Application of CSDMS to Chesapeake Bay Models

Carl Friedrichs, VIMS

and the SURA Estuarine Modeling Testbed Team

<u>Outline of Presentation</u>:

- CSDMS Chesapeake Focus Research Group
- SURA Estuarine Modeling Testbed Project
- Chesapeake Bay Models (lots of ROMS grids)
- Progress implementing ROMS in CSDMS

CSDMS
COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

Presented at CSMDS All-Hands Meeting San Antonio, TX, October 14, 2010

Chesapeake Focus Research Group (http:/csdms.colorado.edu/wiki/CCMP)

Chesapeake Focus Research Group

Introduction

This is the first Geographically-Focused Research Group (GFRG) (*currently **27** members*) associated with CSDMS. The group is a partnership between CSDMS and the Chesapeake Community Modeling Program (CCMP, http://ches.communitymodeling.org/) currently run by the Chesapeake Research Consortium.

CCMP developed as the Chesapeake Bay research community came together to cooperatively build an open source system of watershed and estuary models. Through support from CRC member institutions and the NOAA Chesapeake Bay Office, CCMP modelers have committed to developing a modeling framework that will enable free and open access to code specific to the Chesapeake Bay region. As a complementary activity to the Chesapeake Bay Program (CBP) modeling program, the Chesapeake Community Model Program will strive to develop a comprehensive model consisting of interchangeable individual modules covering all aspects of hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions towards a future linked watershed-estuary model. There are obvious areas of overlap between CSDMS and CCMP, and the CSDMS Chesapeake FRG intends to capitalize on synergies from both programs. We continue to solicit members of the Working Group, and your participation would be welcome.

Our first meeting was held at the Chesapeake Bay Program Office, Annapolis, MD, on April 3, 2009, and our second meeting was held at the Virginia Institute of Marine Science, Gloucester Point, VA, on November 10, 2009. These meetings aimed to get attendees up to speed on the model integration pathway that CSDMS is employing and to solicit guidance in developing short, intermediate and longer term goals for the Chesapeake FRG.

If you are interested in learning more about these meetings, please visit the Chesapeake FRG Reports page. If you would like to participate in the discussions and meetings of the CSDMS Chesapeake Focus Research Group, we invite you to join the group through the link below.

Chair

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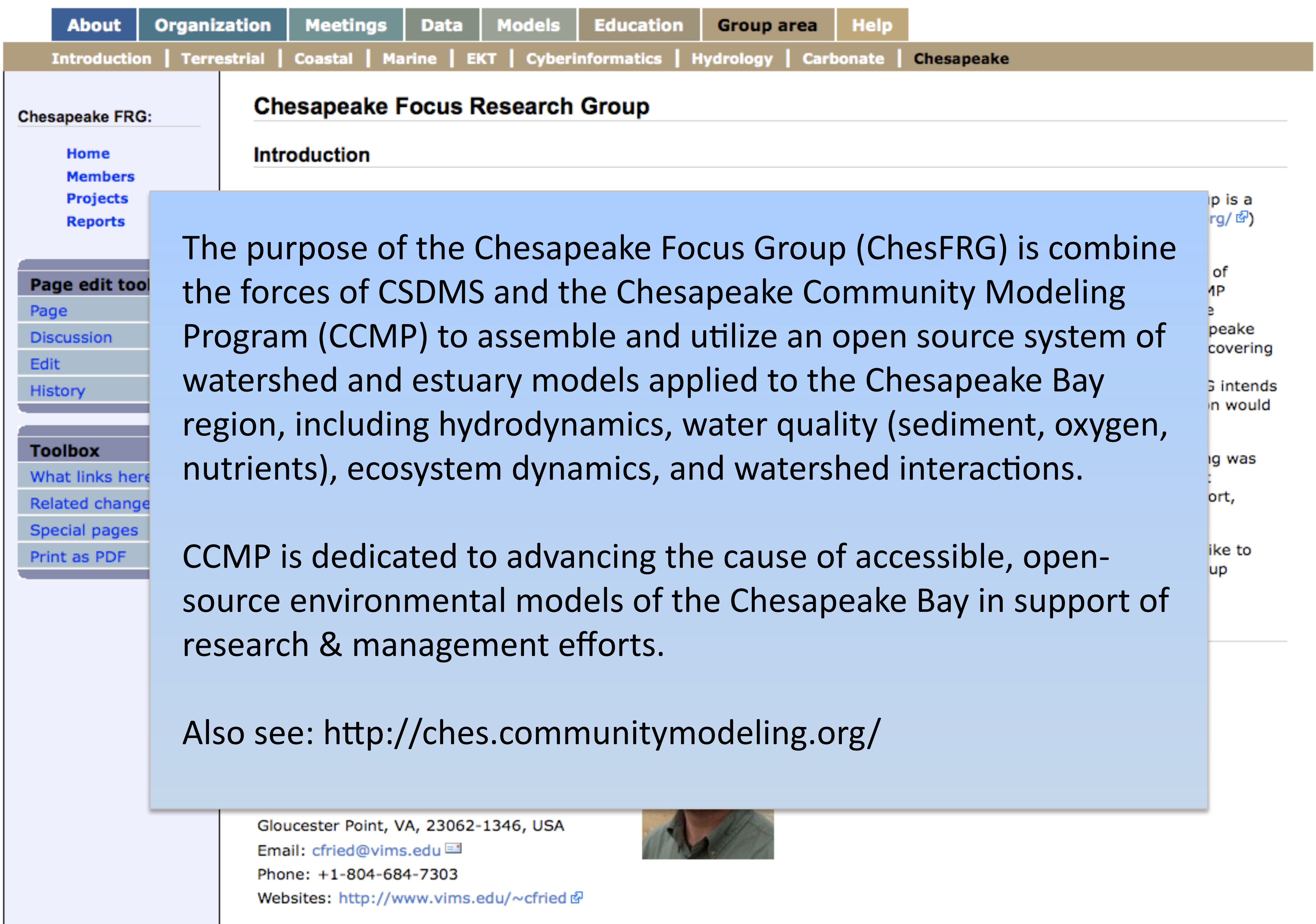
Chesapeake Focus Research Group (http:/csdms.colorado.edu/wiki/CCMP)



The purpose of the Chesapeake Focus Group (ChesFRG) is combine the forces of CSDMS and the Chesapeake Community Modeling Program (CCMP) to assemble and utilize an open source system of watershed and estuary models applied to the Chesapeake Bay region, including hydrodynamics, water quality (sediment, oxygen, nutrients), ecosystem dynamics, and watershed interactions.

CCMP is dedicated to advancing the cause of accessible, open-source environmental models of the Chesapeake Bay in support of research & management efforts.

Also see: http://ches.communitymodeling.org/

Additional Motivation:

THE ASSOCIATED PRESS September 30, 2010, 3:19PM ET

EPA: $491M in 2011 Chesapeake restoration funding

By ALEX DOMINGUEZ

BALTIMORE

The first of what federal officials say will be annual action plans for implementing a Chesapeake Bay restoration strategy was released Thursday, calling for $491 million in funding and projects ranging from cutting farm and suburban runoff to rebuilding oyster reefs.

The Environmental Protection Agency announced the plan in response to an executive order last year by President Barack Obama, putting the federal government at the helm of a previously state-led effort.

Chuck Fox, the EPA's senior Chesapeake Bay adviser, said the funding by various agencies compares to about $290 million for fiscal years 2007 through 2009. However, the plan is subject to approval by Congress.

From text of Chesapeake Bay Executive Order Action Plan for FY2011:

- Action Item WQ 10.3: "NOAA will support research to implement a coupled Regional Ocean Modeling System [ROMS] – Water Quality hydrodynamic model for use in ecological forecasting."
- Action Item SS 4.3: "EPA will establish a Chesapeake Bay Analysis and Synthesis Center to facilitate the formation of synthesis teams of scientists and managers to focus on addressing key environmental issues."
- Action Item SS 5.3: "EPA will make the underlying computer code for all its Bay TMDL related models and tools readily accessible to partners and stakeholders through the Chesapeake Community Modeling Program website [i.e., CSDMS]."
- Action Item SS 13.1: "Initiate the design and development of the Chesapeake Bay Data Enterprise system to share scientific data between partners."

Presently ~ 30 CFRG Members (http:/csdms.colorado.wiki/CCMP_Members)

Tbarchyn	Tom	**Barchyn**	University of Lethbridge	Lethbridge, Alberta		Canada	tbarchyn@gmail.com
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Presently ~ 30 CFRG Members (http:/csdms.colorado.wiki/CCMP_Members)

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- History

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- Related changes
- Special pages
- Print as PDF

6 CFRG members here today

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- **SURA Estuarine Modeling Testbed Project**
- Chesapeake Bay Models (lots of ROMS grids)
- Progress implementing ROMS in CSDMS

CSDMS

COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

Presented at CSMDS All-Hands Meeting San Antonio, TX, October 14, 2010

NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

The first funded CFRG CSDMS project.

Funded by NOAA/IOOS through SURA (Southeastern Universities Research Association). Initially one year of funding (~$800K) which started June 2010.

Part of a larger NOAA/IOOS/SURA larger (~$4M) “Super-Regional Testbed to Improve Models of Environmental Processes on the U.S. Atlantic and Gulf of Mexico Coasts”.

Pilot projects in the larger “Super-Regional Testbed” are addressing three chronic issues of high relevance within the U.S. Gulf of Mexico-U.S. Atlantic Coast region:

- Coastal Inundation
- Estuarine Hypoxia
- Shelf Hypoxia

NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

- Carl Friedrichs (VIMS) – Team Leader

Federal partners

- David Green (NOAA-NWS) – Transition to operations at NWS
- Lyon Lanerole (NOAA-CSDL) – Transition to operations at CSDL; CBOFS2
- Lewis Linker (EPA-CBP), Carl Cerco (USACE) – Transition to operations at EPA; CH3D, CE-ICM
- Doug Wilson (NOAA-NCBO) – Integration w/observing systems at NCBO/IOOS

Non-federal partners

- Marjorie Friedrichs, Aaron Bever (VIMS) – Metric development and model skill assessment
- Yun Li, Ming Li (UMCES) – ROMS hydrodynamics in CB
- Wen Long, Raleigh Hood (UMCES) – ChesROMS with NPZD water quality model
- Scott Peckham, Jisamma Kallumadikal (CSDMS) – Multiple ROMS grids, forcings, O_2 codes
- Malcolm Scully (ODU) – ChesROMS with 1 term oxygen respiration model
- Kevin Sellner (CRC) – Academic-agency liason; facilitator for model comparison
- Jian Shen, Bo Hong (VIMS) – SELFE, FVCOM, EFDC models in CB
- John Wilkin, Julia Levin (Rutgers) – ROMS-Espresso + 7 other MAB hydrodynamic models

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NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

Specific Federal Motivation:

January 2010 NOAA Funding Opportunity Announcement: "FY2010 Integrated Ocean Observing System Community Modeling Environment To Support a Super-Regional Test Bed":

"The program priorities for this funding opportunity are to conduct a super-regional testbed demonstration of the community modeling environment by transitioning models, tools, toolkits and other capabilities to a Federal operational facility to improve the understanding, prediction, and mitigation of the consequences of extreme events and chronic conditions."

NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

Aim:

In order to aid in the transition/improvement of existing models for use in Federal operations/decision making, this project aims is to provide NOAA, EPA, other agencies, and the larger modeling community meaningful guidance on the relative

- accuracy,
- efficiency,
- portability,
- complexity

of existing agency and community models for oxygen dynamics in the Chesapeake Bay and for hydrodynamics in the Chesapeake Bay and adjacent Middle Atlantic Bight (MAB).

NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

How did we choose our models?

- Include existing Federal models presently used in operations/decision making (e.g., NOAA-CSDL CBOFS2, EPA/USACE CH3D, EPA/USACE ICM, Navy/NOAA HyCOM-NCODA, Navy NCOM, NOAA-NWS RTOFS).
- Include other mature, existing open source community models that have a significant number of users around the US and/or globe (e.g., SELFE, FVCOM, EFDC, COAWST, Mercator, and especially ROMS).
- In the horizontal, include structured and unstructured horizontal grids.
- In the vertical, include both z-grids and sigma-grids.
- Include varying degrees of horizontal resolution/model speed.
- Include varying degrees of complexity of model formulation (for ecosystem/oxygen).
- Include structure to aid in linking/swapping of models/grids/forcings (i.e., CSDMS).

NOAA/IOOS/SURA Estuarine Hydrodynamics and Hypoxia Modeling Testbed

Project Deliverables

- General results of data-model intercomparison, including quantification of model accuracy, complexity, efficiency and sensitivity.
- Identification of strengths and weaknesses of various approaches (i.e., structured vs. unstructured; z- vs. sigma-grid; high resolution vs. high performance; more complex vs. simpler water quality formulations).
- Advice to NOAA-CSDL (via Lyon Lanerole, Frank Aikman) and NOAA-NWS (via David Green) for implementing 3-day forecasts of hydrodynamic/water quality conditions.
- Advice to EPA/USACE CBP (via Lewis Linker, Carl Cerco) for scenario-based hydrodynamic/water quality model improvement for "2017" EPA/CBP modeling effort.
- Delivery to NOAA NCBO (via Doug Wilson) of interactive web-based summary of final model output, model data comparisons, and project conclusions .

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- SURA Estuarine Modeling Testbed Project
- **Chesapeake Bay Models (lots of ROMS grids)**
- Demonstration of progress implementing ROMS in CSDMS

CSDMS
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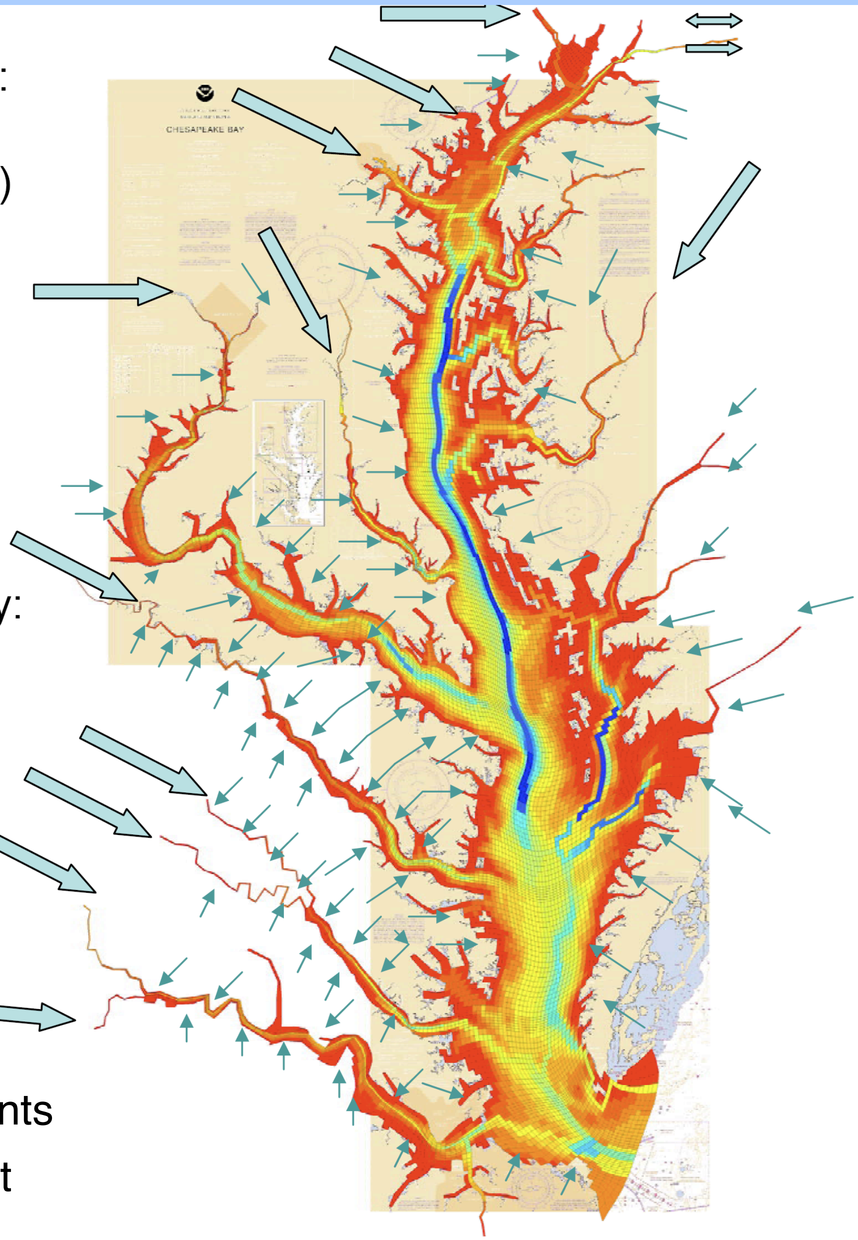
EPA/USACE CBP CH3D Model

- River boundary:
  River input (USGS or WSM)
  INPUT Flow, T/S

- Shore boundary:
  Lateral flow (WSM)
  INPUT Flow, (T/S)

57000 grid points

z-grid, Δz = 5 ft



- Free surface bnd:
  (Heat exchange, Wind, drag…)
- Bottom boundary:
  (friction)
- Ocean boundary:
  (T/S/H)

Impacting circulation /vertical mixing: tides, current, wind, density effects (S/T), freshwater, turbulence.

