Creating 3-D Jet Stream Circulation Visualizations to Investigate Present and Future Climate Conditions

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ABSTRACT

Current global climate models are very capable of simulating the present climate conditions and providing comprehensive projections of the future. Unfortunately, the results of global climate model historical simulations and realistic future projections provide a great deal of information so they are often difficult to interpret and comprehend. To address this problem, the primary goal of this research was to develop software tools to facilitate the investigation of three-dimensional visualizations of the atmosphere to further our understanding of the Earth’s response and the implications of climate change. Output from the National Center for Atmospheric Research’s Parallel Climate Model (NCAR PCM) served as the basis for creating three-dimensional visualizations of the atmospheric jet stream circulation. The visualizations of the data (which were interpolated from global observations) were created using the graphics capabilities of the MATLAB® software program. This report describes the process by which we visualized the jet stream in three dimensions using several map projections and then began the examination of the behavioral changes of the jet stream circulation produced by the PCM over a one hundred-year period from approximately 2002 to 2100. Early results indicated that the jet stream would strengthen, move equatorward, and increase in height in both hemispheres.

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SOARS®, Erik U. Noble, 1
1. INTRODUCTION

"Climate-system models are an important tool for interpreting observations and assessing hypothetical futures" (National Research Council Summary, 2001). Current high-tech global climate models (GCMs; Dai et al. 2001a, Meehl et al. 2000a and 2000b, Boer et al. 2000, Russell and Rind. 1999, Roeckner et al. 1999, Mitchell et al. 1995, Cubasch et al. 1992, Manabe et al. 1991) are very capable of simulating the present climate and provide detailed projections of future conditions. The results of these elaborate climate model projections are so full of information that they are often difficult to comprehend. To address this problem, the primary goal of this research will be to investigate if three-dimensional visualizations can assist in understanding the atmosphere’s response to climate change. The model output used in this research comes from the National Center for Atmospheric Research (NCAR) Parallel Climate Model (PCM) supported by Department of Energy and National Science Foundation. The model output will be used to create 3-D visualizations of the atmospheric jet stream circulation in the 100-year period from approximately 2002 to 2100. The second goal of this project is to study the visualizations and describe any observed changes in the average jet stream circulation over this period.

Since the jet stream is a region of enhanced wind flow aloft that results from air masses of different thermal characteristics meeting and circulating in the middle latitudes, monitoring its behavior intensity changes can provide clues to global climate change. We want to attempt to answer the following questions pertaining to jet stream behavior during this 100-year period:

1. Will the mean jet stream flow strengthen or weaken by 2099?
2. Will the jet stream move poleward or equatorward by 2099?
3. Will the mean jet stream flow change altitude by 2099?

Similar studies on the circulation of the jet stream have been explored with other GCMs. For example, using the Goddard Institute for Space Studies (GISS) model (Rind, 1987), Rind simulated a doubled carbon dioxide experiment with two sets of sea surface temperatures (SST) to analyze influences upon energy balance and atmospheric dynamics with high-latitude amplification of surface temperature change. Differences in meridional circulation (Hadley Cell) intensity and the jet stream magnitude were noted to decrease accompanied by increased high-latitude amplification, a direct reflection of an increasing latitudinal temperature gradient. However, a high degree of doubt was present with these results because of the uncertainties contained with the SST parameters used in the research. In two other studies, “GCM simulated changes of the atmospheric temperature gradients brought about by surface and sea-surface temperature response led to altered jet stream structures and transient eddy activity, affecting precipitation patterns” (Kitoh, 1994), (Hu et al., 2000). The feedbacks of these noticeable changes in both studies led to a weaker, shift of the jet stream towards high latitudes.

This jet stream study will use the NCAR PCM, which is an advanced GCM. It incorporates a highly representative atmospheric/land parameterization component and a high-resolution ocean and sea-ice parameterization components, as compared to models used in previous studies. To meet the challenge of representing the complex results from the GCMs and hopefully to aid interpretation, 3-D visualizations were created using the graphics capabilities of

SOARS®, Erik U. Noble, 2
the MATLAB® software. The massive data sets for the visualizations are based on the PCM model output generated from global observations. The resulting series of images were converted into animations to facilitate examination in three dimensions. The results and method obtained from this project will allow both scientists and non-scientists to better investigate and appreciate GCM forecasts of present and future climate conditions so that they can make informed decisions affecting future impacts upon the climate. The process of creating the animations will be documented to aid future collaborations or projects requiring graphical visualizations of GCM output.

