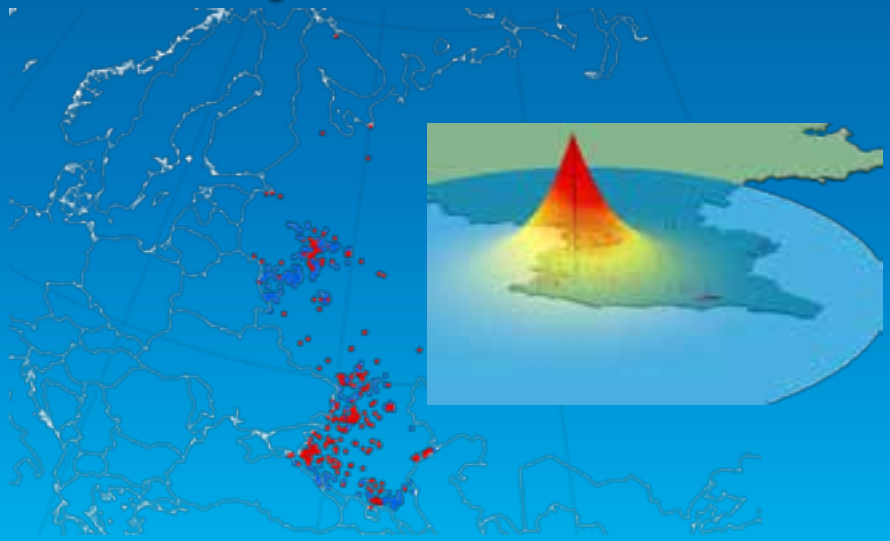
Esri UC | San Diego, CA, USA | 17 July 2014

African swine fever: ArcGIS for modeling risk of the disease spread



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http://www.arriah.ru

- OIE* Regional Reference Laboratory for Foot-and-mouth Disease (FMD) for Eastern Europe, Central Asia and Transcaucasia
- OIE Coordinating Center for Diagnosis and Control of Animal Diseases for Eastern Europe, Central Asia and Transcaucasia
- The Center produces biological preparations of high quality for prevention and treatment of animal diseases
- The Center carries out researches in the framework of several Federal scientific and technical programs as well as international projects

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***OIE** - *Office International des Epizooties*
currently **World Organization for Animal Health**
http://www.oie.int/

My department:
The Center for Information and Analysis

- Monitoring of animal disease situation in Russia and abroad
- Disease mapping, modeling and forecasting
- Reporting to OIE
- Risk analysis in export/import operations with animals and food products

GIS

- Esri customers since 2007 (via Esri-CIS http://www.esri-cis.ru)
- ArcGIS for Desktop Advanced and Basic
- Spatial Analyst, 3D Analyst, Geostatistical Analyst, Data Interoperability

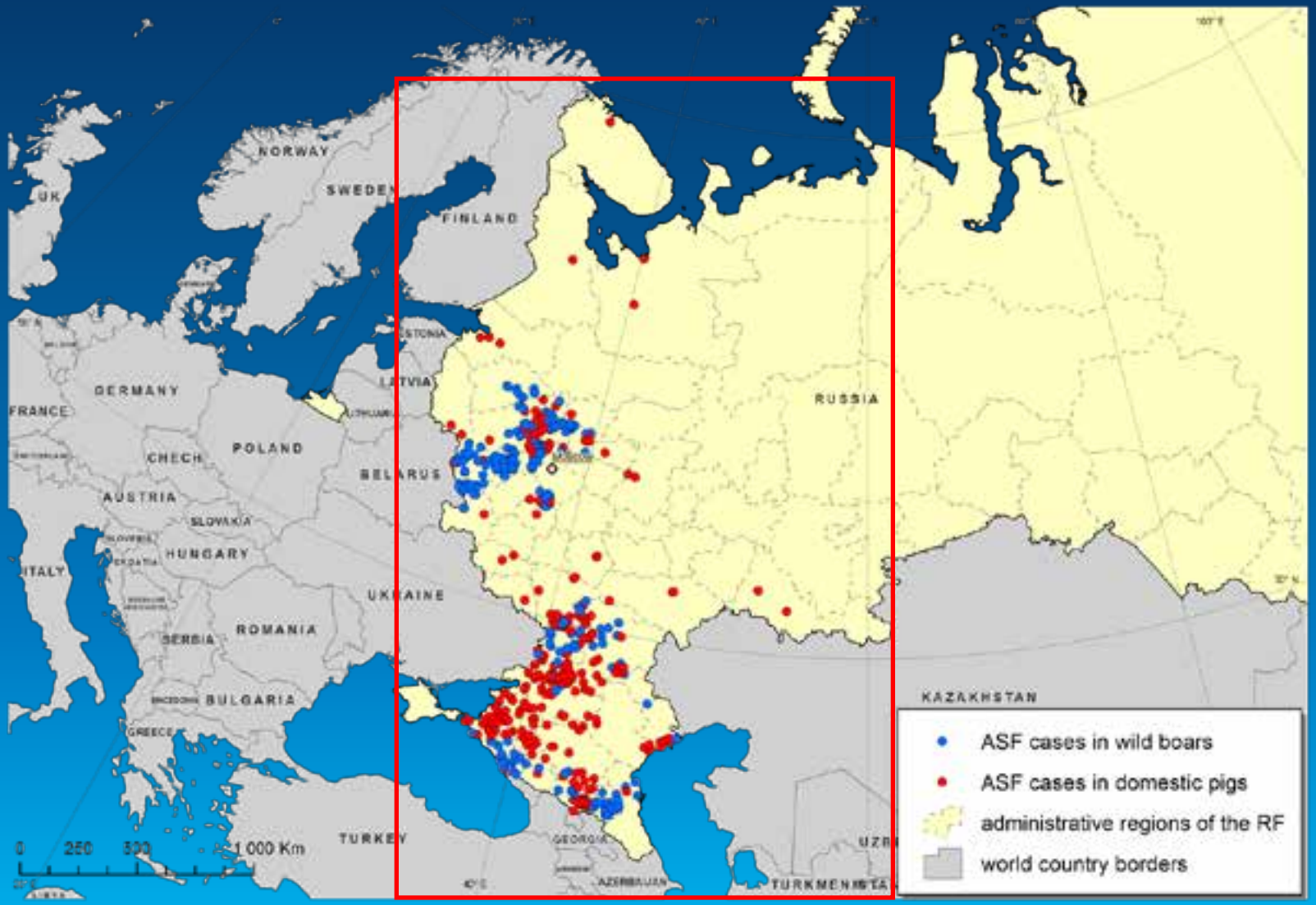
African Swine Fever (ASF)

