Progress in introducing new technology sensor sites for the Met Office long-range lightning detection system.

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1. Introduction

The UK Met Office has run a long-range lightning detection system since 1986, designated ATD (Arrival Time Difference) system. This uses rubidium oscillators at each detector station to provide accurate time stamps of received Sferic waveforms. Thunderstorm locations are issued on the GTS as SFLOC messages, but the data in these messages do not provide the accurate locations that are available to Met Office and commercial users of the system.

A new control computer was introduced during a project lasting from 1996 to 2000. However, the operational detection efficiency of the existing ATD system across Europe has continued to be very variable in recent years. On some occasions detection efficiency around the British Isles is towards 90 per cent, but on other occasions the current detection efficiency in this area is barely 10 per cent.

Figs. 1(a) to (d) show the number of locations reported in an area covering the British Isles and surrounding seas. The ATD locations are compared to those reported by EA Technology (a system originally built for the UK electricity supply industry, claiming 99 per cent detection efficiency over the British Isles, with detection efficiencies lower over the sea.). The numbers of flashes plotted are average values for three months, derived for the years between 2002 and 2004.

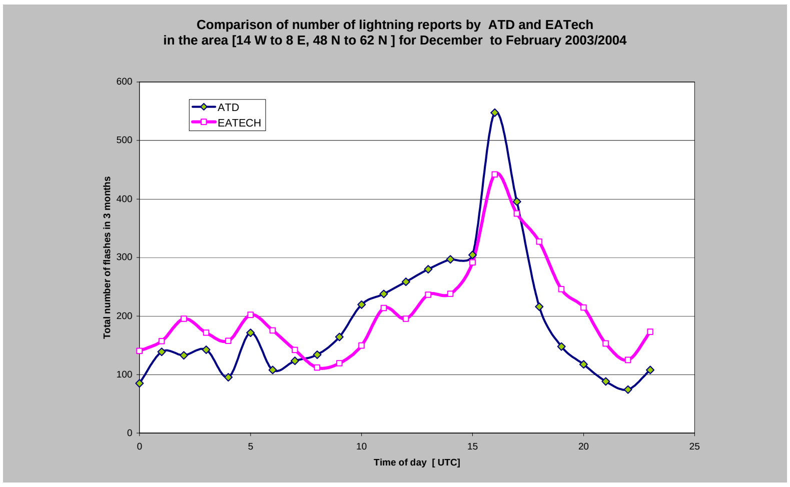

Fig. 1(a) In December to January, ATD was more sensitive than EA Technology from 08 to 17 UTC, but much less sensitive at night when long range activity was highest.

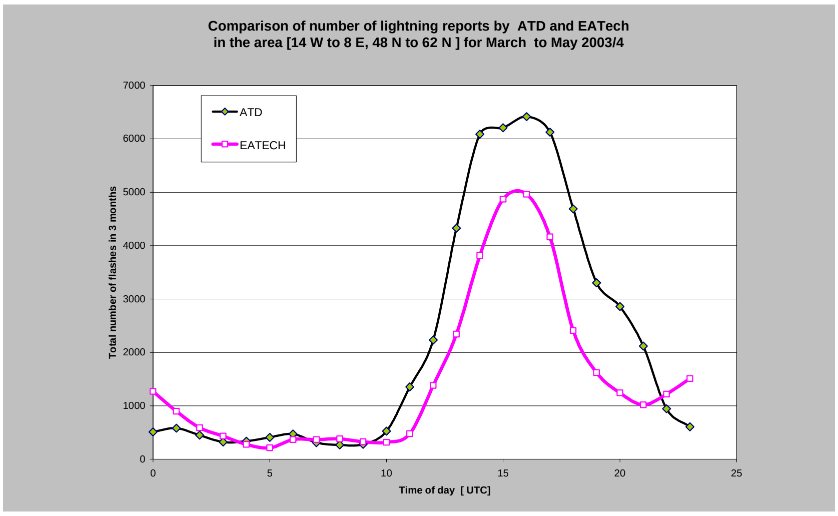

Fig 1(b) ATD performance was good relative to EA Technology from March to April.

