ACCESS Transpose-AMIP: Experimental Procedure and Preliminary Results

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Introduction

This paper documents the setup procedure and initial results from an ACCESS 1.3 Transpose-AMIP II experiment where the ACCESS climate model is run in Numerical Weather Prediction (NWP) mode. The following sections will introduce the experiment and the ACCESS model, the setup procedure for the model and then the run procedure and sample outputs.

Transpose-AMIP II

Transpose-AMIP II is a WMO Working Group on Numerical Experiments (WGNE) and Working Group on Coupled Models (WGCM) endorsed activity to run climate models in weather forecast (hindcast) mode. The premise for these experiments is that centres which run climate and NWP models in a unified system frequently find that model errors are common across timescales. Transpose-AMIP (T-AMIP) type experiments can provide: Process evaluation and insights into bias development through comparison with observations; and, insight into fast processes (e.g. clouds) which are the principal sources of model spread in terms of simulating climate and climate change. Thus running realistically initialized climate models in forecast mode can be used to determine their initial drift from the NWP analyses and/or from the available field data, thereby gaining insights on model parameterization deficiencies.

The Transpose-AMIP II website can be found at (http://hadobs.metoffice.com/tamip/) and the experimental design detailed there requires that 64 global hindcasts are to be produced with an Atmospheric General Circulation Model (AGCM), with each hindcast being 5 days in length. In fact 4 sets of 16 hindcasts are to be run, the first in each set starting at 00UTC on the 15th of the following months and then subsequently at 30 hour intervals: October 2008, January 2009, April 2009 and July 2009. This ensures sampling throughout the annual and diurnal cycles for each grid-point for a given lead time. These periods have been chosen to tie in with the Year of Tropical Convection (YOTC[1]) and various Intense Observational Periods (IOPs). We will refer to this experimental design as T-AMIP for convenience, even though it is actually Transpose-AMIP II. Note that the same procedures could be applied to other periods in the ERA-40 and ERA-Interim reanalyses.

ACCESS

The Australian Community Climate and Earth System Simulator (ACCESS) is a coupled model (CM) (Bi *et al.*, 2013) using an Ocean Atmosphere Sea Ice Soil (OASIS) coupler (Valcke, 2006) to link the atmosphere with land surface, ocean and sea ice components (Puri, 2005). ACCESS versions 1.0 and 1.3 are being used for the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5), Coupled Model Intercomparison Project Phase 5 (CMIP5), and Atmospheric Model Intercomparison Project (AMIP) simulations. These two ACCESS versions are based on the United Kingdom Met Office (UKMO) Unified Model (UM) 7.3 HadGEM2 (Collins *et al.*, 2008) and HadGEM3 (Hewitt *et al.*, 2010), respectively, with a major difference being that the former uses the UKMO Met Office Surface Exchange Scheme (MOSES) land surface scheme (Cox *et al.*, 1999) while the latter the Australian developed CSIRO Atmosphere Biosphere Land

[1]See http://yotc.ucar.edu/ for details.

Exchange (CABLE) scheme (Kowalczyk *et al.*, 2006).

The atmospheric and land surface components of the coupled model can be run with ancillary files providing the information which would normally come from the other components of the coupled model (sea surface temperature, sea ice thickness etc). This version of the coupled model, which is what ACCESS will refer to from now on in this paper, is much faster to run and can be used for Numerical Weather Prediction (NWP) short-term/seasonal forecasting purposes.

We will be using the ACCESS version 1.3 just discussed in these T-AMIP experiments so it will have the same physics and resolution as those used for the CMIP5 AMIP experiment and thus we hope to be able to compare model biases across timescales.

Possible future extensions of this work will be to create an ACCESS 1.0 T-AMIP experiment and to setup the latest ACCESS NWP model to run in T-AMIP mode.

ACCESS T-AMIP Setup procedure

The following steps, covering those listed in the T-AMIP experimental design, were taken to setup the ACCESS T-AMIP procedure. All the scripts and jobs used, examples of the files produced, the location of all the final datasets as well as a README instruction guide can be found: on the Bureau's SAM-FS system in the directory */samcrc/gen/glr/2014/tamip/access1.3;* as well as on the NCI supercomputer *raijin* at */g/data/p66/glr548/tamip_sam/access1.3*; or else please contact the author.

