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INTERNATIONAL CORE STEERING COMMITTEE FOR THORPEX

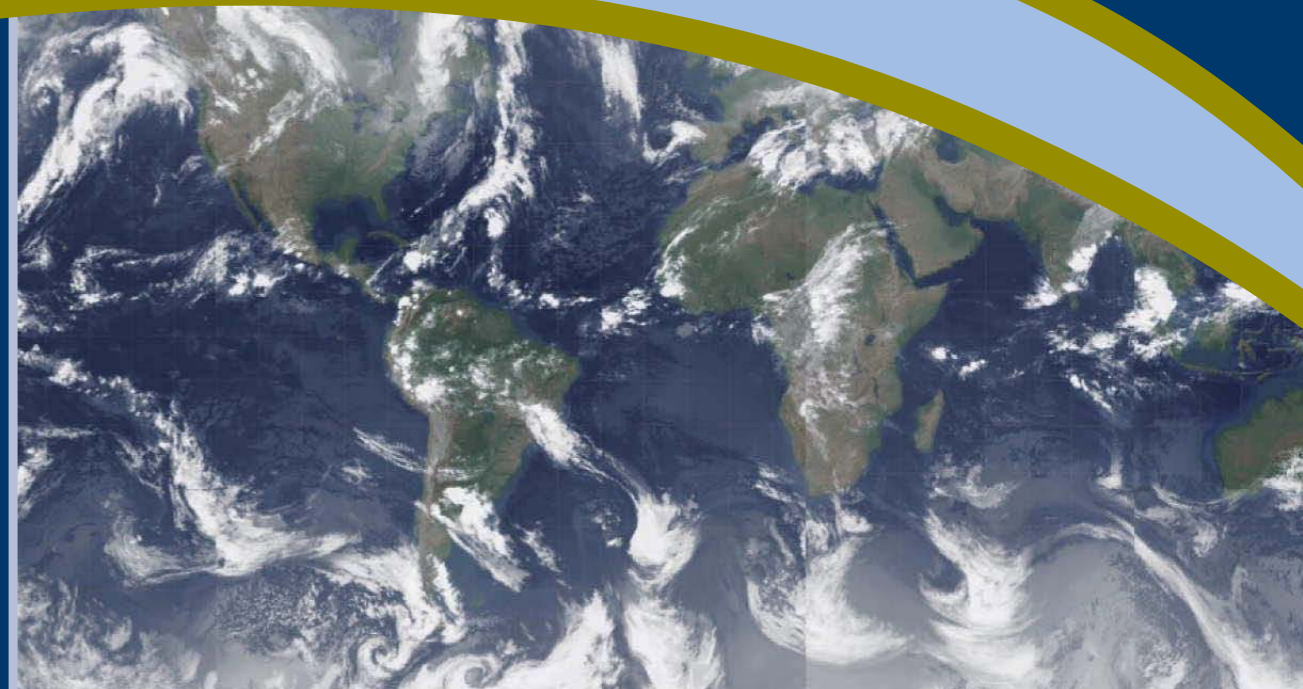
Ninth session
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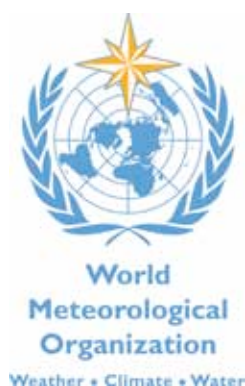
INTERNATIONAL CORE STEERING COMMITTEE FOR

THORPEX

NINTH SESSION

(GENEVA, SWITZERLAND 21-22 SEPTEMBER 2011)

FINAL REPORT



EXECUTIVE SUMMARY

The ninth session of the CAS International Core Steering Committee (ICSC) for THORPEX was held at the World Meteorological Organization Geneva from the 21-22 September 2011. The ICSC proceeded with the work assigned by the CAS, the WMO Executive Council and the World Meteorological Congress. This included reviews of the progress in planning and further development of THORPEX on the global and regional level, financial and administrative matters related to THORPEX management, the International Programme Office (IPO) and the Trust Fund. All documents and presentations considered and discussed at the ICSC9 may be downloaded from <http://www.wmo.int/thorpex>



Participants at the ninth session of the CAS International Core Steering Committee (ICSC9) for THORPEX, 21-22 September 2011, World Meteorological Organization, Geneva, Switzerland

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GENERAL SUMMARY OF THE WORK OF THE MEETING

1. ORGANIZATION OF THE SESSION

1.1 Opening of the Session

1.1.1 The ninth session of the CAS International Core Steering Committee for THORPEX (ICSC 9) was opened by Dr Alan Dickinson (Chair of the ICSC) at 09.00am on Wednesday the 21 September 2011 at the Headquarters of the World Meteorological Organization, Geneva. He invited Dr Deon Terblanche, the recently appointed Director of the ARE, to address the meeting. The Director welcomed participants and expressed his gratitude on behalf of the WMO for the time they had set aside for the meeting. He especially welcomed the Presidents of the CBS and CAS. He noted that THORPEX was a very important programme of the WMO and element of the WWRP and said that great progress had been made in recent years. There were exciting opportunities ahead and he thanked the parent organizations of the participants for their continued support to the programme.

1.2 Adoption of the agenda and working arrangements

1.2.1 The ICSC adopted the agenda (as listed in the contents page above) and agreed the working arrangements for the meeting.

2. REPORTS

2.1 Report of the Chair (CAS/ICSC9/Doc.2.1)

2.1.1 The Chairman noted that it was nearly two years since the ICSC had met and intended that there would not be such a long gap until the next meeting. In the meantime, there had been meetings of CAS and Congress which had considered the work of the THORPEX Programme. The resultant actions were reflected in the Agenda and would be reviewed later. Significant progress was being made and he congratulated all those involved in the programme.

2.1.2 Between the meetings of the ICSC, the THORPEX Executive Committee had continued to monitor progress made with all the activities and had kept the financial situation of the Trust Fund under close review.

2.1.3 The Chairman then invited the participants to use the time available to best effect and keep presentations short and to focus on the key areas, especially on those issues on which the Committee was asked to take a decision or mandate an action.

2.1.4 He then drew special attention to the document provided for the meeting concerning the mid-term review. He thanked Dr David Burrige for preparing this report and for his long standing contributions to the programme as manager of the IPO. There was the issue of the legacy from THORPEX – especially key successes and achievements. It was very important that these are well captured in the mid-term review. They would naturally lead to consideration of post-THORPEX arrangements and projects. The Chairman then said that it was important to begin consideration of these matters in the very near future. He wished the thinking process to begin at this meeting. The ICSC agreed to continue discussion of the THORPEX legacy under Agenda item 9.

2.1.5 The decisions and actions from ICSC 8 were discussed. Many had been completed and work was progressing satisfactorily on the remainder. The permanent ICSC actions were noted.

2.2 Report by the President of CAS (CAS/ICSC9/Doc 2.2)

2.2.1 The President of CAS, Dr Michel Beland, noted the main points of interest for THORPEX arising from CAS XV and Cg XVI. He was pleased that a draft paper on the mid-term had been tabled for discussion and congratulated the Secretariat on the rapid progress now being made to establish the sub-seasonal and polar prediction projects. The reorganization of the WWRP JSC was complete and had proceeded smoothly. The President stressed the importance of effective liaison with the WCRP on topics of common interest. Overlaps should be avoided and good collaborative activities developed.

2.2.2 The Congress welcomed the activities of the THORPEX Regional Committees, Working Groups and field campaigns and offered overall support for the programme. It also endorsed the concept of seamless prediction as the way ahead for the future and invited CAS to move this forward with the NMHSs. The science pointed clearly in this direction. The Congress also especially thanked all those member countries that supported the THORPEX Trust Fund. This support was essential to the continuation of the programme.

2.2.3 Concerning the Global Framework for Climate Services, the President encouraged the meeting to identify activities that could be fed into this initiative. He felt that THORPEX was well positioned to do this.

2.3 Report from the fourth meeting of the WWRP/JSC (CAS/ICSC9/Doc 2.3)

2.3.1 Dr Gilbert Brunet, the Chairman of the WWRP JSC introduced this topic. Following CAS XV the JSC had been re-structured and was now composed of ten independent scientists. The last meeting had taken place in February 2011 and the full report was tabled at this meeting and available on the WMO website. He noted that the WWRP provides an overarching framework for the many Working Groups and activities e.g. concerning nowcasting, mesoscale and tropical meteorology, verification research, SERA etc., as well as THORPEX. He was particularly concerned to encourage the Working Groups to liaise together.

2.3.2 He reviewed the highlights of WWRP activities in some detail e.g. related to the SOICHI RDP/FDP, GIFS-TIGGE developments, the results from major field campaigns and the SDS-WAS. The IPY cluster of projects had proved to be a critical test-bed for evaluation of model performance in polar regions. Also, the MAP-D Phase in conjunction with the E-TReC, had proved a great success and demonstrated how to carry out effective research on the mesoscale. In the nowcasting area the trend was increasingly towards more reliance on numerical methods. Dr Brunet then noted the early plans being put together for an Earth System Prediction Conference in 2013. This would require the full participation of the whole WWRP community, including THORPEX. It could be a useful forum to discuss the legacy of THORPEX and future arrangements (for example, concerning data assimilation) that should be put in place at the end of the programme.

2.3.3 He was pleased to note that the Verification Working Group had held workshops on new techniques and that these had been very well supported with participants from 24 countries. The

SERA Working Group was now in the process of establishing close links with the relevant areas of ICSU.

2.3.4 The development of the WWRP Strategic Plan was then outlined including the links to the GAW and the important cross-cutting elements such as improved weather-climate collaboration. The next meeting of the JSC would review the Plan and consider what progress had been made to achieve the objectives and outcomes desired.

2.3.5 In discussions, the meeting returned to the question of the THORPEX legacy. The President of CBS noted that this was an extremely important topic (including the matter of the potential “operational” legacy) and he looked forward to further debate at this meeting.

