explain why different responses to CP El Niño were previously reported.

O3.8 *Tuesday 13th January, 10:00 – 10:15*

Momentum flux intermittency in a stochastic parameterization of non-orographic gravity waves

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A multiwave stochastic parameterization of non-orographic gravity waves (GWs), representing GWs produced by convection and a background of GWs in the midlatudes, is tuned and tested against momentum fluxes derived from long-duration balloon flights. The tests are done offline using datasets corresponding to the Southern Ocean during the Concordiasi campaign in 2010. We also adopt the limiting constraint that the drag produced by the scheme resembles that produced by a highly tuned spectral GW parameterization, the so-called Hines (1997) scheme.

Our results show that the parameterization can reproduce the momentum-flux intermittency measured during the campaign, which is extremely significant since this strongly impacts on the vertical distribution of the GW drag. We also show that, at the altitude of the balloon flights (around 20 km), the momentum-flux intermittency is in good part due to the GW sources: filtering by the background winds only impacts the intermittency at much higher altitude.

Additionally, we try to reconcile the two different approaches more commonly followed in non-orographic GW parameterizations, namely the multiwave and the spectral schemes. For this purpose, it is shown that the observed universal spectra of GWs as a function of the vertical wavenumber, which is at the basis of most spectral parameterizations, can be obtained as a superposition of individual, narrow-banded periodograms represented in our multiwave stochastic parameterization.

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O3.9 *Tuesday 13th January, 10:15 – 10:30*

Comparing Sudden Stratospheric Warming Definitions in Reanalysis Data

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Sudden Stratospheric Warmings (SSWs) are the main source of variability in the northern hemisphere polar stratosphere during winter. They are characterized by a dramatic warming of the polar stratosphere and weakening of the polar vortex circulation. SSWs can have an impact on surface weather, which makes them a potential tool for seasonal prediction. However, there is no consensus on the definition of SSWs, and multiple methods exist in the literature, yielding discrepancies on the detected events. The aim of this work is to compare the SSWs signatures of eight representative definitions for the 1958-2009 period and using three different reanalysis data. The intra-seasonal distributionof SSWs is indistinguishable across definitions, with a common peak in January. However, the multi-decadal variability is method-dependent, with only three definitions displaying minimum frequencies in the 1990s. Comparison of several SSW benchmarks reveals negligible differences among methods due to the large case-to-case variability of events within a given definition. In the troposphere, the most robust signals across definitions before and after events are dominated by major SSWs, which are detected by most methods. Interestingly, minor SSWs represent the largest source of discrepancy in the surface signals of SSWs across definitions. Therefore, our results indicate that only major SSWs should be considered in future studies, if robust tropospheric signals of SSWs are want to be obtained regardless of the chosen method.

O3.10 *Tuesday 13th January, 10:30 – 10:45*

Tropical widening from isentropic and potential vorticity fields

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In recent years it has been got evidence of a widening of Earth's tropical band. Different authors and assessments have given values between 0.3 and 3.1 degrees/decade. However all the methodologies proposed are constratined and some of the results come out after choosing random values or thresholds. It is well known that the tropopause can be considered as a marker for tropical regions because of its abrupt change in heigth respect to extratopics and close relation of its shape with other dynamical factors. Here we use several 'properties' of the tropopause, fields of potential vorticity and potential temperature to assess the broadening of the tropical regions in our planet. For it we have used both reanalysis and climate model simulations. For it we make use of a recent methodology to determine equivalent latitude based on computation of regions of interest. Our results agree with others existing in the literature, particularly with those that proposed smaller values of tropical widening.

Linking parameterized gravity waves in the LMDz-GCM to their frontal Sources

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Internal gravity waves (GWs) propagating vertically from their tropospheric sources impact the circulation of the middle atmosphere, and are crucial for the reversal of the mesospheric jet and the maintenance of the quasi-biennial oscillation (QBO). Their spatial scales being too small to be represented in current General Circulation Models (GCMs), they need to be parameterized. Nevertheless, mechanisms for GW emission by fronts and jets remain elusive nowadays. As a result, non-orographic GW parameterizations usually asume an arbitrarily uniform source of waves, which makes them insensitive to the annual cycle or to a changing climate.
In this study we take advantage of recent theoretical results on the emission of GWs by potential vorticity (PV) anomalies in vertically sheared flows (Lott et al. 2010, 2012), where GWs are emitted during the evolution of a near balanced flow (i.e. spontaneous adjustment). We then apply the stochastic methods described in Lott et al. (2012) and construct a GW parameterization linked to their frontal sources via PV anomalies. We will show that the scheme produces realistic GW drag, realistic GWs intermittency and that it performs as well as classical schemes that have been thouroughly tuned the last 20 years. We will also present preliminary indications that the annual cycle in the GW forcing (which is related to the anual cycle of the sources) as well as the GW intermittency help the Laboratoire de Météorologie Dynamique Zoom (LMDz) GCM to have a final warming date of the southern polar vortex close to that shown by reanalyses products.

