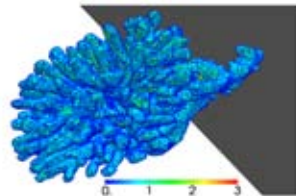
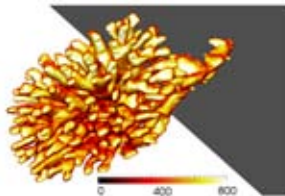


# CORAL: the **HOT** and the **NOT SO HOT**

Robert Ong

Fluid Dynamics Research Group  
Curtin University

12 October 2011



# Underwater coral scene

CORAL: the  
**HOT** and the  
**NOT SO  
HOT**

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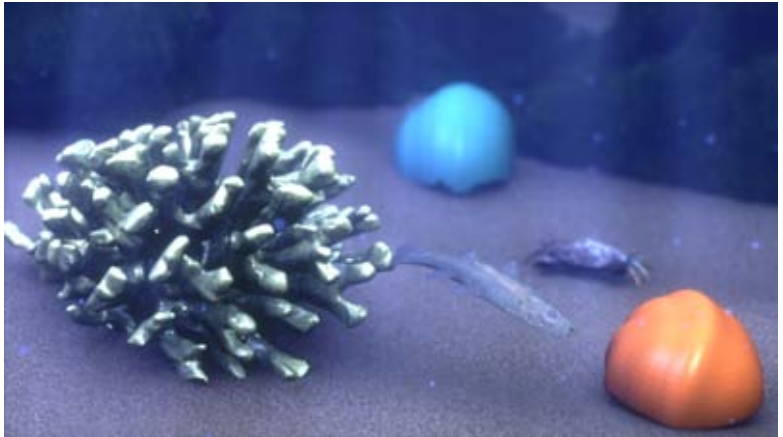
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# Coral bleaching

CORAL: the  
**HOT** and the  
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**HOT**

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- the whitening of corals under stressful thermal conditions
- caused by many environmental stressors, in particular the combination of increased sea surface temperature and elevated levels of solar irradiance



# Coral bleaching

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- the whitening of corals under stressful thermal conditions
- caused by many environmental stressors, in particular the combination of increased sea surface temperature and elevated levels of solar irradiance
- severity of bleaching varies considerably between species



# Coral bleaching

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# Benefits of coral reefs

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- **Habitat:** home to over 1 million diverse aquatic species, including thousands of fish species
- **Income:** billions of dollars and millions of jobs



# Benefits of coral reefs

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# Thermal regions in corals

## CORAL: the HOT and the NOT SO HOT

Robert Ong

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Branching Coral

■ Tissue  
■ Skeleton



Hemispherical Coral



# Objective

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- 1 to determine the hot-spot locations and coral species that are most susceptible to bleaching
- 2 to model coral growth under different flow scenarios



# Objective

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# OpenFOAM

CORAL: the  
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- CFD is used to discretise the Navier-Stokes equations for each and every "volumetric cell"
- **Open Field Operation And Manipulation** open source object-oriented library for numerical simulations in continuum mechanics written in C++ programming language. It uses Finite Volume Method as discretiser



# OpenFOAM

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# OpenFOAM

For example: turbulent kinetic energy equation

$$\frac{\partial k}{\partial t} + \nabla \cdot (\mathbf{u}k) - \nabla \cdot [(v + v_t)\nabla(k)] = v_t[\frac{1}{2}(\nabla(\mathbf{u}) + \nabla(\mathbf{u})^t)] - \frac{\varepsilon_0}{k_0}\varepsilon$$

