Frequently Asked Questions on CH3D and CH3D-IMS
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1. Background

1.1 What does CH3D stand for?

CH3D stands for Curvilinear-grid Hydrodynamics model in three-dimensions (3D).

1.2 What variables do CH3D solve?

CH3D solves the three-dimensional, time-dependent equations of motion for water level, three-dimensional velocities, and three-dimensional fields of temperature and salinity.

1.3 So, is there a CH2D?

Yes, CH2D is the vertically integrated version of CH3D.

1.4 Who developed CH3D?

CH3D was originally developed by Dr. Y. Peter Sheng who is now a Professor in the Department of Civil and Coastal Engineering at the University of Florida.

1.5 When was the original CH3D developed?

The original CH3D was developed by Dr. Sheng in 1986 when he was a Senior Consultant and Head of Coastal Oceanography Group at the Aeronautical Research Associates of Princeton, Inc. (which is now part of the Titan Corporation) in Princeton, New Jersey.

1.6 What is CH3D-WES?

The original CH3D was developed by Dr. Sheng with some support from the U.S. Army Engineer Waterways Experiment Station (WES) in Vicksburg, MS. The model was delivered to WES in 1986. In 1988-89, with the assistance of Dr. Sheng. CH3D-WES was applied to simulate the circulation in Chesapeake Bay. During that time, the original sigma-grid version of CH3D was modified by WES to create a z-grid version of CH3D. In the meantime, Sheng (1990) successfully simulated the Chesapeake Bay circulation using the sigma-grid version of CH3D. The QUICKEST advective scheme was also incorporated into CH3D. Since 1989, CH3D-WES has been maintained strictly by WES. At the University of Florida, CH3D has been substantially improved over the years.

1.7 How has the CH3D evolved over the years?

Dr. Y. Peter Sheng, who developed the original CH3D, joined the University of Florida in 1986. Since then, Dr. Sheng and his group have continued to enhance the development and applications of the CH3D model. The original CH3D, as well as the current version of CH3D maintained by the University of Florida, use the sigma grid in the vertical direction. Since 1986, many new features have been incorporated into the CH3D at the University of Florida. Over the years, CH3D has been coupled to several wave models, a 3-D sediment transport model, a 3-D water quality model, a light model, and a seagrass model. The integrated modeling system which contains the hydrodynamic-wave-sediment-water quality-light-seagrass model is now called CH3D-IMS (Sheng 2000, Sheng et al. 2002). Details of the CH3D-IMS are explained later. CH3D has also been coupled with several wave models for simulating storm surge, wave setup, and coastal flooding.

1.8 What can CH3D be used for?

CH3D can be used to calculate the flow field needed for the following types of studies:

Various research and management studies on estuaries, lakes, rivers, and oceans
Ecosystem modeling and management/restoration
Determination of minimum flow and level (MFL) criteria
Determination of total maximum daily load (TMDL)
Determination of pollutant load reduction goal (PLRG)
Scientific understanding of hydrodynamic and ecological processes
Storm surge and coastal flooding
Flood insurance mapping
Response of ecosystems to anthropogenic and natural climatic changes
Prediction of hypoxia and eutrophication
Sediment transport studies
Calculating flushing rates
Calculating trajectory of larvae, oil spill, etc.
...

1.9 Who are some of the sponsors and users of CH3D?

U.S. Environmental Protection Agency
Sarasota Bay National Estuary Program
Tampa Bay National Estuary Program
Indian River Lagoon National Estuary Program
National Center for Environmental Research and Quality Assurance
U.S. Army Engineer Waterways Experiment Station (now the Engineering Research Center)
U.S. Dept. of Commerce, National Park Service
South Florida Water Management District
St. Johns River Water Management District
Southwest Florida Water Management District

1.10 What language is CH3D written in?

CH3D is currently written in standard FORTRAN which, for numerically intensive applications, is generally much faster than a program written in C. Additionally, we use cpp (C pre-processor) and m4 macros to make the code much more efficient and portable.

