A New Network for the Measurement of Greenhouse Radiative Fluxes with ARM AERI

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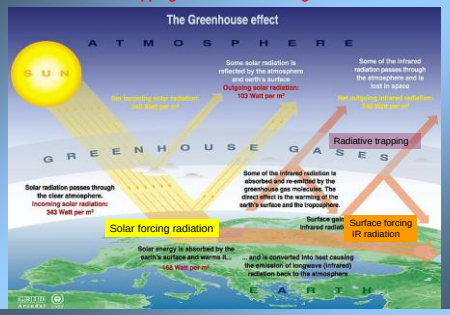
The Objectives include:

- to measure the forcing function of global warming
- to measure the surface forcing radiation of several greenhouse gases
- to cover a range of latitudes including ozone forcing at high latitudes
- to cover a range of regional climates
- studies of tropospheric ozone forcing
- problems related to the water vapour interference
- to investigate the effects of clouds on radiative forcing

Comparison of Great Lakes and AERI Winter Surface Greenhouse Fluxes

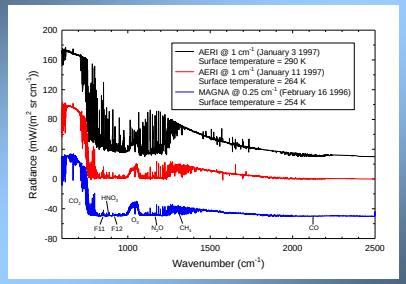
Greenhouse Gas	Emission Band (cm^{-1})	GL Flux (W/m^2)	AERI Flux (W/m^2)
CFC-11	830 - 860	0.10	0.12
CFC-12	all bands	0.21	0.26
CFC-11 + 12	all bands	0.31	0.38
CH_4	1200 - 1400	1.02	1.21
N_2O	1200 - 1300	1.19	1.32
O_3	900 - 1100	3.34	3.02
CO_2	all bands	30.9	37.3

Radiation Balance of the Atmosphere Illustrating Solar Forcing, Radiative Trapping and Surface Forcing IR Radiation



Measurements of Spectral Sky Irradiance with a BOMEM AERI FTS

Comparison of a Great Lakes Spectrum with an AERI Spectrum



Locations of AERI Instruments: the Network

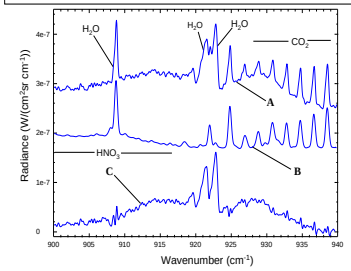
- 1 at U of Winnipeg, Manitoba
- 1 at PEARL in Eureka, Nunavut
- 1 at Imperial College, UK
- 1 at U of Wisconsin, WI
- 7 at 4 ARM sites.
  - NSA, Alaska
  - Darwin, Australia
  - TWP Nauru, equator
  - SGP Central Facility, Lamont, OK
  - SGP Lamont, OK (Extended, secondary)
  - mobile facility

- plus 3 onboard ships U Miami

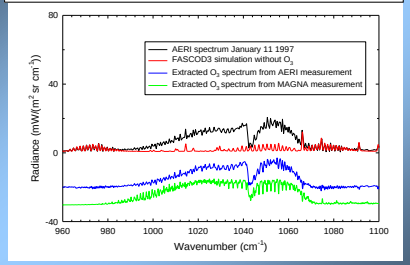
Radiative forcing IPCC usage

- In climate science, radiative forcing is (loosely) defined as the change in net irradiance at the tropopause. "Net irradiance" is the difference between the incoming radiation energy and the outgoing radiation energy in a given climate system and is measured in Watts per square meter. The change is computed based on "unperturbed" values; the IPCC measures change relative to the year 1750. It is the amount of upward thermal radiation absorbed by changes in gases in the atmosphere.
- Greenhouse radiation or IR surface radiative flux is the downward long wave (thermal) radiation from the atmosphere measured at the ground.
- the IR surface radiative forcing = - the top of atmosphere radiative forcing
- The term "radiative forcing" has been employed in the IPCC Assessments with a specific technical meaning to denote an externally imposed perturbation in the radiative energy budget of the Earth's climate system, which may lead to changes in climate parameters .
- The exact definition used is:
  - The radiative forcing of the surface-troposphere system due to the perturbation in or the introduction of an agent (say, a change in greenhouse gas concentrations) is the change in net (down minus up) irradiance (solar plus long-wave; in Wm^{-2}) at the tropopause AFTER allowing for stratospheric temperatures to readjust to radiative equilibrium, but with surface and tropospheric temperatures and state held fixed at the unperturbed values. Radiative forcing defined this way cannot be observed in the real world and is a metric, not an observable.

