

Summary Report of the 21th International TOVS Study Conference (ITSC)

The International TOVS Working Group (ITWG) brings together operational and research users and providers of infrared and microwave satellite sounding data. It is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the Coordination Group for Meteorological Satellites (CGMS). The ITWG organises International TOVS Study Conferences (ITSCs) which have met approximately every 18 to 24 months since 1983. Through this forum, relevant experts exchange information on all aspects of the data processing and use, with a focus on inferring information on atmospheric temperature, moisture, and cloud fields. This includes evaluation of new data, processing algorithms, derived products, impacts in numerical weather prediction (NWP) and climate studies. The group considers data from all sounding instruments that build on the heritage of the TIROS Operational Vertical Sounder (TOVS), including hyperspectral infrared instruments.

This Working Group Report summarises the outcomes of the Twentyfirst International TOVS Study Conference (ITSC-XXI) hosted by EUMETSAT in Darmstadt, Germany between 29 November and 5 December 2017. The ITWG Web site contains electronic versions of the conference presentations, posters and publications which can be downloaded (<http://cimss.ssec.wisc.edu/itwg/>). Together, these documents and web pages reflect a highly successful meeting in Darmstadt.

The International TOVS Working Group (ITWG)

Summary Report of the 21th International TOVS Study Conference (ITSC)

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1. INTRODUCTION AND OVERVIEW

The twentyfirst International TOVS Study Conference, ITSC-21, was hosted by EUMETSAT at the Darmstadtium conference centre in Darmstadt, Germany, between 29 November and 5 December 2017. This time, 180 participants attended the Conference from 49 organizations, providing a wide range of scientific and technical contributions. Eighteen countries and three international organizations were represented: Argentina, Australia, Brazil, Canada, China, Czech Republic, France, Germany, India, Italy, Japan, Norway, Russia, South Korea, Spain, Taiwan, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. Working Groups were formed for key topic areas, leading to very productive discussions.

Apart from excellent support by the local hosts, EUMETSAT, ITSC-21 was sponsored by industry and government agencies. The industry and government agencies included: ABB, Exelis, Harris, Météo France, NOAA/JPSS Program Office, NOAA/GOES-R Program Office, Orbital Systems, SCISYS, and the World Meteorological Organization (WMO). The great success of ITSC-21 was largely thanks to the excellent work of the local organizing committee from EUMETSAT, Sylwia Miechurska, Anne-Marie Andrieux, Julija Mataityte, and Dr Dieter Klaes, as well as the invaluable administrative and logistical support provided by Leanne Avila, Maria Vasys and Dr Allen Huang at SSEC.

The conference was held only two weeks after two significant polar satellite launches, of FY-3D by CMA and JPSS-1/NOAA-20 by NOAA, and about a year after the launch of the first geostationary satellite carrying a hyperspectral infrared instrument (FY-4A of CMA). First results of the ATMS instrument on NOAA-20 were shown (almost) as they came in from the satellite, suggesting expected good performance, and initial evaluations of the hyperspectral IR instrument on FY-4A gave the community a first chance to

appreciate this new capability. Preparations for EUMETSAT's Metop-C (due for launch next year), EPS-SG, and MTG are also providing promising perspectives, as do valuable contributions from Russia, India and Japan. The recent and upcoming launches are testament of a growing diversification of providers, instruments and technology used for passive sounding data, making international coordination of the global satellite observing system all the more important. International coordination to protect relevant microwave frequencies from radio frequency interference (RFI) was also a key topic, prompted by the upcoming World Radiocommunication Conference in 2019.

The group again expressed a strong requirement for state-of-the-art infrared and microwave sounders in at least three complementing orbital planes, and fully supports CMA's efforts to cover the early morning orbit starting with FY-3E. The wide uptake of FY-3 data among international NWP centres establish CMA as a leading provider of satellite sounding data with global reach. Concepts are emerging to provide observations with higher temporal frequency, either through geostationary sounders or through fleets of satellites (e.g., cubesats), and international real-time data exchange and efficient use of such data is essential for optimal exploitation of these resources.

The meeting saw significant progress in enhanced calibration/validation of satellite data and long-term climate data records, not least through fruitful interaction of the NWP and climate communities. The use of metrological approaches combined with reference observations are leading to better quantitative evaluations. These highlight more clearly where better knowledge or reduction of uncertainties is required, for instance in the area of radiative transfer or ocean surface emissivity modelling. Improvements in retrieved products are also more fully appreciated through these calibration-validation efforts. A strong climate session highlighted how well-calibrated data records can be used for trend detections and process studies. A well-attended evening workshop was organised by the EU-funded GAIA-CLIM project to showcase enhanced validation of satellite data through a combination of NWP and reference observations.

