CMS-Flow: Background and Capabilities

Developed for coastal and inlet applications

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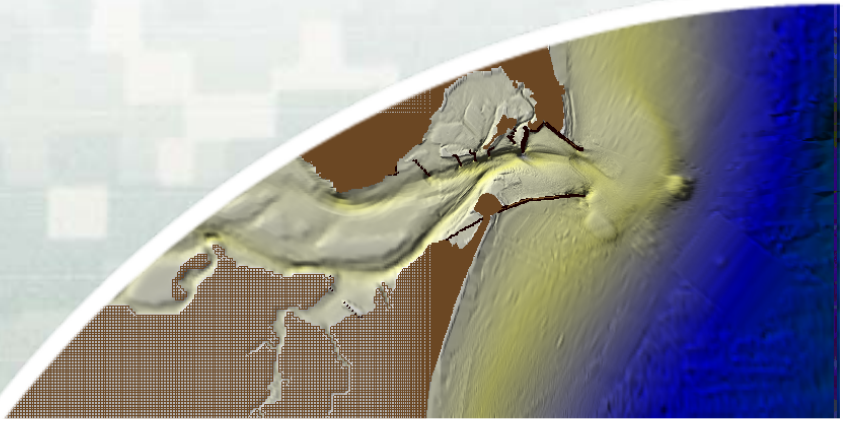

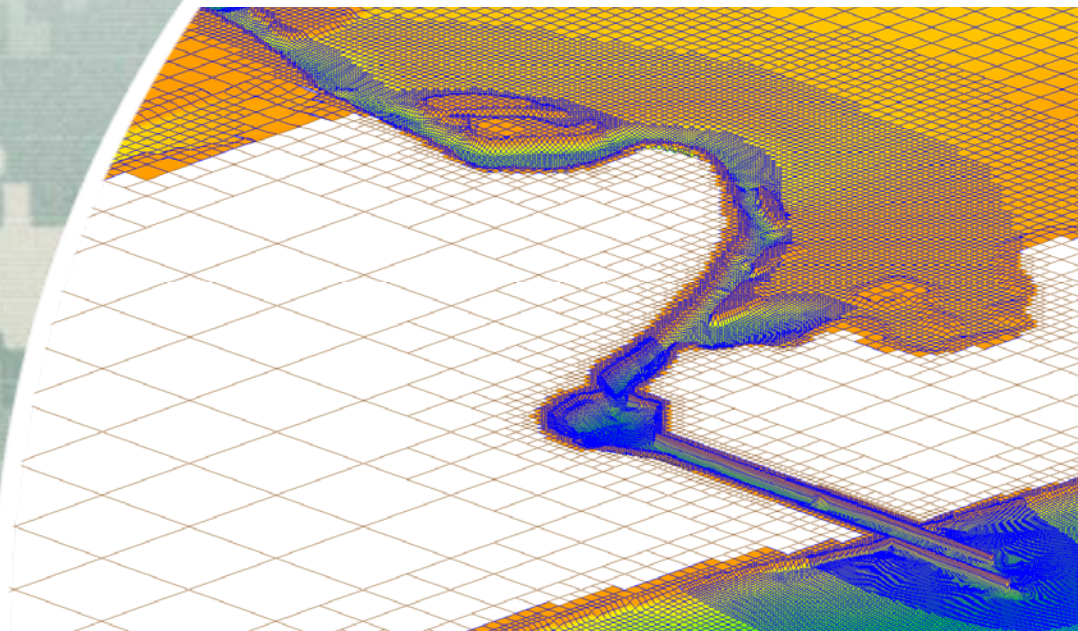

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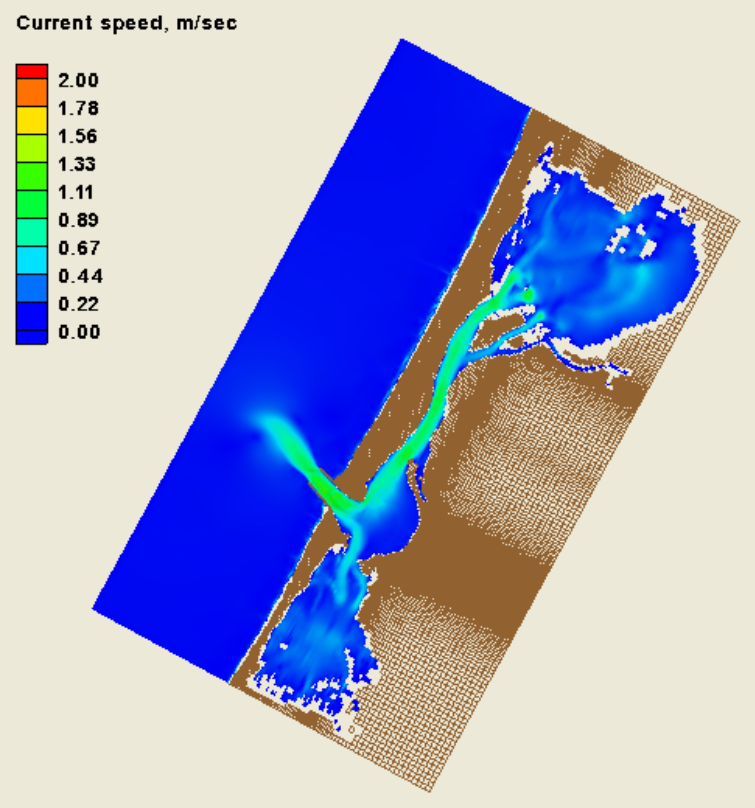
Outline

