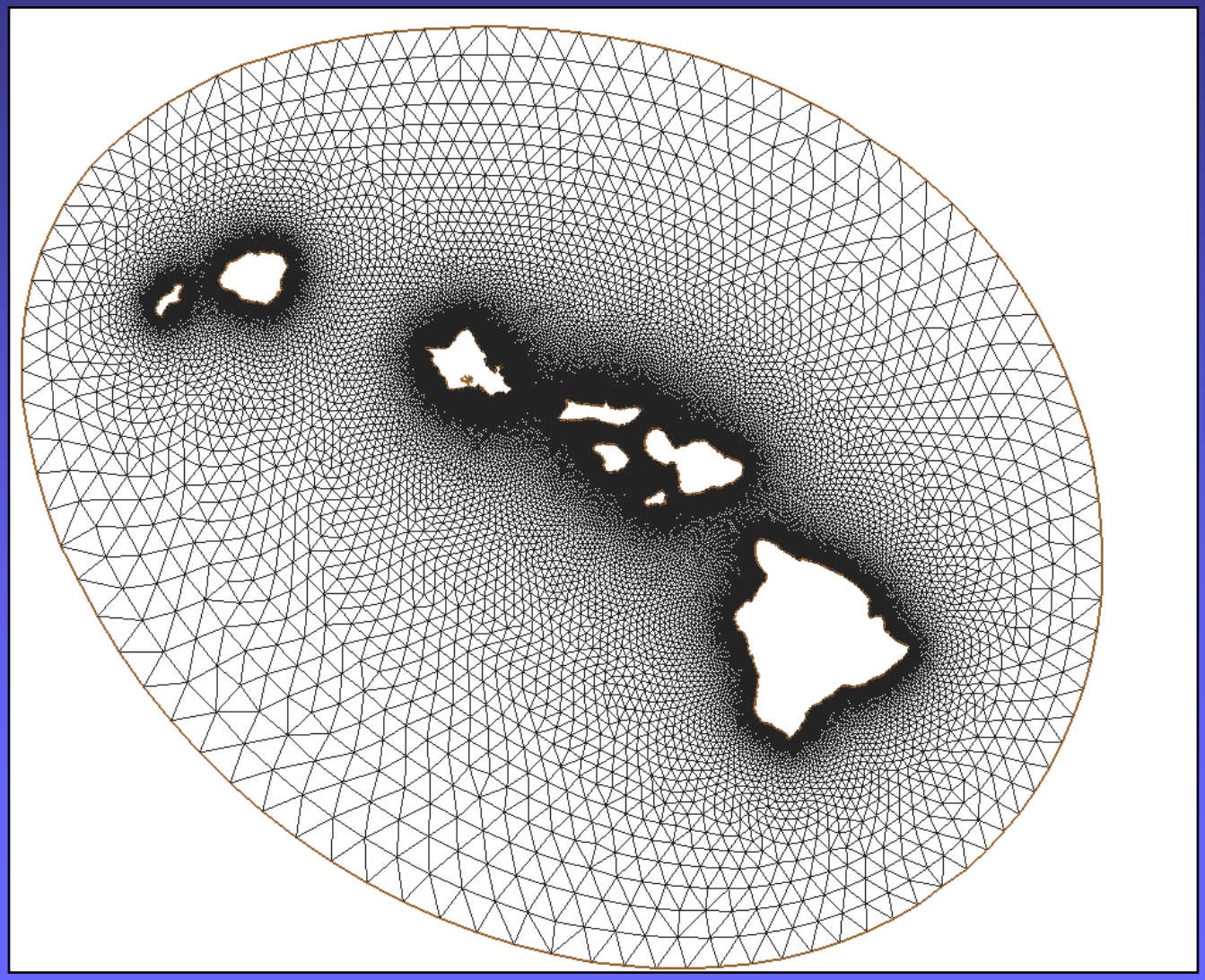
# Water Circulation Modeling

# Modeling Technical Tasks

- Data collection/assessment
- Finite element and finite difference grid development
- Development of model forcing conditions
- **Model simulations**
- **Model validation**
- Simulation analysis