Extraction of the Thermal Emission Band of CFC-12 from the Measured Atmospheric Emission Spectrum



Comparison of an AERI Spectrum for the 1000 cm^{-1} Band of Ozone at 1 cm^{-1} Resolution with a Great Lakes Spectrum at 0.25 cm^{-1}



Uses of the Data from the Network

- Investigate the seasonal and climate regime variations of the surface greenhouse radiation flux.
- Compare the measurements with climate model simulations of the surface greenhouse radiation fluxes for each greenhouse gas.
- Evaluate the reduction of the surface greenhouse radiation by various types of clouds by measuring the reduction in surface radiation under cloudy conditions.
- Conduct complementary measurements of surface greenhouse radiation with radiative trapping measured from space with overpasses of satellites.
- Monitor the increase with time of the greenhouse radiation from each gas.

Acknowledgements

Support and advice from ABB BOMEM

Measured greenhouse fluxes at the Earth's surface

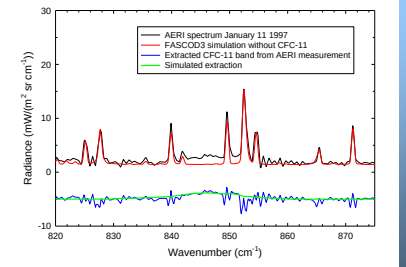
Greenhouse Gas	Emission Band (cm^{-1})	Measured Flux (W/m^2)	Simulated Flux (W/m^2)
CFC11	830 - 860	0.14	0.12
CFC12	900 - 940	0.12	0.11
CFC12	all bands	0.28	0.26
CFC11 & 12	all bands	0.42	0.38
CCl_4	786 - 806	0.046	0.039
CFC113	800 – 830	NA	0.033
HCFC22	780 - 830	NA	0.031
HNO_3	850 - 920	0.085	0.060
N_2O	all bands	0.69	0.67
CH_4	1200 – 1400	0.85	0.80
CO	2000 – 2200	0.032	0.033
CO_2	all bands	21.0	20.2
O_3	950 – 1100	3.26	3.20
Tropospheric O_3	950 – 1100	0.61	0.58

Comparison of simulated greenhouse fluxes for average global conditions using three radiation models

Greenhouse Gas	U.S. CCM3 Flux (W/m^2)	Canadian GCM3 Flux (W/m^2)	FASCOD3 Flux (W/m^2)
H_2O	198.6 (-2.2%)	195.6 (-3.6%)	203.0
CO_2	21.8 (-14%)	22.3 (-12%)	25.3
CH_4	1.89 (+90%)	1.37 (+38%)	0.994
N_2O	1.22 (+30%)	2.03 (+117%)	0.936
O_3	3.40 (+10%)	3.36 (+9.1%)	3.08
CFC11	0.14 (+27%)	0.20 (+82%)	0.11
CFC12	0.30 (+25%)	0.50 (+108%)	0.24
TOTAL	**227.4 (-2.7%)**	**225.4 (-3.6%)**	**233.7**

The value in brackets indicates the percentage difference between the band model result and the FASCOD3 result.

Comparison of an AERI Spectrum for the 850 cm^{-1} Band of CFC11 at 1 cm^{-1} Resolution with a MODTRAN Simulation at 1 cm^{-1}



CONCLUSIONS

- Measurements of the atmospheric thermal infrared spectra have been made at the mid-latitude site for the past several years.
- These high resolution of 0.25 cm^{-1} measurements are similar to those conducted with the AERI instrument at the ARM sites, which have a lower resolution of 1 cm^{-1}.
- The ARM AERI spectra were compared with the Great lakes MAGNA spectra for clear sky conditions.
- The same analysis techniques were used on both spectra to derive greenhouse radiative fluxes for several the greenhouse gases, including H_2O, CO_2, CH_4, N_2O and chlorofluorocarbons.
- The measurements made under cloudy conditions would enable the radiative flux of tropospheric O_3 to be determined.
- The comparisons demonstrate that the AERI resolution is adequate for this type of flux measurement under most sky conditions.
- The extensive analysis of the ARM data would extend the measurements of mid-latitude surface radiative flux.
- It is possible to setup a network for the experimental observations of the driving function of global warming