Standalone ECBILT Experiments

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1 Introduction

The idea here is to do some experiments with a standalone version of the ECBILT 3-level atmosphere model to decide whether it's a suitable candidate for coupling into GENIE. The two main things to consider here are the speed of the ECBILT model and how good its climatology is. To investigate these things, I've done a quick first comparison with a HadAM3 simulation (BRIDGE simulation `tcszd`).

There are two versions of ECBILT that could be used for this comparison. The first is already coupled into the LOVECLIM EMIC, so would require some work to decouple it and set it up for standalone operation. The second is the original standalone ECBILT model[1], which is what I'm going to start with. It has a couple of deficiencies compared to the version included in LOVECLIM, but it's good enough for a quick first look. The main deficiency of the standalone ECBILT version is that it's not possible to change GHG forcings. This is because of the way the LW radiation scheme works: it's an empirical fit to LW radiation absorption from the GFDL GCM. I'm not yet sure what GHG conditions that fitting was done against, but I'm going to press on assuming that it was pre-industrial, as for the UM simulation. For applications in GENIE, we obviously need to be able to change the GHG concentrations so, if results from the first experiments with the standalone ECBILT are promising, I'll probably just transplant the newer LW radiation scheme from the LOVECLIM version of ECBILT (which treats GHGs explicitly) into the standalone ECBILT.

The approach I'm going to take to model validation here is just to convert boundary conditions from a suitable HadAM3 run to the form required to drive ECBILT, do the same sort of atmosphere-only simulation as done in the HadAM3 job and to compare the parts of the climatology most important for long-term GENIE simulations between the two models (also looking at model performance along the way).

As a first simple attempt, I'm going to leave all ECBILT input files unchanged from their defaults except for SST and sea-ice forcing, which are adapted from the HadAM3 simulation. This approach means that there's no need to convert land/sea masks, land cover types, the lake mask used by ECBILT, and so on. If we decide to go further, I'll do simulations using a land/sea mask and other boundary conditions based on the HadAM3 data (probably also updating the ECBILT LW radiation scheme as mentioned above).

2 Code and test platform setup

All the experiments reported here are performed on a machine running Arch Linux (rolling release as of 18 January 2015), with a 3 GHz Intel Core i5-3330 CPU and 16 Gb of main memory. All test runs were performed on a lightly loaded machine. Very few code changes were needed to get the standalone ECBILT code to build with the compiler used (GFortran 4.9.2).

3 Experiment #1

- Run name: `expt-1`.

[1] Downloaded from here `http://knmi.nl/~selten/pro_ecbilt.html`.

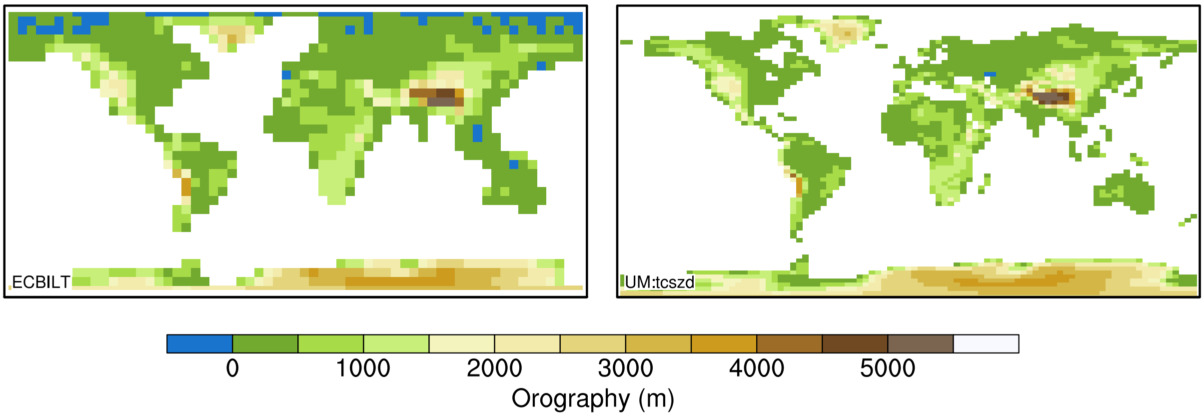

Figure 1: ECBILT and UM orography and land/sea masks used for comparison experiments.

- Original standalone ECBILT code, with only minimal changes for compilation.
- SST and sea-ice forcing converted from UM `tcszd` experiment.
- Simulation length: 100 years; spin-up: 70 years; analysis: 30 years.

3.1 Boundary conditions

Boundary conditions to run the standalone ECBILT model were derived from the BRIDGE `tcszd` HadAM3 simulation. This is a 100-year pre-industrial atmosphere-only simulation with prescribed climatological SSTs and sea ice.

In order to get an initial ECBILT simulation set up quickly, I decided to convert only the SST and sea ice forcing from the HadAM3 simulation, keeping the original ECBILT land/sea mask, orography, lake mask and land surface conditions (e.g. albedo), GHG concentrations and so on. Modifying these latter conditions to match HadAM3 will take more work than the relatively simple SST and sea ice regridding. I'll go ahead and do that if the results from the first simulation are encouraging enough.

Figure 1 shows the land/sea mask and orography for ECBILT and HadAM3 for comparison. One comment needs to be made about the ECBILT land/sea mask here: although some areas that should be ocean are treated as land in the land/sea mask, in particular the Mediterranean, the Great Lakes and the South China Sea, these grid cells *are* treated appropriately as water areas, via the use of a seperate lake mask identifying grid cells that have a significant water fraction.

3.1.1 SST and sea-ice

Conversion of SST and sea-ice from the HadAM3 boundary conditions to the form needed by ECBILT is pretty straightforward.

For the SST, the HadAM3 boundary conditions are given as a monthly climatology of SST. ECBILT requires daily SST on a different grid, so I take the HadAM3 monthly SST fields, Poisson fill to get rid of missing values, regrid to the ECBILT grid, mask with the ECBILT land/sea mask, then use independent periodic interpolation in time at each grid point to generate a daily SST climatology. This data is then converted to the binary format read by ECBILT.