in OpenFOAM, the above is represented below

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# OpenFOAM

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```
solve
(
    fvm::ddt(k)
    + fvm::div(phi, k)
    - fvm::laplacian(nu() + nut, k)
    == nut*magSqr(symm(fvc::grad(U)))
    - fvm::Sp(epsilon/k, k)
);
```



# OpenFOAM

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# Validation of CFD models and solvers against controlled laboratory studies

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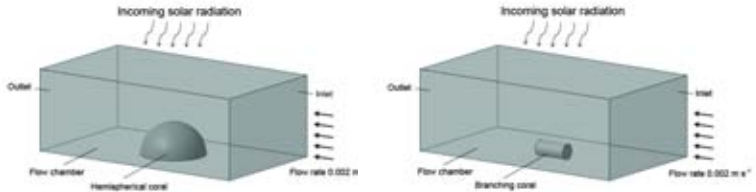
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## Hemispherical and (tip of) branching corals



## Steady-state experiment

# Validation of CFD models and solvers against controlled laboratory studies

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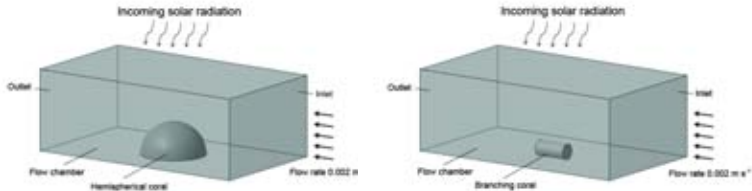
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## Hemispherical and (tip of) branching corals



## Steady-state experiment

## Transient experiment

# Validation of CFD models and solvers against controlled laboratory studies

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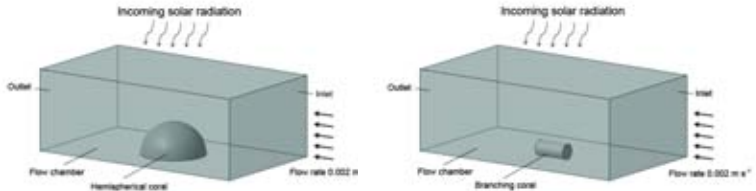
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Steady-state experiment

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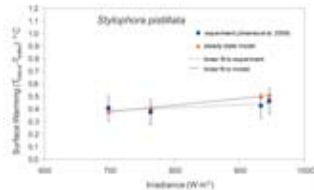
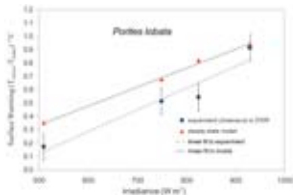
Modeling of coral growth

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## Steady-state results



## Transient results



# Validation of CFD models and solvers against controlled laboratory studies

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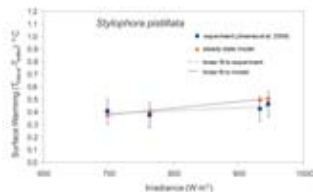
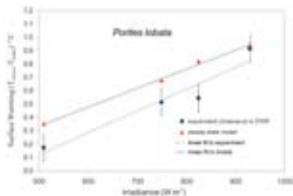
Modeling of  
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Further works

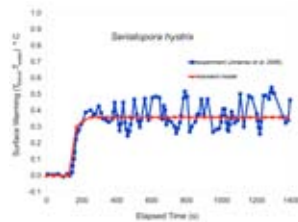
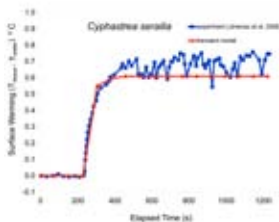
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## Steady-state results



## Transient results



# Validation of CFD models and solvers against controlled laboratory studies

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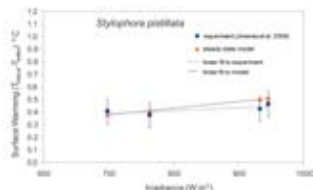
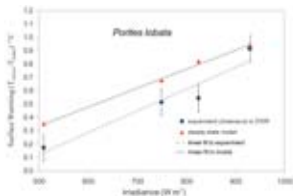
Modeling of coral growth

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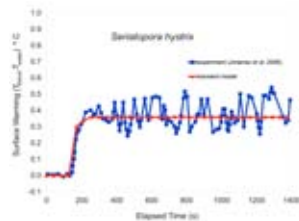
