Description of files for figures and generation of model input data for:

„On the sensitivity of the Devonian climate to continental configuration, vegetation cover, orbital configuration, CO_2 concentration and insolation"

(http://doi.org/10.5880/PIK.2019.002)

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The data are supplementary material to:

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Abstract:

In "On the sensitivity of the Devonian climate to continental configuration, vegetation cover, orbital configuration, CO_2 concentration and insolation" we study the sensitivity of the Devonian (419 to 359 million years ago) to several parameters using a coupled climate model. The data presented here is the model output the results of this manuscript are based on. Additionally, the figures of the publication and scripts (Python and Yorick) to analyse the model output and generate the figures are contained. The model output is provided in different netcdf files. The structure of the model output is explained in a readme file. The data is generated using the coupled ocean-atmosphere model CLIMBER3alpha which models climate globally on a 3.75° x 3.75° (ocean) and 22.5° (longitude) x 7.5° (latitude) (atmosphere) grid. More information about the model can be found in the manuscript.

This Readme contains the description of the files for figures and generation of model input data (Part 1) , the description of model output data (Part 2) and the description of the files for figures of the Supplementary Information (Part 3).

Part 1: Description of files for figures and generation of model input data

Generation of vegetation distribution and continental configuration:

devonian_topography_vegetation.i

function func devn_proc_topo(timeslice=, manualmode=, test1=, test2=)

Calculation of continental temperature:

Sea surface temperature (sst), surface air temperature (ts) and land fraction (frlnd) are given on atmospheric grid

Surface air temperature over continents (ts_cont) can be calculated: ts= ts_cont*frlnd+(1-frlnd)*sst

convert_to_ascii_frlnd_cont.py writes land fraction for each grid cell of the 3 different continental configurations in ModelOutput_p2s_frlnd_….dat file

readoutfile… calculates surface air temperature over continents (annual global mean, averaged over 1000 years)

readoutfileps_tsland	continents.py	continental sensitivity
	vegetation.py	Early, Middle, Late Devonian vegetation and bare, shrubcover, treecover extreme cases
	LeHiralbedo.py	treecover and bare land with albedo values from Le Hir 2011
	bestguess.py	bestguess.py

Figure 1: CO_2 concentration and $\delta^{18}O$ for the Devonian

(CO2_delta18O_Devonian_corrected.pdf)

delta18ODevonian_correcteddata.py

script to generate Fig. 1 (*CO2_delta18O_Devonian_corrected.pdf*)

co2fit.xls

CO_2 data from Foster et al. 2017

419-359 Ma, with LOESS fit and 68% and 95% confidence interval given in the supplementary data

first column: age;

2: fit value;

3&5: lower and upper 95% value;

4&6: lower and upper 68% value

datapointsco2.xlsx

data points from different proxies, given in supplementary material of Foster et al. 2017;

first column: age;

2: upper error bar age;

3: lower error bar age;

4: CO_2;

5: lower error bar CO_2;

6: upper error bar CO_2

Joachimski18oDevonian.xlsx

$\delta^{18}O$ data from Joachimski, personal communication.

$\delta^{18}O$ values from Joachimski et al. 2009, but different NBS120c standard for calibration used (Lecuyer et al. 2003)

first column: age;
2: old data (Joachimski2009);
3: data used in this figure, based on new standard

Figure 2: continental configuration for 3 Devonian time slices (*AllMaps.pdf*)
convert_to_ascii_… files write relevant output variables in .dat files
readoutfilecontinents.py generates maps using the model output written in the .dat files

Figure 3: Schematic representation of vegetation and vegetation maps on grid of original (*DevonianVegetation.pdf*)
DevonianVegetation.pdf
Schematic vegetation sketches generated using inkscape (svg files)
Vegetation maps generated by *devonian_fig3.i*, function devn_plot_veg(timeslice=)

Figure 4: differences between several vegetation runs minus bare land case for different variables relevant to understand influence of vegetation *(Vegetation_Devoniantimes_plus_extremescenarios_1000years.pdf)*
readoutfile_plot_vegminbare_4x5_1000years.py reads relevant output variables for different vegetation runs from model output, based on 1000 years snapshot data (yearly snapshots) saved in snapshots_potsdam2-1000years-yearmean_as_e_qi.nc as well as surface air temperature from 1000 years average in history_p2.nc, and generates the figure based on the data in the .dat files

