Climate- and Fire-induced Vegetation, Agricultural and Albedo Change in Northern Eurasia: Consequences to Gases, Aerosols and Radiative Fluxes

First annual report for the work accomplished under solicitation NNH09ZDA001N-IDS

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Objective: The ultimate goal of this work is to improve our understanding of feedbacks from the terrestrial environment to related climate forgings by quantifying the integrated influence of the impact of biomass burning (BB) and Land Cover Land Use Change (LCLUC) on the energy balance (shortwave, longwave, sensible and latent heat fluxes, aerosol radiative forcing), altered patterns of precipitation, and potential changes in black carbon deposition to the Arctic due to early and more extreme fire seasons and changes in large-scale circulation using current and future GOCART, WRF-Chem, ecosystem and BB emission simulations.

Accomplishments: We have completed several initial tasks that lead us towards achieving our goals, and we believe we are positioned to realize our objectives. Specific accomplishments follow:

* A new module was developed to compute size- and composition-resolved smoke aerosols within WRF-Chem-SMOKE, which has a fully coupled atmospheric dynamic-aerosol-cloud microphysics-precipitation-radiation modules. Aerosol Optical Depth (AOD) and 3D smoke fields were simulated using WRF-Chem-SMOKE and compared with satellite data (MODIS AOD and OMI AI) to analyze changes in cloud properties and resulting changes in the amount and spatio-temporal distribution of precipitation, with the emphasis on the role of uncertainties in smoke emission.

Initial analyses finds that smoke leads to a weaker front and smaller cloud cells with higher water content in the cyclonic center. The stratocumulus system, which was primarily influenced by CCN, shows dominant positive changes in cloud water path, and the stratocumulus system remains longer under smoke-laden conditions. Additionally, the shifts in cloud pattern and properties caused by smoke directly affect precipitation. Smoke tends to initally suppress precipitation and then acts to invigorate precipitaiton. As a result, precipitation is strongly suppressed in the region with ongoing active fires. The implicaiton is smoke can play an important role in lengthening fire lifetime.

* The meteorology data (temperature, precipitation, relative humidity, wind speed) necessary to process fire weather (GEOS-v5) has been downloaded and fire weather parameters have been generated for a 31-year period in preparation for establishing historic, statistical BB emissions relationships that will be used to define future parameters.

Initial analyses show that fire weather indices compare well temporally, spatially, qualitatively and quantitatively at local, regional and continental scales, highlighting the strength of the fire weather data. More importantly, the large-scale meteorological parameters that determine fire weather are able to capture daily, monthly and seasonal patterns of BB and area burned.

* There are two ecological models simulating future land cover in preparation for the nested-model simulations. Major findings include: (1) agriculture in central Siberia would likely benefit

from climate warming; but (2) changes in Land Cover (vegetation and agriculture) would also result in different feedbacks to the atmosphere and climate systems, in terms of an altered landscape albedo, substantially modified hydrological regimes and an extended and altered fire regime.

Tchebakova and colleagues use SiBCliM to predict the taiga will largely be replaced by steppe and forest-steppe ecosystems in Siberia; in eastern Siberia, larch (*Larix dahurica*) taiga is predicted to dominate due to its ability to withstand continuous permafrost; and the model also predicts new temperate broadleaf forest. Additionally, Tchebakova et al. (2011) find that 50 to 85% of central Siberia is predicted to be climatically suitable for agriculture by the end of the century, although soil potential would limit crop advancement and expansion to the north. Crop production could increase twofold as climate warms during the 21st century; traditional crops (grain, potato, maize for silage) could gradually shift as far as 500 km north (~ 50-70 km per decade) and new crops (maize for grain, apricot, grape, gourds) could be introduced in the south, depending on winter conditions, however these would necessitate irrigation in a drier 2080 climate.

Shuman et al. (2011) use Far East to show the low diversity regions in central and southern Siberia have an abrupt vegetation shift from larch-dominated forest to evergreen conifer forest, and the introduction of *L. decidua* prevents the collapse of larch in these low diversity areas and thus mitigates the response to warming. Using MODIS albedo measurements, it is determined that a conversion from larch to evergreen stands in low diversity regions of southern Siberia would generate a local positive radiative forcing of 5.1±2.6 W m-2, which would reinforce the projected warming.

* GEOS-GCM climate simulations have been completed for our historic test period (1997-2010), which includes a variety of distinct variables for FWI, FAREAST, SiBCliM, GOCART and SRB analysis. Future simulations are almost complete for both the A1B and A2 scenarios for all model inputs for 100 years.

Challenges: We have overcome two challenges, which have delayed our progress: the supercomputers at NASA Ames were oversubscribed resulting in a long queue and wait times; and the increased MERRA resolution presented challenges to both the SRB and fire weather teams that had been previously prepared to work at a 1-degree (or 2.5) resolution.

Related Publications: In the last 14 months, we have chaired 4 related sessions at international conferences, presented at 12 national and international conferences, served as an ERL editor, authored 3 conference manuscripts and authored the 3 peer-reviewed manuscripts noted below.

JK Shuman, HH Shugart, TL O'Halloran, **Sensitivity of Siberian larch forests to climate change**, Global Change Biology (2011) Volume 17, 7, pgs 2370–2384, DOI: 10.1111/j.1365-2486.2011.02417

NM Tchebakova, EI Parfenova, GI Lysanova, AJ Soja, **Agroclimatic potential across central Siberia in an altered twenty-first century** (2011) Environ. Res. Lett. 6 045207 doi:10.1088/1748-9326/6/4/045207

M Natarajan, RB Pierce, TK Schaack, AJ Lenzen, JA Al-Saadi, AJ Soja, TP Charlock, FG Rose, DM Winker, JR Worden, **Radiative forcing due to enhancements in tropospheric ozone and carbonaceous aerosols caused by Asian fires during Spring 2008**, JGR