
CALPUFF V 6
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CALPUFF Enhancements for Over Water Applications

CALMET/CALPUFF V 6

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not “official” model

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Modeling of Over Water Emission Sources

- Over water boundary layer
- Sparse meteorological data
- Long transport distances
- PSD Class I issues
- Complex water/land transition zone
- Model evaluation is a challenge

Offshore and Coastal Dispersion (OCD) Model v5

- MMS approved model and EPA guideline model
- Steady-state Gaussian plume model
- Boundary layer parameterized by L
- Offshore buoy data – WD, WS, ΔT, RH
- Standard onshore meteorological data
- Simple TIBL growth
- Virtual source technique beyond transition zone

CALMET/CALPUFF Model Enhancement Project

- Review existing models and algorithms
- Revise/enhance existing model or model components
- Develop software package
- Sensitivity testing and model performance evaluation
- Prepare user's guide

CALMET Enhancements

- COARE over water bulk flux algorithms
- Updated similarity profiles
- Incorporate buoyancy effects in over water mixing height calculations
- Adjustments to heat flux in convective mixing height

CALPUFF Enhancements

- Modified downwash for platforms
- AERMOD turbulence profile option
- Minimum turbulence velocities
- Lateral puff timescale diagnostic option – (1) Draxler and (2) SCIPUFF
- Turbulence advection option
- Non-Boussinesq numerical plume rise

Over Water Surface Layer

- COARE (Coupled Ocean Atmosphere Response Experiment) over water flux model Version 2.6bw
- Iterative computation of momentum, heat, and moisture flux from U, q, ΔT, and z_0
- Calculation of roughness length, z_0

$$z_0 = \frac{0.11\,\upsilon}{u_*} + \frac{\alpha\, u_*^2}{g}$$

COARE z_0 Calculation

- Charnock parameter $\alpha = 0.011$ for u_{10} up to 10 m/s
- Increases linearly to 0.018 at u_{10} = 18 m/s
- Shallow water adjustment for α with a maximum value of 0.032

COARE Options

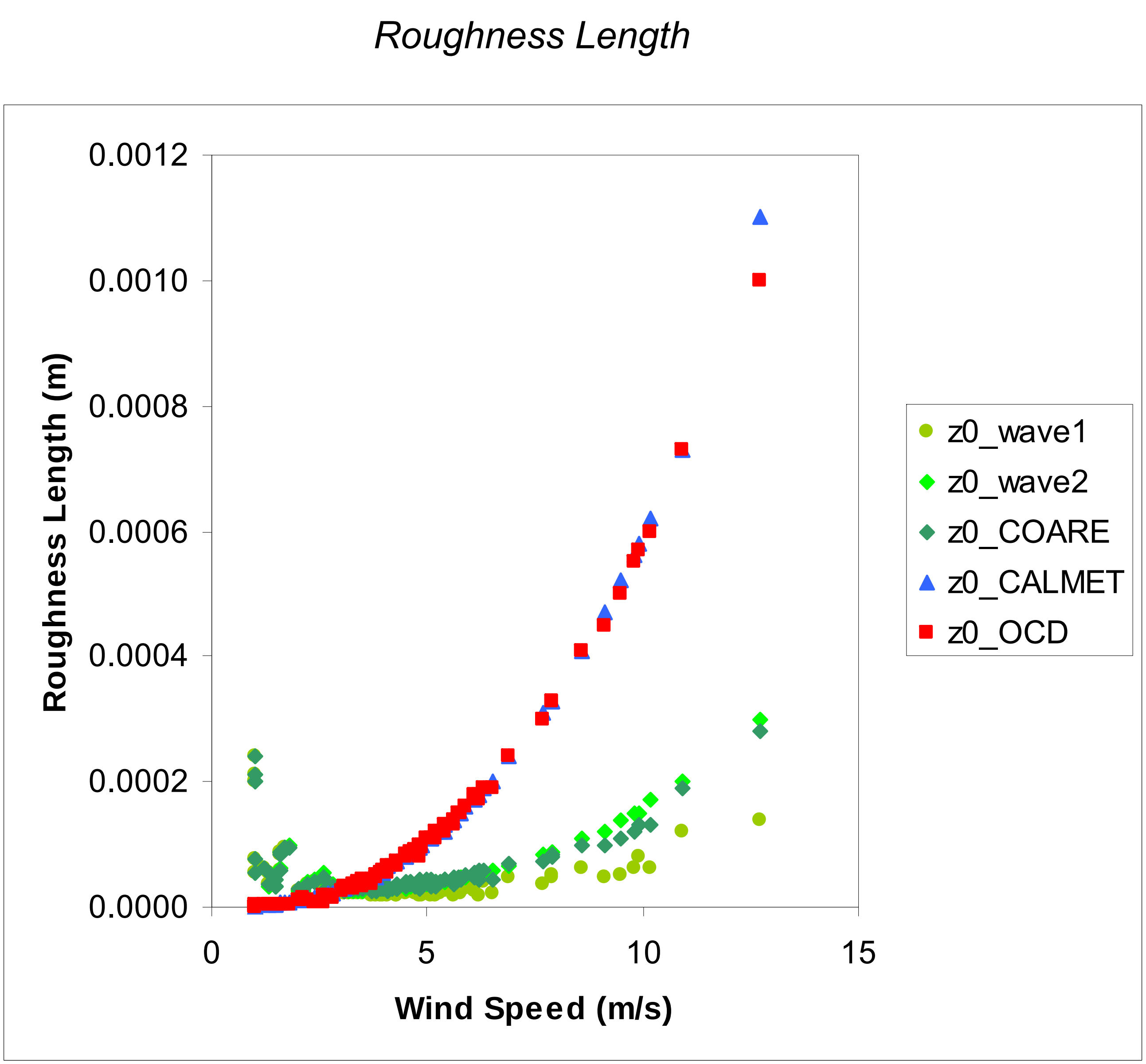
- 0: OCD-like flux model
- 10: COARE with no wave parameterization; can be modified for shallow water
- 11: COARE with Oost et al. (2002) wave option using default values for wave length, L_p, and phase speed of the dominant wave, c_p
- -11: same as above but with observed wave properties

COARE Options (Cont’d)

- 12: COARE with Taylor and Yelland (2001) wave option using default values for significant wave height, H_s, and significant wave slope, H_s/L_p
- -12: same as above using observed wave properties

COARE Results

- Calculated z_0 significantly lower than in OCD, especially for wind speeds > 3 m/s
- Values at low wind speeds need adjustment
- U_* reduced by about 10%
- L about 25% higher for convective conditions and about the same for stable conditions
- Wave information from buoys or remote sensing may be applied


