

SPARC Theme: Atmospheric Dynamics and Predictability

Session Leads: Amy Butler and Seok-Woo Son

27th SPARC SSG meeting

Relevant Activities

DAWG	QBOi
DynVar	SATIO-TCS
FISAPS	SNAP
Gravity Waves	SOLARIS-HEPPA
OCTAV-UTLS	S-RIP

*December 2019
Boulder, CO, USA*

SPARC Theme: Atmospheric Dynamics and Predictability

- “...the need to provide skilful and reliable regional climate predictions from **months to decades** ahead.”
- “On **regional scales**, unlike the global mean, it is the dynamics as much as the thermodynamics that determines climate.”
- “Although seasonal-to-decadal prediction has been regarded as primarily a challenge of the **coupled troposphere-ocean system**, there is increasing evidence that for extra-tropical regions **stratosphere-troposphere coupling** also plays an important role.”
- “..implementation plan steers the SPARC community towards research activities focused on **tropospheric variability and dynamics** with an emphasis on **near-term predictions**.”

Progress and Achievements

Atmospheric dynamics and predictability

DAWG: Data Assimilation Working Group

- Established the “Dynamical Reanalysis” theme to be led by John McCormack, with a team of 9 other researchers
- Work plan for this theme was developed at 2019 DAWG workshop held at Univ. of Colorado/LASP in September:
“Evaluate the quality of new reanalysis data sets in the upper stratosphere/lower mesosphere against independent observations, continue evaluation of trends in dynamical variables (temperature, winds, higher order diagnostics such as PV or the residual circulation/BDC) begun in the S/RIP activity, and begin to address quantification of uncertainties in reanalysis.”

Leads: John McCormack, Quentin Errera

Progress and Achievements

Atmospheric dynamics and predictability

DynVar: Dynamics and Variability

- DynVarMIP – DynVar – SNAP Meeting, Madrid 22-25 October 2019
 - 94 participants from 17 countries
 - 57 oral presentations, 41 posters
 - Support from U. Complutense Madrid (our host), US NSF, WCRP Grand Challenges, SPARC & IAMAS enabled 20+ ECSs to attend
- DynVarMIP (part of CMIP6)
 - Dynamical diagnostics are becoming available
 - 3 community papers are in preparation

DynVar Leads: Daniela Domeisen, Alexey Karpechko

DynVarMIP leads: Ed Gerber, Elisa Manzini

Progress and Achievements

Atmospheric dynamics and predictability

FISAPS: Fine Scale Atmospheric Processes and Structures

- Workshop on Atmospheric Turbulence November 6-8, 2018, at the Leibniz-Institute of Atmospheric Physics (IAP) facility in Kühlungsborn, Germany.
 - 25 scientists, from 7 countries, attended this workshop. 22 talks were presented.
 - Discussed recent modeling and observational research on atmospheric turbulence, as well as applications.
 - see SPARC Newsletter for details
- New research shows that reanalysis indicates increasing wind shears over the North Atlantic (Lee et al. 2019), consistent with projections of climate models.

Leads: Marvin Geller, Hye-Yeong Chun, Thomas Birner

Progress and Achievements

Atmospheric dynamics and predictability

Gravity Waves

- New Study on Orographic Gravity Wave Stress and Drag initiated in 2019 at ISSI
 - High-resolution model (OSSE) validation – detailed comparisons to observations
 - Two week period study already underway – cases include long-duration balloon measurement comparisons
 - Studies of different NH/SH regions with varied orography and wind regimes planned for 2020
 - Additional comparisons to ground-based and field campaign data (radar, lidar, and aircraft measurements)
 - Diverse team of scientists: 50% early career, 43% female. 5 different modeling centers
 - Report on first meeting in July 2019 SPARC newsletter
 - Talk at 2019 AGU fall meeting led by Chris Kruse (PhD 2018)

Leads: Joan Alexander, Kaoru Sato, Fuqing Zhang (who sadly passed away in July)

Progress and Achievements

Atmospheric dynamics and predictability

OCTAV-UTLS: Observed Composition Trends and Variability in the Upper Troposphere and Lower Stratosphere

- Updated the JETPAC (JEt and Tropopause Products for Analyses and Characterization) algorithm to analyze multiple satellite, ground-based and airborne in-situ ozone records in several dynamical coordinates.
- Ozone datasets in UTLS were remapped using multiple combinations of Subtropical jet and tropopause related coordinates (i.e. WMO lapse rate, Potential Vorticity, Potential Temperature).
- Evaluated and ranked coordinate selection for reduction in UTLS ozone variability.

