The Physics & Models of Sediment Budgets in Estuaries
Carl Amos (name means "sand")

Rapporteur: Scott Peckham

models vs. time and space scale
   examples: SEDTRANS, PONTOS, SEDFLUX
   bottom-up and top-down models

SEDTRANS is a bottom-up model (physics-based)

advantages: creation of hypotheses, formulation of scientific questions

SEDTRANS similar to DELFT-3D, Mike21
understanding fundamental processes and algorithms

sediment continuity (budget, balance) is key first step (box models)

disadvantages: Labor intensive, difficult to calibrate, difficult to program

Best method: direct measurements + numerical/physical sim. + "experience"
Experience is the most important, fundamental thing
Boundary conditions are the biggest problem in modeling
Calibration & verification requres detailed synaptic scale data.

Exner equation
need particle settling rate, benthic flux, etc.
can measure each of these terms fairly well and then parameterize
Biggest unknown is what is coming in or going out through the open boundary.
Bedload term (divergence = vertical flux from settling, etc. - b_t)

Definition of terms:
  Age, Transit time, Exposure time, Residence time (most important)
  Each feeds into trapping efficiency of the system.
  Western Sheldt, Belgium (Delft-3D) flood channel vs. ebb channel;
    they don't line up. Amplitude ratios and phase shift determines
    whether sed. transport is landward or seaward (esp. sand)
    M4/M2, M6/M2. Used to explain changes in time in different parts
    of the estuary.
    7 subcells can be defined in terms of the ebb and flood tides;
    different sediment transport in each subcell.

The open boundary problem. Very difficult (even for well-studied and
well-mixed system). Sensitivity analysis for flux rates through the
open boundary.

Illustration for Venice lagoon. Tidal data for mouth of the Grand Canal,
measured for a full year. (1909-1910 compared to 1972-1973)
M2, S2, N2, K2, K1, O1, P1
Overtides and flood vs. ebb dominance. Tidal component amplitudes change
over time (they're not time-invariant!)
10% increase in tidal range over 60 years.
Potential net export (sed. transport) went up by 20% just due to changes
in the tides (1973: 9.2e+4, 1910: 7.9e+4 m^3/yr). Does not take storms
and other effects into account. Actual (vs. potential) transport is not
known. Can compute analog to a Rouse parameter, 1/m.

Key dimensionless number (Ws/U*) can be computed via Bagnold theory & others.
Ws = still-water fall velocity
U* = critical friction velocity
D* = dimensionless grain diameter (van Rijn, 4; Bagnold, 8; Amos, 10)
0.38 (Lido) and 0.29 (Chioggia) (Measured from SSC profiles)
0.31 (Lido) and 0.23 (Chioggia) (Measured from samples)
vs. Bagnold 1966 1.25, van Rijn 2.5 ??

Can we accurately predict the transport pathways, etc. ?
Open boundary problem means we can't even determine filtering efficiency.

Simple answer is we can't balance the sediment budget (so we can't
properly specify boundary conditions).

Numerical modeling in Venice Lagoon. Calibrated for fines (soon sands also).
Shallow Water Finite Element Model (SHYFEM)
No wind, get no net transport in or out.
Two major storm patterns:
   bora wind (strong wind from NE?) no import
   sirocco wind (strong wind from SE, 7 m/s)
Important result: Residence time or filtering efficiency is
not constant in time or space.
Local belief is residence time is about 1 day (vs. 11 to 30 days w/ tide only)

Discussion:

Morten: Can the ebb and flood currents really cross at right angles?

Carl: Yes, this is well-documented in the literature.

??? Question about whether turbulence is properly represented and vertical dynamics.

Bob S.: Question about ???

James: Models are tweaked until they seem to work for each estuary.
Are models getting better?

Carl: Yes, definitely. Hydrodynamics and tides are very well-modeled now.
One area where improvement is needed is in modeling shallow-water waves.

