GEWEX GASS (Global Atmospheric System Studies) Annual Report

Reporting Period: October 2013 – January 2015

Starting date: GCSS and GABLS combined at the end of 2010 to form GASS. It also took joint ownership of the CIRC activity along with GDAP.

URL: http://www.gewex.org/gass_panel.html

Chair(s) and term dates: Jon Petch (end March 2014) and Steve Klein (end March 2015)

GASS Science Steering Committee (SSC): GASS is managed by it SSC which holds a telecon every 2-6 months and gets together in person at Pan-GASS and Pan-GEWEX science conferences which typically occur every 3-5 years). Each GASS project has a GASS SSC member as a sponsor and typically at least one project lead who may not be part of the SSC. Current members of the SSC include: Chris Bretherton, Ann Fridlind, Adrian Lock, Hugh Morrison, Lazaros Oreopoulos, Robert Pincus, Pier Siebesma, Ben Shipway, Gunilla Svensson, and Steve Woolnough. There is not a formal term length for the membership of SSC although it is felt that 4 years is a good length to review member's contributions.

Panel Objectives: GASS provides leadership for the scientific community involved in improving the representation of atmosphere processes in weather and climate models. It addresses this goal primarily through the coordination of scientific projects that bring together experts in process-modeling, observations, and the development of atmospheric model parameterizations. GASS intercomparison projects are typically based around observational field campaigns, or more idealised studies, and take from two to five years from initiation to completion with publication of the results. These intercomparisons makes extensive use of initial value global forecasts with weather and climate models (so called Transpose AMIP), regional convective scale modelling, single column modelling, cloud-resolving or large-eddy simulations and a range of in-situ and remote sensing observations.

Projects Status including Key GASS Achievements in 2014:

- Currently GASS has 10 active projects overall with 4 projects in the later stages. In the past year, a further 4 projects have finished, or finished except for the publication of project results.
- The representation of moist convection and turbulence in atmospheric models with Grey Zone resolution (1-10 km) is being studied using a cold-air outbreak case. 50 scientists attended a Grey Zone project workshop that was held in December 2014 at the Max-Planck Institute for Meteorology and results from several models are being compared.
- The representation of atmospheric boundary layer processes and their interaction with the land-surface is the focus of the joint GASS/GLASS DICE project. Over fifteen different models are involved in the project and a workshop was held at the UK Met Office in October 2013. Additionally, due to significant scientific overlap, scientists working on GABLS4 will meet with those working DICE at an upcoming workshop in May 2015 at MeteoFrance.
- The coupling of large-scale dynamics with tropical moist convection is being studied using the so-called "Weak-Temperature" Gradient methodology. Several models have contributed to this project which aims to learn which are the most robust and valuable methodologies to study the convection-dynamics coupling with both cloud-resolving and single-column models.
- At the pan-GEWEX meeting in July 2014, the GASS Scientific Steering Committee (SSC) met to discuss its project and status. This was the first in-person meeting of the SSC in nearly 2 years and was helpful to discuss the status of GASS's projects and identify future directions.

Future and New Directions:

- Six new projects are in various early stages of project formation spanning topics from process-level studies of aerosol-cloud interactions and radiative transfer to full large-scale model diagnosis of the causes for warm-biases in continental summertime surface air temperatures and transformation of marine air-masses as they advect over sea-ice.
- Preliminary discussions have occurred regarding a 2nd Pan-GASS science conference. An initial discussion with Joe Santanello suggests that this could be conducted jointly with a GLASS, as was done at the last pan-GASS conference in Boulder in September 2012. It is envisioned that this would occur somewhere in Europe probably in the late summer or early fall of 2016.

Issues for attention by the GEWEX SSG:

- *GASS Co-Chair Succession:* Both co-chairs Petch and Klein are past, or at the end of, their nominal periods to serve as GASS co-chair and are keen to pass on responsibility for GASS leadership. In the past year, attempts have been made to locate new co-chairs both within and external to GASS SSC with no luck. Both Petch and Klein will spend less time carrying out GASS management in the future – whether they are replaced or not. GEWEX should address this otherwise GASS will lose the fantastic momentum that has been built over recent years. While ongoing GASS projects will continue to make progress, the spinning up of new projects and the general engagement with the broader WCRP and GEWEX communities is likely to suffer.
- *GEWEX Assistance for a possible 2016 pan-GASS/pan-GLASS conference in Europe:* As was the case for the 2012 joint GASS/GLASS conference in Boulder, it would be nice if we had meeting support through GEWEX. Given past experience, the planning for this workshop would need to begin in early summer of 2015. However, progress on a 2016 pan-GASS/GLASS conference is subject to identifying leaders for this conference; the co-chairs aren't available.

Other Issues and Recommendations:

- *Isotopes:* At the 2014 pan-GEWEX meeting, the subject atmospheric isotopes came up as a potential GEWEX cross-cut activity. At its meeting, the GASS-SSC debated whether the time was ripe to begin an isotope project. The main problem is that any study involving isotopes might tell one only about isotopes and not about the representation of atmospheric processes of convection, turbulence, microphysics, etc. which is what GASS cares about. Subsequent to the GASS SSC, it was concluded that while beginning with a cloud-resolving modelling (CRM) study of isotopes would be best, that it was still premature to begin a CRM benchmark project because there are still relatively few isotope-enabled CRMs and there is not really a suitable isotope case-study dataset on which to base a comparison. Separately, GEWEX co-chair Graeme Stephens was to consult with David Noone.
- *Archiving needs:* Unfortunately, no progress has been made on this subject in the past year, primarily due to the lack of individual(s) with the time and energy to pursue this topic. To recapitulate the issue, GASS continues to have a requirement for a resource to archive their project data. This will need IT equipment to deliver data over the internet and human resource to do the work in gathering and documenting the cases. While there have been ad-hoc archiving done to a mixed degree, there is currently no system to ensure our valuable case studies are easily available to the community.