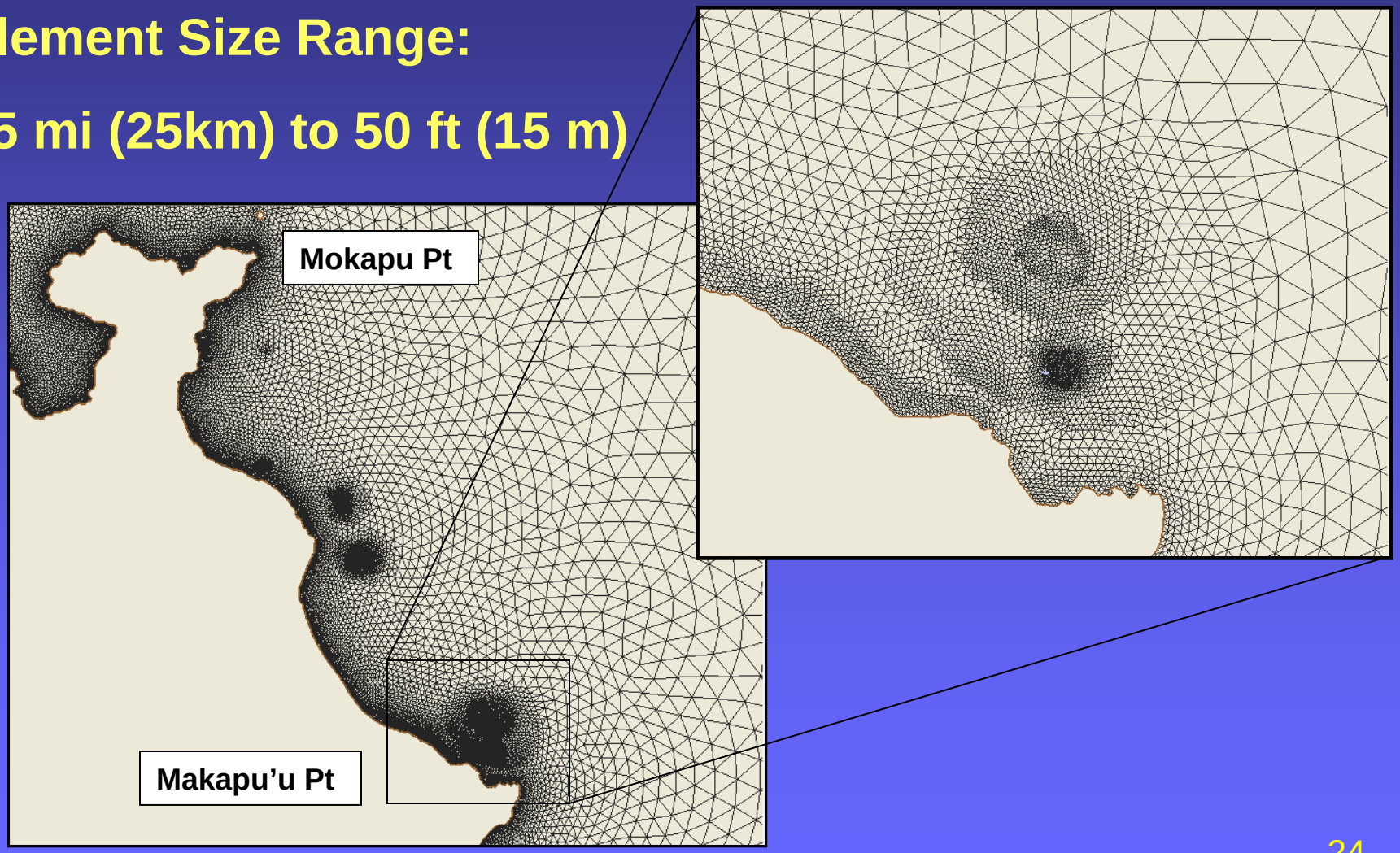
# ADCIRC Model Domain



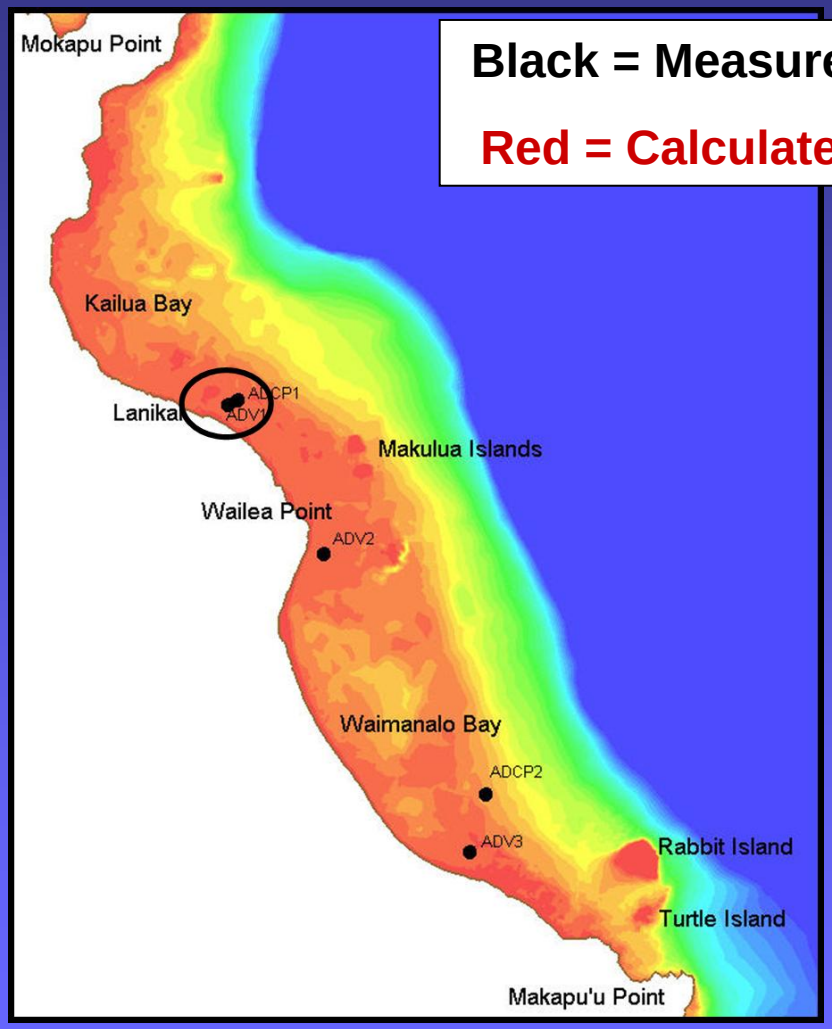
# Circulation Model -ADCIRC

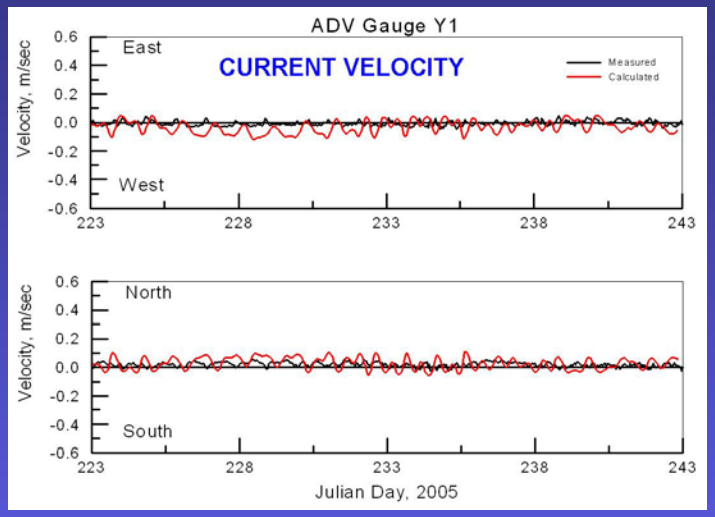
**Element Size Range:**

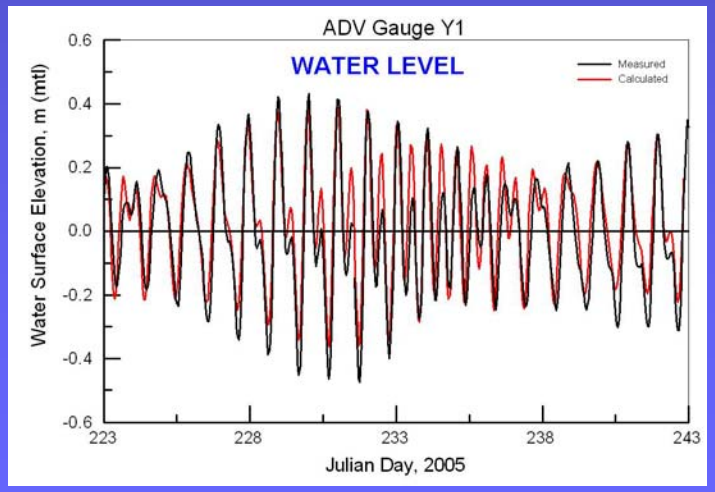
**15 mi (25km) to 50 ft (15 m)**



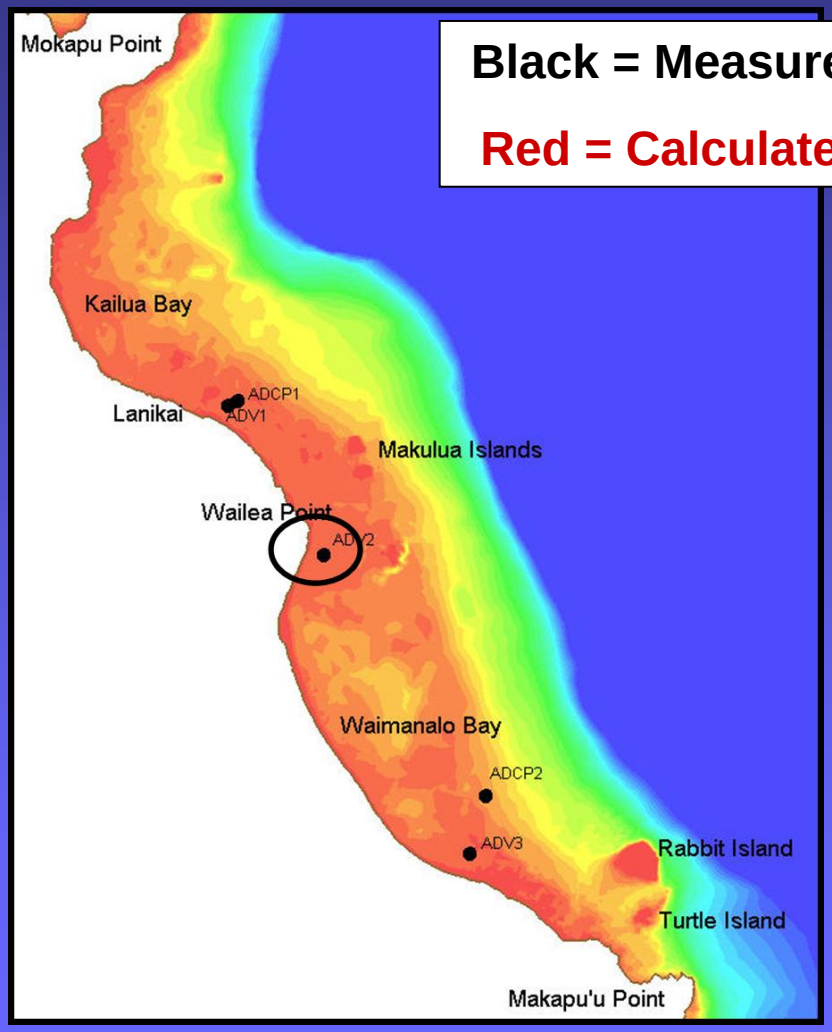
# ADCIRC Comparisons – ADV Gauge Y1

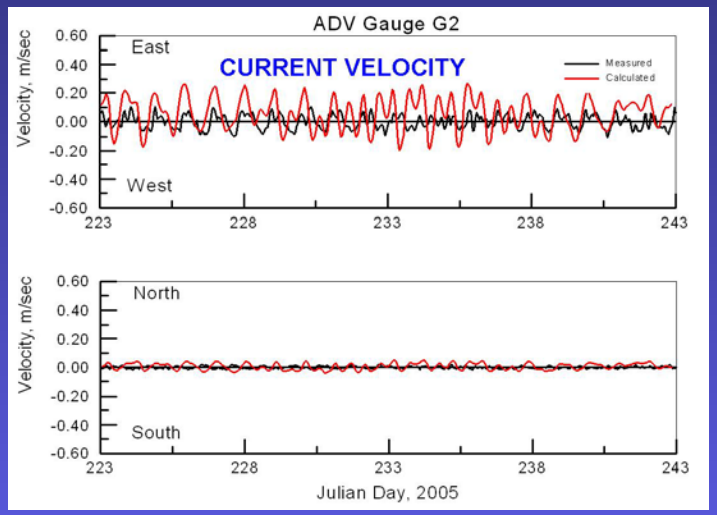


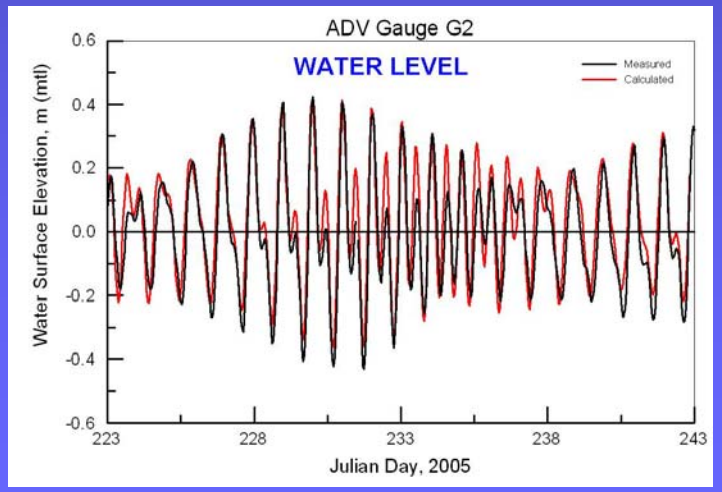



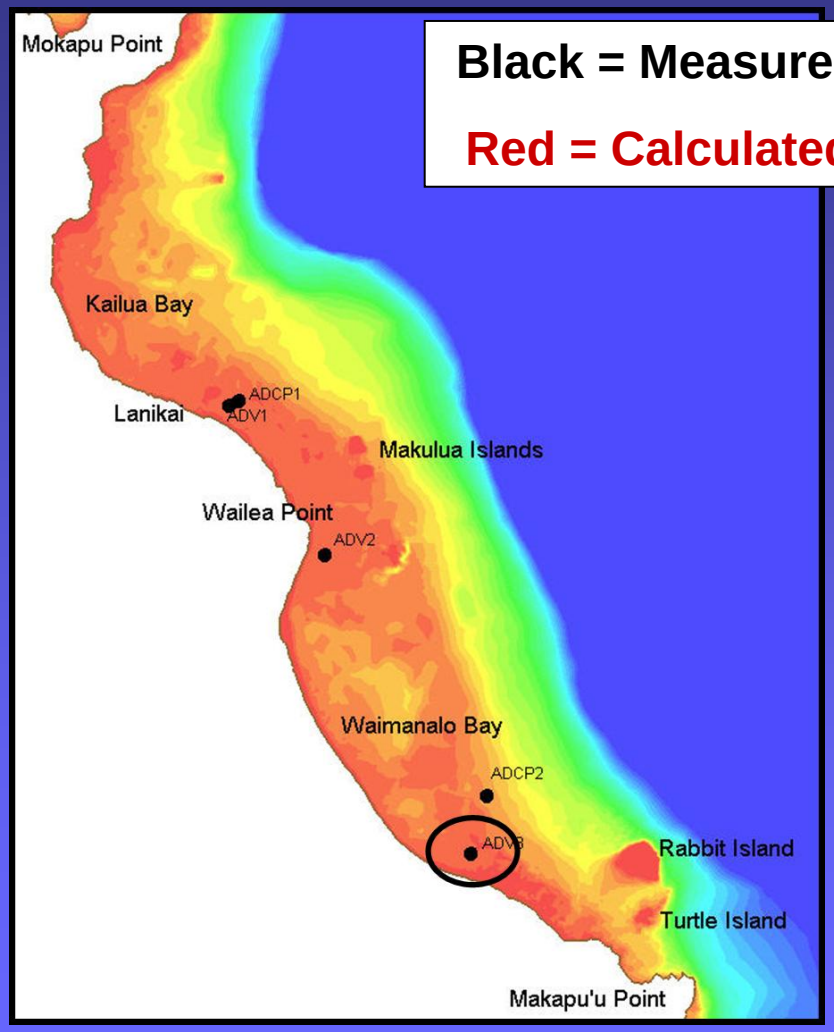
# ADCIRC Comparisons – ADV Gauge G2

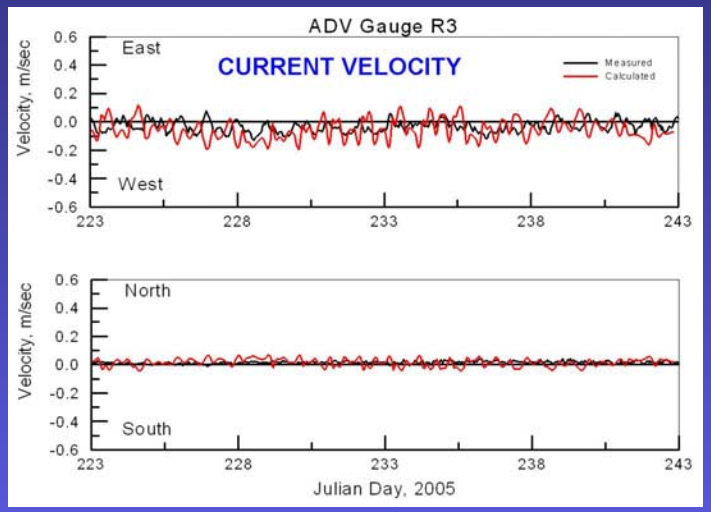


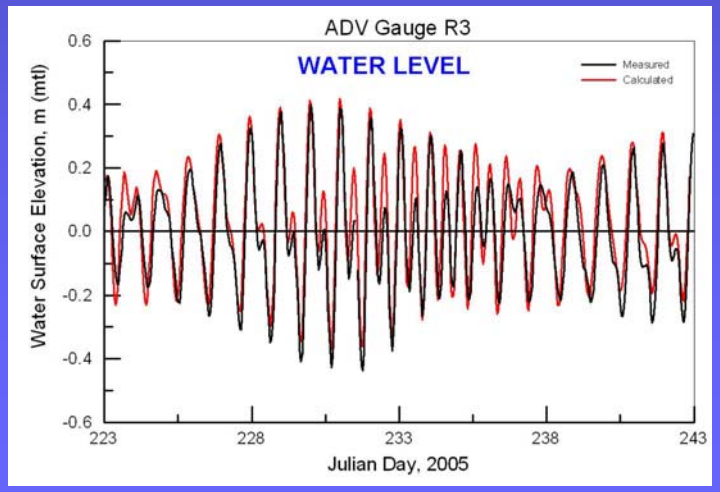



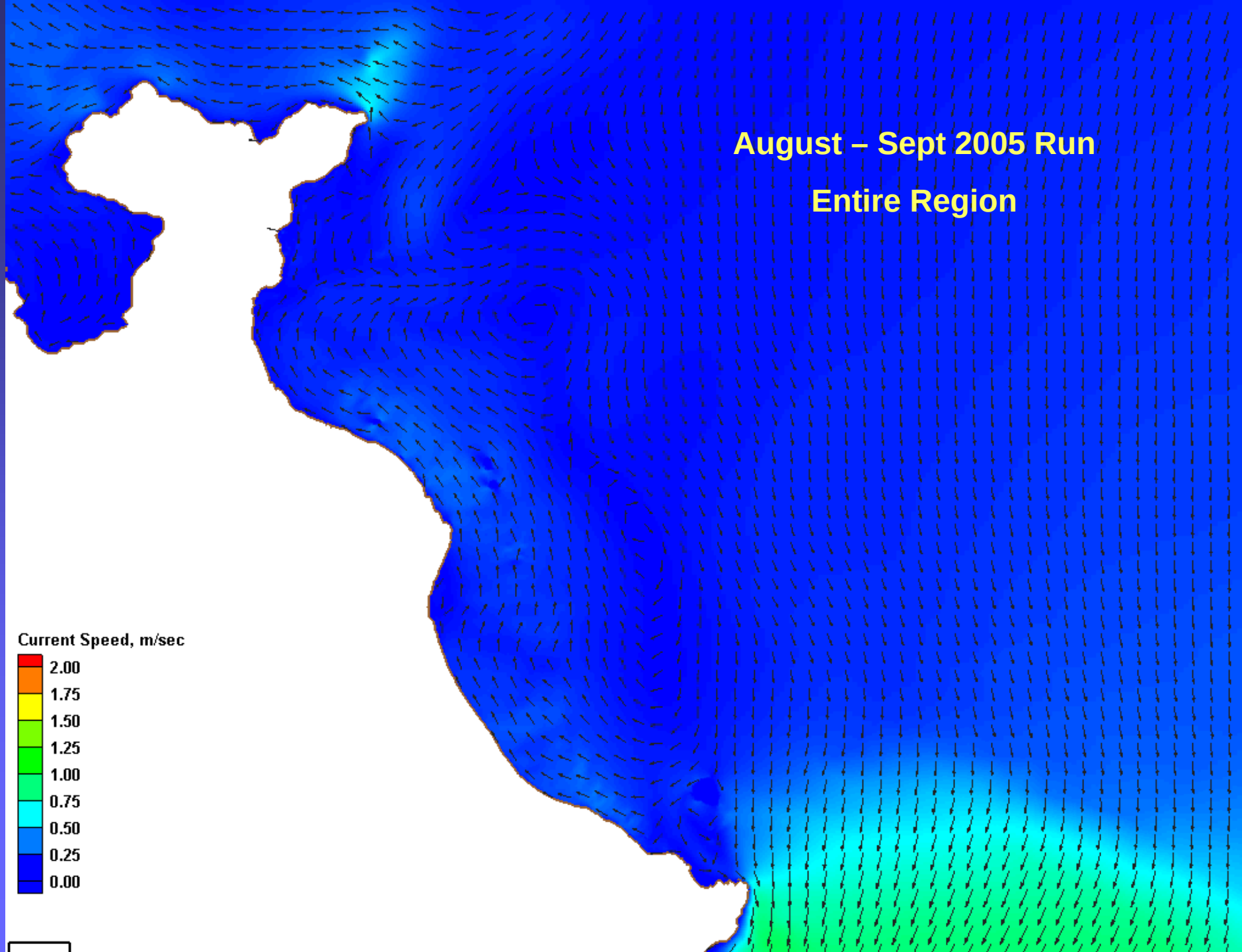



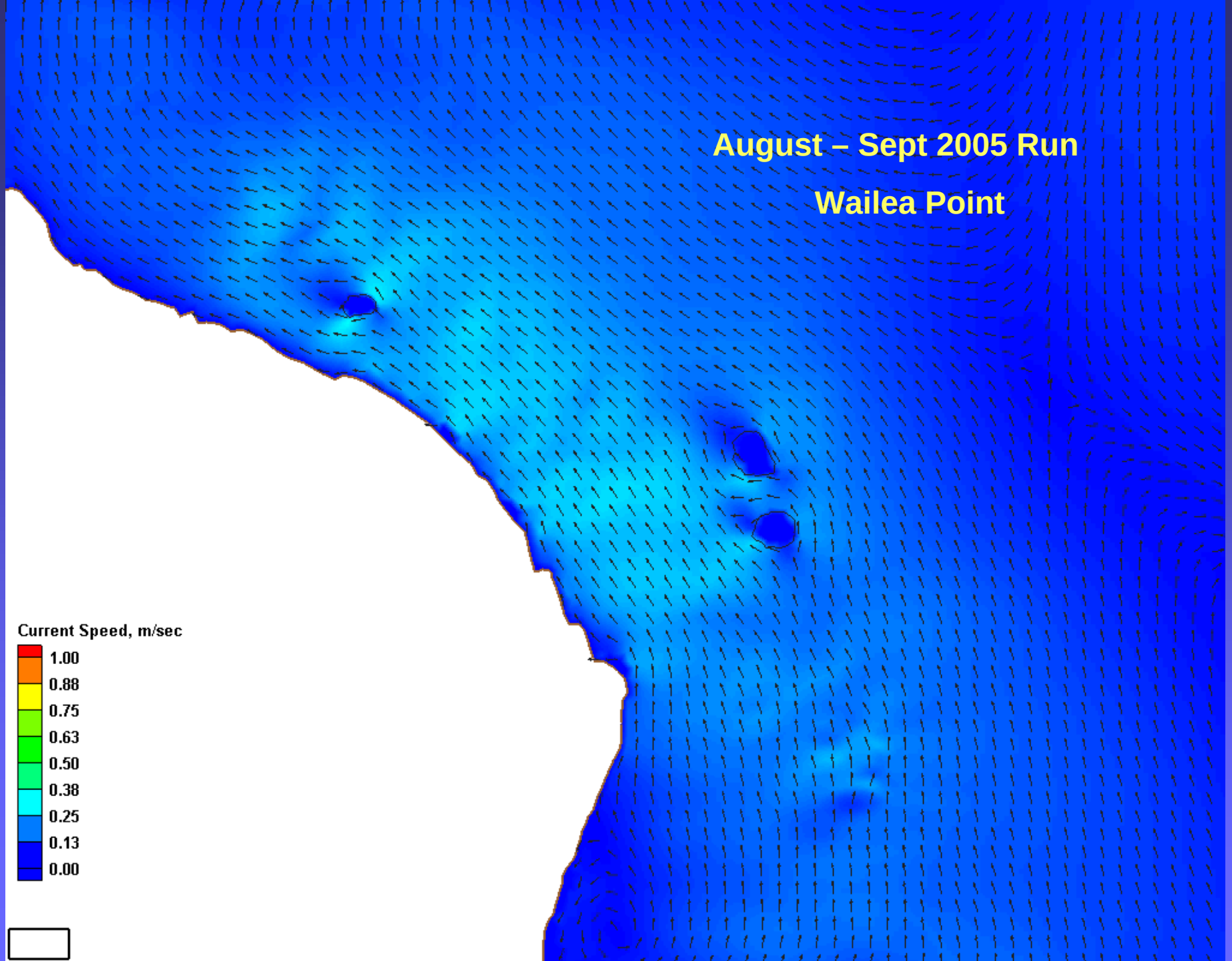
# ADCIRC Comparisons – ADV Gauge R3




August – Sept 2005 Run
Entire Region
Current Speed, m/sec
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

