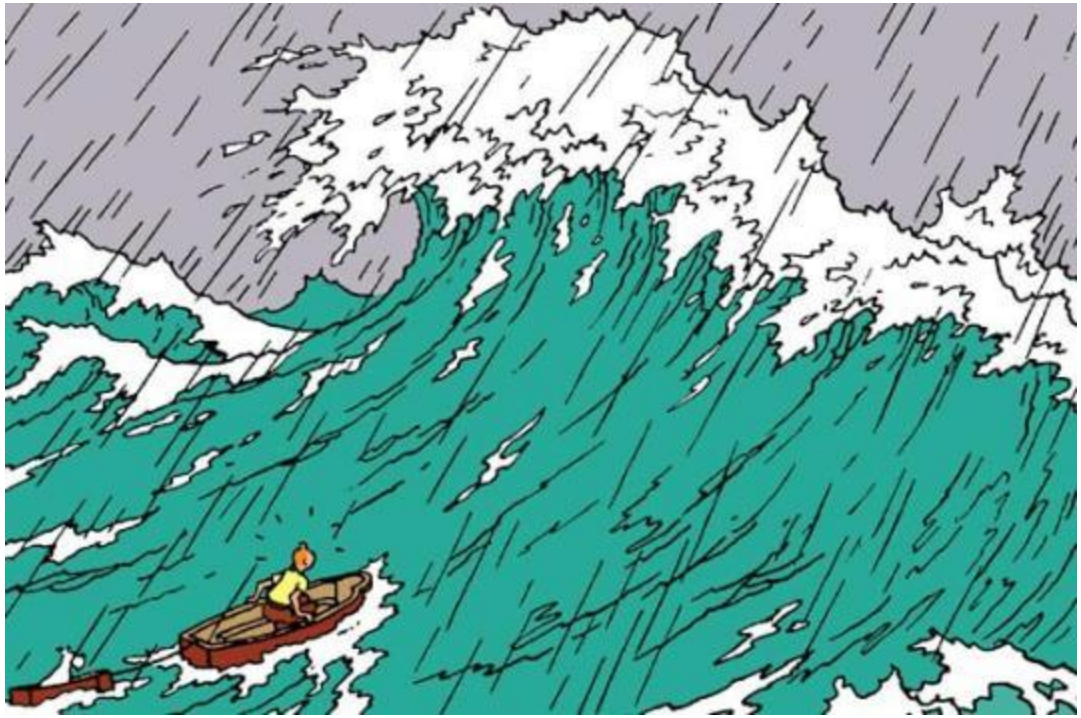
The Wave Modelling (WAM) Group

A historical perspective

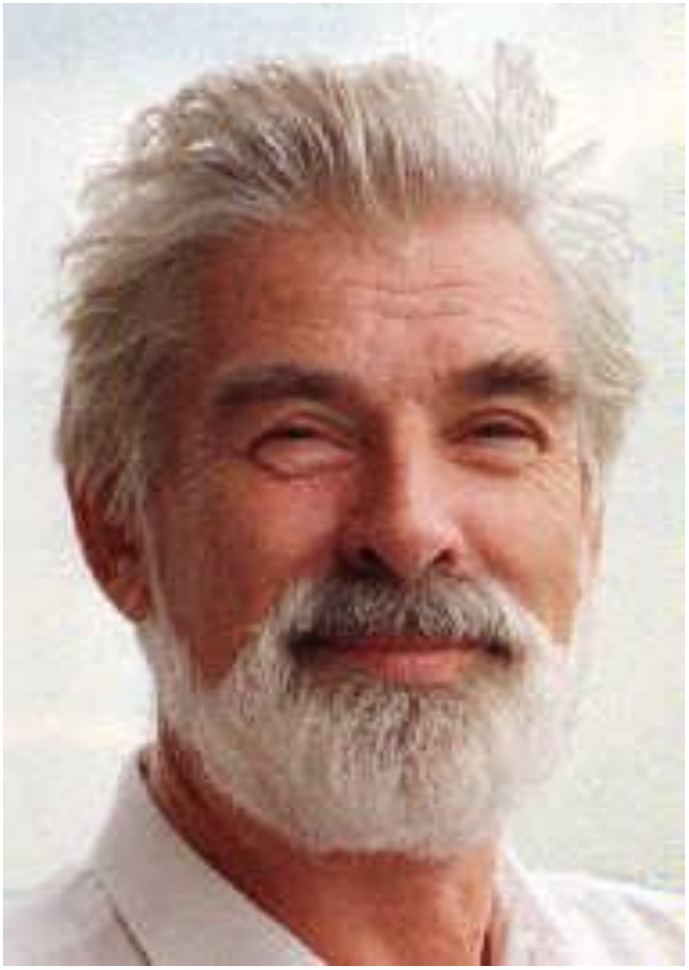


Gerbrand Komen

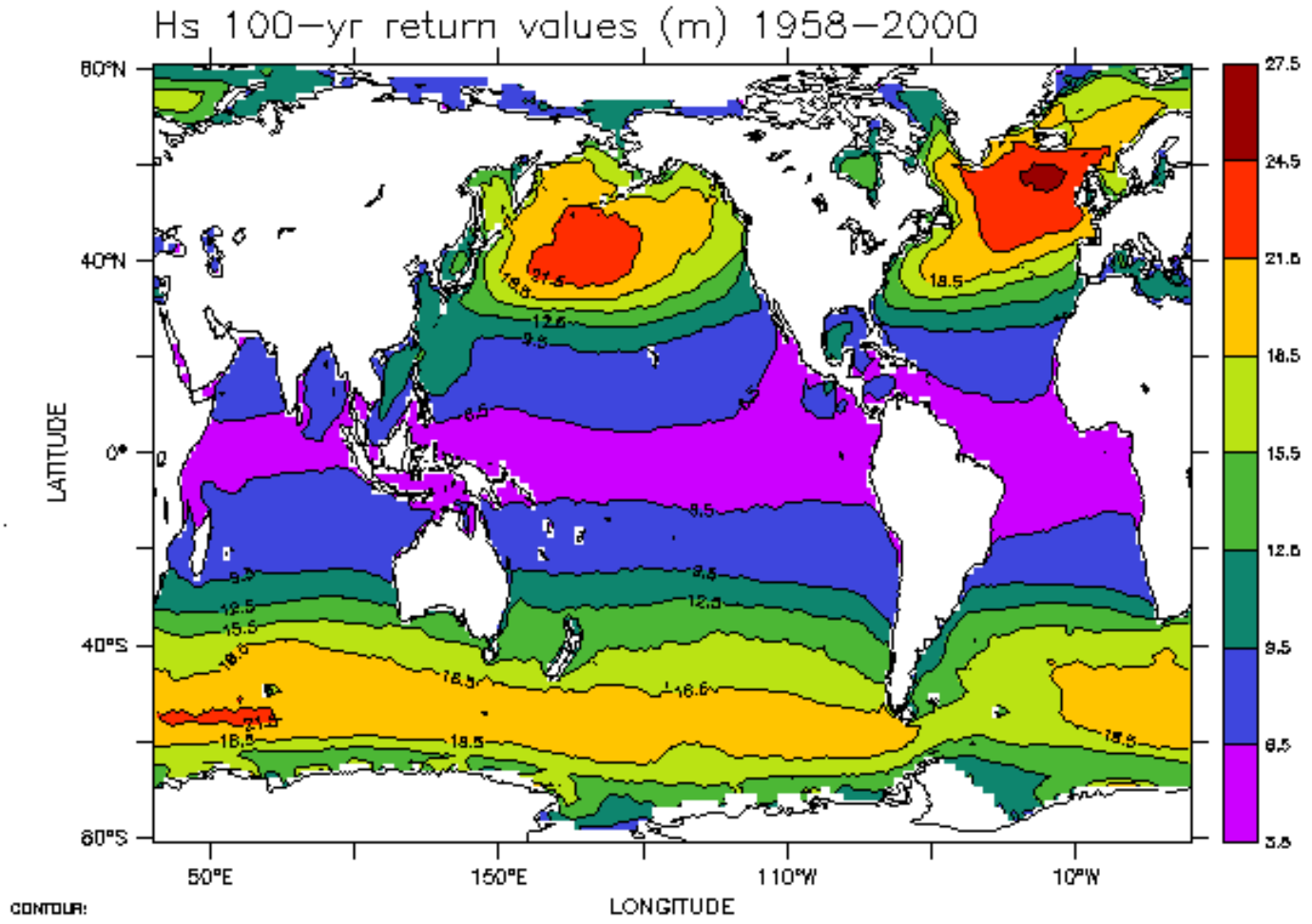
Peter Janssen

Luigi Cavaleri

Hamburg, November 2011

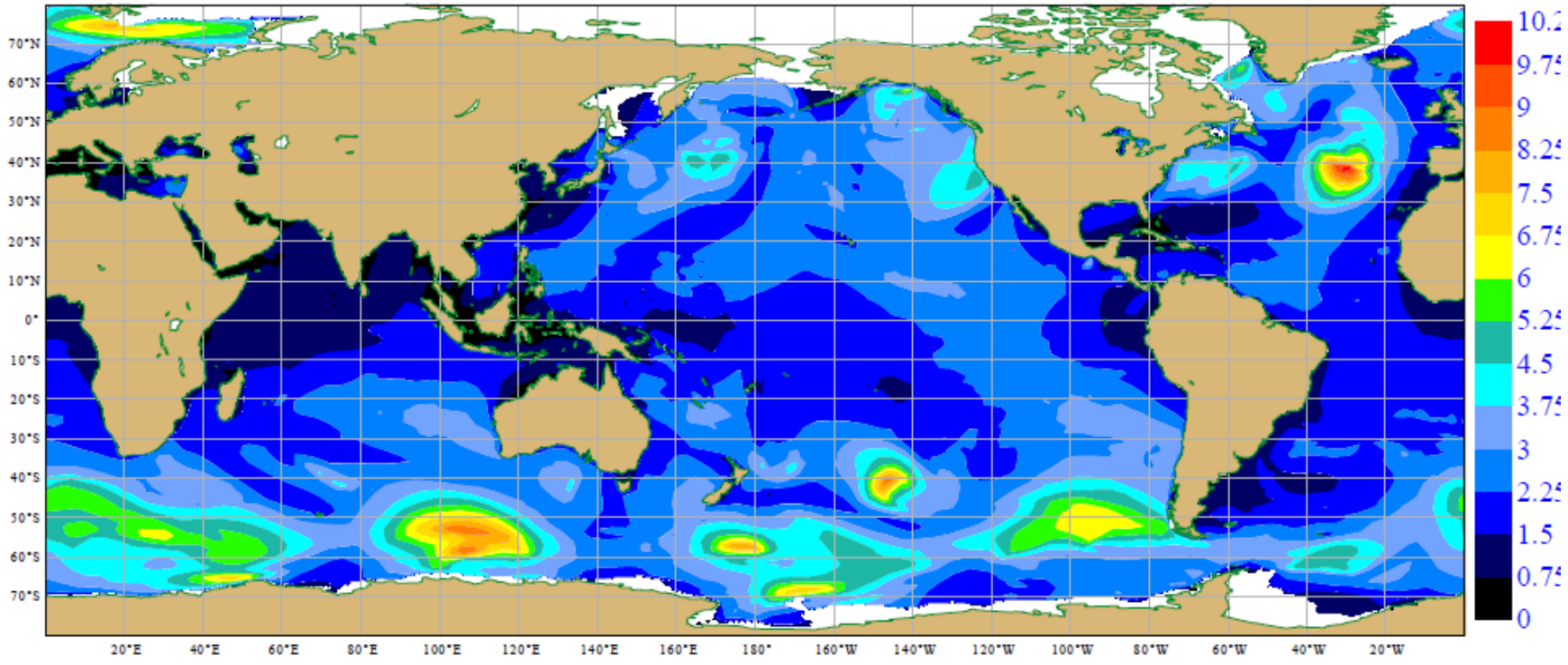


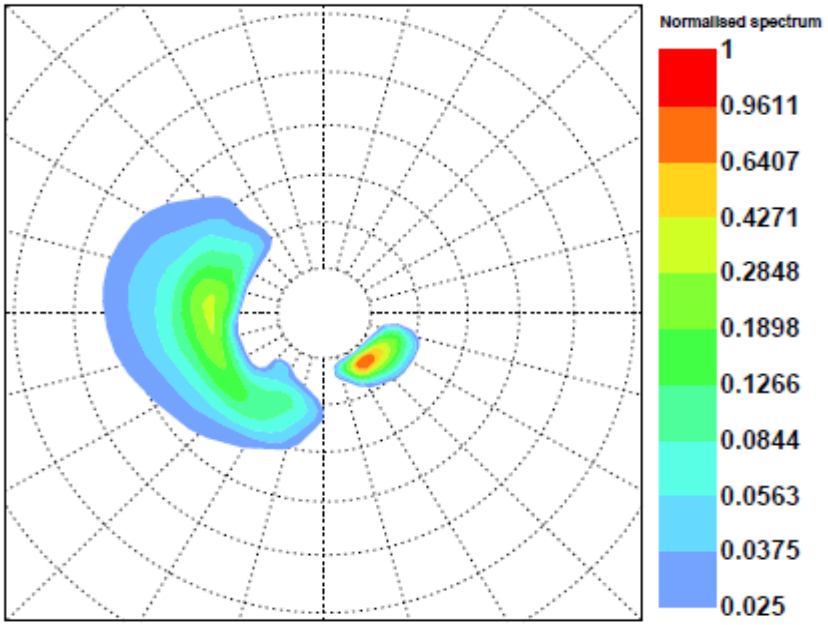
Klaus Hasselmann
80th anniversary

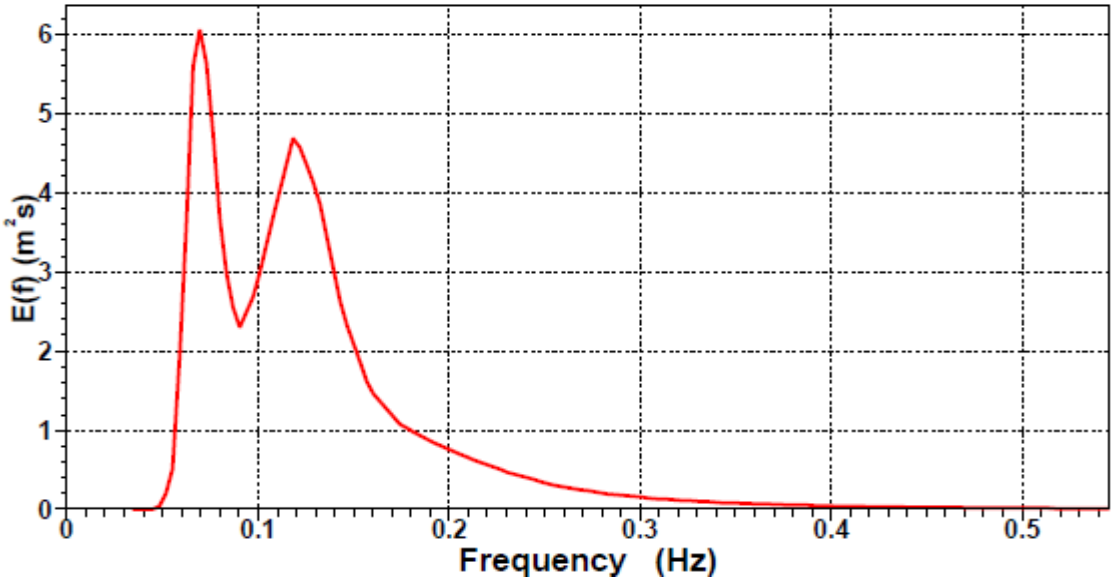


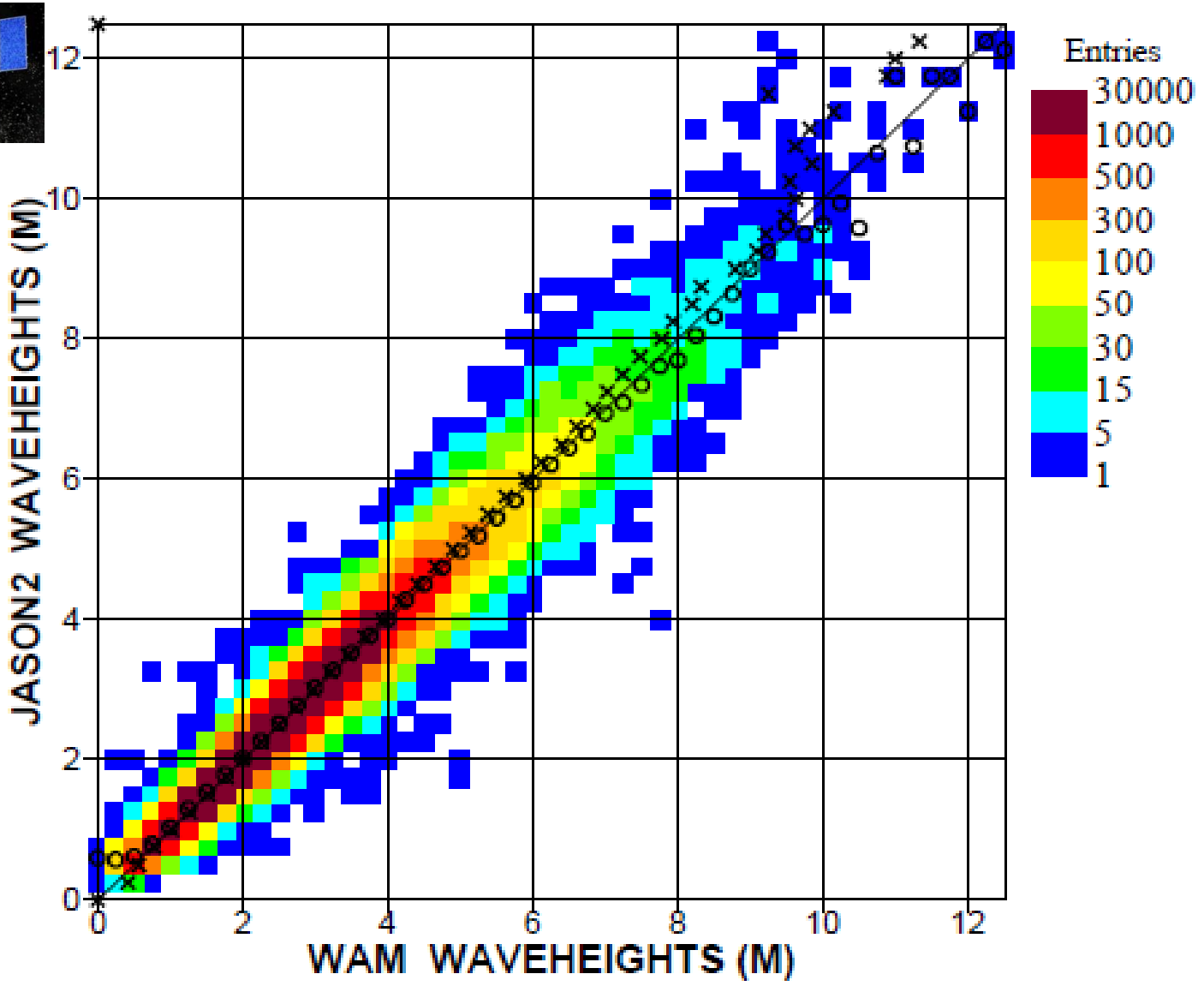
http://www.knmi.nl/waveatlas, Caires, Sterl, Komen and Swail

Tuesday 14 March 2006 00UTC ECMWF Forecast t+36 VT: Wednesday 15 March 2006 12UTC Surface: significant wave height




Normalised spectrum
1
0.9611