References:

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Lott, F., L. Guez, and P. Maury (2012), A stochastic parameterization of non-orographic gravity waves: Formalism and impact on the equatorial stratosphere, Geophys. Res. Lett., 39, L06807, doi:10.1029/2012GL051001.

P3.2 *Poster session: Monday 12th January, 16:45 – 18:30*

Sensitivity study of the definition parameters of the Mixing Layer

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We present a climatological study of mixing layer using chemical tracer-tracer relationships on reanalysis data of ECMWF (ERA-Interim). In the tracer-tracer space, the O_3 and H_2O tracers are used to separate the transition layer air mass from troposphere and stratosphere, and identify the mixing layer. Seasonal cycles of these tracer gases and of their relationships have been studied, and the sensitivity of the mixing layer results to the choice of parameters of the determination method has been revised for all latitudes and seasons on reanalysis data.

Weakening of the stratospheric polar vortex by Arctic sea-ice loss

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Successive cold winters of severely low temperatures in recent years have had critical social and economic impacts on the mid-latitude continents in the Northern Hemisphere.
Although these cold winters are thought to be partly driven by dramatic losses of Arctic sea-ice, the mechanism that links sea-ice loss to cold winters remains a subject of debate.
Here, by conducting observational analyses and model experiments, we show how Arctic sea-ice loss and cold winters in extra-polar regions are dynamically connected through the polar stratosphere. We find that decreased sea-ice cover during early winter months (November–December), especially over the Barents–Kara seas, enhances the upward propagation of planetary-scale waves with wavenumbers of 1 and 2, subsequently weakening the stratospheric polar vortex in mid-winter (January–February). The weakened polar vortex may preferentially induce a negative phase of Arctic Oscillation at the surface, resulting in low temperatures in mid-latitudes.

Analysis of the tropospheric wave-activity injection into the stratosphere preceding polar vortex extremes in the northern hemisphere

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It is already known that the troposphere mainly interacts with the stratosphere through upward propagating tropospheric planetary waves. Furthermore, the meridional Eddy heat flux at 100 hPa (hereafter HF100) is commonly used as a proxy of the upper troposphere wave activity injection into the stratosphere. The aim of this work is to identify the most predominant contributor to the total 100-hPa eddy heat flux prior to the occurrence of polar vortex extremes (weakening and strengthening) in the boreal stratosphere. To achieve this goal the total heat flux is decomposed in three terms, associated with climatological waves (HFclim), anomalous Rossby wave packets (HFanom), and the interaction between both of them (HFclim-anom). The analyzed period is from October to the subsequent April of 1979-2011 using daily ERA-Interim data. Taking into account the evidences of intraseasonal variability in the planetary wave propagation, the study is carried out considering early winter (October-December), midwinter (January-February) and late winter (March-April) separately.
It has found that prior to weak and strong polar vortex events and for the three Winter subperiods, the most contributor to the total HF100 is the term HFclim-anom, except for weak events occurred in early winter. In this later case, the term HFanom is almost as important as HFclim-anom in the wave activity injection into the stratosphere. Overall, the most important term in the total HF100 prior to strong (weak) polar vortex events is opposite to (reinforce) the contribution due to the climatological waves.