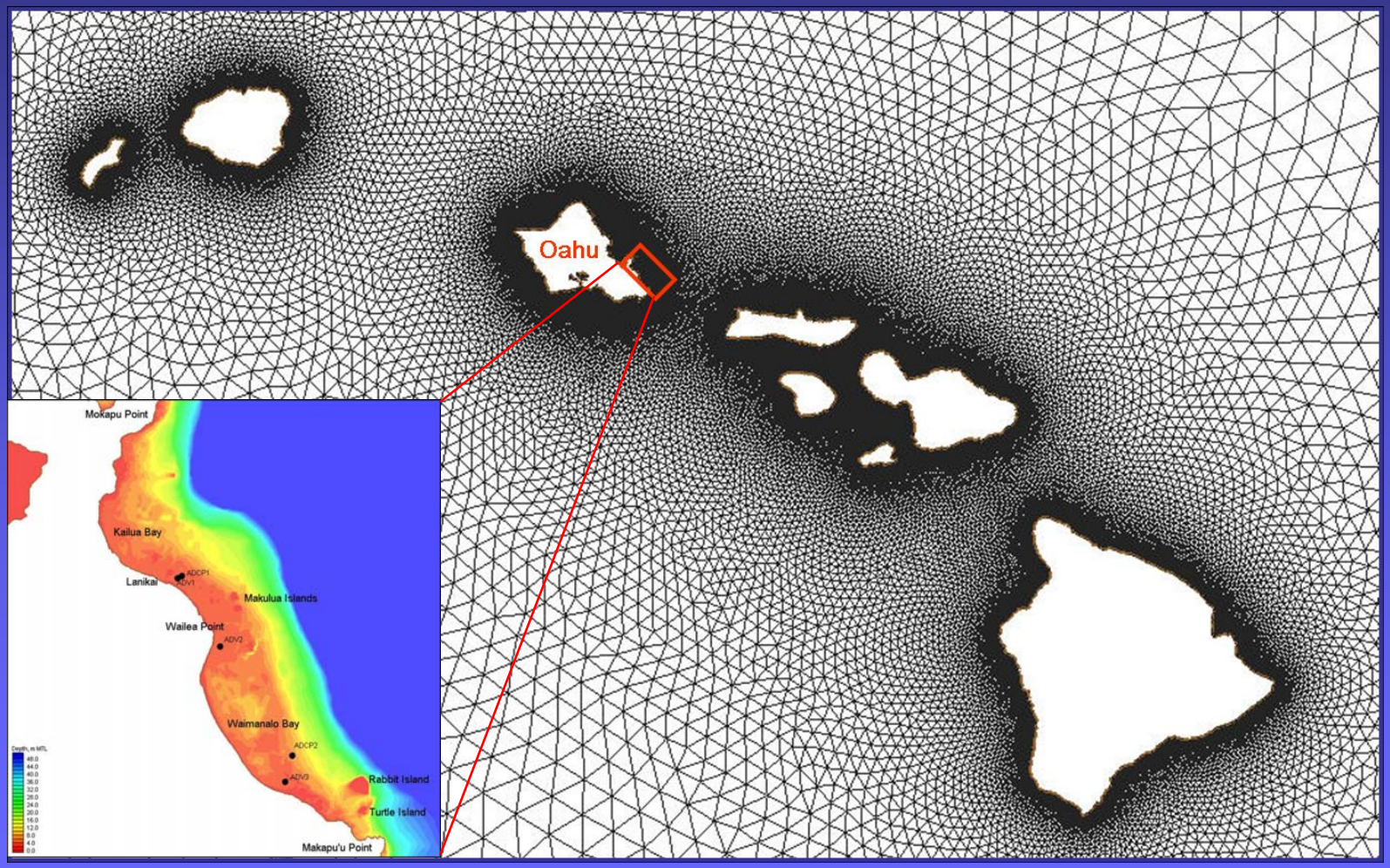

August – Sept 2005 Run
Wailea Point
Current Speed, m/sec
1.00
0.88
0.75
0.63
0.50
0.38
0.25
0.13
0.00

# Wave Transformation Modeling

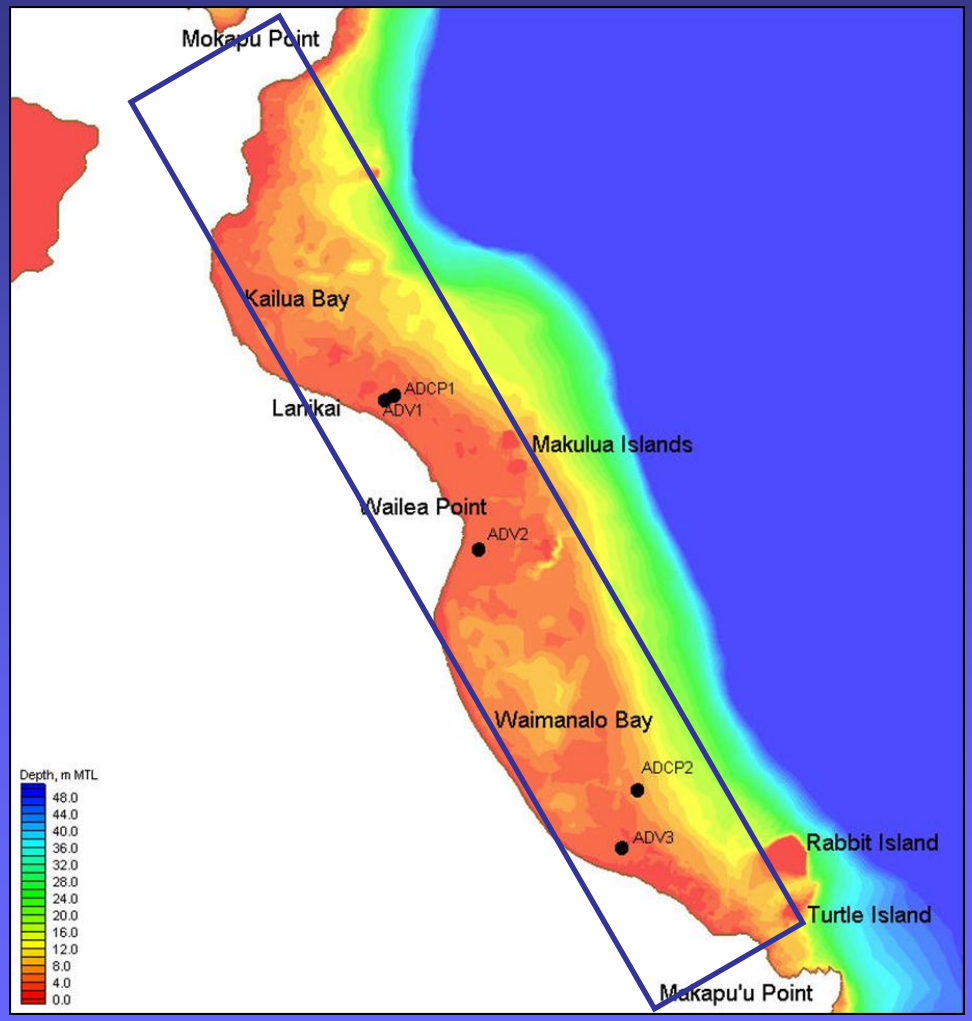
# *Modeling Technical Tasks*

- Data collection/assessment
- Finite element and finite difference grid development
- Development of model forcing conditions
- **Bottom friction formulation**
- **Model simulations**
- **Model validation**
- Simulation analysis

# STWAVE Domain



# Extensive Reef



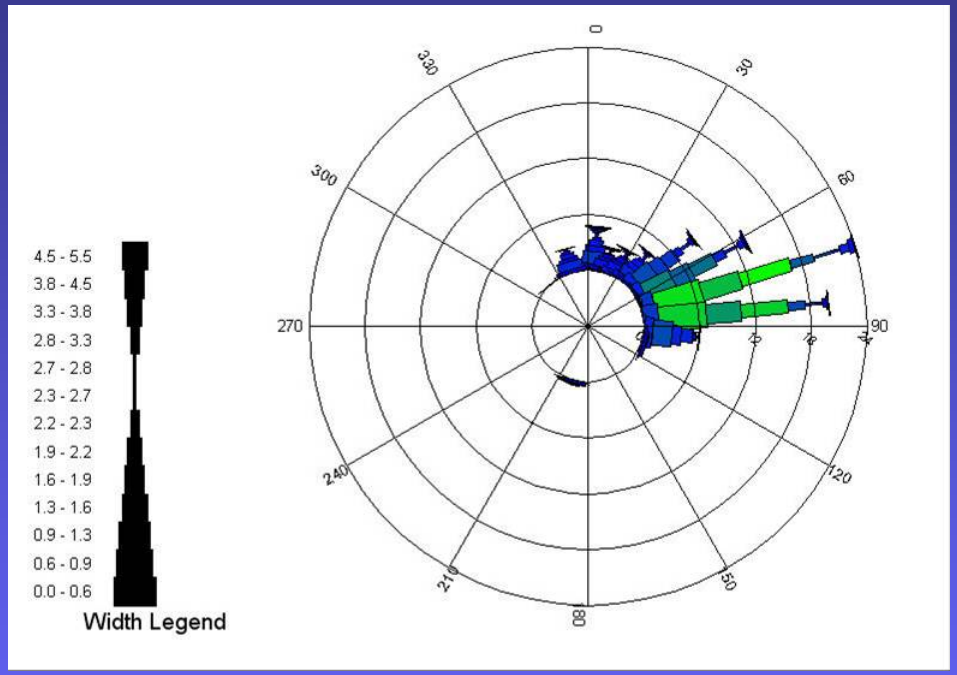
# STWAVE Model

## Steady-State Spectral Wave Model

- Conservation of wave action
- Simplified diffraction
- Wave growth and white-capping
  - Wind input
  - Nonlinear transfers to low frequencies
  - Dissipation at high frequencies
- Depth and steepness-induced breaking
- Refraction and shoaling
- Wave-current interaction
- Bottom friction

*Wave height, direction, period (bulk parameters and spectra), radiation stresses*

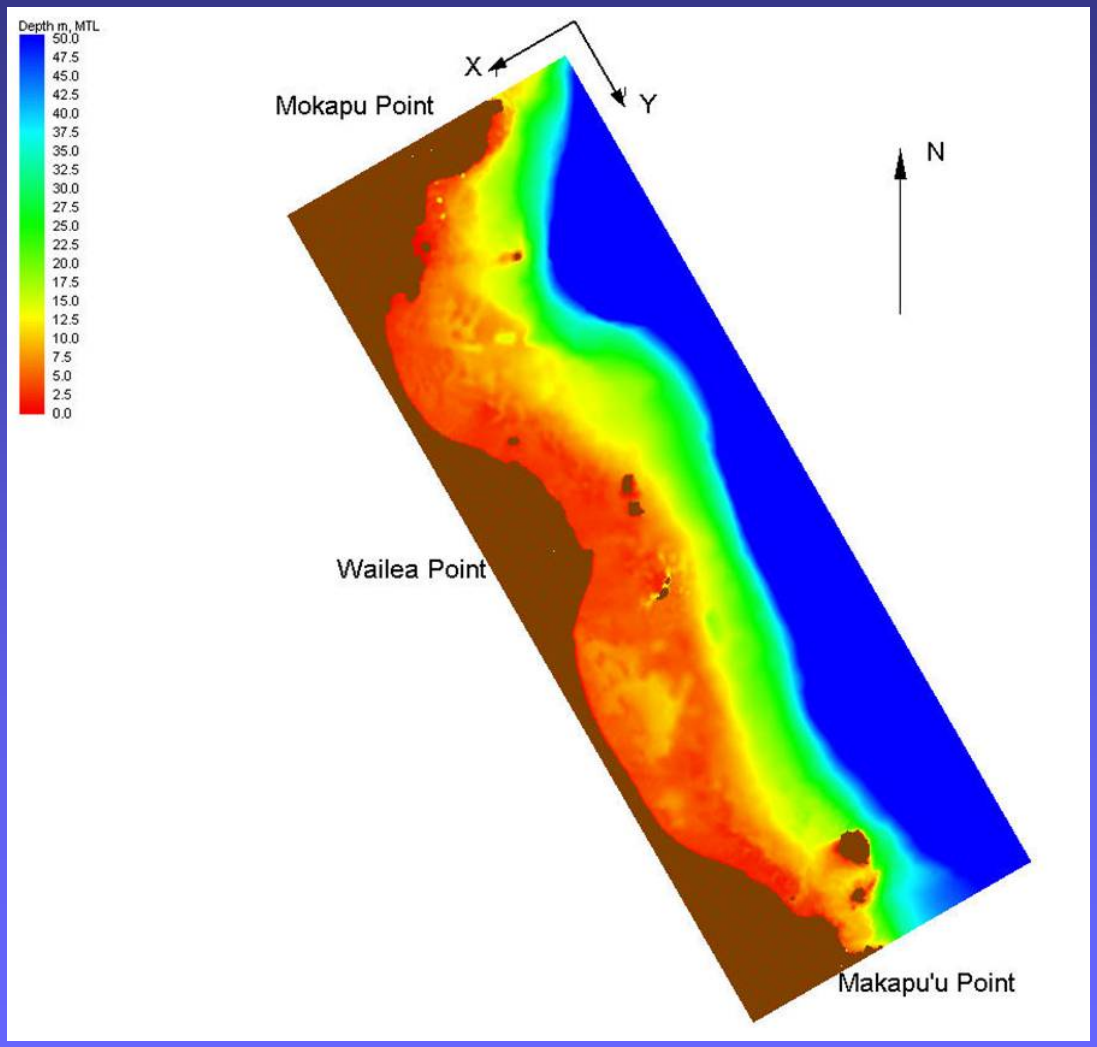
# Offshore Wave Climate – CDIP Buoy Station 098 (2000-2004)



