Curriculum Vitae: Robin J. Hogan

August 2018

A. PERSONAL INFORMATION

Date of Birth	27 July 1974
Nationality	British
Address	European Centre for Medium-Range Weather Forecasts (ECMWF), Shinfield Park, Reading, RG2 9AX
Telephone	+44 (0)118 9492733
ECMWF email	r.j.hogan@ecmwf.int
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Present employment

2014–present	Senior Scientist, European Centre for Medium Range Weather Forecasts, Reading, UK (95%)
2010–present	Professor of Atmospheric Physics, Dept of Meteorology, University of Reading, UK (5% since April 2014)

Previous employment

2011–2014	Head of Department for Research, Dept of Meteorology, University of Reading, UK
2007–2010	Reader in Atmospheric Physics, Dept of Meteorology, University of Reading, UK
2003–2007	Lecturer, Department of Meteorology, University of Reading, UK
1998–2002	Postdoctoral research scientist, Department of Meteorology, University of Reading, UK

Qualifications

1998	PhD in Meteorology, University of Reading, UK
1995	BSc in Physics with Astrophysics (First Class Honours), University of Leicester, UK

B. RESEARCH

My research is concerned with radiation and clouds, and is motivated by the need to improve the accuracy of weather and climate forecasts. Most of my recent work falls into three categories: (1) development of novel and efficient numerical methods for atmospheric radiative transfer, (2) development of novel radar and lidar techniques to retrieve cloud properties remotely, and (3) application of these techniques to improve understanding of cloud processes and to evaluate numerical weather forecast and climate models. Within ECMWF I have responsibility for the development of the radiation scheme. Research highlights are described in Section G.

Research grants awarded

2016 Aeolus/EarthCARE assimilation studies (A3S)
European Space Agency (Co-Investigator)

2016 EarthCARE assimilation project
European Space Agency (Co-Investigator)

2015 Doppler radar and synergy algorithms for EarthCARE (DORSY)
*European Space Agency, ECMWF share **€418k** (Subcontractor; lead ECMWF investigator)*

2014 3D Shortwave Radiative Kernels of Marine Boundary-layer Clouds Using Scanning Radar/Lidar and Array Spectroradiometer
US Department of Energy Atmospheric System Research Program (Co-Investigator)

2012 Initial Training for Atmospheric Remote Sensing (ITARS)
*FP7 Marie Curie Mobility Actions Initial Training Networks, Reading share **€287k** (Co-Investigator).*

2011 Study of shortwave spectra in fully 3D environment: Synergy between scanning radars and spectral radiation measurements
*US Department of Energy Atmospheric System Research Program, **£108k** (Co-Investigator)*

2011 Variational synergistic algorithms for EarthCARE (VARSY)

*European Space Agency, Reading share **€100k** (Subcontractor; lead Reading investigator)*

2011 Dynamical and Microphysical Evolution of Convective Storms (DYMECS)
*NERC Standard Grant, **£547k** (Principal Investigator)*

2010 Aerosols, Clouds and Trace-Gas Observing Network (ACTRIS)
*EU FP7 proposal, Reading share **£278k** (Co-Investigator)*

2010 Synergy algorithms for EarthCARE
*NCEO Mission Support call, Reading share **£250k** (Principal Investigator)*

2009 More Operational Radiosonde Sensors (MORSE)
*NERC Technologies Proof of Concept, Reading share **£168k** (Co-Investigator)*

2009 Radiative Transfer for EarthCARE (RATEC)
*European Space Agency, Reading share **£189k** (Subcontractor; lead Reading investigator)*

2009 FASTER: Development of a Numerical Weather Prediction Testbed
*US Department of Energy Climate Change Prediction Program, **$96k** in year 1 of 5, **$104k** in year 2 (Co-Investigator, lead Reading investigator)*

2009 The effect of 3D radiative transfer on climate
*NERC Standard Grant, **£254k** (Principal Investigator)*

2008 National Centre for Earth Observation
*NERC Centre of Excellence, Reading share around **£7m** (Co-Investigator)*
Dr Hogan is involved in both the Climate Theme and the Hazardous Weather Theme

2007 Cloud and aerosol synergetic products from EarthCARE retrievals (CASPER)
*European Space Agency, Reading share **£60k** (Subcontractor, lead Reading investigator)*

2007 Representing cloud inhomogeneity and overlap in a General Circulation Model
*NERC Small grant, **£53k** (Principal Investigator)*

2007 Aerosol interactions in mixed-phase clouds
*NERC Consortium proposal, Reading share **£254k** (Co-Investigator)*

2006 Cascade: Cloud-system resolving modelling of the tropical atmosphere
*NERC Consortium proposal, Reading share **£1.6m** (Co-Investigator)*

2005 Evaluation of clouds in climate and forecasting models using CloudSat and Calipso data
*NERC Standard Grant, **£198k** (Principal Investigator)*

2005 Improvement of stratocumulus representation in models by the use of high-resolution observations
*NERC Standard Grant, **£245k** (Co-Investigator)*

2005 Balloon-carried instrument for measurement of atmospheric turbulence
*Royal Society Paul Instrument Fund, **£77k** (Co-Investigator)*

2004 All weather Doppler lidar for clouds and boundary layer
*NERC Standard Grant, **£149k** (Co-Investigator)*

2003 The properties of ice clouds and supercooled liquid water layer clouds derived from ground based polarimetric radar and lidar observations
*NERC New Observing Techniques Grant, Reading share **£215** (Co-Investigator)*

Postgraduate and postdoctoral supervision

- 15 research scientists and postdocs supervised as PI: Andrew Barrett, Yann Blanchard, Alessio Bozzo, Julien Delanoë, Debbie Clifford, Mark Fielding, Kirsty Hanley, Shannon Mason, Ewan O'Connor, Kevin Pearson, Nicola Pounder, Jonathan Shonk, Thorwald Stein, Brian Tse and Chris Westbrook
- Supervisor of nine successfully completed PhD students: Jonathan Wilkinson (2007), Jonathan Shonk (2008), Nicky Chalmers (2011), Peter Hill (2012), Andrew Barrett (2012), Natalie Harvey (2013), Julian Mann (2014), Mark Fielding (2015), Sophia Schäfer (2016)
- Formerly on the Monitoring Committee for many other Higher Degree/PhD students
- Supervised 14 masters dissertations, 7 of whom were awarded distinctions, 7 of whom went on to study PhDs and 6 of whom co-authored papers on their dissertation work

Awards

2014 Henry G. Houghton Award, American Meteorological Society, for "broad-reaching, imaginative contributions to understanding the interaction of clouds and radiation through innovations in radiative transfer and remote sensing"

2007 School award for outstanding contributions to teaching and learning support, University of Reading
2005 L. F. Richardson Prize, Royal Meteorological Society, for meritorious papers published under the age of 35
2004 Best poster award at 14th International Conference on Clouds and Precipitation, Bologna, Italy
2000 Highly commended poster prize at Royal Meteorological Society 150th Anniversary Conference, Cambridge, UK
1994 Raymond Hide prize for undergraduate work at the University of Leicester

International invited talks

2018 ICCARUS 2018, German Weather Service (DWD), Offenbach, Germany (26 Feb)
2017 Japan Meteorological Agency, Tokyo (20 Dec)
2017 Workshop on Canadian science and applications of the EarthCARE mission, McGill University, Montreal (1 Mar)
2015 AGU Joint Assembly, Montreal, Canada (7 May)
2014 Fourth Cloud Retrieval Evaluation Workshop (CREW-4), Grainau, Germany (4 Mar)
2013 Fourth International Workshop on Space-Based Snowfall Measurements, Mammoth Lakes, California (6 May)
2012 Gordon Research Conference on Radiation and Climate, Waterville, Maine (14 Jul)
2012 LATMOS, University of Versailles, St-Quentin-en-Yvelines, France (13 Mar)
2011 Gordon Research Conference on Radiation and Climate, Waterville, Maine (14 Jul)
2009 NASA Goddard Institute for Space Studies, New York City (13 Feb)
2009 Climate and Radiation Branch, NASA Goddard Space Flight Center, Greenbelt (4 Feb)
2009 Atmospheric Sciences Division, Brookhaven National Laboratory, Long Island (30 Jan)
2008 CPTEC, INPE, Cachoeira Paulista, Brazil (14 Aug)
2008 Keynote talk at the International Radiation Symposium, Foz do Iguassu, Brazil (7 Aug)
2008 Keynote talk at the ARM Science Team meeting, Norfolk, Virginia (13 Mar)
2007 Keynote talk at 33rd AMS Conference on Radar Meteorology, Cairns, Australia (7 Aug)
2006 EOL/RAL Seminar, National Center for Atmospheric Research (NCAR), Boulder (18 July)
2006 Session on "Scale, scaling and non-linear variability", EGU General Assembly, Vienna (5 Apr)
2003 Department of Atmospheric Sciences, University of Washington, Seattle (17 Nov)
2003 GEWEX Workshop on "3D Clouds and Radiative Transfer", Victoria, BC, Canada (14 Nov)