(1) Model state variables need to be initialised from the European Centre for Medium Range Weather Forecasting (ECMWF) YOTC analyses, available at http://data-portal.ecmwf.int/data/d/yotc

To do this we follow the procedure of Roff *et al.* (2012) and download four 3D fields (U, V, T and Q) and four surface fields (Surface pressure, Skin Temperature, Geopotential and Land-sea mask – with the latter two being invariant) and combine them into one grib file. This is then supplied as the start "dump", or initial conditions, for the UM reconfiguration run job (*saacb* on the Bureau's *ngamai* computer) to produce a N96L38[2] um-formatted initial condition file. Note: this is not the final dump file we need for ACCESS 1.3 T-AMIP, as discussed below.

(2) Atmospheric composition, solar forcing and land use should be as the final year of the CMIP5 AMIP experiment (2008).

The atmospheric mixing ratios of CO2, CH4 (Methane), N2O, CFC11, CFC12, CFC113, HCFC22, HFC125 and HFC134A for the T-AMIP period have been set to the same values as used in the ACCESS 1.3 AR5 RCP4.5[3] experiment. Similarly, the solar forcing and the volcanic forcing are also set to the values from the AR5 RCP4.5 run.

(3) SSTs from ECMWF YOTC should be used in the hindcasts.

The 0.75^{o} resolution SST and Seaice YOTC fields were downloaded for the relevant dates as grib files and were then processed via: converted to netcdf using cdo operators; split into separate SST and Seaice files using nco operators; the SST fields were then extrapolated over land using convsh scripts; converted to ancillary format using Xancil; then interpolated in space to N96L38 resolution using the UM Central Ancillary Program.

(4) Land surface models (LSM) should be initialised using one of the following methods: from fields produced by a land surface assimilation system (e.g. ECMWF or GLDAS); using a suitable climatology: e.g. from GSWP2 or derived from the model's AMIP simulation; or, initialised with a nudging method described by Boyle *et al.* (2005).

We initialize the LSM soil moisture and temperature fields from the ACCESS 1.3 AMIP climatology. With CABLE the normal soil moisture, temperature and frozen fraction fields are just diagnostics set to the grid box average of the tiled CABLE fields. Thus for initializing the model we need the tiled fields but will also get the diagnostic fields for consistency. The 3

[2] N96L38 indicates the resolution of the ACCESS run with: N96 indicating 2x96=192 longitudinal grid points and 1.5x96+1=145 latitudinal grid points; L38 indicating 38 model levels in the vertical.

[3] See http://cmip-pcmdi.llnl.gov/cmip5

diagnostic fields, and corresponding UM STASH codes, are: SOIL MOISTURE CONTENT IN A LAYER, DEEP SOIL TEMP AFTER TIMESTEP, and FROZEN SOIL MOISTURE FRAC AFTER TS (STASH codes 9, 20, and 215). The 25 prognostic fields are: SOIL LAYER 1-6 TEMPERATURE ON TILES, SOIL MOISTURE LAYER 1-6 (ON TILES), FROZEN SOIL MOIST FRAC LYR 1-6 (TILES), SNOW TEMPERATURE LAYER 1-3 (ON TILES), SNOW AGE (ON TILES), and SNOW DEPTH LAYER 1-3 (ON TILES) (STASH codes 301:306, 307:312, 313:318, 323:325, 330, 332:334).

All these fields are collected into a netcdf monthly mean LSM file which is then used to initialize the T-AMIP runs.

The remaining land surface soil and vegetation fields are either initialized to zero, calculated within the model or set to time independent values from ancillary files in the reconfiguration step. See README file for details.

(5) Aerosols concentrations should either be initialised using a climatology calculated from the model's AMIP simulation, or initialised using the nudging method of Boyle *et al.* (2005).

