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Ozone assimilation and its impact on the Environment Canada UV index forecasts

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Introduction

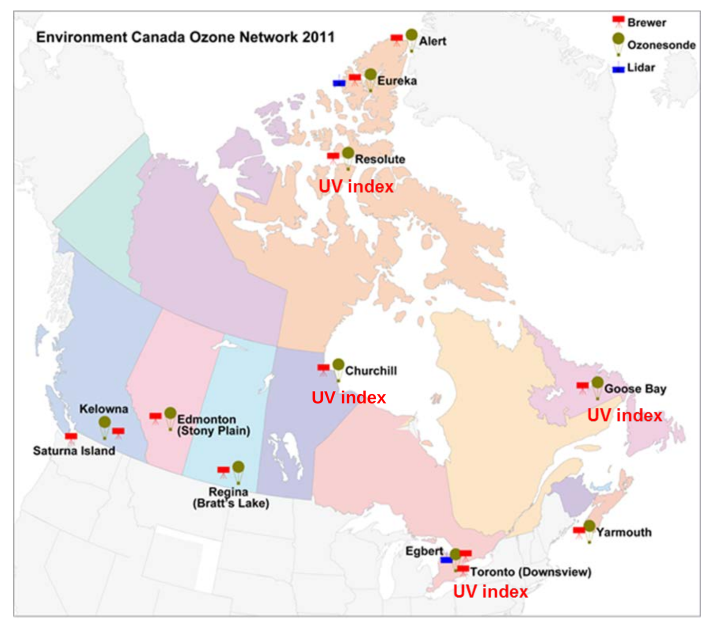
Objective: Investigate improving the UV index forecasting system at Environment Canada.

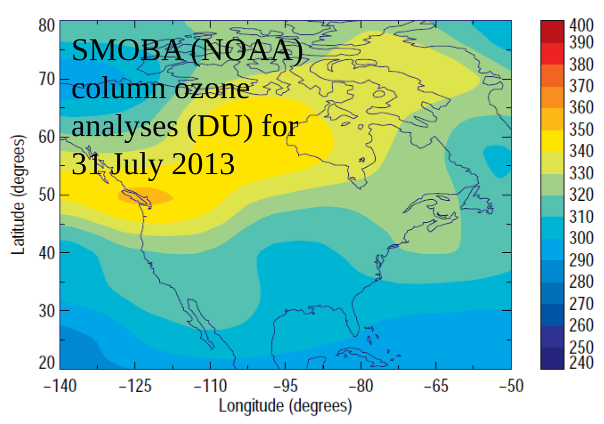
The operational UV index forecasts being provided by Environment Canada (EC) rely on total column ozone maps empirically estimated from meteorological variables followed by scaling with ground-based total column ozone measurements from a few Brewer stations in Canada. In parallel, stratospheric ozone assimilation has been conducted in research mode at Environment Canada for over ten years. A new project has been undertaken to produce UV index forecasts using ozone analyses and resulting model ozone forecasts. The ozone model consists of the LINOZ linearized ozone chemistry scheme. The assimilated ozone data includes GOME2 and SBUV-2 data. The resulting total column ozone and UV index forecasts will be compared to ground-based and satellite measurements and to output of the EC and NOAA operational products.

Current Canadian operational UV index forecasting system

Basic approach implemented 1992: (Burrows et al. (1994) with updates by V. Fioletov and MSC/CMC)

