CCSM Production Accomplishments Report

September 2004 – December 2005

CCSM Production Allocation Accomplishments
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I. Atmosphere Model Working Group (AMWG)

A number of runs were performed to complete documentation of the Community Atmosphere Model (CAM) for the special issue of the *Journal of Climate* (McCaa, Buja). This rounded out our exploration of CAM and CCSM climates to changes in greenhouse gases, aerosols, and dynamical cores.

The slab ocean model (SOM) runs were made, including a suite of about 20 trace constituents, with the spectral, finite volume, and semi-Lagrangian dynamical cores using pre-industrial, present-day, and future forcing scenarios to look at the change in transport processes in CAM (Bundy).

The boundary layer parameterization and shallow convection parameterizations being developed at the University of Washington (UW, Bretherton and Park), in collaboration with NCAR staff (Zhu, Hack, and Rasch), were examined in Atmosphere Model Intercomparison Project (AMIP) and SOM runs. A series of doubled CO_2 tests and perturbed sea surface temperature (SST) simulations were made using the standard CAM3 and CAM+UW at T85 resolution with the new planetary boundary layer (PBL) and shallow convection parameterizations to explore the climate sensitivity of the model and to identify the role of shallow clouds in the model's response (Zhu). The sensitivity of the model solution to the parameterization of deep convection, and its interaction with the alternate formulation for the PBL and shallow convection, was also performed (Rasch, Bundy, Sundararajan).

A matrix of runs was made to explore the sensitivity of the general circulation of CAM to spatial and temporal resolution and method of solution for atmospheric dynamics (e.g., the dynamical core) in an Aqua Planet configuration (Olson). These runs allow a characterization of the strength of the Hadley circulation and the model's predilection for forming a double Intertropical Convergence Zone (ITCZ) to be made for various model configurations.

A large number of numerical experiments was conducted with the CAM3 SOM configuration to quantitatively examine the CAM3 climate sensitivity. Simulations were conducted at T31, T42, and T85 truncations with an emphasis on cloud feedback processes in CAM (Zhu, Shields, Kiehl, Hack). The interactions between low clouds and the interactive ocean were a major component of this work, emphasizing the need to generalize the formulation of boundary layer processes to deal directly with phase change.

A number of exploratory simulations was conducted to document the behavior of CAM at higher horizontal resolution, including T170 and T341 truncations (Caron). The principal objective of these simulations was to quantify the interaction of the resolved scale dynamical motion field with the parameterized physics package. This work was motivated by the variation in climate sensitivity as a function of horizontal resolution. In addition to standard monthly mean output, these simulations produced high temporal resolution output for statistical analysis purposes, as well as for use with the CAM single column modeling tool (SCAM).

A number of runs was made to explore the sensitivity of the model to the formulation of gravity wave drag and turbulent mountain stresses. These runs were made using the finite volume dynamical core, occasionally at higher horizontal and vertical resolution. The position and strength of the midlatitude stationary wave patterns and surface winds are particularly sensitive to these processes (Sassi, Boville).

II. Ocean Model Working Group (OMWG)

The majority of CSL production allocation was divided among the four main foci as described in the 2004 CSL production proposal: Coastal Ocean Processes and Coupling (CPC), Ocean Climate Variability (OCV), Tropical Coupling and Variability (TCV), and The Ocean Mesoscale (TOM). Following the recommendations of the CCSM Advisory Board and the CGD Advisory Committee, and the interests of the OMWG, highest priority was given to TCV. Numerical experiments spanned the fully, partially, and uncoupled (forced ocean) configurations. The majority of these were performed with the low-resolution CCSM3, with allocation not the only factor. At higher resolution a request for sufficient nodes for reasonable completion time has the consequence of not getting through the machine queue.

A. <u>Tropical Coupling and Variability (TCV)</u>

1. Resolved Tropical Instability Waves pump heat into the equatorial cold tongue, and internally generate SST variability that, when used to force CAM, has significant remote impacts.

2. The coupled model cannot sustain realistic zonal pressure gradients along the equator. It was determined that this is because CAM produces too weak (by 40%) zonal winds there, even with observed sea surface temperatures (SSTs). Experiments showed that increasing the wind stress leads indeed to a lengthening of the EL Niño-Southern Oscillation (ENSO) period, and that in CAM an increased wind stress can be achieved by changing the profile of diabatic heating. This suggests that improving the diabatic heating in the western Pacific warmpool atmosphere is key to improving ENSO.