- Contagious viral disease of domestic and wild pigs
- Near 100% mortality
- No vaccine
- No danger for human, but causes huge economic impact:
  - Total swine depopulation at the infected farm and within the risk zone of 5 – 20 km radius
  - Transportation and trade bans within the surveillance zone of 100 – 150 km radius
  - Affects the international pork market
- Currently endemic in the islands of Madagascar and Sardinia, in some African countries

ASF
Main transmission routes

- **Direct contact between infected and susceptible pigs**
- **Transportation of live animals, pork products, contaminated fodders and garbage**
- **Wild pigs (boars) – usually considered secondary and hardly can spread the virus at large distances. But …**
- ***Ornithodoros* ticks – natural reservoir, but not present in Russia**

ASF in Russia: 657 cases as of June 2014



European Part of the RF

2007:
2 cases in wild boar

- Introduction from Georgia is suspected
- ~ 60 cases were confirmed in Georgia in 2007

2008:
62 more cases

2009:
73 more cases

2010:
84 more cases

2011:
63 more cases

2012:
120 more cases

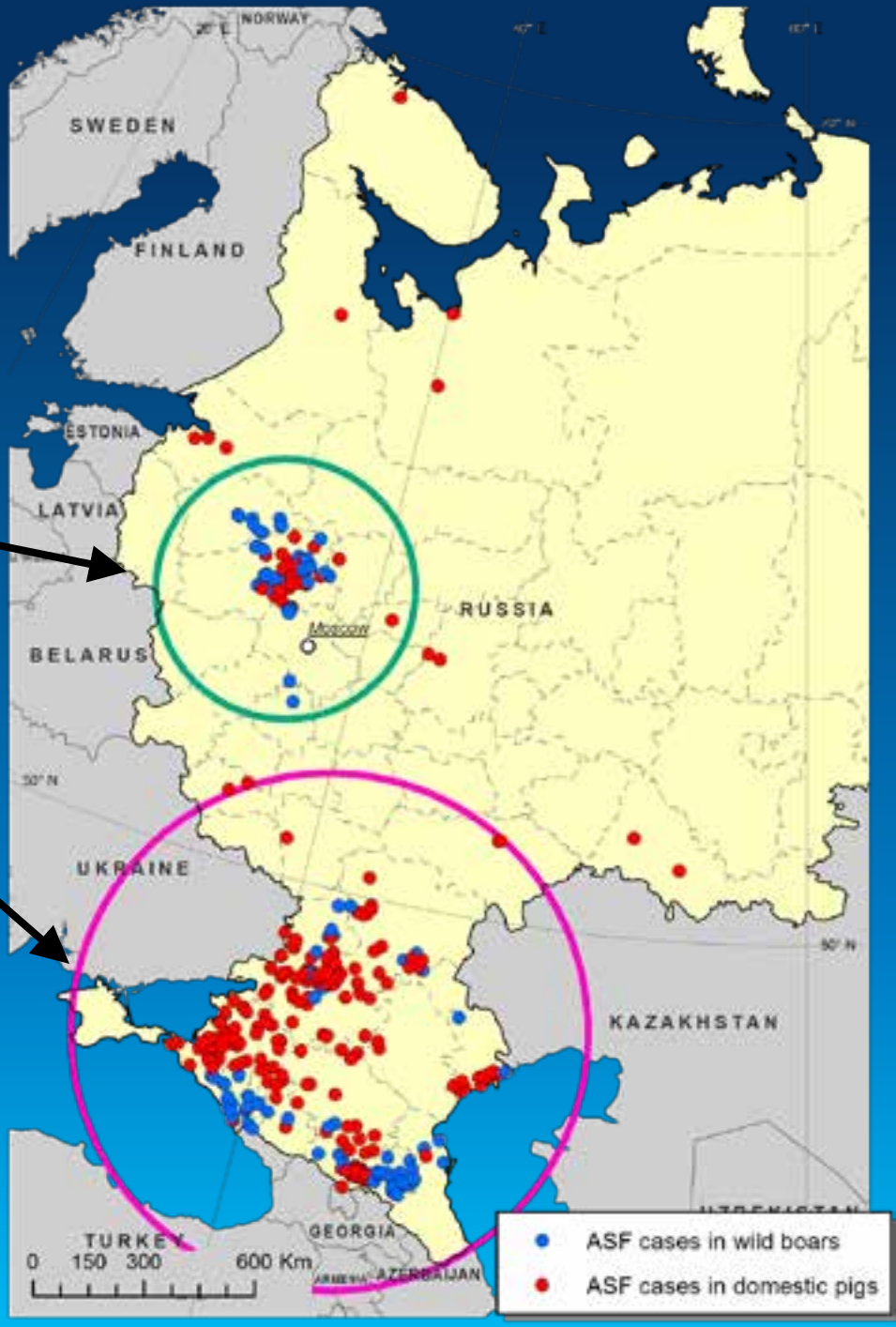
Two large ‘endemic zones’

Zone ‘North’

Zone ‘South’

Zone borders were defined using **‘Standard Distance’** tool
(ArcToolbox → Spatial Statistics Tools → Measuring Geographic Distributions)
with 2-std radius

