LORAN-C BASED SYSTEMS IN METEOROLOGY

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ABSTRACT

There has been growing uncertainty in the meteorological community about the future of upper air soundings using Loran-C radionavigation system. Particularly in Europe, Loran-C is extensively used by the meteorological services for balloon tracking.

1. UPPER ATMOSPHERE WINDS

Profiles of wind speed and direction, measured from the ground level to altitudes of 30 km are some of the critically important input to weather warning and forecasting models.

These are obtained by tracking the weather balloons, either by means of a radiosonde or a radar reflector suspended from it.

Such observations are carried out regularly 2 - 4 times per day on about 700 observing stations forming the global upper-air observation network, working on 12 hour or 6 hour schedules.

Another alternative is the dropsonde, used for research purposes and for tracking intense weather disturbances such as tropical storms. Parachute equipped sondes are dropped from aircraft at an altitude of 5 to 10 km.

Other methods of upper-air wind measurement are in limited use. An acoustic or radio frequency wind profiler radar can be used from the surface up to 500 m or 5 km, respectively. Experimental wind profilers provide even higher altitude winds in good conditions.

Radiosonde is the most common and cost-effective of the several methods. Besides the wind profile, it provides detailed pressure, temperature and humidity (PTU) profiles. The radiosonde network is an indispensable as its accuracy of measurement, the full vertical range and all-weather capability can not be duplicated by the other methods, such as satellite based remote sensors. The data is used in the full range of meteorological services, from local short term forecasts to the climate change analysis.

Tracking can be based Loran-C or GPS, or measurement of the direction of arrival of radio signals with a radiotheodolite, a conventional radar or a transponder radar.

When Loran-C is available, it is the primary windfinding option because of its accuracy, reliability and the inexpensive radiosonde.

Figure 1 Launching a weather balloon

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2. LORAN-C BASED WINDFINDING

Loran-C based windfinding is a cost effective method to meet the World Meteorological Organization (WMO) requirements for upper-air wind: wind speed standard error ±1 m/s from surface to 100 hPa and ±2 m/s from 100 hPa to 5 hPa, WMO (1996).

Unlike most other methods, it does not require free horizon, not even in mountainous areas. Its accuracy is independent of the distance to the radiosonde, and is not deteriorated at elevation angles below 10 degrees, which is a practical limit for radars and radiotheodolites.

2.1 Sounding system

As the interest in this application is in speed and direction of movement only (absolute location is secondary), a number of specific techniques can be applied in these systems.

Vaisala Loran-C receiver uses a cross-chain approach using parts of two Loran-C chains simultaneously. Both ground wave and skywave signal are usable, which makes windfinding outside navigation coverage area possible.

Figure 2 Loran-C sounding system

Another feature that enables windfinding outside coverage areas is the ability to synchronize on the basis of secondary stations only, when the master is too far to be received. The master-station-sync is also available.

Digital signal processing (DSP) is used in nearly all signal conditioning and signal processing stage. Compared to conventional analog implementation, improved precision, high performance and long-term stability result. Self-diagnostics are performed automatically after power-up.

2.2 Automatic chain selection

Before a balloon launch, the receiver detects up to four chains and selects the best chain pair for the sounding. The selection is based on station geometry and the number of available Loran-C transmitters.

The automatic chain selection feature enhances operational capability and simplifies operator's work during Loran-C service breaks and when using chains outside their coverage area.

2.3 . Wind measurement

Determination of wind velocity (speed and direction) is based on Loran-C signals relayed by the radiosonde to a Loran-C receiver at the ground station. A local antenna receives signals directly from transmitting stations and these signals are used for monitoring and synchronizing the Loran-C receiver.

