Geophysical Research Abstracts
Vol. 17, EGU2015-3556-2, 2015
EGU General Assembly 2015

The biogeophysical effect of large-scale afforestation in semi-arid regions

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Forestation in the semi-arid region can significantly influence the surface energy budget and, in turn, the local atmospheric circulations. Such effects could be particularly important in regions under the influence of monsoon regimes, such as the Sahel and North Australia. In these regions, summer solar heating leads first to migration of the equatorial through and the tropical convergence zones (ITCZ) and to the monsoon rain. And second, to a meridional surface temperature gradient that generates low-level easterly jet that acts as a barrier to the penetration of the precipitation into the semi arid areas. In this study we tested the hypothesis that large-scale afforestation in these semi-regions can result in changes in local and regional atmospheric circulation and, consequently, in the precipitation and potential changes in land cover and land use.
The GCM OLAM was used to performing high-resolution simulations (50km horizontal grid scale and 50 vertical layers) of afforestation scenarios in the Sahel and North Australia. These areas (Sahel 2.6 E6 km2 and North Australia 2.1 E6 km2) were afforested with a mature pine forest, using the extensive data form the long-term semi-arid Yatir forest in Israel as a reference forest for surface parameterization. The regional effect of the afforestation was analyzed for the following parameters; Surface energy budget, temperature, Easterly jet stream location and intensity, above forest atmospheric instability, water recycling and precipitation.
Afforestation in the Sahel resulted in large increase of the surface net radiation (45 W m-2), mainly as a result of decrease in albedo (43 W m-2), decrease of incoming short wave radiation (21 W m-2) and increase of downward long wave radiation (13 W m-2) due to higher clouds cover, and decrease in long wave upward radiation (10 W m-2), as a result of the lower surface temperature. Increasing soil moisture because of the new forest is expressed into higher evapotranspiration, i.e. in dramatic increase of the latent heat flux (56 W m-2) and a small decrease in the sensible heat flux (6 W m-2). Model predication has small imbalance (5 W m-2) in energy budget.
The meridional surface temperature gradient increased between 30°N to the forestation area (10°-15°N) to about 10°C, which weakened the core of the Africa Easterly Jet (AEJ) at 600 mb from 12.5 m s-1 to 10 m s-1, and displaced it further north, (from 15°-25°N to 20°-30°N). These changes led to deeper penetration of westerlies winds inland, and displaced the maximum precipitation northward. This was also associated with increasing atmospheric instability, which enhanced moisture convergence over the forested area but also over an equivalent area north of the forest. Overall, precipitation over the Sahel region increased by 600 mm yr-1. Similar effects of afforestation were observed in the model simulation in the semi-arid regions in Australia during the monsoon period. The results show first, the utility of using GCM to extend small-scale detail experimental measurements, and second, the potential implications of large-scale afforestation in semi-arid region on local precipitation and environmental conditions.