Spatially distributed modeling for pesticide assessments in surface water, and USEPA Spatial Aquatic Model

Yuzhou Luo, Ph.D.
Research Scientist III
DPR/EM/SWPP
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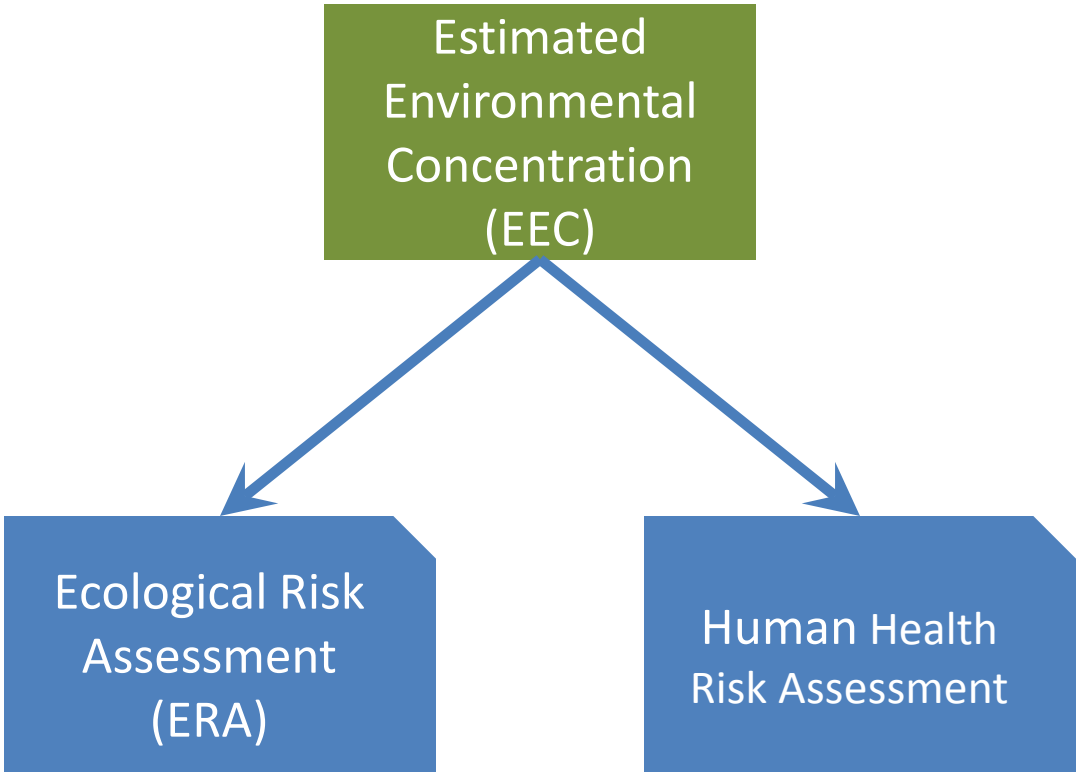
Pesticide risk assessment



Based on "*Pesticide science and assessing pesticide risks*"
http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks

Outline

- Overview of approaches (other than monitoring) for pesticide risk assessments in surface water

- Spatial Aquatic Model (SAM), under development by USEPA

Professional judgement

- Comparison to chemicals with known environmental exposures

Regression equations

- Comparison to chemicals with known exposures
- Regression-based criteria or classifications
  - Pesticide rating, USDA (1992) and later as WIN-PST (2010)
  - "Soil-runoff potential" developed by SWPP (2012)

Table 1. Classification of Runoff Potential from Soils

	Criteria	**Classification**
Dissolved phase	(SOL ≥ 1 and FD > 20 and KOC < 1×10^5) or (SOL ≥ 10 and KOC ≤ 2000)	High (H) runoff potential
	Otherwise	Low (L) runoff potential
Adsorbed phase	(FD ≥ 15 and KOC ≥ 4×10^4) or (FD ≥ 40 and KOC ≥ 1000) or (SOL ≤ 0.5 and FD ≥ 40 and KOC ≥ 500)	High (H) runoff potential
	Otherwise	Low (L) runoff potential

Luo and Deng, 2012. http://www.cdpr.ca.gov/docs/emon/pubs/prem.htm

Tier I modeling

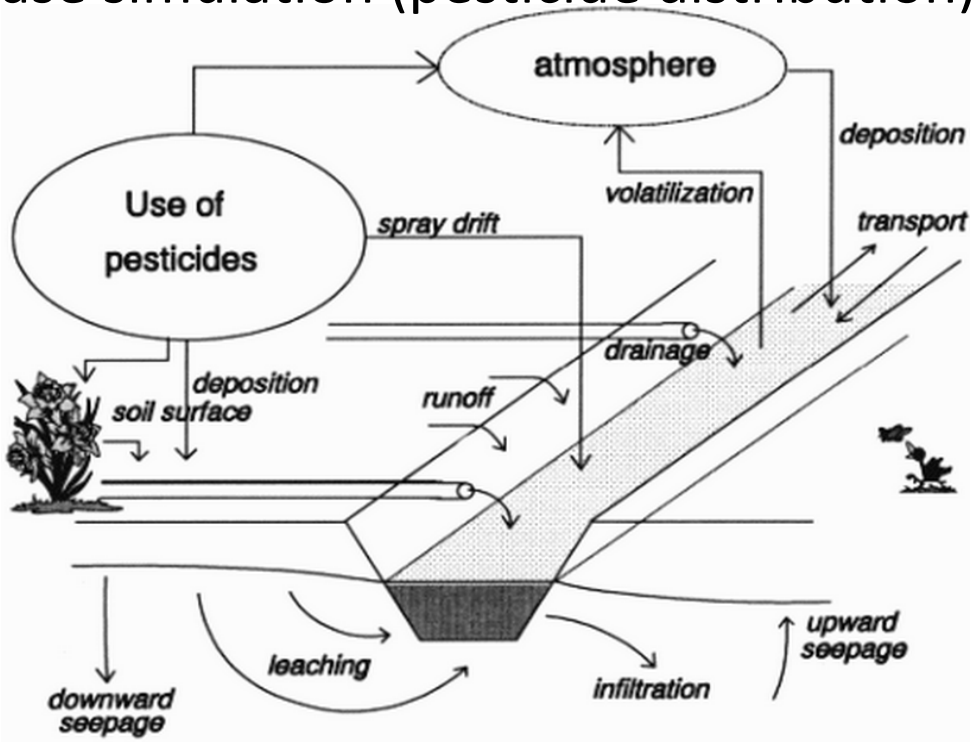
- Comparison to chemicals with known exposures
- Regression-based criteria or classifications
- Tier I, screening level assessments
  - GENEEC (Generic estimated environmental concentration model), USEPA (1995)
  - Tier I rice model, USEPA (2007)
  - Early version of Pesticide Registration Evaluation Model, SWPP (2012)

