Numerical modeling of ocean waves, Tides and Water level elevation

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Wave Growth

- Basic concepts
- Manual forecasting techniques
- Changing Wind
- Swell Forecasting

Wave Heights, Wind and Fetch

- Energy from the wind is transferred to waves
- Waves lose energy
  - White-capping
  - Interaction with sea floor etc
- The greater the wind speed, the higher the waves
- The longer the duration of the wind, the higher the waves
- The greater the distance over which the wind blows (the FETCH) the higher the waves.

Wave height depends on a balance between

Energy IN

and

Energy OUT

Wind-Wave Growth

- Growth usually explained by shear flow instability
  - Airflow sucks at crests and pushes on troughs
- Rate of growth is exponential as it depends on the existing sea state and wave age
- Empirical formulae have been derived from large data set
  - Curves developed for manual forecasting

Characteristic Height and Period of Deep Water Waves

- Empirical Studies show:

t = wind duration
X=fetch
u = wind speed
g = 9.8m/s^2

$$H_c \approx \frac{u^2}{g} h_t\left(\frac{gt}{u}\right) \approx \frac{u^2}{g} h_x\left(\frac{gX}{u^2}\right)$$

Duration limited | Fetch limited

$$T_c \approx \frac{u}{g} p_t\left(\frac{gt}{u}\right) \approx \frac{u}{g} p_x\left(\frac{gX}{u^2}\right)$$

h_t, h_x, p_t and p_x are dimensionless functions.

They all depends on the parameter (gt/u or gX/u^2)

