MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Professor Reginald E. Newell
Department of Earth, Atmospheric,
& Planetary Sciences, Rm 54-1824
77 Massachusetts Avenue
Cambridge, Mass. 02139

Telephone: (617) 253-2940
FAX: (617) 258-9819
E-mail: RENewell@MIT.EDU

January 31, 2000

Mr. Richard Bendura
NASA Langley Research Center
Bldg. 1250, Room 149
21 Langley Blvd.
Hampton, VA 23681-0001

Dear Richard,

Enclosed are three copies of the Final Technical Report entitled "Summary of Research", covering the period October 1, 1995 to March 31, 1999, with a 6 month no-cost extension to September 30, 1999 for Grant NAG-1-1758.

As requested, two copies have been sent to:

NASA Center for Aerospace Information
Attn: Accessioning Department
800 Elkridge Landing Rd.
Linthicum Heights, MD 21090-2934

and one copy to:

Marcia Poteat
NASA Langley Research Center
Grants Office, Mail Stop 126
9A Langley Blvd., Bldg., 1195A
Hampton, VA 23681-0001

Yours sincerely,

Reginald E Newell

Reginald E. Newell

Cc: Mark Pendleton, EAPS HQ, 54-924, MIT
Cheryl Magoveny, OSP, E19-750, MIT
Mary Elliff, Admin. Asst., 54-1710, MIT

PHYSICAL PROCESSES GOVERNING ATMOSPHERIC TRACE CONSTITUENTS MEASURED FROM AIRCRAFT IN PEM-TROPICS

SUMMARY OF RESEARCH

UNDER NASA RESEARCH GRANT NAG-1-1758

FOR THE PERIOD OCTOBER 1, 1995 – SEPTEMBER 30, 1999

Principal Investigator:

Professor Reginald E. Newell
Department of EAPS, Room 54-1824
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

Submitted to:

Mr. Richard J. Bendura
NASA Langley Research Center
Mail Stop 483
Hampton, VA 23681-0001
Phone: (757) 864-5830

By:

Professor Reginald E. Newell
Department of EAPS, Room 54-1824
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139
Phone: (617) 253-2940

Scientific Accomplishments

The MIT group participated in seven publications in the 1999 issues of JGR with sections devoted in PEM-Tropics A, and had two papers which may be considered offshoots of these studies combined with commercial aircraft trace constituents data, one in Nature and one in EOS.

In the meteorological overview (Fuelberg et al., p. 5585, full titles and authors attached) we contributed a set of 1000 hPa divergent wind maps which we calculated from ECMWF data (used in Figure 3), meridional wind cross-sections (Figure 5), velocity potential and divergent wind maps (Figure 6), maps of streamfunction and rotational wind components (Figure 7), and vertical velocity profiles computed from mass balance (Figure 9), these all constituting part of the overall climatology. We also contributed material for the "stalactite" case observed from the DC-8 on Flight 5 on September 3, 1996. This included a map of potential vorticity on 350K (Figure 20), a cross-section of lidar O_3 (from Ed Browell, Plate 5) a cross-section of potential vorticity along 140°W (Figure 21), and a map of specific humidity showing extreme dryness accompanying the high potential vorticity values and the high ozone values, all suggesting subsidence from the local stratosphere (Figure 22).

In the paper on chemical characteristics (Gregory et al., p. 5677) we contributed 12 hour values of the 1000 hPa divergent wind component for the full period of PEM Tropics A; these were used by David Westberg to establish the air mass boundaries and in turn used by Gerry Gregory to set up a table of quantitative values of trace constituents and their ratios both sides of the boundaries. This paper arose from discussions between Dr. Gregory and the PI at the first Science Team meeting. A similar arrangement was made with Dr. Melody Owens at the first PEM Tropics B Science Team meeting and the 12 hour daily divergent wind maps are now in the GTE archive. Dr. Owens will also carry out a comparison between PEMT A and B.

With the extra geographical coverage of the Pacific Basin available for PEMT-A it seemed appropriate to combine PEMT-A data with that from PEM West A and B missions and examine some of the spectral properties to seek information on a variety of space scales and to try to begin to understand what physical processes are responsible for the observed variability in horizontal winds, temperature and trace gases. Questions of interest are how kinetic energy generated in the atmosphere, much of it in large-scale motions, finds its way down to the smallest turbulent motions, where it is ultimately dissipated by viscosity. There are a number of questions extant: Is the major injection via two-dimensional motions? Is large scale convection an important kinetic energy source? Is energy passage always down-scale? At what scales do the two dimensional to three dimensional transfers occur? Are there significant differences between the spectral behavior of wind velocities, temperatures and trace constituents, like water vapor and ozone? The latter question will provide information about the chemical aspects of the physical processes. It may be necessary to carry out the chemical rate equations at smaller scales than hitherto.