2. BACKGROUND AND METHODS

This project began by taking a subset of data output from the PCM model, importing it into graphic visualization software, producing 3-D graphics of the parameterized wind fields, and developing animations to examine changes in the mean-monthly average jet stream over the 100-year period. The subsets were comprised of the east-west wind component (U), north-south wind component (V), time, latitude, longitude, geopotential height, and elevation (pressure level) fields.

The PCM Model

NCAR scientists consider the DOE PCM to be an advanced, state-of-the-art GCM. It was the first NCAR coupled climate model specifically designed to execute efficiently on parallel scalar supercomputer systems and was assembled with the support of the DOE and NSF. According to “Parallel Climate Model (PCM) Control and Transient Simulations,” the documentation paper describing the creation and utility of the PCM written by Washington et al., 2000, the PCM produces historical climate simulations and realistic future climate scenarios that are comparable to observations. The model incorporates several climate components, otherwise known as a coupled model. The PCM models the climate of earth using a standard atmospheric component, as well as sea-ice and oceanic components. The PCM is a twin of the NCAR Climate System Model (CSM). The difference between the two models is that the PCM can be run on shared-memory multi-processor computers and/or distributed memory computers making it more versatile than the CSM, which was built to only run on vector supercomputers.

The PCM sea-ice and ocean components are of considerably higher resolution as compared with the resolution used in other coupled climate models. Previous climate change simulations involving earlier climate models used lower-resolution sea-ice and ocean components and somewhat simpler physical processes. In the PCM, these two high-resolution components allow for more realistic physical processes to be simulated and investigated in climate change scenarios.

The atmospheric component follows the format of the recent third NCAR Community Climate Model version (CCM3), using T42 horizontal resolution, 18 hybrid sigma pressure levels, along with versions of the radiation treatment, boundary-layer, and precipitation physics. The ocean parameter is comprised of the Los Alamos National Laboratory Parallel Ocean Program (POP) model; it uses a grid that contains a displaced North Pole over the Hudson Bay area for the purpose of reducing the immense computing power needed for modeling the physical oceanic properties (temperature, dynamics, etc…) of the North Pole region. The dynamic-
thermodynamic sea-ice component was developed from the Naval Postgraduate School work of Zhang and Hibler (1997) and NCAR MPP architecture. This component forecasts ice thickness and concentration, velocity, snow thickness, ice-surface temperature in response to winds, ocean currents, air and ocean temperatures, humidity, radiation, and interior ice stress.

The 100-year model output dataset we used in this project originated as part of a PCM climate scenario examined previously by other investigators. In their paper, “Effects of Stabilizing Atmospheric CO$_2$ on Global Climate in the Next Two Centuries”, Dai et al., 2001c, generated a climate simulation from historical climate conditions in 1870 to the year 2000, and then projected a climate scenario going to the year 2200 by using the anticipated greenhouse gas concentrations resulting from a newly updated business-as-usual (BAU i.e., “no policies to limit greenhouse gas emissions”) assumption.

There are usually two types of CO$_2$ and other greenhouse gas projections used in model scenarios. These conditions are the BAU and stabilization (STA), which means that CO$_2$ concentrations become constant at a concentration close to 550 ppm in the troposphere (Wigley et al. 1996). The only variation from these two states is the concentration of CO$_2$, illustrated in Figure 1.

![Figure 1. This diagram shows the CO$_2$ concentration and the sulphate emissions used in the PCM. Note that around 2050, there is a large increase in CO$_2$ for BAU and stabilization in CO$_2$ for STA (Dai et al., 2001).](image)

The particular PCM scenario used in this project results with a steady increase in global-mean temperature of $\sim$2.0° C (a 3.3% rise) from the 2000s to the 2090s. The resulting CO$_2$ concentrations increase from 362 ppm in 1995 to 688 ppm in 2095. Details of the BAU 2000-2099 scenario results are presented in Dai et al. [2001a].