Links with the WCRP Grand Challenges:

- *"Clouds, Circulation and Climate Sensitivity" Grand Challenge:* GASS is an active participant in this challenge in several ways: GASS co-chairs Klein and Petch and GASS SSC members Robert Pincus and Pier Siebesma have helped to formulate the challenge through white papers, project meetings, arranging for breakout sessions at the 2014 GEWEX conference, and co-authoring of the summary publication describing the "four questions" of the Grand Challenge. Although this will require more thought, a number of GASS projects are expected to contribute to this Grand challenge including the Grey Zone, Weak Temperature Gradient, Low-cloud feedbacks, and radiative processes projects. One important need identified from breakout at the GEWEX conference was for idealized modelling frameworks to study the response of convection and climate over warm land-surfaces.
- *"Water Availability" Grand Challenge:* Two upcoming projects discussed at the GEWEX conference could align with this challenge, specifically the CAUSES warm bias project with its focus on the coupling of energy and water cycles at the land-atmosphere interface over summertime land masses and a potential GEWEX cross-cut project that will evaluate water cycle processes in high-resolution models (the HiRes project described in the GEWEX Newsletter for the conference). A third potential area of interaction for the "Water Availability" Grand Challenge is in the area of isotope modelling; however, as described above, GASS feels that it is premature to organize a model intercomparison project in this area.
- *"Cryosphere" Grand Challenge:* GASS SSC member Gunilla Svensson is a contributor to the WCRP Polar Climate Prediction Initiative which is a part of this grand challenge.

Additional Co-operation with other WCRP projects:

- GASS is not only under GEWEX but is also a major project supervised by WGNE, and as such contributes to WGNE's plans and presents reports to the annual WGNE meetings
- A number of GASS projects have been conducted jointly with other organization including the just finished MJO project which was a joint project of GASS and the WCRP-WWRP MJO task

force, and the on-going Low-Cloud Feedbacks project which is a joint project of GASS and the CFMIP project of WGCM. Also, CAUSES links closely with the DOE's ASR programme.

- A GASS SSC member, Gunilla Svensson, is a steering committee member of both new Polar project initiatives of WWRP and WCRP and has been a significant contributor to the science and implementation plans being developed by these projects.
- GASS is represented by Steve Woolnough on the joint WWRP/WCRP seasonal prediction project and is helping to be a modelling liaison with the plans toward developing for future tropical convection field campaigns including the Year of Maritime Continent project and a more distant potential monsoon field campaign.
- GASS has always struggled with forging a strong relationship with the iLeaps Aerosol-Cloud-Precipitation-and-Climate initiative (ACPC). This is in part because ACPC has been something of a stop-start initiative with little of substance to engage with. However, we have done our best and currently, SSC member Ann Fridlind has been actively in contact with them as they formulate plans for an Observational System Simulation Experiment aiming to observationally investigate aerosol effects on shallow or deep convection from microscale to mesoscale with a closure approach. A planned workshop in April 2015 in New York City will aim to identify potential conditions, regions, approaches, and issues. GASS has repeatedly come up as a potential source of helpful input and will participate in the next stage if that is reached as envisioned.

Meetings: In the reporting period, the main meeting with GASS attendance was the July 2014 GEWEX conference on the water cycle and the associated pan-GEWEX meeting in the Hague. GASS attendance was quite good with a number of poster and oral sessions being sponsored by GASS, or joint with GLASS. Additionally, there were several breakout sessions for specific GASS projects (GABLS3/4, DICE, and CAUSES) as well as the Clouds Grand Challenge. Finally the GASS SSC held a ½ day meeting during the pan-GEWEX meeting. Apart from the Hague conference, GASS had smaller workshops associated with DICE (at the MetOffice in October 2013) and the Grey Zone projects (at the MPI in December 2014). GASS is interested in organizing, perhaps joint with GLASS, another pan-GASS/GLASS conference in late summer/early fall of 2016 on the same scale as the very successful 1st Pan-GASS science conference 10-14 September 2012 in Boulder, Colorado which had around 200 attendees.

Key Publications: Please see the list of publications provided in the progress reports of the individual projects below.

SUPPLEMENTAL MATERIAL: Progress reports of GASS projects

The following pages present progress reports for individual GASS projects according to their stage of development. Projects which are in the formation or early phase include:

- Clouds Above the United States and Errors at the Surface (CAUSES)
- GABLS4: Stable Boundary Layer on the Antarctic Plateau
- Kinematic Driver model - Aerosol intercomparison project (KiD-A)
- Mid-latitude Cirrus
- Polar Airmass Transition
- Radiative Processes in Observations and Models

Projects which are mature include:

- Grey-Zone
- Land-Atmosphere Interactions (DICE)
- Low Cloud Feedbacks (CGILS)
- Weak Temperature Gradient

Projects where the intercomparison is complete and written up (or close to being written up) include:

- GABLS3: Stable Boundary Layer at Cabauw
- Polar Clouds
- Stratocumulus-to-Cumulus Transition
- Vertical Structure and Diabatic Processes of the MJO

As with most GASS projects there is likely to be significant work carried out in the future based around the output of these projects. It is complete in the sense this is no longer managed by GASS formally. Often the project leads will remain involved in related activities.

CLOUD RADIATION ERRORS AND SURFACE TEMPERATURE BIASES (CAUSES)

SSC sponsors: Jon Petch and Stephen Klein
Project leads: Cyril Morcrette, Hsi-Yen Ma, Jon Petch, Stephen Klein, and Shaocheng Xie
Project status: Early

a. Accomplishments

This proposed project is new with an observationally-based focus, which evaluates the role of cloud, radiation, and precipitation processes in contributing to the surface temperature biases in the region of the central United States and which are seen in several weather and climate models.

The warm bias over the US in summer is common to many GCMs and it is seen in the long-term climate mean and it shows up as a bias within a few days when running the climate models from analyses in NWP mode. While there are many potential causes, we are proposing study of two areas of investigation:

1. What is the contribution of radiation errors to the temperature errors? How much of the errors in radiation result from errors in clouds and their properties? Which cloud regimes contribute most the radiation errors? The analysis will be led by Cyril Morcrette (UK Met Office) and based largely upon Morcrette et al. (2012).

2. What is the relative contribution of precipitation errors to the temperature errors? Does this atmosphere provide the correct amount of precipitation for the soil? Which type of precipitating convection systems dominate the errors in the surface precipitation? Does the surface energy balance reveal signs that evaporation is underestimated due to the lack of soil moisture? The analysis will be led by Hsi-Yen Ma (LLNL) and based largely on Klein et al. (2006).