2.3.6 Dr Tetsuo Nakazawa then outlined the discussion at JSC 4 related to the THORPEX Working Groups. The JSC acknowledged the valuable work carried out by the DAOS WG and recommended establishing good links with the Mesoscale and Nowcasting WGs. It supported publication of the review of targeting in BAMS and a more detailed WMO Report and encouraged close links with groups involved in land surface assimilation. The JSC commended the work of the PDP WG and noted that it was tackling some of the main mission objectives of THORPEX. It noted that boundary layer moisture and cold air outbreaks were important areas to concentrate on. It also urged improved understanding of model errors and noted that the extensive YOTC data sets may help in the regard. The JSC noted the great progress that had been made by the GIFS-TIGGE WG and expressed the hope that archiving of the TIGGE data sets would continue despite the increased volumes of data. It emphasized the importance of enhancing close links with the SWFDPs as prototype ensemble products were developed. It also felt that there was a lack of relevant resources in the S. Hemisphere and implementation of GIFS in association with the SWFDPs could help in this regard.

2.4 THORPEX Progress Reports

2.4.1 Report from the IPO (CAS/ICSC9/Doc. 2.4.1)

2.4.1a Dr Tetsuo Nakazawa introduced document 2.4.1. He reviewed the schedule of meetings that had take place since the ICSC had last met. These amounted to around 26 meetings. He noted some of the highlights such as the PDP Workshop on the diagnosis of model errors and Workshops on Sub-seasonal and Polar Prediction. These latter had been very valuable in charting a way forward for these projects. He also noted that all the Working Groups had met recently and final reports would be placed on the website when available.

2.4.1b He then reviewed the status of the Trust Fund and drew attention to the position at the end of 2010. In response to a question he said that 6 countries had contributed to the Trust Fund during 2010. The situation in 2011 was not yet fully clear and would be discussed further under Agenda Item 6.

2.4.1c In discussion it was noted that the YOTC MJO TF meeting planned for October 2011 in association with the WCRP OSC was not listed in the programme of meetings.

Decision/Action ICSC9 (1): *Add the YOTC MJO TF meeting to the list of WWRP meeting relevant to THORPEX in 2011.*

2.4.1.1 Mid-term Review (CSA/ICSC9/Doc. 2.4.1.1)

2.4.1.1a Dr David Burridge introduced the draft report. He noted that ICSC 8 had asked that the report should be prepared by the IPO in consultation with the Working Groups, the Regional Committees and the PIs of the field experiments. It should record the major successes of the programme, the challenges for the future and indicate possible future directions. This first draft had been prepared on the basis of the inputs received. Some inputs had been delayed and there may still be a need to add any missing material.

Decision/Action ICSC9 (2): *Solicit and supply outstanding contributions to the Mid-term Review.*

2.4.1.1b Dr Burridge then noted that it was possible to present the material in many different ways but felt it was most effective to put the main data sets and field campaigns up front in the document. Thus the first Part of the document considers TIGGE, A-TreC, AMMA, T-PARC , IPY, YOTC etc., before turning to the Working Groups and looking at the possible future topics such as the polar and sub-seasonal prediction projects. It was suggested that the THORPEX data sets may well be one of the greatest legacies from the programme. Part 2 of the document considers the work of the Regional Committees. All RCs had produced very good Science and Implementation Plans, although in some cases implementation of planned activities was rather slow and patchy.

2.4.1.1c In terms of the successes of the programme it was noted that:

- THORPEX had raised the profile of the whole issue of predictability research beyond a few days
- It had carried out major field campaigns e.g. A TReC, E-TReC and T-PARC Summer and Winter
- Made a major contribution to AMMA through the THORPEX –AMMA WG
- Set up and maintained the important TIGGE archives
- Created the IPY cluster of projects
- Promoted research in data assimilation and made great progress in understanding the impacts of observations in NWP systems and investigated the utility of targeted observations in NWP.
- Set up the successful YOTC project jointly with the WCRP
- Contributed to planning for T-NAWDEX
- Held 3 major International Science Symposia, summer schools, workshops etc

2.4.1.1d THORPEX was a 10-year programme and it had entrained nearly all the acknowledged experts in the field. It was now important to look to the future and generate new ideas for future projects. In discussion, the ICSC thanked Dr Burridge for the draft report and agreed that it was now necessary to finalize the report. The ICSC agreed that a revised draft should be put to the WWRP JSC 5 meeting scheduled to take place in the spring of 2012.

2.4.1.1e Following discussion a series of actions was agreed

Decision/Action ICSC9 (3): *The ICSC members are invited to review and provide comments on the mid-term Review to the IPO by the 31 October 2011.*

Decision/Action ICSC9 (4): Add a section to the report concerning the E-TReC (Sarah Jones to provide the key results to the IPO).

Decision/Action ICSC9 (5): Develop a revised version of the mid-term review based on the ICSC comments and add an Executive Summary especially noting THORPEX achievements and benefits.

Decision/Action ICSC9 (6): Distribute the revised mid-term review to WWRP JSC members for comment in January 2012 and table a revised version for discussion at the WWRP JSC 5 meeting in the spring of 2012.

Decision/Action ICSC9 (7): Further revise the mid-term review in the light of comments received from the WWRP JSC 5 and table a “final” version at ICSC10 in autumn 2012.

2.4.2 Report from PDP Working Group (CAS/ICSC9/Doc. 2.4.2)

2.4.2a Dr Istvan Szunyogh noted that the main task of the PDP WG was to identify research problems with significant importance for NWP and to accelerate the transfer of these new techniques from academia to operational practice. They were intent on bringing together the academic community with the NWP centres. The WG had held two meetings, one in July 2010 and the other in July 2011. Close collaboration was maintained with WGNE and two Workshops had also been organized.

2.4.2b The first was held at ETH Zurich jointly with the WWRP and WCRP and considered the diagnosis of model errors. This was a very important topic and a fruitful area for collaboration with WGNE. The models still have large errors and it's essential to have available tools to diagnose these errors and provide useful feedback to model developers. In this regard, the WG had decided to concentrate on two phenomena, the Indian Summer Monsoon and Cyclonic Systems. Neither are well handled in current NWP systems.

2.4.2c The second, larger, workshop was held at the ECMWF. It lasted for one week and attracted more than 100 participants. It was devoted to considering the representation of model uncertainty and error in weather and climate models. A full report will be published by ECMWF towards the end of September 2011.

2.4.2d It was also noted that for convection, radiation and the boundary layer parameterization should be done in a stochastic fashion and this remained an ongoing subject for research. Similarly, the representation of model errors and uncertainties in ensembles and data assimilation needed further work.

2.4.2e The international summer school on “atmospheric predictability” in Banff was reviewed. It had been a very effective event, each lecturer gave several presentations and a considerable number of posters displayed current research interests. There had been more than 100 applications to attend leading to the selection of 32 students who were offered places. The next school is planned for 2013 in the Swiss Alps. A detailed proposal will be written for this event.

2.4.3 Report from the DAOS Working Group (CAS/ICSC9/Doc 2.4.2)

2.4.3a Dr Roger Saunders described the role of the WG which was to address data assimilation issues, promote research into the better use of observations in NWP systems and to provide guidance to THORPEX field campaigns. He noted that there had been two recent meetings of the WG, in Montreal in July 2010 and Exeter in June 2011.

2.4.3b He reviewed the work carried out by the group to better understand the impact of observations in NWP using adjoint sensitivity tools. The impact of observations on short range forecasts was very similar across major NWP centres. The largest impacts were now from AMSU-A radiances, satellite cloud motion winds etc., although the global radiosonde network and data from aircraft continue to make a significant contribution to the overall impact. The UK Met Office results showed that MetOp-A provided around 24% of the total impact. These results are very helpful to space agencies and others involved with developing and maintaining in-situ data networks.

2.4.3c The ConcordIASI experiment was outlined. This had taken place over Antarctica and provided unprecedented data coverage across this extremely remote and very data sparse area. Errors in NWP models tend to be higher in this region. There had been 19 flights of super-pressure balloons each carrying dropsondes which provided around 640 profiles. The coverage over Antarctica was excellent. Adjoint sensitivity calculations show that the dropsondes have a generally positive impact on the 24h forecast error. Assimilation of the gondola data in the stratosphere also has a generally positive impact. Analyses showed that the models have problems with temperatures close to the surface of the Antarctic plateau. The models also showed major errors where strong gravity waves occurred in the stratosphere. WGNE is aware of these results and close collaboration between the groups will be maintained (Florence Rabier is a member both of DAOS and WGNE).

2.4.3d The effectiveness of ground based GPS total column water vapour in NWP was noted. It is also a very cost effective system. However, only the data from the European E-GVAP network were widely available. Data from other parts of the world were not easily accessible in Europe.

Decision/Action ICSC9 (8): *The USA and Europe are encouraged to promote the wider exchange of GPS data. Zoltan Toth and Roger Saunders are asked to take the lead.*

2.4.3e It was also noted that only one scatterometer ASCAT was now available following the loss of QuikSCAT. However, data from the scatterometer on the Indian Oceansat II was proving to be of good quality and was being further assessed prior to operational implementation. It was very encouraging that other countries were beginning to provide high quality valuable data for the global observing system.

2.4.3f The increasing use and value of weather radar data was discussed. Verification of global NWP model precipitation forecasts is needed but the fact that the data is held in different formats does not help international exchange. The ICSC encouraged continuation of the activities (mainly within CBS groups) that would ultimately lead to easier exchange of radar data.

2.4.3g Finally, some of the future interests of the WG were outlined. These included the need to further investigate the ESA wind lidar due to changes in its sampling, address activities in soil

moisture and temperature and consider new observations for convective scale models. The DAOS statement of need for specific additional in-situ data from aircraft and radiosondes in several geographical areas to improve global NWP was described.

2.4.3h The DAOS was also comparing and contrasting current and new data assimilation systems including 4D-VAR with different options of inferring the background errors and the new EnKF systems. It had also requested a review of the nomenclature for the various data assimilation systems both in current use and under development as it can be confusing for non-scientists.

