Development and Current Status of the GEMMACH-Global Modelling System at the Environment and Climate Change Canada

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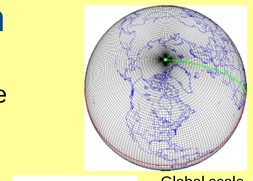
Abstract: The presentation will provide a status on the development of the GEMMACH-Global model at Environment and Climate Change Canada (ECCC). The model is an extension to the global scale of the ECCC's operational regional air quality prediction system. It is an online, one-way coupled meteorology and chemistry model with model top at 0.1hPa. Current configuration utilizes a tropospheric gas-phase chemistry module coupled in upper troposphere, lower stratosphere (UTLS) region with a linearized ozone chemistry parameterization (LINOZ). The objectives for the model are to provide background fields for chemical data assimilation (O3 and NOy species), and high spatiotemporal dynamic chemical boundary conditions for the regional air quality forecast system. In order to fulfill these objectives, a new photolysis module based on Modular Earth Submodel System (JVAL14-MESSy) was implemented replacing a regional module that does not include UTLS reaction rate calculations. The change is evaluated for a 2010 annual run using HTAP global anthropogenic emissions and ECCC's operational weather analyses. In addition, a more detailed gas-phase chemical mechanism is being tested. It is based on the condensed SAPRC07 mechanism, extended to include stratospheric NOy reactions. The presentation will describe the components of the GEMMACH-Global system and show preliminary results on these developments.

GEMMACH-Global Modelling System

Meteorology:

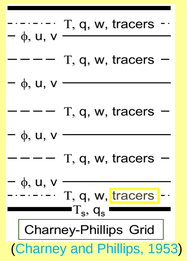
- Global Environmental Multiscale Model in global scale
- Operational NWP model (Côté et al., 1998)
- Global latitude-longitude grids (Arakawa C)
- Hydrostatic, staggered-hybrid vertical coordinate
- Implicit Crank-Nicolson Semi-Lagrangian advection



Chemistry:

On-line, one-way coupled (meteorology ➔ chemistry)
Full process representation of oxidant and aerosol chemistry

- Gas-, aqueous-, heterogeneous-chemistry
- Wet/dry deposition
- Aerosol dynamics
  - 2-bin PM size representation (0-2.5 μm and 2.5-10 μm)
- Stratospheric ozone production from linearized ozone parameterization (LINOZ) (McLinden et al., 2000)



(Charney and Phillips, 1953)

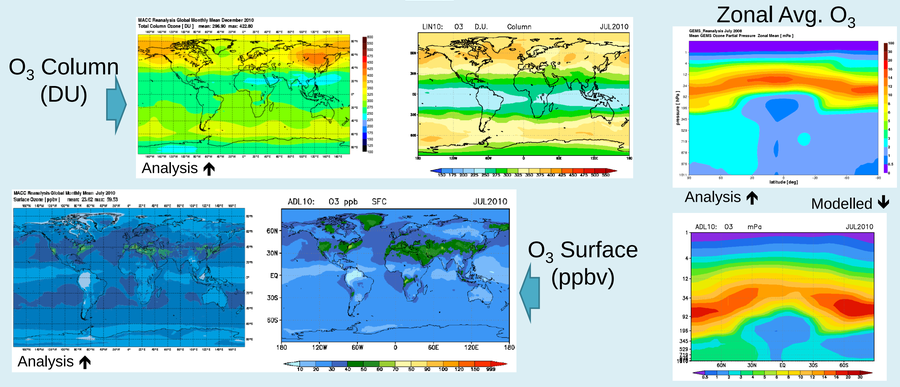
Current configuration:

- model lid at 0.1hPa
- 0.9 degree resolution - 400 x 200 global grid
- Gas-phase only (no aerosol component)
- 2010 Hemispheric Transport of Air Pollution (HTAP) v.2 anthropogenic and GFED3 biomass burning emissions inventory
- Biogenic emissions are modelled online with BEIS3 algorithm and updated global vegetation land cover

Preliminary Evaluation

Compare monthly average surface and column totals with MACC reanalysis of global atmospheric composition dataset (Inness et al., 2013)