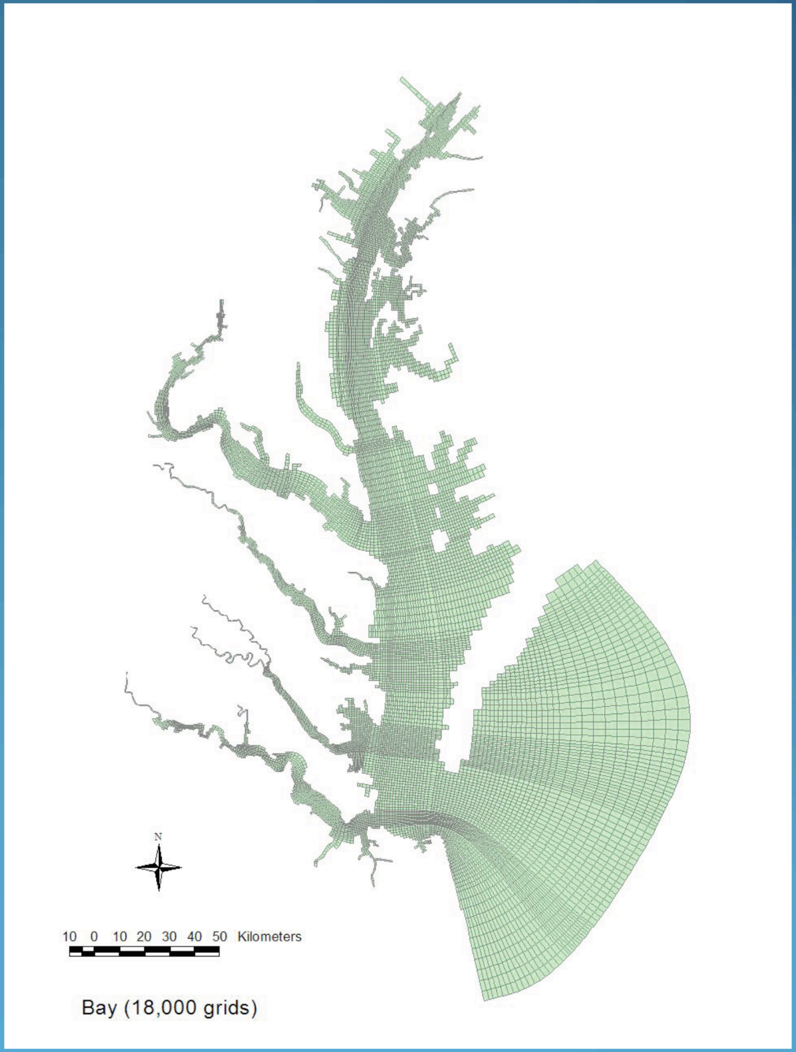
(Slide courtesy Ping Wang, CBPO)

"Environmental Fluid Dynamics Code" (Originally from HydroQual)

The Fine Resolution EFDC model

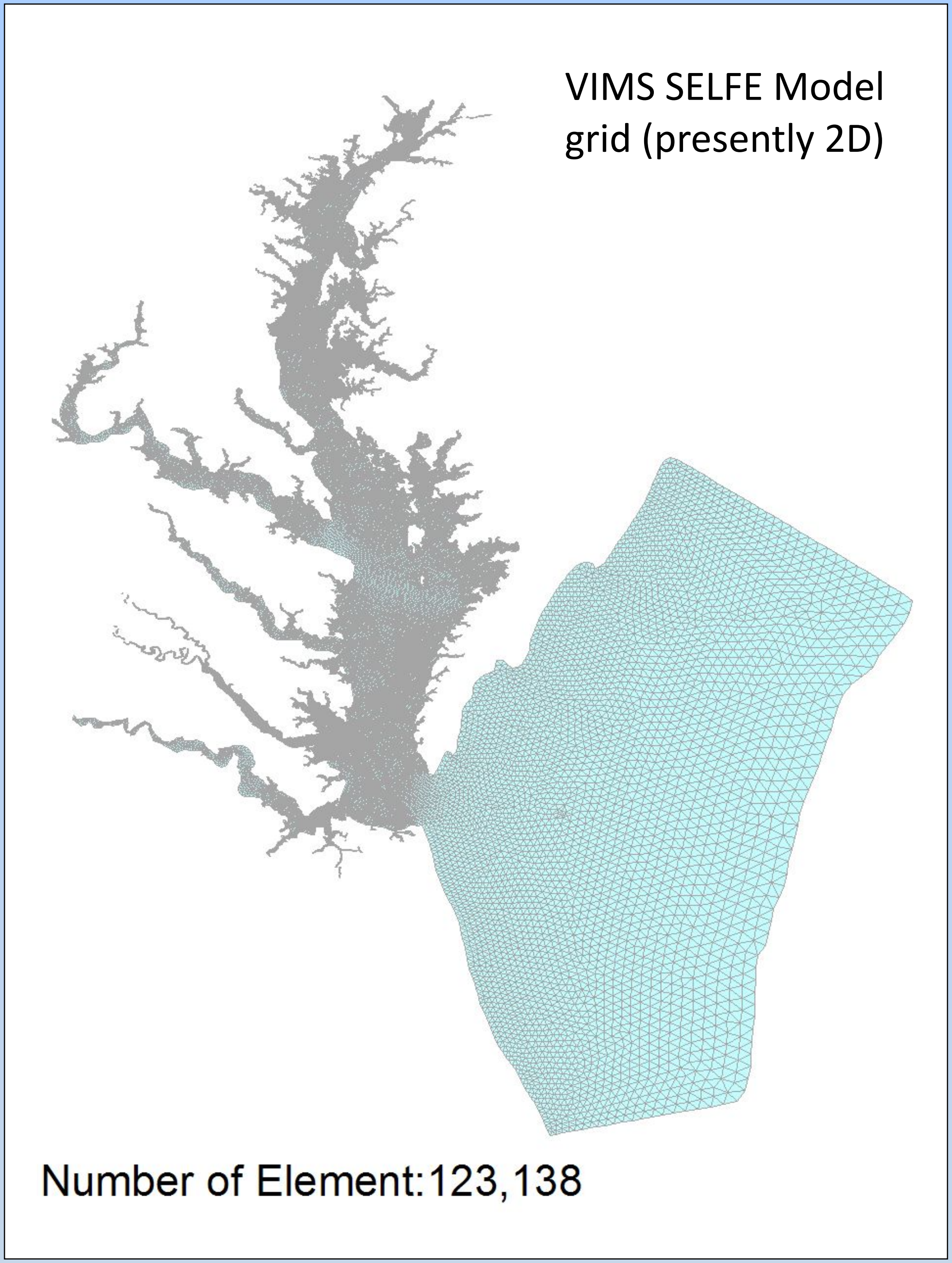
- Refine in tributaries
- There are 18,000 grids in horizontal

20 layer sigma-grid in vertical



Virginia Institute of Marine Science VIMS

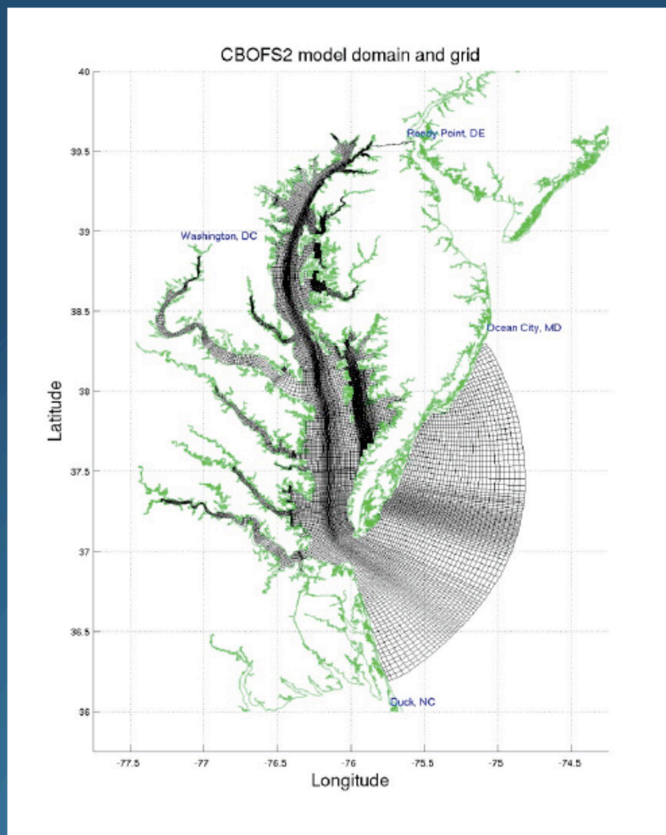
(Slide courtesy Jian Shen)



(Slide courtesy
Jian Shen, VIMS)

ROMS Chesapeake Bay Hydrodynamic Model 1

CBOFS2 Model Domain and Grid



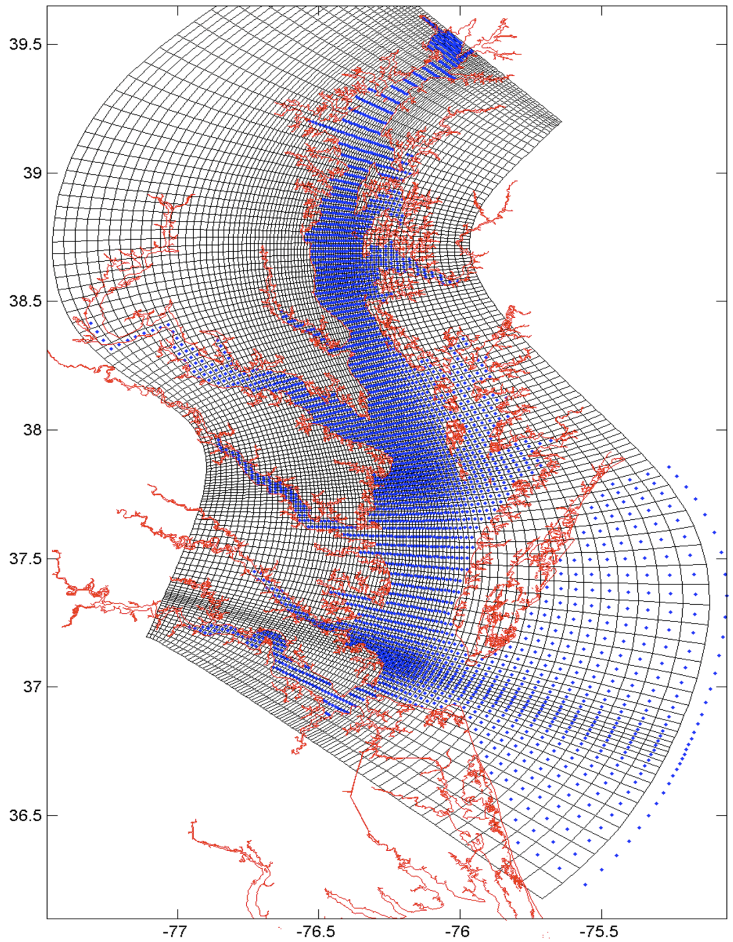
- Extent – Sasquehanna River reservoir (North), 100m isobath & Duck-NC & Ocean City-MD (South), Washington-DC (West), Reedy Point, DE (East along C & D canal)
- Grid is curvilinear and orthogonal
- Grid generated as local segments and pasted together in the DELFT3D grid generator
- Matlab script to go from DELFT3D format to ROMS format (NetCDF)
- 291 x 332 x 20 grid points
- Resolution (m) : $34 \leq \Delta x \leq 4895$ and $29 \leq \Delta y \leq 3380$
- Vertical grid has a σ-formulation with clustering at the ocean surface and the ocean bottom; 20 levels
- Bathymetry from NOS soundings

NOAA/NOS/OCS/Coast Survey Development Laboratory

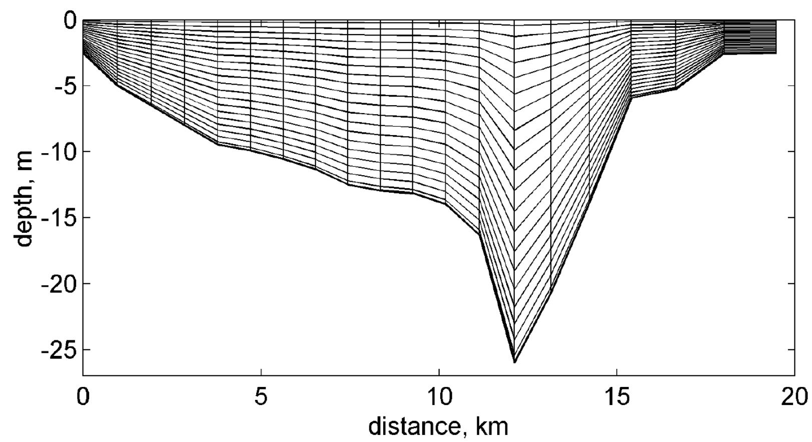
(Slide courtesy Lyon Lanerolle)

ROMS Chesapeake Bay Hydrodynamic Model 2

UMCES (ROMS) Model for Chesapeake Bay



- Curvilinear horizontal coordinates with grid spacing about 1 km.
- Generalized terrain-following vertical coordinate with 20 layers.



Li et al. (2005, 2006, 2007, 2010),
Li & Zhong (2009), North et al. (2008),
Zhong & Li (2006), Zhong et al. (2008).

(Slide courtesy Ming Li)

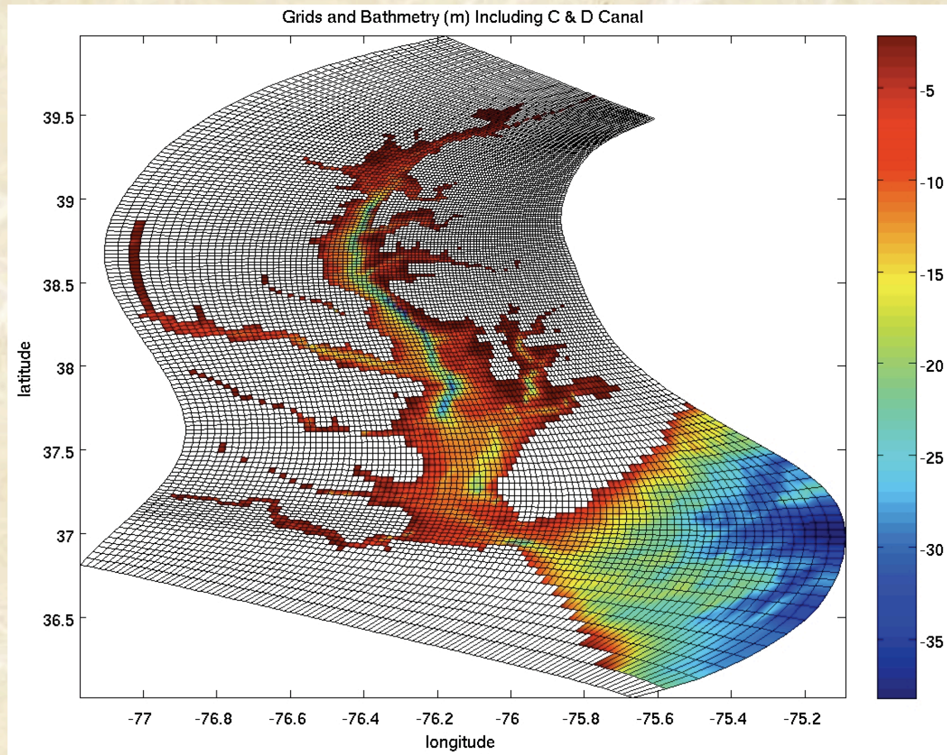
ROMS Chesapeake Bay Hydrodynamic Model 3

ChesROMS Community Model

- ROMS 3.0
- Curvilinear Horizontally
- S-coordinate Vertically
- Includes major tributaries
- Coarse mesh for model development (100*150*20)
- Forcing: Tides, Winds, Heat Fluxes and Rivers
- Currently expanding the biogeochemical model
- Goal: Improved Simulation of BGC processes
- Open Source Available at:

http://sourceforge.net/projects/chesroms/

Grid spacing ~2 km



ChesROMS Team:
Chris Brown, Tom Gross, Raleigh Hood, Mohan Karyampudi, Lyon Lanerolle, Wen Long, Raghu Murtugudde, Dave Potsiadlo, M. Bala Krishna Prasad, Jerry Wiggert, Jiangtao Xu

CERF Presentation, 4 November 2009

(Slide courtesy Jerry Wiggert)

ROMS Chesapeake Bay Hydrodynamic Model 4

Chesapeake Interactive Modeling Project (CHIMP)

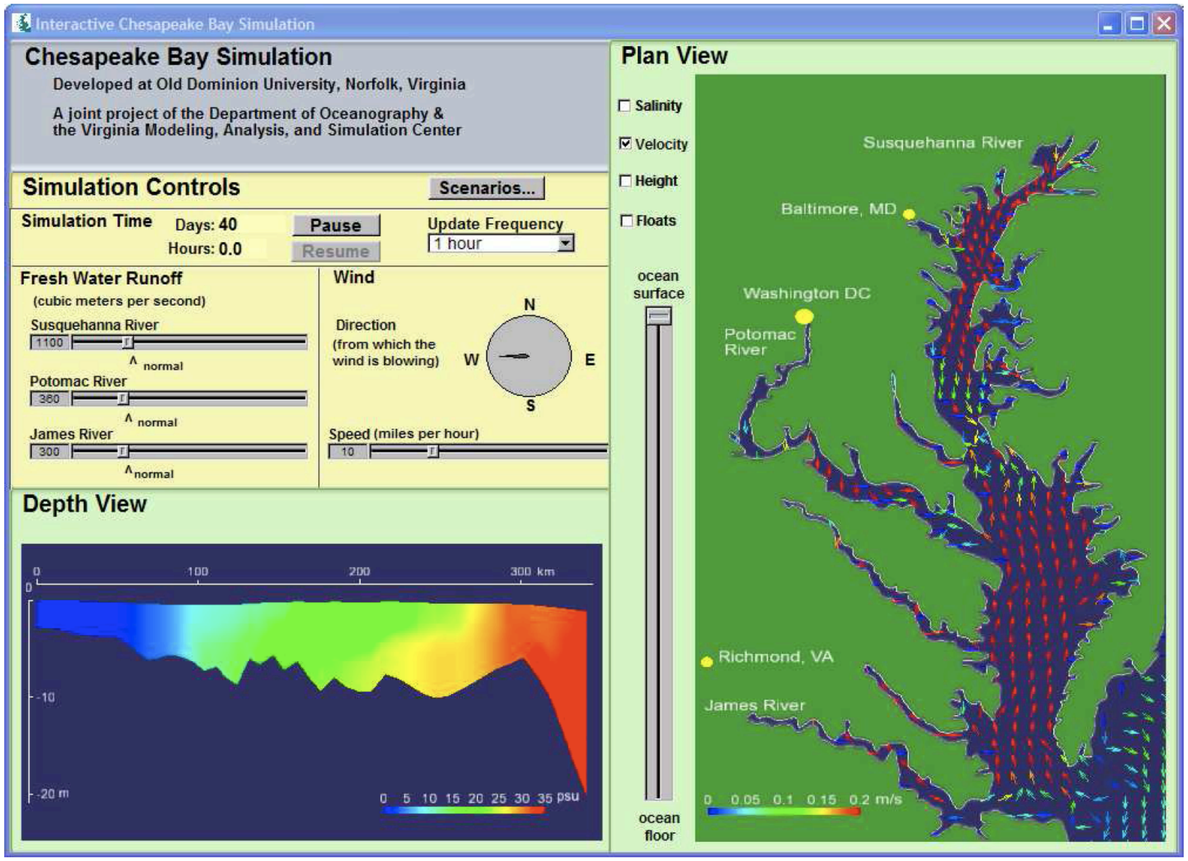


Figure 1. Interactive visualization of Regional Ocean Model System applied to the Chesapeake Bay

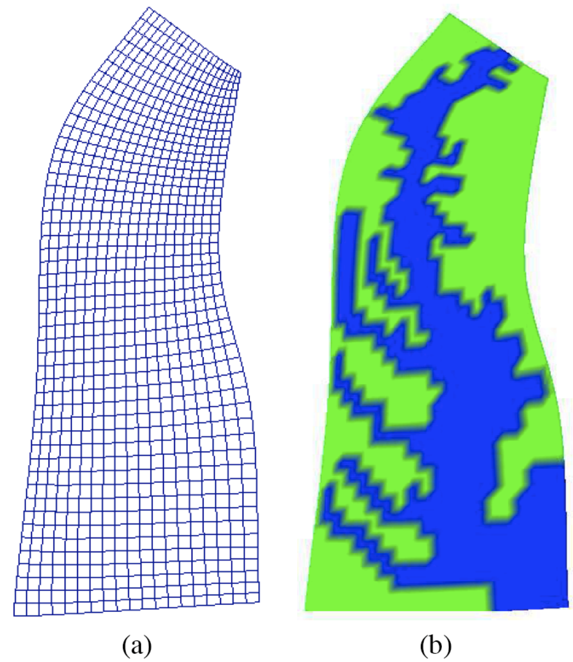


Figure 2. Grid configuration of ROMS on Chesapeake Bay. (a) The top layer of a $20 \times 50 \times 10$ (east-west $\times$ north-south $\times$ vertical layers) grid for Chesapeake Bay. (b) The bay is shown in blue and the land around the bay is shown in green.

