APPENDIX A

MODEL VERIFICATION TECHNIQUES

A.1 INTRODUCTION

Forecast Verification is the process of determining the quality of forecasts. A wide variety of forecast verification procedures exist, but all involve measures of the relationship or set of forecast, and the corresponding observation(s). Any forecast versification method thus necessarily involves comparisons between matched pairs of forecasts and the observations to which they pertain (Wilks, 1995).

The methods employed in the model evaluation section of chapter 6 will be illustrated briefly here. Accordingly, the objective measures of skill or accuracy and their relationship that constitutes the basics of Taylor (2000) scheme are briefly highlighted.

A.2 TAYLOR DIAGRAM

A.2.1 THEORETICAL BASIS

The statistic most often used to quantify pattern similarity is the correlation coefficient. The term "pattern" is used here in its generic sense, not restricted to spatial dimensions. Consider two variables, f_n and r_n, which are defined at N discrete points (in time and/or space). The correlation coefficient (R) between f and r is calculated with the following formula:

$$R = \frac{\frac{1}{N}\sum_{n=1}^{N}\left(f_n - \bar{f}\right)\left(r_n - \bar{r}\right)}{\sigma_f \sigma_r},$$

where $\bar{f}$ and $\bar{r}$ are the mean values, and σ_f and σ_r are the standard deviations of f and r, respectively. For grid cells of unequal area, the above formula would normally be modified in order to weight the summed elements by grid cell area (and the same weighting factors would be used in calculating σ_f *and* σ_r. Similarly, weighting factors for pressure thickness and time interval can be applied when appropriate.

The correlation coefficient reaches a maximum value of one when for all *n*, $\left(f_n - \bar{f}\right) = \alpha\left(r_n - \bar{r}\right)$, where α is a positive constant. In this case the two fields have the same centered *pattern* of variation, but are not *identical* unless $\alpha = 1$. Thus, from the correlation coefficient alone it is not possible to determine whether two patterns have the same *amplitude* of variation (as determined, for example, by their variances).

The statistic most often used to quantify differences in two fields is the root-mean-square (RMS) difference, *E*, which for fields *f* and *r* is defined by the following formula:

$$E = \left[\frac{1}{N}\sum_{n=1}^{N}\left(f_n - r_n\right)^2\right]^{1/2}.$$

Again, the formula can be generalized for cases when grid cells should be weighted unequally.

In order to isolate the differences in the patterns from differences in the means of the two fields, E can be resolved into two components. The overall "bias" is defined as

$$\overline{E} = \bar{f} - \bar{r}$$

and the centered *pattern* RMS difference by

$$E' = \left\{\frac{1}{N}\sum_{n-1}^{N}\left[\left(f_n - \bar{f}\right) - \left(r_n - \bar{r}\right)\right]^2\right\}^{1/2}.$$

The two components add quadratically to yield the full mean-square difference:

$$E^2 = \overline{E} - E'^2.$$

The pattern RMS difference approaches zero as two patterns become more alike, but for a given value of *E’,* it is impossible to determine how much of the error is due to a difference in structure and phase and how much is simply due to a difference in the amplitude of the variations.

The correlation coefficient and the RMS difference provide complementary statistical information quantifying the correspondence between two patterns, but for a more complete characterization of the fields, the variances (or standard deviations) of the fields must also be given. All four of the above statistics (*R, E’,* σ_f *and* σ_r) are useful in comparisons of patterns, and it is possible to display all of them on a single, easily interpreted diagram. The key to constructing such a diagram is to recognize the relationship between the four statistical quantities of interest here,

$$E'^2 = \sigma_f^2 + \sigma_r^2 - 2\sigma_f \sigma_r R,$$

and the Law of Cosines,

$$c^2 = a^2 + b^2 - 2ab\cos\phi,$$

where *a*, *b*, and *c* are the lengths of the sides of a triangle, and ϕ is the angle opposite side *c*. The geometric relationship between *R, E',* σ_f *and* σ_r) is shown figure A.1.

