ISSN 0216-2807

Journal of Applied Sciences in Environmental Sanitation

Volume 3, Number 2: 51-62, May-August, 2008

Sepuluh Nopember Institute of Technology, Surabaya
& Indonesian Society of Sanitary and Environmental Engineers, Jakarta
Open Access http://www.trisanita.org

Research Paper

TRANSPORT OF RADIOACTIVE PARTICLES IN THE MIDDLE EAST FOLLOWING A HYPOTHETICAL NUCLEAR RELEASE

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Received: 10th August 2008; Revised: 1st September 2008; Accepted: 7th September 2008

Abstract: The mathematical air transport and dispersion model MEMO is applied to study the atmospheric air masses flow in a geographic area of 500 x 500 km^2 (domain) on the Middle East region. The aim is to investigate the role of regional atmospheric air flow phenomena in the transport of radioactive particles. The results showed that mesoscale air flow phenomena are mostly dominant in the region under study. Hence, following a hypothetical release of nuclear radioactive particles from the Dimona nuclear facilities situated in the south of Israel, major communities in Israel, Palestinian Authority, Jordan, Lebanon and Syria may be exposed within the first forty eight hours after the nuclear release.

Keywords: Dimona nuclear plant, mesoscale flow, MEMO, cross-border pollution transport

INTRODUCTION

Radioactive particles can be released into the environment through human activities as well as by nuclear accidents. Once the particles are released to the atmosphere and based on their characteristics, atmospheric transport and dispersion processes play crucial roles in their transport, dispersion and fall out or deposition. Accidental release of radioactive particles mostly involves accidents occur in nuclear reactors, similar to Chernobyl power plant accident in 1986 or even to the nuclear submarine accident in Chazhma Cove in August 1985. In such accidents nuclear fuel particles released to the atmosphere may be hundreds of kilo-Becquerel (kB) in activity and even an individual particle may pose a quantifiable health hazard. The detection of individual nuclear particle in the atmosphere, the sampling of air masses containing these particles, and the study of their characteristics over possibly large exposed areas, i.e. a region, is so complicated and expensive. In both Chernobyl and Chazhma Cove, nuclear fuel particles released to the atmosphere were detected in areas hundreds of kilometers from the source [1-2] and in both cases the atmospheric transport and dispersion processes played the crucial role in the transport and deposition of the nuclear particles [3-7]. Similar to the case with air pollution, scientists found that dominant atmospheric conditions play a strong role in assessing exposed areas where fallout may occur [6,8-9]. For assessing any hypothetical nuclear release, it is therefore, a prerequisite to develop methods for atmospheric transport and dispersion that take into account the realistic weather conditions.

The transport and dispersion mechanisms of pollutants in the atmosphere follow the atmospheric flow. Regional scale; known as mesoscale; atmospheric flow phenomena depends strongly on the orography (the topography and its physical characteristics), the land use, the dominant synoptic conditions and the local thermodynamic effects. Flow phenomena such as channeling of winds, sea/land breeze, katabatic/anabatic winds and other regional circulation systems are usually dominant in mesoscale. Dispersion of pollutants in regional scales could be assessed using either field measurements, where wind dispersion parameters such as wind speed and direction can be only attained in specific locations, or using wind-tunnel experiments, where only geometrical similarities are attained, or using mathematical computer models, where relevant physical equations and correlations are solved using analytical and numerical methods. The advancement in computer's performance over the last thirty years enabled building and verifying state of the art computer models that proven to be very effective tools for simulating atmospheric flow on global, regional and local scales. The mesoscale atmospheric dispersion models used for regional scales air flow usually solve numerically the continuity equations of mass, momentum and energy for a model domain with its topographical configurations and characteristics. These models are very good tools for simulating mesoscale atmospheric dispersion phenomena. Some of the mesoscale models have the ability to multi-nesting to finer domains within the model domains, they also could be coupled with other chemical reaction models or even with microscale flow dispersion models.

In the following sections a description of a hypothetical nuclear release caused by a nuclear accident that takes place at the Dimona nuclear facilities located in the southern part of Israel is presented. The methodology used for assessing the possible nuclear particles transport within the atmospheric boundary layer of the domain is describe based on simulating the dominant prevailing mesoscale wind flow phenomena. Based on the resulted wind field characteristics potentially exposed areas within the regional domain will be identified.