Decision/Action ICSC9 (9): *The President of CBS encouraged the DAOS WG to maintain close links with ET-EGOS concerning the evolution of the GOS and the definition of optimal global observational networks.*

2.4.3.1 DAOS Working Group Review of Data Targeting (CAS/ICSC9/Doc. 2.4.3.1)

2.4.3.1a Dr Saunders introduced the paper on the impact of targeted observations on NWP which was written and co-ordinated by Sharan Majumdar. The intention was to publish the full version as a WMO report and a shorter version in BAMS. He illustrated the positive impact of additional dropsondes on the forecast track of tropical cyclone Irene. However, there was no improvement in the forecast intensity of the storm probably due to the models not accurately capturing entrainment of dry air into the system. It was also noted that impacts vary from model to model, for example, typically impacts of targeted observations in the KMA system for the summer T-PARC period are larger than those found by JMA.

2.4.3.1b It is clear that the impact on TC tracks was positive but that the impact of targeted data on the mid-latitudes although generally small and positive were much more variable. It has also been shown that the impact of targeted data in sensitive areas was higher than from randomly selected areas. In the future, it would be useful to look at the impacts on EPS systems and consider the influence of targeted data on longer range forecasts. Also, there is the issue of targeting for predictions on the mesoscale. The DAOS WG intended to look at these topics at future meetings.

2.4.3.1c In conclusion, Dr Saunders noted that the DAOS WG was the leading group in data assimilation within the WMO and had strong links to WGNE, ET-EGOS, SPARC and GLASS. The WG intended to strengthen links with the MFWG and was exploring the possibility of a joint session with this group in 2012. The members felt that the mix of data assimilation and observational topics was important and wished to continue with the current remit. However, there was a now a need to begin to consider arrangements post THORPEX.

2.4.3.1d During the discussion the current position on re-running some USA WSR data was raised. It was noted that this was now to be undertaken by ECMWF but it was not clear at this stage when the results would be available. Also discussed was the matter of designing optimal observational networks for medium range NWP forecasts. It was noted that EUCOS has carried out a number of OSEs in this area with the intention of optimizing the network over Europe and the Atlantic Ocean. One example of progress being made is that EUCOS is beginning to install humidity sensors on aircraft to provide data to supplement the radiosonde network over Europe.

2.4.3.1e Within the WMO the CBS group ET-EGOS is responsible for the future design of the global observing system (GOS). They have published a "vision" for GOS in 2025 and an

associated Implementation Plan. The DAOS WG worked closely with ET-EGOS to ensure that recent scientific results were taken into account in ET-EGOS plans and recommendations. The President of CBS urged that these very close links should be maintained.

Decision/Action ICSC9 (10): *The ICSC encouraged the DAOS WG to consider DA for convective scale models (e.g. for clouds and precipitation).*

2.4.4 Report from the GIFS-TIGGE Working Group (CAS/ICSC9 Doc. 2.4.4)

2.4.4a Dr Richard Swinbank introduced this topic and began by expressing the thanks of the whole Working Group for the excellent service provided by his Co-Chair Dr Zoltan Toth. He noted that because of a change in his responsibilities Dr Toth had decided to stand down as a Co-Chair. The ICSC also expressed thanks to Dr Toth for his long standing service to the WG. Dr Swinbank noted that the WG proposed Dr Young-Youn Park from KMA as the replacement for Dr Toth.

2.4.4b An overview of the TIGGE project was provided. Archiving continued at the three archive centres of the data provided by the ten global production centres. The data sets were being widely used by researchers. More than fifty papers have appeared in the literature. There were generally around sixty active users each month. Large volumes of data were being accessed mainly at NCAR and ECMWF. The TIGGE website at ECMWF had been upgraded to facilitate ease of access and upgrades were also taking place at NCAR and CMA.

2.4.4c The TIGGE-LAM Panel was now organized on a regional basis. It was expected that work on archiving data from limited area ensembles would begin soon in Europe.

2.4.4d A good deal of effort had been devoted to publicizing the TIGGE archives. A new leaflet was available and had been widely distributed at meetings and conferences. TIGGE had also figured prominently in the GEO book "Crafting GEO Information" that was presented to Ministers at the last GEO Plenary.

2.4.4e The focus for the TIGGE WG was increasingly turning to research and development. Initially the effort was devoted to establishing the archive systems. The WG now wished to consider issues such as the combination of multi-model ensembles, calibration, bias correction, probabilistic products etc i.e. to focus on downstream processing. They also wished to look at how to improve the EPS systems themselves through consideration of initial conditions, model errors, verification of ensemble forecasts (with the JWGFR), seamless forecasting (linking to the proposed sub-seasonal project), convective scale ensembles and improvement of EPS skill and products.

2.4.4f Turning to GIFS, Dr Swinbank noted that the primary objective was to realize the benefits of probabilistic products for operations. Initial interests were related to tropical cyclones, heavy precipitation and strong winds. Real progress was being made in developing experimental products e.g. at JMA/MRI and ESRL. Examples of work by Mio Matsueda were shown concerning multi – model probabilistic products of heavy rainfall etc. Cases shown included predictions of extreme rainfall in S Africa (which resulted in severe flooding) compared to TRMM data. The potential for severe weather was identified in the forecasts up to nine days ahead and improved as the lead time reduced. For TCs it was noted that generally the 3 day forecast for the track was very good but intensity remained a problem. Higher resolution models would probably be needed to progress in this area.

2.4.4g The WG was establishing close links with the CBS SWFDP projects and WWRP FDPs/RDPs to begin to trial and test prototype probabilistic products. However, the WG wished to maintain a good balance between TIGGE EPS research and product development. Their intention was to improve product documentation, build close links with users, seek feedback from the RSMCs involved in the SWFDPs, to provide training via SWFDP programmes and ultimately implement real time products in conjunction with the SWFDPs.

2.4.4h The EC GEOWOW project was then outlined. This contained a significant weather element which was led by the ECMWF. It would help achieve many of the objectives of the TIGGE WG including further improvement of the ECMWF archive to enable time series data to be easily extracted.

2.4.4i In discussions, it was noted that the TIGGE archives were set-up for research and development purposes. They were not intended for real time applications. It was noted that once ensemble products had been developed, tested and evaluated and there was agreement for introduction to operational use then suitable arrangements to access the ensemble data in real time would need to be made. This would probably be best done through the SWFDPs who already had in place agreements with NMHSS to obtain real time access to EPS data.

Decision/Action ICSC9 (11): *The ICSC encouraged the GIFS-TIGGE WG to continue to build and strengthen links with the SWFDPs and continue the development of probabilistic products for assessment and evaluation*

Decision/Action ICSC9 (12): *The ICSC invited the GIFS-TIGGE WG in conjunction with the SWFDPs to consider processes that would eventually allow the operational implementation of selected products.*

Decision/Action ICSC9 (13): *The ICSC noted and endorsed the proposed changes to the membership of all the THORPEX WGs.*

2.5 Report from the WWRP/SERA Working Group (CAS/ICSC9/Doc. 2.5)

2.5.1 Brian Mills introduced the work of the SERA group. He discussed the enormous damage from natural disasters and noted that a significant number of these were due to meteorological events. More effort was needed to track avoidable loss since this would enable assessment of the value of services to be estimated.

2.5.2 The purpose of the WG was to advance socio-economic research and applications. Discussions with ICSU concerning establishing closer links with the Integrated Research and Disaster Risk (IRDR) programme were continuing. The focus of the group was on high impact weather i.e. injury, loss of property, outbreaks of disease, disaster preparedness and recovery plans.

2.5.3 The WG had been active across a number of areas. Work is proceeding on an external SERA web site linked to the WMO WWRP site. Development of a publication on the applications of sub-seasonal to seasonal weather and climate predictions was continuing. A guidance document was being prepared that would help projects include a SERA element. A SERA experts and practitioners meeting is being planned for Melbourne in 2012.

2.5.4. The WG plans to work with the Co-Chairs and volunteer members of the JWGVR to develop a small focussed TIGGE project related to TC tracks or heavy precipitation.

2.5.5 Also proposed is a SERA Research Demonstration Project (RDP) – *Understanding the societal and economic dimensions of weather related warning systems*. The SERA WG recommends that it become the general research and application framework within which specific SERA studies would be identified and developed e.g. for the Sochi 2014 Olympics, the Coastal Inundation FDP etc., etc.

2.5.6 It was noted in discussions that the added value from forecast improvements is a difficult topic that requires further work. The SWFDPs who have good links with end users could be useful for studies in this area.

2.6 WCRP update

2.6.1 Dr Ghassem Asrar, Director of the WCRP, provided an update on current and planned activities. The World Climate Research Programme coordinates international climate research, modelling and analysis to improve climate predictions and our understanding of the human influence on climate for *“use in an increasing range of practical applications of direct relevance, benefit and value to society”* (WCRP Strategic Framework 2005-2015). He briefly outlined the WCRP Implementation Plan 2010 – 2015 which includes the interdisciplinary nature of climate science, meeting the needs of society for climate information and activities supporting WCRP integrating themes.

2.6.2 The main activities of the WCRP in 2010/11 were outlined. These included climate modelling coordination (CMIP5, CHFP), regional modelling and analysis, (CORDEX), Global data sets & reprocessing of GEWEX observations, the polar Predictability Initiative, Drought & Extremes Workshops, Reanalysis – plans for a major conference in May 2012 and the WCRP planning for future the Open Science Conference. Concerning modelling he noted that there was a real challenge to bring together all the various strands within the WCRP. Work was spread across many areas so it had been agreed to introduce a Modelling and Data Council for the WCRP. The WCRP was also developing a transition plan to move from WOAP to a Data Council that would coordinate research on observations and the new observations needed for climate research, especially for process understanding and model development.

2.6.3 Some areas of co-operation with WWRP/THORPEX were then outlined. These included YOTC, polar research and modelling, sub-seasonal and seasonal weather and climate, atmospheric chemistry and climate, education and capacity development and potentially Geo-engineering. The good progress with YOTC was noted especially the Giovanni data dissemination framework and setting up of an MJO Task Force, which would meet at the OSC. Particular topics that he wished to see addressed in a collaborative way included ocean-atmosphere coupling and the impact on sub-seasonal skill, the role of resolution on forecast skill, scale interactions and ensemble techniques.

2.6.4 It was noted that the polar prediction research projects being initiated by WCRP and WWRP THORPEX should be especially carefully co-ordinated. Close co-operation was essential. It was recognized that the WCRP Climate Historical Forecast Project (CHFP) could provide a valuable baseline assessment of seasonal forecasts since it had more than of 10 years of the best available models and observational data.

