European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs & MC Meeting at SOFIA (BG), 16-18 December 2015

New Sensing Technologies for Indoor Air Quality Monitoring: Trends and Challenges

Action Start date: 01/07/2012 - Action End date: 30/04/2016 - Year 4: 1 July 2015 - 30 April 2016

Aerosol Lidar Mapping of Large Urban Areas over Sofia Municipality. On the Synergy with in-situ atmospheric sensors.

D.Stoyanov, T.Dreischuh, I.Grigorov, G.Kolarov, Z.Peshev, A.Deleva, I.Nedkov

BULGARIAN ACADEMY of SCIENCES 1869

Prof. Dimitar Stoyanov, DrSc.

Invited Lecturer

Institute of Electronics – Bulgarian Academy of Sciences, Bulgaria

Email: dvstoyan@ie.bas.bg

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

TOPICS

1. Introduction. Air-quality assessment problem.
2. Laser Radars Laboratory & IE-BAS LIDAR Station.
3. Lidar mapping of Sofia area. Review of basic results.
4. On the Synergy of LIDAR Aerosol Maping with City Sensor Networks.
5. Conclusions.

Introduction

The air-quality assessment is a multi-parameters problem in urban areas due to many factors as the small scale urban structures (streets, houses), high space & time dynamic of near surface atmosphere, carrying mixes of aerosol particles, chemical & biological pollutions, etc.

The fast technology progress imposes regular reformulations of requirements to the information, provided by air-monitoring systems.

In this presentation we will present the results from the LIDAR Probing of near surface atmosphere above the Sofia Urban Area. We would like to hope our results will contribute to the creation of advanced AIR Quality Monitoring systems in the Capital City of BULGARIA

Laser Radars Laboratory & IE-BAS LIDAR Station

EUROPEAN PROJECTS

EARLINET-2002-2003

ASOS - 2006-2011

ACTRIS - 2011-2015

ACTRIS-2 - 2015-2018

ESA - NASA
"CALIPSO" project

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

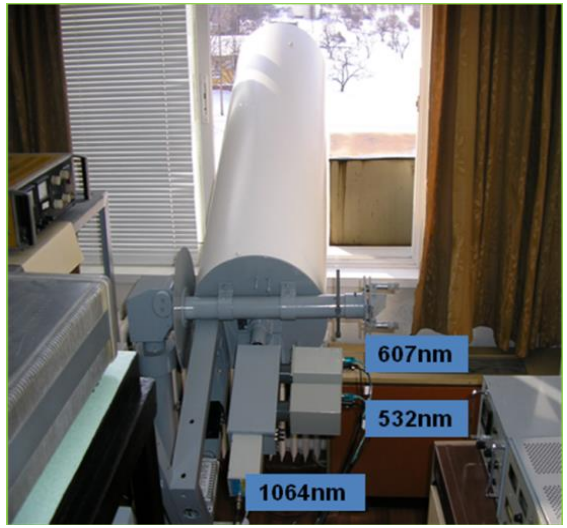
SCIENTIFIC & APPLIED LIDAR RESEARCH in LASER RADARS LABORATORY (IE-BAS)

1. R&D of LIDAR systems for atmospheric probing (hardware & software) since 1975-76.
2. LIDAR sensing of atmosphere (troposphere & stratosphere) and LIDAR ecological measurements since the End of 70-ties, 20-tieth Century.
3. Sofia EARLINET LIDAR Station of IE-BAS, Certified for LIDAR Remote Sensing in troposphere and stratosphere within European Lidar Network (EARLINET).
4. LIDAR DECONVOLUTION Methods for improving the LIDAR resolution.
5. LIDAR diagnostics of fusion plasma in JET (Joint European Torus) in Culham Science Centre, Oxfordshire, UK

IE-BAS LIDAR STATION

3 wavelengths LIDAR (510.6, 578.2 , 627.8 nm) for monitoring of aerosol pollution transport through the troposphere & stratosphere: Saharah dust, volcanic dust, dust by fires, etc. emitted from 3 Continents: EUROPE, AFRICA and Northern AMERICA

Two wavelength scanning lidar on Cu-vapor laser for monitoring (incl. lidar mapping) of Sofia urban area (510.6, 578.2 nm)



3 wavelengths Nd:YAG LIDAR for scanning in horizontal, slope and vertical directions (Vitosha, urban areas, long distance transport of air pollutions) 1064, 532 , 607nm

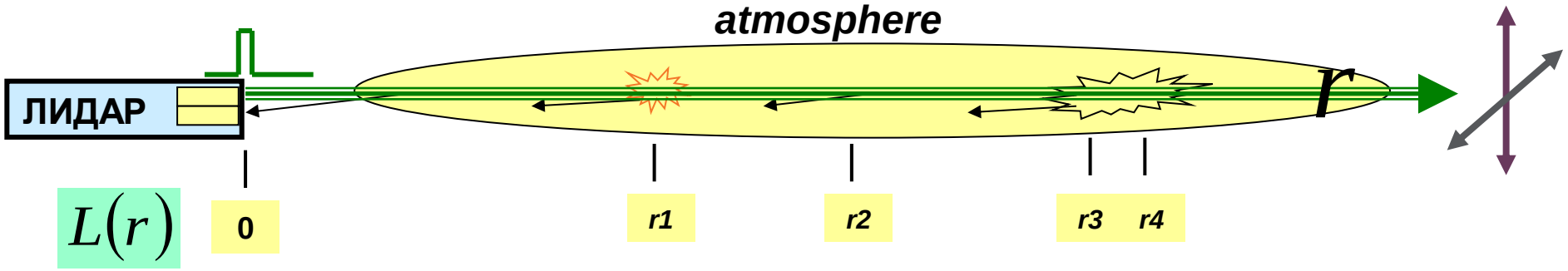
Lidar mapping of Sofia urban area under a Contract of IE-BAS with the Sofia Municipality.

Review of basic results from the high-resolution Lidar mapping (imaging) of aerosol fields

May – December 2015

High resolution LIDAR Mapping of Aerosol Fields

LIDAR (LIght Detection And Ranging)



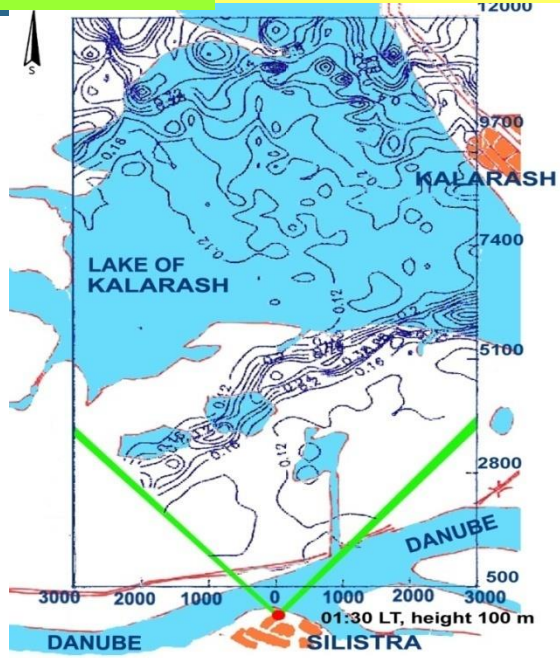
Lidar equation

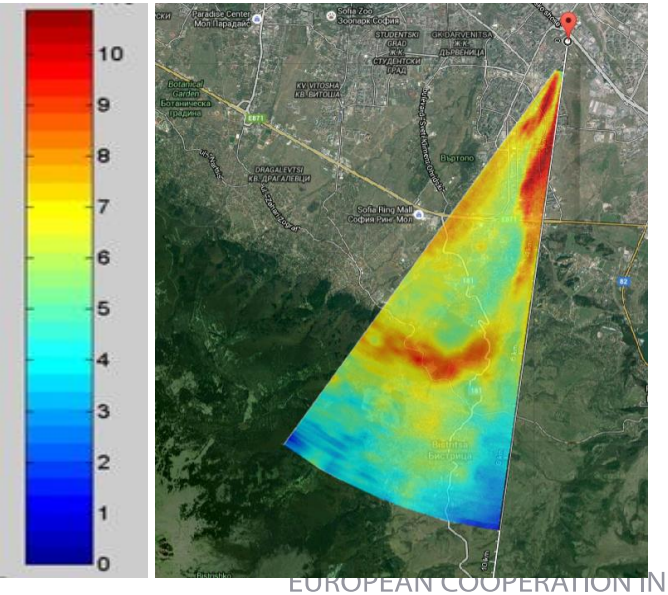
$$L(r) = \frac{1}{r^2} C_{lid} \gamma(r) \beta_{aer}(r) T(0, r)$$

Aerosol mass concentration - $M_{aer}(r) \sim \mu \beta_{aer}(r)$

1993 г $\Delta t_{observ} \sim 23\text{min}$ $\sim 70 sq.km$

LIDAR MAPs





Sector scanning

LIDAR MAPS in horizontal or vertical planes describe the **AEROSOL MASS** concentration distributions in rectangular (X,Y) or radial (r,θ) coordinates with resolutions dX, dY or dR, $d\theta$.