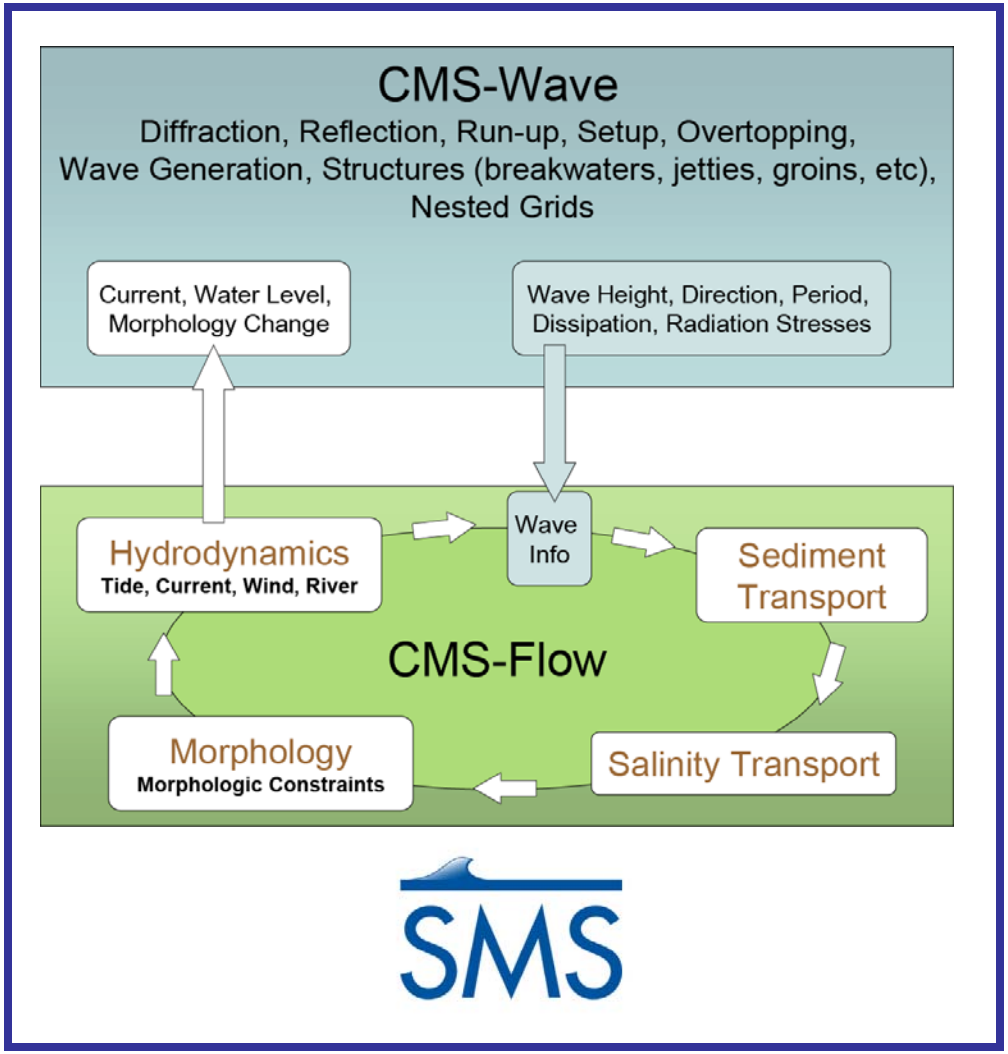
1. Objective
2. Overview of CMS
3. Key Features
4. Governing Equations
5. Recent Additions to CMS-Flow
   - Non-Eq. Sediment Transport
   - Multi-processor capability
   - Salinity
6. Ongoing R&D Activity
7. Documentation and Publications



1. Objective

- **Deliver** to District engineer's desktops **integrated** advanced models that can be used as a **practical** engineering tool for **coastal** shoaling and erosion problems in reduction of O&M costs.
  - Integrated: All relevant processes, models efficiently coupled together
  - Practical: PC-based, user-friendly interface, fast, robust and accurate
  - Deliver: Manuals, tech reports, journal papers, Wiki, workshops, phone help, etc.

