Methane Greenouses and Anti-Greenhouses on the Early Earth

Earth's climate appears to have been warm early in its history despite the faintness of the young Sun. High CO_2 concentrations may have provided the necessary greenhouse warming at first, but once life had evolved, methane was probably an important part of the climate story as well. CH_4 concentrations exceeding 1000 ppmv are predicted prior to the rise of O_2 at ~2.3 Ga, provided that the flux of methane into the atmosphere was comparable to that today. This could have provided sufficient greenhouse effect to compensate for low solar luminosity even if CO_2 levels were no higher than today. If the CH_4 concentration exceeded that of CO_2, however, hydrocarbon smog should have formed in the stratosphere. This would have cooled the Earth by creating an anti-greenhouse effect. Climate during the Archean and early Paleoproterozoic may well have been stabilized by a negative feedback loop involving methane production and haze optical depth.

The rise of atmospheric O_2 at 2.3 Ga wiped out most of this methane and probably triggered the widespread glaciations observed at this time. CH_4 concentrations could still have remained higher than today's level (1.6 ppmv) throughout much of the Proterozoic, however, especially if the deep ocean was sulfidic rather than oxic during this time. A second rise in atmospheric O_2, or in oceanic sulfate, could have led to a further decrease in methane around 750 Ma and perhaps triggered the Snowball Earth episodes that began at that time.