2.6.5 In discussions, it was noted that the modelling work would stay in the current location and that the Council would provide a light touch co-ordination over the top. It would liaise closely with WGNE.

2.7 Report from the President of CBS

2.7.1 The President of CBS emphasized the importance of THORPEX achievements and welcomed the draft document on the mid-term review. There were two main concerns, firstly the potential operational legacy and secondly strengthening the links with relevant CBS groups.

2.7.2 It was noted that ensemble forecasting had blossomed but many NMHSs are still not able to take advantage so capacity building remains important. The proposed sub-seasonal and polar prediction projects were very exciting and it was important to ensure appropriate links with the Global Framework for Climate Services and to deliver near time successes. There is a real challenge to bring the research and operational communities together as this work moves forward.

2.7.3 The opportunity to integrate THORPEX research into the work of WIGOS and the GFDRP was noted. It was essential to build on the research and bring forward new products that could be made available to support and improve predictive services.

2.7.4 The next WMO Congress will take place in 2015 and by then a very effective well thought through proposal for post THORPEX arrangements will need to be tabled. Hence, preparations should begin very soon and could be based on the mid-term review to create a sustainable research programme to support operational activities into the future. To meet Congress timescales final documentation must be available in 2014. A multi-faceted group would be best to take this forward.

2.7.5 The President noted that the sub-seasonal to seasonal and polar projects should be careful to address user needs. The global centres need to see benefits from providing feedback and national and regional centres need to be involved to maintain and develop the necessary observational networks. It was also very important to recognize the roles for the academic research community and governments.

2.8 SWFDPs

2.8.1 Peter Chen introduced this topic. The intention was to improve warning services in developing countries. The 2007 Congress had adopted the vision for the project. It also fitted with two of the WMO strategic thrusts i.e. improved service quality and service delivery as well as improving capacity building activities in forecasting and warning services.

2.8.2 Effort was being devoted to improving services, lead times and the interaction of NMHSs with end users. There were now initiatives in S. Africa, the South Pacific Islands, S.E Asia, E. Africa and (next year) in the Bay of Bengal. More than 40 countries were now participating of whom 20 were least developed countries. The projects organized a data flow from the global to regional and the NMC level. The NMCs remained responsible for the issue of forecasts and warnings within national boundaries. Regional Centres provide a key role in offering guidance and additional products to NMCs. Project Management groups decide what new products will be introduced employing formal change management methods. The SWFDPs in TC basins work also closely with the TC programme.

2.8.3 It was recognized that GIFS-TIGGE research could in principle add important new ensemble products. There was also the need to deal with the short range using e.g. improving

satellite imagery tools. The SWFDP focus was very much on high impact weather out to 5 days ahead e.g. flash floods, heavy rain and strong winds. Also required were training programmes for forecasters and managers. There were identified gaps in expertise and skill in relation to tropical convection, the rapid on-set of severe weather and a general lack of appropriate forecasting tools.

2.8.4 Concerning links with the WWRP it was noted that the essential links were with the GIFS-TIGGE WG and on verification, nowcasting research, sub-seasonal activities and on SERA related topics. The GIFS products being developed were especially interesting. It was expected that these would be evaluated by the Pretoria regional Centre within the S. African SWFDP.

2.8.5 During discussions, it was noted that not all developing countries were moving ahead at the same rate and there was a need for the SWFDPs to focus on those that were falling behind. There may be a need to introduce “advanced” and “less advanced” categories. The overall objective was to achieve sustainable progress and for the countries to become self-sustaining. It was noted that training sessions last two weeks with the second week devoted to disaster managers.

2.8.6 Finally, it was recognized that verification activities were lagging behind. Laurie Wilson was introducing an initiative in this area to get feedback from a range of forecasters and to try to obtain a dedicated person for this general work.

3. THORPEX FIELD EXPERIMENTS

3.1 T-PARC and TCS 08 (CAS/ICSC9/Doc. 3.1)

3.1.1 Pat Harr introduced the main conclusions from these experiments There had been excellent near worldwide participation. A real time “virtual” operations centre had operated in Monterey. Dropsondes were flown from Hawaii, aircraft were based in the W. Pacific and over 500 missions had been flown through 11 tropical systems. The experiment was unique and has achieved a number of “firsts”,

- It was the first operation of the dropsonde
- The first use of ELDORA Doppler radar in typhoons
- The first buoy drops directly in front of a Cat. 5 typhoon
- The first use of C130 aircraft at 31,000ft in this role
- The first four plane systematic targeting
- And the first systematic observations of the full tropical cyclone genesis, evolution and ET process

The main thrust of the T-PARC project was the study of the character of the typhoon as it moved into the mid-latitudes and to examine the important process carefully using all available data sources. Also to study the entire life cycle of tropical storms – this was achieved for SINLAKU which was monitored from beginning to end.

3.1.2 The value of aircraft data in understanding eye-wall replacement processes was well illustrated. An outer eye wall forms and chokes off the inner wall. The use of radar, dropsonde and aircraft data enables successful simulation of this eye wall processes. After replacement the storm increased in intensity. With data from only one flight simulation is not successful.

3.1.3 Recurvature and ET were studied by aircraft based east of Japan. The downstream impacts were being studied using TIGGE data showed increased ensemble variability due to ET. The processes that might contribute to this variability were being studied including the vigorous updrafts that form and the effects due to mid-latitude baroclinicity. ELDORA data were proving valuable to see how the structure of the storm changes as it interacts with the mid-latitudes. East of Japan the system changed from a warm to cold core. Aircraft data is also helping to understand why the predictability is lower downstream. The YOTC data sets are also proving helpful.

3.1.4 The TCS 08 field campaign was also outlined. Since 2008, the two programmes have resulted in a large number of publications in the literature. TCS 08 had also been a very successful field programme which focused on the early stages of storm genesis and evolution. A distributed data archive was available at NCAR. Process studies were being carried out and use of the NASA Giovanni system was proving useful. A special issue of BAMS was planned that would include about 30 papers from the 3rd THORPEX International Science Symposium.

3.2 T-NAWDEX PLANS

3.2.1 The programme was delayed due to issues with availability of aircraft. It was concerned with the factors that may disturb the N. Atlantic waveguide such as ET, polar outbreaks etc., and the potential downstream effects over Europe. The basic idea was to study the forcing over the western Atlantic and the USA and then consider the downstream impacts over Europe.

3.2.2 A two page prospectus is being prepared for all potential investigators. Following this a full proposal will be drafted for a field campaign in 2014 -2015.

3.3 DIAMET (CAS/ICSC9/Doc 3.3)

3.3.1 The contents of Document 3.3 were noted. DIAMET was a part of the UK NERC Storm Risk Mitigation Programme. It involved numerical weather prediction for increased understanding of, and the capability to predict, mesoscale structures in extra-tropical cyclones.

3.3.2 DIAMET field campaigns were being conducted in 2011/2012 using the FAAM BAe 146 research aircraft. The main area of operation is southwest of England. It is still possible that the DLR Falcon will take part in the 2012 flights providing LIDAR measurements of water vapour. A contact point for DIAMET is John Methven at the University of Reading.

4. REGIONAL DEVELOPMENTS AND ACTIVITIES

4.1 African Regional Committee (CAS/ICSC9/Doc. 4.1)

4.1.1 Dr Aida Diongue-Niang introduced the report and noted the somewhat poor performance of NWP and climate models over Africa. THORPEX Africa aims to improve forecasts and help to reduce the impacts of severe weather over the continent. Detailed Science and Implementation Plans were published in 2009 and distributed to all African NMHSs. The Committee had decided to focus on PDP and SERA activities and to assist with this had made plans to develop a High Impact Weather (HIW) information system. At a meeting hosted by ICTP in 2009 a better picture of the various types of high impact weather across Africa was established. This included dry spells, tropical cyclones, flooding, sand and dust storms, landslides, heat waves and heavy precipitation.

4.1.2 The HIW weather information system was intended to contain information on selected case studies of extreme weather to facilitate PDP and SERA studies. Funding bids had not been

successful so the work was proceeding slowly using available resources. Data was being collected for the selected case studies. Also, regional coordinators had been appointed to take forward the cases within their areas and to link with NMHS contact points. The activities included HIW event description and database design, assessment of forecast skill and modelling activities. A case study for W. Africa was described in which 261mm (two thirds of the annual rainfall in Burkina Faso) had fallen in 10 hours. This was associated with easterly waves and a very wet spell in the western Sahel.

4.1.3 An East African case was then outlined. In this event (which occurred in October 1997) between two and ten times the mean monthly rainfall had fallen. Another extreme event had occurred in S. Africa due to a cut off low and this caused widespread severe flooding.

4.1.4 However, due to the lack of available resources progress with the case studies was slow. Work was still in the initial phases and the active participation of the Regional Committee was disappointing. To properly establish the database the efforts of a dedicated person for some time would be required.

4.1.5 Progress with THORPEX Africa had been reviewed at a meeting at the WMO in July 2011. There was a need to try and re-vitalize the project and to engage additional resources. To improve the situation it was agreed that THORPEX Africa activities should be better linked to operations. A template to report HIW would be designed and distributed. Some near time verification will be attempted. It was planned to do some work to customize TIGGE products for application and evaluation in Africa. A small meeting was planned early in 2012 to move these issues forward.

4.1.6 During discussions, the WGs were encouraged to help promote the case studies and encourage participation in them. It was also felt appropriate to try and engage other people in Africa in the work, especially from the Universities. Close links with the SWFDPs in Africa were also encouraged as was initiation of similar activities outside areas currently covered by the projects.