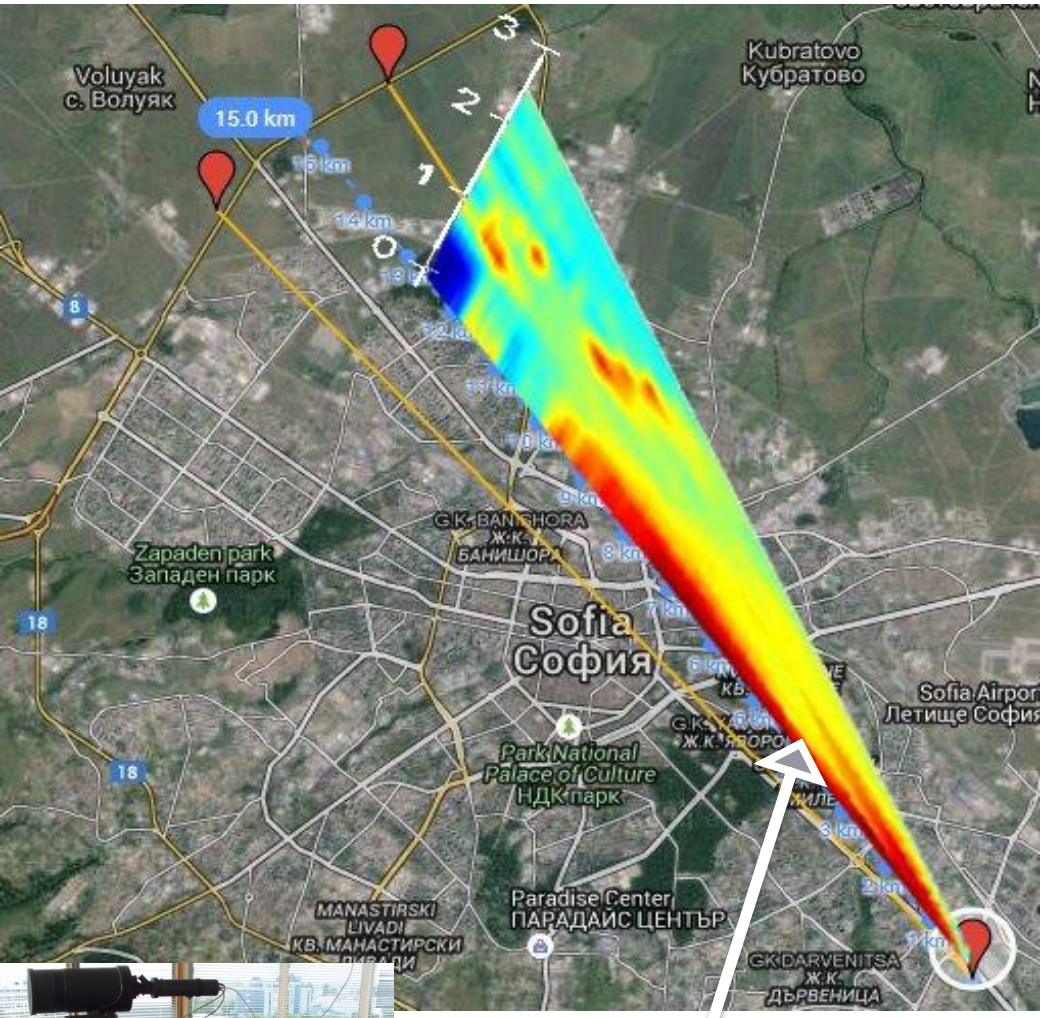
LIDAR MAPS are usually overlapped on the geographical maps.

Aerosols are driven by the wind and can be used as markers for air mass dynamics.

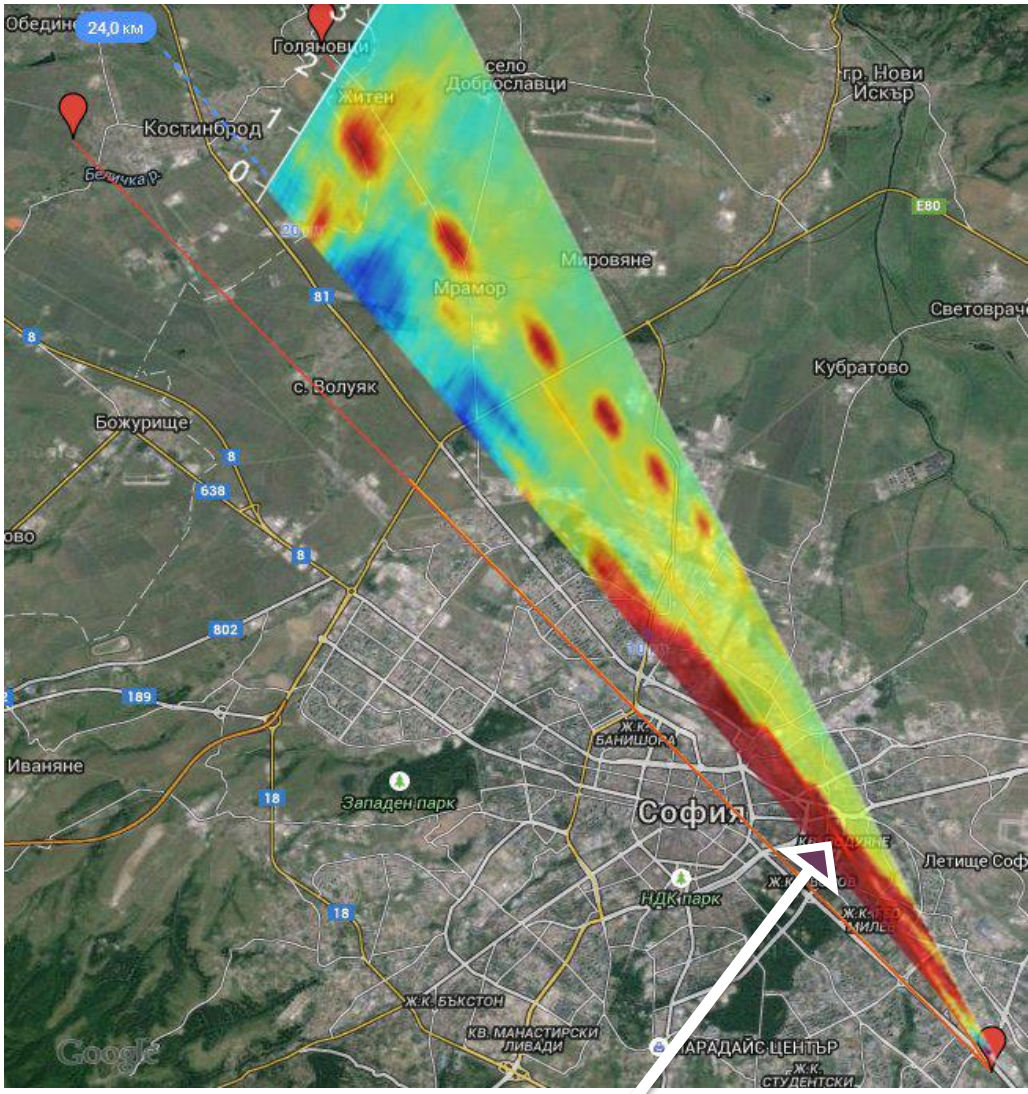
LIDAR Maps can provide a range resolved, near surface 2D information about atmospheric processes. Practically, it is not easy to acquire such information by other techniques.

$$dR_{lidar} \sim 15\text{-}30m, \quad d\theta_{lidar} \sim 1^o \sim 1.7^o.$$

LIDAR vertical section maps of the aerosol distribution along a selected line passing through the city center