0.6407
0.4271
0.2848
0.1898
0.1266
0.0844
0.0563
0.0375
0.025


E(f) (m²s)
0
1
2
3
4
5
6
0
0.1
0.2
0.3
0.4
0.5
Frequency (Hz)


JASON2 WAVEHEIGHTS (M)
WAM WAVEHEIGHTS (M)
0
2
4
6
8
10
12
Entries
30000
1000
500
300
100
50
30
15
5
1

Overview

WAve Modelling group = WAM

- Pre-WAM
- WAM (~1984 – 1994)
- Post WAM

Pre - WAM

Theory

- Wave spectrum, Dynamic equation, Wave generation, Wave-wave interaction, Wave dissipation

Observations

- Swell propagation, JONSWAP, . .

Second generation wave prediction models

- HYPA, GONO, UKMO, . .

Theory: spectral energy balance equation

$$\left\{\frac{\partial}{\partial t}+\mathbf{c_g}\cdot\frac{\partial}{\partial \mathbf{x}}\right\}F(\mathbf{k},\mathbf{x},t)=\sum_{\ell}S_{\ell}(F;\mathbf{u})=S_{in}+S_{nl}+S_{ds}$$

$$\frac{\mathrm{d}}{\mathrm{d}t}N_4 = 4\pi\int|T_{1234}|^2\delta(\mathbf{k}_1+\mathbf{k}_2-\mathbf{k}_3-\mathbf{k}_4)\delta(\omega_1+\omega_2-\omega_3-\omega_4)$$
$$\times[N_1N_2(N_3+N_4)-N_3N_4(N_1+N_2)]\,\mathrm{d}\mathbf{k}_1\,\mathrm{d}\mathbf{k}_2\,\mathrm{d}\mathbf{k}_3. \quad (2.145)$$

Observations: JONSWAP
Spectral evolution under fetch-limited growth conditions

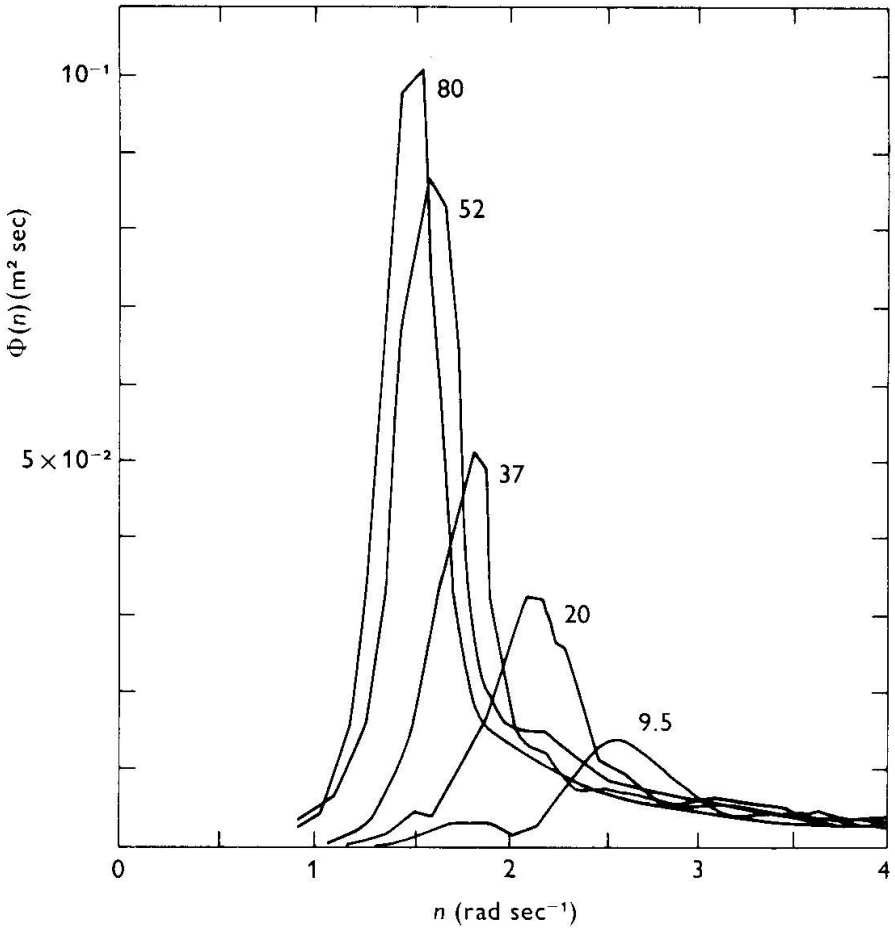


Fig. 4.16. A sequence of frequency spectra measured at increasing fetch (from 9.5 to 80 km) in the JONSWAP experiment (Hasselmann *et al.* 1973).