20 sigma-layers, horizontal grid spacing ~6 km

(Figures from Shen et al. 2007)

Middle Atlantic Bight ROMS model

MARCOOS/ESPreSSO ROMS

RU Coastal Ocean Modeling and Prediction group

John Wilkin, Julia Levin, Gordon Zhang,
Naomi Fleming, Javier Zavala-Garay, Hernan Arango

5 km resolution for assimilation

1 km resolution for forecast

NCEP NAM 3-hour meteorology

1-day average USGS gauge river flow

Additional models to be compared:

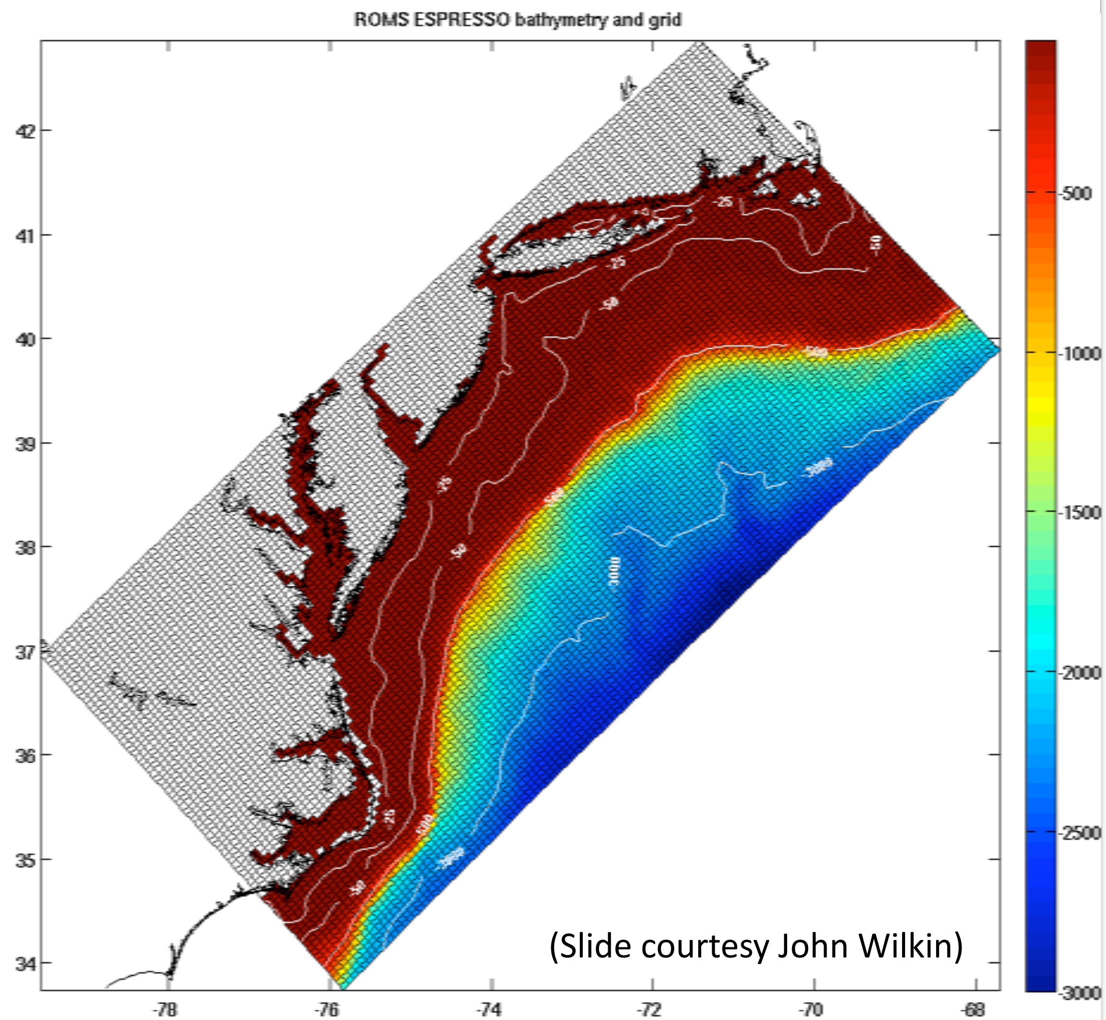
-- USGS COAWST (Coupled Ocean Atmosphere Wave Sediment Transport),

-- NOPP HyCOM-NCODA (Hybrid Coordinate Ocean Model-Navy Coupled Ocean Data Assimilation),

-- NCOM (Navy Coastal Ocean Model),

-- NOAA RTOFS (Real Time Ocean Forecast System),

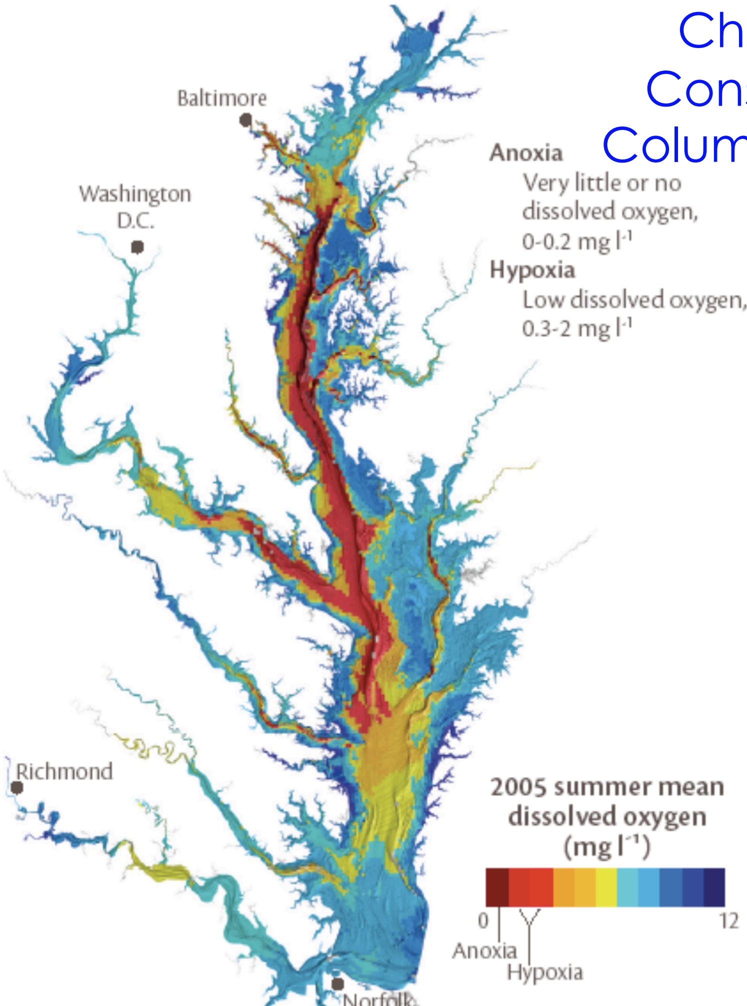
-- European Mercator Global Model



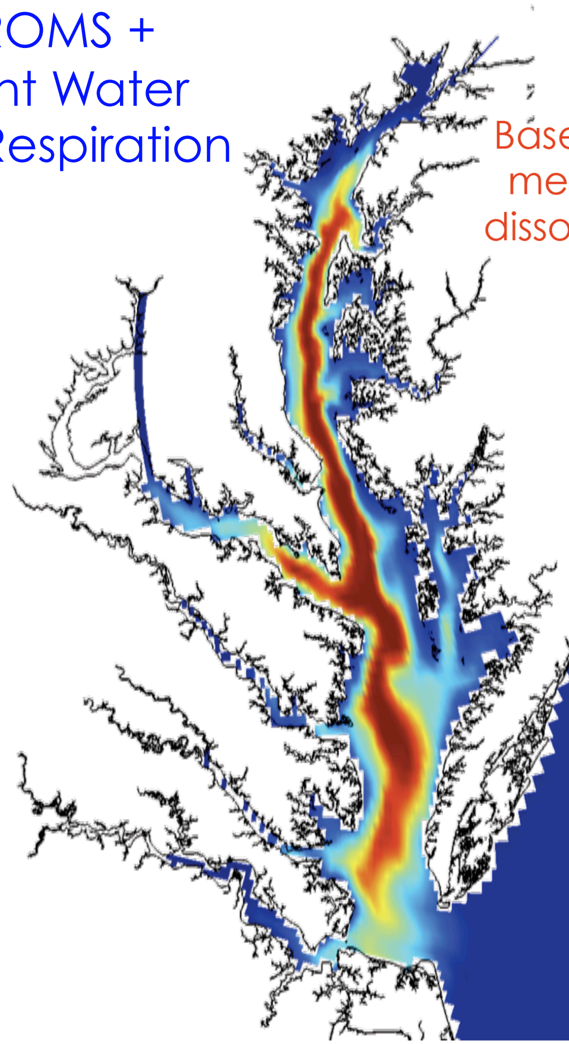
ROMS Chesapeake Bay Hypoxia Model 1

Model Qualitatively Reproduces Extent and Intensity of Hypoxia in the Bay

ChesROMS + Constant Water Column Respiration



Observed summer mean dissolved oxygen 2005



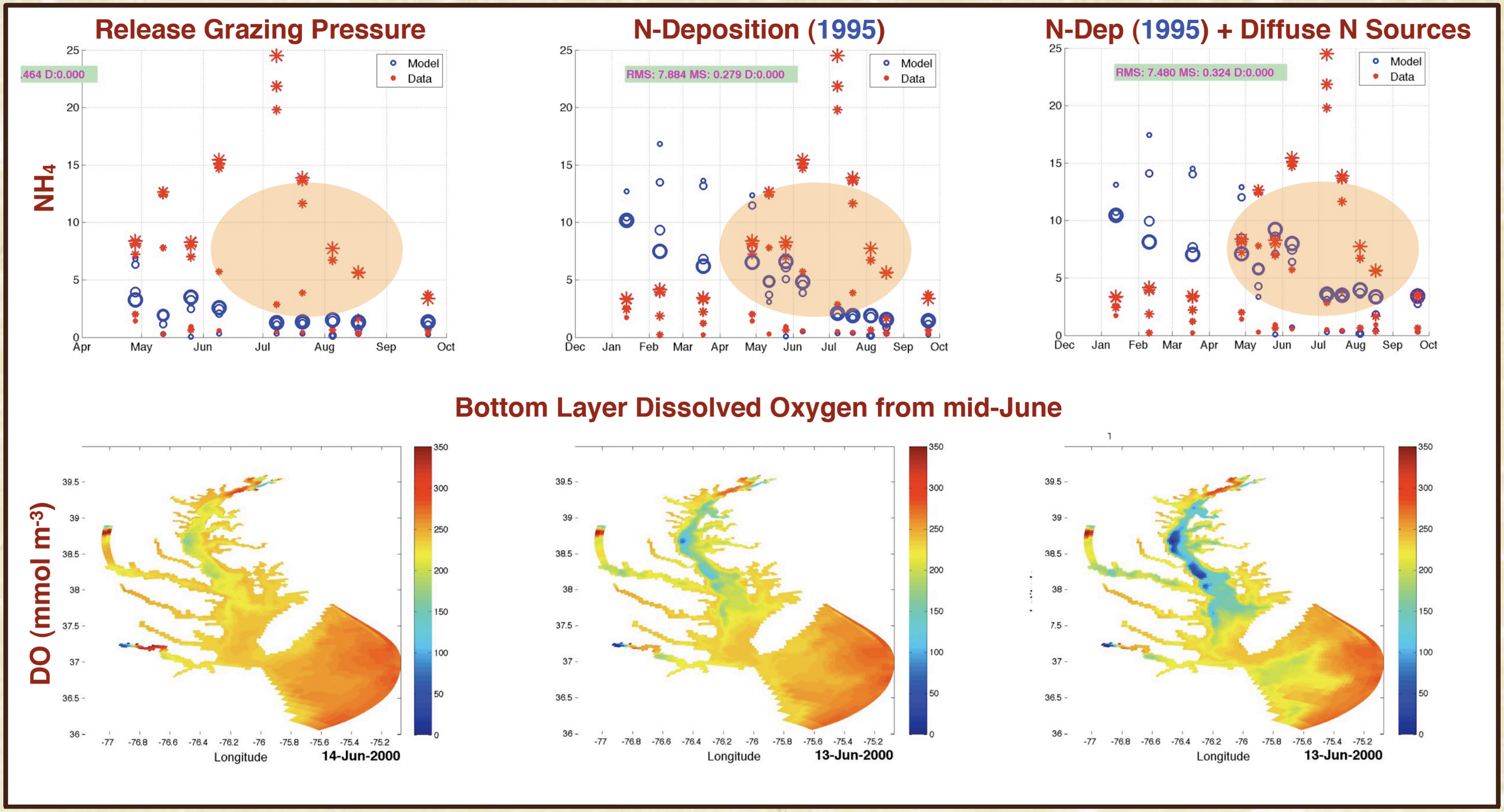
Base Model run mean bottom dissolved oxygen

(Slide courtesy Malcolm Scully)

ROMS Chesapeake Bay Hypoxias Model 2,3,4

Assessing Ecosystem Solution: Upper Bay

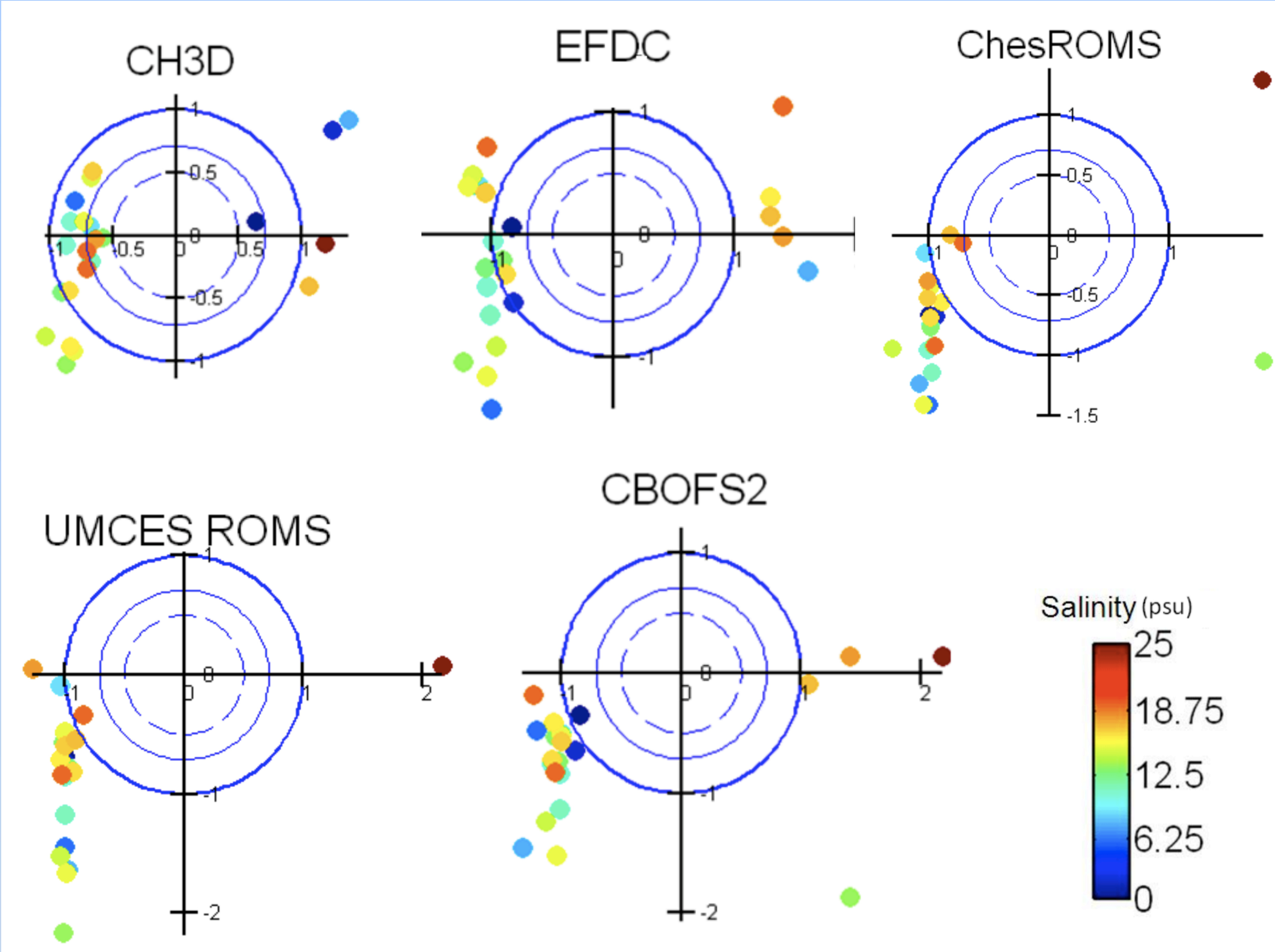
(Grazing Pressure -> N-Dep -> N-Dep + Diffuse Sources: NH_4 & DO)



ChesROMS with Chlorophyll, Nitrate, Ammonium, DON, Oxygen, Detritus, Zooplankton

(Slide courtesy Jerry Wiggert)

Target Diagrams for Maximum dS/dz at 23 EPA Monitoring Stations During 2004

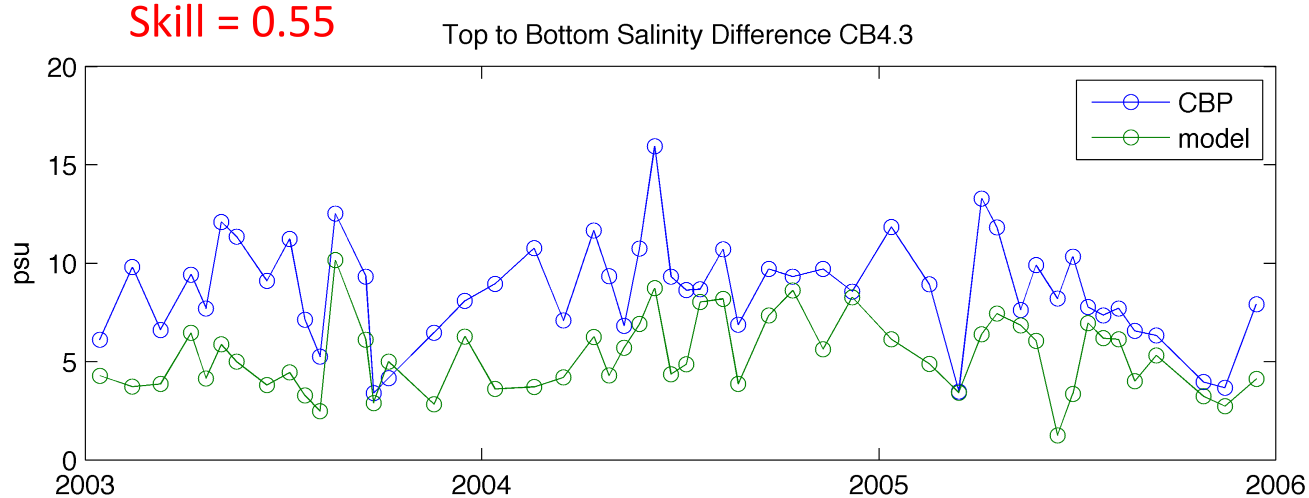


Models don't reproduce stratification well. See poster for explanation!

