Intercomparision and evaluation of the capabilities of simple climate models to project the effects of aviation on climate

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BACKGROUND AND MOTIVATION

➢Why consider simple climate models?

Simple Climate Models (SCMs) provide a useful alternative approach relative to Earth System Models (ESMs) for evaluating the impact of aviation policy options and tradeoffs provided they are sophisticated enough to represent the important controlling processes.

➢Aim of the research:

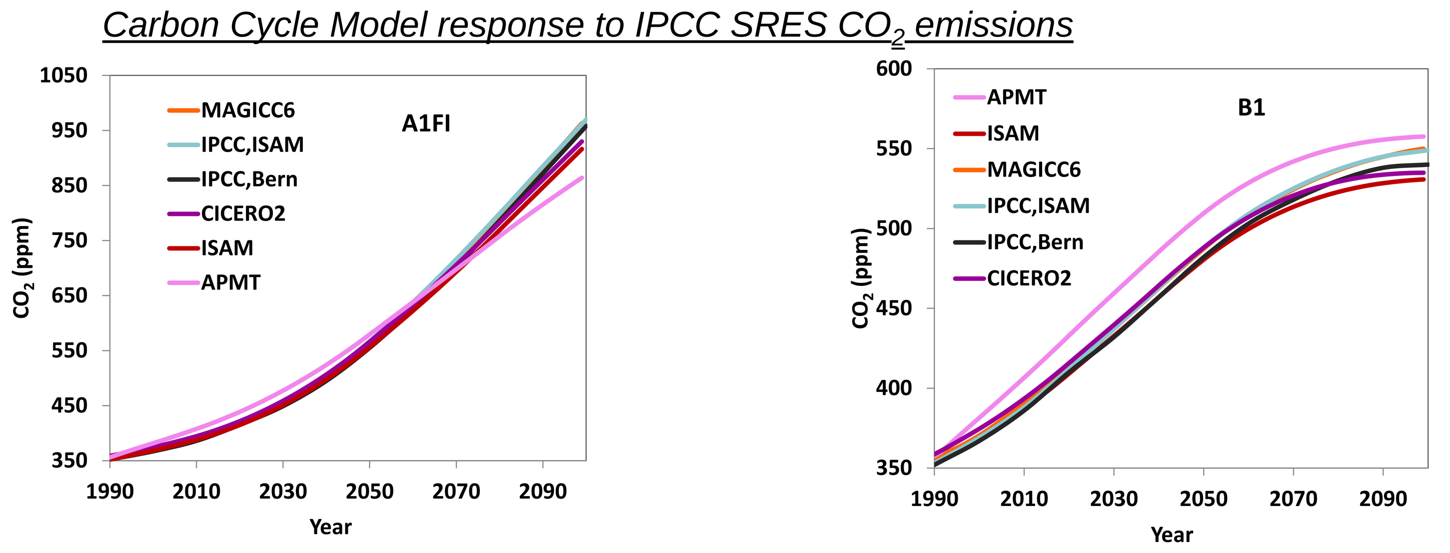
To intercompare the capabilities of carbon cycle and energy balance models and evaluate their projection of aviation effects relative to IPCC and compare the parameterization of effects due to NOx emissions and cloudiness induced by aviation in several existing simple climate models SCMs : APMT, CICERO1, CICERO2 ,MAGICC6 and ISAM at UIUC.