Models

Second generation wave prediction models

- Based on scaling laws
- Included ‘new theory’ without explicitly computing wave-wave interactions
- Validation
- Intercomparison → SWAMP

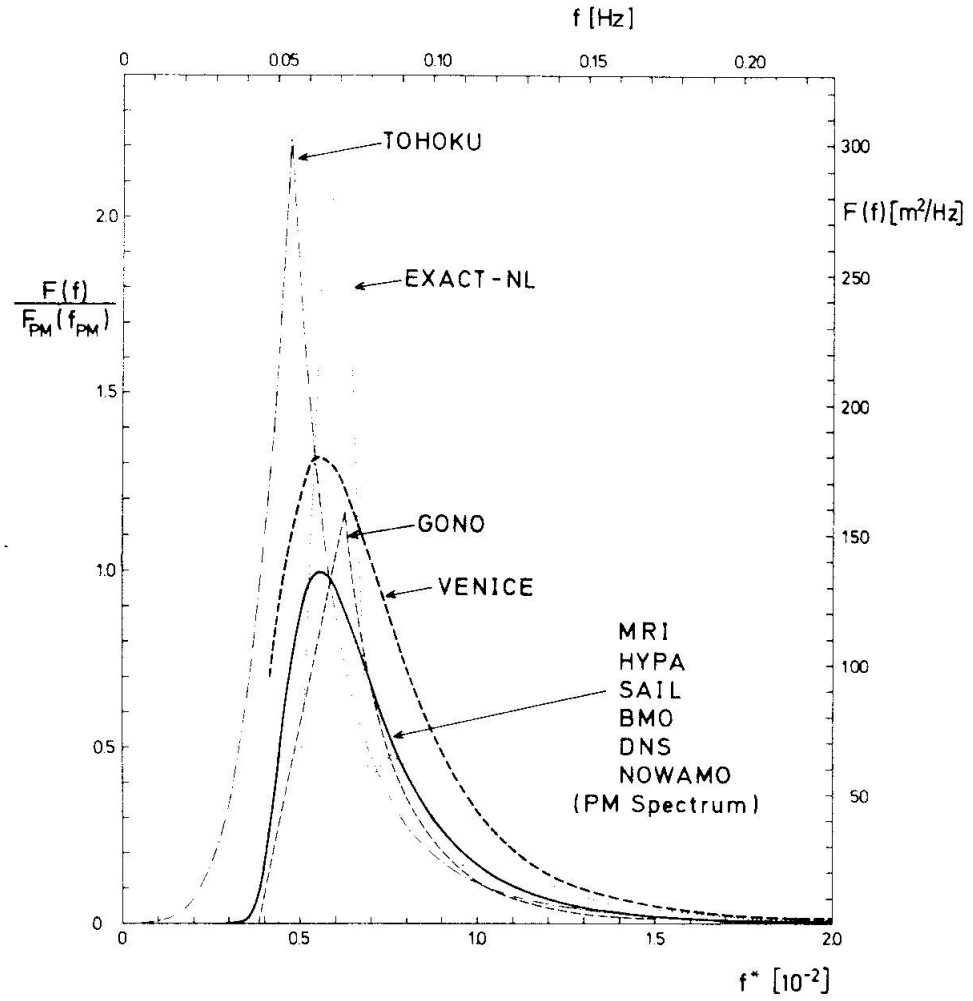


Fig. 7.2. Fully developed equilibrium spectra (Case II). EXACT-NL has no asymptotic equilibrium spectrum; the spectrum shown corresponds to a fetch of 1000 km. The TOHOKU spectrum also grows very slowly beyond the Pierson–Moskowitz spectrum, but wave growth is finally "artificially" arrested when the spectrum reaches the distribution shown.

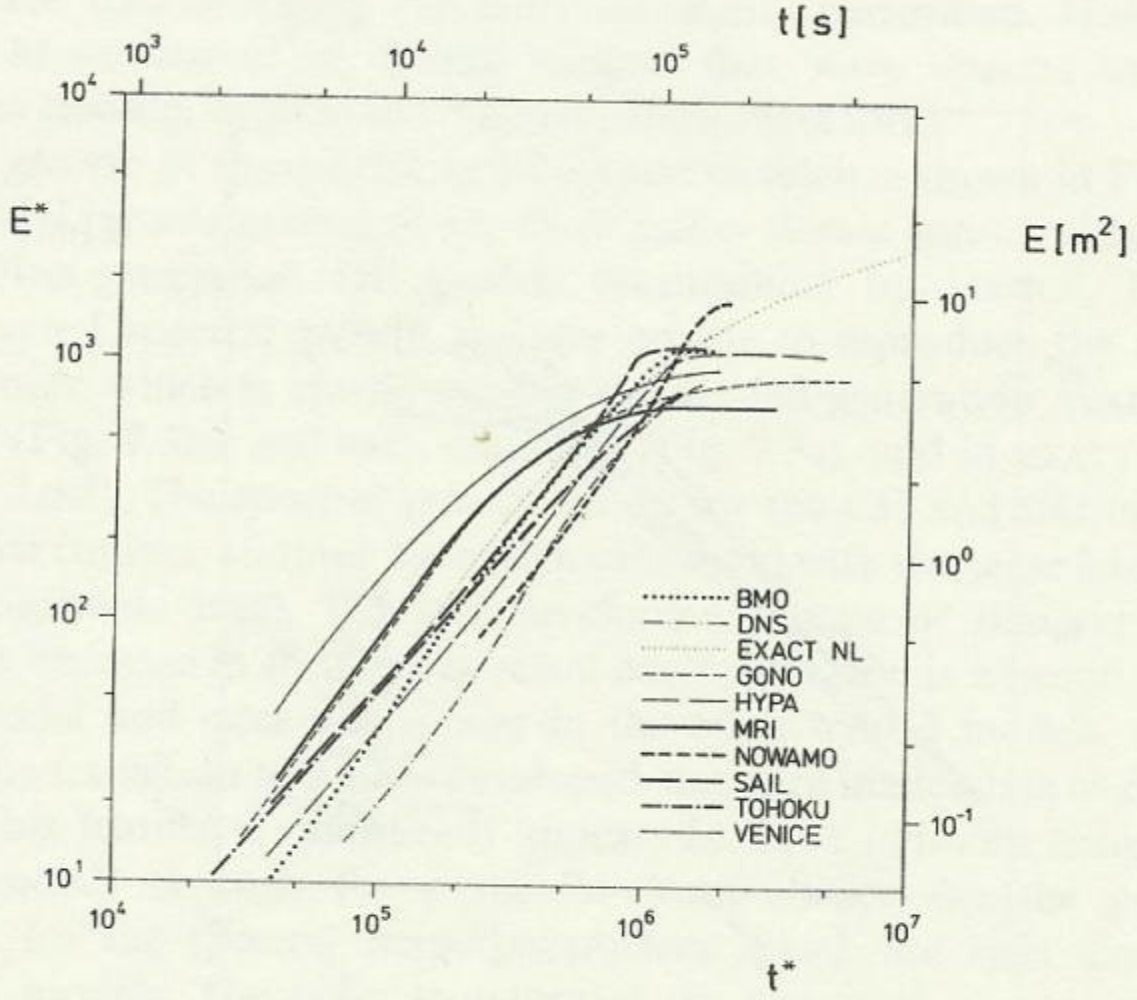
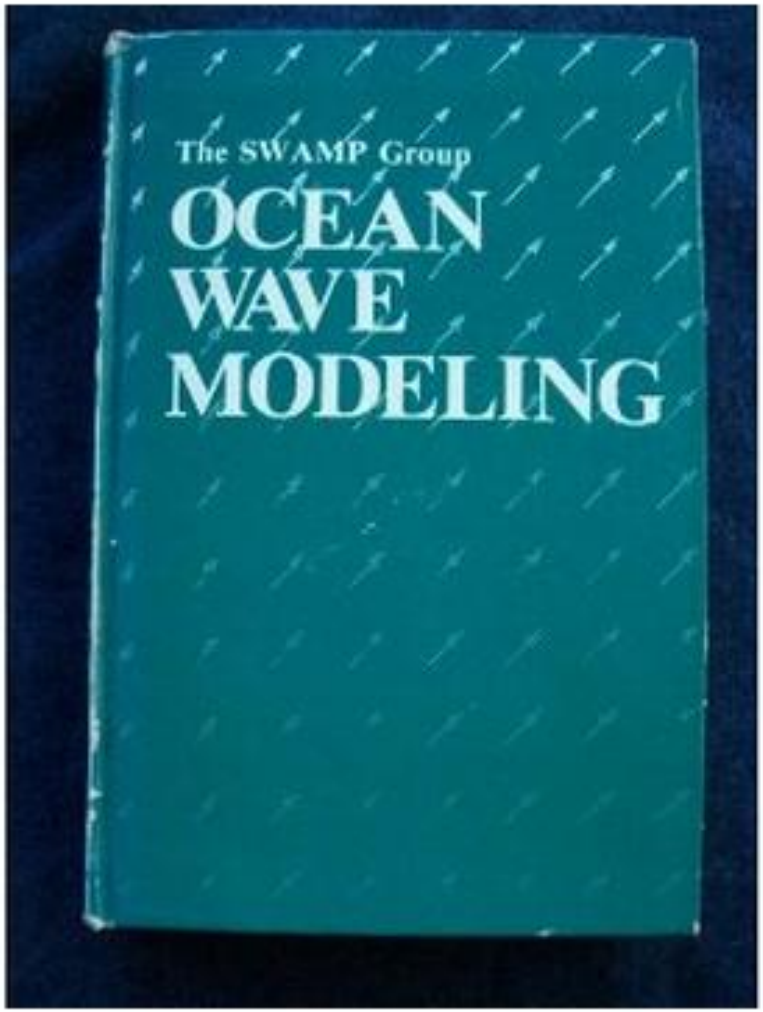


