

# Extending the climate equations beyond EOH

Antti Lehtilä, VTT  
(Dec 10, 2009)

---

## 1 Specifications

The main purpose of the extension is to be able to set climate targets beyond EOH. This is particularly useful for DeltaT targets, because there is a considerable time lag between the decline of emissions and the peak of DeltaT.

What is needed is a way to identify the emissions and climate variables after EOH, with a yearly index. The only link between what happens after EOH and what happens before EOH is via the three emission variables at EOH (CH<sub>4</sub>-MT, N<sub>2</sub>O-MT, CO<sub>2</sub>-GTC). Assuming that we consider 200 years beyond EOH, The value of CO<sub>2</sub> emissions at period t (t>EOH) is governed by the following equation:

$$\text{CO}_2\text{GTC}(t) = \text{CO}_2\text{GTC}(\text{EOH}) * (1 - (t - \text{EOH}) / 200)$$

The emissions of the other two gases are treated similarly.

## 2 Functional design

### 2.1 Setting up the time-space

The extension of the climate equations beyond EOH requires a sufficiently long time-space available for the model. By default, the time-space of TIMES extends to the year 2200 only. Therefore, if longer time-spans are to be considered, the user should add the appropriate EOTIME setting into the RUN file. For example, if the climate equations should be extended to 2300, the following setting should be used:

```
$SET EOTIME 2300
```

The VEDA-FE TIMES user shell may possibly be enhanced by a switch that can be used for setting this control variable from the Case Manager. However, if such a switch is not available, the user can also modify the RUN template used by VEDA-FE, by adding a line like the one shown above into the template, before the BATINCLUDE call for **initsys.mod**.

## 2.2 Activating the extended climate equations

Because full backwards compatibility is a desired property of all new TIMES features, the extended climate equations must be explicitly activated by the user. The activation can be done by specifying any non-negative value for the new Climate Module constant '**EXT-EOH**'. Different values of the constant will have the following meaning:

Value	Meaning
-1 (default)	The feature is deactivated.
0	In this case ' <b>EXT-EOH</b> ' will be automatically adjusted to $E(M)$ , where $M$ is the last model year $m$ for which the end-year <b><math>E(m)</math></b> is specified. The adjusted parameter will then have the same meaning as in the case $\text{EXT-EOH} > 0$ below.
>0	The emissions at EOH will remain constant at the endogenous value in $\text{EOH}=E(T)$ (where $T$ =last <b>milestone year</b> ) until the year $\text{MAX}(\text{EXT-EOH}, \text{EOH})$ , and then develop linearly from that value to the first user-defined emission value in a subsequent year (see section 2.3).

The setting **EXT-EOH=0** may be useful for ensuring that any user-defined target values for the emissions will only be taken into account beyond the last **model year**, even in model runs where a truncated model horizon is used. In such case, when **EXT-EOH=0** is used, the emissions are assumed to remain constant between the truncated EOH and the end of the full model horizon.

A positive value **EXT-EOH=y ≤ EOH** means that a linear development of emissions towards the first user-defined value is requested to start immediately at the EOH, regardless of the model horizon being truncated or not.

Finally, a positive value **EXT-EOH=y > EOH** can be useful if the user wishes the emissions to remain constant at the EOH value until a predefined year  $y > \text{EOH}$ , before turning into the linear development towards the first user-defined value.

**Warning:** If  $0 < \text{EXT-EOH} < E(M) = \text{MAX}_m(E(m))$ , any user-defined global emission bounds for CO2-GTC, CH4-MT or N2O-MT, which may be inadvertently specified at years between **MAX(EXT-EOH, EOH)** and **E(M)**, will also be taken into account as target values for the emission trajectories.

