Załącznik 3 do wniosku o wszczęcie postepowania habilitacyjnego Piotr J. Flatau
Attachement 3 for “habilitacja” application – Piotr J. Flatau

Self-evaluation

by

Piotr J. Flatau

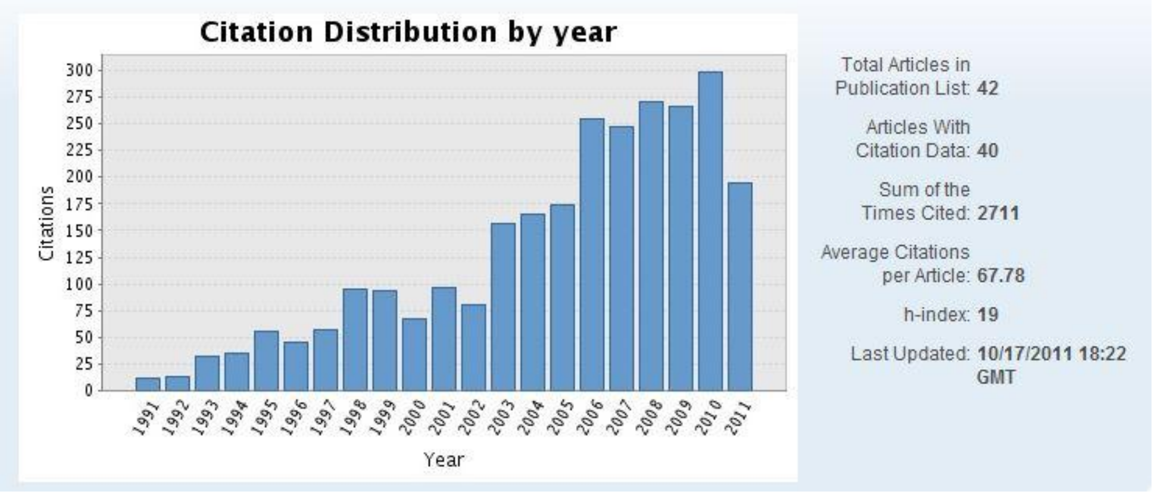
November 2011

1. Table of contents

2. Curriculum Vitae

My CV is available as Appendix 9 (personal data).

3. Scientific Publications in Science Citation index



Total Articles in Publication List: **42**
Articles With Citation Data: **40**
Sum of the Times Cited: **2711**
Average Citations per Article: **67.78**
h-index: **19**
Last Updated: **10/17/2011 18:22 GMT**

Appendix 4a contains list of citations.

4. Scientific contributions - overview

My contributions include publications A1-A46 which are primary published papers, B1-B100 which is “other work” and C1-C3 which is “work in progress”. In this self evaluation I pay particular attention to primary published publications on “Exact Solution to Maxwell Equations: Light Scattering on Arbitrary Non-Spherical Particles” published after my Ph. D. I also discuss my career work which concentrates around the following main topics.

1. Light scattering and fundamentals of radiative transfer
2. Aerosols and their climate forcing properties
3. Cloud, water vapor, and radiation: climate feedbacks
4. Cloud physics
5. Tropical dynamics
6. Numerical modeling
7. Popular science

I will begin with the discussion of single and multiplescattering work. In particular I will discuu exact solution to Maxwell Equations: light scattering on arbitrary non-spherical articles. This topic is closely related to my theoretical physics background. I will also discuss my contributions to climate change through feedbacks with clouds, aerosols, and radiation, as well as studies of tropical dynamics, monsoons and air-sea interactions. Finally, I discuss briefly popular science contributions.

5. Major thesis topic – exact single and multiple scattering methods

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5.1. Single scattering by non-spherical particles in discrete dipole approximation

In 1990 I have pioneered a powerful technique to calculate exactly light scattering by arbitrary particles in the discrete dipole approximation. The review paper **A14** contains basic introduction to discrete dipole approximation. Subsequently I developed myself and with my co-workers this technique such that it is currently one of the most robust, well tested, and worldwide used method of computational electromagnetics. I have developed theoretical, algorithmic, and numerical advances, and tested the method in series of applications. The methodology I developed in 1990' is now applied to scattering by non-spherical particles such as ice crystals, dust, soot, other atmospheric aerosols, marine phytoplankton, realistic cells, Enhanced Raman Scattering Spectroscopy., estimation of the near field and extended to very large size parameter. It is still the only such general technique which allows to study scattering by non-spherical and non-homogeneous particles. In 2007 The Journal of the Optical Society of America (JOSA) included **A14** it in their list of the most-cited papers. At present the paper was cited about 980 times and it is one of the most referenced papers in computational optics.

