Atmospheric Boundary Layer at European Scale PROBE – CA18235

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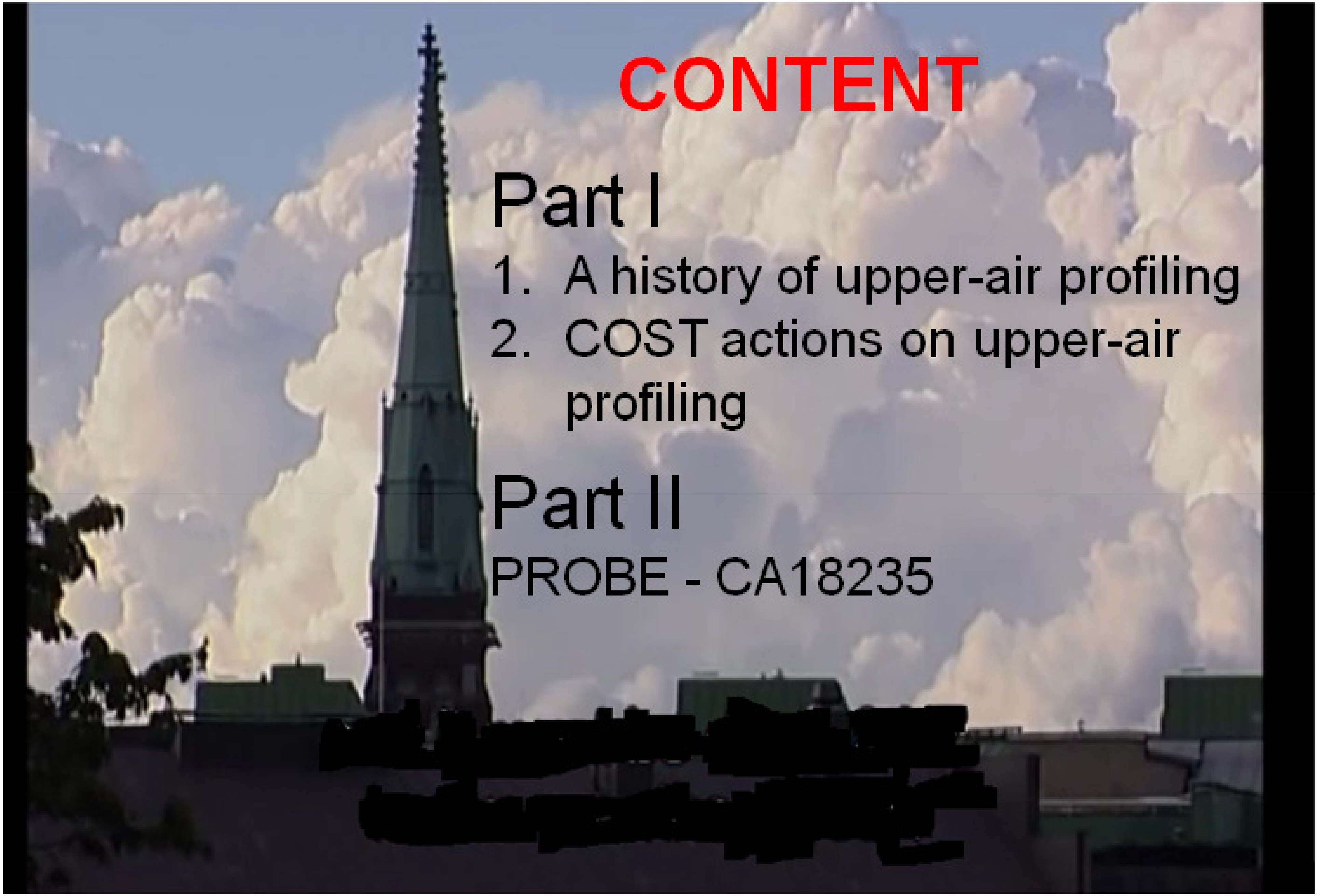
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PROBE - CA18235
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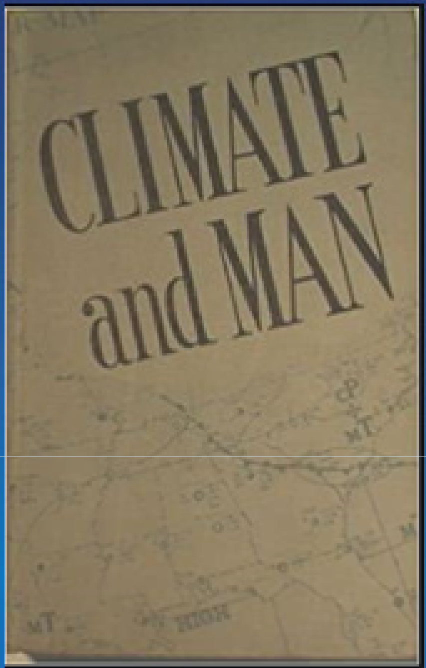
PART I

