Geo-Spatial Model Integration Using ArcGIS and Python

Harutyun Shahumyan, Ph.D.

National Center for Smart Growth

University of Maryland

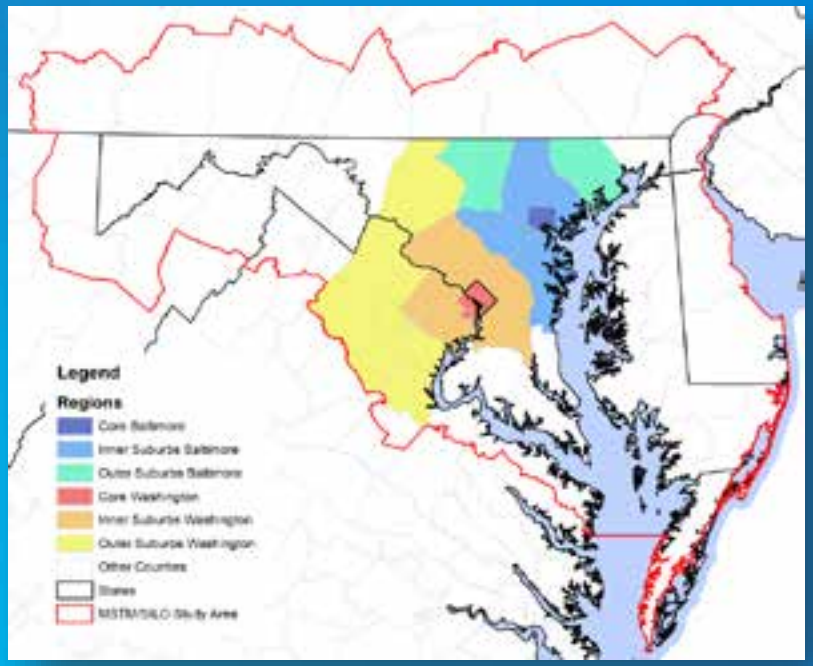
University College Dublin

Plan for Regional Sustainability Tomorrow

http://smartgrowth.umd.edu/PReSTo.html

Project Goals

- To develop, disseminate, and promote the implementation of a sustainable development strategy for the **Baltimore-Washington region**
- To stimulate a science-based conversation about sustainability in this region and to develop baseline and alternative future scenarios.



Baltimore - Washington Region

Interconnected character of human and natural systems such as demographics, transportation, infrastructure, economics, land use, climate, air and water requires an integrated approach in both decision making and modeling.