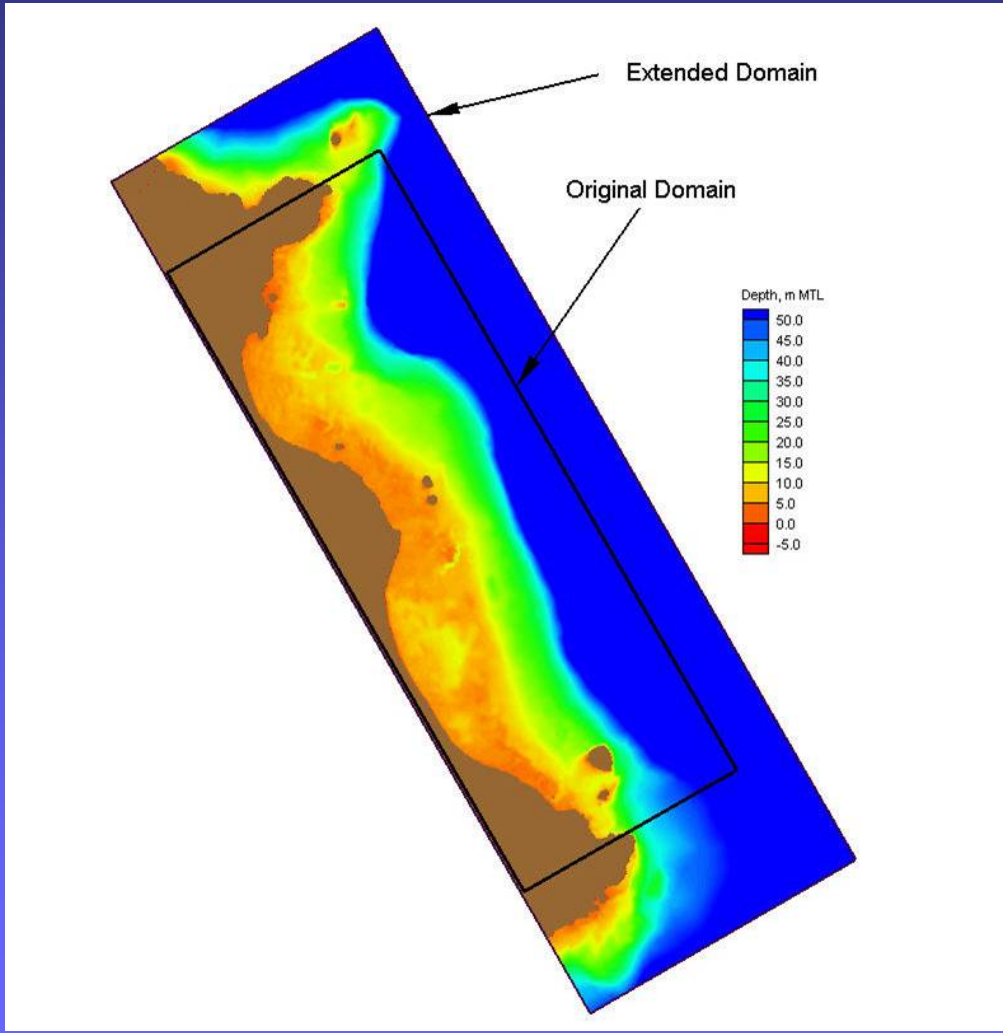

| Wave Conditions | | | |
|---|---|---|---|
| Significant Wave Height, m | Wave Period, sec | Wave Direction, deg from North | Wave Direction, deg from STWAVE axis |
| .75 | 6 | -22.5 | 82.5 |
| 1.25 | 8 | 0 | 60 |
| 1.75 | 10 | 22.5 | 37.5 |
| 2.25 | 12 | 45 | 15 |
| 2.75 | 14 | 67.5 | -7.5 |
| 3.5 | 16 | 90 | -30 |

*Initially discertized into 134 wave conditions*

# Original STWAVE Domain



# Expanded STWAVE Domain



# JONSWAP Friction Formulation

$$S_{bf} = \frac{-1}{g} c_f \frac{\sigma^2}{\sinh^2 kd} E(f,\alpha)$$

| | | |
|---|---|---|
| $S_{bf}$ | = | spectral energy loss from bottom friction |
| $c_f$ | = | friction coefficient |
| $\sigma$ | = | angular wave frequency |
| $k$ and $d$ | = | wave number and water depth |
| $E(f, \alpha)$ | = | wave energy density function (divided by $(\rho_w g)$ |
| $(f, \alpha)$ | = | wave frequency and wave direction |

(Hasselmann et al. 1973, Padilla-Hernandez and Monbaliu 2001)

# Manning's Friction Formulation

$$S_{bf} = \frac{-1}{g}\left(\frac{gn^2}{d^{1/3}}\right)\frac{\sigma^2}{\sinh^2 kd}E(f,\alpha)u_{rms}$$

| | | |
|---|---|---|
| $S_{bf}$ | = | spectral energy loss from bottom friction |
| $c_f$ | = | friction coefficient |
| $\sigma$ | = | angular wave frequency |
| $k$ and $d$ | = | wave number and water depth |
| $E(f, \alpha)$ | = | wave energy density function (divided by $(\rho_w g)$ |
| $(f, \alpha)$ | = | wave frequency and wave direction |
| $u_{rms}$ | = | root-mean-square bottom velocity |

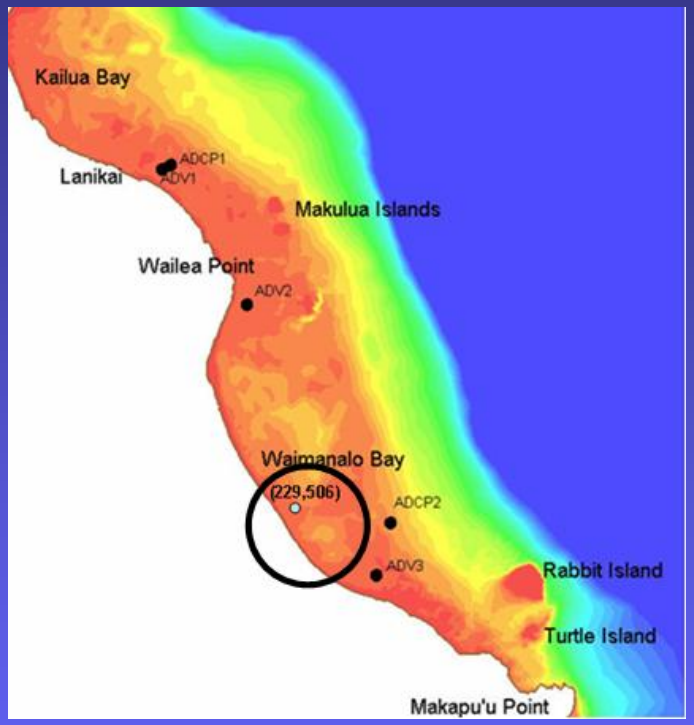
(Holthuijsen 2007)

# STWAVE Test Run

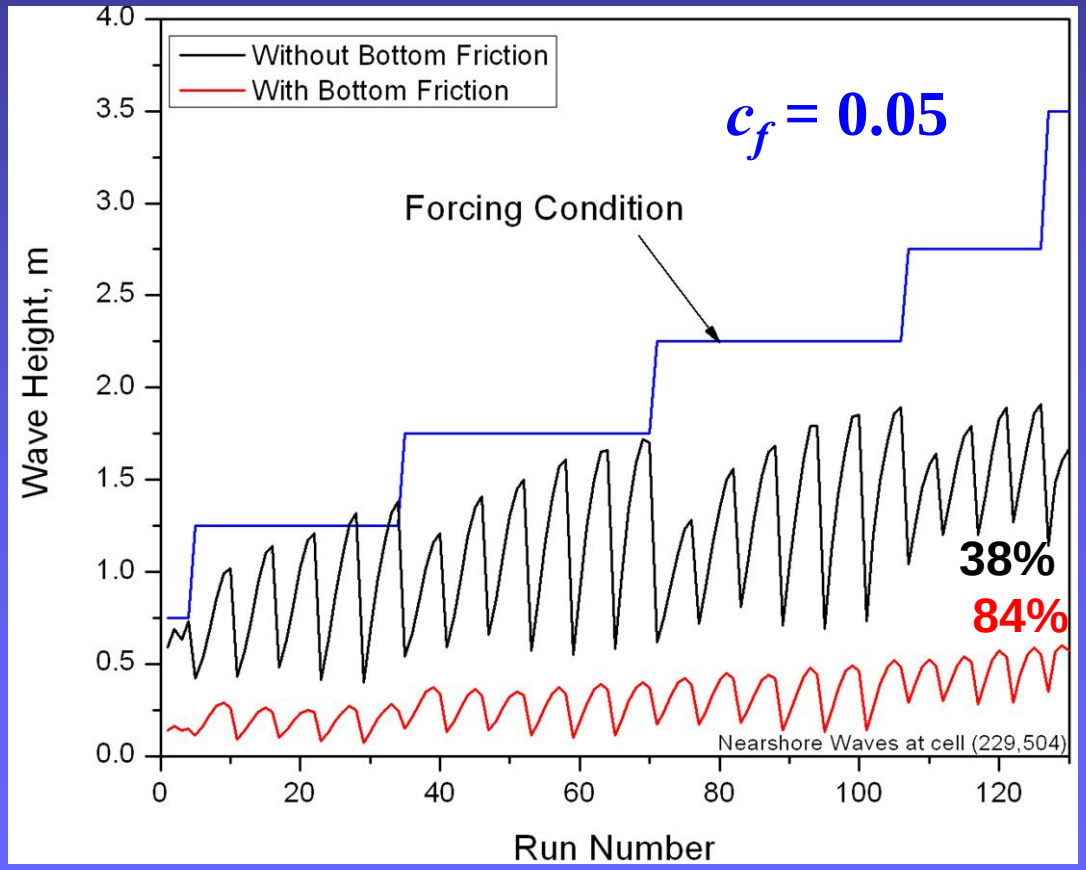
*Test Range*

$c_f$ **0.04 – 0.12**

***n*** **0.15 – 0.25**




ADV1:
$c_f$ = 64-93%
*n* = 62-80%

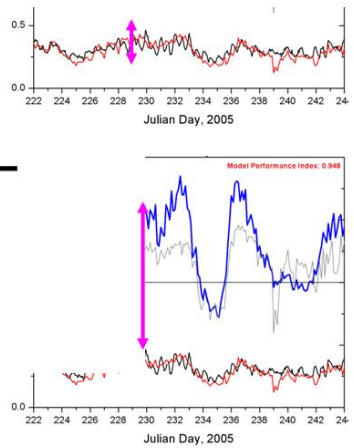


# Model Validation : Model Performance Index

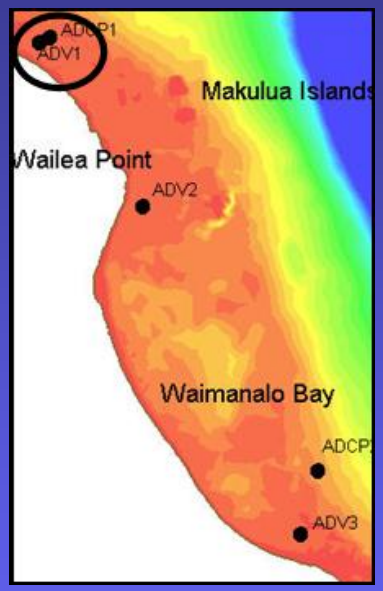
$$MPI = 1 - Error_{rms} / Changes_{rms}$$

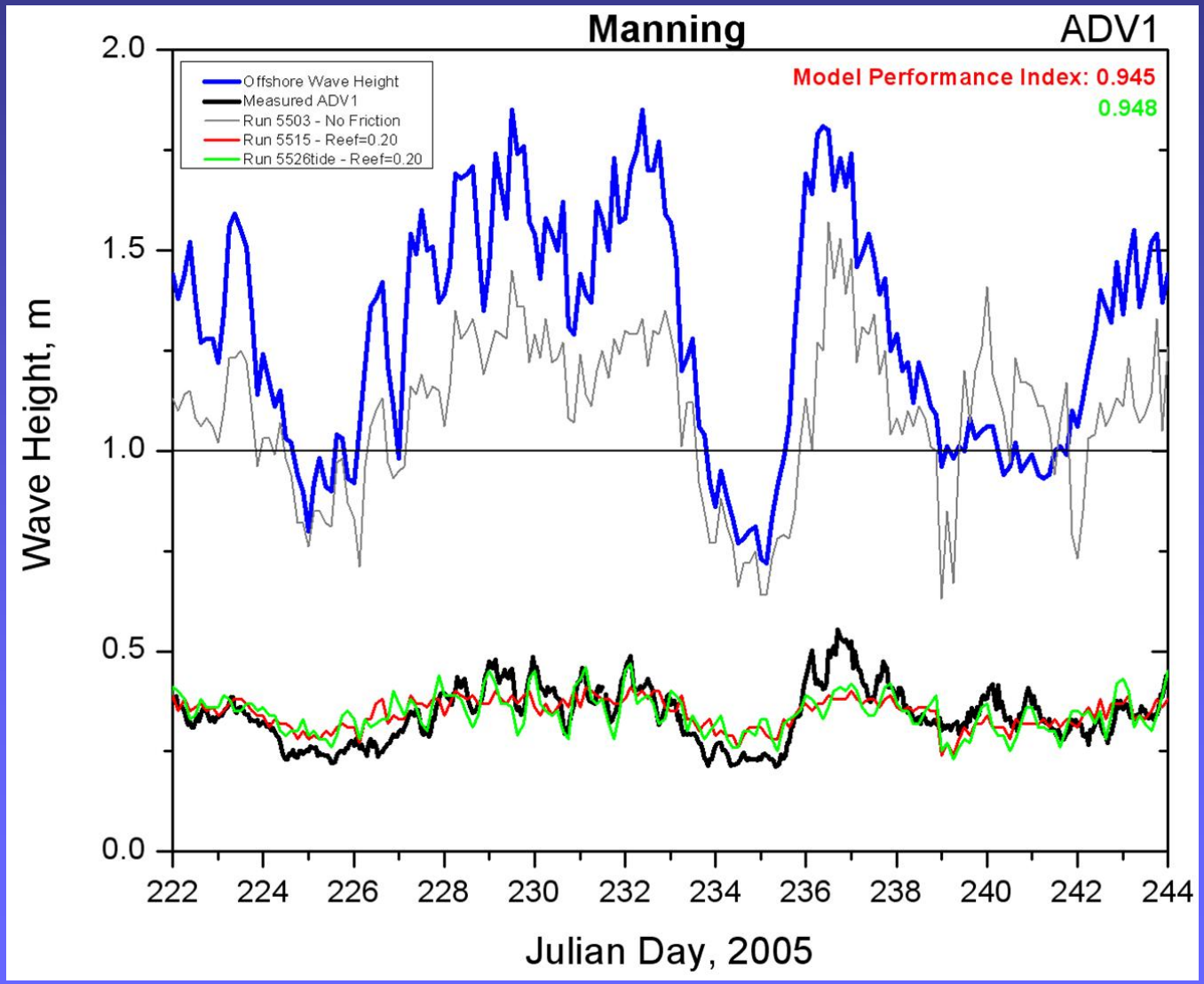
$$Error_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Model-Data)^2}$$

