

# Development of a GIS-based Bird Model Migration Model for the Middle East

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## **Abstract**

A regional model of bird movement is being developed at the International Center for the Study of Bird Migration at Latrun, in cooperation with the Society for the Protection of Nature and Tel Aviv University with the aid of EMC2, the Enterprise Storage Company.

ESRI (Environmental Systems Research Institute) Geographic Information System (GIS) tools are being used for data integration, analysis and geospatial display of historic bird migration data, environmental and landuse data, and near real-time migration data, to create a dynamic model of soaring bird migration in the Middle East. Presently, satellite telemetry data from 48 White Storks have been integrated into the system and seven storks with active transmitters are interactively linked to the system. In the future, telemetry data for other soaring birds will be added. Other data sources included in the model are motorized glider flights tracking Lesser Spotted Eagle, White Stork, Pelican, and Honey Buzzard migration routes and altitudes through Israel and the ground survey network, including the timing and intensity of autumn soaring bird migration across Israel. The information system is also linked to several meteorological datasets. One of the main objectives of the model is to study the relation between changing weather conditions, topography and the spatial distribution, timing and intensity of soaring bird migration. Preliminary results have already shown that a combination of several meteorological variables at the 850mb level, have a significant effect on the daily speed of migration.

The model is being designed in such a way that it can be expanded to include data from other countries and linked in the future to similar systems being developed around the world.

## **Introduction**

Israel is an important bottleneck for bird migrating from Europe and Asia to Africa in the autumn and back in the spring. This is particularly true for soaring birds that avoid crossing large bodies of water such as the Mediterranean Sea because of their dependence on thermals.

The timing, routes and altitudes of migration of soaring birds over Israel has been studied in detail by Leshem and Yom-Tov (1996a, 1996b & 1998) using mainly ground surveys, motorized glider flights, and radar tracking. These aspects of migration were found