Decision/Action ICSC9 (14): *Develop a list of key Africa NMHS, other government and university contacts with both the interest and capacity to participate in THORPEX Africa case studies and R and D.*

Decision/Action ICSC9 (15): *Request all the THOPREX WGs to examine how they can further develop activities to assist the Africa RC (e.g. case studies/demonstration projects, training, capacity building, data etc.,).*

Decision/Action ICSC9 (16): *Utilize the PDP website to post information about the case studies, African RC plans and contact points.*

Decision/Action ICSC9 (17): *Distribute past unsuccessful funding proposals developed by the Africa RC, THORPEX IPO and others to ICSC member.*

Decision/Action ICSC9 (18): *Develop/support/fund networking opportunities for African researchers on request and on a case-by-case basis.*

Decision/Action ICSC9 (19): *Establish collaborations with the on-going African SWFDPs and the West Africa RSMC.*

4.2 Asian Regional Committee (CAS/ICSC9 /Doc. 4.2)

4.2.1 Dr Tsuyuki introduced the Asian report. This Committee has met 7 times and organized three successful Asian THORPEX Science Symposia. The intention was to hold a symposium about every 2 years. At the 7th meeting in Korea it had been agreed to form WGs on NWP and GIFS-TIGGE topics. The ARC also offers strong support to the S.E. Asian SWFDP. It plans to meet again in Tokyo in December 2011 in association with the 2nd Asian Satellite Users Conference.

4.2.2 Brief reports from the members of the ARC were then provided. China had successfully co-organized the 1st YOTC International Science Symposium which was held at the CMA Conference Centre from the 16 to 18 May 2011. There was now more involvement in the international activities of the THORPEX programme and a new website was in operation (www.thorpexchina.org.cn). Support was provided to the Shanghai World Expo 2010 and the Guangzhou Asian Games 2010. Field campaigns formed an important part of THORPEX China plans. Included in these were the Observation Experiment of Mesoscale Predictability on Summer Rainstorms in the Beijing area, the South China Heavy Rainfall Experiments (SChEREX). China also plans to carry out research into key applications of ensemble predictions using the TIGGE database. For the future, it is intended to increase support for THORPEX projects, enhance the Beijing TIGGE archive centre and carry out the Third Tibetan Plateau Experiment.

4.2.3 India was carrying out an FDP concerned with tropical cyclones over the N. Indian Ocean which involved additional measurements from ships and buoys. It was also implementing a project to provide an early warning system of storms in E. India.

4.3.4 Recent updates to the Japanese EPS system were outlined. The MRI has operated a tropical cyclone ensemble forecast information website since May 2010 which was proving very interesting and exciting. A TIGGE monitoring and verification website is also maintained and this site compares the ensemble forecasts produced by the TIGGE data centres. It includes an increasing selection of verification statistics. Japan provides considerable support for the SE Asia SWFDP and is preparing a website to provide the probability of extreme events such as heavy precipitation based on TIGGE data within the area of interest. Japan is also carrying out basic studies on tropical cyclones and research on predictability which have resulted in several publications in the literature. JMA provides TC tracks based on TIGGE CXML data.

4.2.5 Korea is building a national network of radars and in-situ data to improve forecasting of severe weather events. Special observation periods were being carried out. PROBX 2010 was a study of ensemble forecasting using TIGGE data. There are plans to develop a targeted observation system and expand ship based operations to provide more ASAP data in sensitive areas. PROBX 2011 will be focused on forecasting heavy snowfall.

4.2.6 Russia had carried out studies to optimize the Siberian radiosonde network. FROST 2014 was being developed to support the SOICHI Winter Olympics. This would be a mixed FDP/RDP.

4.3 European Regional Committee (CAS/ICSC9/Doc. 4.3)

4.3.1 Prof. Sarah Jones introduced the European report. The European plan had been completed and published on the web. It was a "living document" and would be modified as necessary. The regional Committee had been reformed. The Committee wished to engage other experts from the polar community, SERA specialists and scientists from Eastern Europe. It was clear that Europe was making a significant contribution to all THORPEX areas. Amongst the many

active topics were the Data Targeting System (DTS), TIGGE and TIGGE LAM, YOTC, PANDOWE, PREVASSEMBLE, DIAMET, GEOWOW, ConcordIASI etc.,

4.3.2 Results from the ConcordIASI experiment were outlined. This had been very successful and had provided unique data sets over very data sparse regions. Important results were now emerging. PREVASSEMBLE addresses theoretical ensemble methods for assimilation and prediction. It was a four year programme of the French Agence Nationale de La Recherche. Some of the interest areas for THORPEX are related to when ensembles saturate and theory of ensemble variational assimilation. It would also include quantification of model errors for ensemble prediction.

4.3.3 PANDOWE has received funding for a second three year period from 2011-2014. It has already resulted in 10 peer reviewed papers in the literature. The core priorities will continue from Phase 1 but plans have been made to address new THORPEX priorities such as sources of model error, seasonal prediction and the YOTC initiative. Some specific projects will include blocking, the Rossby waveguide, sub-seasonal time scales, stratospheric influences and the influence of tropical convection on mid-latitude prediction.

4.3.4 The benefits of the GEOWOW project were outlined as well as links to DIAMET and HyMEX and the DWD Hans-Ertel Centre for weather research (which involves the DWD, university groups and other research groups) and whose objectives link directly to THORPEX interests.

4.3.5 The regional meeting held from the 24-27 May 2011 in Karlsruhe had reviewed European aims in THORPEX and attracted 74 participants. Break-out groups made a series of recommendations in the PDP, DAOS and TIGGE areas. A number of overall recommendations emerged. These were related to cross-cutting topics between the WGs (e.g. ensemble DA and verification) and recommended that links between the WGs should be strengthened. It was recommended that a joint workshop with the Verification WG should be held. Also, it was suggested that links with SERA should be improved e.g. by developing projects related to renewable energy. Overall the meeting was considered very useful and it was hoped that others would be planned.

4.3.6 Regarding the THORPEX legacy, it was noted that the THORPEX framework has helped when writing proposals for funding since the topics could be placed in a truly international context. The legacy was very much related to getting research students interested in weather research. Enabling links with the operational community and providing access to models and data by the academic community had also been extremely beneficial.

Decision/Action ICSC9 (20): *The ICSC endorsed the new membership of the European Regional Committee.*

4.4 North American Regional Committee (CAS/ICSC9/Doc. 4.4)

4.4.1 Dr Zoltan Toth introduced document 4.4 on behalf of Malaquias Pena. He described the N. American contribution to the GIFS-TIGGE project. NCAR continues as an archive centre and is upgrading facilities. It was now almost possible to do a science study just using the facilities offered by the website. NAEFS is an operational multi –model system supported by the USA, Canada and Mexico. This forecast system is being improved through the inclusion of new variables, testing and implementation of a downscaling procedure and expansion of the NAEFS membership to include the NOGAPS ensembles.

4.4.2 Winter T-PARC was briefly outlined. It considered the impact of targeted observations in the Pacific on high impact weather over N. America. NOAA, Environment Canada, Russia, and Japan played a leading role. There was a link with the Winter Olympics. The data sets have now been archived by NASA.

4.4.3 N. America also contributed to many other activities including the THORPEX IPY cluster of projects and YOTC. Concerning IPY contributions were made to TAWEPI, STAR and ConcordIASI. In relation to YOTC it was noted that the YOTC Project Office was funded by NSF, NASA and NOAA. High resolution NWP data had been provided by NASA and NCEP.

4.4.4 The last meeting of the NARC took place in Cuernavaca, Mexico in May 2010 and was held in association with the 5th NAEFS Workshop. This was a huge success with more than 100 participants. A Mexican THORPEX Committee has now been formed. Regional model inter-comparisons were taking place and close links with TIGGE –LAM being set up. The next NARC meeting would be in Monterey, USA in Spring 2012 again to be held in association with a NAEFS Workshop. Consideration was being given to setting up an SWFDP for Mexico and Central America.

4.4.5 The US THORPEX Executive Committee comprised four agencies, NASA, NOAA, NSF and the US Navy. Major investments, amounting to \$20M had been made since 2004 as well as significant in-kind contributions to field campaigns. Major changes were however now taking place. The NASA Weather Application Programme was suspended and THORPEX no longer appeared in the NOAA budget. There could therefore be no promise of a contribution to the Trust Fund in future years.

4.4.6 The US THORPEX Science Plan was now approved and available on the web. The US THORPEX Science Steering Committee was being re-constituted and would meet in November 2011. Edmund Chang and Malaquais Pena were the Co-Chairs. A US Implementation Plan was being formulated and it would seek to match academic interests with funding opportunities. The areas being considered were moist processes, extending predictability, ensemble forecasting, observing and data assimilation optimization. There was a strong interest to link to possible European field campaign plans for 2015.

4.4.7 Dr Brian Mills then outlined N. American SERA topics. Some work had been devoted to addressing the SERA elements of the Mexican Plan. Activities in Canada were then outlined. The link to climate was emphasized since users generally required information on a wide range of time scales. The importance of establishing the economic value of weather forecasts was stressed and the added value from improvement in the quality of services. This could help justify additional investment in e.g. the provision of new satellites. There was a desire to see Mexico lead activities in Central America and to possibly build a wider membership of the NARC to cover interests in the region in a more comprehensive way.

4.4.8 In discussions, the potential ending of US contributions to the Trust Fund was a major concern. The ICSC urged the US representative to do all that was possible to continue some level of support. The assessment of the benefits of the US \$20M investment in THORPEX was queried. In response, it was noted that further work was needed to develop a comprehensive paper on this issue. It was suggested that the US THORPEX Executive Committee should follow this up.

Decision/Action ICSC9 (21): *The ICSC endorsed the NARC to approach South American countries about becoming involved in an expanded RC of the Americas given similar interests in Mexico, Central America and the Caribbean.*

Decision/Action ICSC9 (22): *NARC to request IPO support for attendance of Central American, South American and Caribbean participation in the next NARC meeting in Monterey (2012).*

4.5 Southern Hemisphere Regional Committee (CAS/ICSC9/Doc. 4.5)

4.5.1 A representative from the Southern Hemisphere Regional Committee was not available. The document was noted. The benefits of THORPEX in terms of scientific interaction and collaboration amongst Southern Hemisphere scientists were recognized. However, even with a modest plan progress was slow.

4.5.2 The intention was now to refresh the SHRC and take the opportunity to rethink and revitalize the current Plan and be even more focused on what can be achieved. The best opportunities are seen in leveraging the regional SWFDPs, including that in the South Pacific and in organizing scientific collaboration around the Met Office Unified Model.

4.5.3 The possibility of organizing the next WWRP SERA WG meeting, which would take place in Australia, in association with the SHRC was encouraged.