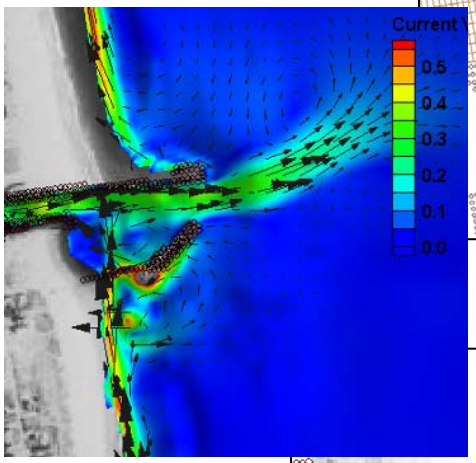
2. Overview of CMS



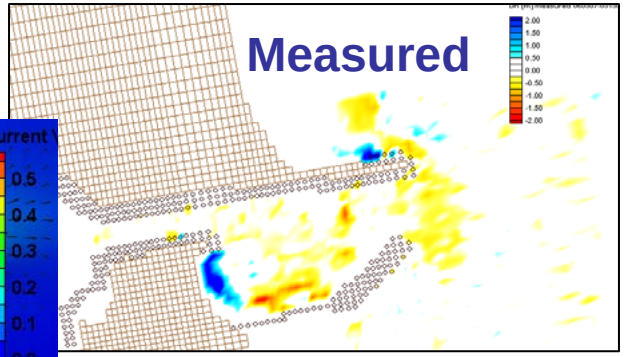
3. Key Features

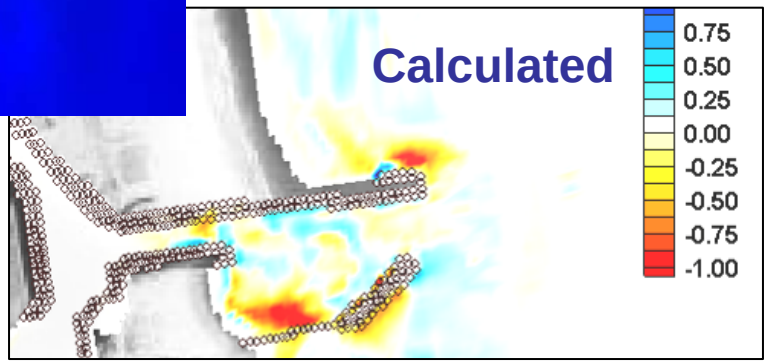
- Non-uniform Cartesian grid - Easy to set up and run
- Finite Volume Method (conserves volume, stable)
- 2D and 3D
- Boundary Conditions & Forcing
  - Waves
  - Wall boundary
  - Flux time series
  - Water level time series
  - Tidal constituents
  - Nested boundary
  - Wave-adjusted BC
  - Wind time series
- Wetting and drying
- Inline sediment and salinity
- Particle Tracking Model
- Parallel Processing on PC

Wave & Tide driven current



Morphology Change





4. Governing Equations

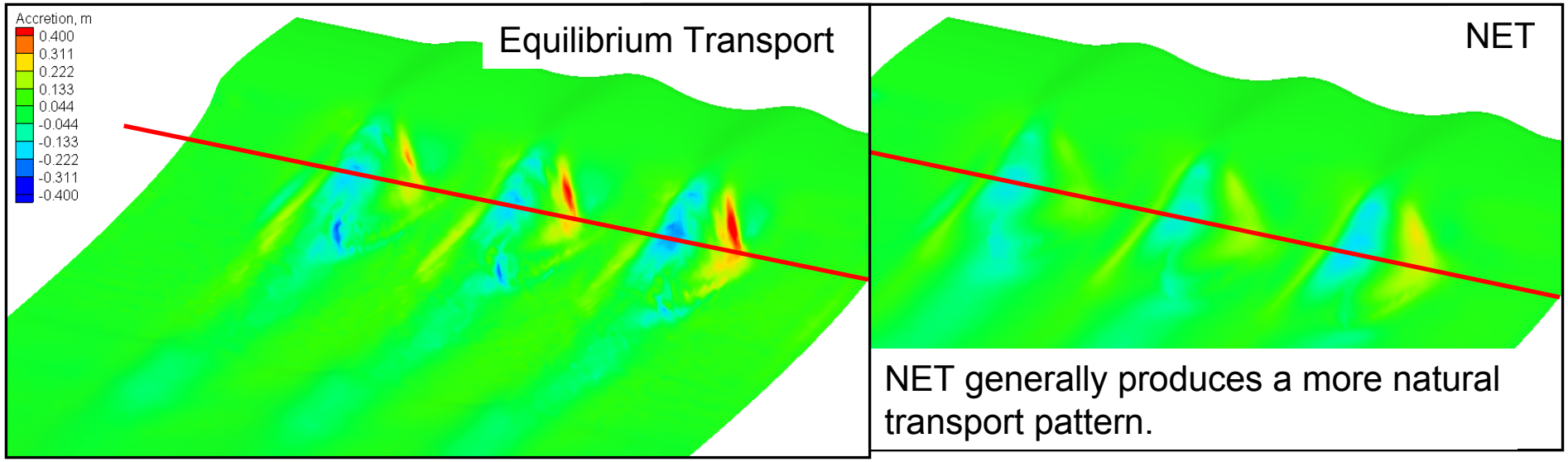
- **Flow**
  - Conservative form of depth-averaged shallow water equations (finite-volume method – FVM)
  - Includes terms for Coriolis pseudo-force, wave forcing, wind forcing, bottom friction, and turbulent diffusion
- **Sediment**
  - Equilibrium Total Load (Exner equation)
  - Equilibrium Bed Load + Advection-Diffusion Suspended Load
  - Non-Equilibrium (Advection-Diffusion Total Load) **NEW**
- **Salinity**
  - Advection-Diffusion equation **NEW**