Roughness Length
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
Roughness Length (m)
0
5
10
15
Wind Speed (m/s)
z0_wave1
z0_wave2
z0_COARE
z0_CALMET
z0_OCD

Over Water Mixing Height

- Over water mixing heights are under predicted by CALMET under light wind conditions
- In Gulf of Mexico predicts 100-200 m vs. 600 m observed in MMS Boundary Layer Study
- Does not consider buoyancy effects over water

Current Overwater Mixing Height

- Overwater mixing height
  - either specified by the user (SEA.DAT)
  - or computed internally: (Blackadar and Tennekes, 1968)

$$h_{water} = \frac{C_W \cdot u_*}{|f|}$$

where

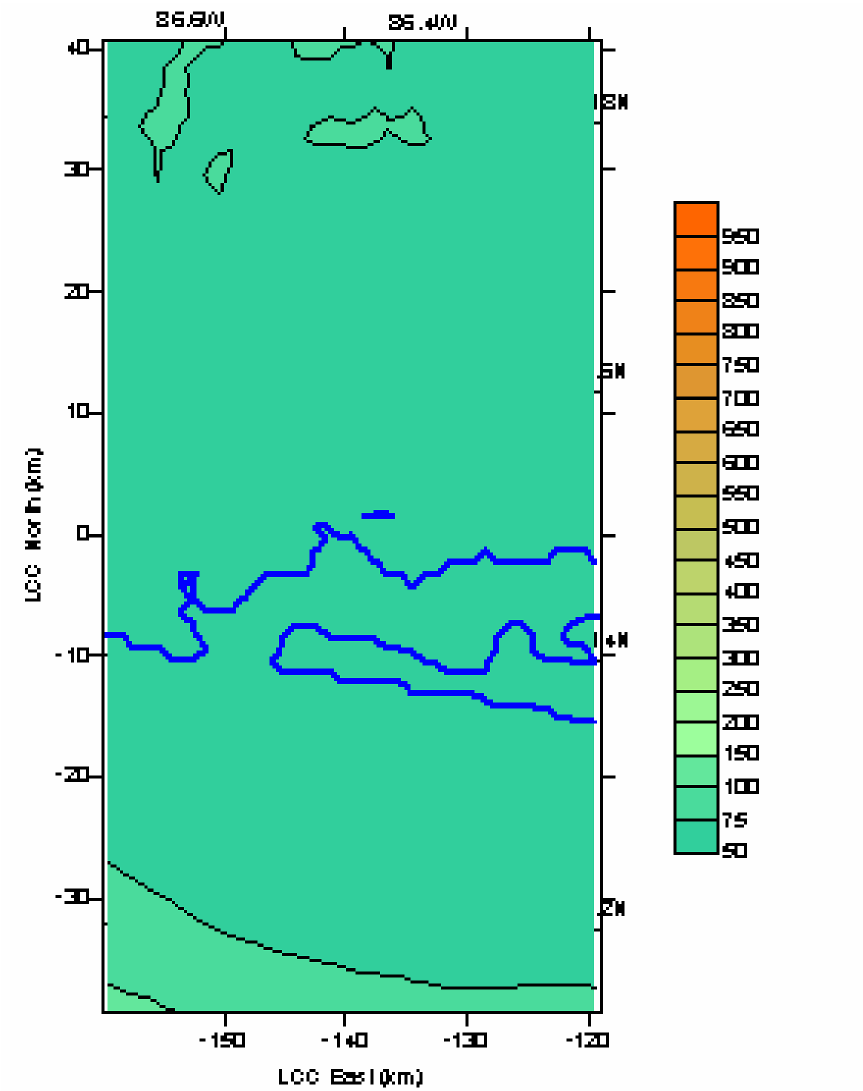
C_W	is a constant (~0.16)
f	is the Coriolis parameter (~10^{-4} s^{-1})

Over water mixing height formulation

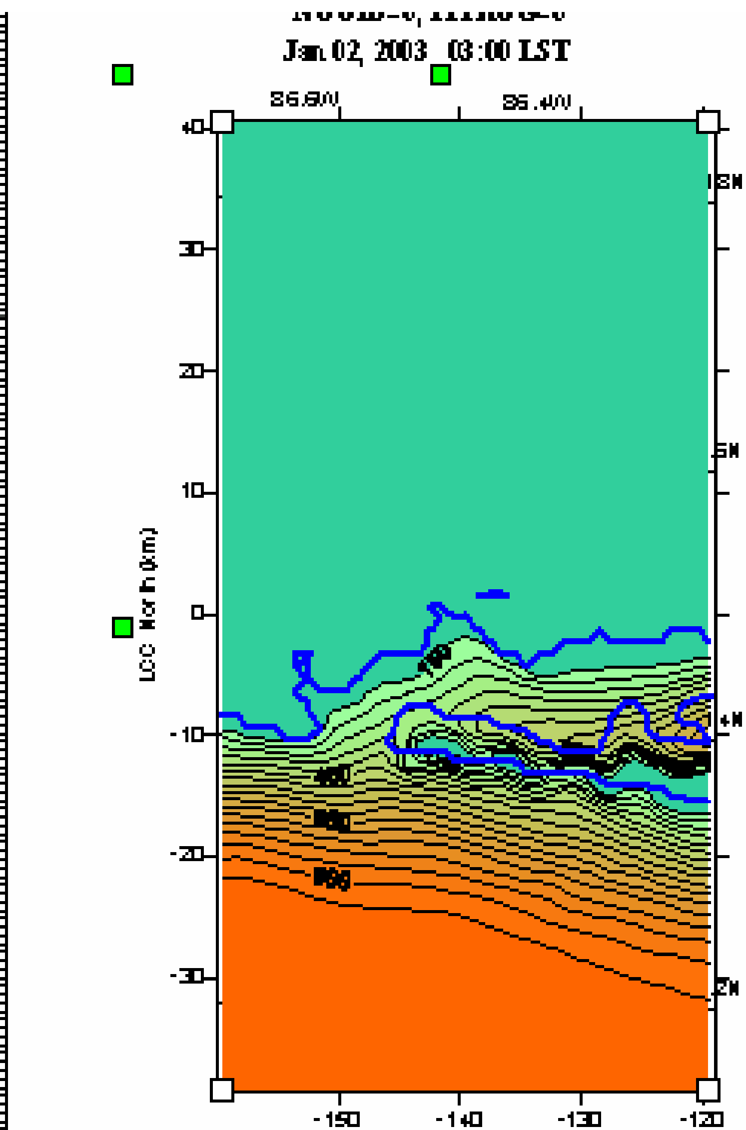
- Batchvarova-Gryning (1991, 1994) mixing height option
- Modified Carson (1973) based on Maul (1980) in existing CALMET
- Rate of change dependent on heat flux
- Over water formula adjusted to prevent “run-away” mixing height values