As we do not have aerosol climatologies we have taken the aerosol concentrations from the ancillary files that were used for the CMIP5 experiment. As the T-AMIP period is in 2008-9 and CMIP5 runs cease in 2005, we have extended the aerosol concentrations to this period by using those ancillaries from the ACCESS 1.3 AR5 RCP4.5 experiment where needed.

(6) Non-state variable prognostics which spin-up quickly (such as cloud fraction for models with a prognostic scheme) can either be initialised from zero, or initialised using the nudging method of Boyle *et al.* (2005).

We initialize to zero all the cloud fields: QCF AFTER TIMESTEP, CONV CLOUD BASE LEVEL NO. AFTER TS, CONV CLOUD TOP LEVEL NO. AFTER TS, CONV CLOUD LIQUID WATER PATH, QCL AFTER TIMESTEP, AREA CLOUD FRACTION IN EACH LAYER., BULK CLOUD FRACTION IN EACH LAYER, LIQUID CLOUD FRACTION IN EACH LAYER, and FROZEN CLOUD FRACTION IN EACH LAYER (STASH codes: 12, 14, 15, 16, 254, 265, 266, 267, and 268)

(7) Now we need to change the dump file created in (1) to a form suitable for ACCESS 1.3 and create the T-AMIP experimental job

Unfortunately ACCESS 1.3 cannot use the initial condition dump file created in (1) yet. This is because the reconfigured file is configured to run with the four soil levels and nine surface types of the MOSES land-surface scheme – which is used in ACCESS 1.0 – and not the six soil levels and seventeen tiles used in the CABLE land-surface scheme run in ACCESS 1.3.

In order to create ACCESS 1.3 initial conditions python scripts are used to copy the atmospheric fields from the ACCESS 1.0 reconfigured file created in (1) onto a basic ACCESS 1.3 AMIP dump file which has suitable levels and tiles. Similar scripts also copy the zeroed cloud fields discussed in (6) and LSM fields for the month of the dump file date taken from the climatology created in (4). A full description of how all the dump fields are initialized is in the README file.

ACCESS T-AMIP Run procedure

On NCI *accesscollab/accessdev* the T-AMIP ACCESS 1.3 run job is *uaoob/vafrb*, respectively, which are copies of *sabmf*, the AR5 ACCESS 1.3 AMIP job. We then changed this experiment by: applying the Atmospheric composition, solar forcing and land use changes in (2); point to the SST and SICE field ancillary files created in (3) and the aerosol ancillaries mentioned in (5); and point to the ACCESS 1.3 initial condition dump file discussed in the paragraph above.

The executable used is the NeCTAR[4] Climate and Weather Science Laboratory standard exe that comes with the original umui job (*sabmf*). However if you wish to change the source code then you can copy the build job for this executable – the standard NeCTAR job *saadb* – and then compile it to create an executable. I have done this in my *accesscollab/accessdev* jobs *uaoog/vafra*, respectively.

This run job can then be run from the UMUI or we can use a *raijin* script (*run_tamip_fcast00* for

[4] See https://www.nectar.org.au/climate-and-weather-science-laboratory

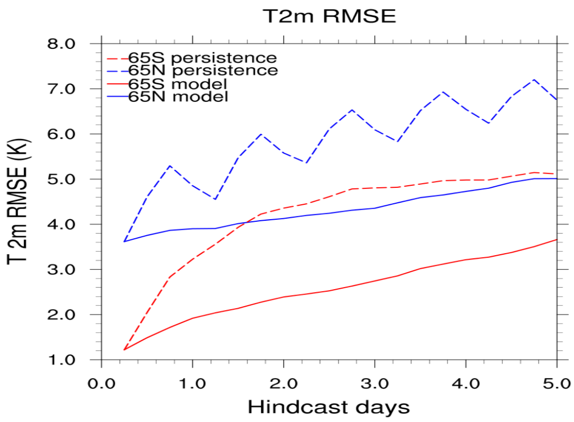

Figure 1 T2m zonal mean RMSE (K) five day hindcast timeseries at 65°N (blue) and 65°S (red) for model (solid line) and persistence (dashed line) T-AMIP outputs. Units are K.

uaoob and described in the README file, or *run_tamip_fcast_acdev* for *vafrb*) to submit several jobs in series. The job runs on 64 processors and takes ~4minutes to complete a 5 day hindcast for one date, so ~4 hours for a full T-AMIP run over all 64 dates.