5. Recent Additions to CMS-Flow (1 of 5)

- **Increased Speed -** Optimization of the coding structure for CMS-Flow has created a 500 to 1,000 percent increase in simulation speed depending on user's selections.
- **Additional Sediment Transport Algorithm -** A Non-Equilibrium Transport (NET) version of the advection diffusion sediment transport algorithm.
- **OpenMP Parallelization** – Parallelization enhances CMS productivity on today's multiple processor PCs.
- **2D Salinity Transport -** Can specify a default global salinity concentration as well as introduce different sediment sources at boundaries.
- **Variable Grain Size** (Phase 1) – Can specify zones of grain size for sediment transport calculations.
- **Improved Stability and Better Error Diagnostics.**

5. Recent Additions to CMS-Flow (2 of 5): Non-equilibrium Sediment Transport

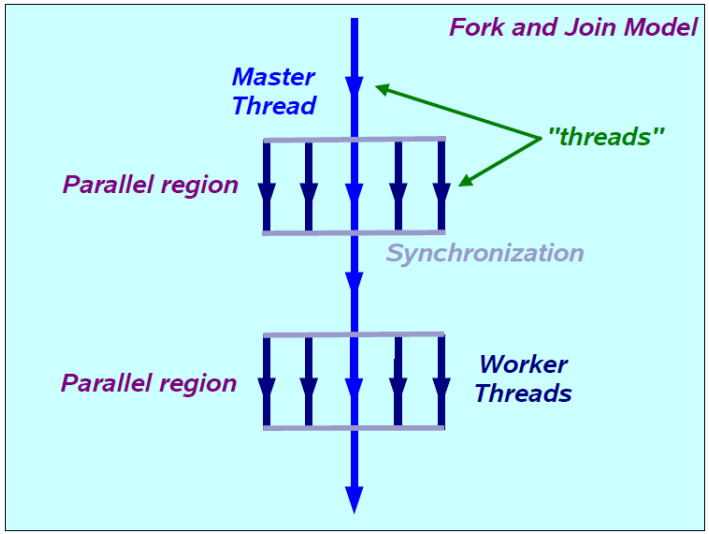
- The NET accounts for temporal and spatial lags between flow and sediment transport
- Can easily handle constrained sediment loading (over- or under-loading)
- Hard-bottom (non-erodible bottom) automatically computed
- Can simulate suspended and bed load separately or combined as bed-material or total load
- More stable than equilibrium (standard) sediment transport



NET generally produces a more natural transport pattern.

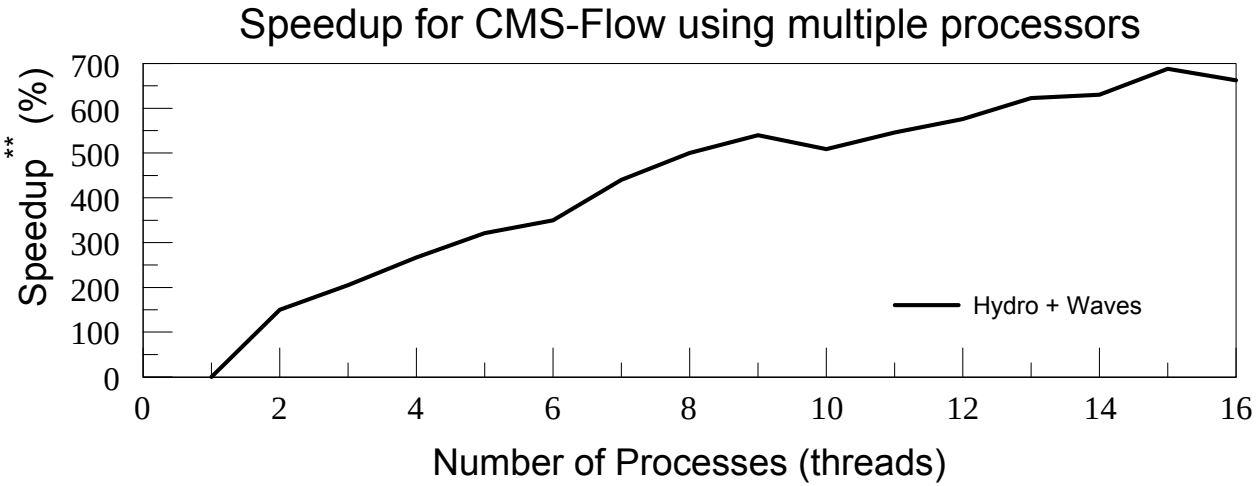
3. Recent Additions to CMS-Flow (3 of 5): Parallel Processing