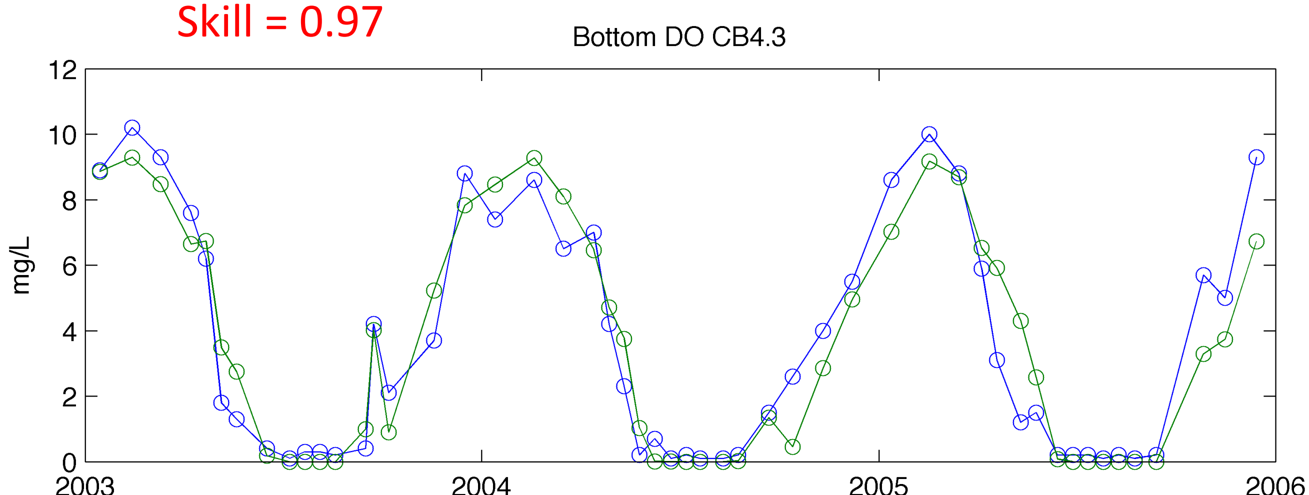
(Slide courtesy Aaron Bever)

It's much easier to reproduce oxygen concentration than salinity stratification(!)

Skill = 0.55

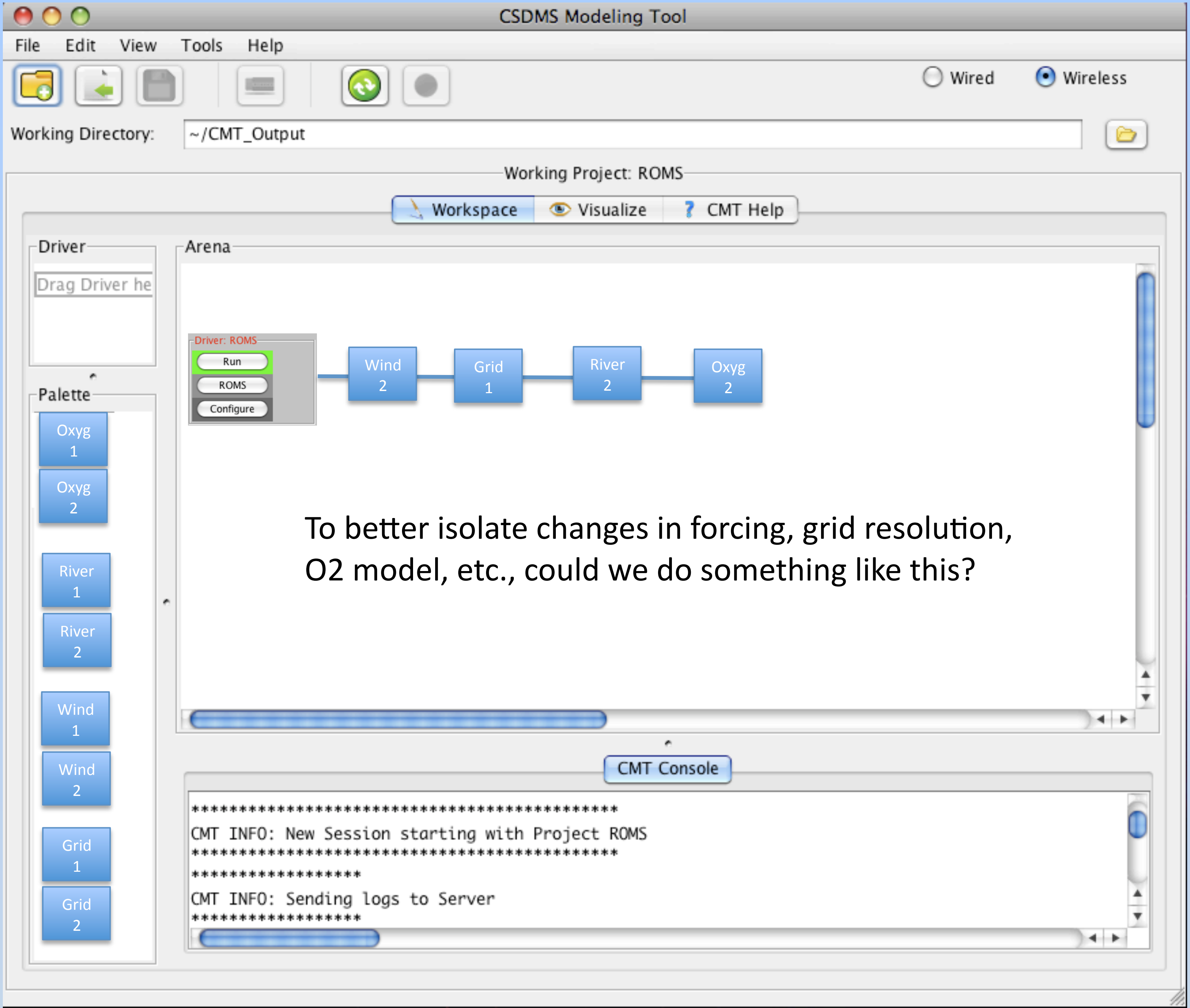


Skill = 0.97



$$Skill = 1 - \frac{\sum \left|X_{\mathrm{mod}\,el} - X_{obs}\right|^2}{\sum \left(\left|X_{\mathrm{mod}\,el} - \overline{X_{obs}}\right| + \left|X_{obs} - \overline{X_{obs}}\right|\right)^2}$$

(Slide courtesy Malcolm Scully)



To better isolate changes in forcing, grid resolution, O2 model, etc., could we do something like this?

Application of CSDMS to Chesapeake Bay Models

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and the SURA Estuarine Modeling Testbed Team

<u>Outline of Presentation</u>:

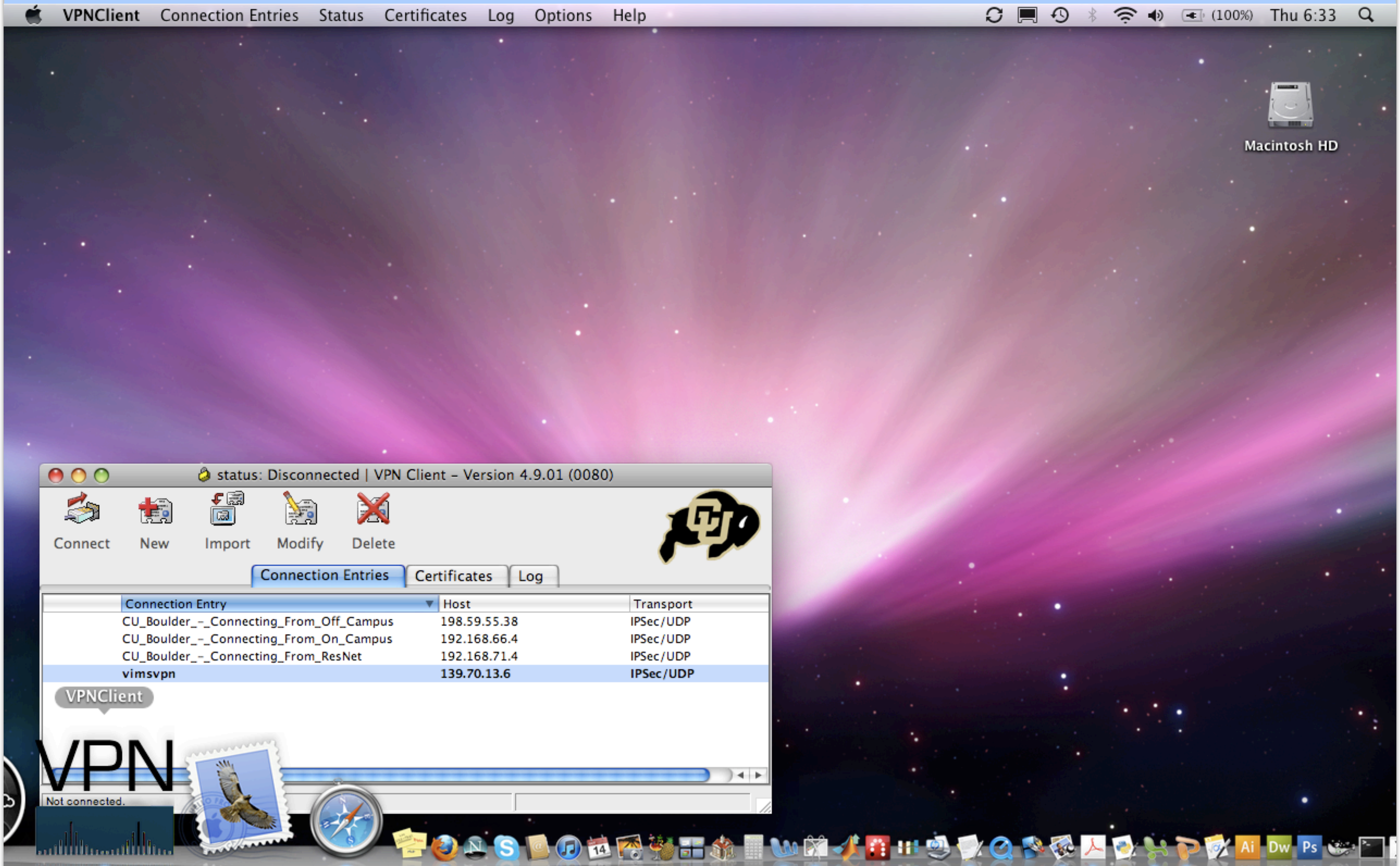
- CSDMS Chesapeake Focus Research Group
- SURA Estuarine Modeling Testbed Project
- Chesapeake Bay Models (lots of ROMS grids)
- **Progress implementing ROMS in CSDMS**

CSDMS

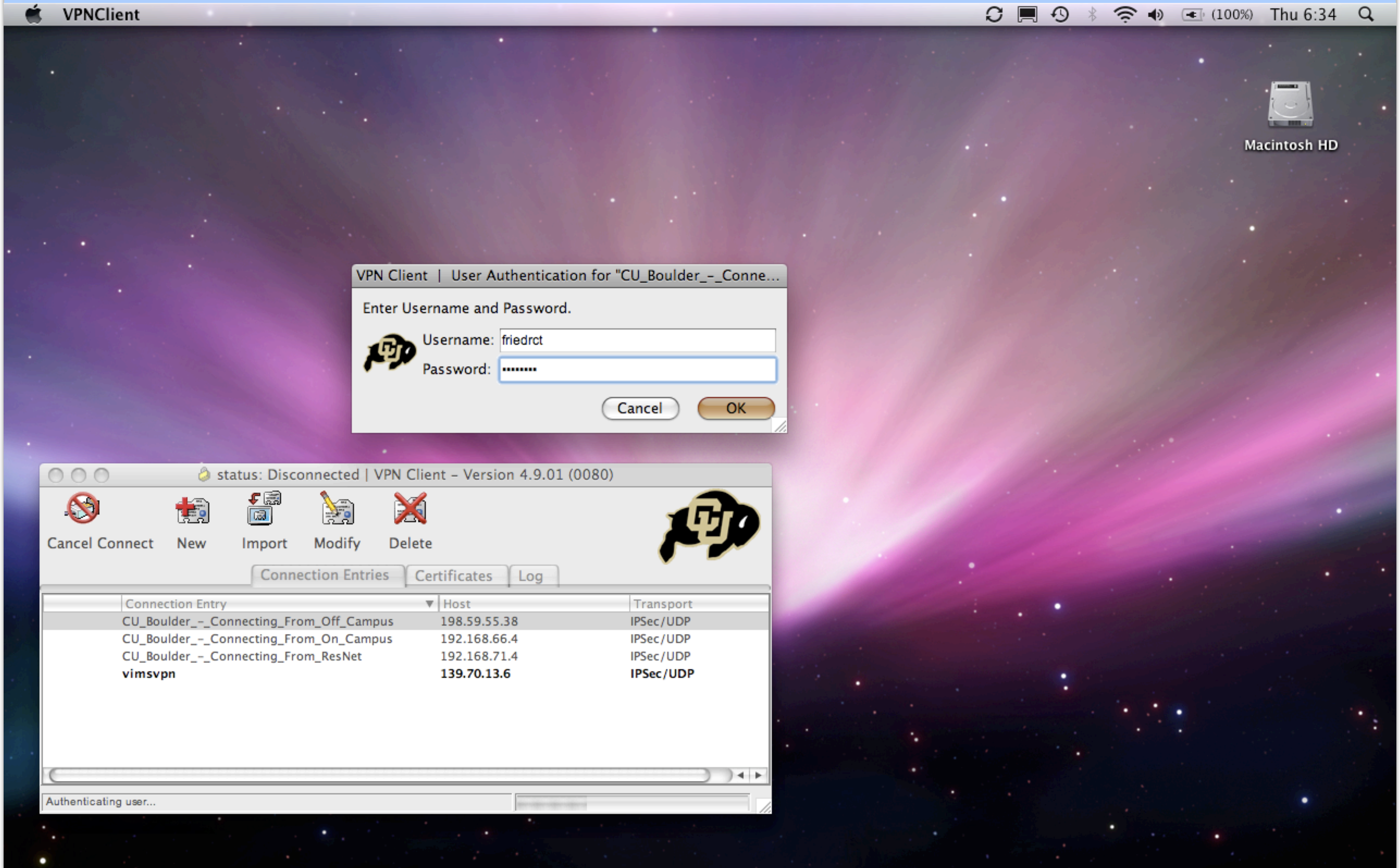
COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