1. A history of upper-air profiling

Beginnings



Climate and Man: Yearbook of Agriculture, 1941
by Gove Hambidge (Editor)

- **Alexander Wilson** at Glasgow, Schotland; in 1749 was rising thermometers on kites;
- **John Jeffries** and aeronaut Blanchard made the first balloon ascents for meteorological purposes in 1784 (Hambidge, 1941);
- Progress was slow down until 1852 when **John Wels** made balloon ascents to 7 km above ground at Kew Observatory in England taking observation of air temperature, pressure and humidity;
- Between 1862 and 1866 **James Glaisher** carried out meteorological observations in a series of historic balloon ascents;

1. A history of upper-air profiling

Beginnings

The Sonnblick Observatory, located in the Austrian Central Alps at an elevation of 3100 m a.s.l. Since 1886 (source: www.sonnblick.net).

- In seventies of 19-th century the first weather observatories established on Mount Washington (1600 m) and Pikes Peak (3581m) , Colorado, in the United States;
- At the same time many mountain observatories were established in Europe like Sonnblick, in 1886;
- Although observations at these stations given a new light on upper-air structure of atmosphere systems they are not represent well enough free atmosphere at their levels because of mountain influence;

1. A history of upper-air profiling

Beginnings

• **Luke Howard** in 1803 named the main classes of the clouds: *cirrus, stratus, cumulus and nimbus*;

•As an indirect means of determining upper-air motion, classification of the forms of clouds and observations of their movements were carried out by many observers beginning in the early nineteenth century;

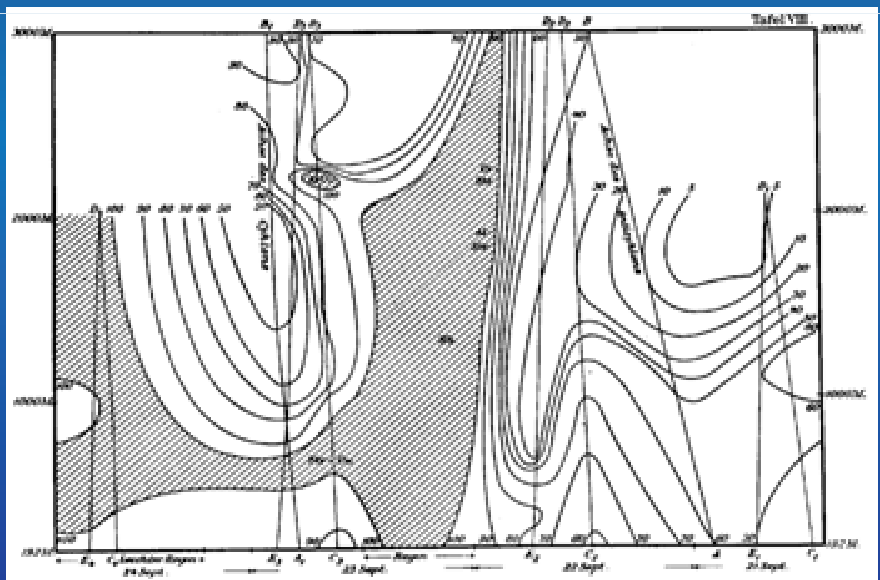
• **Clement Ley's** cloud studies in England (1865-1878) gave the first adequate description of the upper-air wind-flow in cyclones and anticyclones;

• A comprehensive cloud observations summary was done for *Blue Hill Observatory* of Harvard University in the United States by **Clayton** and he concluded that cloud observations can help in precipitation warning for few hours but it has little help for longer periods;

1. A history of upper-air profiling

Beginnings

• In 1893 the first recording instruments (meteographs) were sent up by balloons or kites by Hermite and Besancon in France and a year latter by Rotch and Fergusson in the United States;
• A vertical time cross section for Blue Hill Observatory has been produced for 21-24 Sep. 1898 which is represented in figure below.