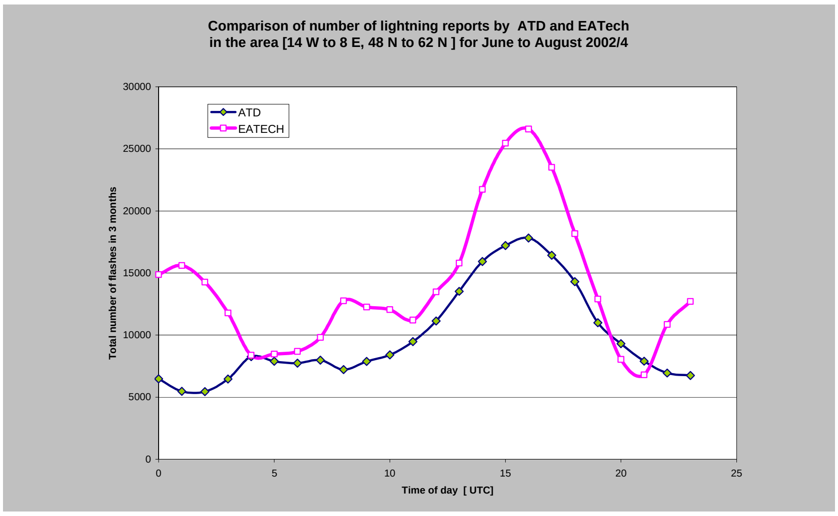

Fig.1(c) ATD was much less sensitive than EA technology for most of June to August lacking the throughput to deal with thunderstorm activity in summer afternoons.

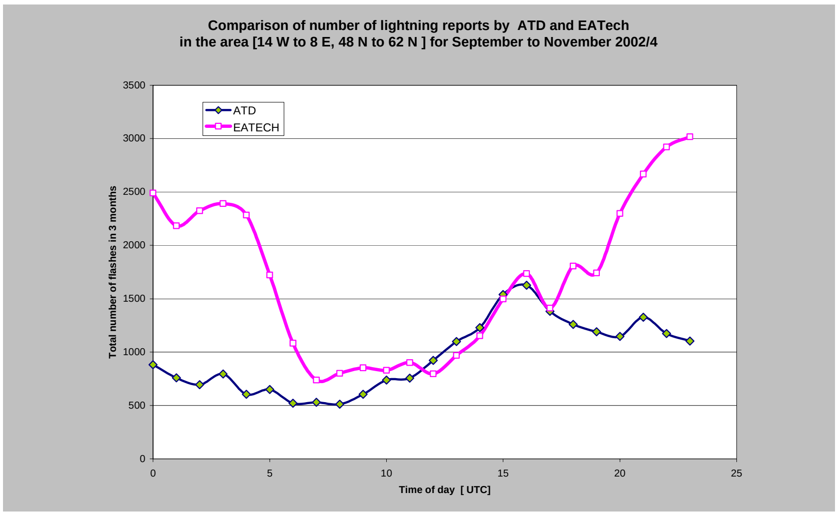

Fig.1 (d) ATD was insensitive around the British Isles during the night from September to November, when very large numbers of strong Sferics were originating in South America.

The number of thunderstorms in the vicinity of the British Isles is relatively small compared to the total number of locations being reported by ATD. In three months the total numbers of flashes reported by ATD will often be 9 million or more in UK summer and around 5 million in UK winter see Fig.2.