- Interpolation of meteorological forecast fields at 18 and 42 UTC (only) to 1.5° resolution for the northern hemisphere.
- Column ozone estimation:
  - Regression equations (one each for 2 seasons and 3 latitude bands between 10 and 75 degrees)
    - 3-7 predictors among height, temperature, relative vorticity, wind components at 400, 300, 250, 200, 150 and 100 hPa
    - Linear interpolation in transition regions between latitude bands
  - Correction applied to column ozone field using Brewer stations measurements (data usually from <5 stations currently being used)
- Clear-sky UV-B irradiance (and UV index; e.g. Fioletov et al, 2010) estimation:
  - Initial value is derived from a fit function dependent on the column ozone and the solar noon zenith angle (with additional correction for the solar zenith angle)
  - *Linear correction for surface altitude (to reflect aerosol and scattering affect) and snow cover for clear-sky UV index*
- All-sky UV index estimation
  - Interpolation of clear-sky UV-B irradiance field to various sites
  - Scaling to clear-sky UV index [1/(25 mW/m^2)]
  - Attenuation of UV index based on opacity and precipitation (with adjustment by forecasters) using Table 1
  - Linear correction for surface altitude and snow cover.





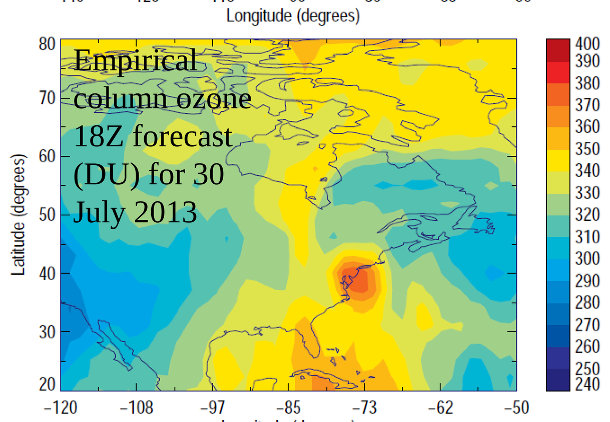


Table 1: Percentages applied to clear-sky values based on opacity and precipitation.

Clouds and weather	XX%
Steady stratiform precipitation (rain, drizzle, freezing rain, freezing drizzle, snow, wet snow, ice pellets) of any intensity with a probability of 90% or more	20
Stratiform precipitation (rain, drizzle, freezing rain, freezing drizzle, snow, wet snow, ice pellets), steady or occasional, of any intensity with a probability of 80% or more	30
Overcast, or continuous fog, or blizzard, or any precipitation with a probability of 80% or more	40
Averaged cloud cover 9 tenth or more, with or without precip.	60
Cloud cover 7 tenth or more WITH precip. having a POP >= 60%, OR steady blowing snow	70
Cloud cover 7 tenth or more (all other cases)	80
Hazy, OR Averaged cloud cover of 6 tenth or more including at least 7/10 of cloud cover in first 3 hours	90
All other cases	100