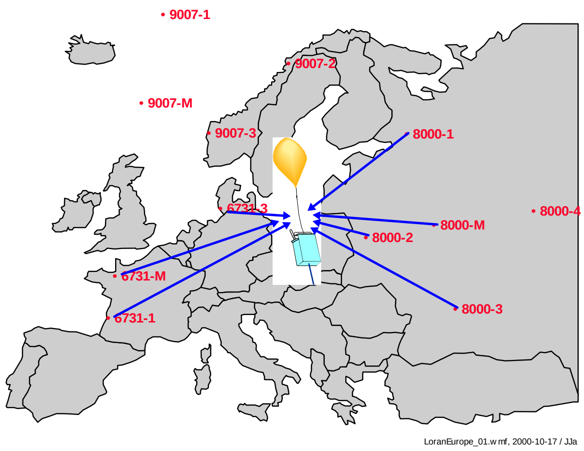

Figure 3 Radiosonde relays Loran-C signals

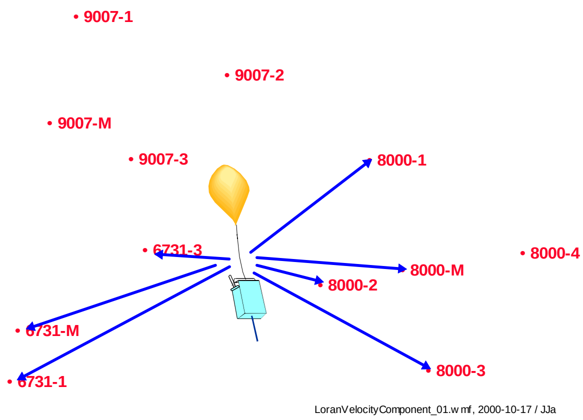

Figure 4 Velocity components

The receiver calculates motion of the radiosonde relative to all transmitting stations. The velocity components are entered into a set of equations from which a wind vector can be solved. Consecutive wind vectors form a wind profile as the radiosonde ascends.

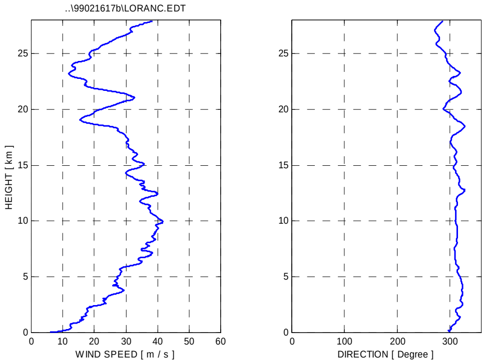

Figure 5 Wind profile

The wind profile together with pressure, temperature and humidity profiles form the contents of a meteorological message discussed in section 3. These messages are distributed world-wide to all national meteorological services within a couple of hours.

2.4 Windfinding accuracy

The accuracy of a windfinding system is affected by a variety of disturbances. These disturbances can depend on the atmosphere, climate, time of the day, time of the year, signal propagation direction, characteristics of the propagation path, system electronics, system software and the geometry of the system transmission stations and receivers to name a few.

Most of these disturbances can not be avoided but their influence to the windfinding solution can be estimated, Jaatinen and Pälä (1998).

In the light of the results from completed tests, the most accurate windfinding system is GPS, offering a 0.1 m/s windfinding accuracy. The second one is a **Loran-C** which offers windfinding accuracy between **0.5 - 1.0 m/s**.

Compared to the GPS tracking alternative, it may be noted that the Loran-C offers fully adequate accuracy with a substantially lower receiver cost. The balloon-borne receiver is lost in the observation. Consequently, it has to be simple and low cost.

These results are in line with other research on the same subject, Jaatinen and Elms (2000), Elms et al. (1996) and Nash (1994).

3. IMPORTANCE OF LORAN-C

Loran-C is a very important part of the meteorological upper air windfinding mix in Europe, North-America and Asia both today and in the future.

Figure 6 shows the reported windfinding method (TEMP messages) percentage distribution world-wide in July 2000 for all synoptic sounding stations.

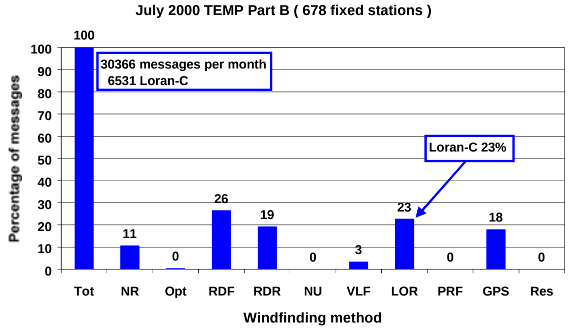

Figure 6 Wind measurement method globally

The labels in Figure 6 and the following figures follow the TEMP message classification:

Tot	Total number of messages
NR	No wind profile, PTU only
Opt	Optical direction finding
RDF	Radio direction finding (radiotheodolite)
RDR	Radar
NU	Not used
VLF	Omega, Alpha, Communications VLF
LOR	Cross-chain Loran-C
PRF	Wind profiler
GPS	GPS navaid based
Res	Reserved

Figure 7 shows the distribution of the 678 fixed synoptic stations of which 129 use Loran-C windfinding. There are also mobile ship-based sounding stations and airplane-based dropsonde stations. This information is also used for weather forecasting.