Presented at CSMDS All-Hands Meeting San Antonio, TX, October 14, 2010

Connect to U Colorado via VPN

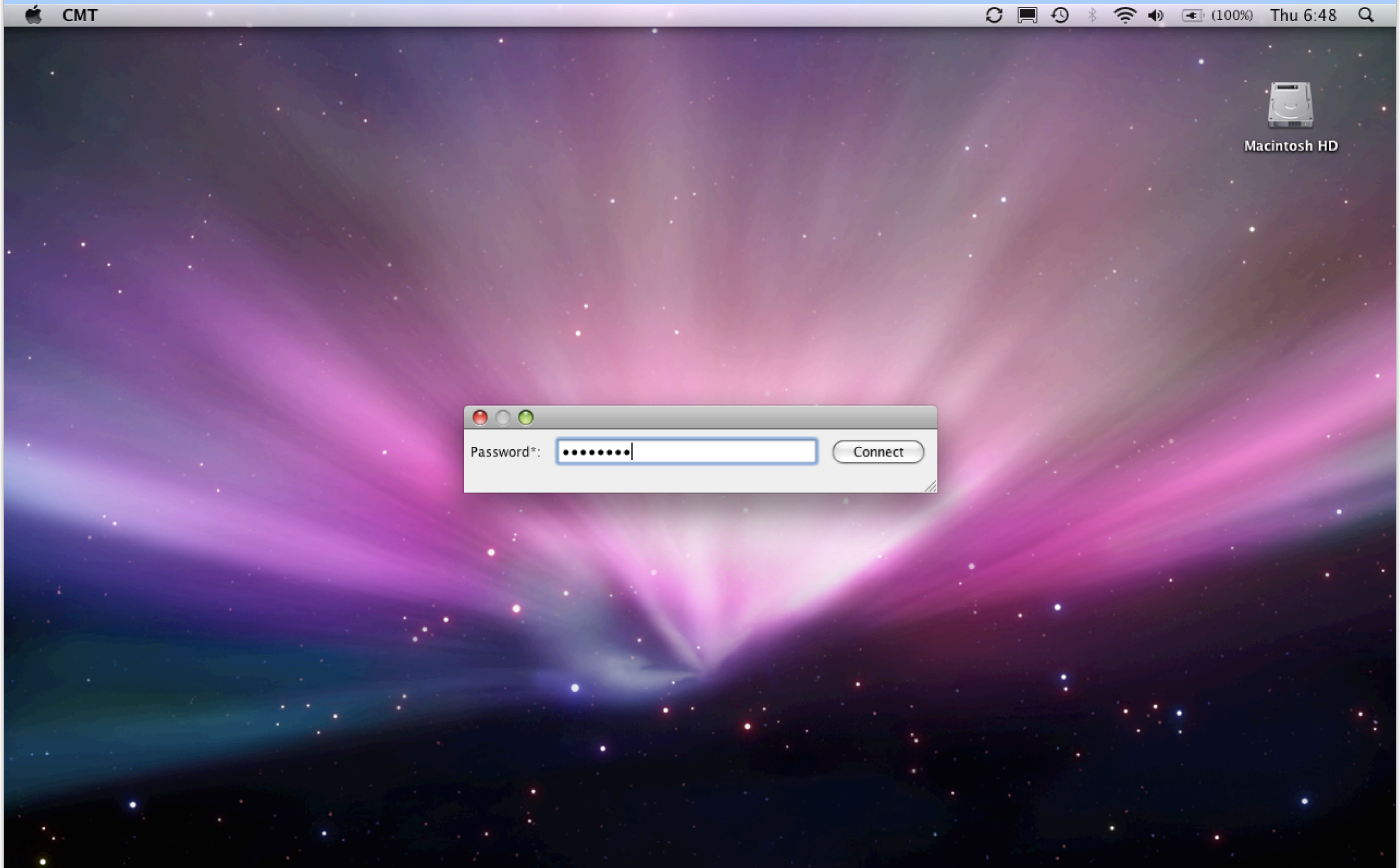


Connect to U Colorado via VPN

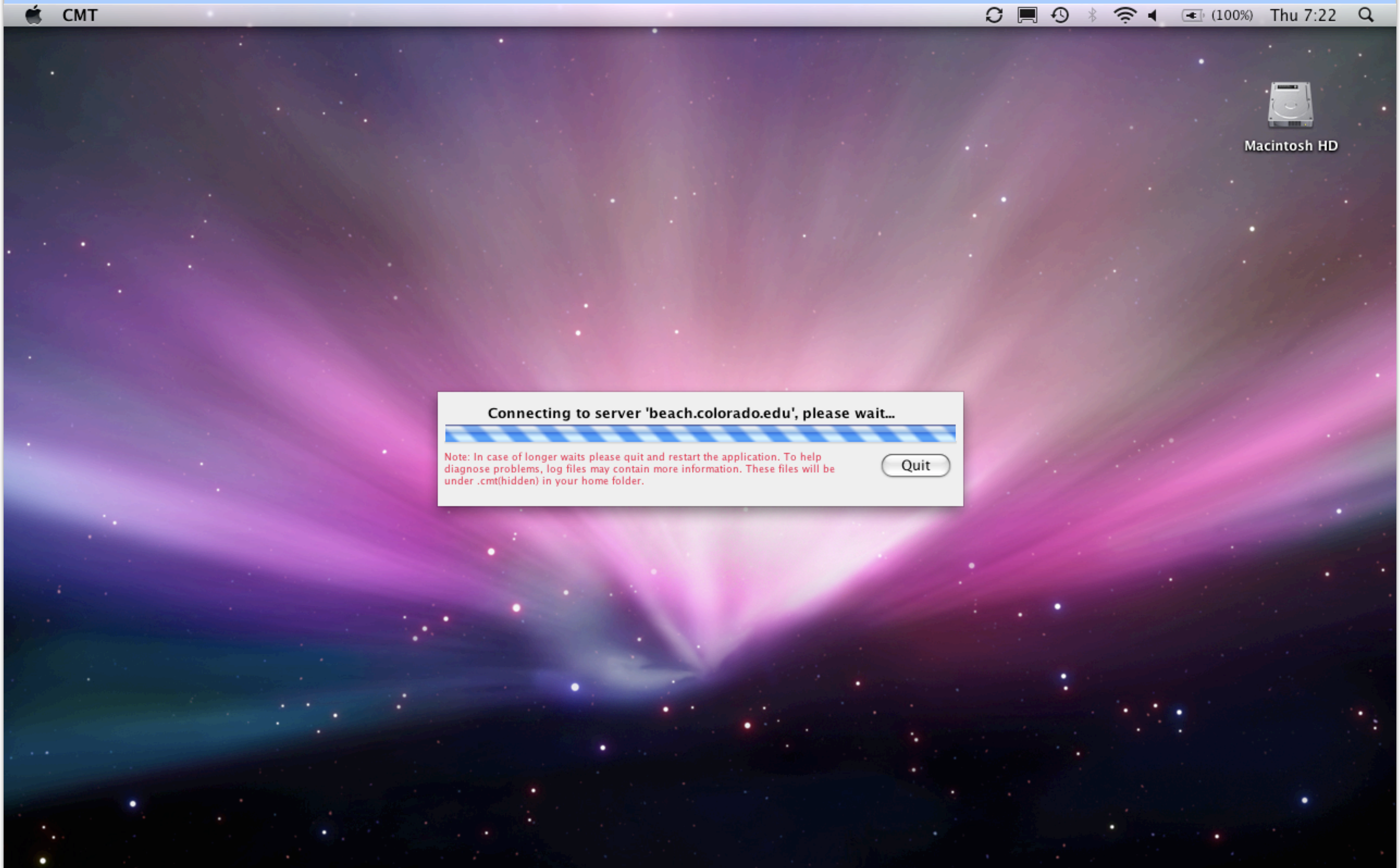


Start up CSMDS Modelling Tool

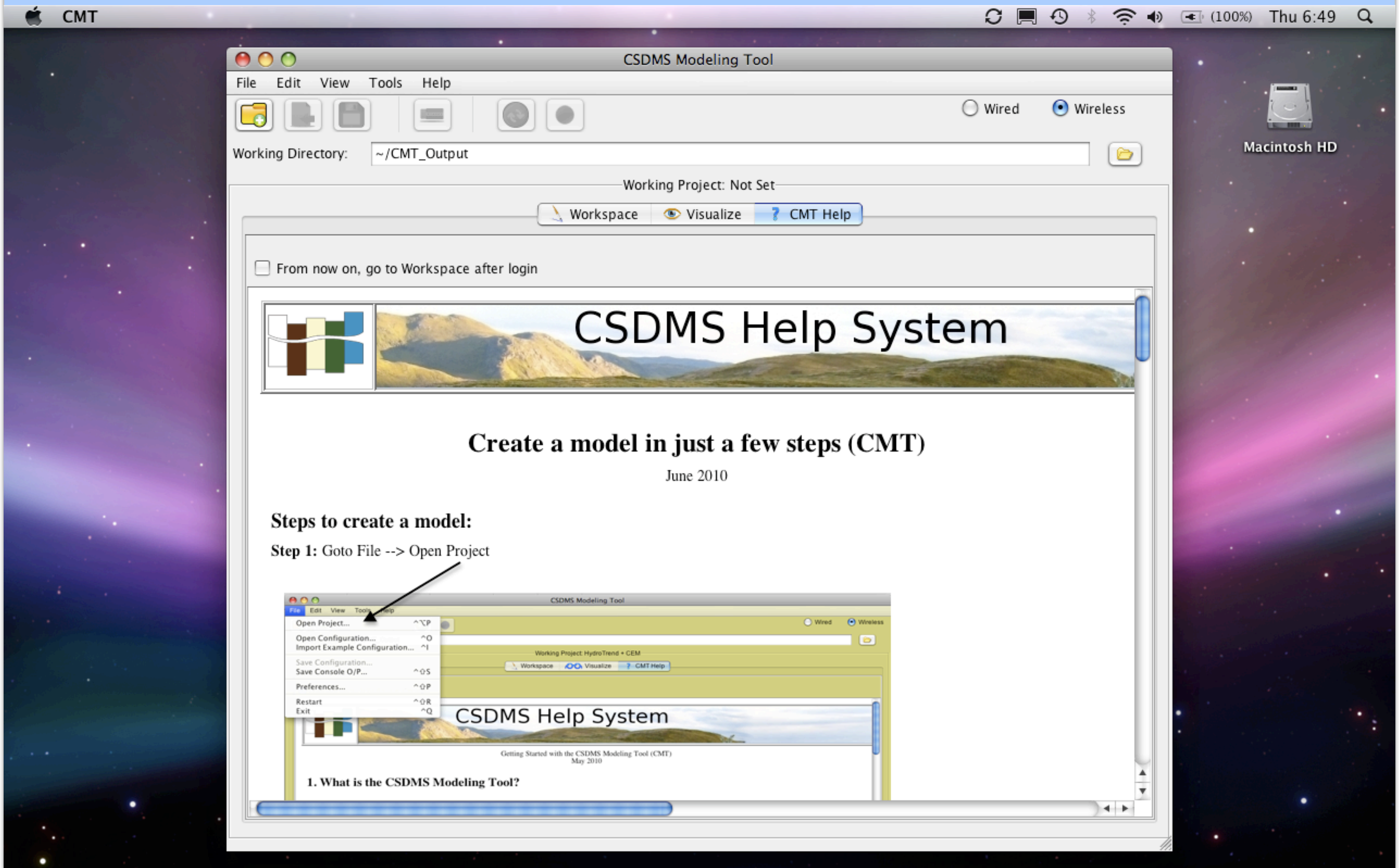
Log into Beach



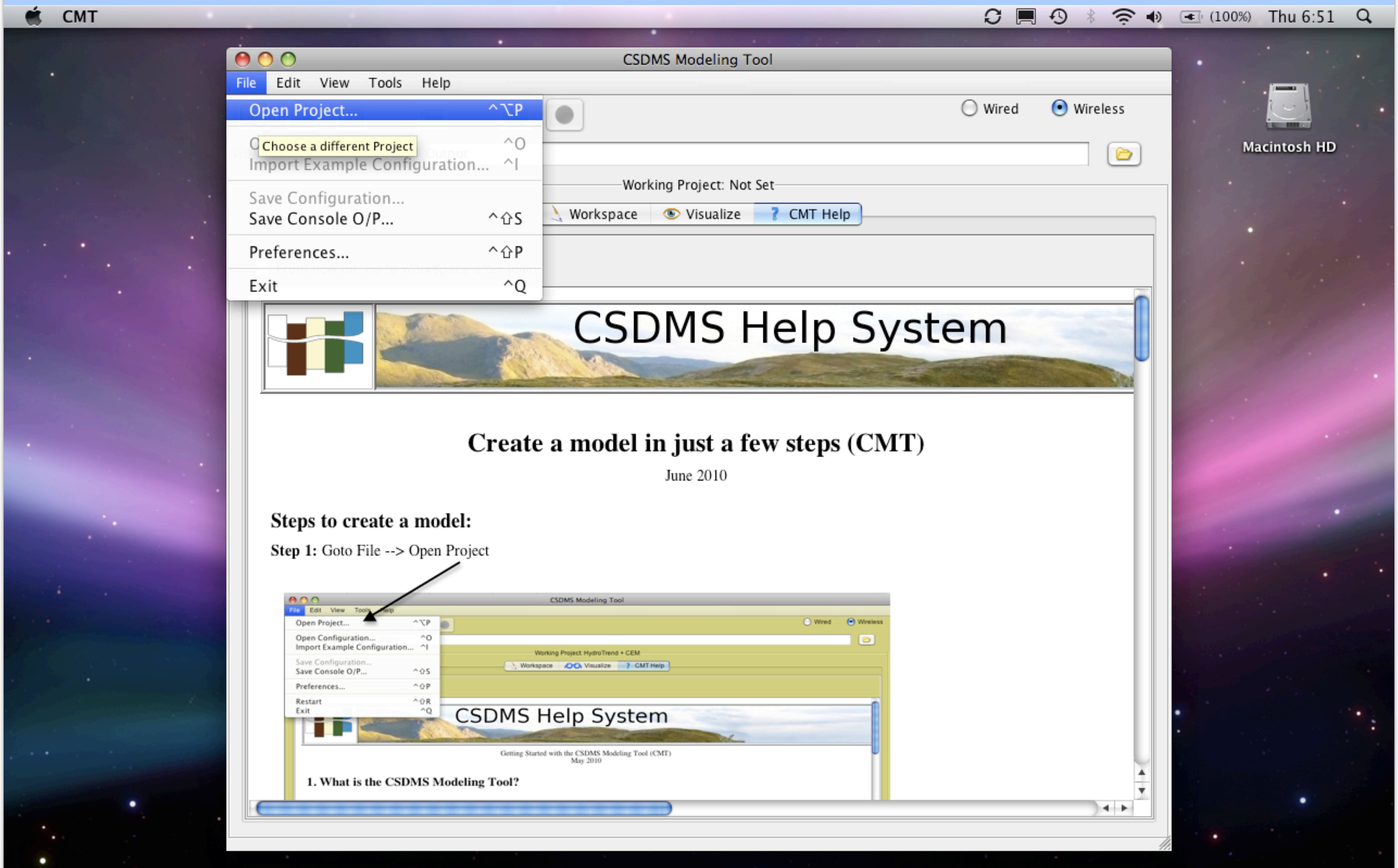
Connecting...


CMT
(100%) Thu 7:22
Macintosh HD
Connecting to server 'beach.colorado.edu', please wait...
Note: In case of longer waits please quit and restart the application. To help diagnose problems, log files may contain more information. These files will be under .cmt(hidden) in your home folder.
Quit