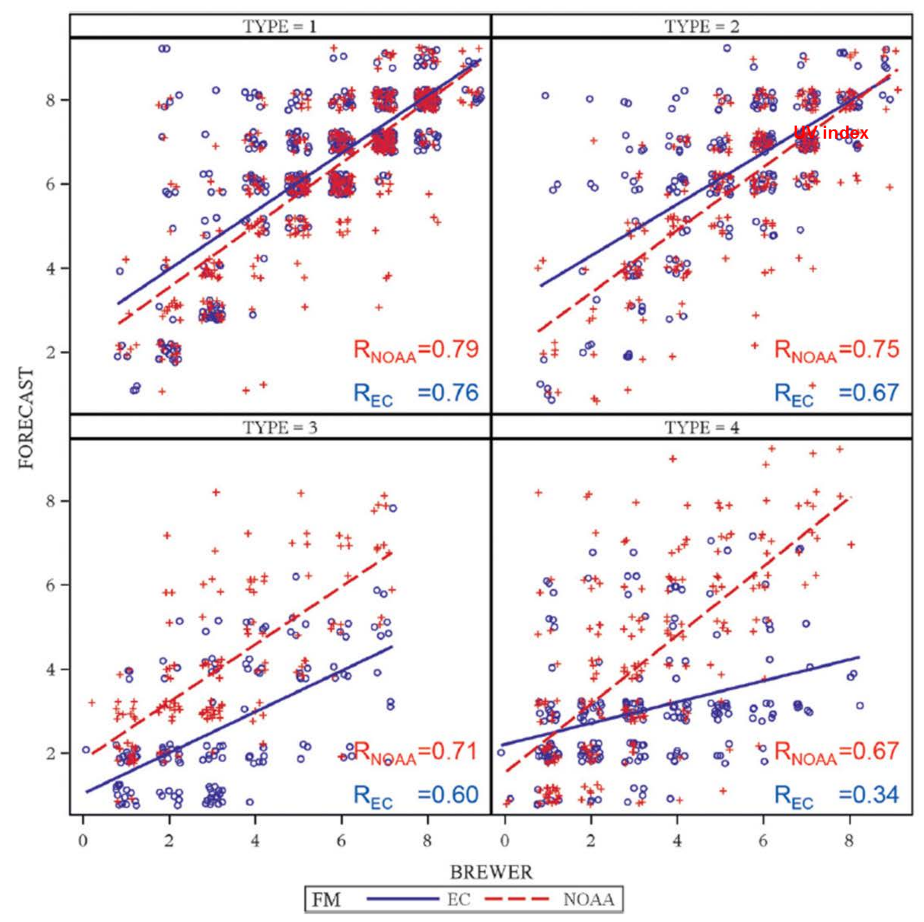


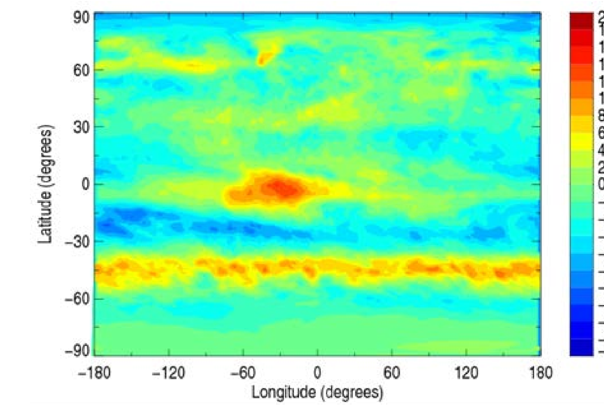
FIG. 5. Scatterplots and linear regression fits of EC and NOAA forecast methods (FM) plotted against collocated Brewer measurements. Blue open circles show EC forecasts, and red plus signs show NOAA forecasts. A small amount of random noise is added to the UV index data for better visualization. Four major weather types are represented: cloud-free sky (type 1), light clouds (type 2), heavy clouds (type 3), and rain (type 4). The correlation coefficients *R* between the measured and forecast values are also shown.

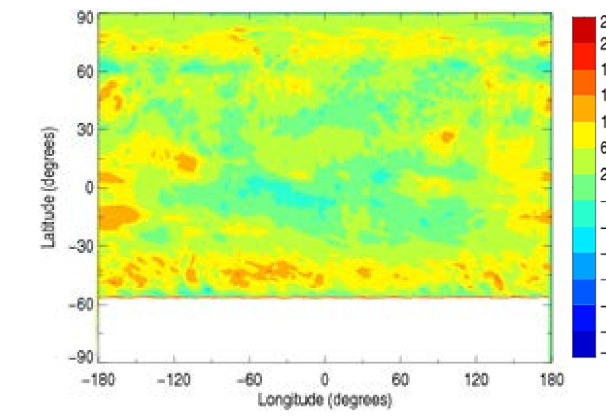
Figure courtesy of He et al. (2010)

Method I preliminary results: Simple application of scaling factors

Time mean differences (DU) of ozone analyses from GOME-2 assim. with ozone analyses from SUBV/2 assim. for July 2008