Decision/Action ICSC9 (23): *Investigate the possibility of combining the next WWRP SERA meeting with a THORPEX SHRC meeting.*

5. INTERNATIONAL COLLABORATION

5.1 GEO (CAS/ICSC9/Doc. 5.1)

5.1.1 Dr Jim Caughey introduced the document. The development of the new GEO Work Plan for 2012-2015 was noted. The Plan adopts a more target driven approach and has a three part structure devoted to infrastructure, institutions/ development and information on societal benefits. The number of GEO Tasks was being streamlined and reduced to 29 compared to the 44 in the current Plan. In addition, an improved Work Plan management structure is being introduced.

5.1.2 The GEO 2015 strategic target for Weather was noted. This would be achieved through the programmes of the WMO. The THORPEX activities will contribute to the achievement of this target in areas such data assimilation, modelling systems and verification and assessment.

5.1.3 There were several THORPEX projects that appear within the Plan. These were WE-01 C1 Global Multi- Model Prediction system for High Impact Weather (the GIFS-TIGGE activities) and WE-01 C2 Use of high Impact Weather Information (which involves, amongst other things, supporting the implementation of THORPEX Africa)

5.1.4 It was through EC funding for GEO implementation that a successful bid for GIFS-TIGGE development was made possible. The GEOWOW project involves further development of the TIGGE archive at ECMWF and testing and trialing of prototype products. It is expected to provide to provide a significant impetus to TIGGE plans and objectives.

5.2 WGNE (CAS/ICSC9/DOC. 5.2)

5.2.1 Dr Andy Brown, Co-Chair of WGNE, introduced Doc. 5.2 and noted that WGNE is jointly sponsored by CAS and WCRP and considers the development of numerical models for all timescales. Close links were maintained with many groups including WWRP and the THORPEX –

PDP WG, GEWEX, SPARC, and other WCRP programmes such as GCSS, GABLS and GLASS. Activities included the Transpose AMIP experiments and SURFA (surface fluxes), cloudy radiances (which was now complete), the “grey –zone” and high resolution AMIP. Verification was an important topic and the performance of NWP models was continuously assessed. The performance in models in polar regions and the development of climate model metrics were being addressed.

5.2.2 Very successful workshops have been held, in association with the PDP WG, at ECMWF and ETH Zurich. The next WGNE meeting was planned for October 2011. In the Spring of 2012, a meeting on the physics of weather and climate models was being arranged, followed by meetings on ocean coupling (also in 2012) and on atmospheric aerosol/chemistry for NWP and seasonal modelling (in 2013). WGNE therefore continued to maintain a wide range of interests.

5.2.3 Links with WWRP/THORPEX are considered crucial and there is desire to improve and extend these links to include the mesoscale WG, DAOS, YOTC and the JWVG. However, in relation to verification it was noted that WGNE did not really consider individual case studies but looked at overall statistics and model intercomparisons.

5.2.4 Considering post THORPEX arrangements, Dr Brown considered that it would not be appropriate for WGNE to become the focal point for data assimilation matters and that this would best be handled in a separate group.

5.3 YOTC (CAS/ICSC9/Doc. 5.3)

5.3.1 Dr’s Mitch Moncrieff and Duane Waliser introduced document 5.3. In 2007, the YOTC Science Plan was completed followed by a comprehensive Implementation Plan. A YOTC Project Office was now in place under the auspices of the US THORPEX Executive Committee. A website provided access to all YOTC documents meetings and future plans. The programme has been widely publicized at international conferences and the AGU. A YOTC session is planned for the AGU in December 2011. A highly successful First YOTC International Science Symposium was organized in Beijing in May 2011 and kindly hosted by CMA and the Chinese Academy of Science.

5.3.2 YOTC data includes global NWP fields from ECMWF, NASA and NOAA at high resolution. The data are available at NCAR. The NASA GIOVANNI satellite analysis and visualization system has been extended to support YOTC. The Cloud-Sat and A-Train data sets are now available to the community.

5.3.3 The YOTC “year” runs from May 2008 until April 2010 includes El Nino, La Nina and Arctic Oscillation conditions giving unique information on climate variability. There is a wide range of on-going collaborative work. This includes multi-model transpose-AMIP experiments, global cloud-system resolving experiments, tropical intra-seasonal multi-model 20year hindcast experiments with additional output and analysis focused on the YOTC period, extension of the GEWEX Cloud System Study (GCSS) for the June-August 2008 period and tropical-extra-tropical interaction studies.

5.3.4 YOTC has set up a Task Force to study the MJO (YOTC MJO TF). Four sub-projects were being implemented. These were related to diabatic processes, boreal summer forecasting metrics, process oriented MJO diagnostics and metrics to aid model development.

5.3.5 The priorities for the future include advocating YOTC at national and international levels and focusing on the YOTC/MJO TF/GLASS project “*Vertical Structure and Diabatic Processes of*

the MJO: A Global Model Evaluation". The next YOTC MJO Task Force meeting would be held in association with the WCRP OSC.

5.3.6 In discussions, it was noted that the ERA interim data does not contain the fluxes/fields needed to carry out process studies and the YOTC data sets are at higher resolution. It was also felt that the ESA satellite data records were not of much interest to YOTC since they were mainly monthly data. The issue of the influence of the MJO on TC frequency was also seen as an important topic for future investigation.

5.4 HYMEX (CASD/ICSC9/Doc. 5.4)

5.4.1 Dr Veronique Ducroq introduced HYMEX and said it was directed at improving understanding of the water cycle in the Mediterranean basin. The emphasis is on hydro-meteorological hazards and modelling the atmosphere-land-ocean coupled system on the event to seasonal and inter-annual timescales. The project runs from 2010-2020. Also included is the assessment of social and economic vulnerability to hydro-meteorological hazards. HYMEX is organized into a series of WGs which will focus on the water budget of the Mediterranean basin, the hydrological continental cycle, heavy precipitation and flash flooding and vulnerability factors and capacity building. The multi disciplinary research and databases within HYMEX are expected to improve observational and modelling systems (especially coupled systems), prediction of extreme events and the accurate simulation of the long-term water cycle and definition of adaptation measures.

5.4.2 The Science Plan was published in 2010 and a new version is expected at the end of 2011. Research field campaigns are interspersed with long observation periods. A comprehensive database has been established. The first Special Observing Period (SOP) (Sept. – Nov. 2012) will consider heavy rain and flash flooding. The second SPO will investigate air –sea exchanges and employ the Preview DTS system for data targeting (with EUCOS assistance) to provide upstream conditions. Flights by two aircraft were planned (the DLR Falcon and a French aircraft). About 50 flight hours would be available. Boundary layer balloons will be flown by CNES. Several islands will be instrumented. To measure air-sea fluxes light aircraft will be used along with buoys and ships.

5.4.3 Many modelling systems will be used for the SOPs and close links with the DAOS WG were sought. It was recognized that HYMEX would provide a good test bed for convective scale EPSs and coupled hydrological systems. However, there was no wetland modelling within HYMEX.

5.4.4 HYMEX was based on strong international partnerships and included many academic and operational organizations. It was noted in discussions that NOAA operates a Hydrometeorological Testbed (HMT) and there may be room to exchange ideas with HYMEX and to improve communications. It was also noted that several N. African countries were involved including Algeria, Tunisia and Morocco.

5.4.5 The HYMEX data policy was noted – all data are freely available after a period of two years. Within this period the data are restricted to those partners funding HYMEX.

5.5 Polar Prediction (CASD/ICSC9/Doc. 5.5)

5.5.1 Dr Gilbert Brunet described the recent activities to set up a polar prediction project. There was a desire to develop a legacy to the THORPEX IPY cluster of projects and to co-ordinate with

the WCRP, YOTC etc., A Workshop hosted by MetNo in October 2010 had been very valuable and made clear recommendations for the way ahead. Amongst these was the formation of a Steering Group (and appointment of a Chair person) to prepare an Implementation Plan. It was now agreed that Thomas Yung would assume the role of Chairperson. The membership of the Steering Group was being developed and would be available soon. A WMO consultant (Neil Gordon) will assist with the preparation of the Plan. It was recognized that it will be very important to co-ordinate the WCRP and WWRP/THORPEX Implementation Plans. Ted Shepperd was expected to assist from the WCRP side.

5.5.2 Vladimir Ryabinin described WCRP developments in this area. The Bergen Workshop had been useful in charting the way forward. There were still many problems with observations in the polar regions. Good coverage in the Arctic Ocean was still not in place. In the Southern Ocean, the situation is even worse. He also emphasized the need for close liaison between WCRP and WWRP/THORPEX in this area.

5.5.3 There was recognition that there was the possibility to set up a GIFS demonstration in association with WCRP polar project. TIGGE could provide useful input on the first 1-2 weeks timescale.

Decision/Action ICSC9 (24): *The ICSC endorsed the polar prediction project. It encouraged the WWRP and WCRP steering groups to co-ordinate their respective Implementation Plans and in particular to identify those activities that should be implemented jointly and those that are best tackled separately.*

5.6 Sub-seasonal prediction (CAS/ICSC9/Doc. 5.5)

5.6.1 Dr Gilbert Brunet introduced document 5.6. A meeting hosted by the Met Office in Exeter during December 2010 had made recommendations for the way ahead. This involved setting up a Planning Group to develop an Implementation Plan. This Plan should give high priority to a few international research activities, improving co-ordination with operational centres, facilitating wide use of the CHFP, TIGGE and YOTC data sets and developing a SERA component. Frederic Vitart (ECMWF) and Andrew Robertson (IRI) have been appointed Co-Chairs of the Planning Group.

5.6.2 The Planning Group will be supported by a WMO consultant (David Anderson). The Group will link to all relevant groups and initiatives including the YOTC MJO TF. It was noted that the project will need to link strongly with the operational centres and it was recognized that the two Co-Chairs should help ensure this was the case. There is also a need to fully engage the academic community. It was expected that the next ICSC would be invited to endorse the Plan as well as the WWRP and WCRP JSCs.