Tier II modeling

- Comparison to chemicals with known exposures
- Regression-based criteria or classifications
- Tier I, screening level assessments
- Tier II, more refined estimates of pesticide conc's
  - PRZM (2006) and EXAMS (2000), and recent updates to PRZM5 and VVWM (2014), USEPA
  - PFAM (tier 2 rice model), USEPA (2013)
  - Pesticide Registration Evaluation Model, SWPP (2014)

Tier II model overview

- Two major components
  - Land-phase simulation (pesticide generation)
  - Water-phase simulation (pesticide distribution)



FOCUS/PRZM-TOXSWA, http://focus.jrc.ec.europa.eu/sw/

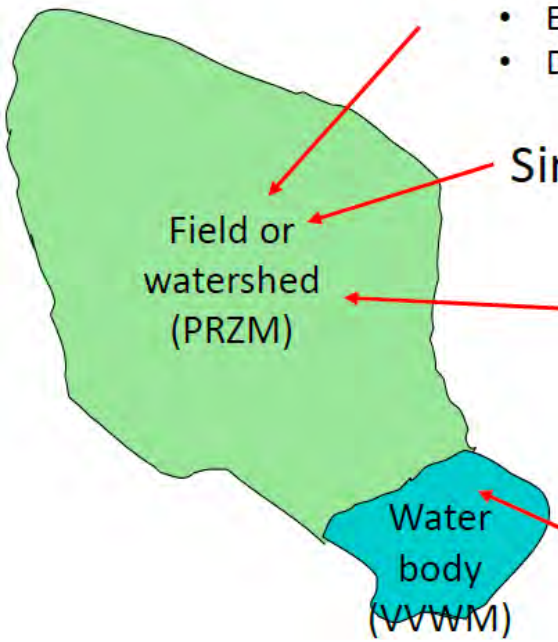
Tier II model overview

- Model components
  - Land phase
  - Water phase

- Model examples
  - PRZM-EXAMS (*PE5*, Nov 2006, USEPA)
  - PRZM-VVWM (*Surface Water Concentration Calculator*, July 2014; *Pesticide in Water Calculator*, Dec 2015, USEPA and Health Canada)
  - PRZM-AGRO (*PA5*, May 2015, Stone Environmental Inc.)
  - PRZM-TOXSWA (EU FOCUS)

Tier II model overview

- Model components; examples
- Environmental description



Fixed field size

- Eco – 10 ha field
- Drinking water – 172.8 ha watershed

Single crop/use area

Regional weather stations
30 years (1961-1990)