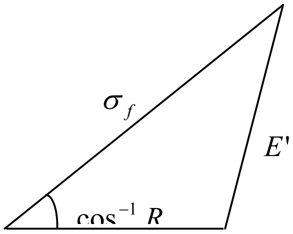

Figure A.1: Geometric relationship between the correlation coefficient, *R*, the pattern RMS difference, *E'* and the standard deviations, σ_f *and* σ_r, of the test and reference fields, respectively.

With the above definitions and relationships it is now possible to construct a diagram that statistically quantifies the degree of similarity between two fields. One field will be called the "reference" field, usually representing some observed state. The other field will be referred to as a "test" field (typically a model-simulated field).

APPENDEX B

PYTHON CODE FOR MODEL OUTPUT MANIPULATION

```
"""
************************************************************
This python script transforms the PRECIS model output to the
correct regional axis and regrids NCEP to PRECIS model
resolution
#***********************************************************
"""
# the following is only needed to confirm the path where the
target #files are found.
import os, sys
here = os.getcwd()
there = os.path.dirname(sys.argv[0])
if there == '': there = os.path.expanduser('~') + '/' +\
'path/'
if here != there:
    if os.path.isdir(there):
        os.chdir(there)
    else:
        print 'File not found!'
        sys.exit()
path = '../final_folder/'
#**********************************************************
from genutil import statistics
from regrid import Regridder
import cdms, MV, MA, cdtime, time, cdutil

#***********************************************************
f1 = path + 'precis file'
precis = cdms.open(f1)
f2 = path + 'ncep file'
ncep = cdms.open(f2)
#***********************************************************
s = precis('variable name')
r = ncep('variable name')
# retrieving the information
ax0=s.getAxis(0)     # time bounds
ax1=s.getAxis(1)     # lat bounds
ax2=s.getAxis(2)     # lon bounds

#***************************************************
# transforming the sigma levels to pressure
ax1.id='pressure'
ax1.units='hPa'
ax1.Length=vertical leves
ax1.First=L1
```

```
ax1.Last=Ln
ax1.axis='Z'
ax1[:]=[L1. , L2 , .....,Ln]
#****************************************************
# Horizontal grid transformation
# Lat
lats=MV.arange(59,typecode=MV.Float)*R+Y0  #where R:
#Estimated resolution and Y0 intial Y value.
lat=cdms.createAxis(lats)
ax1=s.setAxis(1,lat)
lat.id='latitude'
lat.units='degree_north'
lat.designateLatitude()
#Lon
lons=MV.arange(99,typecode=MV.Float)*R+X0
lon=cdms.createAxis(lons)
ax2=s.setAxis(2,lon)
lon.id='longitude'
lon.units='degree_east'
lon.designateLongitude()
"""
**********************************************************
 Regirding of the NCEP Reanalysis data to the transformed
 PRECIS output grid
**********************************************************
"""
inprecis = s.getGrid() # Get the target grid
outncep = s.getGrid()
regncep = r.regrid(outncep)
"""
*************************************************************
* (Statistical analysis)
*************************************************************
"""
# Representation of time-span
# for precis
precistime1 = cdtime.comptime(year 1)
precistime2 = cdtime.comptime(year 2)
# for ncep
nceptime1 = cdtime.comptime(year 1)
nceptime2 = cdtime.comptime(year 2)
# query the spatial and temporal domains that should be
#included in the analysis
precis1 = precis('precis variable', time = (precistime1,\
precistime2), longitude = (x1,x2,'oo'),\
                 latitude = (y1,y2,'oo'))
ncep1 = ncep('ncep variable', time = (nceptime1, nceptime2),\
longitude = (x1,x2,'oo'),\
                 latitude = (y1,y2,'oo'))
#************************************************************
# calculating averages of the two fields
avg_precis = cdutil.averager( precis1, axis='(time)',\
weights=['equal'])
avg_ncep = cdutil.averager( ncep1, axis='(time)',\
weights=['equal'])
```

```
# calculating the RMS between the two fields
rmse = statistics.rms( avg_precis,avg_ncep, axis='xy',\
weights=['equal','equal'])
# calculating the standard deviation
sd_precis = statistics.std( avg_precis, axis='xy',\
weights=['equal','equal'])
sd_ncep = statistics.std( avg_ncep, axis='xy',\
weights=['equal','equal'])
# calculating the pattern correlation
ac_60s=statistics.correlation(avg_precis ,avg_ncep,\
axis='xy', weights=['equal','equal'] )
```

REFERENCES

Ahrens, C.D., 2000: *Meteorology today: An introduction to weather, climate, and the environment,* 6th ed., Brooks/Cole, Pacific Grove.

