Spectral Greenhouse Parameters

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An inter-comparison of the spectral fluxes at the top-of-atmosphere for the three climatological atmospheres representative of the regions visible to an instrument operating from the International Space Station. The dividing line separating the Far-IR from Mid-IR was placed at 650 cm\(^{-1}\) (15.4 μm) since all current and planned orbiting spectrometers [e.g., the Atmospheric IR Sounder (AIRS), the Cross Track Spectrometer (Cris), and the IR Atmospheric Sounding Interferometer (IASI)] observe only the Mid-IR. This dividing line is also close to midpoint of the Planck curve [620 cm\(^{-1}\)] for a temperature of 255K.

Note: the conversion from wave-number to wavelength is given by the equation: \(\omega(\text{cm}^{-1}) = \frac{10000}{\lambda(\mu\text{m})}\)
The spectrally integrated greenhouse parameter: $G_a = \int_{\Delta\omega}^{\omega} G_\omega d\omega$ for the clear sky atmosphere demonstrates that the 35% to 40% of the total-infrared (TIR) greenhouse effect is contributed by the far-infrared (FIR) portion of the spectrum ($\Delta\omega = 100$ to $620 \text{ cm}^{-1}$), which is dominated by the pure rotation band of water vapor.

$G_a = F^t(0) - F^t(\infty)$ is the clear-sky greenhouse parameter

<table>
<thead>
<tr>
<th>Atmosphere</th>
<th>TIR = 0 – 3000 cm(^{-1})</th>
<th>$G_a$ (TIR)</th>
<th>FIR = 100 – 620 cm(^{-1})</th>
<th>$G_a$ (FIR)</th>
<th>$G_a$ (FIR) / $G_a$(TIR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical</td>
<td>457.2343</td>
<td>286.8101</td>
<td>170.4242</td>
<td>175.2530</td>
<td>115.3532</td>
</tr>
<tr>
<td>MLS</td>
<td>424.6092</td>
<td>280.1521</td>
<td>144.4571</td>
<td>167.7780</td>
<td>114.6354</td>
</tr>
<tr>
<td>MLW</td>
<td>311.2003</td>
<td>229.7617</td>
<td>81.4386</td>
<td>138.9886</td>
<td>107.0674</td>
</tr>
<tr>
<td>SAS</td>
<td>391.0380</td>
<td>264.3418</td>
<td>126.6962</td>
<td>159.7458</td>
<td>110.9997</td>
</tr>
<tr>
<td>SAW</td>
<td>248.0812</td>
<td>198.8235</td>
<td>49.2577</td>
<td>120.4759</td>
<td>100.8714</td>
</tr>
</tbody>
</table>
Comparison of the Far-infrared (100 to 620 cm\(^{-1}\)) to the Total-infrared (0 to 3000 cm\(^{-1}\)) radiative cooling rates within the Tropical atmosphere and the Mid-latitude Winter atmosphere.
Comparison of the TOA Spectral Flux and Greenhouse Parameter for the Tropical atmosphere
Comparison of the TOA Spectral Flux and Greenhouse Parameter for the Mid-latitude Summer atmosphere
Comparison of the TOA Spectral Flux and Greenhouse Parameter for the Mid-latitude Winter atmosphere
Effect of $\text{H}_2\text{O}$ amount on Spectral Greenhouse Parameter

The case of a 10% increase in $\text{H}_2\text{O}$ is used to examine the effect of an uncertainty on the retrieval of changes to the greenhouse parameter. The three plots represent the Greenhouse Parameter, the change to the Greenhouse Parameter due to a 10% increase in atmospheric $\text{H}_2\text{O}$, and an estimate of the uncertainty.
A uniformly distributed 10% change to the abundance of water vapor throughout the atmosphere is observed to produce comparable % changes in the Greenhouse Parameter for the Tropical, Mid-latitude Summer, and Mid-latitude Winter climatological atmospheres.
Effect of uncertainties in the measured TOA radiances and the retrieved surface temperature on the Spectral Greenhouse Parameter for the Tropical atmosphere as compared with a 10% change in water vapor amount throughout the atmosphere.
Effect of uncertainties in the measured TOA radiances and the retrieved surface temperature on the Spectral Greenhouse Parameter for the Tropical atmosphere as compared with a 10% change in water vapor amount between 0 and 5 km.
Effect of uncertainties in the measured TOA radiances and the retrieved surface temperature on the Spectral Greenhouse Parameter for the Tropical atmosphere as compared with a 10% change in water vapor amount between 5 and 17 km.
Effect of uncertainties in the measured TOA radiances and the retrieved surface temperature on the Spectral Greenhouse Parameter for the MLS atmosphere as compared with a 10% change in water vapor amount throughout the atmosphere.
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Uncertainty in the derivation of the greenhouse parameter is very dependent upon the H$_2$O abundance in the atmosphere. Reducing the H$_2$O abundance in the Tropical atmosphere to the abundance in the MLS and MLW atmospheres increases uncertainty to the levels the MLS and MLW atmospheres.
An increase in trace species, e.g., CO₂, CH₄, N₂O & CFCs, from 1998 to 2008 in the atmosphere is observed to produce smaller % changes in the Greenhouse Parameter for the Tropical and Mid-latitude Summer atmospheres than for the Mid-latitude Winter atmosphere.
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For the clear-sky case, the greenhouse parameter is more sensitive than the TOA flux to changes in the atmospheric profile.

The middle-infrared and the far-infrared measurements are complementary to one another for detecting changes in the greenhouse parameter associated with changes in the water vapor abundances within the troposphere.

Deriving the greenhouse parameter from TOA measurements is challenging, and the uncertainty in the measurements can easily overwhelm the signal associated with the greenhouse parameter, especially for non-tropical atmospheres.

Cooling Rates in the upper troposphere are dominated by the far-infrared, while cooling rates in the lower troposphere are dominated by the middle-infrared.
Backup Slides

Backup slides for a 100 to 650 cm\(^{-1}\) spectra range for the Far-Infrared (slides 3 & 4), and an alternate with all three images plotted together for slide 9.
The spectrally integrated greenhouse parameter: \( G_a = \int_{\Delta \omega} G_\omega d\omega \) for the clear sky atmosphere demonstrates that the 40% to 50% of the total-infrared (TIR) greenhouse effect is contributed by the far-infrared (FIR) portion of the spectrum (\( \Delta \omega = 100 \) to 650 cm\(^{-1}\)), which is dominated by the pure rotation band of water vapor.

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\]

is the clear-sky greenhouse parameter
Comparison of the Far-infrared (100 to 650 cm$^{-1}$) to the Total-infrared (0 to 3000 cm$^{-1}$) radiative cooling rates within the Tropical atmosphere and the Mid-latitude Winter atmosphere.
A uniformly distributed 10% change to the abundance of water vapor throughout the atmosphere produces a comparable changes in the Greenhouse Parameter for the Tropical, Mid-latitude Summer, and Mid-latitude Winter climatological profiles.

Comparison of the change in the Greenhouse Parameter for the Tropical, Mid-latitude Summer and Mid-latitude Winter atmosphere