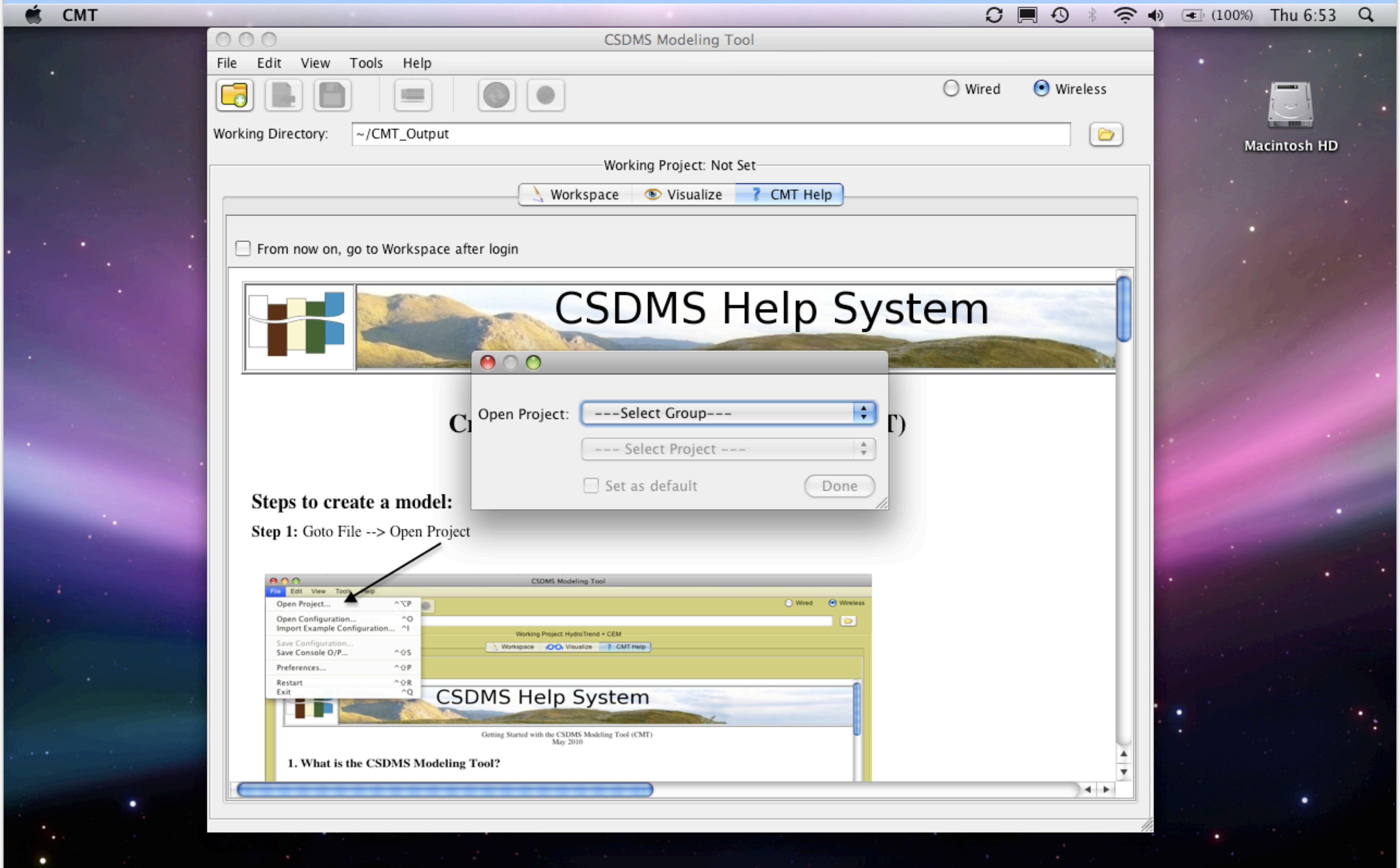
Opening view of CMT



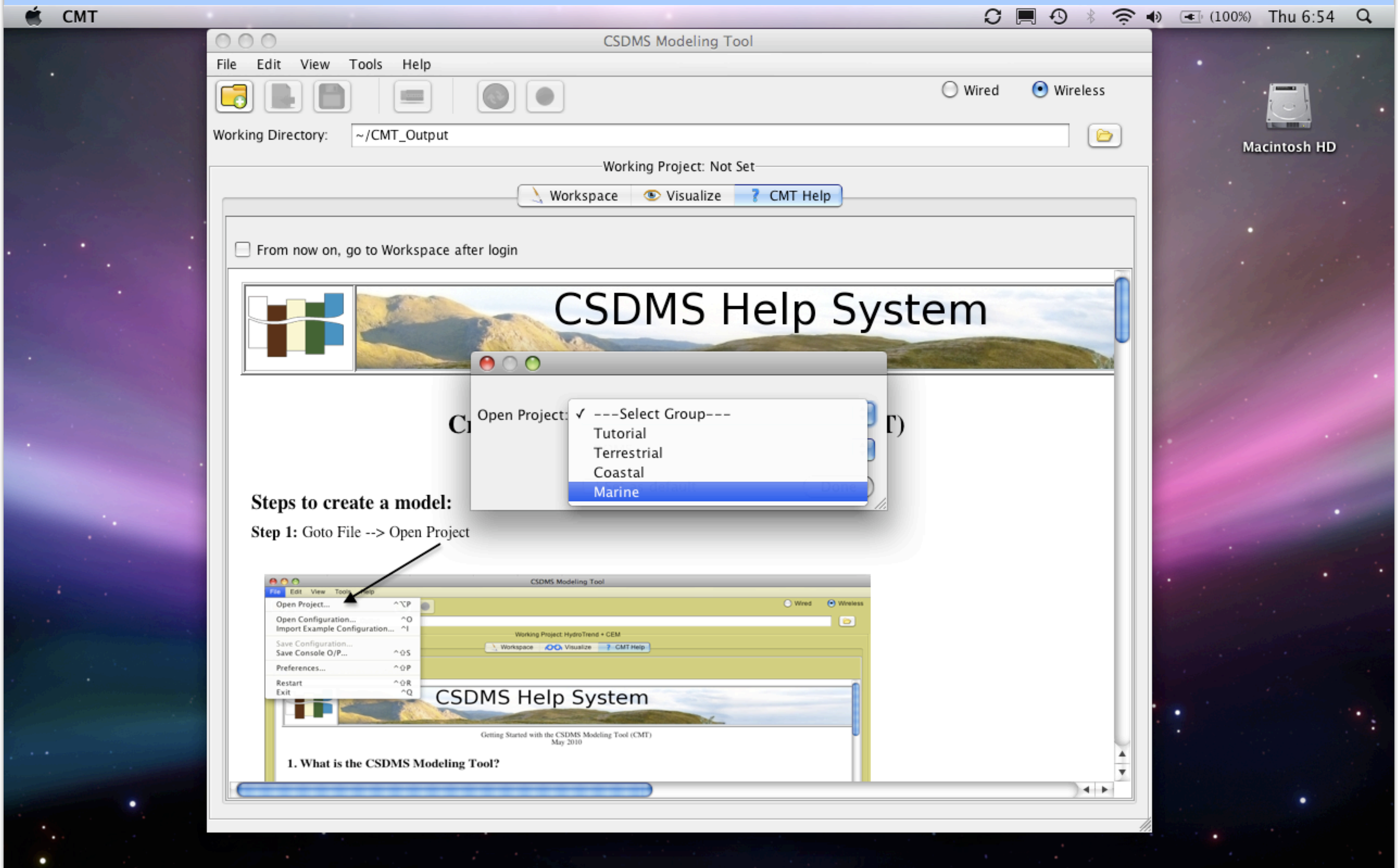
Open a project…



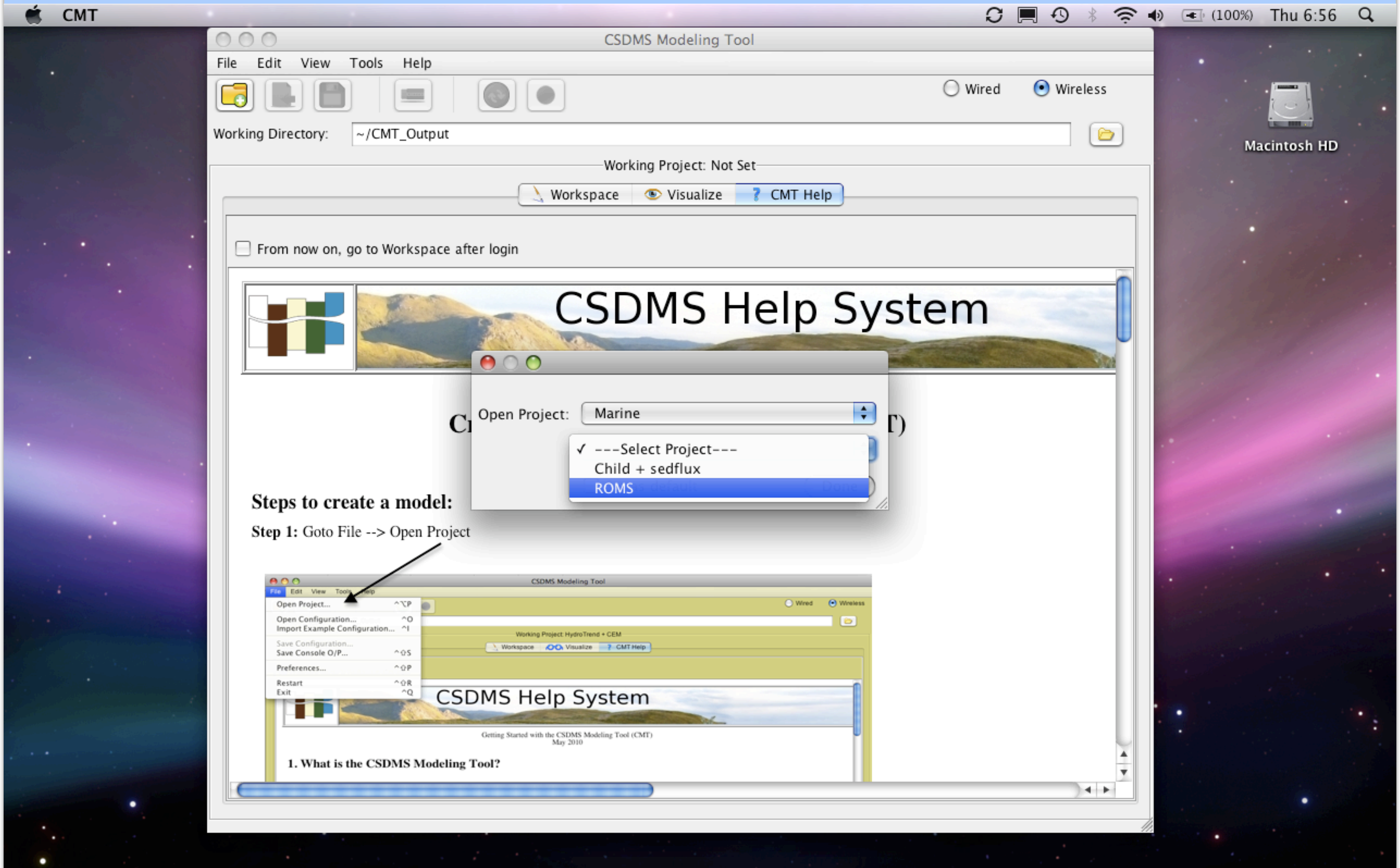
Select group…



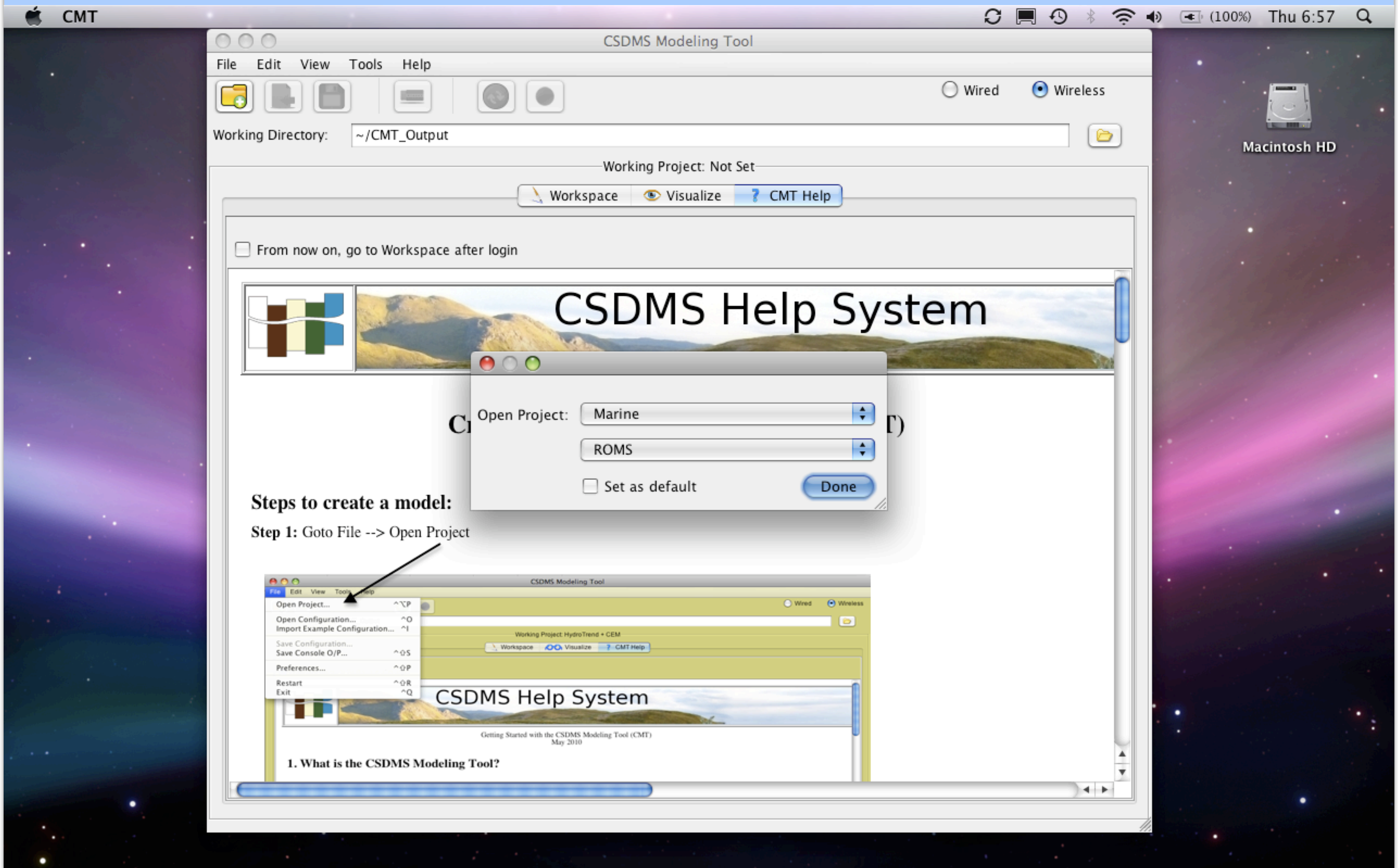
(A lot of overlap with Marine Group interests…)



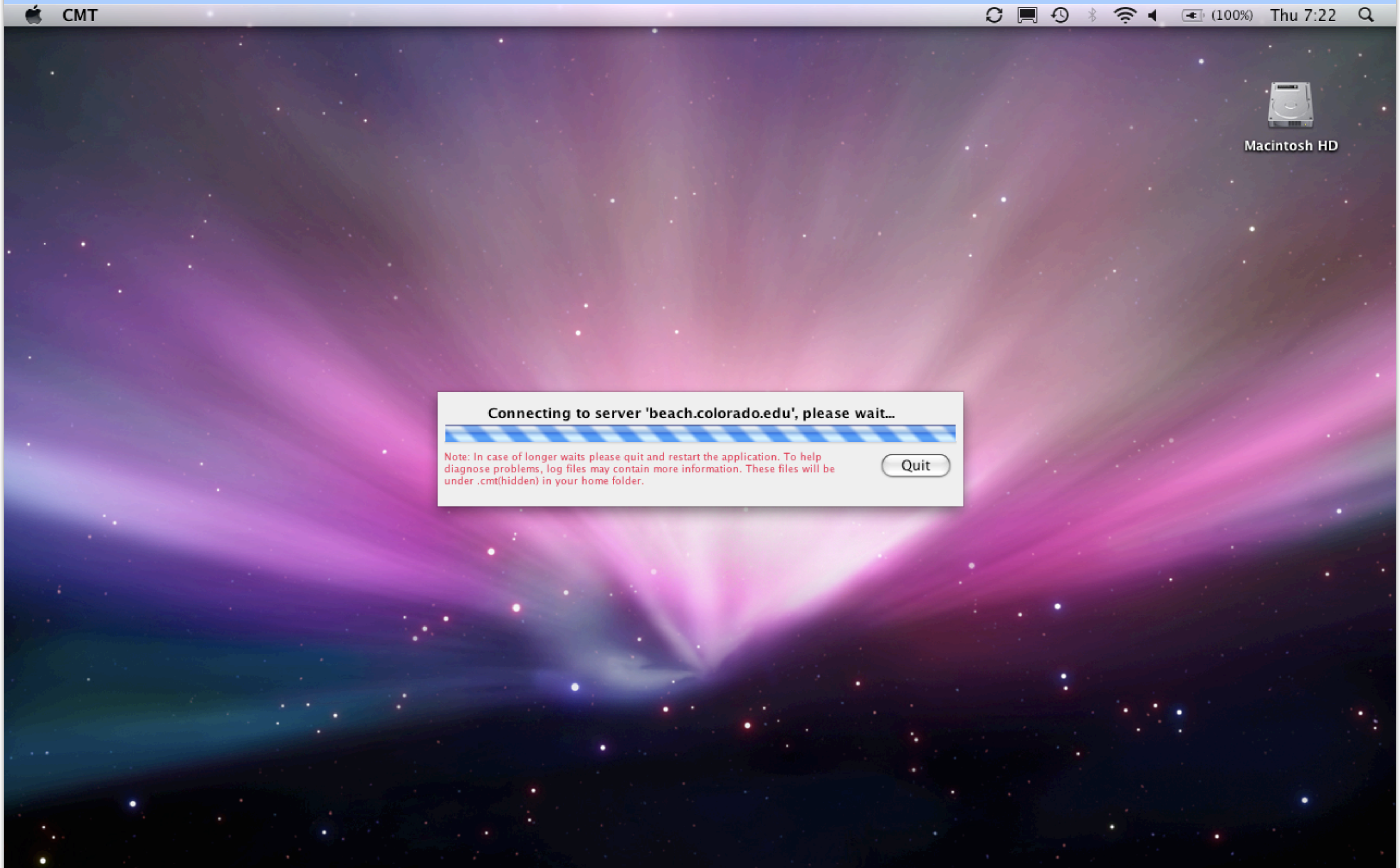
Select Project…



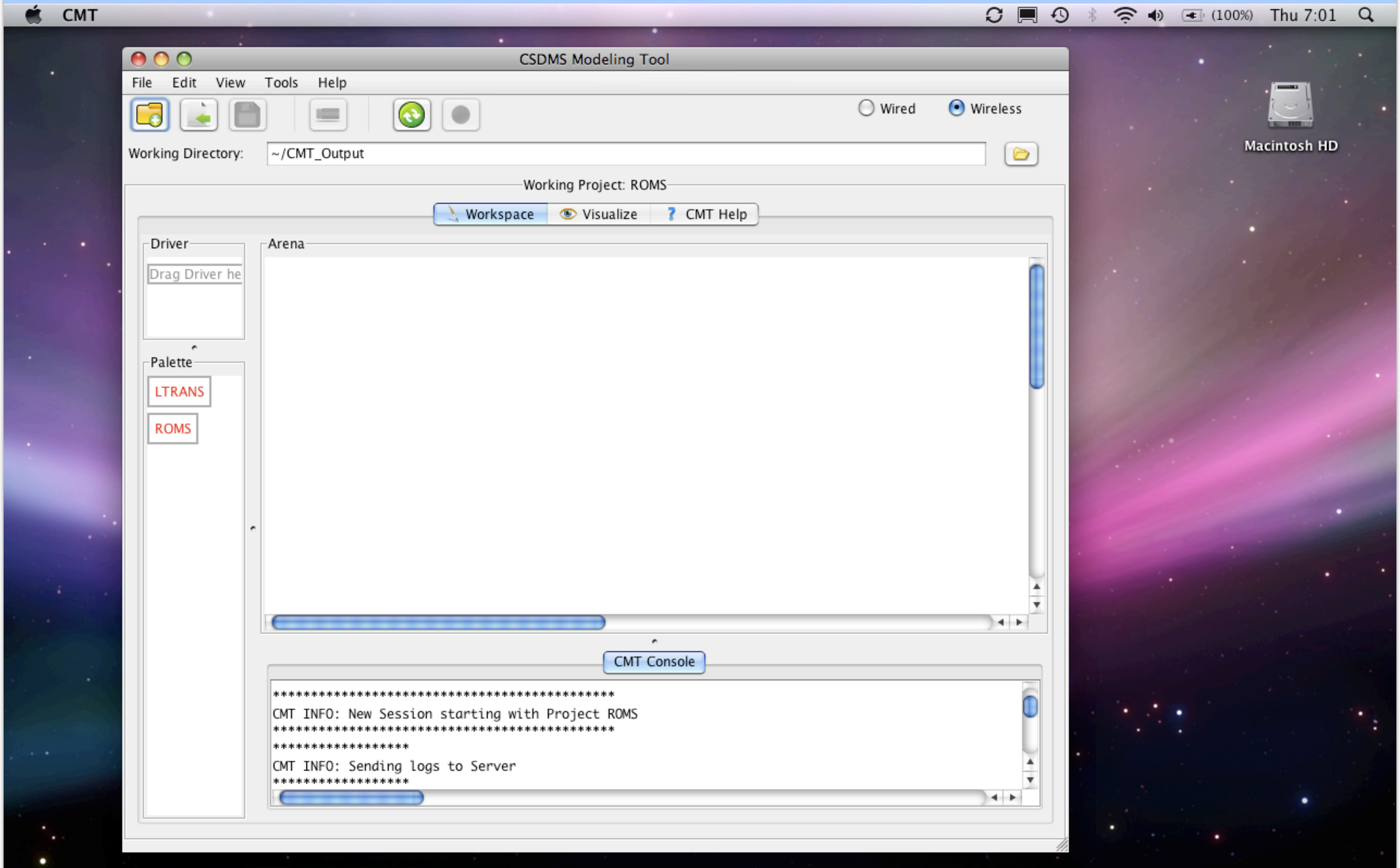
Done...


CMT
Thu 6:57
(100%)
CSDMS Modeling Tool
File Edit View Tools Help
Wired
Wireless
Working Directory:
~/CMT_Output
Macintosh HD
Working Project: Not Set
Workspace
Visualize
CMT Help
From now on, go to Workspace after login
CSDMS Help System
Open Project:
Marine
ROMS
Set as default
Done
Steps to create a model:
Step 1: Goto File --> Open Project

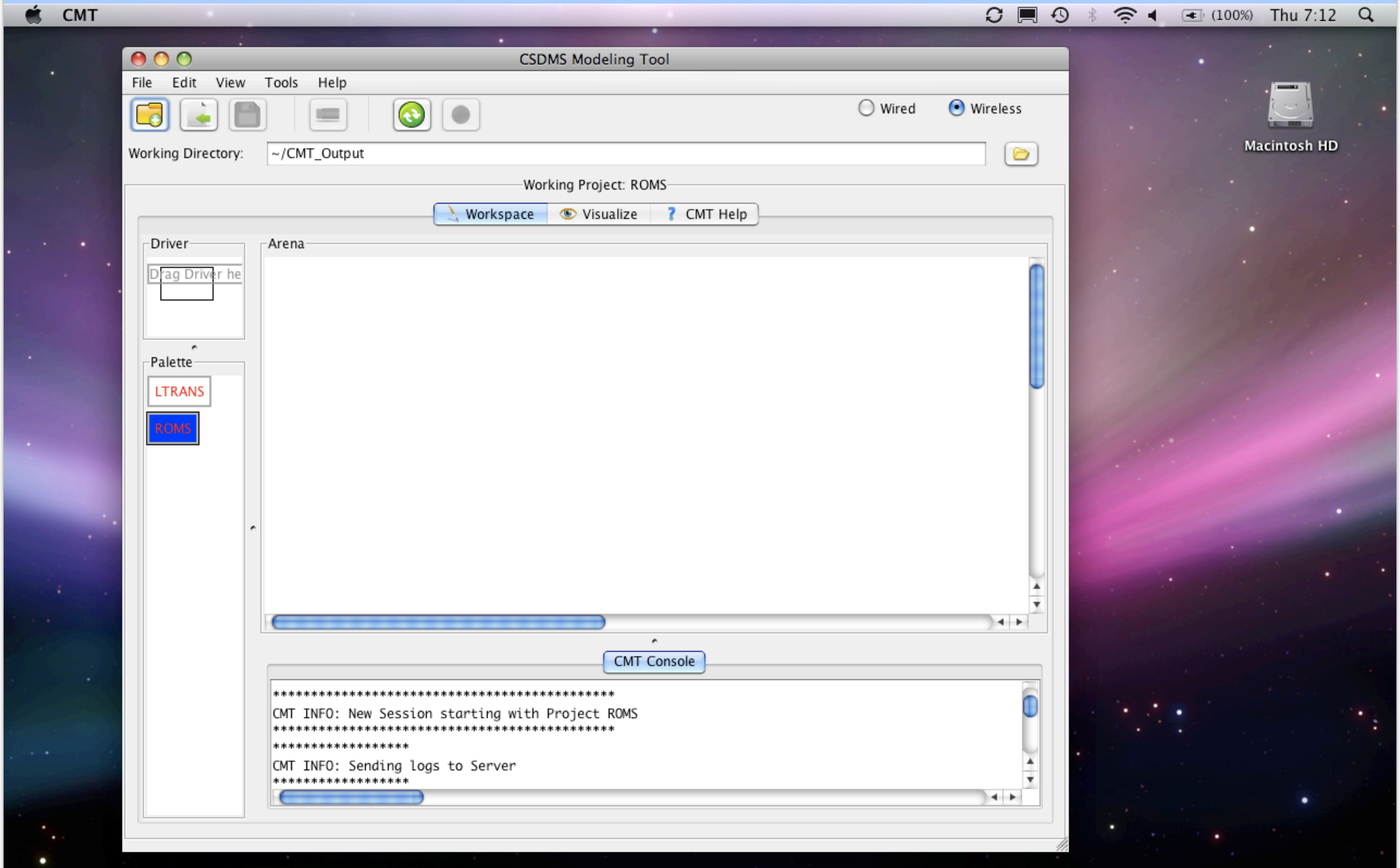
Connecting...


