MAGICC/SCENGEN 5.3: OPERATOR INSTRUCTIONS

Abbreviated from the MAGICC/SCENGEN 5.3 User Manual developed by:
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CONTENTS

TERMS OF USE

1. Introduction – background

MAGICC and SCENGEN are installed in C:\SG53. MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC; **M**odel for the **A**ssessment of **G**reenhouse-gas **I**nduced **C**limate **C**hange) that drives a spatial climate-change **SCEN**ario **GEN**erator (SCENGEN). MAGICC has been one of the primary models used by IPCC since 1990 to produce projections of future global-mean temperature and sea level rise. The climate model in MAGICC is an upwelling-diffusion, energy-balance model that produces global- and hemispheric-mean temperature output together with results for oceanic thermal expansion. The 5.3 version of the software is consistent with the IPCC Fourth Assessment Report, Working Group 1 (AR4). The MAGICC climate model is coupled interactively with a range of gas-cycle models that give projections for the concentrations of the key greenhouse gases. Climate feedbacks on the carbon cycle are therefore accounted for.

Global-mean temperatures from MAGICC are used to drive SCENGEN. SCENGEN uses a version of the pattern scaling method described in Santer et al. (1990) to produce spatial patterns of change from a data base of atmosphere/ocean GCM (AOGCM) data from the CMIP3/AR4 archive. The pattern scaling method is based on the separation of the global-mean and spatial-pattern components of future climate change, and the further separation of the latter into greenhouse-gas and aerosol components. Spatial patterns in the data base are "normalized" and expressed as changes per 1ºC change in global-mean temperature. These normalized greenhouse-gas and aerosol components are appropriately weighted, added, and scaled up to the global-mean temperature defined by MAGICC for a given year, emissions scenario and set of climate model parameters. For the SCENGEN scaling component, the user can select from a number of different AOGCMs for the patterns of greenhouse-gas-induced climate.

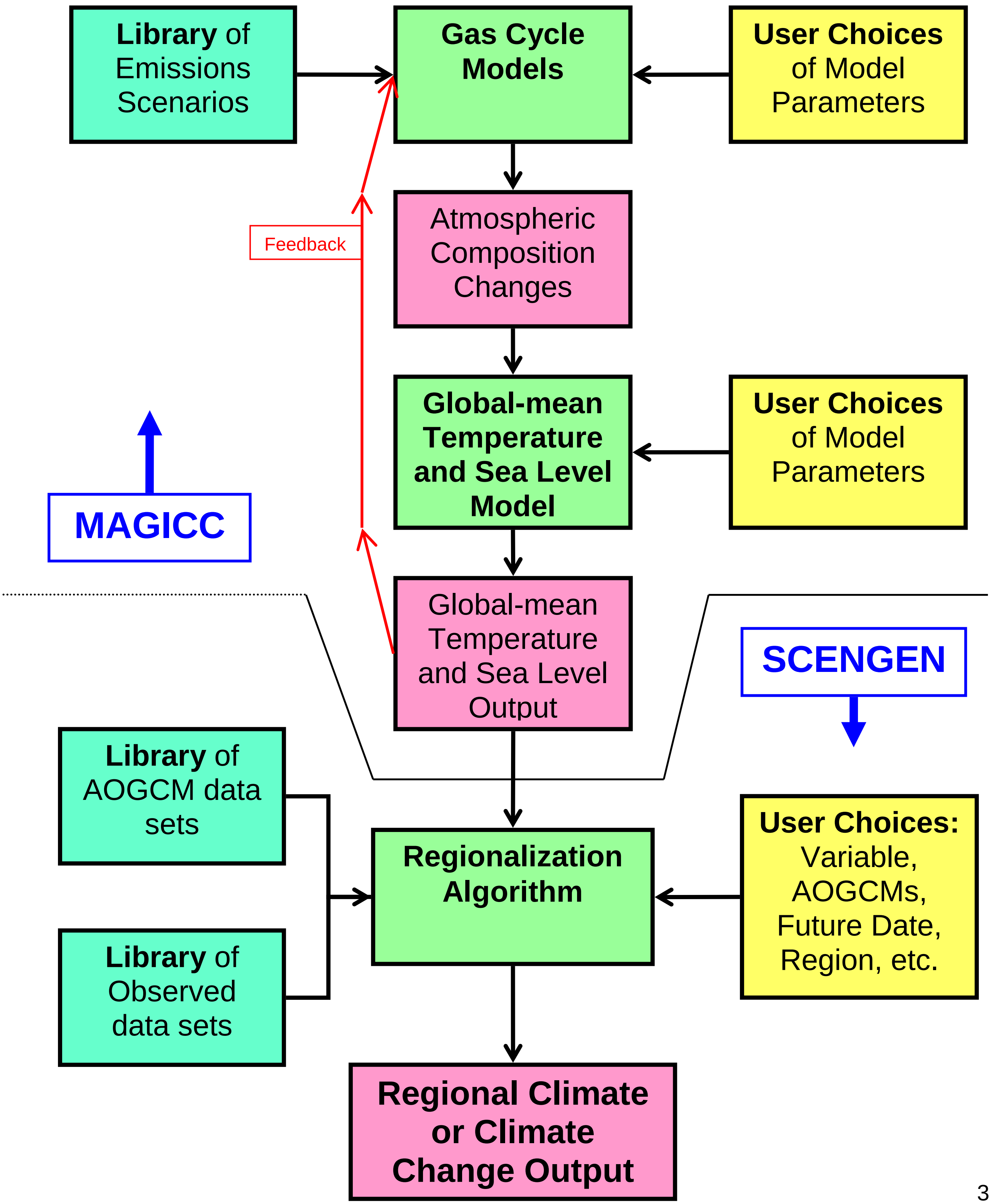
The first step is to run MAGICC. The user begins by selecting a pair of emissions scenarios, referred to as a Reference scenario and a Policy scenario. The emissions library from which these selections are made is based on the no-climate-policy SRES scenarios, including versions of the WRE (Wigley et al., 1996) CO_2 stabilization scenarios. The labels "Reference" and "Policy" are arbitrary, and the user may compare any two emissions scenarios in the library.

The user then selects a set of gas-cycle and climate model parameters. The default ("best estimate") set may be chosen, or a user set prescribed. Both default and user results are carried through to SCENGEN. A flow chart describing how MAGICC/SCENGEN is configured is shown on the next page.

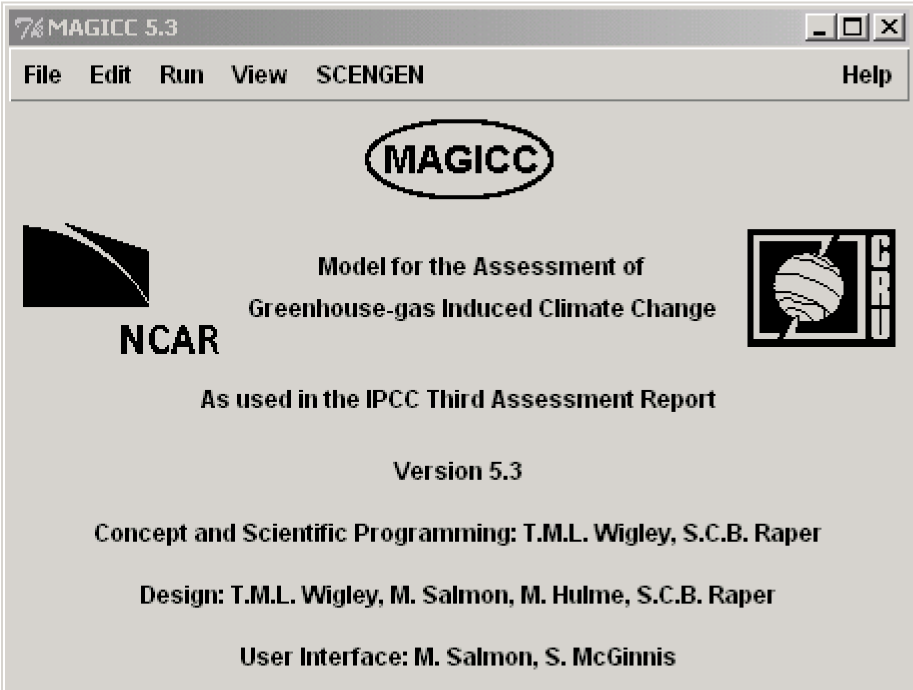
The MAGICC directory contains all the emissions files (***.GAS), various configuration files that set model parameters (***.CFG), and a range of output files generated by MAGICC.