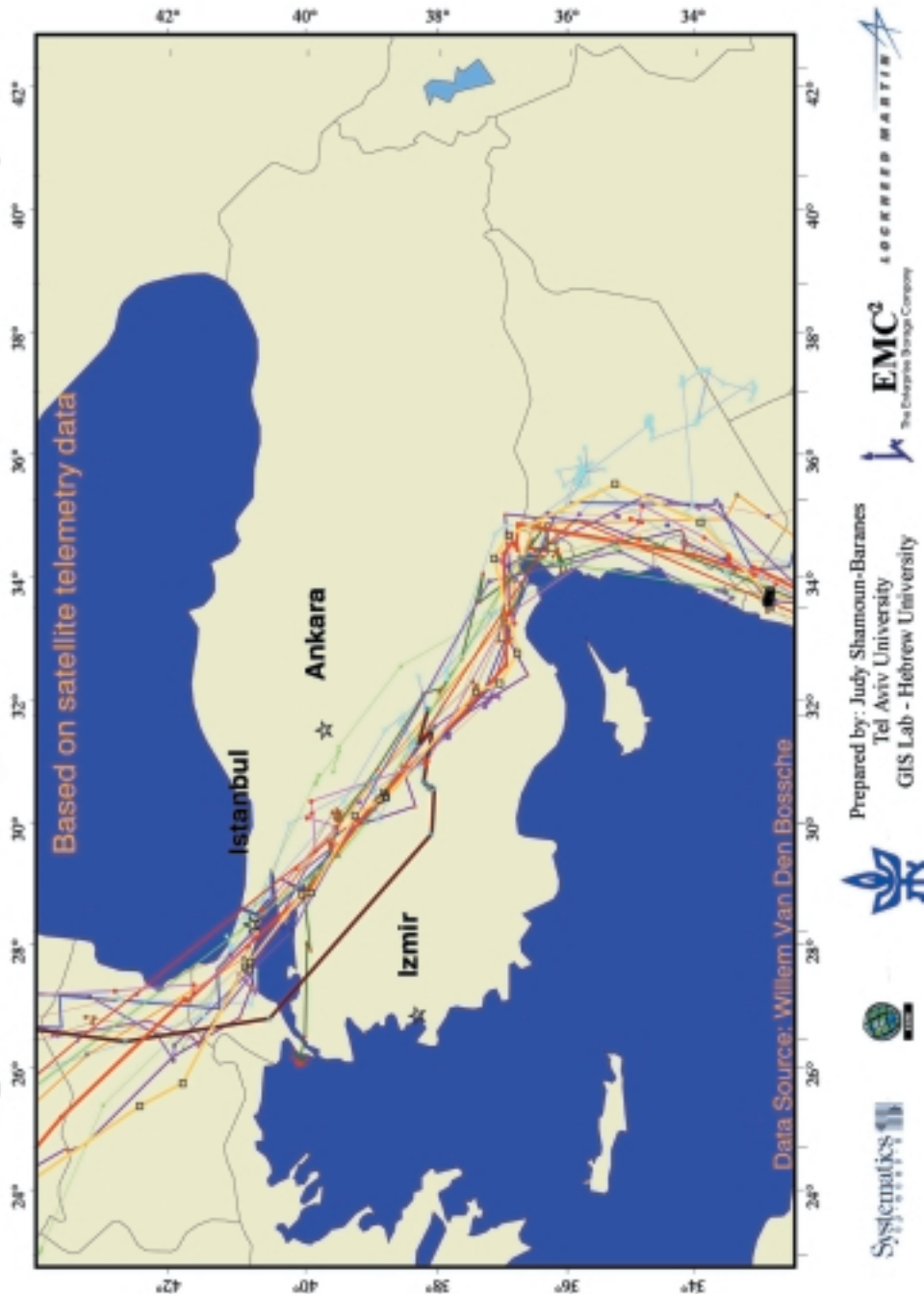
to be fairly predictable. In recent years, knowledge of individual migrants, their migratory route from nesting site to wintering sites, their stop-over sites, how long they spend in each area and how far they travel each day, has been collected using satellite telemetry (Berthold et. al. 1997, Meyburg et. al. 1995). This technology has given new insight into the migratory behavior of certain species.

Though many species of birds show rather consistent temporal and spatial patterns of migration, these patterns are flexible. Weather is assumed to play an important role in affecting migratory behavior. Factors such as passage of cold fronts, barometric pressure, wind direction and intensity have been shown to affect the flight behavior of soaring migrants (Allen et. al. 1996, Liechti et. al. 1996 and Maransky et. al. 1997). However, these studies generally focused on localized events and the effects of meteorological variables on the timing and intensity of soaring bird migration, particularly on a regional scale have not yet been elucidated.