July



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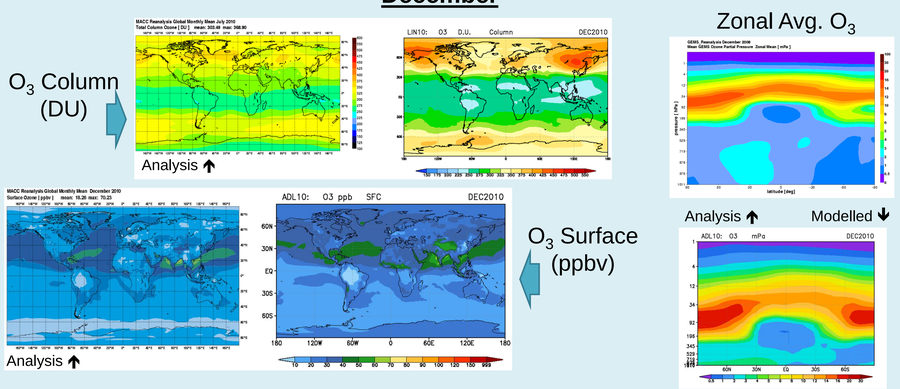


Updates to Photolysis Module

Rate Eq: $J_x(s^{-1}) = \int_\lambda F(\lambda)\, \sigma_x(\lambda,T)\, \varphi_x(\lambda)\, d\lambda$

Φ=quantum yield; σ=absorption cross section; F=solar irradiance/actinic flux

Module Deficiency: Original approach uses lookup tables of pre-calculated, clear-sky J-values as function of solar zenith angles and height above sea-level. The values are scaled by cloud fraction following Chang et al. (1978).

The approach does not account for spatiotemporal varying O_3 column, surface reflectivity and is limited to tabulated J-values between 0-14 km.

Module Update: Adopted the Modular Earth Submodel System (JVAL14-MESSy) implementation of Sander et al. (2014). Photolysis rate calculated by actinic flux ratio (effective optical path) of Landgraf and Crutzen (1998) over 8 wavelength bins.

Table 1. Subdivision of the spectral range into eight bands. λ_{ini} and λ_{fin} are the initial and final wavelength.

Sander et al. 2014

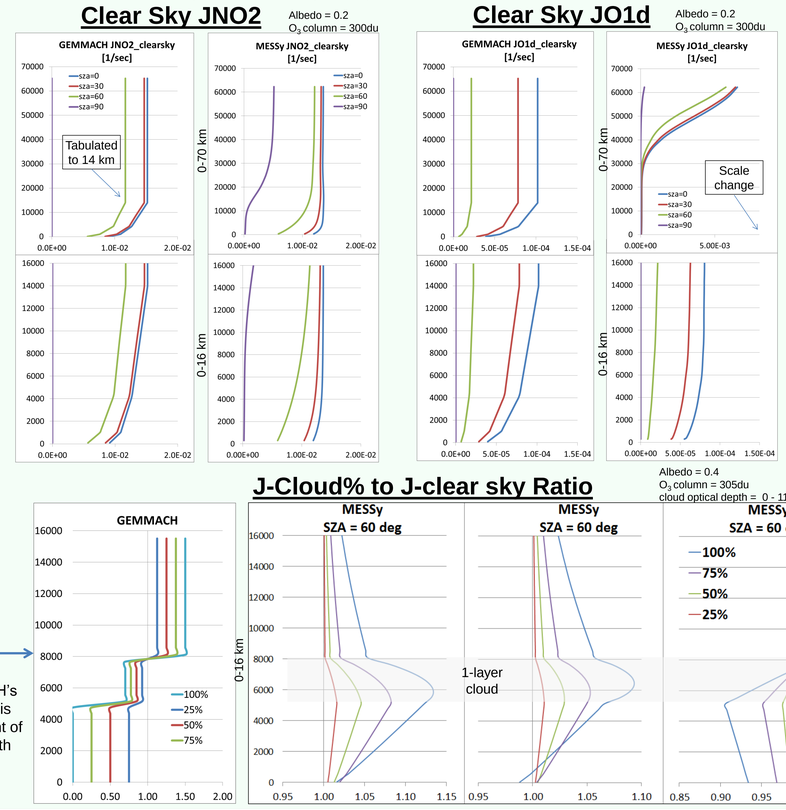
Band	Name	λ_{ini} [nm]	λ_{fin} [nm]
1	Schumann–Runge	178.6	202.0
2	Herzberg	202.0	241.0
3	Hartley	241.0	289.9
4		289.9	305.5
5	UV-B	305.5	313.5
6		313.5	337.5
7	UV-A	337.5	422.5
8	Chappuis	422.5	682.5

$$J_x \approx \sum_{i=1}^{8} J_{i,x}^{a} \times \delta_i$$

$J_{i,x}^{a}$: J-value for purely absorbing atmosphere (function of O_3 column)