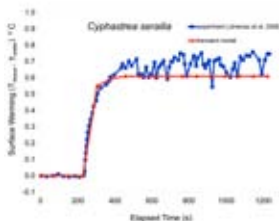
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# RADIANCE

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- 1 the previous section was conducted without detailed calculation of the radiative heat gain
- 2 RADIANCE is open source lighting simulation tool



# RADIANCE

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- 2 **RADIANCE** is open source lighting simulation tool
- 3 uses an efficient and elegant ray-tracing technique to account for the illumination produced by the sky



# RADIANCE

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# Validation study of RADIANCE to sky scanner data

CORAL: the **HOT** and the **NOT SO HOT**

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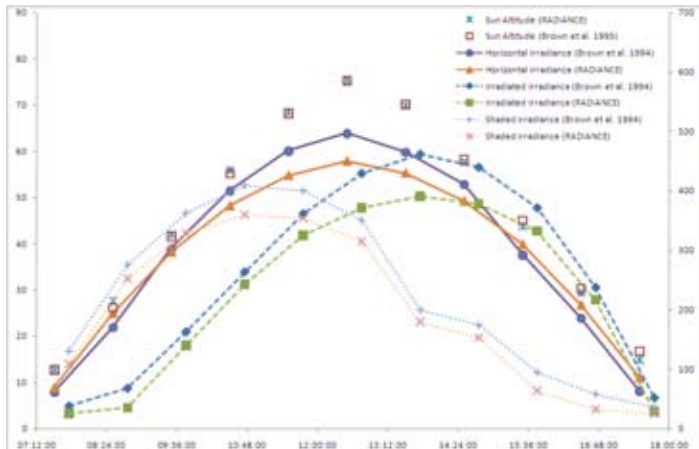
Modeling of coral growth

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Irradiance levels of Photosynthetically Active Radiation (PAR, 400-700 nm) in 4 March 1993 at the surface of coral reef adjacent in Phuket, Thailand



# Illustrative example

## CORAL: the HOT and the NOT SO HOT

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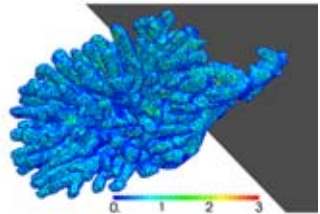
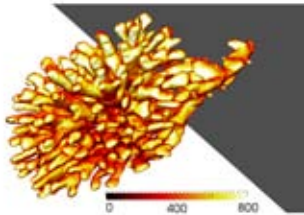
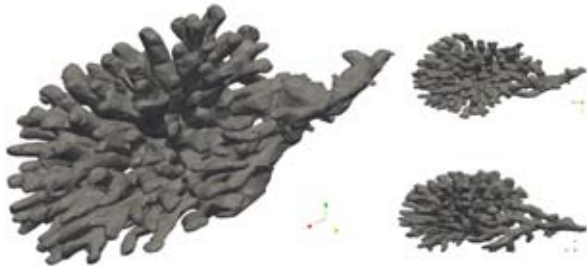
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# Illustrative example - cont'd

CORAL: the **HOT** and the **NOT SO HOT**

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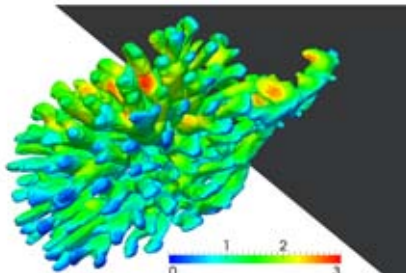
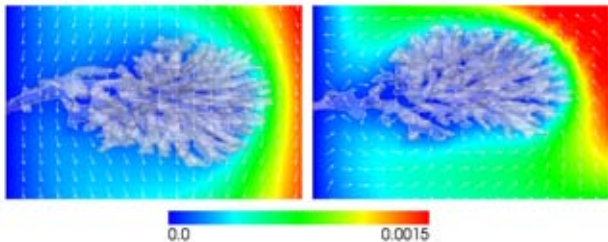
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# Further works

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- Micro Computed Tomography (CT) Scan
- More Validation(s) works needed



# Further works

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- More Validation(s) works needed
- Enhance parallel capability of our dictionaries



# Further works

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# Conclusion

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In summary, we have demonstrated that CFD models can be a powerful tool for investigating the relationship between the thermal microenvironment of corals and its influence on coral bleaching



## Q & A

CORAL: the  
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THANK YOU FOR LISTENING