ELISE action
Webinar Series

Geospatially enabled Modelling, Simulation and Prediction

Danny VANDENBROUCKE, KU Leuven
Chris Little, UK Met Office (Guest speaker)
Lorena HERNANDEZ, European Commission JRC
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21/01/2021 14:00 CET (UTC+1)

European Location Interoperability Solutions for e-Government

Enabling Digital Government through Geospatial and Location Intelligence

ISA²

ISA² Programme & ELISE action

European Interoperability Programme

cross-border *and* ***cross-sector*** *Interoperability solutions*

for ***public administrations, businesses*** *and* ***citizens***

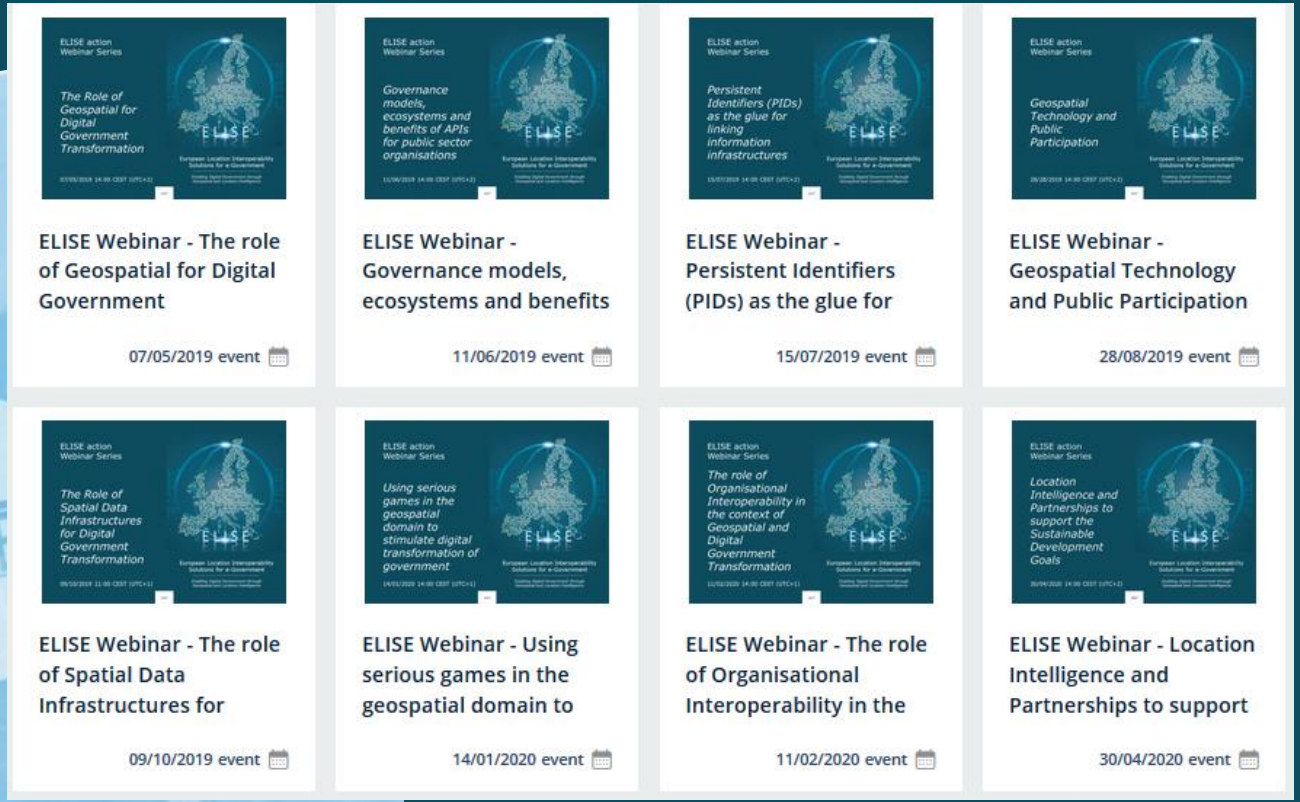
54 different actions tackling **interoperability** from different angles

ELISE action is the **only** action focusing on the **location dimension**

European Location Interoperability Solutions for e-Government

Enabling Digital Government through Geospatial and Location Intelligence

Welcome to the ELISE webinar series



ELISE **Knowledge Transfer** activities

Purpose:

- Engage in **an agile way**
- with **topics** of relevance to the **Digital Transformation**
- **by harnessing the use of spatial data and technology.**
- **Share the results of ELISE activities.**

https://europa.eu/!nP74ph

European Commission

Geospatially enabled Modelling, Simulation and Prediction

ISA²

Forbes

Our speakers

Danny VANDENBROUCKE

Senior Researcher
KU Leuven

Chris LITTLE (Guest speaker)

UK Met Office

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

What we will cover today

1. Introduction
2. Modelling, Simulation and Prediction: some definitions
3. Modelling: not new to the GIS world
4. Zooming in on weather forecasting and agent-based modelling
5. Interoperability efforts and challenges
6. Key take-away messages and conclusions
7. Q&A

Key messages

1 Modelling, simulation and prediction **are not new**, **GIS** has always been an advanced technology to model and simulate, but new developments create **new challenges and opportunities**

2 **Some sectors are more advanced** with regard to the integration of models, simulations and prediction techniques

3 **Specific efforts are needed for reaching interoperability** in modelling, simulation and prediction

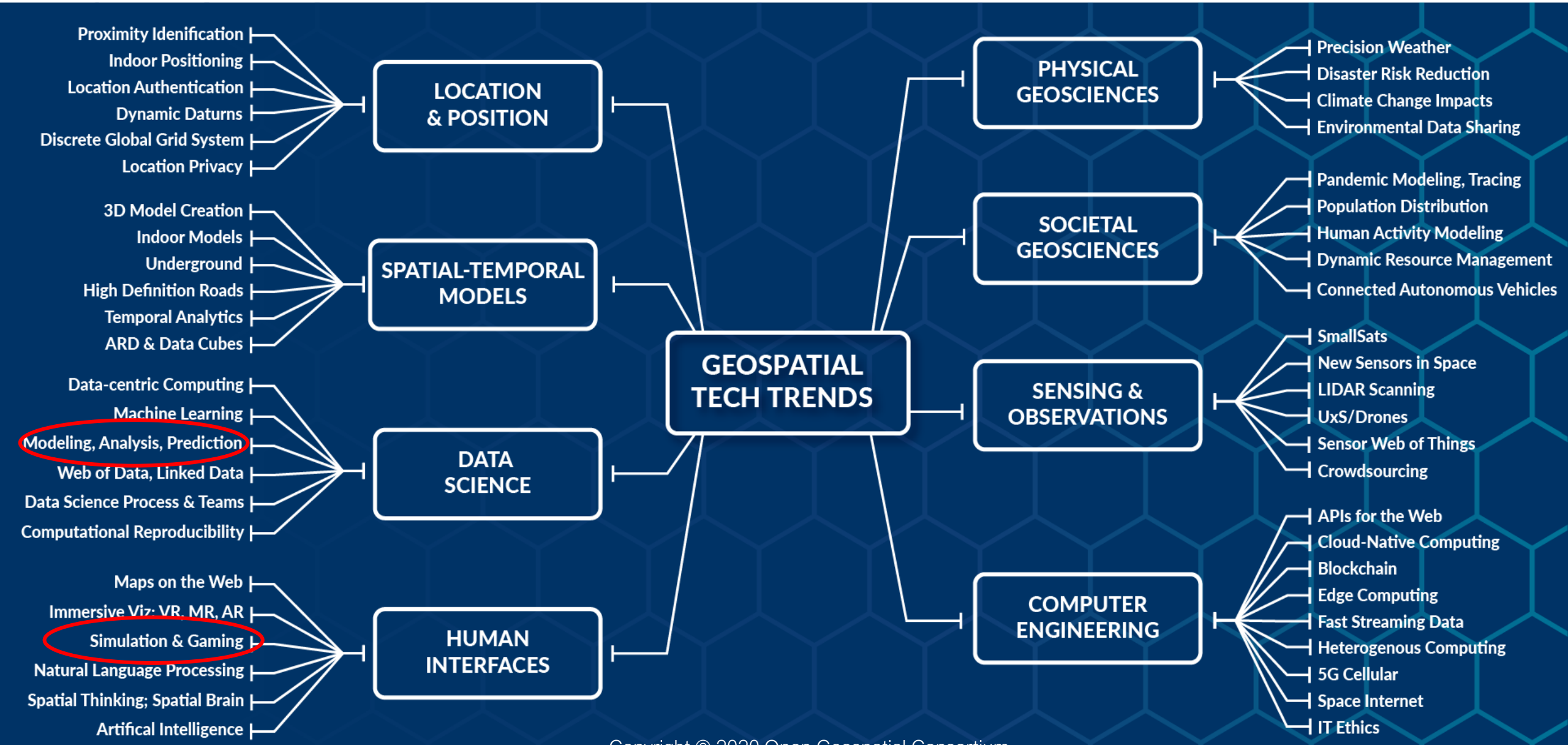
Analyticssteps.com

Many sectors are evolving towards the integration of models, simulation and predictive techniques: **weather and climate, transport and mobility, health (COVID-19), water and forest management, security and disaster management …**