Prompted by calibration/validation efforts and new applications in cloudy areas, there was renewed activity regarding improved radiative transfer, recognising the need for improved spectroscopy and better uncertainty characterisation for enhanced quantitative use of sounding data. Initial work towards better uncertainty characterisation was presented, for instance, regarding line mixing in the important 50 GHz temperature-sounding band and the 183 GHz humidity sounding region. Growing accuracy demands, particularly from NWP, are calling for more work on radiative transfer aspects.

Several presentations again demonstrated the critical importance of satellite sounding data for Numerical Weather Prediction and highlighted the growing sophistication of assimilation approaches. The active assimilation of cloud or precipitation affected radiances is becoming a wide-spread operational activity at several NWP centres, particularly for microwave radiances, but promising activities are also emerging for the infrared. Treatment of uncertainties, both random and systematic, continues to be a hot topic, with renewed attention to the role of forecast model bias in adaptive bias correction schemes. Treatment of three-

dimensional effects and the actual viewing geometry are starting to receive attention, aimed at reducing errors in the forward calculations for radiance assimilation. The use of reconstructed radiances for the efficient assimilation of the full spectral information contained in hyperspectral infrared radiances is showing promising results. Impact studies also demonstrate that assimilation of passive sounding data provides key 3-dimensional information on wind analyses in modern assimilation systems, for instance through the ability to trace humidity structures in 4D-Var. The optimal exploitation of this will become even more important with the provision of data with high temporal resolution, such as from geostationary sounders or fleets of cubesats.

Critically contributing to the successful data usage are the continued developments of processing packages such as the ATOVS and AVHRR Pre-processing Package (AAPP) and the Community Satellite Processing Package (CSPP). The developments of direct broadcast packages also underpin a continued strengthening of fast retransmission services which uses existing local ground stations to process locally received data and to re-distribute it via the GTS to achieve a timeliness of 30 min or better through the DBNet initiative of WMO. The inclusion of software to process Russian satellite data from the Meteor-M N2 series was encouraged for active exploitation of the promising data source.

Most of the meeting was organized in fifteen sessions of oral presentations and associated poster papers. This comprised of 63 longer format oral presentations and 132 poster papers. Each poster was introduced through a short verbal summary to highlight the scientific content. The range of issues covered in oral presentations and posters included the following:

- Current, new and future observing systems and calibration/validation;
- Operational reports from space agencies and NWP centres;
- Data assimilation applications;
- Climate applications;
- Processing software systems;
- Advanced Sounder science;
- Radiative transfer developments;
- Cloud and precipitation applications; and
- Retrieval science.

Working Groups were formed to consider six key areas of interest to the ITWG, including:

- Radiative Transfer,
- Climate,
- Data Assimilation and Numerical Weather Prediction,
- Advanced Sounders,
- International Issues and Future Systems, and
- Products and Software.

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary session at the end of the conference. Working Group reviews and recommendations comprise an important part of the ITSC-21 Working Group Report. A summary of the key recommendations and actions arising from the conference is presented below.

Activities that had taken place since ITSC-20 in Lake Geneva, Wisconsin were presented in a dedicated session of Working Group status reports. Technical sub-groups also met during ITSC-21 to discuss developments and plans concerning specific software packages, shared and in common use.

A special oral session honoured the contributions from Paul van Delst, a long-standing member of the ITWG community and co-chair of the Radiative Transfer Working Group, who sadly passed away last year.

The conference agenda and all of the talks and many of the posters can be viewed at the ITWG Web site, located at <http://cimss.ssec.wisc.edu/itwg/itsc/itsc21/program/index.html>

2. SUMMARY OF MAJOR CONCLUSIONS

The ITSC-21 presentations, posters, Working Group meetings and discussions documented significant issues in many areas and identified areas for future activity. The full list of action items and recommendations can be found in the detailed reports from each working group. The main conclusions and recommendations are summarised below.

Observing system evolution:

1. **To CGMS and other satellite agencies:** The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.
2. **To CGMS and other satellite agencies:** Noting the growing evidence of likely benefits from hyperspectral geostationary soundings, ITWG recommends where possible to work towards the provision of such instruments in plans for future geostationary systems.
3. **To CGMS, other satellite agencies, and users:** ITWG recognises the opportunities arising from the provision of sounder data from small satellites as supplements to the global observing

system, particularly for better temporal sampling. ITWG recommends the evaluation of such missions by appropriate agencies, including already planned missions (e.g., TROPICS).