John Y.N. Cho at MIT has produced two pioneering two papers in the 1999 JGR series, pp. 5697-5716 and 16297-16308. As well as the conventional Fourier spectral approach which deals with the data as energy versus frequency or wavenumber he has applied Stokes-parameter and Doppler-shift analyses (probably for the first time to aircraft data). The main results from this line of investigation were that at scales lengths of 1-100 km vortical modes of motion are dominant over gravity waves over the ocean except in the equatorial zone. This has cast doubt on the relevance and universality of the gravity-wave cascade model in the troposphere. Also the k^{-3} spectrum (where k is the horizontal wavenumber) observed above length scales of 100 km was shown not to be the result of inertial-mode enhancement as proposed previously by certain parties.

Our work on the layered structure of the troposphere has been revised with new algorithms derived by Patrick Stoller (who received a special one year Research Assistantship with us funded by a MIT-Goddard Space Flight Center cooperation). The new algorithm was applied to PEM West A and B plus PEMT A data and results appear in JGR 104, p. 5745-5764, 1999. The influence of the chemical layers on static stability is illustrated in that paper for the first time.

The same approach used for layers from GTE missions has been applied to commercial aircraft water vapor and ozone data from the MOZAIC project. This set of five Airbus aircraft yields two vertical soundings per flight and trace constituent and wind data along the flight track. The findings on layers were reported in Nature 398, 25 March 1999 by our group together with Alain Marenco and Herman Smit of the MOZAIC group. This paper used a much larger sample than available from GTE and concluded that quasi-horizontal layers were ubiquitous in the troposphere, with mean thicknesses of about one kilometer and mean altitudes between 5 and 7 km; layers were found to occupy up to 20% of the lowest 12 km of the troposphere.

We also contributed to the Fenn et al. paper (p. 16,197) by providing digital potential vorticity cross-sections (used in Figures 4, and 5, Plate 4, Table 3 and in the actual characterization of air masses).

Several other papers using data from PEM Tropics A are in review at present.

Full titles, authors, etc. of the papers published in 1999 from the PEM-Tropics A support under NASA Research Grant NAG-1-1758 are attached.

Pacific Exploratory Mission-Tropics A – Publications

Pacific Exploratory Mission in the tropical Pacific: PEM-Tropics A, August-September 1996, J.M. Hoell, D.D. Davis, D.J. Jacob, M.O. Rodgers, R.E. Newell, H.E. Fuelberg, R.J. McNeal, J.L. Raper, and R.J. Bendura, J. Geophys. Res., 104, D5, 5567-5583, 1999.

A meteorological overview of the Pacific Exploratory Mission (PEM) Tropics period, H.E. Fuelberg, R.E. Newell, S.P. Longmore, Y. Zhu, D.J. Westberg, E.V. Browell, D.R.Blake, G.L. Gregory, G.W. Sachse, J. Geophys. Res., 104, D5, 5585-5562, 1999.

Chemical characteristics of Pacific tropospheric air in the region of the Intertropical Convergence Zone and South Pacific Convergence Zone, G.L. Gregory, D.J. Westberg, M.C. Shipham, D.R. Blake, R.E. Newell, H.E. Fuelberg, R.W. Talbot, B.G. Heikes, E.L. Atlas, G.W. Sachse, B.A. Anderson, D.C. Thornton, J. Geophys. Res., 104, D5, 5677-5696, 1999.

Horizontal wavenumber spectra of winds, temperature, and trace gases during the Pacific Exploratory Missions, 1, Climatology, J.Y.N. Cho, Y. Zhu, R.E. Newell, B.E. Anderson, J.D. Barrick, G.L. Gregory, G.W. Sachse, M.A. Carroll, G.M.Albercook, J. Geophys. Res., 104, D5, 5697-5716, 1999.

Measurements of atmospheric layers from the NASA DC-8 and P-3B aircraft during PEM-Tropics A, P. Stoller, J.Y.N. Cho, R.E. Newell, V. Thouret, Y. Zhu, M.A. Carroll, G.M. Albercook, B.E. Anderson, J.D.W. Barrick, E.V. Browell, G.L. Gregory, G.W. Sachse, S. Vay, J.D. Bradshaw, S. Sandholm, J. Geophys. Res., 104, D5, 5745-5764, 1999.

Ozone and aerosol distributions and air mass characteristics over the South Pacific during the burning season, M.A. Fenn, E.V. Browell, C.F. Butler, W.B. Grant, S.A. Kooi, M.B. Clayton, G.L. Gregory, R.E. Newell, Y. Zhu, J.E. Dibb, H.E. Fuelberg, B.E. Anderson, A.R. Bandy, D.R. Blake, J.D. Bradshaw, B.G. Heikes, G.W. Sachse, S.T. Sandholm, H.B. Singh, R.W. Talbot, D.C. Thornton, J. Geophys. Res., 104, D13, 16,197-16,212, 1999.

