Ocean Waves

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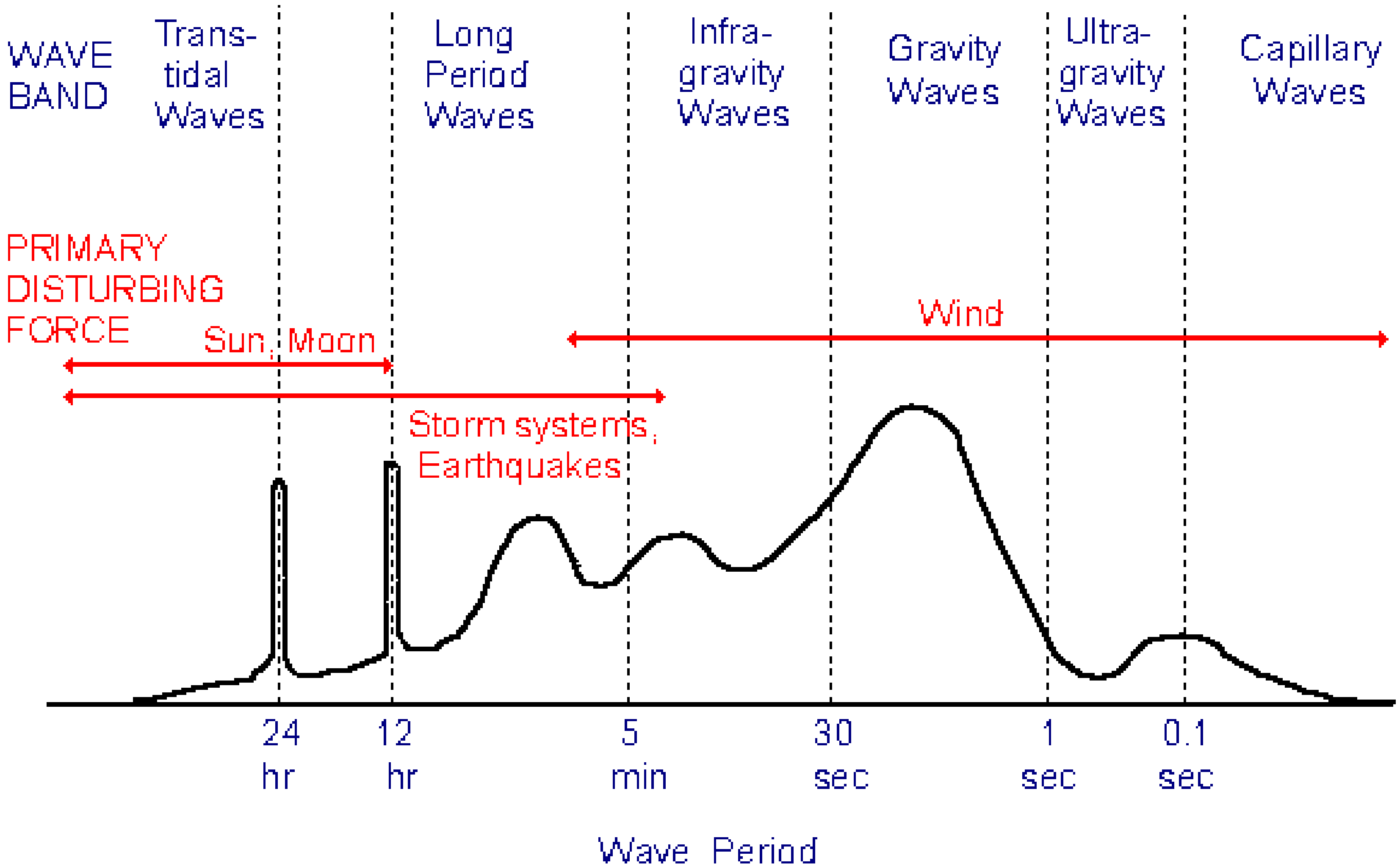
Outline of the Presentation

- Ocean Waves - basics
- Characteristics in deep & shallow waters
- Wave Spectrum
- Model Generation
- Model Classes

Basics

QUALITATIVE WAVE POWER SPECTRUM



Basics

WAVES, CLASSIFICATION, TRANSFORMATIONS

BASIC WAVE PARAMETERS

- Wave amplitude or wave height.
- Wave period or wave length.
- Water depth.