CMT
(100%) Thu 7:22
Macintosh HD
Connecting to server 'beach.colorado.edu', please wait...
Note: In case of longer waits please quit and restart the application. To help diagnose problems, log files may contain more information. These files will be under .cmt(hidden) in your home folder.
Quit

ROMS Project Workspace

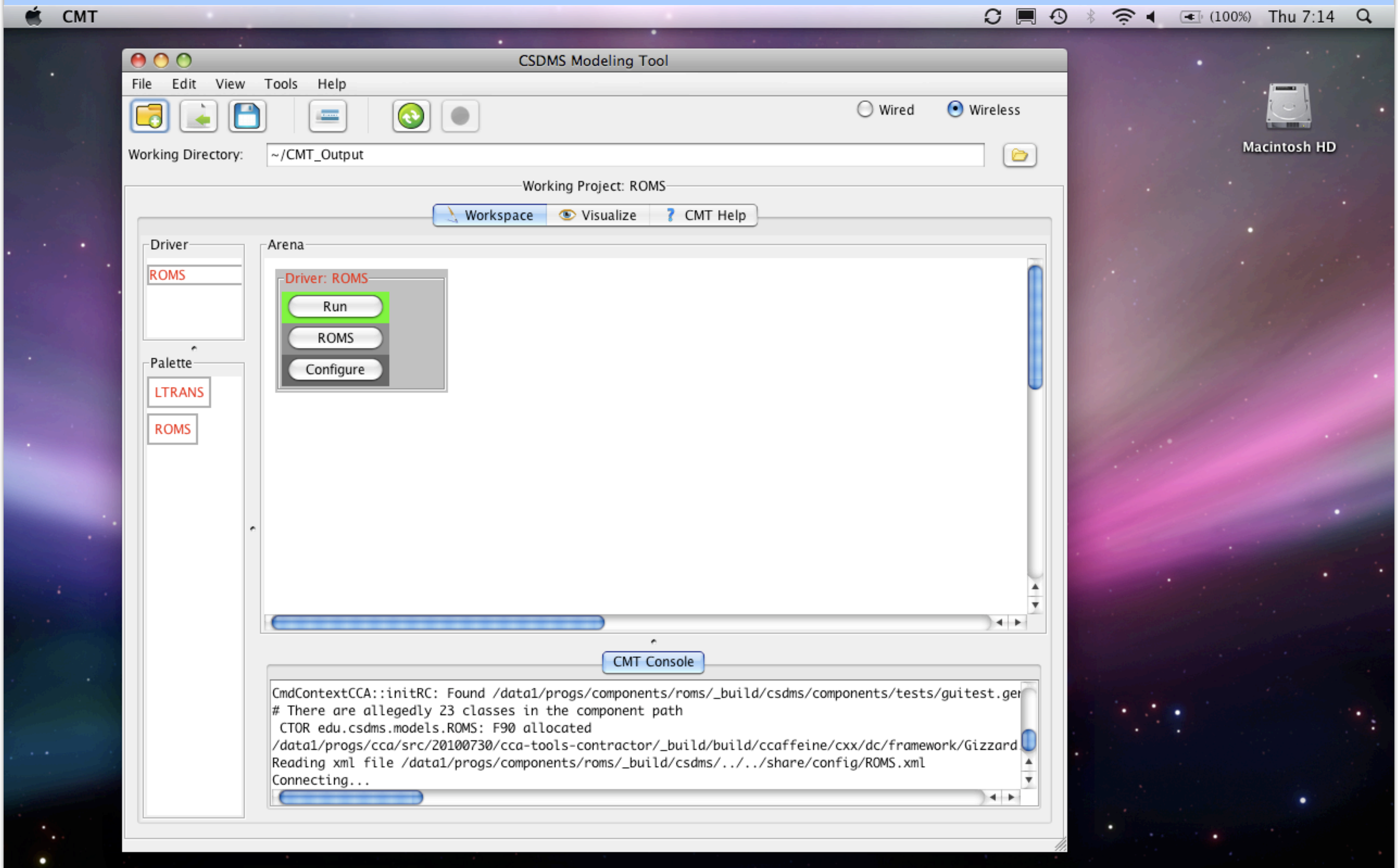


Select ROMS…

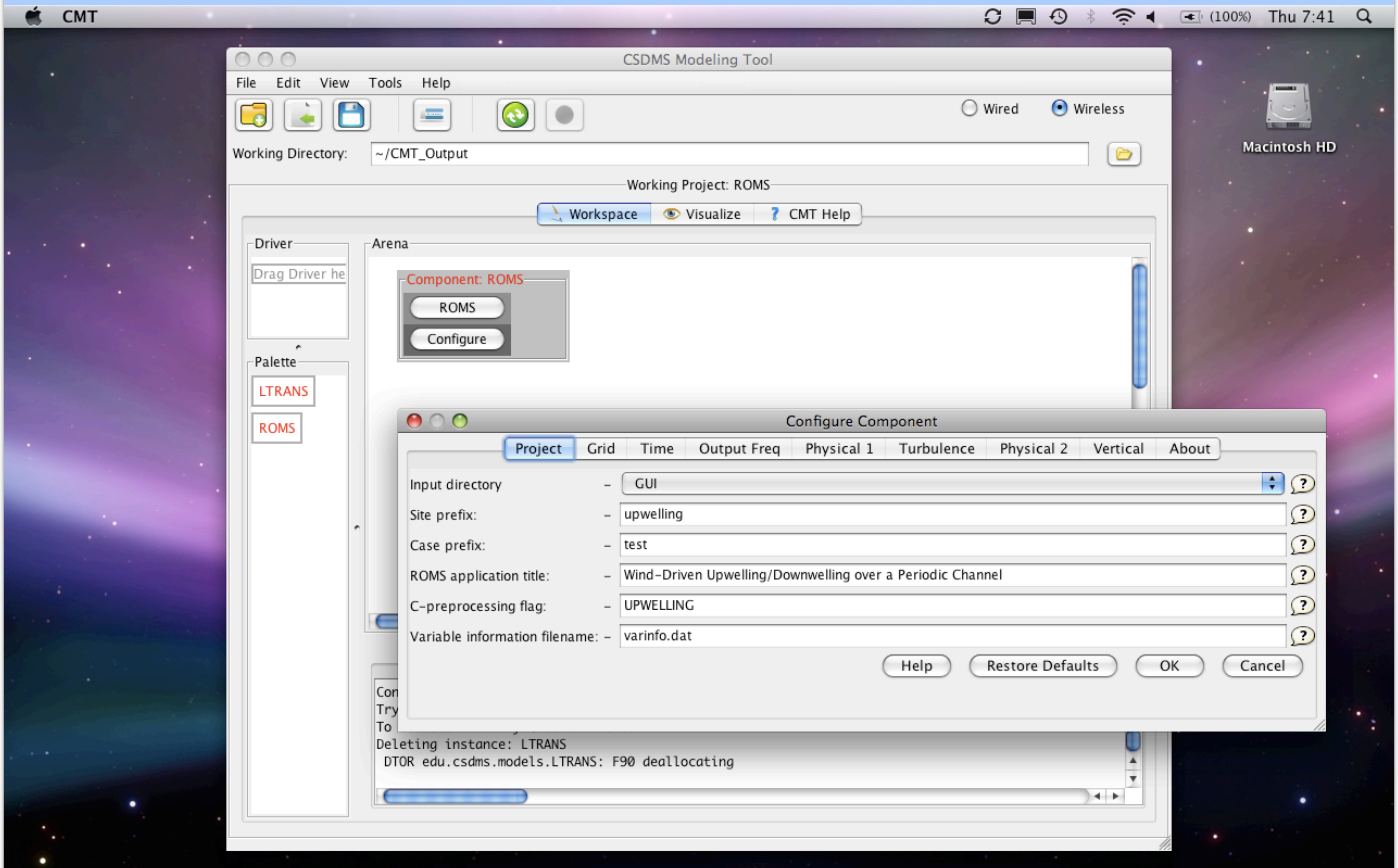


CMT
Thu 7:12
(100%)
CSDMS Modeling Tool
File Edit View Tools Help
Wired
Wireless
Working Directory:
~/CMT_Output
Working Project: ROMS
Workspace
Visualize
CMT Help
Driver
Drag Driver he
Arena
Palette
LTRANS
ROMS
CMT Console
CMT INFO: New Session starting with Project ROMS
CMT INFO: Sending logs to Server
Macintosh HD

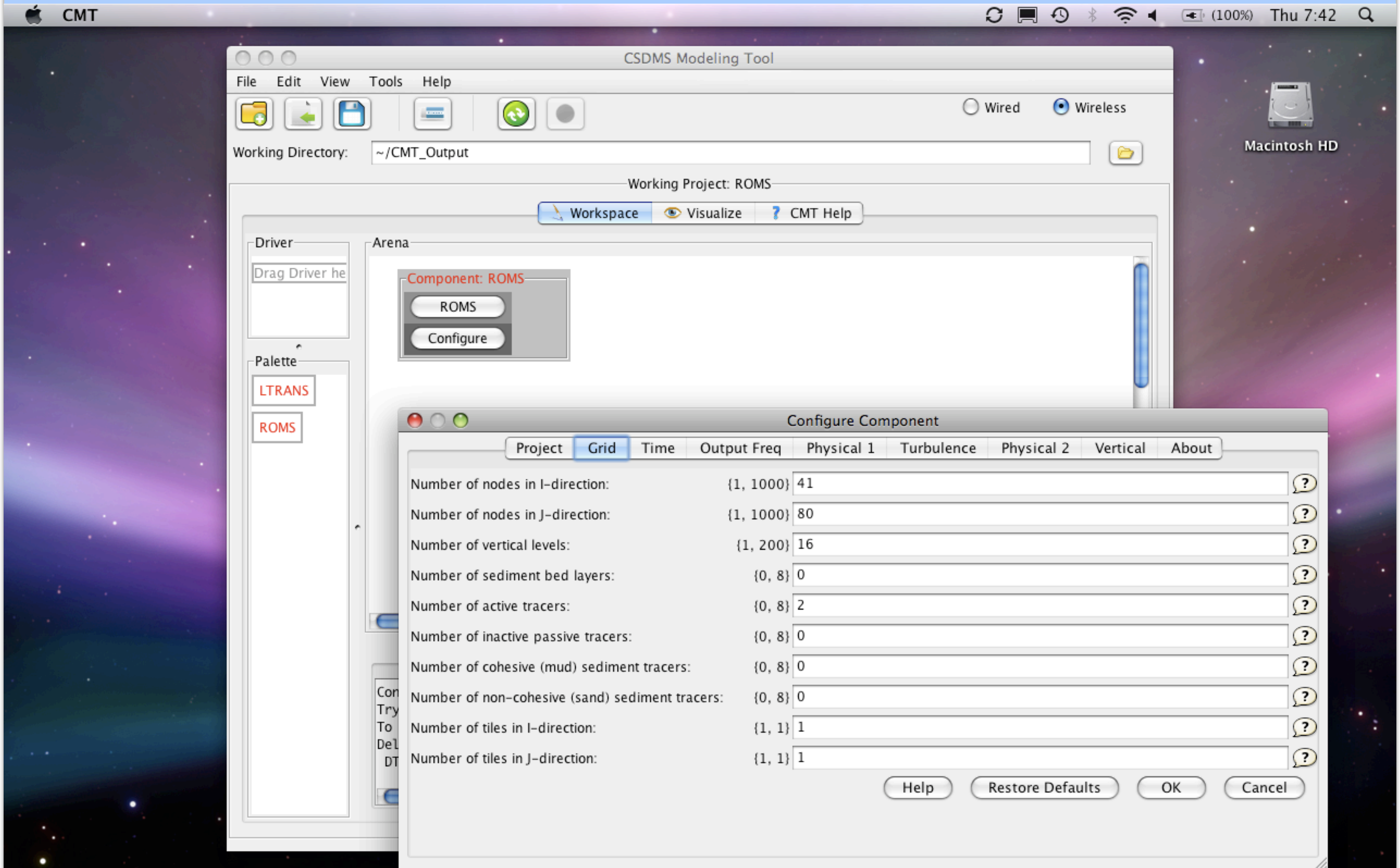
Drag it in and run!