Manual Wave Forecasting Diagram

(Gröen and Dorrestein, 1976

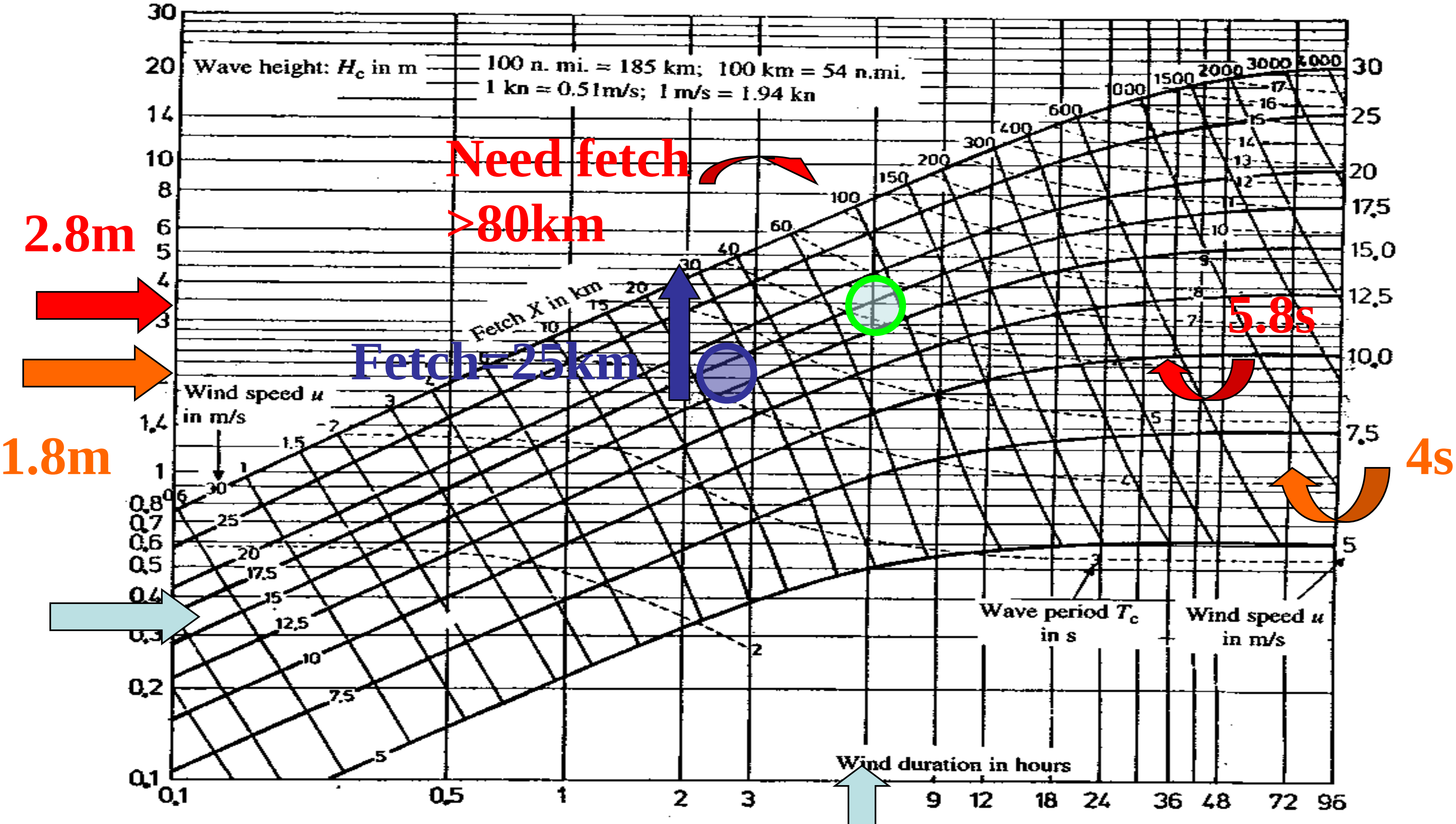


Figure 4.1 — Manual wave forecasting diagram (*from Gröen and Dorrestein, 1976*)