Fixed water body

- Eco – 20k m^3 pond
- Drinking water – 144k m^3 index reservoir

Reference: EPA-HQ-OPP-2015-0424-0036

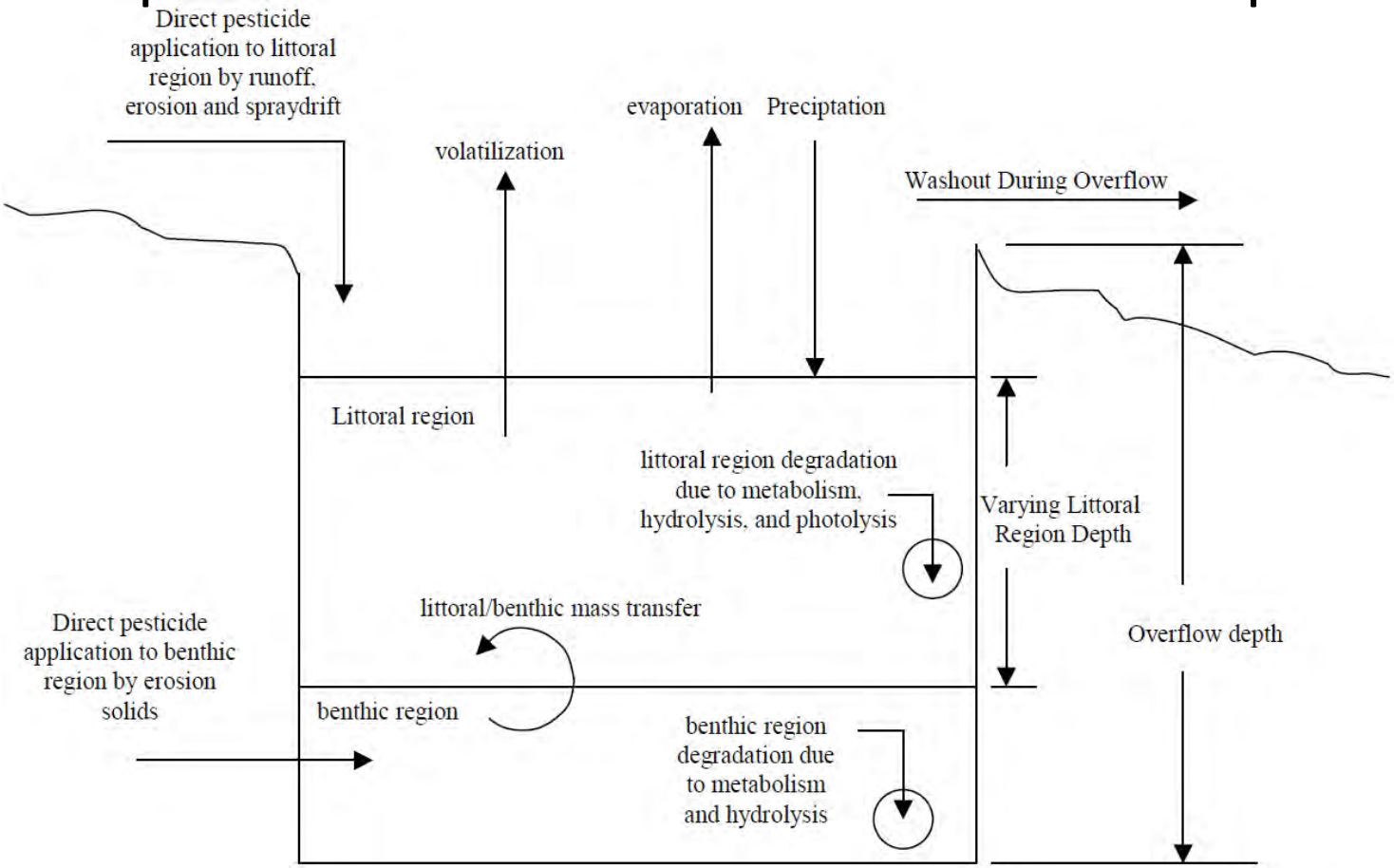
Crop scenarios

- **State-crop** “scenarios” for land-phase simulation

CAalfalfa_WirrigOP.scn	CAalmond_WirrigSTD.scn	CAAvocadoRLF_V2.scn	CAcitrus_WirrigSTD.scn
CAColeCropRLF_V2.scn	CAcornOP.scn	CAcotton_WirrigSTD.scn	CAForestryRLF.scn
CAfruit_WirrigSTD.scn	CAGarlicRLF_V2.scn	CAGarlicRLF_V3.scn	CAgrapes_WirrigSTD.scn
CAImperviousRLF.scn	CAlettuceSTD.scn	CAMelonsRLF_V2.scn	CAnurserySTD_V2.scn
CAOliveRLF_V2.scn	CAonion_WirrigSTD.scn	CAPotatoRLF_V2.scn	CArangelandhayRLF_V2.scn
CAresidentialRLF.scn	CArightofwayRLF_V2.scn	CARowCropRLF_V2.scn	CAStrawberry-noplasticRLF_V2.scn
CAsugarbeet_WirrigOP.scn	CAtomato_WirrigSTD.scn	CATurfRLF.scn	CAWheatRLF_V2.scn
CAWineGrapesRLF_V2.scn	FLavocadoSTD.scn	FLcabbageSTD.scn	FLcarrotSTD.scn
FLcitrusSTD.scn	FLcucumberSTD.scn	FLnurserySTD_V2.scn	FLpeppersSTD.scn
FLpotatoNMC.scn	FLstrawberry_WirrigSTD.scn	FLsugarcaneSTD.scn	FLsweetcornOP.scn
FLtomatoSTD_V2.scn	FLturfSTD.scn	GAOnion_WirrigSTD.scn	GAPeachesSTD.scn
GAPecansSTD.scn	IAcornstd.scn	IDNpotato_WirrigSTD.scn	ILalfalfaNMC.scn
ILbeansNMC.scn	ILCornSTD.scn	INCornStd.scn	KSCornStd.scn
KSsorghumSTD.scn	LAsugarcaneSTD.scn	MEpotatoSTD.scn	MIAsparagusSTD.scn
MIbeansSTD.scn	MICherriesSTD.scn	MImelonStd.scn	MInurserySTD_V2.scn
MNalfalfaOP.scn	MNCornStd.scn	MNsugarbeetSTD.scn	MOmelonStd.scn
MScornSTD.scn	MScottonSTD.scn	MSsoybeanSTD.scn	NCalfalfaOP.scn
NCappleSTD.scn	NCcornESTD.scn	NCcornWOP.scn	NCcottonSTD.scn
NCpeanutSTD.scn	NCSweetPotatoSTD.scn	NCtobaccoSTD.scn	NDcanolaSTD.scn
NDcornOP.scn	NDwheatSTD.scn	NECornStd.scn	NJmelonStd.scn
NJnurserySTD_V2.scn	NYGrapesSTD.scn	OHCornSTD.scn	ORappleSTD.scn
ORberriesOP.scn	ORfilbertsSTD.scn	ORgrassseedSTD.scn	ORhopsSTD.scn
ORmintSTD.scn	ORnurserySTD_V2.scn	ORsnbeansSTD.scn	ORswcornOP.scn
ORwheatOP.scn	ORXmasTreeSTD.scn	PAalfalfaOP.scn	PAappleSTD_V2.scn
PAcornSTD.scn	PAtomatoSTD.scn	PAturfSTD.scn	PAvegetableNMC.scn
PRcoffeeSTD.scn	STXcornNMC.scn	STXcottonNMC.scn	STXgrapefruitNMC.scn
STXmelonNMC.scn	STXvegetableNMC.scn	TNnurserySTD_V2.scn	TXalfalfaOP.scn
TXcornOP.scn	TXcottonOP.scn	TXsorghumOP.scn	TXwheatOP.scn
WAbeansNMC.scn	WAonionsNMC.scn	WAorchardsNMC.scn	WApotatoNMC.scn

“USEPA pond”

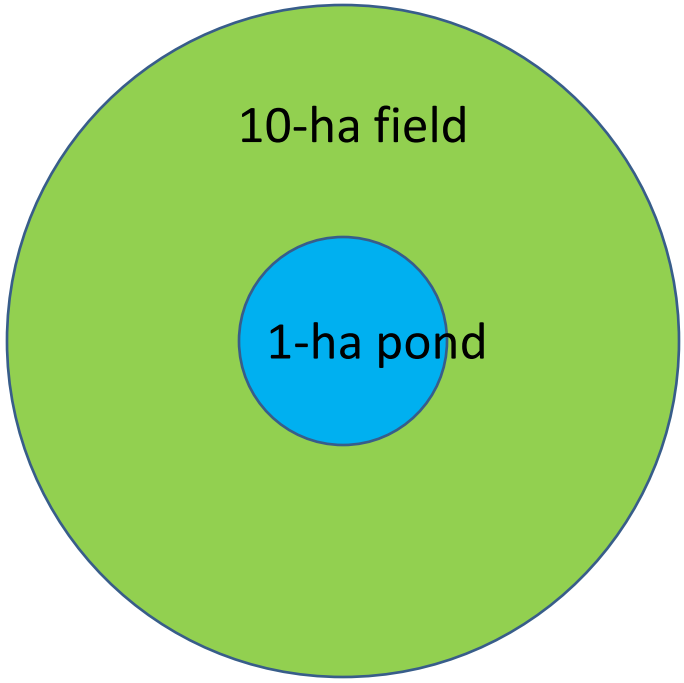
- “USEPA pond” and “index reservoir” for water phase



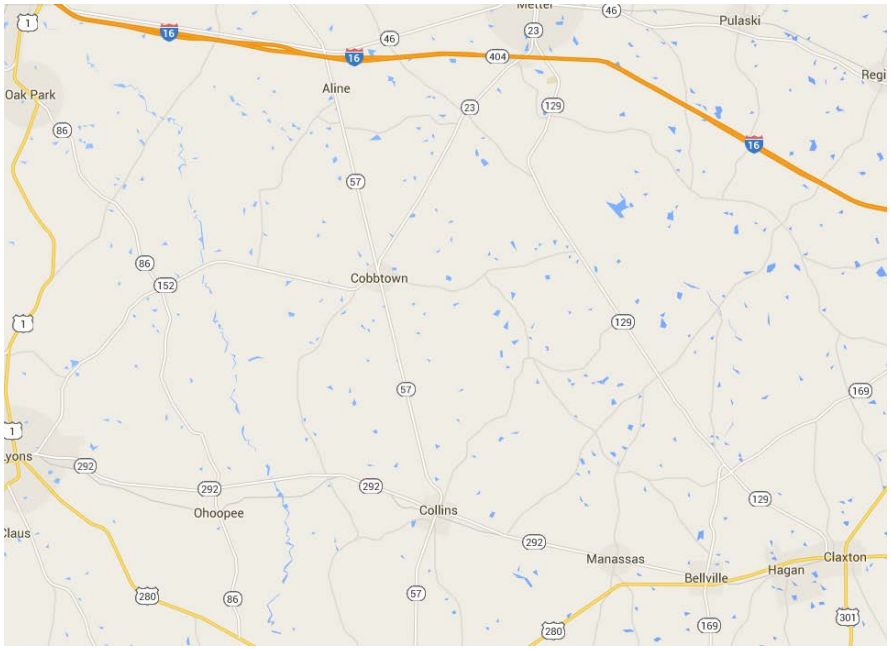
Reference: USEPA/OPP 734F14003

“USEPA pond”