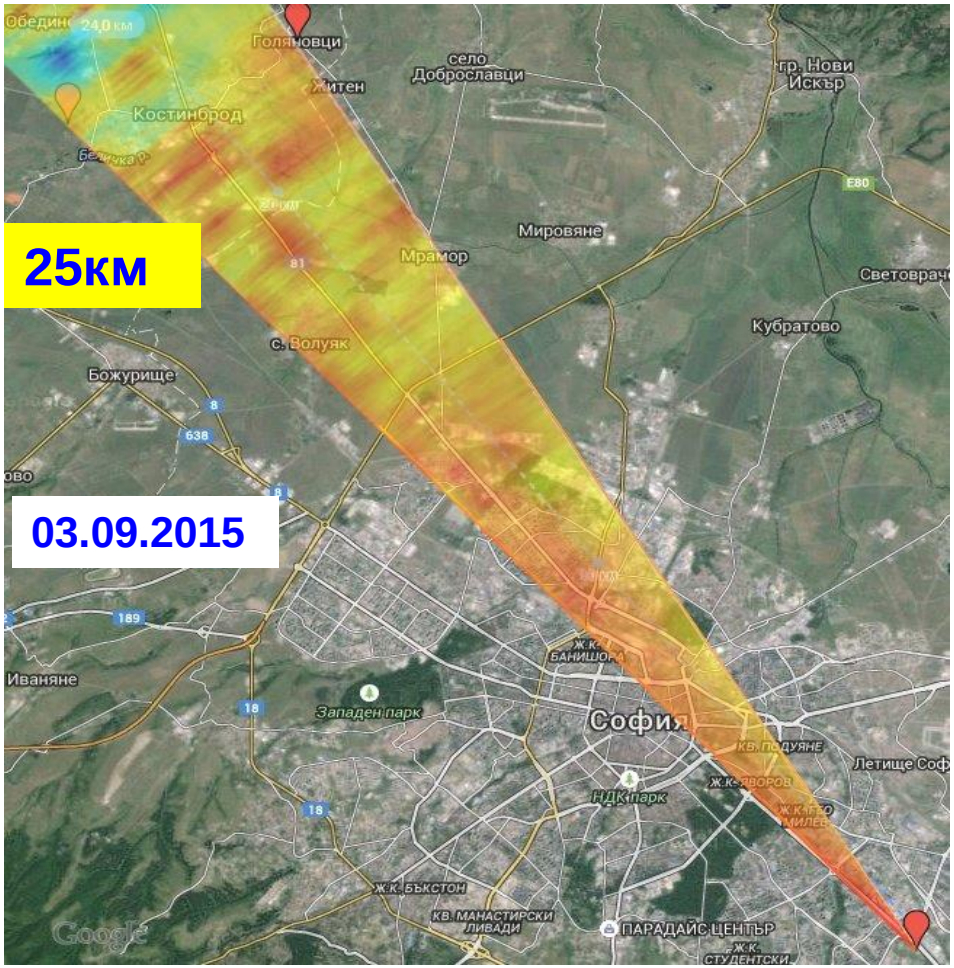


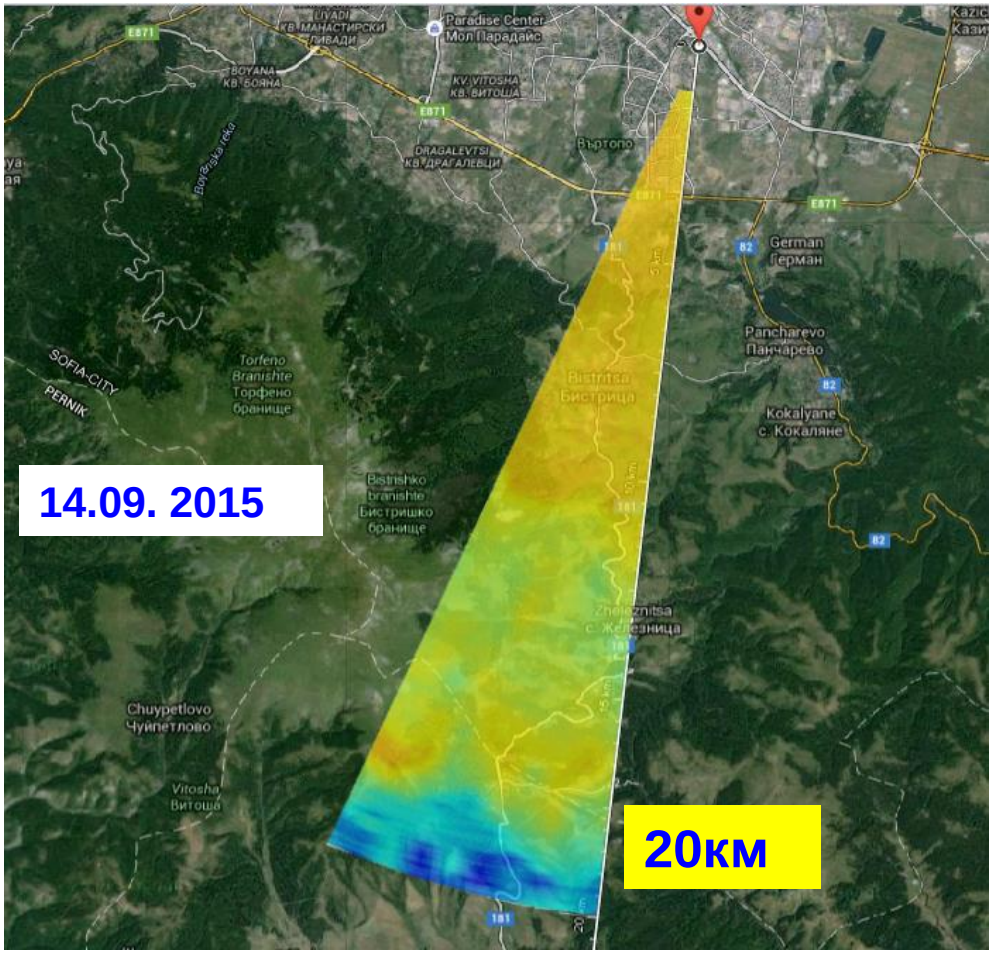
IE-BAS

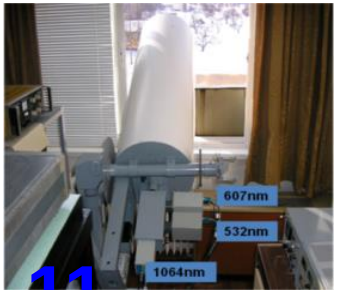


Near surface aerosol layers of higher concentration

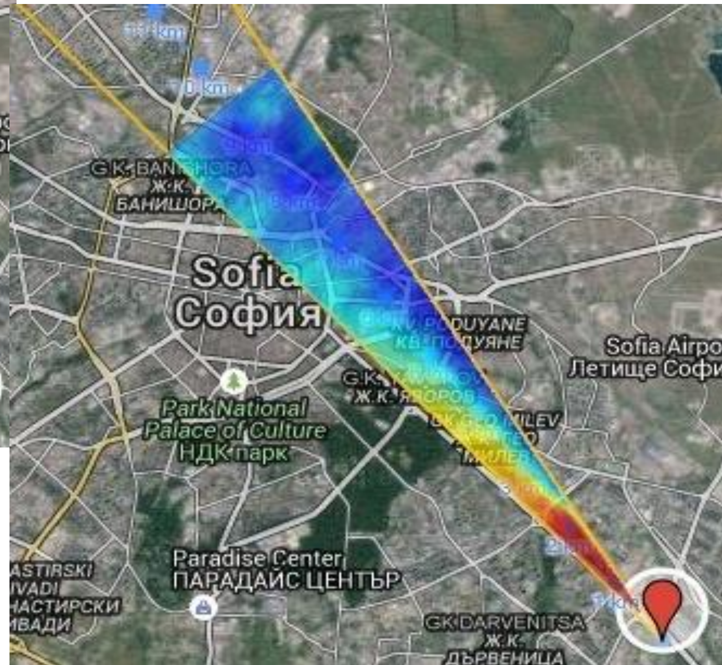
TO the ESTIMATION of the MAXIMUM OPERATIONAL MAPPING DISTANCE from a SINGLE POINT for the CASE of SOFIA REGION

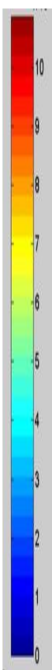






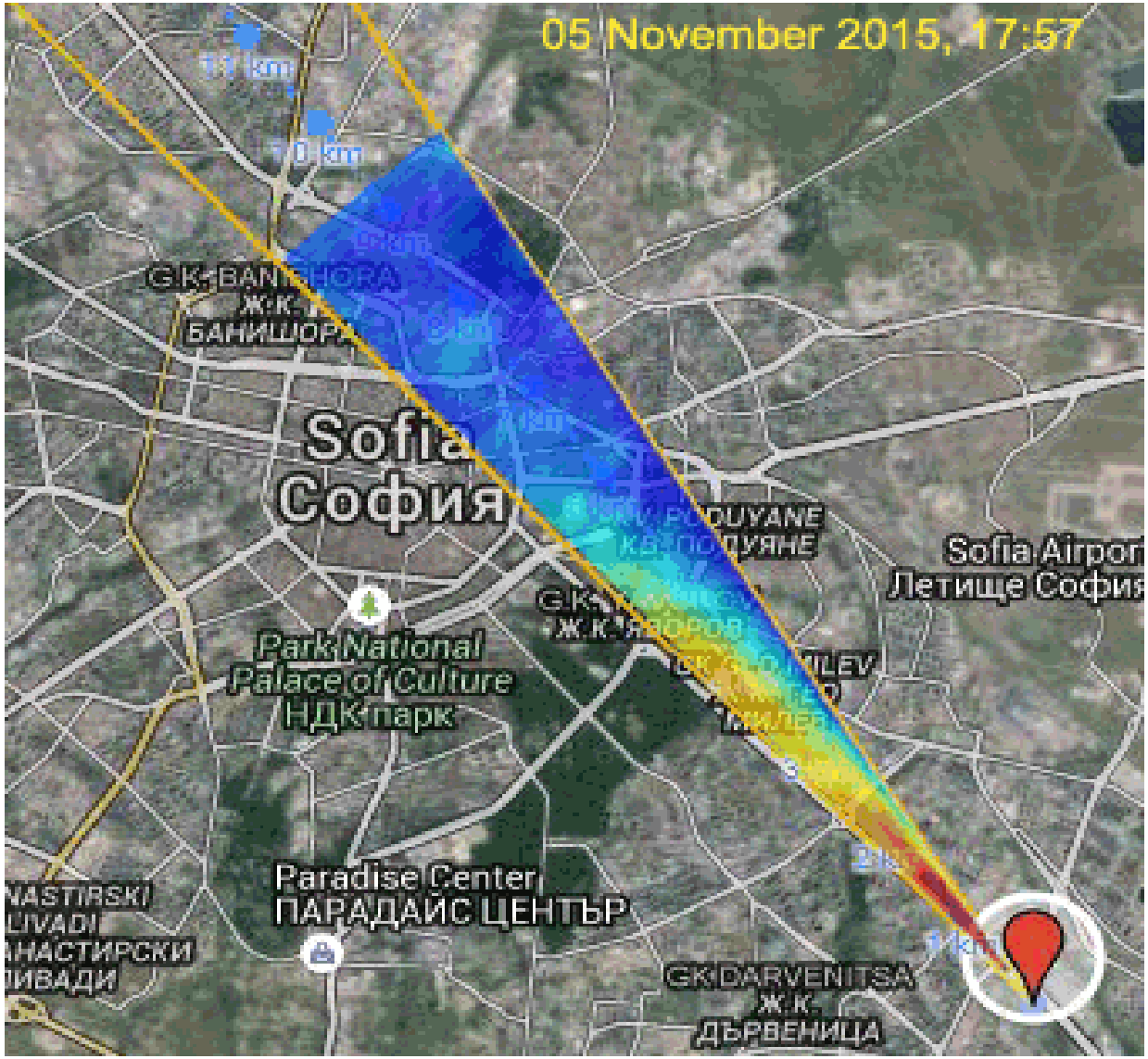
Successive LIDAR MAPs toward the City Center acquired every 30 minutes





05.11.2015 г.

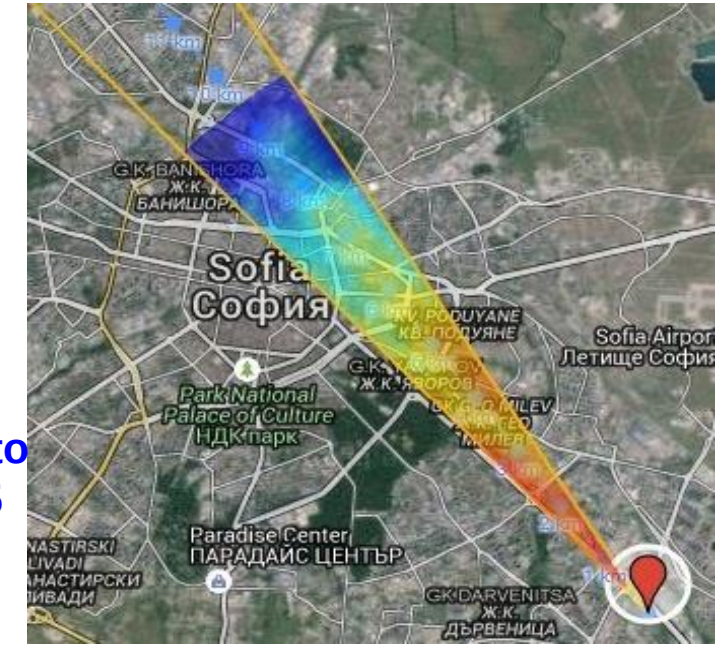
Successive LIDAR MAPs toward the City Center acquired every 30 minutes



18.11.2015 г.