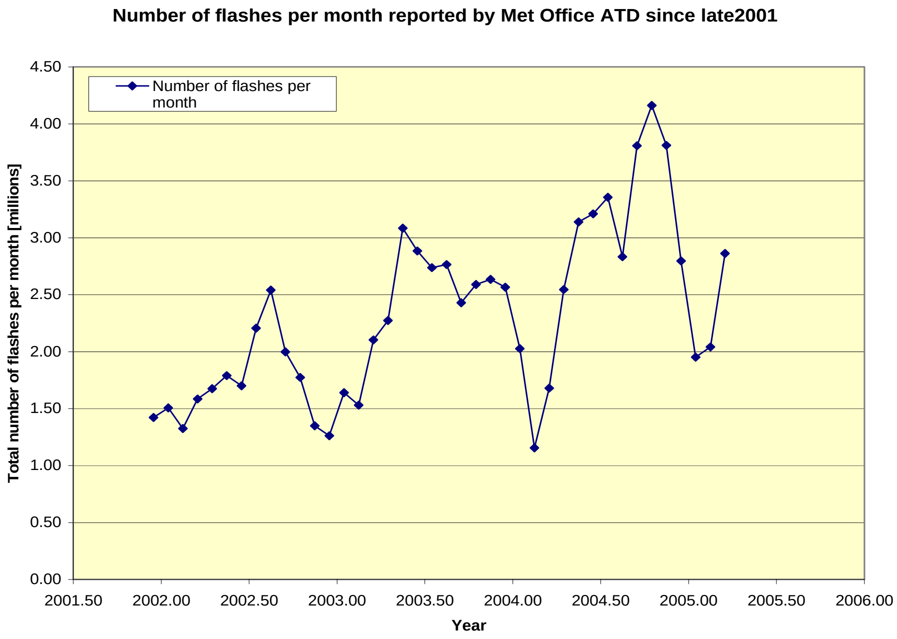

Fig. 2 Number of flashes reported by ATD per month since late 2001

By 2003, it was clear that the current ATD out-stations did not report Sferic waveforms at a sufficiently high rate to allow the ATD system to meet detection efficiency requirements around the UK. Thus, a design for a new out-station (NOS) was required.

2. New out-station

This new out-station was designed by Nigel Atkinson (N.C. Atkinson, personal communication- internal Met Office Document,-ATD101 (2002)]. It is based around a standard PC containing two National Instruments cards for signal processing [PCI-4451] and timing [PCI-6602]. The control and processing software is implemented through the National Instruments graphical programming system LABVIEW. The signal inputs are obtained via a conventional ATD sensor.

Both of the input channels to the PCI-4451 are connected to the same ATD sensor. One channel is operated with a higher gain than the other in order to maximise the dynamic range of the system. The software normally selects data from the high gain channel, but switches to the low gain channel if the high gain is overloaded. The expected effective dynamic range of the Analogue to Digital converters with this arrangement is in the range 80dB. The sampling rate of the 4451 card is set to every 12.8µs, similar to the existing ATD out-stations.

The reference signal for the counting card is provided by the Starloc II GPS system, incorporating a rubidium oscillator, that allows a timing reference to be maintained even if there is a temporary problem with GPS reception.

Processing software is set up to be similar to the existing ATD out-stations in most respects. One significant difference from the existing out-stations is in the Sferic event detection software. Here only "clean waveforms" are now accepted, i.e. those with a well defined threshold peak substantially above noise level. In the existing stations the threshold gain can rise to such an extent that the out-station reports pure noise.

The NOSs do not support the feedback loop that allowed the central computer to request data from out-stations for selected events. All events detected will be forwarded automatically to the Flash Location Processor (FLP).

After several iterations, the configuration for operational New Out-stations (NOS) was finalised in late 2004, see Fig.3.

