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: Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems
STSM start and end date: 11/11/2018 to 18/11/2018
Grantee name: Kseniia Golubenko

<u>PURPOSE OF THE STSM:</u>

(max.200 words)

Ionizations by galactic cosmic ray flux and other space/solar forcing have been already included into the CCM SOCOLv2 (model of the Host institution), however ionization by radon (Rn222) was missing.

The STSM aimed at the introduction of the radon ionization to CCM SOCOLv2 for studying of the impact of GEC through variability of conductivity on climate. The model has been developed in PMOD/WRC, Davos and IAC ETH, Zurich and used for the study of climate and ozone layer changes driven by different anthropogenic and natural forcing agents.

During this STSM we plan to:

• add radon as a tracer to the CCM SOCOLv2;

• obtain and install radon emission and decay data;

• calculate the ionization rates by radon;

• compare total atmospheric conductivity induced by radon, GCR and solar forcing.

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 STSM should enhance our understanding of the physical processes involved in the connection between atmospheric electricity and climate and will enhance the collaboration inside COST Action CA15211 community.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

(max.500 words)

The radioactive isotope Rn222 has a half-life of 3.8 days and can stay suspended in the air and transported over relatively large distances. A global map of radon emissions for July (Figure 1) was produced by Schery and Wasiolek [1998]. A digitized map is used as a source emission of radon in the SOCOLv2 model. Emission units are mBq/m^2*s. First of all, the emissions were converted to g/m^2s, as it is requested for correct calculation of transport module.

During the STSM radon (Rn222) was added and incorporated into the chemical-climate model (CCM) SOCOLv2 as an additional source of atmospheres ionization.

Then, we performed several 2-year long model experiments for the 2004-2005 period to obtain and analyze the distribution of the radon concentration as well as to compare our results with available observations and other model results.

After that we found a proper way to calculate ionization rates from the Rn222 mass-mixing ratio including different units and transformations. Ionization rates by Rn222 were calculated and published by Zhang et al. [2011], main results from this paper were used for comparison with the results obtained with SOCOLv2.

The discussion with the researches in the host institute allowed to get information about the development of new module components, modification and correction of the SOCOLv2 model using knowledge of FORTRAN, Shell scripting. We also discussed how to work with different data formats and how to apply MATLAB for the data interpretation.

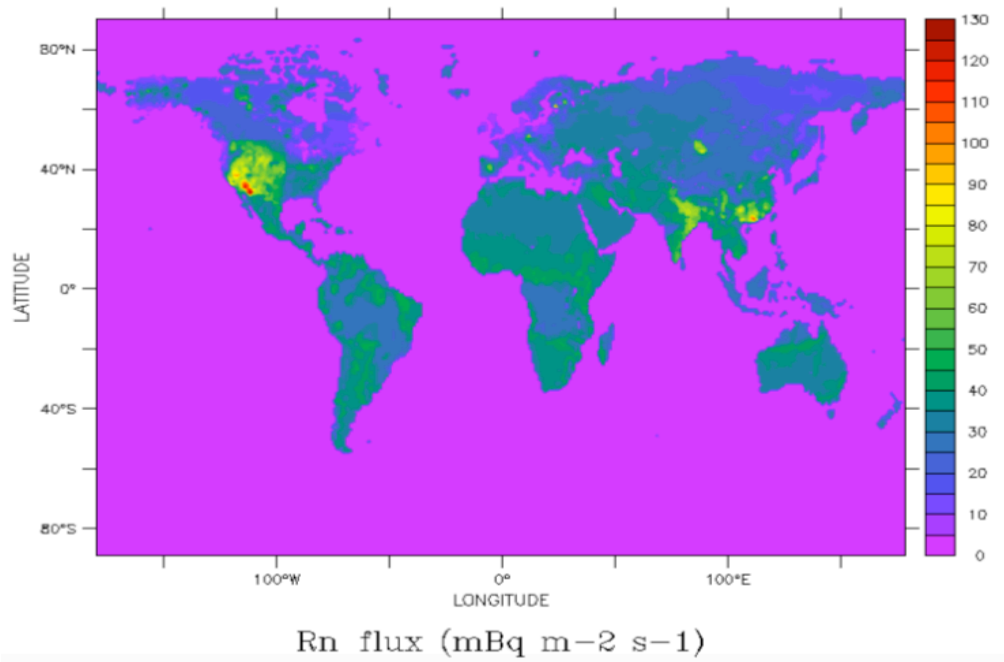

Figure 1: The global distribution of radon flux from the ground during the month of June [Schery and Wasiolek, 1998].

