A model study of the feedbacks between lightning activity and atmospheric temperature and composition changes

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Lightning activity produce extensive excitations, dissociations, and ionizations of the atmospheric constituents. In addition, lightings are one of the main sources of the nitrogen dioxide, nitrous oxide, nitric oxide in the troposphere. On the other hand nitrogen oxides can affect the distribution of the chemically and radiatively active gases and temperature which drive the weather and climate. In turn, climate and weather variability can alternate thunderstorm cloud formation resulting in lightning frequency and distribution changes followed by changes in the nitrogen oxides formation. Thus, positive and negative feedbacks may form due to interrelation between lightning frequency, atmospheric chemistry and weather and climate changes. Both regional and global effects of these feedbacks may be important for atmospheric composition and structure variability. To study the details of these feedback mechanisms two numerical models are exploited: global chemistry-climate model INM-RSHU and WRF-Chem version 3.5(provides the capability to simulate chemistry and aerosols from cloud scales to regional scales). WRF coupled with aqueous chemistry is being used to understand the effect of different processes in thunderstorms on ozone precursors, that is, nitrogen oxides and hydrogen oxide radicals and their precursors (e.g., hydrogen peroxide and formaldehyde).

WRF-Chem is used to simulate the meteorology and chemistry over the region, including northwest of the Russian Federation and Europe (map project – «lambert», 15 km horizontal grid spacing domain, 180 × 180 grid points in the west-east and south-north directions, respectively). The vertical hybrid σ-coordinate has 35 levels from the surface to 50 hPa. Outer domain have longitude of 24.957^{0}N, latitude of 51.604^{0}E.Meteorology input data come from GFS Final Analyses (0.5^0×0.5^0 grid spacing) and contain temperature, U,V- wind components, relative humidity, surface, sea-level pressure, cloudiness etc). The prognostic meteorology parameters include winds, potential temperature, pressure, water vapor, cloud particles etc.

To study lightning effect for multi-week integration (1 june to 31 August, 2013) it was performed model simulation for some group of days: 1) days with thunderstorm,2) days with enhanced convection, 3)days before/after a thunderstorm.

Being subgreed processes, lightning require high resolution model and complex parameterization, that will be able to represent change of the cumulus development

Using independently and simultaneously some convective parameterizations (Manaje moist convective adjustment scheme, Arakawa-Schubert scheme, Betts – Miller scheme, Kuo scheme) allows to simulate lightning flashes and to compare results with satellite data (i.e. choose the optimal convective scheme).Manabe and Strickler parametrisation is based on idea, that if lapse rate is larger than moist adiabatic lapse rate, then vertical moisture and heat are adjusted to make the layer of air be saturated, and lapse rate equals the most adiabatic lapse rate. The excess moisture is considered to be rain. Simple scheme from Kuo is used for deep convection and its basic idea is: the rate of precipitation is balanced by the rate of horizontal convergence of moisture and surface evaporation. In Betts and Miller scheme deep convection and shallow convective are considered separately. If the depth of the convective layer exceeds a specified value, it's deep convection. When the depth of the convective layer is less than the value, it's shallow convection (it will not produce precipitation). Complex scheme from Arakawa and Schubert is based on: 1) assume convection can be represented as an ensemble of entraining plumes with different height and entrainment rates (convective keeps the atmosphere nearly neutral) 2) cloud work function measure of moist convective instability of each type of cloud 3) convective tendencies are very fast, so large scale tendencies approximately balances the convective tendencies.

State of the atmosphere and its composition, depending on convective condition identify basic role of deep convection, show which mechanisms identify gases concentration and lightning initialization.

Combined analyses of convective schemes, meteorology and chemistry show, that atmospheric chemistry is sensitivity to different lightning frequency. It was shown that chemistry –climate-lightning feedbacks can noticeable affect long-term evolution of gases concentration, aerosols in the upper troposphere and lower/middle stratosphere

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