- “USEPA pond” and “index reservoir” for water phase



Modified from Sabbagh, et al. (2010), ES&T, 44, 3839-3845

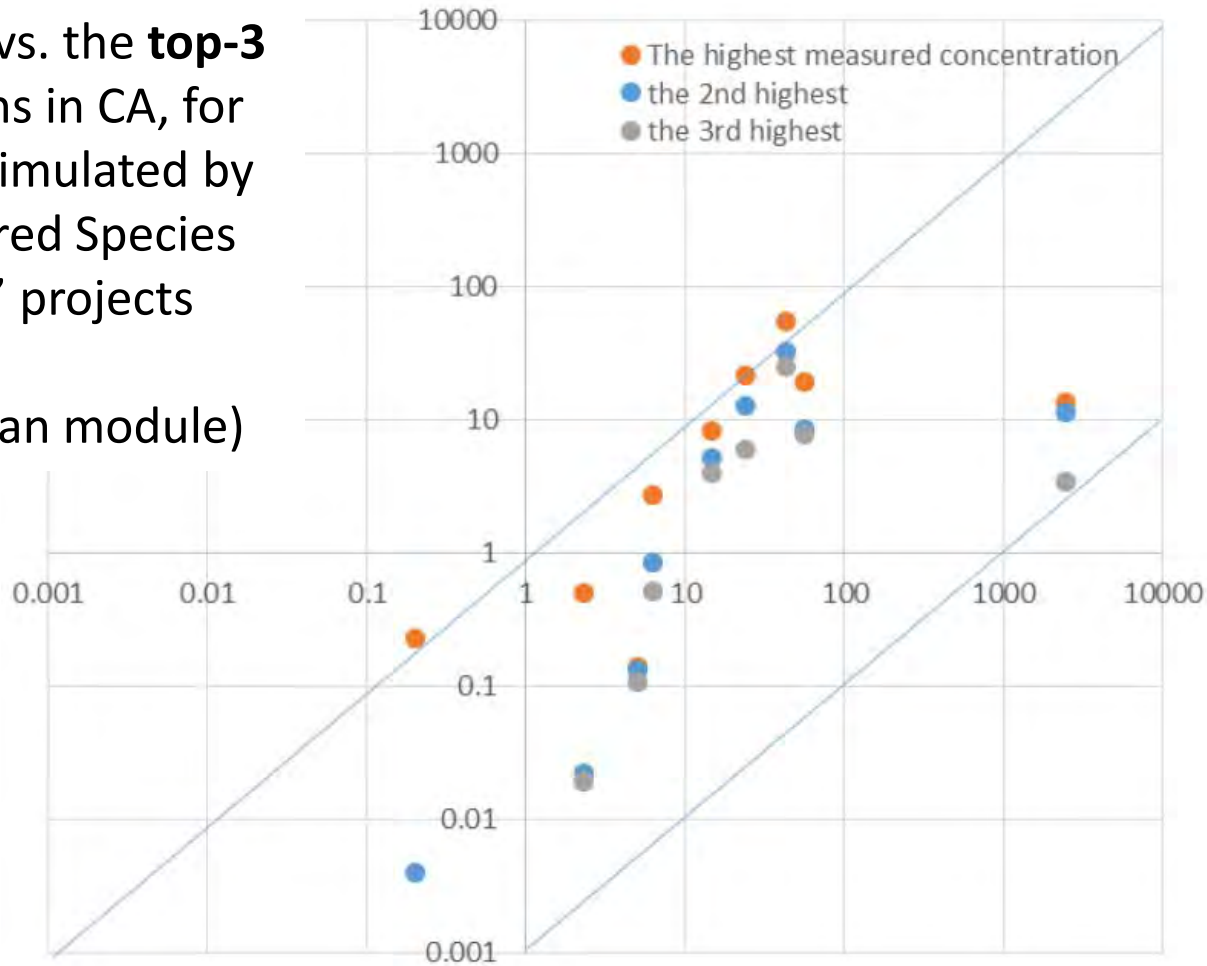


Farm ponds in central Georgia (where the “USEPA pond” is developed by following USDA guidance)

“USEPA pond”

USEPA **predicted** EEC’s vs. the **top-3 observed** concentrations in CA, for all urban use patterns simulated by USEPA in the “Endangered Species Effects Determinations” projects

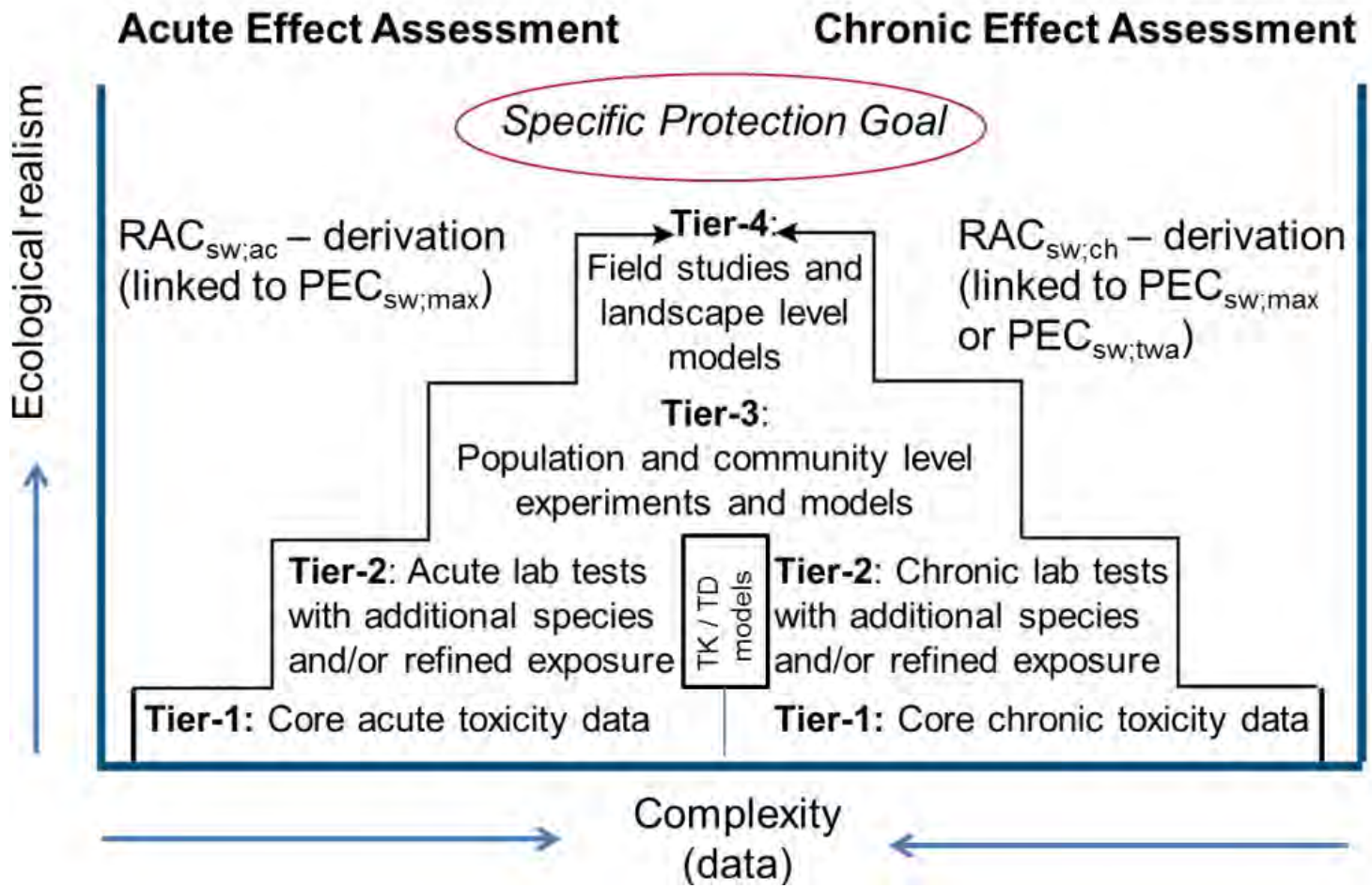
(Luo, 2014, RegEval urban module)



