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# Radiation consequences of the fire in the Chernobyl exclusion zone

# Introduction

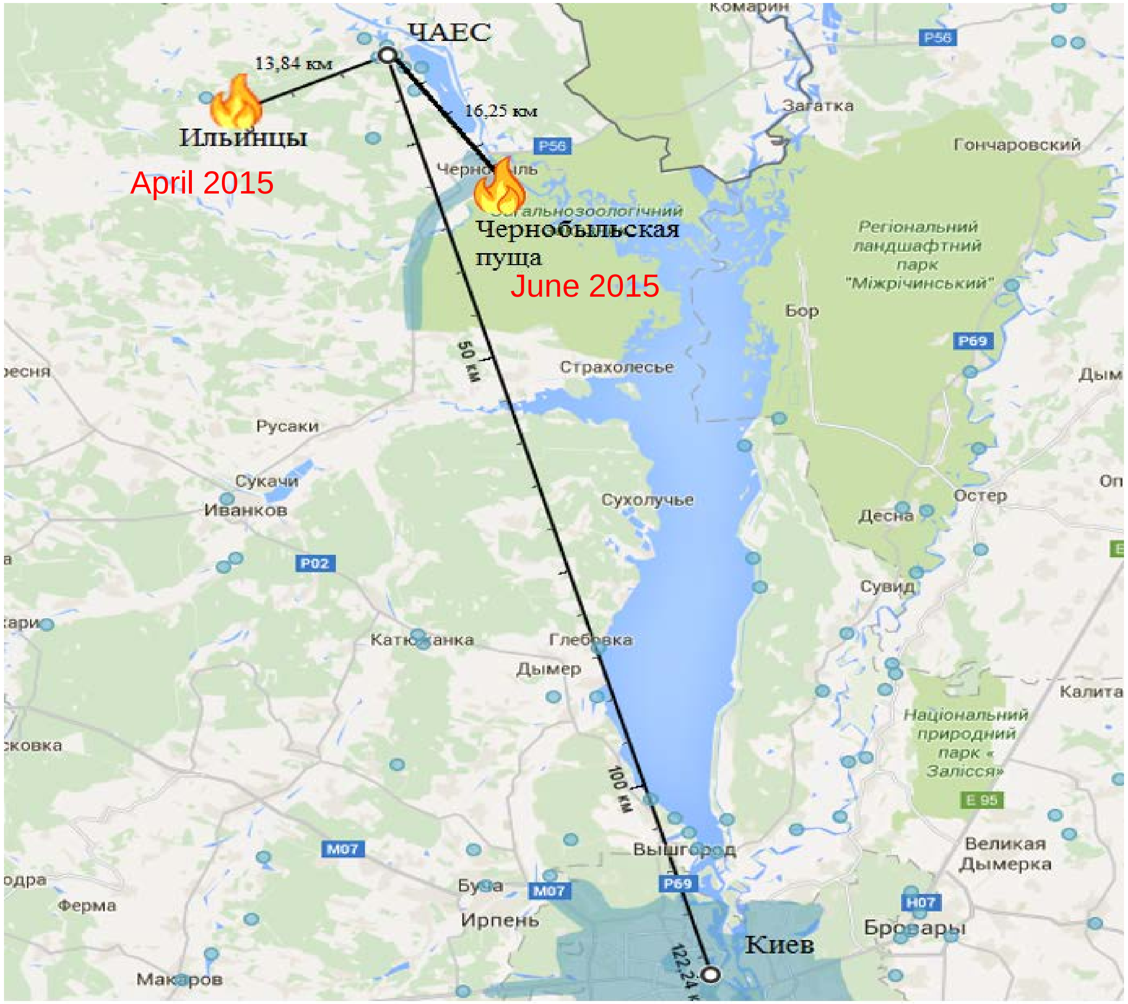
- "Chernobyl threats" periodically become the main topic in the mass media
- This year it has arisen in connection with forest fires in the exclusion zone of Chernobyl NPP
- Approximately 10-15 fires occur in the exclusion zone of Chernobyl NPP every year, including forest fires
- The scale of the fires in the exclusion zone of Chernobyl NPP in 2015 and a huge number of messages in the mass media have led to the wide public response

# Description of event

- The first big forest fire happened in late April 2015
- It was located 14 km south-west of the Chernobyl NPP, near the village of Ilintsy. This fire lasted from 29 April to 2 May 2015 and covered an area of about 350 hectares
- The second big fire in the exclusion zone started on 29 June 2015 in the Chernobyl forestry near the village of Kovshilovka and the village of Polesskoye, close to the Uzh floodplain
- The fire was located 16 km south-east of the Chernobyl NPP and covered an area of about 130 hectares