MATERIALS AND METHODS

The few nuclear power plant accidents occurred in different parts of the world constituted major problems as their adverse effect on health and the environment can easily spread over large areas of hundreds of square kilometers over relatively long time depending on the life time of the nuclear particles involved. International communities should therefore, be aware that such accidents are not vulnerable and that therefore, all needed measures and precautions should be taken into consideration by concerned communities through insuring a degree of preparedness in a hypothetical case where a nuclear power plant malfunctioned. As the Middle East area is no exception, there is a growing concern about a possible plant malfunction or a natural disaster; i.e. earthquake that may adversely affect the plant and a consequence release of radioactive particles from the Israeli nuclear facilities operating in Dimona, in the southern part of Israel. As distances from Dimona to neighboring countries are in the range of few tens of kilometers to few hundreds of kilometers and in view of the topographical configurations of the region, which favors the dominant mesoscale weather phenomena, a question should be raised: In a hypothetical nuclear release case, how could the transport and dispersion processes look like? How would possible dominant mesoscale phenomena affect the transport and dispersion spatially and temporally? These questions are legitimate as the level of secrecy by which Israel deals with the issue and based on some leaked information, countries of the region should be concerned with any hypothetical accident and the scope of radioactive exposure.

Available information showed that Israel has been actively investigating the nuclear option from its earliest establishment [10] and with the assistant of France Israel has construction the nuclear facilities outside the International Atomic Energy Agency (IAEA) inspection regime in Dimona in the Negev desert. The first discovery of the nuclear facility was in 1958 by the United States after one of its fighters captured the facility's construction [11] and later on 1971 imagery satellite CORONA revealed first pictures of the Dimona facilities [12] and in 2000 the Federation of American Scientists posted on its web site new high-resolution satellite imagery of the nuclear reactor that was taken by IKONOS Imagery satellites [13].

In 1989 a Soviet plane took Infra Red (IR) photos to the Dimona facilities. By analyzing the IR photos absence of vegetation around parts of reactor were reported, and in 1998 the US nuclear expert Howard Howe has written an article on the Israeli Hebrew newspaper Yediot Ahronot [14] under the title 'Israeli Nuclear Reactor is on the verge of collapse'. Howe quoted the following: "*The damage of the metal building covering the reactor is severe and may collapse as of the high level radiation*."

Richard Laster [15], an Israeli advocate, has represented forty Dimona nuclear facilities' workers suffered from cancer in the Israeli district court and later in the Supreme Court. Laster, and after the court approval of a compensation scheme to the workers, revealed that the mechanisms developed at the nuclear research facility for monitoring health effects among radiation-exposed workers were inadequate when the plant was first established and remained inadequate for some time [15].

It is worth mentioning that until today Israel, along with Pakistan and India remain the only three countries that have refused to sign the Non-Proliferation Treaty; the global agreement aimed at stopping the spread of nuclear weapons through inspections and sanctions. The UN General Assembly and the IAEA General Conference have adopted 13 resolutions since 1987 appealing Israel to join the Treaty, but all have been ignored.

Mesoscale atmospheric dispersion model

The mesoscale atmospheric dispersion model MEMO is used to simulate the dominant mesoscale processes affecting the region under study. MEMO, which was developed at the Institute of Technical Thermodynamics of the University of Karlsruhe in Germany in cooperation with the Laboratory of Heat Transfer and Environmental Engineering of the University of Aristotle in Thessaloniki, Greece [16], is a non-hydrostatic prognostic atmospheric air dispersion model. It is a fully vectorized computer model which uses terrain-following coordinates. The numerical simulation is based on a staggered grid, which is allowed to be non-equidistant in all directions. The model has the capability of multi nesting within the original domain [17] and coupling with chemical models [16] and with micro-scale models [18-19]. The mesoscale atmospheric model has been used in several institutions is Europe and was selected as the core model of the European Modeling of Atmospheric Constituents (EUMAC) for modeling of the transport and chemical transformation of pollutants in selected European regions. The model inputs are the topographical settings and the corresponding land-use data. Meteorological inputs are the prevailing synoptic parameters; temperature, pressure, wind speed and direction.

