ATLANTIC-THORPEX OBSERVING SYSTEM TEST

PROJECT PLAN

Prepared by: Atlantic-TOST Planning Team

To: Attendees of the Atlantic-TOST Planning Meeting

Summary: This document describes the proposed Atlantic-THORPEX Observing System Experiment, outlines the primary objectives, describes how it will be co-ordinated and identifies key roles, responsibilities, risks and dependencies.

Action required: Discuss and offer advice concerning future definition of this observing system experiment.

Distribution: Restricted

Supporting Docs: Atlantic-TOST Operations Plan (TBD by July 2003)
Atlantic-TOST Science Assessment Plan (TBD by early 2004)

Reference	Date	Author(s)	Content
EUCOS/SP/105	15th April 2003	Bruce Truscott	Strawman version 1
EUCOS/SP/105	7th May 2003	Bruce Truscott	Strawman version 2
EUCOS/SP/105	22nd May 2003	Bruce Truscott	Strawman version 3
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ATLANTIC-TOST PROJECT PLAN

1. INTRODUCTION

1.1 OVERVIEW

The EUMETNET Composite Observing System (EUCOS) Programme and THORPEX share a common goal of testing the hypothesis that the number and size of significant weather forecast errors over Europe and Eastern seaboard of the USA can be reduced by targeting extra observations over oceanic storm-tracks and other remote areas, determined each day from the forecast flow patterns. The Atlantic-THORPEX Observing System Test (Atlantic-TOST) is planned as a field campaign to make a significant contribution towards this common goal. The primary aim of the Atlantic TOST is to test the real-time quasi-operational targeting of observations using a number of platforms (including AMDAR, ASAP ships, extra radiosonde ascents, research aircraft and meteorological satellites). To do this, it is necessary to identify suitable cases for targeting, provide information on the location of sensitive areas, and have the facilities to control each observing system at short notice. The Atlantic TOST will be the first time that the real-time adaptive control of such a complex set of observing platforms has been attempted. It is considered to be an essential preparation or 'proof of concept' for future targeting field campaigns. Additional scientific objectives of the Atlantic TOST will contribute to the understanding of the location and predictability of sensitive areas and the impact of targeted observations on forecast performance [and the benefit of potential new observing platforms].

1.2 BACKGROUND

The EUCOS Programme has been established under EUMETNET[1], a network grouping 18 Western European National Meteorological Services. It has the following primary objectives:

- Define an integrated, ground-based composite observing system optimised at European scale with a view to improve short range forecast over Europe without increasing the overall cost.
- Provide a framework for co-ordinating observing system design studies -aiming at the definition mentioned above - and pilot projects to develop the necessary collective infrastructure for the future implementation of this network.
- Co-ordinate the implementation of the system, in line with EUMETNET Council's decisions concerning its definition.

A more detailed description of EUCOS can be found on the EUCOS web site, www.eucos.net.

THORPEX as a Global Atmospheric Research Programme (GARP) is an international research programme to accelerate improvements in the accuracy of 1 to 14-day weather forecasts for the benefit of society and the economy. The programme builds upon ongoing advances within the basic-research and operational-forecasting communities, and will make progress by enhancing international collaboration between these communities and with users of forecast products. More information about THORPEX can be found on the THORPEX web site, www.mmm.ucar.edu/uswrp/programs/thorpex.html

The Atlantic-TOST will form one of three THORPEX Observing System Tests (TOSTs) planned during 2003/2004. The purpose of these TOSTs is to test and evaluate experimental and operational remote sensing and in-situ observing systems, including (where feasible) their impact on data-assimilation, forecasts and user products. TOSTs are being conducted in preparation for the THORPEX Global Prediction Campaign, which will:

- deploy the full suite of experimental and operational observing systems;

[1] EUMETNET – further background information is available at http://www.eumetnet.eu.org

- provide guidance, through the WMO WWW, to agencies responsible for optimising the design and implementation of the fixed and adaptive components of the existing regional and global observing systems;
- establish the utility of an interactive forecast system that encompasses societal priorities for improved weather products for all nations.

The Atlantic-TOST will also represent the largest and most complex of three OSEs planned as part of the EUCOS Studies Programme during the period 2002-2004 [ref. 1]. It will consist of a two month Special Observing Period (SOP) followed by a short period of data processing before NWP Centres can start their impact assessment studies. The SOP is scheduled to start on **13 October** and end **12 December 2003** (preceded by a 2-3 weeks test of the Operations and Observation Control Centres). It is hoped that scientific assessments will be completed by the **end of 2004**.

Three primary activities can be identified:
(i) Case selection, sensitive area prediction and target area identification;
(ii) Delivery of additional observations;
(iii) Impact assessment.
Each of these are discussed in more detail under section 3 of this document.

The Atlantic-TOST will test the benefit of enhancing the observing system over the North Atlantic, Europe, and the surrounding area, using affordable, potentially operational observing systems as well as research facilities in an effort to improve weather forecasts over Europe and eastern parts of the USA. A winter period has been chosen because it has the greatest frequency of severe weather events, which can result in a high societal impact. In a EUCOS sponsored study [Ref. 2], improved observations over the area shaded in figure 1 were shown to be needed to improve short period forecasts over Northern Europe; for Southern Europe the area extends over the Mediterranean and eastern Atlantic to 10°N. This study has governed the observing area selected for this experiment, described under section 3.1.2. Other studies have shown the sensitive structures to have short vertical scales, in the middle and lower troposphere, often below cloud [Ref. 3]. They are therefore unlikely to be properly observed by current or planned satellite sounding instruments, so the focus is generally on *in-situ* observations although remote sensing devices are also included.

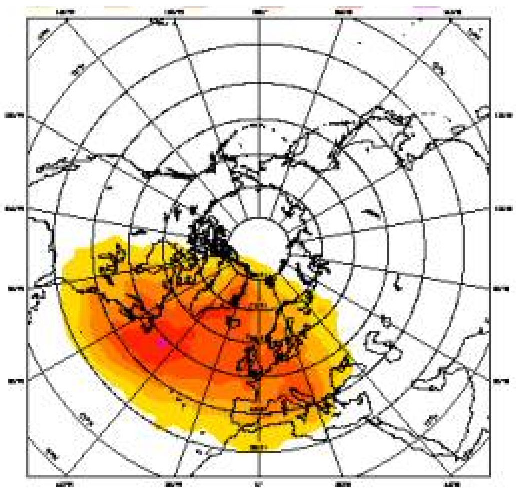


Figure 1: Areas where an improvement in the analysis would have produced an improvement in the 48-hour forecast over Northern Europe (10°W-35°E, 45°N-65°N), averaged over a three-month period for winter 1999-2000.

Recognising that the results from this study will be of significant interest to a large number of people within the meteorological and academic communities the aim will be to engage and involve all appropriate organisations whilst maintaining a focus on the stated objectives.

2. OBJECTIVES AND SCOPE

2.1 SCOPE

The overall long-term objective of a fully adaptive observing system network is to optimise the use of costly and limited observational resources as well as to improve forecasts of high-impact weather events (as measured by their economic and societal benefits). The new concept of targeting uses information from numerical weather forecasts to identify when and where to make future observations in order to give the greatest benefit to subsequent forecasts. This feedback from forecasts to observations and then back through data assimilation to later forecasts is part of an envisaged interactive forecast system that eventually will see the two-way flow of information interactively from observations, through data assimilation and forecasts to end users and back. The development of such an integrated and interactive forecast system is one of the key long-term goals of EUCOS and THORPEX.

Previous trials of observation targeting include the FASTEX research campaign and the operational US Winter Storms Reconnaissance (WSR) program. In both of these campaigns targeting was used to direct dropsonde equipped research aircraft to appropriate locations. The Atlantic TOST will be the first time that the real-time adaptive control of a more complex and representative set of observing platforms (including AMDAR, ASAP ships, extra radiosonde ascents, driftsondes, research aircraft and Met Satellites) has been attempted. It is considered to be essential preparation for future targeting field campaigns, leading towards the THORPEX Global Prediction Campaign. EUCOS has already conducted initial trials of targeting obs through Special Observing Periods (SOPs) for the ASAP ships and Robotic Aircraft [refs 4 and 5]

The Atlantic TOST is primarily, then, a proof of concept experiment. It aims to test the ability to adaptively control the observing system network by directing where and when (and for what period) to make additional observations to supplement the routine observations. The experiment will also test and evaluate experimental observing systems [driftsondes, wind lidar, TAMDAR … *if these are confirmed].* The overall long-term objective of improving forecasts of high-impact weather events will guide the selection of appropriate cases for targeting during the Atlantic TOST. Attention will be focussed on short range (**24 to 72 hours**), **regional scale** numerical weather prediction over Europe and the eastern seaboard of the USA. Specific high-impact weather events of interest include extra-tropical cyclones and extra-tropical transition of tropical cyclones over these regions. A further guide to case selection will be forecast uncertainty. Higher priority will be given to situations where available ensemble predictions indicate a potential high-impact event, but with a large degree of associated uncertainty.