Those cases outside the endemic zones are considered **‘remote’**

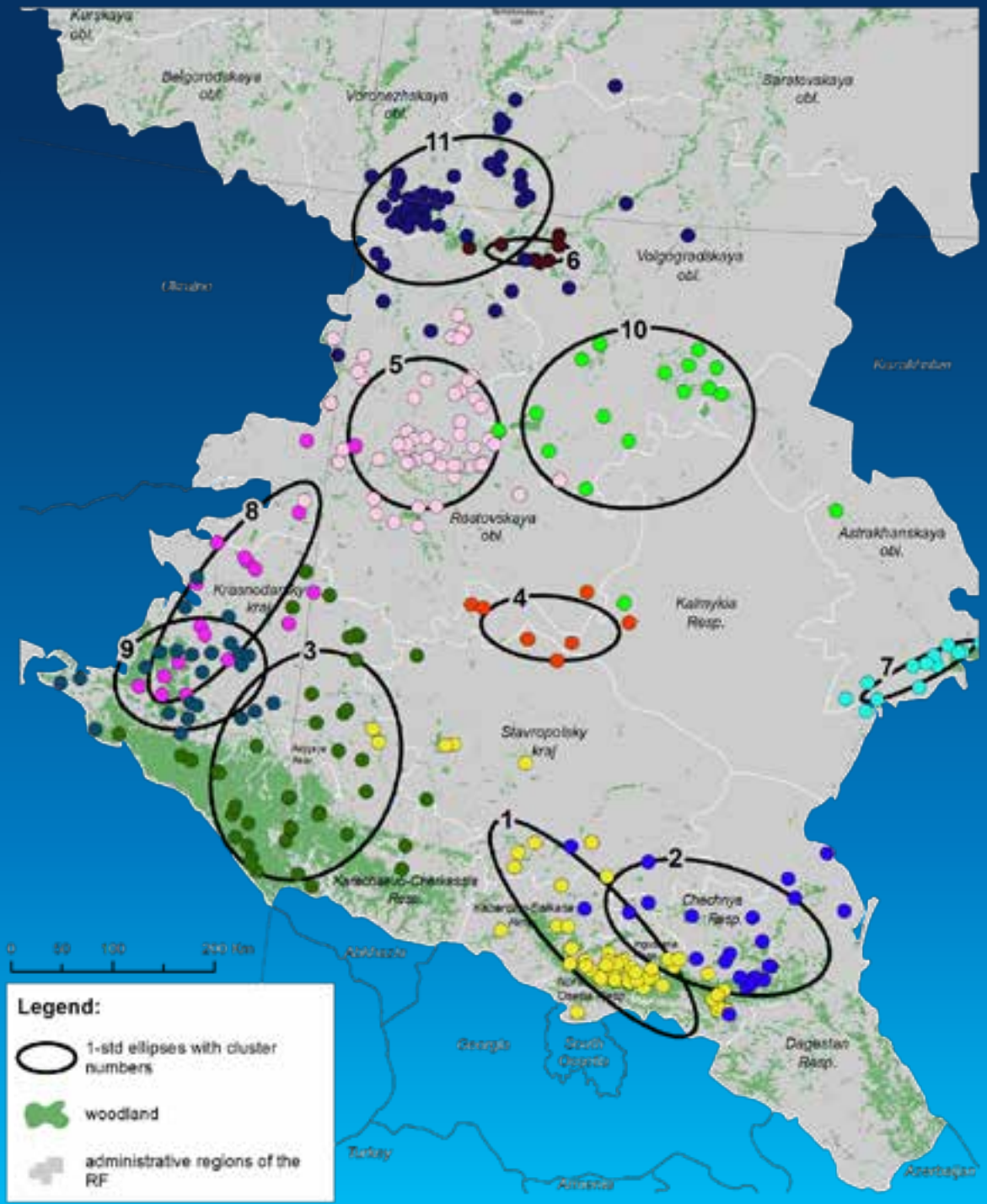


Cluster analysis. Zone ‘South’

1. Use **‘Grouping Analysis’** tool (ArcToolbox → Spatial Statistics Tools → Mapping Clusters) to identify significant spatio-temporal clusters of cases

2. Use **‘Directional Distribution’** tool (ArcToolbox → Spatial Statistics Tools → Measuring Geographic Distributions) to reveal time-space trends of the epidemic spread within clusters

Consider date of outbreak as weight parameter



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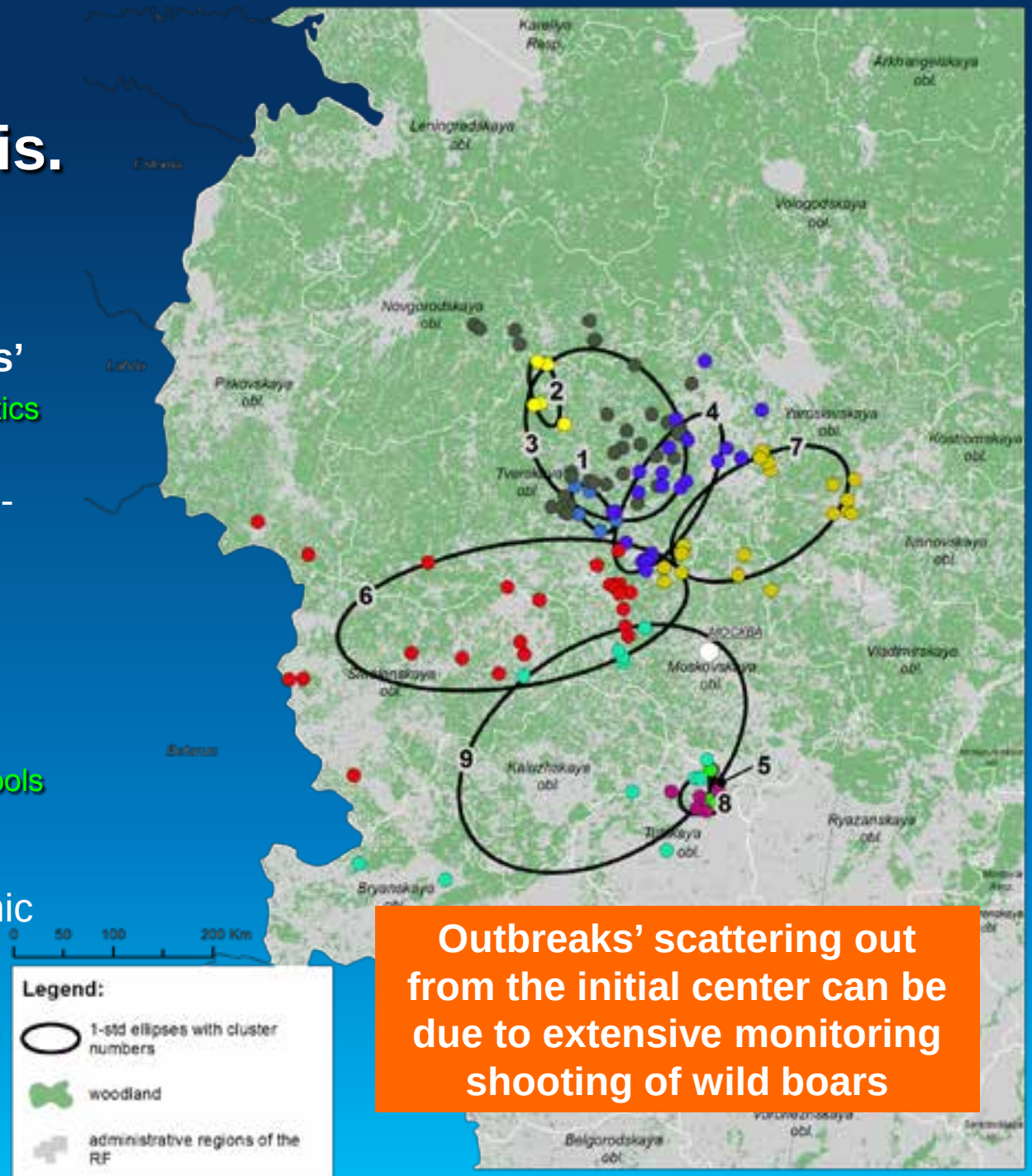


