- 3.4.3 -
Recent developments in WQ Monitoring
3.4.3. RECENT DEVELOPMENTS IN WATER QUALITY MONITORING

(optional)

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Online Module Water Quality Assessment
CONTENTS

Remote sensing/GIS (dr. Hans van der Kwast)
Sensors (dr. Gretchen Gettel)
Mobile phones (dr. Leonardo Alfonso)
Remote sensing; GIS; Water quality modelling

Remote sensing: making use of airplanes, satellites for e.g. monitoring plankton blooms; turbidity in lakes, oceans

Phytoplankton bloom in the Great Lakes, (USA, Canada)

http://www.ec.gc.ca

(Search: remote sensing; choose first item)

GIS: make overlays with water quality ↔ land use ↔ geology. Water quality modelling (e.g. for early warning monitoring)
Chlorophyll-a levels in Lake Taihu

Lake Taihu, China P.R., in MODIS satellite imaging showing chlorophyll-a levels (red is the highest). From: Quingyu et al. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII . Part B4. Beijing 2008
FERRYBOXES

Equipment mounted on ferry boats, to continuously monitor e.g. salinity, water temperature, oxygen, turbidity, etc.

http://www.noc.soton.ac.uk/ops/ferrybox_index.php
GIS and Water Quality Modelling

Hans van der Kwast

- GIS as a separate tool: data processing, model output visualisation.
- Tightly integrated with modelling system: as an important component, e.g., ArcSWAT, MIKE SHE, HEC-RAS, HydroGeo Analyst, etc.
Example: Spatial-Dynamic Modelling of Nitrate in the Scheldt Basin
Introduction

The Scheldt Basin:

- > 10 million people
- Total area 21863 km²
  - France: 6680 km² (31%)
  - The Netherlands: 1859 km² (8%)
  - Belgium: 13324 km² (61%)
    - Flanders: 9375 km² (43%)
    - Wallonia: 3787 km² (17%)
    - Brussels: 162 km² (1%)
- Length: 360 km
Model concept

\[ SSS_x \]
Soil Surface Surplus: Diffuse sources

\[ DI_x \]
Direct Inputs: Point sources

Hydrology: fluxes and residence times

\[ b: \text{Retention and losses in the soil and groundwater} \]

\[ a: \text{Retention and losses in the river network} \]

\[ L_x \]
River load at location \( x \)

Submodels

1. Emissions
2. Hydrology
3. Soil and groundwater fluxes
4. Transport and retention in the river network
Implementation

Å PCRaster environmental modelling language (http://pcraster.geo.uu.nl)
  • Raster based GIS, suitable for distributed dynamic modelling → iterations in time
  • Easy to modify code → scripting
  • Easy to replace/update
    - Maps
    - Series of maps
    - Tables with temporal data

Å Free
Å PCRaster Python library for advanced GIS functionality and coupling with other models/GIS systems
Diffuse sources
Diffuse sources

Datasets:

- Livestock data per province:
  - Number of animals
    - Excretion factors (Cattle = 43 kg/yr vs humans = 3.5 kg/yr)

- Crop data per province:
  - Crop yield
  - Crop factor
  - Atmospheric deposition
    - People not connected to WWTP: from point sources module

Agricultural data (livestock & crops) allocated on agricultural land-use using land-use map
Diffuse sources

Outputs:
Total emission from diffuse sources ($SSS_x$ [kg/year])
Point sources

- $SSS_x$: Soil Surface Surplus: Diffuse sources
- $DI_x$: Direct Inputs: Point sources

Hydrology: fluxes and residence times

- $b$: Retention and losses in the soil and groundwater
- $a$: Retention and losses in the river network

Submodels

1. Emissions
2. Hydrology
3. Soil and groundwater fluxes
4. Transport and retention in the river network

$L_x$: River load at location $x$
Point sources

Datasets:

- Direct emissions from WWTPs
  - Location of WWTPs
  - Connected people and industry
  - Efficiency of pollutant removal
  - Start year of WWTPs

- Direct emissions from industry
  - Location of not connected industry

Land use map 2000
Population density map 2000
Hydrology

\[ SSS_x \]
Soil Surface Surplus: Diffuse sources

\[ DI_x \]
Direct Inputs: Point sources

Hydrology: fluxes and residence times

Diffuse inputs into surface water

\[ b: \text{Retention and losses in the soil and groundwater} \]

\[ a: \text{Retention and losses in the river network} \]

\[ L_x \]
River load at location x

Submodels

1. Emissions
2. Hydrology
3. Soil and groundwater fluxes
4. Transport and retention in the river network
Hydrology

- Evapotranspiration is a function of:
  - Average year temperature
  - Precipitation

- Fractioning of net rainfall in three components function of:
  - Soil type
  - Slope
  - Hydrogeology (conductivity and porosity parameters)
  - Land cover
Hydrology

Average year temperature

[°C]

Total year precipitation

[mm]

Soil Map

Land-use Map
Hydrology

Calculation of discharge:

(DEM = digital elevation map)
Soil & groundwater fluxes

**Submodels**

1. Emissions
2. Hydrology
3. Soil and groundwater fluxes
4. Transport and retention in the river network

**Symbols and Equations**

- $SSS_x$: Soil Surface Surplus: Diffuse sources
- $DI_x$: Direct Inputs: Point sources
- $L_x$: River load at location $x$

**Flows**

- $b$: Retention and losses in the soil and groundwater
- $a$: Retention and losses in the river network