CLASSIFICATION OF WAVES ACCORDING TO PERIOD (SHORT, INTERMEDIATE AND LONG WAVES

Wave Classification (Ippen, 1966)		
Range of d/L	Range of kh = 2πd/L	Types of waves
0 to 1/20	0 to π/10	Long waves (shallow-water wave)
1/20 to ½	π/10 to π	Intermediate waves
½ to ∞	π to ∞	Short waves (deepwater waves)

Dispersion relation

$$\omega^2 = gk\tanh(kh)$$

In deep waters: 'h' is large, hence:

tanh(kh) ≈ 1

$$\Rightarrow \quad \omega^2 = gk$$

$$\Rightarrow \quad L = 1.56\ T^2$$

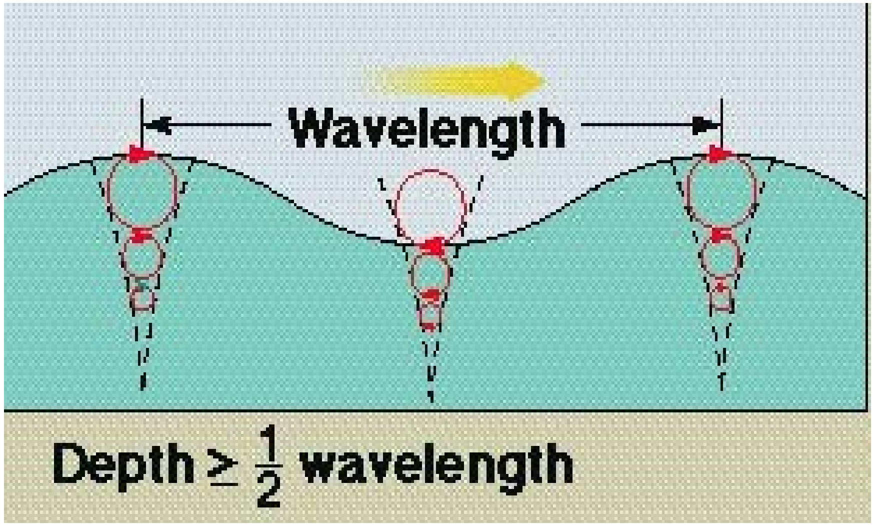
In shallow waters: 'h' is small, hence:

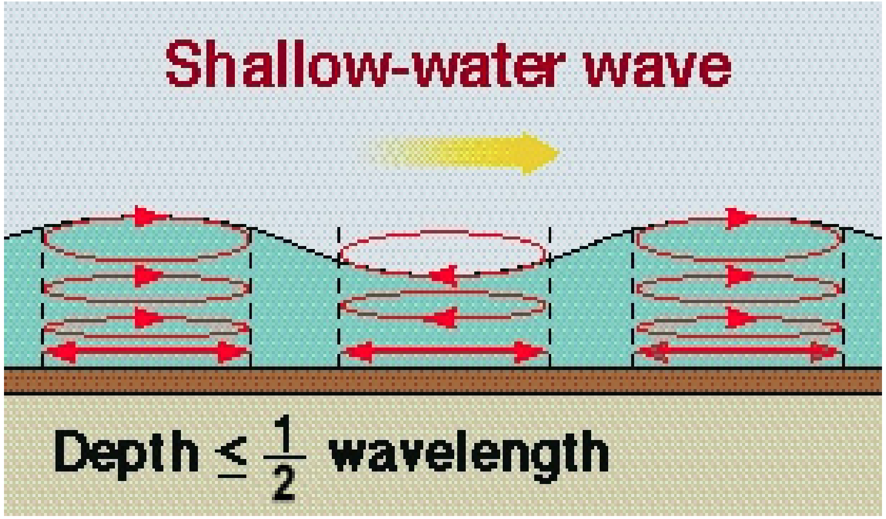
tanh(kh) $\approx$ kh

$$\omega^2 = gk(kh)$$

Speed of long period waves, $C = \sqrt{gh}$

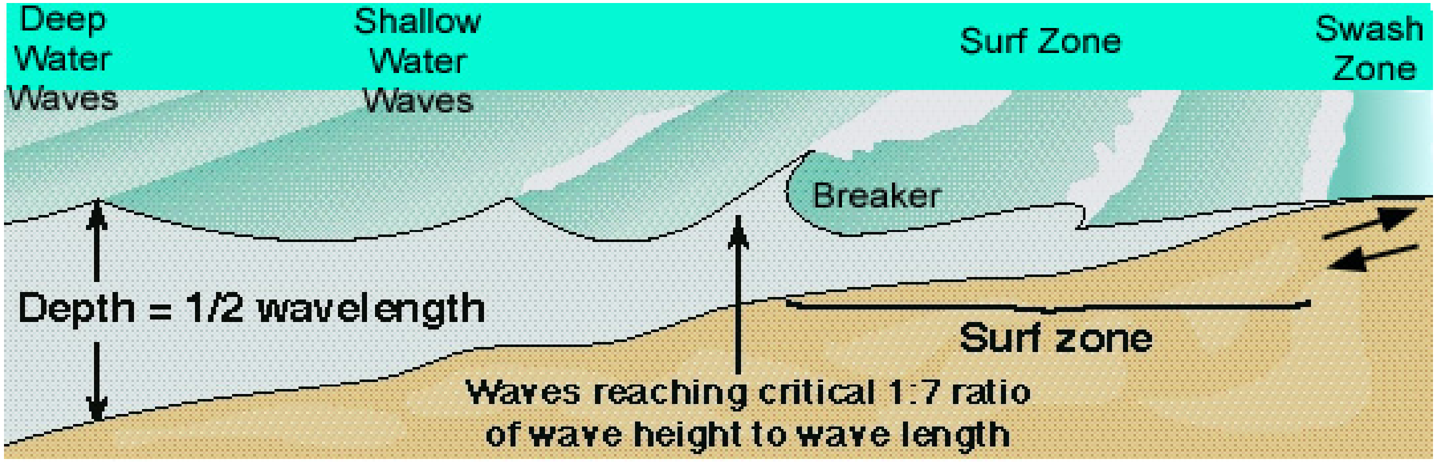
Water Particle Trajectories





Water Particle Trajectories for Long, Short and Intermediate Waves as A Function Depth