1

Modelling, simulation and prediction: some definitions

OGC Tech Trends - 2020Q3



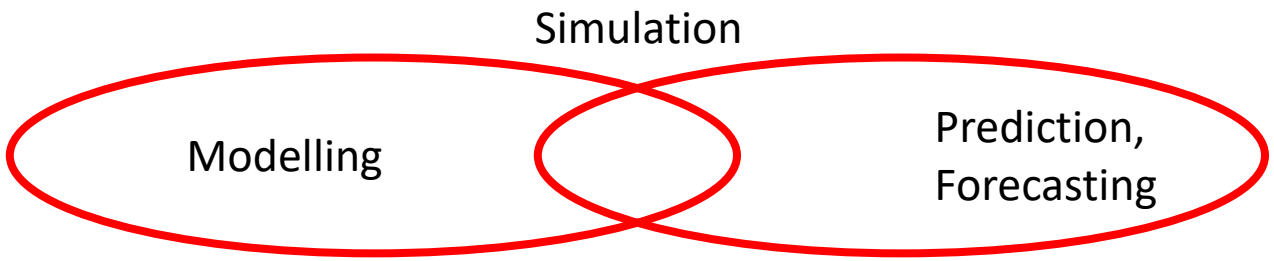
Modelling, simulating, prediction

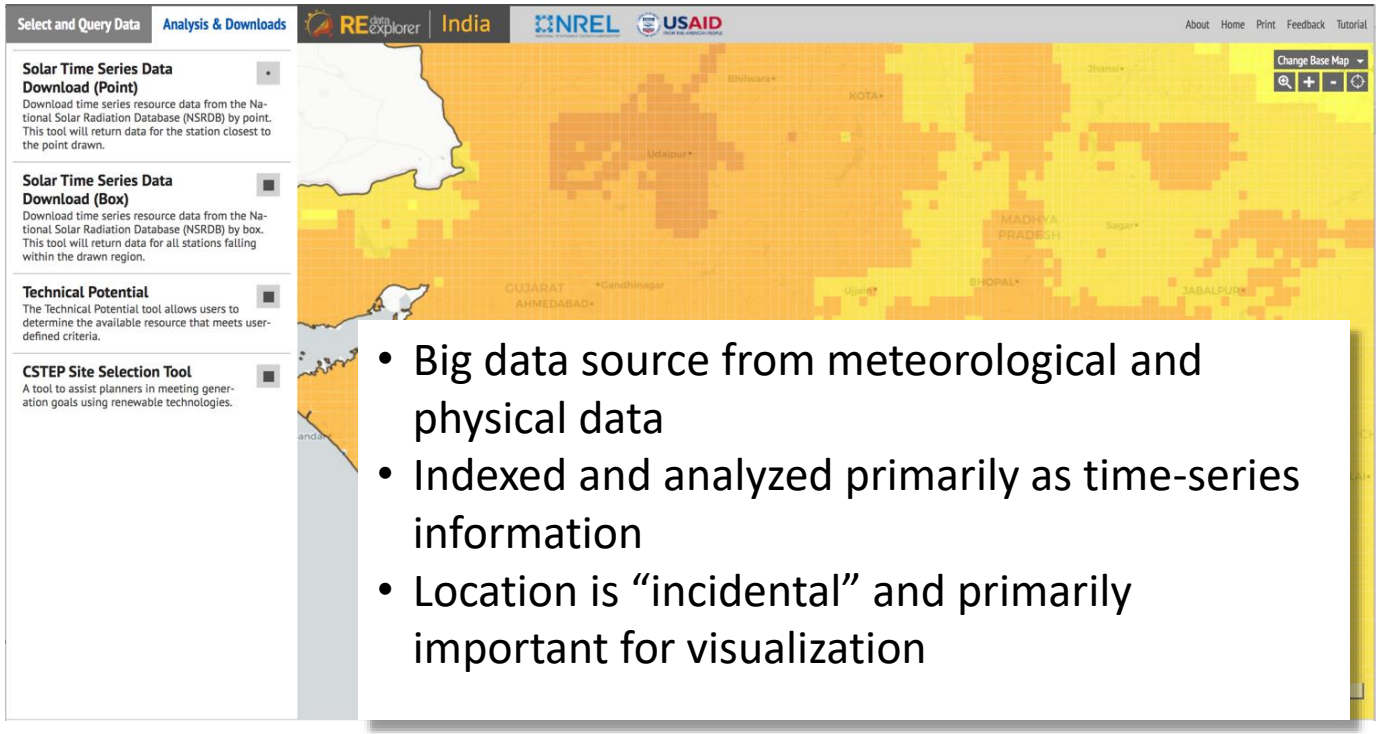
Different but inter-connected concepts and related techniques

1. **Modeling and Simulation to interact with a representation of the real world – "prediction" depends on user interaction**
2. **Simulation and Prediction to analyze some phenomenology - "modeling" establishes the domain of analysis**

OGC (2017)

Modelling, simulating, prediction





- Big data source from meteorological and physical data
- Indexed and analyzed primarily as time-series information
- Location is “incidental” and primarily important for visualization

1. **Modelling - the devising or use of abstract or mathematical models**
2. **Simulation - imitation of a situation or process**
3. **Prediction - the action of predicting something in the future (future state or behavior)**
4. **Forecasting - predict or estimate (a future event or trend)**

Oxford Dictionary (2020)

Modelling, simulating, prediction

Different perspectives: Lagrange versus Eulerian

Britanica.com (2021)

1. **Lagrange function, a quantity that characterizes the state of a physical system.**
2. **An Eulerian trail (or path) is a trail in a finite graph that visits every edge exactly once (allowing for revisiting vertices)**

Are you moving through the model or is the model moving around you ?

Autonomous cars – basic navigation

Car is studded with sensors that position the vehicle against a very precise, pre-determined map, OR

Car is studded with sensors that observe the surroundings and react based upon interpretation of those observations

Decision tree for interaction with the real world follows the latter perspective

OGC (2017)

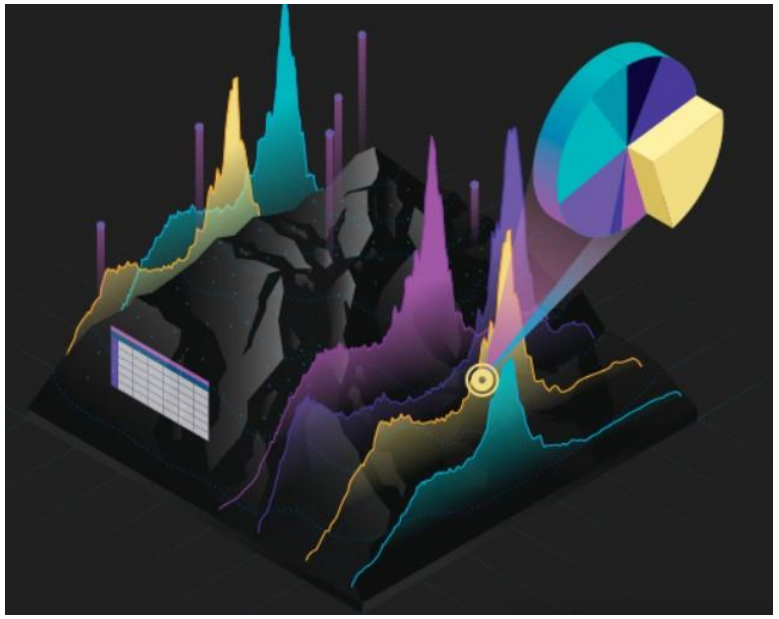
2

Modelling, simulation and prediction: not new to the GIS world

Modelling, simulation and prediction: not new …

A geographic information system (GIS) is a framework for gathering, managing, and **analyzing** data. Rooted in the science of geography, GIS **integrate**s many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as **patterns**, **relationships**, and **situations**—helping users make **smarter decisions**.

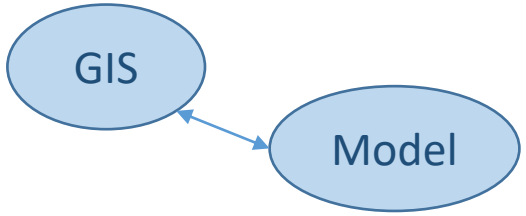
ESRI (2020)



GIS technology emerged in the 70-ies and evolved gradually into modelling engines