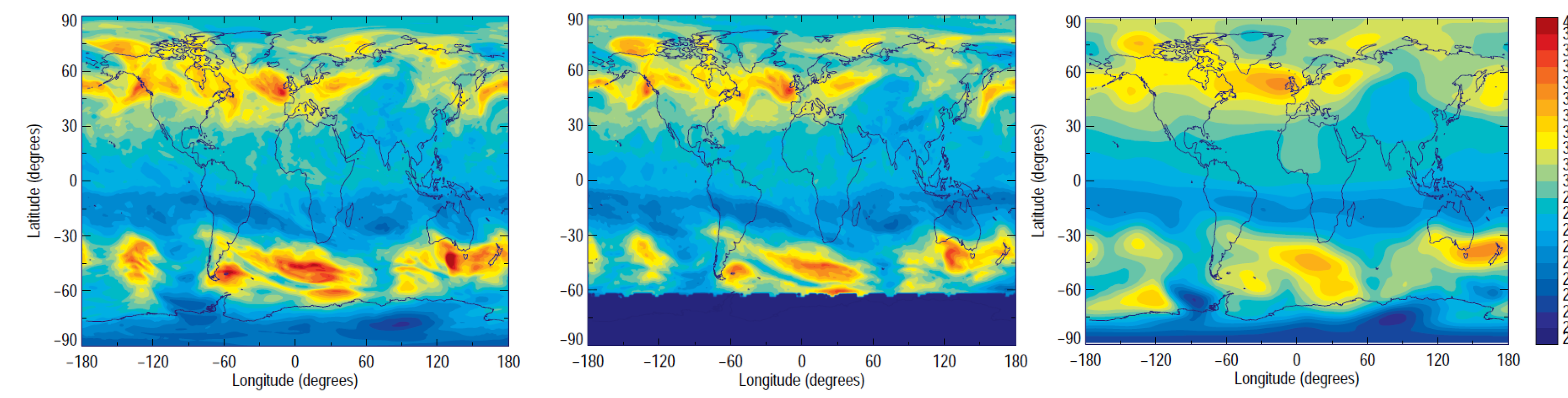
No current ozone bias removal!





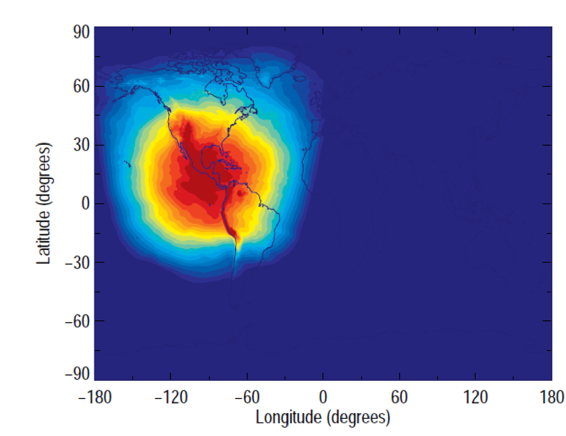
Time mean differences (DU) of ozone analyses (from GOME-2 and SBUV/2 assim.) with OMI daily gridded images for July 2008

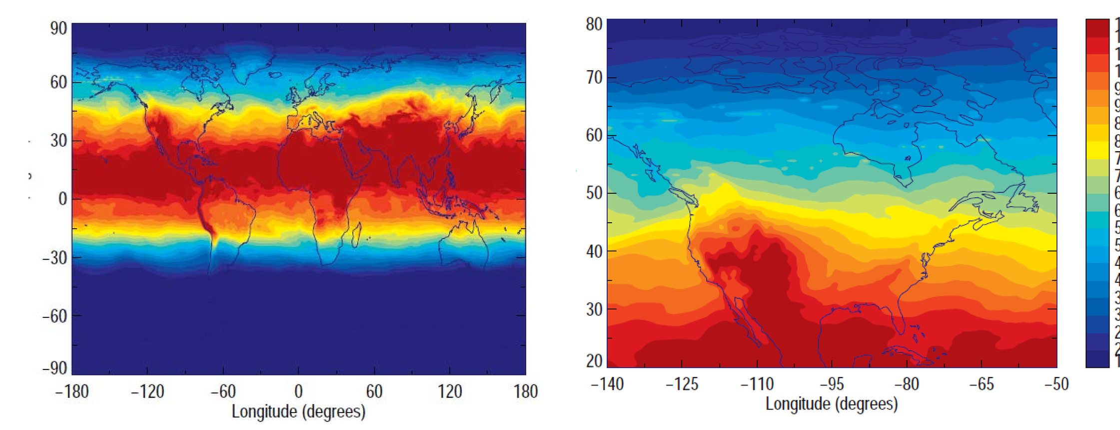
Sample column ozone (DU) for 31 July 2008