1.11 How fast is CH3D?

The CH3D is quite fast. On a single cpu SGI Origin-2000 system with 400mHz cpu, it takes about one day cpu-time to perform a one-year simulation with a total of 500x40x4 grid points and a time step of 60 sec. It is 365 times faster than realtime. The parallel version of CH3D is even faster, depending on which system and how many processors you use. The CH3D-IMS is also very efficient, allowing 100-300 faster than realtime, depending on the total grid points and time steps.

1.12 How much has CH3D improved over the years?

The current CH3D is substantially improved over the original CH3D. In fact, the current CH3D is substantially improved (more robust and more efficient) over the 1989 version of CH3D. Many new features have been added. The original CH3D was optimized for running on a VAX. The 1989 version was optimized for a vector computer. The current CH3D is optimized for running on a parallel computer. The latest CH3D uses a robust pre-conditioned conjugate gradient method, instead of the factorized scheme, for solving the external mode. It also uses the ultimate-QUICKEST scheme for advection. Last but not least, CH3D has been dynamically coupled with a wave model, a sediment transport model, a water quality model, a light attenuation model, and a seagrass model into a fully integrated modeling system, CH3D-IMS.

1.13 What is CH3D-IMS?

CH3D-IMS is an integrated modeling system based on the curvilinear grid system of CH3D. The CH3D-IMS includes the following:

Circulation Model:	CH3D
Wave Model:	SMB, SWAN
Sediment Transport Model:	CH3D-SED3D
Water Quality Model:	CH3D-WQ3D
Light Attenuation Model:	CH3D-LA
Seagrass Model:	CH3D-SAV

See Section 4 for more details on CH3D-IMS.

1.14 What can CH3D-IMS be used for?

Various research and management studies on estuaries, lakes, rivers, and oceans:

Ecosystem modeling and management/restoration
Determination of minimum flow and level (MFL) criteria
Determination of total maximum daily load (TMDL)
Determination of pollutant load reduction goal (PLRG)
Scientific understanding of hydrodynamic and ecological processes
Storm surge and coastal flooding
Flood insurance mapping
Response of ecosystems to anthropogenic and natural climatic changes
Prediction of hypoxia and eutrophication
Sediment transport studies
Calculating flushing rates
Calculating trajectory of larvae, oil spill, etc.

2. Model Features

2.1 What are the special features of CH3D?

CH3D has several advanced features. Of particular importance is the use of non-orthogonal boundary-fitted grids in the horizontal direction, which allows the accurate representation of complex boundaries and internal features of estuarine and coastal water bodies.

2.2 Does CH3D solve the Cartesian equations of motion or transformed equations of motion (in curvilinear grids)?

CH3D solves the transformed equations of motion in the curvilinear grids.

2.3 How were the transformed equations of motion derived?

In the original version of CH3D, the transformed equations were derived from the tensor invariant form of the 3-D equations of motion (Sheng 1986a,b,e,f, 1987, Sheng et al. 1988). Later, CH3D equations were derived from the finite volume approach. (Sheng and Capitao 1989).

2.4 How is the vertical coordinate treated in CH3D?

Either of two methods are used to treat the vertical coordinate: one method uses the sigma grid, while the other uses the z-grid.

2.5 What are the differences between the sigma-grid model and the z-grid model?

The sigma grid converts the vertical coordinate into a relative depth such that sigma is equal to 0 at the free surface and -1 at the bottom. This way, the model allows the same number of grid points in shallow water as well as in deep water. The z-grid works with the actual depth z, so there maybe many grid points in deep water but few points in shallow water.

2.6 What are the advantages and disadvantages of sigma-grid versus z-grid models?

As indicated in the previous answer, sigma-grid model allows equal number of vertical grid cells in shallow and deep waters. The vertical grid points, including the free surface, are unchanged in the transformed plane. In addition, it allows smooth representation of variable bottom topography. The disadvantage is that, without careful treatment, sigma-grid model can cause large error in region with sharp bathymetric change. The current sigma-grid version of CH3D at UF has no problem in region with sharp bathymetric gradient. The z-grid model, on the other hand, does not have this problem. However, the treatment of the free surface boundary requires some special effort. Moreover, the stair-step representation the bottom may cause undesirable vortices and errors.