# Description of event

Map showing fire spots in the exclusion zone. April 2015 and June 2015



# Description of event

- Public concerns about the radiological consequences from the fires in the exclusion zone supported by mass media
- Requests from various organizations, institutions, individuals, friends and relatives
- SSTC activities on response to public concerns:
  - calculations of the fires' radiation consequences for Kiev inhabitants
  - radiation survey in Kiev and publication of the results on SSTC NRS website to reassure the public

# Modelling calculations

- Prognostic estimations of radiological contribution from forest fires to the dose of Kiev population are input data for planning and implementing protective measures
- In the first case (fire in late April 2015), the calculations of the radiation consequences were performed by the Institute of Mathematical Machines and Systems (IMMS) of the National Academy of Sciences of Ukraine (Kovalets I.V., Romanenko A.N. , Anulich S.N., Evdin E.A. (2015) Forecast of the radiation situation during the fire in the Chernobyl exclusion zone using the JRODOS system. Collected papers of the 10th International Scientific Conference "Decision Support Systems. Theory and Practice ", Kiev. June 2015, pp. 62-65).

# Modelling calculations

- For the case of the forest fire in late June 2015, such estimates were carried out by SSTC NRS (Department of Radiation Protection).
- For modeling calculations we used two different computer systems to assess the radiological consequences of the fires:
  - **JRODOS** (European Real Time On-line Decision Support) system;
  - HotSpot 2.07.1 computer code.

# Modeling based on JRODOS calculations

- Assessment of radiation consequences for the population living on territories remote from the source of radioactive release (above 100 km) over a long period of time (from several hours and more) requires the use of models that consider variation in weather conditions throughout the release. The **JRODOS** (European Real Time On-line Decision Support) system was used for such assessment.
- The following input for JRODOS has been specified to estimate radiation consequences:
  - computer model;
  - coordinates of incident;
  - time of release start and time of release end;
  - source term;
  - weather conditions.

# Modeling based on JRODOS calculations

- To assess the radiological situation in this case, a model for detailed description of the release source such as fire was chosen.

- The following input data concerning time and location of fire were taken from the mass media and official information server of the State Emergency Service of Ukraine:
  - the fire started on 29 June 2015 at 17:30 and was extinguished on the night of 5 July 2015;
  - it happened on the territory of Chernobyl forestry (16 km south-east of the Chernobyl NPP);
  - the fire was  spread on an area of about 130 hectares;
  - the underlying surface (dry grass, reeds, peat) was burning. The grass fire was extinguished quite quickly, but the peat fire continued.

# Modeling based on JRODOS calculations

Fire in the exclusion zone. June 2015.

# Modeling based on JRODOS calculations

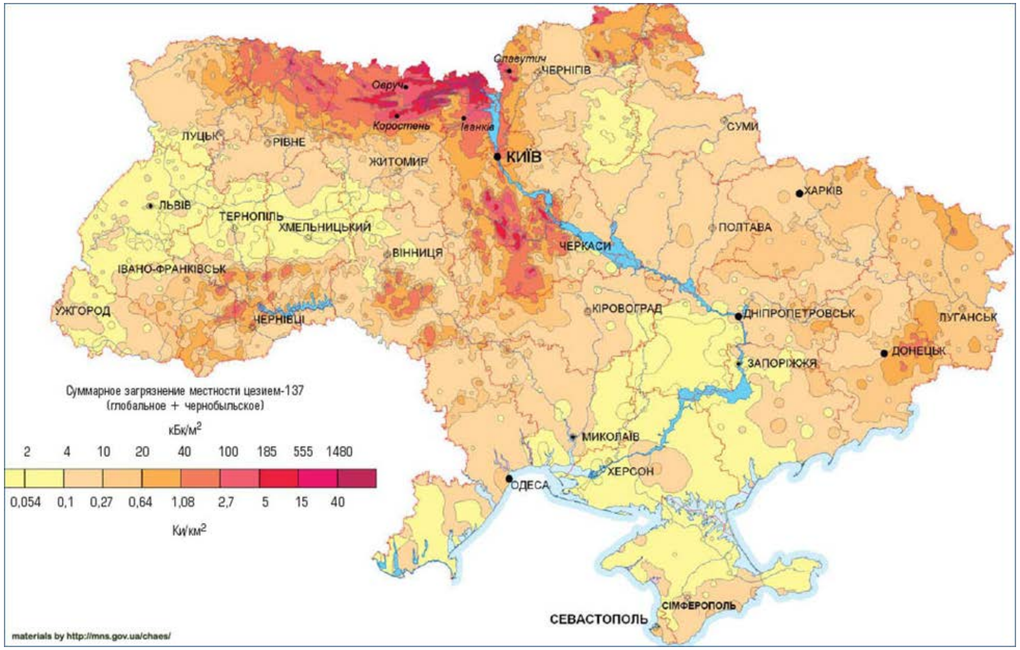
- To describe the source of release we used conservative assumptions to select (describe) input data.