Sample clear-sky UV index images from ozone at 18 UTC, 31 July 2008

The UV index figures below show very initial results of work in progress toward improving the UV index estimation from the prognostic ozone at EC. Further developments and analyses are to be conducted in 2014/2015.

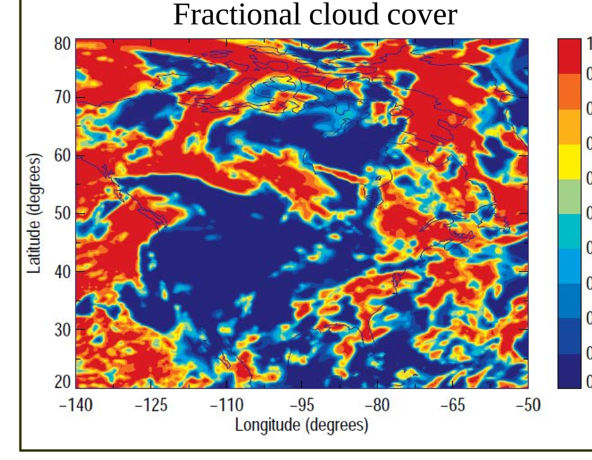


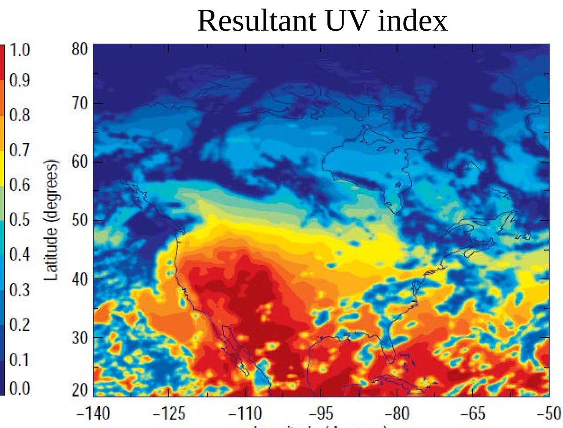


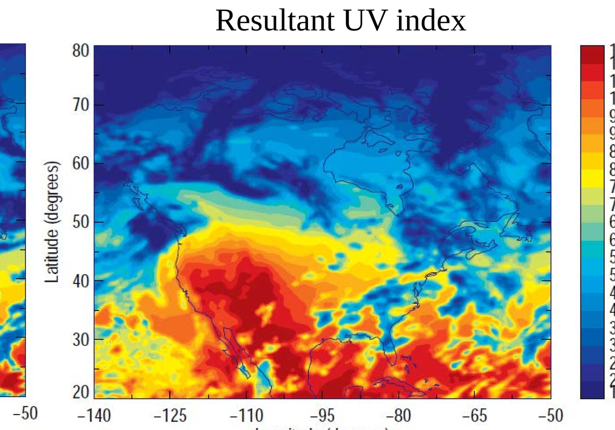
Trial attenuations for all-sky UV index images for solar noon on 31 July 2008