In **A14** the DDA was reviewed. Computational considerations, i.e., the use of complex-conjugate gradient algorithms and fast-Fourier-transform methods, were discussed and I tested the accuracy of the DDA. It was shown that, for moderate dielectric materials, the DDA permits calculations of scattering and absorption that are accurate to within a few percent. In **A19** Improvements in complex-conjugate gradient algorithms applied to the discrete-dipole approximation were reported. It was shown that computational time is reduced by use of the stabilized version of the biconjugate gradient algorithm, with diagonal left preconditioning. This work was subsequently used by many researchers. In **A36** I proposed new algorithms for solution of light scattering on non-spherical particles using one-dimensional variant of discrete dipole approximation. We discuss recent advances in algorithms for matrices with structures in context of the discrete dipole approximation and show that it is possible to apply these advances to form non-iterative solvers and improve algorithmic complexity in case of many incoming plane parallel waves. In **A44** it is shown that the DDA can be extended to targets that are singly or doubly periodic. I generalized the scattering amplitude matrix and the 4x4 Mueller matrix to describe scattering by singly and doubly periodic targets and show how these matrices can be calculated using the DDA. The accuracy of DDA calculations using the open-source code DDSCAT was demonstrated by comparison with exact results for infinite cylinders and infinite slabs. A method for using the DDA solution to obtain fields within and near the target was presented, with results shown for infinite slabs. In **C3** a new method for calculation of the near field in the Discrete Dipole Approximation is presented. It exploits the fact that calculation of sums in basic DDA problem statement can be performed efficiently for sites defined on a regular rectangular grid which includes the original target. The method is 3 orders of magnitude faster in comparison to existing implementations even for moderate amount of dipoles. In the last 20 years I have provided the public domain code DDSCAT (c.f. http://code.google.com/p/ddscat/) which is documented in **B98.** DDSCAT 7 is written in Fortran 90 with dynamic memory allocation and the option to use either single- or double-precision arithmetic. DDSCAT 7 includes options for various target geometries, including a number of periodic structures. A program DDFIELD for near-field calculations is also provided. The DDSCAT code itself was downloaded several thousands of times. The code and publications contributed to better understanding of cloud radiative properties important in climate research, cloud physics (single scattering properties), satellite remote sensing (multi angle measurements such as MISER), radar studies (backscatter by ice), mine detection, material studies, and spectroscopy. This open source approach allowed many researchers to develop better techniques, codes, and methods in computational optics as evidenced by citations to **A14**.

In **A12** I applied two different techniques to the problem of scattering by two spheres in contact: modal analysis, which is an exact method, and the discrete-dipole approximation. Good agreement was obtained, which further demonstrates the utility of the DDA to scattering problems for irregular particles.

5.2. Multiple scattering

Single scattering properties define of clouds determine only one aspect of the scattering properties. Multiple scattering provide means to calculate radiative transfer within the medium. In **A5** I have outlined the general solution the general solution of the one-dimensional, azimuthally averaged radliative transfer equation in terms of a matrix exponential. The link between this fundamental solution and those more commonly used in radiative transfer was established. The formulation is developed for a general vertically inhomogeneous atmosphere with sources. Several new concepts, based on properties of the matrix exponentials, are described in the context of radiative transfer, including the use of the commutator an.d product integrals. It is also demonstrated how the matrix exponential formulation provides for new insights, not only into improvements of the numerical efficiency and stability of the solution, but also into the understanding of radiative transfer through a layered atmosphere. The various concepts introduced in this paper are illustrated throughout by the two-stream simplification of the general radiative transfer equation. I have used multiple scattering solution in a variety of applications – cloud physics, aerosols studies of climate, which will be subject of subsequent discussion. However, light scattering by bubbles is an interesting aspects of marine optics. In **A21** I report on scattering and multiple scattering of submerged micro bubbles which are an efficient source of diffuse radiance and may contribute to a rapid transition to the diffuse asymptotic regime. In this asymptotic regime an average cosine is easily predictable and measurable. In **A23** I report on the influence of submerged bubble clouds on the remote-sensing properties of water. We show that the optical effect of bubbles on radiative transfer and on the estimate of the ocean colour is significant. We present a global map of the volume fraction of air in water derived from daily wind speed data. This map, together with the parametrization of the microphysical properties, shows the possible significance of bubble clouds on the albedo to incoming solar energy.