Nighttime (January 2, 2003 – 3 AM)

Current CALMET (Mechanical -OCD)

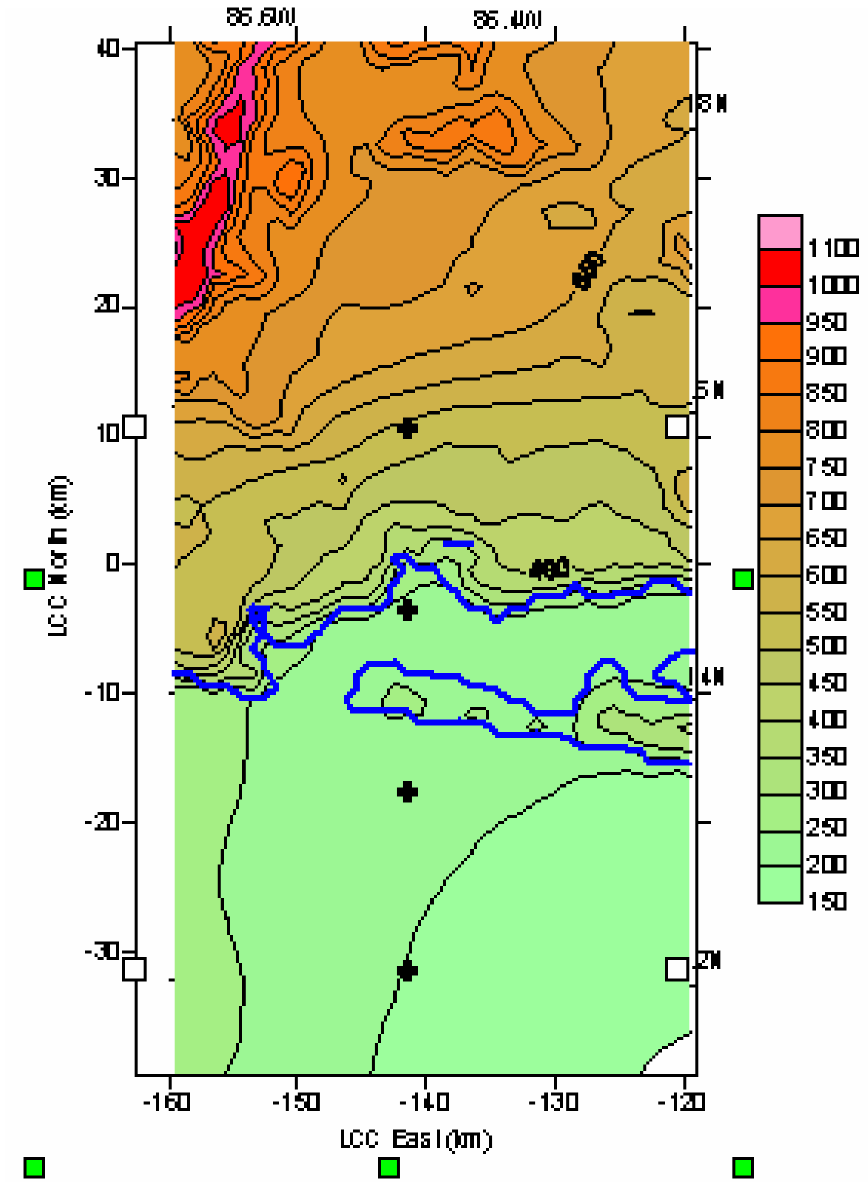


MMS CALMET (BG-COARE)

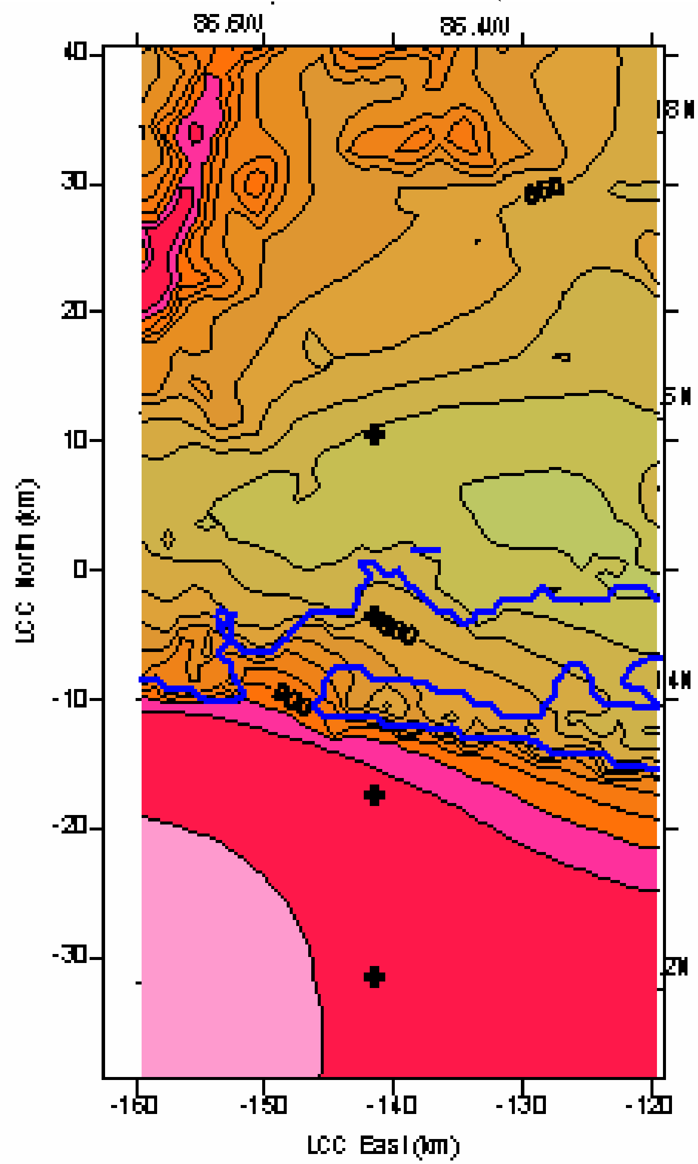


Daytime (January 2, 2003 – 1 PM)

Current CALMET (Mechanical -OCD)



MMS CALMET (BG-COARE)



Thermal Internal Boundary Layer (TIBL)