UK invited talks

2018 EC-Earth Workshop, ECMWF, Reading (30 Jan)
2016 Earth Radiation Budget Workshop, ECMWF, Reading (21 Oct)
2016 Space & Atmospheric Physics Group, Imperial College London (19 Jan)
2014 Scattering, Clouds & Climate Workshop, Mathematics Institute, University of Oxford (25 Mar)
2013 Royal Meteorological Society National Meeting, London (20 Mar)
2012 Workshop on parametrization of clouds and precipitation, ECMWF, Reading (7 Nov)
2012 Space & Atmospheric Physics Group, Imperial College London (1 May)
2011 Space Research Centre Seminar, University of Leicester (18 Mar)
2010 Keynote talk at National Centre for Atmospheric Science Conference, Manchester (5 July)
2010 ECMWF Workshop on "Assimilating satellite observations of clouds and precipitation into NWP models", Reading (15 June)
2010 Workshop of COST Action ES0702: Integrated Ground-Based Observations of Essential Variables for Climate and Operational Meteorology EG-CLIMET, Reading (24 Mar)
2010 Atmospheric, Oceanic and Planetary Physics, University of Oxford (4 Feb)
2009 ECMWF Formal Seminar, Reading (27 Oct)
2008 ECMWF Seminar "Parametrization of subgrid physical processes", Reading (1 Sept)
2008 Royal Meteorology Society meeting on "Ice in the atmosphere", Manchester (23 Apr)
2007 Workshop on High Resolution Modelling, Reading (30 Oct)
2007 Chilbolton 40th Anniversary Celebration, Chilbolton Observatory (11 Apr)
2006 ECMWF Workshop on "Parametrization of clouds in large-scale models", Reading (14 Nov)
2005 Department of Physics, Imperial College London (8 Nov)
2004 School of the Environment, University of Leeds (28 Oct)
2004 ECMWF Formal Seminar, Reading (14 Oct)

2004 Met Office NWP Seminar, Exeter (4 June)
2003 Royal Meteorological Society Physical Processes group meeting, UMIST (4 June)
2002 Royal Meteorological Society Scottish Centre, Edinburgh (13 Dec)

Professional activities: international

- Member of the Joint ESA/JAXA EarthCARE Mission Advisory Group 2017-present
- Elected a commissioner of the International Radiation Commission 2012-present
- Member of Organising Committee of the Fourth International Workshop on Space-Based Snowfall Measurements International workshop on snowfall measurement from space, Mammoth Lakes, California, 6-8 May 2013
- Chaired sessions at the 1999 International Union of Geodesy and Geophysics, 2005 Royal Meteorological Society and 2007 American Meteorological Society radar conferences
- Reviewer for many international scientific journals including *Nature*
- Member of the Programme Committee for the 2007 American Meteorological Society Conference on Radar Meteorology, Cairns, Australia
- Routinely invited to meetings of the EarthCARE Mission Advisory Group, EarthCARE being a joint ESA/Japanese satellite due for launch in 2015

Professional activities within the UK

- Fellow of the Royal Meteorological Society and entitled to use the appellation "FRMetS" (elected in 2007 following nomination by two existing fellows)
- Chair of the NERC Atmospheric Radar Facilities Steering Committee (NARFSC), 2012-2013; member of NARFSC in 2006 and from 2009 to 2013.
- Member of the NERC Service Review Group (SRG), 2009
- Former member of the Management Committee of the UK Universities Weather Research Network (UWERN)
- Wrote most of the science case for renewal of funding for the Chilbolton Facility for Atmospheric and Radio Research (CFARR) to the 2008 NERC Service Review Group; the proposal was awarded the highest possible grade and funding was secured for 5 years at around £0.5M per year
- PhD external examiner twice at Manchester University in December 2006 (Daniel Grosvenor) and November 2011 (Christopher Lee), at St Andrews University in February 2014 (Peter Speirs), and at University of Hertfordshire in December 2016 (Lawrence Taylor)
- PhD internal examiner in Reading in December 2006, September 2007, August 2010 and July 2012
- MPhil internal examiner in Reading in November 2009

Book chapters

Haeffelin, M., S. Crewell, A. J. Illingworth, G. Pappalardo, H. Russchenberg, M. Chiriaco, K. Ebell, **R. J. Hogan** and F. Madonna, 2016: Parallel developments and formal collaborations between European atmospheric profiling observatories and US ARM research programs. Chapter 29 in *The Atmospheric Radiation Measurement Program: The First 20 Years,* American Meteorological Society Monograph.

Hogan, R. J., and I. B. Mason, 2011: Deterministic forecasts of binary events. In *Forecast verification: a practitioner's guide in atmospheric science,* Eds. I. T. Jolliffe and D. B. Stephenson, 2nd Ed., Wiley.

Publications in peer-reviewed journals

Updated August 2018; download PDFs from *www.met.reading.ac.uk/clouds/publications.html*

Publications in review and in press

120. Beljaars, A., G. Balsamo, P. Bechtold, A. Bozzo, R. Forbes, **R. J. Hogan,** M. Koehler, J.-J. Morcrette, A. M. Tompkins, P. Viterbo and N. Wedi: The numerics of physical parametrization in the ECMWF model. *Submitted to Frontiers Earth Sci.*
119. **Hogan, R. J.**: The exponential model of urban geometry. *Submitted to Boundary-Layer Meteorol.*
118. Lock, S.-J., S. T. K. Lang, M. Leutbecher, **R. J. Hogan** and F. Vitart: Treatment of model uncertainty from radiation by the Stochastically Perturbed Parametrization Tendencies (SPPT) scheme and associated revisions in the ECMWF ensembles. *Submitted to Q. J. R. Meteorol. Soc.*

117. Mason, S. L., J.-C. Chiu, **R. J. Hogan,** D. Moisseev and S. Kneifel: Retrievals of riming and snow particle density from vertically-pointing Doppler radars. *Submitted to J. Geophys. Res.*

2018

116. Ahlgrimm, M., R. M. Forbes, **R. J. Hogan** and I. Sandu: Understanding global model systematic shortwave radiation errors in subtropical marine boundary layer cloud regimes. *J. Adv. Modeling Earth Sys.* doi:10.1029/2018MS001346.
115. **Hogan, R. J.,** and A. Bozzo: A flexible and efficient radiation scheme for the ECMWF model. *J. Adv. Modeling Earth Sys.,* doi:10.1029/2018MS001364.
114. **Hogan, R. J.,** T. Quaife and R. Braghiere: Fast treatment of 3D radiative transfer in vegetation canopies: SPARTACUS-Vegetation 1.1. *Geosci. Model Dev.,* **11,** 339-350.
113. Polichtchouk, I., T. G. Shepherd, **R. J. Hogan** and P. Bechtold: Sensitivity of the Brewer-Dobson circulation and polar vortex variability to parametrized nonorographic gravity-wave drag in a high-resolution atmospheric model. *J. Atmos. Sci.,* **75,** 1525-1543.

2017

112. Barrett, A. I., **R. J. Hogan** and R. M. Forbes: Why are mixed-phase altocumulus clouds poorly predicted by large-scale models? 1. Physical processes. *J. Geophys. Res.,* **122,** 9903-9926.
111. Barrett, A. I., **R. J. Hogan** and R. M. Forbes: Why are mixed-phase altocumulus clouds poorly predicted by large-scale models? 2. Vertical resolution sensitivity and parameterization *Submitted to J. Geophys. Res.,* **122,** 9927-9944.
110. Harrison, R. J., G. Pretor-Pinney, G. J. Marlton, G. D. Anderson, D. J. Kirshbaum and **R. J. Hogan**: Asperitas - a newly identified cloud supplementary feature. *Weather,* **72,** 132-141.
109. **Hogan, R. J.,** R. Honeyager, J. Tyynela and S. Kneifel: Calculating the millimetre-wave scattering phase function of snowflakes using the Self-Similar Rayleigh-Gans Approximation. *Q. J. R. Meteorol. Soc.,* **143,** 834-844.
108. Leinonen, J., S. Kneifel and **R. J. Hogan**: Evaluation of the Rayleigh-Gans Approximation for microwave scattering by rimed snowflakes. *Q. J. R. Meteorol. Soc.,* doi:10.1002/qj.3093.
107. Leutbecher, L., S.-J. Lock, P. Ollinaho, S. T. K. Lang, G. Balsamo, P. Bechtold, M. Bonavita, H. M. Christiensen, M. Diamantakis, E. Dutra, S. English, M. Fisher, R. M. Forbes, J. Goddard, T. Haiden, **R. J. Hogan,** S. Juricke, H. Lawrence, D. MacLeod, L. Magnusson, S. Malardel, S. Massart, I. Sandu, P. K. Smolarkiewicz, A. Subramanian, F. Vitart, N. Wedi and A. Weisheimer: Stochastic representation of model uncertainties at ECMWF: State of the art and future vision. *Q. J. R. Meteorol. Soc.,* **143,** 2315–2339.
106. Mason, S. L., J. C. Chiu, **R. J. Hogan** and L. Tian: Improved rain rate and drop size retrievals from airborne Doppler cloud radar. *Atmos. Chem. Phys.,* **17,** 11,567-11,589.
105. Ollinaho, P., S.-J. Lock, M. Leutbecher, P. Bechtold, A. Beljaars, A. Bozzo, R. M. Forbes, T. Haiden, **R. J. Hogan** and I. Sandu: Towards process-level representation of model uncertainties: Stochastically perturbed parametrisations in the ECMWF ensemble. *Q. J. R. Meteorol. Soc.,* **143,** 408-422.

2016

104. **Hogan, R. J.,** and S. Hirahara: Effect of solar zenith angle specification in models on mean shortwave fluxes and stratospheric temperatures. *Geophys. Res. Lett.,* **43,** 482-488.
103. **Hogan, R. J.,** S. A. K. Schäfer, C. Klinger, J.-C. Chiu and B. Mayer: Representing 3D cloud-radiation effects in two-stream schemes: 2. Matrix formulation and broadband evaluation. *J. Geophys. Res.,* **121,** 8583-8599.
102. Schäfer, S. A. K., **R. J. Hogan,** C. Klinger, J.-C. Chiu and B. Mayer: Representing 3D cloud-radiation effects in two-stream schemes: 1. Longwave considerations and effective cloud edge length. *J. Geophys. Res.,* **121,** 8567-8582.