Albrecht, B.A., 1983: *A cumulus parameterization for climate studies of the tropical atmosphere, Part I: model formulation and sensitivity test,* J. Atmos. Sci. 40: 2166-2181.

America on line service, 2002: *Lonely planet World Guide Destination Eritrea* http://www.lonelyplanet.com/destinations/africa/eritrea/

AMS Statement, 2001: *Seasonal to interannual climate prediction (adopted by AMS Council 14 January 2001)*. Bulleting of the American Meteo. Soc., 82: 701-703, 710.

Anthes, R.A., 1977: *A cumulus parameterization scheme utilizing a one-dimensional cloud model,* Mon. weather Rev., 105: 270-286.

Arakawa A. & W.H. Schubert, 1974; *Interaction of a Cumulus Cloud Ensemble with the Large Scale Environment,* Part I, J. Atmos. Sci. 31: 674-701.

Arnell, N.W., D.A. Hudson & R.G. Jones, 2003: *Climate scenarios from a regional climate model: Estimating change in runoff in southern Africa, J. Geophys. Res.*, 108(D16), 4519, doi:10.1029/2002JD002782.

Awosika, L.F., E.S. Diop, T.F. Downing, M. El-Raey, D. Le. Sueur, C.H.D. Magadza, S. Touré & C. Vogel, 2001: *The Regional Impacts of Climate Change,* IPCC Special Report on Climate Change http://www.grida.no/climate/ipcc/.

Bach, W., 1988: *Modelling the climatic response to greenhouse gases,* in Gregory, S. (ed), *Recent climatic change: A regional Approach,* Belhaven Press, London, pp. 8-19.

Bjerknes, V., 1904: *Das problem von der wettervorhersage,* betrachtet vom standpunkt der mechanik und der physik. Meteor. A., 21 1-7.

Bradley, R.S., 1991: *Pre-instumental climate: How has climate varied during the past 500 years,* in Schlesinger, M.E. (ed), *Greenhouse-Gas-Induced climate change: A critical appraisal of simulations and observations,* Elsevier Scie., Amsterdam, pp. 391-409.

Central Intelligence Agency (CIA), 2002: *World fact book of 2002*. http://www.cia.gov/cia/publications/factbook/goes/er.html

Charney, J.G, 1975: *Dynamics of deserts and drought in the Sahel,* Quart. J. Roy. Meteor. Soc. Vol.101, No. 428:193-202.

Charney, J.G. & A. Eliassen, 1964: *On the growth of the hurricane depression,* J. Atmos. Sci.21: 68-75.

Charney, J.G, R. Fjørtoft & J.von. Newmann, 1950: *Numerical integration of the barotropic vorticity equation,* Tellus, 2, 237-254.

Cubasch, U. & R.D. Cess, 1990: *Processes and modeling. Climate Change*: The IPCC Scientific Assessment, Cambridge University Press, Cambridge.

Cubasch, U., G.Meehl, G.J. Boer, G.J. Stouffer, M. Dix, A. Noda, C.A. Senior, S. Raper & K.S. Yap, 2001: *Projections of Future Climate Change*, in Houghton, J.G., Y. Ding, D.J. Griggs, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell & C.A. Johnson (eds*), Climate Change 2001: The scientific Basis*, contribution of working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 525-582

Cunnington, W.M. & P.R. Rowntree, 1986: *Simulations of the Saharan atmosphere dependece on moisture and albedo,* Quart. J. Roy. Meteor. Soc. 112: 971-999.

Davies, H.C., 1976: *A lateral boundary formulation for multi-level prediction models*, Quart. J. Roy. Meteor. Soc. 102: 405-418.

