EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15211
STSM title: Toward a proper analysis of atmospheric conductivity and its variability in a comprehensive Global Electric Circuit: installation of the convective Rn222 transport to the Chemistry ‑ Climate Model SOCOL v.2
STSM start and end date: 18/03/2019 to 30/03/2019
Grantee name: Kseniia Golubenko

PURPOSE OF THE STSM:
(max.200 words)

During the previous K. Golubenko's STSM to Davos in October 2018 the Chemistry ‑ Climate Model (CCM) SOCOL v.2 has been extended to treat radon emission, mixing, advective transport and decay data. A careful calculation of ionization rate by radon was also added to the model. Obtained results during STSM show that the global model SOCOLv2 can reliably reproduce the variations of atmospheric radon concentrations, such as it follows from comparisons of our results with the results of global models ECHAM5 and WACCM.

However, the convective Rn222 transport was not included during 1-weak long STSM. It leads to some errors in radon induced atmospheric conductivity above planetary boundary layer.

The STSM aims at the continuation of the radon induced ionization rates calculations using the CCM SOCOL for studying of the impact of GEC through variability of conductivity on climate.

During this STSM we plan to:
- add convective Rn222 transport
- calculate total atmospheric conductivity including radon.
- prepare new model version for subsequent numerical simulations with Rn222 ionization
- curry out the first calculation of the electric current in the fair weather regions

This STSM is a part of the WG3 activity (see "Electronet" activity plan on http://www.atmospheric- -electricity--net.eu). The WG3 Leader and the Host institution are Dr. E. Rozanov and PMOD/WRC. The first result of this research will be presented during EGU-2019 with acknowledgment for COST support.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS
(max.500 words)

During the Arseniy Karagodin's STSM in 2017 the parameterization of the ionospheric potential (IP) described by Mareev et al. [2014] and atmospheric conductivity were incorporated into chemical-climate model (CCM) SOCOLv2. This allowed us to set about the most urgent part of our work, namely, to simulate the influence of convection on Radon222 distribution and all components of GEC from ionospheric potential to potential gradient with the CCM SOCOLv2.

First of all we added convective Rn222 transport. We have carried out a substantial theoretical study to find a proper way to simulate convection and have chosen the method described byJacob and Prather [1990]. The main idea for our scheme was application of dry convection for regions with instability layers and wet convection for regions with convective cloudiness. When a column of air is unstable with respect to a dry adiabat, the air gets mixed up uniformly within the column. When a column of air is unstable with respect to a wet adiabat, 50 % of the air in the lowest layer of the column moves directly to the highest layer at which it is stable, with no entrainment of air from intermediate layers. Then this air mass decends and mixes homogeneously with the air from intermediate layers.
Then, we performed several 2-year long model experiments for the 2004-2005 years period to obtain and analyze the distribution of the radon concentration as well as to compare our results with available results without convective transport Rn222 (the results of previous K. Golubenko's STSM to Davos in October 2018).
Finally, we have calculated total atmospheric conductivity including radon and, after that, all components of GEC and electric current for three different situations: when we have Rn222 without convection, when convection is dry, and when we have wet convection or connective clouds. In this report we present results for one of this situations (another two types we would like to analysise separately into the frame of the future paper).
The discussion with the researches in the host institute allowed to enhance our understanding of the physical processes involved in the connection between atmospheric electricity and climate and improved the collaboration inside COST Action CA15211 community.

<u>DESCRIPTION OF THE MAIN RESULTS OBTAINED</u>
(max.500 words)

The radon concentration in the atmosphere depends on the transport and not solely defined by its emissions. The Rn222 in the atmosphere can be accumulated in certain locations depending on the preferential wind patterns (the effect of the west-east transfer).
Figure 1 shows us difference between mass mixing ratio with convective transport, which affects the radon concentration in equatorial regions and mass mixing ratio without convection. The equatorial regions has more sources of radon emission but due to conditions of underlying surface provides favorable conditions for convection in the northern hemisphere between 40^0N and 20^0N latitudes. And it gave maximum of Rn222 in this latitudes.