$$Changes_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Off-Data)^2}$$

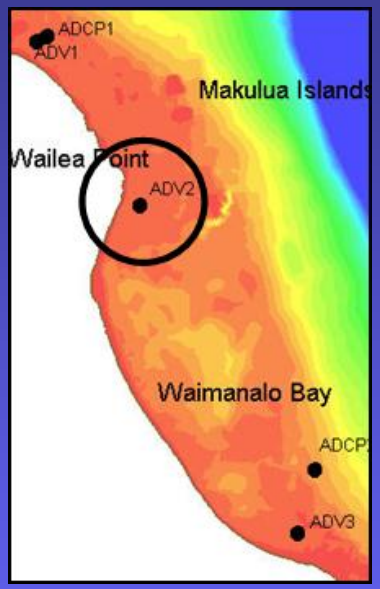


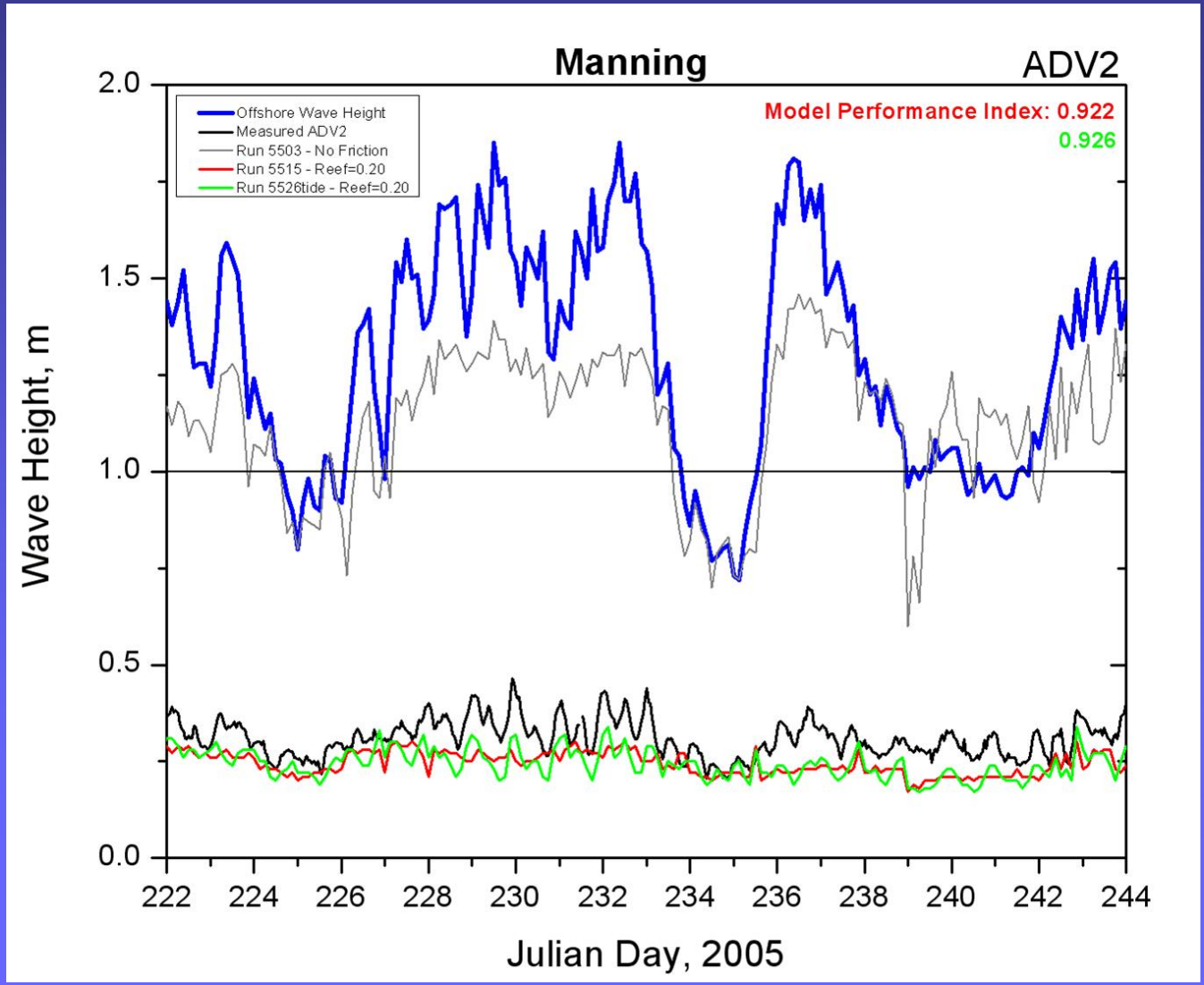
# Model Validation: Manning's Friction



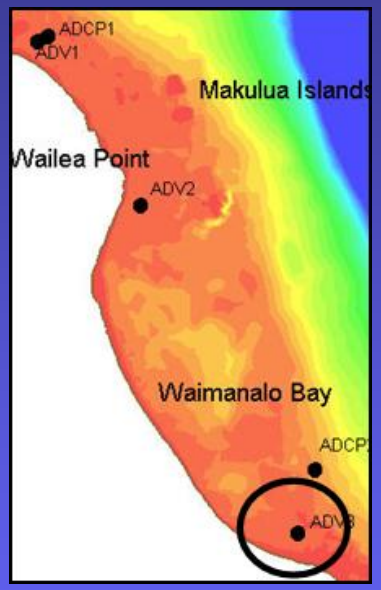



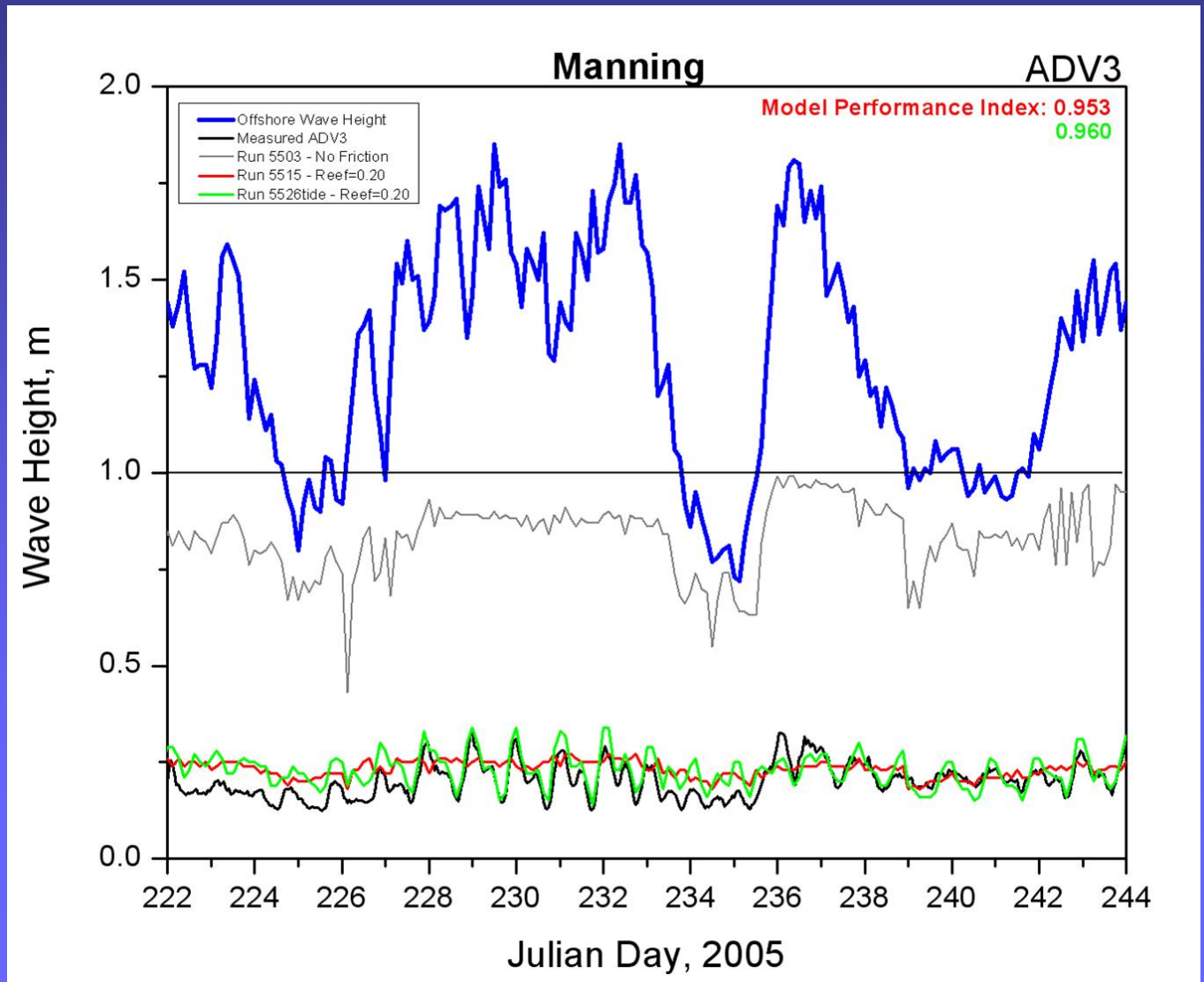
# Model Validation: Manning's Friction



# Model Validation: Manning's Friction

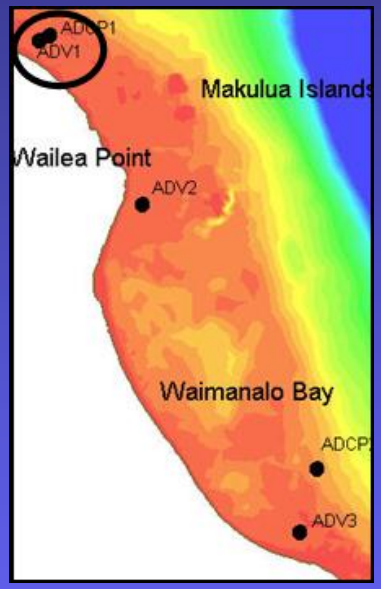


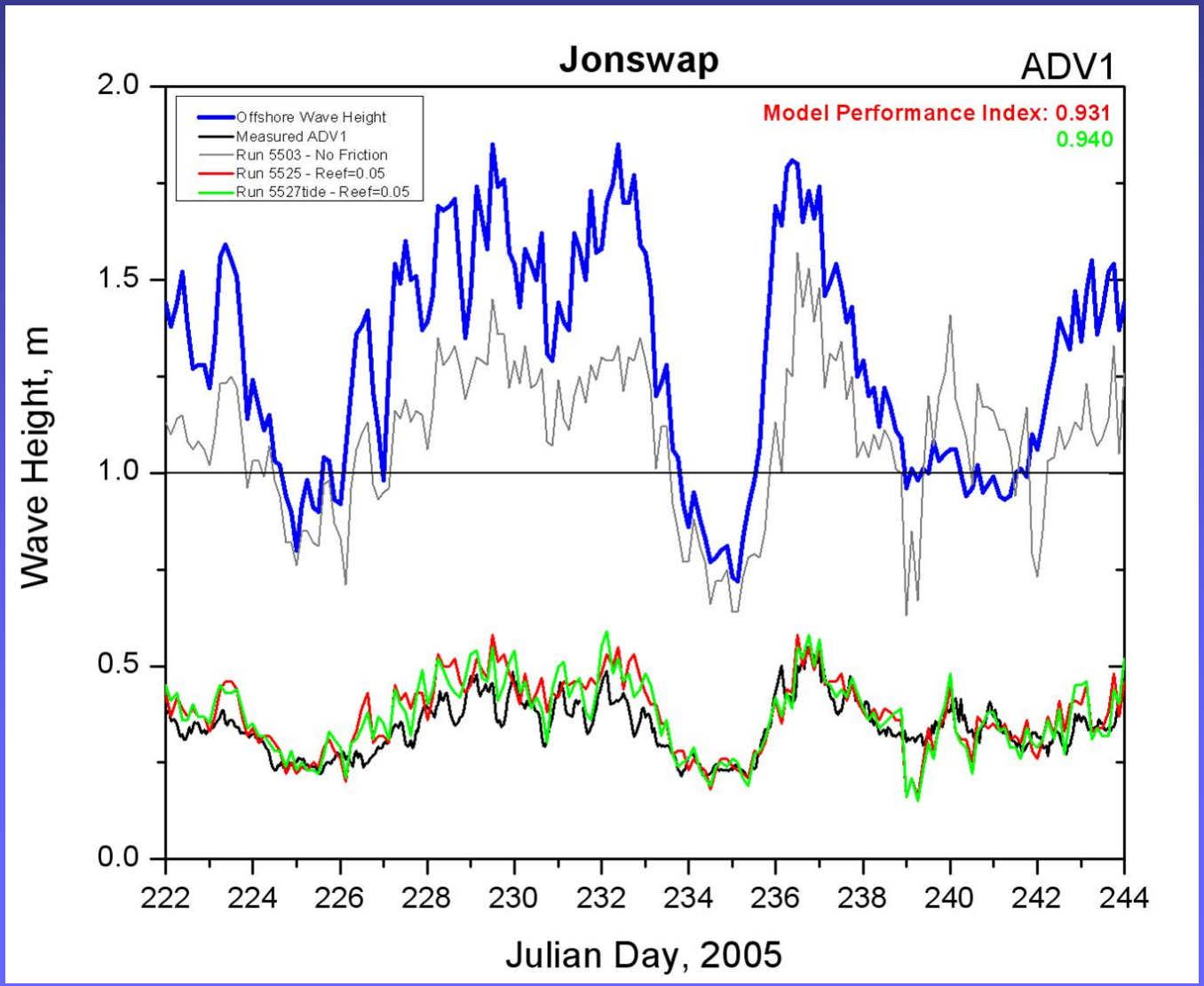



# *Model Performance Index: Manning's Friction*

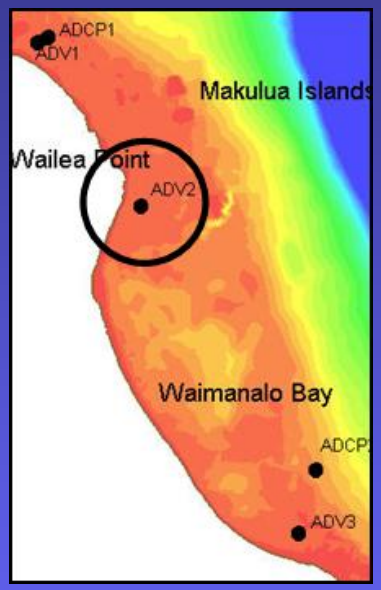
| | n 0.20 | n 0.20 with tide |
|---|---|---|
| ADV1 | 0.945 | 0.948 |
| ADV2 | 0.922 | 0.926 |
| ADV3 | 0.953 | 0.960 |

