Dynamic downscaling of climate change projections of ocean dynamics and biogeochemistry for the Australian region

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1. INTRODUCTION

Global Climate Models (GCMs) are our most effective tool for projecting the response of our environment to rising greenhouse gases in the atmosphere. However, due to the complexity of these global climate models they are formulated at relatively low spatial resolution (e.g., typically between 1 and 2 degrees). Therefore, they do not provide sufficient spatial resolution to make useful regional climate change projections. Further, these GCMs fail to capture important features of ocean circulation (e.g. boundary currents and mesoscale eddies) that are important to how climate change will impact marine systems.

To produce regional climate change projections, it is necessary to apply downscaling techniques to the GCM output. In the case of the atmosphere, Regional Atmospheric Models (RAMs) have a long history of being used to dynamically downscale global weather predictions to provide regional scale predictions (e.g. Lo et al., 2008) and now these dynamical downscaling techniques are being modified and applied to make regional climate change projections (Wang et al., 2004). Although dynamical downscaling of GCMs using RAMs is common (Laprise et al., 2008) there are few examples of dynamical downscaling of climate change projections for the ocean environment. The few published studies have focused on small regional seas like the Baltic and North Seas (Adlandsvik 2008; Meier 2006). Our dynamical downscaling effort is much more ambitious in that we will provide downscaled climate change projections for the entire Australian region for both physical and biogeochemical fields (i.e. Nitrate, Phytoplankton, Zooplankton and Detritus). We take this approach because in the Australian region we know changes in boundary currents, like the Leeuwin Current, with climate change will have a large impact on the ocean's environment. However, to faithfully capture the dynamics of the Leeuwin Current requires a model domain that encompasses a large portion of the oceans surrounding Australia (Ridgway and Condie, 2004). Further, changes in the biogeochemical fields provide information on how the ocean productivity will change with climate change, which is an important driver to how climate change will impact fisheries. The advantage of our approach is that it will obtain downscaled results for the entire Australian region for both physical and biogeochemical fields, but the task will be computationally demanding, which will limit the number of different climate change projections we will downscale. We see our downscaling simulations as being essential to assessing the impacts of climate change on the ocean's environment, and to aiding our ability to sustainably manage our marine environment and resources in the future.

The rest of the report describes how we downscale GCM projections to provide regional information on the impact of climate change on the ocean environment around Australia. In the following sections, we first describe the model used for the downscaling. Second, we describe how we use the future state of the ocean under climate change projections to initialise the downscaling simulation. Third, we present how we use the future climate to drive our downscaling ocean model. Fourth, we provide a short summary of how we carried out the simulations to produce our downscaled climate change projections for the Australian region.

2. CLIMATE DOWNSCALING

2.1 Description of the Downscaling Model

The downscaled ocean model used in this work is the Ocean Forecasting Australia Model (OFAM) that includes a biogeochemical module. OFAM is based on Modular Ocean Model, version 4.0, from the GFDL (Griffies et al. 2004). OFAM is set-up to run on a global grid with variable spatial resolution. The model is eddy resolving in the Australian region (0.1° of longitude and latitude around Australia) with much coarser resolution outside this region (Figure 1).

The biogeochemical module, based on Oschlies and Schartau (2005), was added to OFAM to simulate the dynamics of Nitrate-Phytoplankton-Zooplankton-Detritus in the ocean (Dietze et al 2008). In addition, a shelf tracer was included in the BGC module to track the transport of shelf water into the ocean. The shelf tracer is relaxed to a value of 1.0 with a time constant of 3 hours in regions where the ocean depth is less than 200 m.

This ocean model has been applied to a number of problems. It provides the ocean model for the Bluelink Ocean Data Assimilation System, which is used to make 10-day forecasts of the ocean state (Oke et al. 2005). The model was also used to derive the ocean state around Australia over the last decade (Bluelink Reanalysis, BRAN) (Oke et al. 2008). Dietze et al. 2008 used simulations of the BGC module to explore the dynamics of anti-cyclonic eddies off Western Australia.