## 2.3 Specifying emission trajectories beyond EOH

The global emissions that can be considered by the extended climate equations are the three input emissions to the Climate Module:

- CO2-GTC Global CO2 emissions, expressed in GtC
- CH4-MT Global CH4 emissions, expressed in Mt
- N2O-MT Global N2O emissions, expressed in Mt

The user can specify target emission values for these emissions at any year(s) beyond EOH. For simplicity, the target emission values are specified by using the **CM\_MAXC** parameter, which is normally used for specifying upper bounds for the global emissions, as well as for the temperature and concentrations.

Starting from the year  $B = \text{MAX}(\text{EOH}, \text{EXT-EOH})$ , the emissions will be assumed to develop linearly from the value at EOH to the first user-specified value beyond  $B$ . If no target values are specified, the emissions will be assumed to remain constant at the EOH value. If several successive values are specified, the emissions will develop linearly also between the successive target values.

## 2.4 Specifying other parameters beyond EOH

Bounds on the global atmospheric temperature, forcing or GHG concentrations can be specified at any years beyond the EOH, in the normal way. In addition, exogenous forcing can be specified and is interpolated beyond EOH.

## 2.5 Controlling the years considered beyond EOH

The Climate Equations will be calculated beyond EOH at each of the years for which either a user-defined emission target or a temperature or concentration bound is specified. The years considered beyond EOH thus span between the EOH and the last year for which a CM\_MAXC is specified. However, as described above, any emission bounds between EOH and  $\text{MAX}(\text{EOH}, \text{EXT-EOH})$  will be ignored.

In addition, by default the Climate Equations will be calculated also at each year having a year value divisible by 20. This default year resolution can be changed by using the new Climate Module constant '**BEOHMOD**'. Accordingly, if the user wishes the Climate Equations to be calculated at 10 years' intervals (in addition to the CM\_MAXC years) she can specify the following parameter:

**PARAMETER CM\_CONST / BEOHMOD 10 /;**

The **reporting years** for the climate variables are the same as the calculation years.

## 3 Examples

### 3.1 All emissions decline linearly to zero by 2300

Assume that the model horizon is from 2005 to 2105 (the last milestone year is 2100, and the corresponding last period ends at  $E(T)=2105$ ). We wish to simulate the climate variables up to 2300 by assuming that the emissions of CO<sub>2</sub>-GTC, CH<sub>4</sub>-MT and N<sub>2</sub>O-MT should all develop linearly from the value at EOH to zero in 2300. This can be accomplished by specifying the following parameters (assuming that EOTIME has also been set sufficiently large):

```
PARAMETER CM_CONST / EXT-EOH 0 /;  
PARAMETER CM_MAXC /  
CO2-GTC.2300 0  
CH4-MT.2300 0  
N2O-MT.2300 0 /;
```

The first parameter (**EXT-EOH=0**) ensures that user-defined target values for emissions are taken into account only beyond the full model horizon. The three CM\_MAXC parameters represent the target emission values of zero in 2300.

**Note 1:** The user should make sure that *no other* CM\_MAXC bounds have been defined for the emissions beyond  $E(T)=2105$ .

**Note 2:** The user can additionally specify any upper bounds for temperature change or concentration at any year beyond EOH.

### 3.2 A more complicated example

Assume again that the model horizon is from 2005 to 2105 (the last milestone year is 2100, and the corresponding last period ends at  $E(T)=2105$ ). We wish to simulate the climate variables up to 2300 by making the following assumptions:

- The emissions should remain constant at the EOH levels until 2130;
- The CO<sub>2</sub>-GTC emissions should then decline linearly to zero by 2300;
- The CH<sub>4</sub>-MT emissions should further develop to the level of 150 Mt by 2200, and then to 50 Mt by 2250, where after they stay at 50 Mt;
- The N<sub>2</sub>O-MT emissions should further develop to the level of 10 Mt by 2200, and then to the level of 5 Mt by 2300.

```
PARAMETER CM_CONST / EXT-EOH 2130 /;  
PARAMETER CM_MAXC /  
CO2-GTC.2300 0  
CH4-MT.2200 150  
CH4-MT.2250 50  
N2O-MT.2200 10  
N2O-MT.2300 5 /;
```