For sea ice, again HadAM3 again uses a monthly climatology, but ECBILT uses a "birth/death" map showing, for each grid cell, the month of the year where sea ice first appears and the month when it disappears. To generate a sea ice driver file in this form, the HadAM3 monthly sea ice data is first Poisson filled, regridded and masked to generate a monthly sea ice climatology on the ECBILT grid. Next, some simple heuristics are used to determine "birth" and "death" months for sea ice in each grid cell, and this information is encoded into the ASCII file format used by ECBILT.

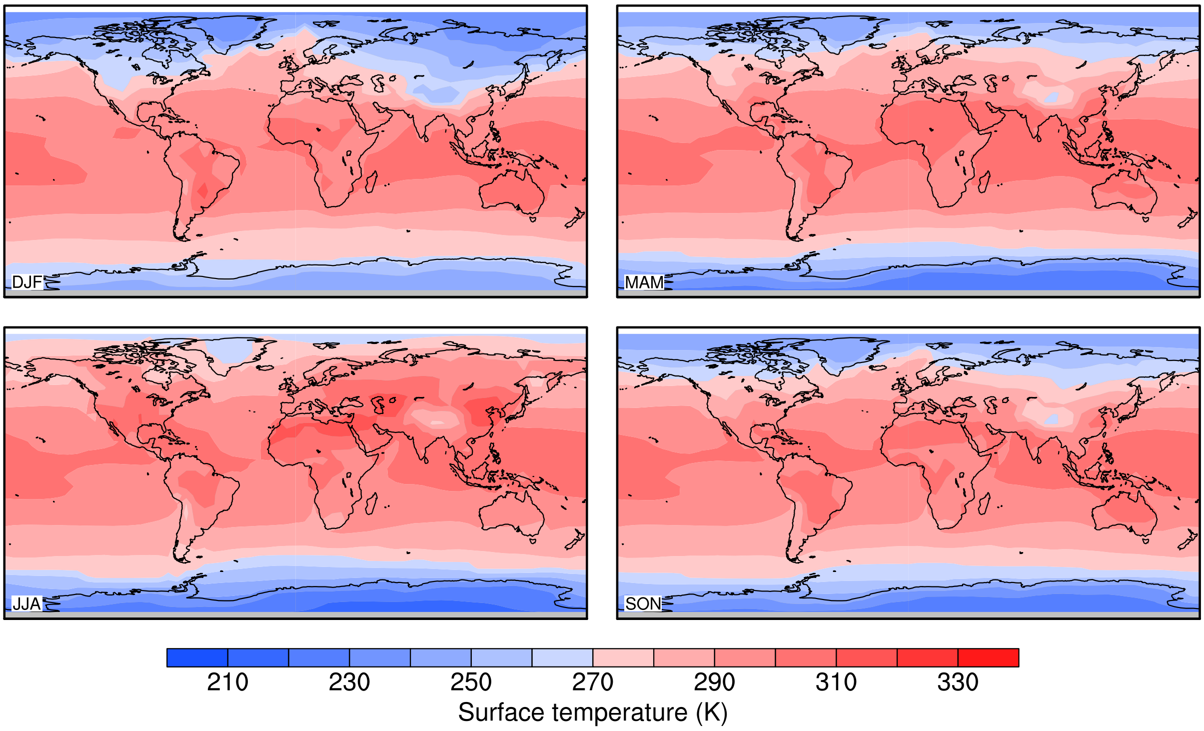

Figure 2: Seasonal surface temperature for ECBILT experiment 1.

3.2 Model performance

The 100-year simulation performed here too about 75 minutes (wallclock and CPU time were about the same), equating to **about 45 seconds per year of simulation**. Replacing the existing LW radiation scheme in ECBILT with the more explicit scheme in the LOVECLIM code will probably slow this down a little bit, but not much.

The ECBILT code is all serial, so there may be opportunities for parallelisation if performance is a problem. The atmosphere runs at a longitude/latitude resolution of 64×32 using a spectral method for stepping the dynamics. I've not yet done any profiling to determine where the best places to look for optimisations are, but that would be the obvious thing to do.

3.3 Model climatology

Figures 2–7 show seasonal climatologies of surface temperature, precipitation, evaporation, $P - E$ and atmospheric circulation for the ECBILT experiment 1 simulation – these should be compared with the HadAM3 HadAM3 `tcszd` simulation results in Figures 8–13 in Appendix B.

Surface temperature The large-scale patterns of surface temperature field in the ECBILT simulation are pretty good. Because of the SST forcing, it's a relatively easy field to get right, but it does show that there are no gross problems with the model. What differences there are between the ECBILT and HadAM3 fields appear mostly to be due to the rougher orography in ECBILT – the Tibetan plateau and western North America near the Rockies are the areas where this is most obvious.

Precipitation The differences between the ECBILT and HadAM3 fields here are more or less what you would expect from a comparison between a lower resolution (in both the horizontal but also, more importantly, in the vertical direction) and a higher resolution model. Winter storm tracks in the Atlantic are not well represented in ECBILT and tropical convective precipitation is much less well localised in ECBILT, with a large diffuse region of precipitation stretching from the western into the