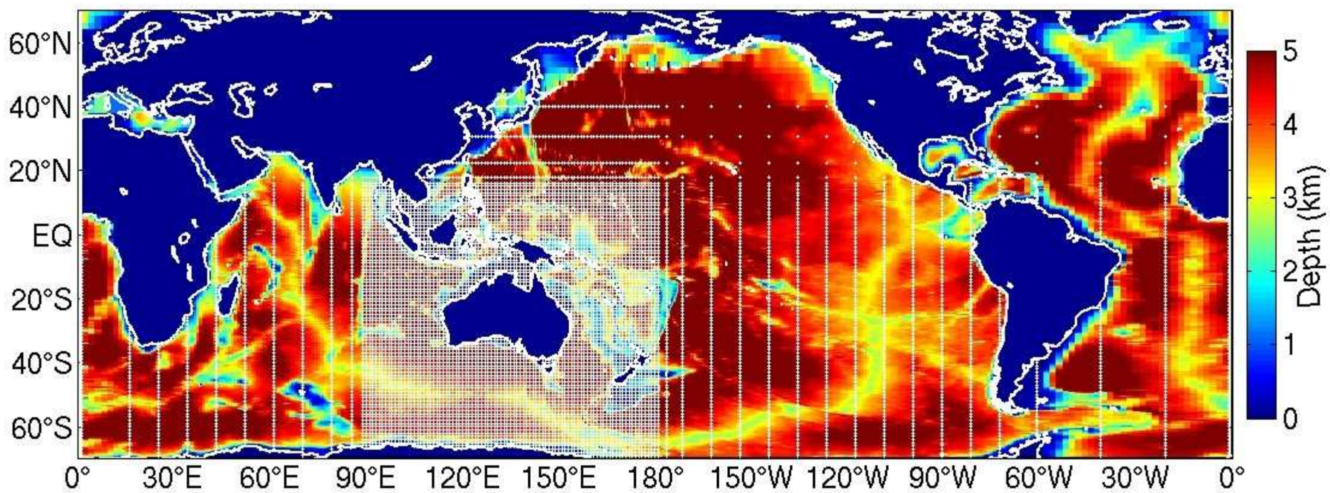

Figure 1 The Ocean Forecasting Australia Model (OFAM) grid and bathymetry, showing the variable spatial resolution over the globe with the highest resolution around Australia. Only every 10th grid point is shown.

2.2 Description of the Climate Projections Used

Many climate models are being used to project the impact of rising greenhouse gases in the atmosphere on our future climate. The recent Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC) (Solomon 2007) has drawn on results from these climate models simulations to assess the impact of climate change. To dynamically downscale AR4 climate change projections, we will use the future state of the ocean (e.g. Temperature, Salinity and Nitrate) and the future climate (i.e. air-sea fluxes of heat, fresh water and of stresses at the ocean surface) provided by global climate model projections. For downscaling the climate change projections, we have access to only monthly mean climate and monthly mean ocean state information.

This report describes how we downscaled two climate model projections from CSIRO Mk3.5 A2 and A1B scenarios (Gordon et al. 2002) for the years 2061 and onward. However, the approach we take is applicable to any year of the climate model projections available on the AR4 website. Presently, a study is being done to assess, which AR4 climate model projections are most appropriate for downscaling in the Australian region (Sun et al., 2008 in prep). For the biogeochemical fields, we use an off-line simulation of the CSIRO Mk3.5 climate model with the same BGC module as the OFAM-BGC simulation to project the future impact of climate change on the marine biogeochemical cycling (Matear et al in prep). Note, a switch to another climate model projection will require an additional off-line simulation of the NPZD model (e.g. as done with the CSIRO Mk3.5 A2 scenario) to enable downscaling of the biochemical fields.

The two experiments used similar techniques to create a future climate, which is the current climate superimposed with climate anomaly from the climate model, to mitigate climate model drifts and biases, while retaining climate change signals. The major differences between the two runs, besides the fact that climate anomaly are taken from two different scenarios, are the way “current climate” is defined and used. In the A2 downscaling run (hereafter “EXP-A2), the current climate is the 6-hourly ERA40 reanalysis field in 1995; while in the A1B downscaling run (hereafter as “EXP-A1B), it is the monthly climatology (keeping 6-hourly diurnal cycle) of ERA40 reanalysis over 10 years from 1990 to 1999. The idea is to educate ourselves about climate downscaling and learn how to interpret the results. EXP-A2 introduced daily variability to climate model projections by assuming that the daily variability from the current climate stays the same in the future. EXP-A1B seeks to understand the response to future climate under the mean climate, by taking 10-year climatology from ERA40 superimposed with monthly climate anomaly. Both experiments have helped us understanding the downscaling process and building capacity for better experiments to be designed and performed in the near future under this project.

3. GENERATING THE INITIAL CONDITIONS

The initial conditions describe the future state of the oceans' physical and biogeochemical fields at the starting time of the downscaled climate change simulation. The initial conditions for the downscaled simulation were generated by combining the present-day ocean state with the anomaly in the ocean state simulated by the climate change projection.

The initial conditions needed to perform the downscaled climate change simulation are contained in twelve restart files summarized in Table 1. This table lists the variables in each of these restart files, how the files were generated, and how the information is passed to the OFAM-BGC code. All the restart files required for the climate downscaling simulation are generated by running the script **make_ic.csh**. These directories also contains all the scripts used by **make_ic.csh** to create the restart files.

3.1 SRESA2 downscaling experiment (EXP-A2)

We use January 1, 1995 from the SPINUP5 simulation to set the present-day physical state of the ocean in our downscaling simulations. This state was generated by initialising the ocean with a blend of Australian and global climatology (Ridgway et al. 2002 and Levitus 2002). OFAM was then forced with heat fluxes, fresh water fluxes and surface stresses from the ERA-40 re-analysis (Upalla et al 2005) and relaxed at the surface to observed daily sea surface temperatures (Reynolds and Smith, 1994) and annual mean sea surface salinities (Levitus 2002) with a time-scale of 30 days. The spin-up simulation was run over years 1991 to 2004 (called SPINUP4), and then restarted in 1993 and ran to the end of 1997 (called SPINUP5) from which we used the results from year 1995 to describe the present day conditions.