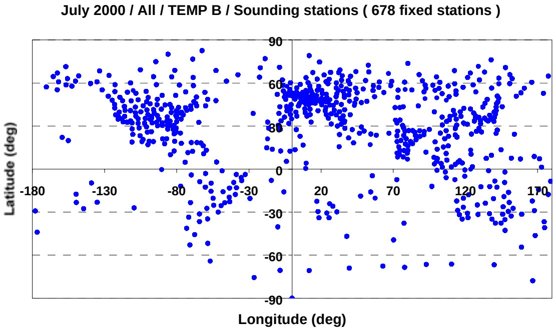

Figure 7 Fixed synoptic sounding stations

Since Loran-C is a regional radionavigation system with coverage in Europe, North America and Asia, these areas are discussed in detail in the following sections. A significant number of messages are obtained using Loran-C windfinding in all three areas.

3.1 Europe

Loran-C is the dominant windfinding method in Europe. 55% of the observation messages are based on Loran-C windfinding.

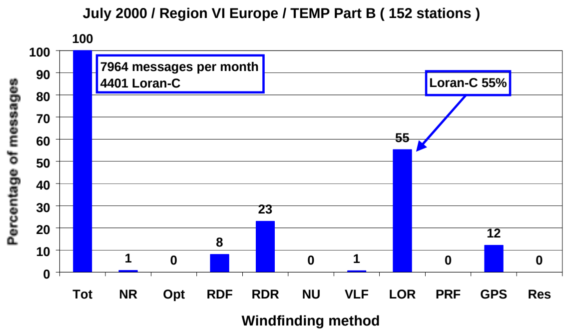

Figure 8 Windfinding method in Europe

3.2 North America

Loran-C is an important part of the windfinding mix in North America. 21% of the meteorological TEMP messages are measured with Loran-C windfinding.

In addition, most special radiosonde observations made for meteorological research in the USA are made by means of this technique.

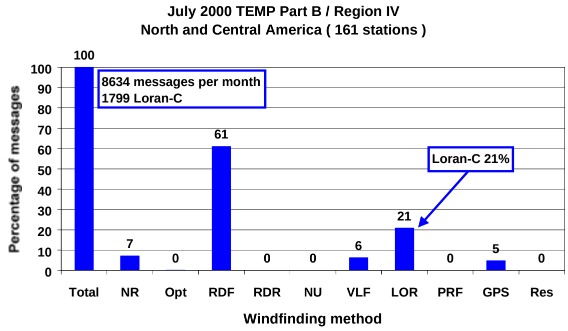

Figure 9 Windfinding method in North and Central America

3.3 Asia

Loran-C is used in areas where it is made available by the Far East Radio Navigation System (FERNS). 9% of the meteorological TEMP messages are measured with Loran-C windfinding.

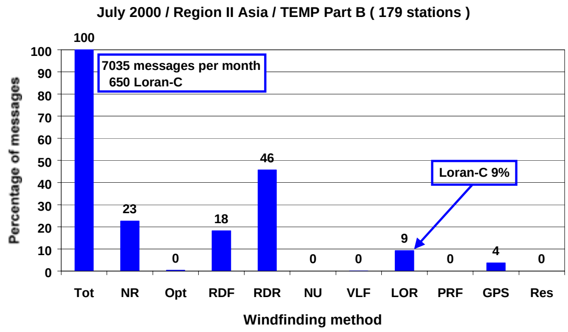

Figure 10 Windfinding method in Asia

3.4 Research and defence forces

The synoptic use covers only half of the yearly radiosonde consumption. Other users of radiosondes and dropsondes are research facilities and defence forces. Also parts of these wind profiles are measured with Loran-C, but the distribution of methods varies as the research projects evolve.

4. SUMMARY

Availability and continuity of service are the two most important factors in meteorological use of Loran-C. In areas where Loran-C is available, it is considered the primary upper-air windfinding method because of the inexpensive radiosonde, good accuracy and high reliability.

This paper shows clearly that Loran-C is very important in Europe, North-America and Asia. If Loran-C were to be closed, the financial consequences to the meteorological community are significant, both in terms of investment in renewed observation systems and in a higher cost of consumable radiosondes.

A reasonable change-over period is absolutely necessary. In addition to the considerable delays due to the budgeting cycles of government organizations, there is a definite requirement of parallel operation of systems to assure that no discontinuity results within the long term climate records.

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