

Forward Modelling 3D Sedimentation over Geological Time

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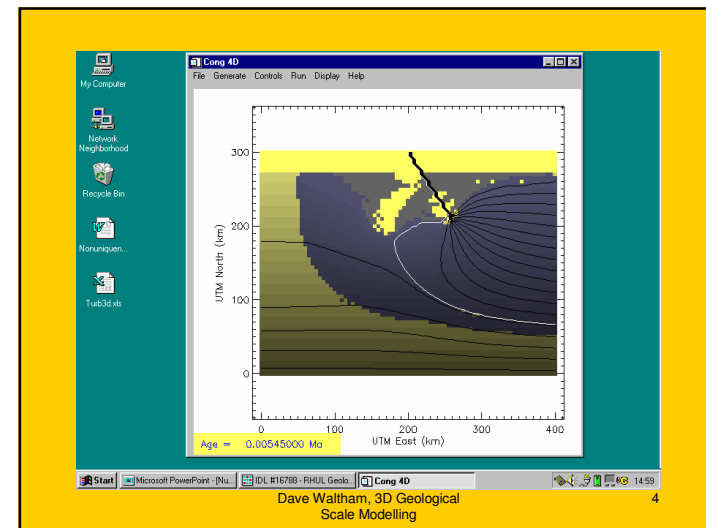
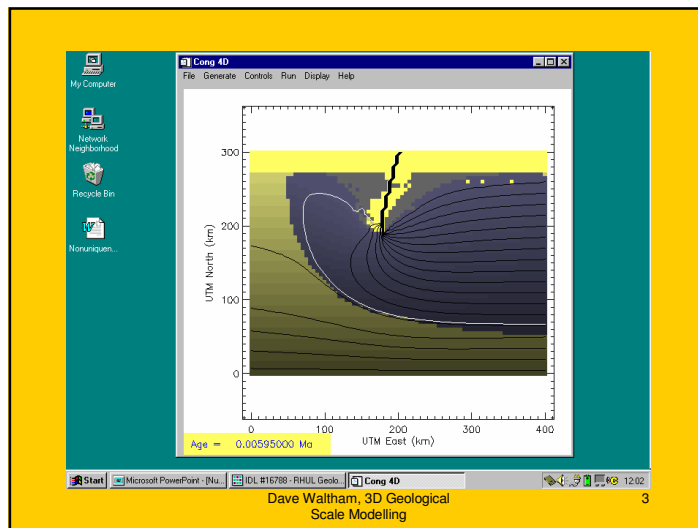
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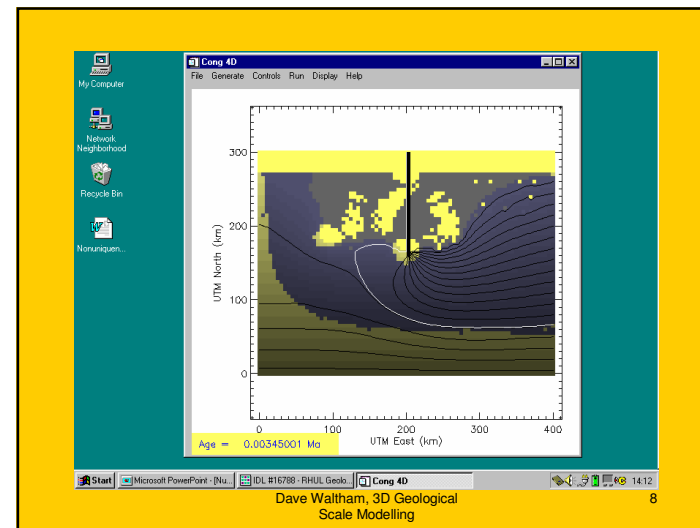
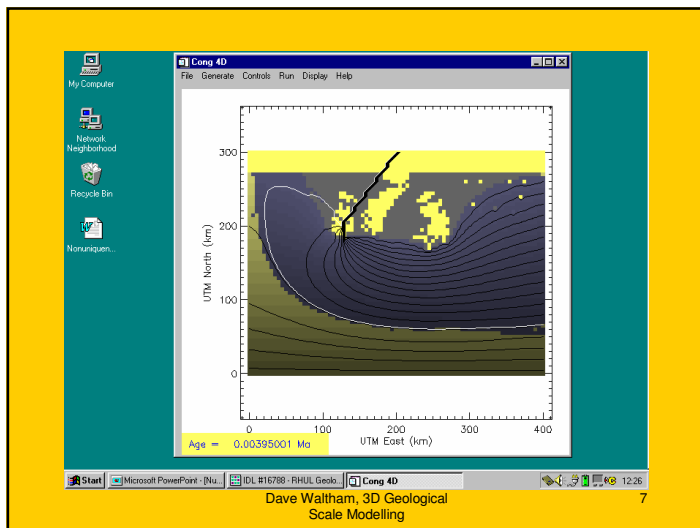
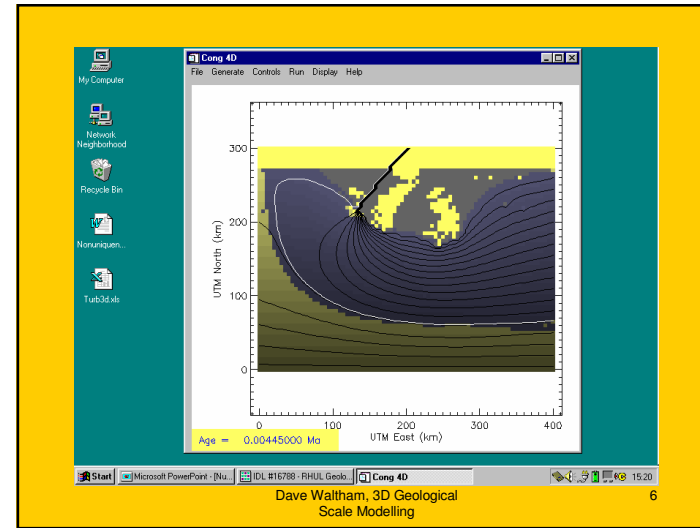
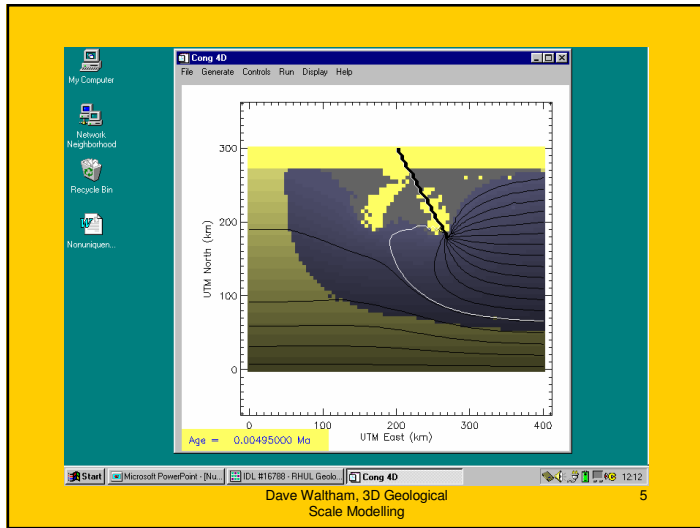
Modelling Example