Davies, H.C. & R.E. Turner, 1977: *Updating prediction models by dynamical relaxation: an examination of the technique,* Quart. J. Roy. Meteor. Soc. 103: 225-245.

Drury, S.A., S.P. Kelley & S.M. Berhe, 1974: *Structure related to the Red Sea evolution in northern Eritrea.* Tectonic, 13 (6), pp. 1371-1380.

Druyan, .M. & S. Hastenrath, 1991: *Modelling the differential impact of the 1984 and 1950 sea-surface temperatures on Sahel rainfall,* Int. J. Climateol. 11: pp. 367-380.

Engelbrecht, F.A., 2000: Nested climate modeling over Southern Africa with a semi-Lagrangian limited area model, unpublished MSc. Dissertation, University of Pretoria, Pretoria.

Engelbrecht, F.A., C.J. deW. Rautenbach, G.L. McGregor & J.J. Katzfey, 2002: *January and July climate simulations over the SADC region using the limited-area model DARLAM*, Water SA Vol. 28 No. 4, pp. 361-373.

FAO, 1994: *Eritrea – Agricultural sector review and project identification*, 3 volumes Report prepared by FAO/IC under Technical Cooperation Programme project TCP/ERI/2353. Rome.

FAO, 2002: *Special report FAO/WFP crop and food supply assessment mission to Eritrea,* FAO global information and Early warning system on food and agriculture WFP, Rome. http://www.fao.org/WAICENT/faoinfo/economic/giews/english/alertes/sptoc.htm

Fischer, G., M. Shah & V. Velthuizen, 2002: Climate Change and Agricultural vulnerability. IIASA special report under UN Instututional contract agreement No 1113 as a contribution to the World Summit on Sustainable Development, Johannesburg 2002.

Folland, C.K., T.N. Palmer & D.E. Parker, 1986: *Sahel Rainfall and world-wide sea temperatures*, Nature 320: 602-607.

Folland, C.K., T.R. Karl & K.Y.A. Vinnikov, 1990: *Observed Climate Variation and change*, The IPCC Scientific Assessment, Cambridge University Press, Cambridge.

Fu, Q., P. Yang & W.B. Sun, 1998: An accurate parameterization of the infrared radiative properties of cirrus clouds of climate models, J. Climate, 11: 2937-2947.

Garbesi, K., K. Karen & R. Van Buskirk, 1996: *Preliminary Wind Energy Resources Assessment for Eritrea*, Energy Research and Training Division, Ministry of Energy, Mines, and Water Resources, Asmara. http://www.punchdown.org/rvb/wind/WINDREP796.html

Gibson, J.K., P. Kallberg, S. Uppala, A. Hernandez, A. Nomura and E. Serrano, 1997: *ERA description. ECMWF Reanalysis Project Report Series 1*, European Centre for Medium Range Weather Forecasts, Reading, UK, 66 pp.

Goddard. L., S.J. Zebiak, C.F. Popelewski, R. Basher & M.A. Cane, 2001: *Currentapproaches to seasonal-to-interannual climate predictions,* Int. J. Climateol. Vol. 21, pp. 1111-1152.

Gordon, H.B. & B.G. Hunt, 1991: *Droughts, floods, and sea-surface temperature anomalies: a modelling approach,* Int. J. Climateol. Vol. 11, pp. 347-365.

Government of Eritrea (GoE), 1994: *Macro-policy*, Govnment of Eritrea, Asmara.

Government of Eritrea (GoE), 1995: *National Environmental Management Plan for Eritrea*, Environment Eritrea, Druckerei Schwenk & Co. GmbH, Frankfurt.

Government of Eritrea (GoE), 1998: *National Economic Policy Framework and Program for 1998-200*, Government of Eritrea, Asmara.

Haltiner, G.J., 1971: *Numerical weather prediction*, Wiley, New York.

Haltiner, G.J. & R.T. Williams, 1980: *Numerical prediction and dynamical meteorology*, Second Edition, Wiley, New York.

Henderson-Seller, A. & K. McGuffeie, 1987: *A climate modeling primer*, John Wiley & Sons, Chichester.