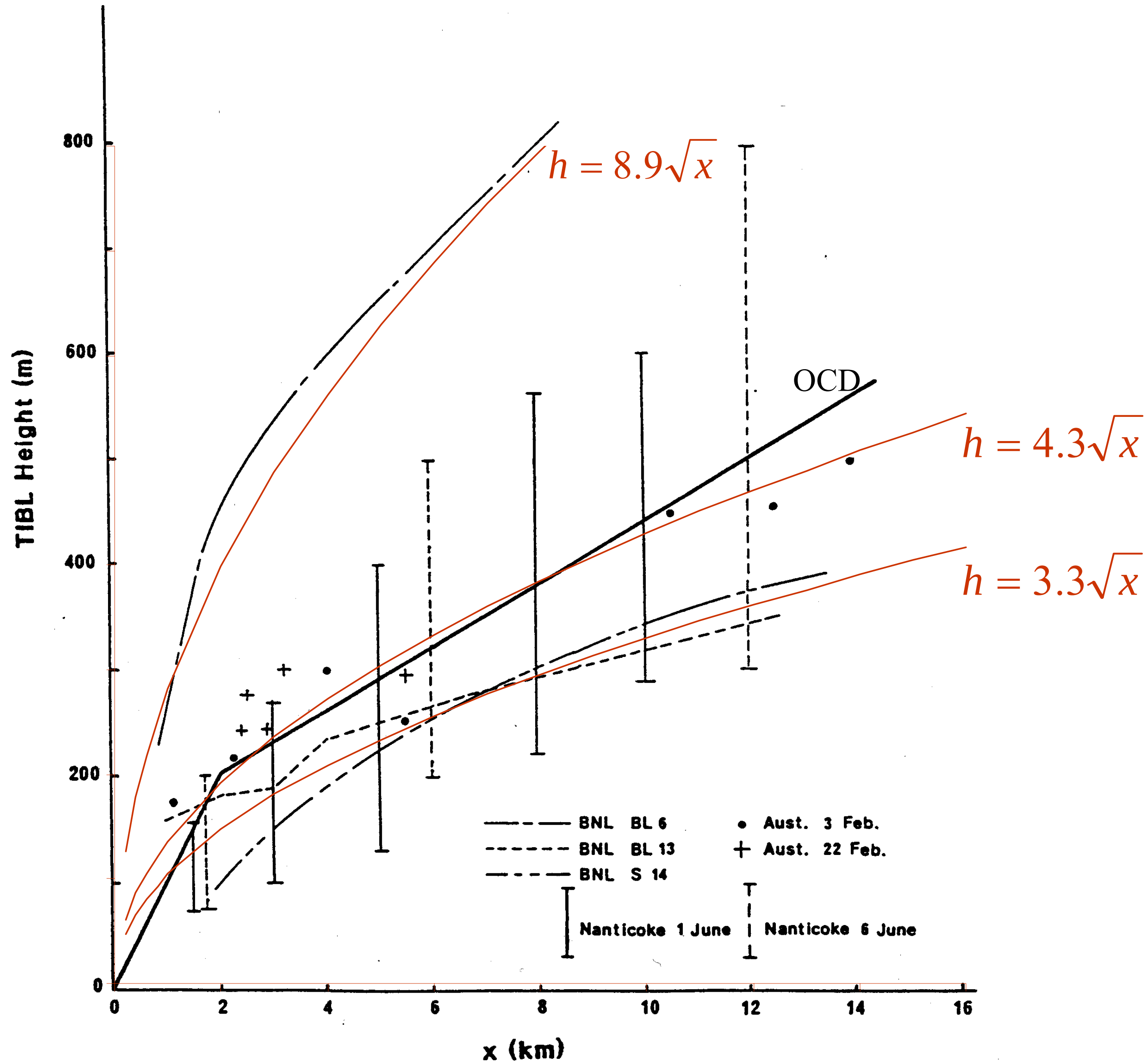
- OCD

$h = 0.1\ x$ for $x \leq 2000m$

$h = 200 + 0.03\ (x\text{-}2000)$ for $x \geq 2000m)$

Designed to approximate a generic TIBL without inputs for wind speed, heat flux, marine layer lapse rate