Angular Spreading of Swell from a Storm

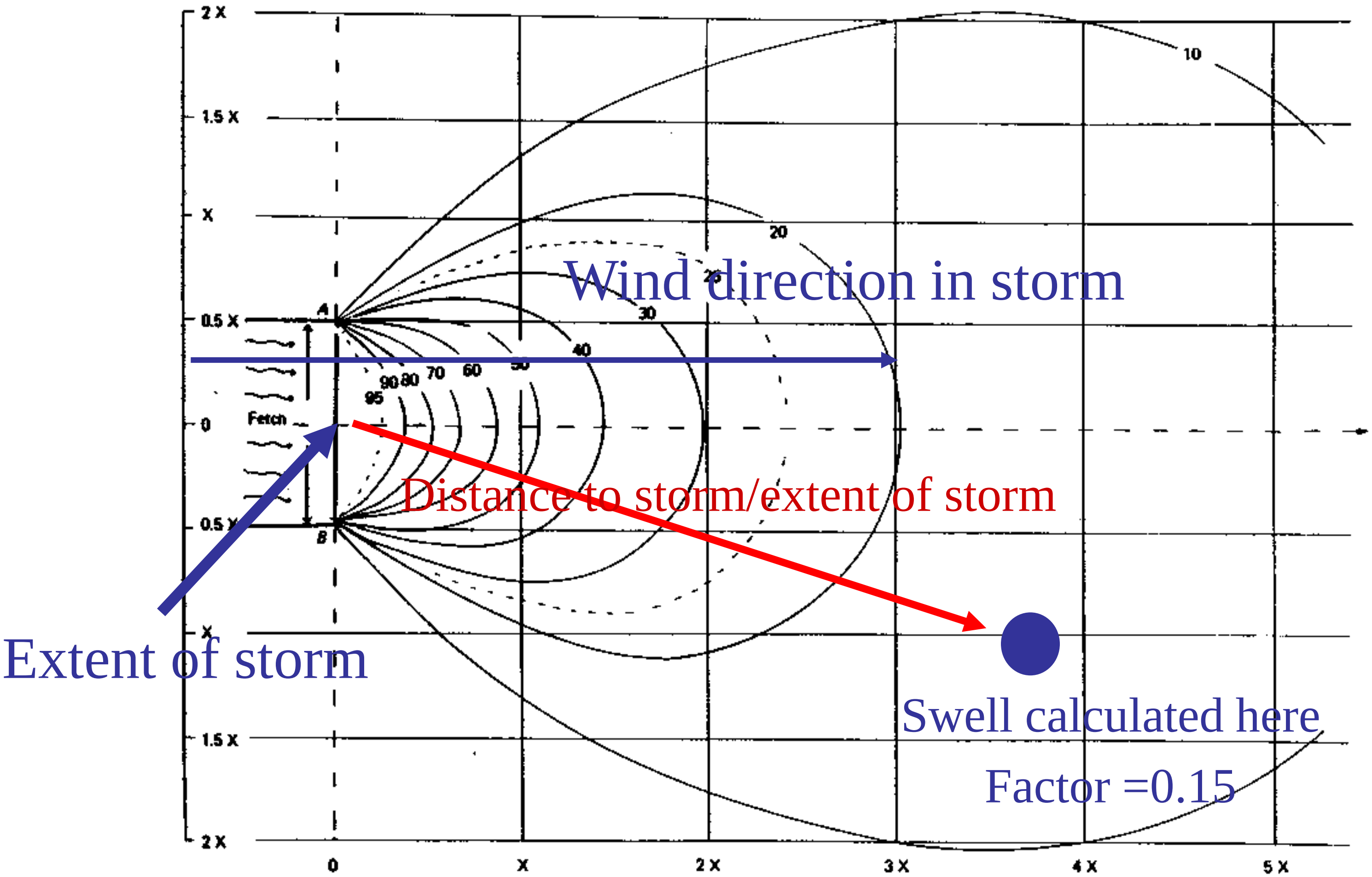