Higher tiered models

- Comparison to chemicals with known exposures
- Regression-based criteria or classifications
- Tier I, screening level assessments
- Tier II, more refined estimates of pesticide conc's
- Higher tiers: more realistic risk assessments
  - Landscape realism
  - Hydrologic realism
  - Ecological realism
  - …
  - SAM is one of higher-tiered modeling efforts

Other higher tiered models



Guidance on tiered risk assessment for plant protection products for aquatic organisms in edge-of-field surface waters, European Food Safety Authority

SAM development

- Expectations
  - Locate the worst-case conditions
  - Simulate other conditions
  - Spatially quantify the magnitude, duration and frequency of exposure exceedance
- Status
  - alpha 1.0 posted, plan for α2.0 proposed
  - FIFRA SAP meeting and final report
- Official documentation
  - Docket #: EPA-HQ-OPP-2015-0424 (http://www.regulations.gov)

SAM =

- Spatially distributed modeling with PRZM, +
- A new water-phase simulator for pesticide fate & transport in stream networks at watershed scale

	PRZM/VVWM (Tier II)	SAM
Modeling scenario, land	One 10-ha field, one crop, with predefined parameters	Millions of fields, various size, field-specific parameters
Simulation engine, land	PRZM	PRZM
Modeling scenario, water	USEPA pond	Water bodies (river, creek, lake, pond, etc.)
Simulation engine, water	VVWM	A new model under development

Spatial resolution

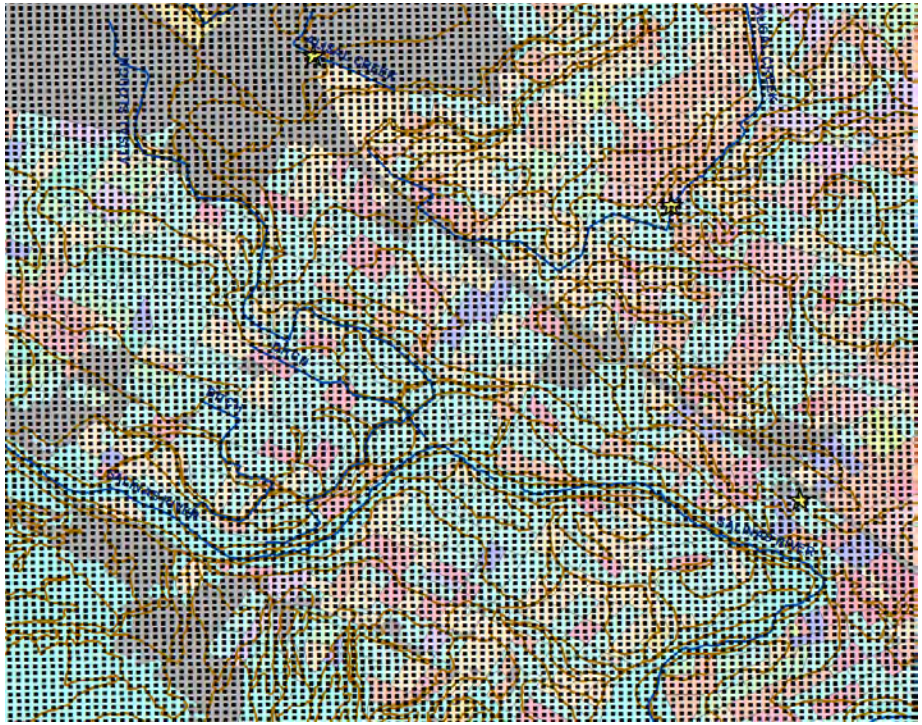
- Land-phase simulation by **scenarios**
  - From "state-crop"; to **"soil-land-weather" scenarios**
    - Soils: USDA Soil Survey Geographic (SSURGO) Database, gridded to 10-m pixel
    - Land cover: USDA Cropland Data Layer (CDL), 30-m
    - Weather: NOAA data, 0.25 degree
  - Final resolution = 10 m

1	1	2	3	3
1	4	4	4	4
5	6	7	7	6
5	7	7	8	8
5	9	6	10	6

<u>Scenarios</u>, as
ID -> soil-land-weather
1-> soil1-land1-weather1
2-> soil2-land1-weather1
3-> soil1-land1-weather2
4-> soil2-land2-weather1
…