OCD TIBL Comparison with Field Data

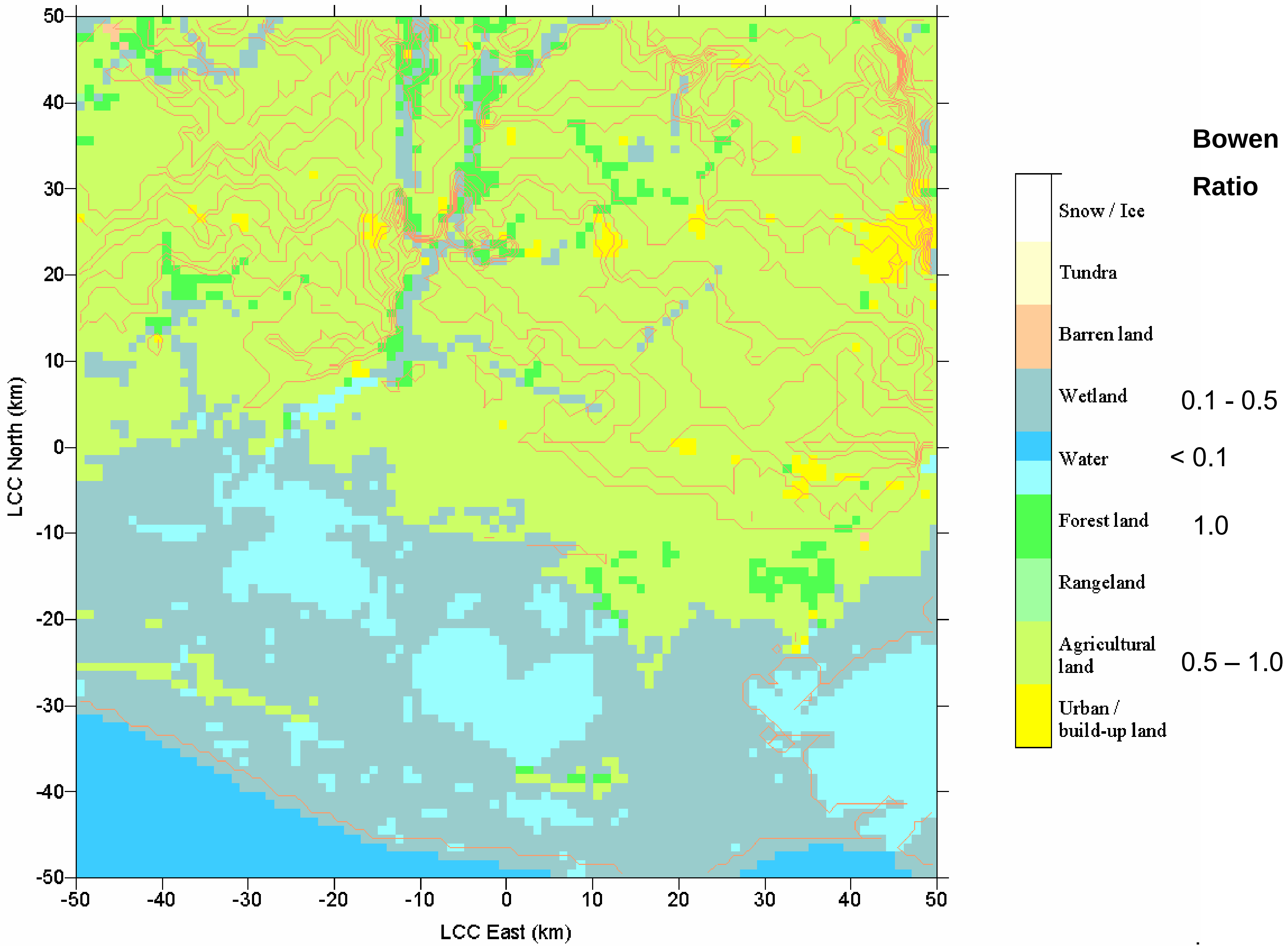


TIBL (Cont'd)

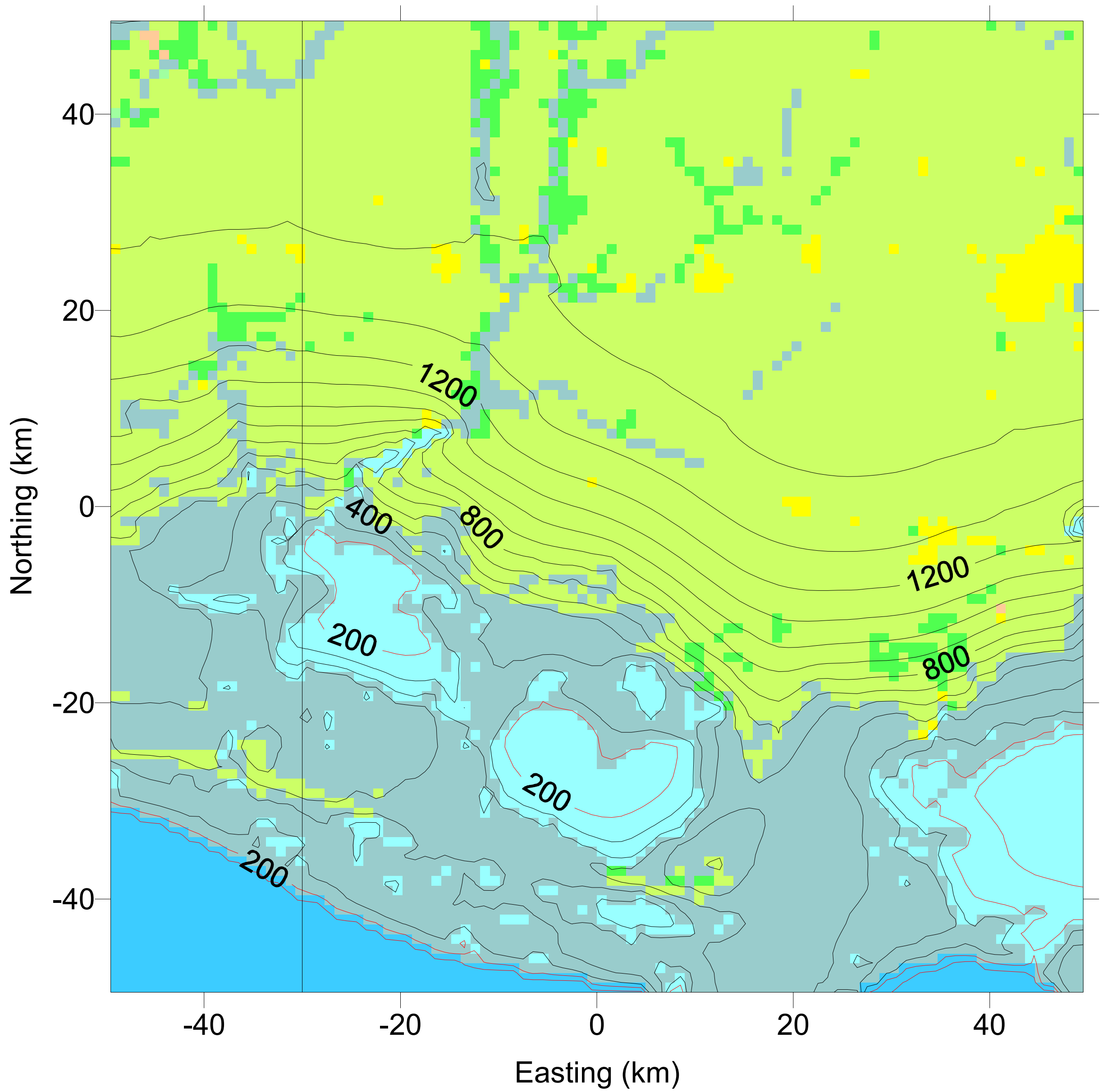
- CALPUFF (Coastal Zone Representation)
  - Gridded land use includes wetlands and inland water bodies
  - Properties tied to land use includes roughness length and Bowen Ratio
  - Sensible heat flux (H) is proportional to Bowen Ratio
  - Computed TIBL growth rate will respond to coastal zone properties:

$$\frac{dh}{dx} = \frac{(1 + 2\beta)H}{\gamma \rho c_p u h}$$

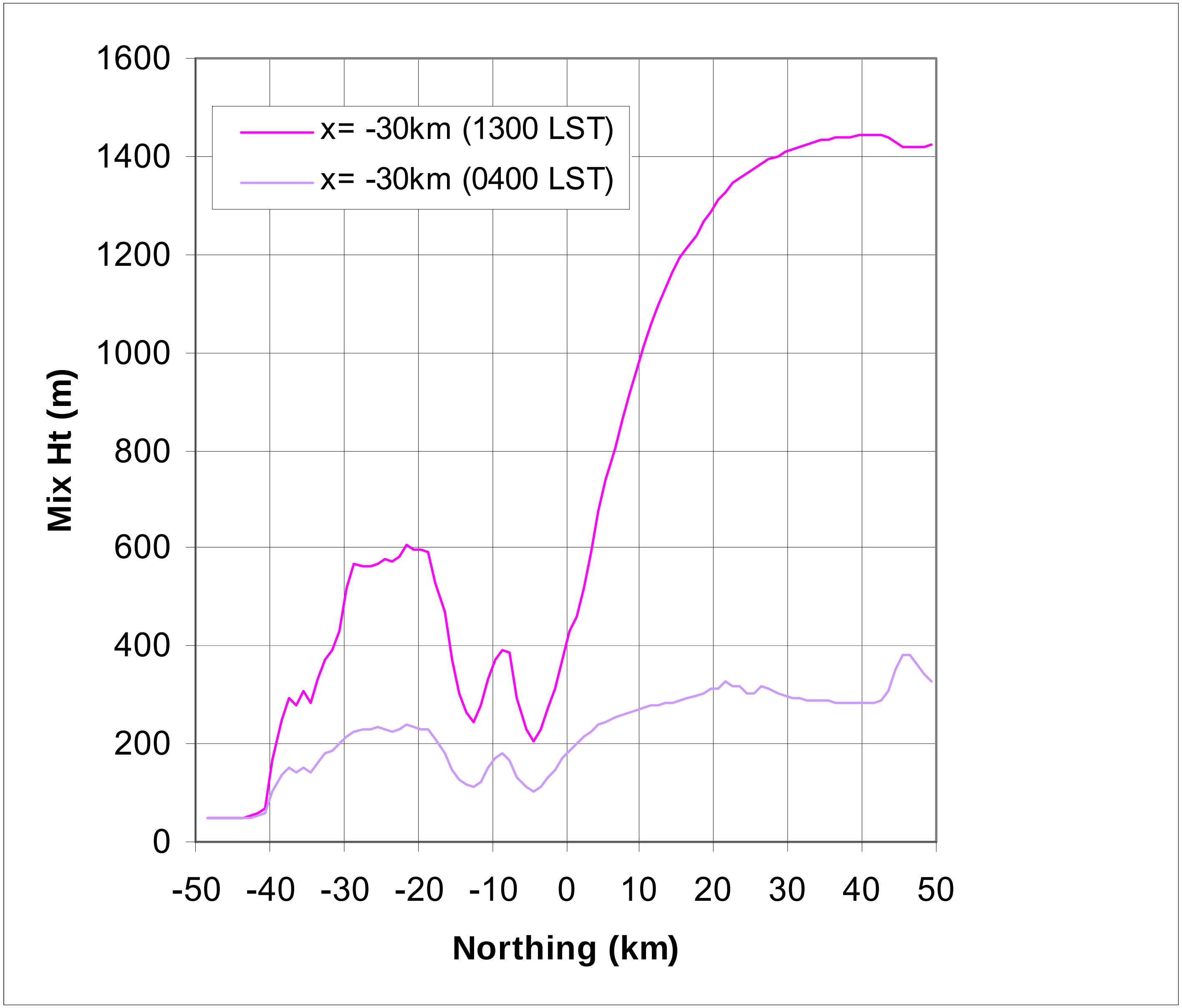
Land Use and Terrain in Lake Charles, LA area



Computed Mixing Heights (m) 1300 LST



Mixing Heights along X=-30km



Model Evaluation Datasets

- Cameron, LA – July 1981 & Dec 1982
- Carpinteria, CA – Sep & Oct 1985
- Pismo Beach, CA – Dec 1981 & June 1982
- Ventura, CA – Sep 1980 & Jan 1981
- Oresond, Denmark/Sweden – May & June 1984

LA and CA Datasets

- Total 110 hours evaluated
- Tracer releases 4-8 km from shore (except 0.5-1 km at Carpinteria)
- Tracer heights 8-13 m above water (except 12-91 m at Carpinteria)
- ΔT range from +5˚C to -4.5˚C
- Winds generally steady

Cameron, Carpinteria, Pismo Beach, Ventura
All CALPUFF Configurations with min. Sigma-v: 0.37 m/s

<u>CALPUFF Configuration</u>

(Modeled Sigma-v ≥ 0.37 m/s)

A -- Modeled Iy, CALPUFF Turbs, Draxler Fy

B -- Observed Iy, CALPUFF Turbs, Draxler Fy

E -- Modeled Iy, AERMOD Turbs, Draxler Fy

F -- Observed Iy, AERMOD Turbs, Draxler Fy

C -- Modeled Iy, CALPUFF Turbs, Variable TLy

D -- Observed Iy, CALPUFF Turbs, Variable TLy

G -- Modeled Iy, AERMOD Turbs, Variable TLy

H -- Observed Iy, AERMOD Turbs, Variable Tly

<u>CALMET Configuration</u>

c0 – OCD overwater BL parameter module

c10d – COARE module (standard "deep water")

c10s – COARE module with shallow water adj.

