

**WORLD METEOROLOGICAL ORGANIZATION  
WORLD WEATHER RESEARCH PROGRAMME**



**INTERNATIONAL SCIENCE PLAN**

*Executive Summary*

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Approved by the CAS International Core Steering Committee for THORPEX

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## MISSION STATEMENT

### **THORPEX: a Global Atmospheric Research Programme for the 21<sup>st</sup> Century**

THORPEX is an international research programme to accelerate improvements in the accuracy of 1-day to 2-week high-impact weather forecasts. These improvements will lead to substantial benefits for humanity, as we respond to the weather related challenges of the 21<sup>st</sup> century. THORPEX research Sub-programmes address: i) global-to-regional influences on the evolution and predictability of weather systems; ii) global observing-system design and demonstration; iii) targeting and assimilation of observations; iv) societal, economic, and environmental benefits of improved forecasts. THORPEX establishes an organisational framework that addresses weather research and forecast problems whose solutions will be accelerated through international collaboration among academic institutions, operational forecast centres and users of forecast products.

The THORPEX International Science Plan:

- ?? Provides the rationale and research agenda for THORPEX by identifying opportunities leading to advances in weather research and forecasting over the next decade
- ?? Defines the goals of THORPEX within the scope of its four research Sub-programmes
- ?? Establishes the foundation for the development of the THORPEX International Research Implementation Plan

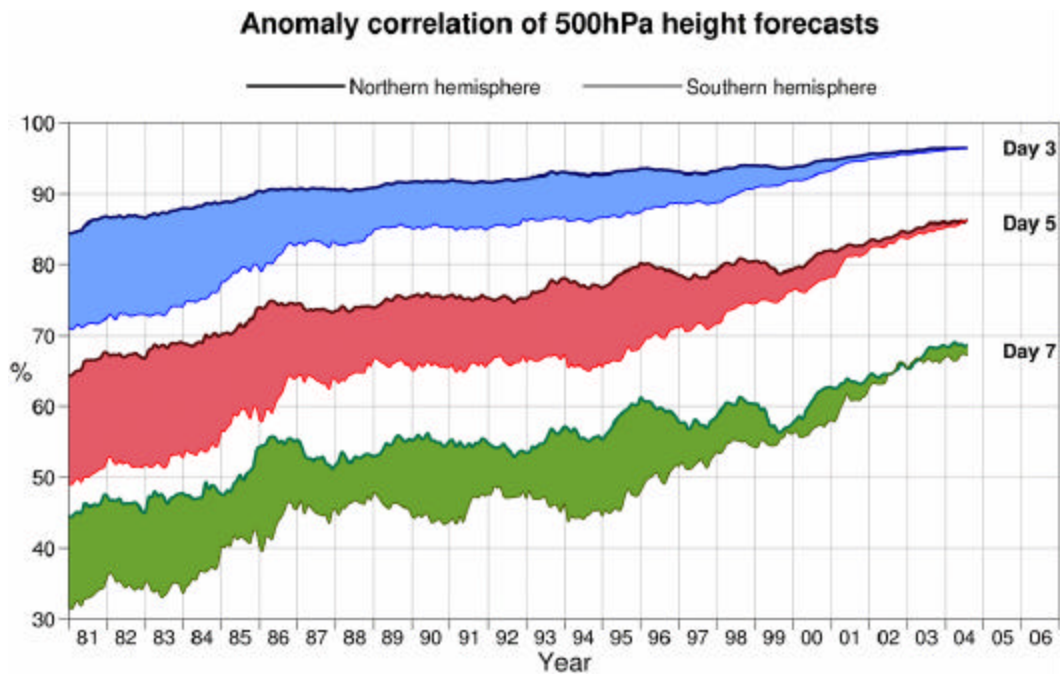
A series of reports on THORPEX will be published that build upon the current definition of the programme, as the research objectives evolve and roadmaps for their implementation emerge.

The Science Plan is currently under a peer-review process, organized by the CAS Science Steering Committee for the World Weather Research Programme.