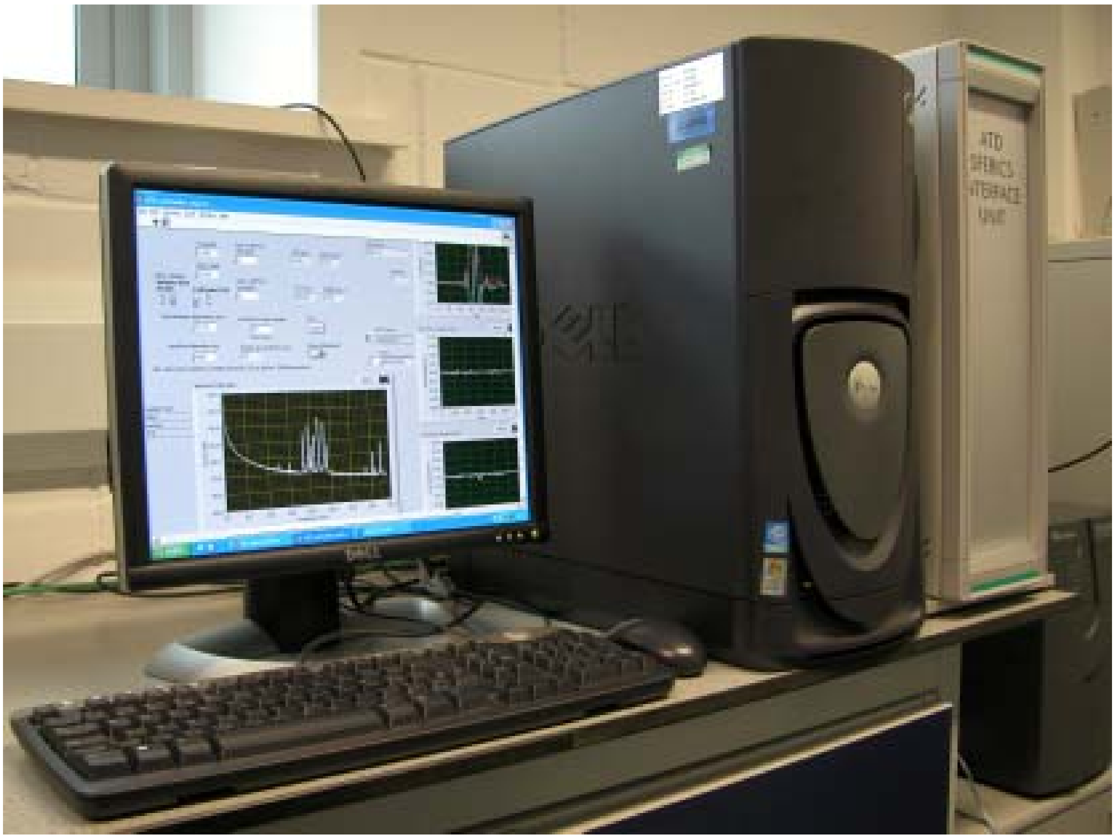

Fig.3 New out-station PC with Sferics display and Interface Unit at Exeter.

2.1 Evaluating the response of the NOS

A prototype new out-station (NOS) was completed and began testing in 2003. By 2004 two improved NOS prototypes were available and could be connected to the existing central computer. This was achieved through an interface computer that selected the information from the NOS requested by the central computer. One NOS was retained in Exeter near the central computer and the other sent to Camborne for evaluation at a site with less than optimum communications availability to the central computer.

The out-stations were evaluated against the following requirements:-

- No large gaps in the supply of waveforms to the central computer.

- A 95 per cent return on Sferic events requested by the central computer.

- An increase in the number of lightning locations reported when using NOS data, especially when operating with only 5 existing out-stations.

- Time differences to be within 2µs of collocated existing out-stations

- Noisiness of reported Sferics should not be high

- The number of Sferic events per hour detected in the UK summertime should be in excess of 60,000

The pre-operational testing of the NOS commenced in June 2004. This showed that gaps in reported data were occurring regularly. Consequently the NOS software was modified in August 2004. At this time the two NOS were incorporated into the operational processing.

Thus, from August onwards:-

- The NOS reported Sferic waveforms without significant gaps, apart from a limited number of gaps caused by problems in communications from Camborne..
- The waveform contribution rate for data requested from the central computer was 97 per cent on average for both Exeter and Camborne NOS
- When the NOS were incorporated in operational processing in August at a time when several existing out-stations were faulty the number of flashes reported doubled. The number of flashes reported per month from September to November were more than a million higher than in 2002 and 2003
- About 90 per cent of the NOS arrival times were within 1µs of the existing out-station at Camborne, and were rarely larger than 1.5µs.
- Noisiness of reported NOS waveforms was of similar quality to the existing out-station.
- During the summer the Exeter NOS often reported more than 60,000 Sferics per hour and on some days as high as 80,000 Sferics per hour. The Camborne antenna unit was found to be less sensitive than the antenna at Exeter, so the total numbers of Sferics reported from Camborne NOS was about two thirds of the numbers from Exeter.
- In winter the rates of reporting at Exeter were rarely larger than 10,000 Sferics per hour.

The results were taken as satisfactory and a decision made to build 5 operational NOS to facilitate testing of a new central computer [Flash Location Processor]. In addition a further 10 out-stations were to be manufactured to complete a new operational long range lightning detection system by 2006.

3. Deployment of NOS systems

When thunderstorm activity in Europe is high in summer and autumn many of the out-stations are rendered insensitive by local thunderstorm activity from time to time. Thus at the time when most throughput is required the number of out-stations able to function at full detection sensitivity is quite limited and may be only 4 out of 7. Thus, a wider spread of ATD out-stations around Europe is required to sustain high detection efficiencies in summer.