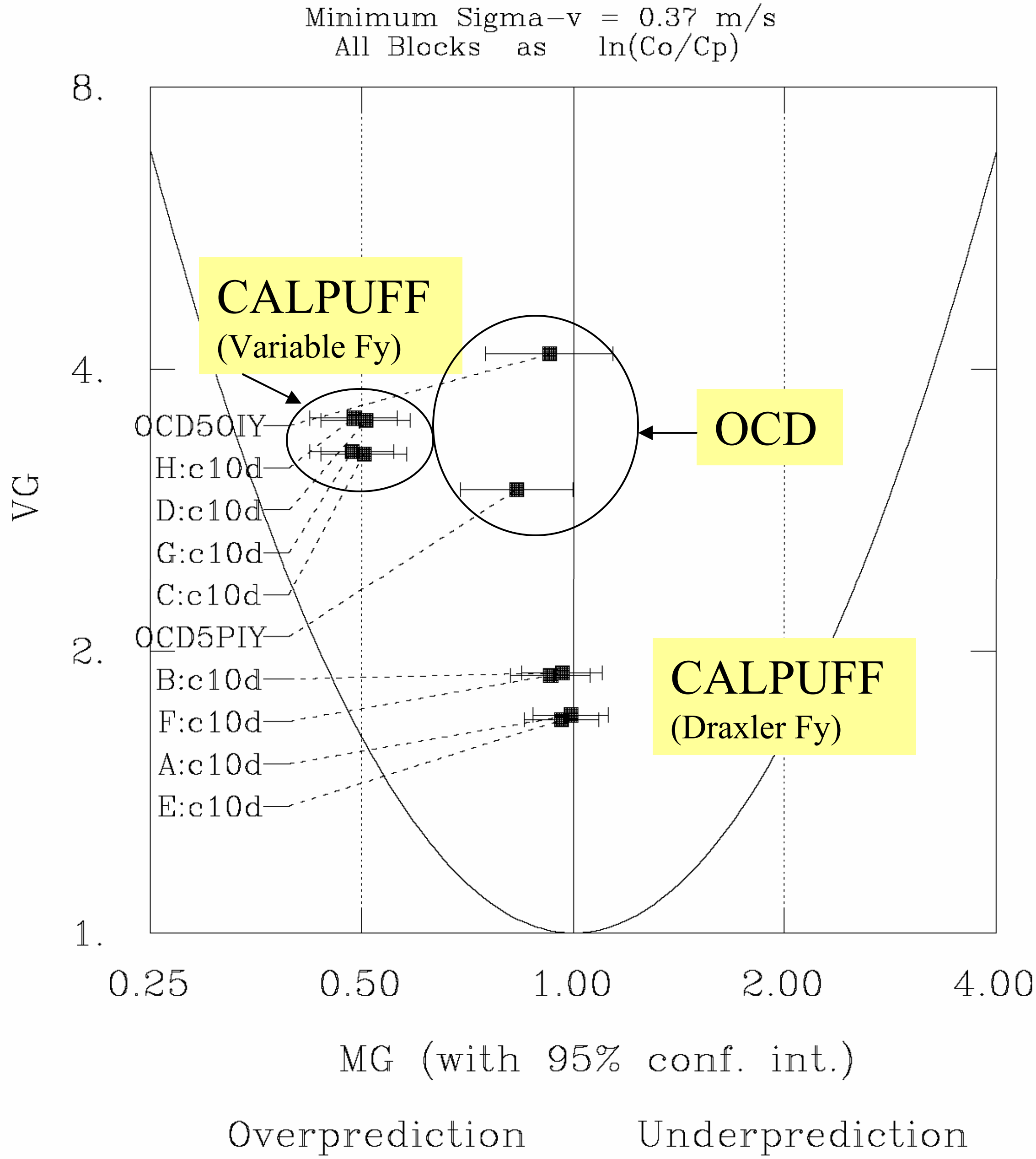
c11 – COARE module with wave option 1

c12 – COARE module with wave option 2

<u>OCD5 Configuration</u>

OCD5PIY - Modeled Iy (Sigma-v ≥ 0.37 m/s)

OCD5OIY - Observed Iy



LA and CA Test Results

- OCD-based over water flux model tends to produce more scatter than COARE option
- Little difference among COARE variations with shallow-water adjustment reducing bias
- CALPUFF shows less scatter and less tendency to over predict than OCD
- Modeled I_y with a minimum σ_v of 0.37 m/s reduces scatter and results in slightly smaller over predictions
- CALPUFF and AERMOD profiles produce similar results with AERMOD slightly more conservative

LA and CA Test Results (Cont’d)

- Overall new CALPUFF improves model predictions over OCD
- New CALPUFF has small bias toward over prediction; scatter is close to factor of 2

Oresund Dataset

- 39 hours of tracer data
- Tracer release heights 95 and 115 m above ground
- Strait is about 20 km wide
- Transport distances range from 22 to 42 km
- 6 days were very stable
- 3 days were neutral/slightly unstable

Oresund

CALMET - CALPUFF Configuration

-Zi1 – No Turb Advection, Maul-Carson Mixing Ht

-Zi1OW – No Turb Advection, Maul-Carson Mixing Ht , Obs Overwater

-Zi2 – No Turb Advection, Batchvarova-Gryning Mixing Ht

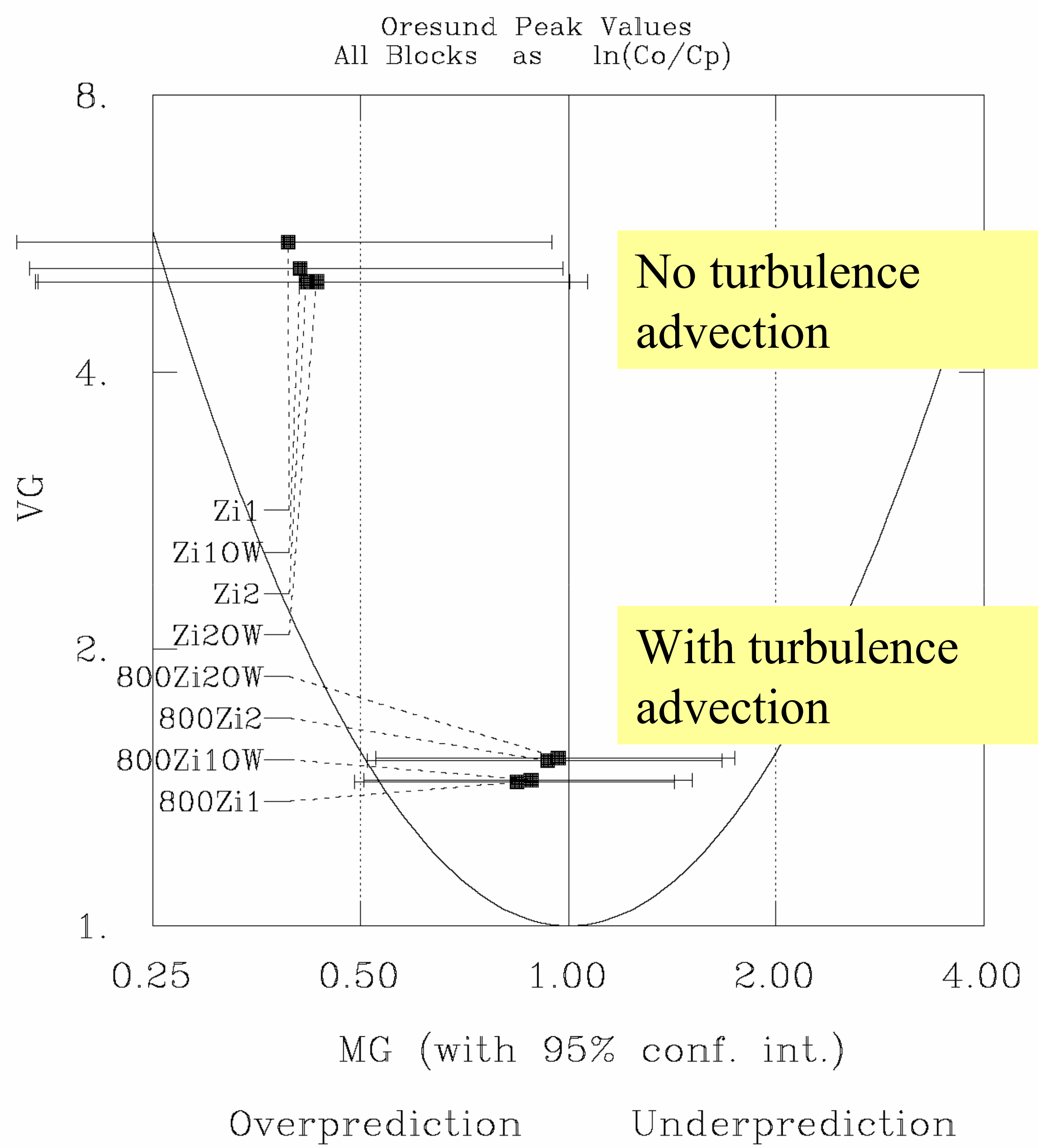
-Zi1OW – No Turb Advection, Batchvarova-Gryning Mixing Ht , Obs Overwater