The User Manual contains examples removed from this document and other detailed information.

STRUCTURE OF THE MAGICC/SCENGEN SOFTWARE

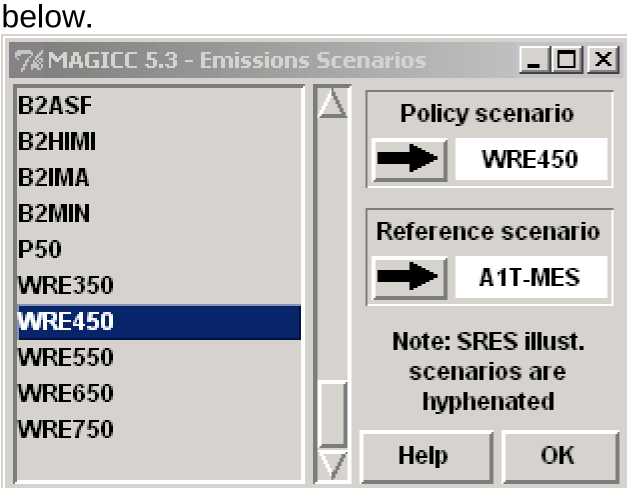


2. Running MAGICC:



The first step is to click on "Edit". This will display a pull-down menu with the choices "Emissions Scenarios", "Model Parameters" and "Output Years".

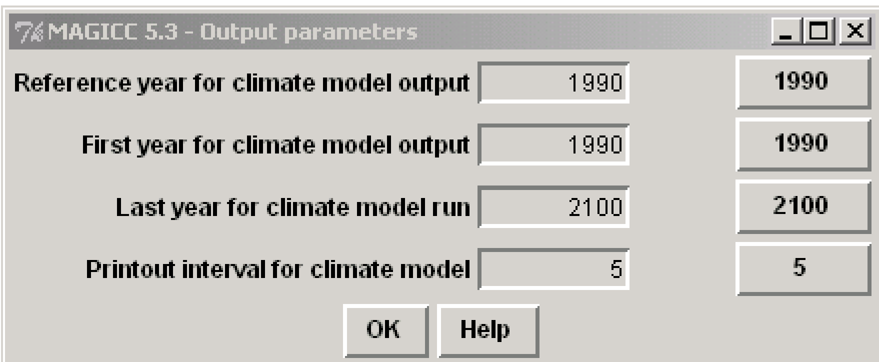
"Emissions Scenarios": select a Reference and Policy scenario.
To select these, click on the Edit window and then Emissions Scenarios, scroll down to and select the chosen scenario(s), and then click on the appropriate selection arrow – as shown below.



Click on “OK” to preserve the selected scenarios. This will close the “Emissions Scenarios” window.

“Model Parameters”: We will use the default settings.

“Output Years”: re-setting the end date. The default setting for MAGICC is to run to 2100. Clicking on “Output Years” will bring up the “Output parameters” window (see below). Here, the user can control the years covered by the displays, and the years covered and time-step interval for output to the Reports files. Buttons on the right of the Output parameters window can be used to return to the default settings. The Output Years selection controls what data are available to SCENGEN. Most emissions scenarios in the library run only to 2100, so selecting a higher number for the last year in these cases will have no effect.



Unless further editing of the inputs is required, **click on Run at the top of the main window**. After a short time, the climate model will be run. Input emissions for the major gases and results for concentration changes, radiative forcing (by gas and total), global-mean temperature and global-mean sea level change can now be viewed by clicking on “View”.

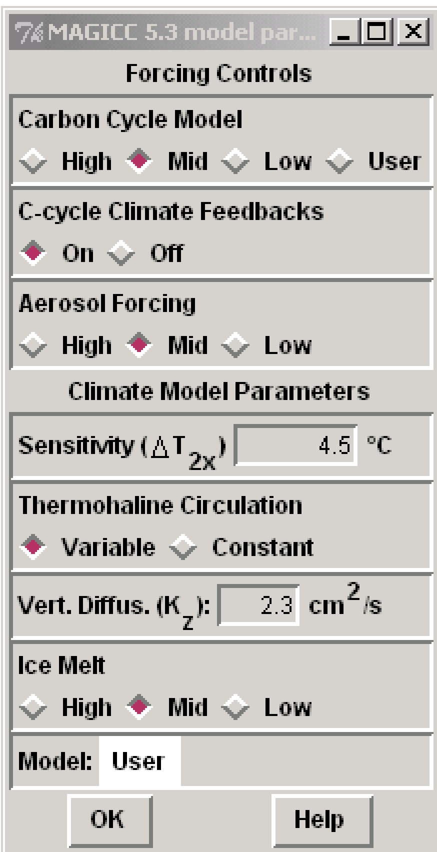
If View is selected, the following window appears …..

The user can select graphical output under **Graphs**, or, in the **Reports** files, to access much more detailed tabulated output.
"Concentrations" shows results for CO_2, CH_4 and N_2O The default is CO_2.

Note that uncertainty ranges displayed in MAGICC are always those for the User model.

A key component of CO_2 projections is the feedback on the carbon cycle due to global warming. This is really a complex set of different feedbacks operating on a regional scale, some positive and some negative. On balance, however, these climate feedbacks are positive leading to significantly higher concentrations than would be the case if they were absent. We can illustrate the importance of these feedbacks with permutations of chosen scenario.

For example, the user can change the amount of warming simply by changing the climate sensitivity. We do this by going back to the Edit button and editing Model Parameters. On the Model Parameters window we change the Sensitivity variable.



We select this with the OK button, and then click on Run. Then, through "View" we examine the CO_2 concentrations again for comparison. The additional warming that occurs when a higher sensitivity is selected leads to a larger climate feedback on the carbon cycle, and, hence, larger concentrations. For the Reference (A1T) emissions scenario, warming in 2100 is 2.48°C for the default climate sensitivity (3.0°C) and 3.37°C for the user sensitivity (4.5°C). The corresponding 2100 CO_2 concentrations are 576 ppm and 595 ppm – an increase of 19 ppm for a warming increase of 0.9°C.

For the Policy scenario, WRE450, concentrations are lower and the effect of climate feedbacks is to increase the 2100 concentration from 423 ppm to 450 ppm (+27 ppm). If we had run the analysis out to 2400 (by selecting 2400 in “Output Years” at the start), it could be seen that the difference increases over time, reaching 38 ppm by 2400 (see Figure below).

Interestingly, the no-climate-policy emissions and concentrations for N_2O in the A1T scenario are actually less than in the policy-driven WRE450 emissions scenario, where N_2O emissions come from the extended MiniCAM Level 2 multi-gas stabilization scenario. This illustrates the profound uncertainties in projecting N_2O emissions both in the absence of or in response to climate policies.

It should be noted that the CO_2 concentration results shown here are somewhat deceptive. By giving results only for one parameterization of climate feedbacks on the carbon cycle they hide very large uncertainties that surround quantification of these feedbacks. Although MAGICC has feedbacks that are similar in magnitude to other carbon cycle models used by IPCC, the Bern model (Joos et al., 2001) and the ISAM model (Kheshgi and Jain, 2003) – see Appendix – some other models have substantially larger feedback effects (Friedlingstein et al., 2006).

Nevertheless, warming uncertainties associated with this particular factor are small compared with uncertainties that arise from our relatively poor knowledge of the magnitude of the climate sensitivity. These uncertainties can be displayed by clicking on the two range buttons on the temperature change output display.

