# Mining co-variation patterns from ecological data: a process to aid the construction and validation of computer models

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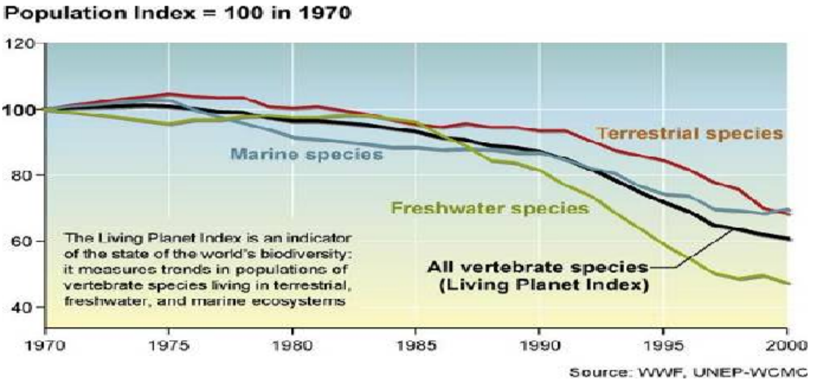
CompSust'2012, Copenhagen

- Fresh waters represent 0.8% of planetary area
  . . . and 2.4% of known species (highest relative richness)
- Most impacted by biodiversity loss



## The Dombes

- Clayey shelf North of Lyon, France
- 1000 $km^2$ with 120 $km^2$ of ponds managed by man since Middle Ages
  - Thousands of ponds
  - Period of drought: pond are emptied for cereal culture (every 4-5 years)
  - Period of water: pond are filled for fish breeding
- Great stock of biodiversity

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## Clear state

- Clear water
- Abundant and diversified sub-aquatic vegetation
- No eutrophication
- Few phytoplankton

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## Turbid state

- Turbid water
- Loss of biodiversity
- Few sub-aquatic vegetation
- Strong eutrophication
- A lot of phytoplankton

# Widespread process

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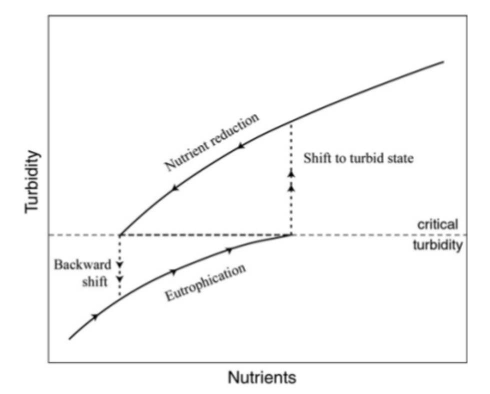
# Hysteresis phenomenon

## How to anticipate the state switch?

We seek to keep ponds clear, but the changing of state is not progressive ; it is violent and hard to anticipate: there are **alternative equilibriums**



# Distinctive features

## Main characteristics

- Complex and complicated ecosystem
- Agricultural exploitation
- Piscicultural exploitation
- Spatiotemporal-temporal dispersion (pond connectivity, seed dispersions, etc.)
- Injection of pollutants (linked to human activities)

## Which questions?

- Climate change impact on biodiversity?
- Local human activities impact on biodiversity?
- How to ensure continuity of ecosystems "services"?
  - Which local private management practices?
  - Which global public practices?

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Compute optimal management practices to reduce algal blooms

- Conserve/restore biodiversity
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- Choices of fish species and fish densities
- Supplementary feeding
- Position in pond network
- Type of cultures
- Rhythm of drought
- Fertilization, liming, permaculture. . .

# Available data

## Data difficult to obtain

- Anthropic constraints (reluctant landowners)
- Few measurement campaigns (financial cost)
- Noisy data
- Long process

# Available data

**Phytoplankton communities**

**Vegetation communities**

**Propagule communities**

# Available data

## Phytoplankton communities

- Collect water samples

## Vegetation communities

## Propagule communities

# Available data

## Phytoplankton communities

- Collect water samples
- Count specimen under microscope

## Vegetation communities

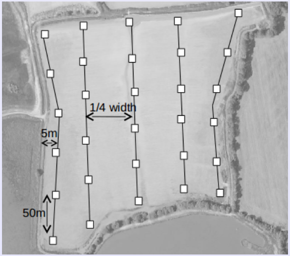
## Propagule communities

# Available data

## Phytoplankton communities

## Vegetation communities

- Define the boundaries of quadras




## Propagule communities

# Available data

## Phytoplankton communities

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- Define the boundaries of quadras
- Collect plant samples