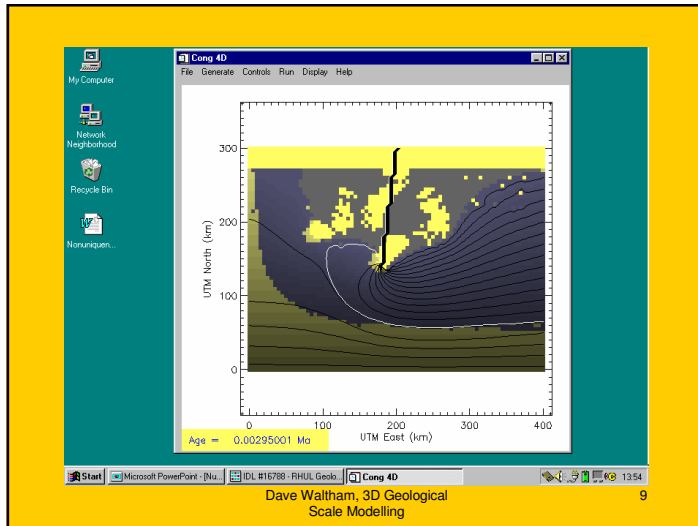
- Lobe switching of a prograding delta.
- Model has:-
 - 2 sediment grain sizes
 - Interacting fluvial and marine currents
 - Time varying sea level and sediment supply