Henderson-Seller, A. & K., McGuffeie, 2001: *Forty years of numerical climate modeling,* Int. J. Climato. 21:1067-1109.

Hewitson, B.C., 2001: *Global and regional climate modeling: Application to Southern Africa,* WRC Report No. 806/1/01, Cape Town.

Hewitson, B.C., 2004: Climate – A cause for concern, in Water Wheel, WRC Water bulletin, Vol. 3 No. 3, pp. 22-26.

Houghton, J.J., L.G.M. Filho, et al., (eds) 1996: *Climate Change 1995: The Science of Climate Change,* Cambridge University Press, Cambridge.

Hurni, H. & T. Koller, 2002: *Eritrea: Sustainable land management in a Sahelian Country,* Syngenta Foundation for Sustainable Agriculture (SFSA). http://www.syngentafoundation.com

IPCC. Climate Change, 2001: *The Scientific Basis,* contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Jones, R., D. Hudson, S. Wilson, G. Jenkins & J. Mitchell, 2003: *Workboook on generating high resolution climate change scenarios using PRECIS,* Hadley Centre for Climate Prediction and Research, Met Office, Bracknell.

Kalnay, E. & Coauthors, 1996: *The NCEP/NCAR 40-year Reanalysis Project,* Bull. Am. Met. Soc., 77, 437-471.

Kalnay, E., S.J. Lord & R.D. McPherson, 1998: *Maturity of Operational Numerical Weather Prediction: Medium Range,* Bulletin of the American Meteo. Society, Vol. 79 No. 12, pp. 2753-2769.

Karen R., 1998: *An Assessment of the Potential for Utility-Scale Wind Power Generation in Eritrea,* Masters Thesis, Environmental Studies Department, San Jose State University, San Jose. http://www.punchdown.org/rvb/wind/karen/kth-TableOfContents.htm

Katayama, A., 1974: *A simplified scheme for computing radiative transfer in the troposphere,* Tech. Rep. No. 6 Dept. of Met., UCLA, pp. 77.

Kayouli, C, T. Tesfai, & A. Tewelde, 2002: *Country Pasture/ Forage Resources Profiles Eritrea*. Halhale Research Center, Halhale.

Kimura, R., 2002: *Numerical weather prediction,* J. winds Engineering & Industrial Aerodynamics, Vol. 90 pp. 1403-1414.

Kuo H. L, 1974: *Further studies of the parameterization of the influence of cumulus convection on large-scale flow,* J. Atmos. Sci. 31: 1232-1240

Krzysztofowicz, R., 2001: *The case probabilistic forecasting in hydrology,* J. of Hydrology, Vol. 249, pp. 2-9.

Lamb, P.J., 1988: *Large scale tropical Atlantic surface circulation patterns associated with sub-Saharan weather anomalies,* Tellus, 30:240-251.

Layton, A.T., & W.F. Spotz, 2003: *A semi-Lagrangian double Fourier method for shallow water equatons on the sphere,* in press, J. Comput. Phys.,Vol. xxx, pp. xxx-xxx.
http//www.sciencedirect.com

Lorenz, E.N., 1963: *Deterministic nonperiodic flow*, J. Atmos. Sci. 20: 130-141.

Leung, L.R., L.O. Mearns, F. Giorgi & R.L. Wilby, 2003: *Regional climate research: needs and opportunities,* Meeting Summaries, Amer. Metor. Soc., pp. 89-95.

MacCracken, M.C. & J. Kutzbach, 1991: *Comparing and contrasting Holocene and Eemain warm periods with greenhouse-gas-induced warming,* in Schlesinger, M.E. (ed), *Greenhouse-Gas-Induced climate change: A critical appraisal of simulations and observations,* Elsevier Scie., Amsterdam, pp. 69-78.

Martyn, D., 1992: *Climate of the World,* Polish Scientific publishers, Warszawa.

McGregor, J.L., 1993: *Economic determination of departure points for semi-Lagrangian models,* Mon. Weather Rev. 119: 1057-1074.

McGregor, J.L., 1995a: *Semi-Lagrangian advection on conformal-cubic grids,* Mon. Weather Rev., 124: 1311-1322.