Fig. 7.6. Nondimensional duration-limited growth curves for the total energy E^* (Case II).

amazon.com, 2011



Ocean Wave Modeling [Hardcover]

Sea Wave Modeling Project (Other Contributor)

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Miami 1981 / Plenum 1985

WAM

Landmarks

- Hamburg 1984: founding of WAM group
  - Susanne Hasselmann Miami 1981, Exact NL
  - Hamburg 1983, numerical study of the actual energy balance growing waves
- Annual meetings (1984 until 1992)
  Funding: EU, SCOR
- ECMWF > 1985 special project
  > 1990 ECMWF Optional Project
- Final report 1994

WAM

Objectives

- Joint development 3G wave model

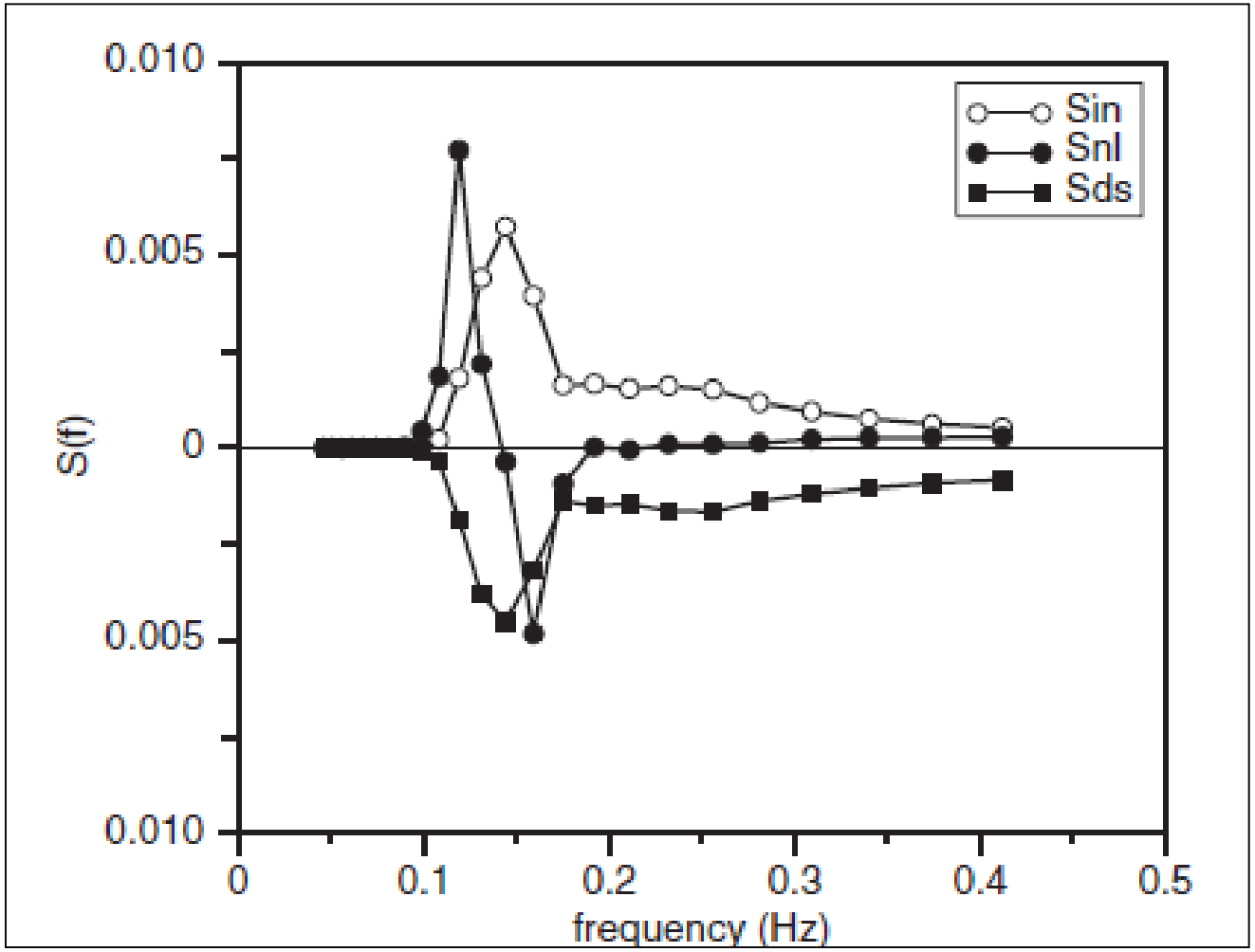
Organisation

- Many people, loosely organized
- Several subgroups
  - model implementation: global/regional
  - reanalysis of wave growth observations
  - directional effects
  - data assimilation of satellite observations