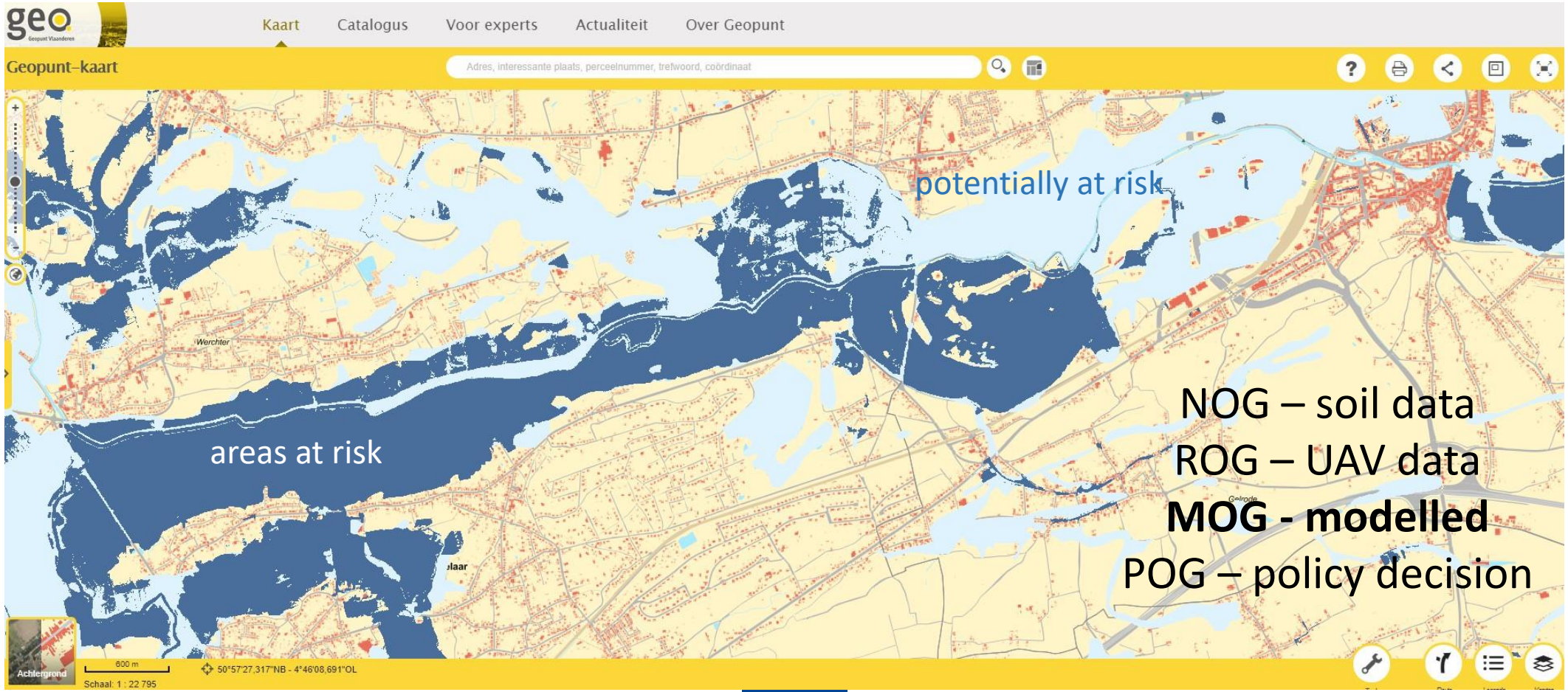
Flood Modelling

Traffic Modelling



Modelling, simulation and prediction: not new …

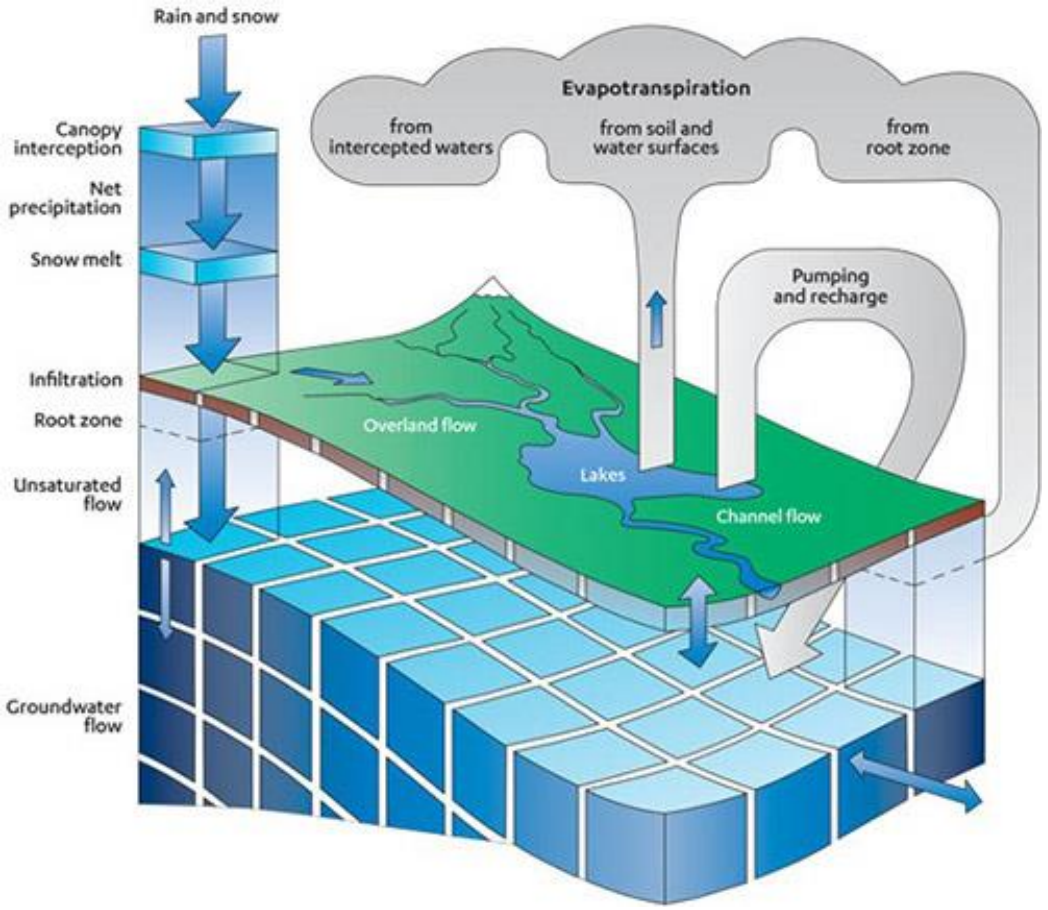
Steady layer, renewed every x years based on new simulations



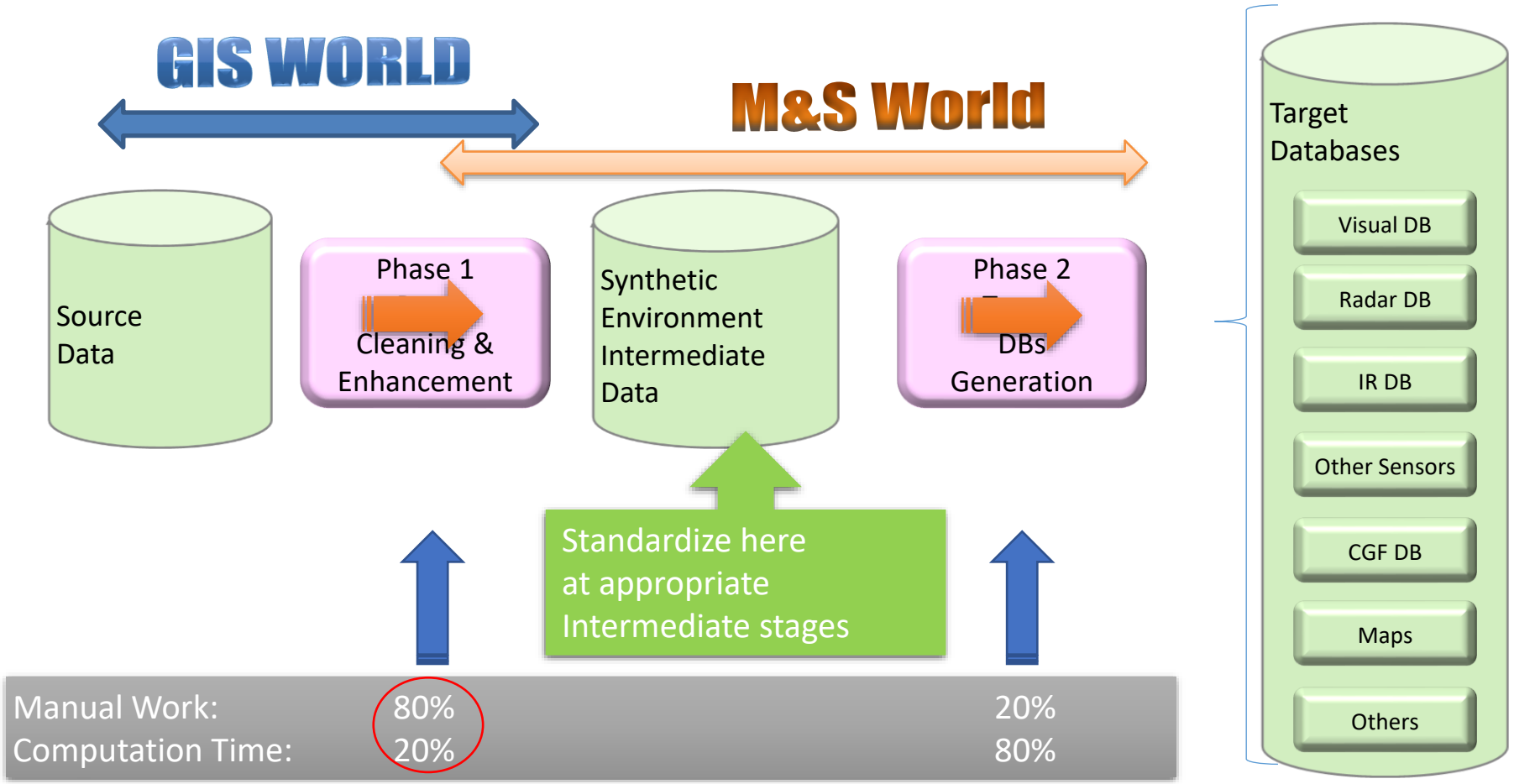
Modelling, simulation and prediction: not new …

This type of modelling has its limitations …

1. **GIS and models separate – GIS layers, other data (e.g. weather data) as input to the model, output back to GIS**
2. **Need to regularly run the model, with new data, because of new human intervention (e.g. new dykes)**
3. **From simple 'models' (risk assessment based on a DTM) to more complex ones (integrating hydrology, hydraulics …)**