2.7 Which version of CH3D is better? Sigma-grid version? Z-grid version?

In principle, the two versions should give similar results. The original sigma-grid version of CH3D produced error in region with sharp bathymetric change. This problem has been fixed since 1989, and the present sigma-grid version of CH3D can accurately simulate the flow in region with sharp bathymetric change. The stair-step representation of the z-grid version of CH3D has not been resolved.

2.8 What are some of the other unique features about CH3D?

CH3D uses a robust vertical turbulence model (Sheng 1986, Sheng and Villaret 1989) which is based on the second order closure model of turbulent transport developed at the Aeronautical Research Associates of Princeton. Another feature is the CH3D treats the external mode (vertically integrated currents and water level) with an efficient factorized scheme with theta method (varying degree of implicitness), while the internal mode with a vertically implicit scheme. Most importantly, both modes are solved with the same time step to ensure that there is strict conservation and consistency.

2.9 How does the vertical turbulence model in CH3D compare with the turbulence model in other models, e.g., Princeton Ocean Model?

The vertical turbulence model used in CH3D is based on the second order closure model of turbulent transport developed at the ARAP. It contains three versions: equilibrium closure, TKE (turbulent kinetic energy)closure, and Reynolds Stress model. The equilibrium closure model is similar to the Mellor and Yamada Level II model, while the TKE closure model is similar to Mellor and Yamada Level III model. See Sheng and Villaret (1989) for details of the vertical turbulence model in CH3D.

2.10 How good is the ARAP vertical turbulence model in comparison with Mellor and Yamada model?

Performance of the two models has been found to be comparable.

2.11 Is there any problem with the mode separation method?

Because of the special treatment in CH3D, the mode separation method does not cause any error. This has been confirmed by comparing the results of CH3D vs. those of other 3-D model which does not use mode separation, as well as by extensive comparison with analytical results and laboratory and field data.

2.12 What are some of the new model features in the CH3D maintained by Dr. Sheng and his group at the University of Florida since 1986?

Dr. Sheng and his group have added the following features to various versions of CH3D, through various funded projects:

The effect of submerged aquatic vegetation on flow.
Moving boundaries - wetting and drying.
Higher-order advective schemes.
Calculation of flushing rates.
A random-walk particle trajectory model.
Wave-induced radiation stresses.
Spatially varying roughness heights.
Shared memory parallel version.
Linkage to GIS.
Dynamic visualization.

2.13 Is there a Graphic User Interface (GUI) for CH3D?

An Arcview-based GUI which includes grid creation and editing along with pre- and post-processing capabilities is being actively developed at the University of Florida.

2.14 Is there a single version of CH3D that contains all the advanced features developed so far?

Not at the present time. Different features have been developed for different sponsored research projects, each with a somewhat different purpose. Putting all the features together in one program will increase the size and complexity of the code and hence reduces the efficiency of the code.

2.15 What are the advantages of CH3D over orthogonal grid models?

The non-orthogonal boundary-fitted grid used by CH3D allows one to more accurately represent the boundaries (shorelines and interior features) in a complex domain.

2.16 What kind of boundary conditions can CH3D handle?

Tidal conditions along open boundaries.
Discharge conditions along river boundaries.
Precipitation, evaporation, wind, heat flux at surface.
Turbulent bottom boundary layer at bottom.

2.17 What about groundwater effects?

Coupling between CH3D with a groundwater model is actively being pursued.

2.18 Where can I find more details about CH3D?

See the reference list.

2.19 How structured is the CH3D programming?

The current CH3D has undergone substantial programming improvements. The code has been made modular to allow easy coupling with other models. Software engineering principles have also been applied to CH3D.