5.3. Light scattering codes

I maintain two home pages related to light scattering as a community service
http://code.google.com/p/ddscat/
http://code.google.com/p/scatterlib/
These home pages provide distribution of some of my original codes including discrete dipole approximations, anomalous diffraction theory, and Mie scattering codes. These pages are used by thousands of worldwide users.

5.4. References (Light scattering and radiative transfer)

References with bold letters are submitted with the file. The numeration follows the Bibliography.

A5. Flatau, P.J., and G.L. Stephens. On the fundamental solution of the radiative transfer equation. *J. Geophys. Res.,* **93**(D9):11037-11050, 1988.

A7. Flatau, P.J., G.L. Stephens, and B.T. Draine. Light scattering by rectangular solids

in the discrete-dipole approximation: a new algorithm exploiting the block-Toeplitz structure. *J. Opt. Soc. Am.*, **7**:593-600, 1990.

A10. Goodman, J.J., B.T. Draine, and P.J. Flatau. Application of fast- Fourier-transform techniques to the discrete-dipole approximation. *Optics Letters*, **16**:1198-1200, 1991.

A12. Flatau, P.J., K.A. Fuller, and D.W. Mackowski. Scattering by two spheres in contact: comparisons between discrete dipole approximation and modal analysis. *Appl. Opt.*, **32**:3302-3305, 1993.

A14. Draine, B.T., and P.J. Flatau. Discrete dipole approximation for scattering calculations. *J. Opt. Soc. Am. A*, **11**:1491-1499, 1994.

A15. Maslowska, A., P.J. Flatau, and G.L. Stephens. On the validity of the anomalous diffraction theory to light scattering by cubes. *Optics Communications*, **107**:35-40, 1994.

A19. Flatau, P.J., and B.T. Draine. Improvements of the discrete dipole approximation method. *Optics Letters*, **22**, 1205-1207, 1997.

A21. Flatau, P.J., J. Piskozub, and J.R.V. Zaneveld. Asymptotic light field in the presence of a bubble-layer. *Optics Express*, 30 Aug. 1999, **5**, 120-124, 1999.

A23. Flatau, P.J., M. Flatau, J.R.V. Zaneveld, and C.D. Mobley. Remote sensing of bubble clouds in sea water. *Quarterly Journal of the Royal Meteorological Society*, **126**, (no.568), 2511-23, 2000.

A24. Piskozub, J., P.J. Flatau, and J.V.R. Zaneveld. Monte Carlo study of the scattering error of a quartz reflective absorption tube**.** *Journal of Atmospheric and Oceanic Technology*, **V18**(N3):438-445, 2001.

A35. Stramski, D., S.B. Wozniak, and P.J. Flatau. Optical properties of Asian mineral dust suspended in seawater, *Limnol. Oceanogr.* **49**, 749–755, 2004.

A36. Flatau, P. J. Fast solvers for one dimensional light scattering in the discrete dipole approximation, *Optics Express*, **12**, 3149-3155, 2004.

A44. Draine Bruce T.; Flatau Piotr J., Discrete-dipole approximation for periodic targets: theory and tests , J. Opt. Soc. Am. A., 25, 2693 2703, 2008,
DOI: 10.1364/JOSAA.25.002693.