McGregor, J.L., 1995b: *Semi-Lagrangian advection on a Cubic Gnomonic projection of the sphere,* in Lin, C., Laprise R. & Ritchie, H. (eds), *Numerical mothodes in atmospheric and oceanic modeling,* Canadian Meteorological and Oceanographic Soc., Ottawa, pp. 153-169.

McGregor, J.L., 1997: *Regional climate modeling*, Meteorol. Atmos. Phys. 63:105-117

McGregor, J.L., K.J. Walsh & J.J. Katzfey, 1993: *Nested modeling for regional climate studies*, in Jakeman, A.J., Beck, M.B. & McAleer, M.J. (eds), *Modeling change in environmental systems*, Wiley, Chichester, pp. 367-386.

Mcguffie, K. and A. Henderson-Sellers, 2001: *Forty years of numerical climate Modeling*, Int. J. Climatol. Vol. 21: 1067-1109.

Mitchell, J.F.B., 1991: *The equilibrium response to doubling Atmospheric C02,* in Schlesinger, M.E. (ed), *Greenhouse-Gas-Induced climate change: A critical appraisal of simulations and observations,* Elsevier Scie., Amsterdam, pp. 49-61.

Ministry of Agriculture (MoA), 2002: *The national action programme for Eritrea to combat desertification and mitigate the effects of drought (NAP),* MoA, Asmara.

Ministry of Land, Water & Environment (MLWE), 1997a: *Agro-Ecological Zones and Legend,* Unpublished report, MLWE, Asmara.

Ministry of Land, Water & Environment (MLWE), 1997b: *State of the environment - Eritrea ,* MLWE, Asmara.

Ministry of Land, Water & Environment (MLWE), 2001: *Eritrea's initial national communication,* under UNFCCC, MLWE, Asmara.

Mohr, P.A., 1961: *The geology of Ethiopia,* Ethiopia Observer, 5(3): 186-193.

Mohr, P.A., 1970: *The geology of Ethiopia,* Addis Ababa press, Addis Ababa.

Mohr, P.A., 1987: *Sturactural style of continental rifting in Ethiopia: Reverse decollements.* Eos 68 (35), 721-730.

Nicholson, S.E., 1979: *The methodology of historical climate reconstruction and its application to Africa,* J. African history, 20: 31-49.

Nicholson, S.E., 1981: *Rainfall and and atmospheric circulation during drought and wetter periods in West Africa,* Mon. Wea. Rev., 109: 2291-2208.

Nicholson, S.E., 1983: *Sub-Sahara rainfall in the years 1976-80: evidence of continued drought, Mon. Wea. Rev., 3: 1646-1654.*

Nicholson, S.E., 1986: *On the causes of African drought.* Final Rep., NSF Contract ATM 8212781, Dept of Geography, Clark University.

Nicholson, S.E. & H. Flohn, 1980: *African environmental and climatic changes and the general atmospheric circulation in late Pleistocene and Holocene,* Climatic Change 2:313-348.

Norris, W.B. & K.G. Doty, 1998: *Meteorological Modeling Protocol,* Sothern Appalachain Mountains Initiative, University of Alabama, Huntsville.

Ogbazghi, W., 2001: *The distribution and regeneration of Boswellia papyrifera (Del.) Hochst. In Eritrea,* Tropical Resources Management Papers, Wageningen University, Wageningen.

Ooyama, K., 1964: *A dynamical model for the study of tropical cyclone development,* Geofis. Int., 4: 187-198.

Owen, J.A. & C.K. Folland, 1988: *Modelling the influence of sea-surface temperatures on tropical rainfall,* in Gregory, S. (ed), *Recent climatic change: A regional Approach,* Belhaven Press, London, pp. 141-153.

Perkey D.J., & C.W. Kreitzberg, 1976: *A time dependent lateral boundary scheme for limited-area primitive equation models*, Mon. Wea. Rev. 104: 744-755.

Rančić, M., R.J. Purser & F. Mesinger, 1995: *A global shallow-water model using an expanded shpherical cube: Gnomonic versus conformal coordinates,* Quart. J. Roy. Meteor. Soc. 122: 959-982.