ACCESS T-AMIP Preliminary Results: NWP

The script above has been run over all four T-AMIP periods and the global average 2m temperature RMSE has been calculated relative to the YOTC analyses.

Figure 1 shows a timeseries of the T2m zonal mean RMSE at 65°N and 65°S, as well as that for persistence. The model (solid) is always better than persistence (dashed) while both have smaller errors in the SH (red). The model RMSE remains relatively stable for the first two days and then increases linearly while persistence has approached saturation by day 3 in the SH but displays a 24 oscillation in the NH. This oscillation can be understood as the persistence hindcast is just the 6 hour hindcast perpetuated out for the 5 day run period. This implies that every 24 hours the atmosphere will be in the same time period as the 6 hour hindcast so it will have the smallest errors then. This oscillation is not seen in the 65°S curve due to the much smaller land masses at this latitude not reacting as strongly to the diurnal solar forcing cycle. We shall also see later that it does not occur in the 10 metre wind fields.

Hovmoller plots (not shown) of these RMSE

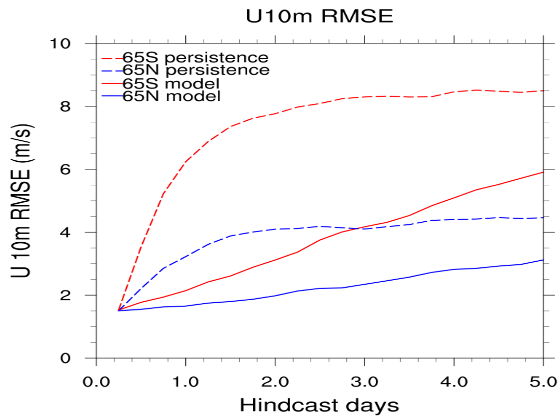

Figure 2 As in Figure 1 but for the U10m RMSE (m/s).

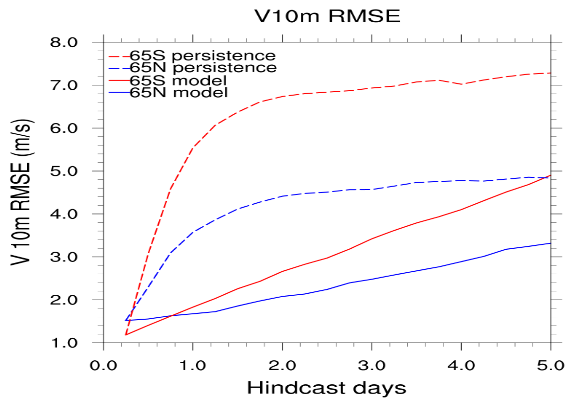

Figure 3 As in Figure 1 but for the V10m RMSE (m/s).

fields show that the smallest errors occur in the tropics with the largest errors occurring in both cases in the Northern Hemisphere (NH) polar region initially, though the model quickly recovers from this while persistence does not. This error is due to the SST and SICE ancillaries not being in balance with the initial condition values, and thus this error remains in the persistence case but quickly adjusts in the model. Meanwhile in the Southern Hemisphere (SH) polar region the errors grow with time for both cases. The minimum error is in the tropics and the persistence 24 hour oscillation is seen to extend over latitudes north of ~45°S.

The corresponding plots for the 10m zonal and meridional winds can be seen in Figures 2 and 3, respectively.