P3.5 *Poster session: Monday 12th January, 16:45 – 18:30*

The future summer NAO trend in CMIP5 and CCMVAL2 models

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In this study we investigate whether the response of the summer NAO (SNAO) to anthropogenic forcing in global climate models is related to the representation of the stratosphere. The SNAO, though weaker and confined to northern latitudes compared to its winter counterpart, is the leading mode of summer SLP variability in the North Atlantic/European sector and strongly modulates precipitation not only in the vicinity of the SLP dipole (northwest Europe) but also in the Mediterranean region, via an upper-level hemispheric wavetrain. The SNAO is generally projected to trend upwards in CMIP3/CMIP5 models, which leads to a consistent signal of precipitation reduction in NW Europe (where the negative influence of the SNAO is well-represented), thus accounting for a large portion of the projected drying in this region. However, the intensity of this trend varies greatly across models, with a few models even projecting significant negative trends, which results in large uncertainties in the magnitude of this projected drying. Moreover, no theoretical framework exists for the sensitivity of the SNAO to external forcing, so it is unclear whether the response of the SNAO to increased greenhouse gases and aerosols will indeed take the form of an upward trend. As a first step to understand the origin of the SNAO trend, we investigate to what extent this trend is dependent on spatial resolution and on whether models fully resolve the stratosphere. We examine both the CMIP5 and the CCMVAL2 ensemble and also analyze the relationship between projected winter and summer NAO trends.

Session 4:

Seasonal and decadal variability/predictions

O4.1 Invited *Tuesday 13th January, 11:15 – 11:45*

The Role of the Stratosphere in Monthly to Decadal Prediction

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The stratosphere has now been shown to impact surface climate in many studies which reproduce similar results with a variety of different climate models. Here we will review the role of the stratosphere in *initialised* seasonal climate predictions out to months ahead and decadal predictions out to years ahead. Clear impacts of stratospheric variability on surface pressure, temperature and extreme events such as storms, frosts and heavy rainfall have all been demonstrated in the last decade and there is evidence that even climate change is affected by stratospheric processes. A striking feature is that the impact is similar across all timescales from months to decades. The ubiquitous pattern that emerges involves a change in the Arctic Oscillation and its regional equivalent, the North Atlantic Oscillation. The mechanism for this link is still debated but there are a few likely candidates, one of which will be emphasized in this talk. While the predictability of the North Atlantic Oscillation has so far been very limited, recent results are much more encouraging. Examples of the longer timescale stratospheric dynamics acting as a source of predictability for the NAO will be provided and clear evidence for the importance of the stratosphere in winter seasonal forecasts will be shown.

O4.2 Invited *Tuesday 13th January, 11:45 – 12:15*

The SPECS project: Climate prediction for climate services

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New tools for the provision of climate information for climate services and adaptation are being created by climate modellers. One of these tools is climate prediction, which produces climate information for the near future on seasonal-to-decadal time scales that is validated against observations, not just in terms of the reproducibility of the mean climate over a long period, but also in its simultaneous correspondence with the best observations available. These tools are now being developed as part of large international efforts that bring together climate scientists and users implementing a new paradigm known as climate services research. This talk will introduce this paradigm and will present the research that is being undertaken in the SPECS FP7 project that illustrates what role stratospheric processes can play.

O4.3 *Tuesday 13th January, 12:15 – 12:30*

Regional Influence of Solar Variability on European Climate

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Solar variability related to irradiance and energetic particle forcing could be an important source of natural climate variations superimposed on the human-induced warming since the late twentieth century in particular on the regional scale. Because of its prominent 11-year cycle, solar variability offers a degree of predictability and could potentially enhance decadal scale predictions. Understanding the influence of solar variability on climate requires knowledge of solar variability, solar-terrestrial interactions and observations, as well as mechanisms determining the response of the Earth's climate system. We will summarize our current understanding of the impact of solar forcing on the atmosphere with special focus on the regional changes over the North Atlantic and Europe from observational and modeling studies. We will present feedback mechanisms for the solar signal transfer and discuss the importance of the solar cycle for decadal climate predictions.

O4.4 *Tuesday 13th January, 12:30 – 12:45*

Simulation of secular temperature trends in the stratosphere, mesosphere and lower thermosphere

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Anthropogenic emissions of greenhouse gases (GHG) warm the troposphere and cool the upper layers of the atmosphere above about 100 hPa. The pattern of temperature change with altitude depends, not just on the rate of emission of GHG, but also on changes in ozone brought about by decreases in the halogen burden of the atmosphere and by the changing temperature itself. We use the Whole Atmosphere Community Climate Model (WACCM) to investigate secular trends in temperature over the last 30 years and to project these changes into the rest of the 21st century. We compare model results against observations and show that WACCM reproduces many details of the observed trends, including the region of small or insignificant temperature trends near the mesopause; these changes may be understood in terms of the interplay among GHG, ozone, temperature, and the global circulation. The vertical profile of the temperature trend changes substantially in the course of the 21st century compared to the last 30 years as ozone responds to the curtailment of halogen emissions and as changing temperatures modify its photochemical equilibrium concentration.