DESCRIPTION OF THE MAIN RESULTS OBTAINED

(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). The first results of the model simulation are presented here. In should be noted that we distribute Radon using only advective transport using the chemistry-climate model SOCOLv2. Convective transport, which affects the radon concentration in equatorial regions was not considered. We plan to do it in the nearest future.

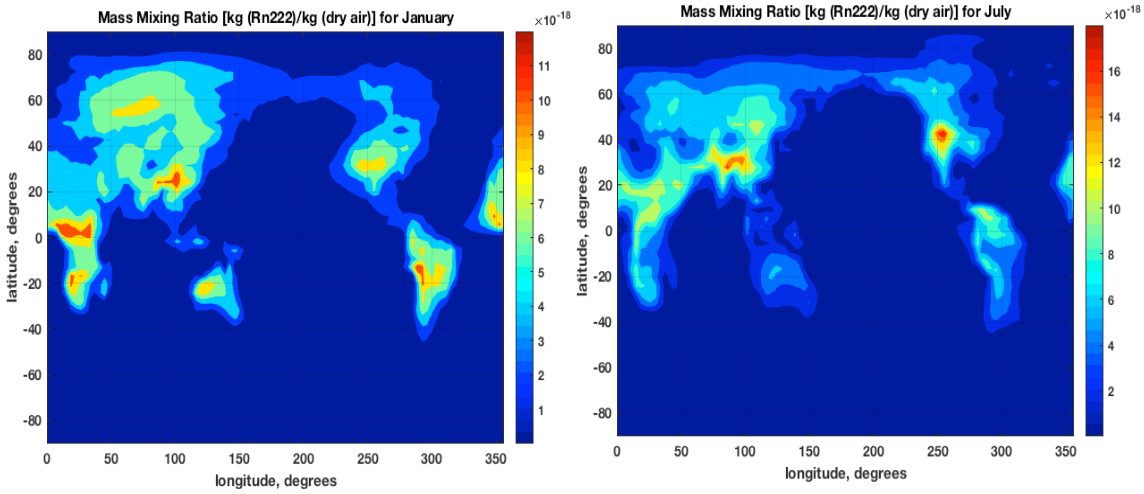

Figure 2: Radon mass mixing ratio (kg/kg) in the lowest model level.

Calculated monthly mean mass mixing ratio of radon for January and July are shown in Figure 2. Obtained values (10^{-18} kg/kg(dry air)) agree well with the results of climatic model WACCM (Lucas, 2010). The northern hemisphere has more sources of radon emission in summer due to conditions of underlying surface. For the southern hemisphere, the opposite situation is obtained.

Highest Radon abundance appears in the regions with strong emission and more stable boundary layer. The mean monthly value of near-surface ionization rate induced by radon for January and July are shown in figure 3.

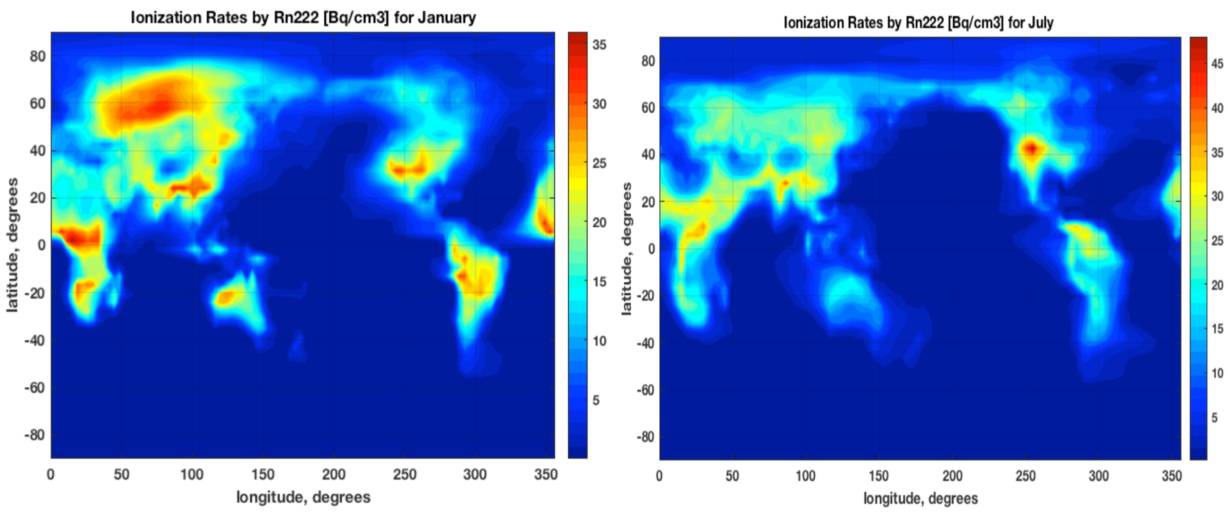

Figure 3: Simulated monthly mean near-surface ionization rate ($s^{-1}cm^{-3}$) induced by radon (Rn222).