3. Adequate reproduction of the North Equatorial Counter Current depends on the proper inclusion of ocean surface velocity in calculating the wind stress.

B. <u>The Ocean Mesoscale (TOM)</u>

1. The parameterization of mesoscale eddies in the mixed layer has both expected and unexpected positive consequences in ocean model solutions. The

distribution of eddy heat flux over the upper 500 m becomes similar to resolved eddy simulations, the mixed layer depth especially in the Southern Ocean deepens, and long-term drifts due to deep ocean cooling are very much reduced.

2. The global 1/10 eddy resolved configuration is progressing at a pace of about 1 simulated day every calendar day, and less than a season will be completed under this allocation.

C. Coastal Ocean Processes and Coupling (CPC)

1. The Galapagos Islands affect the termination of the Equatorial Undercurrent and, hence, the source of waters found along the equatorial coast of South America to about 10°S. Including them also makes the neighboring SST more realistic.

2. Forced ocean experiments utilizing five years of Quick scatterometer (QSCAT) ocean surface wind vector data suggest that wind direction error is a major contributor to the persistent large warm bias generated in CCSM along the eastern boundaries of subtropical and equatorial basins.

3. The excessive North Atlantic sea ice found in finite volume versions of CCSM is not improved by modifying the way air temperature is computed for air-sea flux calculations, suggesting that the winds are a more important factor.

D. Ocean Climate Variability (OCV)

1. Substantial decadal variability in the salinity/temperature makeup of ocean isopycnals is due to diapycnal winter mixing in subtropical regions where the climatological salinity gradient is unstable. This model result is supported by observations from the Array for Real-time Geostrophic Oceanographic (ARGO) float array. The decadal variability appears to be caused by air-sea interaction in the South Pacific, but not in the South Atlantic, where the transport of salty Indian Ocean water may be important.

2. The Gibraltar Overflow has a major effect on the North Atlantic salinity distribution at intermediate depths, but minimal impact on the coupled climate as determined from atmospheric climate measures, such as surface fluxes, mean state, and large-scale variability.

III. Land Model Working Group (LMWG)

The LMWG proposed a transient climate simulation using CCSM (T85x1) for the 230-year period from 1870–2100 to examine the land use forcing of climate relative to greenhouse gases, aerosols, solar variability, and other forcings. This simulation was not performed due to lack of computational resources. Instead, two 50-year simulations were performed using land cover data sets of 1870 and 2000. These simulations revealed a land use forcing of climate that is weaker than found in previous simulations. Ongoing work is studying the reasons for this, but the weak signal appears to be related to the hydrologic cycle of the Community Land Model (CLM).

A series of simulations using CAM/CLM/SOM was performed to examine the importance of surface hydrology and vegetation for climate sensitivity. These experiments highlighted the role of snow, soil water, and dynamic vegetation in determining climate sensitivity. Of particular importance is the expansion of boreal forest into tundra with a warmer climate. Ongoing research is examining the importance of specific parameterizations of the hydrologic cycle to climate sensitivity.

IV. Biogeochemistry Working Group (BGCWG)

The BGCWG usage of resources under this production proposal can be broken down into the following categories: control and transient coupled carbon climate experiments using CSM1.4; initial spin up of the terrestrial carbon-nitrogen model for Phase I of the Coupled-Carbon Cycle Climate Modeling Intercomparison Project (C4MIP), and other scientific experiments performed by researchers in the working group.

A. Previous CSL resources had been used to construct a coupled carbon climate model using CSM1.4 as the underlying climate model. This model was used to perform multi-century pre-industrial control experiments, as well as multiple fossil fuel emission experiments. The experiments spanned the years 1820–2100, with multiple SRES emissions used in the 21st century. The experiments show that the capacities of the land and oceans to store anthropogenic CO_2 are inversely related to the rate of fossil fuel emissions, so that atmospheric CO_2 and, hence, climate warming accelerates with faster CO_2 emissions. The analysis also shows that there is a positive feedback between the carbon cycle and the climate, so that climate warming acts to increase the airborne fraction of anthropogenic CO_2 and amplify the climate change itself.