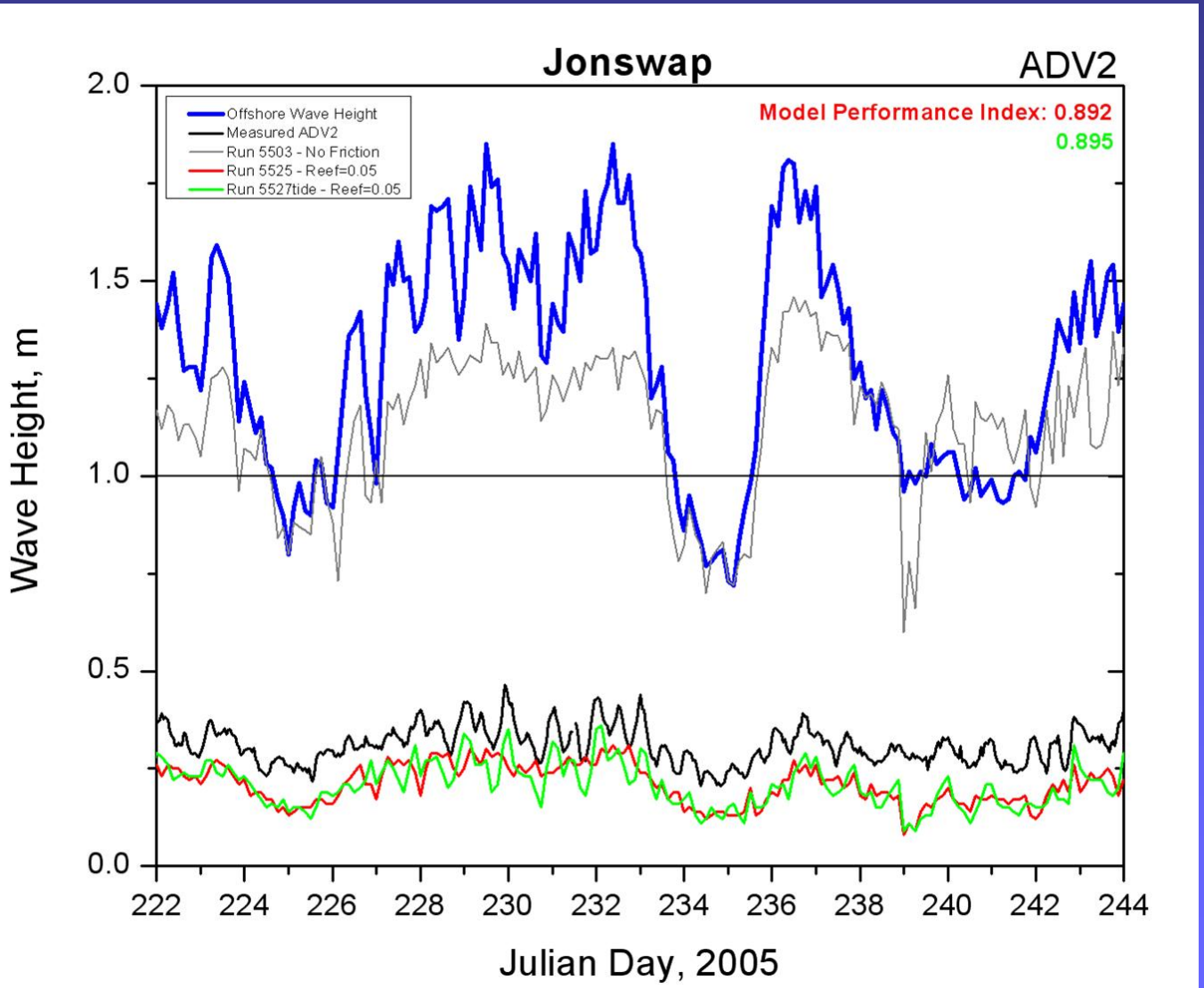
# Model Validation: JONSWAP Friction



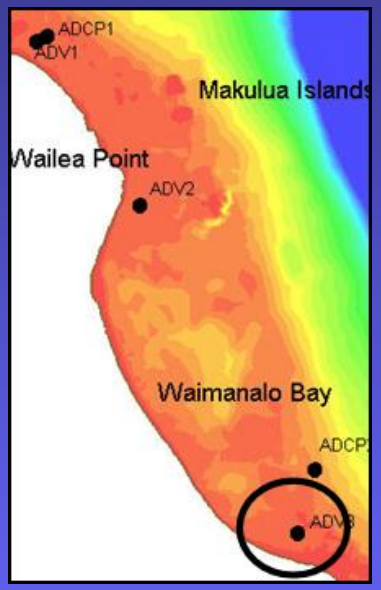



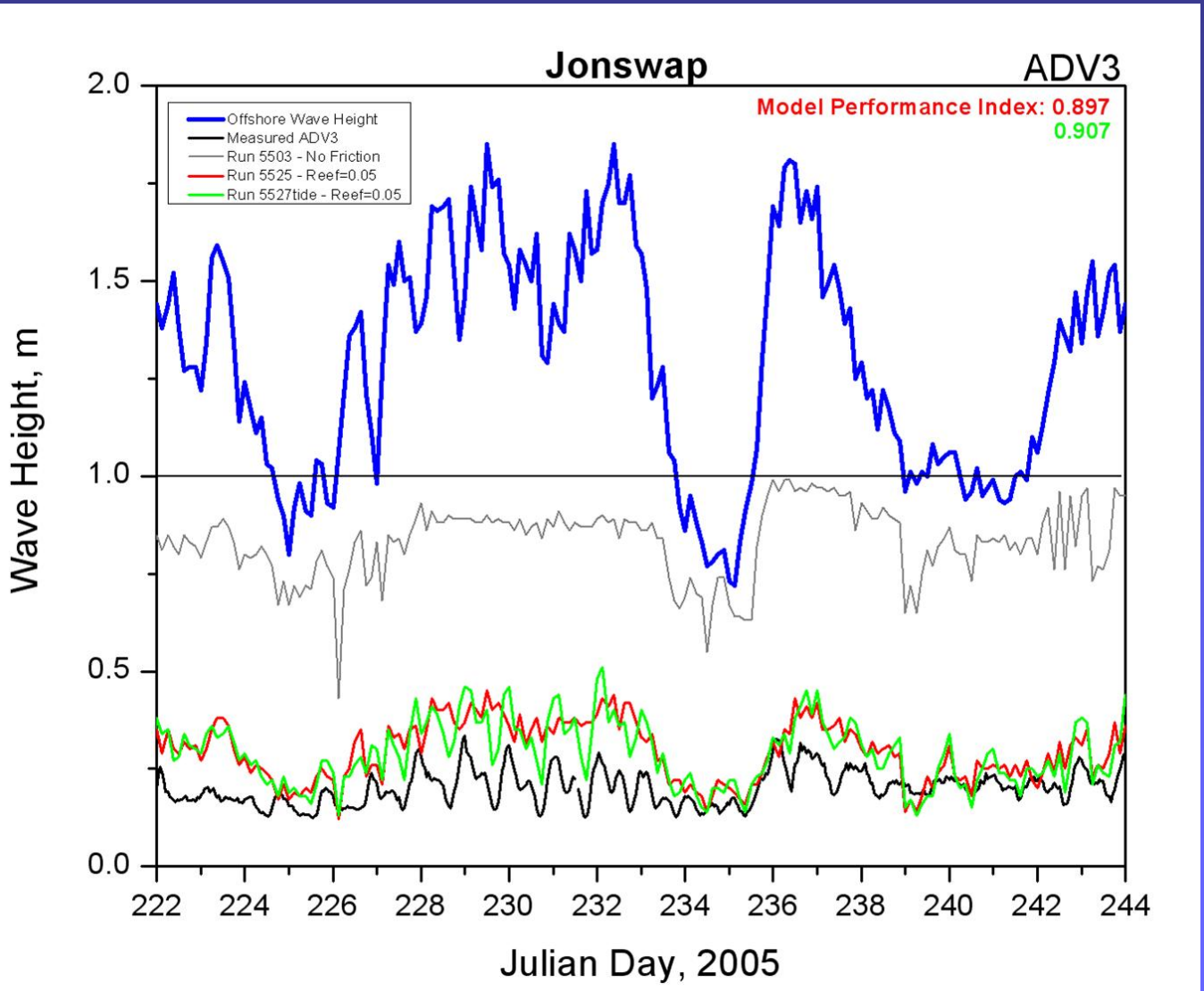
# Model Validation: JONSWAP Friction



# Model Validation: JONSWAP Friction

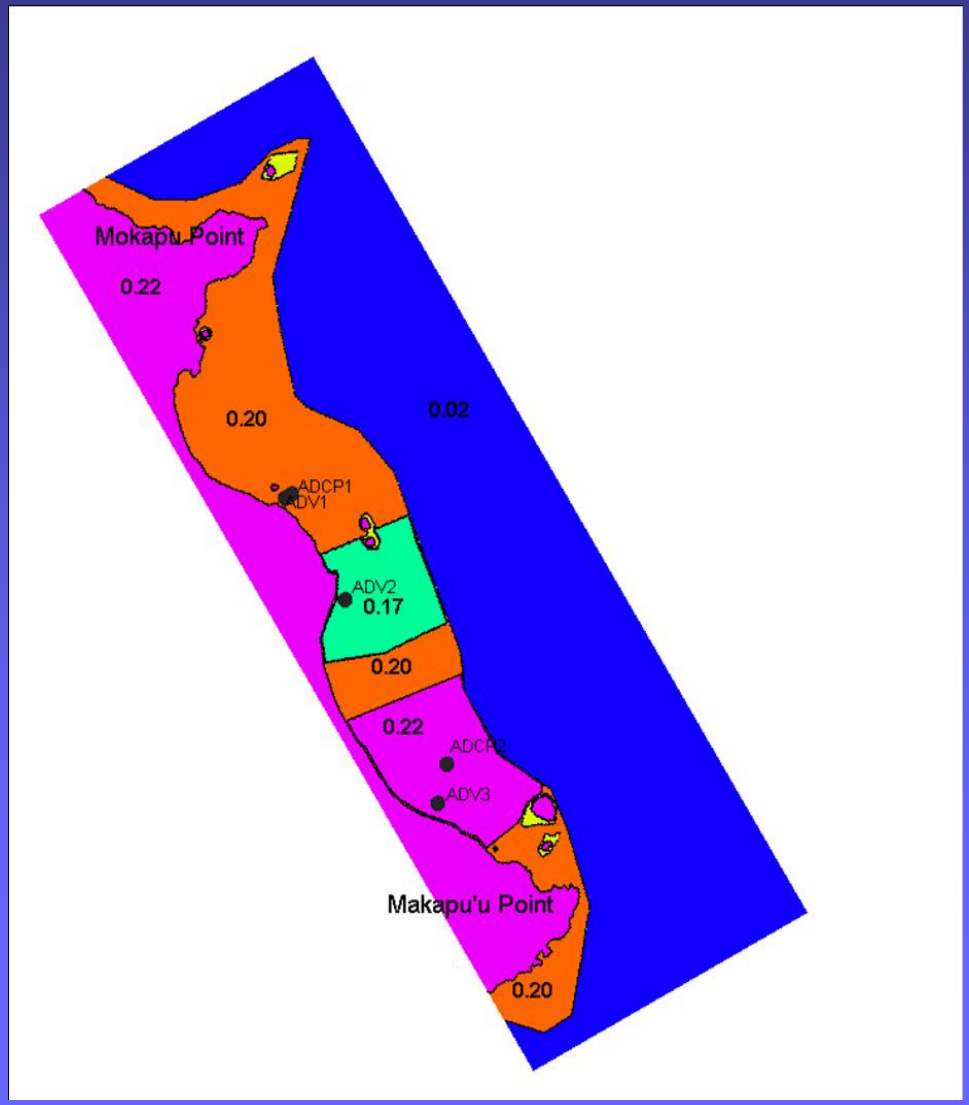


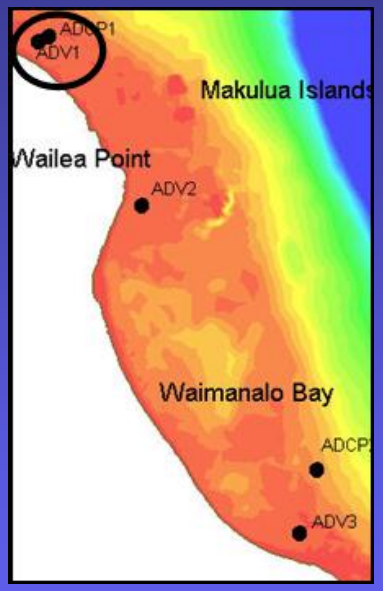
# *Model Performance Index: JONSWAP Friction*

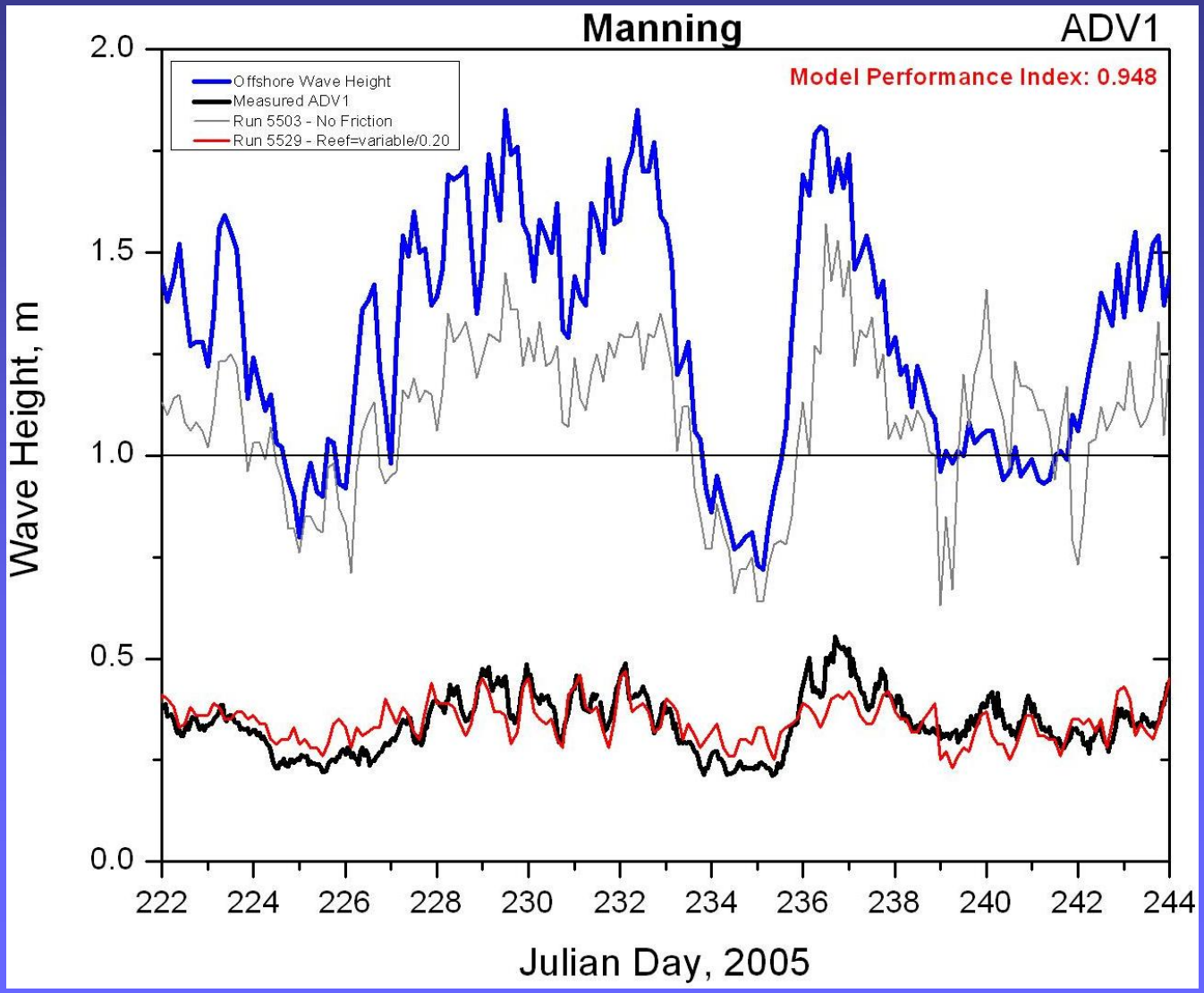
| | $c_f$ 0.05 | $c_f$ 0.05 with tide |
|---|---|---|
| ADV1 | 0.931 | 0.940 |
| ADV2 | 0.892 | 0.895 |
| ADV3 | 0.897 | 0.907 |