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Scale Modelling

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Algorithm Requirements

- Typical model produces around 1000 surfaces at 1000 year intervals.
- Horizontal scales are typically 10s of km.
- Many parameters are unknown and must be inverted for.
- Geologists don't generally have access to supercomputers.

Algorithm Requirements

- Hence, model must be:-
 - Fast
 - Robust
 - Accurate
- Model should simulate:-
 - Sea floor shear stresses due to waves, currents and slopes.
 - Resultant bedload and suspended load transport and deposition.

Algorithm Requirements

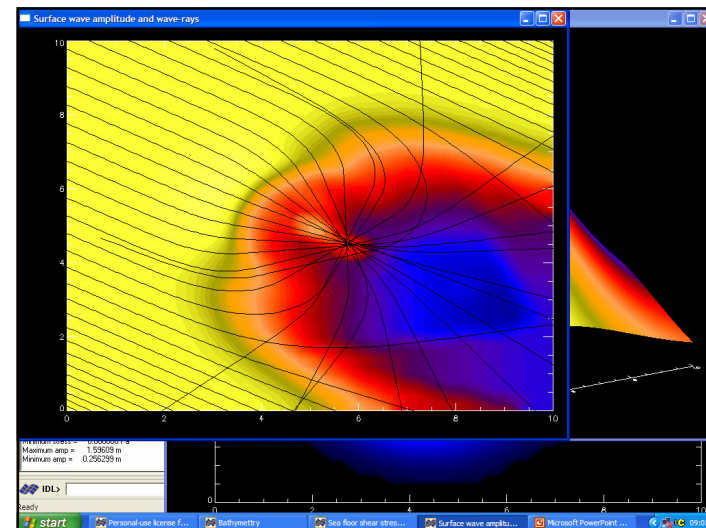
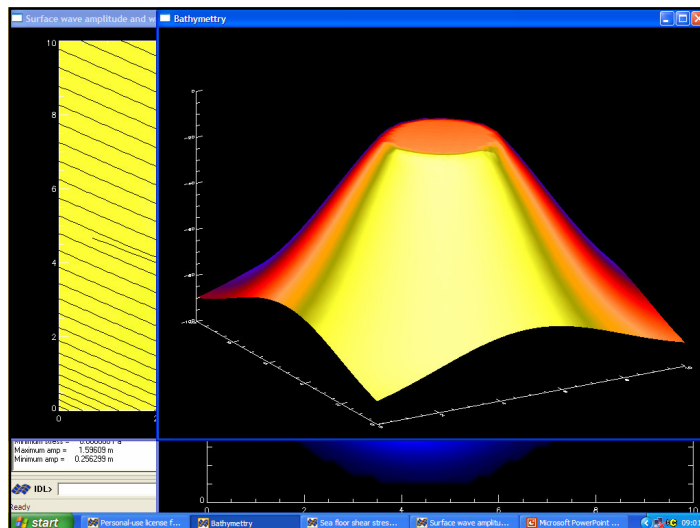
- Hence, lots of simplifications have to be made.
- Have we cut so many corners that the models have become useless?
- Are there useful approaches, well known to Oceanographers, of which the Geological modelling community are ignorant?