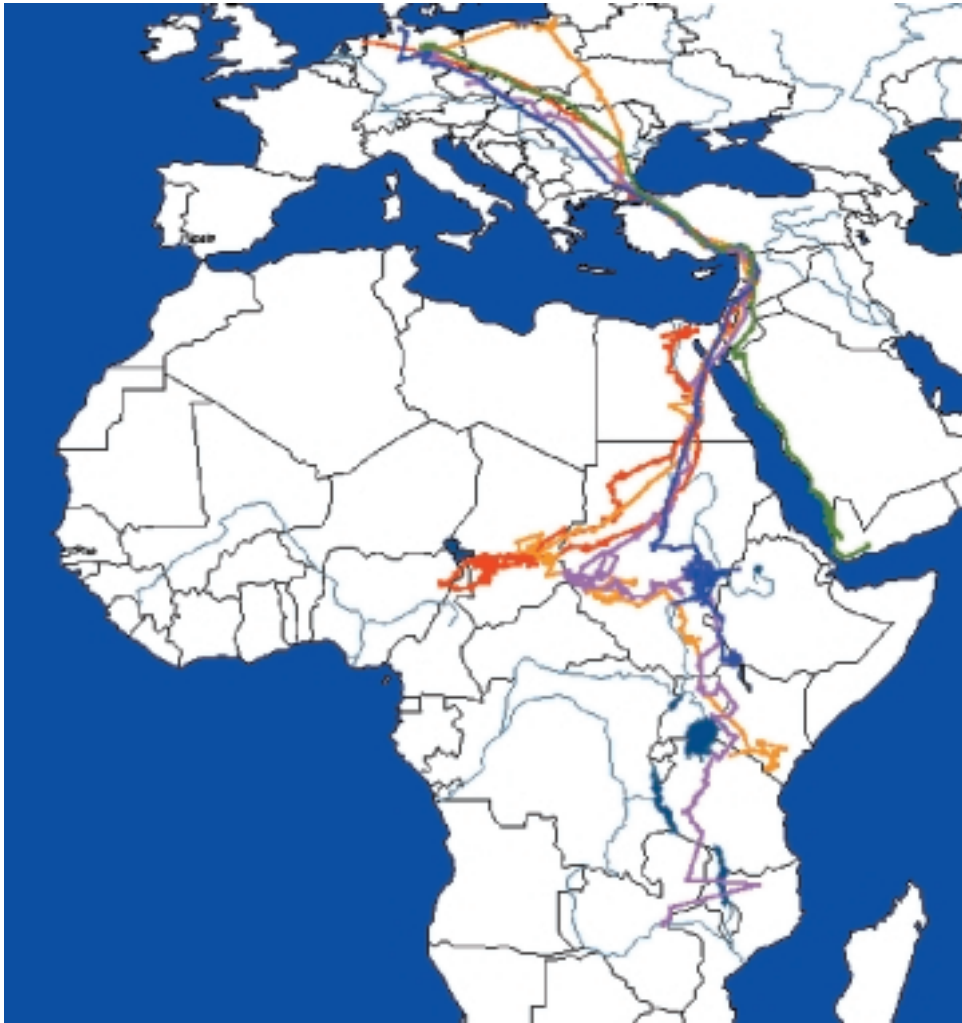
Birds have posed a serious threat to flight safety since the beginning of aviation. In recent years, damage to aircraft, particularly military aircraft, as the result of birdstrikes has increased significantly due to faster and lower flying aircraft, costing hundreds of millions of dollars annually and the loss of lives. The Israel Air Force (IAF) has also suffered severe losses to birdstrikes. Seventy four percent of the serious damage to IAF aircraft was from migrating birds. The data obtained from Leshem and Yom-Tov's study of bird migration over Israel (1996a, 1996b, 1998) was used to develop the "Bird Plagued Zone" regulations and a warning system for the IAF, which has reduced collisions with migrating birds in the IAF by 88% (Leshem 1994). However, the disadvantage of this system is that it is generalized in both time and space and limits flight training for seven months of the year.

In an effort to improve flight safety during the migratory months, the IAF has recently begun the process of creating a network of weather and bird radars throughout Israel in order to develop a real time warning system for the whole country. An integral part of this system, should be an historically based model of bird migration to provide the necessary biological data not only for a real time warning system but as a tool to improve flight planning.

This research project will attempt to develop a dynamic Geographic Information System (GIS) - based model of migratory bird movement in Israel and the Middle East. This project is being conducted in cooperation with the United States Air Force Academy in Colorado Springs where the first phase of a GIS-based Bird Avoidance Model has been developed to reduce bird hazards in the United States. GIS tools enable integration and statistical analysis of data available on several dimensions, as well as graphic representation of these data along with associated databases that can be queried by the user. The quality of the data available will allow us to create a multi-dimensional dynamic model incorporating historic data on bird migration, satellite telemetry data, and environmental data. The interaction between meteorological variables, topography and migration intensity, timing, and spatial distribution will be quantified. By understanding the role of changing weather patterns in determining or altering migratory behavior, migration timing, intensity and