# Model Validation: Manning's Variable Friction Coefficients

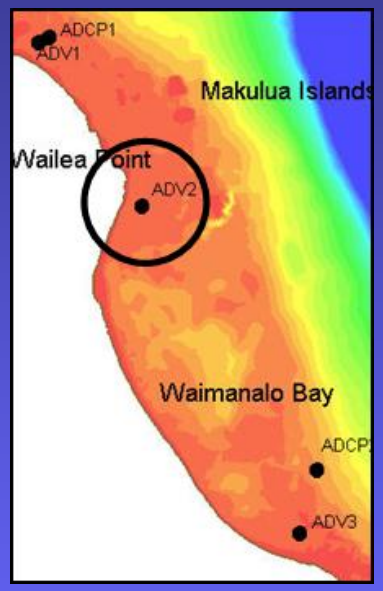


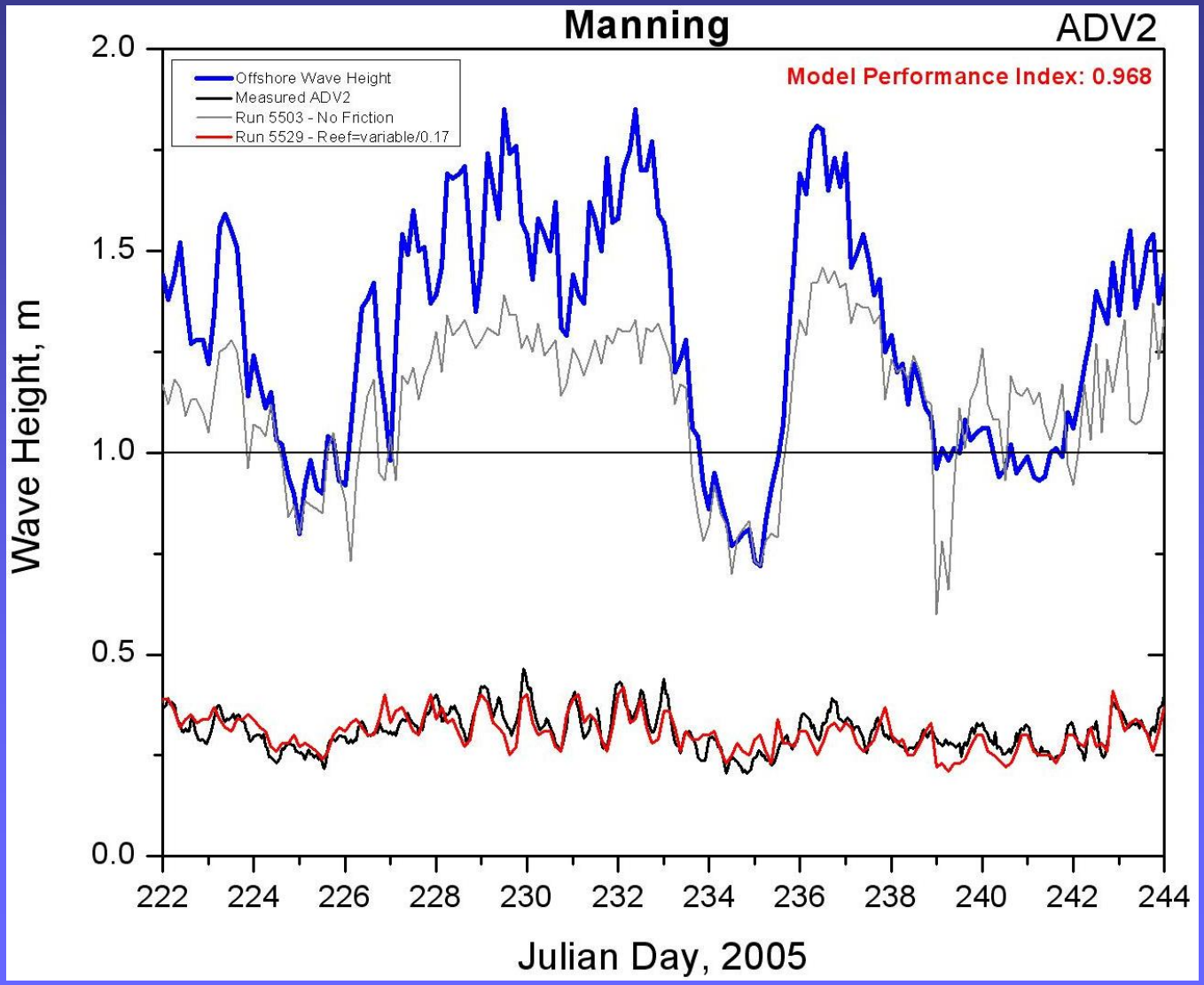
# Model Validation: Manning's (Variable)



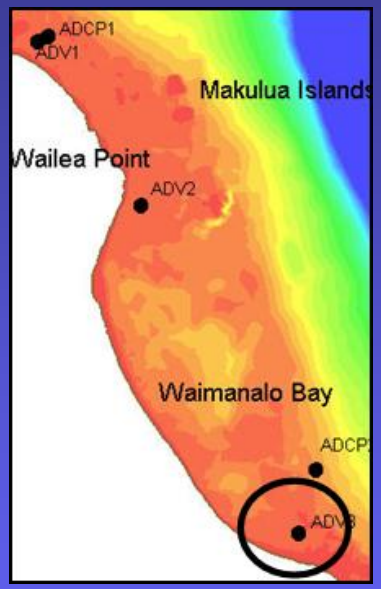



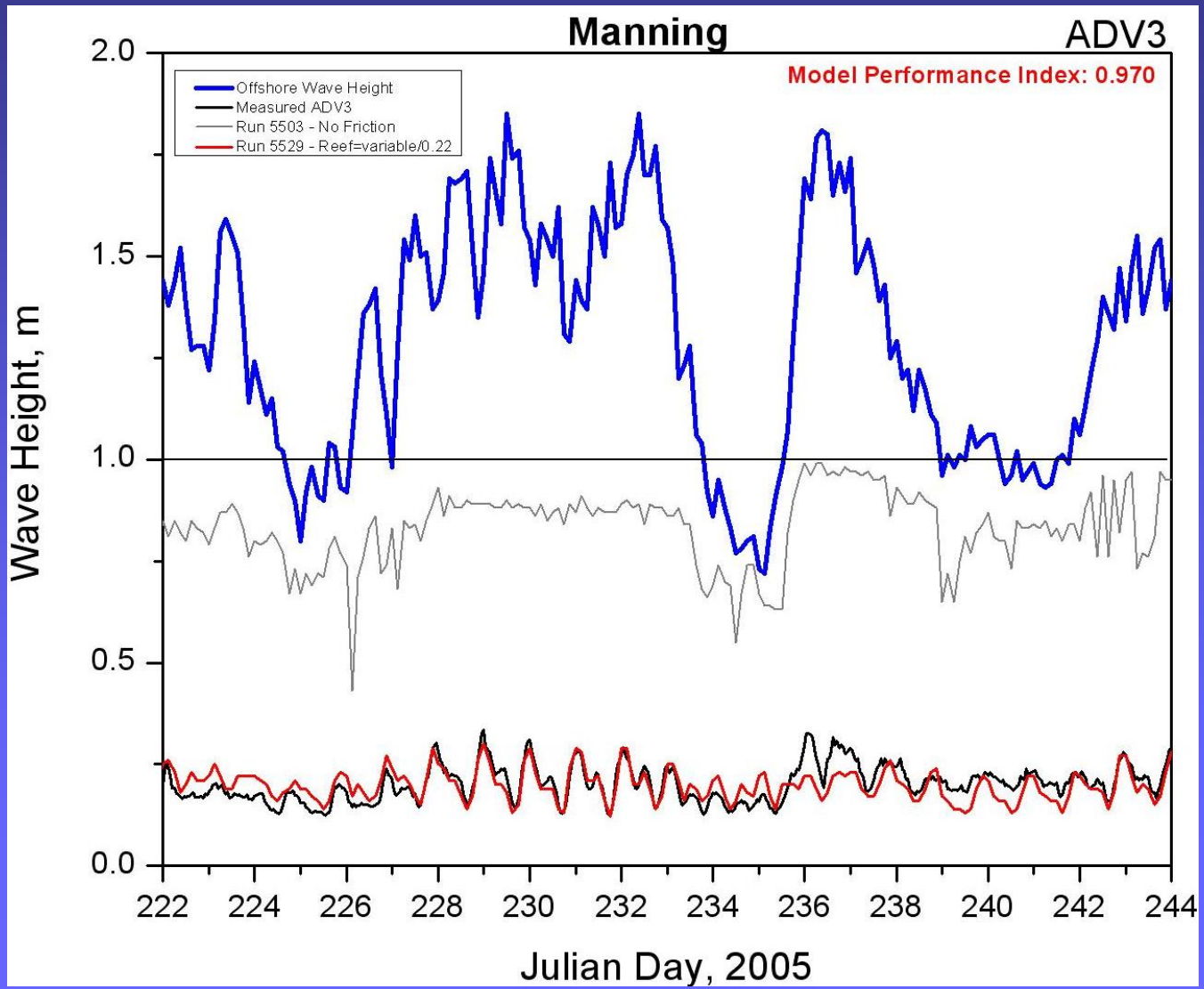
# Model Validation: Manning's (Variable)