In designing the replacement out-stations (NOS) it was decided that maintenance of the out-station would be by module replacement. Replacement of modules (PC or National Instruments processing card) should take place with a possible time delay of several weeks to minimise maintenance costs. Duplication of facilities within the existing out-stations was considered inefficient, because this duplication was not pertinent to the most common operational problem encountered. This was the failure of communications to an out-station site for extended periods.

Thus, processing functionality within the NOS has not been duplicated. Problems with communications failure/insensitivity near thunderstorm activity should be addressed by increasing the number of core NOS sites slightly to provide the necessary improved redundancy in detecting sites. The aim of the redundancy recommended is to allow ATD to continue without serious loss of functionality even if two or three core sites are not contributing to flashes. With the current system, the loss of one or two sites usually has a serious impact on throughput, especially if some of the remaining out-stations are functioning poorly.

Operating costs of ATD are primarily associated with communication costs. However, it is intended that the new system will benefit from much reduced telecommunication costs and this will allow the deployment of more out-stations than in the current system. The cost of building NOS is an order of magnitude cheaper than current ATD out-stations .Thus, the existing ATD out-stations would probably cost £1.4 million pounds to replace with equivalent technology whereas 15 NOS out-stations for ATDNET is costed at £225k.

Thus, a minimum network of 13 stations is proposed for the new ATDNET system with 10 within Europe, see Fig 4. Thus the proposed NOS locations in Europe are:-

1. Exeter which should always contribute and have no communication costs..
2. A site in Ireland [to be negotiated Belmullet, Castor Bay , Valentia, Shannon??]]
3 Lerwick
4. Nordeney, Germany
5. Korpoo, Finland or another site in Finland if earthing continues to prove a problem at Korppoo.
6 Iceland
7. Cyprus, with location chosen to ensure improved communications
8 Gibraltar
9 Payerne, Swizterland or a site in southern France (Toulouse) [for improved short range redundancy] - to be negotiated
10 Azores [for improved redundancy at times of highest thunderstorm activity in Europe and near the British Isles.] – to be negotiated

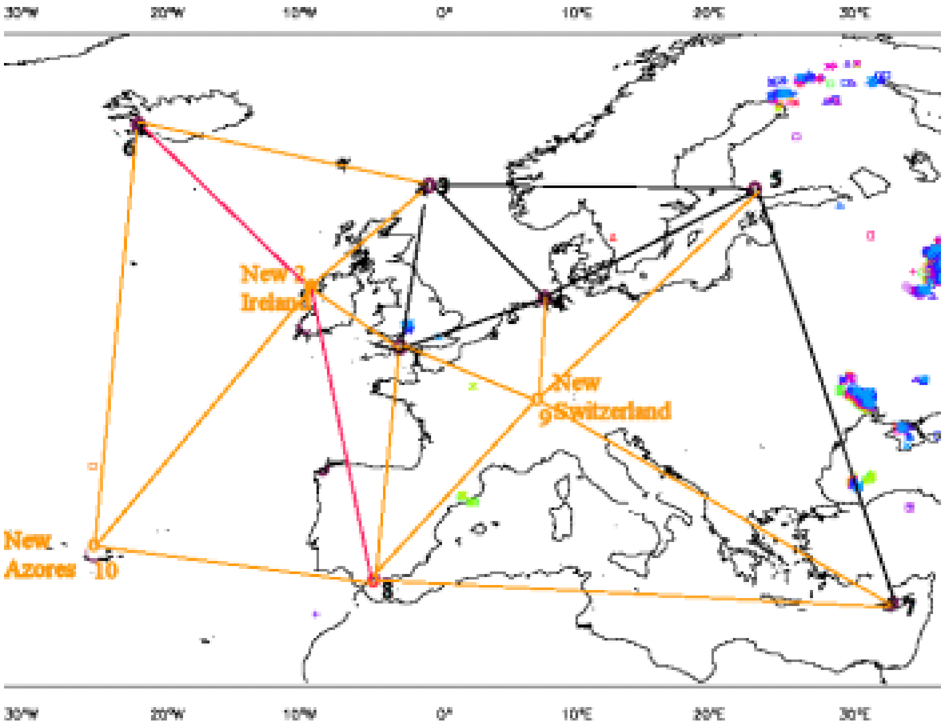

Fig.4. Proposed ATD NOS locations to sustain high detection efficiency for British Isles and European Service areas.