4. **To CGMS and other satellite agencies:** Instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored, in support of maintaining a robust global satellite observing system.
5. **To CGMS and other satellite agencies:** ITWG recommends to develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.
6. **To satellite agencies:** Consider implementing high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.
7. **To CGMS and other satellite agencies:** Climate applications should be appropriately represented during the planning for new meteorological satellite missions.
8. **To space agencies and all agencies involved in GRUAN/ARM:** ITWG recommends to expand the provision of GRUAN and ARM sites, noting the continued need for and scarcity of ground-based reference measurements.

International coordination, DBNet, frequency protection:

9. **To WMO/CGMS and other satellite agencies:** ITWG recommends to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members. ITWG strongly encourages all agencies to actively contribute information to this portal.
10. **To satellite agencies:** to ensure that provision of Spectral Response Functions for MW instruments is routine practice, particularly for future instruments. This is required to facilitate RFI investigations when needed, and to allow optimal radiative transfer calculations. SRFs should be provided on the SATURN portal, including for current and old sensors.
11. **To the NWP community and other relevant agencies:** in support of continued efforts for frequency protection, national meteorological services should attempt to provide an assessment of the economic value of bands based on an impact assessment, as was done by the Met Office in 2005.
12. **To WMO/stations participating in DBNet:** ITWG continues to support low-cost fast delivery initiatives such as DBNet and welcomes recent extensions to further sensors. ITWG recommends more stations to consider contributing FY-3 sounder data.
13. **To Roshydromet:** Roshydromet are encouraged to release a direct broadcast processing package for the Meteor-M N2 series, including level 1 processing for the MTVZA-GY microwave imager.

Data provision:

14. **To satellite agencies:** For new sensors, pre-launch test datasets should be provided well before launch, in order to allow software development teams (e.g., AAPP, OPS-LRS, CSPP) and other operational users (e.g., NWP centres) to test processing software before satellite launch. New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.
15. **To satellite data providers:** The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.
16. **To satellite agencies:** ITWG recommends open access to new satellite data during the calibration/validation phase (particularly for all NWP centres) to help with calibration and validation.
17. **To CMA:** Consider making available as soon as possible the GIIRS hyperspectral data on FY-4A and of HIRAS on FY-3D to the international user community.

18. **To WMO/CGMS/space agencies:** ITWG supports initiatives to make data from R&D and pre-operational missions available, with a timeliness suitable for operational near-realtime applications. We re-emphasize best practise is to consider timeliness requirements early in the planning stage of new missions, including for research and pre-operational missions, and note that high reliability levels (e.g. >95%) do not need to be a requirement at the pre-operational stage or for short-term research missions.
19. **To CGMS satellite agencies and other data providers:** Advance notifications of processing changes should be an integral component of data provision. If a planned change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
20. **To CMA:** Consider implementing a subscription-based anomaly/event notification service, similar to that provided by NOAA and EUMETSAT.

Radiative transfer, optimizing return on investments:

21. **To IRC and agencies involved in radiative transfer developments:** ITWG strongly recommends continuous efforts in radiative transfer modelling developments, especially regarding:
- Line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models.
 - Development of reference-quality ocean-surface emissivity modeling, specifically Infrared, Microwave, for both active and passive simulations.
 - Extension of the frequency range of scattering models to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels).
22. **To IRC and agencies involved in spectroscopy research and radiative transfer development:** ITWG strongly recommends continuous support of theoretical and laboratory spectroscopic studies to improve the accuracy of fundamental parameters required for radiative transfer calculations (e.g., research into spectroscopy of higher frequency microwave channels up to 1000 GHz), as well as efforts to map uncertainties in spectroscopy into radiance uncertainties.
23. **To funding bodies of NWP centres and satellite agencies:** consider, as part of the cost of satellite sounding programs, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

3. FUTURE PLANS

Following the established practice, the group held elections for the future co-chairs of the group after ITSC-21. Anyone who has attended at least three meetings was eligible to vote or stand as candidate. From the five excellent candidates, Liam Gumley (SSEC) and Vincent Guidard (Météo France) were duly elected. ITWG co-chairs are expected to represent and lead the group for the next three conferences.

The next ITSC is expected in 2019. In the meantime, ITWG will continue to inform the infrared and microwave sounding community of the latest news and developments through its Web site (maintained by the University of Wisconsin-Madison/CIMSS) and via the email list (also maintained by CIMSS).

4 ACKNOWLEDGEMENTS

This report relied on the active participation of all ITSC attendees and those working group chairs. We acknowledge that writing of this report is possible only through the collective work of ITWG members.