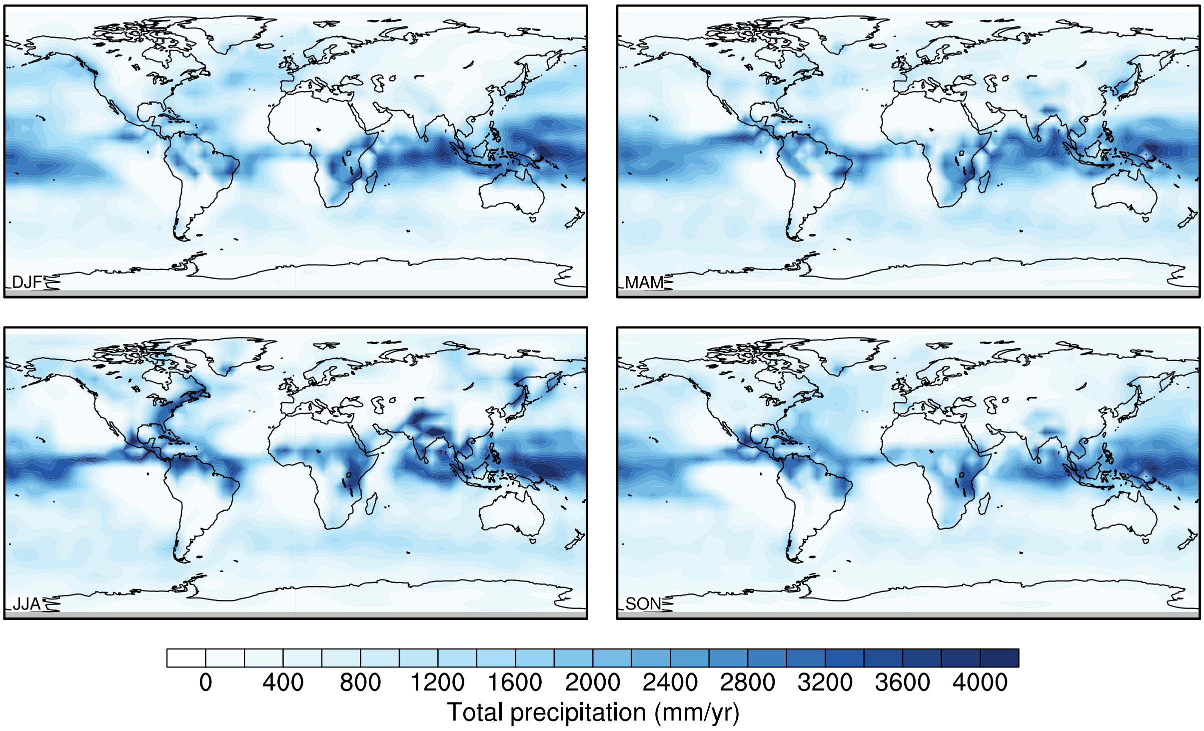

Figure 3: Seasonal precipitation for ECBILT experiment 1.

central Pacific. HadAM3 shows tropical precipitation much more localised over the western Pacific warm pool and narrow bands either side of the equator across the rest of the Pacific. These kinds of deficiencies in precipitation modelling are kind of inevitable in a model with only three levels in the vertical.

Evaporation Similar comments apply here as to the precipitation comparison: evaporation from the ocean is much less well spatially localised in ECBILT, with a large region of the western Pacific showing high evaporation values and no clear ITCZ being visible. Again, hard to get this right even in a model with more levels in the vertical, let alone one with only three!

$P - E$ The spatial patterns of $P - E$ in ECBILT exhibit the same problems seen in the individual precipitation and evaporation plots: the hydrological cycle is generally much more spatially diffuse than in the HadAM3 simulation (and in reality). For both models, the mean annual hydrological cycle is more or less balanced (for HadAM3 the area-averaged annual imbalance is about −2 mm and for ECBILT it's about 23 mm). The patterns of $P - E$ in ECBILT are weaker and more diffuse than HadAM3, although if you squint a little, the spatial patterns of positive and negative moisture budget are more or less right.

Winds Finally, the distribution of upper and lower level winds and vertical pressure velocity follow more or less the pattern that you would expect: the atmospheric circulation in ECBILT is weaker and more diffuse than in HadAM3, particularly in the vertical direction. This vertical smoothing because of the small number of vertical levels in ECBILT is almost certainly the source of the weaker hydrological cycle seen in the $P - E$ plots. Slightly surprisingly though, the spatial patterns and magnitude of the wind stress look pretty good, especially over the oceans.

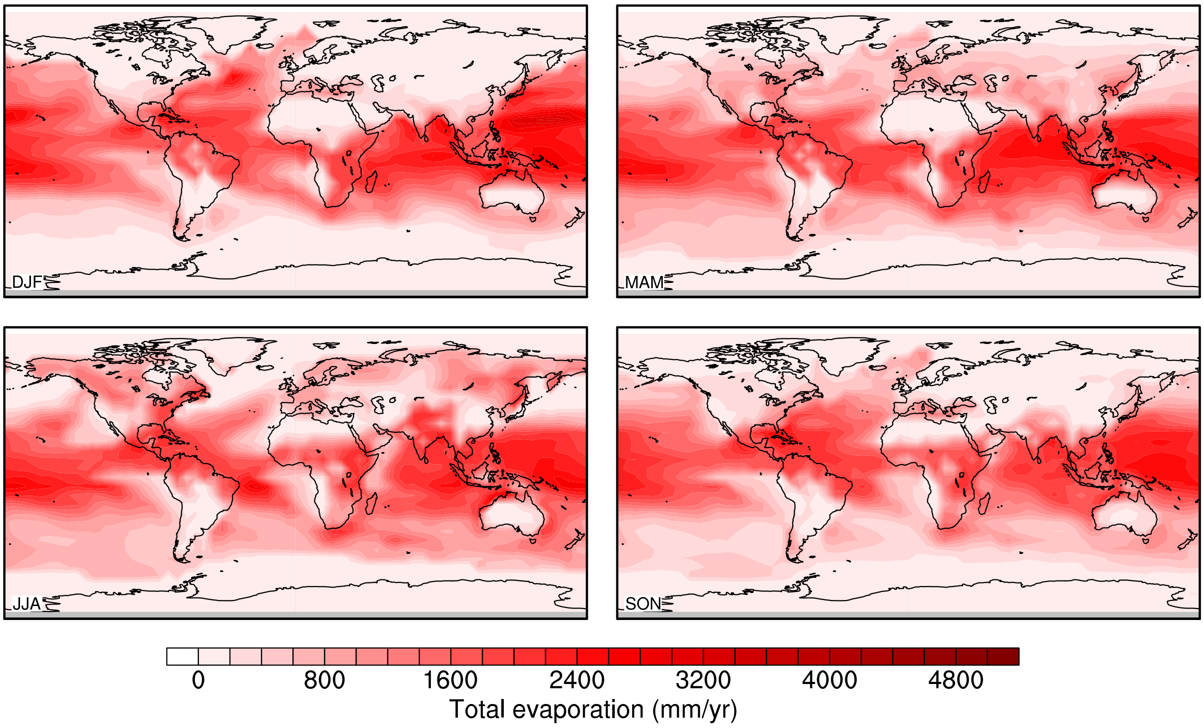

Figure 4: Seasonal evaporation for ECBILT experiment 1.