For the present-day state of the biogeochemical fields we use January 1, 1995 from the spin-up of the OFAM-BGC model. For the OFAM-BGC spin-up, we initialised the physical fields using 1 January, 1993 from SPINUP5. The biogeochemical fields were initialised as follows. Nitrate was initialised to Levitus (2002) annual nitrate field. Phytoplankton in the upper 100 m was set to the SeaWifs annual mean chlorophyll a using a mg –Chla/m^3 to mMol N/m^3 conversion of (50/12*16/106) and zero below this depth. Zooplankton and detritus were initially set to zero. The shelf tracer was sent to one at all depths where the ocean was shallower than 200 m and zero everywhere else. We ran OFAM-BGC spin-up simulation over the years 1993 to 1995 using the same ERA-40 forcing fields as used in SPINUP5 but we used the diagnosed heat and freshwater fluxes associated with relaxation instead of relaxing to surface temperature and salinity. For the heat fluxes, the diagnose heat fluxes are based on the daily fluxes from years 1993 to 1995. For the freshwater fluxes, we used the daily mean diagnosed fluxes computed from years 1993-1997 of SPINUP5. A two year simulation of the OFAM-BGC model is all that is need to allow the upper ocean biogeochemical fields to adjust to the ocean circulation. We use the January 1, 1995 of the OFAM-BGC simulation to set the present-day state of the biogeochemical fields used in our downscaling simulations.

The anomaly in the ocean state from the climate change projection is computed as the difference in ocean state between the climate change projection and the averaged ocean state of the climate model. The average state is defined as the average condition in December from 1990 to 1999. For the downscaling simulation starting in 2061, the anomaly is simply the ocean state in December 2060 minus the average state. The anomaly is computed for both physical and biochemical fields on the Mk3.5 grid and then mapped to the OFAM grid, filling missing points with the nearest neighbours of the Mk3.5 grid.

3.2 SRESA1B downscaling experiment (EXP-A1B)

The initial condition in EXP-A1B was generated slightly differently from EXP-A2. The biogeochemical initial state is the same as in EXP-A2, while the physical initial state is the sum of current climate December climatology (10-year average from 1990 to 1999) and the December climate anomaly from the SRESA1B.

Filename	Variable(s)	Modified ?	Source of variable in downscaled climate model	Input control in OFAM
`ocean_temp_salt.res.nc`	temp, salt	Y	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B) plus climate anomaly	**`field_table`**
`ocean_density.res.nc`	rho_taum1	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_velocity.res.nc`	u, v	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_velocity_advection.res.nc`	advectionu, advectionv	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_sbc.res.nc`	t_surf, s_surf, u_surf, v_surf, sea_lev, frazil	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_freesurf.res.nc`	eta_t, convud, eta_t_bar, eta_u, ud, vd	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_frazil.res.nc`	frazil	N	SPINUP5 (EXP-A2) or SPINUP4_5 (EXP-A1B)	hard coded
`ocean_solo.res`	time and calendar information	Y	Written by **`make_ic.csh`**	hard coded
`ocean_tracer.res`	temp, salt, no3, phy, zoo, det, o2 checksums.	N	OFAM-BGC.	hard coded
`ocean_no3_phy.res.nc`	no3, phy	Y	OFAM-BGC with climate anomaly	**`field_table`**
`ocean_zoo_det.res.nc`	zoo, det	Y	OFAM-BGC with climate anomaly	**`field_table`**
`ocean_o2_dummy.res.nc`	o2 (proxy for shelf tracer)	Y	Reset to 1.0 over shelf, 0.0 elsewhere.	**`field_table`**

Table 1 Restart files used for the OFAM-BGC downscaling simulation with a summary of the modifications made to these files for climate downscaling.

4. GENERATING THE FORCING FIELDS

The downscaled climate projection used the forcing fields in the same way as both the OFAM SPINUP5 and OFAM-BGC simulations. However, the forcing fields for the downscaled climate change simulation are now a combination of the forcing fields from ERA-40, the diagnosed restoring fluxes from SPINUP4 and/or SPINUP5, and the monthly climate anomaly forcing fields derived from the climate change simulation. The six forcing fields used to drive the downscale climate projection are listed in Table 2 with a brief summary of how they were generated. Below is a general description of the approach used to generate these forcing fields. The script **make_force.csh** generates all the forcing fields, which is located in **cherax:~cha526/ofam_2060_mk35_A2/forcing**. The scripts used by **make_force.csh** are also found in this directory. One script in this directory, **make_restore.csh**, which generates the diagnosed restoring fluxes, needs to be run on **`curl.hba.marine.csiro.au`**, where the SPINUP4_5 fields are stored, **/home/blue1/fie048/SPINUP5/force.** The output from **make_restore.csh**, is then transferred to **cherax:/ofam_2060_mk35_A2/forcing/downscale/restore/** where it is used to build the heat and freshwater flux fields for the climate downscaling simulation.