In October 2014, an experimental specification document was distributed via the GASS mailing list. It details the set up and diagnostics required from both NWP-type and climate type simulations as well as simulations that allow one to diagnose the drift towards the climate state. The document detailed the data format and file-naming convention aimed at simplifying the use of data from multiple models. Additionally, an informal survey of the community suggests that there will be participation from 7 modeling groups, including some regional as well as global climate models.

b. Activities for next 1-2 years

The intercomparison has officially begun and first simulation output are requested. A tentative timeline is:

- June 2015: Deadline for participants' data to be submitted to LLNL or Met Office.
- Oct 2015: Participants' Data processed and analyzed.
- Nov 2015: Discuss plots and plans for papers at "ASR Fall Meeting"
- Jan 2016: Circulate outline for planned papers
- March 2016: First draft of the inter-comparison papers led by Cyril and Hsi-Yen
- June 2016: Submit manuscripts

c. List of key publications

A paper summarizing applying some of the methodologies to 2 models was submitted:

Van Weverberg, K., C. J. Morcrette, H.-Y. Ma, S. A. Klein, and J. C. Petch, 2015: Cloud regime analysis to find the causes of surface temperature errors in weather and climate models. Quart. J. Roy. Met. Soc., submitted.

d.List of meetings, workshops held

A breakout session occurred at the pan-GEWEX meeting in the Hague, July 2014, and before that at the ASR/ARM meeting near Washington, D. C., March 2014.

e. Planned meetings and workshops

A breakout session to discuss this project will occur at the ASR/ARM meeting near Washington, D. C., March 2015 as well as the subsequent ASR/ARM meeting in Fall 2015.

GABLS4: STABLE BOUNDARY LAYER ON THE ANTARCTIC PLATEAU

SSC sponsor: Gunilla Svensson
Project leads: Eric Bazile, Bert Holtslag and Gunilla Svensson and Timo Vihma
Project status: Early

a. Accomplishments

As a follow-up on the recommendations from the ECMWF/GABLS workshop in Reading November 2011, a case to test boundary-layer schemes in conditions with stronger stability than previous cases is launched. The aim of the GABLS4 case is to study the interaction of a boundary layer with strong stability (Ri>>1) with a snow surface. This will provide a case with low conductivity and a high cooling potential. The case is based on observations taken at the Antarctic Plateau at DomeC. The case is a "typical diurnal cycle for summer" with an amplitude of about 18K, and a very shallow boundary layer during night. the first one with a full coupling with the surface (snow) scheme and the second one with a prescribed surface temperature. Possibilities for a LES inter-comparison are discussed.

b. Activities for next 1-2 years

The case was announced to the community at several conferences during 2014 and the model results were handed in December 2014. Results for the second part of the experiment are due in May 2015 and they will be discussed at a workshop in May. It is likely that these first submissions will lead to follow-up experiments for the community to tackle. So far, SCM and Land models are involved, we expect LES to take part in a more idealized case setup as well.

c. List of key publications

Bazile E., O. Traullé, H. Barral, T. Vihma, A.A.M. Holtslag, and G. Svensson, 2013: GABLS4: An intercomparison case for 1D models to study the stable boundary layer at Dome-C on the Antarctic plateau. EMS Annual Meeting Abstracts Vol. 10, EMS2013-578, 2013

d. List of Meetings

- AMS BLT meeting Leeds, June 2014
- WWOSC2014, Montreal, August 2014
- Pan-GEWEX meeting, Haague, July 2014

e. Planned meetings, workshops

This case will be discussed at the upcoming GABLS4/DICE workshop on 20-22 May 2015 at MeteoFrance in Toulouse, France.

KINEMATIC DRIVER MODEL AEROSOL INTERCOMPARISON PROJECT

SSC sponsor: Ben Shipway
Project leads: Adrian Hill, Zach Lebo
Project status: Early

a. Accomplishments

The purpose of this Kinematic Driver model Aerosol (KiD-A) intercomparison project is to compare aerosol-aware cloud microphysics models in a consistent framework without the added complexity of dynamically coupled simulations. There are two key objectives to this intercomparison:

- Comparison of detailed cloud microphysical models and their response to aerosol (with no aerosol processing)
- Comparison of detailed cloud microphysical models that include aerosol processing with bulk models with aerosol processing capability

The goal of this project is to have individuals contribute by coupling his/her microphysics parameterization to the Kinetic Driver model (KiD). The coupling is straightforward with examples provided. A suite of simulations is requested with specific model output. Important details and additional information regarding the motivation for this intercomparison project, how to obtain the model and couple it with a microphysics scheme, and the requested output can be found at the following address:

http://appconv.metoffice.com/kid_a_intercomparison/kid_a/home.html

Results of this work will help further our understanding of aerosol-cloud-precipitation interactions.

To date, results have been submitted from groups using 7 different microphysics schemes including those using bulk, bin and superdroplet paramterizations. Where the capability exists, groups have also submitted results from simulations which include the physical processing of aerosol, allowing us for the first time to estimate the importance as well as the uncertainty in this aspect of cloud-aerosol interactions.

b. Activities for next 1-2 years

- Following an assessment of the initial results, the case set up will be reviewed and adjusted.
- The project will be finished and discussed at the 2016 Cloud Modeling Workshop
- A paper reporting the analysis and consequences thereof will be written.
- A follow on project considering a dynamical case will be considered.

c. List of key publications

- Hill, A, B.J. Shipway and I. Boutle, 'How sensitive are aerosol-precipitation interactions to the warm rain representation?', submitted to Journal of Advances in Modeling Earth Systems.
- Shipway, B.J. and Hill, A.A, 2012, Diagnosis of systematic differences between multiple parametrizations of warm rain microphysics using a kinematic framework. Q.J.R. Meteorol. Soc.. doi: 10.1002/qj.1913.
- Bretherton, C., A. Fridlind, H. Morrison, and B. Shipway, 2010: GCSS workshop on microphysics and polar/precipitating clouds. GEWEX News, 20, no. 4, 17-19.
- Shipway, B.J. and Hill, A.A., 2011, The Kinematic Driver model (KiD), Met Office Technical Report No. 549.

d. List of Meetings

A session on this project was held at the Pan-GASS meeting in Boulder, CO, 2012.

e. Planned meetings, workshops

The case will be presented at the cloud workshop on Eulerian vs Lagrangian microphysics at Warsaw in 2015 and will be discussed at the Cloud Modeling Workshop at Exeter UK in 2016.