WAVE BEHAVIOR IN SHALLOW WATER

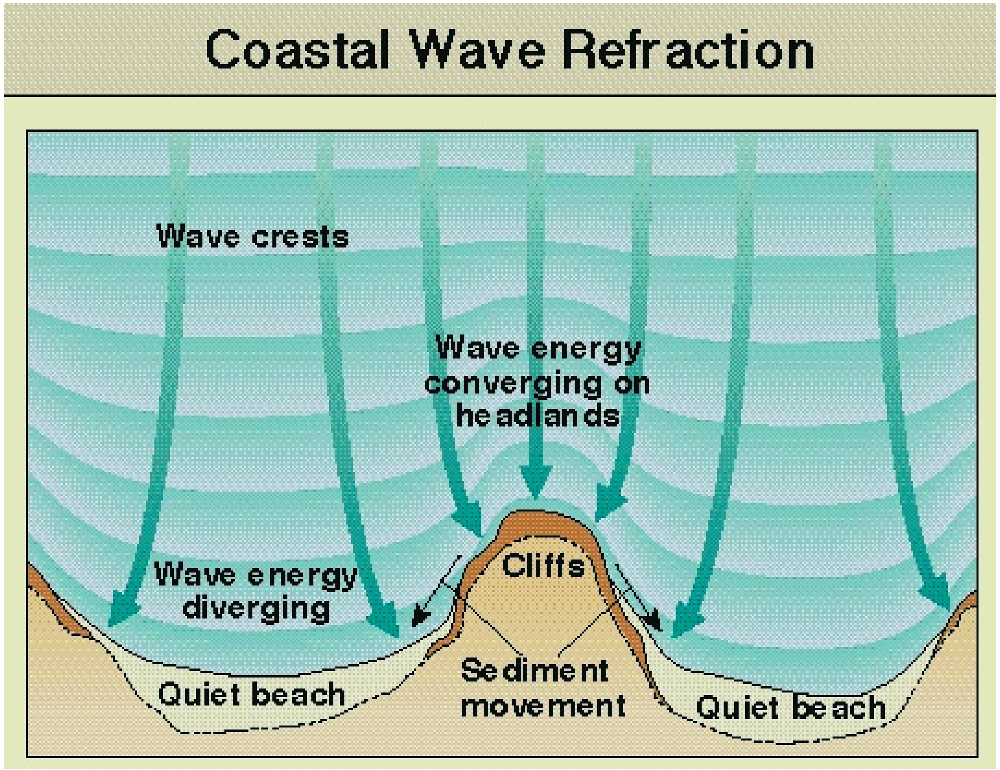


Near shore Wave Processes

WAVE REFRACTION

Wave Refraction in a bay

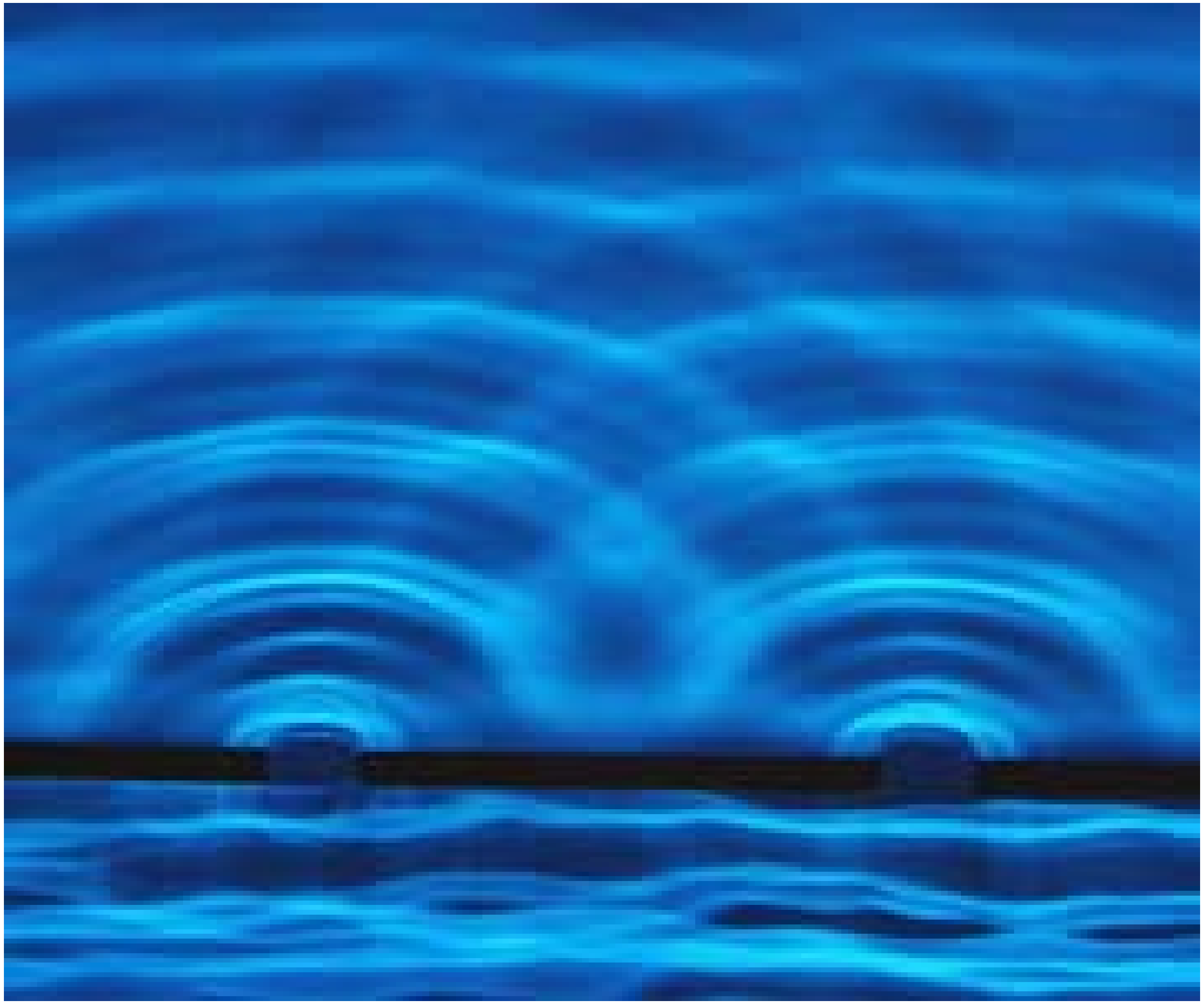
Characteristics in Deep and Shallow waters