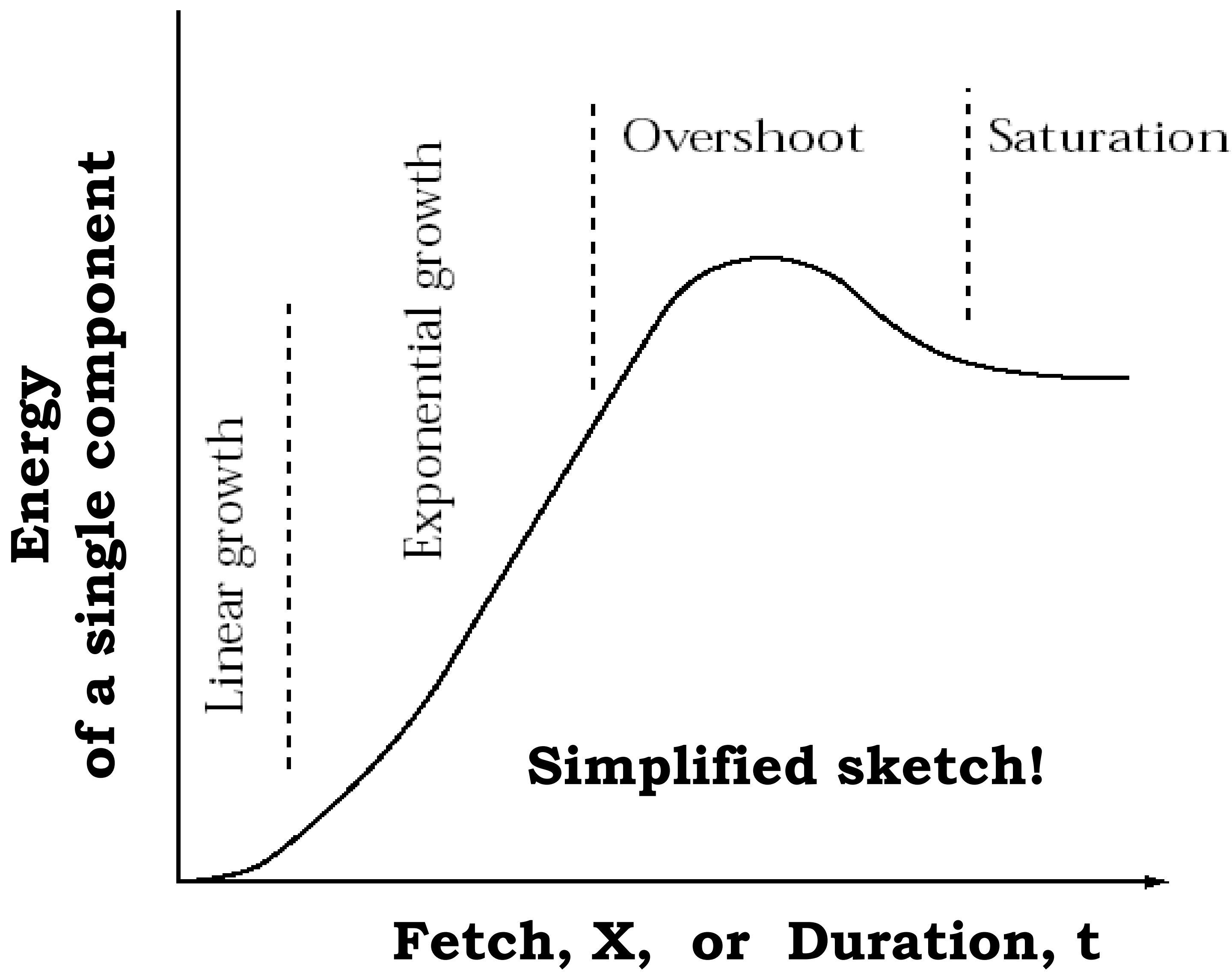