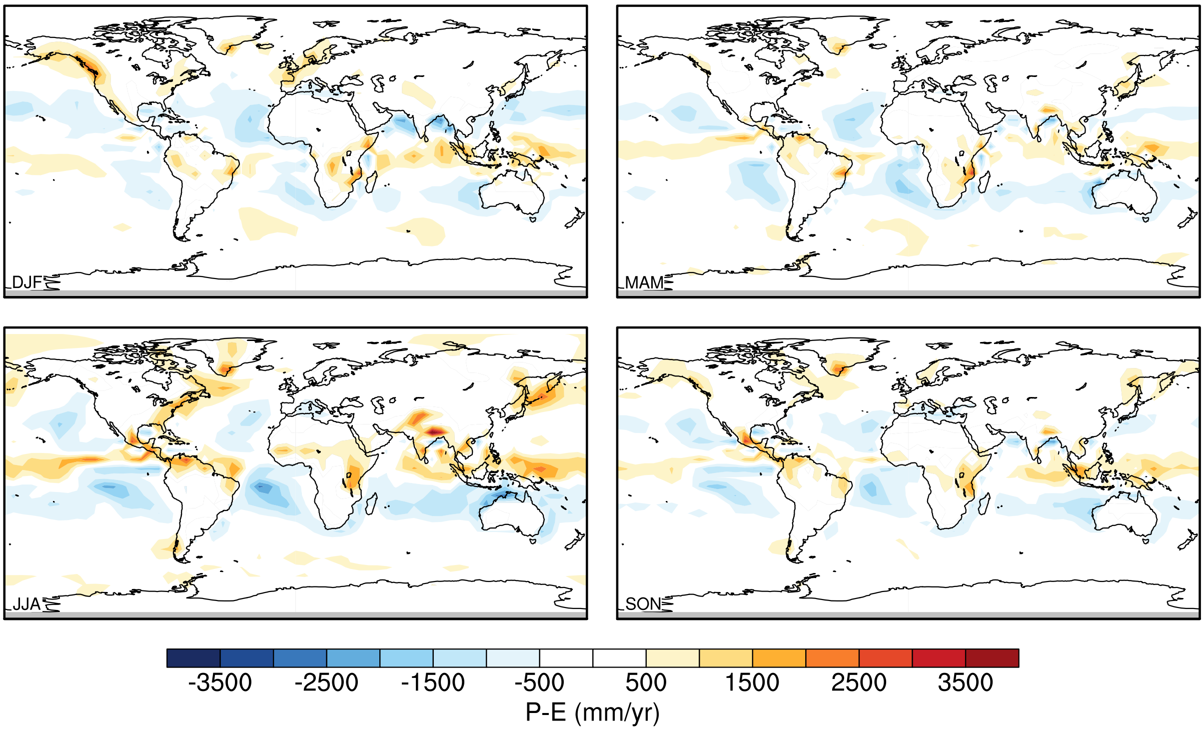

Figure 5: Seasonal precipitation minus evaporation for ECBILT experiment 1.