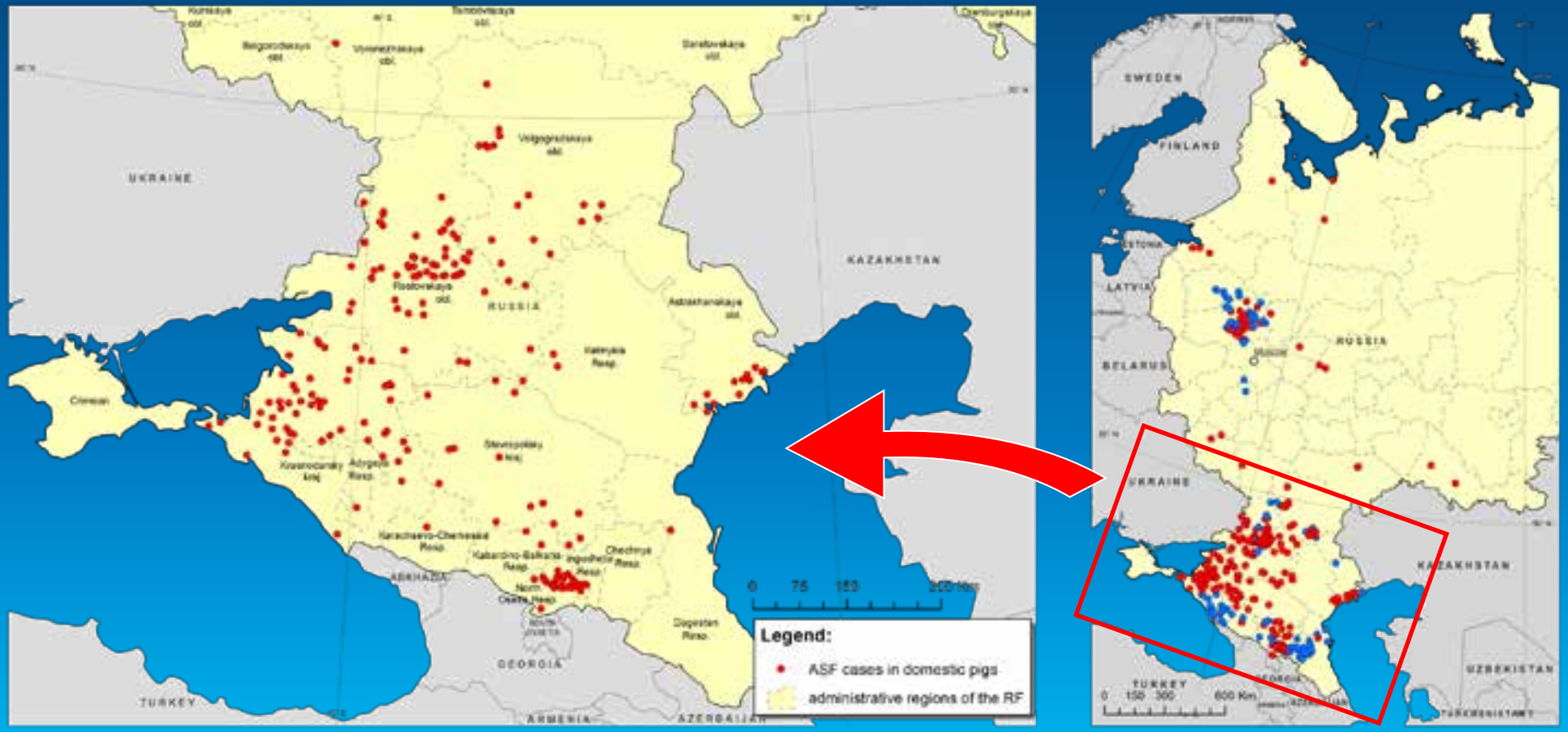
Outbreaks' scattering out from the initial center can be due to extensive monitoring shooting of wild boars

Modeling risk

- Where to expect a next ASF outbreak?
- Which risk factors are associated with the ASF spread patterns?
- Is the current practice of surveillance zones (100 – 150 km radius) effective enough to prevent spread of the disease?

Study area

- Endemic zone ‘South’ as of December 2012
- Only the cases in domestic pigs were considered (N = 211)



Plan of modeling

1. Create a suitability map

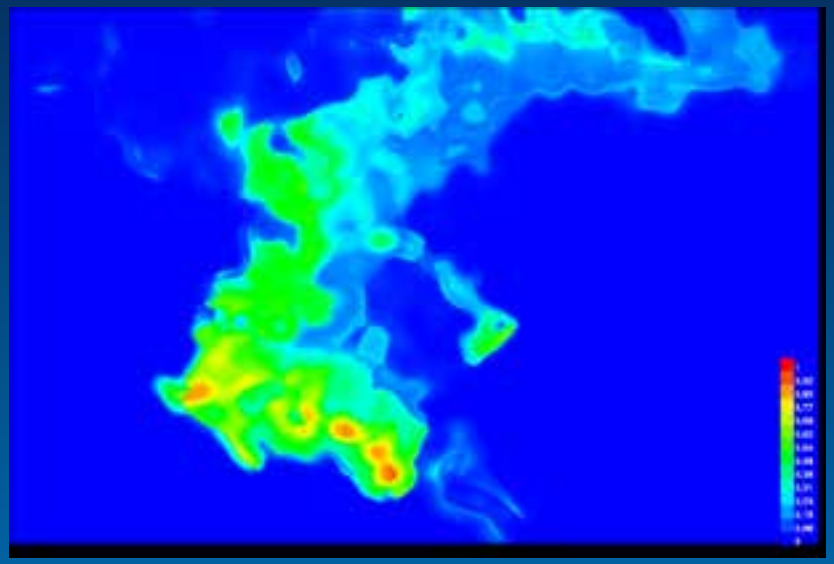
   (define all areas where the ASF outbreak could occur considering underlying socio-economic and geographical conditions)