Leads: Peter Hoor, Luis Millan, Irina Petropavlovskikh

Progress and Achievements

Atmospheric dynamics and predictability

QBOi: Quasi-biennial Oscillation Initiative

- QBOi has completed the analysis and write-up of the five phase one experiments described in *Butchart et al. 2018*.
- Six papers have been submitted this year to a Special Section of the Quarterly Journal of the Royal Meteorological Society – QBO Modelling Intercomparison.
- An additional introductory piece was prepared by the QBOi coordinators grounding the Special Section in the history of SPARC.
- These papers address the following questions related to this Theme:
 - Do models represent the main characteristics of the observed QBO?
 - What are the main processes controlling the modelled QBOs?
 - How does the QBO respond to climate change?
 - How do external forcings impact the QBO?
 - How predictable is the QBO? What are the factors limiting predictability?
 - Do models reproduce observed QBO teleconnections?

Leads: Scott Osprey, Neal Butchart, James Anstey

Progress and Achievements

Atmospheric dynamics and predictability

SATIO-TCS: Stratospheric And Tropospheric Influences On Tropical Convective Systems

- SPARC-GA 2018 in Kyoto, ~ 30 presentations, including but not limited to:
 - the effects of the downward propagating solar tide on the diurnal cycle of convection
 - the impact of the QBO on MJO predictability
 - the impacts of the stratospheric sudden warming on tropical cyclone development
- Relevant meetings in 2019 for presentations of SATIO-TCS-related science:
 - AMS 20th conf. on MA in Phoenix, January 6-10
 - EGU General Assembly in Vienna, April 7-12
 - AMOS Annual Meeting 2019 and the International Conference on Tropical Meteorology and Oceanography in Darwin, June 11-14
 - 27th IUGG General Assembly in Montreal, July 8-18
 - AOGS 16th Annual Meeting in Singapore, July 28- August 2

Leads: Marvin Geller, Peter Haynes, Shigeo Yoden

Progress and Achievements

Atmospheric dynamics and predictability

SNAP: Stratospheric Network for the Assessment of Predictability

- Two significant community papers (thanks to hard work of D. Domeisen) outlining the predictability of the stratosphere and stratosphere-troposphere coupling on S2S timescales. Both to appear in the S2S special issue of JGR.
 - Papers evaluate: Skill of stratosphere vs troposphere and their relationship, signal to noise ratio, predictability of vortex events in the NH/SH, comparison of systems with high and low model tops, ability to capture precursor patterns to SSWs, ability to capture teleconnections (ENSO, QBO, MJO), ability to capture amplification of stratospheric signal at surface, evaluation of changes in predictive skill following strong and weak vortex.
- Inspiring a greater focus on studying extra-tropical dynamics on the S2S timescale.
 - A significant number (~10) of the S2S papers in the special issue have a link to SNAP.
 - At our recent joint meeting with DynVar, there were a large number of talks and posters on initialized prediction and that used the S2S database in particular.

Leads: Andrew Charlton-Perez, Amy Butler

Progress and Achievements

Atmospheric dynamics and predictability

SOLARIS-HEPPA: Solar Influences for SPARC

- Solar variability is a source of decadal climate predictability (Kushnir et al. 2019)
- Solar signals very difficult to separate from internal climate variability (progress in how to extract solar-induced dynamical signals in WG4: methodology)
- SOLARIS-HEPPA WG meeting in Granada, Spain
 - 18./19. September with 17 participants (7 remotely)
 - report on the Granada Working Group meeting submitted for publication in the upcoming SPARC Newsletter

Leads: Katja Matthes, Bernd Funke

Progress and Achievements

Atmospheric dynamics and predictability

S-RIP: SPARC Reanalysis Intercomparison Project

- S-RIP covers all aspects of atmospheric dynamics that can be approached with global atmospheric reanalyses.
- The SPARC S-RIP Report manuscripts (Chapters I-II) were submitted to the SPARC Office for the review process on 25 November 2019.
- The inter-journal special issue on "The SPARC Reanalysis Intercomparison Project (S-RIP)" in Atmospheric Chemistry and Physics (ACP) and Earth System Science Data (ESSD) currently has 36 published/accepted papers and one paper under review (as of 18 November 2019).