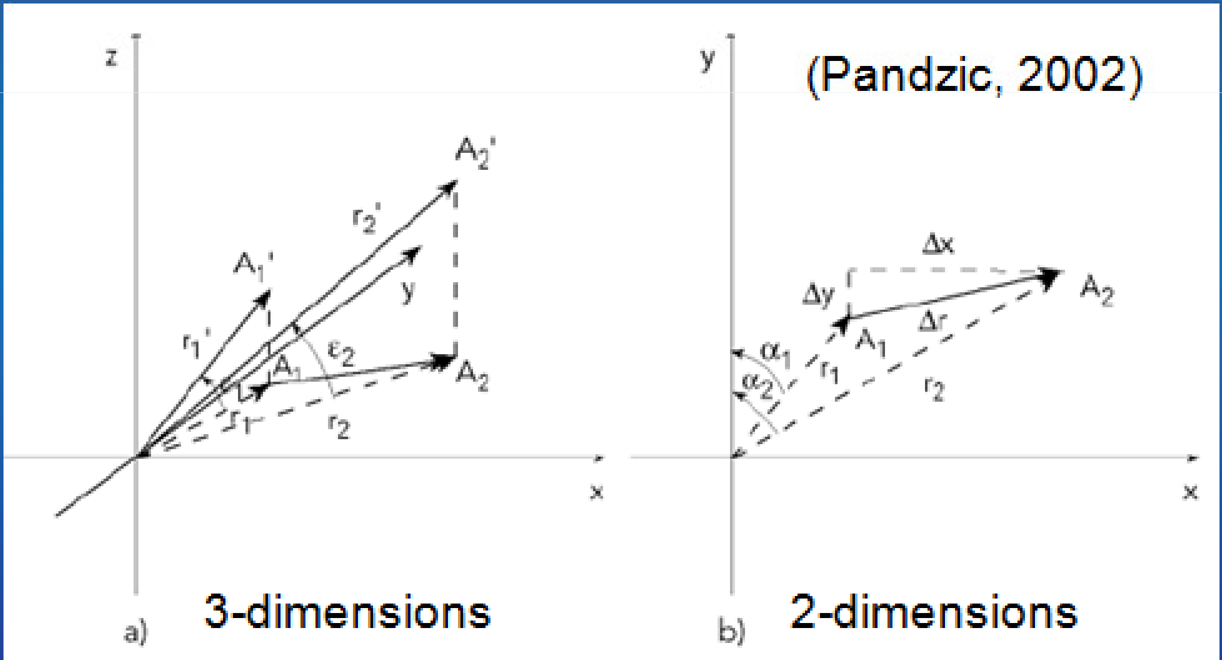


Vertical time cross section of relative humidity during passing a storm over Blue Hill Observatory (U.S.) from 21 to 24 September 1898. (Kutzbach, 1979)

1. A history of upper-air profiling

Pilot balloon observations of wind

• In 1909 **Rotach**, at *Blue Hill Observatory*, made the first upper-air observation of wind by means of a theodolite (a teleskope mounted so as to measure horizontal and vertical angles) with which he observed at regular intervals the elevation and horizontal (azimuthal) angles of a small balloon, called *pilot balloon*;



• Knowing the rate of climb of the balloon, its horizontal path could be plotted and the wind direction and speeds at various heights found;

1. A history of upper-air profiling

Pilot balloon observations of wind

- Although in 18 countries some upper-air obsevations were done before the First World War including pilot balloon observations these data have not been used in real time because of a rather slow data processing even with a delay up to several weeks;
- At the same time theory of Atmospheric Boundary Layer (ABL), about 1km high above the ground, developed e.g. Ekman's spiral theory;