Topographical and land-use data

The model domain is part of the Middle East and is located in the eastern part of the Mediterranean region and could be seen in Fig. 1 as the dashed lines' square.

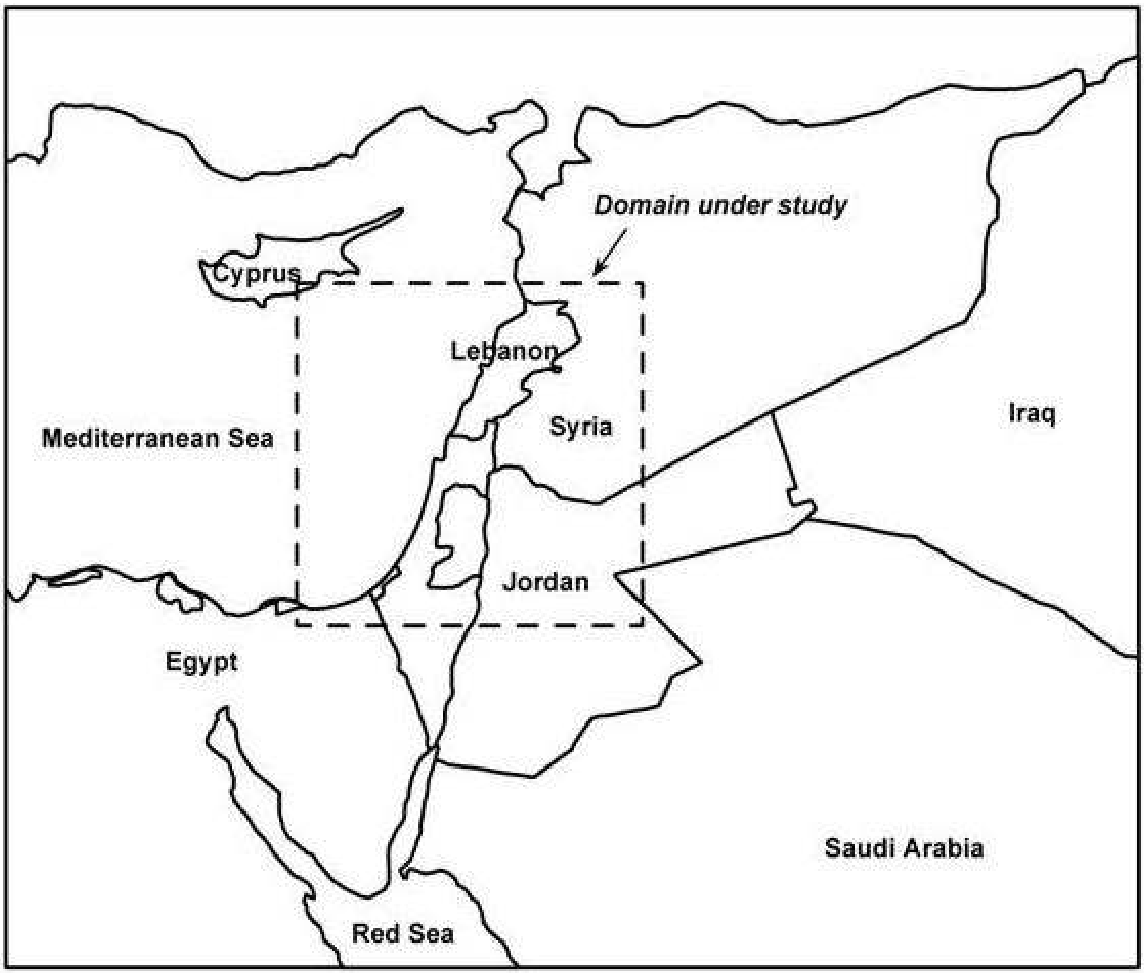

Fig. 1: The extracted model domain

The regional domain, which contains Palestinian Authority, Israel, Lebanon and parts of Jordan, Egypt and Syria, is characterized as an arid and semi-arid part of Asia region. It extends 500 km in both north-south and east-west directions on a grid resolution of 5 km x 5 km in both extensions. The height of the model domain extends to eleven kilometers on non-equidistant levels. Fig. 2 below shows the orography of the extracted domain. The location of the Dimona nuclear facility is marked clearly on the perspective view.