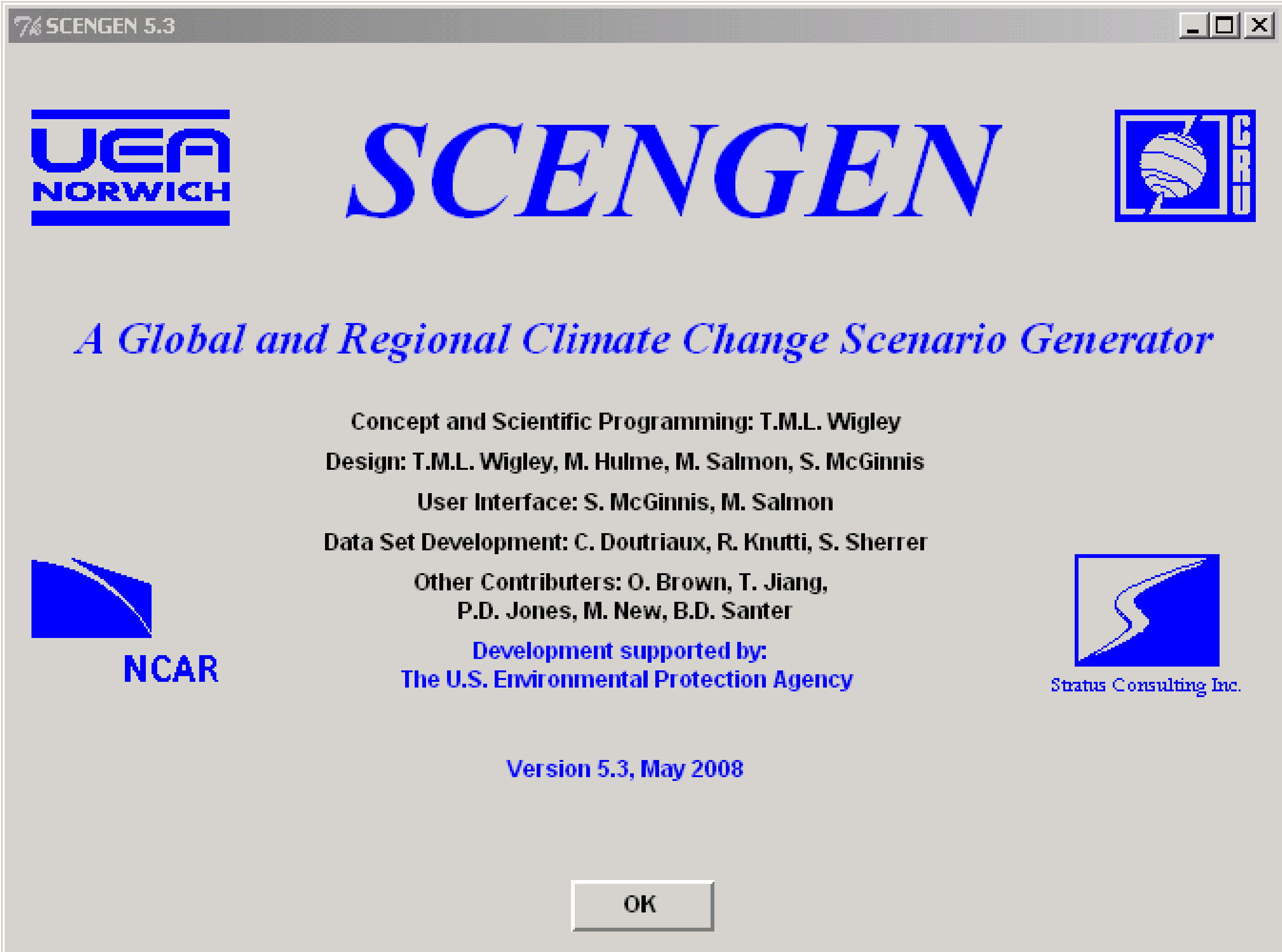
Sea level results based on MAGICC for thermal expansion and TAR models for all other components may be viewed by clicking on the “Sea level” button. The plot below shows the full range of results out to 2400.

It should be noted that uncertainties in sea level rise in MAGICC represent the extreme (and likely very low probability) limits where all uncertainties operate in the same direction. The upper bound shown by MAGICC is what would be expected if the climate sensitivity were 6^{o}C and if all ice-melt parameters are set to maximize the ice melt contribution for this sensitivity. The probability of this combination must be considerably less than the probability of a sensitivity as high as 6^{o}C (viz. 5%), but it is impossible to quantify this probability without carrying out a far more sophisticated analysis. Even the central estimates are important, however, as they show the large inertia in the climate components that contribute to sea level rise. Temperatures stabilize in this case, yet sea level continues to rise inexorably.

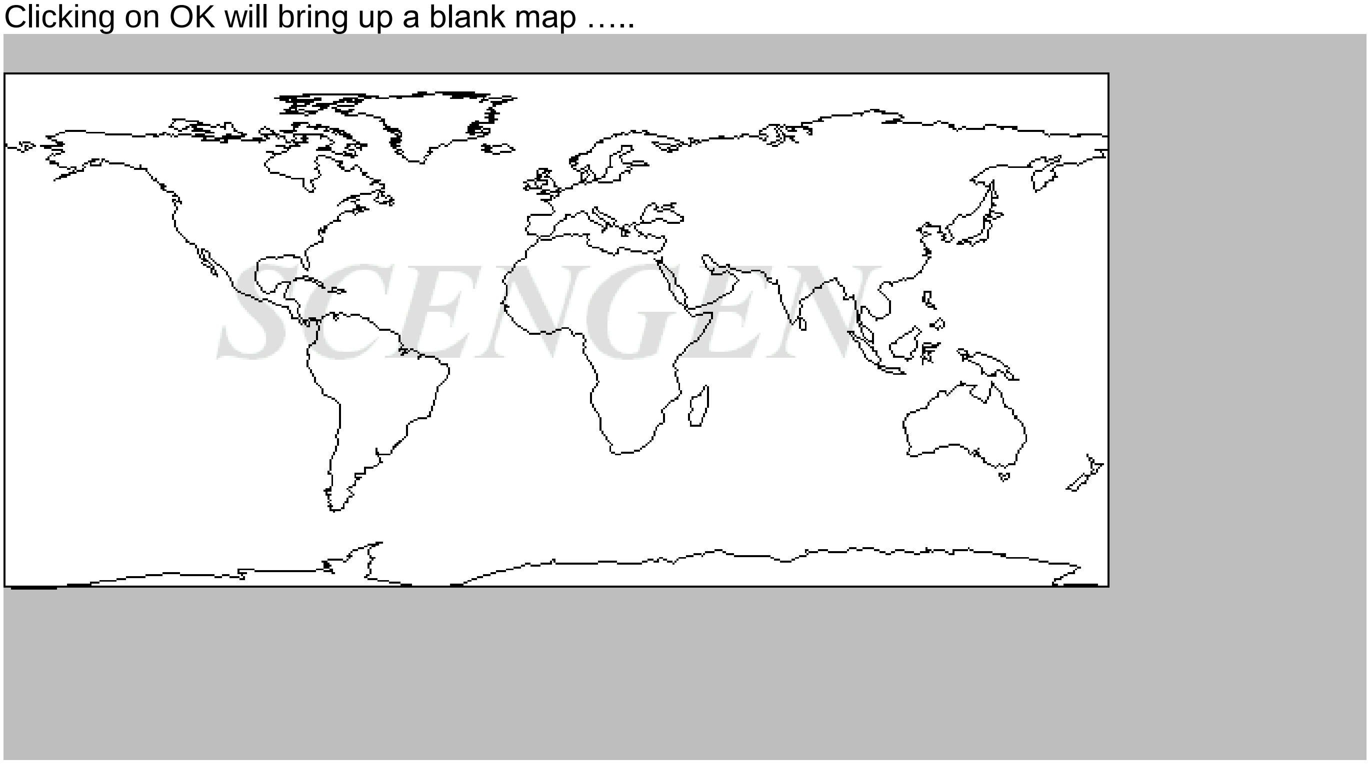
3. Running SCENGEN:

The next step is to go back to the main MAGICC control window, click on the SCENGEN button and then on the “Run SCENGEN” button. This will bring up the SCENGEN title window (see below).

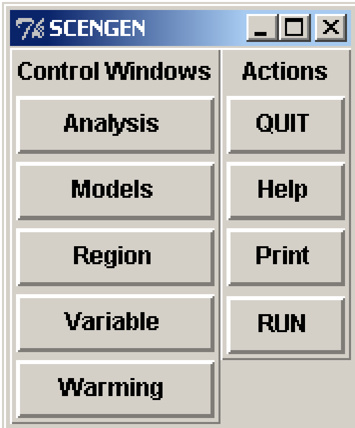
Click on “OK”.



Clicking on OK will bring up a blank map …..



….. and the main SCENGEN selection window.