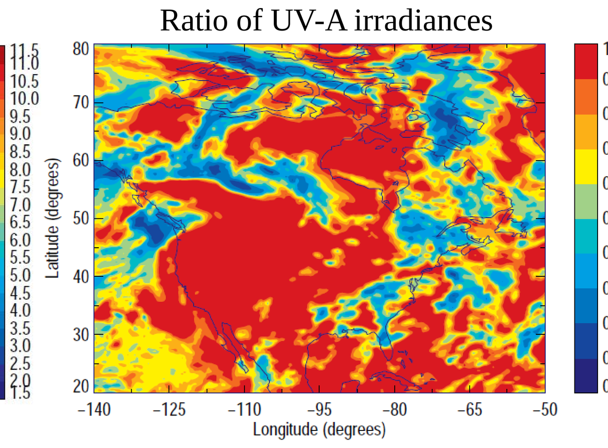
Preliminary scaling based on cloud fraction only (using scaling factors similar to those of Table 1)

Scaling based on ratio of all-sky to clear-sky UV-A (F3) irradiances (see Method II section below)









Overview of ozone and UV prediction system for this study

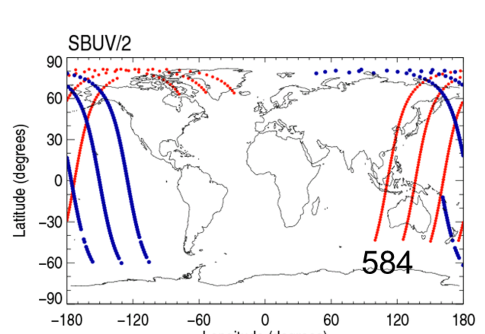
Numerical Weather Prediction (NWP) model: Canadian operational Global Environmental Multiscale (GEM).

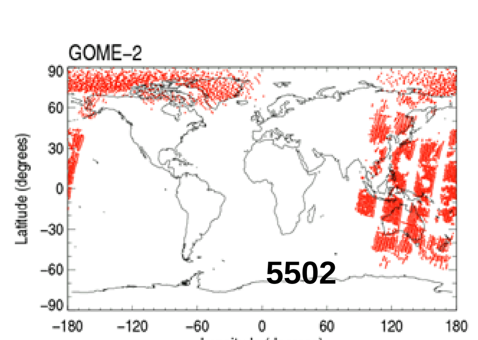
- Spatial resolution setup: uniform 800x600 longitude-latitude grid; 80 vertical levels; lid at 0.1 hPa.
- Ozone model component: LINOZ parameterization of McLinden et al. (2000) which has the form of the Cariolle scheme without the heterogeneous chemistry term; ozone is relaxed toward the Fortuin and Kelder climatology below 400 hPa.

Global incremental assimilations: Done over successive 6hr intervals using the 3D-VAR/FGAT scheme.; T108 resolution.

- Background error correlations are horizontally isotropic and homogeneous with the vertical and horizontal correlations being non-separable for all variables except for ozone..
- Meteorological fields during the ozone assimilation runs are refreshed every 6 hours from rhe GEM weather analysis.
- Assimilated ozone data: GOME-2 total column amounts (MetOp; EUMETSAT) and the SBUV/2 ozone partial column profiles (NOAA 17 and 18) with averaging kernels.
- Assimilation and forecasting period from which sample plots have been produced is Summer 2008.