Leads: Masatomo Fujiwara, Gloria Manney, Lesley Gray

Future Plans

Atmospheric dynamics and predictability

- **Reanalysis intercomparisons of upper stratosphere/lower mesosphere (DAWG)**
 - Will use independent data sets (e.g., lidar ozone and temperature, meteor radar wind profiles, etc.) for validation
 - A report on these intercomparisons for a select period (e.g., NH winter during a major stratospheric sudden warming) by end of third quarter 2020.
 - May make sense to merge with S-RIP moving forward.
- **Dynamic diagnostic output for CMIP6 (DynVarMIP)**
- **Increased focus on the troposphere and extremes**, while maintaining a home for stratosphere dynamics and stratosphere-troposphere coupling (DynVar)
 - Workshop in 2022: bring together stratosphere and extremes communities
 - Community paper: dynamical contributions to extremes

Future Plans

Atmospheric dynamics and predictability

- Focused effort to document and understand (a) **fine-scale structures** in the vicinity of the tropopause and (b) **dissipative processes** in the atmosphere and their treatment in global models (FISAPS)
 - 2-day FISAPS meeting either before or after 2020 AOGS meeting in Seoul, Korea
 - Planned paper on gravity wave treatments in high-resolution models (joint with Gravity Waves and WGNE)
- Understanding **Orographic Gravity Wave Stress and Drag** (Gravity Waves)
 - 2-4 publications from model/obs comparisons and validated model analyses
 - ISSI Team meeting in March 2020
 - Future joint workshop with Pan-GASS project on Surface Drag and Momentum Transport
 - SPARC Gravity Wave Symposium, Frankfurt, Germany Sep 27-Oct 1 2021

Future Plans

Atmospheric dynamics and predictability

- Understand mechanisms controlling the relationships of ozone to dynamical coordinate variables, i.e. **effects of circulation and transport on ozone (OCTAV-UTLS)**
 - ESSD paper explaining the updated JETPAC output products and showcasing some of the dynamical coordinates selected to reduce ozone variability in the UTLS
 - 3rd OCTAV-UTLS workshop planned for 2-5 March 2020
- Understand how **QBO influences seasonal to decadal prediction (QBOi)**
 - Major workshop in 2020 to commemorate 60th anniversary of discovery of QBO.
 - Phase two experiments and a model nudging experiment protocol (in collaboration with SNAP) are being developed
 - Review paper on recent QBO understanding (submitted by end of 2020)
 - 2 further papers extending QBOi analysis to CMIP6

Future Plans

Atmospheric dynamics and predictability

- Finalize reports on **stratospheric reanalysis** products (S-RIP)
 - S-RIP report will be published
 - 5-10 more papers in ACP/ESSD special issue expected
 - Scaled-down activity until 2022, with plans to evaluate new reanalysis products at that time.
- Understand **downward influence of the stratosphere on tropical convection** through multi-scale interactions (SATIO-TCS)
 - Two separate review papers in preparation
 - Workshop Feb 21-25 2020, “VCRP/SPARC SATIO-TCS joint workshop on stratosphere-troposphere dynamical coupling in the tropics”, Kyoto, Japan

Future Plans

Atmospheric dynamics and predictability

- Understand **stratospheric influence on tropospheric predictability** on S2S timescales (SNAP)
 - Additional community paper on stratosphere-troposphere coupling biases in S2S prediction systems
 - Develop protocol for nudging experiments (joint with QBOi) to determine response of extratropical jets to an imposed stratospheric forcing through damping in forecasting systems. Work with operational forecasting centers to perform experiments.
- Extract **solar-induced dynamical signals and their influence on decadal climate predictability** (SOLARIS-HEPPA)
 - HEPPA-SOLARIS workshop, Bergen, Norway, June 8-10 2020

Future Science Questions for this Theme

Atmospheric dynamics and predictability

- How do we better quantify **uncertainties** in reanalyses?
- How can data assimilation improve **seasonal prediction** of dynamical/photochemical processes affecting polar stratospheric **ozone**?
- How does **Brewer-Dobson circulation** in reanalyses respond to a **changing climate**?
- How do we formulate dynamic processes in forthcoming **ultra-high resolution** models?
- Which aspects of stratosphere simulation are most important for simulating **surface impacts**?
- If model tops are raised to the mesopause, are **gravity wave parameterizations** able to respond appropriately on S2S and climate timescales?
- What are the **coupling mechanisms** linking composition, radiation, and dynamics in the **UTLS** to global scale dynamics and climate?
- What is the **climate feedback** to changes in the UTLS composition across scales?