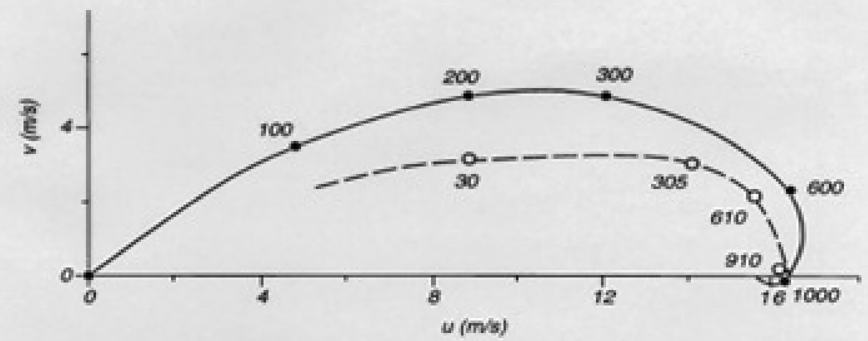


Figure 9.4 Ekman layer in the lowest kilometer of the atmosphere (solid line), with wind velocity measured by Dobson (1914) - - - . The numbers give height above the surface in meters. The Ekman layer at the sea floor has a similar shape. After Houghton (1977: 107).

After Houghton (1997), a comparison between pilot balloon wind observations (Dobson, 2014) and Ekman spiral;

1. A history of upper-air profiling

Early airplane soundings

- A rapid development of the airplane during the First World War resulted in a quick and easy means of obtaining weather observations up to 3 do 5 km above ground and detailed forecast requirements for aircraft operations served as a stimulus to the use of the upper-air data in forecasting;

- The number of airplane stations was gradually increased in United States to about 30 in 1937;

- Despite their advantages over the balloon and kite soundings, the airplane soundings were expensive, and it was impossible to take them during periods of disturbed weather, when they would have been most valuable what objection can be applied also to the pilot balloon soundings;

1. A history of upper-air profiling

Radiosonde observations

- Radiosonde consisting of a lightweight meteograph and radio transmiter attached to a small balloon; each of the three meteorological elements: *air pressure, temperature and relative humidity* is measured by the meteograph and indicated by radio signals which are intercepted at the ground by a radio receiver;
- The radiosonde observations, besides being collected at the ground without loss of time, have been less expensive than airplane soundings and independent of bad weather and they can be obtained at far greater heights;
- The first radiosonde ascent was made before 1930 by the Russian meteorologist Moltchanoff at Sloutsk, near ex Leningrad and the first radio sounding in the U.S. was made by Lange at Blue Hill Observatory in 1935 and number radiosonde stations rised to 30 in 1939 in U.S.;

1. A history of upper-air profiling

Radiosonde observations

Finish scientist Viho Väsälä (1889-1969), developed a light and cheap radiosonde for vertical profiling of atmosphere in 1930s last century.

1. A history of upper-air profiling

Radiosonde observations

- World War II increased the needs for upper-air data and advances were made in radio-theodolite technology that allowed the radiosonde to be tracked in flight so that winds aloft could be obtained. Such observations became known as "rawinsonde" observations. Initially, radio-theodolites were adjusted by hand to track in-flight radiosonde, but by the 1950s automated radio-theodolites (ART) were implemented, which are still used today.
- In the 1990's, rawinsonde technology development continued through improved radiosonde sensors, data processing, and NAVAID systems. One primary advancement was the development of rawinsonde systems that use the Global Positioning System (GPS) to determine winds aloft.