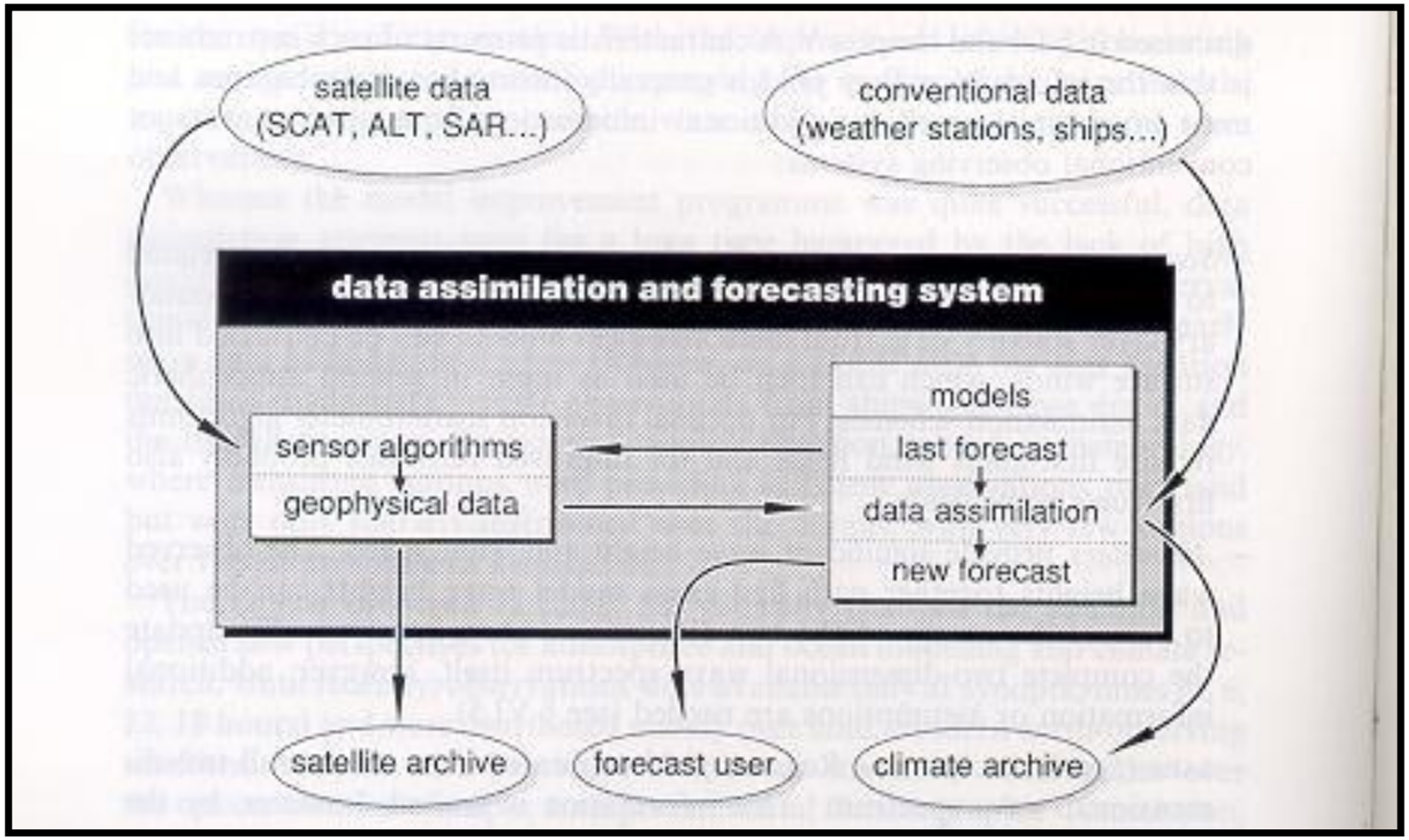
WAM

Modelling group

- Source terms
  - wind input, quasi-linear theory (Peter Janssen)
  - nonlinear transfer
  - dissipation/whitecapping
  - shallow water effects
  - current refraction, sea ice
- Operational implementation at ECMWF and elsewhere
- Validation against observations



The energy balance for growing waves for a typical wind speed



The vision: assimilation of observations and forecasting in one integral system

Susanne Hasselmann, Ninth WAM meeting, Sylt, June 1991
Excursion by boat to Hallig Hooge

Fourth WAM meeting, Venice, 1986

Peter Janssen, KNMI 1994.