Successive LIDAR MAPs toward the City Center acquired every 30 minutes

1)



18:27 to 18:55

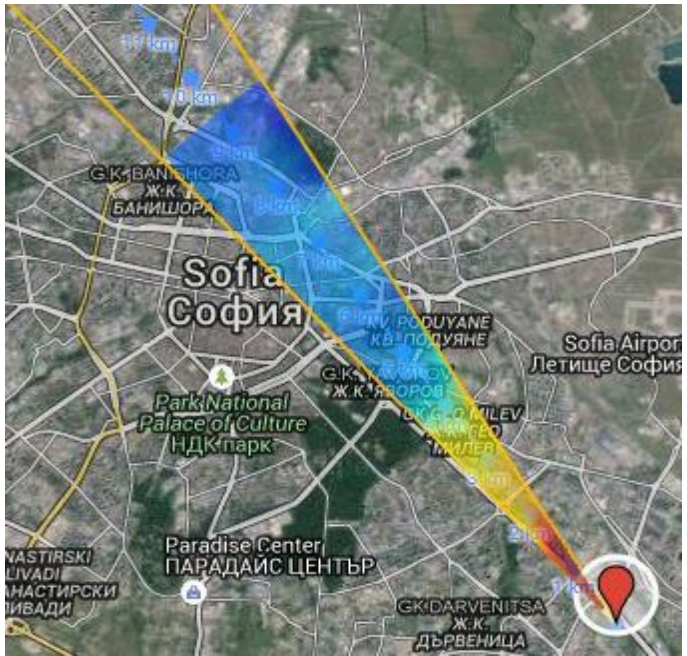
2)

18:55 to 19:22

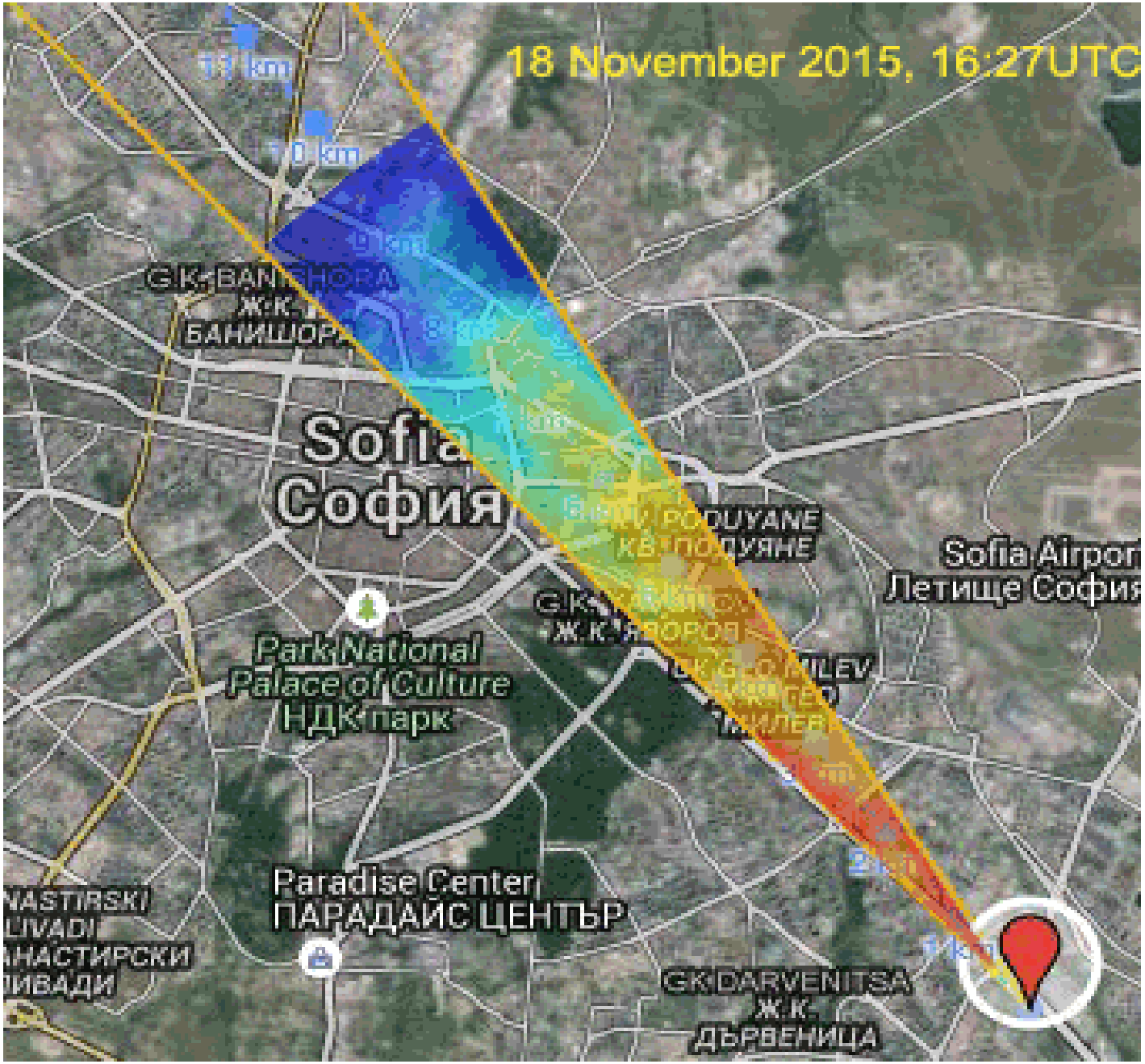
3)

19:22 to 19:49

4)



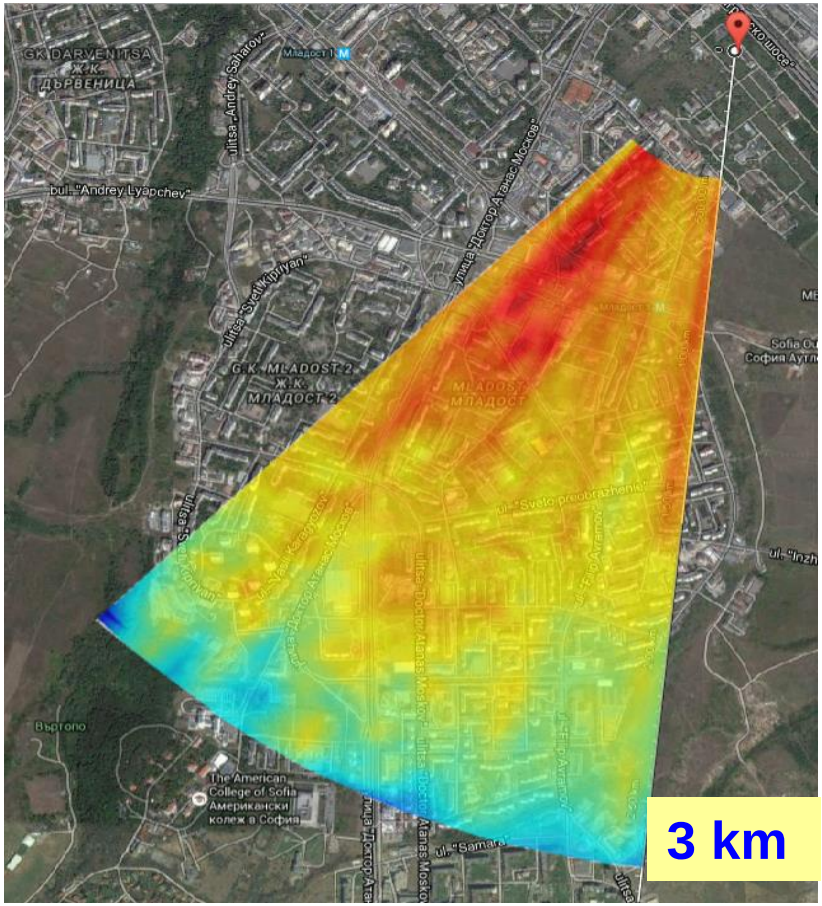
19:49 to 20:18

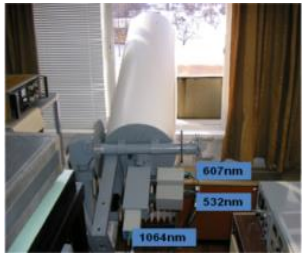

18 November 2015, 16:27UTC
Sofia
София
Park National
Palace of Culture
НДК парк
Paradise Center
ПАРАДАЙС ЦЕНТЪР
Sofia Airport
Летище София
ЖК ДЪРВЕНИЦА