A47 Flatau, P. J. and Draine, B. T., Fast near field calculations in the discrete dipole approximation for regular rectilinear grids, **in press, Optics Express**, 2011, 5 pages

B98. User Guide for the Discrete Dipole Approximation Code DDSCAT 7.1.
B.T. Draine, P.J. Flatau, . Feb 2010. 83pp. e-Print: arXiv:1002.1505 [astro-ph.IM]

6. Tropical dynamics

6.1. Coupled ocean-atmosphere interactions: Madden-Julian Oscillations

I made a strong effort in multidisciplinary topic bridging atmospheric science and oceanography. I made some important contribution to this field. Paper **A18**, which cited 160 times in 2011, was one of the first to show how large atmospheric phenomena depends on atmosphere-ocean interaction. We show that existing theories of the Madden–Julian oscillation neglect the feedback between the modification of sea surface temperature by the convection and development of a convective cluster itself. We show that the convection-generated SST gradient plays an important role in cluster propagation and development. The relative importance of radiative and evaporative fluxes in SST regulation was also discussed. Various Tropical Ocean Global Atmosphere Coupled Ocean–Atmosphere Response Experiment and Central Equatorial Pacific Experiment observation platforms were used to estimate the effects of equatorial convection on SST changes during March 1993. The data include drifting buoys and TAO-buoy array measurements, combined with the Navy Operational Global Atmospheric Prediction System analyzed surface wind fields and Geostationary Meteorological Satellite cloud-top temperatures. It was shown that during the equatorial convection episode SST is decreasing under and to the west of the convective heat source due to the large wind velocities and solar flux reduction. To the east of the source, in the convergence region of a Kelvin wave, low wind speeds and high insolation cause the SST to increase The data was used to formulate an empirical relationship between wind speed and the 24-h SST change on the equator.

6.2. Tropical cyclones

Most recently I concentrated on air-sea interaction during tropical cyclones passage including multi year climatology, case studies, coupled model validation, and participation in 3 field projects. My M. Sc. and now Ph. D. student Dariusz Baranowski and myself have collaborated with professors Dean Roemmich and Peter Niller of SIO and professor Jim Price of WHOI. Paper **C2** was submitted for publication to Journal of Geophysical Research (Oceans). I was advisor of M. Sc. dissertation “Interaction of tropical cyclones with the ocean”, University of Warsaw, Atmospheric Science Group, June 2009. This work is based on ARGO floats, some of them with high repetition rate, and complementary results from two field projects – THORPEX Pacific Asian Regional Campaign/Tropical Cyclone Structure08 **(TPARC/TCS)** in 2009 as well as The Impacts of Typhoons on the Ocean in the Pacific (ITOP) which took place in 2010. A short (but reviewed) publication **A46** is related to this M. Sc. work. Importance of this research is that it shows that tropical cyclones are driven by energy from the ocean but only recently ARGO floats are ubiquitous enough to provide global glimpse of tropical cyclones – ocean interaction on decadal time scale.

6.3. References (Tropical dynamics)

A18. Flatau, M., P.J. Flatau, P. Phoebus, and P.P. Niiler. The feedback between equatorial convection and local radiative and evaporative processes: the implication for intraseasonal oscillations. *Journal of the Atmospheric Sciences*, **54**, 2373-2386, 1997.

A25. Flatau, M.K., P.J. Flatau, and D. Rudnick. The Dynamics of Double Monsoon Onsets. *Journal of Climate,* **14**, No. 21, pp. 4130–4146, 2001.

A30. Flatau, M.K., P.J. Flatau, J. Schmidt, and G.N. Kiladis. Delayed Onset of the 2002 Indian Monsoon, *Geophysical Research Letters*, **30**, doi:10.1029/ 2003GL017434, 2003.

A46 Dariusz B. Baranowski, Piotr J. Flatau, Szymon P. Malinowski, Tropical cyclone turbulent mixing as observed by autonomous oceanic profilers with high repetition rate, 13th European Turbulence Conference, 12–15 September 2011, Warsaw, Poland, 3pages.

C2. Dariusz B. Baranowski1, Piotr J. Flatau and Sue Chen, Air-sea interaction between two collocated typhoons**,** in-preparation, 2011.