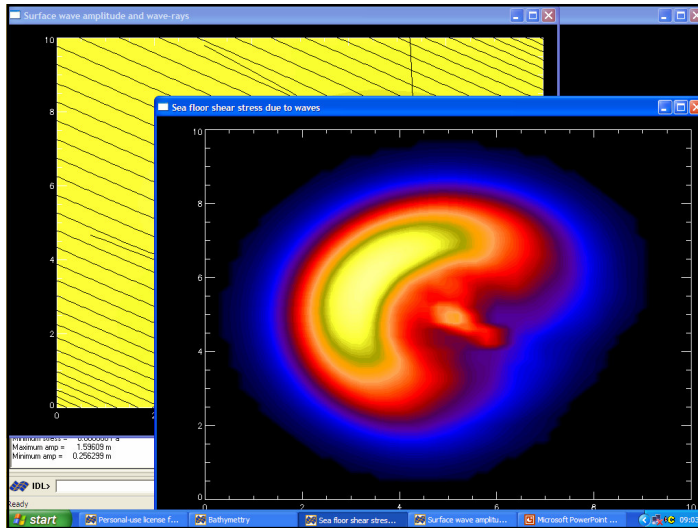
Waves

- Fetch limited fully developed sea
- Hence, in deep water,
 - wave period, $T = 0.729U = 2\pi/\omega$
 - wave amplitude, $A = 0.0151U^2$
- In shallow water, period remains fixed but the wave amplitude is calculated using linear wave theory and ray tracing.

Waves

- Neglects
 - existence of a full wave spectrum
 - existence of multiple wind directions and strengths during typical 1ky time step
 - enhanced erosion during wave breaking