MID-LATITUDE CIRRUS

SSC sponsors: Hugh Morrison
Project leads: Andreas Muhlbauer and Thomas Ackerman
Project status: Early

a. Accomplishments

Initiation of the cirrus model intercomparison project based on a case study from the U. S. DOE Small Particles in Cirrus (SPartICus) field campaign. The objective of this case study is to investigate the microphysical and macrophysical evolution and life cycle of a deep-wave cirrus observed over the ARM Southern Great Plains (SGP) site in Oklahoma and to compare simulated cirrus cloud properties and radiative effects among models and with observations. Special emphasis is on the contribution of small ice crystals in cirrus and the role of homogeneous and heterogeneous ice nucleation. Simulations are compared and evaluated with in situ aircraft observations and with various ground-based and space-borne remote sensors. This project specifically targets cloud-system resolving (CSRM) models, cloud-resolving (CRM) models, large eddy simulation (LES) models and single column models (SCM) with advanced cloud microphysics schemes such as multi-moment bulk microphysics parameterizations or bin microphysics schemes. A detailed description of the project can be found at http://www.atmos.washington.edu/~andreasm/case3_midlatitude_cirrus/case3_midlatitude_cirrus.html.

b. Activities for next 1-2 years

The following activities are envisioned:

- Finalize case setup and logistics for participating models
- Analyse model results, focusing on cirrus macrophysical and microphysical properties through detailed intercomparison of models and comparison of models with in-situ and remotely sensed observations
- Draft a paper detailing results from the model intercomparison

c. List of key publications

Muhlbauer, A., W. W. Grabowski, S. P. Malinowski, T. P. Ackerman, G. H. Bryan, Z. J. Lebo, J. A. Milbrandt, H. Morrison, M. Ovchinnikov, S. Tessendorf, J. M. Thériault, G. Thompson, 2013: Reexamination of the State of the Art of Cloud Modeling Shows Real Improvements, *Bulletin of the Amer. Meteor. Soc.*, 94, 45-48, doi: http://dx.doi.org/10.1175/BAMS-D-12-00188.1

Muhlbauer, A., T. P. Ackerman, J. M. Comstock, M. Deng, G. Diskin, and P. Lawson, 2015: Evaluation of cloud resolving model simulations of midlatitude cirrus with ARM and A-Train observations, submitted to *J. Geophys. Res.*

d. List of Meetings

The following meetings have been held for this project:

- January 2012, Introduction of the project during the MACPEX/SPartICus Science Team Meeting (Salt Lake City, UT, USA)
- March 2012, Discussion of the project during the U. S. DOE ASR Science Team Meeting (Arlington, VA, USA) at a breakout meeting on cirrus, where the case was introduced
- July 2012, International Cloud Modeling Workshop (Warsaw, Poland); a breakout session devoted to the cirrus intercomparison project
- September 2012, 1st pan-GASS conference (Boulder, CO, USA); a breakout session on cirrus clouds centered around the intercomparison project including detailed presentations of the case and preliminary results

e. Planned meetings, workshops

No Meetings are currently planned.

POLAR AIRMASS TRANSITION

SSC sponsor: Gunilla Svensson
Project lead: Felix Pithan
Project status: Early

a. Accomplishments

This is an idealized case to examine the models ability to capture the correct processes that changes the marine air mass when it is advected over the sea ice. This process involves cooling and stabilization of the airmass, condensation and cloud formation, radiative properties and glaciation to form snow and eventually the typical Arctic inversion should be present. The setup is based on conceptual understanding and there are currently no observations to compare with. Nevertheless, this is an important case to study to help motivate the observational efforts promoted by WWRP Polar Prediction Project and WCRP Polar Climate Predictability Initiative.

b. Activities for next 1-2 years

About 10 model centers have run the case and the results are currently analysed and will be summarized in a paper. The results and possible extensions might be discussed at the GABLS4/DICE workshop.

c. List of key publications

The case is based on the experiments presented in:

Pithan, F., G. Mederios and T. Mauritsen, 2014: Mixed-phase clouds cause climate model biases in Arctic wintertime temperature inversions. Climate Dynamics, 43, 289-303.

d. List of Meetings

Poster presentation at the Pan-GEWEX meeting, Hague, July 2014

e. Planned meetings, workshops

Possible discussions at the GABLS4/DICE workshop, May 2015 and at the YOPP (Year of Polar Prediction) meeting, Geneva, July 2015

RADIATIVE PROCESSES IN OBSERVATIONS AND MODELS

SSC sponsors: Robert Pincus and Lazaros Oreopoulos
Project leads: Robert Pincus and Eli Mlawer
Project status: Early

a. Accomplishments

This relatively new GASS project is envisioned as an extension and expansion of the Continual Intercomparison of Radiation Codes (CIRC) project. CIRC is the latest of a series of intercomparisons of radiation codes made in the GASS spirit, testing approximate against reference models and observations for a small set of well-characterized cases. During the reporting period, CIRC was highlighted as a major ARM accomplishment in a monograph about the first 20 years of ARM (see publication list below). The CIRC project presented a Working Group progress report at the International Radiation Committee (IRC) business meeting at COSPAR 2014 in Moscow.

In addition to CIRC, this GASS activity supports the component of the Radiative Forcing Model Intercomparison Project (RFMIP) which assesses the accuracy of clear-sky radiative forcing by greenhouse gases at the global scale (i.e. as relevant to climate sensitivity and feedback analyses). RFMIP was formally awarded association with the sixth phase of the Coupled Model Intercomparison Project (CMIP6). Preliminary planning for this activity was performed, including a trial study of $4xCO_2$ radiative forcing experiments based on four CIRC cases that was presented at the 2014 AMS Radiation Conference in Boston, MA. This trial run suggested there is much room for assessment and improvement of GCM radiation parameterizations of gas absorption.

b. Activities for next 1-2 years

The gaseous forcing component of RFMIP is expected to come to the forefront of this project's activities in the next 1-2 years. This includes the final determination of the forcing experiments that will be included in this effort, running reference line-by-line calculations for these experiments for a large and diverse set of base atmospheres, supporting members of the global modelling community as they participate in this RFMIP component, and, finally, leading the analysis of the results.

CIRC intends to use RFMIP experience and outcomes to identify and design new observationally-based cases that will help resolve questions about model performance that may arise. Examples of such potential issues are the impact of ignoring or poorly resolving the spectral dependence of surface albedo and of choosing different water vapor continuum parameterizations.

c. List of key publications

Oreopoulos, L., and E. Mlawer (2010). The Continual Intercomparison of Radiation Codes (CIRC): Assessing anew the quality of GCM radiation algorithms Bull. Am. Met. Soc., 91, 305-310doi:10.1175/2009BAMS2732.1

Oreopoulos, L., et al. (2012), The Continual Intercomparison of Radiation Codes: Results from Phase I, J. Geophys. Res., 117, D06118, doi:10.1029/2011JD016821.