Total ozone trends over the Iberian Peninsula for the period 1979-2012

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The ozone layer protects all living organisms from harmful ultraviolet radiation. Furthermore, ozone plays a key role in weather and climate on regional to global spatial scales, acting as a major greenhouse gas. Hence, the study of the temporal ozone variability over mid-latitude regions becomes a major issue in the scientific research. The main goal of this work is to analyze the total ozone column (TOC) trends over the Iberian Peninsula during the period 1979-2012 using TOC data provided by the Multi Sensor Reanalysis (MSR), which has been created from the assimilation of fourteen satellite retrieval datasets. The analysis is focused on two sub-periods (1979-1994 and 1995-2012) in order to detect changes in the ozone trend pattern. The results show that the ozone depletion was statistically significant at the 95% confidence level during the first sub-period in the entire region of study (except in the Southerner locations), with linear trends from -4.2%/decade to -2.6%/decade. These linear trends present a clear dependence on latitude, being higher for the Northerner locations than for the Southerner. By contrast, the analysis of the second sub-period (1995-2012) shows positive ozone trends with the highest values (+1.6%/decade) in the Iberian Northeastern region. This result highlights that the stratospheric ozone layer over mid-latitude regions may be responding as expected to the controls on ozone-depleting substances imposed by the Montreal Protocol

P4.2 *Poster session: Monday 12th January, 16:45 – 18:30*

Dynamical characterization of total ozone column in the Iberian Peninsula emphasizing the double tropopause events

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The monitoring of the ozone is of great relevance for the atmospheric science community, due to the role played by this trace gas in the climate system. The dynamical aspects affecting the total ozone column (TOC) are analyzed in this study. To this purpose, Brewer spectroradiometer measurements, in five ground-based sites of the Iberian Peninsula, and reanalysis data from ERA-Interim are employed to evaluate daily values of TOC, NAO (North Atlantic Oscillation) index, and the pressure, height and temperature of the tropopause. Events characterized by a double tropopause (DT) in the vertical atmospheric structure are also identified. TOC and tropopause characteristics are found to be linearly correlated. These linear fits show both seasonal and latitudinal dependences. The events with DT cause a fall in the ozone column level that is about 10% in winter and spring with respect to the usual cases with a single tropopause. The total weight of the DT events with respect to the annual TOC values is about 20%, with a negligible occurrence in summer and autumn. The Iberian Peninsula, a latitudinal belt of 8º, presents a South-North decreasing gradient of these events. The daily NAO index can explain 30% of the TOC winter variability. Finally, the DT events are found to be more frequent during phases with positive NAO.

Hemispheric distributions and solar-induced variability of NOy produced by Energetic Particle Precipitation in 2002-2012 as measured by MIPAS

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The MIPAS Fourier transform spectrometer on board Envisat has measured limb emission spectra in the mid-IR for a 10-year period (2002-2012) which have been used to retrieve vertical profiles of the six principal reactive nitrogen (NOy) compounds (HNO3, NO2, NO, N2O5, ClONO2, and HNO4) with global coverage and independent of illumination conditions. From these data, the contribution of NOy produced by energetic particle precipitation (EPP) has been discriminated from the background NOy by using a tracer correlation method based on co-located MIPAS CH4 and CO measurements. The obtained EPP-NOy distributions demonstrate a regular indirect EPP impact on the entire stratosphere (down to 22-25 km) by polar winter descent and show a clear solar cycle signal in consonance with the change in the geomagnetic activity. Furthermore, a pronounced hemispheric asymmetry is observed, with higher concentrations of EPP-NOy in the Southern Hemisphere (SH) and a larger variability in the Northern Hemisphere (NH). In this paper, possible drivers of the observed hemispheric asymmetry are discussed. We also show by multi-linear regression of the temporal evolution of EPP-NOy with the Ap index that 80-90% of the SH inter-annual variability (excluding direct contributions by Solar Proton Events) can be attributed to changes in the geomagnetic activity. This tight relationship holds throughout the winter season and at all vertical levels. In the NH, a similar well-correlated relationship is found until mid-winter. Afterwards, the Ap correlation breaks down above the 2 hPa level in years with elevated stratopause occurrence.