Decision/Action ICSC9 (25): *The sub-seasonal to seasonal project was endorsed with the understanding that closely related activities (e.g. those of the MJO Task Force) will be acknowledged and incorporated into the Implementation Plan*

6. PROGRAMME OF WORK FOR 2011/2012

6.1 The programme of meetings for the coming months was reviewed and ICSC members were invited to send revisions to the IPO. The budget for 2012 was discussed. It was noted that if some of the assumed contributions to the Trust Fund are not actually made then revision to the expected position at the end of 2012 will be required.

6.2 It was also noted that the costs of the kick-off meetings for the polar and seasonal projects will come from the budget of the Director of the ARE.

7. DECISIONS AND ACTIONS

7.1 The decision and actions arising from the meeting were reviewed and agreed upon and are summarized in Annex II.

8. DATE AND PLACE OF THE NEXT MEETING

8.1 It was agreed that ICSC10 would be held at the World Meteorological Organization (WMO) in Geneva during the autumn of 2012.

9. CLOSURE OF THE MEETING

9.1 Before closing the meeting the Chairman said he wished to return to the question of the THORPEX legacy and future arrangements. He noted that there are many dimensions to this issue. For example, there was the issue of the WG structure beyond THORPEX, the recognition that THORPEX had been valuable in attracting resources for weather research, the challenge of transitioning THORPEX research to operations and the need to identify the new science that needs to be carried out. A further THORPEX science symposium would be useful, either alone or in conjunction with another suitable event.

9.2 Congress had noted the need for an Earth-System prediction initiative to build upon the THORPEX legacy. The WWRP was discussing this topic and appropriate possible ways forward. It was also noted that there needed to be a clear process to consider options and prepare proposals for WMO bodies. This would require considerable time and a start should be made now.

9.3 The Chairman proposed that the task of preparing a position paper on this matter should be given to the THORPEX Executive Committee. The EC would consult and table a paper at ICSC10. This way ahead was accepted by the ICSC. All ICSC members are invited to send in their views and opinions on the way ahead.

Decision/Action ICSC9 (26): *The EC is invited to convene a meeting early in 2012 to discuss the THORPEX legacy and consider recommendations for the future. All ICSC members are invited to send the views on the way ahead to the IPO by the end of November 2011.*

Decision /Action ICSC9 (27): *The IPO should identify and evaluate opportunities for a Fourth THORPEX International Science Symposium either alone or in combination with other possible events e.g. the proposed WWRP OSC in 2013.*

INTERNATIONAL CORE STEERING COMMITTEE FOR THORPEX

NINTH SESSION

(GENEVA, SWITZERLAND 21-22 SEPTEMBER 2011)

List of Participants

Name	Email	Country
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LIST OF ACTIONS AND DECISIONS ARISING FROM ICSC 9

ICSC9 Action / Decision	Responsibility	Status
ICSC9 (1): Add the YOTC MJO TF meeting to the list of WWRP meetings relevant to THORPEX in 2011.	IPO	ASAP
ICSC9 (2): Solicit and supply outstanding contributions to Mid-term Review report	THORPEX WG Co- Chairs, project representatives, RC Co-Chairs, IPO	ASAP
ICSC9 (3): Review and provide comments (content/details) on the mid-term Review report to the IPO.	ICSC Members	31 October
ICSC9 (4): Add a section to the mid-term review concerning the E-TReC	Sarah Jones to provide key results and the IPO to incorporate	ASAP
ICSC9 (5): Develop a revised version of the mid-term Review report based on ICSC comments and add an executive summary especially noting THORPEX achievements and benefits.	THORPEX IPO	31 December 2011
ICSC9 (6): Distribute the revised mid-term review to WWRP JSC members for comment in January 2012 and table a revised version for discussion at the WWRP JSC 5 in Spring 2012.	THORPEX IPO, WWRP-JSC	Distribute January 2012 Discuss Spring 2012
ICSC9 (7): Further revise the mid-term review in the light of comments received from the WWRP JSC 5 meeting and present a "final" version to the ICSC 10 in autumn 2012.	IPO	Spring 2012
ICSC9 (8): The USA and Europe are encouraged to liaise concerning the issue of wider exchange of GPS data.	Zoltan Toth and Roger Saunders	ASAP
ICSC9 (9): The President of CBS encouraged the DAOS WG to maintain close links with EGOS concerning the evolution of the GOS and the definition of optimal global observational networks.	DAOS WG	On-going
ICSC (10): The ICSC encouraged the DAOS WG to consider DA for convective scale models (e.g. for clouds, and precipitation).	DAOS WG	Next meeting
ICSC (11): The ICSC encouraged the GIFS-TIGGE WG to continue to build and strengthen links with the SWFPDs and continue the development of probabilistic products for assessment and evaluation.	GIFS-TIGGE WG and SWFPDs	On going

ICSC9 Action / Decision	Responsibility	Status
ICSC9 (12): The ICSC invited the GIFS-TIGGE WG in conjunction with relevant SWFDPs to consider the processes that would allow the operational implementation of selected products.	GIDS-TIGGE WG and SWFDPs	On going
ICSC9 (13): The ICSC noted and endorsed the proposed changes to the membership of all the THORPEX WGs.	ICSC	Completed
ICSC9 (14): Develop a list of key African NHMS, other government, and university contacts with both the interest and capacity to participate in Thorpex African case studies, and R&D	African RC	December 2011
ICSC9 (15): Request for all Thorpex (and WWRP?) WGs to examine how they can further develop activities to assist the African RC (case studies/demonstration projects, training, capacity-building, data, etc.)	THORPEX WGs	On-going (make a focus at next respective WG meetings?)
ICSC9 (16): Utilize PDP web site to post information about African RC plan, case studies, and African contacts	African RC, PDP WG	Early 2012
ICSC9 (17): Distribute past unsuccessful funding proposal(s) developed by African RC, Thorpex IPO, and others, to Thorpex and WWRP WGs	African RC, THORPEX IPO	ASAP
ICSC9 (18): Develop/review/fund proposals to support networking opportunities for African researchers on request and on a case-by-case basis	African RC, THORPEX IPO	2012 fiscal year
ICSC9 (19): Establish closer collaborations with on-going African SWFDPs and West Africa RMSC	African RC	2012
ICSC9 (20): The ICSC endorsed the new membership of the European RC	ICSC	
ICSC9 (21): The ICSC endorsed the NARC to approach South American countries about becoming involved in an expanded RC of the Americas given similar interests to Mexico, Central America and the Caribbean	ICSC, NARC to follow-up with SA contacts	
ICSC9 (22): NARC to request for IPO support for attendance of Central American, South American and Caribbean participation in next NARC meeting in Monterey (2012)	ICSC, THORPEX IPO	
ICSC9 (23): Investigate possibility of combining next WWRP SERA WG meeting with a	Brian Mills, SHRC	

ICSC9 Action / Decision	Responsibility	Status
THORPEX SH RC meeting		
ICSC9 (24): The ICSC endorsed the polar prediction project. It encouraged the WWRP and WCRP Steering Groups to co-ordinate their respective Implementation Plans and in particular to identify those activities that should be implemented jointly and those that are best tackled separately	WWRP and WCRP Polar Project Steering Groups	Spring 2012
ICSC9 (25): The sub-seasonal to seasonal project was endorsed with the understanding that closely related activities (e.g., those of the MJO Task Force) will be acknowledged and incorporated into the Implementation Plan	Steering Group	January 2012
ICSC9 (26): The EC is invited to convene a meeting early in 2012 to discuss the THORPEX legacy and consider recommendations for the future. All ICSC members are invited to send the views on the way ahead to the IPO by the end of November 2011	EC and ICSC members	Early 2012 End of November 2011
ICSC9 (27): The IPO should identify and evaluate opportunities for Forth THORPEX International Science Symposium alone or in combination with other possible events e.g. the proposed WWRP 7)	IPO	Spring 2012

THORPEX MANAGEMENT STRUCTURE

(As agreed at the ninth session of the THORPEX ICSC)

1. THORPEX International Core Steering Committee

- i. **Representatives of Nations** (Canada, France, Korea, Russia, South Africa, Morocco, Japan, Australia, UK, USA, Germany, India, Norway, China) who have voting rights.
- ii. **Representatives of International Organizations and Committees** who have observer status - currently:
 - iii.

President of CAS	Michel Beland
EUMETSAT	Alain Ratier
EUMETNET	Stefan Klink
ECMWF	TBD
Chair of the WWRP/JSC	Gilbert Brunet
Chair of the WWRP/SERA WG	Brian Mills
Co-Chair of the WGNE	Andy Brown
CGMS	TBD
CBS	Fred Branski
WCRP/JSC	Anthony Busalacci
- iv. **One representative from each THORPEX Working Group and Regional Committee** who have observer status
- v. **Members of the ICSC Executive Committee** who have voting rights if they are members of category i (representatives of nations)
- vi. **Secretariat** including D/AREP, D/IPO(C/WWRP) and the Manager/IPO

2. ICSC Executive Committee membership

The THORPEX Executive Committee (EC) comprises the following drawn from the ICSC membership.

	Currently
Chair – the ICSC Chair	Alan Dickinson
A Trust Fund representative	Zoltan Toth

Representative of the Co-Chairs	Richard Swinbank
A representative from the WWRP/JSC	Gilbert Brunet
A representative from the CAS Management Board	Michel Beland
A representative of CBS	Walter Zwiefelhofer
A secretariat	THORPEX/IPO

3. Working Groups

Three working groups, reporting to the ICSC and the EC as required, are charged with developing and coordinating the THORPEX programmes.