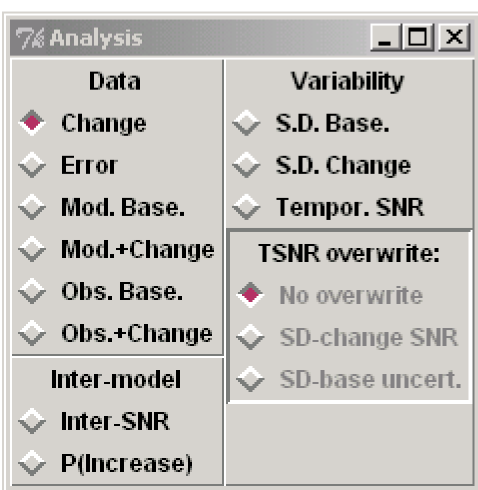


Below are three examples illustrating some of the capabilities of SCENGEN 5.3.

<u>*EXAMPLE 1:*</u>

This first example is a comparison of different model results for **changes in the spatial patterns of annual-mean precipitation.** The MAGICC case used is as above, a Reference emissions scenario of A1T-MES and a Policy scenario where CO_2 concentrations follow the WRE450 stabilization profile.

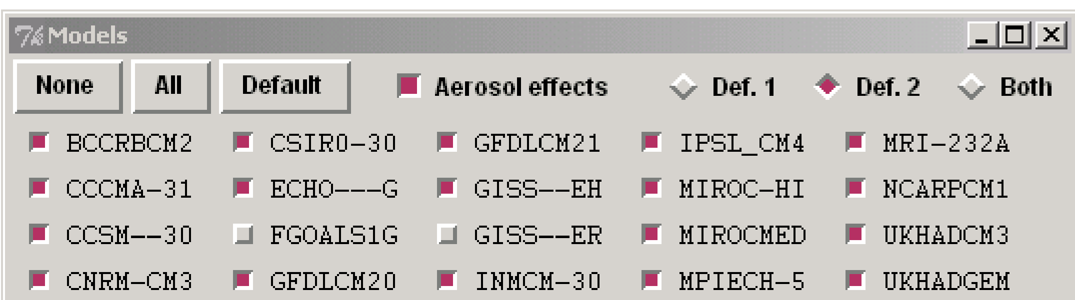
The first step is to click on “Analysis” in the above SCENGEN window. This will bring up the “Analysis” window shown below. The other windows will remain in place and can be moved around to more convenient positions if required.



Note that this window has changed from that used in version 4.1. The bottom right panel is new and now allows users to examine inter-model uncertainties in variability: specifically, in the model-mean baseline inter-annual standard deviation, s.d. ("SD-base uncert"), and the model-mean s.d. change ("SD-change SNR") – see item (10) in Section 3.2 above. Uncertainties in s.d. change are very large – i.e., there are large inter-model differences in projections of variability change, as will be shown below.

Under "Data", the default selection is "Change" indicating that the analysis to be performed by default will be of changes in the mean state for a particular selected variable. If this button is not lit up, click on "Change" to select an analysis of climate change. The following steps will select: (1) the AOGCMs to be used (displayed results are for the average across the selected models); (2) the analysis region (we will use the full globe); (3) the analysis variable and season (we use annual precipitation); and (4) the analysis year, emissions scenario, and MAGICC parameter set. These selections (including the type of analysis – "Change", etc.) may be made in any order.

We first select the models to be used to define the change. As noted above, the displayed results will give the average change over the selected models. A crucial and unique aspect of SCENGEN is that averages across models are based on **normalized** results (following the original implementation of this idea in Santer et al. (1990)). Using normalized results ensures that each model pattern of change receives equal weight and the average is not biased towards models with high climate sensitivity. To select the models to use, go back to the SCENGEN window and click on "Models". This will bring up the window shown below.

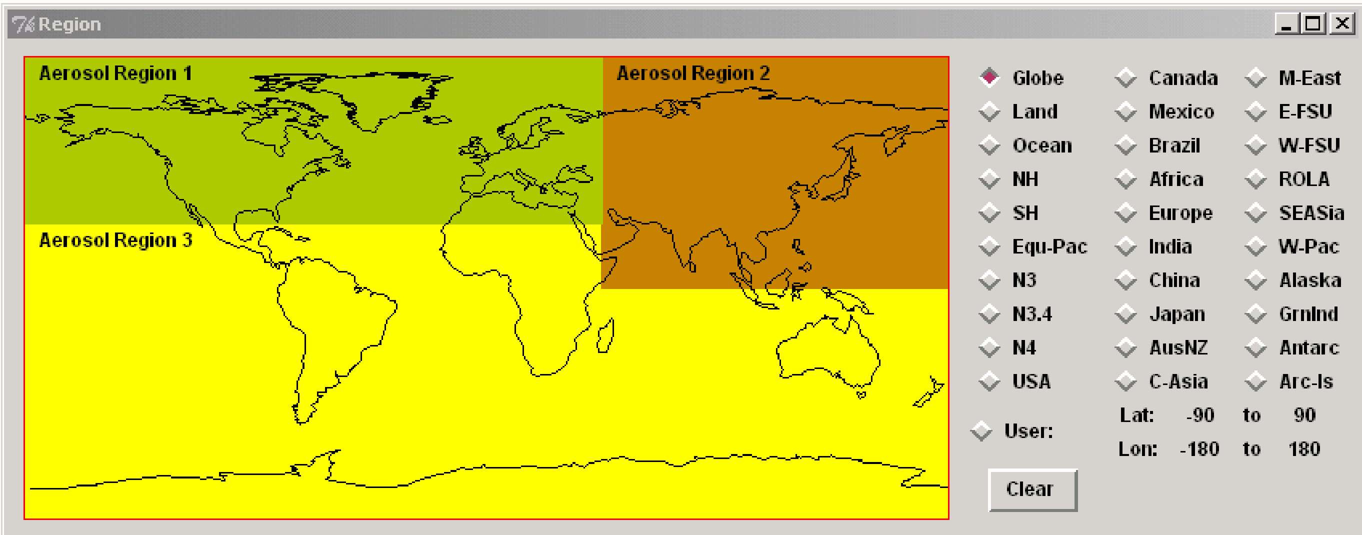


Certain models (a selection of U.S. models) will be lit up as default. The user can select any set of models, from a single model to all models, and SCENGEN will produce results averaged over the selected models. For further information on these models, see the IPCC Fourth Assessment Report (Randall and Wood, 2007)

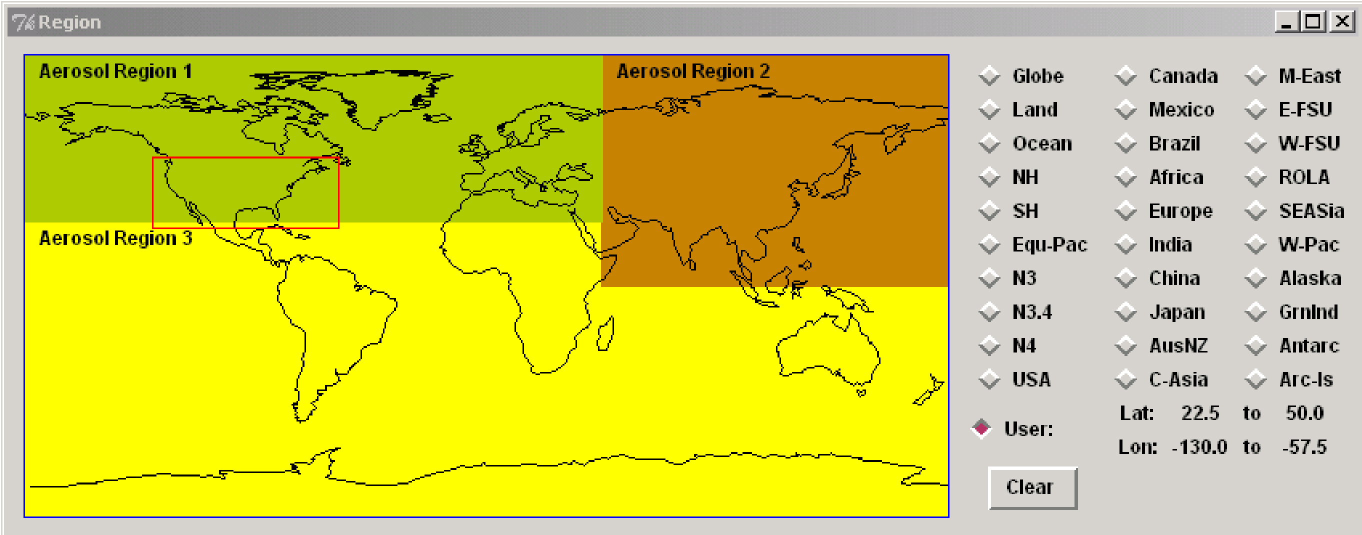
For the present example we use all models except FGOALS and GISS-ER (for reasons stated above). To get the above selection, the user should click on "All" and then click on FGOALS and GISS-ER to de-select these two models. Next, the user has the option of using Definition 1 or Definition 2 changes. Def. 1 uses the difference between the start and end of a perturbation experiment. Def. 2 uses the difference between the perturbed state and the control climate at the same time. If a model has any spatial drift (and most models do) then Def. 2 is a way of removing this drift (under the justifiable assumption that the drift is approximately common to both the perturbed and control runs) – normally one should use Def. 2.

