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# Report on the Drag Project

**Ayrton Zadra**  
**RPN/ECCC**



**Pan-WCRP Modelling Groups Meeting**  
UK Met Office, Exeter, United Kingdom, 9-13 October 2017

# Related events (past and future)

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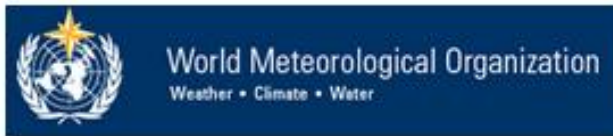
- ***Workshop on Angular Momentum Budget***, 20-22 April 2015 at Univ. Reading
- ***ECMWF workshop on “Drag processes and their links to large-scale circulation”***, ECMWF, Reading, 12-15 September 2016
- Various presentations and posters on drag/momentum processes at the ***5<sup>th</sup> WGNE workshop on Systematic Errors***, June 19-23, 2017, Montréal, Québec, Canada
- Theme "*Surface drag and momentum transport: orographic drag, convective momentum transport*", ***2nd Pan-GASS Meeting*** 'Understanding and Modelling Atmospheric Processes', 26 February to 2 March 2018 | Lorne, Victoria, Australia

# Summary of the ECMWF workshop

<https://www.ecmwf.int/en/learning/workshops-and-seminars/drag-processes-and-their-links-large-scale-circulation>

## Drag processes and their links to large-scale circulation

ECMWF | Reading | 12-15 September 2016



- **ECMWF/WCRP/WWRP** workshop
- with the support of **SPARC/WGNE/GASS** and **NCAR**
- 50 participants from the main numerical weather prediction (NWP) and climate centres, as well as from several universities
- the participants included well-established scientists and early-career scientists, six of whom were partially supported by WMO

# Summary of the ECMWF workshop

<https://www.ecmwf.int/en/learning/workshops-and-seminars/drag-processes-and-their-links-large-scale-circulation>

## Drag processes and their links to large-scale circulation

ECMWF | Reading | 12-15 September 2016



### Objectives:

- assess the current state of our **understanding of drag processes**
- assess the **impact of those processes on the large-scale circulation** on timescales ranging from numerical weather prediction to climate
- review how these processes are **represented in global models**
- discuss and sharpen the **research questions**, to achieve substantial advances in this area
- foster **collaborations** and stimulate **further research** addressing these questions



# Summary of the ECMWF workshop

<https://www.ecmwf.int/en/learning/workshops-and-seminars/drag-processes-and-their-links-large-scale-circulation>

## Workshop conclusions and recommendations:

- 1. Consolidate knowledge** regarding the **impacts of drag processes** on the large-scale circulation, e.g. **by reproducing results in different models**, and develop a **more quantitative understanding** of effect of drag on aspects of circulation, such as the mean state, stationary waves, synoptic systems. Understand **what level of parametrization is required** to reproduce given phenomena and whether there are **processes that are currently not represented** in global models.
- 2. Seek to further understand intermodel differences** in surface stress, for example through the following activities: a **survey regarding the ancillary files**, in which all centres would provide details on corresponding databases and methods as well as samples of ancillary fields; numerical experiments aiming to better define the **appropriate sub-grid scales** for orographic fields as a function of the **model's (effective) resolution**; **extending the WGNE Drag project** by **comparing the tendencies** given by the various parametrizations in **regions of maximum uncertainty**, and by using relevant **single-column model experiments**.

# Summary of the ECMWF workshop

<https://www.ecmwf.int/en/learning/workshops-and-seminars/drag-processes-and-their-links-large-scale-circulation>

## Workshop conclusions and recommendations:

3. Explore the use of **high-resolution simulations**, which can now be performed at resolutions of a few hundred metres over large regions, to help **understand the underlying processes** contributing to orographic drag and to **constrain the parametrizations**. As surface drag cannot be observed on large scales, this type of simulation could provide a reference estimate of surface drag that would be extremely valuable for improving the parametrizations used in global models.
4. Explore **new methods** to identify the parametrizations responsible for **model errors** and devise **ways of optimising poorly constrained parameters** that go beyond empirical tuning. These can include **initial tendency diagnostics, nudging techniques, data assimilation methods**, but also a **more process-level-based evaluation** of the phenomena represented by the parametrizations (e.g. waves vs turbulence) or the **evaluation of theoretically understood far-field responses to changes in drag**.
5. Make more extensive **use of existing direct or indirect observations** to evaluate the representation of drag processes in models. Here examples include **emerging observations of momentum fluxes**, gathered either in observational campaigns or at permanent supersites, and scatterometer **wind data or bulk measures of drag impacts on the circulation**, such as the change in wind direction throughout the boundary layer.



# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

## Science steering committee:

Keith Williams ([WGNE](#) co-chair)  
Barbara Casati ([JWGFVR](#))  
Greg Flato ([WGCM](#))  
Nils Wedi ([WGNE](#))  
Bill Merryfield ([WGSIP](#))  
Francois Bouyssel ([WGNE](#))  
Hai Lin ([S2S](#))  
Mike Ek ([WGNE](#), [GEWEX](#), [GLASS](#))  
Eric Maloney ([MDTF](#))  
Kazuo Saito ([MRI-JMA](#))  
Judith Berner ([PDEF](#))

**WMO liaison:** Michel Rixen ([WCRP](#))

**Local organizer:** Ayrton Zadra ([WGNE](#) co-chair)

One of the themes of the workshop was

## ***Atmosphere-land-ocean-cryosphere interactions:***

- *errors in the representation of surface fluxes and **drag processes***
- *stable boundary layer issues*
- *impact of coupled modeling*



The poster features a dark blue background with a light blue, abstract, wave-like pattern at the top. The main text is in white and gold. The title 'WGNE WSE-2017' is in large white letters. Below it, the workshop details are in gold: '5th workshop on systematic errors in weather and climate models'. The dates and location are in white: 'June 19-23, 2017, Centre Mont Royal, Montreal, Quebec, Canada'. At the bottom, there is a white URL and a photograph of the Montreal skyline across a body of water.

**WGNE WSE-2017**

5th workshop  
on systematic errors  
in weather and climate models

June 19-23, 2017  
Centre Mont Royal  
Montreal, Quebec, Canada

[collaboration.cmc.ec.gc.ca/science/rpn/wgne\\_wse/index-en.html](http://collaboration.cmc.ec.gc.ca/science/rpn/wgne_wse/index-en.html)





# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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Oral presentations related to drag & momentum processes:

1. Irina Sandu: ***How uncertainties in surface drag impact the large-scale circulation (keynote presentation)***
2. Andrew Elvidge: ***Constraining the source of significant variation in orographic drag representation in NWP and climate models: a model intercomparison of mean and subgrid orographic fields***
3. Jenny Lindvall: ***Wind turning in the boundary layer - observations, reanalysis and CMIP5 models***

# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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Posters related to drag & momentum processes:

1. Annelize van Niekerk: ***Quantifying the uncertainty in parametrized orographic drag and its impact on the large scale atmospheric circulation***
2. Felix Pithan: ***Missing orographic drag leads to climate model biases in jet streams, blocking and storm tracks***
3. Gunilla Svensson: ***Impact of boundary layer wind turning on the general circulation***
4. Huang-Hsiung Hsu: ***Improving Madden-Julian Oscillation Simulation: Atmosphere-Ocean Coupling and Land/Orographic Effect***
5. Inna Polichtchouk: ***Zonal-mean circulation response to reduced air-sea momentum roughness***
6. Irina Sandu: ***Orographic drag uncertainties impact forecast skill***
7. Nils Wedi: ***High resolution forecast error with reduced precision***

# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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## Summary of conclusions:

- research done on surface drag has increased substantially in recent years
- the Drag Project led by WGNE has been promoting an important progress on this, and was highlighted in different oral and poster sessions
- the partitioning between different drag processes, resolved and parameterized (turbulent and orographic), is very uncertain and has been shown to be important for producing circulation spread among models
- some progress has been made towards constraining and validating parameterized drag processes, particularly orographic processes, using high resolution simulations

# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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## Summary of conclusions:

- Sandu, using the ECMWF Integrated Forecasting System (IFS), demonstrated how the differences between the representation of the orography resolved or the sub-grid orography in the models affect the performance of medium-range weather forecasts
- by using a smoother resolved orography, degradation of the forecasts the skill of large-scale atmospheric circulation occurs both in the medium and short range and in longer time scales in winter in the Northern Hemisphere.
- however, this deficiency can only be partially solved by using more variability in the sub-grid orography, which suggests that the parameterized drag does not affect the flow in exactly the same way as the drag on the grid scale (Sandu)

# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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## Summary of conclusions:

- among the different processes, orography is particularly important, especially in regions of deep terrain
- preliminary results of the first inter-comparison of orographic fields (mean and subgrid) indicate that several aspects impact the representation of the resolved and parameterized orography between models:
  - different observational datasets for the orography
  - filtering of the data differs between models
  - the algorithm used to compute the subgrid standard deviation, the anisotropy, the slope and the geographical orientation of the subgrid-scale orography differ

# Drag at the 5<sup>th</sup> WGNE workshop on systematic errors

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## **Summary of conclusions:**

- a climatology of Planetary Boundary Layer (PBL) height based on radiosoundings are being used to evaluate the wind turning angle in the PBL in CMIP5 models and ERA Interim reanalysis over the globe (Lindvall and la Svensson).
- both quantities are generally smaller in the models than what is observed.
- such information is important for cyclone development and large-scale flow
- this provides a new way of evaluating deficiencies in the model using novel datasets.

# Drag session in pan-GASS

## Understanding and Modelling Atmospheric Processes

The 2nd Pan-GASS meeting

26th February 2018 - 2nd March 2018,  
Lorne, Victoria, Australia



### **Scientific Committee**

Ben Shipway (Chair), Meteorological Office, UK

Peter Bogenschutz, Lawrence Livermore National Laboratory, USA

Walter Hannah, Lawrence Livermore National Laboratory, USA

Daniel Klocke, Hans Ertel Center for Wea. Res., Deutscher Wetterdienst, GER (GASS co-chair)

Hugh Morrison, National Center for Atmospheric Research, USA

Mike Pritchard, University of California Irvine, USA

Catherine Rio, Centre National de Recherches Météorologiques, FRA

Irina Sandu, European Centre for Medium Range Weather Forecasts, UK

Martin Singh, Monash University, AUS (local contact)

Xubin Zeng, University of Arizona, USA (GASS co-chair)

Yunyan Zhang, Lawrence Livermore National Laboratory, USA



# Drag session in pan-GASS

## Understanding and Modelling Atmospheric Processes

The 2nd [Pan-GASS](#) meeting

26th February 2018 - 2nd March 2018,  
Lorne, Victoria, Australia



- includes the theme ***Surface drag and momentum transport*** (e.g. orographic drag, convective momentum transport)
- WGNE encourages contributions and participation – please help advertise
- deadline for abstract submission is 31-Oct-2017

# Some recent drag-related publications

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Elvidge, A. D., Vosper, S. B., Wells, H., Cheung, J. C. H., Derbyshire, S. H. and Turp, D. (2017), Moving towards a wave-resolved approach to forecasting mountain wave induced clear air turbulence. *Met. Apps*, 24: 540–550. doi:10.1002/met.1656

Pithan, F., T. G. Shepherd, G. Zappa, and I. Sandu (2016), Climate model biases in jet streams, blocking and storm tracks resulting from missing orographic drag, *Geophys. Res. Lett.*, 43, 7231–7240, doi:10.1002/2016GL069551.

van Niekerk, A., Shepherd, T. G., Vosper, S. B. and Webster, S. (2016), Sensitivity of resolved and parametrized surface drag to changes in resolution and parametrization. *Q.J.R. Meteorol. Soc.*, 142: 2300–2313. doi:10.1002/qj.2821

Vosper, S. B., Brown, A. R. and Webster, S. (2016), Orographic drag on islands in the NWP mountain grey zone. *Q.J.R. Meteorol. Soc.*, 142: 3128–3137. doi:10.1002/qj.2894

Sandu, I., A. Zadra and N. Wedi, 2016: [Orographic drag impacts forecast skill](#). [ECMWF Newsletter Issue 150, Winter 2017](#).

Sandu, I. and A. Zadra, 2016: [Experts discuss role of drag processes in NWP, climate models](#). [ECMWF Newsletter Issue 149, Autumn 2016](#).

Sandu, I. and co-authors: Pathways to accurately representing the dynamic impacts of orographic models. In preparation, to be submitted to *Nature Partner Journal (NPJ) Climate and Atmospheric Science*

# For discussion

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- WGNE Drag Project: ways forward?
- Momentum transfer (modelling and verification) for YOPP?