2.20 Do CH3D and CH3D-IMS guarantee local and global conservation of mass and momentum?

Yes. We have run both CH3D and CH3D-IMS simulations over more than one year and found that local and global conservation is strictly satisfied.

3. Applications

3.1 Where has CH3D been applied?

CH3D has been applied to the following waters:

Chesapeake Bay	1987-1990
James River, Virginia	1987-1990
Lake Okeechobee, Florida	1989-1993
Sarasota Bay, Florida	1990-1994
Tampa Bay, Florida	1994-1996
Indian River Lagoon, Florida	1991-2002
Florida Bay, Florida	1994-1996
St. Johns River, Florida	2002
Biscayne Bay, Florida	2002
Charlotte Harbor, Florida	1997-2002
Gulf of Mexico	2001-2002
Pinellas County and offshore	1999-2002

3.2 Which version of CH3D should be used?

Depends on the problem, since there is not a single version of CH3D that contains all the advanced features.

3.3 Which version of CH3D should be used for storm surge and coastal flooding simulations?

Definitely the version of CH3D (Sheng and Alymov 2002) that has been used to simulate storm surge and coastal flooding previously. In that study, CH3D was enhanced and dynamically coupled with REF/DIF and SWAN. It can also handle moving boundary due to flooding and drying of the shoreline.

3.4 Can I use the Chesapeake Bay version of CH3D for storm surge and coastal flooding simulations?

See answer for the previous question. The CH3D-WES used for Chesapeake Bay has not been applied to storm surge studies.

3.5 Can CH3D be used with rectangular grid or orthogonal curvilinear grid?

Yes. CH3D can be used with any structured grid (rectangular, orthogonal curvilinear, or non-orthogonal curvilinear) with quadrilateral cells.

3.6 How can I generate the grid for CH3D?

Elliptic grid generation method can be used to generate the boundary-fitted grid needed for CH3D. Orthogonal grid generation program can also be used to generate orthogonal grid which can be used by CH3D. Rectangular grid, which can be easily generated, can also be used by CH3D.

3.7 Can CH3D be coupled with my model?

The current version of CH3D is modular and can be coupled with any other well written model relatively easily.

3.8 Is CH3D well documented?

Yes. CH3D is well documented with both printed and online help manuals.

4. CH3D-IMS: An Integrated Modeling System

4.1 What are included in the CH3D-IMS integrated modeling system?

Circulation model - CH3D
Wave model - SMB, SWAN
Sediment transport model - CH3D-SED3D
Water quality model - CH3D-WQ3D
Light attenuation model - CH3D-LA
Seagrass model - CH3D-SAV

4.2 How are these component models coupled to each other in CH3D-IMS?

They are dynamically coupled and they use the same time step and curvilinear spatial grid.

4.3 What are included in the 3-D sediment transport model (SED3D) in CH3D?

CH3D-SED3D includes a fine sediment transport model as well as a coarse sediment transport model. The fine sediment transport model is based on the theory described in the 3-D sediment transport model developed for USEPA (Sheng et al. 1991). Some of Dr. Sheng's work on sediment related research can be found in the references list, e.g., Sheng (1986c and f, 1989a and c, 1993), Sheng and Villaret (1989), Sheng et al. (1990c, 1991, 1994), The coarse sediment transport model uses some theory described in van Rijn (1991). The processes included in the CH3D-SED3D are: advection, turbulent mixing, settling/flocculation, deposition, and resuspension, and wave-current interaction inside bottom boundary layer. The bottom sediment layer is also updated.

4.4 What water quality constituents are included in CH3D-WQ3D?

The 3-D water quality model in CH3D includes:

A nitrogen cycling model with dissolved and particulate, organic and inorganic nitrogen species
A phosphorus cycling model with dissolved and particulate, organic and inorganic phosphorus species
A phytoplankton carbon model
A zooplankton model
A dissolved oxygen model

4.5 How comprehensive are the processes included in the water quality model of CH3D-IMS?

The processes and constituents included in the CH3D-WQ3D are more comprehensive than those in the USEPA WASP model. Of particular importance for application to shallow estuarine and lake waters is the inclusion of two sediment layers (one aerobic layer and one anaerobic layer) with active exchange of nutrients between sediment and water column through diffusion of dissolved species and resuspension of particulate nutrients.