- To assign the average thermal power of fire we took the following values of the parameters:
  - **S** - the area of the fire surface was accepted as 30 hectares ($1.3 \cdot 10^6$ $m^2$);
  - **h** - the height of the burnt underlying surface: the fire height above the ground was accepted as zero, the peat burning depth was taken equal to 0.5 m;
  - **ρ** - the peat density – 1500 $kg/m^3$;
  - **q** - the average combustion heat of peat – 23 MJ/kg;
  - **t** – the burning time – 7 days.

- The average thermal power of fire was equal to **W**=61798 MW.

# Modeling based on JRODOS calculations

- Activity of the release was taken from measurements of contamination in the Chernobyl exclusion zone. The total activity of 137Cs, taking into account the fire surface area and surface contamination 3.7 E+5 Bq/$m^2$, was equal to 4.81E+11 Bq.



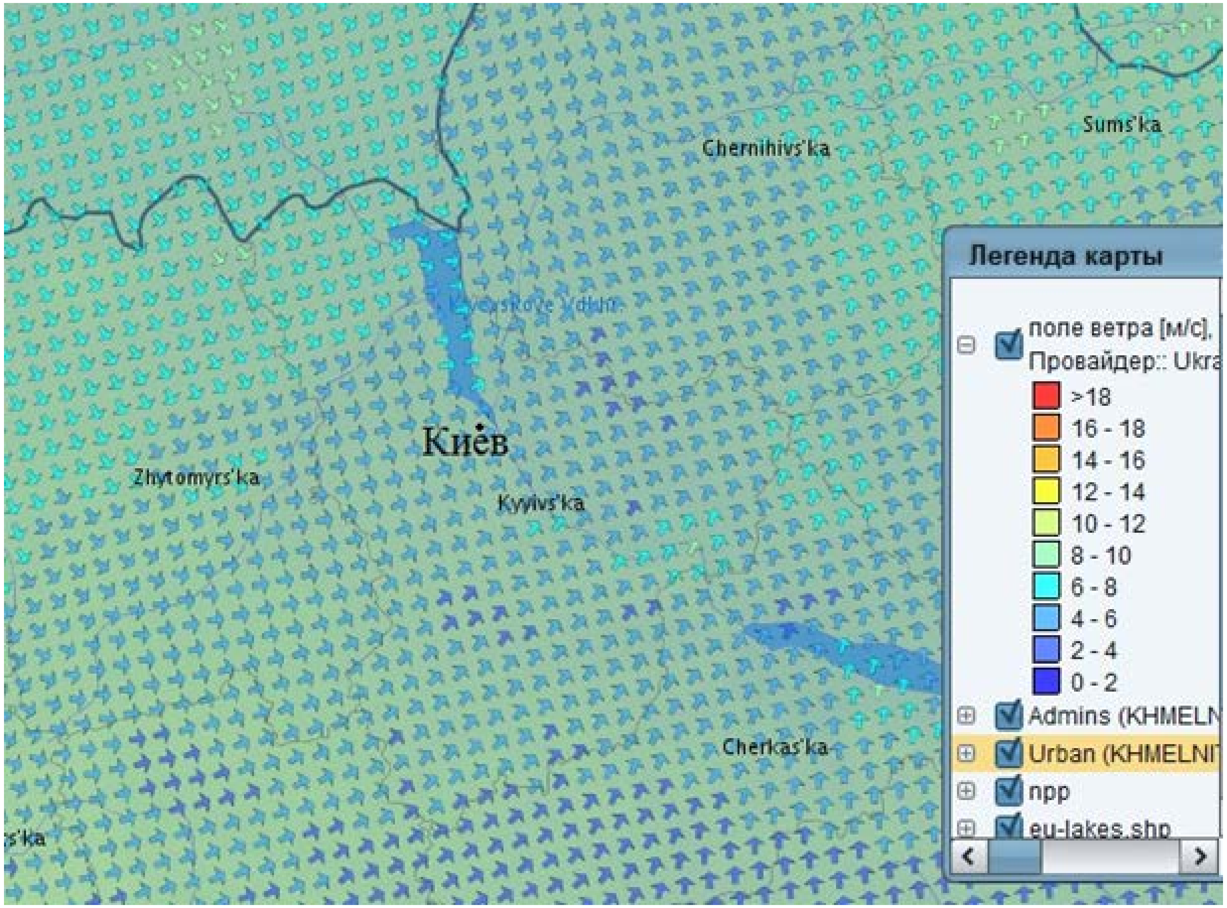

The map (http://chornobyl.in.ua/karta-radionulid-ukraine.html) shows the area of Ukraine contaminated with 137Cs.

