

Incorporation of a Four-Stream Solar Radiative Transfer Model into CanAM4.2

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1. Introduction

- What is the impact on instantaneous fluxes and climate simulated by the Canadian Atmospheric Model (CanAM) version 4.2 when using a 4-stream rather than a 2-stream solar atmospheric radiative transfer model.

2. The models

- Within CanAM the grid-mean radiative transfer is computed using the Monte Carlo Independent Column Approximation (McICA) by sampling subcolumns containing multiple layer, each being horizontally homogeneous,

$$\langle F \rangle = (1 - A_c) \sum_{k=1}^K F(\alpha_{clr}, k) + A_c \sum_{k=1}^K F(\alpha_{cld}, k)$$

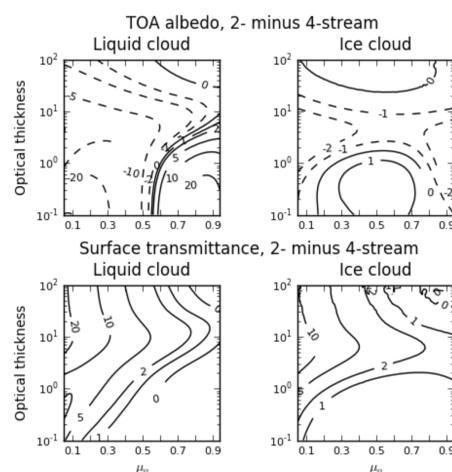
- This allows computation of fluxes for subcolumns using radiative transfer models without including complex structure.
- Currently a delta Eddington 2-stream solution is used to compute solar fluxes. This is replaced by a delta 4-stream solution.

3. The simulations

- Transient simulations with CanAM4.2 for the period 2000-2009
- Sea surface temperature, sea-ice and emissions specified as in CMIP5 for historical and RCP4.5 scenario.
- A pair of simulations
 - 2-stream active and 4-stream called as diagnostic
 - 4-stream active and 2-stream called as diagnostic.
 - “active” means CanAM interacts with the radiative fluxes,
 - “diagnostic” is second calculation using the exact same input as for “active” but different solver.
- A third simulation was performed to compute the impact on the direct radiative effect of aerosols.

4. Offline calculations

- Atmosphere over Point Reyes, CA and a black surface
- Homogenous and overcast cloud inserted at ~850 hPa, liquid cloud has an $r_{eff} = 15 \mu m$ while ice cloud has $r_{eff} = 40 \mu m$.
- Differences consistent with previous calculations and illustrate strong dependence on zenith angle and optical thickness.

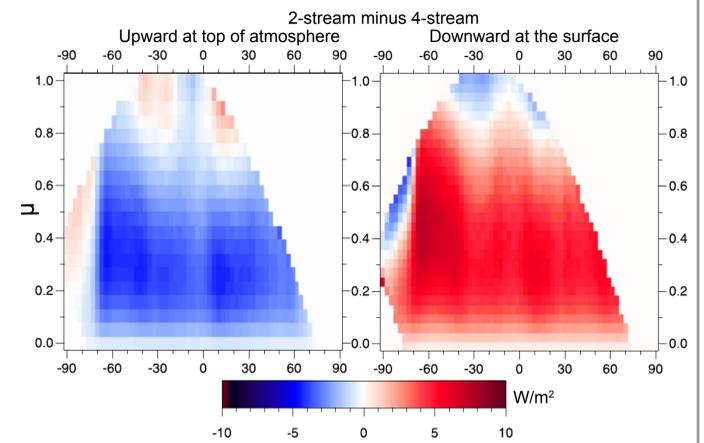


von Salzen, K.; Scinocca, J. F.; McFarlane, N. A.; Li, J.; Cole, J. N. S.; Plummer, D.; Verseghy, D.; Reader, M. C.; Ma, X.; Lazare, M. & Solheim, L. The Canadian Fourth Generation Atmospheric Global Climate Model (CanAM4). Part I: Representation of Physical Processes Atmosphere-Ocean, 2013, 51, 104-125.

Zhang, F., Z. Shen, J. Li, X. Zhou, and L. Ma, 2013: Analytical Delta-Four-Stream Doubling-Adding Method for Radiative Transfer Parameterizations. J. Atmos. Sci., 70, 794-808, doi: 10.1175/JAS-D-12-0122.1.

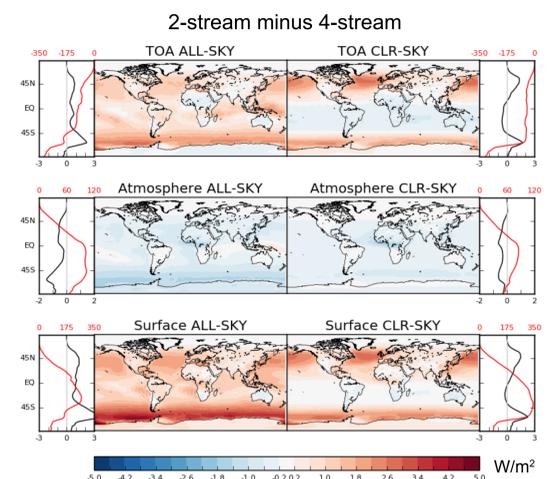
5. Instantaneous differences in solar fluxes (January)

- Sampled every hour
- Affected by range of surfaces, cloud and aerosols so difference is more complex.
- Largely consistent with offline calculations.



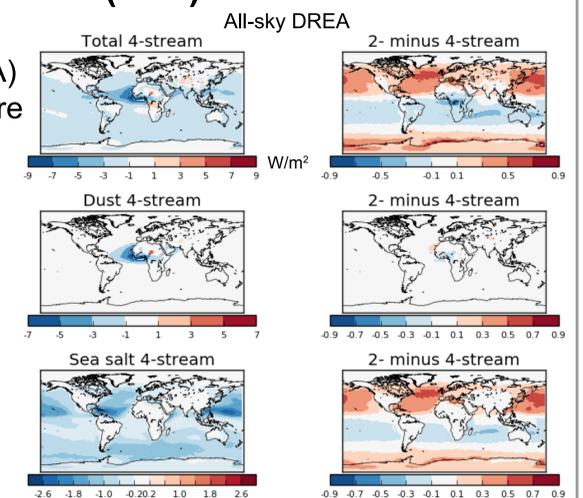
6. Instantaneous differences in solar fluxes (DJF)

- Integrated above difference over all μ
- Showing net downward (down-up)
- While difference is small relative to total, it is systematic larger following locations with low sun angles, more polarward regions.
- This can be important in coupled model simulations.



7. Direct radiative effect of aerosols (DJF)

- Direct radiative effect of aerosol (DREA) is the difference between an atmosphere with aerosols and one without.
- Locally the impact of using a 4-stream model can result in significant changes in the DREA.
- Mostly from sea-salt, likely due to combination of low solar zenith angle and co-located higher burdens.



8. Effect on simulated energy budget

- The 4-stream increases the global mean absorbed radiation in the atmosphere, reducing the net energy at the TOA and surface.
- Given the prescribed SST and sea-ice impact on climate is relatively small.
- Could have larger effect on coupled model, especially due to zonal structure.