We chose to use this particular 100-year data set because we wanted to visualize how the BAU scenario will influence the circulation of the jet stream, just one important component within the coupled climate system related to global temperature changes.
MATLAB Software

We chose MATLAB as the programming language of choice because of the software’s ability to interpret matrices and for its versatility in projecting graphics in three-dimensional format. Developed by MathWorks, Inc., the name MATLAB stands for Matrix laboratory, because the system is designed to make matrix computations particularly less time consuming as compared to using object-oriented executable computer programming languages such as Fortran. The MATLAB environment allows the user to manage variables, import and export data, perform calculations, generate plots, and develop and manage files. Also, MATLAB has built-in functions that allow a user to rotate and zoom into a three-dimensional projection and we found the ability to view our projections and animations up-close and at many different angles very desirable.

The PCM output was provided to us in the grid format known as Network Common Data Form (netCDF). Conveniently, MATLAB is capable of ingesting netCDF files reinforcing its suitability to this project. A netCDF file is self-describing, machine independent, and is a format where an immense amount of data can be stored. The format is appendable and sharable; one writer and multiple readers may concurrently retrieve the same netCDF file. One can access the headers in a netCDF file without having to first view all the data. As a result, a small data set can be accessed without having to read all of the proceeding data.

Visualization

MATLAB and the MATLAB Mapping Toolbox were used to generate two-dimensional and three-dimensional images from the model output and then combine the images to form animations of the monthly averaged wind speeds from 2000 to 2099. The same scripts (programming syntax code) developed for displaying the jet stream component within the PCM output can be applied to any other or all of the components contained within GCM output. Several script examples are included in the Appendix.

The visualization process began by determining the wind speed component, which required calculating the square root of both the U and V components of the wind field. MATLAB was used to compute the U and V arrays from the PCM output. These wind speeds were used to create a two-dimensional color animation of the monthly maximum and minimum averages displayed over a world map for the entire 100-year period. Each wind speed value was displayed according to its corresponding latitude and longitude grid. An example of the two-dimensional image for the month of January 2050 is shown in Figure 2.
Figure 2. The oscillations of wind speed maxim and minima are present in both the southern and the northern hemisphere. The color bar indicates wind speed in m/s.

Scientists have traditionally used this type of two-dimensional display for viewing data with time. In figure 2, the seasonal oscillation of the different mean wind speed is apparent in both the southern and the northern hemispheres. Unfortunately, this view does not allow us to determine the height of the jet stream, nor can we specify one particular wind speed value or view wind speeds at all altitude levels at once.

The next step to creating a three dimensional representation of the high wind speeds in the jet stream involved specifying a wind speed value typical of jet stream pace, a value between 30 to 70 m/s, to create an isosurface. An isosurface is a graphical depiction of any specific reference threshold value used to display variables in three-dimensional projections. We were able to make an isosurface of a specified wind speed by displaying it and all speeds above the reference value (35 m/s) encased within a colored tube, as seen in Figure 3.
Figure 3. Isosurface of U wind component from the PCM. The color bar indicates wind speed; all values at 35 m/s are encased in red.

Several mapping projections contained within the mapping toolbox of the MATLAB software were tested for ease of interpretation. After choosing the Robinson world map projection, we produced an animation of the monthly averaged jet stream circulation by compiling a series of images. A one-frame example of this depiction is shown in Figure 4.
Figure 4. Tropical jet stream isosurfaces can be seen in both hemispheres. The polar jet stream is also indicated to the north.

In images like Figure 4, we have the ability to view the wind speed averages at all atmospheric levels over all latitude and longitude values. Animation clearly shows the changes the jet stream strength due to seasonal oscillations. Animation clearly shows the changes the jet stream strength due to with the seasonal oscillations. We also have the ability of viewing on different map projections. This successful presentation of the average jet stream position and strength in three dimensions verifies that the PCM is working to produce mean-wind data images of what is expected based on actual observations of the atmosphere. A large amount of effort went into discovering a method of producing the PCM output in three dimensions.