LIDAR MAPPING TOWARD VITOSHA MOUNTAIN

IE-BAS

03.11.2015

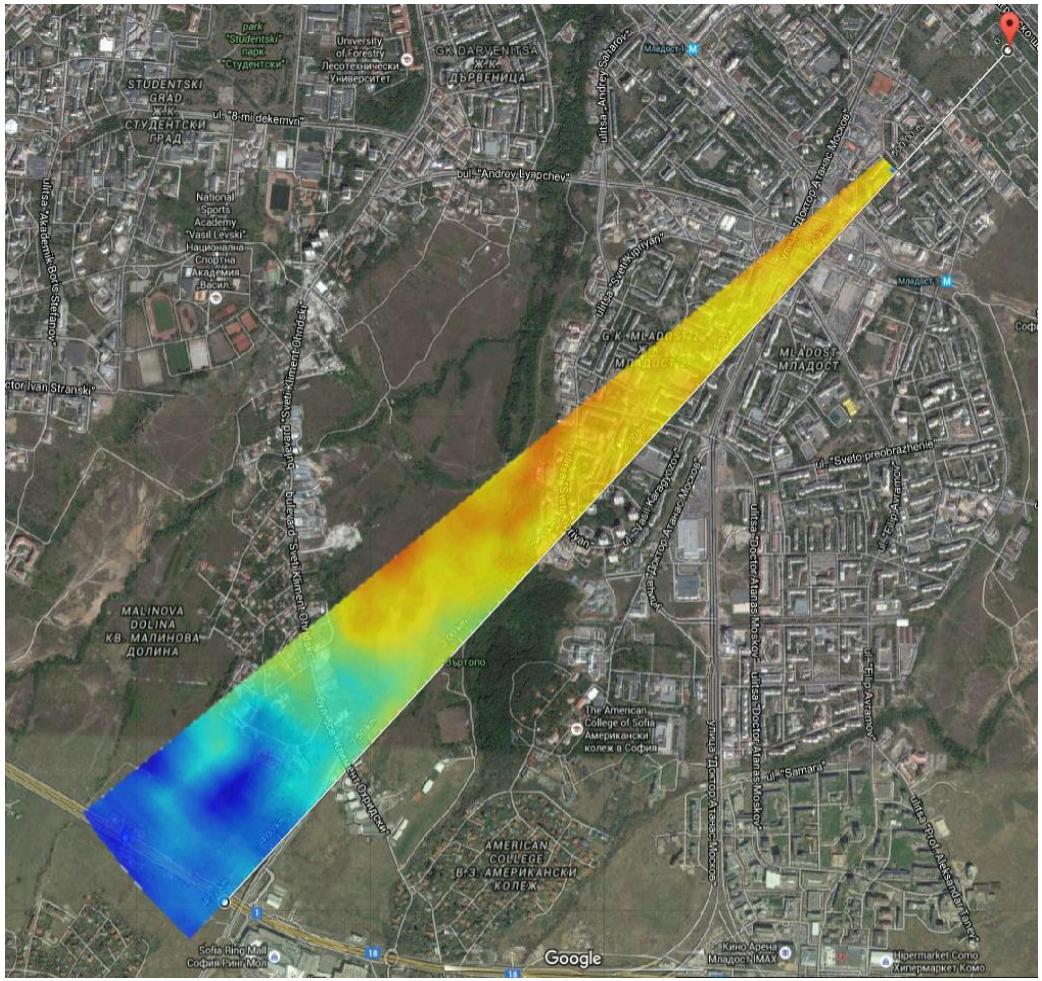


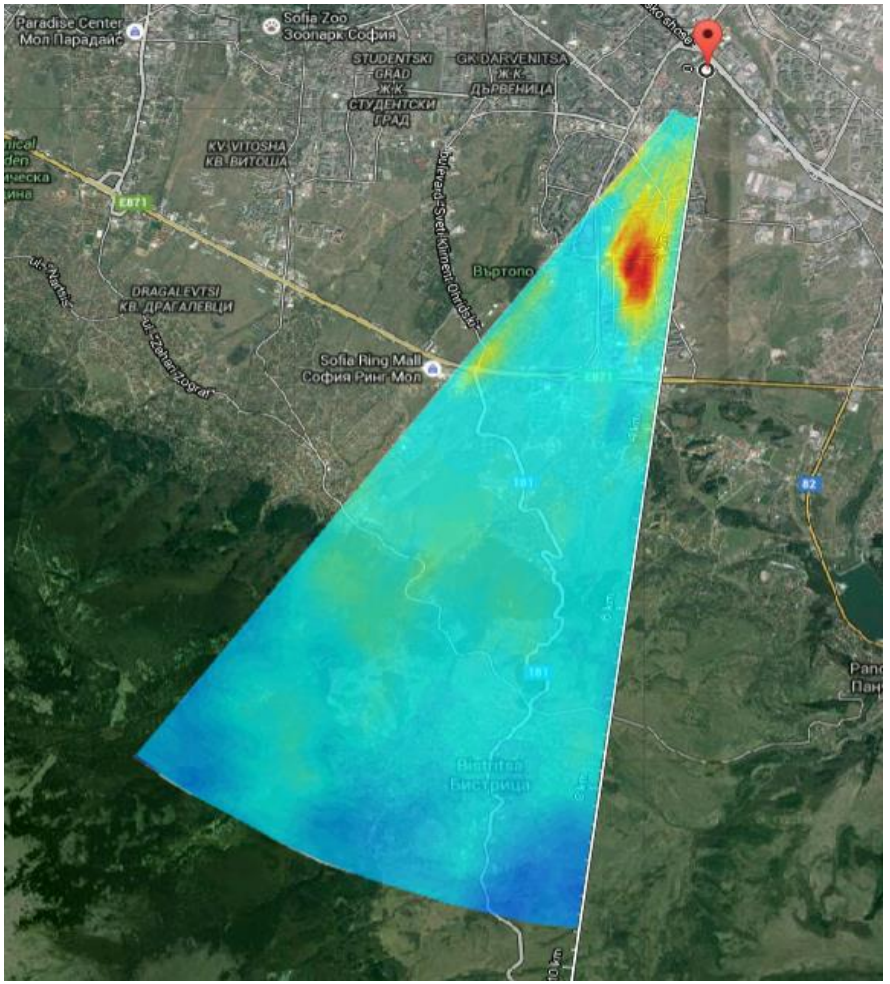


toward Vitoshta Mountain

Coloured LIDAR MAP of aerosol field distribution in a horizontal sector of 40^0 , measured in daily conditions (12:03 – 14:48).

04.11.2015

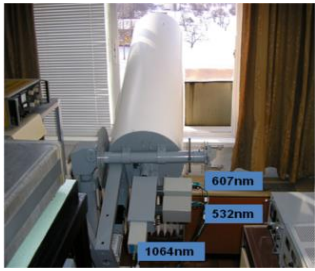




12:40h to 13:10h

18:42h to 20:14h

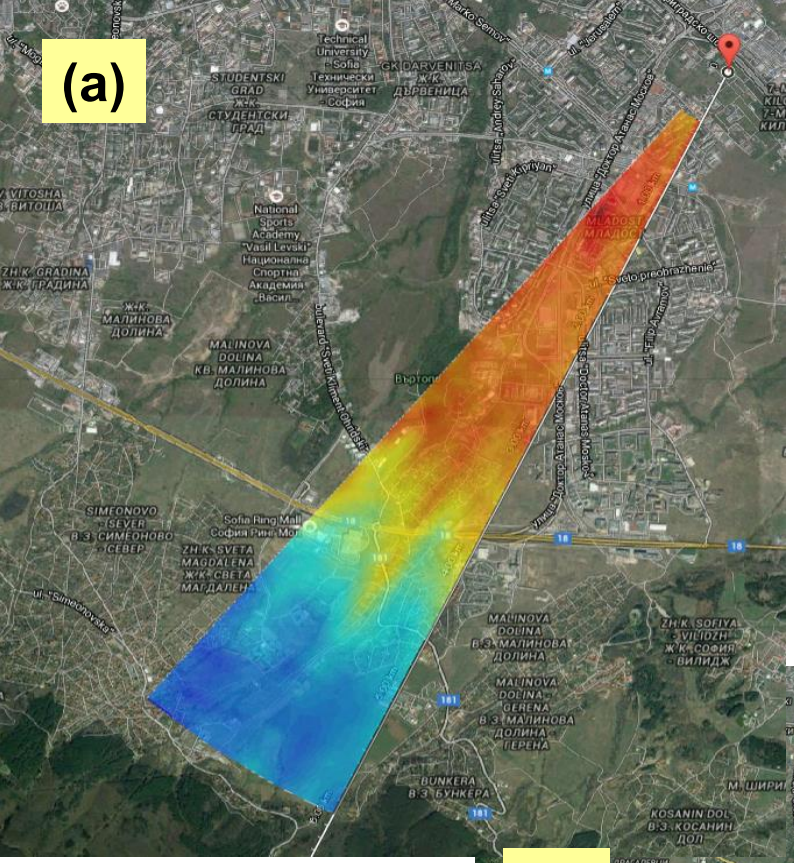
Coloured LIDAR MAP of aerosol field distribution toward VITOSHA Mountain

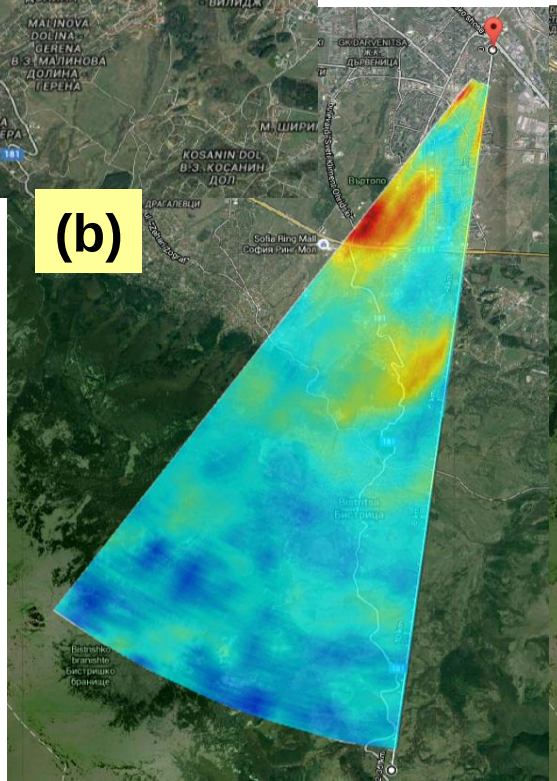


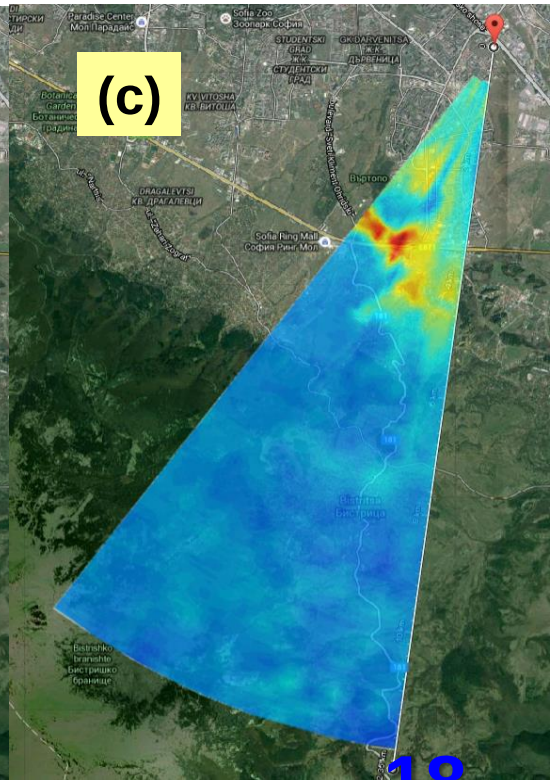
Coloured LIDAR MAP of aerosol field distribution toward VITOSHA Mountain

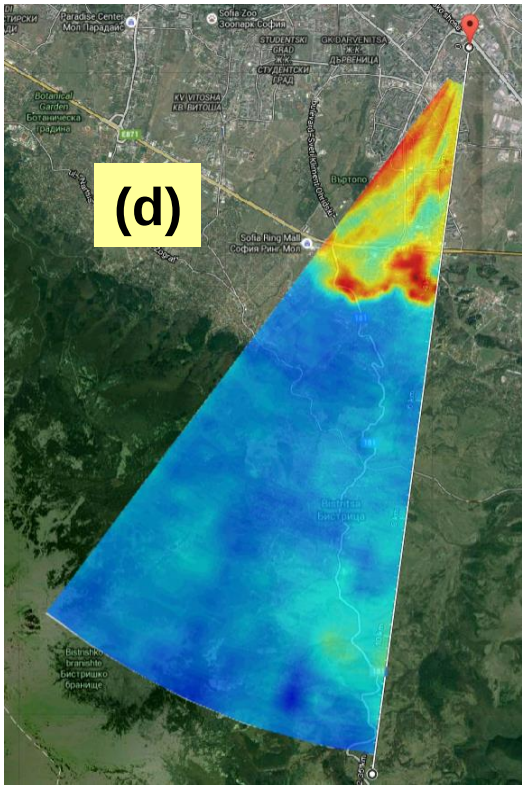
05.11.201

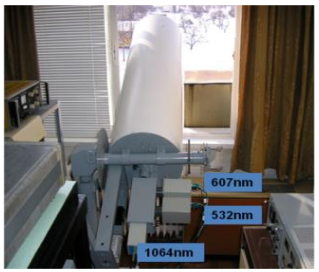
12:26h – 13:25h. (a);
18:37h – 19:33h. (b);
19:36h – 20:29h (c);
20:35h – 21:28h (d);