Scott: Question about 3 inflows to Venice Lagoon and possibility of opening and closing them in dynamic response to conditions.
Carl: May work, but they don't want to close gates, due to appearances?

Morten: Are there too many models?

Eric W.: ??

Carl: Perhaps top-down and bottom-up modeling can be used together.

Bob: Model show-downs; need to get water part right first before sed. part.

Eric W. : What about bedform predictions?

Carl: Can't do this well yet. Processes not well understood.

James: They can do it on very small scales and idealized cases, but can't upscale them yet to larger-scale models. Large-scale models often "paint in" the bedforms.

James: Future is to use "coupling systems". CCA and ESMF.
ROMS, CCST, ADCIRC, etc.

Carl: Another problem is the benthic boundary layer.

Bob S.: A lot of the bedform work is being doing for fresh water. What about salt water.

Carl: Wave loading, bubble formation, etc. have explored fresh vs. saltwater effects. 1 micron size synthetic fibers in very low concentrations can reduce drag for 40 to 50% (in oil systems?) But not considered yet in modeling.

James: What about fluid muds?

Gerardo: Recent book on fluid muds. (Winterwerp)

Carl: That book is difficult to use; doesn't use Cartesian coordinates. Lots of tensors.

Eric W.: Very strong currents, 2-3 meter high bedforms. Sand with some mud, forms huge shoal (30 km long), 3-4 meter high , choked. Whole system is basically ponded (for 2 to 3 years). Series of about 30 sand waves all moving upriver with the tide. Modeling can't be used to get sand transport for these kinds of systems/events. Field data is required. Models have limits.

Carl: Go back to Emphasis Report (60 estuaries around coast of Britain) Models, yes, but GIGO. Know the system; someone with lots of experience. Lots of field verification. Certainly not turnkey.

Morten: I agree. No person can do it all by themselves. Everyone has their own area of expertise.

Gerardo: Fieldwork must be multidisciplinary.

Carl: Verification should not be done by modeler, but by those with experience.

Eric W.: Has prepared 5 slides to show the group. Comment to Carl: It is probably not the physics that is taking care of the sewage (in Venice Lagoon), but the biology.

Group should write a joint review paper. What did we bring that is new?
(Get his PowerPoint slides, simple summary given here.)
What makes an estuary change in time and what is the human impact?
1. Relative sea-level change (still not at a steady-state)
2. Change in sediment/water input from watershed.
   2.1 sediment starvation (from dams) These systems are infilling, because of sediment from the sea. e.g. Ord Estuary (Australia), Red River (Vietnam)
Key Questions:

Is it common for estuaries to flip from exporter to importer of sediment.
Role of river floods?
Infilling scenario, influence of biology on the net budget and flocculation?
  Movie of a little creature (zooplankton) "dismantling" a floc ?

James: 5 possible "models"
1. Do nothing.
2. Series of papers (for SCOR)
3. Write state-of-the-art review papers on assigned topics as a collection.
4. (Eric) Write a single review paper (w/ one "hero") and combine various "nuggets".
5. (Gerardo) A paper by some subset of the working group and report to SCOR, in addition to any of the other 4 models.

John M.: Time to finish a special issue is power function of number of papers. A lot easier to write one paper with a "hero". Only one paper was written in the past two years (by James).

James: What is everyone willing to do? Go around the room to each person (1 min).
Yoshi: Not one but several synthesis papers in special issue, regional case studies.
Carl: He agrees. Needs new information to advance the science.
Maria: Also agrees. Topics of the workshop are very clear, can synthesize.
??: Also agrees with special issue and chosen topics.
Eric W.: Single synthesis.
Bob S.: Same
Gerardo: Single paper or 2 or 3 synthesis papers to break up the topics.
Morten: Against special issue. One to 3 synthesis papers (at most 2?).
Pedro: Single, synth. paper, plus case studies
John M.: Same ??
James: Would be willing to contribute 2 pages to 1 synthesis paper (e.g. 2 pages on sea-level)
Final tally: 5 for a special issue, 5 for a single paper.