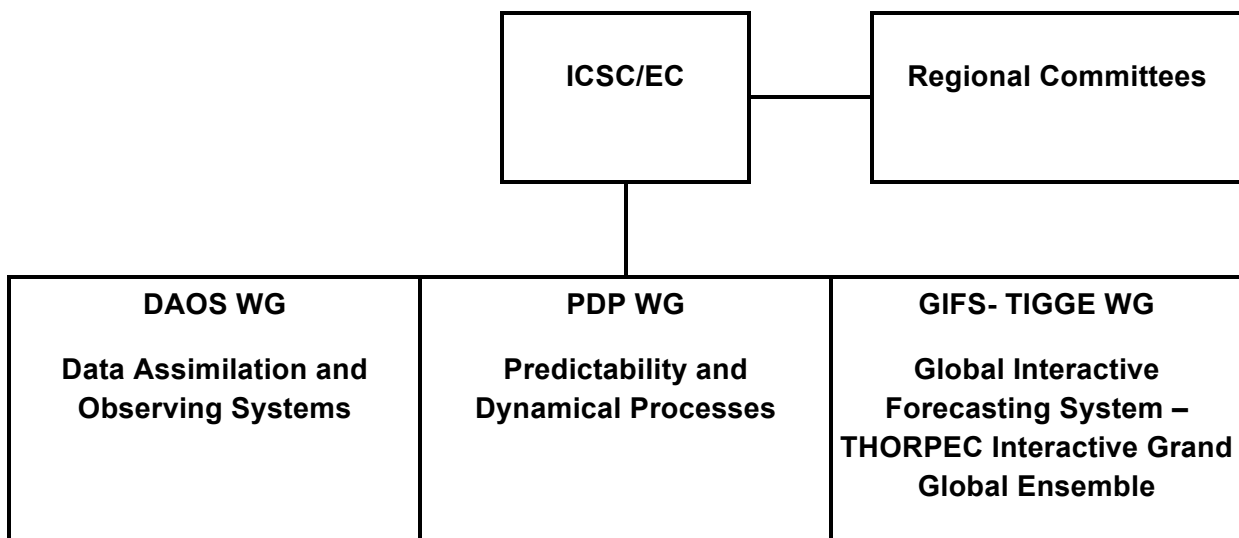
- Predictability and Dynamical Processes Working Group (PDP WG)
- Data Assimilation and Observing Systems Working Group (DAOS WG)
- Global Interactive Forecasting System (GIFS) – THORPEX Interactive Grand Global Ensemble Working Group (GIFS-TIGGE WG)

4. Regional Committees

Nations and consortia of nations have established THORPEX Regional Committees (RCs) that define regional priorities for participation in THORPEX within the framework of the THORPEX International Science and Implementation Plans. These THORPEX Regional Committees develop regional activities within the framework of the international plans and their plans are discussed by the EC and reviewed and approved by ICSC. To date Regional Committees have been established for Asia (ARC), Africa (AfRC), Europe (ERC), North America (NARC) and the Southern Hemisphere (SHRC).

5. Organigramme

The organigramme for the agreed Management Structure is:



6. Working Group Membership (as of 1 October 2011)

Data Assimilation and Observing Systems Working Group (DAOS WG)

Members	Affiliation
Ron Gelaro, co-chair	NASA, USA
Roger Saunders, co-chair	Met Office, UK
Mark Buehner	Environment Canada, Canada
Bertrand Calpini	MeteoSwiss, Switzerland
Carla Cardinali	ECMWF, UK
Tom Hamill	NOAA, USA
Tom Keenan	CAWCR, Australia
Stefan Klink	DWD, Germany
Rolf Langland	NRL, USA
Andrew Lorenc	MetOffice, UK
Sharan Majumdar	RSMAS, Univ Miami, USA
Florence Rabier	Météo-France, France
Michael Tsyroulnikov	HydroMet Centre, Russia
Chris Velden	Univ Wisconsin-CIMSS, USA
Bin Wang	Chinese Academy of Sciences, China

Predictability and Dynamical Processes Working Group (PDP WG)

Members	Affiliation
Heini Wernli (Co-chair)	ETH, CH
Istvan Szunyogh (Co-chair)	Texas A&M University, USA
Craig Bishop	NRL, USA
Pat Harr	NPS, USA
Shuhei Maeda	JMA, Japan
John Methven	University of Reading, UK
Mark Rodwell	ECMWF, UK
Olivier Talagrand	LMD, France

Global Interactive Forecast System (GIFS)-THORPEX Interactive Grand Global Ensemble Working Group (GIFS-TIGGE WG)

Members

Affiliation

Richard Swinbank, Co-chair	Met Office, UK
Young-Youn Park, Co chair	KMA, Korea
Philippe Arbogast	Meteo-France, France
Gong Jiandong	CMA, China
Masayuki Kyouda	JMA, Japan
Osvaldo Moraes	CPTEC, Brazil
Michael Naughton	BoM, Australia
Tiziana Paccagnella	ARPA-SIM, Italy
David Richardson	ECMWF, UK
Doug Schuster	NCAR, USA
Laurie Wilson	EC, Canada
Yuejian Zhu	NOAA/NCEP, USA

LIST OF PERMANENT THORPEX ICSC ACTIONS

Number	Reference	Action	Responsible	Status/Due
ICSC-P/01	Cg-XIV ICSC-2	To encourage WMO Members to actively participate in implementation of THORPEX	ICSC, RCs, IPO	Ongoing
ICSC-P/02	Cg-XIV ICSC TOR	To assist WMO Members in the International coordination of THORPEX	ICSC, IPO, SSC-WWRP, WGNE, CBS	Ongoing
ICSC-P/03	Cg-XIV	To assist WMO Members from developing countries in their utilization of THORPEX-related forecast product	ICSC, RCs, CBS, IPO	Ongoing
ICSC-P/04	Cg-XIV	To assist THORPEX in coordination with CBS, WCRP, JCOMM and other WMO programmes as appropriate	ICSC, IPO	Ongoing
ICSC-P/05	Cg-XIV	To facilitate the participation in THORPEX of other international bodies	ICSC, IPO	Ongoing
ICSC-P/06	ICSC TOR	To provide the global and regional priorities with respect to the THORPEX sub-programmes	ICSC, RCs	Ongoing
ICSC-P/07	ICSC TOR	To provide guidance to the NMHSs on the timely transition of THORPEX research and development to operations	ICSC, RCs, CBS	Ongoing with CBS involvement
ICSC-P/08	Cg-XIV ICSC TOR	To identify and mobilize national and international resources, financial, technical and human, to support THORPEX activities	ICSC, RCs, IPO, all members	Ongoing
ICSC-P/09	ICSC-3/17	ICSC members and Regional Committees to provide quarterly progress reports on activity and plans to the Chair of ICSC and IPO. Regional Committees to submit reports to the Chair of ICSC and IPO not later than at least 6 weeks prior the session of the ICSC	ICSC Chair, members, RCs, IPO	Ongoing
ICSC-P/10	ICSC-2/02 ICSC-3/15	All THORPEX members to make annual contributions to the THORPEX Trust Fund in accordance with the approved budget and not later than 31 March	All THORPEX members	Ongoing
ICSC-P/11	ICSC-2/02 ICSC-3/16	All THORPEX members to make provisions and ensure allocation of necessary funds for next year before 31 October	All THORPEX members	31 October

ICSC-P/12	ICSC-2/04 ICSC-3/14	ICSC members to consider secondment of experts to serve at the THORPEX IPO and to inform the ICSC Chair and WMO/AREP Director on any progress	All THORPEX members	Ongoing
ICSC-P/13	ICSC-3/18	ICSC Members to regularly update status of implementation of actions and inform the IPO	ICSC, IPO	Ongoing
ICSC-P/14	ICSC-3/09	ICSC members to pursue national inputs to GEO framework and Implementation Plan. ICSC with assistance of IPO to provide when appropriate related THORPEX requirements for consideration in relevant GEO deliberations	ICSC, IPO	Ongoing
ICSC-P/15	ICSC-3/11	The Regional Committees to ensure that regional plans are developed in coordination with ICSC core sub programmes, and between regions, and are consistent with the International Science and Implementation Plans	ICSC, RCs	Ongoing

LIST OF THORPEX SERIES PUBLICATIONS

1. International Core Steering Committee for THORPEX, Third Session, 16-17 December 2003, Montreal, Canada. Final Report. WMO/TD-No. 1217, WWRP/THORPEX No. 1.
2. M.A. Shapiro, A.J. Thorpe, 2004: THORPEX International Science Plan Version 3. WMO/TD-No.1246, WWRP/THORPEX No. 2.
3. International Core Steering Committee for THORPEX. Fourth Session 2-3 December 2004, Montreal, Canada. Final Report. WMO/TD-No. 1257, WWRP/THORPEX No. 3.
4. THORPEX International Research Implementation Plan Version 1. WMO/TD-No. 1258, WWRP/THORPEX No. 4.
5. First Workshop on the THORPEX Interactive Grand Global Ensemble (TIGGE), Reading, United Kingdom, 1-3 March 2005, WMO/TD-No. 1273, WWRP/THORPEX No. 5.
6. Symposium Proceedings - The First THORPEX International Science Symposium, 6-10 December 2004, Montreal, Canada, WMO/TD-No. 1237 WWRP/THORPEX No. 6.
7. Symposium Proceedings – The Second THORPEX International Science Symposium, 4-8 December 2006, Landshut, Bavaria, Germany, WMO/TD-No. 1355, WWRP/THORPEX No. 7.
8. International Core Steering Committee for THORPEX. Sixth Session 25-27 April 2007, Geneva, Switzerland. Final Report. WMO/TD-No. 1389, WWRP/THORPEX No. 8.
9. The YOTC Science Plan – A Joint WCRP-WWRP/THORPEX International Initiative. WMO/TD-No. 1452, WCRP-130, WWRP/THORPEX No. 9.
10. African Science Plan – Version 1. WMO/TD-No. 1460, WWRP/THORPEX No. 10.
11. WWRP/THORPEX African Implementation Plan – Version 1. WMO/TD-No. 1462, WWRP/THORPEX No. 11.
12. International Core Steering Committee for THORPEX. Seventh Session 18-20 November 2008, Geneva, Switzerland. Final Report. WMO/TD-No. 1495, WWRP/THORPEX No. 12.
13. International Core Steering Committee for THORPEX. Eighth Session 2-4 November 2009, Offenbach, Germany. Final Report. WMO/TD-No. 1522, WWRP/THORPEX No. 13.
14. Weather Research in Europe – A THORPEX European Plan, Version 3.1. WMO/TD-No. 1531, WWRP/THORPEX No. 14.
15. Targeted Observations for Improving Numerical Weather Prediction: An Overview. WWRP/THORPEX No. 15.
16. International Core Steering Committee for THORPEX. Ninth Session 21-22 September 2011, Geneva, Switzerland. WWRP/THORPEX No. 16.