## EXECUTIVE SUMMARY

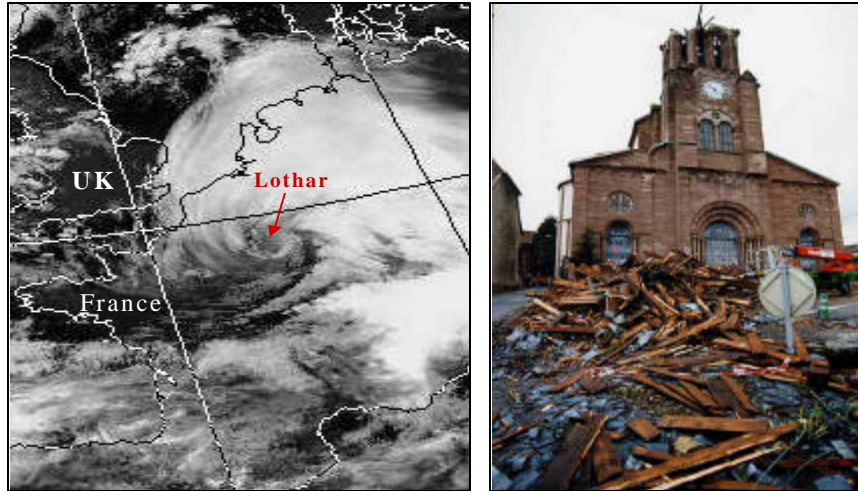
### **Rationale**

The success of numerical weather prediction represents one of the most significant scientific, technological and societal achievements of the 20<sup>th</sup> century. Despite the notable increase in forecast skill over the past quarter century (Fig.1.1), there is a necessity for further improvements, particularly, in the accuracy of high-impact weather forecasts and in the use of weather forecast information. High-impact weather forecasts are defined by their effect on society, the economy and the environment. They are typically associated with forecasts of cyclones of extratropical and tropical origin that contain significant embedded mesoscale weather and its impacts. These include localized flooding by convective and orographic precipitation; blizzard snows; dust-storms; destructive surface winds (Fig.1.2). They also encompass forecasts of meteorological conditions affecting air quality, periods of anomalous high/low temperature, drought, and non-extreme weather with high societal/economic impact. Many of these events are characterised as low probability, but with high risk, in that the event is unlikely, but the consequences of occurrence may be catastrophic. Improving the skill of high-impact weather forecasts is one of the great scientific and societal challenges of the 21<sup>st</sup> century. THORPEX responds to this challenge.



**Fig. 1.1:** Evolution of forecast skill for the northern and southern hemispheres: 1980-2004. Anomaly correlation coefficients of 3, 5, and 7-day ECMWF 500-mb height forecasts for the extratropical northern and southern hemispheres, plotted in the form of running means for the period of January 1980-August 2004. Shading shows differences in scores between hemispheres at the forecast ranges indicated (from Hollingsworth, *et al.* 2002).

Recent developments in atmospheric science and technology provide the opportunity for further improvements in the accuracy of high-impact weather forecasts and in their use and value to society. These developments include: i) advances in knowledge of the theoretical and practical limits of atmospheric predictability, including the influence of inter-annual and sub-seasonal climate variability on forecast skill; ii) expanding observations of the Earth System with satellite, airborne, marine and land-based observing technologies; iii) weather forecast systems capable of assimilating observations from the above diverse technologies; iv) advanced forecast procedures aided by improvements in numerical techniques, parameterised and explicit representations of physical processes, ensemble forecast techniques, and exponential increases in the speed and memory of supercomputers; v) innovative approaches to the design and implementation of forecast systems that will advance the societal and economic utilisation of weather information. In the same way that the atmosphere encompasses the globe, the expertise to exploit and further these advances resides across many nations, international organisations, and diverse scientific disciplines. During the years ahead, new technologies, scientific paradigms, forecast systems, and societal/economic application strategies will emerge, as they have in the past, presenting significant opportunities. THORPEX will adapt its research to capitalise on these opportunities.



**Fig. 1.2:** The societal and economic impact of the  $\sim 150 \text{ km h}^{-1}$  surface winds associated with extratropical cyclone “Lothar”. *Left* Dundee Satellite Station infrared image of Lothar at 0754 UTC 26 December 1999. *Right:* Lothar’s destruction of the church in Balliveirs, France (courtesy of Emmanuel DeBraize)

THORPEX establishes a contemporary organisational framework to address global weather research and forecast problems whose solutions require international collaboration among academic institutions, operational forecast centres, and users of forecast information. This includes engagement with other international programmes within the World Meteorological Organisation (WMO), the International Council of Science (ICSU) and the Intergovernmental Oceanographic Commission (IOC). In this regard, THORPEX aspires to be the second Global Atmospheric Research Programme (GARP); building on the accomplishments of the First GARP Global Experiment (FGGE) during the 1960s and 70s.

THORPEX is developed and implemented as a part of the WMO World Weather Research Programme (WWRP). International co-ordination for THORPEX is established under the auspices of the WMO Commission for Atmospheric Sciences (CAS) through its Science Steering Committee for the WWRP, and joint CAS/JSC Working Group on Numerical Experimentation (WGNE). The THORPEX International Science Steering Committee (ISSC) develops the core research objectives with guidance from the THORPEX International Core Steering Committee (ICSC) whose members are nominated by Permanent Representatives of countries with the WMO. Research objectives are developed under four Sub-programmes: *Predictability and Dynamical Processes*, *Observing Systems*, *Data Assimilation and Observing Strategies*, *Societal and Economic Applications*. These Sub-programmes have the responsibility to: i) coordinate the research activities envisaged in the THORPEX International Science and Implementation Plans; ii) collaborate with other international programmes when relevant expertise is required and mutual benefit is derived. Nations and consortia of nations have established THORPEX Regional Committees that define regional priorities for participation in THORPEX within the framework of the THORPEX International Science and Implementation Plans.