**Diagram Description**

- The diagram illustrates the flow of soil and groundwater fluxes, starting with emissions and hydrology, then focusing on soil and groundwater fluxes, and finally considering transport and retention in the river network.
Results

Contribution of Provinces to N load at Rupelmonde

- Antwerpen, 5%
- Limburg (B), 12%
- Oost-Vlaanderen, 25%
- Vlaams Brabant, 13%
- West-Vlaanderen, 13%
- Hainaut, 19%
- Namur, 1%
- Picardie, 0%
- Brabant Wallon, 6%
- Nord - Pas-de-Calais, 6%

Contribution of Regions to N load at Rupelmonde

- WALLONIA, 26%
- FLANDERS, 68%
- PICARDIE, 0%
- NORD PAS-DE-CALAIS, 6%
Conclusions

• The GIS-based model enables us to
  • easily update maps and tables
  • easily perform scenario analysis (e.g. implementation of measures, climate scenarios)

• The modular setup of the model enables us to easily replace or add modules in order to
  • add more spatial/temporal detail
  • model other pollutants (nutrients, pesticides, heavy metals,...)
NEW DEVELOPMENTS: SENSORS

Gretchen Gettel
New Developments

Open Source Sensor Design
Example: [www.publiclaboratory.org](http://www.publiclaboratory.org)

New Sensor technology developed for oceanic systems is increasingly applied to freshwater systems, especially in Great Lakes, but also in river systems.
Water Quality Sensor

Developed during the Water Hackathon on March 22-25 in New York City, the water quality sensor is a multipurpose tool for collecting data remotely. This tool is rapidly changing and is being used as part of the on-going research initiative called Don'tFlushMe.

This tool consists of an Arduino microcontroller, a set of water quality sensors, and a network.
Publish open-source plans to build your own water quality devices from devices purchased in electronic supply shops.
New Sensor technology: Satlantic NO₃ Sensor

http://satlantic.com/

What are the characteristics of a NO₃ sensor?
What kind of applications is this appropriate for?
Example: Satlantic NO₃ Sensor

**Accuracy:** ± 2 εM (0.028 mg/l) or ± 10% of reading, whichever is greater

**Detection range:** 0.5 to 2000 εM *(0.007 to 28 mg/l-N)

**Applications:**
- Long term nitrate monitoring
- Water quality assessment in estuaries and coastal environments
- Freshwater nutrient loading studies
- Watershed TMDL assessment
- Phytoplankton bloom prediction
- Wastewater monitoring
Example: Satlantic Biological Optical Sensor (BOSS)

Å Chlorophyll a by fluorescence
Å Optical properties of DOM (Fluorescence, Absorbance)

\textbf{trp} w Tryptophan
\textbf{tyr} y Tyrosin
Sensors are deployed on buoys or sondes
Telemetry or real-time data from remote sensors
Great Bay, New Hampshire (USA) \(\overset{\text{ï}}{\text{ï}}\) Under threat of eutrophication
Telemetry or real-time data from remote sensors

http://www.cooa.unh.edu/data/buoys/great_bay/
Other variables

Dissolved oxygen
Conductivity
pH
Temperature
MOBILE PHONES AND PUBLIC PARTICIPATION FOR DATA COLLECTION

Leonardo Alfonso
Motivation

- Mobile phones are promising devices for data collection
- Possibility to transfer data by different means (Cellular networks, Internet, infrared, radio, television, fax)
- Possibility to transfer data in a variety of formats (text, photo, video, sound)
- Positive experiences of public participation in monitoring (e.g., Au et al. 2000; Bromenshenk and Preston 1986; Stokes et al. 1990)
- Public awareness on environmental issues
- Improvement of collaboration among all stakeholders
- Cost effectiveness of data collection activities
- High coverage in space and time.
Data collection during an extreme event is difficult → Considerable amount of data is missed
Models cannot be calibrated and validated for the extreme conditions
FIELD EXPERIMENT

Objective: Pros and cons of public participation in monitoring with mobile phones.

Experiment run in four stages:

- Platform preparation, field gauge labeling
- Pilot test with students
- One-day experiment in the city of Pijnacker (NL) and nearby areas
- One-month experiment with residents
Gauge labelling

Before

After
Stage 1

• Pilot test with Hydroinformatics students at UNESCO-IHE
• To test platform robustness
  - Simultaneous incoming SMS (text)
  - Simultaneous website visits
• Result: Good performance; some mobile operators unable to send SMS: Lebara, Lycamobile. Not possible to use web-based SMS like Skype
Stage 2

A 1-day experiment in Pijnacker region
A Mainly students willing to participate

A Results: Expected random errors from reading, especially because of the different scales of the gauges
Stage 2

(a)  
(b)  
(c)
Mobile-Terminated SMS

SMS sent on 14-07-10 15:35

SMS sent on 17-07-10 09:40

SMS sent on 22-07-10 15:50

“Rainfall event expected, could you please read the closest gauge and send SMS?”
Rainfall event is coming, the experiment starts.

A water level value of -1.0 is read at gauge 3 (for instance).

Send an SMS with the text -1.0 3 to the number 4915705000052.

Data is processed at UNESCO-IHE.

Information is analyzed in the field.

Up-to-date water level graph at each location.

Information is analyzed in the office.

Gauge locations in Google Maps.
Conclusions, future work

- Combination between public participation and mobile phones is promising in validating models.
- A second source of information is needed for validation of public SMS, e.g., pictures taken with mobile phones.
- Other applications, like colorimetric analysis (see Unit 6; colour intensity $\rightarrow$ concentration; app for reading off?)
- Can you think of other applications?