Figure 3.3 — Angular spreading factors (as percentages) for swell energy

% spreading factor for energy

Take square root for swell height

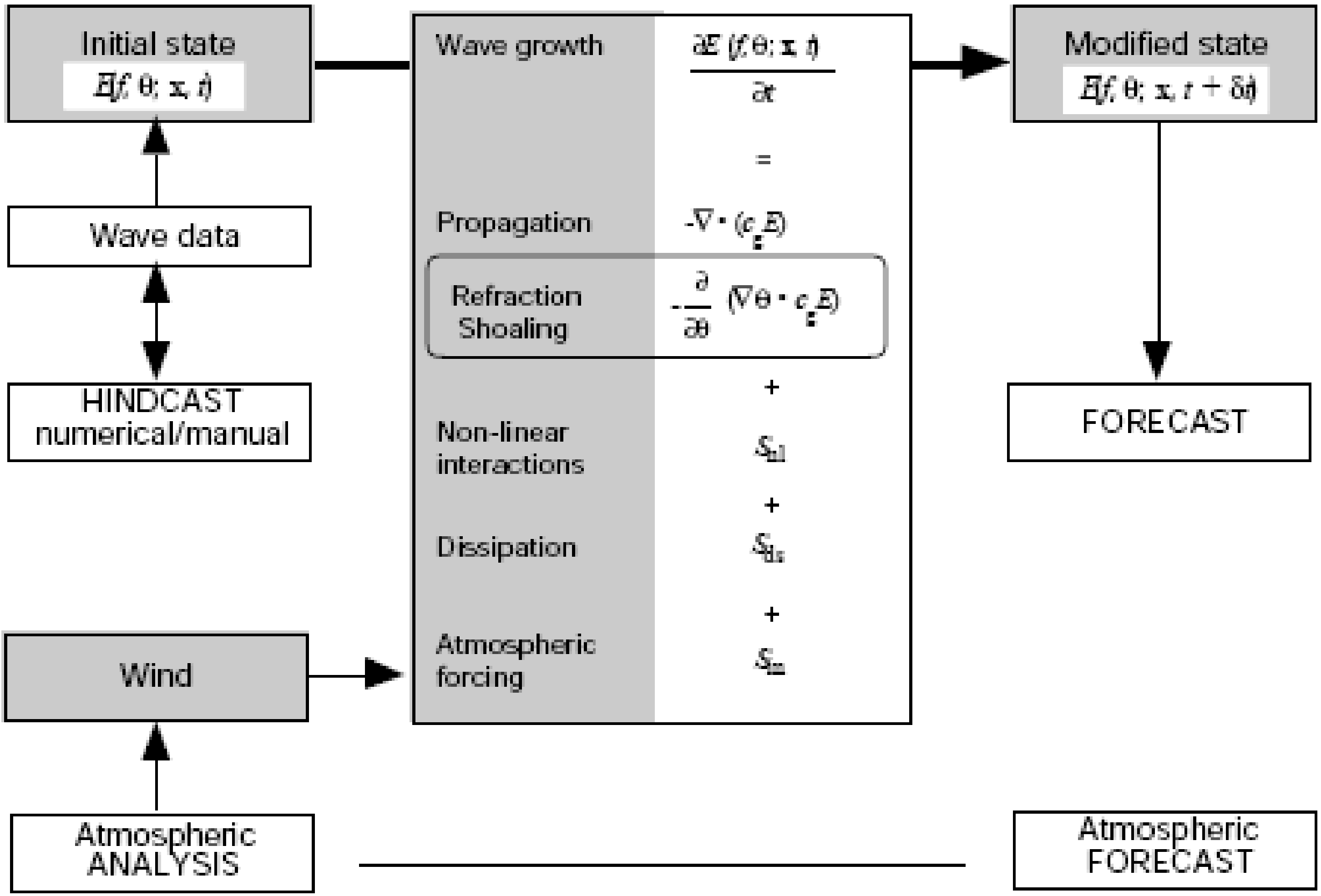
Eg: Swell = √0.15 * Hc


Energy
of a single component
Linear growth
Exponential growth
Overshoot
Saturation
Simplified sketch!
Fetch, X, or Duration, t