Modelling, simulation and prediction: not new …



Sogitec and SISO

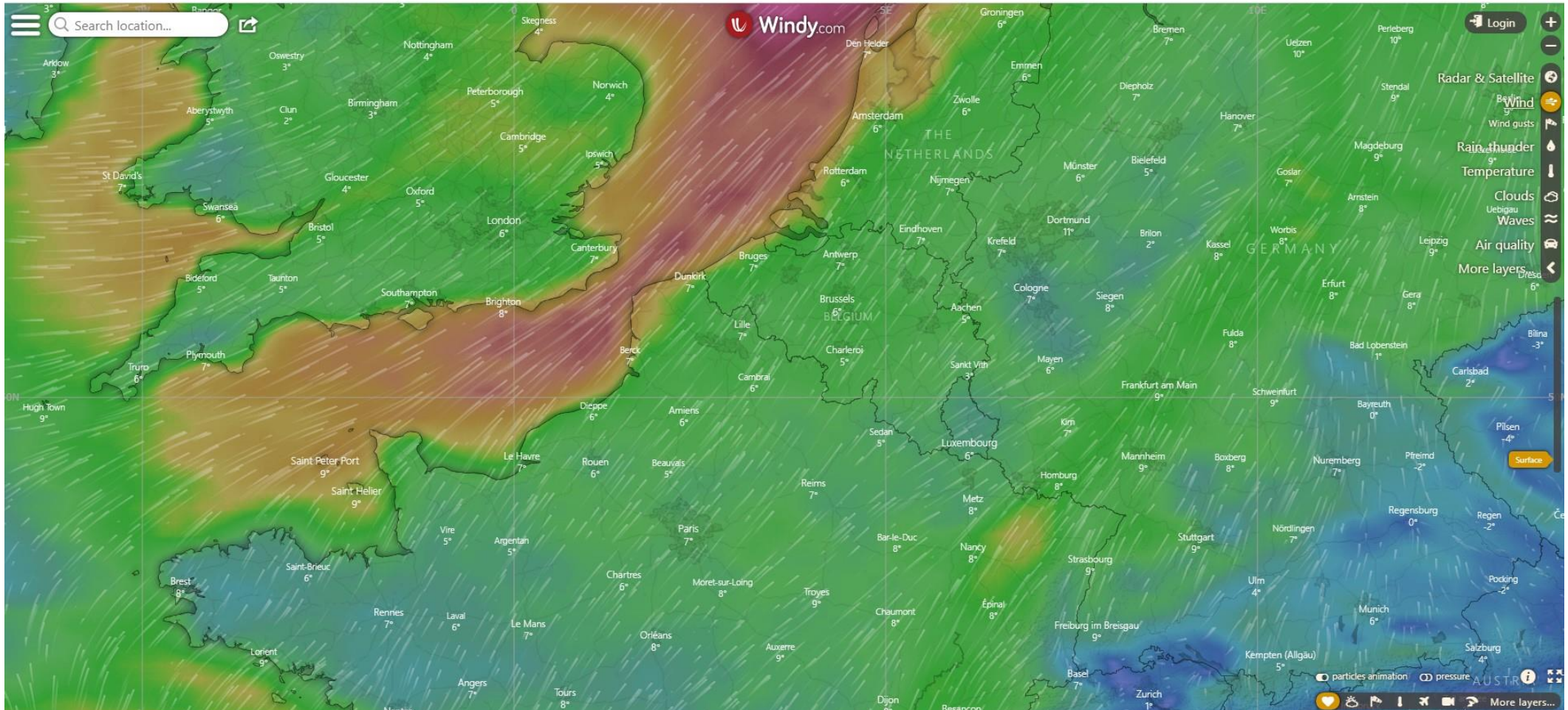
Courtesy Sogitec and SISO

3

Zooming in on two examples: weather forecasting and agent-based modelling

Example 1: weather forecasting …

www.windy.com



Example 1: weather forecasting …

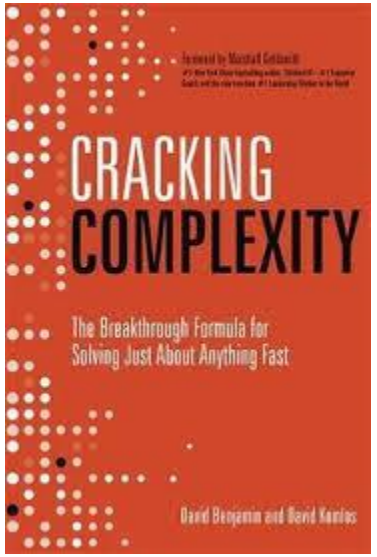
$$p = \rho R T$$ Ideal Gas Law (Equation of State)

$$\Delta T = \Delta q / c_p + (1/\rho)\Delta p$$ First Law of Thermodynamics

$$\Delta p = -\rho g \Delta z$$ Hydrostatic Law

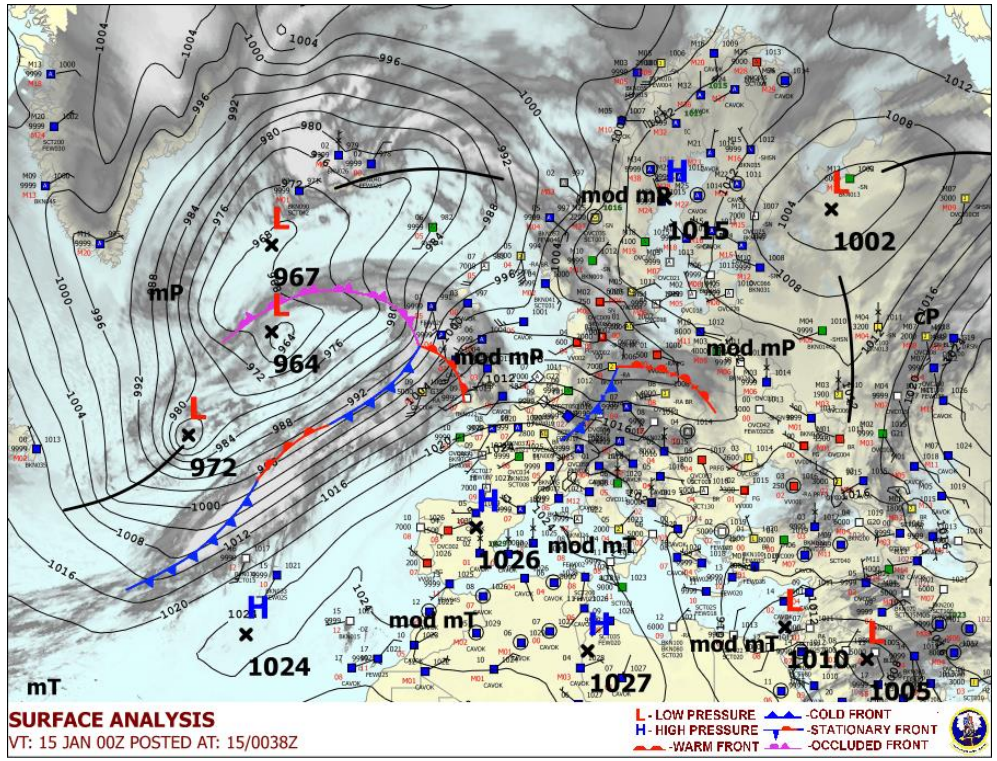
$$\vec{a}_h = \Sigma\left(\vec{F}_h / m\right)$$ Newton's Second Law of Motion

$$\frac{1}{\rho}\frac{\Delta\rho}{\Delta t} = -DIV$$ Conservation of Mass Applied to the Atmosphere (Equation of Continuity)