Currents

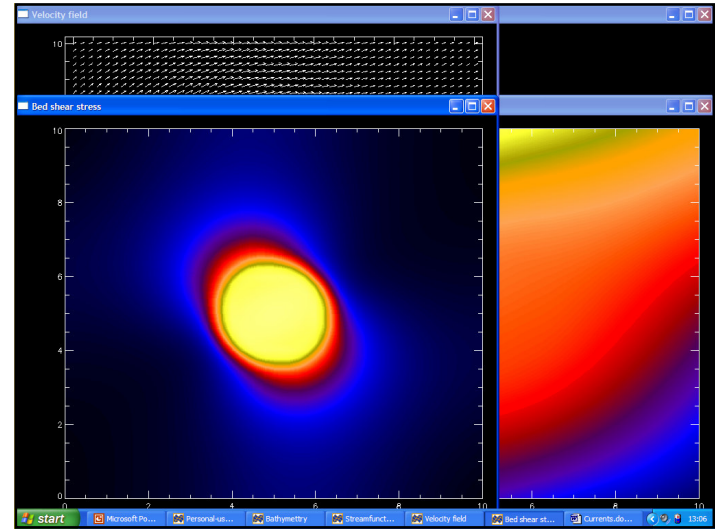
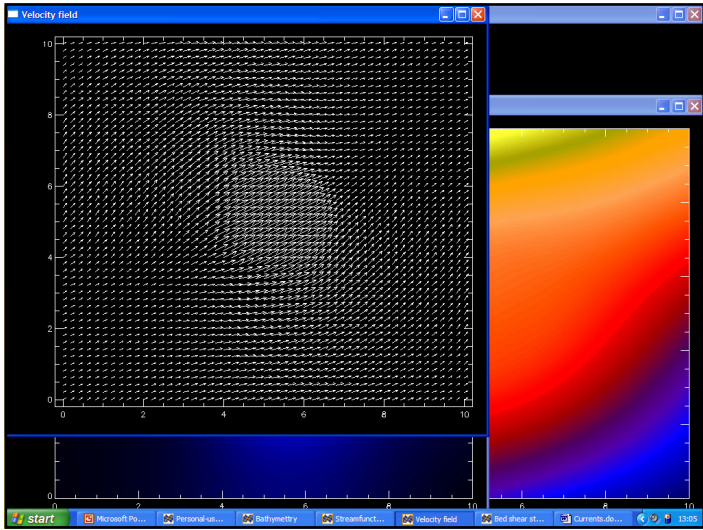
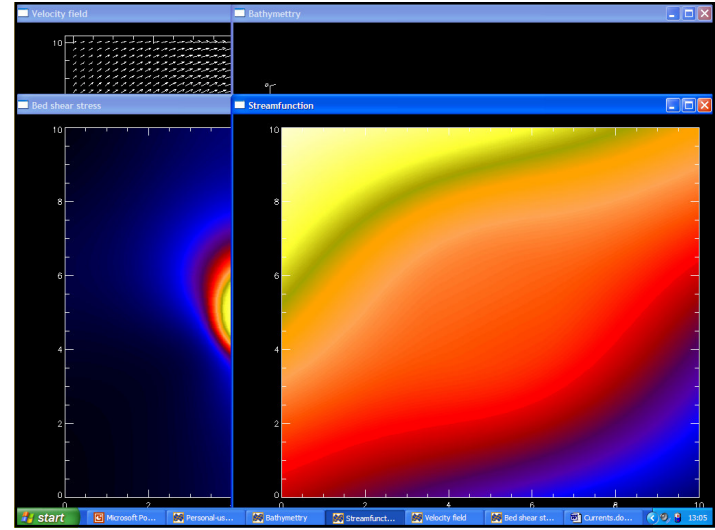
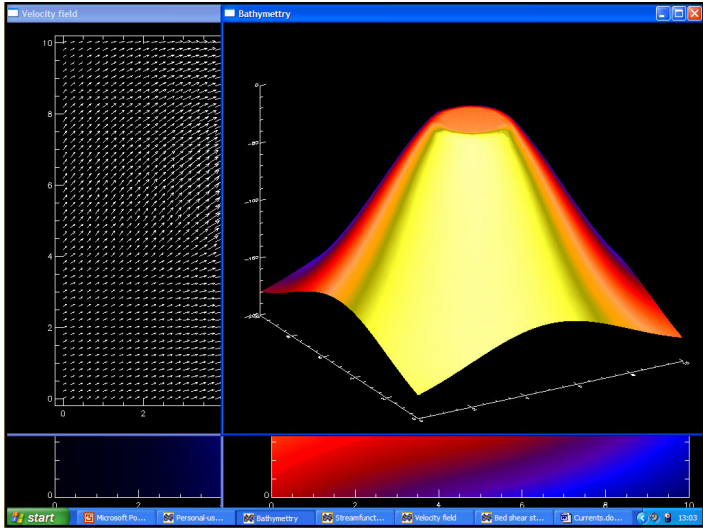
- In 2d flows (e.g. flow around a wing cross-section) the potential flow assumption is often used (i.e. $\nabla \cdot \mathbf{v} = 0$ and $\nabla \times \mathbf{v} = 0$).
- A naïve implementation of the same algorithm for depth-variable 2d flows (i.e. $\nabla \cdot \mathbf{z}\mathbf{v} = 0$ and $\nabla \times \mathbf{v} = 0$) gives incorrect results (e.g. very high flow rates over shallow platforms).
- However, 2d potential flow has property of minimizing total kinetic energy and this idea can be generalized.

Currents

- Hence minimize $K = (\rho/2) \int_V U^2 dV$
- Assume the law of the wall
 $U = (u^* / \kappa) \ln(h/z_o)$
- Shear stress from $\tau = \rho u^{*2}$
- Calculus of variations gives
 $\nabla \cdot (\alpha \nabla \psi) = 0$
where $\alpha = \alpha(z)$ and ψ is the streamfunction.

Currents

- Neglects
 - depth variable direction to flow
 - thermohaline effects
 - Coriolis forces



Final Comments

- We have algorithms for modelling long-term evolution of the sea floor under the influence of currents and waves.
- Comparison to the Cocos Islands is underway at University of Bristol (Smart & Whittaker).
- Are the models any good?
- Are we missing some well known tricks?