Figure 5: Annual global mean surface air temperature for different orbital parameters (*devn_temp_orbital.pdf*)
generated by *devonian_fig5.i,* function devn_plot_orbital(season=)

Figure 6: Global mean annual surface air temperature, Arctic temperature and maximum Arctic overturning showing the typical mode of climate variability found in our Devonian simulations *(Modes.pdf)*
convert_to_ascii.py writes relevant output variables in .dat files; the run used has a short time step (1 hour) and does not split ocean timesteps
readoutfilemodesplot.py generates the figure (Modes.pdf) based on the data in the .dat files

Figure 7: Description of feedback loop to explain the mode of climate variability (*modestransition.pdf*); plot inside is generated in the same way as Fig.6 (*Modes_inplot.pdf*)

Figure 8: **Physical properties on the Northern hemisphere for different modes and transition between them** *(4modes.pdf)*
convert_to_ascii.py writes relevant output variables in .dat files; the run used has a short time step (1 hour) and does not split ocean timesteps
readoutfilemom.py generates the figure (*4modes.pdf*) based on the data in the .dat files

Figure 9: Northern part of the global overturning stream function between depths of 780m and 3500m, warm and cold mode *(GLB_OVER.pdf)*
convert_to_ascii.py writes global overturning in *ModelOutput_momh_24p5_3600s.dat* files; the run used has a short time step (1 hour) and does not split ocean timesteps

readoutfile_streamfunction.py generates the figure (*GLB_OVER.pdf*) based on the data in the .dat files

Figure 10: Surface air temperature maps and sea surface temperature maps with ocean surface velocities of best-guess simulations for Early, Middle and Late Devonian *(Bestguess_maps_withsst.eps)*

convert_to_ascii_p2history.py writes annual mean surface air temperature in .dat files
convert_to_ascii_isis.py writes annual mean ice fraction in .dat files
convert_to_ascii_temp.py writes ocean surface temperature and surface velocity in .dat files
readoutfile_withtemp.py generates the figure (*Bestguess_maps_withsst.eps*) based on the data in the .dat files

Figure 11: Contribution to temperature change between Early and Late Devonian simulation caused by different boundary conditions

generated by *devonian_fig10.i*, func devn_plot_sens

Figure 12: **Modeled and reconstructed (Joachimski et al. 2009) sea surface temperatures in the tropics** (*SST_Devonian_correcteddata_withfit.pdf*)
tempDevonianwithfit_correcteddata.py

black dots: modeled temperatures, annual average between 30 and 10°S; error bars indicate temperature range from 30 to 10°S
red and blue crosses: temperature estimates from δ^{18}O data (Joachimski et al. 2009), using different calibration standards

tempJoachimski2009withfit.xlsx

temperature data from Joachimski et al. 2009
Column 1: age,
2: δ^{18}O,
3: temperature;
other columns are Loess fit with uncertainties which we do not use here

tempJoachimskicorrected.xlsx

temperature data from Joachimski et al. 2009, personal communication, using a different calibration standard than in 2009 (Lecuyer et al. 2003) and a different temperature equation (Lecuyer et al. 2013) in column 3, different one (Pucéat et al. 2010) which is not shown in our plot in column 4.
Column 1: time
Column 2: δ^{18}O
The LOESS fits shown in the plot are created with Python and therefore differ slightly from the one in Joachimski et al. 2009

Part 2: Description of model output data

Each run's name gives all relevant information about the parameter setting:

for example:
c3beta_devn_380Ma_1500ppm_1319Wm2_O23p5_E0p000_P000_bare

c3beta	model version
devn	period in Earth history (Devonian)
380Ma	continental configuration
1500ppm	CO_2 concentration
1319Wm2	solar constant
O23p5	obliquity in degree
E0p000	eccentricity
P000	precession in degree
bare	vegetation cover

The sensitivity runs for the different variables are in the corresponding folder:

bestguess
co2
continents
flips
orbital
solarconstant
vegetation

c3beta_devn_380Ma_1500ppm_1319Wm2_O23p5_E0p000_P000_bare
is the Middle Devonian standard run which is used for comparison in most of the sensitivity runs

In the vegetation folder:
c3beta_devn_380Ma_1500ppm_1319Wm2_O23p5_E0p000_P000_…

different Devonian vegetation distributions:
earlydevveg
middledevveg
latedevveg

extreme scenarios: covering all continents with bare land, shrub, trees:
bare
shrubcover
treecover

using the albedo values of Le Hir et al. 2011 for bare land and tree-covered continents:
LeHir_albedo_bare
LeHir_albedo_treecover