Mlawer, E.J., M.J. Iacono, R. Pincus, H.W. Barker, L. Oreopoulos and D.L. Mitchell (2015), Contributions of the ARM program to radiative transfer modeling for climate and weather applications, *The Atmospheric Radiation Measurement Program: The First 20 Years*, Meteor. Monograph, Amer. Meteor. Soc., in press.

d.List of meetings, workshops held

RFMIP Planning Workshop, Hamburg, 3-5 September 2014

e. Planned meetings and workshops

None at this time

GREY ZONE

SSC sponsor: Pier Siebesma
Project Committee: Pier Siebesma, Andy Brown, Christian Jakob, Jeanette Onvlee.
Case Leaders: Paul Field, Adrian Hill, Stephan de Roode, Pier Siebesma, Lorenzo Tomassini
Project Status: Mature

a. Accomplishments

WGNE has recently expressed the need to organize a systematic evaluation project of atmospheric models that operate in the so called Grey Zone Resolution range of 1~10km. As a response a Grey Zone Project has been established and the project committee has performed a survey and came with the conclusion that especially from the mesoscale model community there was a strong preference to select a cold air outbreak as a first intercomparison study for the Grey Zone Project.

The Case leaders have worked over the last 12 months to set up a cases for a full hierarchy of models (global, LAM and LES) based on observations from the CONSTRAIN experiment during which a classic cold air outbreak over the North Sea north of Great Britain was observed. Realistic high resolution simulations with the correct classic spatial mesoscale features with 2 independent LES models have been produced.

The case has been released in 2013 and many modellers have submitted model results. In total we received results from 6 LES codes, 7 mesoscale models and 7 global models. December 1-3 2014, around fifty scientists visited the first Workshop on the Grey Zone Project organized by Lorenzo Tomassini at the Max Planck Institute for Meteorology in Hamburg, Germany. They came together to present and discuss i) the model results of the intercomparison study based on the CONSTRAIN cold air outbreak ii) novel ways of representing physical processes (clouds, convection and turbulence) in models that operate in the Grey Zone with respect to these processes and iii) to discuss any further coordinated actions.

b. Activities for next 1-2 years

The following activities are planned for this project:

- April 2015: Submission deadline of the 2nd round of the cold air outbreak
- May-Sept 2015: Analysis Results
- Late 2015: Drafts ready for submission of 4 papers (2 on the mesoscale/global model results, 1 on the LES results and 1 general BAMS-like paper)
- 2016: There is interest to have a follow-up case on deep convection along the same lines (i.e. exploring the resolution-dependency of convection-representation)

c. List of key publications

- GEWEX Newsletter report on the Grey Zone Project and the 1st Grey Zone Workshop.

d. List of Meetings

- December 1 - 3, 2014 at the Max Planck Institute for Meteorology in Hamburg, Germany.

e. Planned meetings, workshops

LAND-ATMOSPHERE INTERACTIONS (DICE) (JOINT WITH GLASS)

SSC sponsor: Adrian Lock
Project leads: Martin Best and Adrian Lock
Project status: Mature

a. Accomplishments

This project grew out of the GABLS/ECMWF workshop in Nov 2011 where there was a consensus that the atmospheric boundary layer and land surface communities needed to work more closely together. At the pan-GASS meeting in Sept 2012, it was proposed to initiate a project, joint between GASS and GLASS, on a clear-sky diurnal cycle case study, from the same observational campaign as was used for GABLS2. The period chosen consists of 3 full diurnal cycles covering a range of different stable boundary layer regimes. The intercomparison, initially, has three components. In stage 1, land surface and single column (atmosphere only) models are run separately (uncoupled) for the 3 day period forced entirely by observed quantities (noting that the soils in the LSM must be spun up by running, forced by observations, for several years of data previous to the campaign to ensure these are in balance for each model). In stage 2 the two models are run coupled. These two stages allow the impact of coupling to be evaluated. In stage 3 the submitted results from the models in stage 1 are used to derive multiple forcings (ie the surface fluxes are extracted from the LSM and the near-surface atmospheric variables from the SCM) so that each participant can run an ensemble of LSM and SCM simulations. This then allow the sensitivity of each model to differences in forcing to be quantified. Overall this project should both promote greater understanding of each model's strengths and weaknesses, help quantify the importance of coupling the two systems together and give insight into what aspects are important for surface coupling sensitivity.

The case was released in Spring 2013 and so far 10 LSM and 12 SCM are participating so far. Detailed analysis and final checking of datasets received is underway with draft papers planned to be completed by summer 2015.

The project website is http://appconv.metoffice.com/dice/dice.html

b. Activities for next 1-2 years

The following activities are envisioned for this project:

- Complete overview analysis of intercomparison data received and submit papers describing the key results
- Discuss draft papers and plan additional analysis at the upcoming synthesis workshop
- Discussions underway for potential special issue to collate DICE-related studies from the participants

c. List of key publications

Best, M., A. Lock, J. Santanello, G. Svensson, and B. Holtslag (2013) A New Community Experiment to Understand Land-Atmosphere Coupling Processes. *GEWEX News*, May 2013.

d. List of Meetings

Past meetings include:

- Workshop at the Met Office, Exeter from 14-16 October 2013
- Break-out meeting held at the GEWEX conference in The Hague on 15th July 2014

A synthesis workshop in May 2015 will be held at MeteoFrance (Toulouse) joint with GABLS4.

LOW CLOUD FEEDBACKS: CFMIP-GASS INTERCOMPARISON OF LES AND SCMS (CGILS)

SSC sponsor: Chris Bretherton and Adrian Lock
Project leads: Peter Blossey, Chris Bretherton, Minghua Zhang
Project status: Mature

a. Accomplishments

CGILS was formulated in 2008 to help understand physical mechanisms of low cloud feedback in climate models, and why these feedbacks differ substantially across models. The strategy has been to use a column modeling framework to intercompare subtropical marine boundary layer cloud response to idealized climate changes between different LES and SCMs, using cases grounded at least loosely in observations. Three locations along the GPCI were selected corresponding to different summer cloud regimes: S12 (well-mixed Sc), S11 (Cu under Sc) and S6 (trade cumulus).