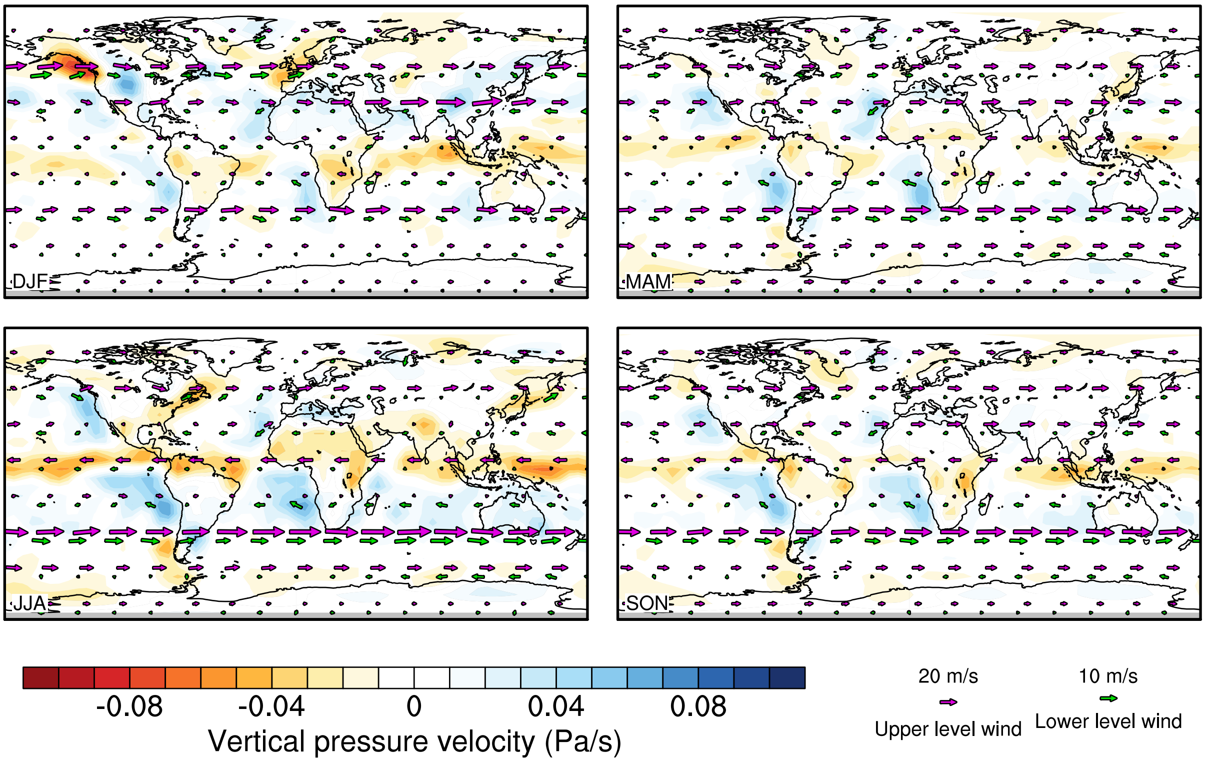

Figure 6: Seasonal circulation plots for ECBILT experiment 1: arrows show upper level and lower level winds, colours show middle atmosphere vertical pressure velocity.

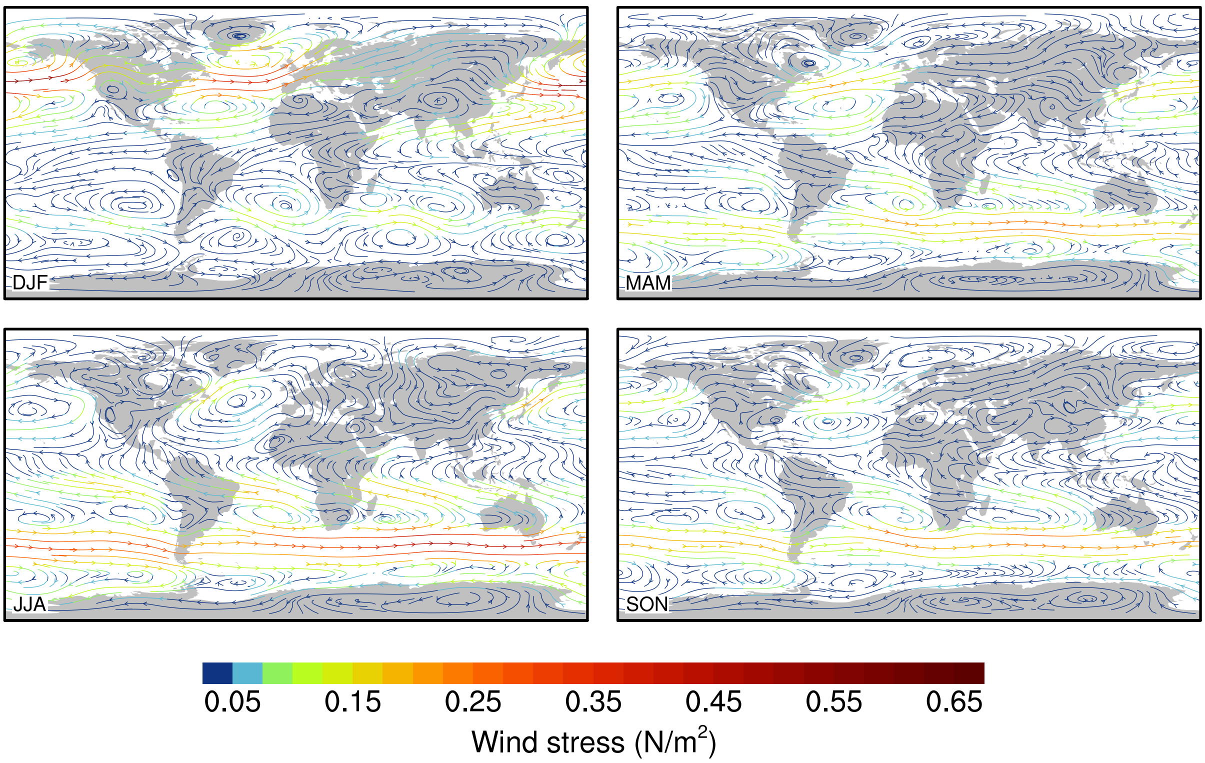

Figure 7: Seasonal surface wind stress plots for ECBILT experiment 1.

4 Experiment #2

- Run name: `expt-2`.
- Original standalone ECBILT code, with only minimal changes for compilation.
- Land/sea mask, orography, SST and sea-ice forcing converted from UM `tcszd` experiment.
- River routing mask converted to new land/sea mask by hand.
- Original ECBILT albedo data: the albedo code uses a simple interpolation scheme based on fixed latitude-dependent values read in at startup for bare-soil, TOA and ocean albedo. This will need to be modified to calculate albedos based on land surface characteristics.
- Simulation length: 100 years; spin-up: 70 years; analysis: 30 years.

4.1 Boundary conditions

- UM land/sea mask regridded to ECBILT grid.
- Dummy ECBILT lake mask – all land/sea contrasts already included in input `mask.dat` file (ECBILT allows you to distinguish between lakes and ocean, but the distinction doesn't make any difference for the atmosphere model).

A ECBILT code changes

All experiments

- Wind stress calculation: incorporation of `cwdrag` drag coefficient for wind stress.