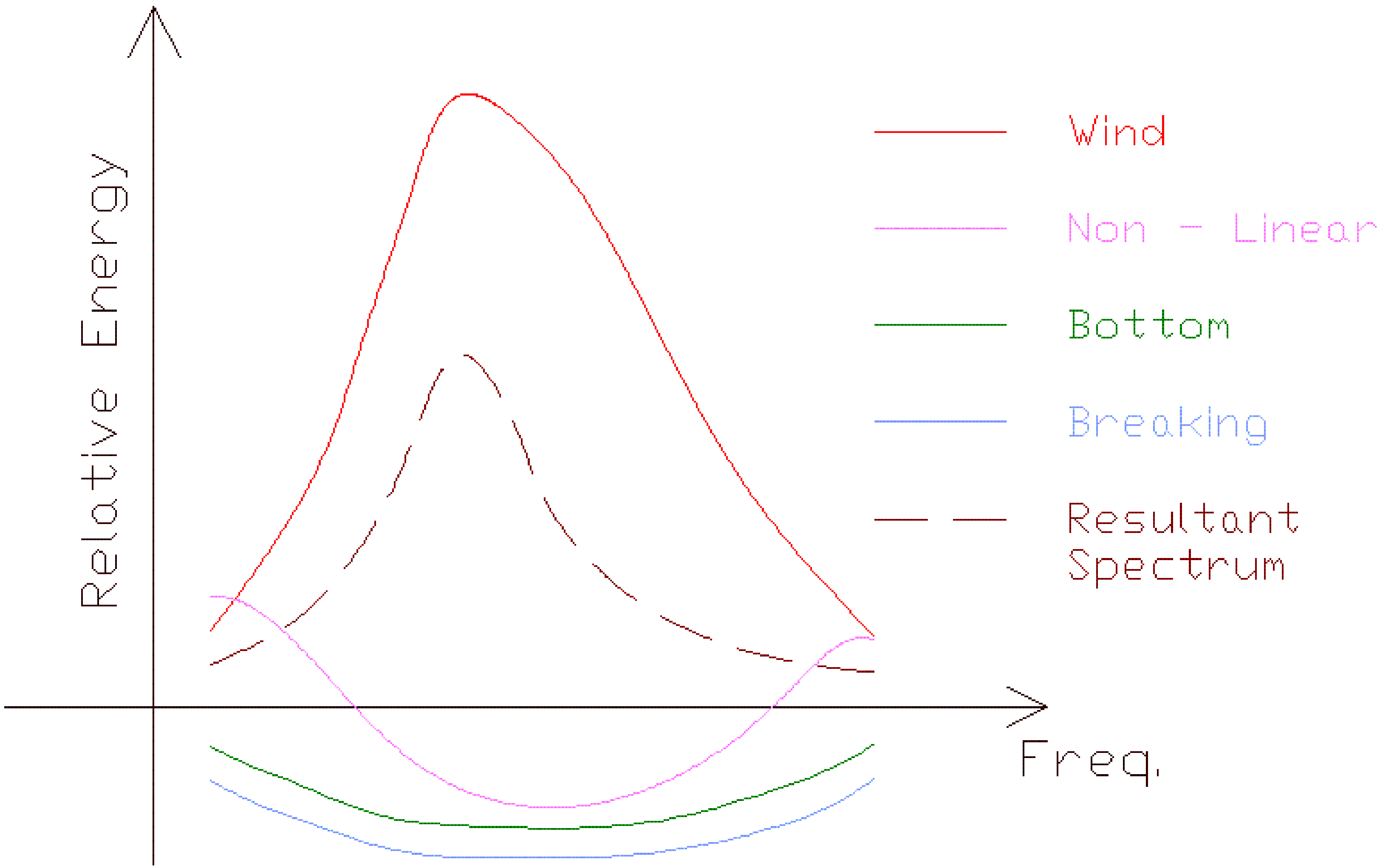
Numerical Wave Modeling

3G wave models

$$\frac{\partial E}{\partial t} + \nabla \bullet \left(c_g E \right) = S = S_{in} + S_{nl} + S_{ds}$$



Numerical Wave Modeling



State-of-art wave models:

- WAM
- WAVEWATCH - III
- SWAN
- MIKE-21

WAM Model (operational at ECMWF)

The original WAM model software that has been developed over a period of seven years (1985-1992) is fairly general (WAMDIG 1988, Komen *et al.* 1994). Spectral resolution and spatial resolution are flexible and the model can be run globally or regionally with open and closed boundaries. Open boundaries are important in case one wishes to use results from a coarse resolution run as boundary conditions for a fine mesh, limited area run. Options such as shallow water, depth refraction or current refraction may be chosen.

WAVEWATCH III (Tolman 1997, 1999a) is a third generation wave model developed at NOAA/NCEP in the spirit of the WAM model. It is available at NOAA

WAVEWATCH III solves the spectral action density balance equation for wavenumber-direction spectra. The implicit assumption of this equation is that properties of medium (water depth and current) as well as the wave field itself vary on time and space scales that are much larger than the variation scales of a single wave. A further constraint is that the parameterizations of physical processes included in the model do not address conditions where the waves are strongly depth-limited. These two basic assumptions imply that the model can generally by applied on spatial scales (grid increments) larger than 1 to 10 km, and outside the surf zone.

SWAN (simulating waves near shore) is a third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters. SWAN is supported by Office of Naval Research (USA). It can be downloaded from the DELFT university

SWAN accounts for the following physics:

Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth.
Wave generation by wind.
Three- and four-wave interactions.
White-capping, bottom friction and depth-induced breaking.
Wave-induced set-up.
Propagation from laboratory up to global scales.
Transmission through and reflection (specular and diffuse) against obstacles.
Diffraction.