## Propagule communities

# Available data

## Phytoplankton communities

## Vegetation communities

- Define the boundaries of quadras
- Collect plant samples
- Identify plant characteristics

## Propagule communities

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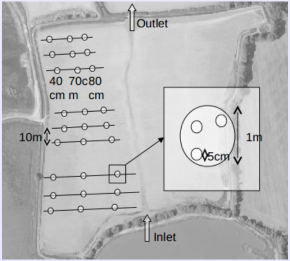
- Define propagule context



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# Raw data

- 154 parameters for 90 ponds
- Near-monthly basis from 2009 to 2011, and more is coming
  - Architecture of the pond and management policies
    - Surface
    - Geographical position and links with neighbouring ponds
    - Fishing and agricultural data
  - Established lake vegetation
    - 55 samples species
    - Floating VS submerged
  - Several chemical levels
    - Nitrogen
    - Nitrate compounds
    - Carbon compounds
    - Ionic activity
  - 94 genera of bacteria and algae belonging to 7 families

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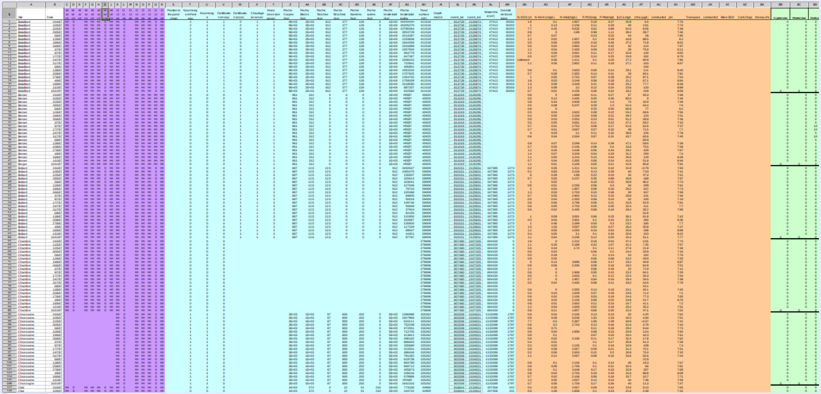

Use data mining techniques to identify important relationships in the data that could guide modeling and data gathering process

- Database of at most 154 attributes per measure
- No discretization of data

# Co-variation patterns

Use data mining techniques to identify important relationships in the data that could guide modeling and data gathering process

- Database of at most 154 attributes per measure
- No discretization of data
- Ability to combine numerical and categorical attributes
- Find all frequent patterns

# Co-variation patterns

Identify sets of numerical attributes that behave similarly (with **itemset mining** [Prado et al. EGC'2012]):

1. Records are sorted w.r.t every attributes $\rightsquigarrow$ index ranking
2. For all sets of attributes we compute the ratio of the number of pairs of records (among all possible pairs) for which all attributes in the set have the ranking index in the first record significantly different than in the second one $\rightsquigarrow$ correlation ratio
3. High ratio implies that attributes in the set behave similarly $\rightsquigarrow$ potentially interesting covariation patterns
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# Results

## Examples of covariation patterns

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[P-Ptot(mg/L)[c]+, CHLOROPHYTES-] 0.52
[N-Ntot(mg/L)+, P-Ptot(mg/L)[c]+, chl.a+] 0.55731
[N-Ntot(mg/L)+, chl.a+, DINOPHYCEES+, CHLOROPHYTES-] 0.50988
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**Warning**

These are **not** rules . . . yet.

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We can consider all the ponds together (global behaviour)
. . . or specific ponds (local behaviour)
. . . or specific attributes (ecologically pertinent questions)

# Going further

How to build a global view of covariation networks?