Example 1: weather forecasting …

It is about complex interrelated phenomena …



Temperature

Pressure

Humidity

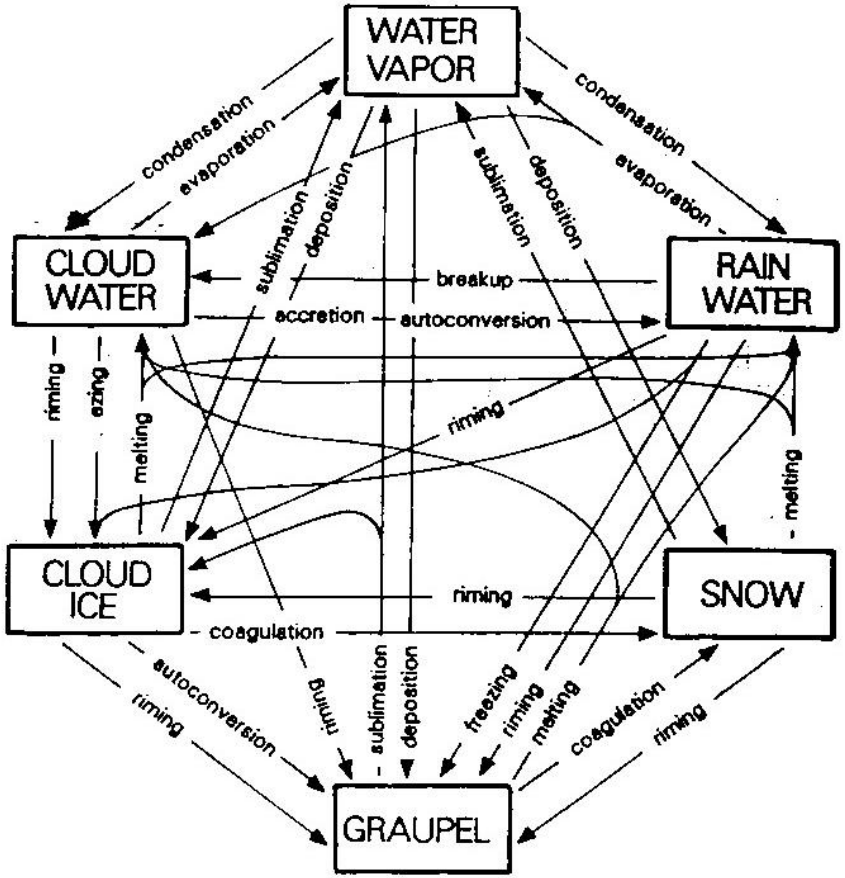
Visibility

Cloud

Wind

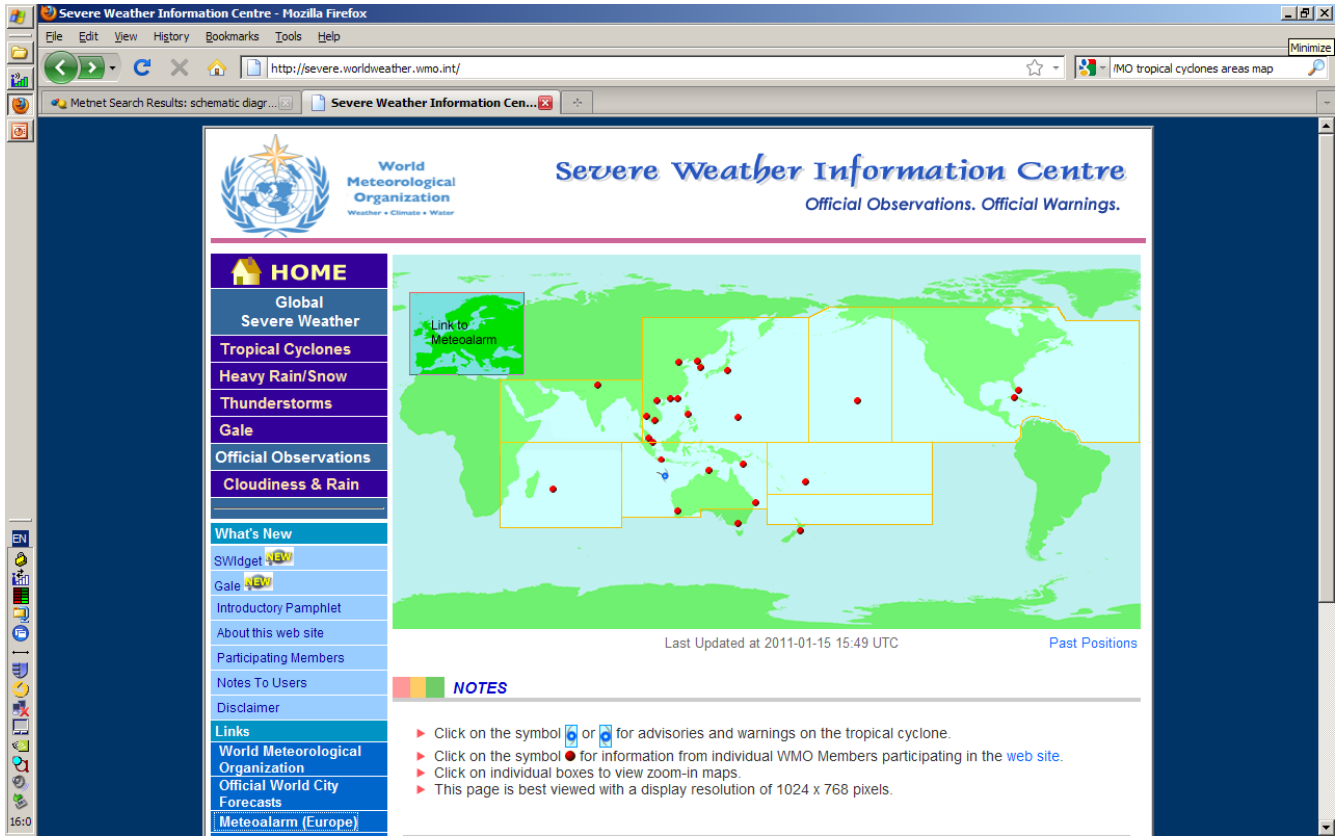
Snow

Rain

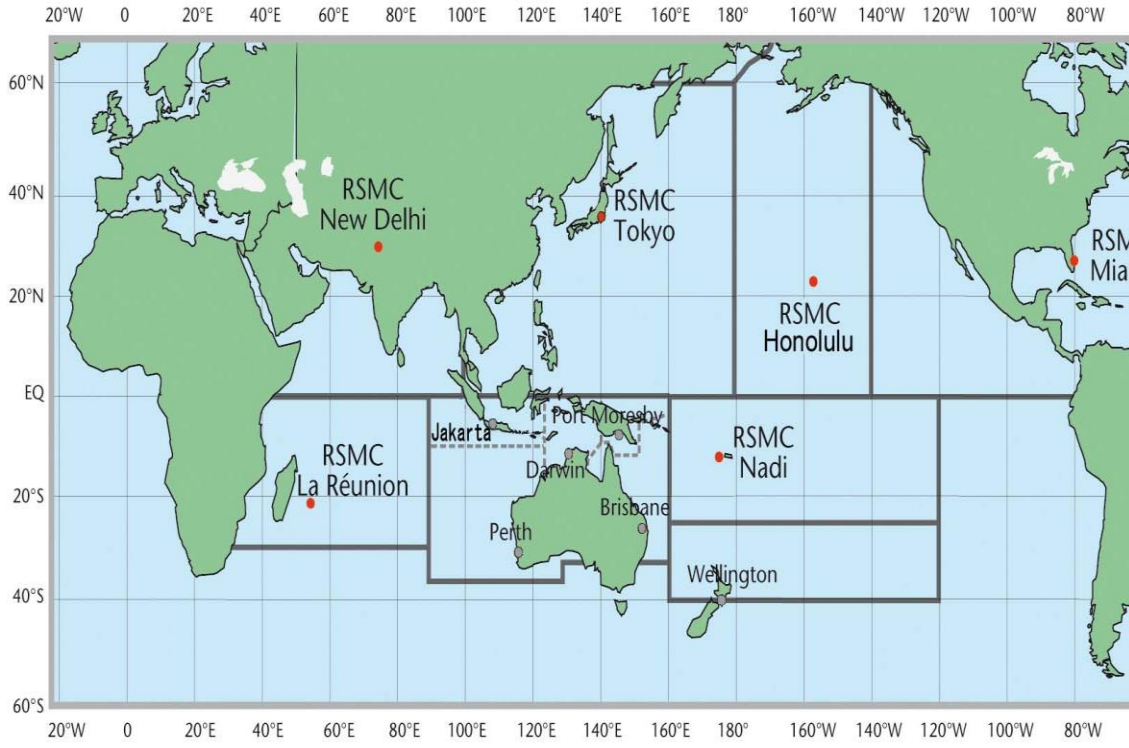


Example 1: weather forecasting …

Tropical storms



http://www.wmo.int/pages/prog/www/tcp/index_en.html

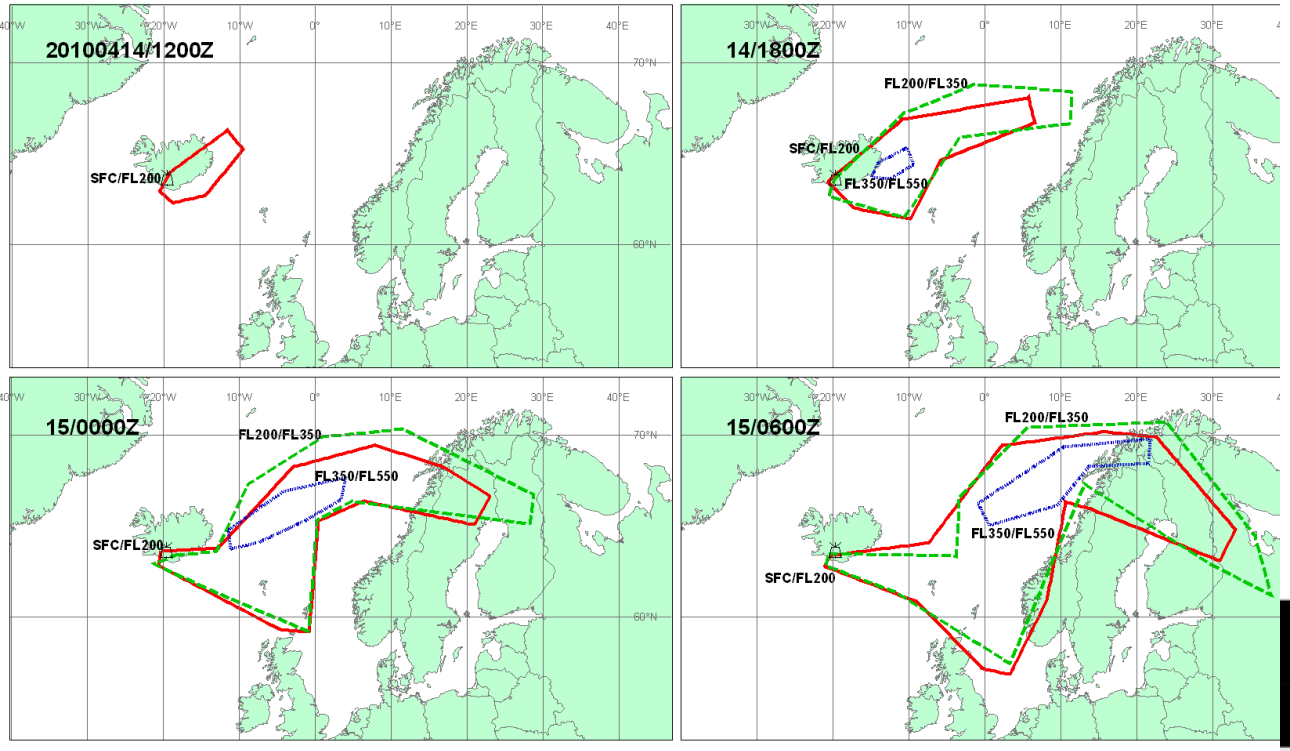


Several weather

Example 1: weather forecasting …

1. Some parameters harder to forecast(e.g. rain)
2. The issue of scale is important
3. Dealing with uncertainty

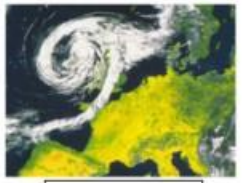
Weather to be factored in in case of volcanic outbreak