**THORPEX core objectives:**

?? Increase knowledge of global-to-regional influences on the initiation, evolution and predictability of high-impact weather. This objective includes research on: i) the excitation of Rossby wave trains by extratropical cyclone development, large-scale topography, continent/ocean interfaces, organised tropical and extratropical convective flare-ups, and the

role of these processes in the consequent development of high-impact weather; ii) the dependence of predictive skill on inter-annual and sub-seasonal climate variability, e.g., El Niño Southern Oscillation (ENSO); Pacific North-Atlantic oscillation (PNA); North-Atlantic Oscillation (NAO); Arctic Oscillation (AO); monsoon circulations; iii) the relative contribution to the limits of predictive skill by uncertainty in observations, data assimilation, model formulation and ensemble prediction system design.

?? Contribute to the design and demonstration of *interactive forecast systems* that allow information to flow interactively among forecast users, numerical forecast models, data-assimilation systems and observations to maximise forecast skill. As an example, targeted observing strategies incorporate dynamical information from the numerical forecast model itself to identify when, where, and what types of observations would provide the greatest improvement to specific weather forecasts of societal, economic, and environmental interest.

?? Contribute to the development of advanced data assimilation and ensemble prediction systems. This effort will include: i) improving the assimilation of existing and experimental observations, including observations of water in its three phases and atmospheric composition (e.g., ozone; aerosols); ii) developing adaptive data assimilation and targeted-observing strategies; iii) incorporating model uncertainty into data-assimilation systems and in the design of ensemble prediction systems; iv) evaluating the utility of multi-model ensemble prediction systems.

?? Develop and apply new methods that enhance the utility and value of weather forecasts to society, economies and environmental stewardship through: i) user-specific probabilistic forecast products; ii) the introduction of interactive procedures that make the forecast system more responsive to user needs; iii) the design of and training in the use of user-specific forecast products. Research will identify and assess the societal/economic costs and benefits of THORPEX recommendations for implementing interactive forecast systems and improvements in the global observing system.

?? Carry out THORPEX Observing-System Tests (TOSTs) and THORPEX Regional field Campaigns (TReCs). TOSTs: i) test and evaluate experimental remote sensing and *in-situ* observing systems, and when feasible, demonstrate their impact on weather forecasts; ii) explore innovative uses (e.g., targeting) of operational observing systems. TReCs are operational forecast demonstrations contributing to the design, testing and evaluation of all components of interactive forecast systems. They are organised and coordinated by regional consortia of nations under THORPEX Regional Committees, e.g., Europe; Asia; North and South America; Southern Hemisphere. TReCs address forecasts of regional weather systems, e.g., arctic storms and cold-air outbreaks; extratropical cyclones over Europe, Asia, and North America; warm-season heavy precipitation over Asia; organized equatorial convection flare-ups; tropical-to-extratropical cyclone transformations. TReCs require collaboration between Regional Committees. THORPEX will explore the opportunities to carry out TReCs in conjunction with major international programmes such as the International Polar Year (IPY) and the African Monsoon Multi-disciplinary Analysis (AMMA).

?? Demonstrate all aspects of THORPEX interactive forecast systems, over the globe for a season to one year to assess the utility of improved weather forecasts and user products. This includes the *THORPEX Interactive Grand Global Ensemble* (TIGGE) that integrates developments in observing systems, targeting, adaptive data assimilation, model improvements, forecast user requirements, and a multi-model/multi-analysis ensemble prediction system.

?? Coordinate THORPEX research with the World Climate Research Programme: Coordinated Observation and Prediction of the Earth System (WCRP/COPES) and the mesoscale/microscale community to address the observational and modelling requirements for the prediction of weather and climate for two weeks and beyond.

?? Facilitate the transfer of the results of THORPEX weather prediction research and its operational applications to developing countries through the WMO by means of appropriate training programmes.

### **THORPEX is unique, in that**

?? It establishes an organisational framework to address today's global weather research and forecast problems whose solutions require international collaboration between academic institutions, operational forecast centres, and users of forecast information. Its research domain spans global-to-regional influences on high-impact weather forecasts.

?? It has at its heart the contemporary paradigm in which weather forecasting is an interactive process, with information flowing between forecast users, forecast models, data assimilation and global and regional observing systems.

?? It addresses the influence inter-annual and sub-seasonal atmospheric and oceanic variability on high-impact forecasts out to two weeks, and therefore aspires to bridge the "middle ground" between medium-range weather forecasting and climate prediction. This provides a link with programmes addressing the improvement of sub-seasonal, seasonal, and global climate change prediction systems.

?? It will conduct regional and global campaigns as demonstrations and assessments of new observing technologies and interactive forecast systems. Thereby, THORPEX will provide guidance to the World Weather Watch (WWW) and forecast centres on improvements to forecast systems, and to relevant bodies, such as the WMO Commission for Basic Systems (CBS), concerning optimisation of global and regional observing-systems.

## **1.2 Reference Material**

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