7. Aerosols and their climate forcing properties

7.1. Field projects

Many of my publications in this field are based on experimental field project. These field projects were part of large international efforts and included participation in their design and in the data collection as well as data analysis. I also guided Ph. D. students as an advisor. Thus many of the publications are not with me as a fist author but I provided research guidance. The aerosol field studies in which I participated include

- United Arab Emirates Unified Aerosol Project UAE2, 2004
- ACE Asia (Honolulu – Yokosuka, Japan) March-May, 2001

- Indian Ocean Experiment, 1999, February-April, 1999. Tropical Indian Ocean and Arabian Sea, 2 months.
- Subsonic aircraft: Contrail and Cloud Effects Special Study April, 1996, Salinas, KS, 2 weeks
- Atmospheric Radiation Measurement (Unmanned Aerospace Vehicle, Enhanced Shortwave Experiment (ARM-UAV-ARESE) 1995, 6 weeks
- NOAA P3 aircraft measurements-radiation, Central Equatorial Pacific Experiment, Equatorial Pacific, 1993, 2 months

7.2. Dust radiative properties

I was one of the principal investigators and lead group of several students and postdocs during the United Arab Emirates-Unified Aerosol Experiment (UAE2) in 2004. This field project targeted the coastal and desert regions of the United Arab Emirates. The main scientific goal was to evaluate and improve satellite derived aerosol and ocean products commonly used by the scientific community. I published papers **A41** and **A42** on the basis of the results from that UAE2 field project. I was the advisor of the Ph.D. thesis "Optical properties of atmospheric aerosols in the Persia Gulf – experimental results", Polish Academy of Sciences, Institute of Geophysics, 2009, written by Joanna Remiszewska (see also **B95**). Paper **A41** is partially based on her thesis and describes radiative forcing by aerosols in that scarcely studied region. The importance of this research was to provide estimate of dust radiative forcing (UAE has large desert areas) which is a subject of considerable debate between climate change experts.

7.3. Infrared and solar radiative forcing

In **A27** we present direct radiometric observations of aerosol radiative forcing taken during the MINOS experiment (2001) at Finokalia Sampling Station located on NorthEastern shores of Crete, Greece. This data gives observational proof for the large role of absorbing aerosols in the Mediterranean. The negative surface forcing and large positive atmospheric forcing values observed for the Mediterranean aerosols is nearly identical to the highly absorbing south Asian haze observed over the Arabian Sea. The results of this paper were subsequently reported in the review paper **A28** which was published in Science magazine. Another important contribution was **A29** were we demonstrate that aerosols have important warming effects at thermal infrared (IR) wavelengths that have rarely been observed and are commonly ignored in climate models. We used high-resolution spectra to obtain the IR radiative forcing at the surface for aerosols encountered in the outflow from northeastern Asia. The spectra were measured by the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) from the NOAA Ship Ronald H. Brown during the Aerosol Characterization Experiment-Asia (ACE-Asia). These results highlight the importance of aerosol IR forcing which should be included in climate model simulations.

7.4. Sea-salt transport

I developed, together with my Ph. D. student Marcin Witek, a new parameterization of atmospheric aerosol transport including sea salt parameterization and specialized numerical advection schemes. This is presented in **A43** and **A45**. Of importance is that these theoretical developments were based on very unique observations of sea salt concentrations performed at sea (other measurements from islands are contaminated by land effect). My student Marcin Witek defended his Ph. D. thesis “Sea salt aerosol in global transport models - results, validations and model improvements”, University of Warsaw, Atmospheric Science Group, 2008. The importance of this research is related to the fact that is a dominant aerosol component over the ocean and it influences cloud fractional cover and, in turn, amount of incoming solar radiation and therefore may contribute to the equilibrium sea surface temperature.

7.5. References (Aerosols and their climate forcing properties)

A26. Welton, E.J., K.J. Voss, P.K. Quinn, P.J. Flatau, K. Markowicz, J.R. Campbell, J.D. Spinhirne, H.R. Gordon, and J.E. Johnson. Measurements of aerosol vertical profiles and optical properties during INDOEX 1999 using micropulse lidars,

Journal of Geophysical Research – Atmospheres, **107**, D19, 8019, doi:10.1029/2000JD000038, 2002.

A27. Markowicz, K., P.J. Flatau, M.V. Ramana, P.J. Crutzen, V. Ramanathan. Absorbing Mediterranean aerosols lead to a large reduction in the solar radiation at the surface, *Geophysical Research Letters*, **29**, pp. 29-1 to 29-4, 10.1029/2002GL015767, 2002.