# Modeling based on JRODOS calculations

- Weather conditions were determined for a period from 06:00 GMT of 29 July to 00:00 GMT of 6 July 2015.
- The numerical weather prediction data (meteorological fields) were presented by the Institute of Mathematical Machines and Systems (IMMS) of the National Academy of Sciences of Ukraine, which developed the weather research and forecast system (WRF-Ukraine). This system is currently applied to provide prognosis data for the JRODOS system, installed at Ukrainian NPPs.
- These numerical weather prediction data were obtained on the basis of actual weather data using meteorological model built with the help of WRF-Ukraine.

# Modeling based on JRODOS calculations

Meteorological model developed with WRF-Ukraine system
(31 June 2015, 12:00)

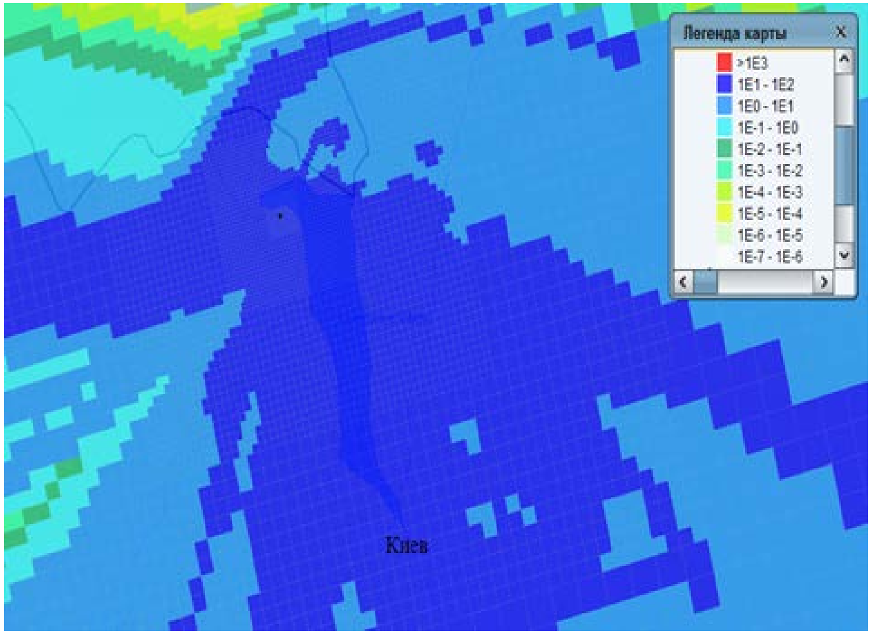


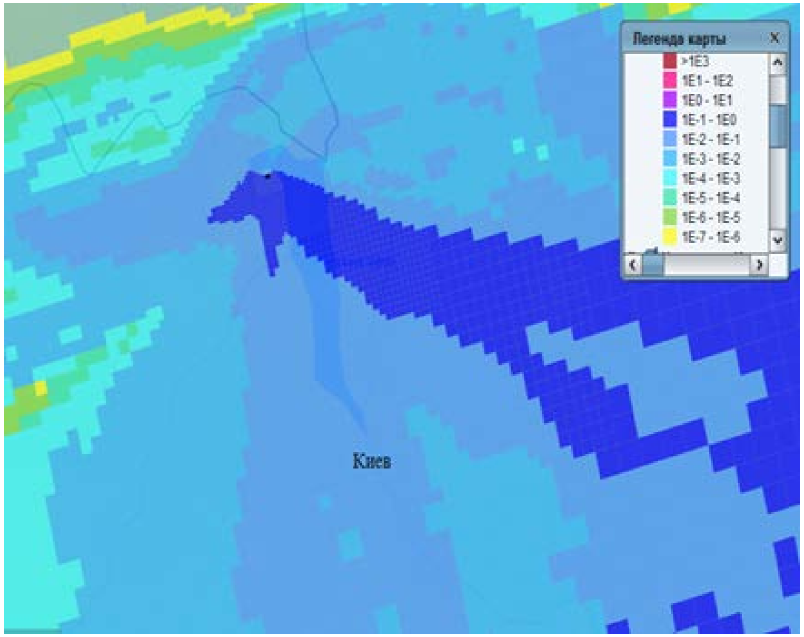
# Modeling based on JRODOS calculations

- Analysis of the weather parameters shows that the cloud would mainly spread in the southeast direction.