Summary of Phase 1 results (finished)

The climate perturbation ('P2S') studied in Phase 1 of CGILS, completed in 2012, was a 2 K SST increase, a corresponding moist-adiabatic increase of free tropospheric temperature, and an 11% decrease in mean subsidence. Zhang et al. (2012) document the detailed case specification. After some iterations of the case specification, 15 SCMs (representing single-column versions of many of the world's leading climate models) and 6 LESs submitted final results, described in a set of four papers published in 2013-2014. For the S12 case, the LES models also considered a variation 'P2' on the climate perturbation with no subsidence change, and one LES also considered other climate perturbations that CMIP models suggest will accompany global warming in the subtropics, such as CO2 increase, wind speed and free-tropospheric relative humidity changes, and increased inversion strength.

The cloud response of the SCMs scattered widely between each other and away from their parent GCMs. Because of the smallness of the climate perturbation and the use of steady forcings, the SCMs responses were distorted by locking of cloud features to discrete grid levels. In general, models and cases with active shallow cumulus parameterizations tended to show positive cloud feedbacks (Zhang et al 2013). After harmonization of the radiation and surface flux schemes, the LES models produced more similar responses. Without subsidence, all LESs showed cloud thinning in the warmer climate, but reduced subsidence counteracted this to varying degrees in the different models (Blossey et al. 2013). Thus LES suggested that there are multiple compensating cloud responses whose net result dictates the overall cloud feedback (Bretherton et al. 2013). In the S6 (shallow cumulus) case the equilibrium cloud-layer depth in each LES was also sensitive to its microphysical parameterizations (Blossey et al. 2013; Bretherton et al. 2013).

CGILS Phase 2 (ongoing)

At the Sept. 2012 Pan-GASS meeting, CGILS Phase 2 of was formulated. Based on sensitivity studies with a single LES (Bretherton et al. 2013) and recent results on the fast adjustment of clouds in GCMs, two further forcing perturbations were added to the original case, for all three locations. The first (4CO2) was a quadrupling of CO2 with no change in surface or free-tropospheric temperature. The second (dCMIP3) uses composite forcing perturbations taken from the CMIP3 multimodel mean for a CO2-doubled climate (Bretherton et al. 2013). So far, six LES have successfully run the perturbed cases, and all show reductions in cloud cover and albedo with both forcing perturbations, consistent with the single-LES results.

The other prong of CGILS Phase 2 was to test whether more consistency between SCMs and GCMs, as well as between LES and observed climatology, could be obtained using transient (synoptically-varying) forcing at each location, derived from a summer of ECMWF analyses provided to us by Martin Koehler, and adding the climate perturbations as a uniform-in-time increment to these transient forcings. It was decided that one LES group (Blossey and Bretherton at UW) would test out the feasibility of this approach. The approach worked for the S6 (trade cumulus case), but problems arose for the S11 (decoupled stratocumulus case) in a 4xCO2 case with observed SSTs because the simulated inversion sank too low to be consistent with the ECMWF forcings, which have strong vertical and temporal gradients near the ECMWF-analyzed inversion height. It was agreed to try a simpler approach with composite periodic forcings that might be better controlled for such effects. The goal is to obtain a transient–forcing setup with a connection to real observations that is tractable for LES, can be logically

extended to a future climate, and which involve inversion fluctuations of 500-1000 m that are larger than the grid spacing of a SCM, minimizing grid-locking artifacts.

b. Activities for next year

The steady-forcing results from CGILS Phase 2 have been finalized and are being written up for JAMES (tentative citation below). Brian Medeiros of NCAR has volunteered to coordinate an SCM intercomparison based on these steady-forcing cases, but this is not yet organized.

Blossey and Bretherton have worked extensively on realistic periodic-forcing setups. They have developed an approach which works well for one case (S6), but still leads after a while to abrupt cloud breakup for another case (S11) that may make it a challenging comparison for SCMs. A satisfying resolution has not yet been found. So far, the LES cloud response in the transient forcing case is rather similar to in the steady forcing case, with 4xCO2 and overall warming of the atmosphere and ocean column both independently producing cloudiness reductions. We will discuss next steps at the June 2015 CFMIP meeting, if not before.

c. List of key publications

M. Zhang and 39 co-authors, 2013: CGILS: First Results from an International Project to Understand the Physical Mechanisms of Low Cloud Feedbacks in General Circulation Models. *J. Adv. Model. Earth Syst*, **5**, DOI: 10.1002/2013MS000246. – Overview of CGILS SCM and LES results.

M. Zhang, C. S. Bretherton, P. N. Blossey, Sandrine Bony, Florent Brient and Jean-Christophe Golaz, 2012: The CGILS experimental design to investigate low cloud feedbacks in general circulation models by using single-column and large-eddy simulation models. *J. Adv. Model. Earth Syst.*, **4**, doi:10.1029/2012MS000182. – CGILS Phase 1 case specifications

P. N. Blossey, C. S. Bretherton, M. Zhang, A. Cheng, S. Endo, T. Heus, Y. Liu, A. Lock, S. R. de Roode and K.-M. Xu, 2013: Marine low cloud sensitivity to an idealized climate change: The CGILS LES Intercomparison. J. Adv. Model. Earth Syst., **5**, doi:10.1002/jame.20025 --Phase 1 LES results

C. S. Bretherton, P. N. Blossey and C. R. Jones, Mechanisms of marine low cloud sensitivity to idealized climate perturbations, 2013: A single-LES exploration extending the CGILS cases. *J. Adv. Model. Earth Syst*., 5, doi:10.1002/jame.20019 – Phase 1 Single-LES sensitivity study

Blossey, P. N, C. S. Bretherton, A. Cheng, J. J. van der Dussen, S. Endo, T. Heus and A. Lock, 2015. Marine low cloud sensitivity to increased CO_2 and a CMIP3 composite climate perturbation: Phase 2 of the CGILS LES intercomparison. *J. Adv. Model. Earth Syst*., in preparation.

d. Meetings in 2014

July 2014: Session at CFMIP workshop, Egmont aan Zee, NL– detailed presentations of results
July 2014: GASS session at pan-GEWEX meeting, den Haag, NL – review of overall findings and plans

e. Planned meetings, workshops in 2015

June 2015: CFMIP workshop, Monterey, CA.