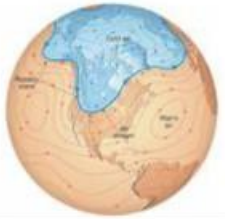
VA ADVISORY SUMMIT ELEV: 1666M RMK: NIL

Tornado
1km
10 minutes
30 minutes
200m

Thunderstorm
10 km
1 hour
3 hours
2 km



Front
100 km
12 hours
36 hours
20 km

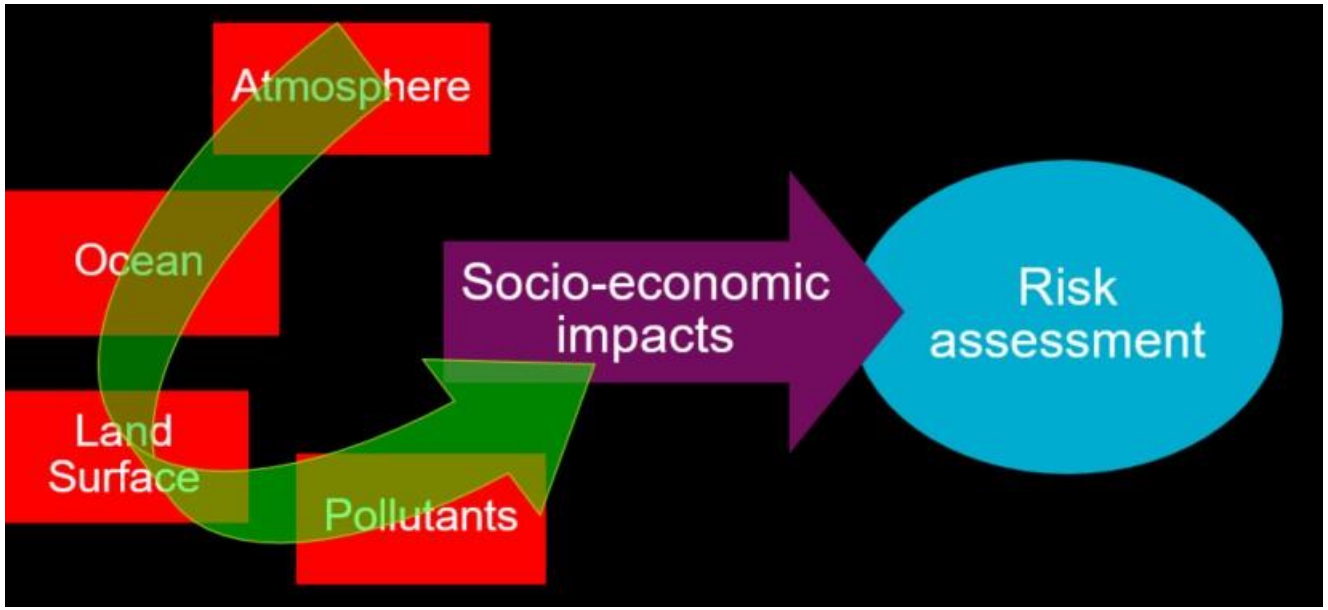


Planetary Wave
10000 km
3 days
9 days
2000 km

increasing scale
increasing lifetime
increasing predictability

…but if we know what the planetary wave characteristics will be in 9 days, we can give an accurate probabilistic tornado forecast

Example 1: weather forecasting …



Towards an integrated approach for hazard prediction, monitoring and risk assessment

Example 2: Agent-based modelling in traffic management

Axios.com

SUSTAPARK - Tool to provide strategic advice on urban parking planning, evaluation & simulation

1. **Transport & Mobility Leuven**
   ➔ **Parking aspects**
2. **SADL, K.U. Leuven**
   ➔ **Spatial model**
3. **Université Libre de Bruxelles**
   ➔ **Parking search behavior**

ABM
Agent Based Modelling

Drivers spend two days a year trying to find a parking space - and it costs motorists £733 EACH in time and fuel
(Daily Mail, 2017)

dailymail.co.uk

toronto.ca

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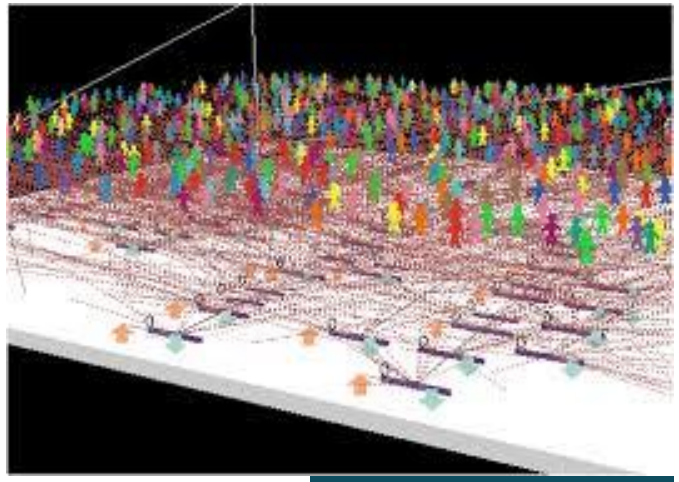
Example 2: Agent-based modelling in traffic management

"Simulating actions and interactions of autonomous individuals (agents) in a network to predict the actions of complex phenomena"

(Dieussaert et al., 2009)



JRC, ABM for Smart Grid (2020)

Agent = driver

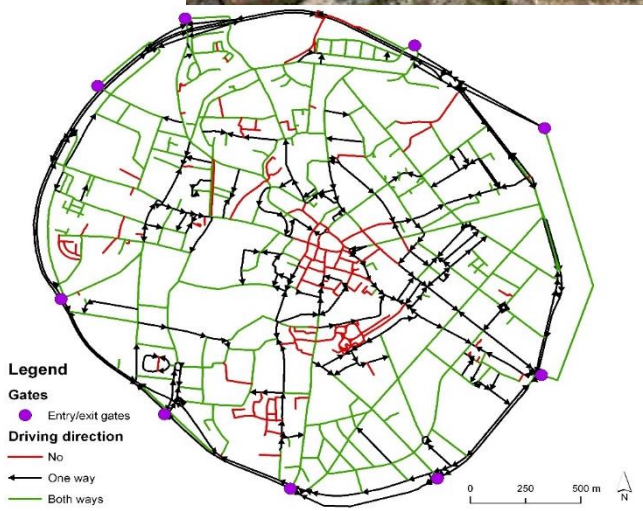
Behaviour

Model = flexible & dynamic

On transport mode, multi-mode in the future

City of Leuven

Flandertoday.eu

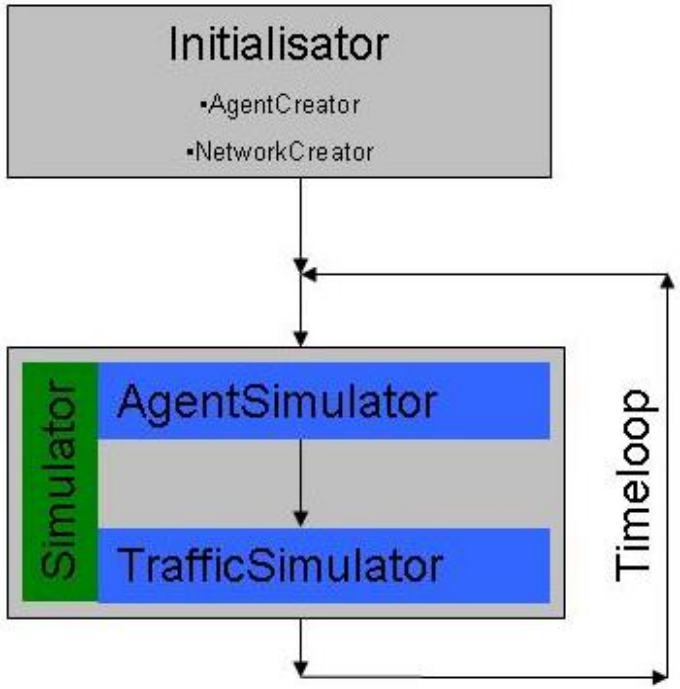


Example 2: Agent-based modelling in traffic management

Simulation characteristics

1. One day periods
2. Temporal resolution: 1 second
3. Spatial resolution: street segment
4. Group of agents representing driver population
5. Agents' movement based on activity schedules

Slideshare.net



Hipwallpaper.com

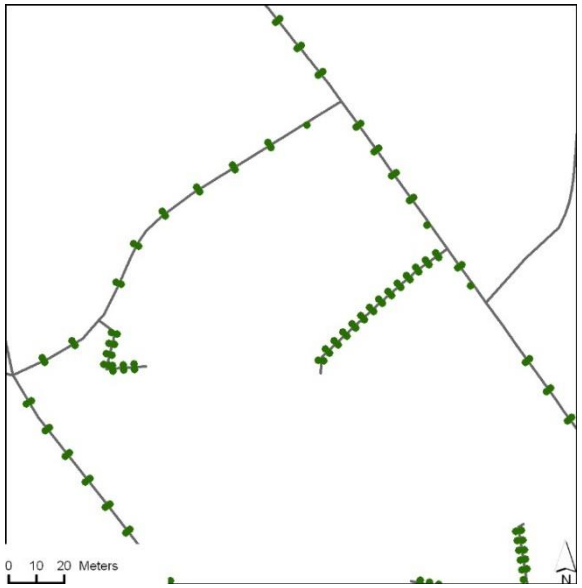
Initialization – Agent dataset with activity schedules, network creation

Simulation – Every time step agents' state & traffic is updated

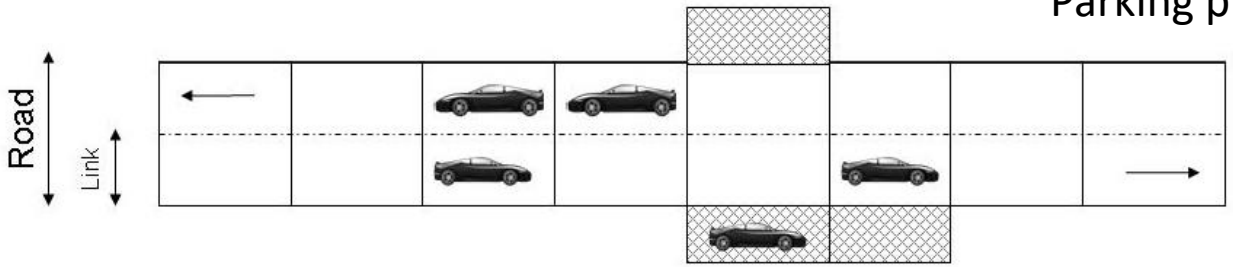
Example 2: Agent-based modelling in traffic management