The benefits of the additional targeted observations for weather forecasts will be assessed so far as is feasible, in line with the overall EUCOS and THORPEX goals. However it is recognised that a full evaluation of the benefits of targeted observations is likely to require a substantial effort using a large database of events accumulated over a number of experimental campaigns. The data gathered during the Atlantic TOST will contribute to this database, and it is hoped that results of studies using the TOST data will be able to guide the planning of future experiments.

2.2 OBJECTIVES

2.2.1 Real-time adaptive control of observations

The primary aim of the Atlantic TOST is to test the real-time quasi-operational targeting of observations using a number of platforms. To do this, it is necessary to identify suitable cases for targeting, provide information on the location of sensitive areas, and have the facilities to control each observing system at short notice. The Atlantic TOST will be the first time that the real-time adaptive control of such a complex set of observing platforms has been attempted.

The Atlantic TOST will be an ‘operational’ demonstration of the current capability for targeting. This will be carried out in a realistic international context, where:

- different sensitive area prediction methods may indicate different target regions for observations;
- targeting will be needed for more than one observation type
- there may be varying user requirements (different users may be interested in different forecast weather events).

Real-time decision-making processes necessary for the selection of target areas and deployment of observational resources will be developed and used in the Atlantic TOST. This it is hoped will provide a benchmark for future developments. Evaluation of the performance during the TOST and results of subsequent research on the impacts from the experiment will highlight key aspects where development is needed and guide future studies.

2.2.2 Sensitive area predictions

A number of methods will be used to predict areas where additional observations are expected to be particularly beneficial. These will be run in parallel throughout the TOST. This will provide a substantial sample over which to compare the predictions made using the different methods. It should be stressed that some of the sensitive area predictions have a significant subjective component, requiring forecasters to identify features and regions of interest. Such a system can only be properly tested in a real-time, ‘operational’ situation. This is generally difficult to achieve, but will be made possible as part of the TOST by specifically committing forecaster resources. Thus the TOST dataset of sensitive area predictions will be a valuable resource that would not otherwise be available.

As well as providing for comparison of sensitive area prediction methods, the dataset will be used to study the sensitive areas themselves. Where are they and how do they vary from day to day? What are the implications for the observing system (e.g. problems with satellite data in cloudy regions)? It will also provide an opportunity to compile more information about the climatology of sensitive areas based on different methods.

2.2.3 Potential new observing systems

It is hoped that the Atlantic-TOST will provide useful results that will be helpful when developing strategies and requirements for new observing systems, (both in-situ and remote). Better definition of the nature of sensitive areas and an improved understanding of our current ability to observe them will be particularly useful. This it is hoped will help:

- define the future requirement for in-situ observations that complement the space segment

- better understand the current weaknesses/limitations associated with today’s observing technologies.

Emerging observing technologies will also be operationally deployed during the TOST, including the Driftsonde (see section 3.2.1) and various remote sensing instruments that will be fitted to research aircraft (i.e. airborne wind lidar). If feasible, data from these systems will be archived within the Atlantic-TOST dataset for subsequent assessment.

2.2.4 Impact studies

The TOST will cover a period of around 2 months, throughout which time the non-research-aircraft resources will be available for targeting (with limitations on the number of driftsonde flights). This gives a comparable period to FASTEX or the WSR program and will provide a substantial sample of sensitive area predictions. There is, however, no guarantee over how many suitable (potential high impact) cases may occur. The uncertainty over the number of events that may occur means that it is likely to be several years before a collection of significant results can be obtained from an accumulated set of cases. The Atlantic-TOST does however provide an important and valuable start to this process.

Noting the uncertainty concerning the type and number of cases that will be available, it is then not appropriate to give precise plans for impact study experiments at this stage. Rather, a number of options will be considered and final decisions will be made depending on what cases occur. At the least these should give some information on the worth of additional observations over the N Atlantic region. If there are a number of significant cases then further more detailed information may be derived, and in addition these cases can be used, together with the FASTEX data and that from other (and future) experiments to build up a database for targeting studies. An outline of possible impact study experiments is given in Annex 1; information on centres that plan to contribute to these studies is given in Section 5.

Assessment of the benefit of the additional observations will as far as possible follow the guidance given in the THORPEX Science Plan. However it is recognised that the Atlantic TOST campaign alone is unlikely to provide sufficient data for a full evaluation of for example the economic benefit of targeted observations. Despite these limitations it is hoped that the Atlantic TOST data will be a useful test-bed for the development of evaluation tools, again providing a basis for future studies.

2.2.5 Extra-tropical transition of tropical cyclones

A tropical cyclone (TC) undergoing extra-tropical transition (ET) in the North Atlantic may become a high impact weather event for the east coast of the USA and Canada and their maritime waters. Atlantic TCs can also be the cause of high impact weather in Europe either directly by transforming into an extra-tropical system that then moves towards Europe and intensifies, or indirectly by perturbing the mid-latitude flow downstream of the tropical cyclone itself. The interaction between a TC and the mid-latitude environment is also a source of significant errors in numerical weather prediction models.

A number of activities have already been planned to observe and study tropical cyclones, and tropical-to-extra-tropical cyclone transition (ET) during the SOP of the Atlantic TOST. The Atlantic-TOST field campaign will seek to link with the groups carrying out this work in order to co-ordinate activities where possible, to include the observational data within the TOST dataset and to exchange research results.

The scientific objectives of the ET component of the TOST are to increase our knowledge and understanding of the structure, processes and predictability of the interaction between tropical cyclones and the mid-latitude flow, and to gather data to study the impact of extra observations in and around an ET event on the predictability of the cyclone undergoing transition and of the downstream mid-latitude flow. To date no targeted observations have been made in the vicinity of tropical cyclones undergoing ET. The ability to predict sensitive regions for targeting additional TC observations will be tested during the TOST.

Further details of the background and planned scientific objectives for the studies of ET, including the Atlantic TOST component are given in Annex 2.

3. PRIMARY ACTIVITIES

3.1 CASE SELECTION AND SENSITIVE AREA PREDICTION

Before it is possible to carry out case selection and sensitive area prediction it is necessary to identify the *verification regions* and the *forecast time-scales*.

3.1.1 Verification Regions

The primary aim of this study is to assess the benefit to short-range forecasts of additional observations targeted over the eastern part of the US and Canada, the North Atlantic, Europe and the surrounding area. Whilst a single, large verification region would simplify the running of the experiment, it is likely that the resulting sensitivity predictions would be dominated by the most severe system developing anywhere in the observing area at that time. To focus more specifically on a chosen weather event without introducing unacceptable complexity, **a small number of fixed verification regions have been defined**. Three proposed areas are indicated on Fig 2. The co-ordinates for these regions are:

Northern Europe (15W-35E, 45N-65N),
Southern Europe (15W-35E, 30N-50N)
Western Atlantic (40W-85W, 30N-65N)

The most appropriate verification area(s) will be selected on a case by case basis according to the predicted synoptic situation and possibly the availability of data targeting resources.