Experiment 3

Experiment 4

B HadAM3 `tcszd` comparison results

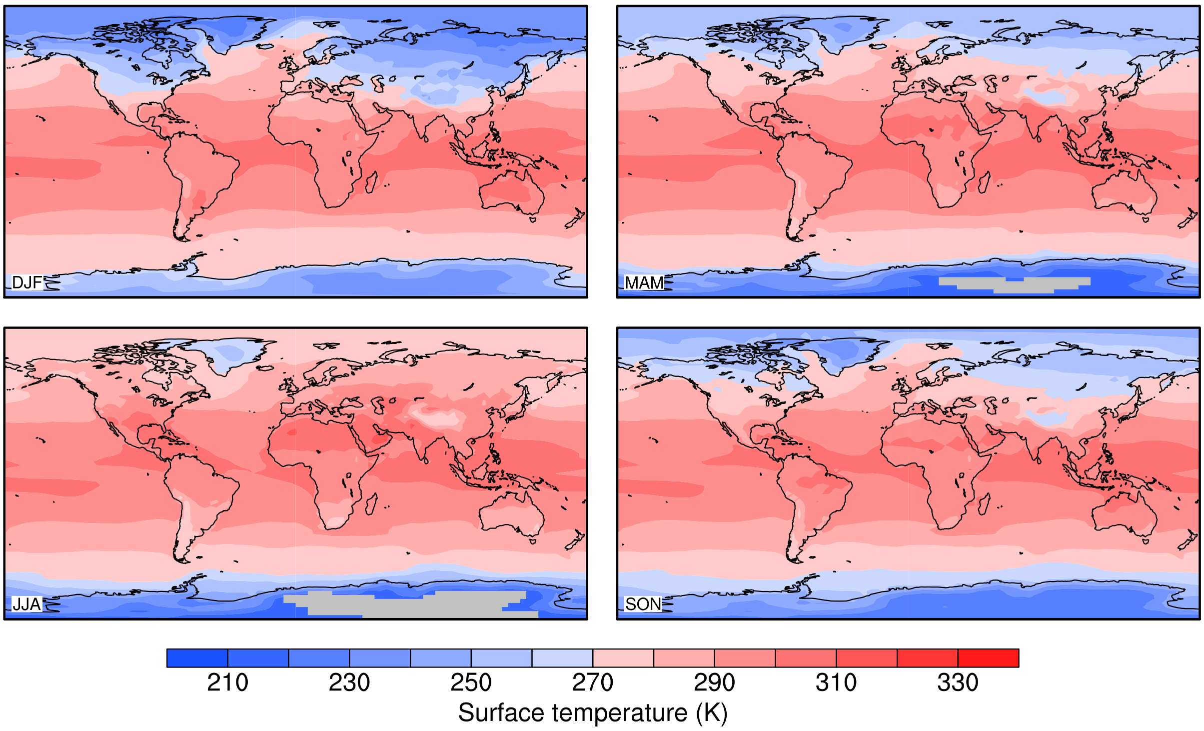

Figure 8: Seasonal surface temperature for HadAM3 `tcszd` comparison simulation.

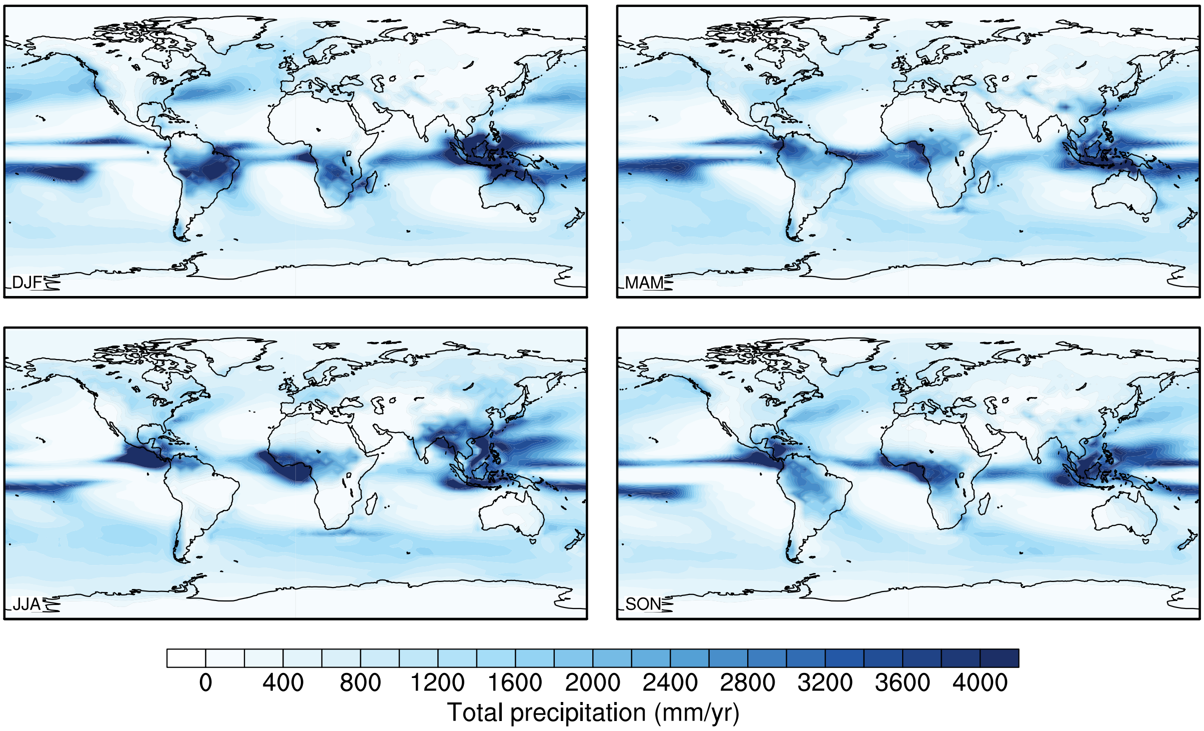

Figure 9: Seasonal precipitation for HadAM3 `tcszd` comparison simulation.