2015

101. Fielding, M. D., J.-C. Chiu, **R. J. Hogan,** G. Feingold, E. Eloranta, E. J. O'Connor and M. P. Cadeddu: Joint retrievals of cloud and drizzle in marine boundary layer clouds using ground-based radar, lidar and zenith radiances. *Atmos. Meas. Tech. Discuss.,* **8,** 1833-1889.
100. Hanley, K. E., R. S. Plant, T. H. M. Stein, **R. J. Hogan,** J. C. Nicol, H. W. Lean, C. Halliwell and P. A. Clark: Mixing length controls on high resolution simulations of convective storms. *Q. J. R. Meteorol. Soc.,* **141,** 272-284.

99. Harvey, N. J., **R. J. Hogan** and H. F. Dacre: Evaluation of boundary-layer type in a weather forecast model using long-term Doppler lidar observations. *Q. J. R. Meteorol. Soc.,* **141,** 1345-1353.
98. **Hogan, R. J.,** and A. Bozzo: Mitigating errors in surface temperature forecasts using approximate radiation updates. *J. Adv. Modeling Earth Sys.,* **7,** 836-853.
97. Illingworth, A. J., H. W. Barker, A. Beljaars, H. Chepfer, J. Delanoe, C. Domenech, D. P. Donovan, S. Fukuda, M. Hirakata, **R. J. Hogan,** A. Huenerbein, P. Kollias, T. Kubota, T. Nakajima, T. Y. Nakajima, T. Nishizawa, Y. Ohno, H. Okamoto, R. Oki, K. Sato, M. Satoh, U. Wandinger and T. Wehr: The EarthCARE Satellite: the next step forward in global measurements of clouds, aerosols, precipitation and radiation. *Bull. Am. Meteorol. Soc.,* doi:10.1175/BAMS-D-12-00227.1.
96. Nicol, J. C., **R. J. Hogan,** T. H. M. Stein, K. E. Hanley, P. A. Clark, C. E. Halliwell, H. W. Lean and R. S. Plant: Convective updraught evaluation in high-resolution NWP simulations using single-Doppler radar measurements. *Q. J. R. Meteorol. Soc.,* **141,** 3177-3189.
95. Stein, T. H. M., **R. J. Hogan,** P. A. Clark, C. E. Halliwell, K. E. Hanley, H. W. Lean, J. C. Nicol and R. S. Plant: The DYMECS project: A statistical approach for the evaluation of convective storms in high-resolution NWP models. *Bull. Am. Meteorol. Soc.,* **96,** 939-951.
94. Stein, T. H. M., D. J. Parker, **R. J. Hogan,** C. Birch, C. E. Holloway, G. Lister, J. H. Marsham and S. J. Woolnough: The representation of the West-African Monsoon vertical cloud structure in the Met Office Unified Model: An evaluation with CloudSat. *Q. J. R. Meteorol. Soc.,* doi:10.1002/qj.2614.
93. Wood, R., M. Wyant, C. S. Bretherton, J. Remillard, P. Kollias, J. Fletcher, J. Stemmler, S. deSzoeke, S. Yuter, M. Miller, D. Mechem, G. Tselioudis, C. Chiu, J. Mann, E. J. O'Connor, **R. J. Hogan,** X. Dong, M. Miller, V. Ghate, A. Jefferson, Q. Min, P. Minnis, R. Palinkonda, B. Albrecht, E. Luke, C. Hannay and Y. Lin: Clouds, aerosol, and precipitation in the marine boundary layer: An ARM Mobile Facility deployment. *Submitted to Bull. Am. Meteorol. Soc.*

2014

92. Chiu, J. C., J. Holmes, **R. J. Hogan** and E. J. O'Connor: The interdependence of continental warm cloud properties derived from unexploited solar background signal in ground-based lidar measurements. *Atmos. Chem. Phys., 14,* 8389-8401.
91. Delanoë, J., A. J. Heymsfield, A. Protat, A. Bansemer and **R. J. Hogan:** Normalized particle size distribution for remote sensing application. *J. Geophys. Res.,* **119,** 4136-4148.
90. Fielding, M. D., J. C. Chiu, **R. J. Hogan** and G. Feingold: A novel ensemble method for retrieving cloud properties in 3D using ground-based scanning radar and zenith radiances. *J. Geophys. Res.,* **119,** 10912-10930.
89. **Hogan, R. J.,** Fast reverse-mode automatic differentiation using expression templates in C++. *ACM Trans. Mathematical Softw.,* **40,** 26:1-26:16.
88. **Hogan, R. J.,** and C. D. Westbrook: Equation for the microwave backscatter cross section of aggregate snowflakes using the Self-Similar Rayleigh-Gans Approximation. *J. Atmos. Sci.,* **71,** 3292-3301.
87. Mann, J. L., J. C. Chiu, **R. J. Hogan,** E. J. O'Connor, T. S. L'Ecuyer, T. H. M. Stein and A. Jefferson: Aerosol impacts on drizzle properties in warm clouds from ARM Mobile Facility maritime and continental deployments. *J. Geophys. Res.,* **119,** 4204-4227.
86. Pearson, K. J., G. M. S. Lister, C. E. Brich, R. P. Allan, **R. J. Hogan** and S. J. Woolnough, 2013: Modelling the diurnal cycle of tropical convection across the "Grey Zone". *Q. J. R. Meteorol. Soc.,* **140,** 491-499.
85. Stein, T. H. M., **R. J. Hogan,** K. E. Hanley, J. C. Nicol, H. W. Lean, R. S. Plant, P. A. Clark and C. E. Halliwell: The three-dimensional morphology of simulated and observed convective storms over southern England. *Mon. Weath. Rev.,* **142,** 3264-3283.

2013

84. Bianchi, B., P.-J. van Leeuwen, **R. J. Hogan** and A. Berne, A variational approach to retrieve rain rate by combining information from rain gauges, radars and microwave links. *J. Hydrometeorol.,* **14,** 1897-1909.

83. Ceccaldi, M., J. Delanoe, **R. J. Hogan,** N. L. Pounder, A. Protat and J. Pelon: From CloudSat-CALIPSO to Earth-Care: Evolution of the DARDAR cloud classication and its validation using airborne radar-lidar observations. *J. Geophys. Res.,* **70,** 708-724.
82. Fielding, M. D., J. C. Chiu, **R. J. Hogan** and G. Feingold, 2013: Cloud reconstructions for shortwave surface radiation closure: Evaluation of 3D scanning cloud radar scan strategy. *J. Geophys. Res.,* early online view, doi: 10.1002/jgrd.50614.
81. Harvey, N. J., **R. J. Hogan** and H. F. Dacre, 2013: A climatology of boundary-layer types derived using Doppler lidar. *Q. J. R. Meteorol. Soc.,* early online view, doi: 10.1002/qj.2068.
80. **Hogan, R. J.,** and J. K. P. Shonk, Incorporating the effects of 3D radiative transfer in the presence of clouds into two-stream radiation schemes. *J. Atmos. Sci.,* **70,** 708-724.

2012

79. Chiu, J. C., A. Marshak, C.-H. Huang, T. Varnai, **R. J. Hogan,** D. M. Giles, B. N. Holben, E. O'Connor, Y. Knyazikhin, W. J. Wiscombe, 2012: Cloud droplet size and liquid water path retrievals from zenith radiance measurements: examples from the Atmospheric Radiation Measurement Program and the Aerosol Robotic Network. *Atmos. Chem. Phys.,* **51,** 350-365.
78. Hill, P. G., **R. J. Hogan,** J. Manners and J. C. Petch. Parametrising the horizontal inhomogeneity of ice water content using CloudSat observations. *Q. J. R. Meteorol. Soc.,* **138,** 1784-1793.
77. **Hogan, R. J.,** L. Tian, P. R. A. Brown, C. D. Westbrook, A. J. Heymsfield and J. D. Eastment, 2012: Radar scattering from ice aggreates using the horizontally aligned oblate spheroid approximation. *J. Appl. Meteorol. Climatology,* **51,** 655-671.
76. Pounder, N. L., **R. J. Hogan,** T. Varnai, A. Battaglia and R. F. Cahalan, 2012: A variational method to retrieve the extinction profile in liquid clouds using multiple field-of-view lidar. *J. Appl. Meteorol. Climatology,* **51,** 350-365.
75. Shonk, J. K. P., **R. J. Hogan** and J. Manners, 2012: Impact of improved representation of horizontal and vertical cloud structure in a climate model. *Clim. Dyn.,* **38,** 235-2376, doi: 10.1007/s00382-011-1174-2.
74. Zhao, C., S. Xie, S. A. Klein, A. Protat, M. D. Shupe, S. A. McFarlane, J. M. Comstock, J. Delanoë, M. Deng, M. Dunn, **R. J. Hogan,** D. Huang, M. P. Jensen, G. G. Mace, R. McCoy, E. J. O'Connor, D. D. Turner and Z. Wang, 2012: Toward understanding of differences in current cloud retrievals of ARM ground-based measurements. *J. Geophys. Res.,* **117,** D10206, doi:10.1029/2011JD016792.