-800Zi1 –Turb Advection (800s), Maul-Carson Mixing Ht

-800Zi1OW –Turb Advection (800s), Maul-Carson Mixing Ht , Obs Overwater

-800Zi2 –Turb Advection (800s), Batchvarova-Gryning Mixing Ht

-800Zi1OW –Turb Advection (800s), Batchvarova-Gryning Mixing Ht , Obs Overwater



Oresund Test Results

- Turbulence advection option significantly improves results
- Selection of minimum σ_v value had little effect in this case
- Use of Batchvarova-Gryning mixing height values reduced over prediction compared to Maul-Carson method

Conclusions

- Minimum σ_v over water results in improved predictions
- COARE flux model is superior to the OCD method
- Standard COARE option appears suitable
- Batchvarova-Gryning mixing height scheme improves model performance
- Turbulent advection helps improve results when large gradients occur
- SCIPUFF Lagrangian timescale approach is unacceptable (large over predictions)

MMS 5-Yr Dataset

- Gulf of Mexico Domain
- Period 2000-2004
- USGS terrain & land use files
- 13 buoy stations
- 21 upper-air stations
- 230 NWS surface met stations
- 271 NWS precipitation stations
- 201 ozone stations (AIRS and CASTNET)

MMS 5-Yr Dataset (Cont'd)

- Gridded prognostic meteorological output fields from RUC model
- 50 tiles
- 20 km resolution
- Year 2003 completed
- Remainder complete in summer 2007

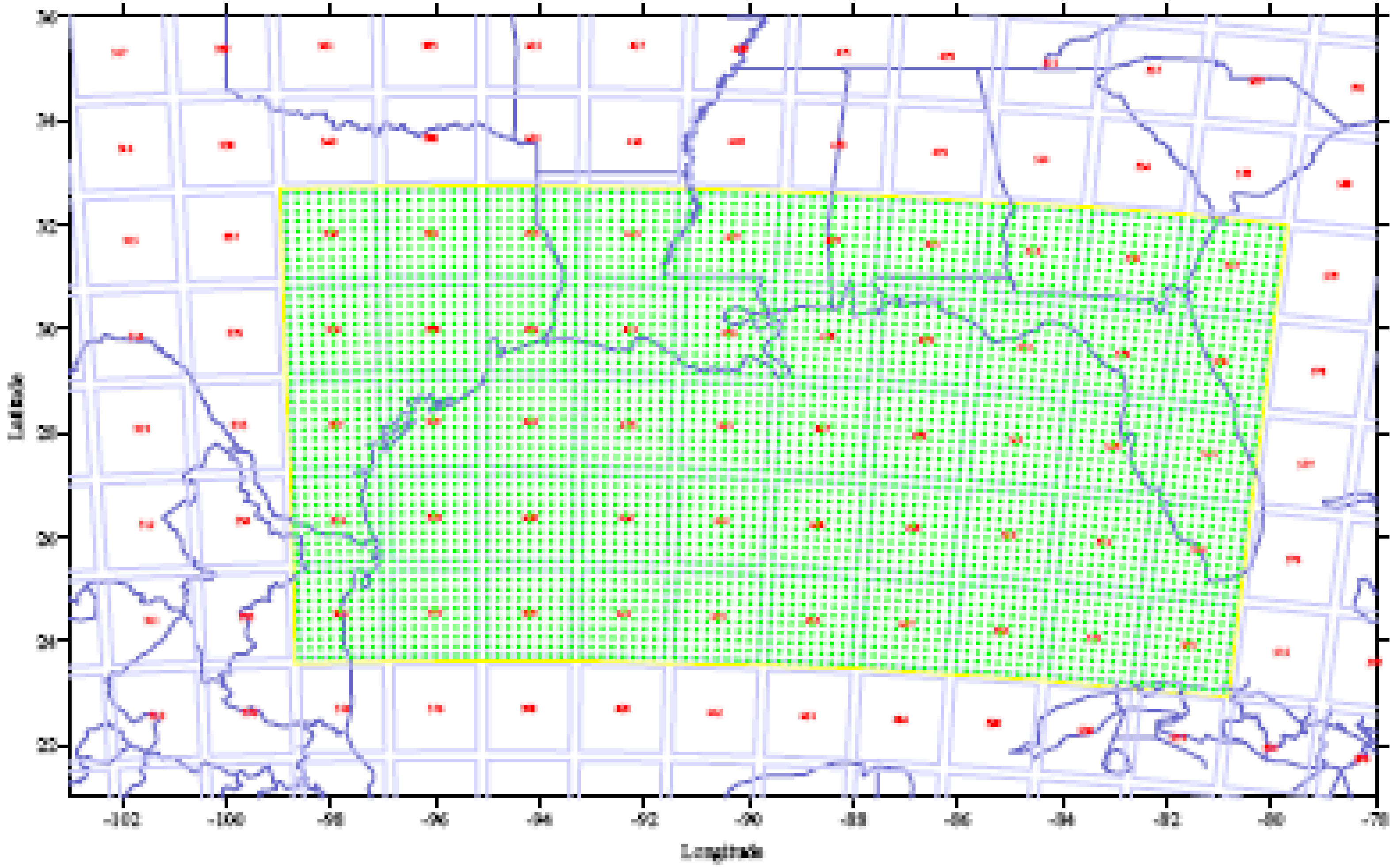


Figure 5-6. Locations of the RUC data tiles in the MMS standard data set.

CALPUFF Final Report

- http://www.gomr.mms.gov/homepg/espis/espisfront.asp
- Click ESPIS
- Enter Contract 31071
- Contact: Dirk.Herkhof@mms.gov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