- The estimates were carried out for 137Cs radionuclide because it makes the greatest contribution to the dose. Instantaneous concentration of 137Cs, integral concentration of 137Cs in the surface layer of the atmosphere, and 137Cs fallout were calculated.
- The estimate resulted in a pattern showing 137Cs radionuclide spread in the atmosphere during the fire.

# Modeling based on JRODOS calculations

The figure represents a map of 137Cs integral concentration in the surface layer (Bq/m$^3$) and 137Cs fallouts (Bq/m$^2$) in a period from 29 June to 5 July 2015.



# Modeling based on JRODOS calculations

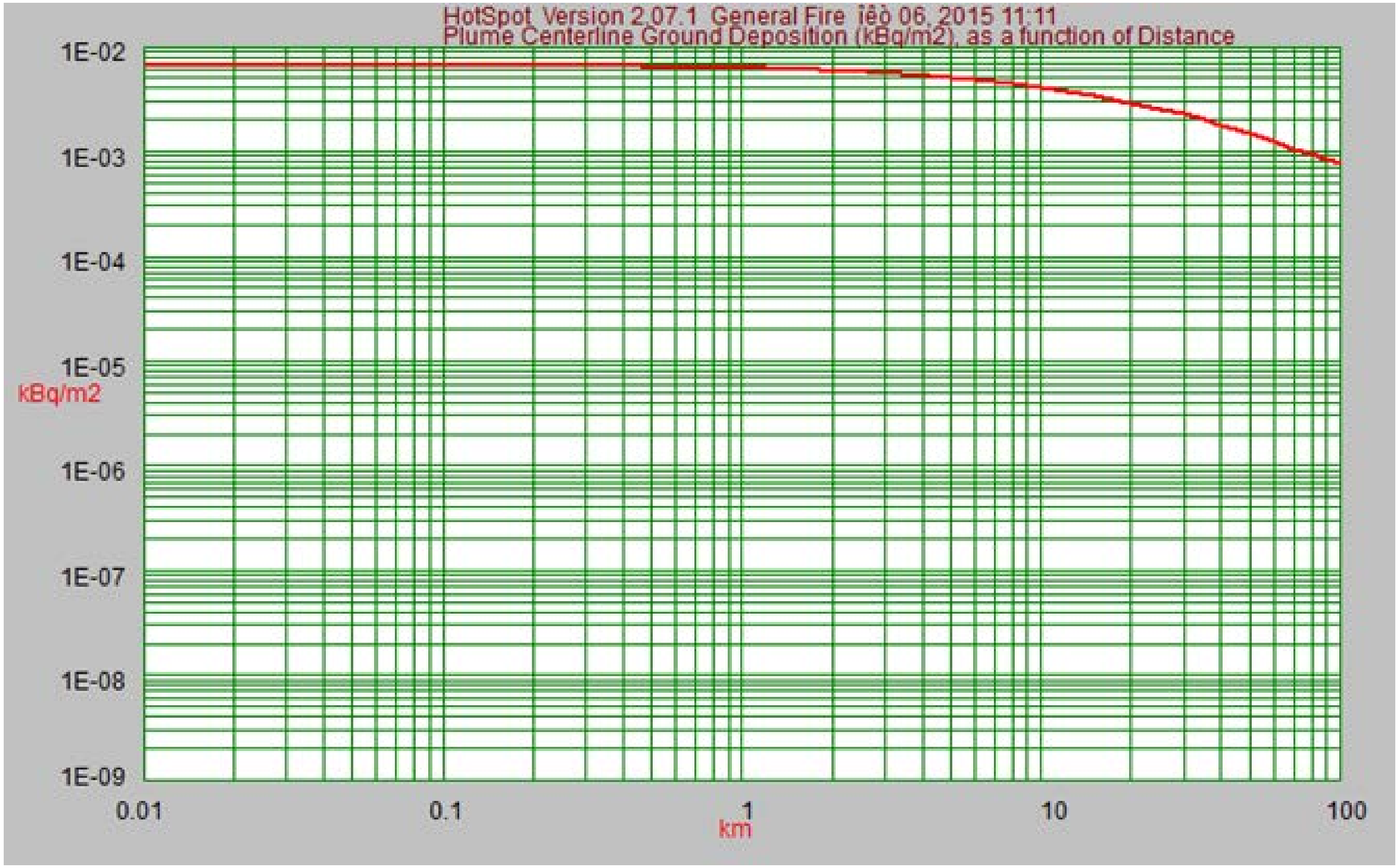
- The results of calculation show that the predicted (estimated) radioactive contamination is insignificant.
- Maximum 137Cs fallout in Kiev was 2.18 Bq/m$^2$, which is several orders of magnitude lower than the existing contamination in Ukraine (http://chornobyl.in.ua/karta-radionulid-ukraine.html).
- The maximum effective dose at the boundary of the exclusion zone in the period in question was 6.06 nSv, which is also several orders of magnitude lower than natural background.