Next, the user must decide whether or not to include the spatial effects of aerosols. Normally, these effects should be included (which is done by clicking on the “Aerosol effects” button). The option not to include aerosol effects is to allow the user to determine how important these effects are. The “Models” window shown above corresponds to these selections.

Next, return to the SCENGEN window and click on “Region”. The map below will be displayed.



The map shows the regions used for the breakdown of SO_2 emissions in the MAGICC emissions files, together with a set of analysis region selections. (Emissions from ocean and air transport are divided equally over the three regions.) The default region is the whole globe, and this is what will be used in the present examples. The user can select from a range of “hard-wired” regions, or can mouse out a rectangular latitude/longitude region on the map. To do this, click on “User” and use the mouse to define a region. The latitude/longitude domain will be shown numerically on the right. The selected region appears as a red rectangle – see the map below -- and the domain limits appear on the bottom right of the window. (Note that the hard-wired regions are generally not rectangular.) For user-selected rectangular regions the latitude and longitude ranges shown correspond to the full domain. Latitude values are in degrees north from the equator, and longitude values are in degrees east.

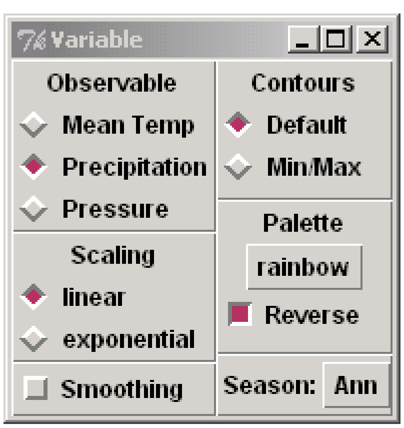


Selecting a grid-box region means that most calculations will be carried out specifically for that region. This includes area averages for the selected variable (see below), and a range of other statistics. These results are not displayed, but are given in tabulated form in various output files in the ENGINE/IMOUT or ENGINE/SDOUT directory (see Table 5 above).

After experimenting with the user region option, return to using the whole globe by clicking on “Clear” and then “Globe”.

Now return to the SCENGEN window and click on “Variable”. The “Variable” window (below) will appear. The default is annual-mean temperature. Click on “Ann” to see the other season options, and then return to “Ann”. Next click on “Precipitation”, since this is the variable we will use for the examples. Note that the “Reverse” light will come on, since the standard rainbow color scheme for precipitation (red for dry to blue for wet) is the opposite of that usually used for temperature (blue for cold to red for hot). This can be de-selected by clicking on the “Reverse” button.

This window gives the user the option to use linear or power law (exponential) scaling. The latter is a way of avoiding physically unrealistic results that can (albeit only rarely) occur with linear scaling if the global-mean warming is large. For these examples we will stick with linear scaling. For precipitation changes, exponential scaling is preferred. Users should experiment with both scaling methods to see the differences.

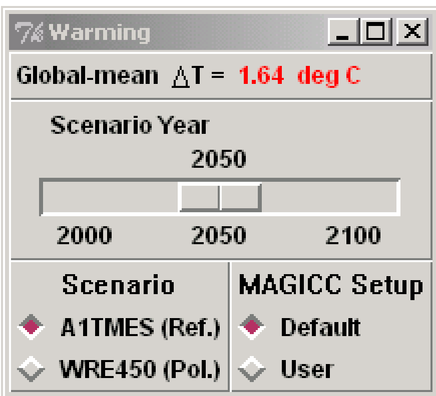


There are two new options on the “Variable” window. First there is a spatial smoothing option that replaces all output fields by an area-weighted 9-box smoothed field (see item (5) in Section 3.2 above). Second, there is now a range of color palette schemes and an improved method for choosing contour levels and intervals (see item (6) in Section 3.2).

Selecting the spatial smoothing option means that, if a single 2.5 by 2.5 degree grid box is selected as the region, the results will be area averages over the nine grid boxes centered on the selected grid box. If spatial smoothing is selected, this will be applied to all output array files and displays.

To change the palette, click on the “rainbow” button. To change the contour levels to span the range of grid-box values better, click on the Min/Max button.

Return again to the SCENGEN window and click on “Warming”. The following window will appear …..

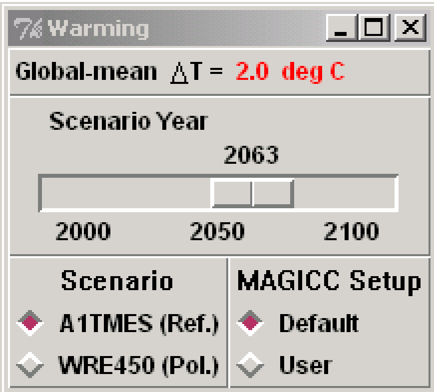


This is where the user selects the following:

(1) the emissions scenario, either the Reference or the Policy case. The names displayed show only the first nine letters of the headers on the emissions files.
(2) the scenario year (i.e., the central year for a climate averaging interval of 30 years, as indicated by the length of the slider bar. The default year is 2050, as shown.
(3) a particular configuration for the MAGICC model, Default (i.e., “best guess”) or User.

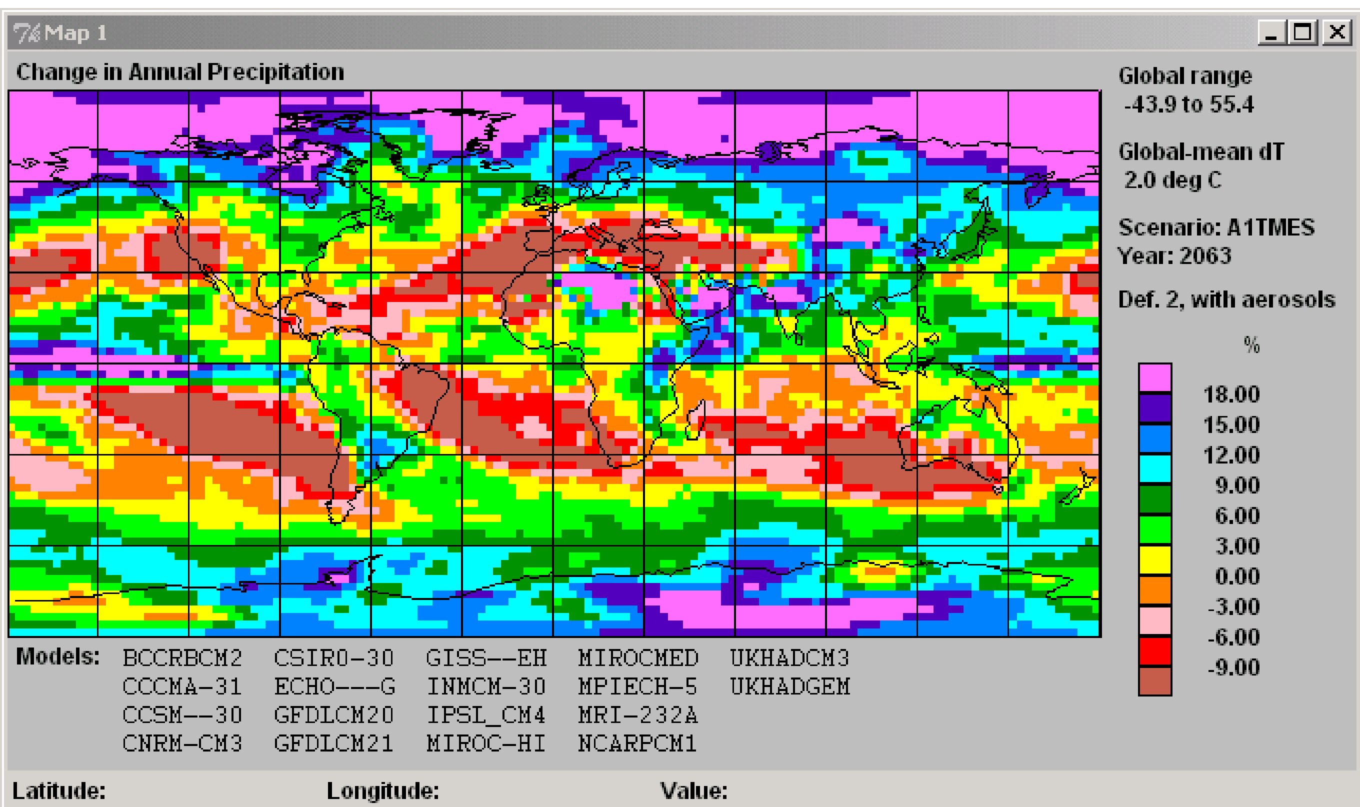
These factors determine the global-mean temperature change from 1990 to 2050 (red 1.64 degC at top of window in this case) that is used for scaling the normalized patterns of change. Within the code, this global-mean temperature change is broken down into four components (a ghg component, and aerosol components for the SO_2 emissions in the three emissions regions shown above) and these are used as weights for the pattern scaling algorithm.