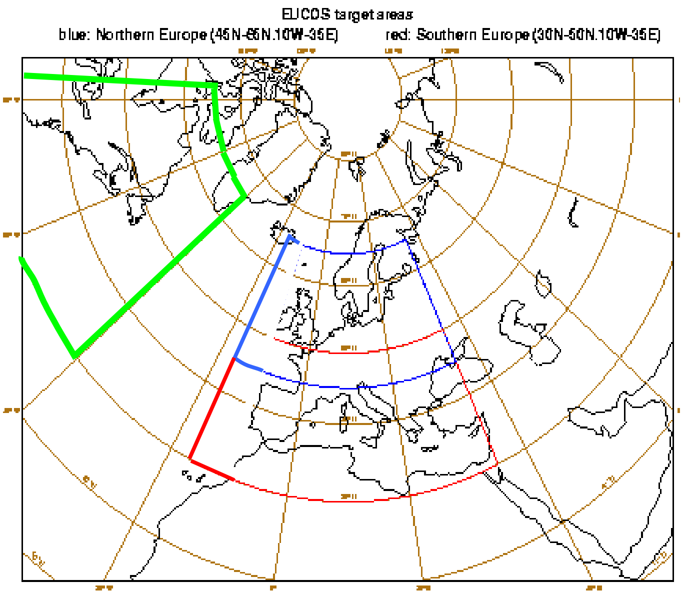


Figure 2: Previous verification regions adopted by EUCOS.

Sensitive Area Prediction Centres will have some flexibility in selecting a smaller 'sub-area' within the agreed verification area as the basis for their predictions.

3.1.2. Forecast Time-scales

As stated earlier, the Atlantic-TOST will focus on forecasts in the range T+24 to T+72 hour. It should be noted that in order to provide 48-hour warning to the observation providers of a deployment intended to improve a T+72 forecast, the products used to identify and select that case would be based on the T+120 - T+144 ensembles (as illustrated in the diagram included at annex 3).

3.1.3 Primary Area of Interest For Observations

When considering the forecast timescale together with the verification regions it is possible to define a *primary area of interest.* This is the region within which data targeting is likely to be required in order to improve short-range European weather forecasts (although observing outside of this area is not necessarily excluded from the experiment). It is defined as 10N-90N, 70W-40E, and is illustrated by figure 3.

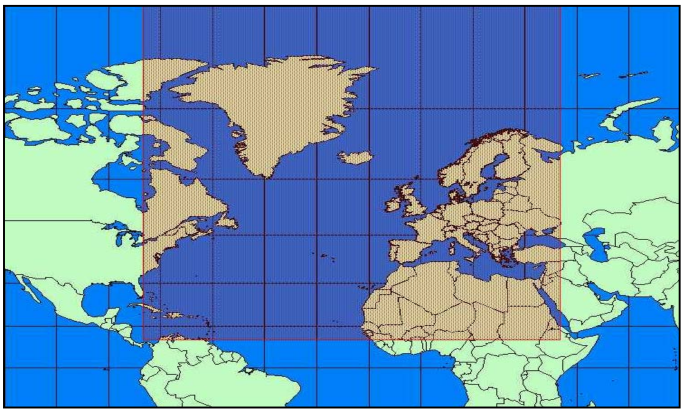


Figure 3: Primary Area of Interest

3.1.4 Case selection

Cases of interest are those where additional targeted observations are expected to improve 1-3 day forecasts of high impact weather in the verification regions. Higher priority will be given to situations where available ensemble predictions indicate a potential high-impact event, but with a large degree of associated uncertainty.

The following criteria will be used in selecting cases for sensitive area calculations and potential targeting. Details will be presented in the Operations Plan.

i) Potential future high-impact weather event in one of the verification regions
and/or
Significant uncertainty in the forecast of this event

ii) Likelihood of additional observations being available in expected target area

3.1.5 The Observation Target Area Selection Process

Target areas will be identified *24 - 48 hours* in advance of observation deployment. To achieve this, the following process, (similar to that used within the US Winter Storms Recognisance Programme), will be followed:

(i) Forecasters and/or NWP experts at the Operations Centre and sensitive area prediction centres (SAPCs) will identify threatening cases by examining the 3 to 6 day forecasts (3.1.4 above);
(ii) Agreement will be reached on the case(s) that warrant further study, the choice of verification area(s) and forecast timescale to be used for sensitive area prediction;
(iii) When one or more interesting case is identified, each SAPC will run their sensitivity software and provide their results to ECMWF who will collect the predictions and make them available to all on a web site, (note ECMWF continuously operate their sensitive area prediction system);
(iv) Based on a comparison of the sensitive area predictions, cases worthy of investigation will be selected and the location(s) of the observation target area(s) identified;
(v) A definition of the target area(s) will then be provided to the *Observation Control Centres* (OCCs) who arrange data delivery (discussed under section 4);
(vi) A 3-4 day outlook will also be provided to the OCCs highlighting potentially interesting events;

Three or four centres are expected to provide sensitive area predictions, (listed under section 5.1). At least two different prediction techniques will be used, (Ensemble Transform Kalman Filter (ETKF) and Singular Vectors).

The characteristics of each of the predictability systems are likely to affect their application during the experiment. Systems focussed on the 24 hour forecast timescale using a European verification area will for example be most suitable for predictions over the Eastern Atlantic. Others that are able to operate over longer forecast timescales will be able to identify sensitive regions further upstream, over the western Atlantic and possibly beyond.

The table below gives a provisional schedule for the daily tasks of the Operations Centre. The schedules have been prepared with the following considerations

- Observations will be centred around a nominal **18 UTC observation time** (daylight flights over Atlantic)
- Significant time is required for calculation of sensitive areas (after identification of suitable cases)
- Involvement of N American centres in discussion of target area selection
- Approx 48 and 24 hour notice required to observation system operators

OPERATIONS CENTRE TIMETABLE		
Time (UT)		**Action**
0630	daily	All 12UT ECMWF ensemble data and 00UT deterministic data available (and other forecast data to be confirmed)
0830	daily	Interested parties post suggested case(s) on ECMWF web site
0900	daily	Conference to select case(s) and or evaluate latest forecast for previously selected case. (Verification area and forecast timescales agreed)
0930	d-2 d-1	SAPCs requested to calculate sensitive areas or update previous calculation
1000	daily	Update on availability of observing platforms from OCC's
1600	d-2 d-1	Conference of SAPCs and Ops Centres to decide observation target areas or confirm those previously selected.
1630	d-2 d-1	Ops centres request targeted obs. From OCCs or confirm or cancel previously requested targets
1700	d-2 d-1	Planned additional targeted obs posted on web site. (d-1, confirm cancel or update –latter only if change in platform availability)

3.1.6 Responsibility

Sensitive area predictions will be made by a number of centres, based on initial selection of cases. Telephone conferences are planned to discuss case selection and the results of the sensitivity calculations. **It is however important that responsibility for taking the final decision on target area selection and observation deployment is clearly identified. This responsibility will be designated to the staff member in charge of the Operations Centre (Exeter) who will take the final decision on target area and deployment. All participants will be bound by this decision. The individual will have to be known and named in advance, documented within the Operations Plan.**

3.2. DELIVERY OF ADDITIONAL OBSERVATIONS

Two Observation Control Centres (OCCs) will be established:
- One within Europe to co-ordinate the supply of observations from European observing systems (provided by EUCOS)
- Another within North America to provide the same liaison between the USA/Canadian components.

These centres will receive the information about the target area(s) and co-ordinate the supply of observations (discussed under section 4.2). The table below gives a provisional schedule for the daily tasks of the Observation Control Centres.

OBSERVATION CONTROL CENTRES TIMETABLE			
European Time (UT)	**N American Time (UT)**		***Action***
1000	To be defined	Daily	Update on availability of observing systems made available to the Ops Centre. This will be in two parts: – Short term availability: 1 – 2 days – Longer term outlook: 3 – 6 days
1200	To be defined	Daily	In the event that a target area was observed the previous day, data monitoring results will be analysed and message availability summaries made available to the Ops Centre.
1630	1630	d-2 d-1	Ops centres request targeted obs. from OCCs or confirm or cancel previously requested targets
1800	1800	d-2 d-1	Planned additional targeted obs posted on web site *or* cancellation issued. - d-2: provide 48-hour warning - d-1: confirm cancel or update – latter only if change in platform availability *Note: Cancellations can not be issued with 12-hours of observation deployment*
2000	2000	d-2 d-1	Plans received from observations system operators for providing the requested observations *or* confirmation that the cancellation has been received and actioned.

3.2.1 The Observing Components

Plans currently include the deployment of the following observing systems, some of which can be targeted whilst others must be deployed in a more traditional, non-targeted manner.