# Modeling based on HotSpot calculations

- In estimates of radiological consequences from the fire, another computer code, HotSpot, was used as an alternative.
- The input data were the same as for JRODOS calculations:
  - the total activity of 137Cs release was 4.81E+11 Bq,
  - the fire height was 0 m,
  - the release radius was 643 m,
  - the heat emission was 5.5·E+10 kcal/h.
- Since weather conditions were accepted as constant, their conservative values were chosen:
  - the average wind speed 6 m/sec,
  - the wind direction 270°, associated atmospheric stability class D,
  - the maximum estimated distance of release spread 100 km,
  - the deposition rate 0.89 cm/sec.

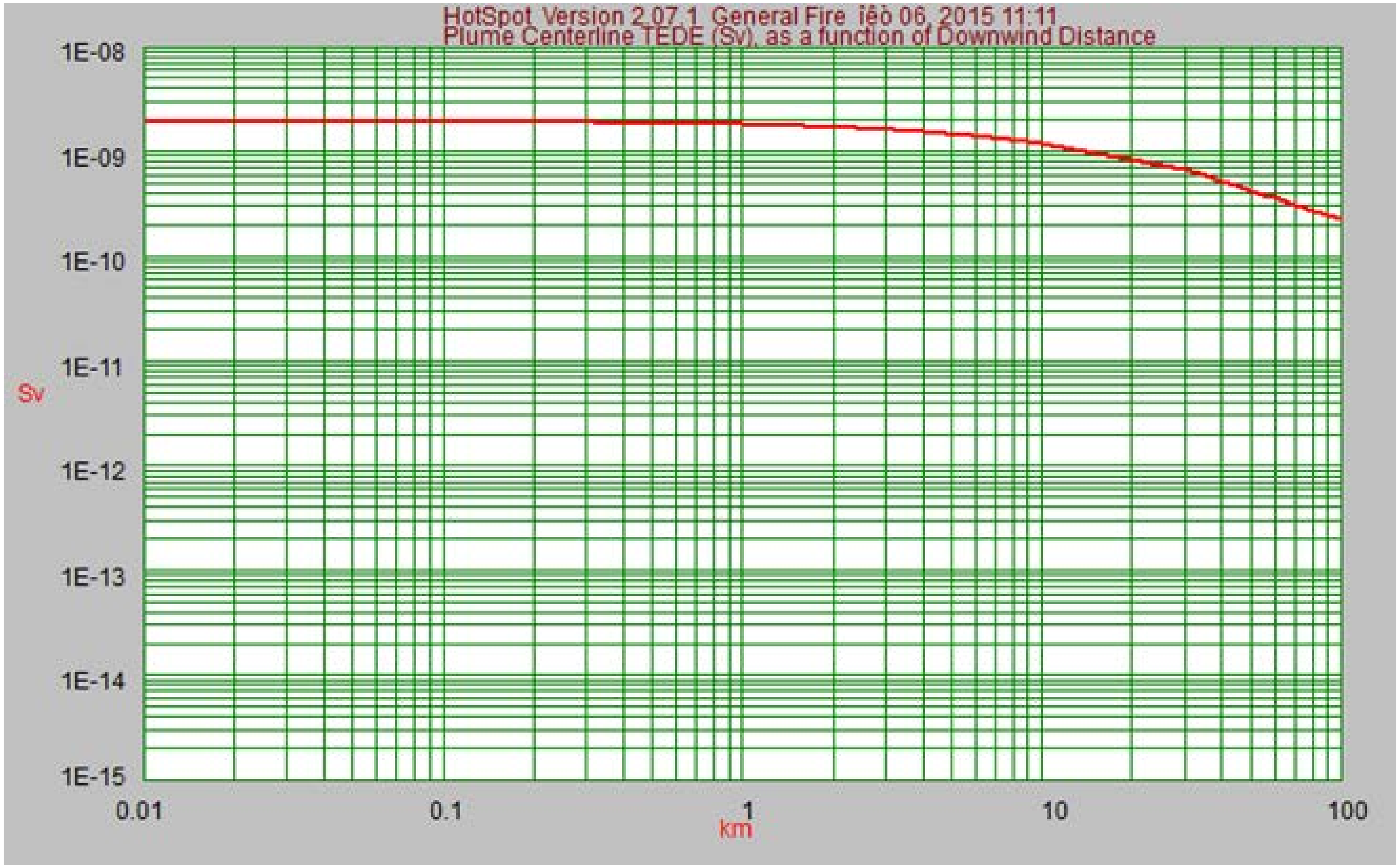
# Modeling based on HotSpot calculations