For the present examples we will use the default emissions scenario (A1T-MES, the selected Reference scenario), and default parameters for MAGICC. We also slide the temperature bar across to 2064 to give a warming of 2 degC – see window below.

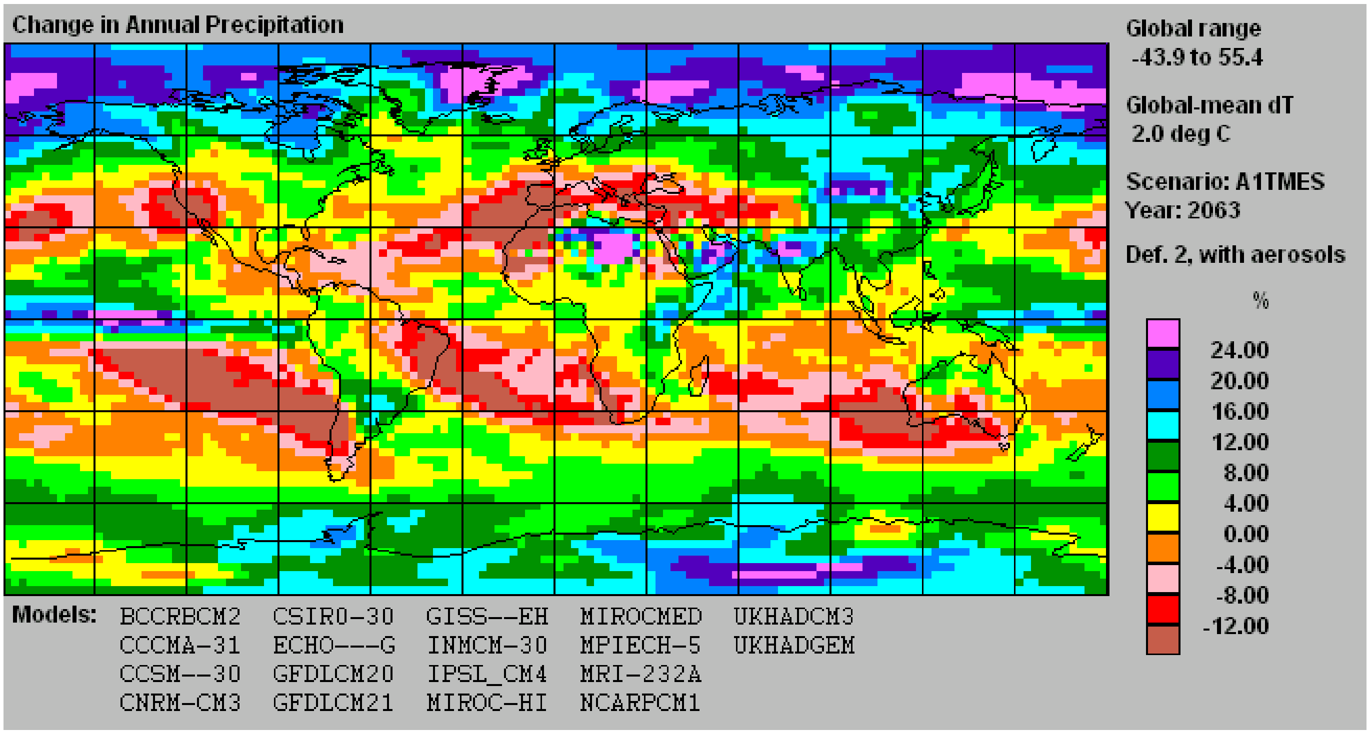


At this stage, all necessary user selections for SCENGEN have been made.

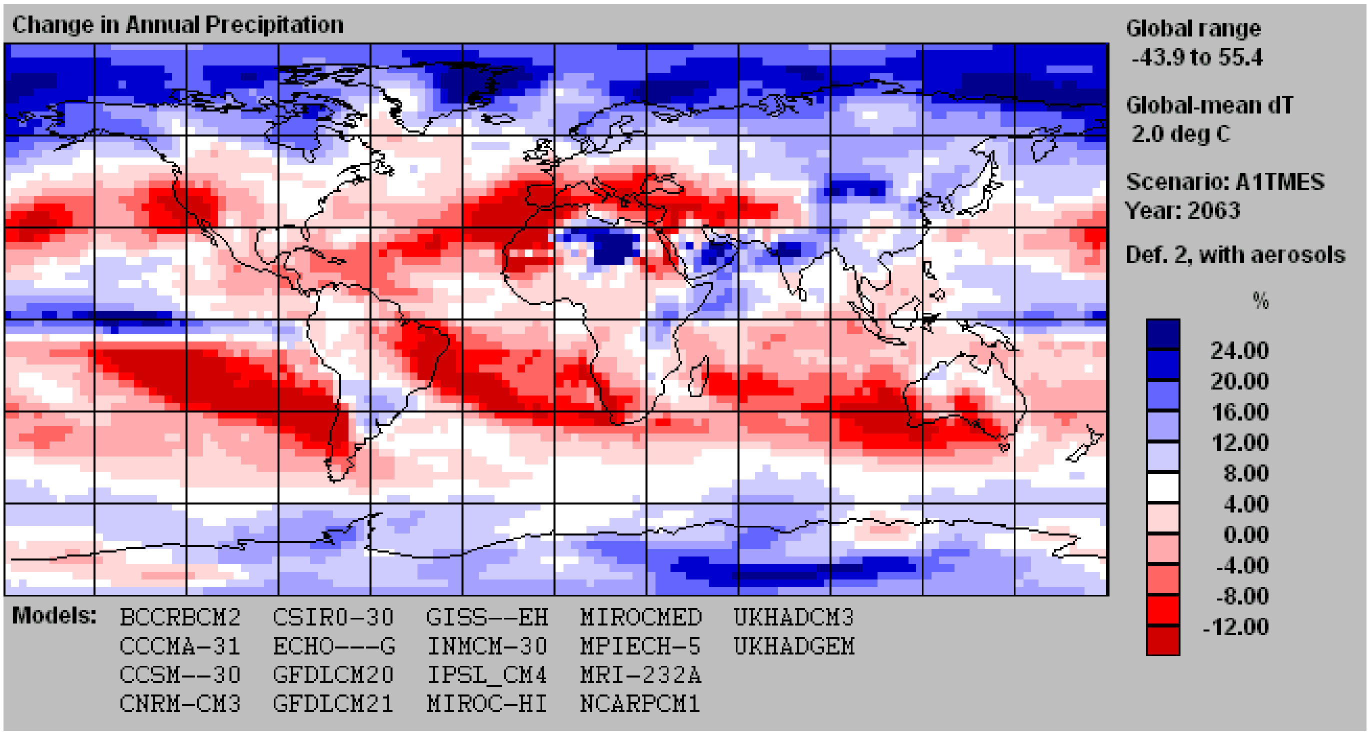
Return now to the SCENGEN window and click on "RUN" to run the SCENGEN software. After a short time, a map will appear – see below. This shows the change in annual-mean precipitation for the 30-year interval centered on 2064 (for the A1T emissions scenario, and "best guess" climate model parameters in MAGICC) averaged over all 18 selected AOGCMs.