- OpenMP parallelization
- SMS interface implementation is underway…
  - Access via “Advanced” tab in model control
  - Add card: OPENMP_THREADS <white space> #



- Up to 16 threads on modern machines
- Works best on grids with >20,000 cells

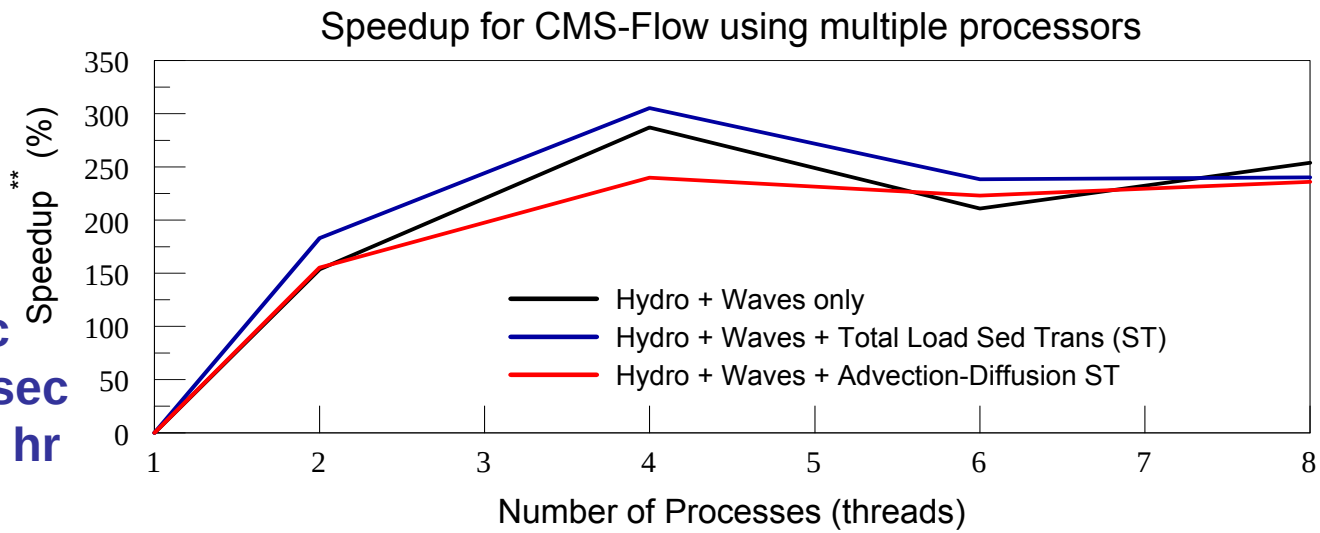
3. Recent Additions to CMS-Flow (4 of 5): Parallel Processing