Top View of Refraction Phenomenon

WAVE REFRACTION

WAVE DIFFRACTION



Long Waves and Extreme Waves in Nature

- **Tidal Waves**
- **Swell Waves**
- **Seiches (Resonance in Basins)**
- **Freak Waves**

Characteristics in Deep and Shallow waters

Characteristics in Deep and Shallow waters

Difference Between Sea (Wind) and Swell Waves

- "**Sea (Wind) Waves**" are produced by local winds and measurements show they are composed of a chaotic mix of height and period. In general, the stronger the wind the greater the amount of energy transfer and thus larger the waves are produced.

- *As sea waves move away from where they are generated they change in character and become swell waves.*

- "**Swell Waves**" are generated by winds and storms in another area. As the waves travel from their point of origin they organize themselves into groups (Wave trains) of similar heights and periods. These groups of waves are able to travel thousands of miles unchanged in height and period.

- Swell waves are uniform in appearance, have been sorted by period, and have a longer wave length and longer period than sea waves. Because these waves are generated by winds in a different location, it is possible to experience high swell waves even when the local winds are calm.

Wave spectrum

Model forms for wave spectra:

Usually expressed as: E(f); E(f,θ) (or) E(k)

As wave number and frequency are connected by the dispersion relation.

(i) Philips spectrum:

Usually used to represent the high frequency part of the spectrum. In general form:

$$E(f) = 0.005\frac{g^2}{f^5} \quad \text{if} \quad f \geq \left(\frac{g}{u}\right)$$

$$= 0 \text{ (else)}$$

Earlier used for representing the tail

Wave spectrum

(ii) Pierson-Moskowitz spectrum (1964):

Used for a fully developed sea (equilibrium state when fetch and duration are unlimited):

Originally developed based on sub-set of 420 (1955 – 1960) wave measurements with ship-borne wave recorder (Tucker, 1956).

$$E(f) = \frac{\alpha g^2}{(2\pi)^4 f^5} e^{-0.74\left(\frac{g}{2\pi f U}\right)^4}$$

where, α = non-dimensional quantity = 0.0081

U = wind speed at 19.5 m above seasurface

Peak frequency of P-M spectrum:

$$f_p = 0.877\frac{g}{2\pi U}; \quad H_{1/3} = 0.0246\ U^2 \text{(for fuly developed seas)}$$

Hence, $H_{1/3} = 0.04\ f_p^{-2}$

Wave spectrum

(ii) JONSWAP spectrum (1973):

JONSWAP (1973) gave a description of wave spectra growing in fetch limited condition. Basic formulation of the spectrum is expressed in terms of peak frequency rather than wind speed.

$$E(f) = \frac{\alpha g^2}{(2\pi)^4 f^5} e^{-1.25\left(\frac{f}{f_p}\right)^4} . \gamma(f)$$

where, γ is peak enhancement factor which modifies the interval around spectral peak making it more sharper than PM spectrum (otherwise shape is similar). Using JONSWAP results, Hasselmann (1976) proposed a relation between variance and peak frequency for wide range of growth stages.

$$\mathrm{H_{m0}} \approx \mathrm{H_{1/3}} = 0.0414 f_p^{-2} (f_p U)^{1/3}$$

(or) $\mathrm{f_p} = 0.148 H_{m0}^{-0.6} U^{0.2}$

where, $U = U_{10}$ (wind speed at 10 m height)