*The map, part of the development of a GIS-based bird migration model for the Middle East, shows the migration routes of White Storks fitted with transmitters received by satellite over Turkey. This data can be used by the Turkish, Israel, US, NATO Air Forces, to avoid collisions with migrating birds.*



*These are five White Stork migration routes from their nesting sites in Germany to their wintering sites in Africa, representing 77 white storks that were fitted with satellite transmitters as a part of a joint German-Israeli research program. Several of these birds can be followed in real-time through the Internet. The second phase of the project is being led by Judy Shamoun-Baranes who is developing a Geographic Information System (GIS) based model of bird migration, integrating all the available data on soaring bird migration in the region into one database. The stork Siegfried (green route) migrated away from the regular route along the eastern part of the Red Sea and was shot by a Yemenite office. The transmitter was later returned to Germany.*

orientation can be more accurately predicted than currently possible. GIS is a fairly new tool in the field of ornithology and is mainly used for mapping of bird territories and distribution (Shaw & Atkinson, 1990 and Witham & Kimball, 1996). In the future, this model can serve as a template for expansion to include data from other regions.

### **Research Objectives**

1. To create an empirical migratory bird movement model based on historic data for autumn and spring migration in the region using GIS as the key tool for data integration, analysis, and geospatial display.
2. To study the interaction between meteorological events and the timing and intensity of bird migration on a regional scale.
3. To study the interaction between climatic variables, topography, and soaring birds migrating over Israel on a local scale.
4. To incorporate the biological implications of the meteorological aspects of the project into the GIS-based bird migration model.

## **Materials and Methods**

### **Biological data:**

The most abundant soaring bird species migrating over the region will be analyzed in this study, including the White Stork (*Ciconia ciconia*) which will be the pilot species for most steps of the project, Honey Buzzards (*Pernis apivorus*), Lesser Spotted Eagles (*Aquila Pomarina*), and White Pelicans (*Pelecanus onocrotalus*).

Following is a list of the data that is presently available for spatial display and analysis. Motorized glider data from autumn and spring, 1986-1989, used to map individual flock migration routes through Israel, including date, time, coordinates, and altitude of birds when they entered and left each thermal for Honey Buzzards, Lesser Spotted Eagles, White Storks, and Pelicans.

Satellite telemetry data for White Storks as well as several Lesser Spotted Eagles from 1994 to the present including date, time and coordinates of individual bird movements throughout the migratory season. Distance traveled and speed of flight can be calculated from the above information. Though the PTT's (Platform Transmitter Terminal) using Argos satellites theoretically transmit coordinates every 90 minutes or so, the quality of these locations varies greatly. Location classifications A, B, and Z are automatically removed. Only locations 0 (resolution above 1000 meters), 1 (better than 1000 meters), 2 (better than 350 meters), and 3 (better than 150 meters) are used.

Northern Valleys Autumn Soaring Bird Migration Survey from 1990 -1999, including number of birds, time, date, species, and station (kilometers from coast). For previous years and other ground surveys, only daily summaries for each station/species are available.

### **Model Design**

GIS will be used as the primary tool for data integration, geospatial display, and analysis

of multidimensional data. The associated biological and environmental databases (attribute data) will be queried using GIS and statistical tools.

The consolidation of the digital database for importation into a GIS is being performed using Microsoft applications, particularly Excel, Access and text editors. Environmental Systems Research Institute, Inc. (ESRI) applications, particularly ArcView with the Spatial Analyst and ArcInfo (UNIX platform), are being used for data integration, spatial, and temporal display, which will be followed by analysis of the relation between different data layers. Initial training in the use of GIS was obtained at the US Air Force Academy in Colorado Springs. Environmental and man-made data that are presently being used includes a digital terrain model (DTM) of Israel developed by John Hall, and hydrological data (source: Digital Chart of the World, ESRI 1993).