Estimated 137Cs fallouts resulting from the fire in the exclusion zone from 29 June 2015 to 5 July 2015



# Modeling based on HotSpot calculations

Estimated 137Cs effective dose resulting from the fire in the exclusion zone from 29 June 2015 to 5 July 2015



# Modeling based on HotSpot calculations

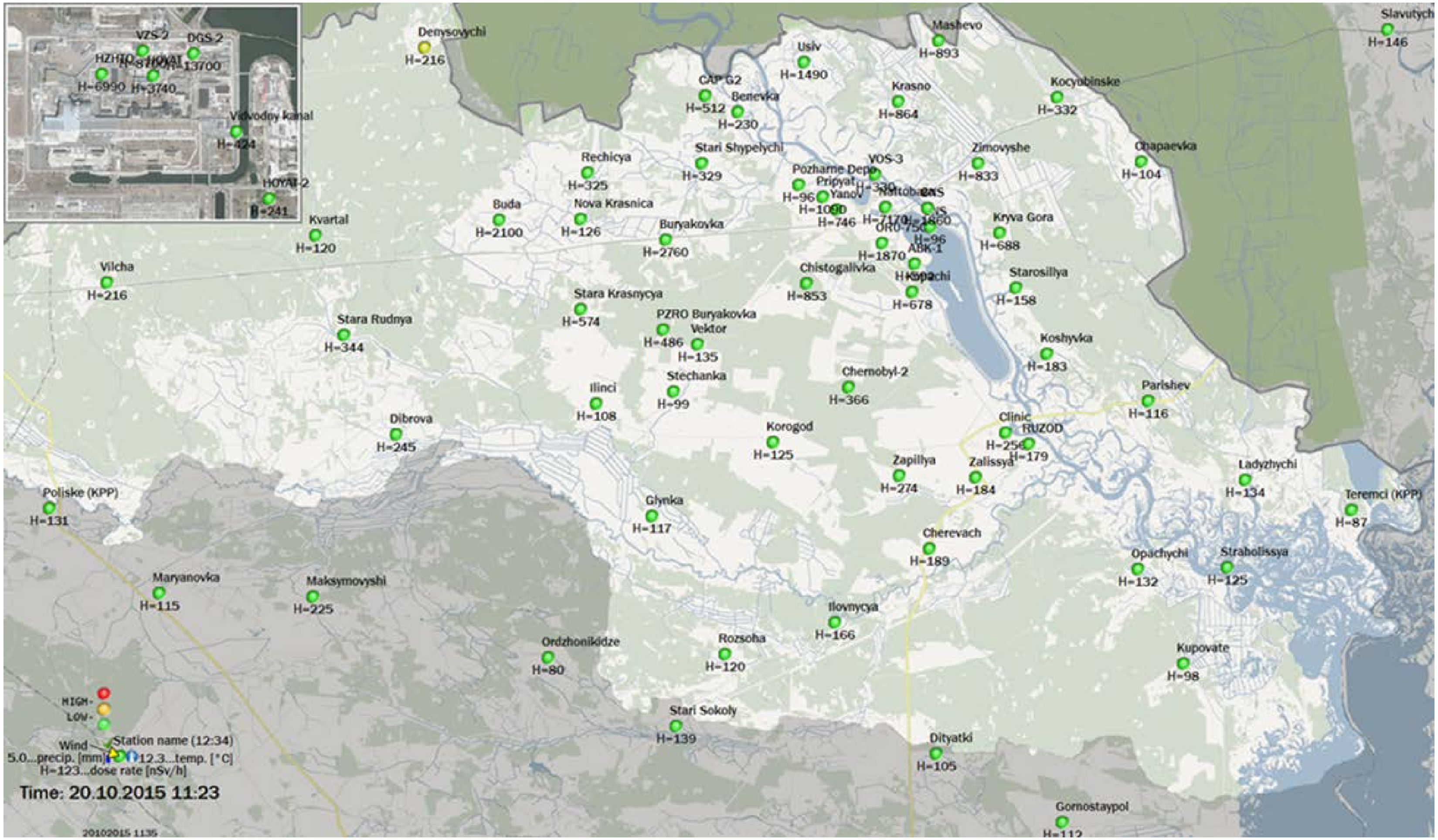
- The results of calculation show that the 137Cs fallout near Kiev (100 km from the fire point) was 22.3 Bq/m$^2$ and the effective dose was 42 nSv accordingly.
- The radiological consequences from the fire estimated with the two computer systems differ within one order of magnitude, which is quite clear given the degree of conservatism accepted in model calculations.
- The JRODOS system provides a more realistic picture but requires input data arrays and computer modules and the HotSpot code (with conservatively chosen weather parameters) gives a more conservative evaluation but produces quick results.