Figure: Coordinates of assimilated SBUV/2 and GOME-2 data for a sample 6 hours



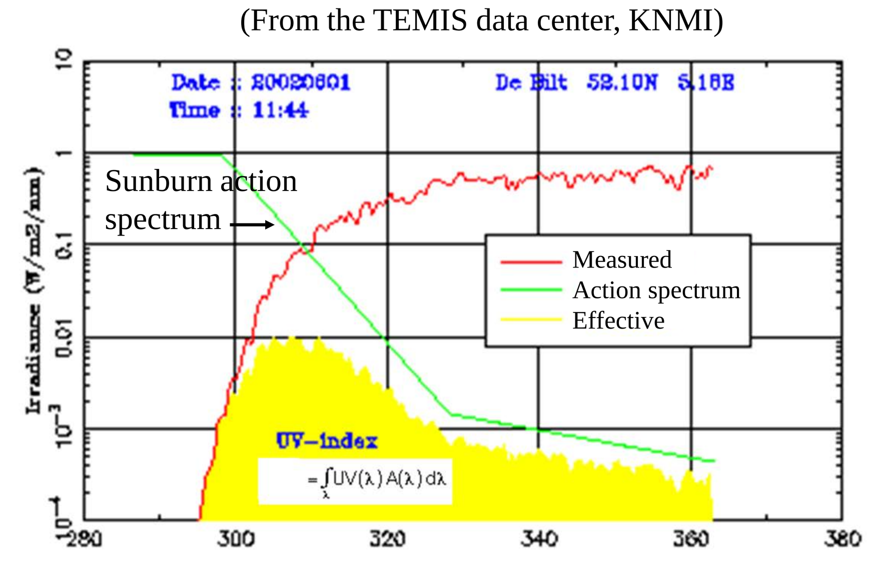


UV index estimation improvements being investigated

Method I: Clear-sky UV index is instead estimated by applying a scaling factor to the prognostic total column ozone of the forecasts (also in consideration of altitude, snow cover). Attenuation of clear-sky values based on model opacity and precipitation could be done using a scale similar to Table 1 or ratios, as done at NCEP/NOAA, of UV bands.

Method II: UV index estimation for both clear-sky and all-sky conditions from a weighted combination of 2-4 UV broadband model irradiances. Since 2009, the radiative transfer scheme used in Environment Canada's NWP models is that of Li and Barker (2005). This uses the correlated-k distribution (CKD) method for gaseous transmission. It uses 9 LW and 4 SW frequency intervals. The VIS and UV part of the SW spectrum is dealt with in four bands with UV-C (F_1), UV-B, UV-A (F_3) and F_4 separately considered.

Sample ultra-violet spectra
(From the TEMIS data center, KNMI)



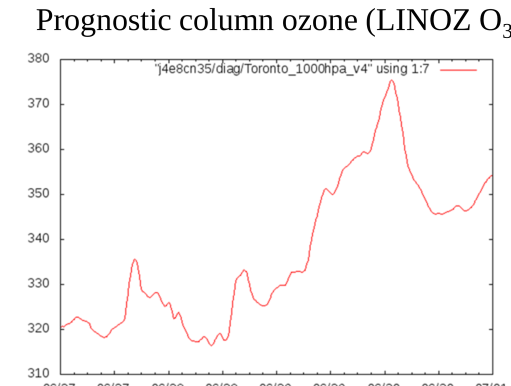
400 nm

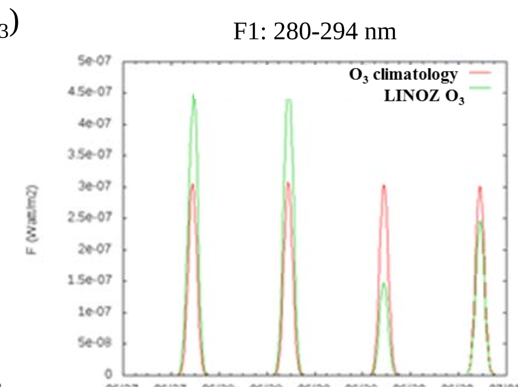
GEM radiation code (cccmarad) F_1 F_2 F_3 F_4