The domain is unique in its topographical configurations. Mountains run from north to south with heights ranging from several hundred meters to about 3000 meters above sea level in the north. The mountains are around few ten of kilometers from the Mediterranean coast in the south and run very close to the coast in the north. It also characterized by the Jordan Rift valley, which also runs in north-south direction and goes as deep as 400m below sea level in the Dead sea area. A large part of the domain is a desert area. The topographical and land-use data for the said domain were extracted from raw data containing topographical extensions and corresponding land-use on grids are part of Land-Sat images stored and maintain by the US-Geological Services. The image data are based on Lambert Azimuthal Area Projection optimized for Europe and Asia with equidistance pixel size of 30 arc-second; corresponding to 1,000.0 x 1,000.0 m^2.

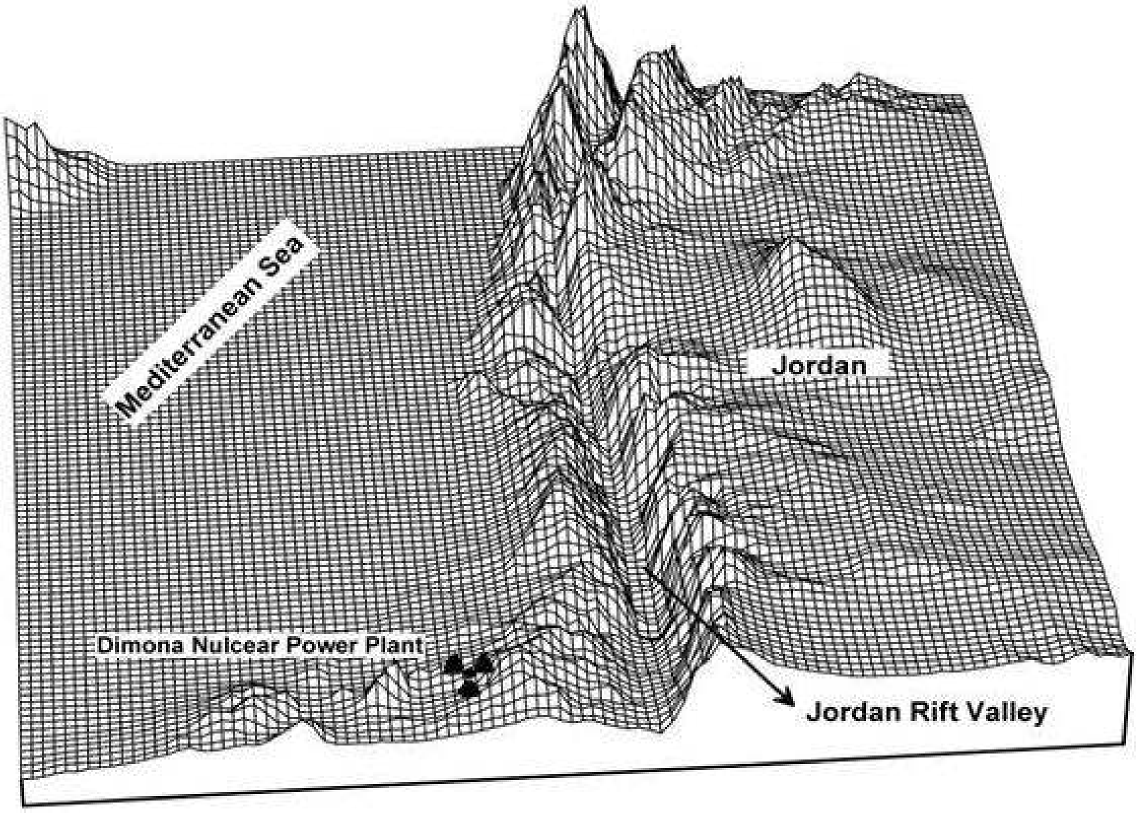

Fig. 2: The perspective view of the model domain

Meteorological and synoptic data

Data chosen as input to MEMO are those characterize the dominant meteorological conditions of the chosen region during summer season, i.e. July through to September. The wind flow during summer is characterized by the sea-land breeze dominant circulation. On land, and when solar heating has seized at night, fall winds characterize the western mountain flow towards the cost and usually increase with time and become southeast [20-21]. The subtropical ridge moves northwards and covers Israel and the PA. On the surface, the land is affected by the dominant synoptic Persian Trough [22], which brings west to north-westerly winds. Winds blow over the Mediterranean Sea and slightly cool the coastal areas. On the ground, the nocturnal wind blows at this season is mild (less than $3 m.s^{-1}$) and might change from onshore to offshore over few hours.

RESULTS AND DISCUSSION

MEMO runs on the SIEMENS vector and parallel processor SNI VPP 300 of the University of Karlsruhe. The processor has 16 processing elements; each has around 2.2 Gega-Flop second. For the 50 x 50 x 30 grid point model run, a 90 minutes computing time was required to run a 24 hour simulation. Figure 3(a) and (b) show the wind fields at a height of approximately 10 m above the ground level for 05^{00} Local Standard Time (LST), 09^{00} LST, 13^{00} LST, 17^{00} LST and 21^{00} LST.