'Intelligent' road network

- Cellular automaton (1 cell = 7.5 m)
- Single-lane links
- Cross roads: modelled as 'First In, First Out'
- Parkings coupled to one cell
- Border: entry/exit gates



Parking places



Geospatial data

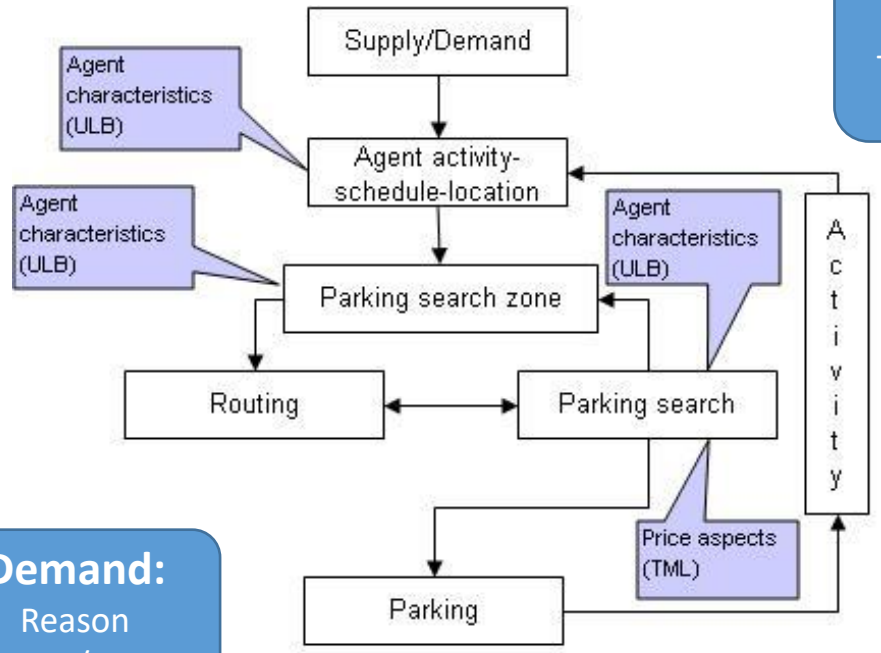
1. Road network (driving direction, speed, hierarchy)
2. Parking places (private, on-street, central parking lots / garages

Non-spatial data

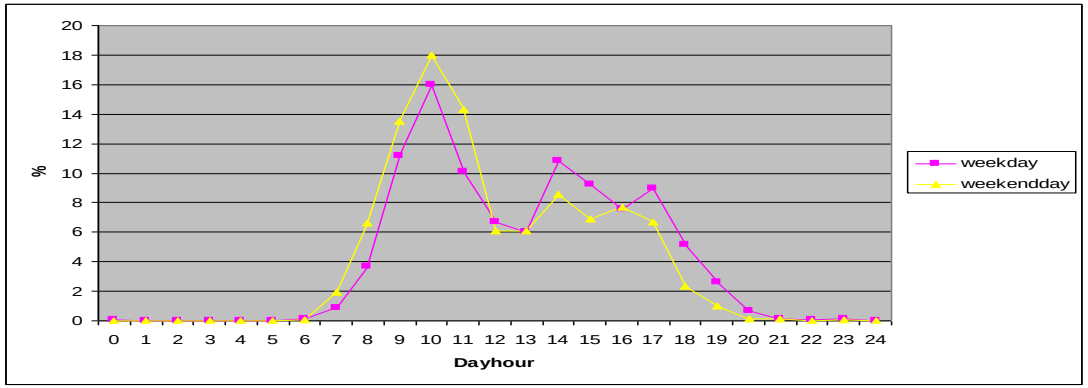
1. Activity schedules (local surveys)
2. Agent population (local surveys)

Base data

Example 2: Agent-based modelling in traffic management

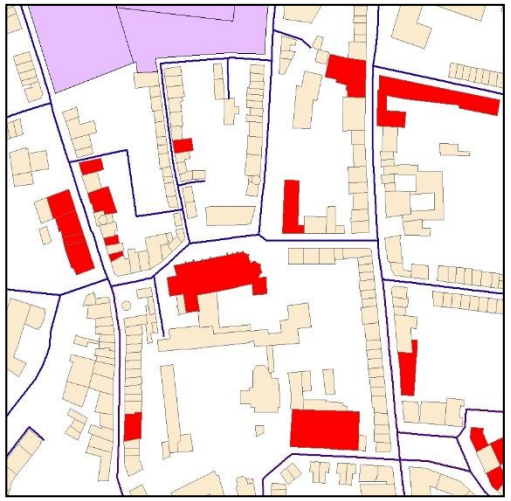


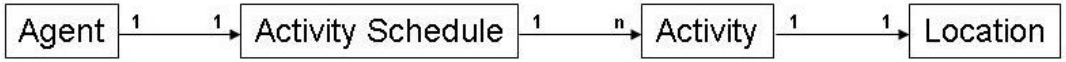
Agent A
To work (8:05 // X)
To shop (16:40 // Y)
Home (17:45 // Z)



Search Strategies
Utility = f(d,t,p)

Demand:
Reason
Space / Time





Example 2: Agent-based modelling in traffic management

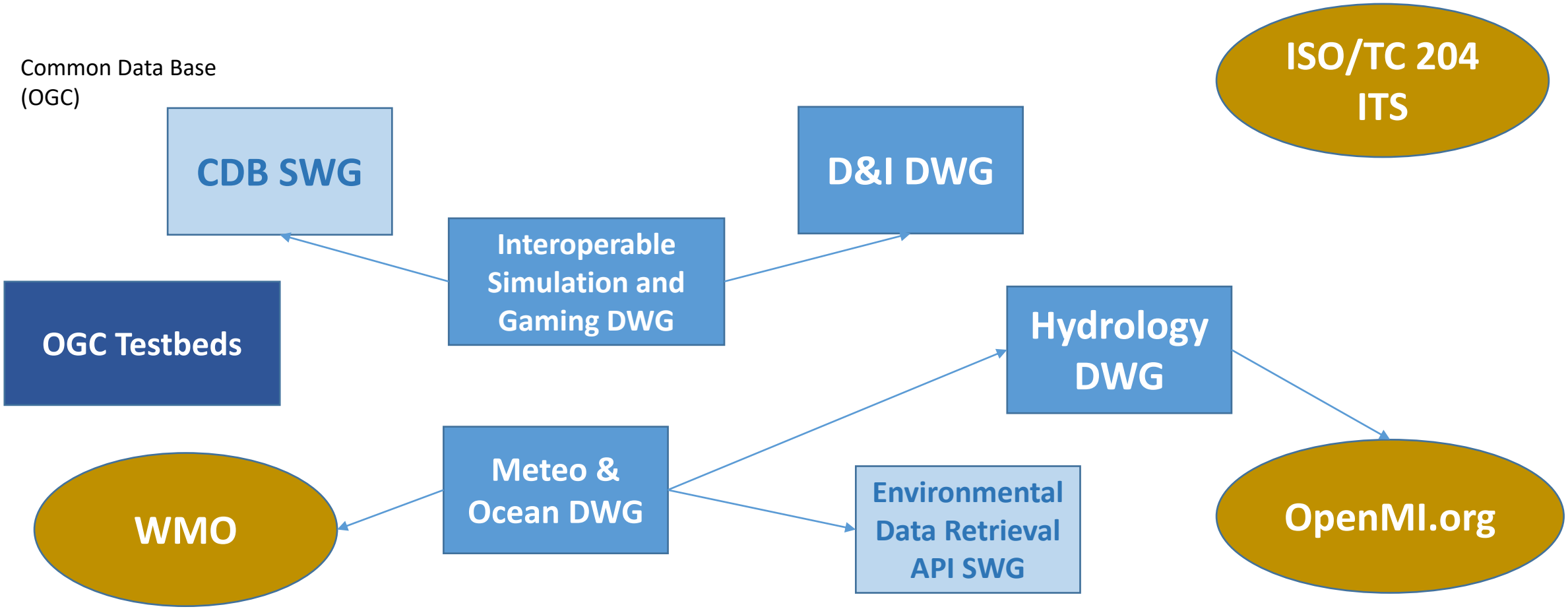
ABM has been used to plan new (central) parking spaces, to implement pricing schemes, etc. Other things could be added such as integrating other transport networks (multi-mode), or ecological parameters

Future work could be on automatic data collection (big data)

Rac.co.uk

4 *Interoperability efforts and challenges*

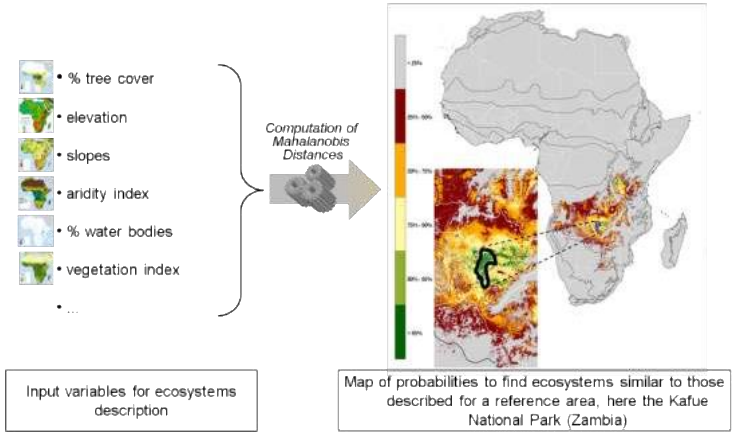
Standardization activities & Modelling-Simulation-Prediction