4.6 What is the light attenuation model included in the CH3D-IMS?

See Christian and Sheng (2002a and b). The model calculates the attenuation of PAR due to water, chlorophyll, non-algal particulate matter, and color (yellow substance) which is related to dissolved organic material.

4.7 What is the seagrass model included in the CH3D-IMS?

It is a modified version of the model developed by Fong et al. (1997) for Florida Bay. It calculates the growth and decay of seagrass biomass due to light, nutrient, temperature, and salinity.

4.8 Has CH3D-IMS been applied and validated?

Yes. CH3D-IMS has been applied to several ecosystems in Florida and validated with data: Sarasota Bay (Sheng et al. 1996a), Tampa Bay (Sheng et al. 1996b, Yassuda and Sheng 1998, Sheng et al. 2001), Indian River Lagoon (Sheng et al. 2002). The Indian River Lagoon application has been validated with data over the entire 1998.

4.9 We are interested in developing an integrated model for our estuary (e.g., Venice Lagoon, Johor Strait, Guanabara Bay, etc...), is CH3D-IMS applicable?

Yes. Assuming there are sufficient data for model calibration and validation, CH3D-IMS can be applied to your estuary. Certainly, depending on the particular estuary, some processes contained in the CH3D-IMS may have to be modified or further enhanced.

5. Development in progress

5.1 What are some of the new developments in the CH3D/CH3D-IMS camp?

Non-hydrostatic model.
Unstructured grid model.
Graphical User Interface (GUI).
Surface water-ground water interaction.
Removal of mode separation.
Eulerian-Lagrangian method.
Forecasting.
Grid computing.

5.2 When will these new developments be ready?

Soon. Stay tuned.

6. Computer Hardware

6.1 What kind of computer platforms can CH3D and CH3D-IMS be run on?

Originally, CH3D was developed on a VAX in 1986. The present CH3D can be configured to run on any computer platform: SGI, SUN, DEC, IBM, PC etc.

6.2 Where is CH3D and CH3D-IMS typically run at the University of Florida?

CH3D and CH3D-IMS are typically run on a 4-cpu SGI Origin-2000 system and a 16-cpu SGI Origin-3400 system.
It can also be run on PC with Linux or Microsoft Windows operating system.

6.3 Can CH3D and CH3D-IMS be run on any parallel computers?

Yes, a shared memory version of CH3D has been developed and will run on any shared memory platform (SGI, SUN, DEC, IBM, PC, etc.).

6.4 Can CH3D and CH3D-IMS be run on any cluster, Beowulf or otherwise?

A message passing version of CH3D is actively being developed to run in a cluster environment.

7. Acquiring CH3D and CH3D-IMS

7.1 Is CH3D in the public domain?

Although CH3D-WES is in principle in the public domain, CH3D at the University of Florida is not in the public domain.

7.2 Can I, as a general public, obtain a copy of CH3D?

Presently we are not in the position to provide a free copy of CH3D to the general public. If you are interested, inquiry should be directed to Dr. Y. Peter Sheng at pete@coastal.ufl.edu.

7.3 Can companies or federal/state/local agencies, acquire a copy of CH3D?

We are in the position to conduct research with CH3D and provide the code as part of the deliverables for a sponsored research project. Again, please direct your inquiry to Dr. Sheng at pete@coastal.ufl.edu.

7.4 Can CH3D become a “community model”?

Yes. CH3D is certainly a good candidate for community model. In fact, this is being considered right now. With some necessary support and effort, this could happen soon.

7.5 What if there is a feature I want, but it is not yet available in CH3D?

Email us to discuss.

7.6 Can I obtain an executable version of CH3D to test drive?

Email us to discuss.

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