(i) AMDAR Aircraft

This fleet of more than 600 European aircraft are operated by the EUMETNET-AMDAR Programme (a component of EUCOS). They are controlled using ground based 'Optimisation Systems' developed by airlines. These systems activate the aircraft automatically to satisfy a predefined observing programme over Europe (in terms of the frequency at which profiles are required over European airports) and to deliver data when the aircraft fly to/from selected long-haul destinations. Although relatively few observations will be available over many parts of the poorly observed Atlantic, the aim will be to deliver the greatest number possible within the defined target areas.

Environment Canada is currently in the process of installing AMDAR software on Canadian aircraft and developing an advanced system to control coverage and process the data. If available in time for the TOST, it is hoped that data from these aircraft can be included within the study.

(ii) ASAP Ships

Approximately 13 European ASAP ships will be operating in the Atlantic at the time of the SOP. These will be co-ordinated under the EUMETNET-ASAP Programme, another component of the EUCOS Programme. They will routinely conduct up to four soundings each day but will be asked to make additional launches (at a maximum frequency of once every 3-hours) when required. No US or Canadian ASAP units will be available.

(iii) Additional Radiosonde Ascents

Additional launches will be provided on request from European and eastern US and Canadian stations. The stations able to provide this service will be identified in advance as it is understood that local constraints (such as staff availability) will mean that not all sites can make additional launches. These stations will be expected to conduct their normal observing programme and carry out additional soundings when requested.

(iv) Research Aircraft

The research aircraft listed in the table below will, it is hoped, provide dropsonde and other measurements (such as wind lidar from the DLR Falcon).

Aircraft	Operator	Targeted Dropsonde capability?	Operating Base	Available Flying Time (directly in support of the NA-TOST)	Availability		
					Duration	Start Date	End Date
DLR Falcon	DLR	Yes	Iceland (Kevflavik)	30 hours (5 flights: 50 dropsondes in total)	2 weeks	27th Oct	21 Nov
NOAA P3's (2 aircraft)	NOAA	Yes	MacDill until early Dec (possible temporary deployment to other locations there after)	To be defined	Full 2½ months (shared)	Oct 1st	Mid Dec
NOAA G-4	NOAA	Yes	MacDill until early Dec (possible temporary deployment to other locations there after)	To be defined	Full 2½ months (shared)	1st Oct	Mid Dec
Citation	UND	To be confirmed	Bangor, Maine	To be defined	1 month	15 Nov	15 Dec
ER-2	NASA	No	Bangor, Maine	To be defined	1 month	15 Nov	15 Dec
Convair 580	Canada	Yes	Halifax / St Johns	4 flights – 150 dropsondes	TBD	Early Oct	Late Oct
C-130 (J and H models)	US Air-force	To be confirmed #	To be confirmed	To be confirmed	To be confirmed		

\# Some preliminary discussions have also begun with the US Air Force to investigate whether they could alter their training schedule to include some dropsonde missions in support of the Atlantic-TOST.

In general, the selection of flight tracks will follow a similar method to that used for US Winter Reconnaissance Programme. This involves the definition of a large number of predefined flight tracks, which include dropsonde release locations. The most appropriate flight track is then selected on a case by case basis to best observe the given target region.

(v) Additional Drifting Buoys

EUCOS is arranging the deployment of 20 drifting buoys in addition to those that will be routinely deployed by the European Group on Ocean Stations (EGOS). These additional deployments are being targeted within the winter and summer climatological sensitive areas previously identified by ECMWF [ref. 2]. The winter area is centred to the East of the coast of Newfoundland, where deployments will be made in August/September 2003. The summer region is located to the West of the Iberian Peninsula and the Bay of Biscay (deployments carried out March/April 2003). Data will remain available throughout the SOP.

In the US, ten Metaocean Wind Buoys will be deployed by Vessels of Opportunity to form the 2003 Hurricane WOTAN Array. There are also plans to air drop an array of 8 SVP and minimet drifters from Scripps this summer about 150 km ahead of a hurricane of opportunity.

(vi) Driftsonde Flights

Support for continued development and testing of driftsondes may be possible from NSF. NCAR would operate this system, which has recently moved into the proof-of-concept phase. It is hoped that Driftsondes, illustrated by figure 4, will be operated from Bangor, Maine. The deployment of four gondolas is currently

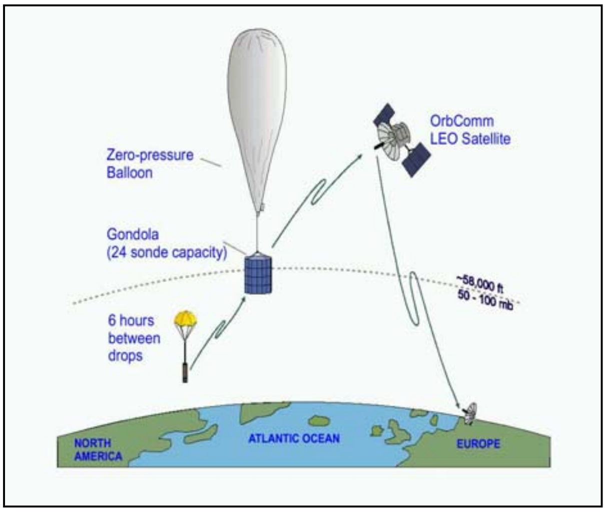


Figure 4: The Driftsonde System

planned, each having a capability of releasing 20 dropsondes on demand. This is considered an interesting emerging technology that has the potential to make a useful contribution towards the experiment.

(vii) Satallite Rapid Scan Winds

EUMETSAT have agreed to operate Meteosat-6 to provide rapid scan winds (10 minute interval). It will not be possible to redefine the scan region during the SOP, so a single, large area will be adopted covering a large part of the Northern Atlantic. Some early products from MSG may also be available.

Special GOES scanning strategies will be set up for the TOST. Due to operational requirements, it will not be possible to achieve a continuous rapid-scan cycle, instead an SRSO (Super Rapid Scan Operations) will be triggered when we have an observation target area within the GOES footprint. This special scan will provide rapid imaging for 8-minute periods, one period every hour, for 6-8 consecutive hours (routine duration of an SRSO).

3.2.2 The Requirement for Observations Outside Sensitive Regions

It is reasonable to assume that additional observations will benefit the forecast irrespective of their location in relation to sensitive areas (provided they are accurate). In order to compare the relative benefit of targeted vs. non-targeted observations it is necessary to *also make additional observations from outside of the target regions*. Whilst this is not generally a problem, careful planning will be required to obtain maximum value from the important yet limited contribution from research aircraft. Efforts will be made to avoid flights solely for the generation of data outside target regions. Instead these non-targeted observations will be made whilst in transit to the nominated target area if at all possible.

3.3 IMPACT ASSESSMENT

Finally, we need to evaluate the outcomes of the Atlantic-TOST to provide guidance for future THORPEX campaigns and the evolution of the composite observing system. This assessment will cover the predictions of sensitive areas, the operational decision making and control of the observing systems, and the impact of additional observations on forecasts. The choice of impact studies will depend on the type and number of cases that occur during the TOST and it is therefore not appropriate to give detailed plans before the observational campaign. Rather, a number of options will be considered and final decisions will be made depending on what data and cases occur.

It is clearly necessary to carefully co-ordinate the impact assessments in order to ensure that they complement one-another and collectively tackle all of the necessary issues. An ***Atlantic-TOST Science Assessment Plan*** will be prepared early in 2004 in order to facilitate this lead by a small scientific planning team. The Plan will collate the evaluation studies, taking account of the outcomes from the observational phase of the TOST, and will therefore be prepared once this phase is completed.

Many operational NWP systems are run by the participants, and experiments with FASTEX data [Ref. 6] have shown that the impact of targeted observations can depend strongly on the system used to assimilate them. It is therefore important to use several different NWP systems to run observing system experiments (OSEs), producing forecasts with and without the targeted observations. A number of NWP Centres are expected to run OSEs. . It is also important to consider additional benefits that can be derived from *existing data* (by the adaptation of thinning algorithms for example).

3.3.1 Impact Study Scenarios

Impact study scenarios will be proposed by each of the evaluation centres and recorded within the Science Assessment Plan. Annex 1 to this document provides some initial thoughts concerning the scenarios that might be tested and information on centres that plan to contribute to these studies is given in Section 5.