A downside to using this method is that only one wind speed average threshold value can be specified as an isosurface. In Figure 4, only the mean-wind speeds greater than or equal to 35 m/s are displayed. Although, we were successful at depicting the jet stream in 3-D this view did not allow us to easily assess changes in the jet stream over the 100-year period.
3. DISCUSSION

To better investigate the change in the jet stream, we tried an approach as seen in Figure 5. First, we subtracted the wind magnitudes for the year 2099 from the values from 2000. This clearly shows the differences between the 100-year period. The differences show that change has occurred from the beginning to the end of the record. The blue to red dipole seen in the bottom plot indicates that there has been a shift of the jet streams equatorward and upwards in elevation. Since the difference represents the change in the smoothed wind speed values over all longitudes, not all of the information about the wind speed values is shown. Viewing this change in 3-D animation provides information as time progresses.

![Figure 5](image)

*Figure 5. Color bars indicate wind velocity. The wind speeds strengthen in the southern hemisphere in the higher altitudes.*
The next step involved reducing the seasonal wind speed oscillations contained within the original output. To do this, we developed an animation displaying the ten-year running averages of the model output wind speeds. Figure 6 is one example of these results in three dimensions for the 2085 to 2095 period.

**Ten-Year Running Average for 2005 to 2015 and 2085 to 2095**

**Isosurface of 35 m/s**

![Image of 3D isosurface](image)

*Figure 6. The figure on the left represents the 10-year running average for 2005 to 2015; the right represents the 10-year running average for 2085 to 2095.*

We can clearly see the mean wind speeds in both hemispheres, with the southern hemisphere being the larger area of higher values. Unfortunately, this method did not reveal any appreciable change from the beginning to the end of the century in the latitudinal movement or the jet stream height during the 100-year time period. The changes that were present were very small.

To address this problem, we calculated the anomalies of the 10-year running averaged data so that only the differences of the mean wind speed values were shown in the animations. The maximum and minimum values of the positive/negative anomalies were 4/-2.5 m/s, respectively. Both 2-D and 3-D animations were developed via this approach. Figure 7 is an example of the 2-D 10-year running anomaly.
Figure 7. The green (red) indicate negative (positive) anomalies in m/s.

In this view, the anomalies are visible; strengthening (yellow) and weakening (dark green) of the jet stream winds occurs in both hemispheres. However, depth is still not apparent. By creating a three dimensional visualization of the same positive mean wind speed anomaly data from 2000 to 2999 (shown in Figure 8) displays the jet stream growth shown by the positive anomalies during the 100 year period is much more apparent.

Figure 8. This depicts positive anomaly growth from 2000 to 2099.

This view clearly shows the increasing strength of the mean jet stream values in both hemispheres with time. The changes in wind speed are not visible until the middle of the time period. The changes in the wind speed are not visible until the middle of the time period (approximately 2040) and they increase dramatically by the end of the century.
To distinguish the movement of the mean jet stream position from 2000 to 2099, we created an animation showing both the positive (red) and negative (yellow) wind speed anomalies displayed over the same map projection. Figure 10 presents the anomalies as seen from three different viewing angles for the 2085-2095 period.

![Image](image.png)

**Figure 9.** 3-D depictions of the 10-year average anomalies for the 2000 to 2099 period. The positive anomalies (greater than 1.5m/s) are shaded in red and the negative anomalies are shaded in yellow (less than –1.4 m/s).

Figure 10 illustrates the abilities of the MATLAB software to zoom and rotate the projected image. Investigating the data in this manner, we were able to see that there is an equator-ward shift in the mean jet stream position in both hemispheres from the beginning to the end of the 21st Century. We were also able to determine that the jet stream core moves upward. It should be noted that this is a representation 3-D height changes since we had to stretch the altitude parameter in all of the 3-D visualizations to aid interpretation.

4. CONCLUSION

In closing, it is safe to say that this was a very successful project, especially given the amount accomplished in the 10-week period. A new method of displaying GCM output in three dimensions was created. To the knowledge of those involved in this project this is the first time that three-dimensional visualization has been achieved using NCAR global climate model data. In particular, the component investigated here (the jet stream) was successfully visualized using many of the capabilities of the MATLAB software. Initial investigation of the visualizations showing the predicted model behavior of the jet stream, indicate that there is potential for strengthening of the jet stream winds, and an equatorward shift in both hemispheres and arise in jet stream level height during the PCM 2000 to 2099 BAU climate scenario. These preliminary results were especially exciting to observe since we did not initially expect to get this far in the project during the 10-weeks allotted.