Spatial resolution

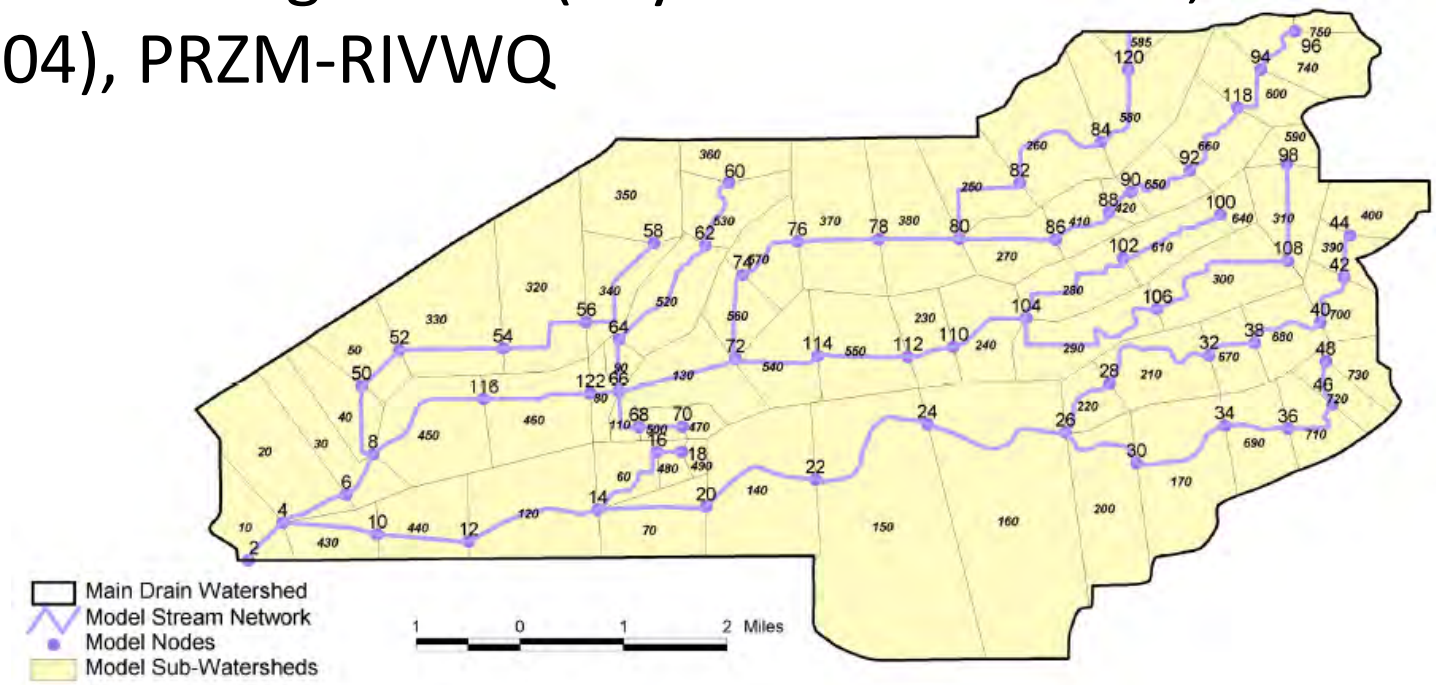
- Land-phase simulation by **scenarios**
  - “soil-land-weather” scenarios
  - Example 1, lower Salinas River



1	1	2	3	3
1	4	4	4	4
5	6	7	7	6
5	7	7	8	8
5	9	6	10	6

Spatially continuous application of PRZM in California

- Diazinon in the Sacramento River Basin's main drainage canal (Snyder and Williams, 2004), PRZM-RIVWQ

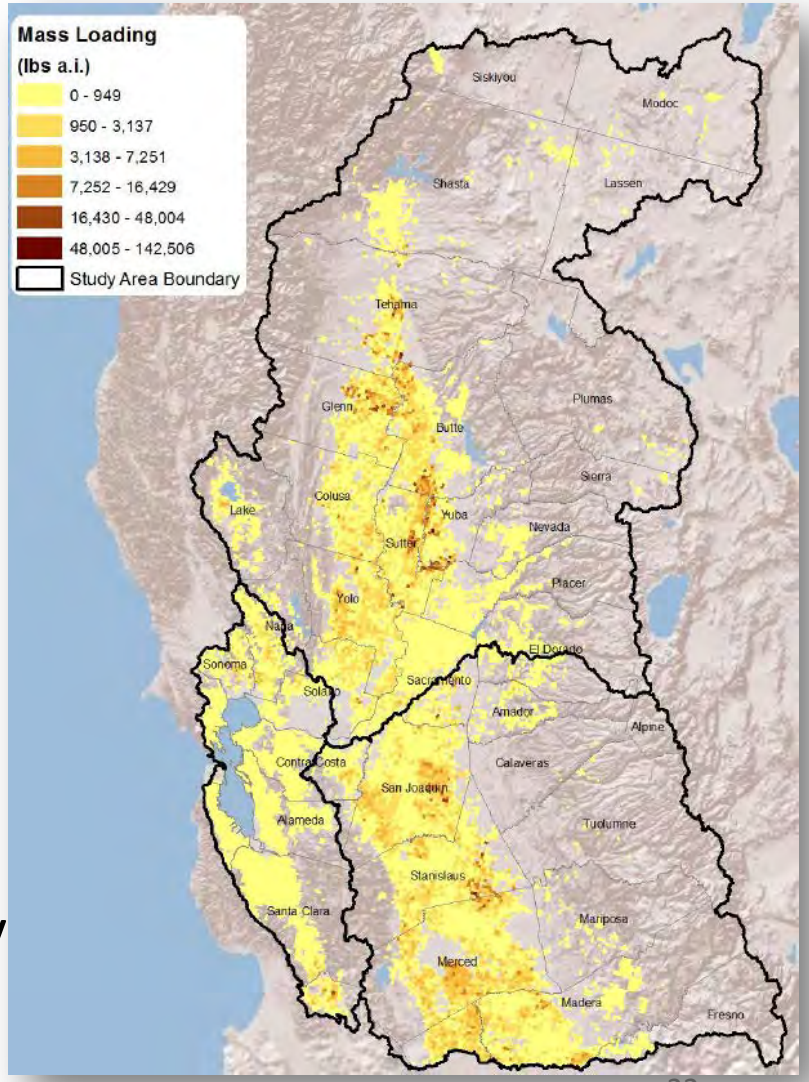


SACRAMENTO RIVER watershed PROGRAM

WATERBORNE ENVIRONMENTAL

Spatially continuous application of PRZM in California

- 5 pesticides in Sacramento River watershed (Dasgupta et al., 2006), PRZM only
- Chlorpyrifos in the Central Valley (Luo et al., 2010), PRZM only
- "CoPST" project: 40 pesticides in Sacramento River & San Joaquin River watersheds, and Bay–Delta (Hoogeweg et al., 2011), PRZM only



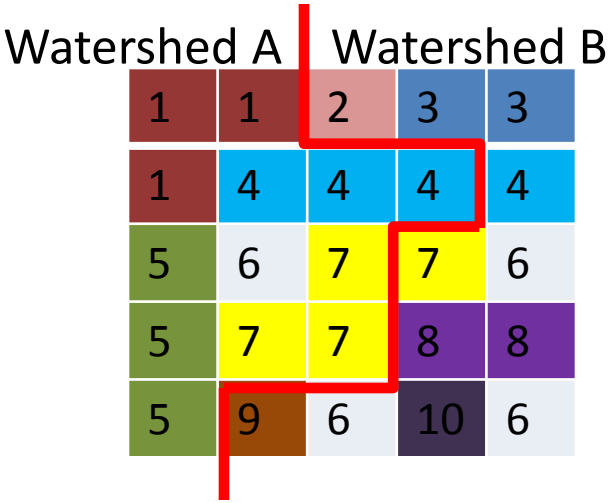
(Hoogeweg et al., 2011)

Spatial resolution

- Land-phase simulation by **scenarios**
- Water-phase by **watershed "recipe**"
  - From "USEPA pond" (a conceptual, static water body); to water bodies in each watershed
  - Watershed delineation
    - HUC12
    - Catchment
  - Water body types considered
    - Lotic (streams, rivers)
    - Lentic (lakes, reservoirs)