Economy - Projections

Transportation - MSTM Travel Demand Model

Growth – SILO Land Use Model

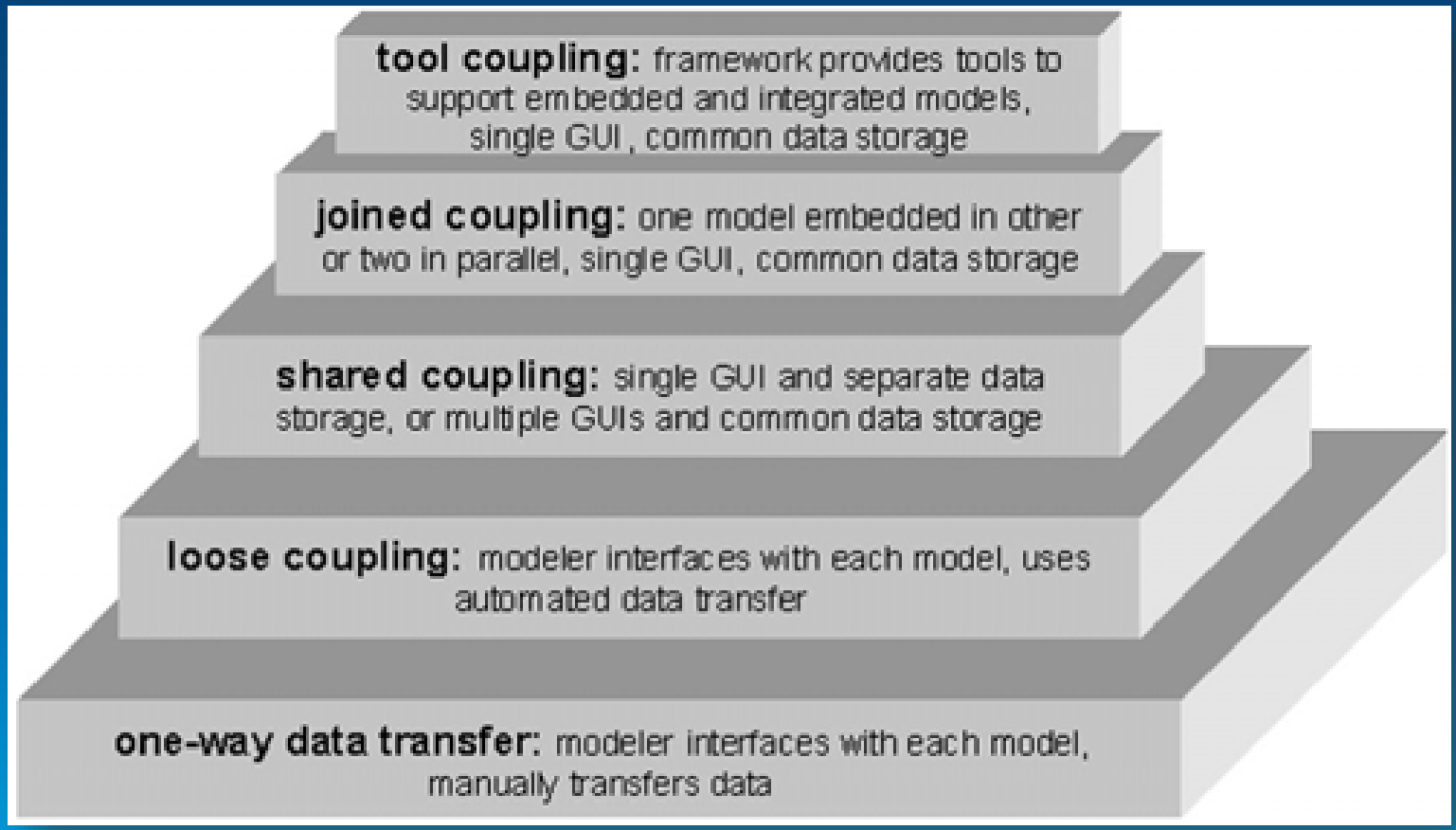
Emissions - MEM Model

Building & Energy GHG - BEM Model

Land Cover Change & Water Quality Models

CWRF Climate Model

Progression of Model Coupling Methodologies



*Source: Brandmeyer, J. E. & H. A. Karimi (2000). "Coupling methodologies for environmental models." Environmental Modelling & Software **15**(5): 479-488.*

Table 1
Advantages and disadvantages of the five coupling methodologies

Methodology	Advantages	Disadvantages
One-way data transfer	Programming changes to the models unnecessary. Source code not required; suitable for proprietary models. Faster implementation with lower initial cost. Suitable for converting data between model versions.	Data conversion required between spatial and temporal scales, data file formats. Manual data editing. Quality assurance required for data conversions. New conversion procedures required when update model or system. User responsible for documenting all data transfer and conversion steps. Increased modeler, simulation time.
Loose coupling	Lower initial cost.[a] Can link models and components with minimal changes to existing code. Testing protocols address each model, not direct model interactions. Independent model development path. Supports distributed computing. Supports encapsulation for object-oriented programming (OOP).	Data conversion programs required between each set of coupled models. Conversion maintenance when data structure changes for one model. Data redundancy problems. Requires permanent data keys. Performance depends on network speed.
GUI coupling	Potentially reduced training time due to intuitive GUI.[b] Potentially easier to create input files. Potentially reduced execution time through reduced user interaction time. Supports proprietary code.[c]	Additional layer between model and user, without improving the model. Required automation of all model interactions. Model update requires GUI update. Programmers must anticipate all model applications and user needs.
Data coupling	Simpler data maintenance. Supports DBMS for consistency and easier maintenance. Reduced number of file conversion programs. Improved version control for data. Elimination of data redundancy. Supports data queries.	Potential limitations on data types. Rich language supporting geospatial and attribute data types, relationships. Overall model performance depends upon DBMS, server speed. Model interfaces depend upon DBMS.
Embedded coupling	Reduced development cost. Access to master model capabilities. Reusability for master model's code. Eliminates network communications.	Requires single computing system. Source code required for embedded model. Functionality limited to language provided by the master. Difficulty of code optimization. Changing the master may require changing embedded models. Increased computer requirements if all possible techniques and models are embedded.[d]
Integrated coupling	Promotes code reusability. Supports distributed, heterogeneous computing environments. Reduced model development cost.	Higher initial cost to facilitate integration of additional components. Network affects component performance. Shared routines required throughout the heterogeneous environment.
Tool coupling	Supports community model development. Supports both legacy and new models. Supports version control for data and code. Supports encapsulation for OOP. Supports distributed computing. Supports automated data backup. Supports DBMS with data dictionary.	Higher initial cost due to framework design and development. Relies on network and server speed. Model applications and user needs must be anticipated. Requirement for rich data language.