Future Science Questions for this Theme

Atmospheric dynamics and predictability

- Are QBOs in climate models simulated for the right reasons? What are the causes of common biases found in models? Can climate models accurately represent **QBO teleconnections**?
- Can we understand what drives changes in **QBO** under climate change forcings? Is predictability of the QBO and its teleconnections realized in seasonal to decadal forecasting systems?
- How important is resolving the **Whole Atmosphere** (mesosphere-stratosphere-troposphere) for predictability across timescales?
- Can we quantify how much **predictive skill** can be gained from stratospheric variability on S2S or longer timescales?
- Can we improve **near-term prediction of regional climate and extremes**? How?
- What can we say about regional climate change from a dynamical perspective?
- Why do models predict what they predict? What are **robust versus model-dependent** changes?

Possible Collaborations to Pursue

Atmospheric dynamics and predictability

- Regional climate and extremes community
- Storm tracks community (workshop in 2021, Corsica)
- IGAC (and in general, the chemistry community)
- Aviation community (FISAPS)
- Expanding collaboration to developing and international programs/institutions (including public, private, and non-profit) that may benefit from information about climate dynamics
- WGNE = Working Group on Numerical Experimentation
 - e.g., QBOi suggested working with them on development of high resolution or convection-permitting models in order to reduce the dependence of simulated QBOs on parameterizations
- Highlighting SPARC's contributions to IPCC and WMO/UNEP ozone assessments
- Mesosphere-stratosphere-troposphere (MST) radar community, NDACC
- WWRP/WCRP S2S project
- CLIVAR/GEWEX/CliC- where are the interfaces between atmospheric dynamics and ocean/ice/hydrology that SPARC is uniquely capable of addressing?

What direction would you like to see SPARC move forward to?

- Increased **interaction** among activities (more joint webinars or workshops).
- Support for **fundamental research** and arguing against using poorly understood aspects of model simulations for impact studies.
- Retaining focus on **basic science** issues that underpin **climate modelling**.
- **Process-level** understanding to improve physics in models for timescales from long-range weather to climate.
- Maintain current **diverse** portfolio of SPARC activities. Smaller, **focused** groups often work best.
- SPARC-centered activities at major conferences should be organized and **travel support** for early-career and keynote speakers should be offered.
- Maintain role of focusing on the **underpinning science**, which is essential for delivering broader WCRP objectives.
- Improve **capacity-building** activities.
- Continue **bottom-up** approach to answering science questions. SPARC works well through a combination of match-making and ground-up initiatives- continue this.
- More emphasis on **fostering engagement with society**.
- **Infrastructure** aspects (i.e. the role of SPARC data centre) could be reinforced.

Other Comments on WCRP plans

Atmospheric dynamics and predictability

- Need to identify how SPARC can specifically address IP's key science questions.
- Continued **long-term measurements** of stratosphere is needed; future of these observations from satellites is in doubt. WCRP plans should address this.
- SPARC should emphasize that **underlying science issues** must be understood before reliable science advice can be given.
- Plan should address future increases in **higher resolution climate models** and the new science issues that will arise.
- Work of SPARC naturally fits within WCRP SP objectives 1, 2, and 3. But SPARC needs to secure **funding** to continue supporting workshops/assemblies which generate collaboration.
- Top-level goals of WCRP are honorable and much needed, but **IP must address how these goals will be implemented and funded.**

Other Comments on WCRP plans

Atmospheric dynamics and predictability

- We appreciate that greater understanding of the climate system requires knowledge of sources and sinks of water, energy and carbon, but also that flows are generally mediated through changes to drivers of *momentum* which are most readily identified as waves/eddies and their accompanying teleconnections. **Atmospheric Dynamics** should be emphasized.
 - To more efficiently address our activities objectives, it would be beneficial that these ideas should explicitly appear in the WCRP Strategic Plan 2019-2028 text, specifically on page 11.
- Defined project goals and lifecycles are important but **community** is equally so (and arguably results in greater collaboration and output). WCRP isn't a funder of science but both the SP and IP read like it is. WCRP funds collaboration.