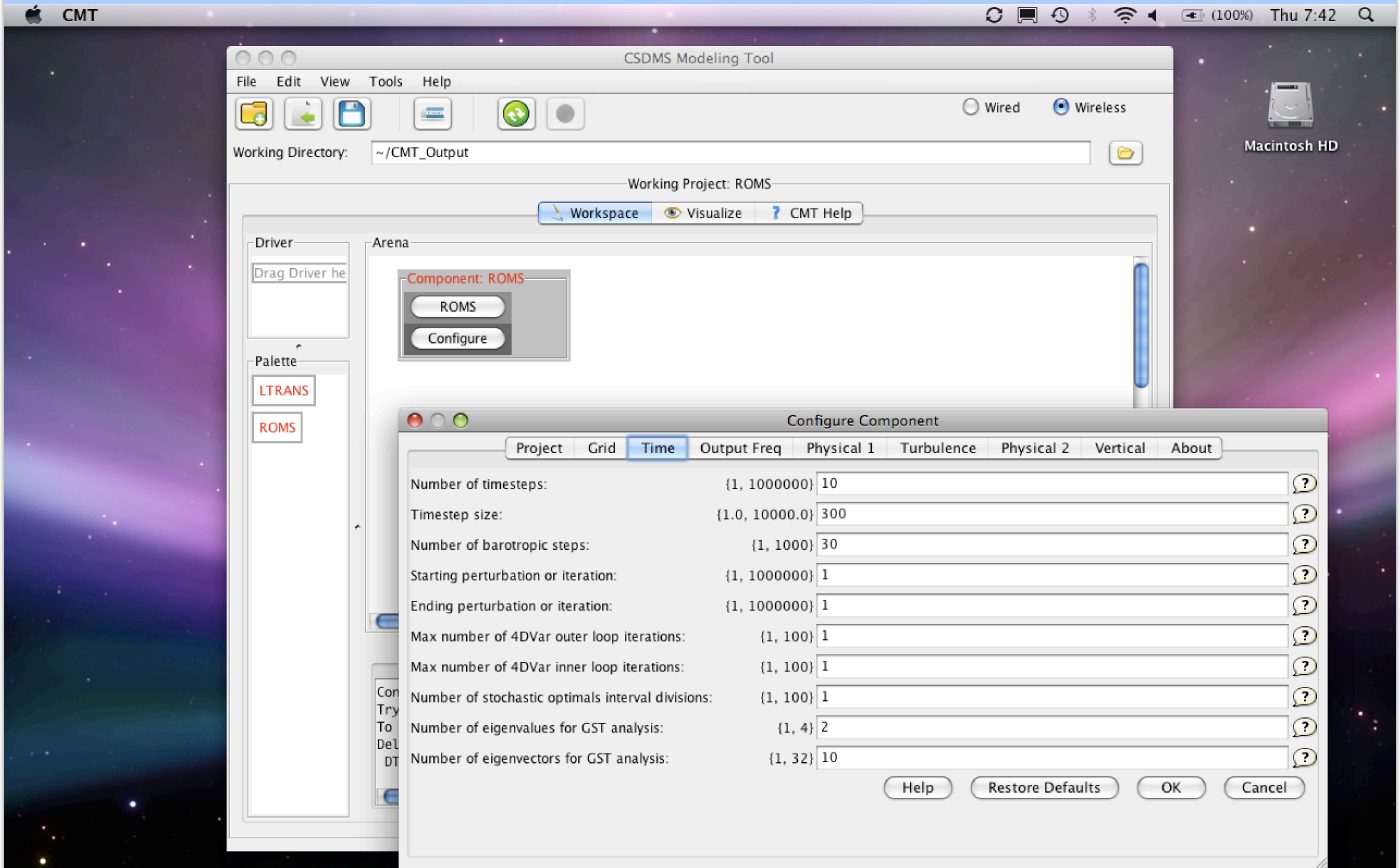
Adjust configurations



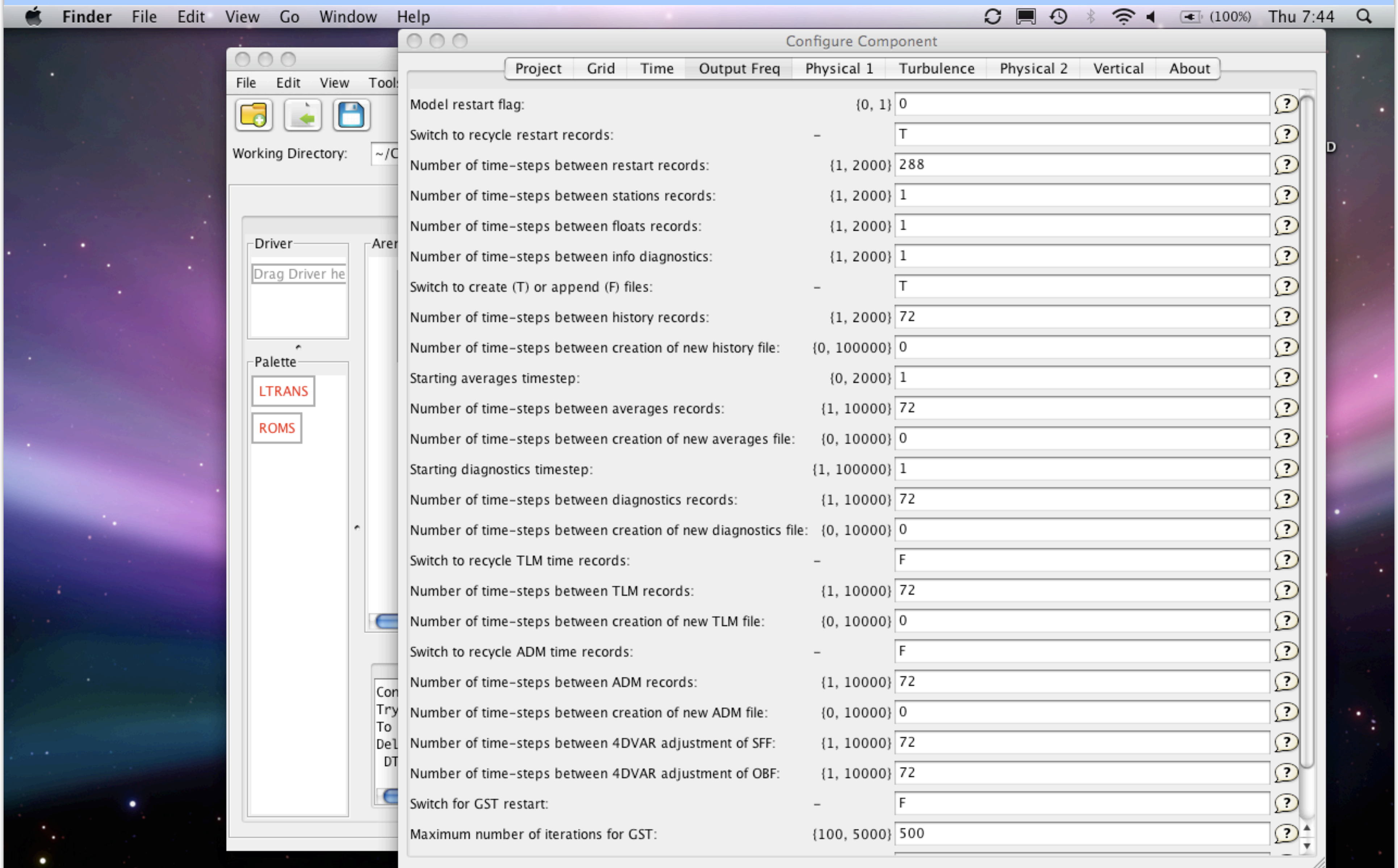
Grid properties



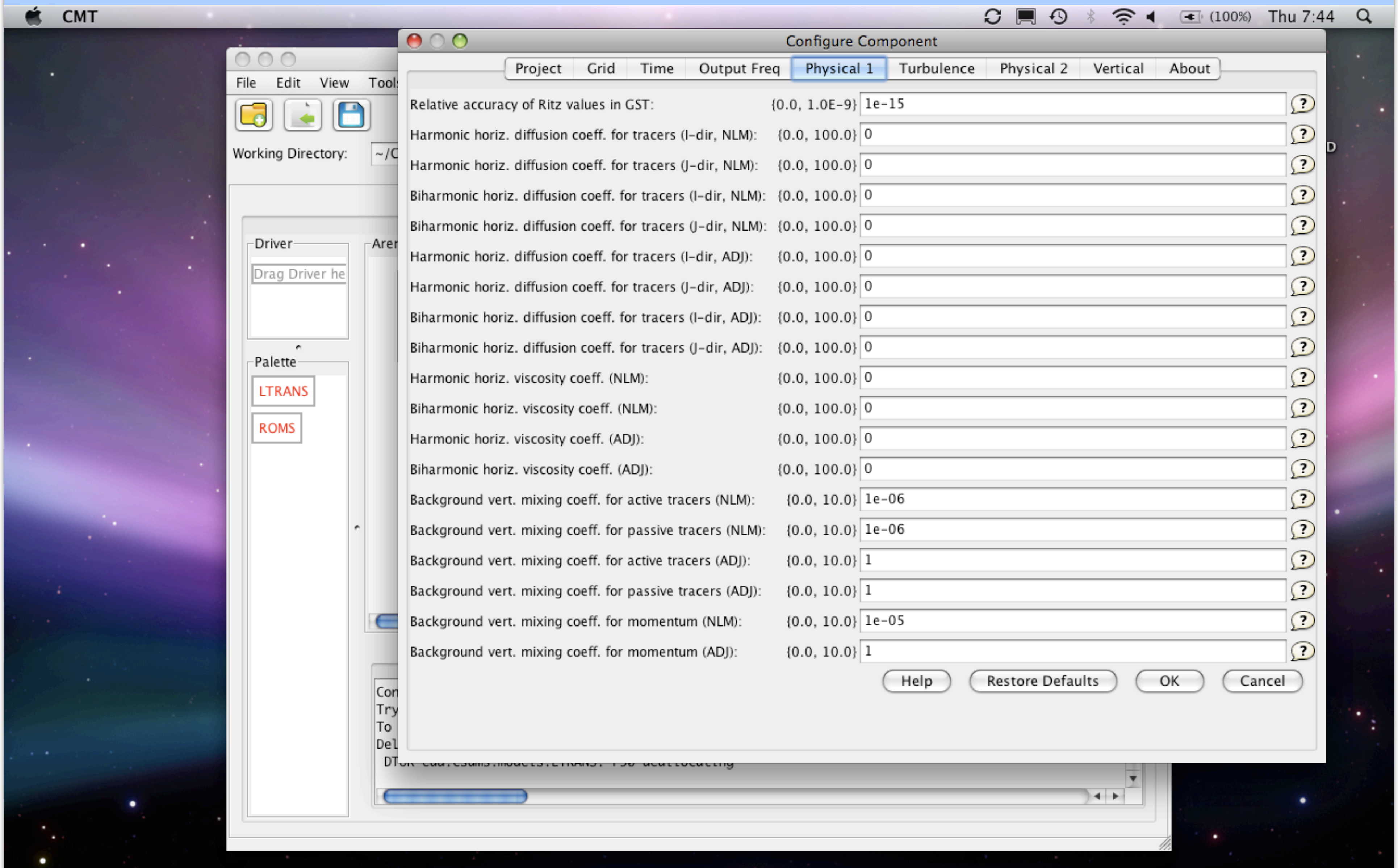
Time step info



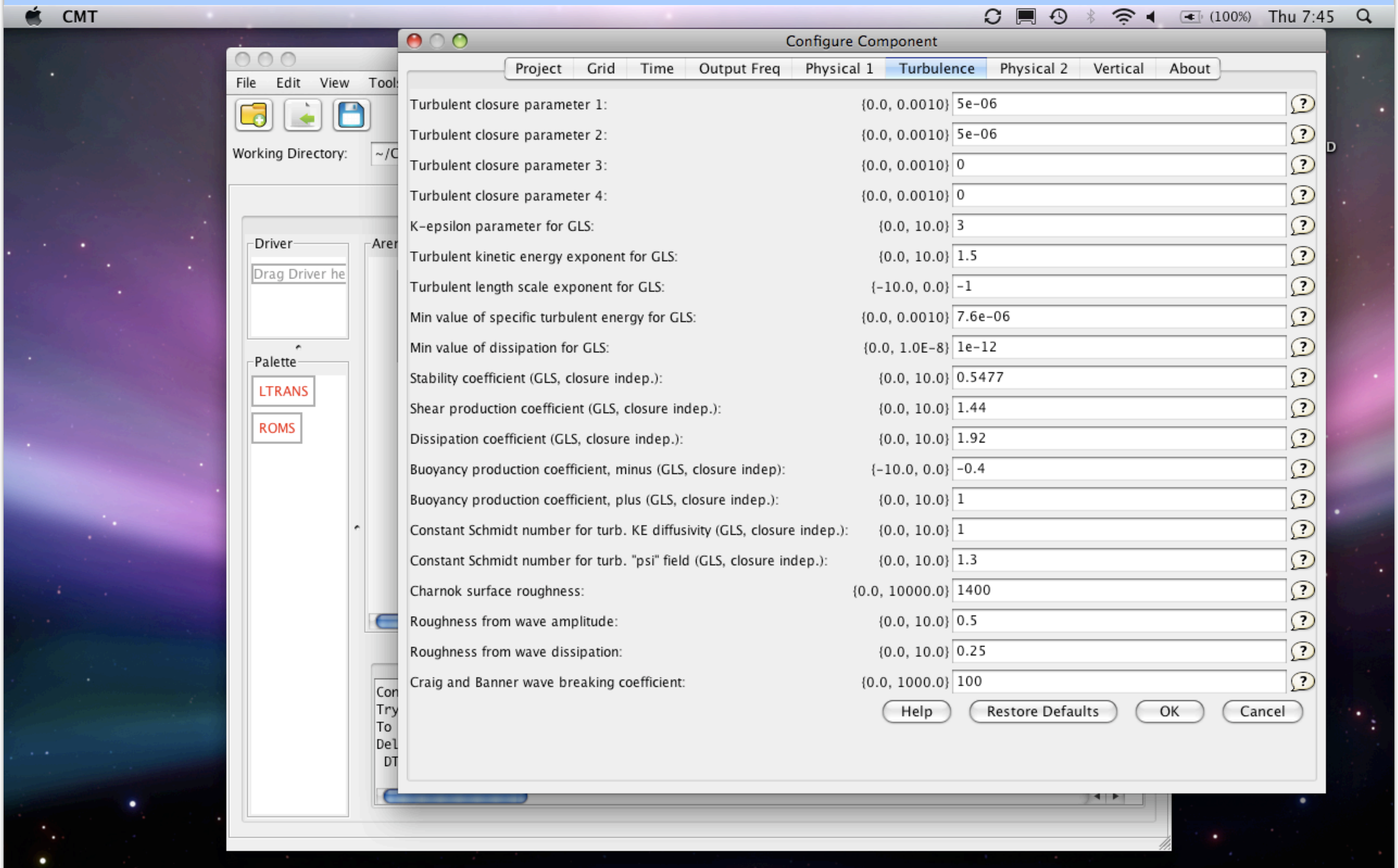
Output properties



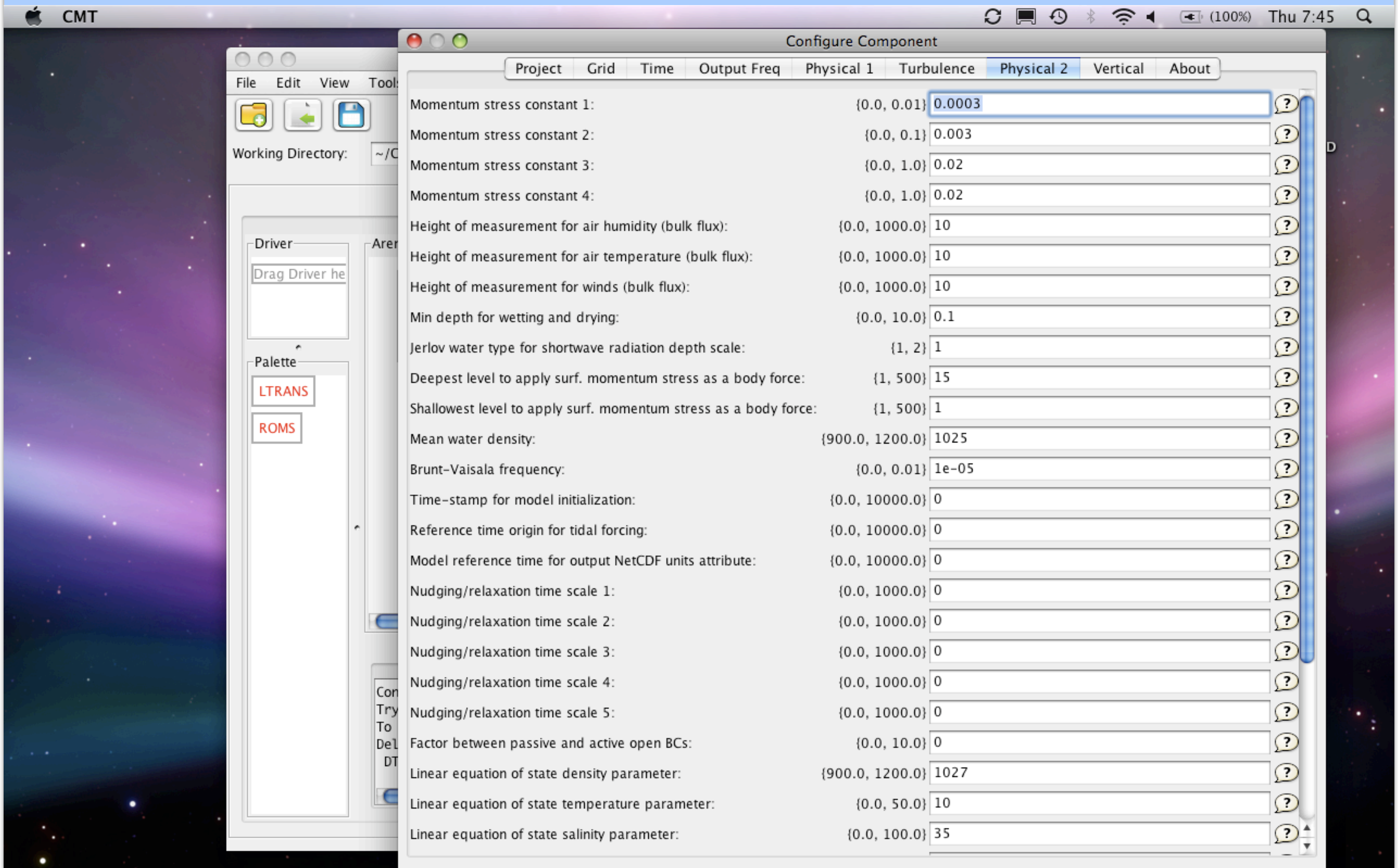
Background diffusion



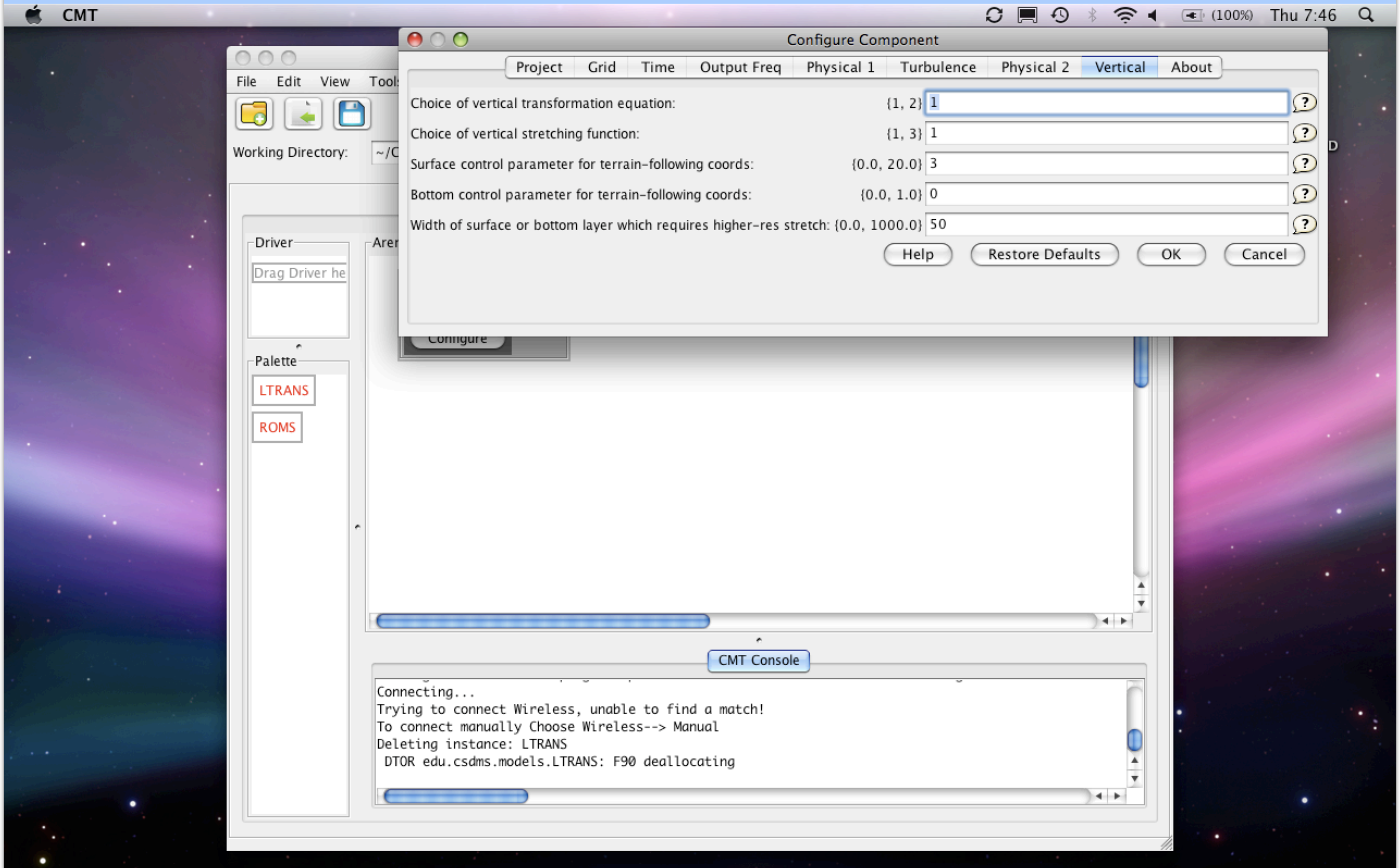
Turbulence closure



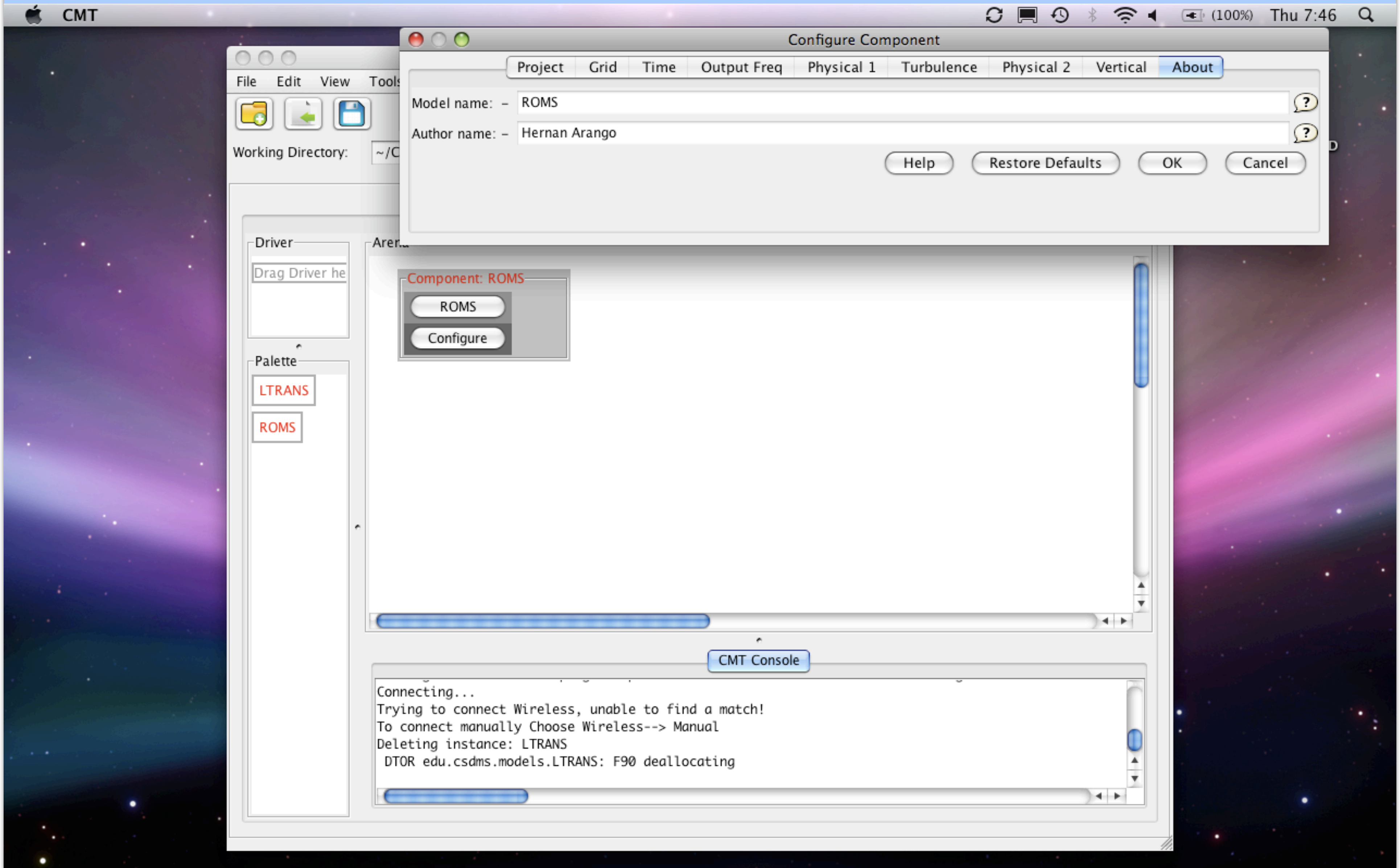
Surface boundary conditions



Grid stretching



Thanks Hernan!



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