Numerical Modeling of Ocean Waves

- Model Classes
- Model Generation
- Numerical Wave Modeling → Indian context

Wave energy balance comprises of source and sink mechanisms

$$\frac{\partial E}{\partial t} + \nabla . C_g E = S_{in} + S_{nl} + S_{ds} + S_{bot} + ???????$$

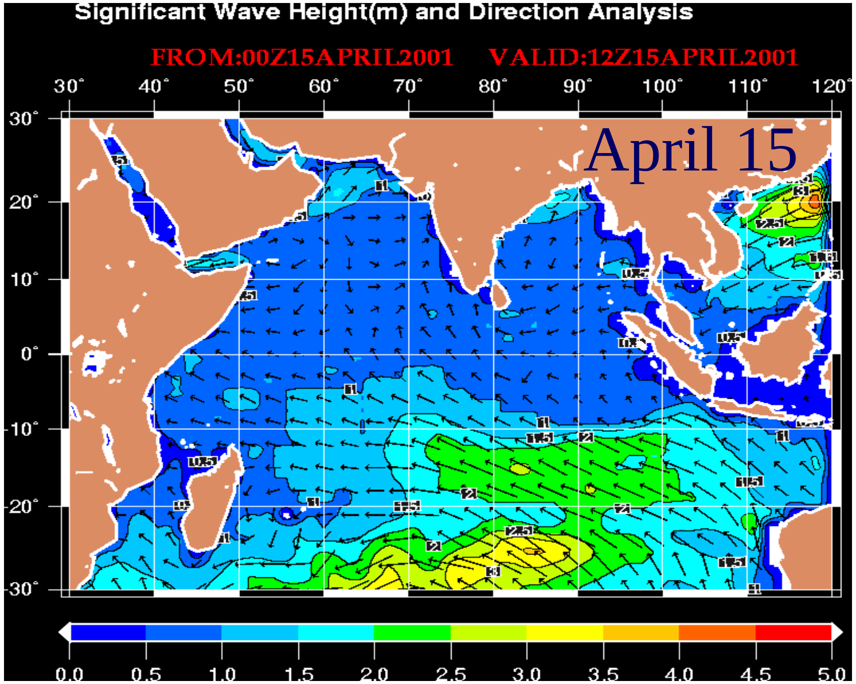
S_{in} => *Wind input*

S_{nl} => *Non linear wave-wave interactions*

S_{ds} => *Wave dissipation due to white-capping*