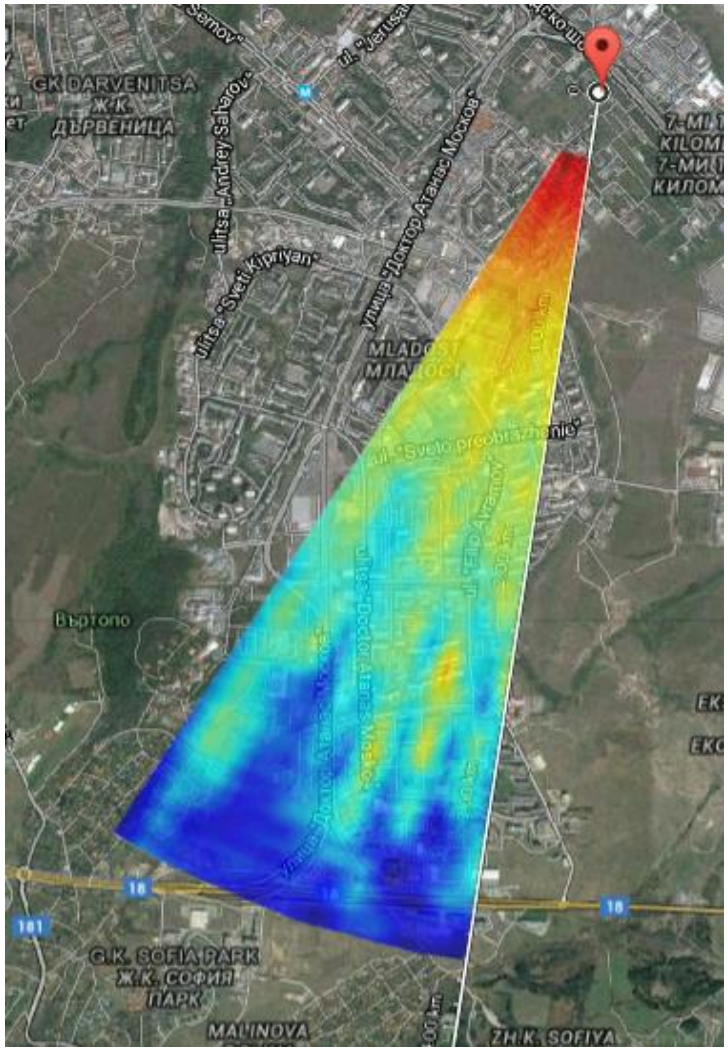




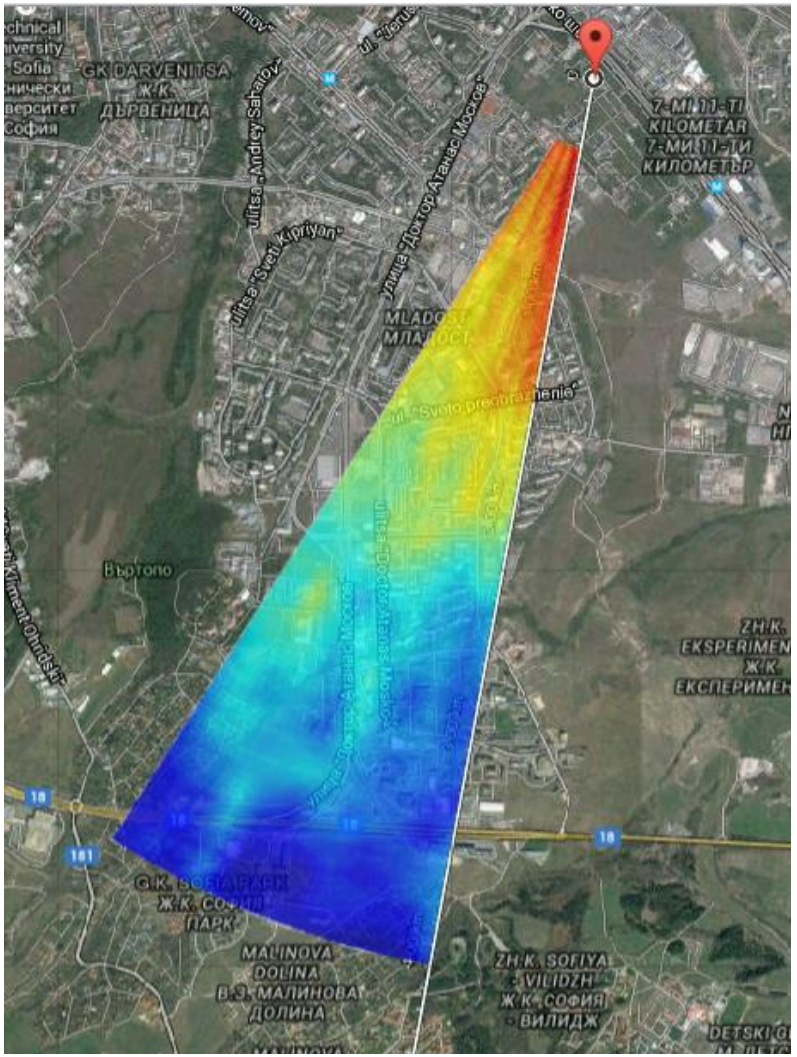


Coloured LIDAR MAP of aerosol field distribution toward VITOSHA Mountain

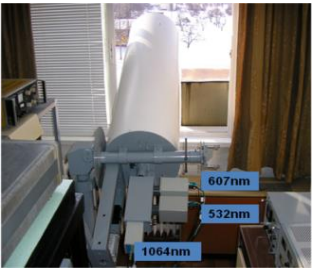
06.11.2015

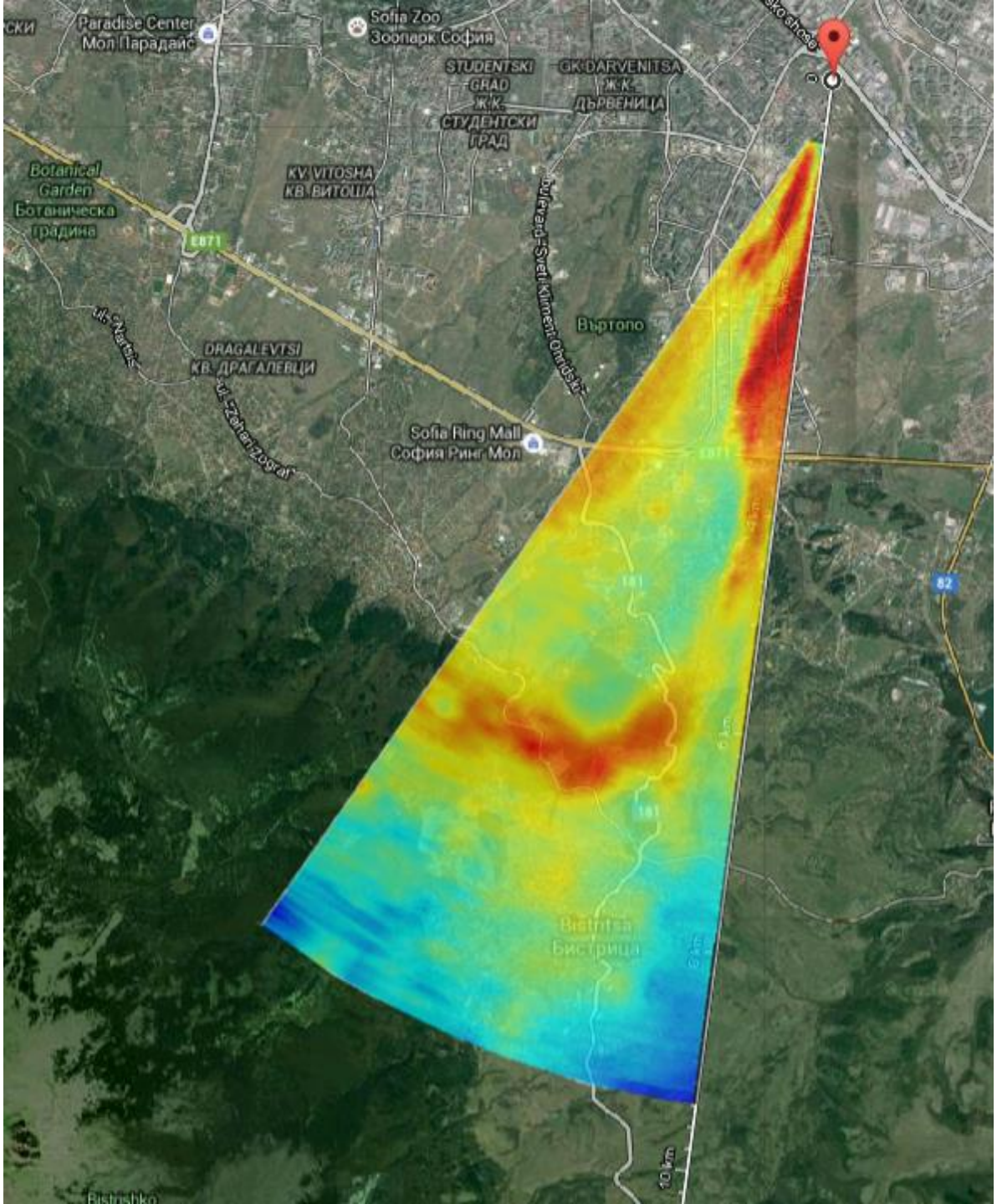


10:24h – 11:39h



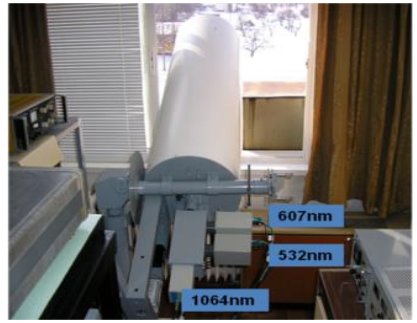
11:48h-12:53h





06.11.2015

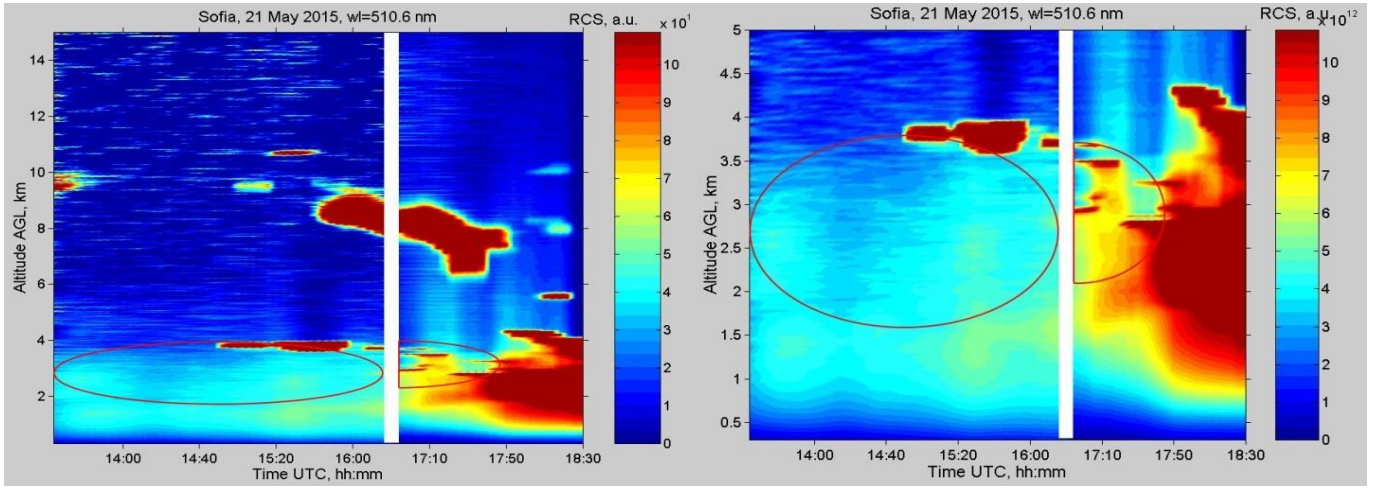
18:23h-19:19h

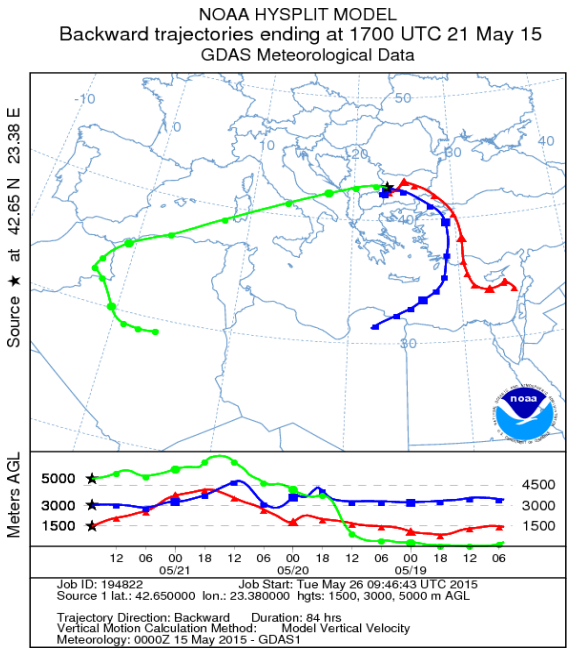


LIDAR MEASUREMENT OF SAHARAN DUST AEROSOL ABOVE SOFIA 21.05.2015 г.

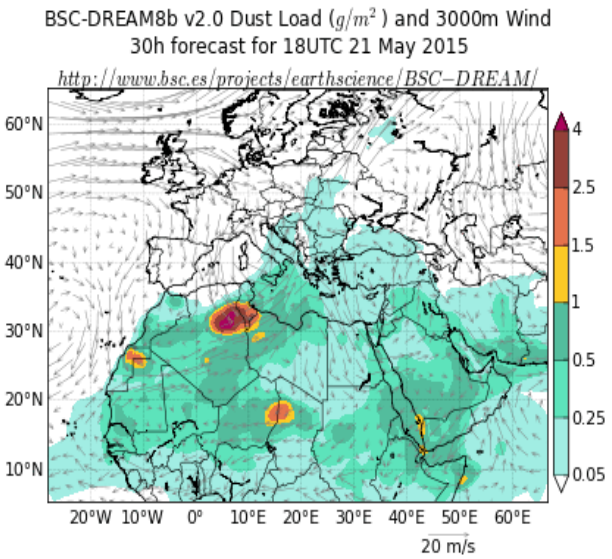
Altitude

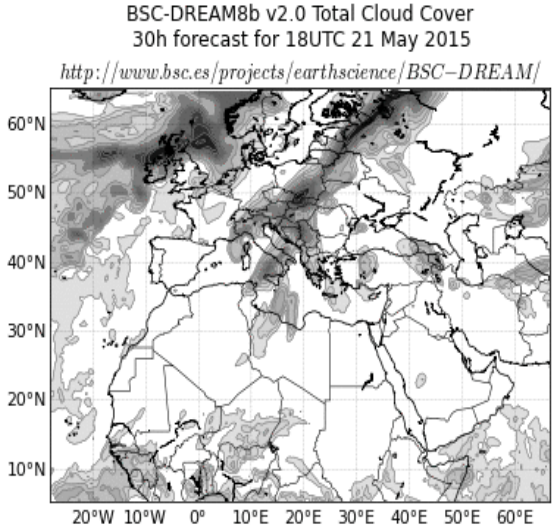
time





http://www.ie-bas.dir.bg/Departments/LidarData/Quicklooks.htm