B. The coupled carbon-nitrogen ecosystem for the CLM that was developed under the development proposal has been used to perform spin-up phase experiments for Phase I of C4MIP. In addition, a full suite of experiments testing the behavior of the CLM3-CN (carbon nitrogen) carbon cycle in offline and partial coupled mode (CAM/CLM) have been completed, and results were presented by Peter Thornton at the Fall meeting of AGU. These experiments include a sequence of spin-up runs designed to bring the carbon and nitrogen states on land into equilibrium with the offline or coupled climates; long control simulations with constant CO_2 concentrations and constant nitrogen deposition; and experiments testing the consequences for the carbon cycle of increasing CO_2 concentration, increasing nitrogen deposition, and the combined effects. These results are currently being prepared for publication, targeting submission in early 2006.

C. The final part of the CSL production proposal was used to evaluate the behavior of atmospheric chemistry and aerosols. After an evaluation against present-day measurements, we have performed a set of multi-year simulations to analyze the chemistry-climate response under various aerosol emission scenarios. These simulations, performed with CAM coupled to the SOM, were all 10 to 15 years in duration, long enough to exhibit differences that are statistically significant. The analysis has shown the importance of aerosol loading on surface temperature and the hydrological cycle. In addition, a strong response in tropospheric ozone, hydroxide (OH), and nitrogen oxides was found; this response is a combination of modified chemical uptake on aerosols and change in the climate (water vapor feedback on OH). This analysis was published in Geophysical Research Letters (Lamarque et al., 2005).

In addition, papers documenting the dust and sea salt algorithms in the CCSM and looking at the climate response of dust and sea salts to climate change have been submitted (Mahowald et al., 2006a; Mahowald et al., 2006b). Work looking at the solubility of the iron in the mineral aerosol was also supported by the production CSL computer time, and resulted in one new paper by Luo et al. (2006).

V. Polar Climate Working Group (PCWG)

Since September 2004, a number of model simulations has been performed using CSL resources to improve the polar climate simulations and to elucidate important aspects of the polar climate system. The accomplishments from these studies are outlined below.

A. Diagnoses of the influence of the parameterized ice thickness distribution on simulated polar climate and feedbacks. Analysis of simulations at present-day and $2XCO_2$ levels shows that the albedo feedback mechanism is considerably stronger when an ice thickness distribution is used. This may contribute to the high polar amplification in CCSM3. Additionally, the presence of an ice thickness distribution modifies other important feedbacks, including the negative ice thickness-ice growth rate mechanism and ice dynamic feedbacks. A paper documenting these effects has been accepted for the *Journal of Climate* CCSM special issue (Holland et al., 2006).

B. Diagnoses of the influence of sea ice on ocean heat uptake in a changing climate. The effects of a decreasing sea ice cover, similar to that seen in an increasing CO_2 scenario, have been isolated by reducing the albedo of bare sea ice. The results of this integration have been compared to a 1% increasing CO_2 simulation to determine the influence of the sea ice changes on ocean heat uptake. For both the northern and southern high latitudes, the changes in sea ice cover are critical for modifying ocean ventilation and increasing ocean heat uptake. These results are documented in Bitz et al. (2006).

C. Assessment of the effect of the sea ice albedo formulation on simulated feedbacks. Simulations have been performed with a modified ice albedo parameterization to assess the influence on the albedo feedback. This parameterization gives a very similar present-day climate, but appears to modify the polar amplification response to $2XCO_2$ levels. Analysis is under way to further quantify these effects.

D. Diagnoses of simulated cold air outbreaks. The ability of the CCSM3 to simulate the penetration of Arctic air masses into middle latitudes in North America and Eurasia has been assessed. Additionally, changes in these events in future climate scenarios and the influence of terrestrial snow cover on these extreme events have been diagnosed. These results are documented in Vavrus et al. (2006), and further papers are in preparation.

VI. Climate Variability Working Group (CVWG)

To complement existing runs of CAM3 at T85 resolution completed under the previous CSL allocation, analogous integrations of CAM3 at T42 resolution were performed at NCAR during the allocation period August 2004–December 2005. These consist of a 5-member ensemble of AMIP integrations for the period 1950–2001 forced with the newly compiled observed SST and sea ice data set of Hurrell et al. (2005), and a 5-member AMIP ensemble forced with the same SST and sea ice data set, plus the observed history of greenhouse gas, aerosol, solar, and volcanic forcing. These experiments are designed to provide a more realistic simulation of the observed climate than conventional AMIP experiments, and provide a useful benchmark for comparison of the CCSM3 Climate of the 20th Century runs. In addition to these global SST/sea ice forcing runs, a 5-member ensemble of AMIP integrations for the period 1950–2001 was performed in which the observed SST forcing is confined to the global tropics (20°N–20°S). These experiments allow an assessment of tropical SST forcing of climate variability worldwide, as well as an evaluation of the contribution of extra-tropical SST forcing when compared to the global AMIP simulations.