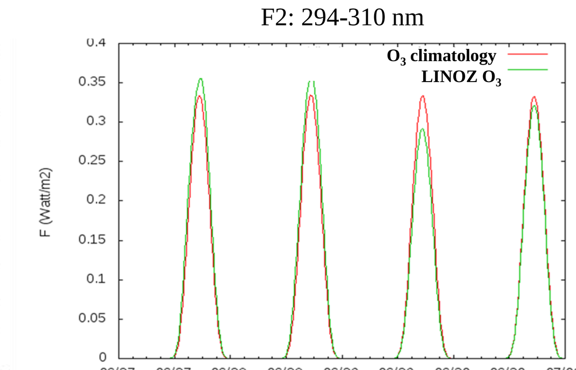
UVI = $\Sigma(E_i l_i)$ for i=1,4

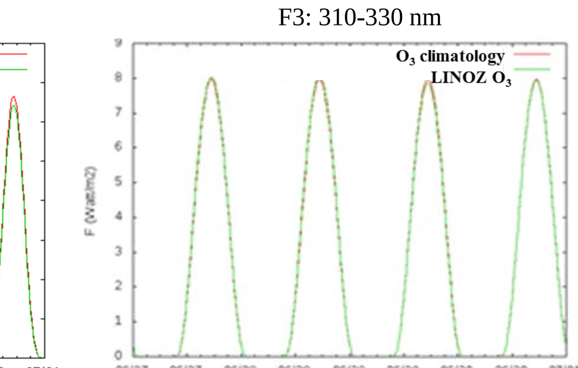
Method II preliminary results: Sensitivity of broadband UV irradiances at the surface to ozone and cloud cover

Sensitivity of clear-sky irradiances (Watts/m^2) to ozone

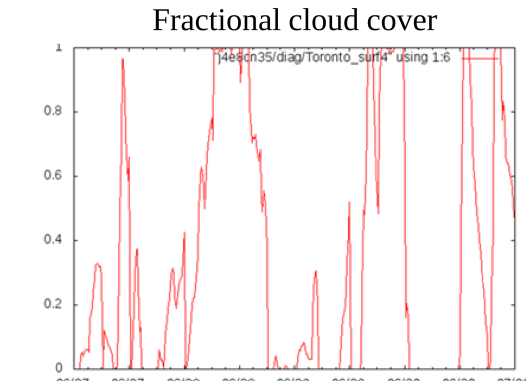


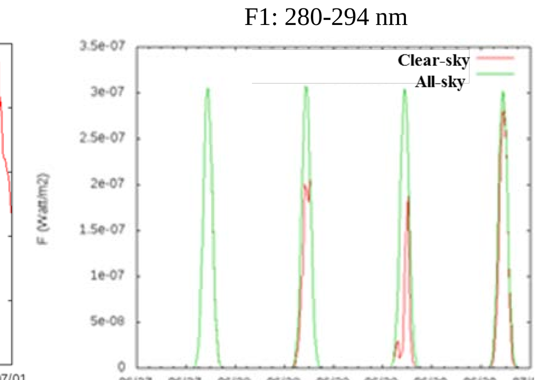


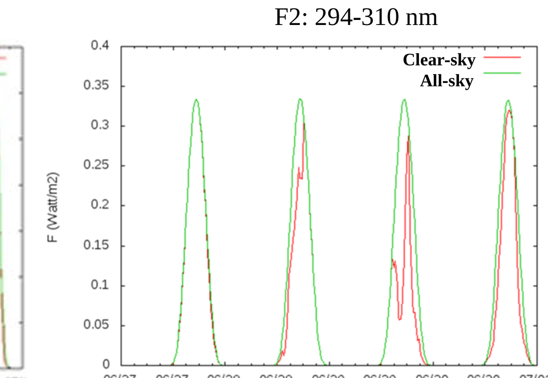


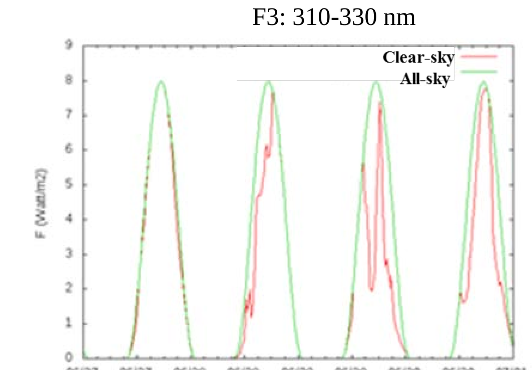


Sensitivity of irradiances (Watts/m^2) to clouds









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