3.3.2 Assessment

It is recognised that the Atlantic TOST campaign alone is unlikely to provide sufficient data for a full evaluation of for example the economic benefit of targeted observations. Nevertheless it is hoped that the Atlantic TOST data will be a useful test-bed for the development of evaluation tools, providing a basis for future studies.

It is important not only to assess the impact of the targeted observations in terms of NWP improvements, but also consider whether the resulting forecasts would have had a significant 'end point' benefit. Forecasters will be asked to carry out a subjective analysis comparing the operational output against experimental runs. Where possible, assessment will also be made of the potential economic impacts of the targeted data.

3.3.3 Review Our Success in Predicting and Targeting Sensitive Regions

Noting the objectives and challenging nature of this study, it is important to review our success in predicting the location of sensitive areas and our ability to target them with additional observations. Representatives from the Sensitive Area Prediction Centres will be responsible for reporting on their success in identifying the sensitive regions. This report should compare and contrast the different techniques used, highlighting their relative strengths and weaknesses. It is also important to monitor the performance of the Observing Network throughout the period, requiring information to be recorded on the number and type of observations that were generated for each event.

4. Operational and Technical Aspects

4.1 CASE SELECTION / SENSITIVE AREA PREDICTION

An ***Operations Centre***, working in close contact with other international teams (such as the SAPCs) will be established to:

i) Identify potentially interesting cases (based on ensemble forecasts) and commission sensitive area predictions;
ii) Compare and contrast predictions from the SAPCs.
iii) Select the target areas where additional observations are required and communicate this requirement to the Observation Command Centres (OCCs).

The Operations Centre is expected to be run ***7 days per week*** and consist of a small team located within the Met Office's National Meteorological Centre, Exeter who will communicate on a daily basis with other international teams. It will start operating on 22 September to ensure that any difficulties can be resolved before the start of the SOP (13th October). It may be necessary not only to rely on the predictability systems to identify sensitive regions, as it is likely that these will not be compatible with all potentially interesting situations; input from experienced forecasters and scientists will therefore be essential.

As this approach relies on complex interactions between several international teams each of them must clearly understand their roles and responsibilities and be fully aware of the decision making process. These aspects will be documented in detail within an ***Atlantic-TOST Operations Plan***. This document will be prepared to define all operational aspects of this field campaign.

Once agreed, output will be issued by the Operations Centre to the ***Observation Command Centres*** (described under section 4.2). The information provided will include:

(i) Clear identification of the location of the target region(s) . It is anticipated that these will first be provided 48-hours in advance (when possible) and then confirmed (or cancelled) 24-hours before data targeting is required;
(ii) Requests for any specific types of targeted observations (if considered appropriate)
(iii) A future outlook, providing information about the likely data targeting requirement in 3 to 6 days time.

4.2 DATA DELIVERY

As noted above, sensitive areas will be determined 24-48 hours in advance of deployment so that extra observations can be directed to the selected areas. This technique has been tested successfully in the FASTEX and NORPEX experiments, using dropsondes from research aircraft and has been used operationally by the successful US Winter Storm Reconnaissance Programme (WSRP).

Observation delivery will be centrally co-ordinated by two ***Observation Command Centres* (OCC's)**. EUCOS will co-ordinate the European Observing Systems and <NCAR?>, co-ordinating the US and Canadian components. Both centres will be required to function operationally, 7 days per week. Figure 5 illustrates how instructions and advice will flow from the Operations Centre, through the OCC's to the participants operating the various components of the observing system.

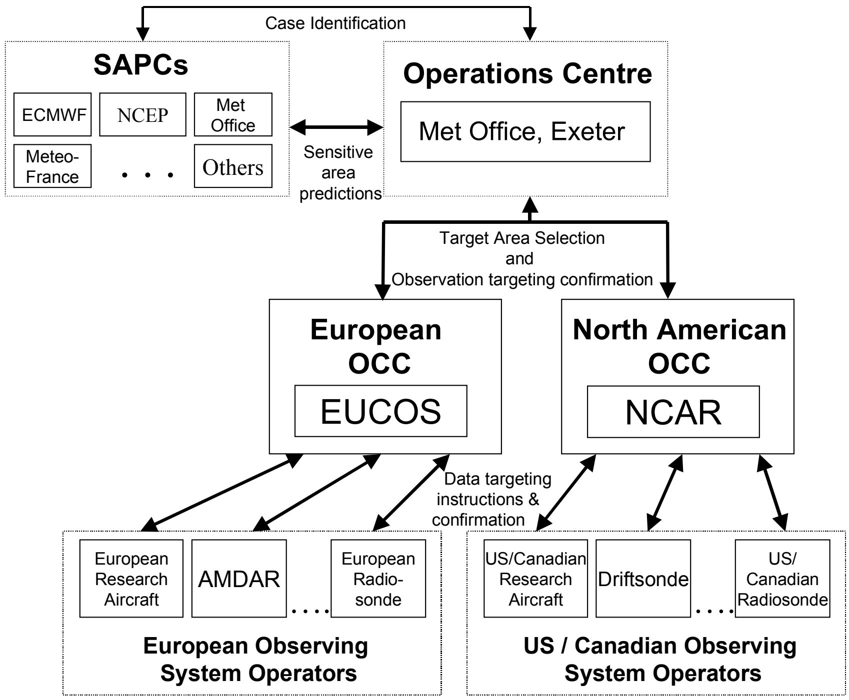


Figure 5: The flow of instructions and advice through the controlling systems.

It will be necessary to agree clear roles and responsibilities for the OCC's. It is also necessary to define the processes by which the various components of the observing system will receive their instructions. These details will be described in detail within the **ATLANTIC-TOST Operations Plan**.

4.2.1 Data Exchange

Most of the observing systems planned for deployment will generate observations with known characteristics and a proven performance standard (including the driftsonde, which releases standard dropsondes).

The following data exchange strategy will be adopted:

- As much of the data as possible to be ***exchanged in real time over the GTS;***
- If possible, 'targeted' observations will be exchanged using **unique bulletin headers** making them easy to identify during the assessment phase;
- Should it not be possible to use unique bulletin headers, it will be necessary to identify alternative methods of identifying the data after the SOP has ended;
- For those elements where GTS data exchange is not possible, a method of archiving them within the TOST dataset will need to be identified.

4.2.2 Data Archiving

As noted above, much of the data will be exchanged over the GTS, and will therefore be made available to the NWP centres for inclusion within their operational data archives. It is important however that at least one centre is made responsible for creating a complete Atlantic-TOST Dataset that contains all of the data provided in support of the TOST (including any that could not be exchanged over the GTS). ECMWF have agreed to provide this facility.

Creation of a TOST dataset is a large undertaking. As a significant quantity of data will not be exchanged operationally it is not practical to complete this task in real time. Instead a two-stage approach will be taken.

Stage 1: All data will be archived (real time, non-real time and sensitivity info) by one archive centre so that all data is contained within one dataset. This will involve gathering all of the data from participants either operationally from the GTS or in slower time using other methods. Observation providers supplying data in a non-real-time mode will be responsible for preparing the data in a way that makes insertion within the dataset as simple as possible.

Stage 2: Identification of TOST additional data from the rest of the archive dataset being performed as a separate function after the SOP.

The rationale is that the post-SOP dataset creation should be done once, for all collaborators to benefit from, thus producing a test data set for NWP impact assessment. In this way the post-SOP impact assessments by the various centres should have a dataset where individual data types can easily be identified to either add-in or take-away from model runs to gauge impact.

This dataset will be made available to all of the participants especially those not having access to the GTS.

4.2.3 Data Monitoring

Data monitoring will be important for two primary reasons:

1. The availability, timeliness and quality of data must be confirmed and corrective action taken as appropriate;
2. It is important to maintain records that identify the data that has been generated in a targeted manner both within the observation target areas (‘positive’ targeting) and outside the regions (‘negative’ targeting as discussed under section 3.2.2)

The strategy for most components of the observing system will be to make use of the currently available monitoring results that are routinely output by participants. EUCOS for example currently provides routine data monitoring services for EUCOS designated stations and links to centres providing more detailed output. Observation providers will initially be asked to identify methods of monitoring the data they generate. This information will be used to prepare the Operations Plan, which will consider how currently available QEv services could be used during the SOP and identify the need for additional products should suitable output not already be available.