[a] Charnock et al. (1996).
[b] Mandel (1997).
[c] Blodgett et al. (1995).
[d] Arentze et al. (1996).

*Source: Brandmeyer, J. E. & H. A. Karimi (2000). "Coupling methodologies for environmental models." Environmental Modelling & Software **15**(5): 479-488.*

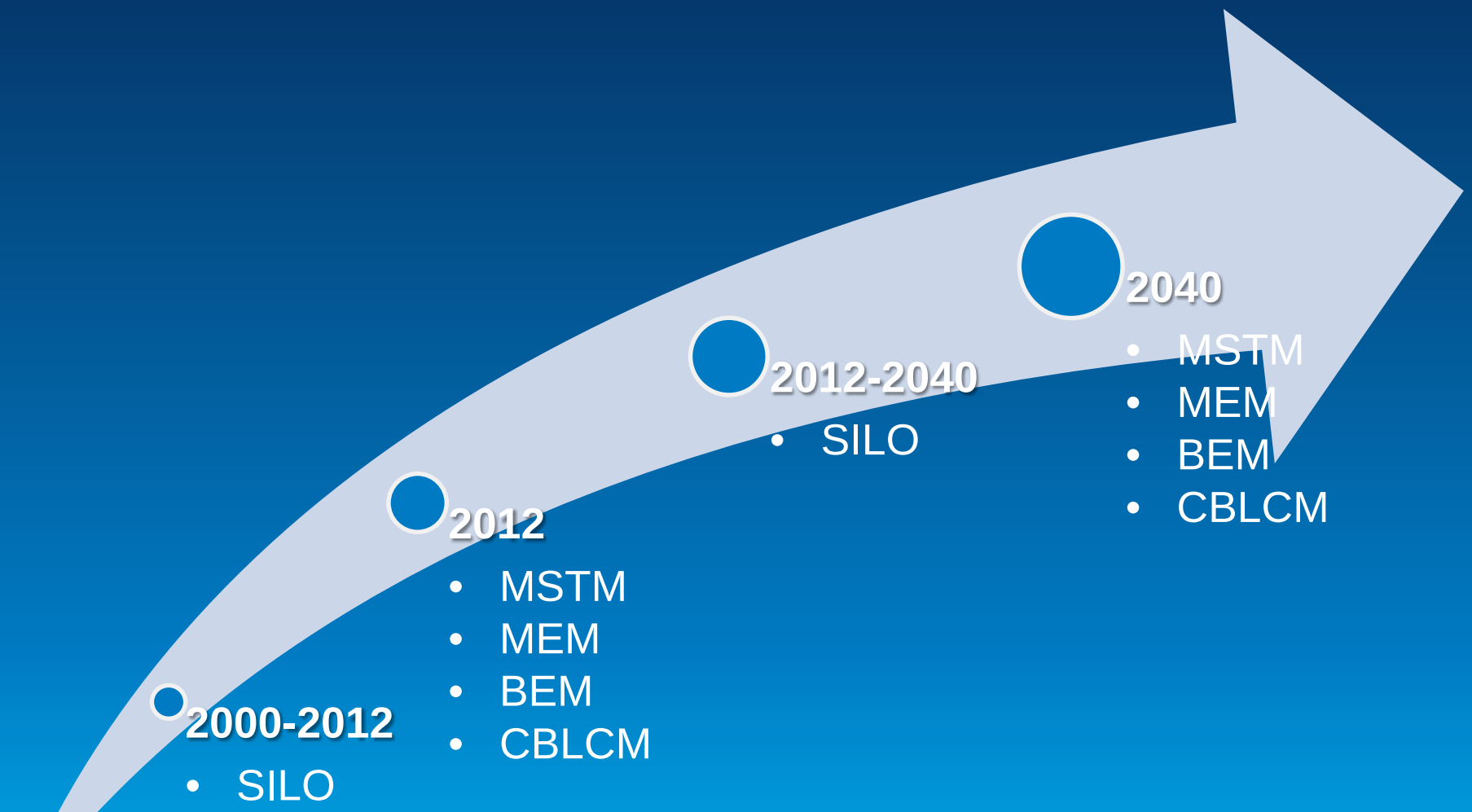
Models' Characteristics

Model	Environment	Operation System	Developer/ Licensing	Simulation Period	Sim. years	Run time
MSTM	CUBE	Windows	Scripts: Open source CUBE: CitiLabs	2012 or 2040	1	15-16 hour
SILO	Java	Multi-platform	Open source	2012-2040	23	4-5 hour
MEM	CUBE	Windows	EPA (MOVES) / CitiLabs	2012 or 2040	1	< 30 min
BEM	Excel	Multi-platform	NCSG	2012 or 2040	1	< 1 min
CBLCM	C / C++	CentOS	USGS	2012-2040	4	3 hour

Data flow between the models

To / From	MSTM	SILO	MEM	BEM	CBLCM
MSMT		§ High occupancy vehicle travel time between zones § Transit travel time between zones	§ All trips within the region § Vehicle types and age distribution § Average speed distribution		
SILO	§ Population § Employment			§ Property data: building type, age, area, rooms, use, heating fuel, location, etc.	§ Household estimates § Employment estimates § Zonal accessibility to population by auto & transit