A28. Lelieveld, J., H. Berresheim, S. Borrmann, P.J. Crutzen, F.J. Dentener, H. Fischer, J. Feichter, P.J. Flatau, J. Heland, R. Holzinger, R. Korrmann, M.G. Lawrence, Z. Levin, K. Markowicz, N. Mihalopoulos, A. Minikin, V. Ramanathan, M. de Reus, G.J. Roelofs, H.A. Scheeren, J. Sciare, H. Schlager, M. Schultz, P. Siegmund, B. Steil, E.G. Stephanou, P. Stier, M. Traub, C. Warneke, J. Williams, and H. Ziereis. Global air pollution crossroads over the Mediterranean, *Science*, **298**, 5594, pp. 794-799, 2002.

A29. Vogelmann, A.M., P.J. Flatau, M. Szczodrak, K.M. Markowicz, and P.J Minnett. Observations of large aerosol infrared forcing at the surface, *Geophysical Research Letters*, **30**, No. 12, 1655, doi:10.1029/2002GL016829, 2003.

A31. Markowicz, K.M., P.J. Flatau, P.K. Quinn, C.M. Carrico, M.K. Flatau, A.M. Vogelmann, D. Bates, M. Liu, and M.J. Rood. Influence of relative humidity on aerosol radiative forcing: An ACE-Asia experiment perspective, *J. Geophys. Res.*, **108** (D23), 8662, doi:10.1029/2002JD003066, 2003.

A32. Markowicz, K.M., P.J. Flatau, A.M. Vogelmann, P.K. Quinn, and E.J. Welton. Clear-sky infrared radiative forcing at the surface and the top of the atmosphere, *Q. J. R. Meteorol. Soc.*, **129**, pp. 2927–2947 doi: 10.1256/qj.02.224, 2003.

A33. Conant, W.C., J.H. Seinfeld, J. Wang, G.R. Carmichael, Y. Tang, I. Uno, P.J. Flatau, K.M. Markowicz, and P.K. Quinn. A model for the radiative forcing during ACE-Asia derived from CIRPAS Twin Otter and R/V Ronald H. Brown data and comparison with observations, *J. Geophys. Res*., **108** (D23), 8661, doi:10.1029/2002JD003260, 2003.

A34. Seinfled, J.G., G.R. Carmichael, R. Arimoto, W.C. Conant, F. Brechtel, T.S. Bates, T.A. Cahill, A.D. Clarke, S.J. Doherty, P.J. Flatau, B.J. Huebert, J. Kim, K.M. Markowicz, P.K. Quinn, L.M. Russell, P.B. Russell, A. Shimizu, Y. Shinozuka, C.H. Song, Y. Tang, I. Uno, A.M. Vogelmann, R.J. Weber, J-H. Woo, and X.Y. Zhang. ACE-ASIA: Regional Climatic and Atmospheric Chemical Effects of Asian Dust and Pollution, *Bulletin of the American Meteorological Society*, **85**, No. 3, pp. 367–380, 2004.

A37. Remiszewska, J., P.J. Flatau, K.M. Markowicz, E.A. Reid, J.S. Reid, and M.L. Witek. Modulation of the aerosol absorption and single-scattering albedo due to synoptic scale and sea breeze circulations: United Arab Emirates experiment perspective, *J. Geophys. Res.*, **112**, D05204, doi:10.1029/2006JD007139, 2007.

A38. Witek, M.L., P.J. Flatau, P.K. Quinn, and D.L. Westphal. Global sea salt modeling: results and validation against multicampaign shipboard measurements, *J. Geophys. Res.*, **112**, D08215, doi:10.1029/2006JD007779, 2007.

A39. Wells, K.C., M. Witek, P. Flatau, S.M. Kreidenweis, and D.L. Westphal. An analysis of seasonal surface dust aerosol concentrations in the western US (2001–2004): Observations and model predictions, Atmospheric Environment, doi:10.1016/j.atmosenv.2007.04.034, 2007, 41, 6585-6597.

A40. Witek, M.L., P.J. Flatau, J. Teixeira, and D. Westphal. Coupling an ocean wave model with a global aerosol transport model: a sea salt aerosol parameterization perspective, Geophysical Research Letters, 34, L14806, doi:10.1029/2007GL030106, 2007.