5. *Roles and Responsibilities*

An overview of the roles and responsibilities is provided below. The Operations Plan will provide a more detailed definition.

5.1 Case Selection and Sensitive Area Prediction

The table below lists the NWP Centres that will provide sensitive area predictions, describes the prediction technique they plan to use and identifies a contact person

Centre	Prediction Technique	Contact
ECMWF	Singular vector (Continuously operated: 24,48 and 72 hour forecast ranges. Up to 3 fixed verification regions)	Martin Leutbecher
MeteoFrance	Singular vectors (18 hours forecast range)	Jean Pailleux
Met Office	ETKF based on ECMWF ensemble (24-72 hour forecast range)	Dave Richardson
NCEP (not confirmed)	ETKF based on NCEP ensemble	Zoltan Toth

Each of these Centres will have a responsibility to follow the case selection process outlined under section 3.1.3 and documented in detail within the Operations Plan. Once the verification region and forecast timescale have been agreed, each Centre will be expected to perform their sensitivity assessment based on these criteria. Should multiple cases be identified, two or more verification regions and timescales may be defined in which case the Centres will agree which case each of them will examine.

These centres will also have the following collective responsibilities:
(i) Documenting the sensitive area prediction aspects of the Operations Plan
(ii) Conducting a final review to consider how successfully sensitive areas were predicted.

The Operations Centre will be responsible for assessing the predictions and providing instructions to the Observation Command Centres. In addition the Operations Centre will also liase with the Centre directing the Tropical Cyclone aircraft flights, in particular to co-ordinate observations in potential ET cases. Experimental sensitive area predictions will be made for such cases, specifically by the following centres

Centre	Prediction Technique	Contact
NRL	Singular vectors (for tropical cyclone)	Pat Harr
University of Miami	ETKF: operated primarily in support of tropical cyclone activities	Sim Aberson

5.2 Observation Delivery

The tables below list the European and US/Canadian components of the ATLANTIC-TOST observing system, the Organisation/ Programme that is responsible for operating them and identifies a contact person. The observation types and data exchange techniques provided by each of the observing systems will be defined in detail within the Operations Plan.

5.2.1 European

Observing System	Operator	Contact
AMDAR Aircraft	EUMETNET-AMDAR Programme	Ture Hovberg (SMHI) (Ture.Hovberg@smhi.se)
ASAP Ships	EUMETNET-ASAP Programme	Klaus Hedegaard (DWD) (Klaus.Hedegaard@dwd.de)
Selected Radiosonde	EUCOS	Steve Stringer (Met Office & EUCOS) (steve.stringer@metoffice.com)
Moored and Drifting Buoys	EUMETNET Surface Marine Programme (under EGOS)	Pierre Blouch (Meteo-France) (blouch@shom.fr)
Research Aircraft	Falcon - DLR	Andreas Dörnbrack (andreas.doernbrack@dlr.de)
Meteosat 6 (@ 10 deg E)	EUMETSAT (Rapid scan winds 10 min)	Simon Elliott (elliott@eumetsat.de)
MSG	EUMETSAT (Some early products may be available during commissioning)	

5.2.2 US / Canadian

Observing System	Operator	Contact
Radiosonde	US National Weather Service	Dave Parsons (parsons@ucar.edu)
	Met. Service Canada (MSC)	John Merrick (john.merrick@ec.gc.ca)
Research Aircraft	NOAA G-IV: NOAA	Sim Aberson (sim.Aberson@noaa.gov) Dave Parsons (parsons@ucar.edu)
	Convair 580: Met. Service Canada	Walter Strapp (walter.strapp@ec.gc.ca)
	DLR Falcon: DLR	Andreas Dörnbrack (andreas.doernbrack@dlr.de)
	Citation : UND	John Murray (John.J.Murray@nasa.gov)
	NASA ER-2: NASA	John Murray (John.J.Murray@nasa.gov)
	NOAA P3s (2 aircraft): NOAA	Sim Aberson (sim.Aberson@noaa.gov)
Other aircraft	US Air Force	Sim Aberson (sim.Aberson@noaa.gov) Dave Parsons (parsons@ucar.edu)
Driftsonde	NCAR (1 site: 2 to 3 flights)	Dave Parsons (parsons@ucar.edu)
TAMDAR	NASA	Tom Daniels *Email address required*
MDCRS (AMDAR)	NOAA/FSL	Bill Moninger (moninger@fsl.noaa.gov)
Satellite	GOES rapid scan winds	Chris Veldon (chris.veldon@ssec.wisc.edu)

Each of the organisations responsible for operating elements of the observing system are expected to consider responding to requests from the relevant OCC which will be responsible for:

- setting up the necessary systems and processes required to co-ordinate their components of the targeted observing system
- delivering the data requested by the Operations Centre;

- monitoring data returns and the providing feedback to the Operations Centre

5.3 IMPACT STUDY ASSESSMENT

The following centres will conduct Observing System Experiments.

Centre	Model	Assimilation Technique	Contact
ECMWF	ECMWF global spectral	4D_Var	Erik Anderson
MeteoFrance	ARPEGE global spectral	4D-Var	Florence Rabier Jean Pailleux
Met Office	Met Office Unified Model (grid point)	3D-Var	David Richardson
DWD			
DMI.			
NCEP	NCEP global spectral	3D-Var	Zoltan Toth
Others			

Details of the scenarios to be used will depend on the number and types of weather events that occur during the TOST . These will then be built in to the Science Assessment Plan to ensure that studies are well co-ordinated, deal with the necessary issues and avoid unnecessary duplication. If possible studies should be completed by the end of 2004. It is expected that the data produced during the TOST will also be used by other research groups.

6. *Dependencies and Risks*

The tables below lists the dependencies and risks associated with each component of the experiment.

6.1 Operations Plan

Centre	Description of Risk / Dependency	Risk
Europe & N.America	Operations Plan needs to be produced in draft by end August'03 otherwise the TOST is in jeopardy. Depends on input from various contributors	Med / High

6.2 Sensitive Area Prediction

Centre	Description of Risk / Dependency	Risk
Meteo-France	Sensitive area computation software not installed in time	Low
Meteo-France	Operational forecaster (who controls sensitivity suite) may need to be diverted to higher priority forecasting work	medium
Met Office	Must establish the capability (by implementing the NCEP ETKF solution)	Low
Met Office	ECMWF ensemble data not available	Low
All	Failure of operational forecast/computer system	low
All	Failure of sensitive area computation or post-processing software (no night-time or weekend call out)	Low
All	Potential difficulties exchanging the products and displaying the information for access by the Operations Centre	Medium

6.3 Operations Centre

Centre	Description of Risk / Dependency	Risk
Met Office	Delay to Met Office relocation of the National Met. Centre could impact on the setting up of the Ops Centre. Alternative arrangements would be necessary.	Low/Med
SAPCs	Failure of one or more of sensitive area predictions to reach Operations Centre. Decisions would be based on the available information.	Med
TOST website	Failure of TOST website. Backup exchange techniques should be identified.	Med

6.4 Data Delivery

Observing System	Operator	Description of Risk / Dependency	Risk
AMDAR	E-AMDAR	Need to secure support from the European airlines	Low
ASAP	E-SAP	Need to secure support from the ship operators	Low
Radiosonde Ascents	IM Portugal	Nominated stations are currently subject to technical difficulties	Medium/high
Driftsonde	NCAR	Need to secure funding from the US National Science Foundation to extend the testing programme.	Medium
Research aircraft	DLR, NOAA (G-IV)	Insufficient funding is available to operate these aircraft for the TOST or too few flights will be possible	Medium
Satellite (Meteosat)	EUMETSAT	Not possible to operate in 5-7,5 minute rapid scan mode	Low /Medium
Satellite (GOES)	NOAA / NESTIS	Not possible to operate in Super Rapid Scan Operations mode	Low /Medium
All	All	Time differences make the operation of the various components of the observing system very difficult	Low/Medium

Observation Command Centre	Description of Risk /Dependency	Likelihood
European & US	Difficulties providing a 7-day / week service	Medium
European & US	Failure to understand the target area definitions from the Ops Centre	Low
European & US	Difficulties instructing the observation providers of the requirement	Medium
European & US	Failure to maintain knowledge of observing system availability on a daily basis	Medium