S_{bot} => *Wave dissipation due to bottom friction*

Improvement of source/sink terms is an active and fertile area of research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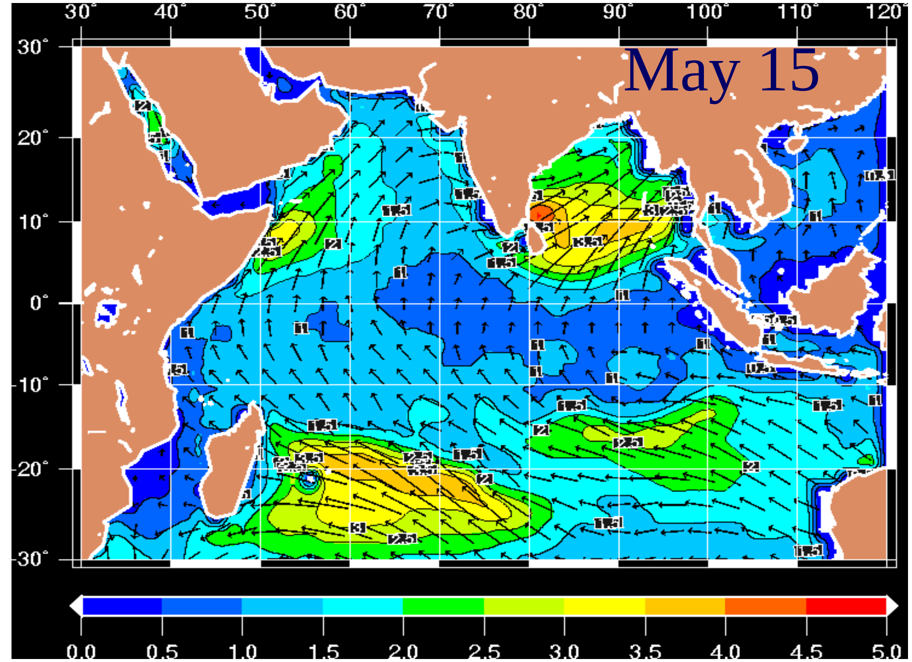
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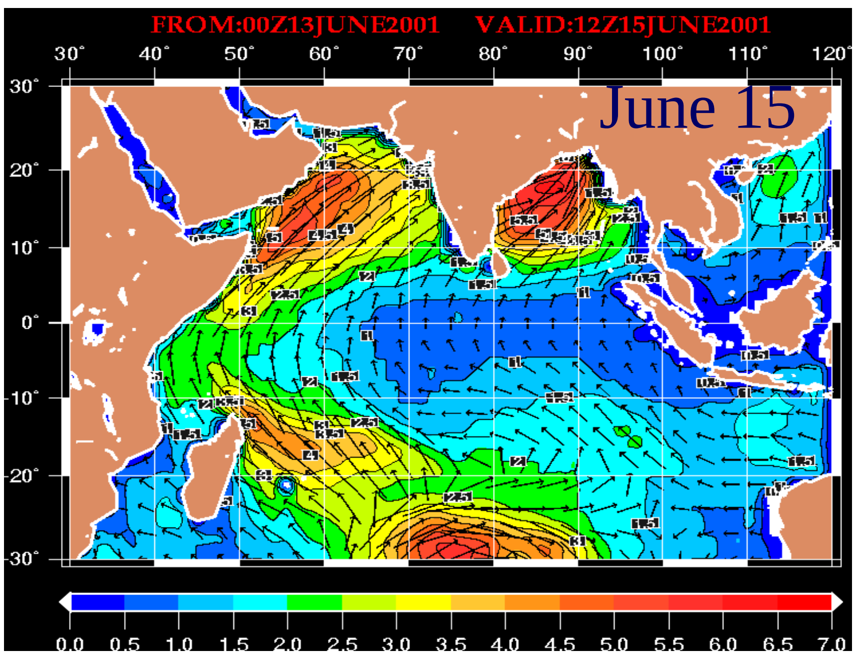
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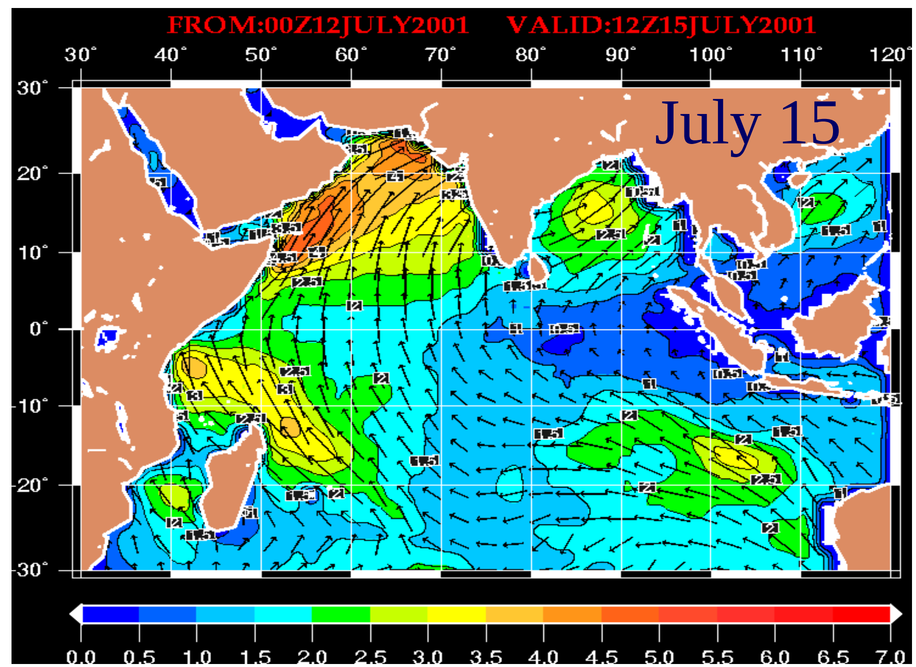
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Thank You