Horizontal wavenumber spectra of winds, temperature, and trace gases during the Pacific Exploratory Missions, 2, Gravity waves, quasi-two-dimensional turbulence, and vortical modes, J.Y.N. Cho, R.E. Newell, J.D. Barrick, J. Geophys. Res., 104, D13, 16,297-16,310, 1999.

Ubiquity of quasi-horizontal layers in the troposphere, R.E. Newell, V. Thouret, J.Y.N. Cho, P. Stoller, A. Marenco, H.G. Smit, Nature, 398, 316-319, 1999.

Trace gas study accumulates forty million frequent-flying miles for science, J.Y.N. Cho, R.E. Newell, V. Thouret, A. Marenco, H. Smit, EOS Trans. AGU, 80, 34, 377, 383-384, 1999.

Data available to Science Team

In addition to the scientific publications there were a number of working memos drawn up summarizing the digital data in different ways; some have been duplicated in other sources since they were drawn. A list updated to December 1998 is attached. Memo 7 was not completed. Note that memos 8c and 8a were partly in video form being selections of highlights from the video tapes used to produce cloud descriptions. Memos that were unique were included in the GTE data base.

Massachusetts Institute of Technology
Miscellaneous PEM-Tropics Memos
December 21, 1998

MIT PEM-Tropics Data Memos

6b Divergent Wind Maps on 200 hPa
Y. Zhu

7 TBD

8a Aircraft Videotape Comments and Cloud Descriptions in PEM-Tropics. Full version, DC-8.
Irina Marinov

8b Aircraft Videotape Comments and Cloud Descriptions in PEM-Tropics. Full version, P3-B.
Irina Marinov

8c Aircraft Videotape Comments and Cloud Descriptions in PEM-Tropics. Short form: Compound Tape 1
Irina Marinov

8d Aircraft Videotape Comments and Cloud Descriptions in PEM-Tropics. Short form: Compound Tape 2
Irina Marinov

9 Time Series of NO, SO_2, DMS, and Flight Altitude for the P3-B
Y. Zhu

10 Vertical Velocity at 500 hPa
Y. Zhu

11 PEM-Tropics A Sea Surface Temperature From NOAA, July 30 - October 4, 1996
Y. Hu

12 PEM-Tropics A TOVS Total Ozone Analysis: August 1 - October 2, 1996
Y. Hu

13a Ozonesondes as Vertical Profiles: Easter Island, 8/20/95 - 6/28/97
Y. Zhu

13b Ozonesondes as Vertical Profiles: New Zealand, 1/11/95 - 3/25/98
Y. Zhu

13c Ozonesondes as Vertical Profiles: Samoa, 8/18/95 - 2/20/98
Y. Zhu

13d Ozonesondes as Vertical Profiles: Tahiti, 7/31/95 - 2/05/98
Y. Zhu

13e Ozonesondes as Vertical Profiles: Fiji, 2/6/97 - 2/13/98
Y. Zhu

14a.1 Vertical Profiles: CO, CH_4, H_2O, and O_3 from the DC-8
Y. Zhu

14a.2 Vertical Profiles: CO, CH_4, H_2O, and O_3 from the P3-B
Y. Zhu

14b.1 Vertical Profiles: T, T_d; θ, $θ_e$; H_2O; and RH from the DC-8
Y. Zhu

14b.2 Vertical Profiles: T, T_d; θ, $θ_e$; H_2O; and RH from the P3-B
Y. Zhu

14c.1 Vertical Profiles: Propane, Propene, Ethane, and Ethene from the DC-8
Y. Zhu

14c.2 Vertical Profiles: Propane, Propene, Ethane, and Ethene from the P3-B
Y. Zhu

14d.1 Vertical Profiles: Propane/Ethane, Propene/Propane, Ethyne/CO, and O_3 from the DC-8
Y. Zhu

14d.2 Vertical Profiles: Propane/Ethane, Propene/Propane, Ethyne/CO, and O_3 from the P3-B
Y. Zhu

15a Vertical Profiles: C_2H_2 (pptv), CO (ppbv), C_2H_2/CO (10^{-3}), O_3 (ppbv) from the P3-B
Y. Zhu

15b Vertical Profiles: C_2H_2 (pptv), CO (ppbv), C_2H_2/CO (10^{-3}), O_3 (ppbv) from the DC-8
Y. Zhu

16a Vertical Profiles: H_2O_2 (pptv), OH (1000 m/cc), CH_3OOH (ppbv), O_3 (ppbv) from the P3-B
Y. Zhu

16b Vertical Profiles: H_2O_2 (pptv), CH_3OOH (pptv), O_3 (ppbv) from the DC-8
Y. Zhu

17 Linear Correlation: O_3 vs. PV from the DC-8