The radon-related ionization reaches its maximum in the middle- and low-latitude areas. It should be noted that in winter very high ionization rates appear between 40^0N and 70^0N, 0^0S and 30^0S. Strong radon-related ionization often occurs in winter at low temperature (for example, Russia region), which provides favorable condition for the ion induced aerosol nucleation. It may be important for the aerosol size distribution, cloud properties, and can have some climate effect (Kazil et al. [2010]). In summer, high ionization rates are located only in the northern hemisphere between 5^0N and 40^0N. It may be caused by a strong and constant source of radon emission in South America (as expected on global radon map shown in Figure 1).

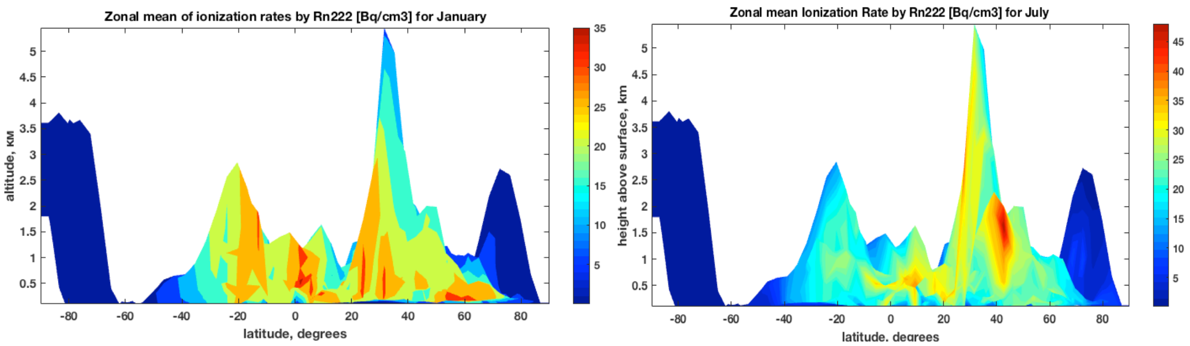

Figure 4: Simulated zonal mean ionization rates ($s^{-1}cm^{-3}$) induced by radon (Rn222)

Figure 4 presents latitude-altitude distribution of zonal mean ionization rates. The radon-related ionization reaches its maxima near the surface, where the Radon concentration is enhanced. Over the high latitudes, the ionization rates are not so strong because the Radon sources are weaker over the surfaces covered by ice and snow.

The ionization rate results were compared with the results of Rn222 simulations with ECHAM5 by Zhang et al. [2011]. The simulations SOCOLv2 shows higher ionization rates values (~20 Bq/cm^3 by SOCOLv2 and ~9 Bq/cm^3 by ECHAM5), it may be explained as different input source type. In general, the distribution of ionization rates from SOCOLv2 looks similar with ECHAM5 distributions.

CONCLUSIONS AND SUMMARY

During this STSM all goals were fulfilled in time:

- we added radon as a tracer to the CCM SOCOLv2;
- we obtained and installed radon emission and decay data;
- we calculated the ionization rates by radon;

We introduced the radon ionization to CCM SOCOLv2 for studying of the impact of external forcing on GEC and climate.

The ionization rates were estimated based on the activity concentration of Radon222. In this STSM global simulations were performed with the SOCOLv2 model to simulate radon activity in the lower atmosphere.

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.

The radon-related ionization rates in boreal winter due to increased atmospheric stability leads to seasonal mean as high as 20 $cm^{-3}s^{-1}$. In the middle- and low- latitude continental areas the zonal mean of radon-induced ionization rate is up to 30 $cm^{-3}s^{-1}$ on 2000 m elevation. Further analysis of ionization rates shows that in Russia and Canada strong radon-related ionization often occurs in winter at low temperature, which provides favorable condition for the ion induced aerosol nucleation [Lucas, 2010].

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)

After the mission, we plan to perform the model run on the computer cluster in St. Petersburg University and the results will be carefully analyzed and compared with available observations and other climatic models. We intend to continue collaboration with Physikalisch-Meteorologisches Observatorium Davos improving the new modules incorporated to model during this STSM and calculate total atmospheric conductivity induced by radon (Rn222), GCR and solar forcing in Home institution. We also intend to add convective Rn222 transport. Results will be used to prepare at least one paper to a refereed journal and presentations for scientific conferences with acknowledgements to the COST CA15211 action.

REFERENCES

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