WEAK TEMPERATURE GRADIENT

SSC sponsor: Steve Woolnough
Project leads: Steve Woolnough, Adam Sobel, Sharon Sessions, Gilles Bellon, Shuguang Wang, Chimene Daleu
Project status: Mature

a. Accomplishments

This project arose out discussions preceding and at the Pan-GASS meeting in Boulder, with the objective of comparing two methods of parametrizing the feedbacks from the large-scale tropical circulation in process models of convection. A comprehensive project specification was released in December 2013 and results from 5 CRM and 8 SCM models were submitted during the Spring/Summer of 2014 with analysis conducted over the summer http://www.met.reading.ac.uk/~fj019034/WTG_project/.
A paper on the behaviour of the Weak Temperature Gradient and Damped Gravity Wave methods for experiments with uniform SSTs is near submission, the main findings of this study are that: (i) there is a wider diversity of behaviour in WTG than DGW methods; (ii) there is a wider diversity of behaviour in SCMs than CRMs; and (iii) that the behaviour in WTG method is sensitivity to the treatment of the large-scale in the boundary layer.

b. Activities for next 1-2 years

Following the initial analysis of the non-uniform SST case and the division of the results into two papers a further set of experiments has been requested, and the modeling centres have agreed to submit results during February 2015. Additional analysis and paper preparation will occur during spring 2015. Early discussion has begun on a set of additional experiments with interactive radiation but the specification and timeline for this has not been finalized.

c. List of key publications

d. List of Meetings

Results have been presented at the 7th International Scientific Conference on the Global Energy and Water Cycle, The Hague, 14-17 July 2014 and the AGU Fall Meeting, San Francisco, 15-19 December 2014.

e. Planned meetings, workshops

None

GABLS3: STABLE BOUNDARY LAYER AT CABAUW

SSC sponsor: Gunilla Svensson
Project leads: Gunilla Svensson and Bert Holtslag
Case leads: Fred Bosveld and Sukanta Basu
Project status: Finished, subject to final publication of papers

a. Accomplishments

The third GABLS intercomparison, based on a case selected Cabauw, the Netherlands, with the aim to study the model's performance for the LLJ development, morning and evening transitions and surface-atmosphere coupling. The intercomparison consists of a SCM and a LES case coordinated by Fred Bosveld and Sukanta Basu, respectively. The latter is focusing on a shorter time span than the SCM. Two papers on the SCM case are in the final publication state in Boundary-Layer Meteorology. The LES case focused on the nighttime conditions and the morning transition. Main findings from these studies are that the LES is able to capture the transition fairly well after considerable effort was put on the case setup. The SCM results show large variability and strong sensitivity to the forcing provided and the results are analyzed using a method which allows the interpretation of differences among models in terms of the dominating physical processes in the stable boundary layer, i.e. coupling to the soil, turbulent mixing and long wave radiation. Substantial differences among models are found in the representation of these three processes.

c. List of key publications

Basu, S., et al., 2014, GABLS Intercomparison of Large-Eddy Simulation models with Cabauw observations. In preparation for Boundary Layer Meteorology.

Bosveld F.C., P. Baas, E. van Meijgaard, E.I.F. De Bruijn, G.-J. Steeneveld and A.A.M. Holtslag, 2014. The third GABLS intercomparison case for model evaluation, part A: Case Selection and Set-up. Boundary Layer Meteorology, 152, 133-156, DOI: 10.1007/s10546-014-9917-3.

Bosveld F., P. Baas, G.J. Steeneveld, A.A.M. Holtslag, F. C. Bosveld, W. M. Angevine, E. Bazile, E. I.F. de Bruijn, D. Deacu, J. M. Edwards, M. Ek, V. E. Larson, J. E. Pleim, M. Raschendorfer, and G. Svensson, 2014: The third GABLS intercomparison case for model evaluation, Part B: Single Column Model results and process understanding. Boundary-Layer Meteorology, 152, 157-187. DOI: 10.1007/s10546-014-9919-1.

Holtslag, A.A.M., G. Svensson, P. Baas, S. Basu, B. Beare, A.C.M. Beljaars, F.C. Bosveld, J. Cuxart, J. Lindvall, G.J. Steeneveld, M. Tjernström, and B.J.H. Van De Wiel , 2013: Diurnal cycles of temperature and wind – A challenge for weather and climate models. Bulletin of the American Meteorological Society. 94, pp. 1691-1706, doi:10.1175/BAMS-D-11-00187.1

POLAR CLOUD

SSC sponsors: Ann Fridlind
Project leads: Mikhail Ovtchinnikov
Project status: Finished

a. Accomplishments

This case was a follow up to previous MPACE and SHEBA intercomparisons, but under different conditions and using a more constrained model setup with respect to ice particle properties, model's spatial resolution, and parameterization of radiative effects. The case received quite wide participation, and follow-up sensitivity studies were performed by the groups running both size-resolved bin microphysics and bulk microphysics schemes. It was found that the two independent bin microphysics models agreed quite well, and differences between bin and bulk schemes could be closely attributed to the parameterization of ice particle size distribution. When bulk scheme ice size distribution parameters were set to the mean fit to bin scheme results, bin and bulk scheme results were brought into agreement, as well, emphasizing the importance of representation of ice particle size distribution.

c. List of key publications

Ovchinnikov, M., A.S. Ackerman, A. Avramov, A. Cheng, J. Fan, A.M. Fridlind, S. Ghan, J. Harrington, C. Hoose, A. Korolev, G.M. McFarquhar, H. Morrison, M. Paukert, J. Savre, B.J. Shipway, M.D. Shupe, A. Solomon, and K. Sulia, 2014: Intercomparison of large-eddy simulations of Arctic mixed-phase clouds: Importance of ice size distribution assumptions. J. Adv. Model. Earth Syst., 6, no. 1, 223-248, doi:10.1002/2013MS000282.