Luigi (’Gigi’) Cavaleri, Sixth WAM meeting, Valencia, 1989

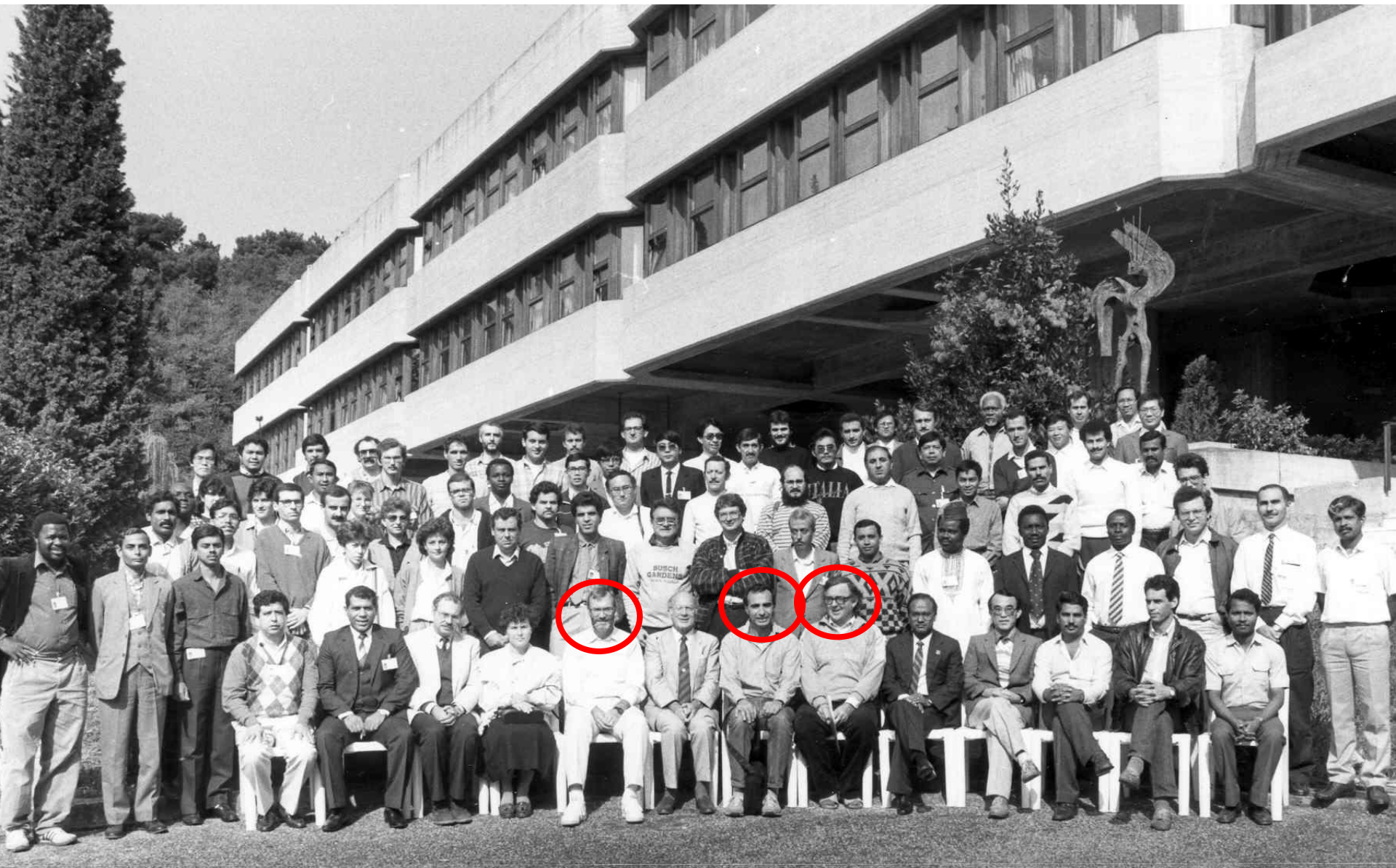
Heinz Günther, Sendai, 1984

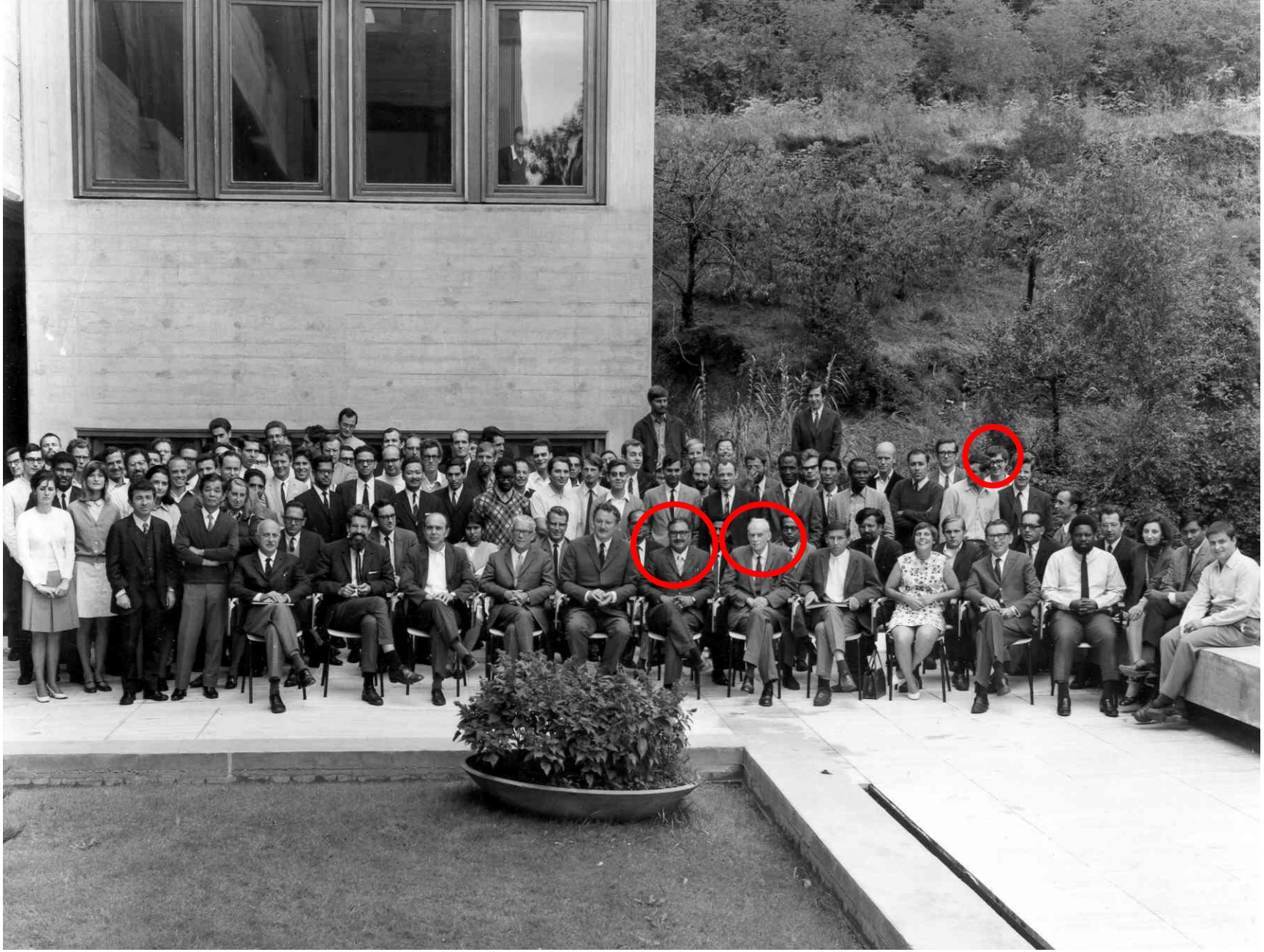
Liana Zambresky with her cat

Vince Cardone, Mark Donelan, Lewex Symposium, Baltimore, 1986

WAM Outreach

- Annual meetings (1984 - 1992)
- Course on Ocean Waves and Tides (ICTP, 1988)
- Dynamics and Modelling of Ocean Waves (1994)

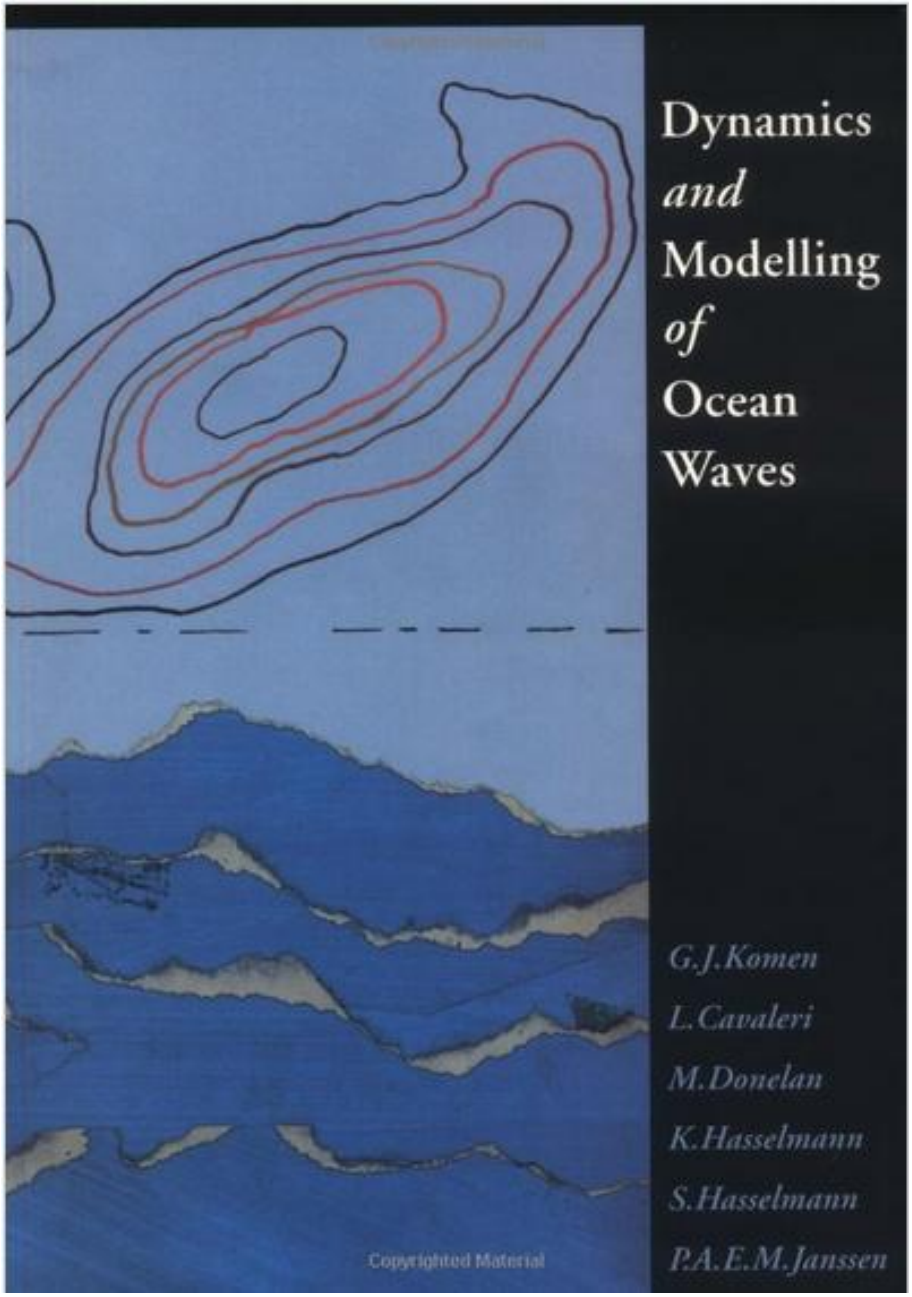

Course On Ocean Waves And Tides.
I.C.T.P. 26 Sept. 28 Oct. 1988. Trieste.