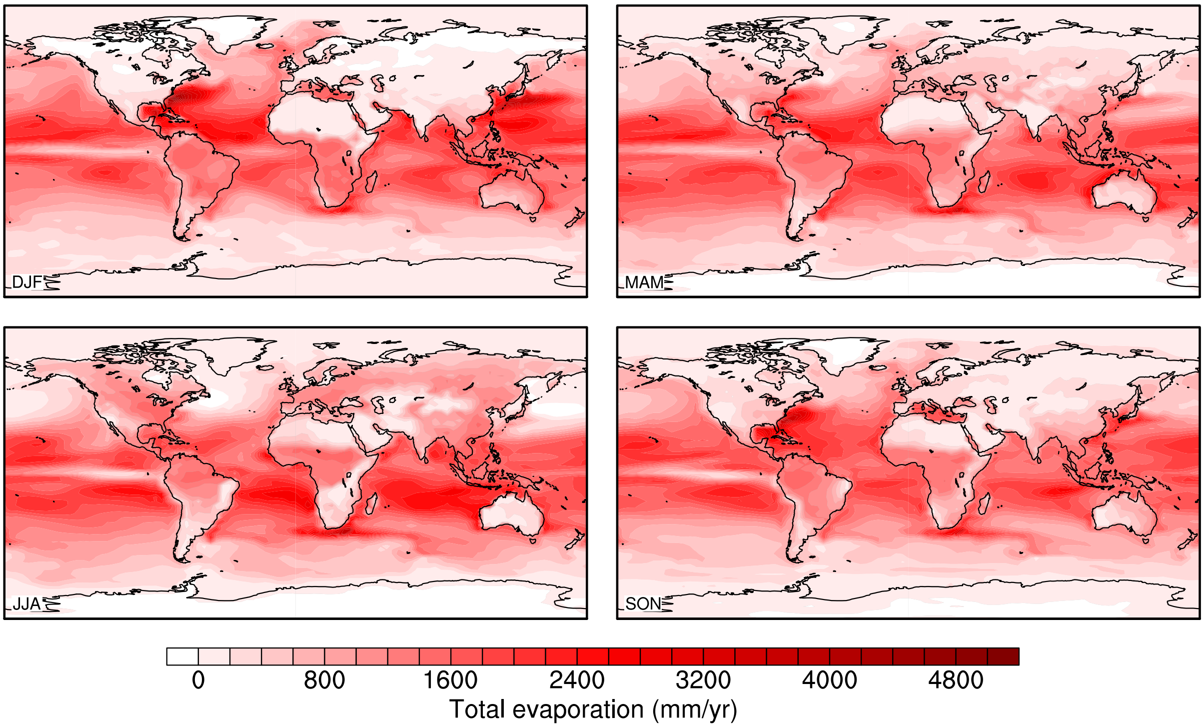

Figure 10: Seasonal evaporation for HadAM3 `tcszd` comparison simulation.

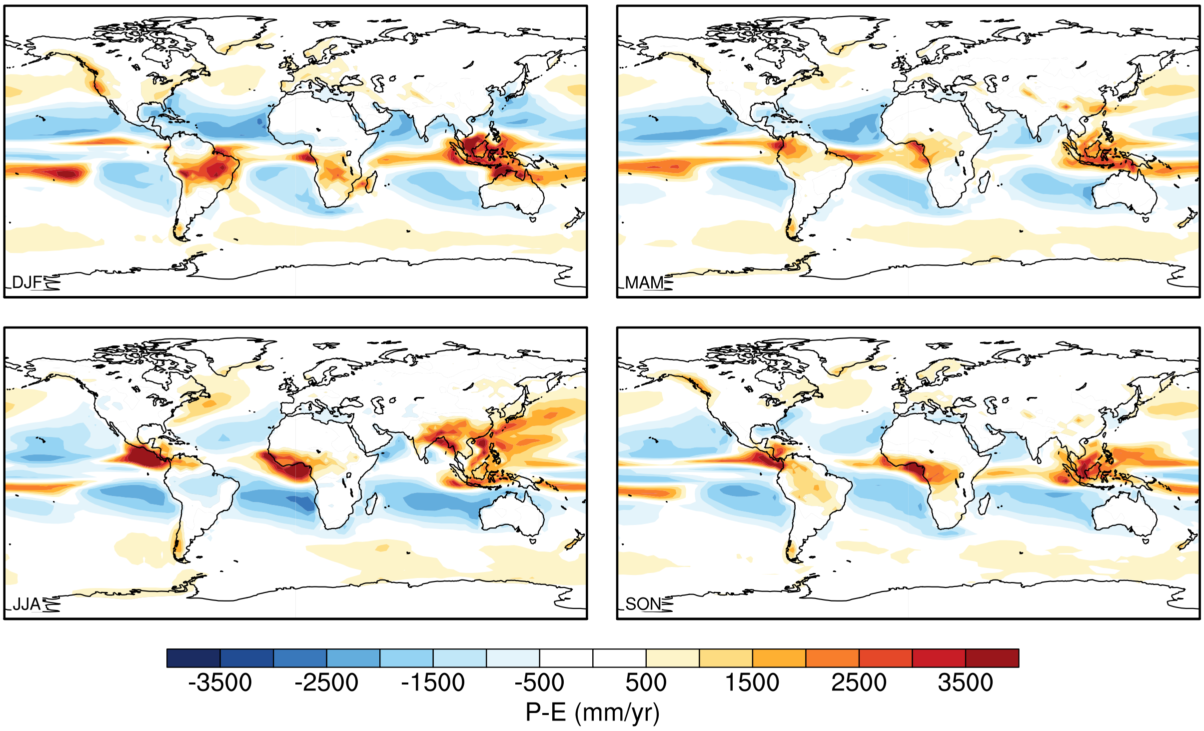

Figure 11: Seasonal precipitation minus evaporation for ECBILT experiment 1.