RESULTS

CARBON CYCLE MODELS

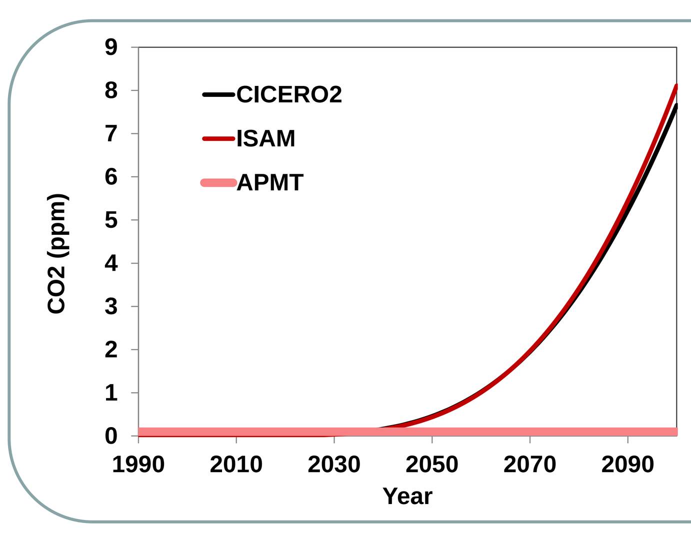
- MAGICC6 and CICERO2 : Applied analytical representation of ocean mixed layer Impulse response Function (IRF), relates the CO_2 partial pressure in the ocean to the total inorganic carbon content in the ocean and to the CO_2 partial pressure in the atmosphere through coupling with air-sea mass transfer. (MAGICC6 IRF: was calibrated against the 3-D-GFDL model , CICER2 IRF was calibrated against Bern 3D model.
- AMPT and CICERO1: Atmospheric IRF that is represented by a series of exponentials, with constant coefficients, was calibrated against Bern 3D model under a baseline scenario. (an instantaneous release of 1 ppm CO_2 into the background atmosphere with 378 ppm CO_2).
- ISAM: Complex carbon cycle that calculates the CO_2 concentration by solving for those processes that explain CO_2 transpiration through the whole ocean column, biosphere and atmosphere.

Carbon Cycle Model response to IPCC SRES CO_2 emissions



IPPC B1: APMT/Bern Simple IRF response higher than other models (~ 17 ppm higher than average of other models @ 2100).
IPCC A1FI: APMT/Bern Simple IRF response higher at about year 2050 and lower at about year 2100 (~ 54 ppm lower than average of other models @ 2100).

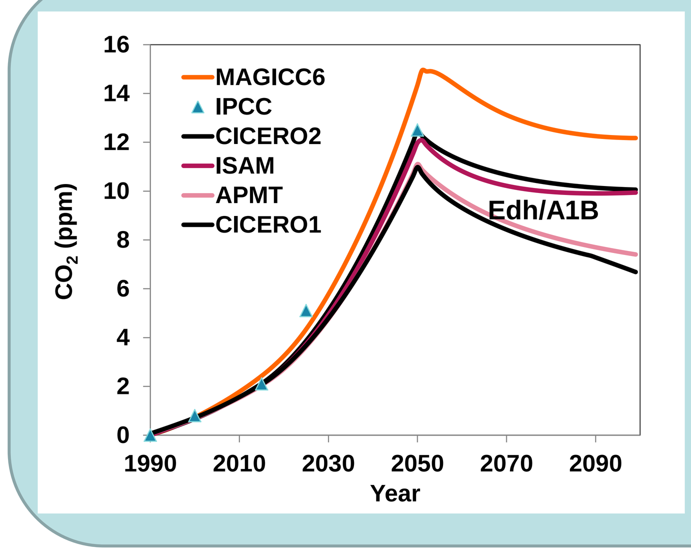
Bern Simple IRF model describes CO_2 perturbations around baseline scenario but breaks down when scenario deviates substantially from baseline.



Difference in carbon cycle response to aviation Edh scenario for two different background scenarios (AIFI and B1)

CO_2 airborne % depend on background?

No: APMT
Yes: CICERO2 and ISAM



Aviation Edh scenario up to 2050 and zero emission afterward , A1B background scenario

APMT and CICERO-1 project lower change in atmospheric CO_2 concentration for aviation perturbation (~ 1.5 ppm lower@2050 relative to IPCC, ISAM and CICERO2) due to using the simple atmospheric IRF that degrades outside of the original calibration scenario.