4.1 SRES A2 downcaling forcing

The 6-hourly ERA-40 forcing fields come from year 1995. The diagnosed daily restoring heat fluxes come from year 1995 of the SPINUP5. The diagnosed daily restoring freshwater fluxes are computed from the averaged daily fluxes from years 1993 to 1997 of SPINUP5. The diagnosed heat fluxes are the same as what is used for year 1995 of the OFAM-BGC spinup. The diagnosed heat and freshwater fluxes are re-interpolated on to the spatial and temporal grid of the ERA-40 forcing fields (6 hourly, 2.5 degree latitude/longitude). Using the forcing fields from the climate change projection, the monthly climate anomaly forcing fields are computed as the difference between the monthly forcing field in the year of the downscaling simulation and the monthly climatology (defined as the monthly fields averaged over years 1990 - 1999). By using anomaly fields to force our downscaled simulation, we reduce any systematic biases that may exist in our climate model projection due to the coarse resolution of the model. This monthly climate anomaly field is then interpolated onto the spatial and temporal grid of the ERA-40 forcing fields. We then compute the new forcing fields on the ERA-40 grid as follows:

$$Force_{2060\_applied} = Force_{1995}^{ECMWF} + Force_{diagnosed}^{OFAM\_SPINUP5} + (Force_{2060}^{climate\_model} - \overline{Force_{1990s}^{climate\_model}})$$

As summarised in Table 2, not every term in the above equation is used for each forcing field. For the surface stresses, there is no diagnosed flux term. For sensible heat, evaporation and solar radiation fluxes both the diagnosed and climate anomaly terms are zero. The climate anomaly fluxes and diagnosed fluxes are only applied to the thermal radiation flux and precipitation flux terms. This assumes all the changes in the heat and freshwater fluxes projected by the climate model simulation occur to the thermal radiation and precipitation fluxes, respectively. Within the model, only the changes in net surface heat flux and freshwater flux are relevant, which is why the anomalies do not need to be added all flux components. The one heat flux that is unique is solar radiation which can penetrate into the ocean and, for this simulation, this is assumed to be the same in the future.

4.2 A1B downscaling experiment

The climatological ERA-40 monthly forcing fields (including 6-hourly diurnal cycle) are computed from 1990 to 1999. The diagnosed monthly restoring heat fluxes, freshwater fluxes come from monthly climatology of the SPINUP4_5. The monthly climate anomaly forcing fields are computed in the same way as in the EXP-A2 experiment. We then compute the new forcing fields on the ERA-40 grid as follows:

$$\mathrm{Force}_{\mathrm{2060\_applied}} = \mathrm{Force}^{\mathrm{ECMWF}}_{\mathrm{1990s}} + \mathrm{Force}^{\mathrm{OFAM\_SPINUP4\_5}}_{\mathrm{diagnosed}} + (\mathrm{Force}^{\mathrm{climate\_model}}_{2060} - \mathrm{Force}^{\mathrm{climate\_model}}_{\overline{\mathrm{1990s}}})$$

Where the 10-year monthly climatology of ERA40 over 1990-1999 is used as the base climate, and diagnosed monthly climatology from SPINUP4_5 is used as additional forcing term. The reason for this choice is to use the ten-year time mean of the current climate instead of a single year as the base climate, to remove the potential bias in the climate model, and make it easier to interpret the experiment results.

Forcing Field	EXP-A2 Forcing Sources	EXP-A1B Forcing Sources
evaporation.nc	1995 ERA-40.	1990s ERA40 climatology
EW_surf_stress.nc, and , **NS_surf_stress.nc**	1995 ERA-40 plus the climate anomaly.	1990s ERA40 climatology plus the climate anomaly.
surf_sensible_heat_flux.nc	1995 ERA-40.	1990s ERA40 climatology.
surf_solar_rad.nc	1995 ERA-40.	1990s ERA40 climatology.
surf_thermal_rad.nc	1995 ERA-40, plus the climate anomaly, and the diagnosed daily heat restoring term from SPINUP5 for year 1995	1990s ERA40 climatology, plus the climate anomaly, and the diagnosed monthly climatology of heat restoring term from SPINUP4_5.
total_precip.nc	1995 ERA-40, plus the climate anomaly, and the diagnosed daily fresh water restoring term from SPINUP5 as a daily average for years 1993 to 1997.	1990s ERA40 climatology, plus the climate anomaly, and the diagnosed monthly climatology of heat restoring term from SPINUP4_5.

Table 2. Forcing files used for the downscaled model simulation, along with a brief summary of the make up of these forcing fields. The file **data_table** controls the filenames and variables of the forcing files which are fed into OFAM-BGC. The time axes of all these forcing fields need to be modified to reflect the year of the climate downscaling simulation.