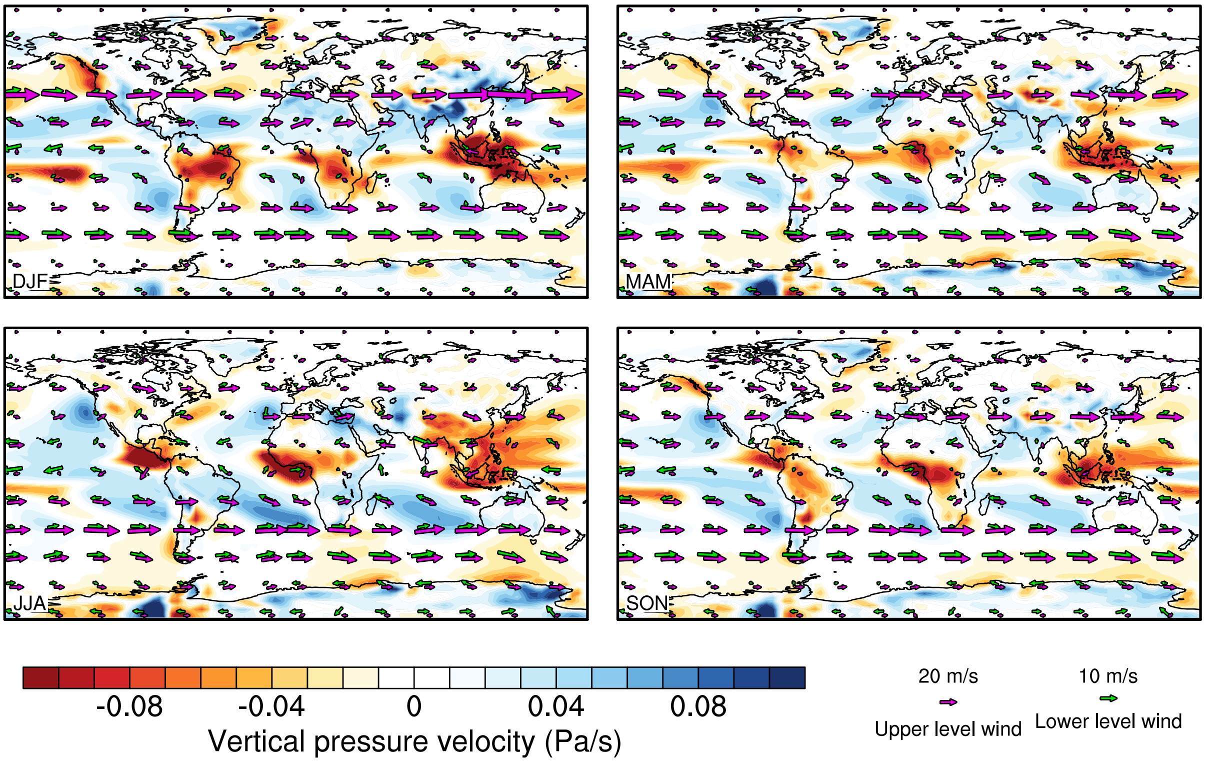

Figure 12: Seasonal circulation plots for HadAM3 `tcszd` comparison simulation: arrows show upper level and lower level winds, colours show middle atmosphere vertical pressure velocity.

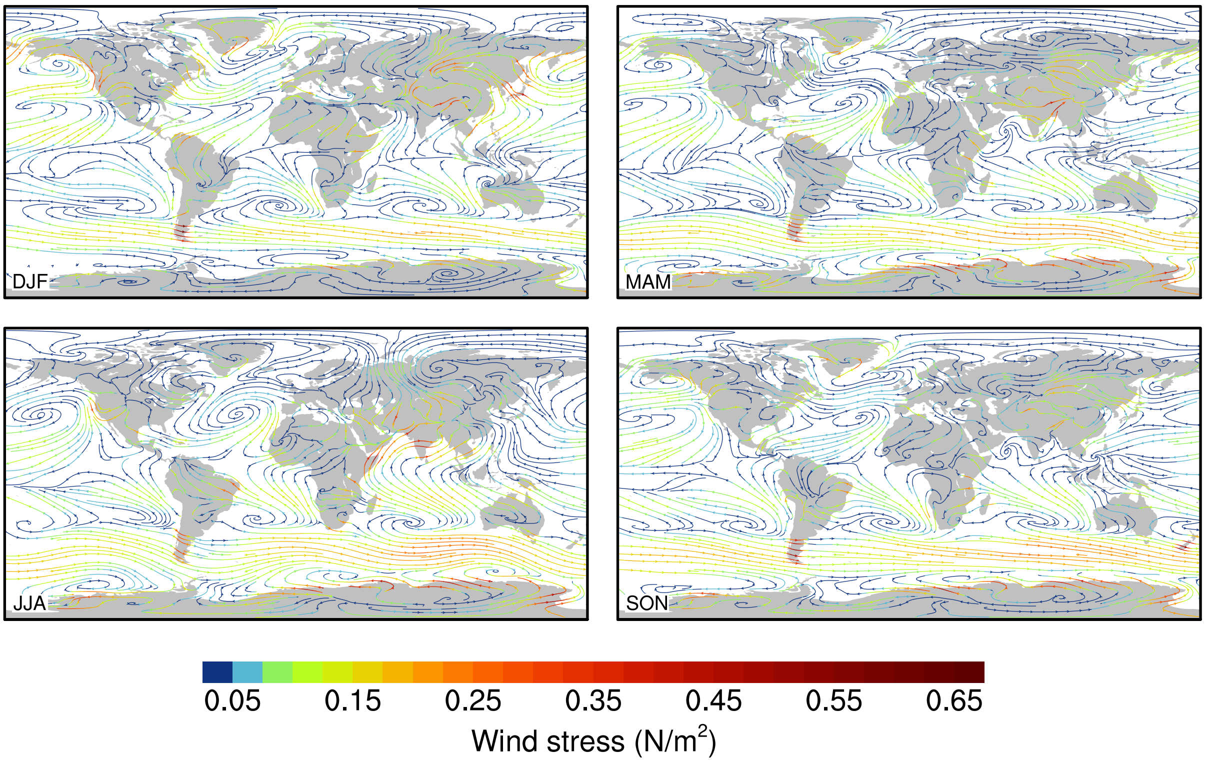

Figure 13: Seasonal surface wind stress plots for HadAM3 `tcszd` comparison simulation.