4. Long rang coverage

4.1 Service area

Currently, ATD can provide a 24 hour thunderstorm detection service over the areas shown in Fg.5. The area of coverage is governed by the properties of Sferic propagation, with least loss of sensitivity with distance travelled occurring along sea tracks. Thus, in autumn and winter most of the locations reported by ATD are in South America., Central America, the Caribbean and Africa. In summer when the numbers of storms in Europe is very much higher, then the area of long range coverage shrinks since the ATD out-stations are operating at lower sensitivity. ATD's sensitivity to storms in central, southern and eastern Africa only becomes useful for relatively short time in the middle of the day, when the number of thunderstorms in the Americas drops to a level that the storms in Africa can be sensed. In North and West Africa the system provides useful thunderstorm detection throughout the day.

South Africa is well outside of the Service Area covered throughout the day, but wishes to collaborate in extending the ATD service area to cover the whole of Africa. Meteo France also wishes to cooperate in extending the coverage towards La Reunion.

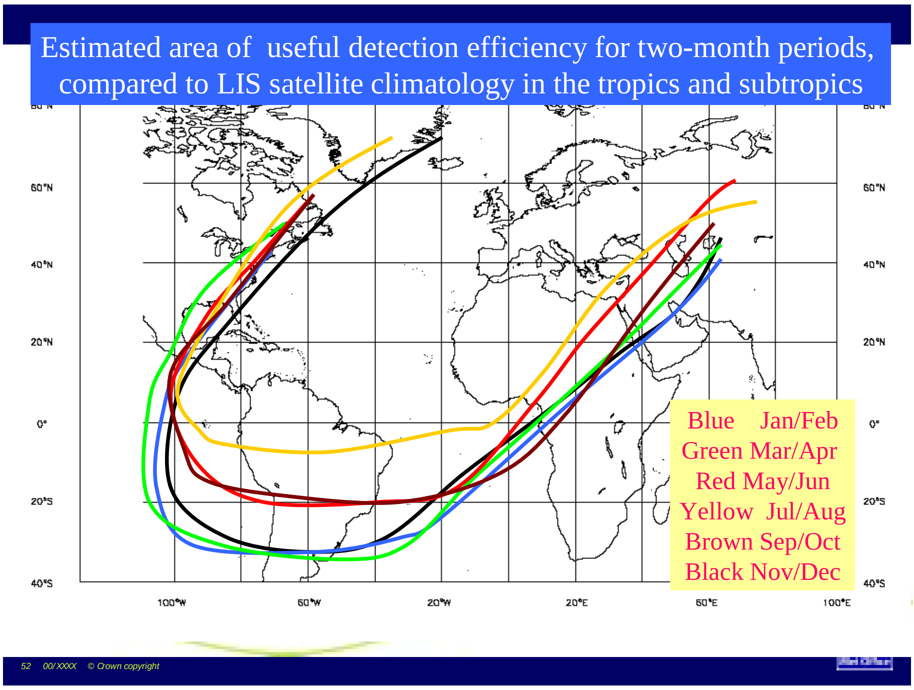

Fig.5. Estimates of the range off current ATD service area where most large thunderstorms are detected 24 hours a day.

4.2 Long range NOSs

To minimise the radial errors in long-range locations and to support the quality control in Europe by improving location accuracy in the long range areas, 3 more NOS sites will definitely be added to the new system. These will be numbers 11, 13 and 15, see below. Number 12 would be necessary to ensure good redundancy and location accuracy in central and east Africa.

11 South Africa [test ability to keep long range communications cheap]- essential, collaboration with South Africa started

12 Kenya/Tanzania- choose Mombassa or Dar-es-Salaam – essential to be negotiated

13 Ascension Island or St Helena- essential

14 Oman [Muscat] or Bombay or Karachi to improve coverage in the direction of India – funding to be negotiated

15 La Reunion or Mauritius together with Meteo France –essential, negotiation in progress

On this basis it is proposed that the ATDNET flash location processor be capable of receiving data from up to 20 sites without significant modification.

Note: The feasibility of adding out-stations in addition to the 13 recommended will depend on the cost of the communication link, or the willingness of another Met service/Agency to pay for the annual cost of the link. The cost of long-range communications for the future is to be identified by the pilot deployment of out-station 11. Once these communication costs have been identified, it will be possible to finalise the out-station deployment plans, given a target annual communication costs for ATDNET of £50k.