1. A history of upper-air profiling

Discovering weather radar

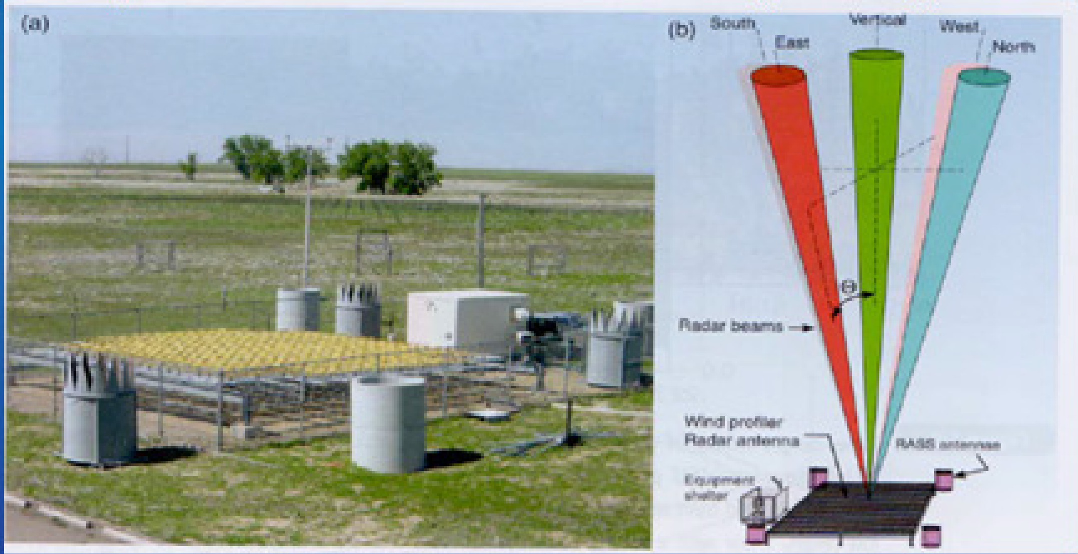
• During the World War II i.e. in 1940 it was noticed that radars , used in aviation, had an echo unknown origin and it was concluded that is echo of precipitation what means a weather radar has been discovered which measures position and radar echo form the target;

Weather radar from Montreal in 1954. (after Fabry, 2015)

1. A history of upper-air profiling

ABL Doppler radar wind profilers and RASS air temperaure profilers

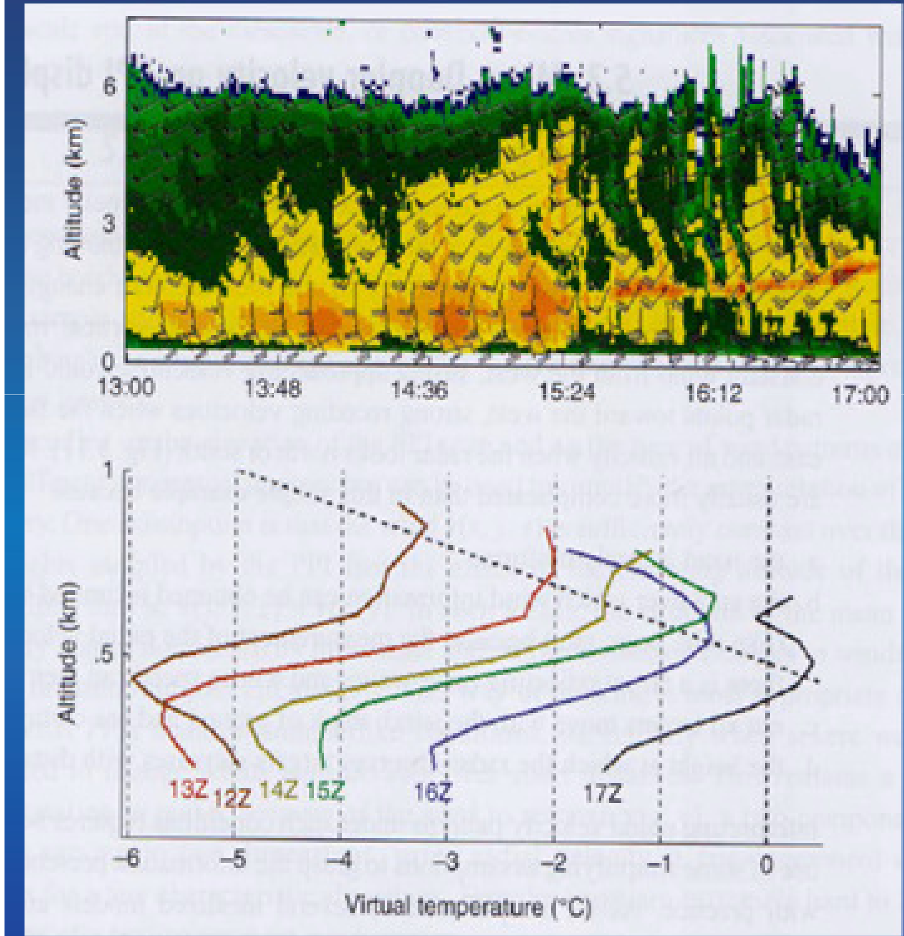
Doopler radars have been deployed operationaly since 1990s in the U.S. and thay are a standard now. They measure radial velocity of target in addition to its echo intensity and 3-D location, while RASS uses *radio acustic sensors* for air temperature observations (Fabry, 2015);



a) Wind profiler photo together with air temperature profiler (RASS – radio acustic sounding system) from Platteville (Colorado, U.S.);
b) illustration of wind profiler and air temperature profiler measurement process. (after Fabry, 2015)