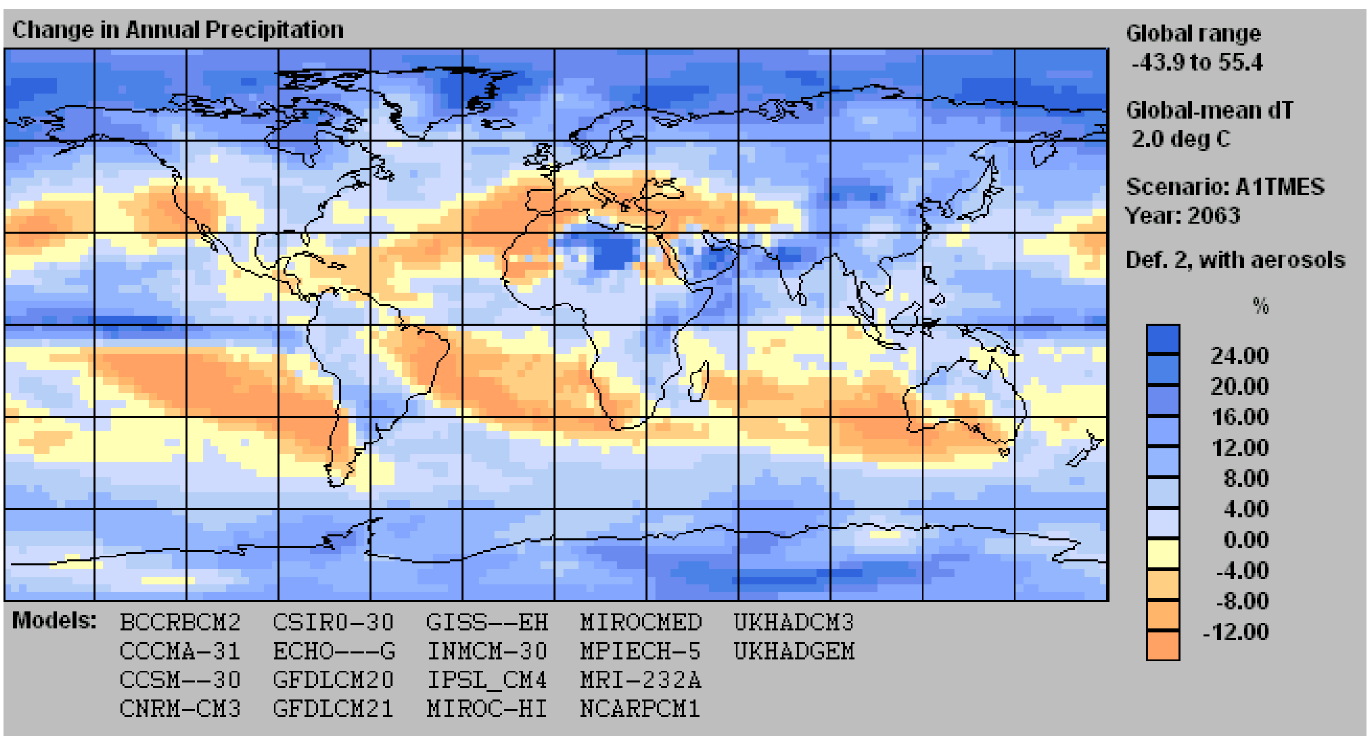
The default display is as shown above. Mousing over the map will show specific grid-box values in the lowest panel of the display. We now illustrate other possible displays. First, we use the "Min/Max" option on the "Variable" window, which will ensure that approximately 5% of the grid-box values will lie above (below) the highest (lowest) contour level.



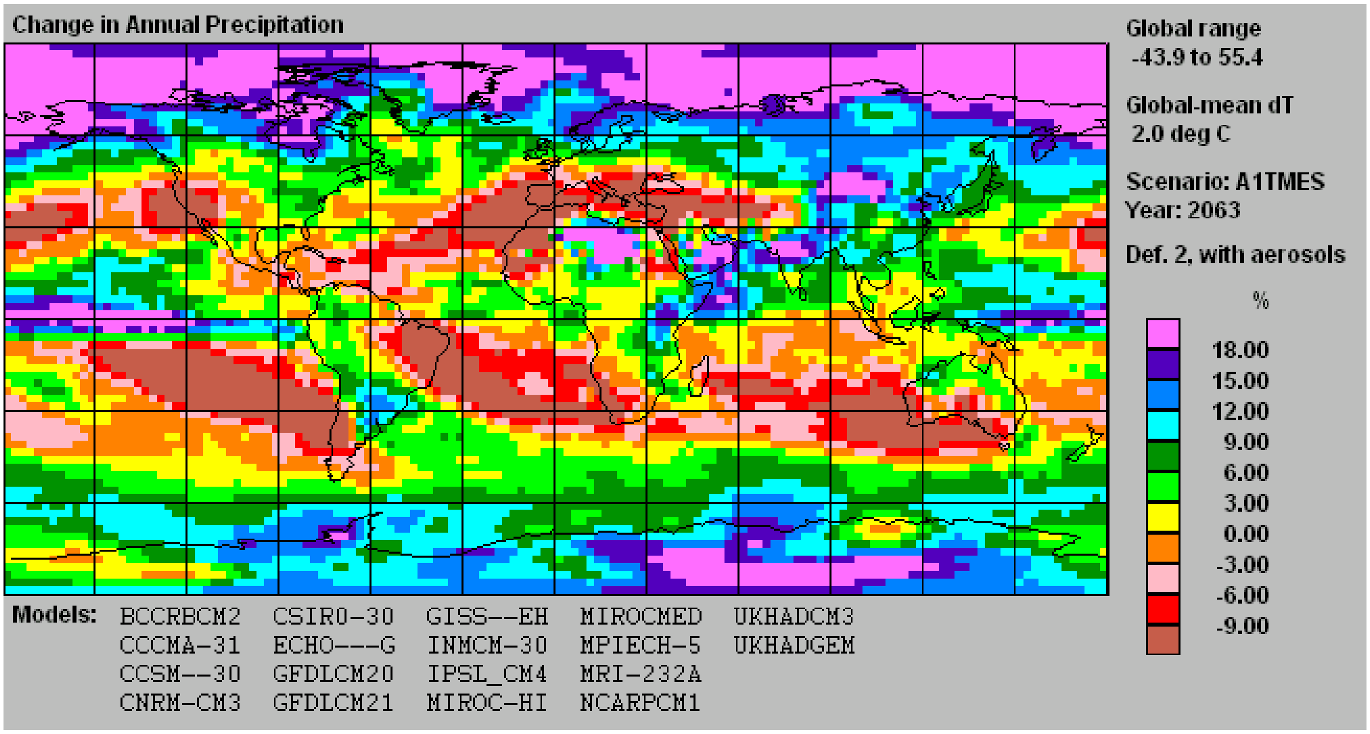
(In the above and subsequent displays the top and bottom parts of the full panel have been deliberately suppressed.) Next, we retain the Min/Max contouring and select the red-blue color palette – below.