5. Examples of current performance

The Met Office ATD is a fully operational system, with worldwide output accessible hourly to users of the Met Office HORACE workstation.

The old out-stations are becoming difficult to maintain and Figs 6(a) to (c) show operational output in March 2005, with the ATD system functioning in an interim state with 5 old out-stations and 2 new out-stations in the UK.

Output from a renewed system dependent entirely on new out-stations and a new central processor should be available operationally before 2007.

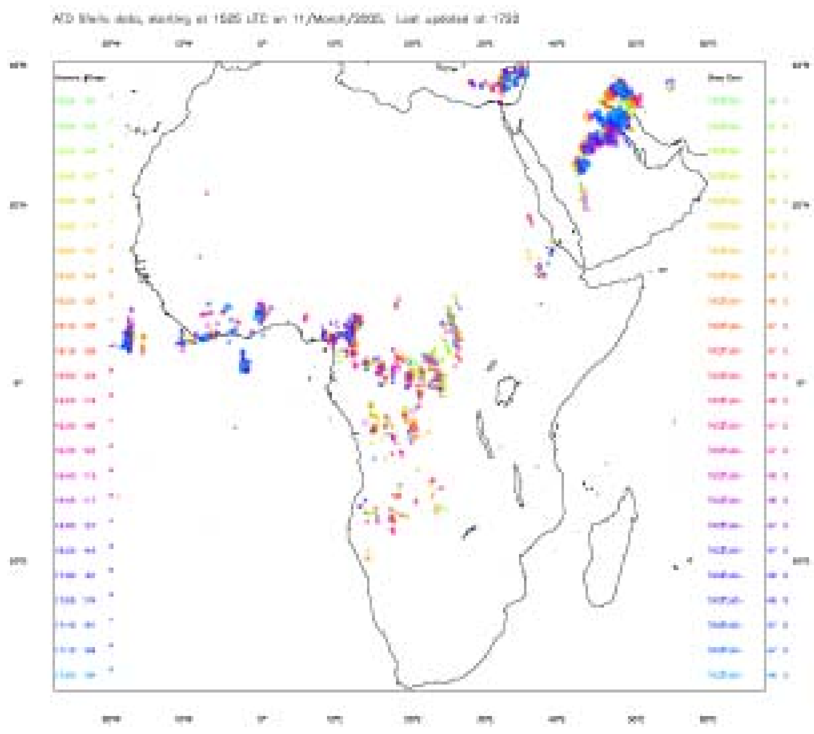

Fig. 6(a) Long-range lightning detection over Africa, 17.00, 11 March 2005.