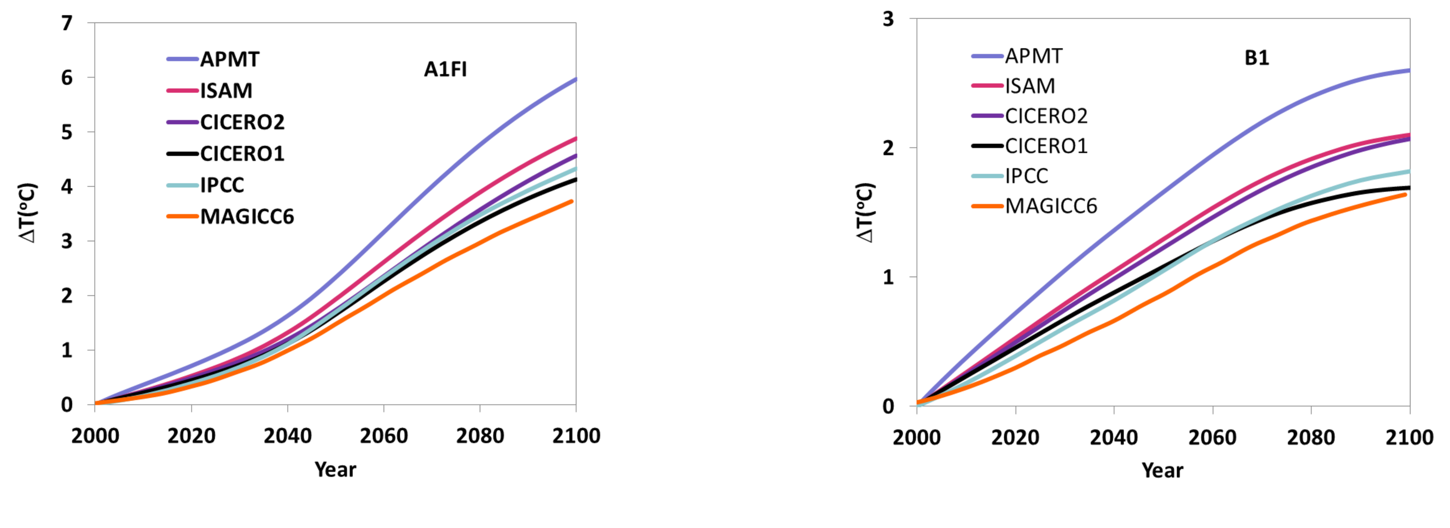
ENERGY BALANCE MODELS

Ocean submodel

ISAM: 19-box ocean
MAGICC6 and CICERO2: 40-box ocean
CICERO1: 2-box ocean
APMT: 1-box ocean (mixed layer)