1. A history of upper-air profiling

ABL Doppler radar wind profilers and RASS air temperaure profilers



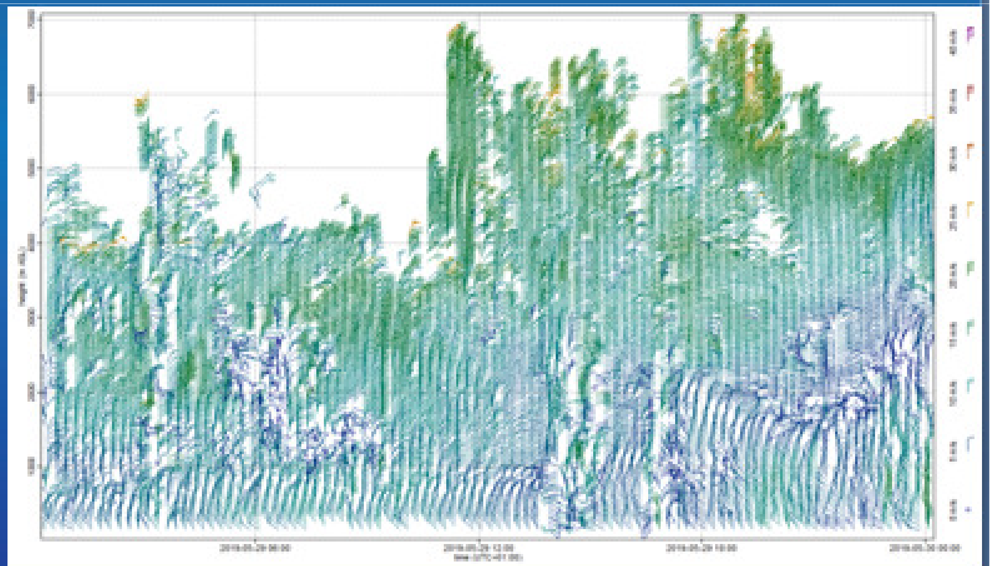
Top: Time-height section of radar reflectivity and horizontal wind from a UHF (Ultra-High Frequencies) ABL wind profiler in Montreal (Canada) during passing a warm front in winter („wamer“ colours indicate higher reflectivities i.s. solid precipitation and „colder“ rain); *Bottom*: Associated air tempe-rature profiles measured hourly by RASS. (after Fabry, 2015)

1. A history of upper-air profiling

ABL Doppler radar wind profilers and RASS air temperaure profilers

Wind profiler at *Dubrovnik* (Croatia) weather station deployed in May 2019 within AdriaMORE interregional EU Project Italy-Croatia.

Vertical profile of wind (right) for Dubrovnik weather station for 29 May 2019 observed by wind profiler



1. A history of upper-air profiling

ABL Doppler radar wind profilers and RASS air temperaure profilers

The network of wind profilers in Europe within EUMETNET e-profile Programe. Stage in May 2019. Blue colours indicate weather Doppler radars and red ones ABL wind profilers. (source: http://e-profile.eu/#/wp_profile)

2. COST actions on upper-air profiling

A review

- COST Action 75 (1993-1997): *“Advanced Weather Radar Systems in Europe”;*

- EU COST Action 720 (2001-2005): "*Integrated Ground-based Remote-Sensing Stations for Atmospheric Profiling*“;

- COST Action 727 (2004-2009): *“Atmospheric Icing on Structures Measurements and data collection on icing: State of the Art”;*

- COST Action ES0802 (2009-2013): *“Unmanned Aerial Systems in Atmospheric Research”*

- COST Action ES1303 (2013-2017): “*Towards operational ground based profiling with ceilometers, Doppler lidars and microwave radiometers for improving weather forecasts (TOPROF)”*

