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The lapse-rate feedback leads to polar temperature amplification.

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The atmospheric temperature will change in response to a radiative forcing of the climate system, but the temperature change may not be constant with height in the atmosphere. The dependence of the temperature change on hight gives rise to the lapse-rate feedback. In a warmer climate, the saturated mixing ratio of water vapour increases more at lower than at upper levels in the troposphere. Therefore due to enhanced latent heat release, the atmosphere tends to warm more in the upper than in the lower troposphere in regions where strong convection is present, such as at tropical latitudes. This results in enhanced radiation back to space, and in a more efficient cooling of the Earth system. This is contributing to a negative lapse-rate feedback. The opposite situation prevails at the high latitudes where stable stratification conditions in the lower troposphere result in a larger warming of the surface-near atmosphere than of the upper troposphere. This is contributing to a positive lapse-rate feedback. Hence the lapse-rate feedback is assumed to be negative at low, and positive at high latitudes.

Here we explore the lapse-rate feedback and its effect on the climate system using a slab-ocean climate model, the Community Climate System Model version 4. By locking the temperature change throughout the troposphere to that at the surface in calls to the radiation code, the lapse-rate feedback is suppressed on-line in the model. Doubling-of-CO_2 experiments where the lapse-rate feedback is suppressed are compared with experiments where it is retained. In a similar way the surface-albedo feedback is suppressed by keeping the surface albedo fixed in the entire model system.

On the basis of model versions where either one or both of the feedbacks are suppressed, we are able to separate the effect of the surface-albedo and lapse-rate feedback. For instance we can estimate the contribution to the polar temperature amplification due to each of the feedbacks. The results show that the lapse-rate feedback contributes significantly to the amplification of the surface temperature in the polar areas. The lapse-rate feedback accounts for around 15 %, and the surface-albedo feedback 40 % of the amplification in the Arctic. In the Antarctic, 20 % of the amplification can be attributed to the lapse-rate feedback and 60 % to the surface-albedo feedback. Further it is found that the surface-albedo and lapse-rate feedbacks interact considerably at high latitudes to the extent that they cannot be considered independent feedback mechanisms at the global scale.