2. Given a most recent ASF outbreak estimate ring zone of most probable virus transmission

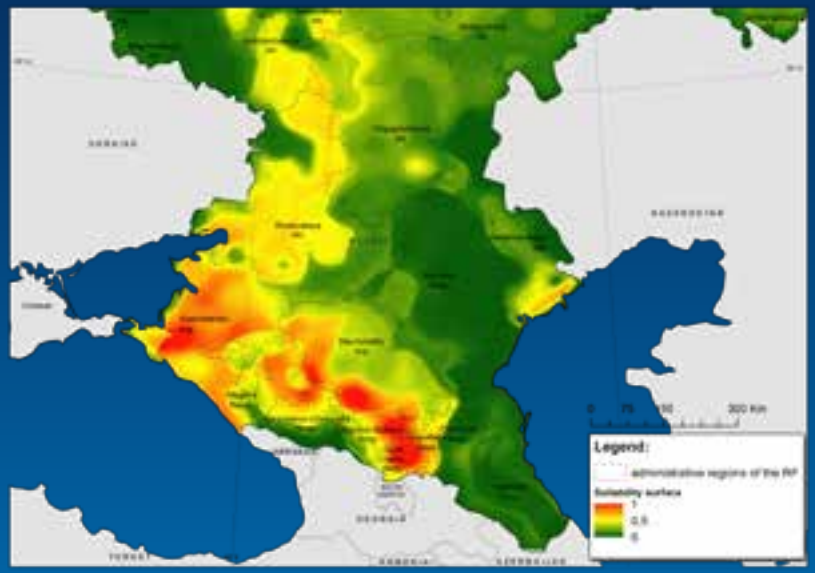
3. Combine suitability map with ring zone to obtain a risk map of the ASF emergence given a most recent outbreak

1. Suitability map

- Use <u>Maximum Entropy</u> modeling method
- Analyze a set of known location points *vs* a set of spatial explanatory variables
- Primary use in health and ecology: ecological niche modeling *(i.e. identification of habitat area of some particular species given its observed locations)*
- Here we use socio-economic and geographical variables instead of environmental:
  - *Swine population density*
  - *Human population density*
  - *Road network density*
  - *Density of settlements (towns, villages)*
- All densities were calculated by 'Kernel Density' tool (ArcToolbox → Spatial Analyst Tools → Density), then converted to ASCII format (ArcToolbox → Conversion Tools → From Raster)



MaxEnt output – probability of observing an outbreak considering a combination of explanatory variables

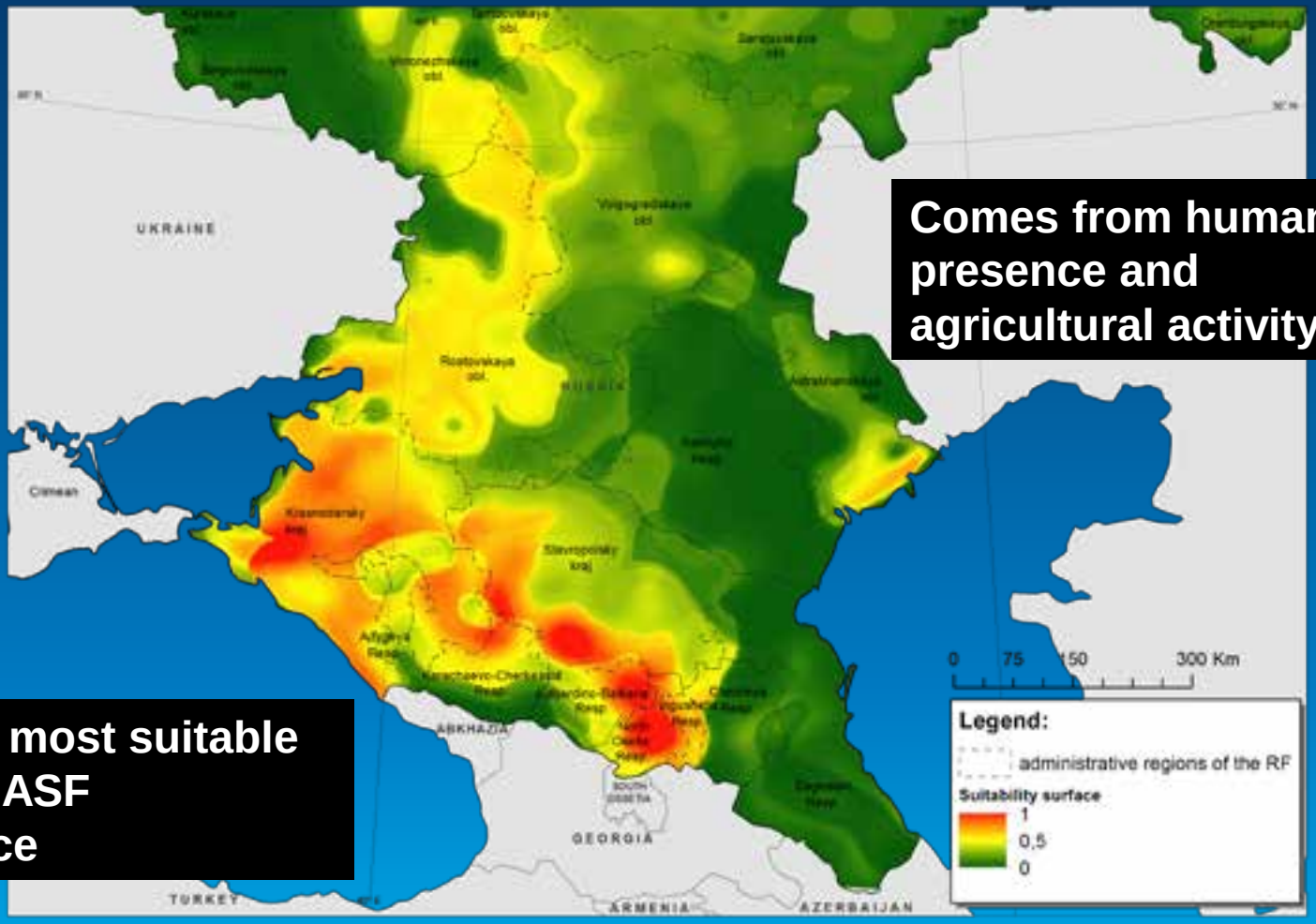


MaxEnt output overlaid with the base map in ArcGIS

Raster conversion from ASCII to Esri grid was used

(ArcToolbox → Conversion Tools → To Raster)

Suitability map:

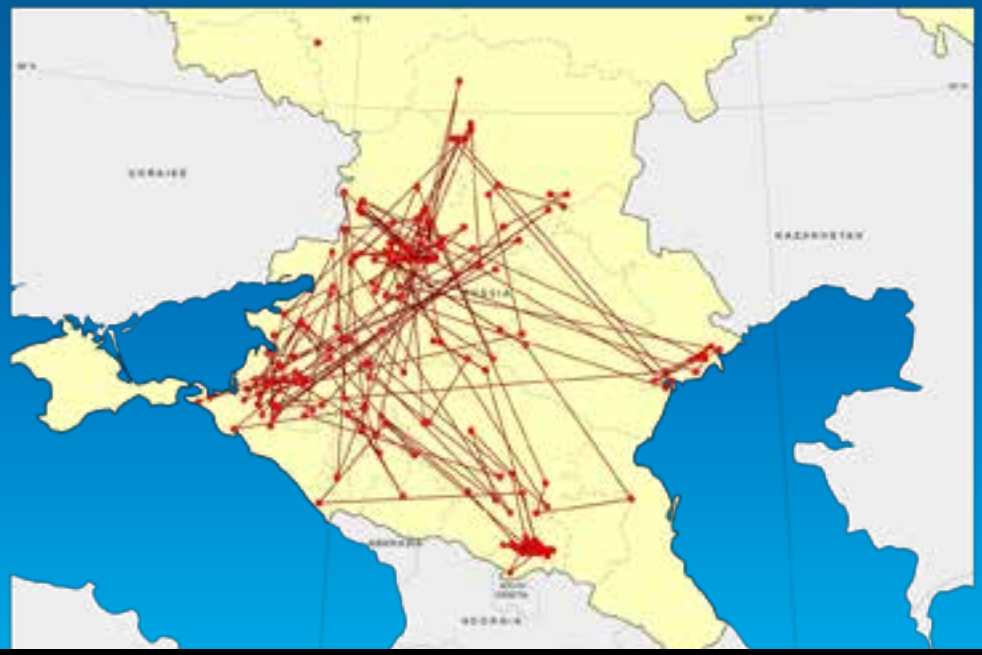


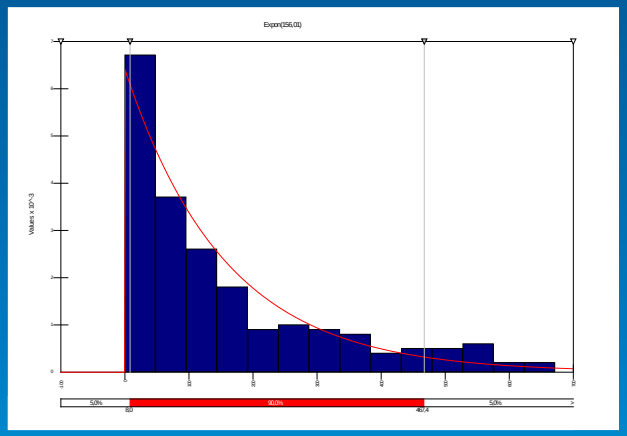
Comes from human presence and agricultural activity

Indicates most suitable areas for ASF emergence

2. Ring zone of probability

- Consider all existing ASF outbreaks a sequence of random events sorted by the date of occurrence
- Calculate distances in each pair of subsequent outbreaks
- Fit a distribution to the set of distances



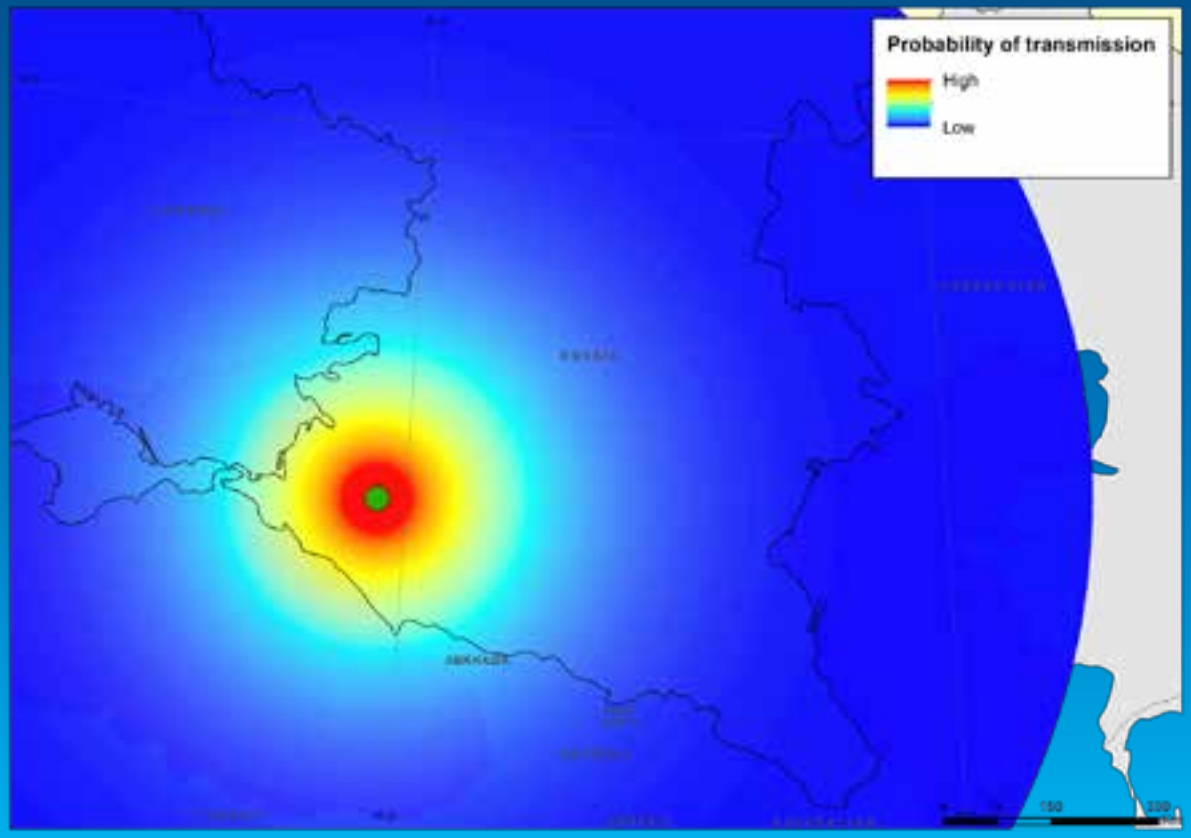


Distances → Expon(156.01)