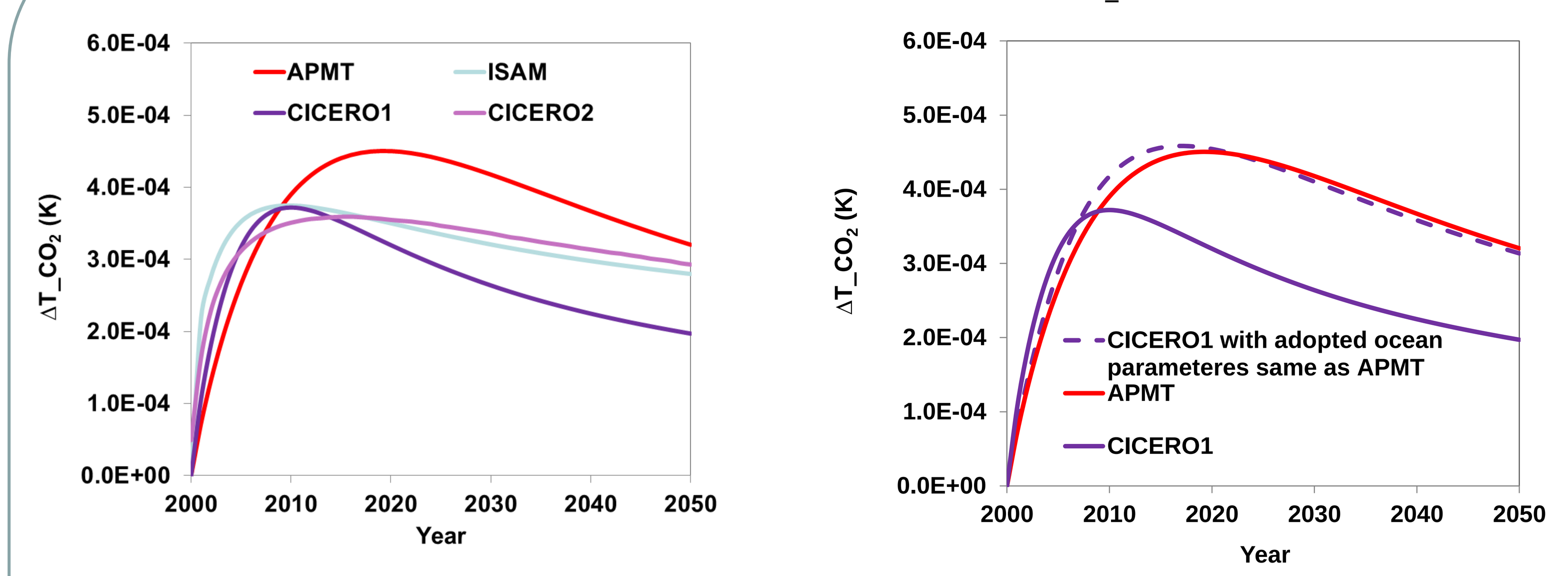
Energy Balance/Temperature Response Models, versus IPCC TAR

Energy balance model forced with RFs from IPCC TAR for total radiative forcing from 1990 to 2100, IPCC temperature response also from IPCC TAR, comparison relative to year 2000, MAGICC temperatures from full IPCC scenario, not forced with RFs from IPCC TAR.

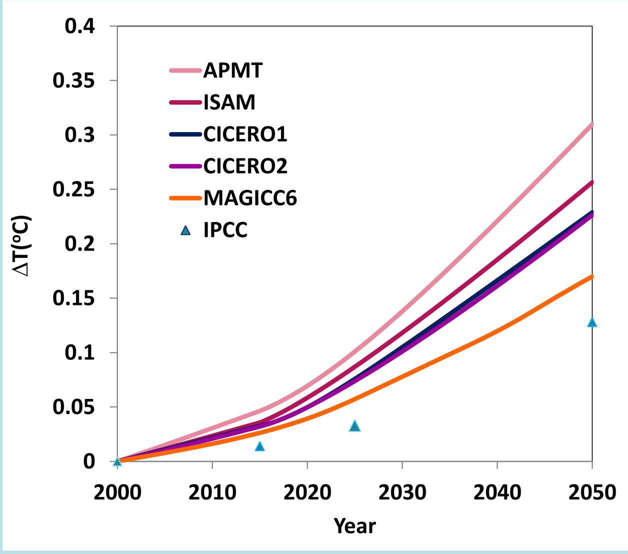


- APMT/Shine consistently higher than other models and IPCC for all scenarios, APMT energy balance model treat ocean as just a mixed layer (one-box) with no heat transfer to deep ocean; therefore, produces higher warming.

Temperature change derived by a 654 Tg impulse of CO_2 at year 2000



- When APMT ocean submodel parameters are adopted in CICERO1 (zeroing deep ocean flux and adopting the same mixed layer heat capacity), it produces similar temperature change as CICERO1.