Humboldt Bay, CA

Flow grid: ~50,000 cells

Hydro Timestep: 0.5 sec



Flow grid: ~42,000 cells

Hydro Timestep: 0.5 sec

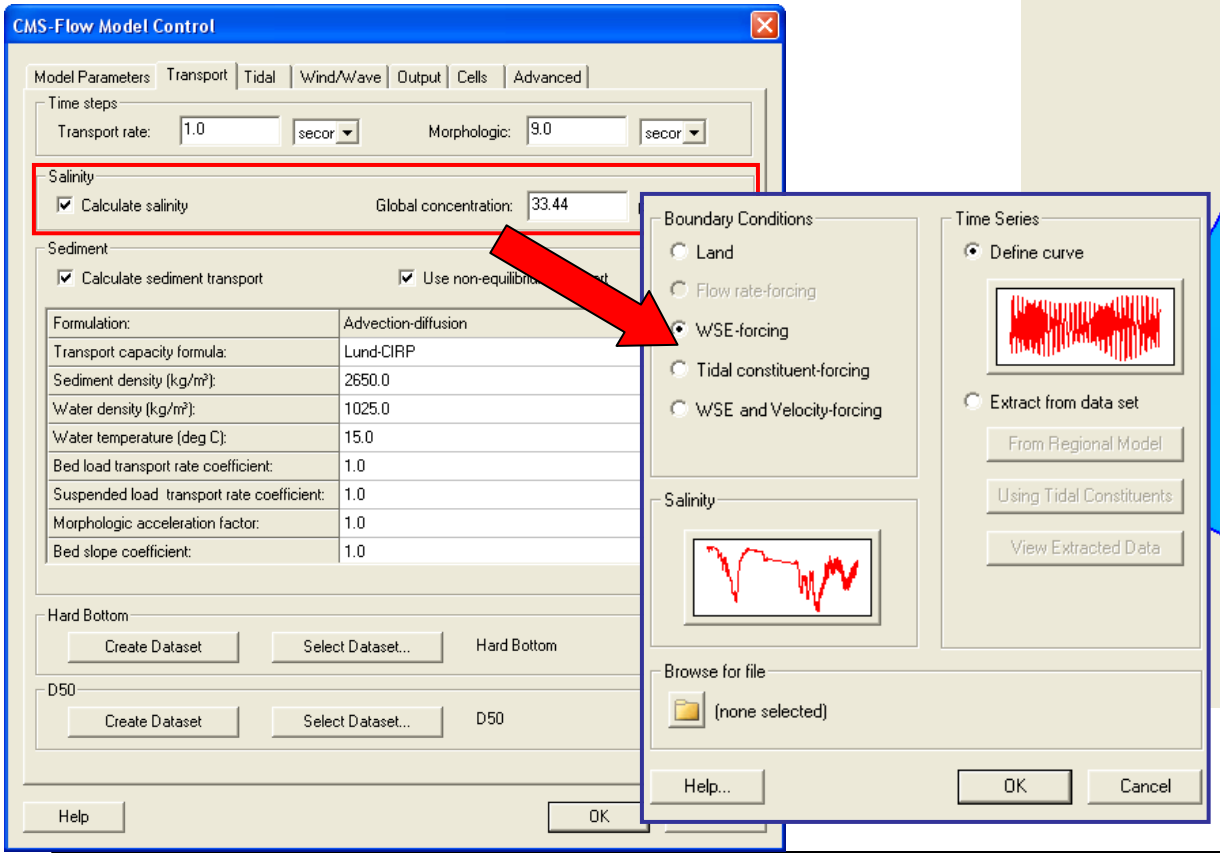
Transport Timestep: 10 sec

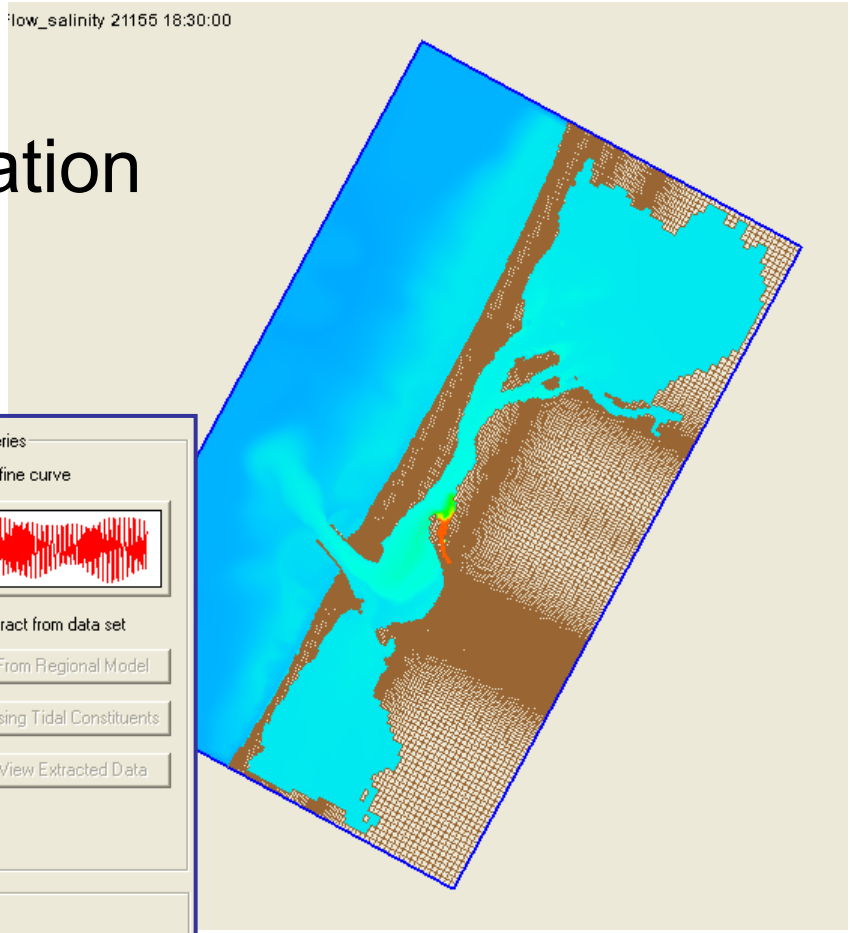
Morphology update: 0.5 hr

****Speedup = (Run time for 1 thread) / (run time for *n* threads) * 100**

3. Recent Additions to CMS-Flow (5 of 5): Salinity

- Measure of water quality
- Influences sediment flocculation

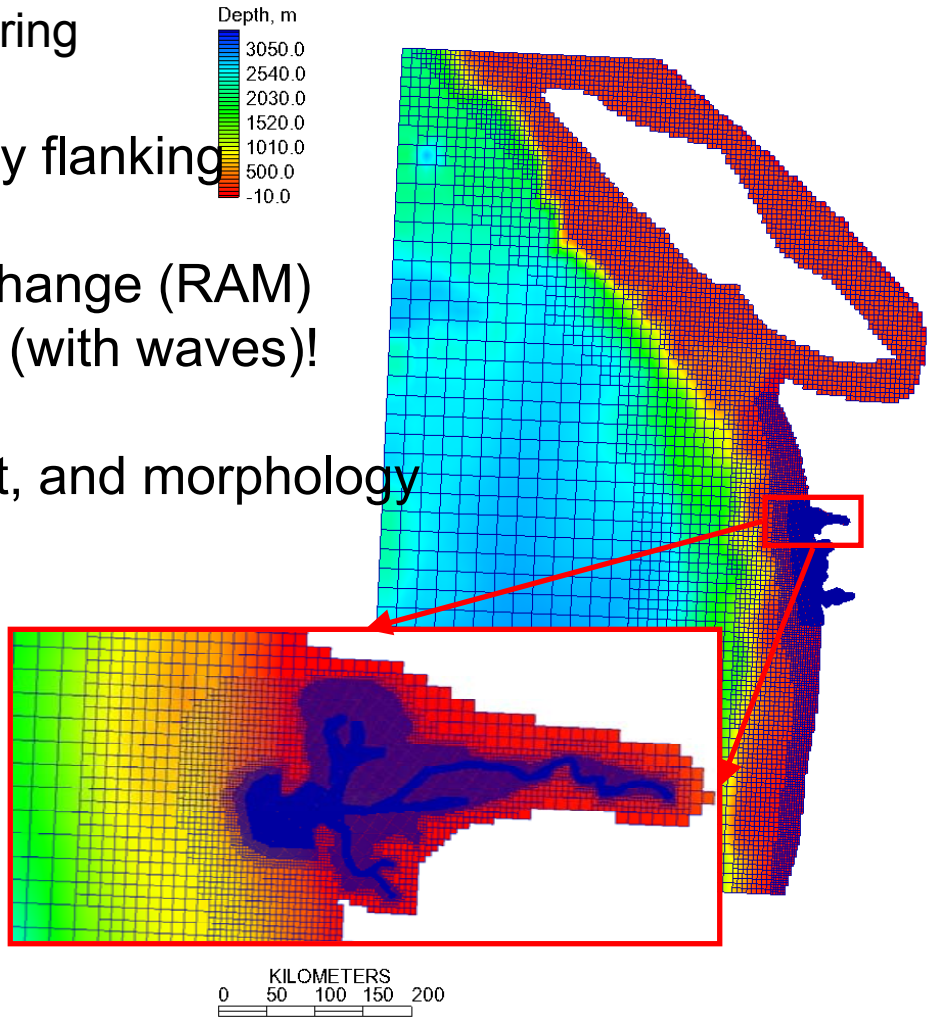




Humboldt Bay, CA

6. Ongoing R&D Activity

- Multiple-sized sediment transport (Phase 2)
  - Hiding/exposure, armoring, bed layering
- Cohesive sediment transport
- Barrier overwash and breaching, jetty flanking
- Weirs/culverts, permeable jetties
- Rapid Assessment of Morphology Change (RAM)
- Implicit solution – 10-30 times faster (with waves)!
- Telescoping grids
- CMS3D: 3D flow, sediment transport, and morphology change; salinity transport



7. Documentation

- CIRP website

http://cirp.usace.army.mil/

- Wiki Website

http://cirp.usace.army.mil/wiki/

7. User Manuals

- Demirbilek, Z., K. J. Connell, N. J. MacDonald, and A. K. Zundel. 2008. **Particle Tracking Model in the SMS 10: IV. Link to Coastal Modeling System,**. Coastal and Hydraulics Engineering Technical Note ERDC/CHL CHETN-IV-71. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

- Brown, M. E., and N. C. Kraus. 2007. **Tips for developing bathymetry grids for Coastal Modeling System Applications,** Coastal and Hydraulics Laboratory Engineering Technical Note ERDC/CHL CHETN-IV-69. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

- Buttolph, A. M., Reed, C. W., Kraus, N. C., Ono, N., Larson, M., Camenen, B., Hanson, H., Wamsley, T., and Zundel, A. K. 2006. **Two-Dimensional Depth-Averaged Circulation Model CMS-M2D: Version 3.0, Report 2, Sediment Transport and Morphology Change,** Technical Report ERDC/CHL-TR-06-7, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.