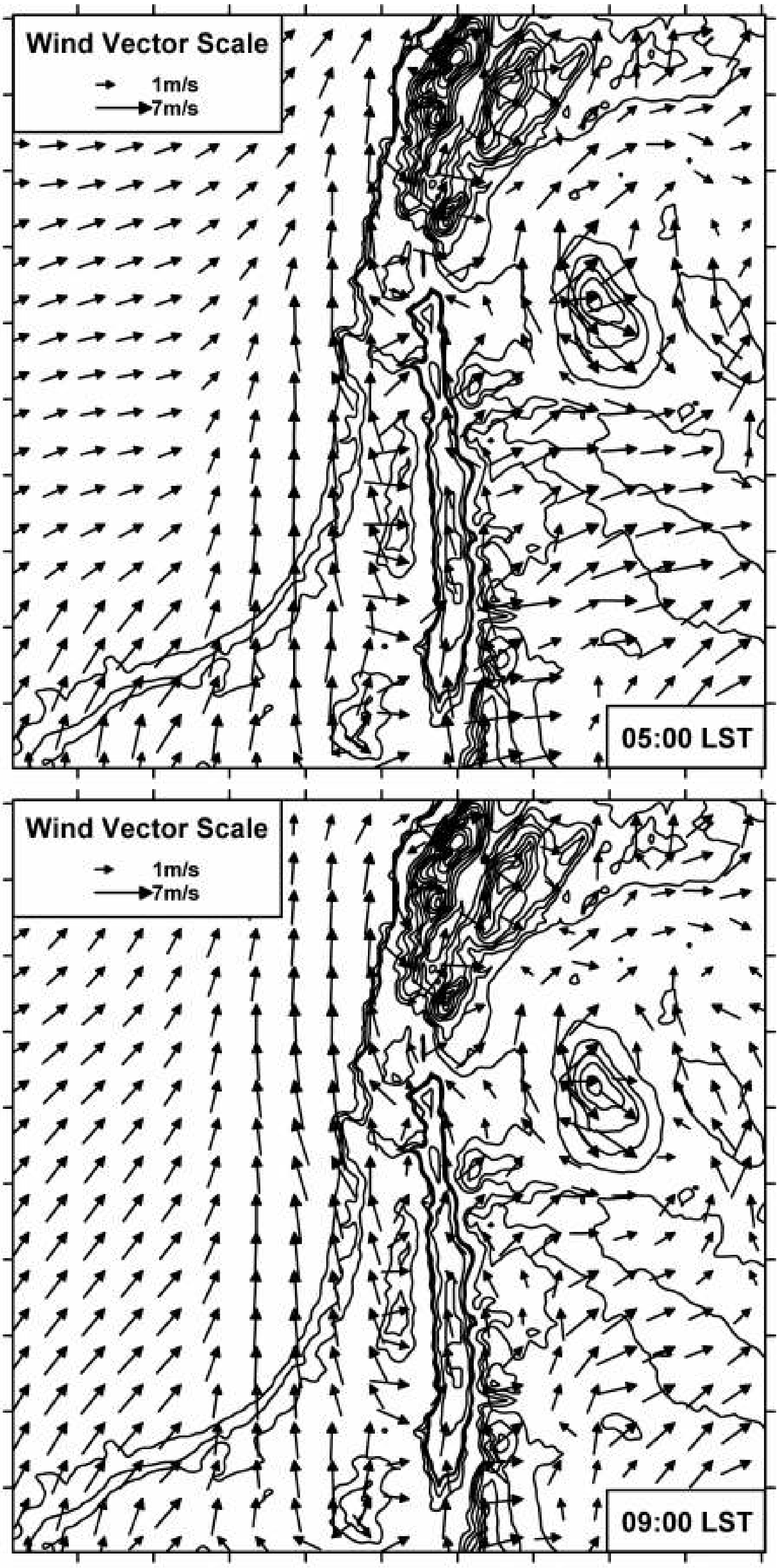

Fig. 3(a): Horizontal wind at 10 m above the ground at 05^{00} and 09^{00} LST

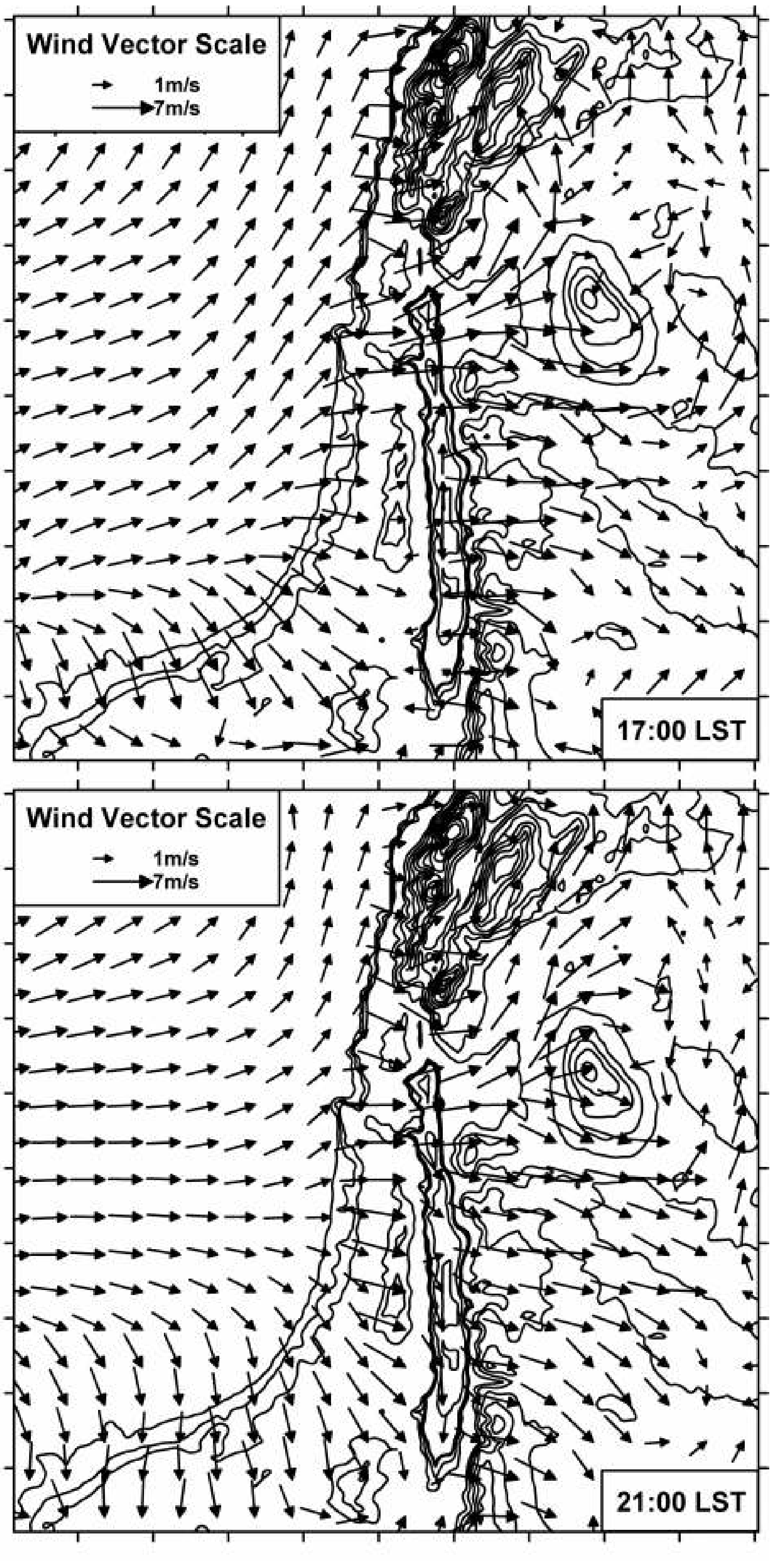

Fig. 3(b): Horizontal wind at 10 m above the ground at 17^{00} and 21^{00} LST

In these Figures it is obvious that the surface wind pattern is dominated by the moderate westerly flow over the Mediterranean Sea and down slope winds in the Alarab, Lebanon Eastern and western mountains ridges.

At 09^{00} LST the situation is practically identical that of 05^{00} LST where the occurrence mountain (katabatic) winds to the east and west of the mountain chains. The development of sea breeze starts noon due to sea-land differential cooling. Later, as the katabatic wind arrives from the western slopes of the mountain ridges, the wind intensity increases and becomes southeast. The land breeze is a wind with an eastern component due to katabatic wind and differential cooling therefore; it is defined as the component of