6.5 Impact Study Assessment

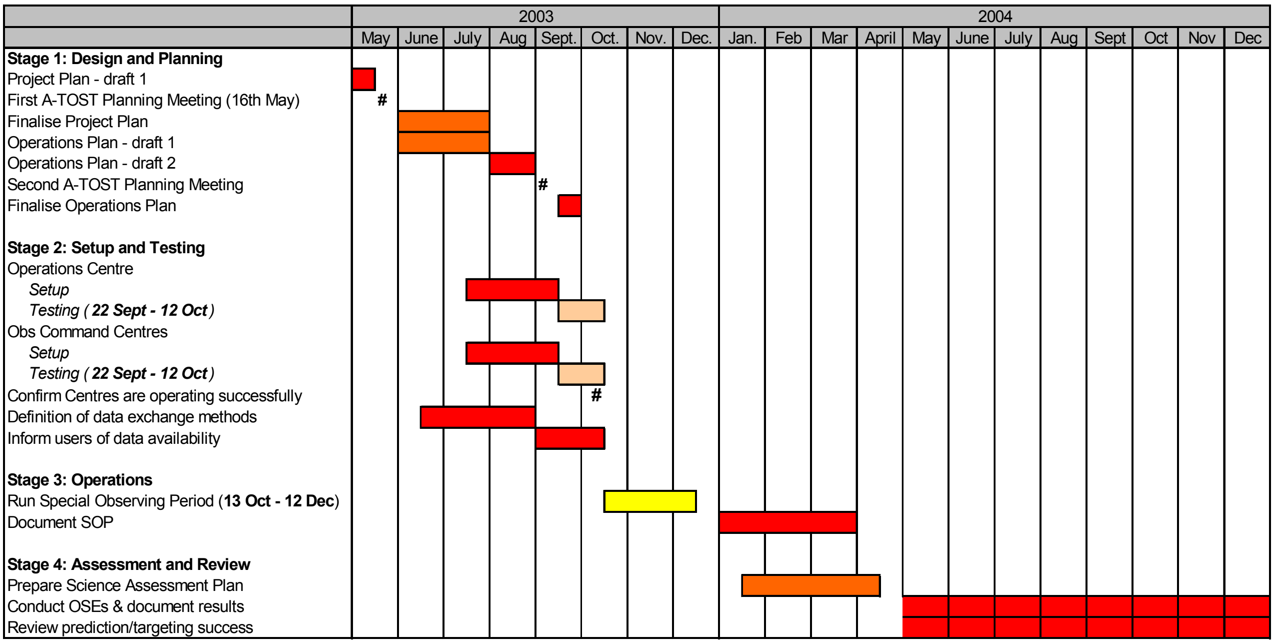
Assessment Centre	Description of Risk / Dependency	Likelihood
All Centres	Insufficient data or too few cases to conduct any useful studies. #	Medium
# The precise choice of impact study experiments will depend on the types of weather event that occur during the TOST. The plans for impact studies have been designed with this in mind. For example if there are few significant events, studies can focus more on the benefits of routine targeting of AMDAR or on the use of targeting in the assimilation of satellite data. The risk of no useful impact work is therefore low		

7. *High Level Action Plan*

The work associated with the Atlantic-TOST can be broken down into the following four stages.

Stage Number	Title	Description
1	Design and Planning	Finalise the Project Plan and preparation the Operations plan, including: - definition of the scientific objectives - confirmation of the participants and their roles - definition of the communication / interaction methods between participants - agreement on data exchange / monitoring methods - definition of the responsibilities of the Operations and Observation Command Centres.
2	Set-up and testing	Setting up and test the: - Operations Centre - Observation Command Centres
3	Operations	Perform the Special Observing Period
4	Assessment and Review	Assessing the impact of the targeted data and our success in predicting and targeting the sensitive areas

The chart below provides a high level illustration of the way in which the Atlantic-TOST will be planned and implemented.



Stage 1: Design and Planning

This stage focuses on preparing the Project Plan and Operations Plan. The Project Plan provides an initial description of the Atlantic-TOST and forms the basis for an agreement between the participants to commence the detailed planning. The Operations Plan (Ops Plan) focuses on the running of the Special Observing Period (SOP), acting as an 'instruction manual' for the operational aspects of the TOST. Preparation of the Ops Plan will rely heavily on strong, proactive support from all those involved in the TOST, many of whom will have responsibility for drafting sections of the document.

Two meetings of the Atlantic-TOST Planning Committee have been scheduled. The first took place in May and considered the draft Project Plan. A second meeting will be held in September to finalise the Ops Plan.

The key deliverables from this stage are:
- A draft version of the Project Plan for discussion at the first Atlantic-TOST planning meeting (mid May)
- A final version of the Project Plan (August)
- A draft version of the Ops Plan for discussion at the second Atlantic-TOST planning meeting (early September)
- A final version of the Ops Plan by the end of September.

Stage 2: Setup and Testing

The Operations Centre (Ops Centre) and the Observations Centres (one for European observing systems and a second for those operated by North American and Canadian participants) will need to be established ready for trial operation starting on 22nd September.

From *22nd September until 12th October*, all three centres will run in a test mode. This will involve full interaction between TOST participants according to the timetables defined under sections 4.2.5 and 4.4.5 of this document, although no additional observations will actually be deployed. The purpose of the test period is to identify the parts of the decision making and communications process that require improvement before the SOP.

It will also be necessary to gather information about the data being generated in support of the TOST so that a data exchange strategy can be defined for each observing component. GTS users will then be informed of the data that will be made available in real time and asked to configure their systems accordingly. A data archiving strategy will be defined so that data exchanged in non-real time is also captured within a TOST dataset.

Stage 3: Operations
The operational stage of the TOST is scheduled for the period *13th October – 12th December*. During this period all systems will function operationally according to sections 4 and 5 of this document.

As part of the Operations phase, the SOP will be documented early in 2004. This will require careful collection of records so that each case can be recorded in terms of:
- The decisions made and actions taken during the case selection, sensitive area prediction and target area identification phase;
- Details of the target area;
- A record of the instructions issued by the OCCs;
- Details of the observing strategies employed by each component of the observing system;
- A record of the extra, targeted observations deployed for each case.

Stage 4: Assessment and Review
The final stage of the TOST will focus on assessing how successful we were in predicting sensitive areas and targeting them with additional observations and how much impact the observations has on the quality of the resulting forecasts. This stage will be co-ordinated by the Science Planning Team (described under section 3.3.5 of this document). This team will be responsible for preparing a Science Assessment Plan. It is hoped that results will be available by the end of 2004.

7.1 TOST Leadership

TOST leadership will be handled within two phases:

Phase 1: The Field Campaign

Phase 1 focuses on stage 1, 2 and 3 of the TOST. It will be lead by EUCOS and will involve the establishment of a small planning group who will collate the inputs from those managers responsible for the various components of the system. It must be stressed that proactive support from these managers will be crucial to enable the planning process to be completed to schedule.

Phase 2: Scientific Assessment

Stage 4, the final stage of the TOST will focus on assessing how successful we were in predicting sensitive areas and targeting them with additional observations and how much impact the observations has on the quality of the resulting forecasts. This stage will be lead by the Science Planning Team. This team will be responsible for preparing the Science Assessment Plan. It is hoped that results will be available by the end of 2004.

8. Financial Matters

Organisations providing predictions of sensitive areas, participating within the Operations Centre, operating the Observation Command Centres and carrying out impact study assessments are expected to carry their own costs. EUCOS will make a contribution towards the costs of the data archiving centre.

Generally, observation providers will also carry their own costs, although EUCOS will provide funding for additional observations from the EUMETNET components of the observing system (such as ASAP and AMDAR). EUCOS will also provide a limited contribution towards the costs of operating the DLR Falcon and NOAA GIV research aircraft.

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Annex 1: Atlantic-TOST Observing System Experiments Suggested Scenarios For Testing

1. Choosing scenarios

One of the purposes of TOST is to obtain information about what targeted observing systems are likely to give cost-effective, positive impact on NWP forecasts over Europe. The scenarios described below are designed to help provide this information. Consideration has been given to scenarios that are likely to give measurable impact on mean forecast skill. Also, the technical feasibility and resources required for carrying out the experiments has been considered.