Rautenbach, C.J. deW., 1999: Introduction of a hybrid vertical co-ordinate to an Atmospheric General Circulation Model, Unpublished PhD thesis, University of Pretoria, Pretoria.

Richardson, L.F., 1922: *Weather prediction by numerical process,* Cambrige University Press, reprinted Dover, 1965.

Rind, D., 1991: *Climate variability and climate change,* in Schlesinger, M.E. (ed), *Greenhouse-Gas-Induced climate change: A critical appraisal of simulations and observations,* Elsevier Scie., Amsterdam, pp. 69-78.

Robert, A., 1981: *A semi-Lagrangian, semi-implicit numerical integration scheme for the primitive meteorological equations,* Atmos. Ocean 19: 35-46.

Ropelewski, C.F. & S. Halpert, 1991: *The Southern Oscillation and northern hemisphere temperature variability*, in Schlesinger, M.E. (ed), *Greenhouse-Gas-Induced climate change: A critical appraisal of simulations and observations,* Elsevier Scie., Amsterdam, pp. 369-376.

Rossby, C.G., 1939: *Relation between variations in the intensity of the zonal circulation of the atmosphere and the displacements of the semi-permanent centers of action,* J. Marine Res., 2.38-55.

Sadourny, R., 1972: *Conservative finite-differencing approximation of the primitive equations on quasi-uniform spherical grids,* Mon. Weather Rev., 100: 136-144.

Schreck III, C.J. & F.H.M. Semazzi, 2003: *An investigation of the variability of the climate of Eastern Africa during the resent decades*, Contribution to Exchange, No. 27.

Slingo, J.M., 1987: *The development and verification of a cloud prediction scheme for the ECMWF model,* Quart. J. Roy. Meteor. Soc. 106: 899-927.

Smith, R.N.B., 1990: *A scheme for predicting layer clouds and their water content in a general circulation model,* Quart. J. Roy. Meteor. Soc. 116: 435-460.

Staniforth, A. & J. Côté, 1991: *Semi-Lagrangian integration schemes for atmospheric models – a review,* Mon. Wea. Rev. 119: 2206-2223.

Sundquist, H., 1978: *A parameterization scheme for non-convective condensation including prediction of cloud water content,* Quart. J. Roy. Meteor. Soc. 104: 677-690.

Taylor, K.E., 2000: *Summarizing multiple aspects of model performance in a single diagram,* PCMDI Report No. 55, UCRL, Livermore.

Trenberth, K.E., G.W. Branstator & P.A. Arkin, 1988: *Origins of the 1988 North American drought,* Science, 242: 1640-1645.

University of Asmara (AU) & Ministry of Agriculture (MoA), (1998): *Rehabilitation of degraded lands, Eritrea*, Second Edition, Asmara.

UNFCCC, 2003: *Caring for Climate,* a guide to the climate change convention and the Kyoto Protocol, UNFCCC, Bonn.

Van Buskirk, R., G. Karina G. & R. Karen, 1997: *Wind resource assessment of Eritrea, Africa: Preliminary results and status,* in Solaris, G. (ed), *Proceedings of the 2nd European & conference on Wind Engineering,* edited by G. Solari, June 1997, Italy. http://www.punchdown.org/rvb/wind/ITPAPER2.html

Viner, D., M. Hulme & S.C.B. Rapper, 1995: *Climate change scenarios for the assessments of the climate change on regional ecosystems,* J.therm. Biol. Vol.20, No. 1/2., pp. 175-190.

Walker, J. & P.R. Rowntree, 1977: *The effect of soil moisture on circulation and rainfall in a tropical model,* Quart. J. Roy. Meteor. Soc. 103: 29-46.

Wilks, D., 1995: *Statistical methods in the Atmospheric Sciences – An introduction,* Academic Press, Inc., San Diego.

Wilson, S., D., Hassell, D. Hein, R. Jones, & R. Taylor, 2003: *Installing and using the Hadley Centre regional climate modeling System-PRECIS,* version 0.9a, Hadley Centre for Climate Prediction and Research, Met Office, Bracknell.