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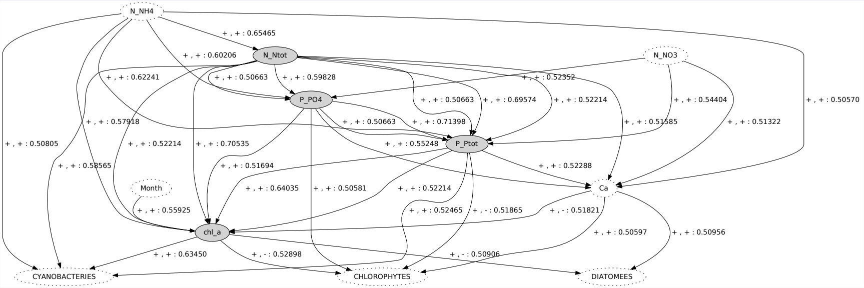

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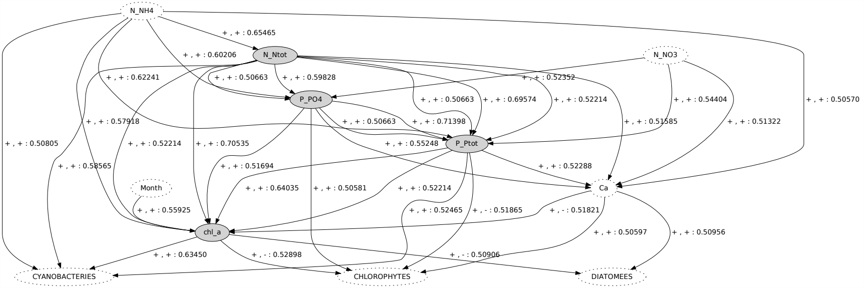


- Identify pertinent attributes (e.g. all the chemicals that are positively correlated to an increase of Chlorophyll-A)
- Identify ecological relationships (e.g. during the periods when Cyanobacteria increase, how do the Euglenophytes behave?)
- Locate feedback loops
- Help building a computer model to explore a precise behaviour of the system

# Examples

- Nitrogen and Phosphorus are positively linked in all ponds
- Nitrogen and Nitrates are negatively linked in most of the ponds
- The “Épansardières” pond is the most representative
- The “Aubergères” pond is the most singular
- Floating and submerged plants behave differently and are very representative of global pond state
- Green and blue algae behave differently and are very representative of pond states

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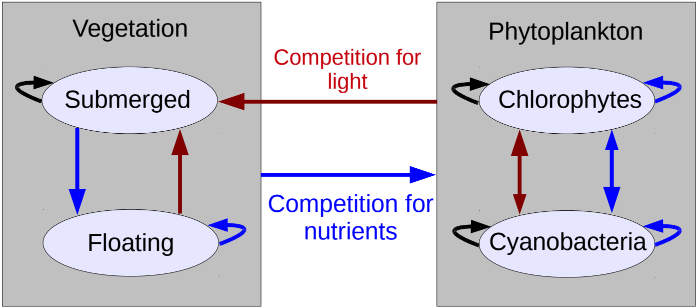
## Vegetation

- **Floating:**
  - Leaves spread atop the surface
  - Very competitive for light
  - Less competitive for nutrients
- **Submerged:**
  - Less competitive for light
  - Very competitive for nutrients

## Phytoplankton

- **Chlorophytes (green algae):**
  - Faster reproduction
  - Less competitive for light
- **Cyanobacteria (blue algae):**
  - More competitive for light
  - Strong effect on water turbidity


Vegetation
Submerged
Floating
Competition for light
Competition for nutrients
Phytoplankton
Chlorophytes
Cyanobacteria

## Equations

| Variation of population concentration | = | × | × | - |
|---|---|---|---|---|
| $\frac{dS}{dt}$ | = | × | × | - |
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| $\frac{dG}{dt}$ | = | × | × | - |
| $\frac{dB}{dt}$ | = | × | × | - |