5. RUNNING OF THE DOWNSCALED MODEL

This section describes the running of the downscaled model simulation. The procedure is essentially the same as that used for the OFAM-BGC spinup, only the initial condition files (Table 1) and forcing files (Table 2) are modified. The downscaled climate projection model simulations are run at the High Performance Computing and Communication Centre (HPCCC), using the NEC SX-6 supercomputer. While the execution of the model is on the SX-6, the data is ultimately migrated, merged and stored on the Altix computer '**`cherax`**.' There is a single script file, **batch_wamsi.csh**, that handles all the necessary commands to continually run the model. The steps that make up this batch file are described in Table 3.

Table 3 describes the sequence of commands called by **batch_wamsi.csh**, and summarizes what these commands do. The script **batch_wamsi.csh** can be run repetitively to continue the model integration and the output will be added to the home drive of **cherax**. This batch file and the scripts it calls are all located in the directory **~cha526/mom4/exp/wamsi/**. Most of the scripts called are submitted to the SX-6, and the batch file waits for the script to be completed before executing the next script file. 'Lock' files are used to ensure only a single batch process is executing at any one time, and that the batch file only continues to execute if the previous script exited cleanly.

In the initial conditions for the downscaling simulation, only the temperature and salinity fields are modified, which results in velocity and density fields that are not dynamically consistent with these fields. To allow the system to reach a dynamical balance the OFAM is first run with a reduced time step (360 s instead of 720 s) for 5 days to allow the velocity and density fields to adjust to the new temperature and salinity fields. The reduced time-step is needed to overcome this shock to the system and prevent numerical instabilities from crashing the model. This is done by editing **run_norelax** and changing the values of **days = 15** to **5**, and **dt_ocean = 720** to **360**. The script **batch_wamsi.csh** is then executed. After one run of **batch_wamsi.csh t**hese values in **run_norelax** must be changed back to their original values (15 and 720).

In the downscale climate change simulation both the initial physical and biogeochemical fields are out of equilibrium with the new forcing fields. To allow the system to reach quasi-equilibrium we will run the simulation for at least 3 years (2061 to 2063) and only consider results from the third and subsequent years as useful.

Script	**Output Files**	**Directory with Output**	**Action**
run_forcing_wamsi	**sw_flux.nc**, **lw_flux.nc**, **t_flux.nc, q_flux.nc**, **lprec.nc**, and **tau.nc**	**mawson:~/workdir_wamsi/INPUT/**	Generates the forcing field files at the resolution of and at the times required by the downscaled model.
run_norelax	**ocean_*.nc.[0000-0020]**	**mawson:~/workdir_wamsi/**	Copies executable (**fms_wamsi.x**), namelist (**input.nml**) and table files (**data_table**, **field_table**, **diag_table**) to **mawson:~/workdir_wamsi**/ and runs OFAM.
cp_wamsi and **cpRESTART_wamsi**		**cherax:~/wamsi_output/wamsi/migrate/** ,and, **cherax:~/wamsi_output/wamsi/restart/**	Migrate the output of the model and the restart files into the **cherax** home directory.
merge_wamsi	**ocean_*.nc**	**cherax:~/wamsi_output/wamsi/data**	Merges together output from separate CPUs.
clean_mawson		**mawson:~/workdir_wamsi/**	Removes the output files to avoid exceeding disk.

Table 3 Execution sequence of the OFAM for the downscaling simulation.

6. SUMMARY

While global climate models are extensively used to investigate the impact of rising Greenhouse Gases on our future climate, their coarse resolution limits their ability to reproduce realistic ocean boundary currents and capture mesoscale features in the ocean. Both of these ocean features are critical to how climate change may impact marine ecosystems. This technical report describes how we intend to dynamically downscale global climate change projections to resolve the important boundary currents and mesoscale features in the Australian region. This is an ambitious challenge and one that has not been achieved by overseas researchers. Although we are at an early stage in this effort we have already generated some promising results from our downscaling of the CSIRO Mk3.5 Scenarios A2 and A1B emissions scenario for the decade starting in 2060. We have improved our understanding of dynamical downscaling from these experiments, and we expect future runs will be more physically coherent. We are convinced our approach will provide useful regional climate change projections for the Australian marine region. The initial results have already generated much interest in our simulation and we see exciting opportunities to use our downscale climate projections to investigate marine climate change impacts in the Australian region.

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The figures below show samples of the climate anomaly fields of heat flux (**Error! Reference source not found.**), fresh water flux (Figure 3) and surface stresses (Figure 4) from the CSIRO Mk3.5 Global Climate Model simulation with the A2 emission scenario. Each of the figures shows a climate anomaly field from January (left column) and July (right), to encapsulate the seasonal range over the globe. The top row of each is figure is for the year 2061, going down to 2065 in the bottom row. Rows may be compared to gauge the interannual variability in the forcing that comes from the climate model projection for the 2061-2065 period.