2011

73. Barker, H. W., M. P. Jerg, T. Wehr, S. Kato, D. P. Donovan and **R. J. Hogan,** 2011: A 3D cloud construction algorithm for the EarthCARE satellite mission. *Q. J. R. Meteorol. Soc.,* **137,** 1042-1058.
72. Dacre, H. F., A. L. M. Grant, **R. J. Hogan, S**. E. Belcher, D. Thomson, B. Devenish, F. Marenco, J. Haywood, A. Ansmann, I. Mattis and L. Clarisse, 2011: Evaluating the structure and magnitude of the ash plume during the initial phase of the 2010 Eyjafjallajokull eruption using lidar observations and NAME simulations. *J. Geophys. Res.,* **116,** D00U03, doi:10.1029/2011JD015608.
71. Delanoë, J., **R. J. Hogan,** R. M. Forbes, A. Bodas-Salcedo and T. H. M. Stein. 2011: Evaluation of ice cloud representation in the ECMWF and UK Met Office models using CloudSat and CALIPSO data. *Q. J. R. Meteorol. Soc.,* doi: 10.1002/qj.882.
70. Marenco, F., and **R. J. Hogan,** 2011: Determining the contribution of volcanic ash and boundary layer aerosol in backscatter lidar returns: a three-component atmosphere approach. *J. Geophys. Res.,* **116,** D00U06, doi:10.1029/2010JD015415..
69. Stein, T. H. M., J. Delanoe and **R. J. Hogan,** 2011: A comparison between four different retrieval methods for ice-cloud properties using data from the CloudSat, CALIPSO, and MODIS satellites. *J. Appl. Meteorol. Climatology*, **50,** 1952-1969.
68. Stein, T. H. M., D. J. Parker, J. Delanoe, N. S. Dixon, **R. J. Hogan,** P. Knippertz, R. I. Maidment and J. H. Marsham, 2011: The vertical cloud structure of the West African monsoon: A four-year climatology using CloudSat and CALIPSO. *J. Geophys. Res,* **116,** D22205, doi: 10.1029/2011JD016029.

2010

67. Battaglia, A., S. Tanelli, S. Kobayashi, D. Zrnic, **R. J. Hogan** and C. Simmer, 2010: Multiple-scattering in radar systems: a review. *J. Quant. Spectroscopy,* **111,** 917-947.
66. Bouniol, D., A. Protat, J. Delanoë, J. Pelon, D. P. Donovan, J.-M. Piriou, F. Bouyssel, A. M. Tompkins, D. R. Wilson, Y. Morille, M. Haeffelin, E. J. O'Connor, **R. J. Hogan,** A. J. Illingworth, 2010: Using continuous ground-based radar and lidar measurements for evaluating the representation of clouds in four operational models. *J. Appl. Meteorol. Climatology.,* **88,** 883-898.
65. Delanoë, J., and **R. J. Hogan,** 2010: Combined CloudSat-CALIPSO-MODIS retrievals of the properties of ice clouds. *J. Geophys. Res.,* **115,** D00H29, doi:10.1029/2009JD012346.
64. **Hogan, R. J.,** 2010: The full-spectrum correlated *k* method for longwave atmospheric radiative transfer using an effective Planck function. *J. Atmos. Sci.*, **67,** 2086-2100.
63. **Hogan, R. J.,** C. A. T. Ferro, I. T. Jolliffe and D. B. Stephenson, 2010: Equitability revisited: Why the 'equitable threat score' is not equitable. *Weath. Forecasting.,* **25,** 710-726.
62. O'Connor, E. J., A. J. Illingworth, I. M. Brooks, C. D. Westbrook, **R. J. Hogan,** F. Davies and B. J. Brooks, 2010: A method for estimating the turbulent kinetic energy dissipation rate from a vertically-pointing Doppler lidar, and independent evaluation from balloon-borne in-situ measurements. *J. Atmos. Oceanic Technol.,* **27,** 1652-1664.
61. Pearson, K. J., **R. J. Hogan,** R. P. Allan, G. M. S. Lister and C. E. Holloway. Evaluation of model representation of the evolution of convective systems using satellite observations of outgoing longwave radiation. *J. Geophys. Res.,* **115,** D20206, doi:10.1029/2010JD014265.
60. Shonk, J. K. P., **R. J. Hogan,** J. M. Edwards and G. G. Mace, 2010: Effect of improving representation of horizontal and vertical cloud structure on the Earth's radiation budget—1. Review and parameterisation. *Quart. J. Roy. Meteorol. Soc.,* **136,** 1191-1204.
59. Shonk, J. K. P. and **R. J. Hogan,** 2010: Effect of improving representation of horizontal and vertical cloud structure on the Earth's radiation budget—2. The global effects. *Quart. J. Roy. Meteorol. Soc.*, **136,** 1205-1215.
58. Westbrook, C. D., A. J. Illingworth, E. J. O'Connor and **R. J. Hogan,** 2010: Doppler lidar measurements of oriented planar ice crystals falling from supercooled and glaciated layer clouds. *Quart. J. Roy. Meteorol. Soc.,* **136,** 260-276.
57. Westbrook, C. D., **R. J. Hogan,** E. J. O'Connor and A. J. Illingworth, 2010: Estimates of drizzle drop size and precipitation rate using two-colour lidar measurements. *Atmos. Meas. Technol.,* **3,** 671-781.
56. Wilkinson, J. M., **R. J. Hogan** and A. J. Illingworth, 2010: Using Doppler radar and a simple explicit microphysics model to diagnose problems with ice sublimation depth scales in forecast models. *Q. J. R. Meteorol. Soc.,* **136,** 2094-2108.

2009

55. Barrett, A. I., **R. J. Hogan** and E. J. O'Connor, 2009: Evaluating forecasts of the evolution of the cloudy boundary layer using diurnal composites of radar and lidar observations. *Geophys. Res. Lett.,* **36,** L17811, doi:10.1029/2009GL038919.
54. Harrison, R. G., A. M. Heath, **R. J. Hogan** and G. W. Rogers, 2009: Comparison of balloon-carried atmospheric motion sensors with Doppler lidar measurements. *Rev. Sci. Inst.,* **80,** 026108.
53. **Hogan, R. J.,** A. L. M. Grant, A. J. Illingworth, G. N. Pearson and E. J. O'Connor, 2009: Vertical velocity variance and skewness in clear and cloud-topped boundary layers as revealed by Doppler lidar. *Quart. J. Roy. Meteorol. Soc.* **135,** 635-643.
52. **Hogan, R. J.,** E. J. O'Connor and A. J. Illingworth, 2009: Verification of cloud fraction forecasts. *Quart. J. Roy. Meteorol. Soc.,* **135,** 1494-1511.

2008

51. Delanoë, J., and **R. J. Hogan,** 2008: A variational scheme for retrieving ice cloud properties from combined radar, lidar and infrared radiometer. *J. Geophys. Res.,* **113,** D07204, doi:10.1029/2007JD009000.
50. Dunbar, T. M., E. Hanert and **R. J. Hogan,** A one-dimensional finite-element boundary layer model with a vertically adaptive grid. *Bound. Layer Meteorol.,* **128,** 459-472.

49. Harrison, R. G., N. Chalmers and **R. J. Hogan**, 2008: Cloud determinations from surface solar radiation measurements. *Atmos. Res.,* **90,** 54-62.
48. Heymsfield, A. J., A. Protat, R. Austin, D. Bouniol, **R. J. Hogan,** H. Okamoto, K. Sato, G.-J. van Zadelhoff, D. Donovan and Z. Wang, 2008: Testing and evaluation of ice water content retrieval methods using radar and ancillary measurements. *J. Atmos. Sci.,* **47,** 135-163.
47. **Hogan, R. J.,** 2008: Fast lidar and radar multiple-scattering models—1. Small-angle scattering using the photon variance-covariance method. *J. Atmos. Sci.,* **65,** 3621-3635.
46. **Hogan, R. J.,** and A. Battaglia, 2008: Fast lidar and radar multiple-scattering models—2. Wide-angle scattering using the time-dependent two-stream approximation. *J. Atmos. Sci.,* **65,** 3636-3651.
45. **Hogan, R. J.,** A. J. Illingworth and K. Halladay, Estimating mass and momentum fluxes in a line of cumulonimbus observed by a single high-resolution Doppler radar. *Quart. J. Roy. Meteorol. Soc.,* **134,** 1127-1141.
44. Shonk, J. K. P., and **R. J. Hogan,** 2008: Tripleclouds: an efficient method for representing cloud inhomogeneity in 1D radiation schemes by using three regions at each height. *J. Climate,* **21,** 2352-2370.
43. Westbrook, C. D., **R. J. Hogan** and A. J. Illingworth, 2008: The capacitance of pristine ice crystals and aggregate snowflakes. *J. Atmos. Sci.,* **65,** 209-219.
42. Wilkinson, J. M., **R. J. Hogan** and A. J. Illingworth, 2008: Use of a lidar forward model for global comparisons of cloud fraction between the ICESat lidar and the ECMWF model. *Mon. Weath. Rev.,* **136,** 3742-3759.
41. Zhong, W., **R. J. Hogan** and J. D. Haigh, 2008: Three-dimensional radiative transfer in mid-latitude cirrus clouds. *Quart. J. Roy. Meteorol. Soc.,* **134,** 199-215.