Three-dimensional animation was not the most enlightening view in all PCM output data component investigations undertaken to date, but was especially helpful in others. Envisioning model output in three-dimensions is a new step in trying to understand our potential future global climate based on the GCM tool. This venture has shown the potential benefit of examining PCM
output in this manner and laid a new framework for NCAR scientists to continue to explore the value of 3-D visualizations for assessing climate change. This new method can be applied to viewing all aspects of the global climate, not just the jet stream. We encourage more research to be carried out in this manner.
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APPENDIX
MATLAB Scripts

1. 2D Monthly Averages for 2000 to 2099

% Author: Erik U. Noble  July 23, 2002
% This script allows user to import NCAR PCM output for 2D animation.
% The output is in the NetCDF format.
% All of the Atmospheric netCDF files were stored in the CGD directory:/data/pcm/NI/SAER/soars/atm/
% There are 10 files that include 120 time steps.
% The wind speed is calculated and isosurfaced in 2D
% All resulting images are compiled into a movie mpg file
% This script includes the Geopotential Height Variable, Z3.
% This format is what Scientists usually use to view data with time.
% The seasonal oscillation can be seen through the years.
% Disadvantage- depth cannot be seen!
% There are stronger Winter winds in the corresponding hemisphere due
% ...to stronger temperature gradient from equator to pole.
% Open NETCDF file to read latitude and longitude data colormap(jet)
clear;
tic
runnumber=1;
fid=netcdf('data/pcm/NI/SAER/soars/atm/BAU-Ens.atm.200D.nc', 'nowrite');
lon = fid('lon') (:);
nfiles = 3;  % nfiles designates the amount of files to use (1 to 10).
lon = fid('lat') (:);
nmonths = 120;  % nmonths designates the amount of months to use (1 to 120).
% If the levels are needed, use lev = fid('lev') (:);
% Close the NETCDF file
fid = close(fid);
% This command loads up the the information for plotting
% coastlines on a map projection from the MATLAB mapping toolbox
% Do not use next two lines if mapping toolbox isn't available.
load coast; coastlat = lat; coastlon = long;
clear long; clear lat;
M=movimn(nfiles*nmonths);
% The mapping legend:
% maplegend = [cells/angleunit north-latitude west-long]
% Do not use mapping commands if mapping toolbox isn't available.
atmlegend = [ 128/360 87.8838 0]
figure(1); clf
set(gca,'CLim', [0 70]); colorbar('horiz'); colormap(jet);
axesm robinson  % Set the projection type.
% See the mapping toolbox manual for other projections.
% surfl puts the temperature data onto the map. See
% www.mathworks.com/access/helpdesk/help/toolbox/map/surfl.shtml
% This loop calls each netCDF file
for j=1:nfiles
atmospheredata=['data/pcm/NI/SAER/soars.atm.' num2str(200+(j-1)) '.D.nc';
fid = netcdf(atmospheredata, 'nowrite');
% This loop calls 1 to 120 months, specified by nmonths variable.
for k=1:nmonths
counter = (j-1) * 120 + k;
% Wind components, U and V are read in to use in calculations.
% Each component is read in with time as the 'k' loop variable,
% Example 'U' (k,'all of lat','all of long', 'all of Z3')
u = fid('U')(k, 1:18, 1:64, 1:128);
u = permute(u,[2 3 1]); % lat, lev, lon
v = fliplr(v([1 11]));
Z3 = permute(Z3,[2 3 1]);