the offshore wind orthogonal to the coastline. Winds then extend from the north to the south with the horizontal flow seems to cover the central part of the domain with an average surface wind speed of 2ms^{-1}. In the evening and as the sea-breeze intensifies, the Persian trough makes wind blows to south-east and south of the domain (17^{00}LST and 21^{00}LST) starting in the southern part of the domain, i.e. north of Ashdod.

Considering the location of the Dimona nuclear facilities the prevailing dominant synoptic conditions which obviously favors the transport and dispersion of radioactive particles over specific parts of the domain, it is possible to assess which parts of the domain may be exposed mostly after any hypothetical release. Based on the dominant synoptic conditions and the surface wind flow in magnitude and directions it could be seen that in a hypothetical release of radioactive material from Dimona nuclear facilities that may happened during Summer the area that may be exposed by the nuclear material within the first two days (48 hours) of the release extends to north, east, and south directions of the nuclear facilities. Considering the approximate distances of some major cities in the region from the nuclear facilities and their locations relative to the Dimona nuclear facilities (Table 1), it is obvious that most of these cities and communities living in the surrounding areas may be under serious exposure threat.

Table 1: Approximate Distances of Major Cities in the region from Dimona Nuclear Facilities

City	Approximate Distance from DNPP in km	Direction to DNPP
Jerusalem	100	NE
Gaza	70	NW
Tel-Aviv	130	N
Amman	165	NE
Beirut	350	N
Damascus	325	NE
Cyprus	430	NW

Nuclear particles of different sizes released from the site may cover a large geographic area crossing the boarders of the neighboring countries. In fig. 4 below, the possibly exposed area in the first two days of the release is seen as marked with dashed line.