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- Progressive change in nutrient disponibility $\rightsquigarrow$ brutal shift of equilibrium
- Progressive increasing of available nutrients (N) (e.g. from 0 to 10 $mg.L^{-1}$ with 0.01 steps)
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  - Advantage to submerged plants and chlorophytes
  - Clear state
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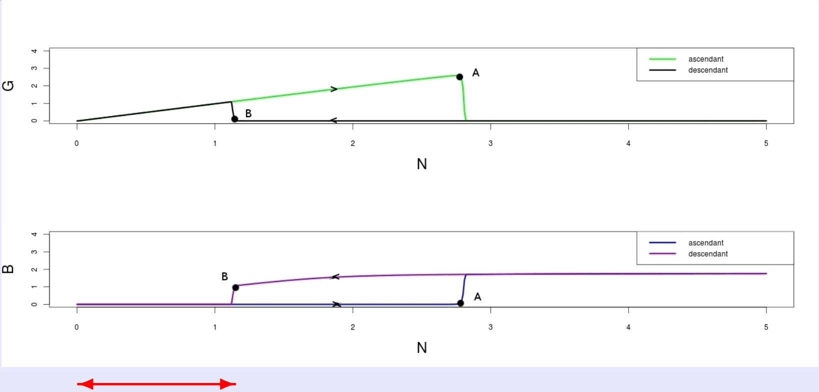
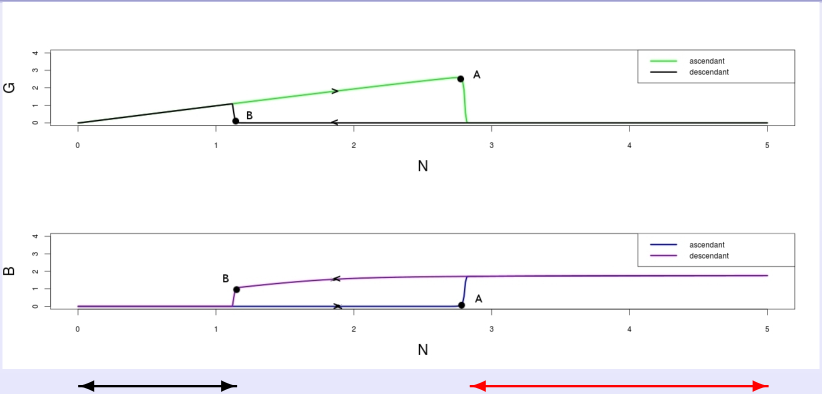