% Wind Speed calculation
wind = sqrt(u.^2 + v.^2);
clear u v Z3

% Graphing 2-D command
set(gca,'YDir','normal');
% meshm puts the temperature data onto the map with a regular grid.
% Use surfm command for plotting with a "general grid'.
% See %www.mathworks.com/access/helpdesk/help/toolbox/map/surfm.shtml
meshm(wind(:,:,7),atmlegend); clear wind;
axis off; axis tight;
% Plot coast lines 'See page 2-3 of the mapping toolbox
plotm(coastlat, coastlon,'K')
% Use next two lines with imagesc
xlabel('Longitude')
ylabel('Latitude')
time = (counter-1)/12; % Number of years
year = floor(time); % Floor rounds down to the nearest integer.
month = counter-year*12;
'Wind Speed (m/s) at 189 Millibars'];
title(text,'HorizontalAlignment','center','FontSize',15);
% worldmap;
lighting phong;
% Movie Creation
M(:, counter) = getframe(gcf);
end
fid = close(fid);
end;
movie(M)
%mpgwrite(M,'hsv', 'TwoDMonthlyAverage.mpg')
movie2avi(M, 'TwoDMonthlyAverage.avi', 'fps', 6)
toc
2. 3D Animation of Monthly Average Wind Speed for 2000-2099

% Author: Erik U. Noble
% July 23, 2002
% This script allows the user to import NCAR PCM model output in the form of netCDF files.
% All of the Atmospheric netCDF files were stored in the CGD directory:
% There are 10 files that include 120 time steps.
% The wind speed is calculated and the iso-surfaces are plotted 3 dimensionally upon a map projection.
% All resulting images are compiled into a movie file and saved as an .mpeg file.
% This script includes the Geopotential Height Variable, Z3.
% Open NETCDF file to read latitude and longitude data, which doesn't change at all.
clear;
 tic
 runnumber=1;
 fid=netcdf('data/pcm/SOARS/atm/BAU-Ens.atm.200D.nc', 'nowrite');
 lon =fid('lon') ();    nfiles = 3;  % nfiles designates the amount of files to use (1 to 10).
 lat =fid('lat') ();    nmonths = 120;  % nmonths designates the amount of months to use (1 to 120).
 lev =fid('lev') ();
% If the levels are needed, use lev =fid('lev') ();

% These next two commands create a matrix of latitude and longitude.
 lonmtx = (lon*ones(1,length(lat)));
 latmtx = lat*ones(1,length(lon));
% Close the NETCDF file
 fid =close(fid);
% Graphing 3-D command
 load topo
% This loop calls each netCDF file
 M = moviein(nfiles*nmonths);
 for j=1:nfiles
   atmosphere=netcdflid(fid,'data/pcm/SOARS/atm/BAU-Ens.atm.200D.nc');
   fid = netcdf(atmosphere, 'nowrite');
   % This loop calls each of the 1 to 120 months, specified by nmonths variable.
   for k=1:nmonths
     counter = (j-1) * 120 + k;
     % Wind components, U and V are read in to use in calculations.
     % Each component is read in with time as the 'k' loop variable, with all other lat,lon,Z3 data.
     % Example 'U' (k,'all of lat', 'all of long', 'all of Z3')
     u = fid('U')(k, 1:18, 1:64, 1:128);
     v = permute(v,[2 3 1]);  % lat, lev, lon
     Z3 = fid('Z3')(k, 1:18, 1:64, 1:128);
     Z3 = permute(Z3,[2 3 1]);
     % Wind Speed calculation
     windspeed=sqrt(u.^2 + v.^2);
     clear u v
     figure (1); clf
     axesm eqcyl
     meshm(topo,topolegend,size(topo),topo/10);
     dememmap(topo)
     axis tight
     daspectm('meters',200)
     view(70,30)
     [x,y] = mfwdtran(latmtx,lonmtx,Z3);
     for q=2:length(lev)
       x(:,q)=x(:,1);
       y(:,q)=y(:,1);
     end

SOARS®, Erik U. Noble, 17
end
isom = isosurface(x,y,Z3,windspeed,35); % 35 meters per second
clear Z3 windspeed x y
hisol = patch(isom);
clear isom
set(hisol,'FaceColor','red','EdgeColor','none','Clipping','off'); % to display all of Isosurface

camlight(45,35)
lighting phong
% If Title is needed use these commands below.
time = (counter-1)/12; % Number of years
year = floor(time); % Floor rounds down to the nearest integer.
month = counter-year*12;
text(1,-3.5,0,[' Year ' num2str(2000+year) ' Month ' num2str(month)...
 'newline Isosurfaces of Wind Speed at 35 m/s'], 'FontSize',16);
%[num2str(counter) ' ' num2str(time) text] %-- for editing purposes
%title(text);

% Movie Creation
M(counter) = getframe(gcf);