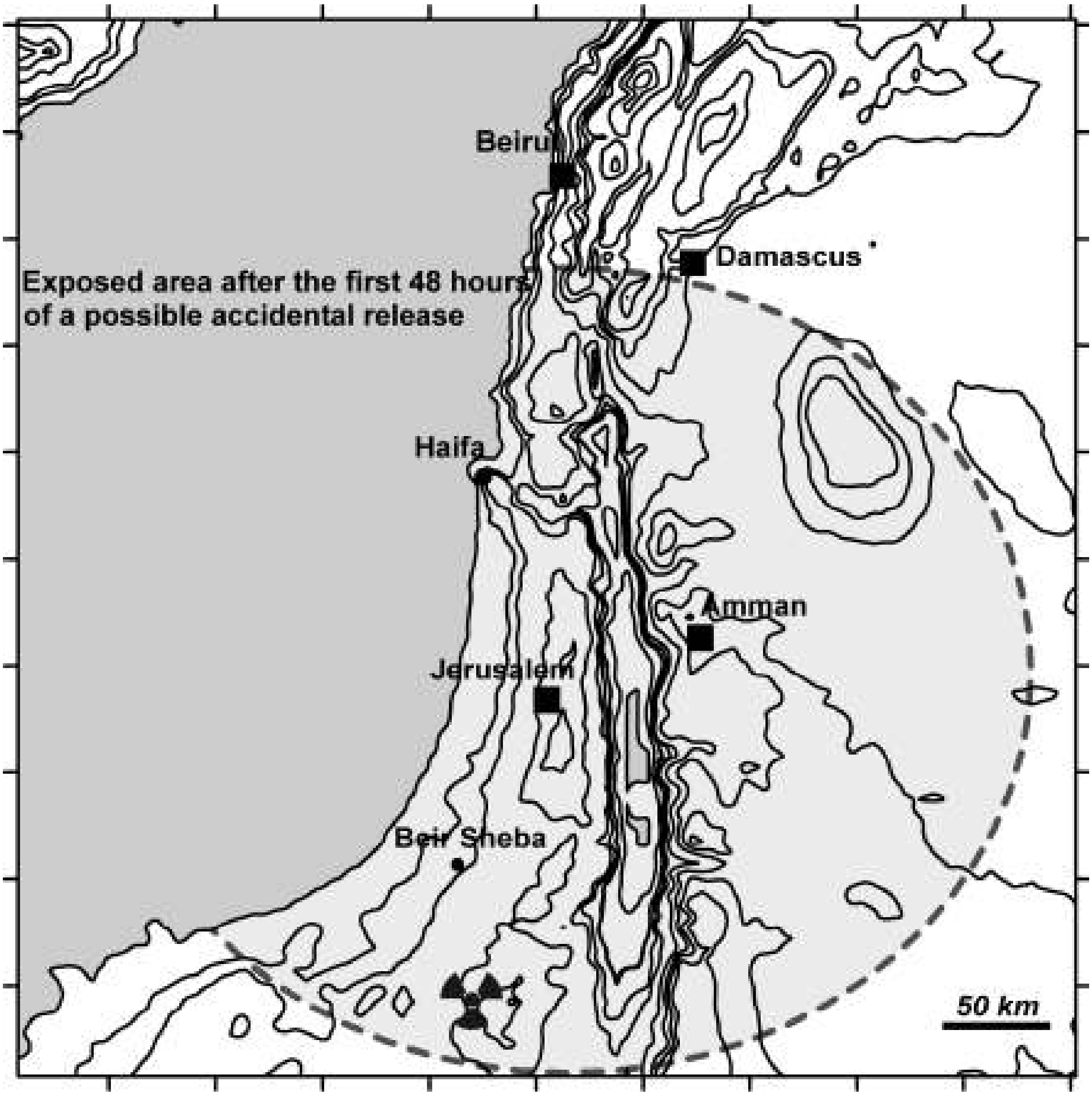

Fig. 4: Possibly exposed area after 48 hours of the nuclear release

The exposed area will certainly extends with time depending on atmospheric air masses flow characteristics and amounts and characteristic of the released radioactive particles. It also depends on the heights of the release and for that reason air parcel trajectories at different height.

CONCLUSIONS

A prognostic air dispersion mathematical model (MEMO) was used to simulate the wind flow pattern in a model domain of 500 x 500 km^2 area of the Middle East region to investigate the mechanism of cross-border air masses carrying radioactive particles transport in a part of the Middle East region. The outcomes of the study clarifies that the underlying topography and the land classification which favors the domination of mesoscale atmospheric phenomena, crucially affects all the transport phenomena in the domain under investigation. On the bases of the distances of major cities in the region from the nuclear emission source, and the prevailing dominant atmospheric air flow phenomena it is possible that in any hypothetical nuclear release from Dimona nuclear facilities air masses carrying nuclear particles could reach several area in Israel, Palestinian Authority, Jordan, Lebanon, and Syria within the first forty eight hours. Additional investigation on the bases of air parcel trajectories could also be performed that will give indications on the vertical extensions of the atmosphere and the heights of the nuclear particles' releases.

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