Wave models specifications

Input quantities

Bathymetry
Surface wind fields (space and time resolution) :

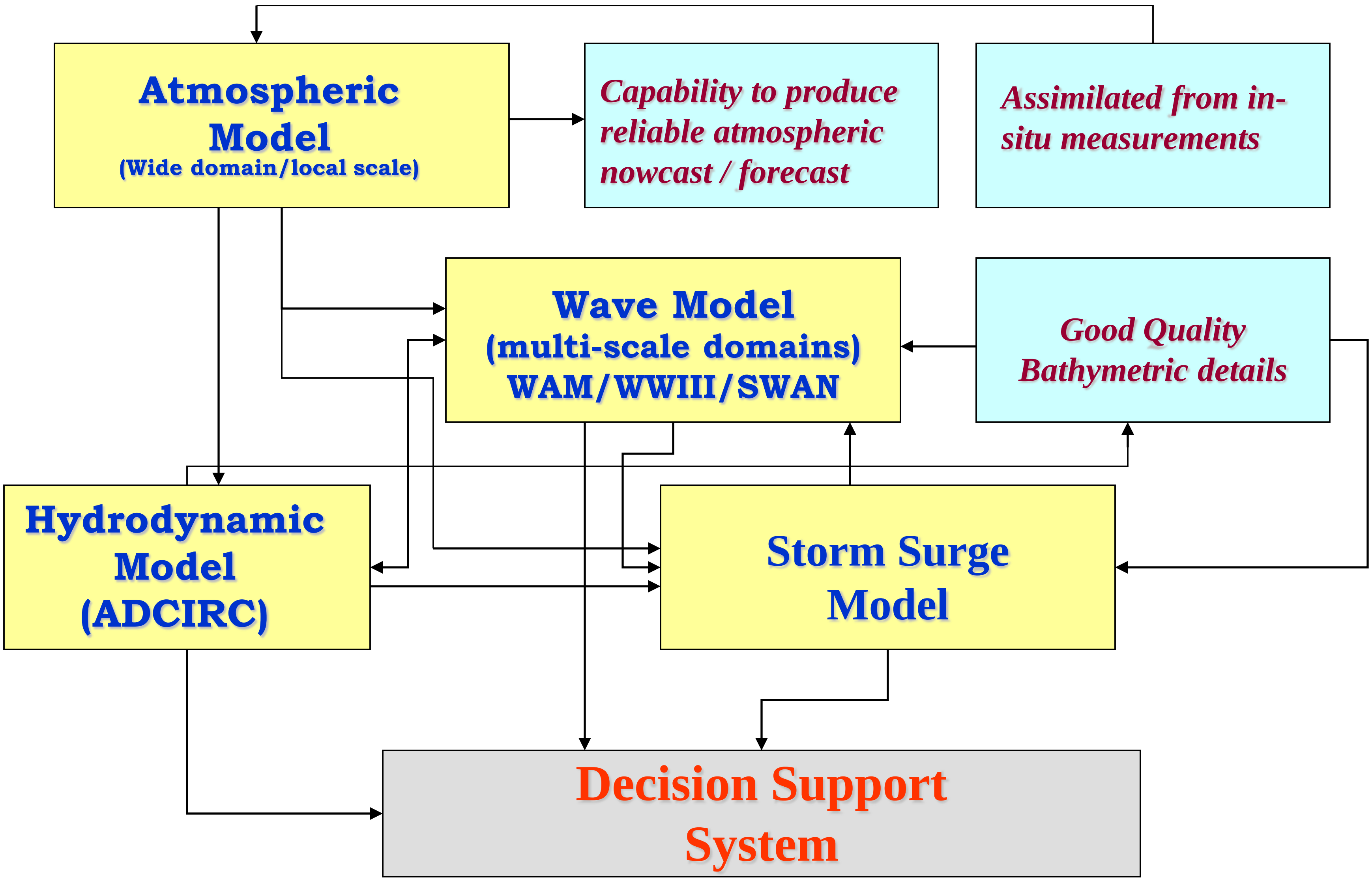
Output quantities

one- and two-dimensional spectra,
significant wave height, mean and peak wave periods,
average wave direction and directional spreading,

Optional outputs
one- and two-dimensional spectral source terms,
root-mean-square of the orbital near-bottom motion,
dissipation, wave-induced force (based on the radiation-stress gradients), set-up, diffraction

Components in a forecasting system

The various components involved in a wave-current-tide-surge forecasting system should essentially integrate the following numerical models:



Thank You