

Aviation and turbulence in the free atmosphere.
Imperial College London, South Kensington Campus, London,
Wednesday, 15th January 2014

The Royal Meteorological Society special interest group on Aviation Meteorology held a meeting on the topic of turbulence in the free atmosphere on 15 January 2014 which was supported by the Environmental Physics Group. The organiser, Bob Lunnon, introduced the importance of being able to forecast turbulence for both safety reasons and to reduce the operational delays and the costs incurred. Six speakers presented their work on the state of turbulence research highlighting where advances have been made and where further work is required in the future. The Royal Meteorological Society special interest group on Aviation Meteorology originated this meeting at Imperial College, on the topic of turbulence in the free atmosphere. The organiser, Bob Lunnon, introduced the importance of being able to forecast turbulence for both safety reasons and to reduce the operational delays and the costs incurred. He highlighted the existing aviation forecasts produced by the Met Office's World Area Forecast Centre and the SIGMETs which are provided on a regional basis by the local meteorological organisations. The afternoon's first talk was from Bob Sharman of NCAR. He identified three main areas for improvement in future turbulence forecasting; the provision of observations on an aircraft scale; better nowcasting and forecasting capabilities; and finally enhanced understanding of the underlying mechanisms for turbulence in all its forms.

This led on to his work on the GTG (Graphical Turbulence Guidance), which combines an ensemble for clear air turbulence (CAT) predictors into a single product and has been used over the USA and more recently globally.

The diagnostics used are converted to eddy dissipation rate (EDR), an ICAO standard for turbulence monitoring which is aircraft independent. Verification using PIREPS and aircraft automatic observations shows that the GTG consistently performs better than any individual diagnostic.

In understanding the nature of CAT, parametrisation is used because we do not yet have the capability of sub aircraft scale modelling. As a consequence, EDR is not calculated directly from a model but instead from the parametrised diagnostics.

Paul Williams from the University of Reading referred back to classical fluid dynamics in the first part of his talk to describe turbulence and how it manifests itself. In laboratory testing it was shown that even in a neutrally stratified atmosphere (where the Richardson number is $>1/4$) it is possible for Kelvin–Helmholtz instability to form in a region and cause turbulence where it may not have otherwise formed. The source of turbulent events often is many hundreds of miles from where turbulence is experienced, demonstrating that gravity wave propagation is a feature requires further research.

In the second part of his talk Dr Williams explored the theory that the change in our climate resulting from a doubled CO₂ atmosphere may have altered the number and severity of CAT cases, particularly in relation to North Atlantic air traffic. He noted that historical data sets may indicate that there has already been an increase in turbulence, other factors such as the way the observations are made and how the data is reanalysed could have an impact. He has used the CMIP3 model data which is known to represent upper air winds well. His analysis of a range of different CAT diagnostics showed that, in every case, there was an increase of the median turbulence value by 10-40% and the extremes by 40-170%. This increase in turbulent events in a doubled CO₂ world was featured heavily in the world's media.

From modelling and laboratory testing the talks moved to the European funded project DELICAT which is due to finish in April 2014. Patrick Vrancken from the German Aerospace Centre (DLR) described the project and its aim of using an aircraft mounted LIDAR to identify CAT 15-30km ahead of the aircraft.

Jacek Kopeć from the University of Warsaw, was part of the meteorological component working on generating a climatology of CAT over Europe which found that the winter months show a greater likelihood of encountering CAT than during the summer. They also used forecaster and model forecasts of CAT to determine where to fly during the flight trails in summer 2013. Due to the timing of the trials, very little turbulence was forecast and what was experienced was predominantly classified as light.

The results of the project are still being finalised but the major conclusions show that there is some correlation with the RMS LIDAR data and that of the direct observations. During the talk the many obstacles that needed to be overcome were highlighted, such as getting approval for a forward facing LIDAR on the aircraft, the cooling system requirements and the complexity of taking observations from an aircraft. Research has come a long way since LIDAR was first considered for turbulence identification and DELICAT is helping further the potential of this type of warning system.

Moving on to the future of forecasting in the UK, the Met Office's Piers Buchanan presented Phil Gill's presentation on verification of turbulence and the use of ensembles. The Met Office has access to observations from some 747-400s aircraft. From these observations, turbulence climatologies are formed. The Met Office Ensemble Prediction System has been used in a trial and is expected to be used by WAFC forecasters to forecast turbulence in the near future. Similar to the GTG, a number of CAT diagnostics are used along with an ensemble of models with slightly different initial conditions. The output offers uncertainty estimates of the CAT likelihood rather than categorisation of CAT strength.

The combination of the predictors, ensembles and climatology for CAT forecasting generated better statistical skill and relative economic scores than individual predictors.

Finally identifying turbulence through satellite monitoring was investigated in a talk by Peter Francis of the Met Office. His work primarily looked at overshooting tops

in deep convective storms and the associated gravity waves and wind shear associated with such events which can propagate many hundreds of miles from the source. The satellite used for the identification of the convective tops was Meteosat Second Generation which was able to make use of all available wavelengths to identify the physical shape and structure of the convection but also the temperature at the top of the cloud mass.

In the future, Meteosat Third Generation will have a significantly higher refresh rate and resolution that will enable the transient nature of overshooting tops to be tracked by the satellite technology. An animation clearly demonstrated the benefits of the new generation where the gravity waves propagated out from a storm cell over several hundred miles which indicated the impact gravity waves can have on aviation.

The closing remarks concluded that there is a wide range of research investigating all types of turbulence which affect airline operations. Ensembles and multi use predictors pave the way to future turbulent predicting methods for forecasting a few minutes ahead out to several days which will benefit all of aviation.

Lauren Reid

Forthcoming Environmental Physics Group Events

Climate Change 2013. The physical science basis

Institute of Physics, Portland Place, London

Wednesday 5th February 2013

The Summary for Policy Makers of the Working Group 1 contribution to the fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5) was published in September 2013 and the full report will be published for the first time in January 2014. To mark this event, and to celebrate the large UK contribution to the report, a one day science meeting will be held on Wednesday 5th February 2014 at the Institute of Physics, Portland Place, London. Lead Authors of the report will present key new findings of the AR5, and the associated evidence base, also highlighting outstanding research challenges. The target audience is the UK climate science community and other interested scientists. The meeting is being organised by the National Centre for Atmospheric Science, the Met Office, the Royal Meteorological Society and the Environmental Physics Group of the Institute of Physics

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