PART II

COST Action CA18235

PROBE

PROfiling the atmospheric Boundary layer at European scale

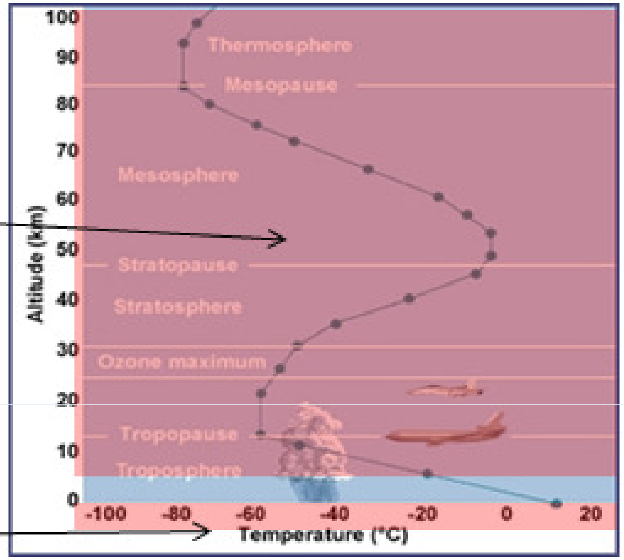
Objectives, People, and Achievements

Link: http://probe-cost.eu/

Motivation

- The Atmospheric Boundary Layer (ABL) is the single most important under-sampled part of the atmosphere*

Satellite



Surface

- Observation gap in the ABL, particularly important in nowcasting and severe weather initiation

- For NWP applications, the top-priority atmospheric variables not currently adequately measured**
  - wind profiles
  - temperature and humidity profiles (in cloudy areas)

*U.S. National Research Council Reports **WMO guidance on NWP obs

Main research question

- How can the observational gap in ABL profiling be closed efficiently and cost effectively on a European scale?

- ABL is the atmospheric layer where
  - exchanges of heat, moisture, and other constituents, take place with the surface, biosphere and anthropogenic activities
  - most human activities take place, affected by wind, temperature, humidity, fog, clouds, precipitation, and air quality

- Better characterization of the ABL is key many applications: Weather, Climate, Air Quality, Satellite sensing, Urban planning, Renewable energies, Insurance, Transport, Construction.

Main challenges

Challenge 1: Capacity building to enhance **knowledge transfer** between academia, industry, and end-users for fully exploiting the potential of ABL profiling for societal benefit

Challenge 2: Enhancing pan-European research coordination to develop **advanced ABL profiling** products and tools for data assimilation and long-time series reanalysis

Challenge 3: Enhancing coordination between operational agencies, academia and industry to **tailor measurement networks** for well identified applications

Challenge 4: Capacity building to **improve the operation and data quality** of existing state-of-the-art ABL profiling instruments towards a European network application

- 3 objectives per main challenge

Proposed Work Plan

WG1	WG2
Transfer to applications Review user-requirements, transfer know-how to end-users	**Advanced ABL profiling** Synergy, best estimate, new and improved ABL products
WG3 **Tailored measurement networks** Data & metadata, networking, optimal measurement strategies	**WG4** **Operation and data quality** ALC, DWL, MWR, CR + emerging technology (DIAL, IR,…)

- 3 tasks per main WG

Achievements so far

- Connecting people from 26 countries
- Identifying core group (Chairs, Grant Holder, Working Groups, Communication manager, ITC Grant coordinator, STSM coordinator, Training school coordinator)
- BAST paper presenting PROBE
- On-line survey of stakeholder needs
- Preparing this meeting

PROBE

- **Full Members (26 FM,** 13 ITC**):** Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Rep., Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Israel, Italy, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland, UK
- **International Partners (5 IP):** China, Japan, South Korea, UAE, USA
- **Near-Neighbour Countries (2 NNC):** Armenia, Russian Fed.