The CVWG has also begun a set of IPCC scenario runs with CCSM3 at T42 resolution in conjunction with the Climate Change Working Group (CCWG). Currently, these are being performed at DOE's Oak Ridge National Laboratory (ORNL). The purpose of these experiments is to provide a large ensemble (~30 members) of integrations driven by a fixed, standard "business-as-usual" climate change scenario during 2001–2050. Such a large ensemble will allow an assessment of uncertainties in climate projections resulting from intrinsic system variations, as well as the evolving properties of interannual variability. This project will also include a large ensemble (~40 members) of short (~10-year duration) integrations of CAM3 driven by the surface boundary conditions from years 2041–2050 of the CCSM3 climate change scenario integrations. This set of integrations will be used to assess the change in the likelihood of extreme events, for which a large ensemble is crucial.

Under the previous CSL allocation to the CVWG, a new coupled model was developed in which a predictive ocean mixed layer model (MLM) was coupled to the thermodynamic component of the CCSM Sea Ice Model version 4 (CSIM4) and to CAM2. This model configuration provides a useful tool for understanding the role of ocean mixed-layer processes in climate variability, and in terms of complexity, falls in between the CCSM and the CAM coupled to a SOM. A 150-year "control" simulation was conducted in which the MLM is active at all ocean grid points. Analysis of this control integration and of further experiments in which the ocean MLM coupling is active only in selected regions are given in Cassou et al. (2006) and Kwon and Deser (2006). This model configuration is in the process of being extended to CAM3.

Analysis of climate variability in the CCSM3 (T85 and T42) control integrations, as well as the AMIP integrations with CAM3 described above, is reported in three manuscripts in press in the CCSM3 Special Issue of the *Journal of Climate* (Alexander et al., 2006; Deser et al., 2006; and Meehl et al., 2006). These papers examined atmosphere-ocean variability in the extratropical Northern Hemisphere (Alexander et al., 2006), tropical variability including the ENSO phenomenon (Deser et al., 2006), and global monsoon variability (Meehl et al., 2006). Other papers in press in the same issue of *Journal of Climate* also make use of the CAM3 AMIP integrations, including Hack et al. (2006a); Hack et al. (2006b); and Hurrell et al. (2006). The full text of these papers is given at http://www.ccsm.ucar.edu/publications/jclim04/Papers_JCL04.html.

VII. Abrupt Change Task Group (PaleoWG & Polar Climate WG)

A. Understanding Abrupt Climate Change in the Paleoclimate Record. Freshwater-forced simulations for the cold glacial state near the Last Glacial Maximum (LGM) and the warm interglacial state of the Holocene have been finished to investigate the response of the T42x1 CCSM3 to anomalous Coupled Model Intercomparison Project (CMIP) freshwater forcing of 1 Sv for 100 years into the North Atlantic and the dependence of this response on the background climate state. The control simulations are the LGM and Holocene simulations completed by the Paleoclimate Working Group under their CSL production allocation. Each simulation was extended beyond the termination of the freshwater impulse to allow the model climate to return to its baseline control climate for a total length of 414 years for the Holocene simulation and 545 years (and still running) for the glacial simulation.

For both scenarios, the North Atlantic climate responds dramatically during the freshwater impulse, with a complete shutdown of the thermohaline circulation (THC), regional cooling in excess of 12°C, and equatorial expansion of sea ice. The ITCZ in the Atlantic shifts southward and the Southern Hemisphere warms. Some notable differences exist in the response to, and the recovery from, the freshwater impulse depending on the baseline climate state. The Holocene freshwater simulation displays more cooling over Europe and North America than the glacial freshwater simulation. The bipolar response with cooling in the Northern Hemisphere and warming in the Southern Hemisphere is more pronounced in the glacial freshwater simulation. After the termination of the freshwater impulse, the Holocene freshwater simulation shows recovery in around 200 to 300 years, similar to previous CMIP simulations, but the CCSM3 glacial freshwater simulation is still recovering after 500 years.