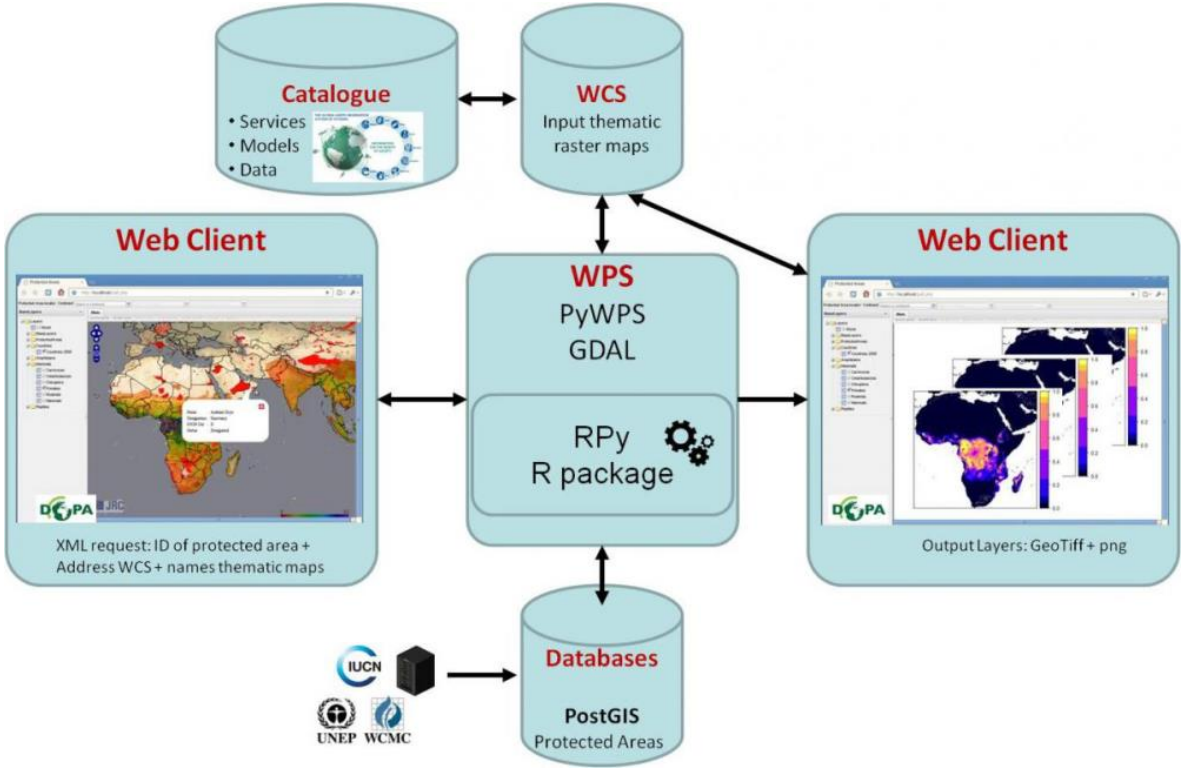


OGC Standard used for modelling

There are already several OGC standards that are used for modelling and simulation such as WPS, or CDB. The example shows the eHabitat project

Dubois et al, 2013





eHabitat is a Web Processing Service (WPS) designed to compute the likelihood of finding ecosystems with similar conditions

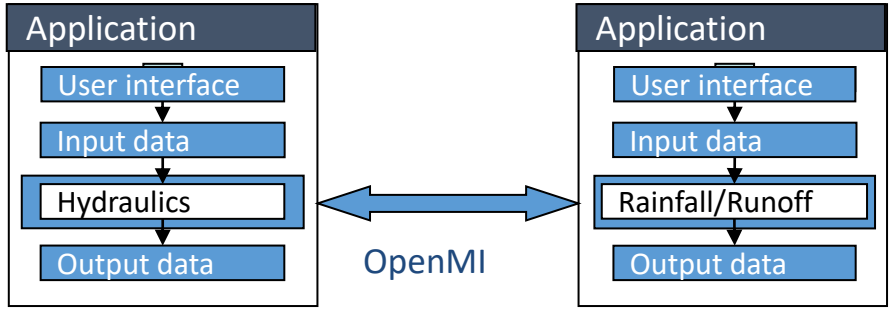
OGC OpenMI standard

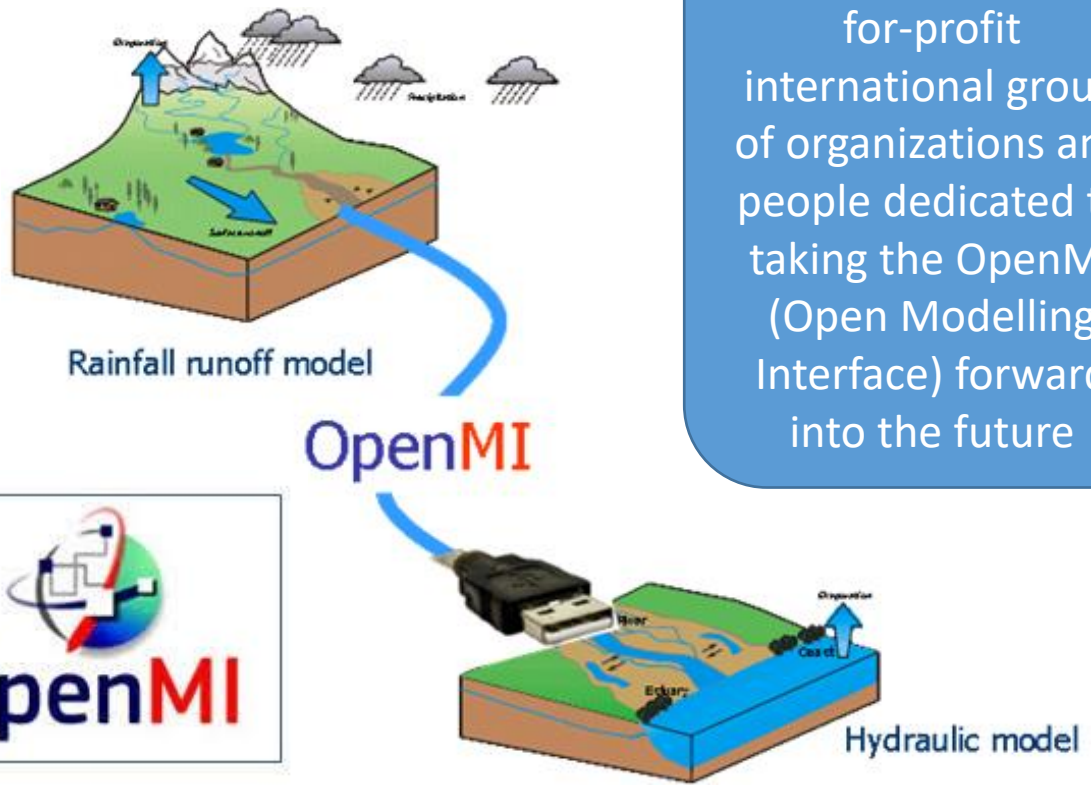
An interface standard (API) for:

run time (in memory) data exchange between models, databases & other components

Whose purpose is to:

improve ability to model complex scenarios





The OpenMI Association is an entirely open not-for-profit international group of organizations and people dedicated to taking the OpenMI (Open Modelling Interface) forward into the future

European Commission

Model Web Initiative (GEO)

A dynamic web of models, integrated with databases and websites, to form a consultative infrastructure where researchers, managers, policy makers, and the general public can go to gain insight into "what if" questions

GEO GROUP ON EARTH OBSERVATIONS

From: Stefano Nativi[1] and Gary Geller[2]
[1] (National Research Council of Italy)
[2] (NASA JPL)

Part of GEOSS IN-05 component:
GEOSS Design and Interoperability

ISA²

ELSEVIER

Environmental Modelling & Software
Volume 39, January 2013, Pages 214-228

Environmental model access and interoperability: The GEO Model Web initiative ☆

Stefano Nativi [a], Paolo Mazzetti [a], Gary N. Geller [b]

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Abstract

The Group on Earth Observation (GEO) Model Web initiative utilizes a Model as a Service approach to increase model access and sharing. It relies on gradual, organic growth leading towards dynamic webs of interacting models, analogous to the World Wide Web. The long term vision is for a consultative infrastructure that can help address "what if" and other questions that decision makers and other users have. Four basic principles underlie the Model Web: open access, minimal barriers to entry, service-driven, and scalability; any implementation approach meeting these principles will be a step towards the long term vision. Implementing a Model

5

Key take-away messages & conclusions

Concluding remarks

The use of modelling, simulation and prediction techniques is **not entirely new to the geospatial world**, GIS has always been used to analyze, model and simulate

Modelling, simulation and prediction is used in **many application domains**: climate change, weather forecasting, transport modelling, spread of pandemic diseases, environmental and water management …

Several **geospatial standards** are available or under development to support modelling, simulation and prediction activities: OGC but also dedicated initiatives exist or have seen light recently

Challenges & priorities

The growth of **huge amounts of data** from sensors, satellite imagery … provide new opportunities for more advanced M-S-P; at the same time this is a challenge

Recent **technological developments** (SWE, IoT, …) will make future modelling, simulation and prediction richer and more robust, leading to an improved usability

The dedicated initiative to evolve towards a **dynamic web of models** rather than a web of data/information is promising and should get more attention

Q&A

Thank you

Stay tuned

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ELISE playlist