Spatial resolution

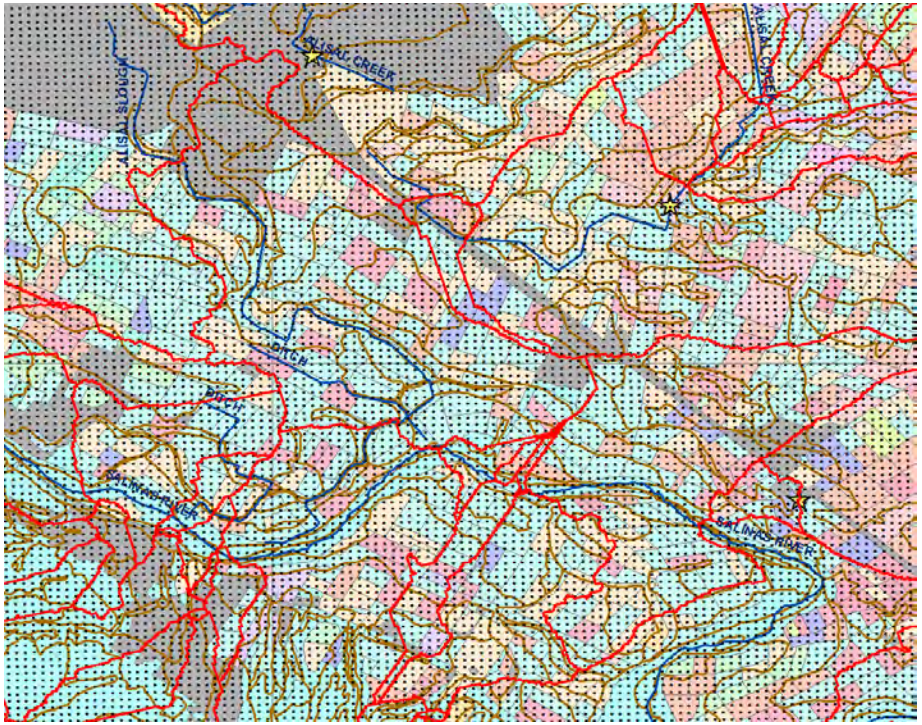
- Land-phase simulation by **scenarios**
- Water-phase by **watershed "recipe"**
  - Recipe: a list of scenarios included in a watershed



<u>Recipes</u>, as
watershed->scenario (%)->
A->1 (100%)
  ->4 (75%)
  ->5 (100%)
  …
B->2 (100%)
  ->3 (100%)
  ->4 (25%)
  …

Spatial resolution

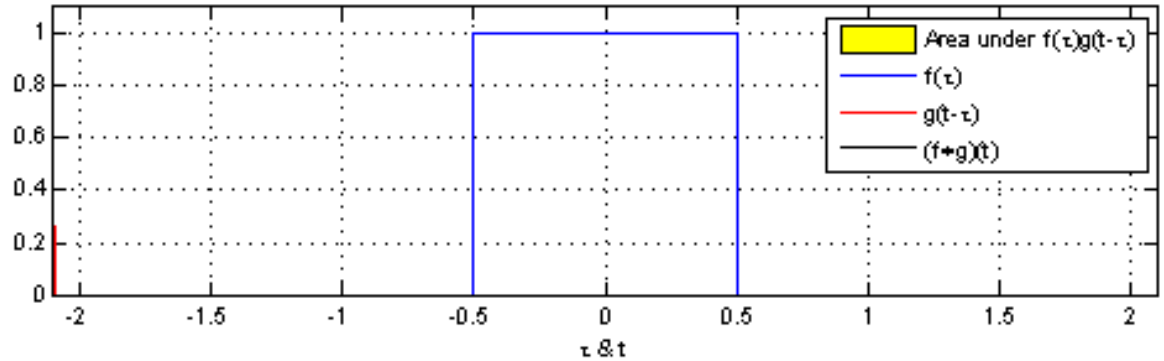
- Land-phase simulation by **scenarios**
- Water-phase by **watershed "recipe"**
  - Recipe: a list of scenarios included in a watershed



Lower Salinas River, showing land use, soil, grid cells, and catchments (red)

Water/pesticide transport

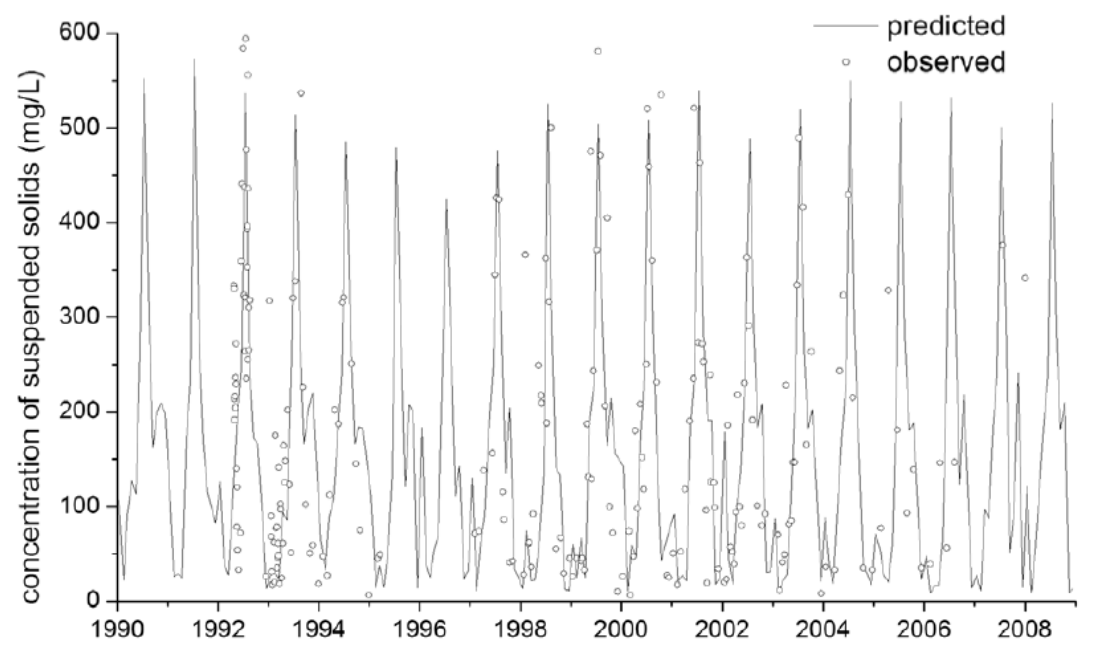
- In-stream routing of water and dissolved pesticide
  - Modeling approach: convolution
- Streamflow and chlorpyrifos/diazinon loadings in the Orestimba Creek as an example (Luo et al., 2009)



https://en.wikipedia.org/wiki/Convolution

Sediment/pesticide transport

- In-stream routing of SS and sorbed pesticides
  - Modeling approach: convolution with a separate module for water-sediment exchange, e.g., Luo et al, 2011