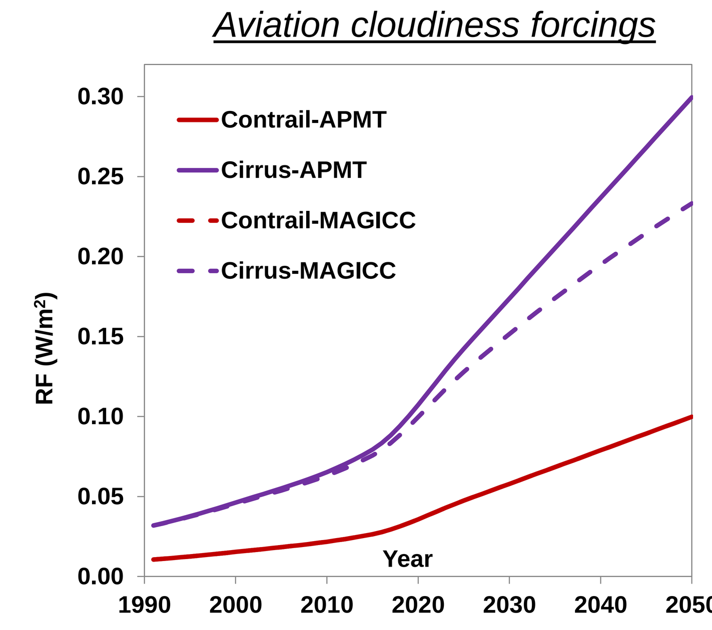
The SCMs 's energy balance models were forced to RFs for Edh aviation scenario from IPCC [1999]

APMT produces higher temperature change for aviation perturbation (~0.1 °C higher than average of other models @ 2050) due to using Shine energy model that doesn't count for heat transfer to deep ocean.

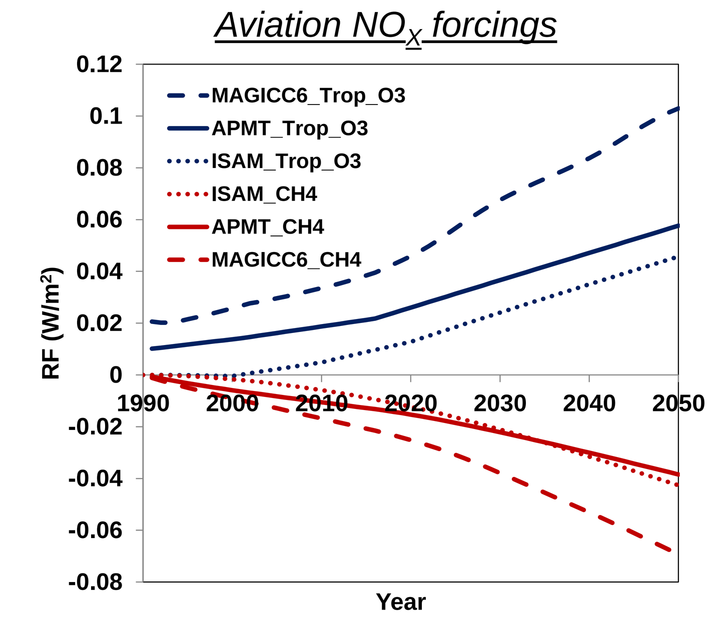
NO_X/CLOUDINESS EFFECTS

Edh aviation scenario , A1B IPCC background scenario

Aviation cloudiness forcings



Aviation NO_X forcings



- APMT and MAGICC6: linear scaling of contrail and cirrus forcing based on fuel inventory
- MAGICC6: cirrus forcing saturates at 17.5 times the year 2000 forcing
- Different parameterization of aviation NO_X effects in the SCMs
- Nearly a factor of 2 difference in the 2050 O_3 and CH_4 RFs

SUMMARY AND CONCLUSION

- **Future airborne fraction of CO_2 depends on background atmosphere, not accounted for in simple Bern atmospheric IRF models, increasingly important further in future.**
- **Temperature models with slab ocean results in a higher temperature projection for CO_2 and non- CO_2 aviation compounds. A multi-box ocean model gives the best results in terms of sufficiently representing the ocean temperature response.**
- **Projection of aviation NO_X and cloudiness effects varies due to various parameterizations used in the SCMs.**
- **Further study with Earth System Model (ESM) (CESM5) is ongoing to determine the level of sophistication necessary to sufficiently capture the processes associated with aviation NO_X/cloudiness effects.**
- **SCMs, if sophisticated enough to represent the important controlling processes, can be used for policy options, otherwise doing policy option with ESMs requires days($$) of super computer time**.

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