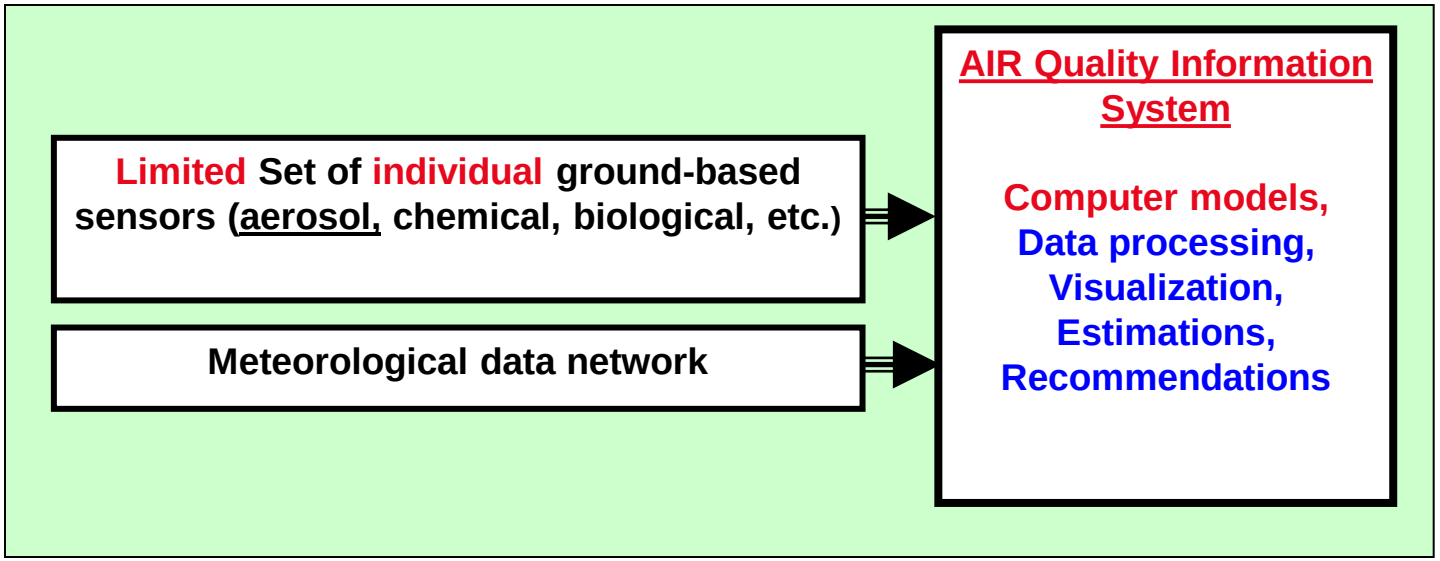




On the SYNERGY of LIDAR MAPPING and Urban in-situ sensors networks for improving the information of air-quality monitoring

The effectiveness of LIDAR MAPPING can be essentially increased by incorporating it with the City Sensor Network (SYNERGY Approach).

Typical block-schematic of city air-quality monitoring system



The information capabilities of such systems depend strongly on the spatial resolution of sensor networks over the city area

Comparative spatial resolutions

Lidar Maps Linear Resolution

dR_{lidar}~15m to 120m

City Sensors Network Resolutions

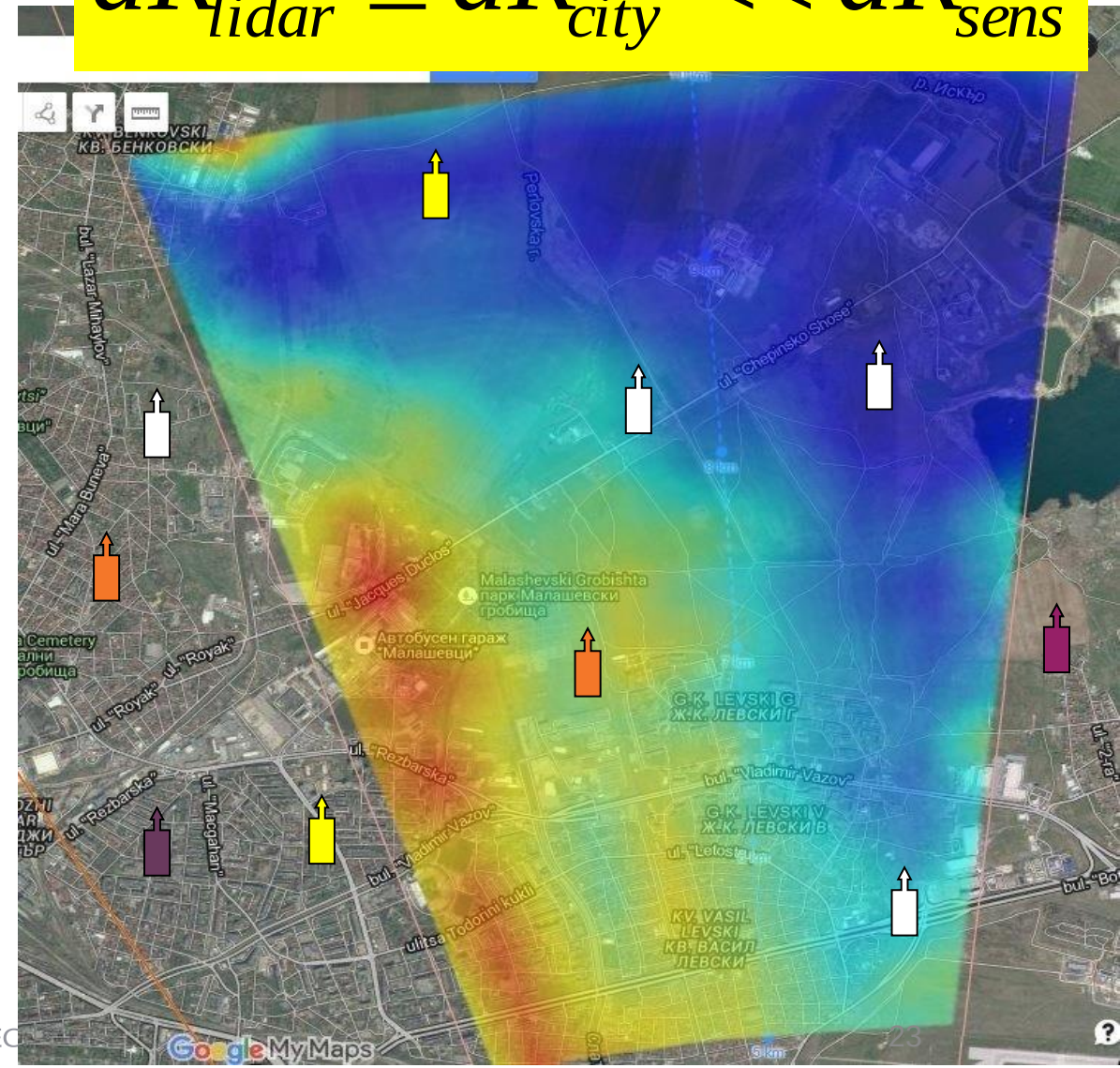
dR_{sens}~ 500m – 1-3km and more

City Area Characteristics Lengths:

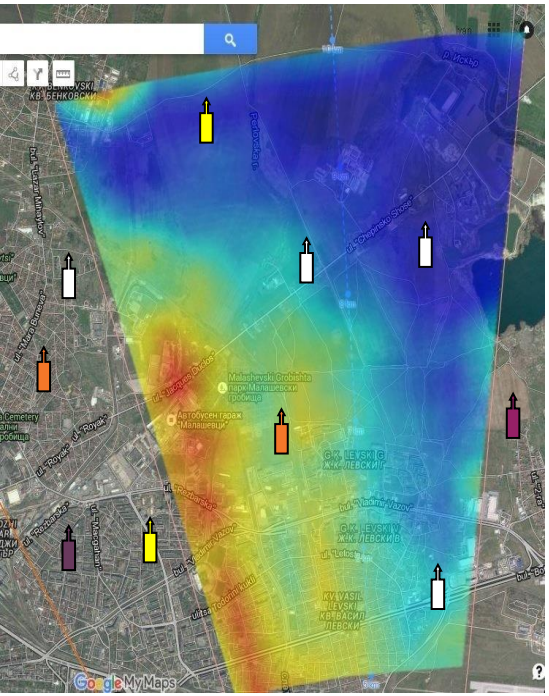
dR_{city}

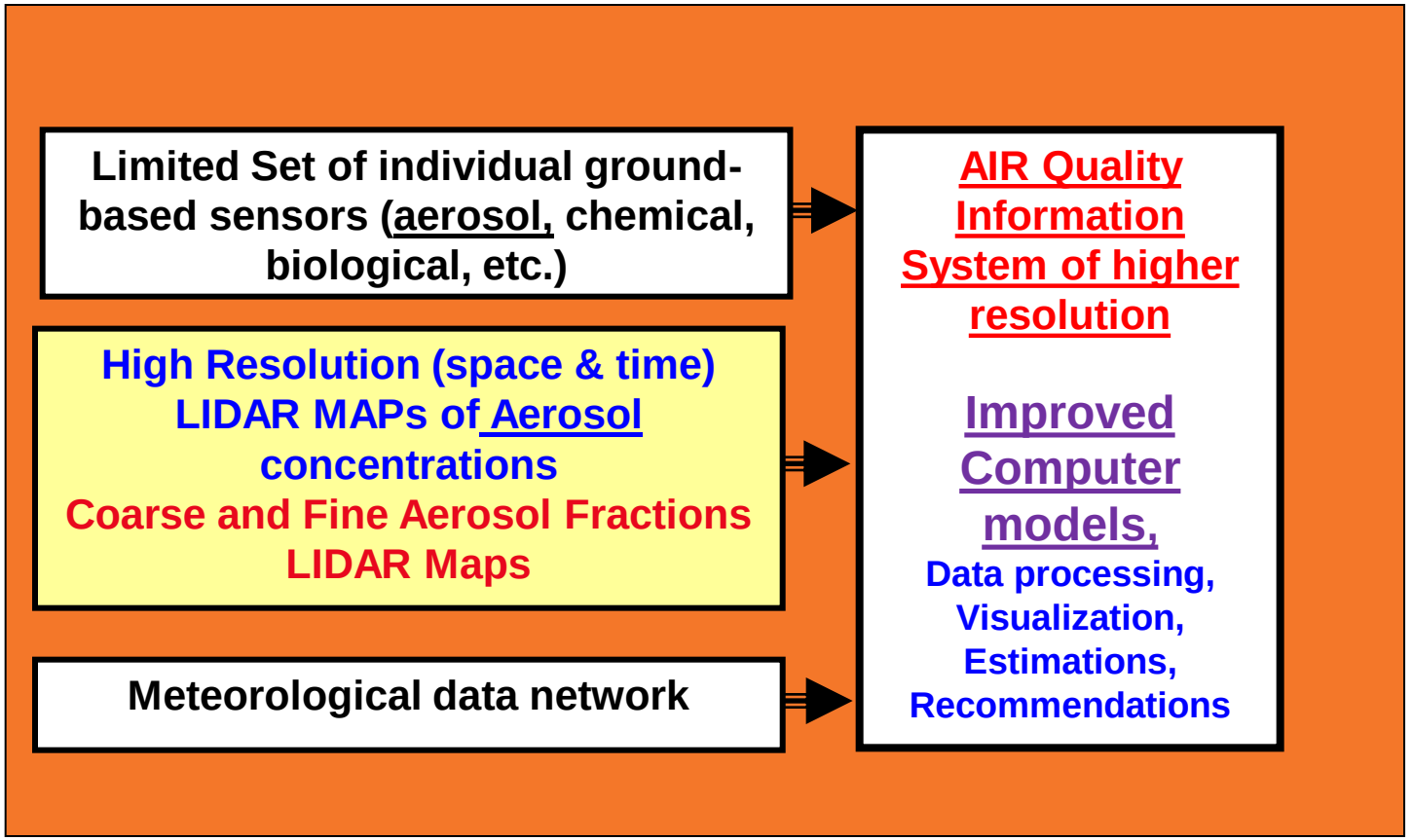
Streets ~30m - 150m
Buildings ~ 20m - 100m
Inner courtyards ~ 30m – 150m

$$dR_{lidar} \leq dR_{city} << dR_{sens}$$



GENERAL BLOCK-SCHEMATIC OF AIR-QUALITY INFORMATION SYSTEM OF HIGHER SPACE & TIME RESOLUTION





LIDAR MAP can be considered as a high resolution network of a large number of distributed aerosol sensors, overlapped on the existing city networks

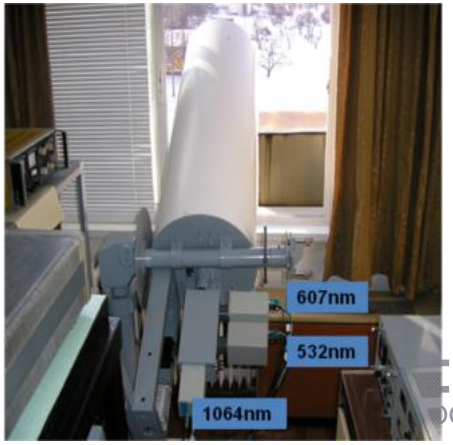
SYNERGY APPROACH within the LIDAR MAPPED DATA

I. Extraction (independent) of a lot of high resolution aerosol near surface statistical characteristics from LIDAR Maps and their incorporation into computer models of advanced AIR Monitoring System:

i) Visualisation of near surface turbulent motions; ii) Evaluation of near surface wind vector distribution; iii) Qualitative and Quantitative estimations of air-masses transport over the urban areas; etc.

II. Separation of LIDAR Maps into Coarse and Fine Aerosol Fractions LIDAR Maps based on the wavelength dependence of aerosol scattering.

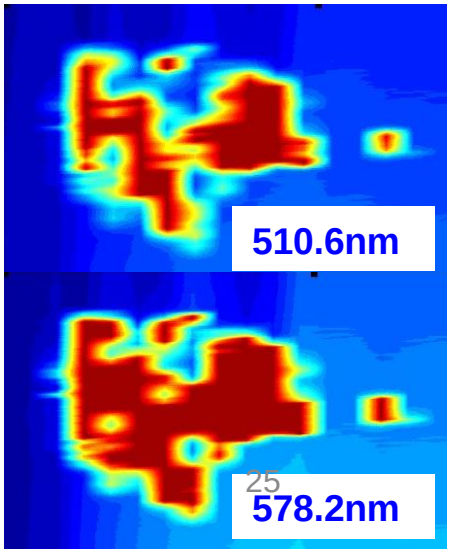
1064, 532 nm



510.6, 572.8 nm

510.6, 572.8, 627 nm

Cyrus clouds



CONCLUSIONS

1. Demonstrated capabilities of the LIDAR monitoring over the Sofia Urban Area under a Contract with the Sofia Municipality.
2. Two LIDARs of the IE-BAS Sofia LIDAR Station were used to scan toward the City Center (West) and the Vitosha Mountain (South),etc.
3. Large number of high quality & high resolution LIDAR Maps, overlapped on the geographical map of Sofia have been got.
4. The operational distances for LIDAR mapping exceed **25 km** for both scanning Lidars. The estimated altitudes of the aerosol layers of increased concentration are within ~ 500-700m.
5. Analysed the application of LIDAR mapping for creation of high-resolution air-quality monitoring system, based on the **Synergy** of LIDAR high-Resolution maps with existing AIR-Quality Systems.

FINAL CONCLUSION

LIDAR technologies, developed in **Bulgarian Academy of Sciences, Laser Radars Lab. of IE-BAS** can be applied for creation of **novel Air-Monitoring system to cover the entire Sofia Area**.

ACKNOWLEDGEMENTS

The team of LIDAR scientists from the Laser Radars Laboratory of the Institute of Electronics to the Bulgarian Academy of Sciences would like to express its special thanks to:

SOFIA MUNICIPALITY ;

- **Mrs. J. FANDAKOVA – MAYOR of SOFIA**,
- **Mrs. M.Boyadjiiska - Dep. MAYOR of SOFIA.**
- **Mrs.N.Makarova – Director**, Mun. Land, Forest, Water & Environment., SOFIA Municipality.
- **Mr.L.Petrunov** – Mun. Land, Forest, Water & Environment, SOFIA Municipality.

For their special attention to the **LIDAR Research** in **Bulgarian Academy of Sciences** as well as for the Financing of the above Contract for LIDAR monitoring of Sofia Urban Area.

D.Stoyanov, T.Dreischuh, I.Grigorov, G.Kolarov, Z.Peshev, A.Deleva, I.Nedkov

Thank you