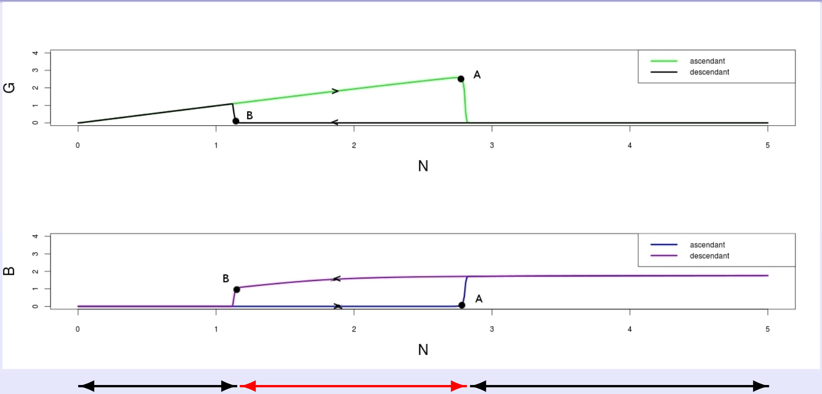

## Phytoplankton dynamics

- Values of N before point B: chlorophytes dominance



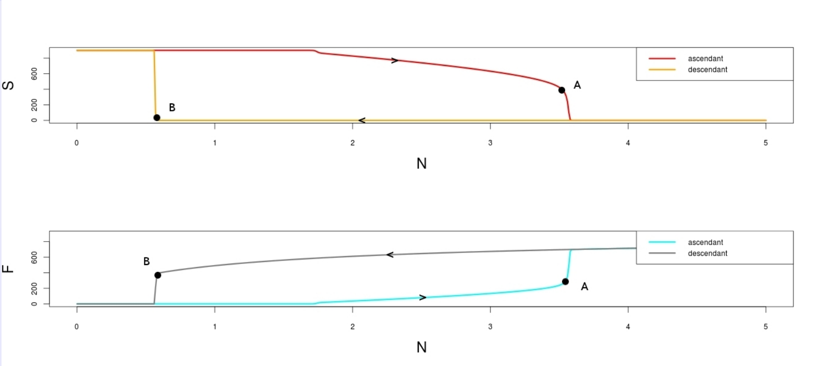

## Phytoplankton dynamics

- Values of N after point A: cyanobacteria dominance



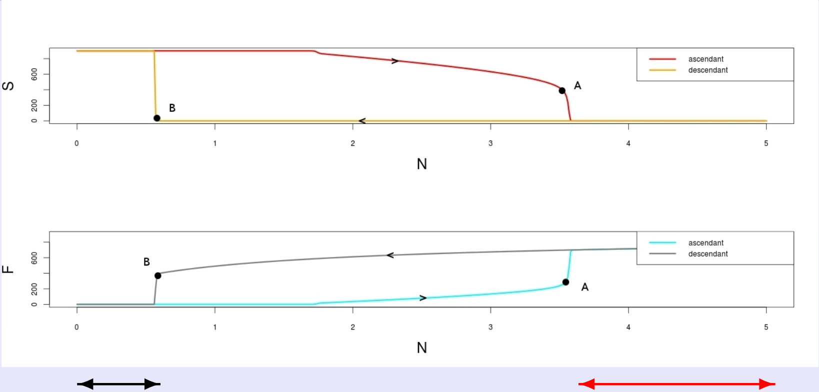

## Phytoplankton dynamics

- Between A and B: two stable states depending on earlier system state



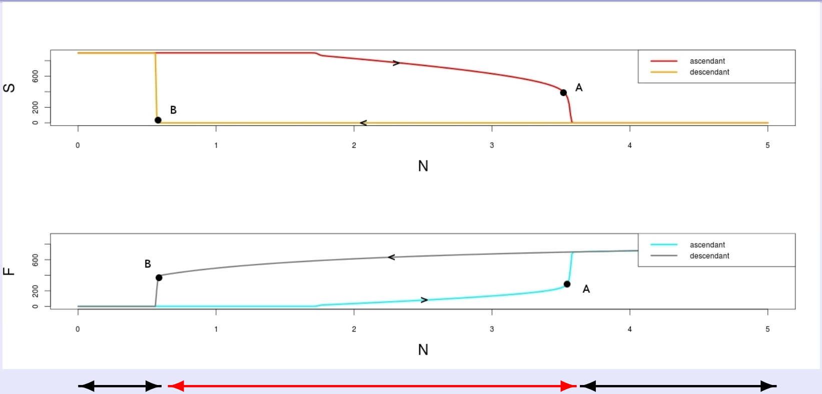

## Vegetation dynamics

- Values of N before point B: submerged plants dominance




## Vegetation dynamics

- Values of N after point A: floating plants dominance

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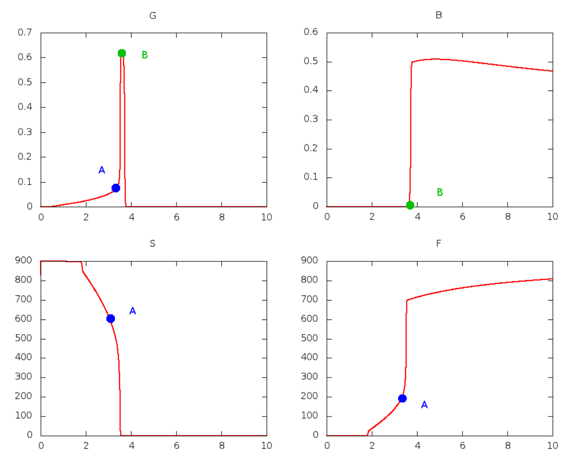
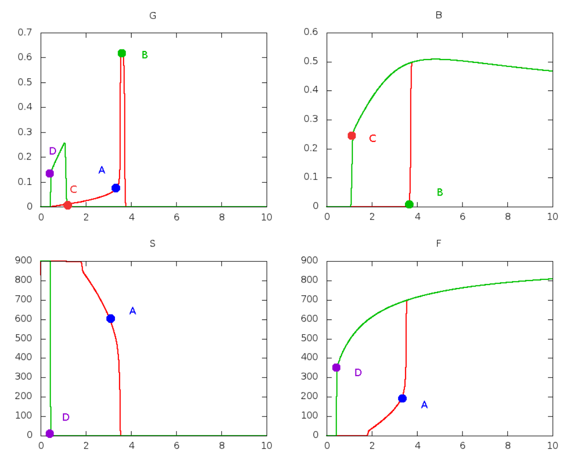


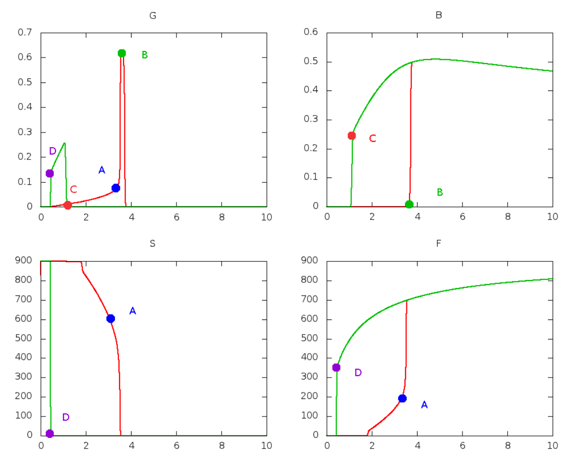

## Dynamics of complete model

Increasing of available nutrients N.