### **Meteorological Analysis**

This phase of the project is being performed in cooperation with Prof. Pinhas Alpert and Anat Baharad from the Department of Geophysics and Planetary Sciences, Tel Aviv University. Meteorological data for the regional analysis will be extracted from the NASA data set which provides data at a resolution of  $2.5^{\circ}$  every six hours, or the National Center for Environmental Prediction (NCEP) data set providing data at a resolution of  $1.8^{\circ}$  every 12 hours. Both data sets may be used depending on the resolution needed for the analysis. The parameters initially examined in the pilot study included vertical wind (omega), wind direction and speed, temperature, barometric pressure, relative humidity and geopotential height at 850 mb. Wind direction and speed is in the form of x,y vectors and was calculated as in relation to the migration direction as following/opposing wind vector and side wind vectors.

Using satellite telemetry (initially studying White Storks), the distance traveled per day or the estimated hourly speed of migration will be calculated and used for statistical analysis with each weather variable separately, as well as in multiple regression analysis. For the pilot model discussed below, ACE statistical process was used with the aid of Dr. Yoav Dvir from the Mathematics Department of Tel Aviv University.

The soaring bird migration network data, initially for species with a short temporal peak in migration, will be used to examine the relationship between migration timing and intensity and the weather variables found to have a significant effect on migration in the previous section. The first day of arrival in Israel (of 90% of the population) and the peak day of migration each year will be used for analysis. These dates will then be used to extrapolate the migration starting point in Europe several days before the birds reached Israel according to their average daily distance traveled (Leshem & Yom-Tov 1996b). Weather variables will be examined in those regions where it is estimated that the birds were several days previous to arriving in Israel. The Lesser Spotted Eagle will be studied first because of its relatively short peak in migration and geographically limited breeding grounds.

Temperature, barometric pressure, wind direction, and wind speed - obtained from synoptic



stations of the Israel meteorological service - will be used to analyze the interaction between local migratory movements, climatic changes, and topography.

## **Preliminary Results**

### **Mapping the Data**

Digital sources of historic avian data, including stork migration routes obtained through satellite telemetry, motorized glider routes, and the northern valleys autumn migration survey were collected and reformatted for compatibility with GIS data types.

Presently, all satellite telemetry and motorized glider data available have been incorporated as GIS vector coverages. Annual migration paths from satellite tracking were assembled as separate GIS coverages for each year.

Once the data were incorporated into the GIS, it was possible to perform a more rigid quality test. Even following the filtering of satellite locations A, B, and Z several data points were found to be unreliable. Either they were found in points incongruous to the migration path, or too far for a bird to migrate within the designated amount of time. These points were eliminated manually using both text editor tools and GIS editing tools.

The motorized glider data has been overlaid on a DTM of Israel and the satellite telemetry data has been overlaid on a drainage coverage representing permanent water.

By overlaying White Stork migration paths from the satellite telemetry data using GIS, a first draft for recommendations to the Israel Air Force for flight training limitation over Turkey during the migratory months was created (Figure 1).

### **Pilot meteorological analysis**

Migration routes of six White Storks from 1994-1995 were used for the pilot meteorological analysis. The NASA GEOS-1 Assimilation Data Subset was used to provide meteorological data at the 850mb level for Europe to Africa. ACE statistical analysis was used to create a model combining those parameters with the most significant effect on the daily speed of migration. The result of the preliminary test was a strong model combining several meteorological factors. The meteorological variable with the strongest effect on migration speed were: following/tail wind followed by omega (vertical wind), geopotential height, temperature, and finally, specific humidity. As the wind vector in the direction of migration increased, so did migration speed. The presence of a wind vector perpendicular to the axis of migration decreased the speed of migration.

Although these are only preliminary results for six White Storks and two migration seasons the potential for creating such models is clear. This study uses a unique combination of remote sensing of bird migration (satellite telemetry) along large expanses of territory and global meteorological databases that are available to the public, rather than relying on local meteorological services which are often uncooperative or difficult for foreign

researchers to access. A forecasting model based on such data makes regional modeling more than just a concept, but actually possible with resources that are available internationally, some even over the Internet.

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