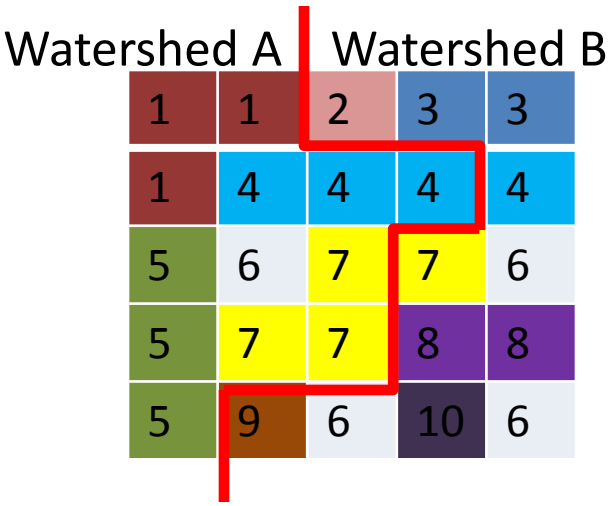


Observed and predicted monthly flow-weighted concentrations of suspended solids at the site OCRR (Orestimba Creek @ River Road)

Simulation design

- Pre-processing
  - Spatial analysis for scenarios, recipes
  - Hydrologic simulation
- Chemical-specific simulation
  - User-specified info: chemistry data and label info
  - PRZM simulation for each scenario, generating edge-of-field pesticide masses
  - In-water fate/transport simulation for each recipe, generating concentrations in a water body based on PRZM results and hydrology data

Simulation design



<u>Land-phase simulation by scenarios</u>

1-> Run PRZM for $M_1(t)$, daily mass loading
2-> Run PRZM for $M_2(t)$
3-> Run PRZM for $M_3(t)$
4-> Run PRZM for $M_4(t)$
…

<u>Watershed recipes</u>

A->1 (100%*M_1)
->4 (75%*M_4)
->5 (100%*M_5)
…

B->2 (100%*M_2)
->3 (100%*M_3)
->4 (25%*M_4)
…

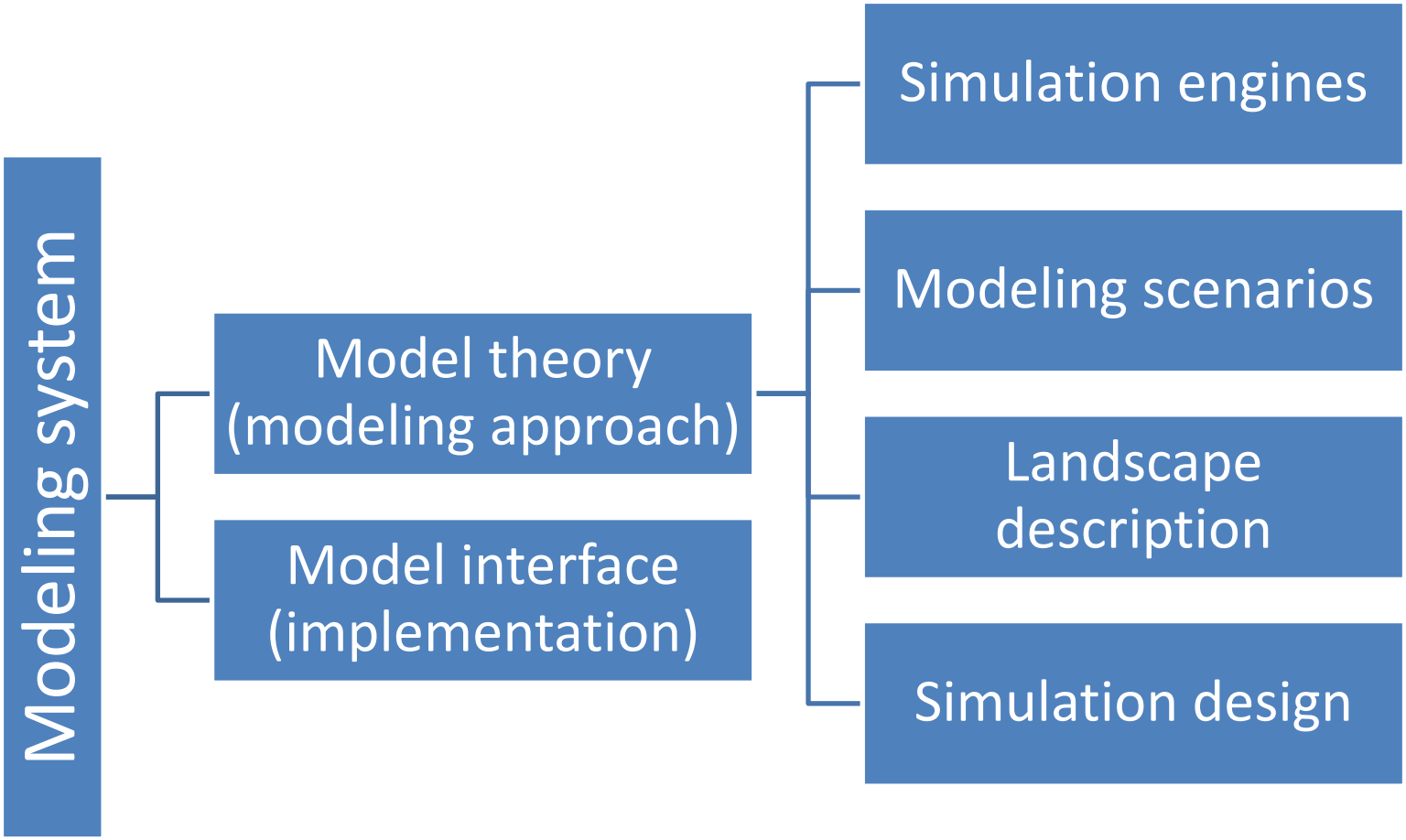
…

$M_A(t)$, daily mass loading to A
$M_B(t)$
…

In the stream network, simulations for pesticide routing, accumulation, dissipation…

Final results: $C_A(t)$, $C_B(t)$, … daily concentrations at each watershed outlet

Model analysis



(Luo, 2014)

Example of model analysis

- Pesticide in Water Calculator
  - Simulation engines: PRZM, VVWM
  - Modeling scenarios: (land) USEPA tier-II crops scenarios; (water) “USEPA pond/reservoir” scenarios
  - Landscape description: not required
  - Simulation design: one PRZM run -> one VVWM run
  - Model interface

Example of model analysis

- Spatial Aquatic Model
  - Simulation engines: PRZM, and a water model under dev.
  - Modeling scenarios: (land) “soil-land-weather” scenarios; (water) lotic and lentic water body scenarios
  - Landscape description: watershed “recipes”
  - Simulation design: multiple PRZM runs -> stream network
  - Model interface: http://qed.epa.gov/ubertool/sam/

Implications to SWPP

- Make connections to modeling/monitoring efforts
  - Monitoring prioritization model at HUC12 scale
  - Catchment scale is used in the “Ag Monitoring” workgroup
  - “Data analysis” workgroup is proposing to use PRZM results (at the same resolution as SAM, but for CA) to assist statewide monitoring data analysis
- Participate in the SAM development and application with CA field conditions

Thanks

Yuzhou Luo, Ph.D.
Research Scientist III
CA Department of Pesticide Regulation
yuzhou.luo@cdpr.ca.gov
(916) 445-2090