Chair, Vice-Chair, Grant Holder

WG Chairs, Co-Chairs

Key functions

Core group

Role	Person serving	Country
MC Chair	**Martial Haeffelin**	FR
MC Vice-chair	**Nico Cimini**	IT
GH Scientific Representative GH Manager	**Anca Nemuc** **Alexandru Tilea**	RO
WG 1 chair(s) Knowledge exchange	**Henri Diemoz** Simone Kotthaus	IT FR
WG 2 chair(s) Advanced ABL profiling	**Pauline Martinet** Ewan O'Connor	FR FI
WG 3 chair(s) Tailored measurement networks	**Anne Hirsikko** Uli Löhnert	FI DE
WG 4 chair(s) Operation and data quality	**Chris Walden** Christine Knist	UK DE
STSM coordinator	**Iwona Stachlewska**	PL
Science communication manager	**Claudia Acquistapace**	DE
Training school coordinator	**Ekaterina Batchvarova**	BG
ITC Grant coordinator	**Klara Jurcakova**	CZ

BAST research Article

Bulletin of Atmospheric Science and Technology
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RESEARCH ARTICLE

Check for updates

Towards the profiling of the atmospheric boundary layer at European scale—introducing the COST Action PROBE

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(1) ABL products for new stakeholders

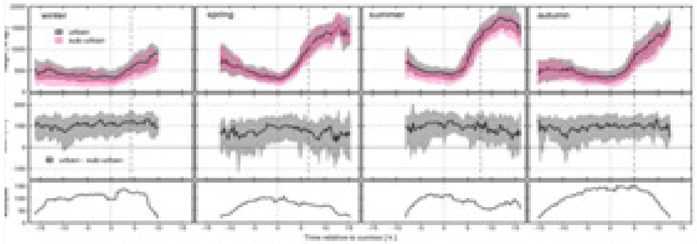

Fig. 2 Seasonal diurnal pattern of mixed layer height (MLH) relative to time since sunrise detected by ALC at a central urban and a sub-urban location in the megacity of Paris, France, during the period December 2016–October 2019; (top row) solid line is the median MLH with shading the inter-quartile range, (middle row) median and inter-quartile range of instantaneous differences and (bottom row) number of samples

(2) Advanced ABL profiling products

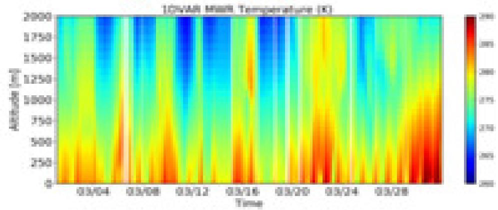

Fig. 5 1-month time series (March 2019) of temperature profiles from MWR operating in three observatories in Europe (top to bottom: Jülich, Germany (50.91° N, 6.41° E), Lindenberg, Germany (52.21° N, 14.12° E), SIRTA, France (48.80°, N 2.36° E). The profile retrievals are obtained consistently throughout the prototype network by processing the MWR brightness temperature observations with the Net1D software developed within the COST action TOPROF

(3) Demonstrating the added value of regional networks

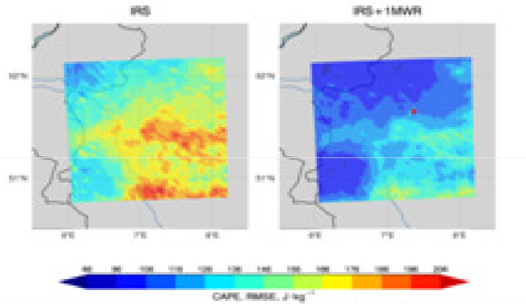

Fig. 3 Left: root-mean-square error of CAPE index calculated from simulated IRS observations over an area in the west of Germany. Right: root-mean-square error of CAPE index calculated from IRS observations including the observations of a single MWR at the grid point marked with red star. Domain size and resolution are 150 × 150 km² and 4 km, respectively (figure courtesy of Maria Toporov, University of Cologne, Germany)

(4) Innovative methods to improve data quality

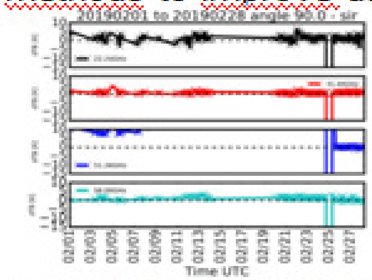

Fig. 4 MWR calibration monitoring through online O-B statistics. Data from the MWR at the SIRTA observatory near Paris (48.80° N, 2.36° E) during February 2019 are shown. Untypical large bias is detected at 51.26 GHz, which is corrected after the recalibration performed on February 25

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