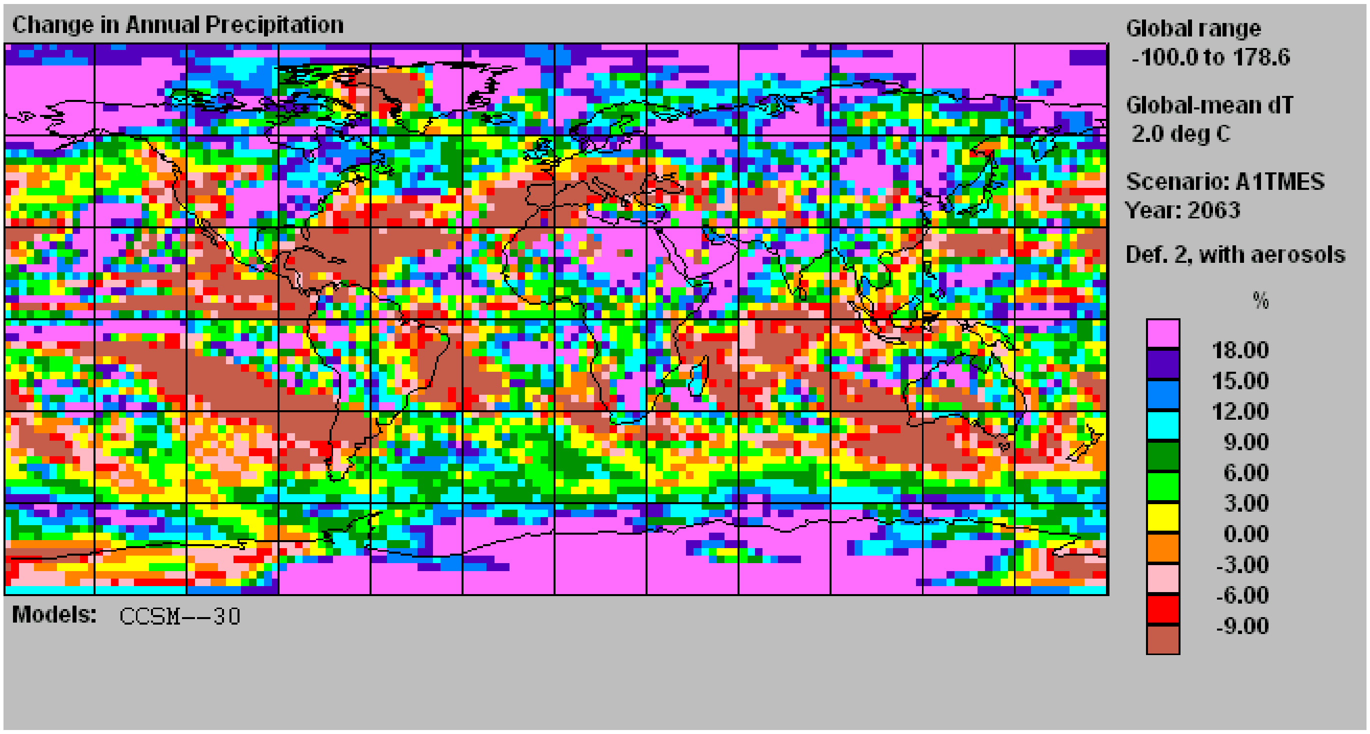


Finally we select the AR4 color palette. This palette has the yellow/blue boundary as the zero contour level.



We now compare the multi-model average results with those for a single AOGCM. For the single model we choose NCAR's Community Climate System Model (CCSM3). We show below the multi-model result for default contouring and palette (repeated from above) with the CCSM3 result immediately below this.





It can be seen that there are clear similarities between the multi-model mean pattern and the CCSM3 result – although the latter pattern is, understandably, more noisy. In both cases, precipitation increases in high latitudes and decreases in subtropical regions and in places like the Mediterranean Basin and southwest Australia. Overall, changes in CCSM3 are much larger than in the multi-model mean, implying that there are cancelling effects when a number of models are averaged.

The visual similarity, however, is deceptive, and the overall pattern correlation between CCSM3 changes and the mean of the remaining 17 selected models is quite small (r = 0.372). Pattern correlation results such as this may be found in OUTLIERS.OUT (in folder …ENGINE/IMOUT), for which an extract is given below. (To produce this Table, you will have to go back to the original 18-model selection and re-run SCENGEN.)

Note that CCSM3 precipitation changes are biased high relative to other models ("BIAS" in the Table below is model-i minus the mean of the remaining models for 1ºC global-mean warming). Note also that the results in the Table below do not correspond precisely to the maps above, since OUTLIERS results are based solely on the normalized precipitation changes (i.e., they do not account for scaling up to the MAGICC global-mean temperature change, nor do they account for aerosol effects on precipitation change). Nevertheless, these OUTLIERS results provide a good indication of the more general pattern similarities.

COSINE WEIGHTED STATISTICS

MODEL	CORREL	RMSE %	BIAS %	CORR-RMSE %	NUM PTS
BCCRBCM2	.442	7.050	.420	7.038	10368
CCCMA-31	.562	5.997	-.171	5.994	10368
CCSM--30	.372	8.507	1.002	8.448	10368
CNRM-CM3	.312	7.945	.175	7.943	10368
CSIR0-30	.351	9.214	.616	9.193	10368
ECHO---G	.327	8.519	-.861	8.475	10368
GFDLCM20	.456	10.139	.510	10.126	10368
GFDLCM21	.402	11.190	-2.166	10.979	10364
GISS--EH	.396	7.854	.515	7.837	10368
INMCM-30	.424	7.049	.178	7.047	10368
IPSL_CM4	.397	10.135	-1.085	10.077	10358
MIROC-HI	.523	5.478	.539	5.452	10368
MIROCMED	.599	5.624	-.219	5.620	10368
MPIECH-5	.342	15.497	.870	15.473	10361
MRI-232A	.365	10.688	.257	10.685	10363
NCARPCM1	-.067	15.157	.822	15.135	10368
UKHADCM3	.424	10.049	-.940	10.005	10368
UKHADGEM	.522	6.514	-.119	6.513	10368

The above results provide a strong indication that there are large inter-model differences between AOGCM precipitation change projections. A further indication of these large inter-model differences can be obtained using Inter-SNR and P(Increase) – see these buttons on the "Analysis" window. We explore these further below.

Appendix 1: Halocarbons

MAGICC includes the following 30 halocarbons ...

CFC11, CFC12, CFC13, CF_4, CFC113, CFC114, CFC115, C_2F_6, CCl_4,$CHCl_3$, CH_2Cl_2, MCF, Ha1211, Ha1301, HCFC22, HCFC123, CH_3Br, HFC141b, HFC142b, HFC125, HFC134a, Ha2402, HFC23, HFC32, HFC43-10, HFC143a, HFC227ea, HFC245ca, C_4F_{10}, SF_6

In the input emissions files, only the 8 most important can be specified. These are ...

CF_4, C_2F_6, HFC125, HFC134a, HFC143a, HFC227ea, HFC245ca, SF_6

The other 22 gases are divided into two groups, gases controlled under the Montreal Protocol and all other gases.

Montreal gases (CFC11, CFC12, HCFC22, etc.) have fixed future emissions, controlled by the Protocol. The concentrations and forcings for these are hard wired into the code. For the other gases the emissions vary according to the SRES scenario, but the differences between the scenarios are small. Most inter-scenario differences in halocarbon forcing arise through differences in the emissions of the above 8 gases. MAGICC therefore uses an average total radiative forcing for the other gases, again hard wired into the code. The forcing error in doing this is tiny -- a few thousandths of a W/m^2 in 2100.

Acknowledgements:

Over the years, many people have contributed to the development of MAGICC and SCENGEN and the science that these software packages encapsulate. These include: Olga Brown, Charles Doutriaux, Mike Hulme, Tao Jiang, Phil Jones, Reto Knutti, Seth McGinnis, Malte Meinshausen, Mark New, Tim Osborn, Taotao Qian, Sarah Raper, Mike Salmon, Ben Santer, Simon Scherrer and Michael Schlesinger.

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The AOGCM modeling groups are gratefully acknowledged for providing their climate simulation data through the Program for Climate Model Diagnosis and Intercomparison (PCMDI). We also acknowledge PCMDI for collecting and archiving these data, and the World Climate Research Programme's Working Group on Coupled Modelling for organizing the model data analysis activity. The CMIP3/AR4 multi-model data set is supported by the Office of Science, U.S. Department of Energy.

PRINTING TIPS

There is currently no built-in printing capability for SCENGEN, but it is easy to import the maps into other programs and print them from there.

To perform a screen-capture of a SCENGEN map window, simply click on the window and press Alt+Prnt Scrn. This copies an image of the window to the clipboard. You can then paste the image into a document in another program like Microsoft Word by typing CTRL+V. If you want to edit the image (to trim off borders or annotations, for example), one can paste it into a simple image editor like Microsoft Paint, which is typically found in the “Accessories” menu.

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Version 1, June 2008
Version 2, September 2008

The primary modification in Version 2 is to the section on sea level rise. Additional information about the carbon cycle model has been added, the Section on model selected has been modified with more information added on the OUTLIERS Table, and a new Appendix inserted giving information about how MAGICC handles halocarbons.