APPENDIX B – FILE LOCATIONS

The table below gives the locations of the various files used in, and output from, the downscaled climate model simulation. Included below are the directories that contain the files to generate initial conditions and forcing fields, and the files used to run the model. All the directories below can be accessed in the directory:

`cherax:~cha526/ofam_2060_mk35_A2/ and ~sun036/ofam_2060_mk35_A1B`

Directory	**Description of files contained**
`doc/`	Copies of documentation, including this report.
`ic/`	Location of scripts required (including **`make_ic.csh`**) and subdirectories used to generate initial conditions
`downscale/`	
`template/`	Restart files from SPINUP5 and OFAM-BGC used as a template to generate the initial condition for the downscale climate anomaly model.
`base/`	Files from SPINUP5 (and SPINUP4) and OFAM-BGC used as a basis to generate the initial condition.
`output/`	Location of output of **`make_ic.csh`** . Modified restart files to be used as initial conditions. These are copied to **`mawson:~/workdir_wamsi/RESTART/`** to start the model.
`climate_model/`	
`projected/`	Climate model output for the future initial condition. *
`base/`	Climate model output for the present/base climatology, *
`forcing/`	Location of scripts required (including **`make_forcing.csh`**) and subdirectories used to generate forcing fields.
`ecmwf/`	
`original/`	Copies of forcing fields used as a basis for SPINUP5, copied from **`mawson:~cha526/mom4/ofam/ECMWF_DATA/`**
`output/`	Location of output of **`make_forcing.csh`**. Modified files to be used as forcing fields. These are copied to **`mawson:~/mom4/wamsi/preprocessing/`**
`downscale/restore/`	Diagnosed relaxation fluxes, as generated by **`make_restore.csh`** and copied to this location.
`interp/`	Directory with code developed to interpolate ECMWF forcing to OFAM grid.
`climate_model/`	
`projected/`	Climate model output for the future forcing. *
`base/`	Climate model output for the present/base climatology, *
`workdir/`	Location of copies of subdirectories used by OFAM at runtime, originals were at **`mawson:/cs/flush1/cha526/workdir_wamsi/`**
`INPUT/`	Set of forcing files generated to run OFAM.
`RESTART/`	Sample of restart files to run OFAM.
`exp/`	Files and scripts used to control OFAM, including the batch file

	that handles the running of the downscaled climate model, **`batch_wamsi.csh`**. Contents of this directory were originally at **`cherax:~cha526/mom4/exp/wamsi/`**
`  tables/`	Files read by OFAM to control input and output.
`  exec/`	Copy of the executable used.
`preprocessing/`	Directory where forcing is downscaled before running the model. Contents of this directory were originally at **`mawson:~cha526/mom4/wamsi/preprocessing/`**
`  source/`	Source of fortran code used to downscale the forcing files.
`  template/`	Template files used to downscale the forcing.
`restart/`	Subdirectories with sets of restart files.
`data/`	Model output of the climate projection model. Data actually sits in **`~cha526/wamsi_output`** and is linked to this directory.

* - files copied from
`/cs/datastore/u/csdar/hir020/Mk3.5_DBI.dir/MOM2/avg.dir/`

Table 4 Location of source files used to generate forcing fields.

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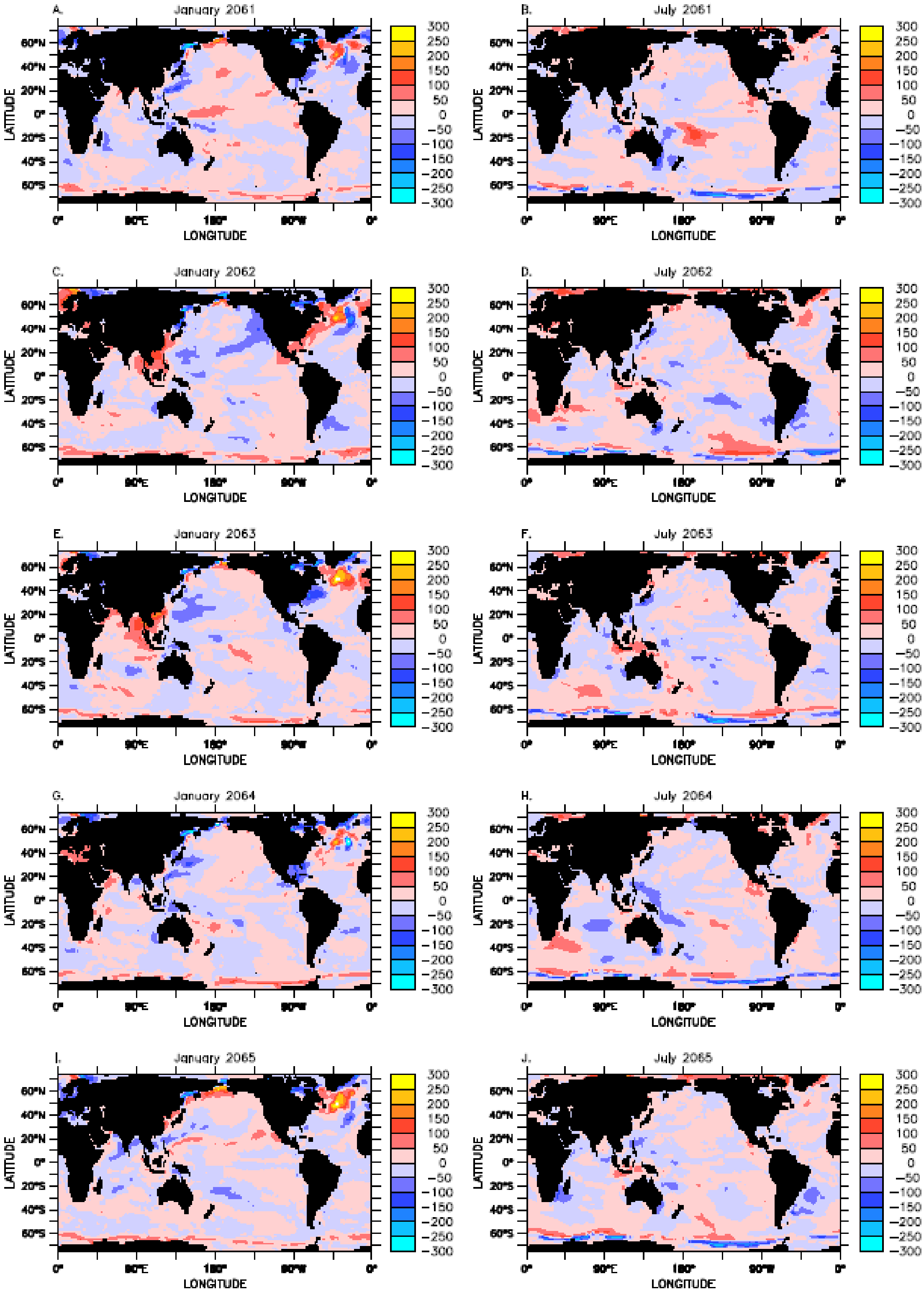