In the flips folder:
c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare
standard run, with ifort15 compiler, timestep 12 hours, strong variability found

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_timestep0p25
test influence of 6 hour timestep

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_3600s
shorter time step 1 hour, this is the run our evaluation in Chapter 4 is based on

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort15_rconvect_restartmittel3502

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort15_rconvect_restartmittel3602
test of influence of different convection scheme and restart from different times of standard run

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort17_newstart
new start with different compiler: ifort17

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort17_restartgross3402
restart from standard run, changing the compiler at t=3402 on a large fluctuation

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort17_restartklein3202
restart from standard run, changing the compiler at t=3202 on a small fluctuation

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_ifort17_restartmittel4602
restart from standard run, changing the compiler at t=3202 on a medium fluctuation

c3beta_devn_380Ma_1500ppm_1319Wm2_O24p5_E0p069_P315_bare_snapshots
standard run with snapshots saved in a 10-year interval starting after 4000 years to 6000 years

Model output:
Most relevant files:

snapshots contain monthly values of the variables for the model year given in the name

Ocean model data:	snapshots.00….01.01.dta.nc
	overturn.00….01.01.dta.nc
Atmosphere model data:	snapshots_potsdam2.00….01.01.dta.nc
Ice model data:	snapshots_isis.00….01.01.dta.nc

for some model runs, files containing selected snapshots variables for 1000 years were generated:
snapshots_potsdam2-1000years-yearmean_….nc (atmosphere) and
snapshots-1000years-yearmean_….nc (ocean)

history files contain yearly values of the variables for each model year the simulation was run

Ocean model data:	history.nc
Atmosphere model data:	history_potsdam2.nc
Ice model data:	history_isis.nc

topog.dta.nc contains information about topography and cells

Part 3: Description of files for figures in Supplementary Information

Figure S1: Difference in surface air temperature for different continental configuration *(Continent_maps_diff.pdf)*

> *convert_to_ascii_p2history.py* file writes tsann in ModelOutput_p2h_.…dat files for each continental configuration
> readoutfilediff.py generates surface air temperature difference maps using the model output written in the .dat files

Figure S2: Sea surface temperatures and ocean surface velocities for different continental configuration (*Continents_maps_sstuv*)

> *convert_to_ascii_temp.py* file writes relevant output variables in ModelOutput_momh_… _continents.datfiles for each continental configuration
>
> *readoutfile_withtemp.py* generates maps using the model output written in the .dat files

Figure S3: Difference in surface air temperature for different solar constants *(Solar_maps_diff.pdf)*

> *convert_to_ascii_p2history.py* file writes tsann in ModelOutput_p2h_.…dat files for each solar constant
> readoutfilediff.py generates surface air temperature difference maps using the model output written in the .dat files

Figure S4: Difference in surface air temperature for different CO2 concentration *(CO2_maps_diff.pdf)*

> *convert_to_ascii_p2history.py* file writes tsann in ModelOutput_p2h_.…dat files for each CO2 concentration
> readoutfilediff.py generates surface air temperature difference maps using the model output written in the .dat files

Figure S5: Difference in cloud cover for different vegetation cover (additional information to Fig.4 in the main part) (*Vegetation_Devoniantimes_clouds_1000years.pdf*)

> readoutfileps_plot_vegminbare _4x5_1000years.py uses model output for total cloud cover (1000 years from yearly snapshots) to generate difference maps of total cloud cover for different vegetation cover

Figure S6: Difference in surface air temperature for different albedo for bare land and tree (*Albedo_maps_diff.pdf)*

> *convert_to_ascii_p2history.py* file writes tsann in ModelOutput_p2h_.…dat files for each albedo used constant
> readoutfilediff.py generates surface air temperature difference maps using the model output written in the .dat files

Figure S7: Difference of evaporation minus precipitation for our standard model run (380Ma, 1500ppm, 1319 W/m^2, median orbit, bare land) (*eminp_maps_diff.pdf*)

> *convert_to_ascii_p2history.py* file writes annual evaportion and precipitation in ModelOutput_p2h_.dat file
> readoutfilediff.py generates difference map using the model output written in the .dat files

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