2007

40. Gaussiat, N., **R. J. Hogan** and A. J. Illingworth, 2007: Accurate liquid water path retrieval from low-cost microwave radiometers using additional information from lidar and operational forecast models. *J. Atmos. Oceanic Technol.,* **24,** 1562-1575.
39. Gounou, A., and **R. J. Hogan,** 2007: The effect of horizontal photon transport on the radiative forcing of contrails. *J. Atmos. Sci.,* **64,** 1706-1716.
38. Harrison, R. G., and **R. J. Hogan,** 2007: Response to comment on "In-situ atmospheric turbulence measurement using the terrestrial magnetic field - a compass for a radiosonde" by Ralph D. Lorenz. *J. Atmos. Oceanic Technol.,* **24,** 1521-1522.
37. Harrison, R. G., G. W. Rogers and **R. J. Hogan,** 2007: A three-dimensional magnetometer for motion sensing of a balloon-carried atmospheric measurement package. *Rev. Sci. Inst.,* **78,** 124501.
36. Heymsfield, A. J., G.-J. van Zadelhoff, D. P. Donovan, F. Fabry, **R. J. Hogan** and A. J. Illingworth, 2007: Refinements to ice particle mass dimensional and terminal velocity relationships for ice clouds—2. Evaluation and parameterizations of ensemble ice particle sedimentation velocities. *J. Atmos. Sci.,* **64,** 1068-1088.
35. **Hogan, R. J.,** 2007: A variational scheme for retrieving rainfall rate and hail intensity from polarization radar. *J. Appl. Meteorol. Climatology,* **46,** 1544-1564.
34. Illingworth, A. J., **R. J. Hogan,** E. J. O'Connor, D. Bouniol, M. E. Brooks, J. Delanoë, D. P. Donovan, J. D. Eastment, N. Gaussiat, J. W. F. Goddard, M. Haeffelin, H. Klein Baltink, O. A. Krasnov, J. Pelon, J.-M. Piriou, A. Protat, H. W. J. Russchenberg, A. Seifert, A. M. Tompkins, G.-J. van Zadelhoff, F. Vinit, U. Willen, D. R. Wilson and C. L. Wrench, 2007: Cloudnet—continuous evaluation of cloud profiles in seven operational models using ground-based observations. *Bull. Am. Meteorol. Soc.,* **88,** 883-898.
33. Naud, C., K. L. Mitchell, J.-P. Muller, E. E. Clothiaux, P. Albert, R. Preusker, J. Fischer and **R. J. Hogan,** 2007: Comparison between ATSR2 stereo, MOS O_2 A-band and ground-based derived cloud top heights. *Int. J. Remote Sens.,* **28,** 1969-1987.
32. Westbrook, C. D., **R. J. Hogan,** A. J. Illingworth and E. J. O'Connor, 2007: Theory and observations of ice particle evolution in cirrus using Doppler radar: evidence for aggregation. *Geophys. Res. Lett.,* **34,** L02824, doi: 10.1029/2006GL027863.

2006

31. Forbes, R. M., and **R. J. Hogan,** 2006: Ice sublimation depth scales in frontal cloud. *Quart. J. Roy. Meteorol. Soc.,* **132,** 865–884.
30. Harrison, R. G., and **R. J. Hogan,** 2006: In-situ atmospheric turbulence measurement using the terrestrial magnetic field—a compass for a radiosonde. *J. Atmos. Oceanic Technol.,* **23,** 517–523.
29. **Hogan, R. J.,** 2006: Fast approximate calculation of multiply scattered lidar returns. *Appl. Optics,* **45,** 5984–5992.
28. **Hogan, R. J.,** D. P. Donovan, C. Tinel, M. A. Brooks, A. J. Illingworth and J. P. V. Poiares Baptista, 2006a: Independent evaluation of the ability of spaceborne radar and lidar to retrieve the microphysical and radiative properties of ice clouds. *J. Atmos. Oceanic Technol.,* **23,** 211–227.
27. **Hogan, R. J.,** M. P. Mittermaier and A. J. Illingworth, 2006b: The retrieval of ice water content from radar reflectivity factor and temperature and its use in the evaluation of a mesoscale model. *J. Appl. Meteorol. Climatology,* **45,** 301–317.
26. Marsham, J., S. Dobbie and **R. J. Hogan,** 2006: Evaluation of a large eddy model simulation of a mixed-phase altocumulus cloud using microwave radiometer, lidar and Doppler radar data. *Quart. J. Roy. Meteorol. Soc.,* **132,** 1693–1715.
25. Mittermaier, M. P., A. J. Illingworth and **R. J. Hogan,** 2006: Assessing vertical resolution requirements for operational weather radar data quality. *Atmos. Sci. Lett.,* **7,** 9–14.

2005

24. Brooks, M. E., **R. J. Hogan** and A. J. Illingworth, 2005: Parameterizing the difference in cloud fraction defined by area and volume as observed with radar and lidar. *J. Atmos. Sci.,* **62,** 2248–2260.
23. Clark, P. D., T. W. Choularton, P. R. A. Brown, P. R. Field, A. J. Illingworth and **R. J. Hogan,** 2005: Numerical modelling of mixed-phase frontal clouds observed during the CWVC project. *Quart. J. Roy. Meteorol. Soc.,* **131,** 1677–1694.
22. Field, P. R., **R. J. Hogan,** P. R. A. Brown, A. J. Illingworth, T. W. Choularton and R. J. Cotton, 2005: Parameterization of ice particle size distributions for mid-latitude stratiform cloud. *Quart. J. Roy. Meteorol. Soc.,* **131,** 1997–2017.
21. **Hogan, R. J.,** and S. F. Kew, 2005: A 3D stochastic cloud model for investigating the radiative properties of inhomogeneous cirrus clouds. *Quart. J. Roy. Meteorol. Soc.,* **131,** 2585–2608.
20. **Hogan, R. J.,** N. Gaussiat and A. J. Illingworth, 2005: Stratocumulus liquid water content from dual-wavelength radar. *J. Atmos. Oceanic Technol.,* **22,** 1207–1278.
19. O'Connor, E. J., **R. J. Hogan** and A. J. Illingworth, 2005: Retrieving stratocumulus drizzle parameters using Doppler radar and lidar. *J. Appl. Meteorol.,* **44,** 14–27.
18. Tinel, C., J. Testud, **R. J. Hogan,** A. Protat, J. Delanoë and D. Bouniol, 2005: The retrieval of ice cloud properties from cloud radar and lidar synergy. *J. Appl. Meteorol.,* **44,** 860–875.

2004

17. Field, P. R., **R. J. Hogan,** P. R. A. Brown, A. J. Illingworth, T. W. Choularton, P. H. Kaye, E. Hirst and R. Greenaway, 2004: Simultaneous radar and aircraft observations of mixed-phase cloud at the 100-m-scale. *Quart. J. Roy. Meteorol. Soc.,* **130,** 1877–1904. [Contribution: Analysis of the radar data; production of four of the figures; contribution to the scientific interpretation.]
16. **Hogan, R. J.,** M. D. Behera, E. J. O'Connor and A. J. Illingworth, 2004: Estimating the global distribution of supercooled liquid water clouds using spaceborne lidar. *Geophys. Res. Lett.,* **32,** L05106, doi:10.1029/2003GL018977.
15. Mittermaier, M. P., **R. J. Hogan** and A. J. Illingworth, 2004: Using mesoscale model winds for correcting wind-drift errors in radar estimates of surface rainfall. *Quart. J. Roy. Meteorol. Soc.,* **130,** 2105–2123.
14. O'Connor, E. J., A. J. Illingworth and **R. J. Hogan,** 2004: A technique for auto-calibration of cloud lidar. *J. Atmos. Oceanic Technol.,* **21,** 777–786.

2003

13. **Hogan, R. J.,** and A. J. Illingworth, 2003: Parameterizing ice cloud inhomogeneity and the overlap of inhomogeneities using cloud radar data. *J. Atmos. Sci.,* **60,** 756–767.
12. **Hogan, R. J.,** D. Bouniol, D. N. Ladd, E. J. O'Connor and A. J. Illingworth, 2003a: Absolute calibration of 94/95-GHz radars using rain. *J. Atmos. Oceanic Technol.,* **20,** 572–580.

11. **Hogan, R. J.,** P. N. Francis, H. Flentje, A. J. Illingworth, M. Quante and J. Pelon, 2003b: Characteristics of mixed-phase clouds—1. Lidar, radar and aircraft observations from CLARE'98. *Quart. J. Roy. Meteorol. Soc.,* **129,** 2089–2116.
10. **Hogan, R. J.,** A. J. Illingworth, E. J. O'Connor and J. P. V. Poiares Baptista, 2003c: Characteristics of mixed-phase clouds—2. A climatology from ground-based lidar. *Quart. J. Roy. Meteorol. Soc.,* **129,** 2117–2134.
9. Phillips, V. T. J., T. W. Choularton, A. J. Illingworth, **R. J. Hogan** and P. R. Field, 2003: Simulations of the glaciation of a frontal mixed-phase cloud with the Explicit Microphysics Model. *Quart. J. Roy. Meteorol. Soc.,* **129,** 1351–1371.