HawthsTools for ArcGIS was used: http://spatialecology.com

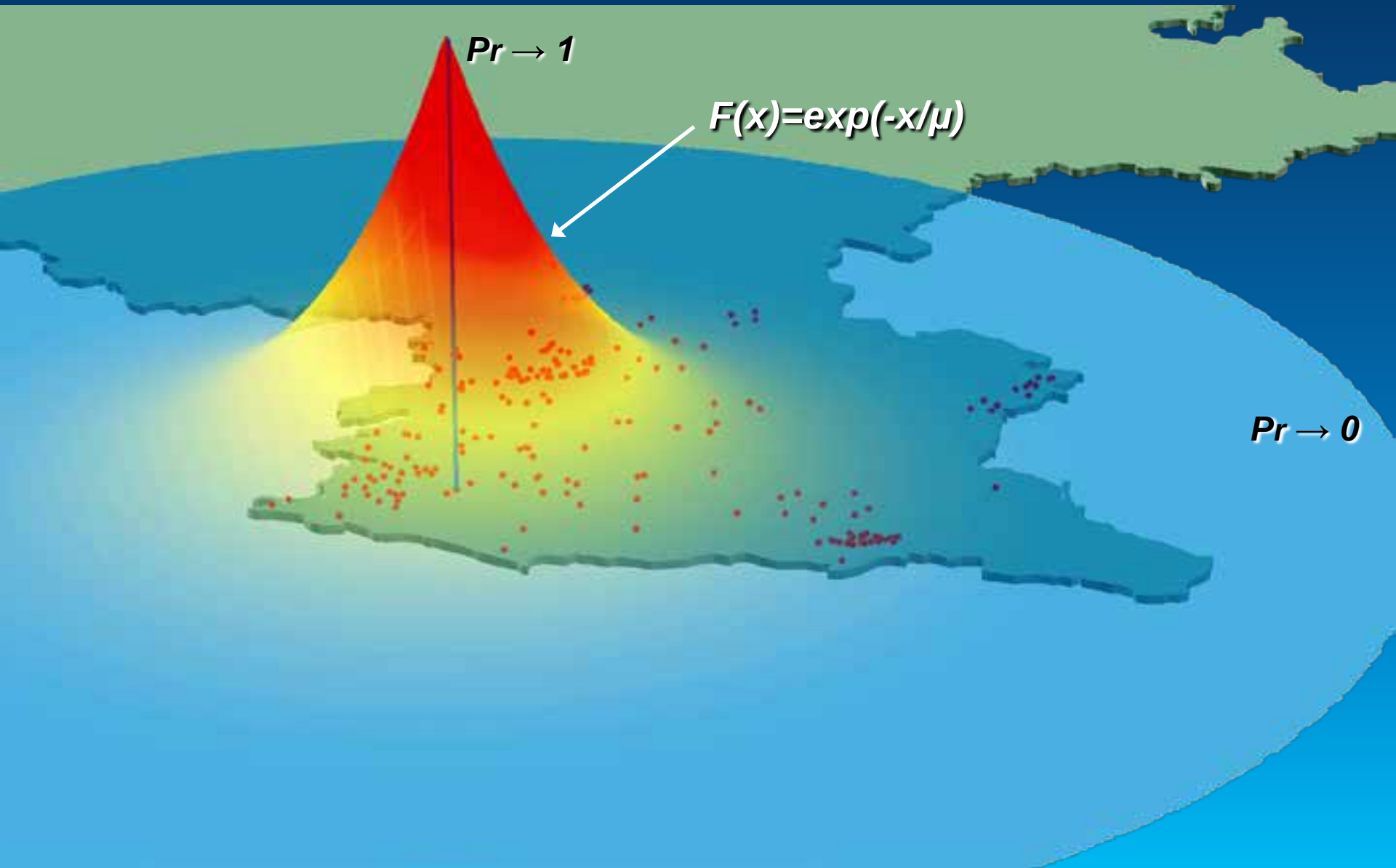
Ring zone of probability

- **Gives an idea of a distance of most probable virus transmission from the affected farm**



A raster surface centered at the affected farm decreasing exponentially ~*exp(-x / μ)*, where *x* is a distance from the farm, *μ* = 156.01 km

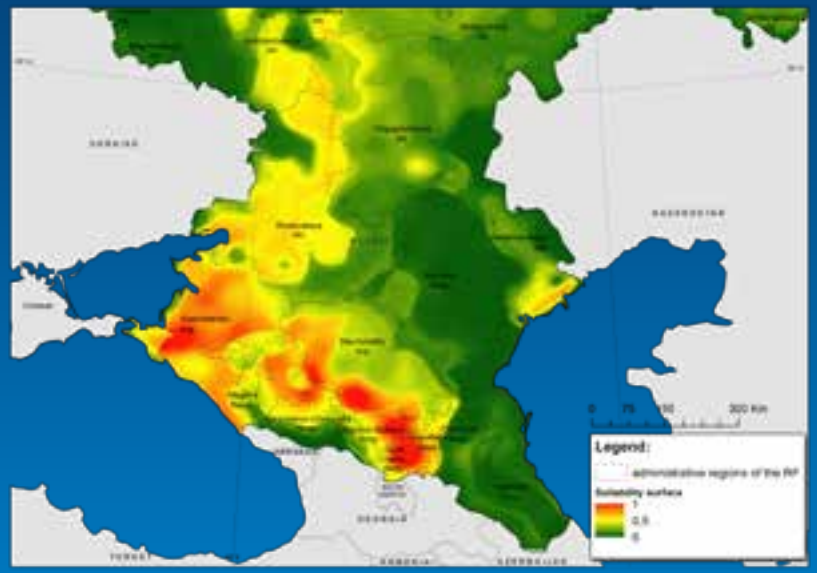
… in 3D view (using ArcScene)

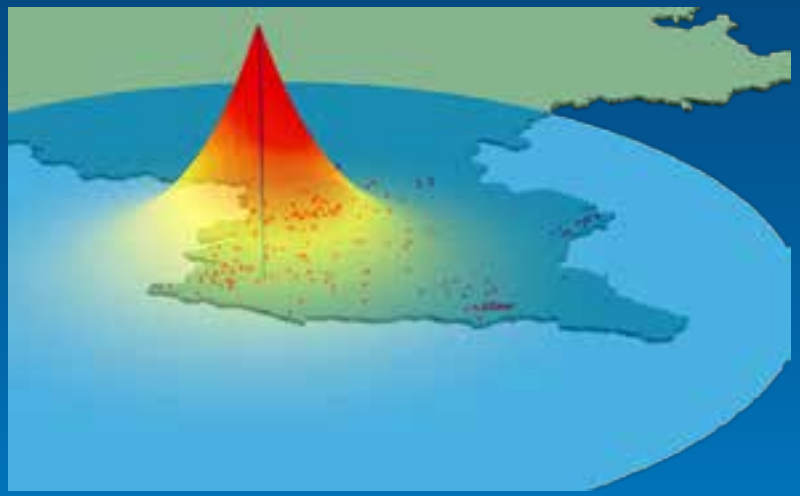


Important finding…

Mean risk distance of 156 km exceeds the conventional radius of surveillance zone (100 – 150 km) that clearly indicates weakness of current measures of disease prevention !