STRATOCUMULUS-TO-CUMULUS TRANSITION

SSC sponsor: Adrian Lock
Project leads: Stephan de Roode, Irina Sandu, Roel Neggers
Project status: Finished, subject to final publication of papers

a. Accomplishments

This project studies the stratocumulus to trade cumulus transition, one that is of climatological importance for understanding low cloud cover variations in the marine subtropics. There are two parallel LES intercomparisons as well as SCM intercomparisons. These intercomparisons are being run in collaboration with a European project, EUCLIPSE. In combination these cases challenge models to produce both a realistic transition compared to detailed in situ data and also a realistic sensitivity of the speed of transition to changes in environmental forcing. Results suggest the LES do a good job of capturing these details, although requiring very high (5m) vertical resolution. One of the motivations for this intercomparison was that these transitions would present a particular challenge for SCMs, many of which would need to make the transition between different parameterizations of vertical mixing. Over 20 SCMs have participated and, although many do indeed struggle to generate realistic transitions, it is encouraging that those organizations that have worked hard to develop these aspects of physical parameterizations (invariably using previous GCSS intercomparison cases) can do a much better job.

b. Activities for next 1-2 years

The final activity to complete this project will be submission of a SCM paper describing these studies in much more detail; a draft paper was circulated in September 2014. Separate spin-off work is continuing to investigate the difference between forcing the SCM with mean forcing as compared to running an ensemble of SCM and taking the mean. While of general interest to GASS this is not considered part of this intercomparison.

c. List of key publications

Neggers et al: Single-column model simulations of subtropical marine boundary-layer cloud transitions under weakening inversions. In preparation

van der Dussen, J. J., S. R. de Roode, A. S. Ackerman, P. N. Blossey, C. S. Bretherton, M. J. Kurowski, A. P. Lock, R. A. J. Neggers, I. Sandu, and A. P. Siebesma (2013), The GASS/EUCLIPSE model intercomparison of the stratocumulus transition as observed during ASTEX: LES results, J. Adv. Model. Earth Syst., 5, doi:10.1002/jame.20033.

De Roode, S.R. et al (2012) LES Results of the GASS-EUCLIPSE Lagrangian Stratocumulus to Shallow Cumulus Transition Cases, *AMS-BLT Conference*, https://ams.confex.com/ams/20BLT18AirSea/webprogram/Manuscript/Paper208663/intercomparison_lags.pdf

Lock, A.P. (2011) GCSS/CFMIP/EUCLIPSE Meeting on Cloud Processes and Climate Feedbacks. *GEWEX News*, August 2011

d. List of Meetings

The following meetings have been held for this project:

- September 2010, Joint workshop with EUCLIPSE on the Transition and CGILS cases held at KNMI (deBilt, Netherlands)
- June 2011, joint meeting with CFMIP and EUCLIPSE including further discussions on the Transition and CGILS cases held at the Met Office (Exeter, Devon, UK)
- April 2012, some discussion of progress alongside an otherwise EUCLIPSE-only meeting at MeteoFrance (Toulouse, France)
- September 2012, Discussion of project at the 1st pan-GASS meeting (Boulder, CO, USA)

e. Planned meetings, workshops

No more meetings are currently planned, although work will continue.

VERTICAL STRUCTURE AND DIABATIC PROCESSES OF THE MJO

SSC sponsors: Jon Petch and Steve Woolnough
Project leads: Jon Petch, Duane Waliser, Prince Xavier, Nick Klingaman, Xianan Jiang & Steve Woolnough
Project status: Finished, subject to final publication of papers

a. Accomplishments

This project, conducted jointly between GASS and the WCRP-WWRP MJO task force, studied the vertical structure of diabatic process in the MJO in global models and its relationship to MJO simulation fidelity using 3 sets of model integrations: 20 year climate simulations, 2-day hindcasts from 2 YOTC MJO cases (E&F), and 20-day hindcasts of the same events. Over the spring/summer of 2012 data submissions for one or more components of the project were received from 23 modelling centres. The initial analysis of the 3 components has been carried out and papers on each component have been submitted and are under revisions following the review process. In response to the reviewers and editor's comments, a further short synthesis paper is being developed.

A database of the output from these simulations is available at
https://earthsystemcog.org/projects/gass-yotc-mip/

b. Activities for next 1-2 years

See papers through review process. This includes the planned synthesis paper.

c. List of key publications

- Petch, Jon, Duane Waliser, Xianan Jiang, Prince Xavier, and Steve Woolnough: A Global Model Intercomparison of the Physical Processes Associated with the Madden-Julian Oscillation, 2011, *GEWEX News*, 21, 3-5.
- Jiang, X., D. E. Waliser, P. K. Xavier, J. Petch, N. P. Klingaman, S. J. Woolnough, Bin Guan, G. Bellon, T. Crueger, Charlotte DeMott, C. Hannay, H. Lin, W. Hu, D. Kim, C.-L. Lappen, M.-M. Lu, H.-Y. Ma, T. Miyakawa, J. A. Ridout, S. D. Schubert, J. Scinocca, K.-H. Seo, E. Shindo, X. Song, C. Stan, W.-L. Tseng, W. Wang, T. Wu, K. Wyser, X. Wu, G. J. Zhang, and H. Zhu, 2014: Vertical structure and physical processes of the Madden-Julian Oscillation: Exploring key model physics in climate simulations. *(under revision for JGR)*
- Klingaman, N. P., S. J. Woolnough, X. Jiang, D. Waliser, P. K. Xavier, J. Petch, M. Caian, C. Hannay, D. Kim, H.-Y. Ma, W. J. Merryfield, T. Miyakawa, M. Pritchard, J. A. Ridout, R. Roehrig, E. Shindo, F. Vitart, H. Wang, N. R. Cavanaugh, B. E. Mapes, A. Shelly, and G. Zhang, 2014: Vertical structure and physical processes of the Madden–Julian Oscillation: Linking hindcast fidelity to simulated diabatic heating and moistening. *(under revision for JGR)*
- Xavier, P. K., J. C. Petch, N. P. Klingaman, S. J. Woolnough, X. Jiang, D. E. Waliser, M. Caian, S. M. Hagos, C. Hannay, D. Kim, J. Cole, T. Miyakawa, M. Pritchard, R. Roehrig, E. Shindo, F. Vitart, and H. Wang, 2014: Vertical structure and physical processes of the Madden-Julian Oscillation: Biases and uncertainties at short range. *(under revision for JGR)*
- Klingaman, Xianan Jiang, Prince K. Xavier, Jon Petch, Duane Waliser, Steven J. Woolnough: Vertical structure and physical processes of the Madden–Julian oscillation: Synthesis and summary. *(to be, or recently, submitted to JGR)*

d. List of Meetings

The following meetings have been held for this project:

- 1st pan-GASS meeting in Boulder September 2012 where preliminary results were discussed
- GASS/MJO-TF meeting on Diabatic Processes in the MJO, Singapore Met Office, 3-5 June 2013 – discussion of model analysis and plans for future work on CINDY/DYNAMO case