2002 and earlier

8. **Hogan, R. J.,** P. R. Field, A. J. Illingworth, R. J. Cotton and T. W. Choularton, 2002: Properties of embedded convection in warm-frontal mixed-phase cloud from aircraft and polarimetric radar. *Quart. J. Roy. Meteorol. Soc.,* **128,** 451–476.
7. Donovan, D. P., A. C. A. P. van Lammeren, H.W. J. Russchenberg, A. Apituley, **R. J. Hogan,** P. N. Francis, J. Testud, J. Pelon, M. Quante and J.W. F. Goddard, 2001: Cloud effective particle size and water content profile retrievals using combined lidar and radar observations—2. Comparison with IR radiometer and in situ measurements of ice clouds. *J. Geophys. Res.,* **106,** 27 449–27 464.
6. **Hogan, R. J.,** C. Jakob and A. J. Illingworth, 2001: Comparison of ECMWF cloud fraction with radar-derived values. *J. Appl. Meteorol.,* **40,** 513–525.
5. Donovan, D. P., A. C. A. P. van Lammeren, **R. J. Hogan,** H.W. J. Russchenberg, A. Apituley, P. N. Francis, J. Testud, J. Pelon, M. Quante and J. Agnew, 2000: Combined radar and lidar cloud remote sensing: Comparison with IR radiometer and in-situ measurements. *Phys. Chem. Earth,* **25,** 1049–1055.
4. **Hogan, R. J.,** and A. J. Illingworth, 2000: Deriving cloud overlap statistics from radar. *Quart. J. Roy. Meteorol. Soc.,* **126,** 2903–2909.
3. **Hogan, R. J.,** A. J. Illingworth and H. Sauvageot, 2000: Measuring crystal size in cirrus using 35- and 94-GHz radars. *J. Atmos. Oceanic Technol.,* **17,** 27–37.
2. Kilburn, C. A. D., D. Chapman, A. J. Illingworth and **R. J. Hogan,** 2000: Weather observations from the Chilbolton Advanced Meteorological Radar. *Weather,* **55,** 352–355.
1. **Hogan, R. J.,** and A. J. Illingworth, 1999: The potential of spaceborne dual-wavelength radar to make global measurements of cirrus clouds. *J. Atmos. Oceanic Technol.,* **16,** 518–531.

Other publications (e.g. conference proceedings and ECMWF Technical Memoranda)

43. Shepherd, T. G., I. Polichtchouk, **R. J. Hogan** and A. J. Simmons: Report on Stratosphere Task Force. ECMWF Technical Memorandum 824.
42. Hogan, R. J., M. Ahlgrimm, G. Balsamo, A. Beljaars, P. Berrisford, A. Bozzo, F. Di Giuseppe, R. M. Forbes, T. Haiden, S. Lang, M. Mayer, I. Polichtchouk, I. Sandu, F. Vitart and N. Wedi: Radiation in numerical weather prediction. ECMWF Technical Memorandum 816.
41. Polichtchouk, I., **R. J. Hogan,** T. G. Shepherd, P. Bechtold, T. Stockdale, S. Malardel, S. J. Lock and L. Magnusson. What influences the middle atmosphere circulation in the IFS? ECMWF Technical Memorandum 809.
40. Geer, A. J., M. Ahlgrimm, P. Bechtold, M. Bonavita, N. Bormann, S. English, M. Fielding, R. Forbes, **R. J. Hogan,** E. Hólm, M. Janiskova, K. Lonitz, P. Lopez, M. Matricardi, I. Sandu and P. Weston: Assimilating observations sensitive to cloud and precipitation. ECMWF Technical Memorandum 815.
39. **Hogan, R. J.,** and A. Bozzo, 2016: ECRAD: A new radiation scheme for the IFS. ECMWF Technical Memorandum 787.
38. Leutbecher, L., S.-J. Lock, P. Ollinaho, S. T. K. Lang, G. Balsamo, P. Bechtold, M. Bonavita, H. M. Christiensen, M. Diamantakis, E. Dutra, S. English, M. Fisher, R. M. Forbes, J. Goddard, T. Haiden, **R. J. Hogan,** S. Juricke, H. Lawrence, D. MacLeod, L. Magnusson, S. Malardel, S. Massart, I. Sandu, P. K. Smolarkiewicz, A. Subramanian, F. Vitart, N. Wedi and A. Weisheimer: Stochastic representation of model uncertainties at ECMWF: State of the art and future vision. ECMWF Technical Memorandum 785.
37. Ollinaho, P., S.-J. Lock, M. Leutbecher, P. Bechtold, A. Beljaars, A. Bozzo, R. M. Forbes, T. Haiden, **R. J. Hogan** and I. Sandu: Towards process-level representation of model

uncertainties: Stochastically perturbed parametrisations in the ECMWF ensemble. ECMWF Technical Memorandum 784.
36. **Hogan, R. J.,** and A. Bozzo, 2015: Mitigating surface temperature errors using approximate radiation updates. ECMWF Technical Memorandum 746.
35. **Hogan, R. J.,** and S. Hirahara, 2015: Effect of solar zenith angle specification on mean shortwave fluxes and stratospheric temperatures. ECMWF Technical Memorandum 758.
34. **Hogan, R. J.,** 2010: The full-spectrum correlated k method for longwave atmospheric radiative transfer: treatment of gaseous overlap. Proc. 13th AMS Conf. on Atmospheric Radiation, Portland, Oregon, 28 June - 2 July 2010.
33. Pearson, K. J., R. P. Allan, **R. J. Hogan** and G. Lister, 2009: How well do high resolution models represent tropical convection? Proc. EUMETSAT Conf., Bath, 21-25 Sept 2009.
32. Chalmers, N., **R. J. Hogan** and R. P. Allan, 2008: Investigating the radiative impact of clouds using retrieved properties to classify cloud type. Proc. International Radiation Symposium (IRS 2008), Foz do Iguassu, Brazil, 4-8 Aug 2008.
31. Delanoe, J. M. E., and **R. J. Hogan,** 2008: Algorithm Theoretical Basis Document for ACM-Ice-Reading (variational radar-lidar-radiometer ice cloud retrieval), produced for ESA as part of the project "CASPER" (Cloud and Aerosol Synergetic Products from EarthCARE Retrievals).
30. **Hogan, R. J.,** and J. K. P. Shonk, 2008: Radiation parametrization and clouds. Proc. ECMWF Seminar, 1-4 Sept 2008.
29. Wilkinson, J. M., **R. J. Hogan** and A. J. Illingworth, 2008: Use of a lidar forward model for global comparisons of cloud fraction between the ICESat lidar and the ECMWF model. ECMWF Technical Memorandum No. 555, 23 pp.
28. **Hogan, R. J.,** 2007: A variational scheme for retrieving rainfall rate and hail reflectivity fraction from polarization radar. Proc. 33rd AMS Conf. on Radar Meteorology, Cairns, Queensland.
27. **Hogan, R. J.,** and A. Battaglia, 2007: Accounting for multiple scattering in spaceborne radar and lidar observations. Proc. 33rd AMS Conf. on Radar Meteorology, Cairns, Queensland.
26. **Hogan, R. J.,** A. J. Illingworth, E. J. O'Connor, D. Bouniol, M. E. Brooks, J. Delanoe, D. P. Donovan, J. D. Eastment, N. Gaussiat, J. W. F. Goddard, M. Haeffelin, H. Klein Baltink, O. A. Krasnov, J. Pelon, J.-M. Piriou, A. Protat, H. W. J. Russchenberg, A. Seifert, A. M. Tompkins, G.-J. van Zadelhoff, F. Vinit, C. D. Westbrook, U. Willen, D. R. Wilson and C. L. Wrench, 2006: Cloudnet: Evaluation of model clouds using ground-based observations. Contribution to ECMWF Workshop proceedings.
25. Bouniol, D., A. J. Illingworth and **R. J. Hogan,** 2004: Deriving turbulent kinetic energy dissipation rate within clouds using ground based radar. Proc. 3rd European Conf. on Radar Meteorology and Hydrology, 281-285.
24. Brooks, M. E., **R. J. Hogan** and A. J. Illingworth, 2004: A long term comparison of cloud properties observed by vertically pointing radar and lidar with their representation in operational NWP models. Proc. 14th Int. Conf. on Clouds and Precipitation, Bologna, Italy, 1293-1294.
23. Gaussiat, N., **R. J. Hogan** and A. J. Illingworth, 2004: Cloud water content and cloud particle characteristics revealed by dual wavelength cloud radar observations. Proc. 14th Int. Conf. on Clouds and Precipitation, Bologna, Italy, 524-527.
22. **Hogan, R. J.,** and S. F. Kew, 2004: A 3D stochastic cloud model for investigating the radiative properties of inhomogeneous cirrus clouds. Proc. 14th Int. Conf. on Clouds and Precipitation, Bologna, Italy, 1669-1672:
21. O'Connor, E. J., **R. J. Hogan,** A. J. Illingworth and J.-L. Brenguier, 2004: Characteristics of drizzle and non-drizzling stratocumulus as revealed by vertically pointing cloud radar and lidar. Proc. 14th Int. Conf. on Clouds and Precipitation, Bologna, Italy, 612-615.
20. Bouniol, D., A. J. Illingworth and **R. J. Hogan,** 2003: Deriving turbulent kinetic energy dissipation rate within clouds using ground based 94 GHz radar. Proc. 31st AMS Conf. on Radar Meteorology, Seattle, 192-196.
19. Illingworth, A. J., and **R. J. Hogan,** 2002: Clouds: do they obscure the forecast? Planet Earth, UK Natural Env. Res. Council, Summer 2002, 12-13.
18. Illingworth, A. J., **R. J. Hogan,** M. E. Brooks and E. J. O'Connor, 2002: Use of cloud radar and lidar data for validating clouds in operational forecasting models. EarthCARE Workshop,

jointly held with 2nd International Workshop on Spaceborne Cloud Profiling Radar/Lidar, Tokyo 17-18 July 2002.