An initial comparison between the Holocene experiment and proxy data from the 8.2 ka event suggests that the model's sensitivity to freshwater forcing is reasonable. The model captures the spatial extent and approximate magnitude of cooling in the northern extratropics and drying in the northern tropics. A more detailed comparison of the high-resolution Cariaco Basin record with model output indicates that both show a rapid development of anomalies within several decades followed by a slower, century-scale recovery. These results were presented at the Fall AGU meeting; journal papers are in preparation.

B. Experiments to elucidate abrupt change mechanisms. A series of shorter simulations with instantaneous large freshwater inputs to the North Atlantic were performed. Half of the experiments have a modern initial or "background" climate state, and the other half have a LGM background state. As above, these experiments show that the background climate state has a strong influence on the transient response to freshwater anomalies. The large initial climate change recovers in a matter of decades with a modern background state, while there is little sign of recovery after more than a century with a LGM background state. We conducted at least three runs with each background state to explore the influence of natural variability as well (through the initial strength of the THC) and found its influence is smaller, although significant as well. These results were presented by Bitz and Chiang in December 2005 at the AGU meeting. A journal article is in preparation as well. Simulations with initial changes to the sea ice cover were also conducted with the LGM "background" climate state. In contrast to hosing experiments, the climate recovers in a matter of years.

VIII. Paleoclimate Working Group (PaleoWG)

A. Last Millennium. Three segments of 100-year length were simulated with CCSM3 at T42x1 resolution. Spread over these runs, a total of 100 years were run after September 1, 2004. The goal of the simulations was to provide a comparison to the long transient simulations run with CSM1.4 for three selected periods where natural forcings were in interesting configurations: 1100–1200 with high solar activity but low volcanism; 1400–1500 with significantly decreasing solar irradiance and strong volcanic pulses in the center; and 1780–1880 with relatively modest solar irradiance changes but very significant volcanism. The agreement with CSM1.4 is very good on the global scale, confirming that the transient behavior of CCSM3, despite higher sensitivity, is giving comparable results in response to natural forcing.

B. Paleoclimate Modeling Intercomparison Project (PMIP-2). Several long simulations have been completed for the LGM and Holocene as part of the second phase of PMIP-2. We have extended our T42x1 CCSM3 atmosphere-ocean simulations for the LGM to 530 years and the mid-Holocene (6 ky BP) to 430 years to reduce trends in the oceans that resulted from the changed forcings and boundary conditions. We also now have a T42x1 CCSM3 atmosphere-ocean-vegetation simulation for the mid-Holocene. The results from these three simulations will appear in Chapter 6 of the IPCC AR4 and are being analyzed by a number of international research projects as part of PMIP-2.

In addition, two CCSM3 sensitivity simulations have been completed for these time periods. In contrast to a previous CSM1.4 LGM simulation, CCSM3 simulated a warmer North Pacific at LGM. A sensitivity simulation with CCSM3 identified the new reconstruction for LGM ice sheets used as PMIP-2 boundary conditions, and in particular the higher Canadian ice sheet, as the reason for this difference. An 8.5 ky BP Holocene simulation has allowed analysis of the role of the evolving orbital forcings in the Holocene. This simulation also provided the initial conditions and control for the 8.2 event simulation conducted by the Abrupt Climate Change Task Group. Papers published or in press describing these simulations are Otto-Bliesner et al. (2006), Gladstone et al. (2005), and Masson-Delmotte et al. (2006).

C. Mid-Holocene Transient Behavior. CCSM3 T31x3 is being used to assess the capability of the model to simulate the transient behavior of the climate system observed in Holocene proxy records associated with the time-varying orbital, solar constant, volcanic, and greenhouse gas forcings starting at 6 ky BP. Initial equilibrium simulations have been completed for 6 ky BP and pre-industrial (ca. 1750 AD) to allow spin up and comparison of vegetation predicted by the dynamic vegetation model of CCSM3. These are the first fully-coupled predictive vegetation simulations completed by CCSM3 and were done in collaboration with the Terrestrial Sciences Section. As observed in the proxy records, grasses extend into the Sahara and boreal forests increase their northern extent during the Holocene at 6 ky BP as compared to the pre-industrial simulation. The transient Holocene simulation is currently running.

