AN UPDATE ON THE HYCOM
SOLAR RADIATION PENETRATION SCHEME

By

A. BIROL KARA
ALAN WALLCRAFT, HARLEY HURLBURT AND ZHONGPING LEE

Naval Research Laboratory (NRL)
Stennis Space Center
An Update on the HYCOM Solar Radiation Penetration Scheme

Naval Research Laboratory, Stennis Space Center, MS, 39529

8th HYCOM NOPP GODAE Meeting, Oct. 27-29, 2004, RSMAS, Miami, FL

| 1. REPORT DATE | OCT 2004 |
| 2. REPORT TYPE | |
| 3. DATES COVERED | 00-00-2004 to 00-00-2004 |
| 4. TITLE AND SUBTITLE | An Update on the HYCOM Solar Radiation Penetration Scheme |
| 5a. CONTRACT NUMBER | |
| 5b. GRANT NUMBER | |
| 5c. PROGRAM ELEMENT NUMBER | |
| 5d. PROJECT NUMBER | |
| 5e. TASK NUMBER | |
| 5f. WORK UNIT NUMBER | |
| 6. AUTHOR(S) | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) | Naval Research Laboratory, Stennis Space Center, MS, 39529 |
| 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | |
| 10. SPONSOR/MONITOR’S ACRONYM(S) | |
| 11. SPONSOR/MONITOR’S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT | Approved for public release; distribution unlimited |
| 13. SUPPLEMENTARY NOTES | 8th HYCOM NOPP GODAE Meeting, Oct. 27-29, 2004, RSMAS, Miami, FL |
| 14. ABSTRACT | |
| 15. SUBJECT TERMS | |
| 16. SECURITY CLASSIFICATION OF: | |
| a. REPORT | unclassified |
| b. ABSTRACT | unclassified |
| c. THIS PAGE | unclassified |
| 17. LIMITATION OF ABSTRACT | Same as Report (SAR) |
| 18. NUMBER OF PAGES | 13 |
| 19a. NAME OF RESPONSIBLE PERSON | |

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
• HYCOM subsurface heating parameterization
  
  (1) Longwave radiation*

  (2) Shortwave radiation

  (3) Latent heat flux

  (4) Sensible heat flux
Bulk Heat Flux Parameterization

- Total heat flux is available from archived products
  - SST drifts if total flux alone is used to force an OGCM

- HYCOM uses model SST and a bulk heat flux parameterization
- Feedback between SST and heat flux to prevent SST drift
- No need for explicit relaxation to SST

- MICOM uses constant exchange coefficients
- HYCOM has
  - several options for exchange coefficients
  - a blackbody longwave correction
Subsurface Heating Parameterization

• Net heat flux at a given depth, $z$:

$$Q(z) = Q(0) + [Q_{sw}(0) - Q_{sw}(z)],$$  \hspace{1cm} (1)

• Net heat flux absorbed at the sea surface, $z = 0$:

$$Q(0) = Q_{LW} + Q_{L} + Q_{S},$$  \hspace{1cm} (2)

  o $Q_{LW}$: net longwave radiation at the sea surface,
  o $Q_{SW}$: net shortwave radiation at the sea surface,
  o $Q_{L}$: latent heat flux,
  o $Q_{S}$: sensible heat flux.

• NOTE:

  o HYCOM’s “surface” heat flux is not $Q(0)$, but
  o rather the near surface flux absorbed in layer 1
  o e.g., $Q(1)$ when the top model layer is 1 m thick.
(1) Longwave Radiation

- Input from archived products (e.g., ECMWF, NCEP, etc)
- A correction is needed. Why?
  - They use their model SST
  - Different from HYCOM SST
- HYCOM uses a **blackbody correction** (Kara et al 2004a):

\[
Q_{LW}(T_s) = Q_{LW}(T_{sa}) - (4.506 - 0.0554 T_s)(T_s - T_{sa}).
\]

  - \(T_s\): HYCOM SST
  - \(T_{sa}\): Atmospheric model SST
- The effects of clouds are independent of SST
A linear approximation to the blackbody radiation

- Cubic formulation (Josey et al. 2003)
- Linear approximation (Kara et al. 2004a)
(2) Shortwave Radiation

- Previous parameterizations in HYCOM
  - Jerlov water types (Halliwell 2004)
  - 2-band scheme (Kara et al. 2004b)
    - Turbidity-dependent split: red and blue spectrums.
    - Based on SeaWiFS $k_{\text{PAR}}$ climatology (2004c).
    - Attenuation coefficient, $k_{\text{PAR}}$: depth-independent

- New parameterization in HYCOM (in progress)
  - Fixed frequency ranges:
    - Visible spectrum (350–700 nm), also called PAR
    - Infrared spectrum (700–2400 nm)
  - Will use absorption and backscattering coefficients
  - $k_{\text{PAR}}$ depends on depth and solar angle
The shortwave radiation at a given depth \( z \) is split into two parts:

\[
Q_{SW}(z) = Q_{PAR}(z) + Q_{IR}(z),
\]

\[
Q_{PAR}(z) = Q_{PAR}(0) \exp(-z k_{PAR}),
\]

\[
Q_{IR}(z) = Q_{IR}(0) \exp(-z k_{IR}),
\]

\( Q_{PAR}(z) / Q_{PAR}(0) : 350 \text{ to } 700 \text{ nm} \)

\( Q_{IR}(z) / Q_{IR}(0) \implies 700 \text{ to } 2500 \text{ nm} \)
Latent Heat Flux

- Bulk formulation: \( Q_L = \rho_a C_L L V_a (q_a - q_s) \)

- Previous exchange coefficient \( (C_L) \) in HYCOM (Kara et al. 2002):
  - based the COARE (v2.6) algorithm (Fairall et al. 1996)
  - excluded \( V_a < 4 \text{ m s}^{-1}, V_a > 20 \text{ m s}^{-1} \)
  - \( C_L \) was dependent on \( (T_a - T_s) \) and \( V_a \)

- New \( C_L \) parameterization in HYCOM (Kara et al. 2004d)
  - based on the COARE (v3.0) algorithm (Fairall et al. 2003)
  - includes \( V_a \) from 1 to 40 m s\(^{-1}\)
  - \( C_L \) is dependent on \( (T_a - T_s) \), \( V_a \), and RH as well

- NOTE: Calculate \( Q_L \) using HYCOM SST at each time step
Previous exchange coefficients for the latent heat flux (RH=100%)
New exchange coefficients for the latent heat flux (for varying RH)

Is including relative humidity in $C_L$ important?

![Graph showing the relationship between air-sea temperature difference and latent heat flux coefficient for varying relative humidity. The graph includes lines for RH=100%, RH=80%, RH=60%, RH=40%, and RH=20%, with $V_a = 1$ m s$^{-1}$.
What could be the typical error in latent heat flux without RH?

\[ Q_L = \rho_a C_L L V_a (q_a - q_s) \]
where \( T_a - T_s = 2^\circ C \) and \( q_a - q_s = 3 \text{ g kg}^{-1} \)
• Global HYCOM simulation with
  o the RH–dependent exchange coefficients
  o the depth–dependent shortwave radiation

• Shortwave radiation attenuation:
  o need two satellite–based input fields for HYCOM
  o (1) absorption coefficient
  o (2) backscattering coefficient
  o form a climatology (2001–2003) using MODIS

MODIS: Moderate Resolution Imaging Spectroradiometer