The zonal wind error is now largest in the SH (red) in both cases, with the model doing much better than persistence and no

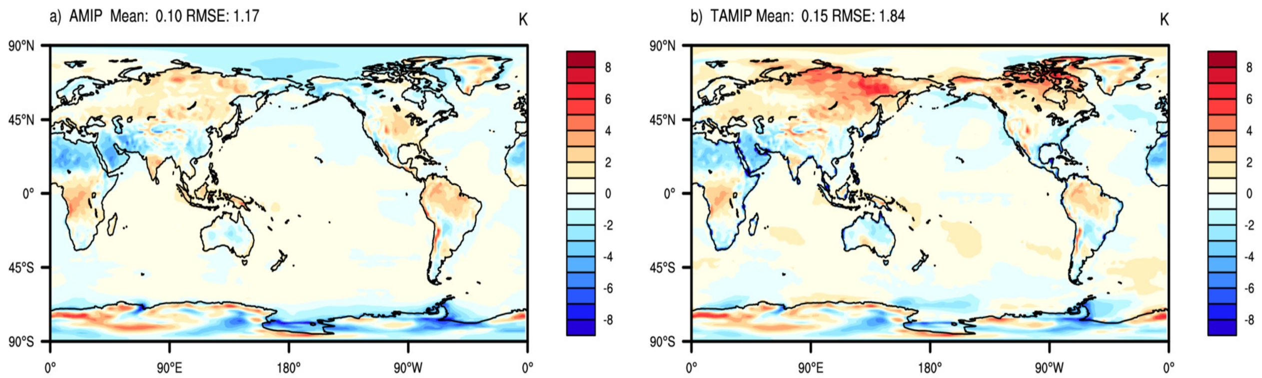

Figure 4 (a) AMIP and (b) T-AMIP SAT biases, see text for details. Units are ^{o}C.

indication of the T2m oscillation is seen in the persistence plots. Persistence reaches its maximum error within ~2 days while the model gradually increases over the full 5 day period but well below persistence values.

The V10 hindcast is similar to, though smaller than, U10 with: largest error in SH mid-latitudes; model always better than persistence; persistence saturates by ~2 days while the model error steadily grows.

These plots demonstrate how the ACCESS T-AMIP experimental procedure can be used to calculate typical NWP diagnostics and compare them to other forecasting systems. In this case we have just compared RMSE between model and persistence outputs but there is nothing to stop us from using other NWP diagnostics (skill score, anomaly correlation, biases, etc) and comparing with outputs from other models such as the standard ACCESS NWP model.

ACCESS T-AMIP Preliminary Results: Coupled model and AMIP comparison

Bi et al. (2013), referred to as B13 below, described the ACCESS 1.0 and 1.3 Coupled Models and presented results from their CMIP5 simulations, including some from the 'present climate' which is the 30-year average over 1976-2005 from their 20th century historical simulations. We have calculated some corresponding figures for the ACCESS 1.3 T-AMIP runs, as well as for a full ACCESS 1.3 AMIP run, for comparison.

Figure 4 shows the AMIP and T-AMIP surface air temperature (SAT) bias, relative to ERA-Interim reanalysis 1979-2008 data. Note that similar biases (not shown) were seen when compared to ERA-Interim re-analyses just for 2008-2009.

The bias is generally small over the oceans, due to pre-scribed SST and SICE, while over the land masses both show: warm biases over equatorial regions (Africa, South America

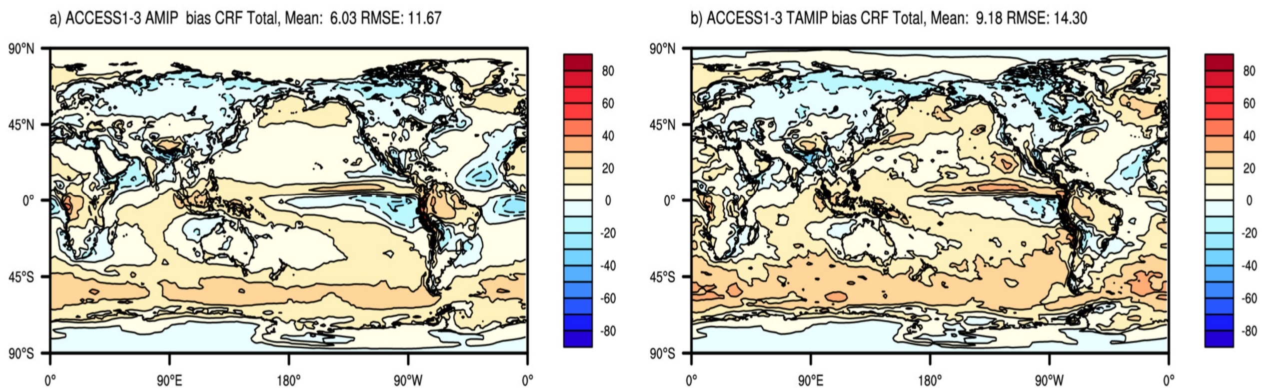

Figure 5 (a) AMIP and (b) T-AMIP mean Total CRF biases, see text for details. Units are W m–2.