% From here, save image as jpeg file at 2 eye viewing angles for 3D.
%filenameR = ['R' num2str(runnumber) 'F' num2str(2*counter,%03.0f) '.jpg'];
%filenameL = ['R' num2str(runnumber) 'F' num2str(2*counter-1,%03.0f) '.jpg'];
% View of Left Eye = view(70,30);
% View of Right Eye = view(72,30);
% command for making the jpegs: left view first, right view second.
%sprintf ('-f1', '-djpeg99', filenameL);
%sprintf ('-f2', '-djpeg99', filenameR);
end
fid = close(fid);
end
movie(M)
mpgwrite(M,'hsv', 'Big3DJetStr.mpg')
movie2avi(M, 'Big3DJetStr.avi', 'fps', 6)
toc
3. 3D Animation of 10-year Running Average for 2000-2099

% Author: Erik U. Noble
% Ten-year Running Average 3D Plot
% User is able to plot in 3D.
clear;
tic
runnumber=1; % Run Number
fid=netcdf('/data/pcm/SOARS/atm/BAU-Ens.atm.2005-2095Sm.nc', 'nowrite');
lon = fid{'lon'} (:);
timesteps = 91; % Timesteps "91".
lat = fid{'lat'} (:);
lev = fid{'lev'} (:);
% If the levels are needed, use lev = fid{'lev'} (:);
% These next two commands create a matrix of latitude and longitude.
lonmtx = (lon*ones(1,length(lat)));
latmtx = lat*ones(1,length(lon));
% M=moviein(91);
% Graphing 3-D command
load topo
for k=1:timesteps;
    % Wind components, U and V are read in to use in calculations.
    % Each component is read in with time as the 'k' loop variable, with all % other lat,lon,Z3 data.
    % Example 'U' (k,'all of lat', 'all of long', 'all of Z3')
    u = fid{'U'}(k, 1:18, 1:64, 1:128);
    u = permute(u,[2 3 1]); % lat, lev, lon
    v = fid{'V'}(k, 1:18, 1:64, 1:128);
    v= permute(v,[2 3 1]);
    Z3 = fid{'Z3'}(k, 1:18, 1:64, 1:128);
    Z3 = permute(Z3,[2 3 1]);
    % Wind Speed calculation
    windspeed=sqrt(u.^2 + v.^2);
clear u v;
    % Find the maximum and minimum wind speed values.
    max=max(max(windspeed))
    min=min(min(windspeed))
end
year = 1999 + k;
figure (3); clf
axesm eqcylind
meshm(topo,topolegend,size(topo),topo/10);
demcmap(topo)
axis tight
daspect('meters',200)
view(50,35)
[x,y] = mfwdtran(latmtx,lonmtx,Z3);
for q=1:length(lev)
    x(:,q)=x(:,1);
    y(:,q)=y(:,1);
end
isom = isosurface(x,y,Z3,windspeed,30); % -1 meters per second
clear windspeed Z3 x y
hisol1=pcolor(isom);
set(hisol1,'FaceColor','red','EdgeColor','none','Clipping','off');% Very important command
% text = [%'Decadal Running Average ', 'newline ', ' Years ' num2str(year)...  
% ' to ', num2str(year + 10) , ' 30 m/s','newline ', ' Isosurfaces of 30 m/s'];

SOARS®, Erik U. Noble, 19
% Movie Creation
%M(k) = getframe(gcf);
% From here, save image as jpeg file at 2 eye viewing angles for 3D.
filenameR = ['TenYrR AvgR' num2str(runnumber) 'F' num2str(k, '%03.0f')... 'R.jpg'];
filenameL = ['TenYrL AvgR' num2str(runnumber) 'F' num2str(k-1, '%03.0f')... 'L.jpg'];
% View of Left Eye = view(70, 30);
% View of Right Eye = view(72, 30);
% command for making the jpegs: left view first, right view second.
print('-f3', '-djpeg99', filenameL);
view(52, 35)
print('-f3', '-djpeg99', filenameR);
end

end

%movie(M)
%mpgwrite(M, 'hsv', 'TenYrRunningAvg3D.mpg')
%movie2avi(M, 'TenYrRunnAVG3D.avi', 'fps', 5)

toc
REFERENCES