Figure 2: Heat flux anomaly (future projection minus base climatology, in W m^{-2}) for January and July from the Mk3.5 A2 scenario for years 2061 to 2065.

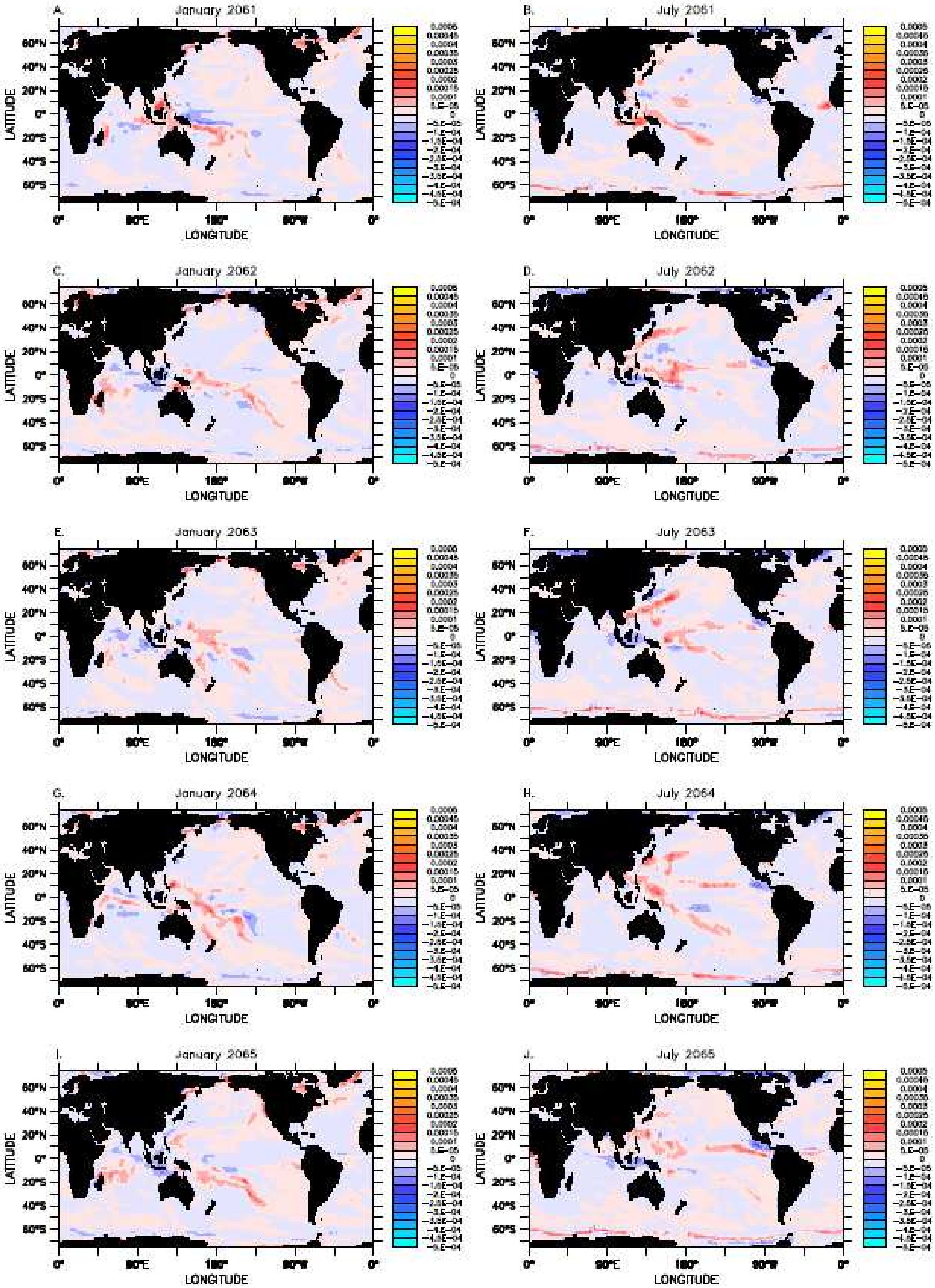

Figure 3. Freshwater flux anomaly (future projection minus base climatology, in kg m^{-2} s^{-1}) for January and