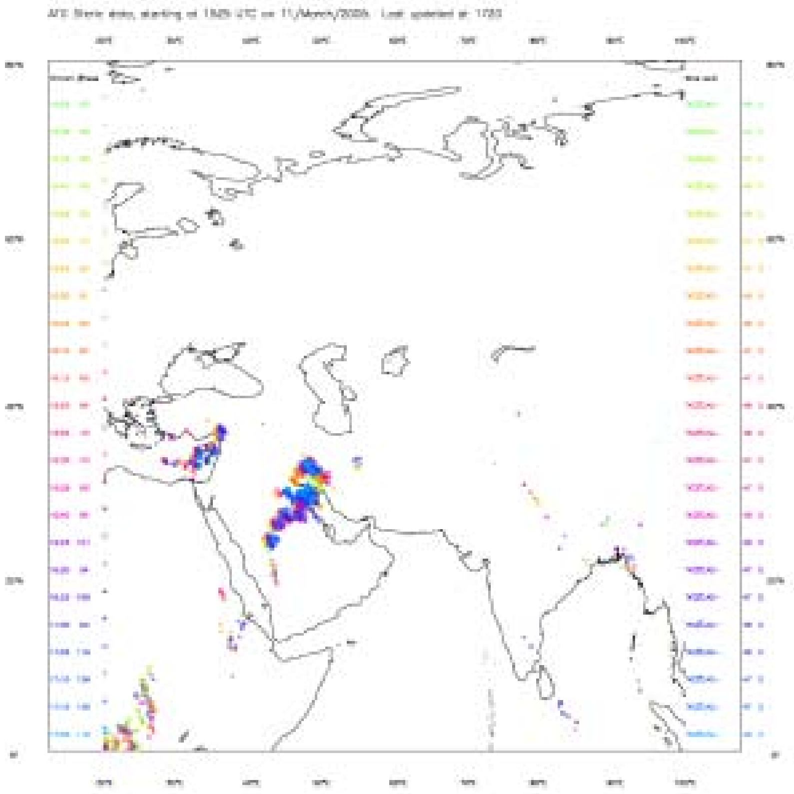

Fig. 6(b) Long -range lightning detection over Asia 17.00, 11 March2005

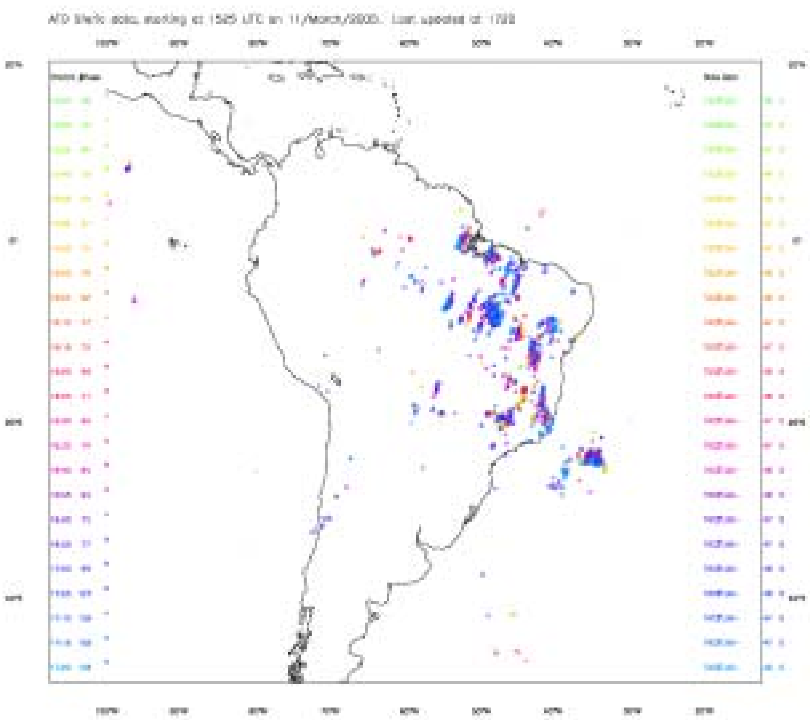

Fig. 6(c) Long-range lightning detection over South America, 17.00, 11 March 2005

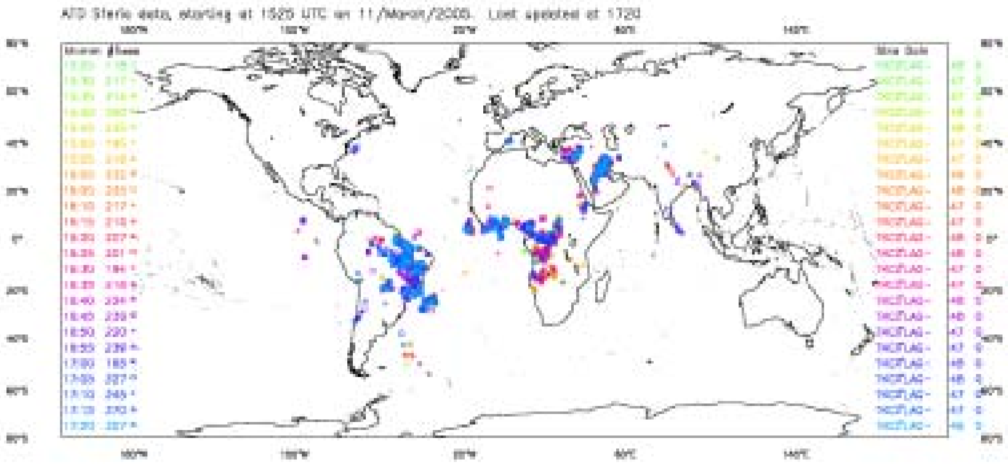

Fig. 6(d) All flashes reported at 17.00, 11 March 2005