7. Publications: Sediment Transport

- Sánchez, A., and Wu, W. 2010. **"A Non-equilibrium Sediment Transport Model for Coastal Inlet Applications".** *Journal of Coastal Research*, Submitted Oct 2009.
- Camenen, B., and Larson, M., 2008. **"Equivalent Roughness Height for Plane Bed Oscillatory Flow,"***Estuarine, Coastal, and Shelf Science*, Vol 81, pp 409-422.
- Camenen, B., and Larson, M., 2008. **"A General Formula for Non-Cohesive Suspended Sediment Transport,"** *Journal of Coastal Research*, Vol 24, No. 3, pp 615-627.
- Camenen, B., and Larson, M. 2007. **"A Unified Sediment Transport Formulation for Coastal Inlet Application,"** Contract Report ERDC/CHL-CR-07-1, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.
- Camenen, B., and Larson, M. 2007. **"A Total Load Formula for the Nearshore,"** *Proceedings Coastal Sediments '07 Conference*, ASCE Press, Reston, VA, 56-67.
- Hanson, H., and Camenen, B. 2007. **"Closed Form Solution for Threshold Velocity for Initiation of Sediment Motion Under Waves,"** *Proceedings Coastal Sediments '07 Conference*, ASCE Press, Reston, VA, 15-27.
- Camenen, B. and Larson, M., 2006. **"Phase Lag Effects in Sheet Flow Transport,"** *Coastal Engineering*,Vol 53, pp 531-542.
- Camenen, B., Bayram, A., and Larson, M., 2006. **"Equivalent Roughness Height for Plane Bed Under Steady Flow,"** *Journal of Hydraulic Engineering*,Vol 132, No. 11, pp 1146-1158.
- Gravens, M. B., and Wang, P. 2007. **"Data Report: Laboratory Testing of Longshore Sand Transport by Waves and Currents; Morphology Change Behind Headland Structures,"** Technical Report ERDC/CHL-TR-07-8, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.

7. Publications: Applications/Projects

- Beck, T.M., and Wang, P. 2009. **Influences of channel dredging on flow and sedimentation patterns at microtidal inlets, West-central Florida, USA.** Proceedings Coastal Dynamics 2009.
- Li, H., Brown, M. E., Smith, T. D., Podoski, J. H., 2009 (draft). **Evaluation of Proposed Channel on Circulation and Morphology Change at Kawaihae Harbor and Pelekane Bay, Island of Hawaii, HI**, Technical Report ERDC/CHL-TR-XX-XX, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
- Seabergh, W.C., Smith, E.R., and Rosati, J.D. 2009 (draft). **Sabine-Neches Waterway, Sabine Pass Jetty System: Past and Future Performance,** ERDC/CHL-TR-09-X, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS
- Demirbilek, Z., Lin, L., and Nwogu, O. G. 2008. **Wave Modeling for Jetty Rehabilitation at the Mouth of the Columbia River, Washington/Oregon, USA,** ERDC/CHL-TR-08-3, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.
- Barcak, R. G., Kraus, N. C., Lin, L., Smith, E. R., Heilman, D. J., and Thomas, R. C. 2007 **Navigation Improvement, Mouth of the Colorado River, Texas,** *Proceedings Coastal Sediments '07 Conference*, ASCE Press, Reston, VA, 1502-1514.
- Wang, P., Tidwell, D. K., Beck, T. M., and Kraus, N. C. 2007. **Sedimentation Patterns in a Stabilized Migratory Inlet, Blind Pass**, FL. *Proceedings Coastal Sediments '07 Conference*, ASCE Press, Reston, VA, 1377-1390.
- Zarillo, G. A., and Brehin, F. G. A. (2007) **Hydrodynamic and Morphologic Modeling at Sebastian Inlet, FL,** *Proceedings Coastal Sediments '07 Conference*, ASCE Press, Reston, VA, 1297-1310.
- Wamsley, T. V., Cialone, M. A., Connell, K. J., and Kraus, N. C. 2006. **Breach History and Susceptibility Study, South Jetty and Navigation Project, Grays Harbor, Washington,** ERDC/CHL-TR-06-22, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
- Hughes, S. A., and Cohen, J. 2006. **Half Moon Bay, Grays Harbor, Washington: Movable-Bed Physical Model Study,** Technical Report ERDC/CHL-TR-06-15, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

Publications: Various

- Wu, W., Sánchez, A., and Mingliang, Z., 2010. **An Implicit 2-D Shallow Water Flow Model on an Unstructured Quadtree Rectangular Grid**, *Journal of Coastal Research*, Submitted Oct 2009
- Demirbilek, Z., Lin, L., Seabergh, W.C., Mase, H., and Zheng, J.I. 2009. **Laboratory and Numerical Studies of Hydrodynamics Near Jetties,** *Coastal Engineering Journal* Vol. 51, No. 2, 143-175.
- Sánchez, A. 2008. ***Interactions between wetlands and tidal inlets,*** Coastal andHydraulics Engineering Technical Note. ERDC/CHL CHETN-IV-72. Vicksburg,MS: U.S. Army Engineer Research and Development Center.
- Seabergh, W. C., Demirbilek, Z., and Lin, L. (2008). **Guidelines Based on Physical and Numerical Modeling Studies for Jetty Spur Design at Coastal Inlets,** *International Journal of Ecology & Development (IJED)*, Vol. 11, No. F08, pp 4-19.
- MacDonald, N. J., Davies, M. H., Zundel, A. K., Howlett, J. D., Demirbilek, Z., Gailani, J. Z., Lackey, T. C., and Smith, J. (2006). **PTM: Particle Tracking Model; Report 1: Model Theory, Implementation, and Example Applications,** Technical Report ERDC/CHL-TR-06-20, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.