A41. Markowicz, K.M., P.J. Flatau, J. Remiszewska, M. Witek, E.A. Reid, J.S. Reid, A. Bucholtz, and B. Holben. Observations and modeling of the surface aerosol radiative forcing during the UAE2 experiment, Journal of Atmospheric Sciences, 2008, 65, 2877-2891, DOI: 10.1175/2007JAS2555.1 (From Submitted)

A42. Markowicz, K.M., P.J. Flatau, A.E. Kardas, J. Remiszewska, and K. Stelmaszczyk. Ceilometer retrieval of the boundary layer vertical aerosol extinction structure, Journal of Atmospheric and Oceanic Technology, 25, 928-944, DOI: 10.1175/2007JTECHA1016.1, 2008. (From Submitted)

8. Clouds, water vapor, and radiation: climate feedbacks

8.1. Cloud microphysics and climate

Paper **A8** was cited 405 times as it turned out to be one of the first papers showing that cloud microphysics may be relevant to cloud forcing. This paper examines the effects of the relationship between cirrus cloud ice water content and cloud temperature on climate change. A simple mechanistic climate model is used to study the feedback between ice water content and temperature. The central question studied in this paper concerns the extent to which both the radiative and microphysical properties of cirrus cloud influence such a feedback. To address this question, a parameterization of the albedo and emissivity of clouds is introduced. Observations that relate the ice water content to cloud temperature are incorporated in the parameterization to introduce a temperature dependence to both albedo and emittance. The cloud properties relevant to the cloud feedback are expressed as functions of particles size re, asymmetry parameter g and cloud temperature and analyses of aircraft measurements, lidar and ground based radiometer data are used to select re and g. It was concluded that prediction of cirrus cloud feedback on climate is both premature and limited by our lack of understanding of the relationship between size and shape of ice crystals and the gross radiative properties of cirrus.

8.2. References (Clouds, water vapor, and radiation: climate feedbacks)

A8. Stephens, G.L., S-C. Tsay, P.W. Stackhouse, and P.J. Flatau. The relevance of the microphysical and radiative properties of cirrus clouds to climate and climate feedback. *J. Atmos. Sci.*, **47**:1742-1753, 1990.

A16. Collins, W.D., F.P.J. Valero, P.J. Flatau, D. Lubin, H. Grassl, and P. Pilewskie. Radiative effects of convection in the tropical Pacific, *Journal of Geophysical Research*, **101**, 14999-15012, 1996.

A17. Valero, F.P.J., W.D. Collins, P. Pilewskie, A. Bucholtz, and P.J Flatau. Direct radiometric observations of the water vapor super greenhouse effect over the equatorial Pacific Ocean. *Science*, 21 March 1997, **275**, (no.5307): 1773-6.

A20. Valero, F.P.J., A. Bucholtz, B.C. Bush, S.K. Pope, W.D. Collins, P.J. Flatau, A. Strawa, and W.J.Y. Gore. Atmospheric radiation measurements enhanced shortwave experiment (ARESE): Experimental and data details, *J. Geophys. Res.*, **102**(D25), 29929-29938, 10.1029/97JD02434, 1997.

A22. Collins, W.D., A. Bucholtz, P.J. Flatau, D. Lubin, F.P.J. Valero, C.P. Weaver, and P. Pilewski. Determination of surface heating by convective cloud systems in the central equatorial Pacific from surface and satellite measurements. *Journal of Geophysical Research-Atmospheres,* **V105**(ND11):14807-14821, 2000.

9. Cloud physics

9.1. Cloud microphysics parameterization (theoretical work)

I have made several theoretical contributions to the field of cloud microphysics. Perhaps the most influential was a report which was never official published - report **B14.** This scheme was used in several mesoscale models for many years. It includes well know mesoscale model RAMS. In **B14** the new bulk microphysics scheme developed for use in the Colorado State University Regional Atmospheric Mesoscale Model ((RAMS) was described. This scheme includes several unique concepts and should be easily transportable to other modeling systems. The new concepts include: Unifying treatment of different distributions (constant, gamma, Marshall- Palmer, and log-normal) which makes it possible to define the distribution-weighted properties in a simple and concise way. The introduction of a interaction scheme for water classes simplifies the description of all microphysical processes such as collection, vapor deposition, melting, riming, etc. A new method of finding exact and ;approximate integrals for collection processes is described. The scheme includes: cloud water, rain, pristine crystals, snow, graupel, and aggregates but the framework exist for additional classes such as hail. The introduction of two ice categories (pristine and snow) should improve prediction of ice properties and help properly parameterize other processes which are based on microphysics parameterization (such a s radiative effects of cirrus clouds). A new set of prognostic equations for concentrations is included which will be used for modeling of such diversified situations as convective systems with imbedded stratiform regions or orographic systems.