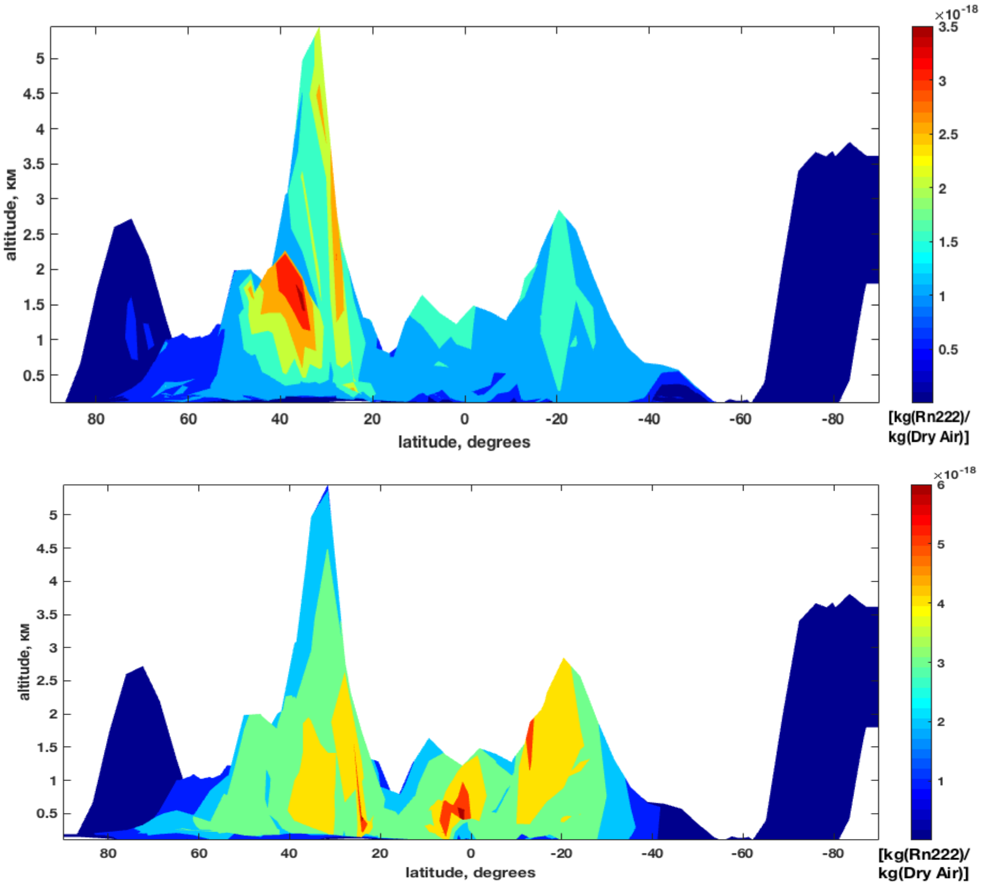

Figure 1. Simulated zonal mean Rn222 mass mixing ratio [kg(Rn222)/kg(Dry Air)]. Top panel is mass mixing

ratio including convective transport, bottom panel is without convection.

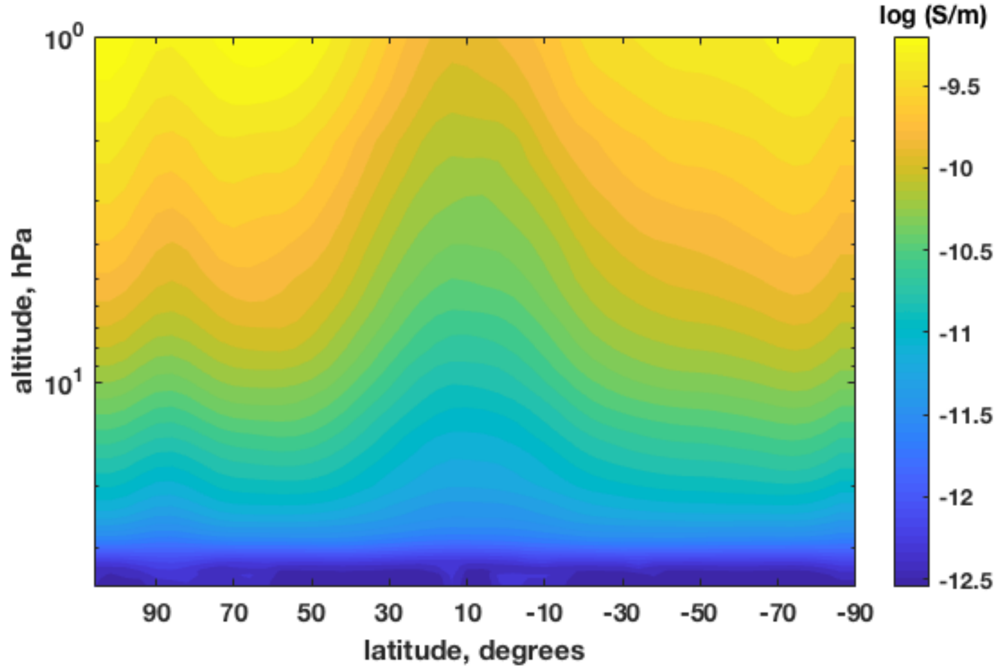

Figure 2. Model conductivity at 30^0E longitude.

The calculated ionization rates from the Rn222 mass-mixing ratio was used for the conductivity calculation. The simulated conductivity profiles (figure 2) were compared with the results of conductivity simulations with WACCM by Baumgartener et al. [2013]. The simulations with WACCM shows lower conductivity values (~ -10 log (S/m) by WACCM and ~ -9.5 log (S/m) by SOCOLv2), it may be explained by different treatments of the ionization sources or aerosol content. In general, the distribution of conductivity by SOCOLv2 looks similar with WACCM distributions. Increase of ionization toward the geomagnetic poles results to increase of conductivity toward high geographic latitudes. Temperature variations lead to further conductivity variability with respect to latitude. In the lower troposphere, further decreases that may be related to aerosol are found (aerosol – it is next step of our research). This is important to note, as local sources of aerosol may seasonally have a large regional, and possibly global, impact on the total conductivity of the atmosphere.