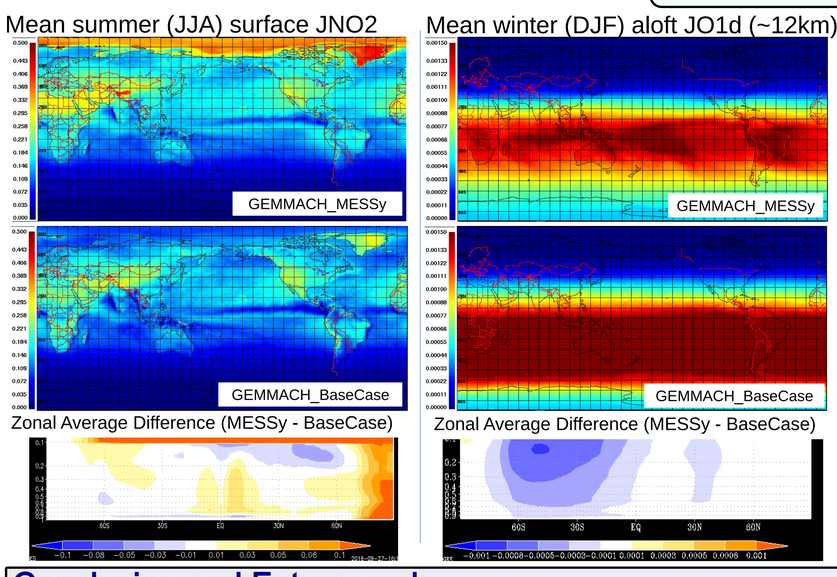
δ_i: actinic flux ratio (actual / purely absorbing atmosphere). accounts for gas, aerosol and cloud scattering

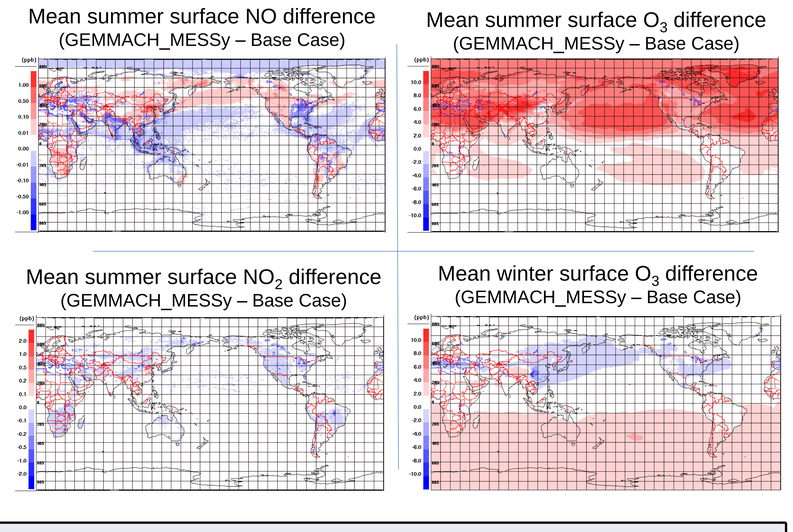
Implications: Ozone column is now accounted online dynamically with high resolution surface reflectivity consistent with modeling system. Attenuation of actinic flux by cloud is calculated online with Slingo (1989) cloud water radiative properties and column specific cloud fraction base on two-stream Practical Improved Flux (PIFM) radiative transfer of Zdunkowski et al. (1980).



Seasonal Analysis

Two annual simulations were carried out comparing model sensitivity to photolysis module update in the GEMMACH-Global.





Conclusion and Future work

The GEMMACH-global model's photolysis module was updated with implementations based on Jval-14-MESSy. Results showed significant differences in rate profiles through clouds and at levels aloft. The are also higher spatial variability near surface from the consideration of spatiotemporal varying of O_3 column and surface albedo. These resulted in higher O_3 concentrations across the domain, but mixed conditions for NOx on surface, and reductions a loft due to cloud attenuation. The development continues to implement a new gas-phase chemical mechanism. The mechanism is based on SAPRC07cs (Carter, 2010) with 11 new reactions for upper troposphere and lower stratosphere, as well as 6 new reactions for troposphere isoprene oxidation.

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