9.2. Field projects

Many of my publications related to cloud physics are related to experimental work. in this field are based on experimental field project. These field projects are multiyear efforts and included participation in their design and in the data collection as well as data analysis.

- CAPE2010, Kennedy Space Center, Advanced Pulse Doppler Radar studies of clouds, 2010
- CAPE2009, Kennedy Space Center, Advanced Pulsed Doppler Radar studies of clouds, 2009

- Subsonic aircraft: Contrail and Cloud Effects Special Study April, 1996, Salinas, KS, 2 weeks
- ARM-UAV April-May, 1996, Blackwell-Tonkawa, OK, 2 weeks
- Atmospheric Radiation Measurement (Unmanned Aerospace Vehicle, Enhanced Shortwave Experiment (ARM-UAV-ARESE) 1995, 6 weeks
- NOAA P3 aircraft measurements-radiation, Central Equatorial Pacific Experiment, Equatorial Pacific, 1993, 2 months
- First International Satellite Cloud Climatology Regional Experiment -II Coffeyville, Kansas, 1992, 6 weeks
- First International Satellite Cloud Climatology Regional Experiment -I Madison, Wisconsin, 1986, 6 weeks

I have received awards for organization of these projects

- NASA International Satellite Cloud Climatology Project for *outstanding contributions to increasing the understanding of cloud process for climate studies, 1992*

- DOE letter for excellent execution of ARESE mission, 1995

9.3. Altocumulus and high resolution radar analysis

One of the most rewarding research in the last 3 years for me were two field projects related to “forgotten clouds” – the altocumulus clouds. I made a major effort in their organization. To that end I used instrumentation which I purchased using the $400K instrumentation grant from DoD DURIP. I prepared and deployed all of these instruments including lidar, ceilometer, radar, sky camera, aerosol measurements; I collected and processed the data. This field experiments have been conducted in the Kennedy Space Center (KSC) near the Cape Canaveral, Florida. One of the key experimental instruments utilized was the high-resolution dual-polarization, C-band Doppler, the largest radar of its type. This radar was initially developed in 1994 and has been routinely utilized by NASA to monitor Space Shuttle launch debris, starting with the post-Columbia disaster, STS-114 Space Shuttle return to flight. We have shown that this radar is not only capable of detecting single hydrometeors within naturally occurring cloud systems but can provide a view of the internal structure and circulation of clouds in unprecedented detail largely as a result of its unique combination of power and a phenomenal 0.5m range resolution (typical resolution of weather radars is hundreds of meters). I prepared **paper C1** which is an exciting scientific discovery – namely observation of individual droplets, their trajectories and oscillations in the free atmosphere 2-7 kilometers above the surface. These are the first observations of its type. The importance of this research is related to the fact that not much is known about mid-level clouds because they are far from the surface and difficult to study. I am also working on a paper related to maintenance of altocumulus clouds through interaction between turbulence, radiation, and cloud microphysics. These clouds are an important component of climate change research but their parameterization in global circulation models is still elusive.

9.4. References (Cloud physics)

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C1. Jerome M. Schmidt, Piotr. J. Flatau, Paul. R. Harasti, Robert. D. Yates, Ricky Littleton, Michael S. Pritchard, Jody M. Fischer, Erin. J. Fischer, William J. Kohri, Jerome R. Vetter, Scott Richman, Dariusz B. Baranowski, Mark J. Anderson, Ed Fletcher, and David W. Lando, Radar Observations of Individual Rain Drops in the Free Atmosphere, submitted to Geophysical Research Letters, 2011, 24 pages.

10. Numerical modeling

10.1. Findings

I worked with several numerical weather predictions models mostly on physics parameterizations such as documented elsewhere in this document (cloud physics, radiative transfer, turbulence). On occasion I worked on numerical schemes as is documented in the references below.

10.2. References (Numerical modeling)

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A6. Flatau, P.J., R.A. Pielke, and W.R. Cotton. Application of symbolic algebra to the generation of coordinate transformations. *Environmental Software,* **3**:158-160, 1988.

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