July from the Mk3.5 A2 scenario for years 2061 to 2065.

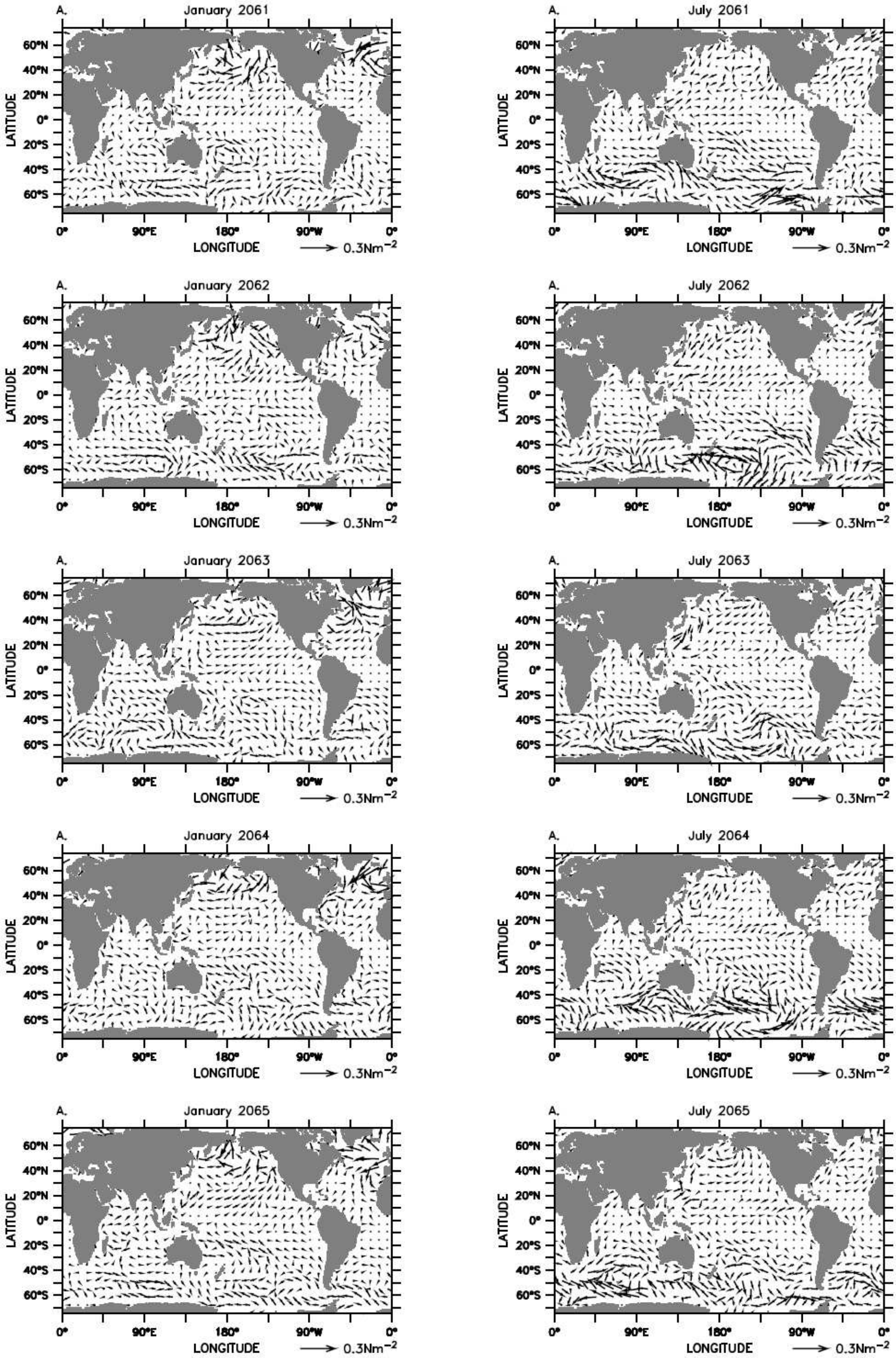

Figure 4. Surface stress anomalies (future projection minus base climatology, in N m^{-2}) for January and July from the Mk3.5 A2 scenario for years 2061 to 2065.

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