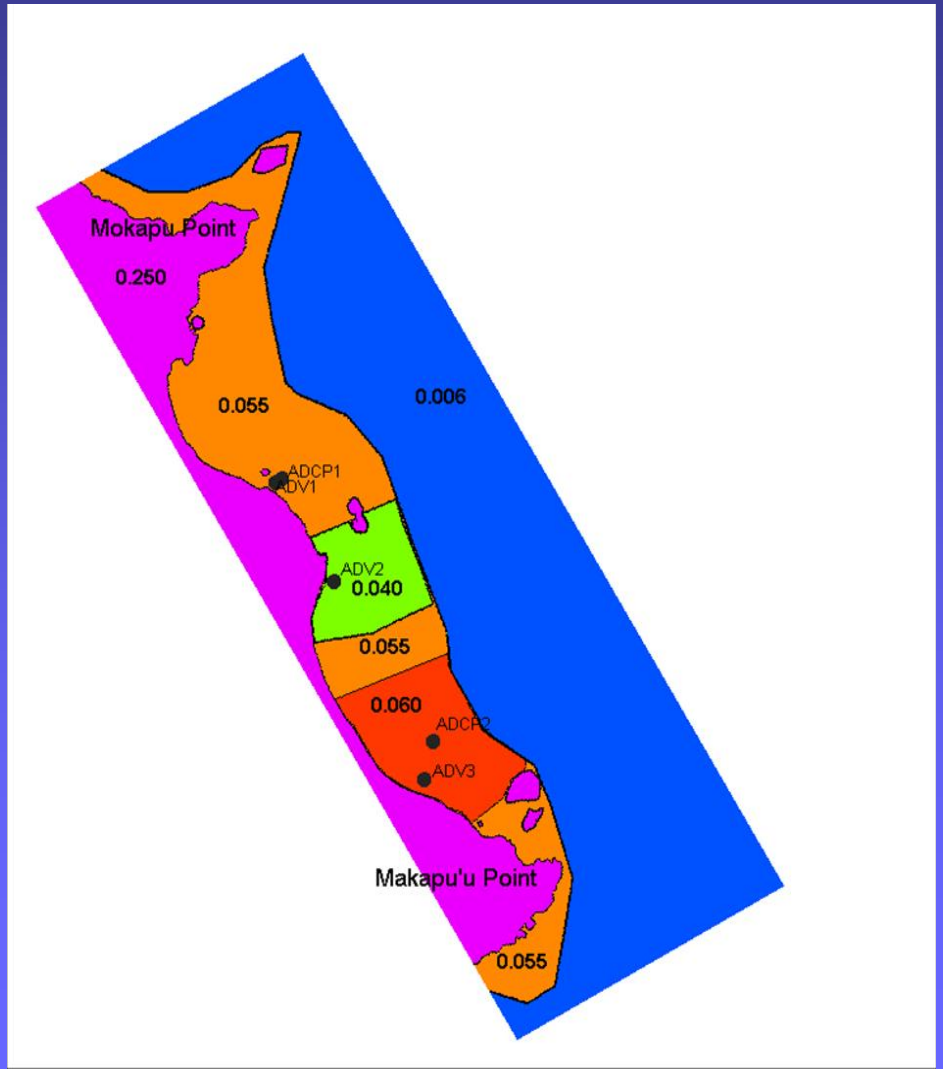



# Model Validation: Manning's (Variable)

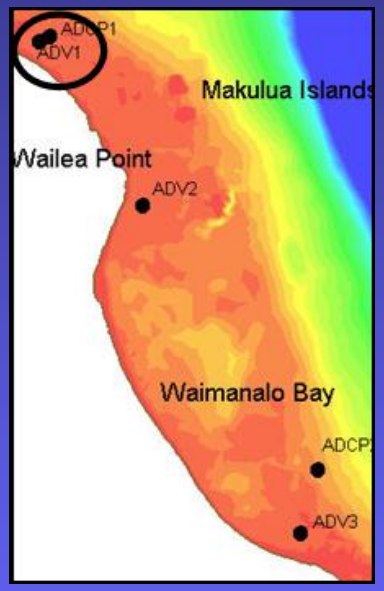


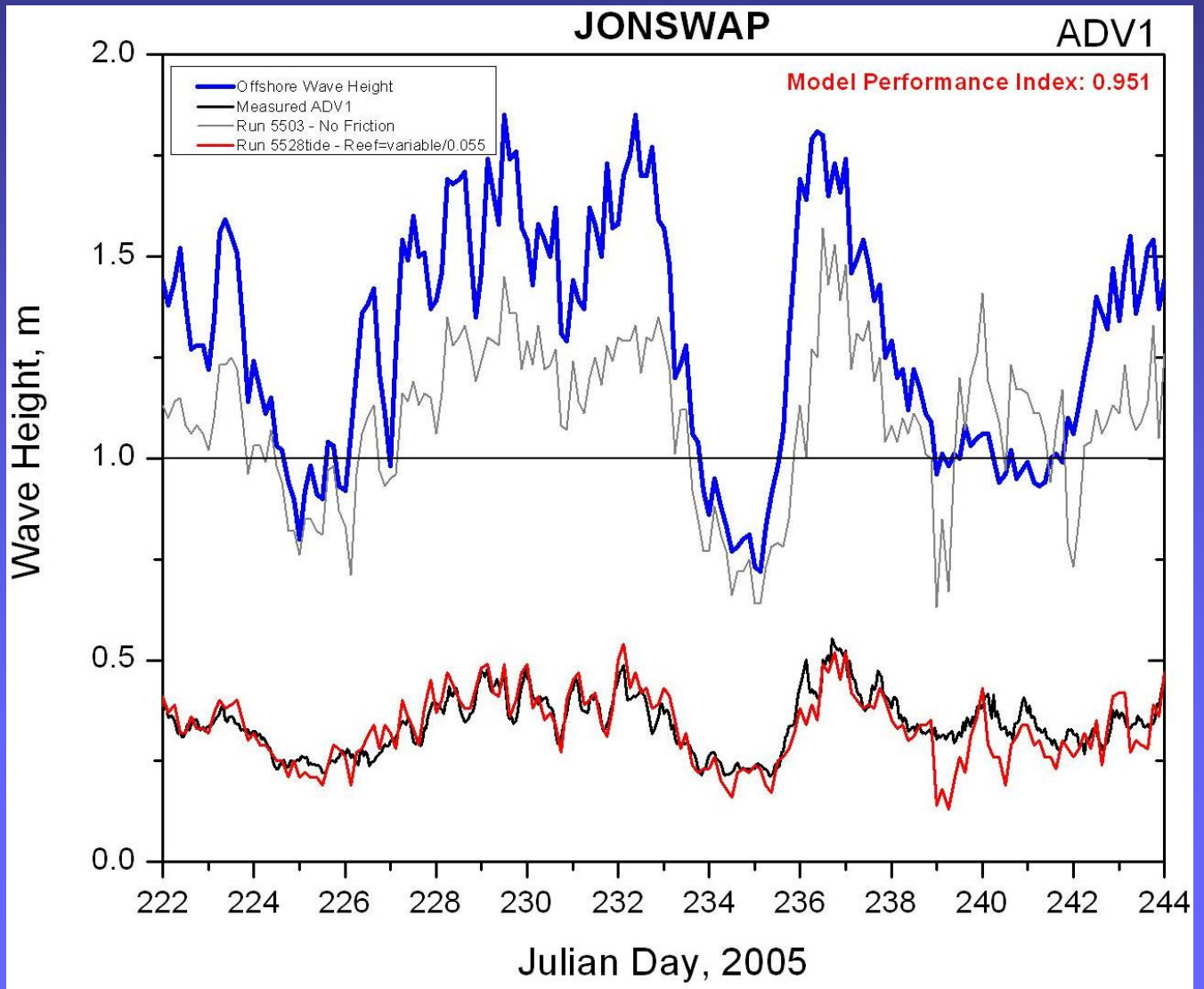



# Model Validation: JONSWAP Variable Friction Coefficients

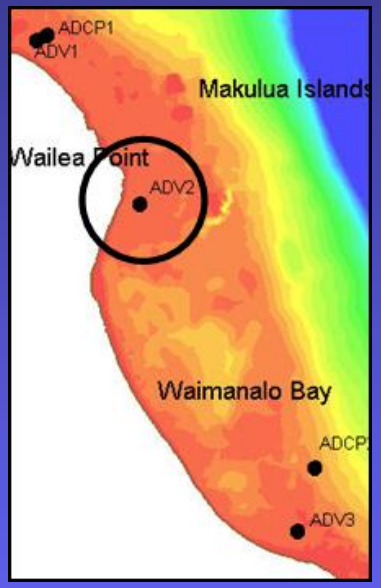


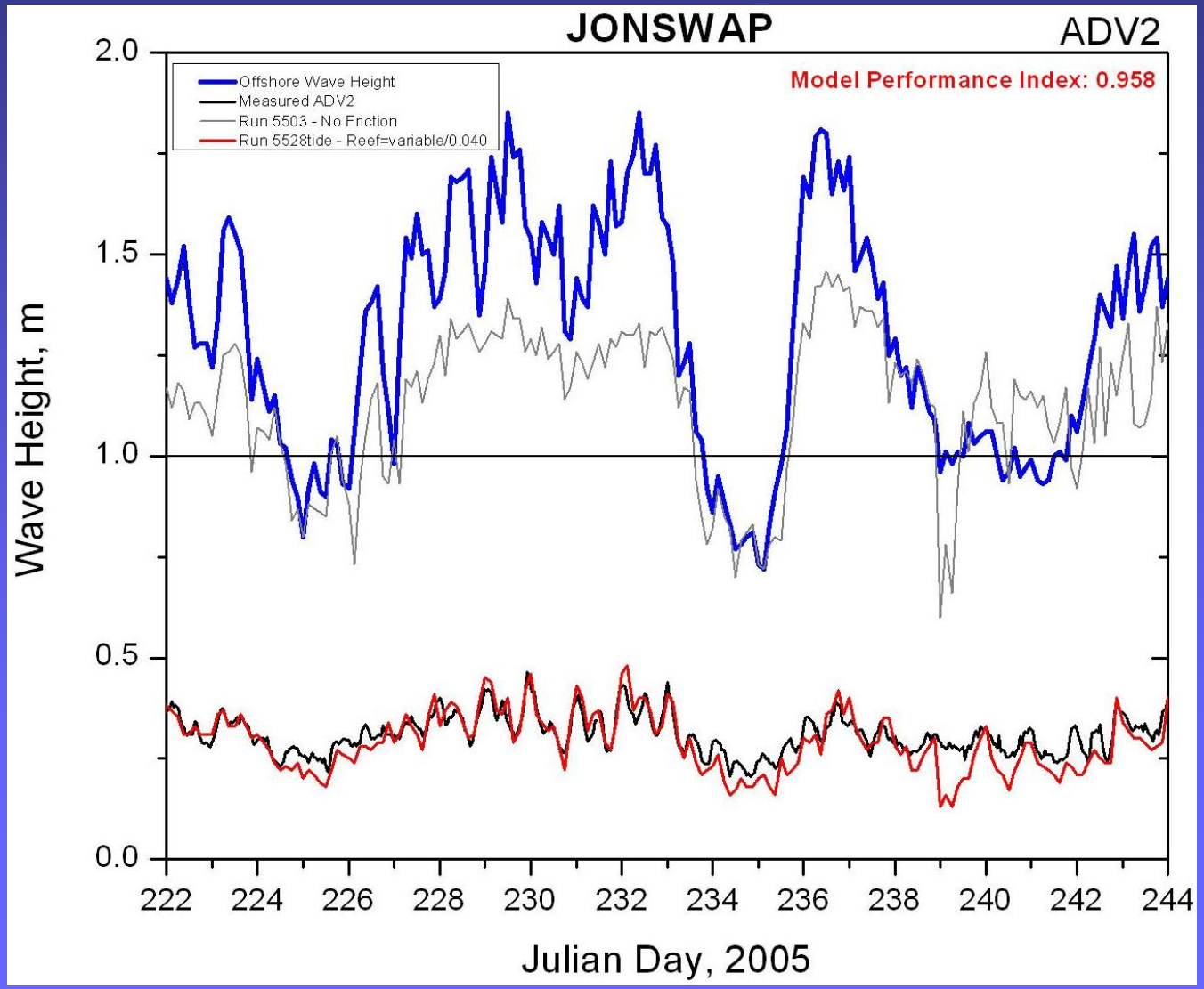
# Model Validation: JONSWAP (Variable)



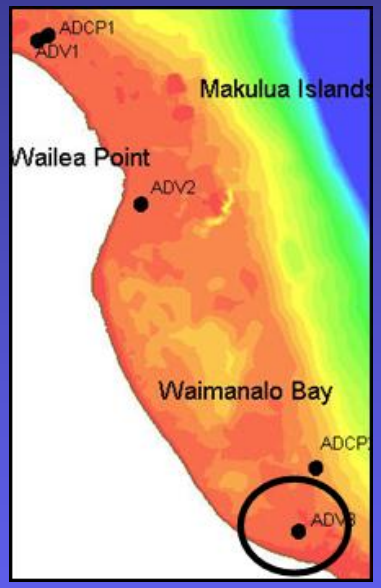



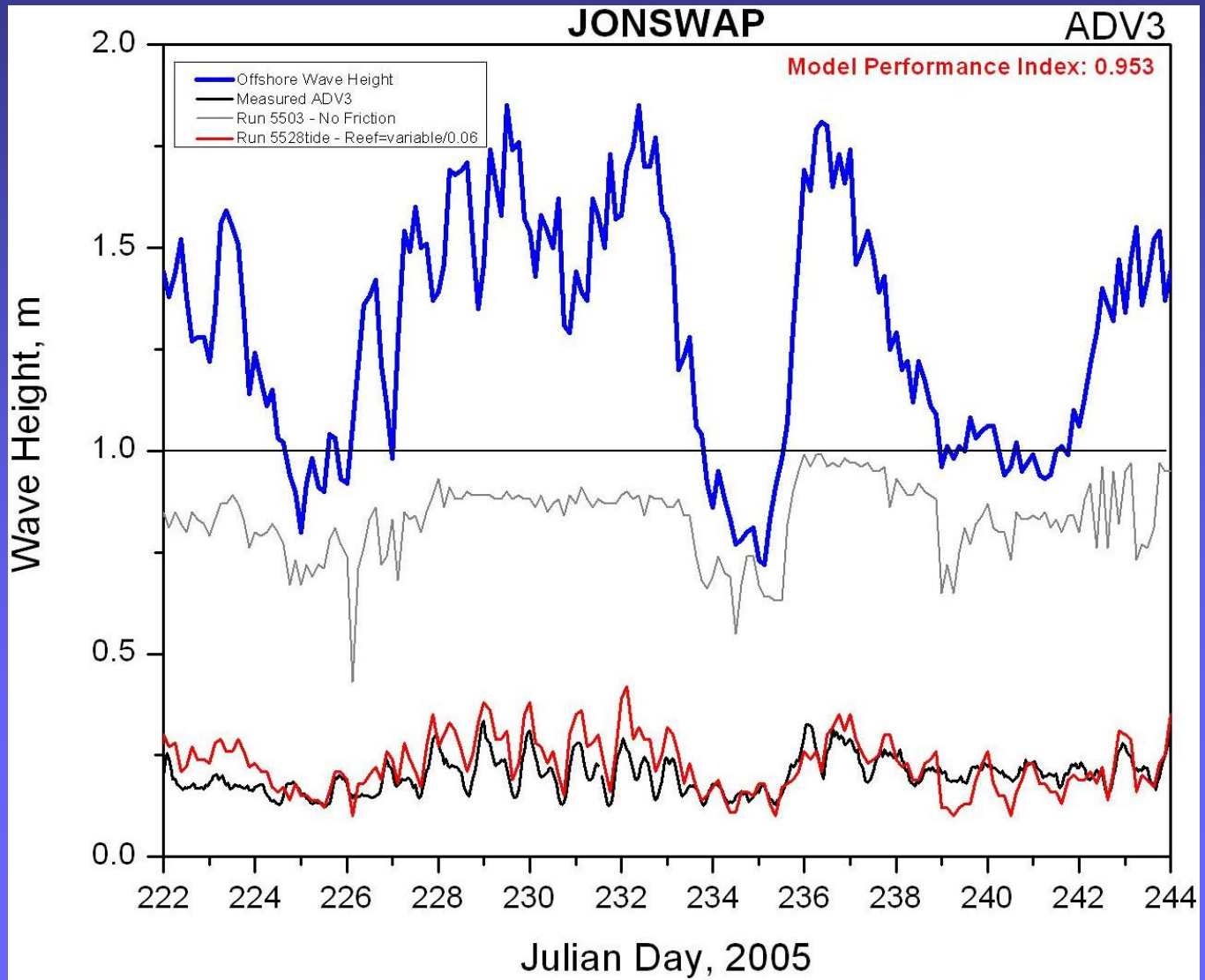
# Model Validation: JONSWAP (Variable)



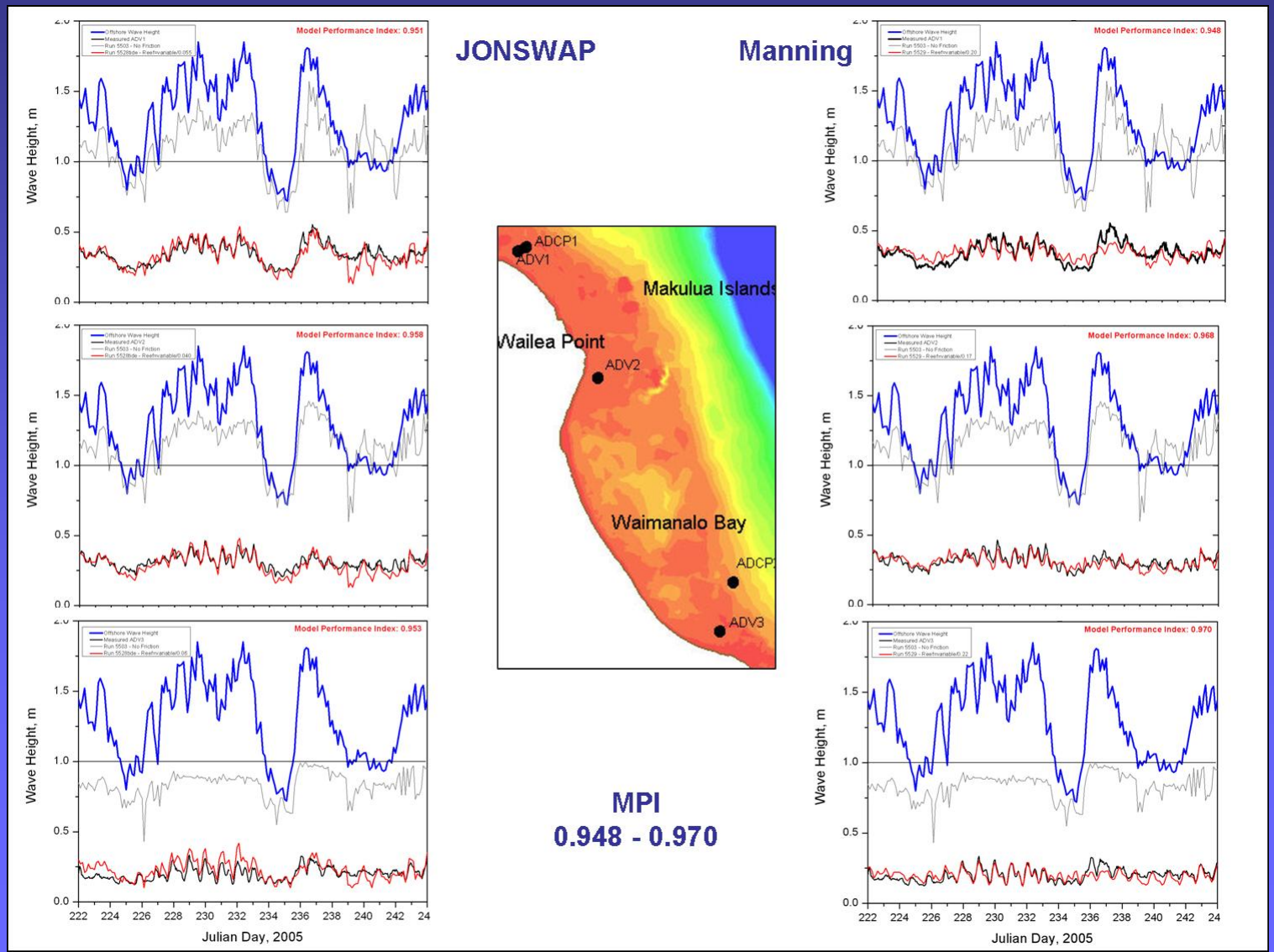



# Model Validation: JONSWAP (Variable)



# Field Data Collection – Comparison



# Summary

- Bottom friction implemented in STWAVE
- Applied range of JONSWAP and Manning friction coefficients
- Validated to 2005 field data
- Included tidal fluctuation
- STWAVE with bottom friction captures the large reduction in wave height from the offshore to the nearshore
- An attempt at simulating the variability in reef condition was made by varying the friction coefficient in patches
- Model Performance Index values of ~0.95 indicate the model is capturing wave transformation/dissipation over the reef