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Modelling salinity exchange between drinking water ponds and groundwater in southern Bangladesh

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INTRODUCTION AND CONTEXT

The coastal region of southern Bangladesh is often subjected to tropical cyclones arriving from the Bay of Bengal, which bring in large quantities of sea water. As most coastal communities rely on drinking water ponds that do not have a barrier system, this incoming seawater greatly affects the drinking water quality and so the health of the community.

OBJECTIVES

• Create two Lagrangian models for salt transport, one describing dispersion as normally distributed, one describing it as lognormally distributed

• Compare these models to the advection-dispersion equation

• Understand how the models describe situations where advection acts against molecular diffusion

• Acquire preliminary values of soil and water parameters through calibration

POND-GROUNDWATER LAYOUT

• Pond of seasonally varying depth overlying silty, homogeneous soil with seasonally varying groundwater levels
• Measurements recorded of changes in pond level and fluctuations in hydraulic head at points A and B
• Measurements recorded of concentration in the pond and at points A and B
• A nearby river was recorded breaking its banks and entering the pond, bringing in additional salt particles
• Differences in diffusion between soil and pond were accounted for by considering retardation and tortuosity
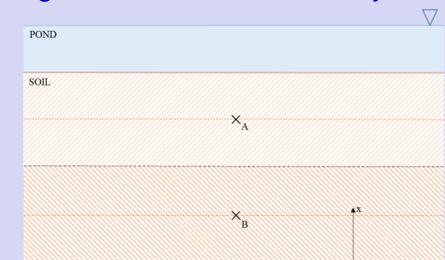

LOGNORMAL LAGRANGIAN MODEL

• Molecular diffusion acts according to a normal distribution
• Mechanical dispersion acts according to a lognormal distribution around the mean advective flux
• Not possible for a particle to disperse against the mean advection
• Less computationally intensive
• Better fit overall, especially to the pond concentration
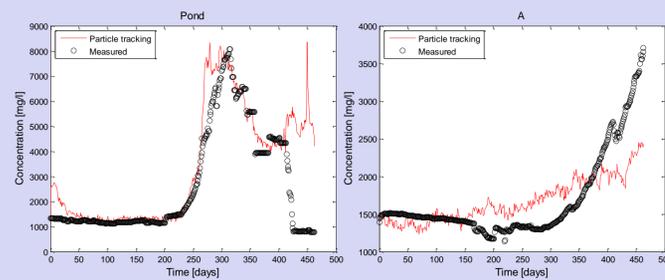
NORMAL LAGRANGIAN MODEL

• Molecular diffusion acts according to a normal distribution
• Mechanical dispersion also acts according to a normal distribution around the mean advective flux
• This means for low velocities and high standard deviations particles can disperse against advection
• More computationally intensive
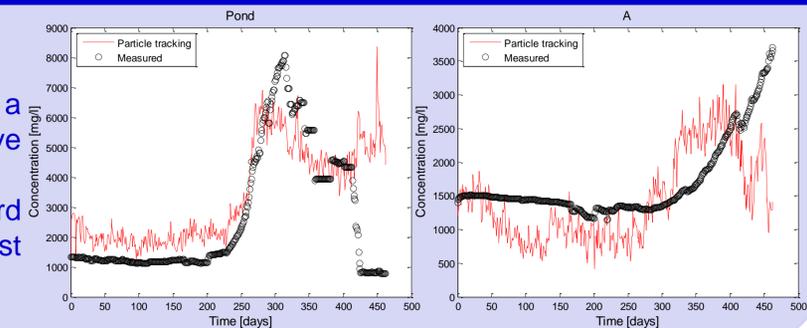
ADVECTION-DISPERSION EQUATION

One-dimensional Eulerian description of fluid flow is given by the advection-dispersion equation:

$$\frac{dC}{dt} = D\frac{d^2C}{dx^2} - U\frac{dC}{dx}$$

Where D is the coefficient of hydrodynamic dispersion, U is the velocity, C is the concentration and x the spatial ordinate.
This was solved using explicit Euler difference methods, and input into MATLAB using ode15s. The solution was obtained for a simple single strata system and the two strata system shown above right
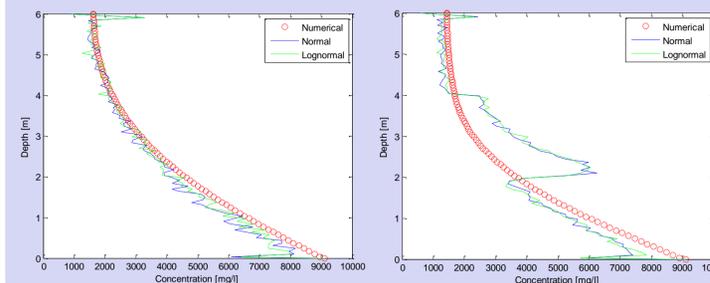
CONCLUSIONS

• In the absence of incoming river water, the Lagrangian models fit the Eulerian description, apart from concentration accumulation at a stratum boundary
• It seemed both Lagrangian models could fit the data if calibration were to be continued
• Normal models can account for movement against advection using either diffusion or dispersion. Lognormal models can only use diffusion – these models are correspondingly very sensitive to diffusion but insensitive to dispersion
• Diffusion coefficients in the pond ranged from 5e-3m^2/d to 1e-2 m^2/d. These larger values are due to the incorporation of turbulence
• The diffusion coefficients for the soil ranged from 5e-4m^2/d to 7e-3m^2/d, as scaled from the pond diffusion

REFERENCES

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