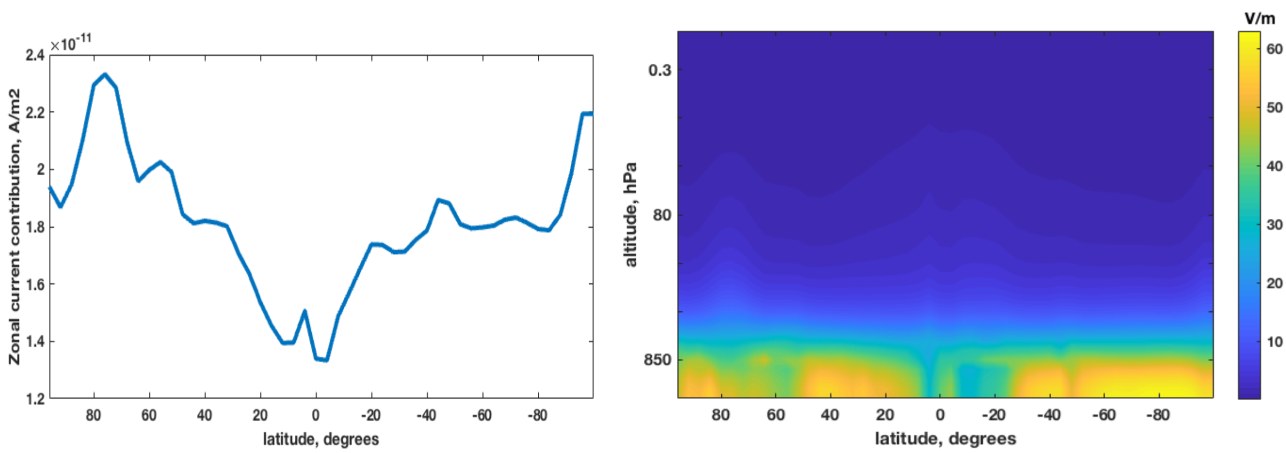

Figure 3. Zonal current contribution, A/m^2 (left panel), Potential Gradient, V/m (right panel)

Atmospheric electrical parameters can be sensitive to changes of local weather conditions, particularly concerning precipitation (convective area) and wind. The decrease of atmospheric electricity coincides with an increase of lower troposphere conductivity, associated with enhanced ionization rates. Simulated zonal current (figure 3) was compared with the total current map produced by Tropical Rainfall Mission Measurement (TRMM) satellite precipitation radar measurements [Lucas, 2010] and observations by geophysical observatorys in UK. Results of SOCOLv2 represent the full picture of prototype atmospheric electrical parameters and may to be use as analog for them.

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CONCLUSIONS AND SUMMARY

In this STSM global simulations were performed with the SOCOLv2 model.

During this STSM all goals were fulfilled in time:
- we added convective Rn222 transport
- we calculated total atmospheric conductivity including radon.
- we prepared new model version for subsequent numerical simulations with Rn222 ionization
- we made the first calculation of the electric current in the fair weather regions

Obtained STSM's results show that the global model SOCOLv2 can reliably reproduce the variations of components of GEC from ionospheric potential to potential gradient, such as it follows from comparisons of our results with the results of global model WACCM and avaible observation data.

Results of this research gave us an opportunity to continue studying of the impact of GEC through the variability of conductivity on climate and ozone layer changes driven by different anthropogenic and natural forcing agents.

FUTURE COLLABORATIONS (if applicable)

We intend to continue collaboration with Physikalisch – Meteorologisches Observatorium Davos improving the new model version for subsequent numerical simulations with Rn222 ionization with updating modules incorporated to model during this STSM for the calculation all components of GEC including the regions with fair weather. We plan to publish the model results obtained from this STSM and present it in scientific conferences with acknowledgements to the COST CA15211 action.

REFERENCE

Mareev, E. A., and E. M. Volodin (2014), Variation of the global electric circuit and Ionospheric potential in a general circulation model, Geophys. Res. Lett., 41, 9009 –9016, doi:10.1002/2014 GL062352.

Daniel J. Jacob & Michael J. Prather (1990) Radon-222 as a test of convective transport in a general circulation model, Tellus B: Chemical and Physical Meteorology, 42:1, 118-134, DOI: 10.3402/tellusb.v42i1.15196

Baumgaertner, A., J. P. Thayer, R. R. Neely III, and G. Lucas (2013), Toward a comprehensive global electric circuit model: Atmospheric conductivity and its variability in CESM1(WACCM) model simulations, JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 9221–9232, doi:10.1002/jgrd.50725

Lucas, G. M. (2010), Investigating the physical mechanisms that impact electric fields in the atmosphere. Thesis, B.S., University of Wisconsin.