3. Combine suitability surface and ring zone to obtain final risk map



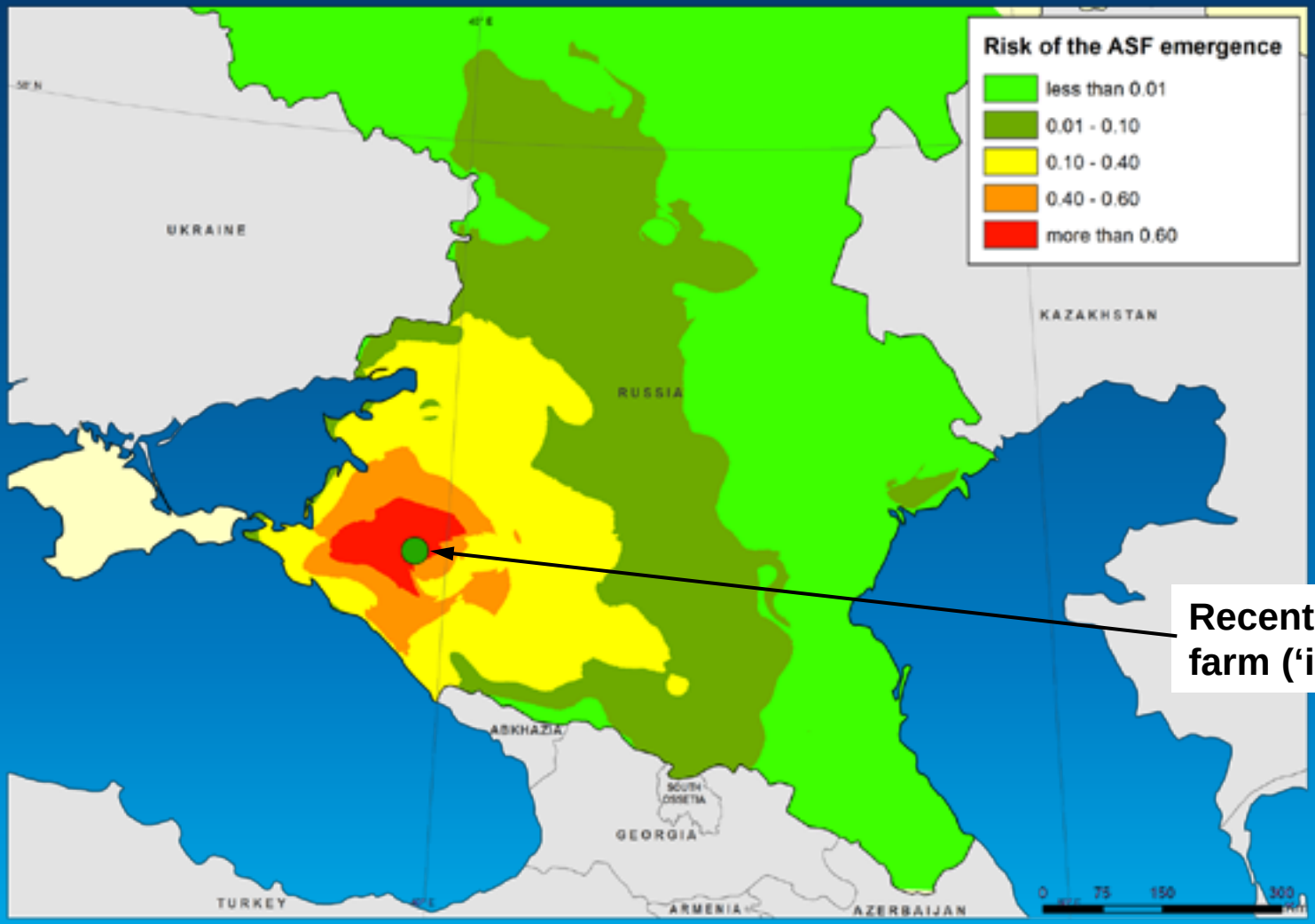


Use raster calculator

(ArcToolbox → Spatial Analyst Tools → Map Algebra)

to multiply two rasters…

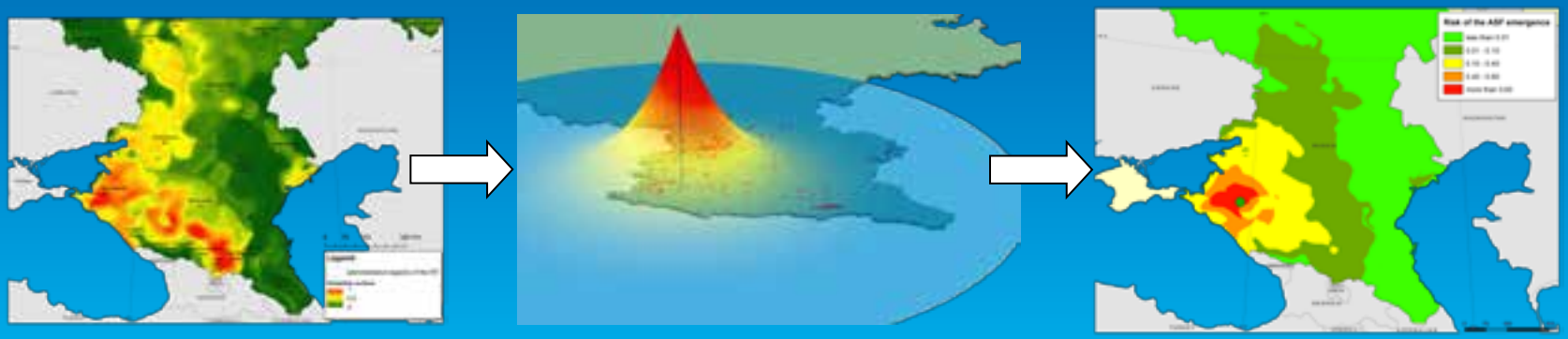
Final risk map



Recently affected farm ('index case')

Conclusions

- Indicates the areas of risk of the disease spread from a recently affected farm → allows predicting an area of a next ASF outbreak
- Clearly demonstrates that the practice of 100-km surveillance zones can hardly prevent the spread of the disease
- Considers the real-world distribution of pig population and thus better defines a potential surveillance zone



- This study is published in

  Spatial and Spatio-Temporal Epidemiology journal, 2014:

  Spatio-temporal modeling of the African swine fever epidemic in the Russian Federation, 2007–2012
  (currently in press)

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http://www.sciencedirect.com/science/article/pii/S1877584514000161

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- **USDA Centers for Epidemiology and Animal Health**, Fort Collins, CO, USA
- **International Society of Geospatial Health GnosisGIS** (http://www.gnosisgis.org/)


Thank you for your attention!