IX. Climate Change Working Group (CCWG)

The CCWG production activities fell into three categories: IPCC data processing, continuation of freshwater CMIP integrations, and startup of coupling the T170 atmosphere with the 1-degree ocean model.

The CCSM IPCC simulations were completed during the beginning of this CSL cycle, and a massive effort was put into post-processing and publishing the IPCC data at PCMDI. To support DOE and NSF regional modeling efforts, we saved two additional sub daily data streams for each of the CCSM IPCC scenarios. By design, the raw and post-processed data products from the different IPCC scenarios are being kept at DOE and NSF sites where they were computed. The CCSM3 IPCC contribution was the largest of any group in the world. This large distributed data set is being freely distributed to the U.S. climate research and education community via the DOE Earth System Grid

Previous CSL studies into the effect of additional freshwater due to climate change induced ice melt on the THC continued. The Bering Strait is a narrow and shallow pathway connecting the Pacific and Atlantic through the Arctic with an annual mean throughflow about 0.8 Sv northward. This throughflow transports a significant amount of freshwater to the Arctic and the Atlantic (Aagaard and Carmack, 1989; Woodgate et al., 2005). Previous studies indicate that the transport from the Pacific to the Arctic through the Bering Strait plays an important role in the freshwater budget of the world oceans (Wijffels et al., 1992; Huang and Schmitt, 1993; Aagaard and Carmack, 1989); and it can affect the strength of the THC (Reason and Power, 1994; Goosse et al, 1997; Wadley and Bigg, 2002), the deep western boundary currents in the Atlantic; and the separation point of the Gulf Stream from the eastern coast of America (Huang and Schmitt, 1993). It may also influence the world climate (DeBoer and Nof, 2004). Here, we study the relationship of the THC and the transport at the Bering Strait through artificially adding freshwater flux into the northern North Atlantic using CCSM2. Our preliminary results show that as the THC slows down due to freshening in the North Atlantic, the flow from the Pacific into the Arctic through the Bering Strait weakens, and even reverses direction. In other words, instead of a freshwater source to the Arctic and Atlantic, the Bering Strait throughflow could be a freshwater sink. This could be one of the reasons causing a stable climate during the Holocene. To further isolate the effect of the Bering Strait throughflow on THC, we are performing a set of new experiments. We will perform a control run with a closed Bering Strait, and we are expecting to run it for 300 years, about 187 years of the integration is done already. We will perform a hosing run with closed Bering Strait and 1 Sv of additional freshwater flux added in the northern North Atlantic between 50°N and 70°N for 100 years. Then this flux will be switched off for another 200 years. This run has been integrated for 130 years already. After these two experiments are finished, we are going to compare these results with those from the experiments we performed earlier with open Bering Strait.

The standalone T170 CAM has recently been made available and, with the IPCC data post-processing spinning down, we are beginning the process of coupling the T170 atmosphere to the 1-degree ocean.

X. Software Engineering Working Group (SEWG)

The CCSM3 release was accompanied by several thousand years of control runs. The CSL production allocation was utilized to complete these control simulations. Scenarios for these control runs included present-day, pre-industrial, 1%CO_2 ramped and both 2xCO_2 and 4xCO_2 capped. Each of these scenarios was run at T85x1, T42x1, and T31x3 resolutions. Output data sets from all the control runs have been made available on the Web as part of the CCSM3 public release via the Earth System Grid. The following table indicates control runs that were completed after May 1, 2004.

Description	Resolution	Years Run	Machine
1990 control	T31x1	359–880	Bluesky
1870 control	T31x1	400–553	Bluesky
1780 control	T31x1	0–433	Bluesky
1%CO2/uncapped	T31x1	399–569	Bluesky
1%CO2/2x	T31x1	479–635	Bluesky
1%CO2/4x	T31x1	549–708	Bluesky
1990 control	T42x1	682–1000	Blackforest
1870 control	T42x1	400–701	Bluesky
1780 control	T42x1	230–599	Blackforest
1990 control	T85x1	510–700	Bluesky
1990 control	T85x1	600–621	Bluesky (needed for IPCC)
1870 control	T85x1	360–380	Bluesky (needed for IPCC)
1%CO2/4x	T85x1	549–701	Bluesky

XI. References

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