17. **Hogan, R. J.,** C. Jakob and A. J. Illingworth, 2001: Comparison of ECMWF winter-season cloud fraction with radar derived values. ECMWF Technical Memorandum No. 333, 20pp.
16. **Hogan, R. J.,** A. J. Illingworth and P. R. Field, 2000: Characteristics of mixed-phase clouds from radar and lidar observations. Proc. 13th Int. Conf. on Clouds and Precipitation, Reno, Nevada, 705-708.
15. **Hogan, R. J.,** A. J. Illingworth and C. Jakob, 2000: Validation of cloud fraction and overlap using radar and lidar observations: ECMWF/EuroTRMM Workshop on assimilation of clouds and precipitation, ECMWF, Nov 2000, 235-255.
14. **Hogan, R. J.,** A. J. Illingworth and H. Sauvageot, 1999: Cloud characteristics from dual-wavelength millimetre-wave radar. Proc. 29th AMS Conf. on Radar Meteorology, Montreal, Canada, 457-459.
13. **Hogan, R. J.,** C. Jakob and A. J. Illingworth, 1999: Comparison of ECMWF cloud cover with radar derived values. Proc. 29th AMS Conf. on Radar Meteorology, Montreal, Canada, 460-462.
12. Illingworth, A. J., and **R. J. Hogan,** 1999: Overview of the flights and datasets, CLARE'98 Cloud Lidar & Radar Experiment, ESTEC Int. Workshop Proc. WPP-170, Noordwijk, The Netherlands, 13-14 Sept 1999, 17-24.
11. **Hogan, R. J.,** and J. W. F. Goddard, 1999: Calibration of the ground-based radars used in CLARE'98, *Ibid.,* 63-68.
10. **Hogan, R. J.,** and A. J. Illingworth, 1999: Analysis of radar and lidar returns from clouds: Implications for the proposed Earth Radiation Mission, *Ibid.,* 75-82.
9. **Hogan, R. J.,** A. J. Illingworth, J. W. F. Goddard, S. C. H. M. Jongen and H. Sauvageot, 1999: Stratocumulus liquid water content from dual-wavelength radar, *Ibid.,* 107-110.
8. Donovan, D. P., A. C. A. P. van Lammeren, J. W. F. Goddard, H. Sauvageot and **R. J. Hogan,** 1999: Cloud effective radius and water contents inferred from combined lidar and radar observations during CLARE'98, *Ibid.,* 147-152.
7. **Hogan, R. J.,** and A. J. Illingworth, 1999: A climatology of supercooled layer clouds from lidar ceilometer data, *Ibid.,* 161-166.
6. **Hogan, R. J.,** A. J. Illingworth and P. R. Field, 1999: Polarimetric radar observations of the growth of highly aligned ice crystals in the presence of supercooled water, *Ibid.,* 167-172.
5. Donovan, D. P., A. C. A. P. van Lammeren, **R. J. Hogan,** A. J. Illingworth, P. N. Francis, J. Testud, J. Pelon, M. Quante and J. W. F. Goddard, 1999: Comparison of lidar/radar ice cloud parameter retrievals with in-situ measurements, *Ibid.,* 173-177.
4. **Hogan, R. J.,** and A. J. Illingworth, 1999: Implications for the split mission scenario, *Ibid.,* 215-216.
3. **Hogan, R. J.,** C. Jakob and A. J. Illingworth, 1999: Comparison of ECMWF cloud cover with radar derived values, *Ibid.,* 217-221.
2. **Hogan, R. J.,** 1998: Dual-wavelength radar studies of clouds. PhD thesis, University of Reading, UK, 151 pp.
1. **Hogan, R. J.,** A. J. Illingworth and H. Sauvageot, 1997: Dual-wavelength determination of cirrus microphysical properties. Proc. 28th AMS Conf. on Radar Meteorology, Austin, Texas, 364-365.

C. TEACHING

At the Department of Meteorology, University of Reading I have engaged in a very wide range of teaching methods including lectures, problem classes, computer classes, laboratory practicals, field-site practicals, field trips, small-group tutorials, team projects, undergraduate and postgraduate project supervision, oral presentations and leading the Department-wide "Weather and Climate Discussion". The feedback from the modules I teach is consistently good. In terms of learner support, I introduced an undergraduate mentoring scheme in the Department, in which first year students are each introduced to two "buddies" from higher years, to whom they can then go for work-related advice and other issues. In 2007, I received the "School award for outstanding contributions to teaching and learning support" from the School of Mathematics, Meteorology and Physics at the University of Reading. My specific contributions are as follows:

2014-2018 Radiation (ECMWF training course):
6 contact hours per year
2014 Numerical Weather Prediction (undergraduate):
18 contact hours: lectures and computer practical
2011, 2013 Speaker at the NCAS Climate Modelling Summer School (Cambridge and Oxford)
2011 Introduction to Numerical Modelling (postgraduate: MSc and PhD)
24 contact hours: computer classes and lectures
2010 Remote Sensing (undergraduate)
9 contact hours
2008, 2011 Boundary Layer Meteorology (undergraduate):
2008: 28 contact hours: lectures and field-site practicals
2011: 20 contact hours: lectures and computer practical
2007–2008 Convener of BSc Projects
2007 Convener of MSc Dissertations
2005–2011 Weather and Climate Discussion (undergraduate and postgraduate):
5 contact hours per year
2004–2010 Academic tutor for 3–4 MSc students each year
2004–2008 Boundary Layer Meteorology (postgraduate: MSc and PhD):
25 contact hours per year: lectures and practicals (computer, laboratory and field-site)
2004 Weather Systems Analysis (undergraduate):
30 contact hours: lectures and practical workshops
2003–present Supervised eight undergraduate projects
2003–2007, 2010 Surface Energy Exchange (undergraduate): *19 contact hours per year: field-site practicals*
2003, 2007, 2010 Team project (postgraduate): *8 contact hours per year*
2003, 2006 Dorset field trip (undergraduate and postgraduate): *16 contact hours per year*

D. UNIVERSITY ADMINISTRATION

My management skills and rapport with the students have been well recognised within the Department of Meteorology, and in my most recent administrative role I was one of the four Heads of Department, with responsibility for research. Achievements in this role included:

- Led the organisation and writing of the case for investment in the School of Mathematical and Physical Science as part of the Climate and Environmental Science Initiative of the University of Reading's 2011-2013 Academic Investment Project. The case was very well received and the School went on to appoint 20 new academics. I was heavily involved in all aspects of the recruitment process of many of the 15 excellent academic appointments in Meteorology.
- Co-wrote the proposal that led to the Department of Meteorology being awarded a prestigious Regius Professorship in 2013 by the Queen, one of just 12 institutions to receive this honour on the event of her Diamond Jubilee. A Regius Professorship is a rare privilege, with only two being created in the last century. The current holder is Professor Keith Shine FRS.
- Initiated and led activities to nurture research activity in the Department, included a discussion session involving the whole Department on "Writing High Impact Papers" (January 2012), and a workshop on "Writing Successful Proposals" (October 2012).
- Initiated the Ian James Prize for the best PhD thesis submitted in the Department of Meteorology in a calendar year.

In the past I have managed the full range of taught degrees within the Department, first as Director of Undergraduate Studies and then as Director of MSc Programmes. I led a detailed proposal to bolster the core physics content of the undergraduate Meteorology degrees, important for those going on to research careers; this was enthusiastically welcomed by other members of staff, and was taken forward via the introduction of a new undergraduate programme "Environmental Physics". The posts I have held are as follows:

2011–2014 Head of Department for Research
2010–2011 Director of Research, Meteorology
2009–2010 PhD admissions tutor
2007–2008 Manager of the Meteorology Laboratories
2006–2007 Director of MSc Programmes, Meteorology

2006	Director of Undergraduate Studies, Meteorology (sabbatical cover, Jan–Sept)
2003–2005	Chair of the School of Mathematics, Meteorology and Physics Staff-Student Liaison Committee

Additional specific administrative responsibilities:

2012	Acting Joint Met Office Chair
2011–2014	Member of the School of Mathematical and Physical Sciences Steering Committee
2011	Chair of the Meteorology/ESSC Strategy Group
2009–2014	Member of the School of Mathematics, Meteorology and Physics Higher Degree by Research Board of Studies
2008–2011	Mentor for two new members of academic staff
2006–2007	Member of the School of Mathematics, Meteorology and Physics Teaching and Learning Committee and Board of Studies
2004	Designer of the Departmental Research Brochure
2003–2005	Member of the Faculty of Science Staff-Student Committee
2003–2006	Coordinator of module evaluation questionnaires, including designing a new School-wide system
2003–2014	Personal tutor for 15 undergraduate students

E. ACHIEVEMENTS AT ECMWF

My primary responsibility at ECMWF is to improve the treatment of solar and infrared radiative transfer. A major achievement was the introduction of my new radiation scheme, ecRad (Hogan and Bozzo 2016, 2018), which became operational in July 2017 and amounts to around 16,000 lines of code. Compared to the old scheme, ecRad is more flexible, less noisy and around 41% faster for the same scientific configuration. Via the availability of my SPARTACUS solver, it is the first radiation scheme for a global model capable of representing the 3D radiative effects of clouds. The offline version (*https://confluence.ecmwf.int/display/ECRAD*) currently has 17 users in 8 countries. It has also been adapted for use in the Meso-NH and ICON models. I have additionally implemented techniques to mitigate the problems associated with calling the radiation scheme infrequently in time and space, leading to forecast improvements at coastlines (Hogan and Bozzo 2015) and in the stratosphere (Hogan and Hirahara 2016).