Processing flow order and simulation periods



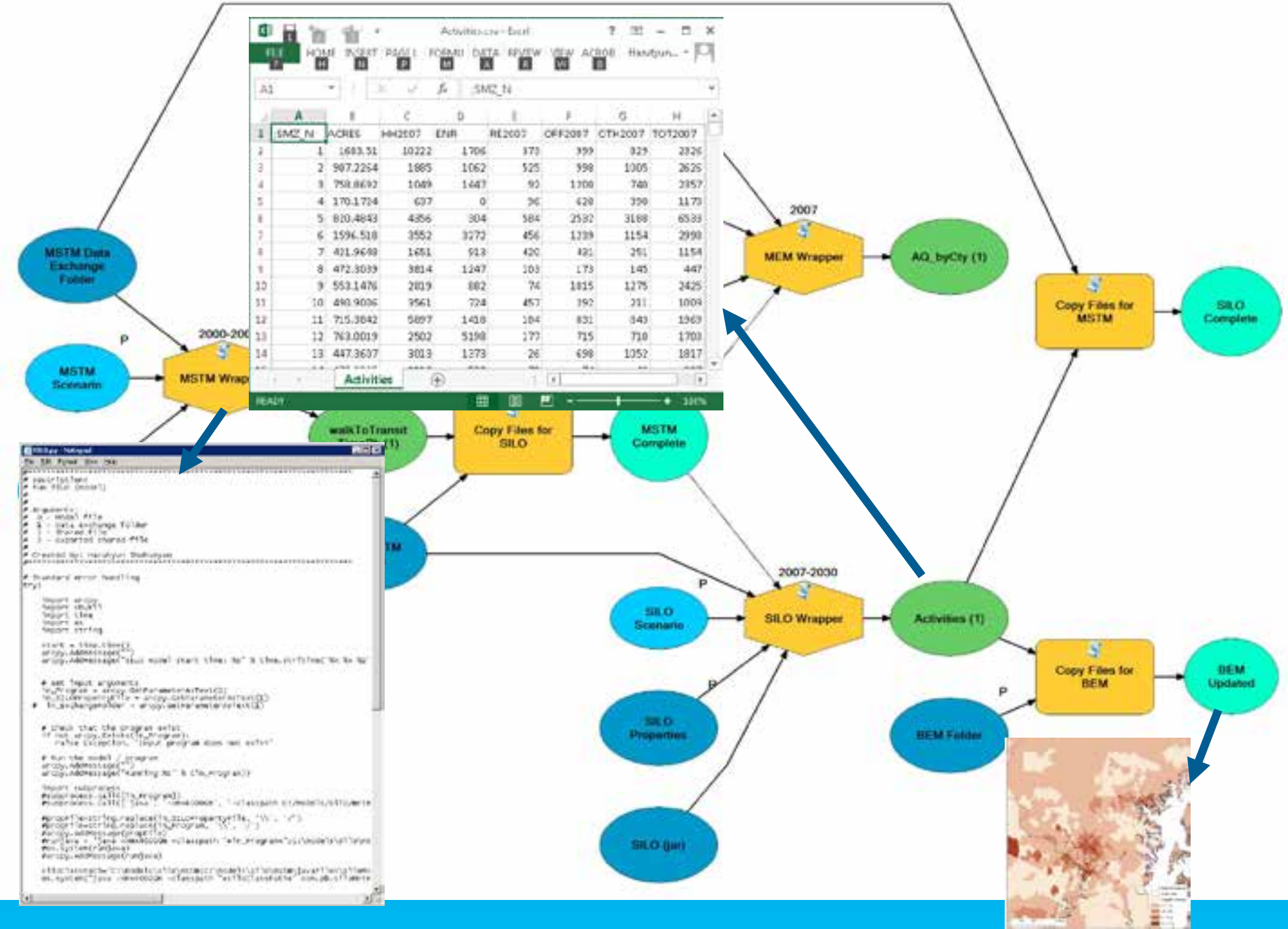
Practical Value and Key Requirements of Integration

- Ability to develop models independently, such that they may be plugged-in easily.
- A modular approach supporting reusability and adding new components.
- User friendly graphical interface.
- Minimizing manual data transfer.
- Minimal or no change in source codes of the models.

- Capacity to link models developed in different programming languages and environments.
- Ability to deal with different licensing requirements.
- Compatibility with GIS for easy data visualization and spatial analysis.
- Minimal costs and efficient timing for implementation.

Model Coupling Tools

- Open Modelling Interface (OpenMI)
- Community Surface Dynamics Modeling System (CSDMD)
- Earth System Modeling Framework (ESMF)
- Model Coupling Toolkit (MCT)
- O-PALM
- OASIS
- FLUX
- Kepler