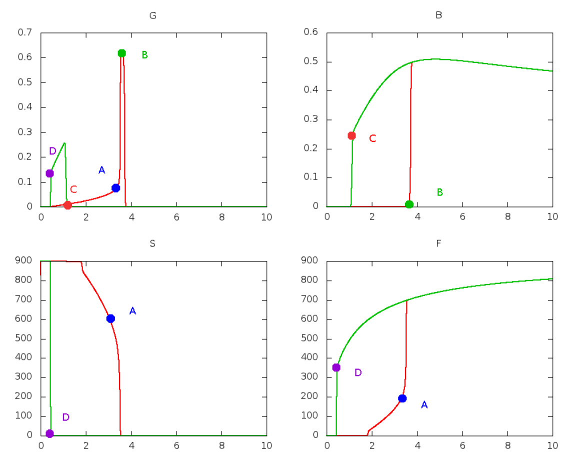

## Dynamics of complete model

Decreasing of available nutrients N.



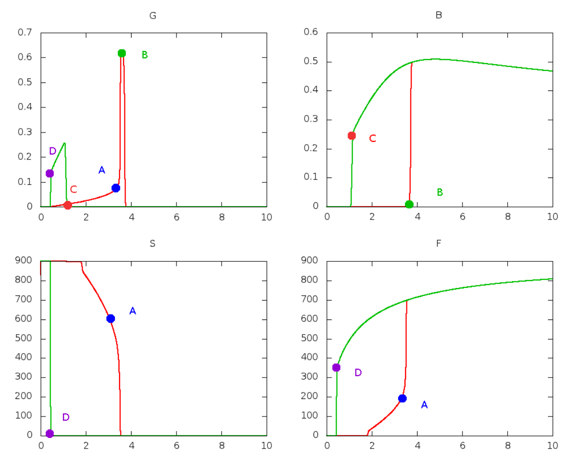

## Dynamics of complete model

**Before point D:** only one equilibrium where submerged plants and chlorophytes dominate



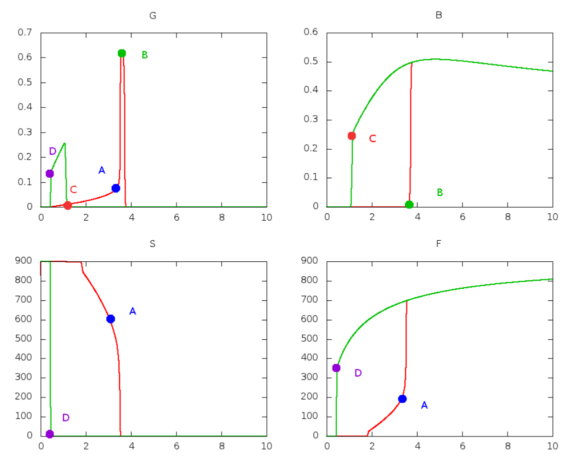

## Dynamics of complete model

**After point B:** only one equilibrium where floating plants and cyanobacteria dominate




## Dynamics of complete model

**Between C and A:** these two equilibriums coexist




## Dynamics of complete model

**Between D and C and between A and B:** third equilibrium where floating plants and chlorophytes dominate

## Assessment

- Alternative equilibriums
- Clear state with submerged plants and chlorophytes for low values of N
- Turbid state with floating plants and cyanobacteria for high values of N
- Third stable state with floating plants and chlorophytes
- Resistance of the submerged plants to the high depth (surprise!)
- Important effect of depth and spatial diffusion

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## Prospects

- Parameterize the model wrt. pond data (iRace, dedicated measurements occurring right now. . . )
- Incorporate more parameters into the model
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- Consider the effect of regular drainings
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Thank you for your attention!