2. The scenarios

The 'targeted' observations under consideration are all dropsondes and driftsonde reports; the extra ASAP, AMDAR, drifting buoy reports and reports from land stations that will be provided for TOST; and Meteosat-6 rapid scan winds.

The first two scenarios will assess the maximum impact of the targeted observations:

1. All data less all the targeted observations (the existing network).
2. All data, including all the extra data (the fully enhanced network).

The following scenarios are designed to assess the impact of individual observing systems:

3. The existing network plus all the dropsonde data.
4. The existing network plus all the driftsonde data.
5. The existing network plus the targeted ASAP data.
6. The existing network plus the extra radiosonde data from land stations.
7. The existing network plus the extra drifting buoy data.
8. The existing network plus the extra surface reports from land stations.
9. The existing network plus extra data from aircraft.
10. The existing network plus the data from METEOSAT-6 / GOES rapid scan winds.

The following scenarios are designed to assess the impact of selected combinations of observations systems:

11. The existing network plus all the extra oceanic profile data (dropsonde, driftsonde, ASAP).
12. The existing network plus all the extra profile data (dropsonde, driftsonde, ASAP, radiosondes from land stations).
13. The existing network plus all the extra AMDAR, ASAP data plus the extra radiosonde reports from land stations ('low cost' partially enhanced network).

It may also be desirable to assess whether or not the 'sensitive' areas were correctly located. This can be verified by performing experiments which:
(i) eliminate all observations from the sensitive areas only
(ii) include all observations within the EUCOS area except those in the 'sensitive' area.
These experiments could be performed using all available observations or only those of a certain type (e.g. dropsondes).

Annex 1: Atlantic-TOST Observing System Experiments Suggested Scenarios For Testing

3. Implementation

It is suggested that all NWP Centres test scenarios 1 and 2, as the difference in the results of these experiments is likely to give the maximum impact from targeted observations. These runs could be started before the end of the SOP.

Which of the other scenarios are run will depend on the availability of the extra observations taken during the SOP and the availability of computing resources at the NWP Centres. For example, if few extra ASAP reports are available during the SOP it may not be worth expending computing resources testing scenario 5 as a positive impact on mean scores is unlikely to be seen. The decision on which of scenarios 3-13 (or others) are to be tested, and which Centres carry out the experiments, could be taken after the SOP has finished when the availability of observations is known.

To facilitate comparison of results, it is suggested that a verification method be agreed before the experiments are started.

Annex 2: Extra-Tropical Transition of Tropic Cyclones

When a tropical cyclone (TC) moves polewards and starts to undergo extratropical transition (ET, Jones et al. 2003 and refs.) it initiates complex interactions with the midlatitude environment such that the nearly symmetric distributions of winds, clouds, and precipitation concentrated about the mature TC circulation center develop asymmetries that expand greatly in area. The asymmetric expansion of areas of high wind speeds and heavy precipitation may cause severe impacts over land without the TC center making landfall. Due to interactions between the TC and midlatitude circulation, regions of heavy precipitation may be embedded in large cloud fields that extend far ahead of the cyclone center. If the heavy precipitation associated with the primary structure of the TC then falls over the same region as the pre-storm precipitation, the potential for flooding is increased. The poleward movement of a TC also may produce extremely large surface wave fields due to the high wind speeds and increased translation speed of the TC that results in a trapped-fetch phenomenon. Thus a TC undergoing ET in the North Atlantic is a high impact weather event for the east coast of the USA and Canada and their maritime waters.

During the interaction between a TC and the midlatitude flow, low potential vorticity air in the upper-level TC outflow typically leads to downstream ridging on the tropopause. This may modify the tilt of a trough to the west of the TC, impacting the TC motion and rainfall distribution (Henderson et al. 1999; Atallah and Bosart 2003). Further downstream, the modified tropopause structure may initiate explosive extratropical cyclogenesis (Hoskins and Berrisford 1988) or promote the formation of a cut-off low that may move back into the tropics exciting tropical convection or initiating tropical cyclogenesis. The interaction between the TC circulation and a low-level midlatitude baroclinic zone may result in enhanced precipitation ahead of the TC resulting in a secondary development on the baroclinic zone and a similar tropopause modification to that caused by the TC outflow. In addition, the upper-level TC outflow may excite a midlatitude Rossby wave train thus modifying the weather far downstream of the TC itself. Thus Atlantic TCs can be the cause of high impact weather in Europe either directly by transforming into an extratropical system that then moves towards Europe and intensifies, or indirectly by perturbing the midlatitude flow downstream of the tropical cyclone itself. For example, the downstream impact of Atlantic TCs has been linked to severe precipitation events in the Mediterranean (Pinto et al. 2001).

The interaction between a TC and the midlatitude environment is a source of significant errors in numerical weather prediction models, both with regard to the forecast of the TC track and structure and with regard to the evolution of the downstream midlatitude environment. Because of the lack of observations and the inability of numerical models to adequately resolve the structure of the TC undergoing ET, diagnoses of the changes involved in the interaction are often inconclusive. Furthermore, the downstream modification of the midlatitude flow can lead to significant forecast errors in the 3-14 day forecasts such that errors in the representation of a TC may lead to a degradation of the forecast globally.

Current understanding of the interaction between tropical cyclones and the mid-latitude flow suggests that an improved representation in NWP models of four specific features could impact the subsequent forecast:

- the structure of the tropical cyclone, or of its remnants in the midlatitudes;
- the structure of the upper-level midlatitude trough upstream of the tropical cyclone;
- the interface between the tropical cyclone and the midlatitude jet, especially ridging on the tropopause downstream of the tropical cyclone;
- the interaction between the tropical cyclone and a low-level baroclinic zone.

Due to the large variability between different cases of ET, the relative importance of these features may vary from event to event.

To date no targeted observations have been made in the vicinity of tropical cyclones undergoing ET. Apart from reconnaissance flights into Hurricane Michael (2000) and Tropical Storm Karen (2001) as they were undergoing ET (Abraham et al. 2003), very few in-situ measurements are available for ET over the ocean. Calculations of sensitive areas for a target area around the forecast track of an ET event by the Naval Research Laboratory suggest that sensitive regions may be located close to the tropical cyclone during the early stages of ET, with sensitivity appearing in the region of a trough upstream of the tropical cyclone later in the ET. Singular vectors calculated from ECMWF data for the ET of Hurricane

Annex 2: Extra-Tropical Transition of Tropic Cyclones

Lili (1996) highlighted a sensitive region associated with a tropopause depression (Browning et al. 2000). Neither the sensitive regions based on singular vectors for target areas located over Europe/the east coast of North America nor other techniques used to calculate sensitive areas have been applied yet to ET.

A crucial factor in operational forecasting of ET is being able to diagnose when an ET event is underway and when it is complete. Since the majority of ET events occur over the ocean, the development of satellite techniques for such diagnosis is of vital importance. A combination of satellite tools can be
used in this regard, including microwave-based observations from polar-orbiting satellites (e.g., AMSU, SSMI, TRMM) and geostationary satellite Vis/IR/WV. Derived products such as satellite winds from the geo-satellites and Quikscat will help define the evolving ET wind structures. In-situ data during a number of ET events is necessary in order to help develop and validate such satellite diagnostic techniques. Effective assimilation of quantitative satellite data/products in ET events is also an area ripe for exploration.

The scientific objectives of the ET component of the TOST are to increase our knowledge and understanding of the structure, processes and predictability of the interaction between tropical cyclones and the midlatitude flow, and to gather data to study the impact of extra observations in and around an ET event on the predictability of the cyclone undergoing transition and of the downstream midlatitude flow.

Specific goals are:

- To obtain an over-sampled dataset of the significant features associated with ET in order to test targeting and observing strategies and to calibrate and validate remotely sensed data sets of various parameters during ET.
- To obtain targeted observations in sensitive areas related to the ET event.

To investigate the viability of the various techniques available for the prediction of sensitive areas associated with ET.

- To examine the interface between the upper-level outflow from the TC and the midlatitude flow, and how the interaction between the two affects the predictability of both the downstream flow and the enhanced precipitation in the pre-storm environment.
- To examine and validate numerical forecasts of ET with observations.
- To examine whether the TC structure must be observed in order to accurately forecast ET.
- To understand the dynamical and physical processes that contribute to poor numerical weather forecasts of TC/midlatitude interaction.

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Annex 3: Sensitive Area Selection Process