MSTM Data Exchange Folder
MSTM Scenario
P
2000-200
MSTM Wrap
walkToTransit
Copy Files for SILO
MSTM Complete
2007
MEM Wrapper
AQ_byCity (1)
Copy Files for MSTM
SILO Complete
2007-2030
SILO Scenario
SILO Wrapper
Activities (1)
Copy Files for BEM
BEM Updated
SILO Properties
BEM Folder
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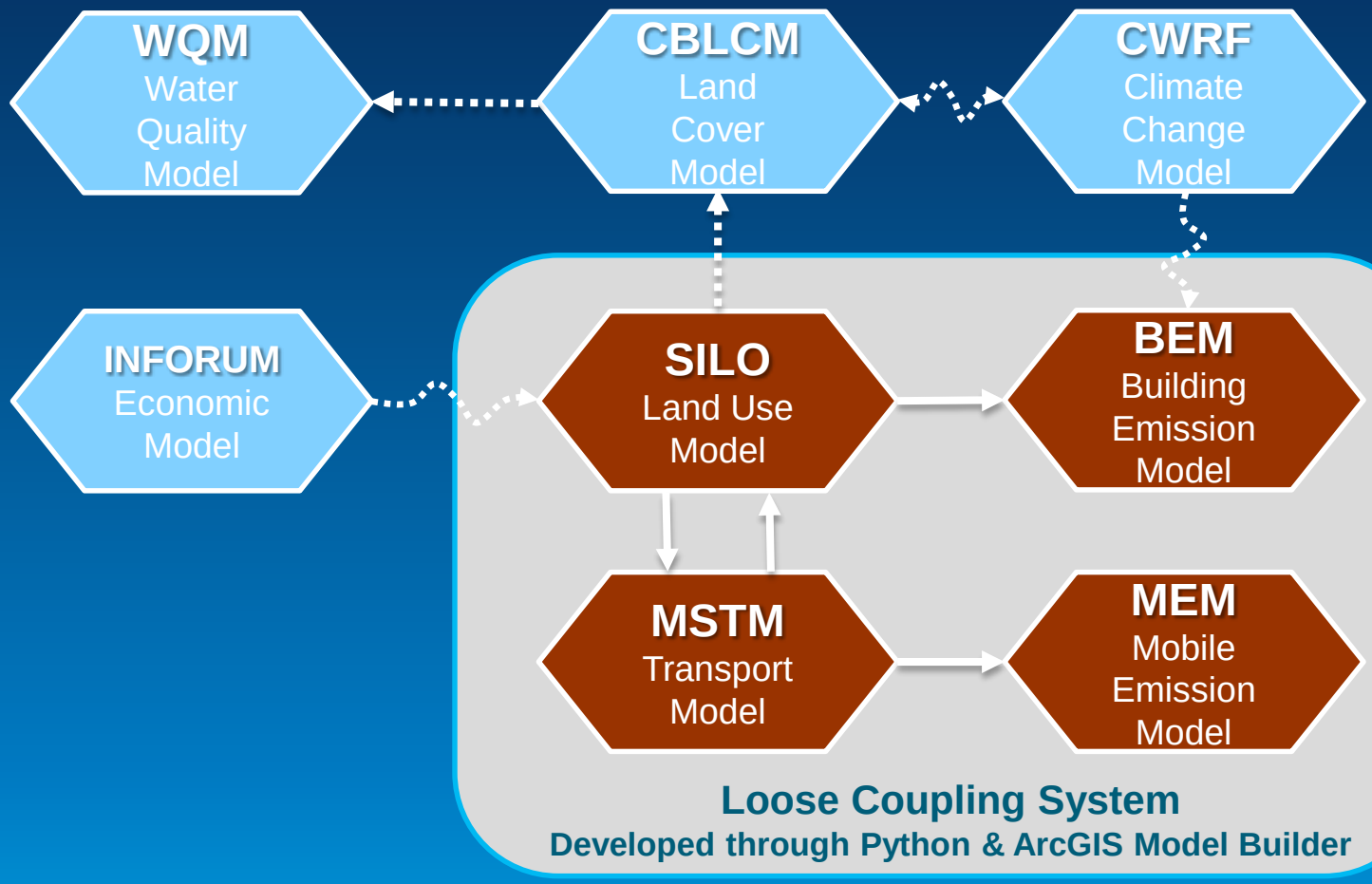
Activities
SMZ_N
ACRES
HH2007
EMP
RE2007
OFF2007
OTH2007
TOT2007

Current Status and Future Work



Models	Current Data Exchange
Installed and coupled on the designated server	Automatic (loose coupling)
Installed on different remote servers or PCs	Manual (coupling is under development)
	To be determined