# Data on actual measurements

- The actual radiological data in the fire area and potentially affected territories were obtained by direct measurement of radiological parameters as follows:
  - radiation background in the exclusion zone was and is checked with the Ecocenter automated radiation monitoring system (ARMS) at 39 points on a continuous basis.
- These data were provided to the control center every 30 minutes in routine mode and every two minutes in case of emergencies. Information on the radiological situation in the exclusion zone can be seen in real-time mode at the Ecocentre website: http://srp.ecocentre.mns.gov.ua/MEDO-PS/index.php?.

# Data on actual measurements

Radiation monitoring system in the Chernobyl exclusion zone



# Data on actual measurements

- Staff of the Chernobyl Specialized Enterprise (with Ecocentre in its structure) conducted surveys on the fire-affected territory. On 30 June 2015, the Ecocentre mobile operational group conducted radiological survey.

- No significant increase in the gamma exposure dose rate or beta-particle flux was found.

- However, an air sample taken in the fire area near the urban village of Polesskoye contained 2.5·E-3 Bq/m$^3$ of 137Cs, which is one order of magnitude higher than the reference level established in the health standard "Basic Reference Levels, Exemption Levels and Action Levels for Radioactive Contamination of Objects in the Exclusion and Resettlement Zone" for the former populated settlements, where specific categories of personnel are staying.

# Data on actual measurements

- According to ARMS, average values of equivalent dose rate (EDR) in the fire area as of 1 June 2015, 08:00, were as follows:

| No. | ARMS control point | EDR, nSv/h | Reference levels, nSv/h |
|---|---|---|---|
| 1. | Ilovnitsya | 169 | 380 |
| 2. | Buryakovka | 3232 | 7500 |
| 3. | Buryakovka radwaste disposal site | 511 | 1100 |
| 4. | Vektor | 128 | 270 |
| 5. | Chistrogalovka | 1004 | 2300 |
| 6. | Stara Krasnitsa | 598 | 1250 |
| 7. | Buda | 2163 | 4300 |

- The distance from the fire sites in the southwest part of the exclusion zone to the town of Chernobyl was 20 km, to Chernobyl NPP was 23 km, to the Buryakovka radwaste disposal site and Vektor site was 10 km, and to the southern boundary of the exclusion zone was 5-10 km.

# Data on actual measurements

- The exposure dose rates in air and on soil at the Chernobyl weather station and at control points in Kiev were measured by the Central Geophysical Observatory, and the results were published at its site http://www.cgo.kiev.ua.
- According to these data, the exposure dose rate in air at control points in Kiev did not differ from the background level from 29 June 2015 to 5 July 2015 and was between 8 μR/h and 12 μR/h.

# Data on actual measurements

- Following messages on the first fire, personnel of SSTC performed radiation survey in the city of Kiev, using the RanidSONNI laboratory to identify potential areas with abnormal radiological parameters.

# Data on actual measurements

- The measurements of the dose rate and specific air activity revealed no anomalies.
- The results of the radiation survey were posted on the SSTC NRS website http://sstc.kiev.ua/en/enterprise-news/1768-radiological-survey-in-kyiv.

# Conclusions

- The concentration of 137Cs did not lead to noticeable doses for the population outside the exclusion zone.
- Additional 137Cs fallouts outside the exclusion zone were lower than the existing contamination levels in Ukraine.
- In general, there was no need to take any measures for public protection.

Thank you for your attention!