I have had several leadership roles at ECMWF:

- 2018: I led the organization of an ECMWF workshop on "Radiation in the Next Generation of Weather Forecast Models" held 21-24 May 2018. The workshop brought together over 50 radiation experts from 12 countries (*https://www.ecmwf.int/en/learning/workshops/workshop-radiation-next-generation-weather-forecast-models*).
- 2017: I led one of two Special Topic Papers to ECMWF's Science Advisory Committee, on "Radiation in Numerical Weather Prediction" (Hogan et al. 2017, ECMWF Technical Memorandum 816).
- 2016-2018: I led ECMWF's "Stratosphere Task Force", which brought together scientists from several ECMWF departments to work together to tackle ECMWF's longstanding problems with stratosphere analyses and forecasts. We contracted Professor Ted Shepherd FRS and Dr Inna Polichtchouk of the University of Reading to contribute to the activity. The outcomes were summarized by Shepherd et al. (2018, ECMWF Technical Memorandum 824).
- 2016-2017: I coordinated the technical merging and scientific assessment of branches from the Physical Aspects team to Cycle 43R3 of ECMWF's Integrated Forecast System.

F. ENTERPRISE AND OUTREACH

- Three-hour presentations on Weather Forecasting and Thunderstorms at Year 3 of St Columba's School, St Albans, 12 March 2013, 10 March 2015, 11 March 2016 and 9 March 2017. This included many interactive demonstrations and a weather forecasting game (*http://www.met.rdg.ac.uk/~swrhgnrj/schools*). The last visit also included a 40-min talk on a career in scientific research to GSCE and A-Level students

- I have collaborated with a new company *HALO Photonics* in the evaluation of a 1.5-μm Doppler cloud lidar. This is a pioneering new technology in lidar design, allowing continuous, unmanned measurements of wind at a far lower cost than ever before. It is now operating continuously at Chilbolton, I have published a paper (Hogan et al. 2009) with the Director of the company (Dr Guy Pearson) using the instrument, and the company has had many subsequent orders for these instruments.
- My fast automatic differentiation software "Adept" (*www.met.reading.ac.uk/clouds/adept*) is freely available and used by several companies including 4Dx (for their pulmonary imaging software), Wells Fargo bank and Cimarex Energy company.
- I have provided commentary on high profile scientific issues; for example, I was quoted in the 7 November 2009 issue of *New Scientist* in an article entitled "Tomorrow's weather: cloudy, with a chance of fractals". I was interviewed on Radio Oxford on 29 August 2013.
- I created a web-site (*www.met.reading.ac.uk/radar/realtime*) displaying high resolution imagery from the cloud observing instruments at Chilbolton in real time, as well as storing an archive of previous images. This is very useful for understanding the properties of the atmosphere immediately above our heads and is used frequently in the Department's weekly "Weather and Climate Discussion". The site now gets around 1000 hits per month.
- I created a web-site (*www.met.reading.ac.uk/clouds/maxwell*) containing many animations of electromagnetic waves that illustrate the physics behind a wide range of optical phenomena and the workings of optical and microwave instruments. This site is an excellent educational resource and receives around 500 hits per month, as well as being used within the Department in our radiative transfer and remote sensing lecture courses. A visitor to the web site told me "The animations on your Maxwell2D page are fantastic. Despite a PhD in optics I'd only read about many of the effects you have demonstrated; you have really brought them to life."
- In the final work-package of the EU Cloudnet project we collaborated with lidar manufacturer *Vaisala* and radar manufacturers *Gematronik* and *Degreanne* in proposing the specification of a European network of cloud observing stations.

G. RESEARCH HIGHLIGHTS

My published papers have attracted over 3400 citations and I have an h-index of 35 (Web of Knowledge Author="Hogan RJ", Address= "Reading or ECMWF or European"). According to Google Scholar I have over 5100 citations and an h-index of 42.

1. Cloud structure and radiative transfer in weather forecast and climate models

The distribution of clouds in climate models is very important for the way in which they modulate solar and terrestrial radiation, and hence for forecasting surface temperature. Hogan and Illingworth (2000) introduced the concept of an "overlap parameter" to describe how clouds are overlapped vertically, extended to describe the overlap of cloud inhomogeneities (Hogan and Illingworth 2003). The resulting "exponential-random" overlap scheme has been implemented in a number of climate models used by the Intergovernmental Panel on Climate Change (e.g. the US GFDL and NCAR models, the German ECHAM5 model and the UK Met Office model), as well as the ECMWF model. I have developed a novel stochastic model to generate realistic 3D cirrus clouds and determine their radiative properties (Hogan and Kew 2005). I have quantified the role of 3D radiative transfer on the radiative forcing of both aircraft contrails (Gounou and Hogan 2007) and natural cirrus (Zhong et al. 2008), and developed a fast technique "SPARTACUS" to represent 3D radiative transfer in global models (Hogan and Shonk 2013; Hogan et al 2016). I have since adapted SPARTACUS for application to radiative transfer in vegetation (Hogan et al. 2018). With a PhD student I developed the Tripleclouds scheme to represent cloud horizontal structure efficiently in the radiation schemes of models (Shonk and Hogan 2008, 2010) and have implemented this in the Met Office and ECMWF models (Shonk et al. 2012, Hogan and Bozzo 2018). I developed a method to significantly improve the efficiency of the treatment of gaseous absorption (Hogan 2010). My "ecRad" radiation scheme is used operationally in the ECMWF model (Hogan and Bozzo 2018) and available at *https://confluence.ecmwf.int/display/ECRAD*. The innovativeness of my radiative transfer work was specifically praised in the citation for my 2014 Henry G. Houghton Award of the American Meteorological Society.

2. Mixed-phase clouds

A series of papers has uncovered the importance of mixed-phase clouds (those that contain a mixture of liquid water and ice), particularly the role of embedded convection and ice multiplication (Hogan et al. 2002), their radiative importance (Hogan et al. 2003b), their poor representation in current forecast models (Hogan et al. 2003c), their global distribution (Hogan et al. 2004) and their spatial structure (Field, Hogan et al. 2004). The findings of the first three were highlighted in NERC's 2001–2002 Annual Report (page 9) as "a key scientific advance", and led to my being awarded the 2005 L. F. Richardson prize of the Royal Meteorological Society. This work has spawned a number of modelling studies co-authored by myself (e.g. Phillips et al. 2003, Clark et al. 2005, Marsham et al. 2006), and with a PhD student we developed a single-column model to investigate the reasons why they are poorly captured in large-scale models (Barrett et al. 2017a,b).

3. Evaluation of clouds in forecast models

I have pioneered methods to evaluate objectively the representation of clouds in forecast models using data from the Chilbolton Observatory in Hampshire. This has included the development of retrieval algorithms (such as the dual-wavelength radar technique of Hogan and Illingworth 1999 and Hogan et al. 2000), and the first evaluation of model cloud fraction and ice water content (Hogan et al. 2001, 2006). This work was taken to a new level in the EU Cloudnet project (*www.cloud-net.org*; Illingworth, Hogan et al. 2007), in which my algorithms were used to evaluate 7 operational models over 4 European sites. The Cloudnet data archive hosted at Reading now has over 40 users from around the world. I secured funding from the US Department of Energy to further develop and apply the Cloudnet algorithms to decade-long datasets from the various US "Atmospheric Radiation Measurement" sites worldwide, providing an even tighter constraint on forecast models. I led the DYMECS project, which used a novel storm-tracking algorithm for the large weather radar at Chilbolton to evaluate the structure and updraft strength of convective clouds in the Met Office cloud-permitting forecast model (Stein, Hogan et al. 2015; Nicol, Hogan et al. 2015).

4. Development of synergy algorithms for CloudSat, Calipso and EarthCARE

I am recognised as a world expert in combining active and passive satellite instruments for retrieving the properties of clouds. With NERC funding, a postdoc and I have developed and applied a method for combining data from the CloudSat radar, the Calipso lidar and the MODIS radiometer to retrieve ice cloud properties (Delanoë and Hogan 2008, 2010). It is based on the rigorous mathematical approach of optimal estimation theory (similar to data assimilation). We used it to reveal significant discrepancies in the ECMWF and Met Office forecast models, and ECMWF have used using these results to guide the development of their new cloud scheme (Delanoë et al. 2011). Our retrievals are available for several years of CloudSat and Calipso data from *http://www.icare.univ-lille1.fr/projects/dardar/*. Our algorithm has inspired the development of the "official" CloudSat-Calipso ice-cloud algorithm in the US.

My work in evaluating the potential for a proposed satellite (EarthCARE), to carry a cloud radar and lidar on the same platform, was instrumental in its being selected by the European Space Agency (ESA) for deployment. I am a member of the EarthCARE Mission Advisory Group and am centrally involved in developing algorithms for EarthCARE, having been awarded four ESA grants since 2007 (CASPER, RATEC, VARSY, DORSY). These have supported my pioneering of the first "unified" synergetic retrieval scheme, in which the properties of clouds, aerosols and precipitation are retrieved simultaneously by combining radar, lidar and radiometer. Two important algorithmic breakthroughs have made this possible. The first is a new, rapid model for radar and lidar multiple scattering (Hogan 2006, 2008; Hogan and Battaglia 2008), including the use of the time-dependent form of the two-stream radiative transfer equations for the first time, and available at *http://www.met.reading.ac.uk/clouds/multiscatter*. The second is my new, fast method for automatic differentiation (Hogan 2014), released in the C++ package "Adept" at *http://www.met.reading.ac.uk/clouds/adept*. Another important development has been the Self Similar Rayleigh Gans Approximation for computing ice-particle scattering by microwaves (Hogan and Westbrook 2014; Hogan et al. 2017), available at *http://www.met.reading.ac.uk/clouds/ssrga*.