and the Maritime continent) and land masses poleward of 45^{o}N; and, cold biases over the sub-tropics and polar regions. This similarity in SAT over the land masses is understandable as while AMIP has evolved the land surface parameters, we have just imposed the AMIP climatology LSM fields for the T-AMIP simulation. If compared to the ACCESS 1.3 CM results in B13 Fig. 3(b) then the T-AMIP and AMIP land mass biases are very similar.

Figure 5 shows the AMIP and T-AMIP annual mean Total cloud radiative forcing (CRF) biases, relative to the ISCCP observations 1983–2007 mean.

In both AMIP and T-AMIP the Total CRF has a strong positive bias in the Southern Ocean as well as the tropical land masses (Africa and South America) and the Maritime. Examining the corresponding short-wave and long-wave CRF biases (not shown) these Total biases are mainly due to the short-wave forcing, except perhaps over the Maritime continent region. These CRF biases have similar characteristics to those seen in the ACCESS 1.3 CM CRF bias plots in B13 Figure 6.

Both the SAT and CRF biases indicate that the ACCESS T-AMIP experimental procedure is able to simulate the climate biases seen in the ACCESS AMIP and CM runs. This suggests that ACCESS T-AMIP could be a valuable tool in examining the development of these systematic biases in the ACCESS model.

Conclusions and Future work

The international Transpose-AMIP experimental procedure is a protocol for enabling climate models to be run in NWP simulations to enable the better understanding of possible error sources. This paper describes how ACCESS 1.3 has been setup to run the Transpose-AMIP experiment. Details of the changes required are listed along with the run procedure for carrying out this experiment. Sample outputs from a run of the ACCESS 1.3 T-AMIP experiment have also been provided. A full T-AMIP simulation takes ~4 hours, with ~4min for each of 64 dates when using 64 processors

Input datasets, scripts, example outputs and a README file which explains the setup and run procedures in greater detail, can be found on the Bureau’s SAM-FS system in directory */samcrc/gen/glr/2014/tamip/access1.3,* as well as on the NCI supercomputer *raijin* in */g/data/p66/glr548/tamip_sam/access1.3*; or you can contact the author. The README file also gives a breakdown of where the various fields in the T-AMIP dump file come from.

The ACCESS T-AMIP hindcast means have been compared with persistence hindcasts using a typical NWP diagnostic (RMSE) over several surface fields (T2, U10, V10) and shown to have smaller errors.

The ACCESS T-AMIP simulation means have been compared with ACCESS AMIP outputs of surface air temperature (SAT) and cloud radiative forcing (CRF) and have been shown to have similar biases. These SAT biases over land masses are similar to those in the ACCESS Coupled Model while the CRF biases also show the Southern Ocean biases seen in the Coupled Model. This suggests that the long-term ACCESS biases do manifest themselves in the T-AMIP short-term NWP type runs.

Future work will be to:

- extend the range of standard NWP diagnostics (skill score, anomaly correlation, bias and RMSE etc) available for ACCESS T-AMIP;
- use the ability of T-AMIP to simulate the AMIP and CM biases to gain insight on ACCESS model parameterization deficiencies;
- extend T-AMIP to ACCESS 1.0 and GA6, the UKMO Global Atmosphere 6.0 model;

- extend the ACCESS T-AMIP protocol to enable it to run with other re-analyses/analyses and over other time periods e.g. the latest ACCESS NWP standard analyses;
- and, to run the latest ACCESS NWP model in T-AMIP mode to enable a direct comparison of the ACCESS climate and NWP models.

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