Python Wrappers & ArcGIS Model Builder

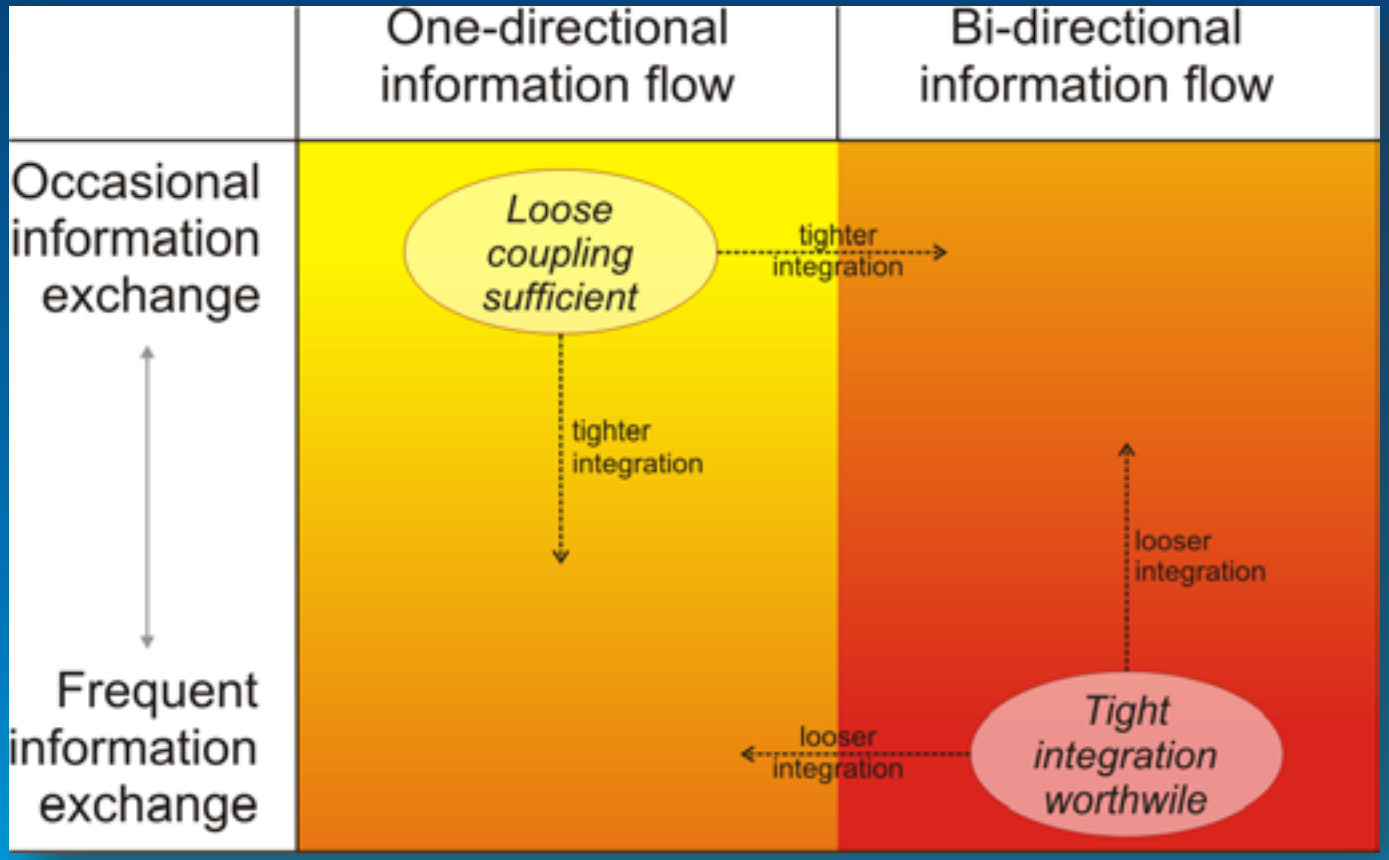
Benefits

- No need to change the source codes of the models.
- Runs models developed in different environments.
- Can be extended with additional models over time.
- General user interface showing process flow.
- Rich visualisation & mapping capabilities with ArcGIS.
- Easy to implement.

Limitations

- Parallel model runs and dynamic data exchange during simulation time steps are not supported.
- Model processes run independently from one another.
- Data exchanged between modules are written to and read from a hard drive. No in-memory data exchange.

Reasons for loose coupling and tight integration



Courtesy of Dr Rolf Moeckel

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Harutyun Shahumyan

harut@umd.edu

Harutyun.Shahumyan@ucd.ie

http://smartgrowth.umd.edu