ICTP, 1968 with Abdus Salam and P.A.M. Dirac

October 1988, Acqua Alta platform, ISDGM/CNR

Selected students, Course on Ocean Waves and Tides, 1988



1994

Final Report, published by CUP

500+ pages

Book presentation, KNMI 1994

Post WAM

ECMWF

- Medium-range forecasting
- New satellites, real time comparison
- Operational validation of different wave models (JCOMM)
- Research on freak waves; interaction of ocean waves with airflow and ocean circulation

WISE group

- Many regional applications

KNMI

- Decadal variability in global extreme statistics

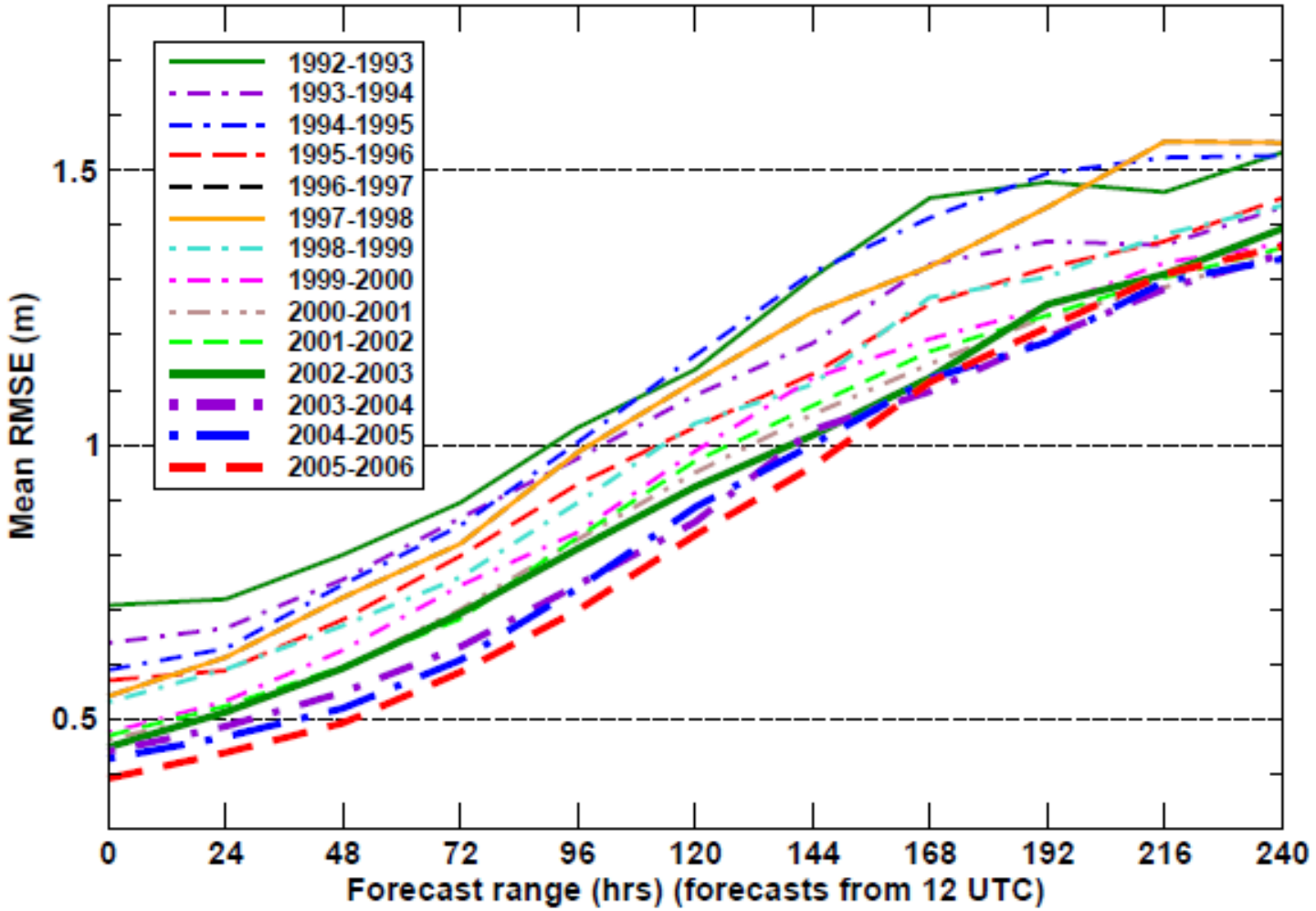
Post WAM

Improving medium-range forecasting at ECMWF

- Surface winds (≈ 70%)
- Representation of wind input source term
  (two-way interaction between waves and airflow)
- Representation of wave dissipation
- Numerics
- Representation of unresolved bathymetry

Wave height comparison with buoy data

from October to March

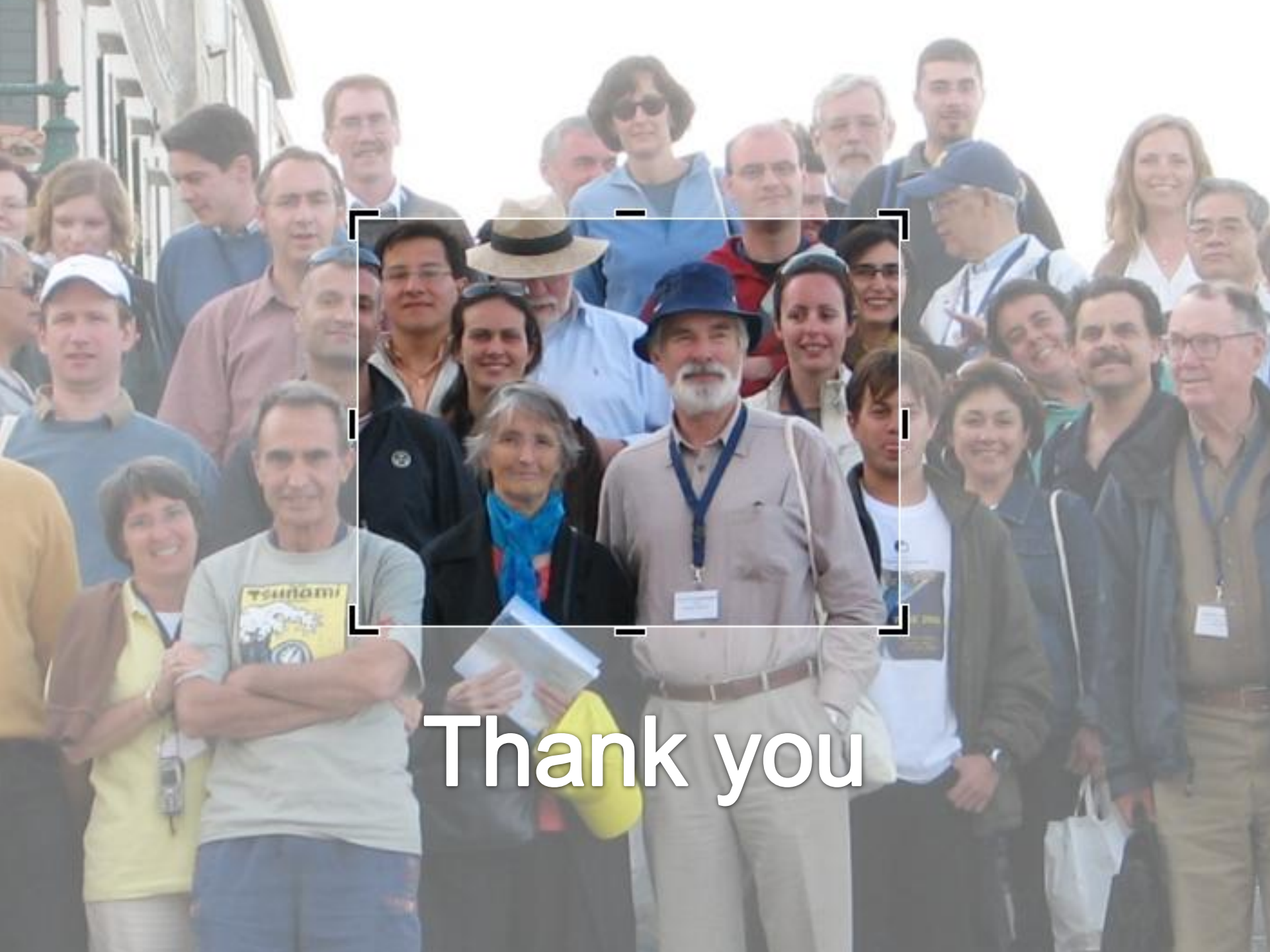


Many challenges remain, even today . .

Klaus (and Susanne) Hasselmann' made essential contributions to

- Dynamical description of the evolution of ocean waves
- A third generation wave prediction model for global and regional applications
- Wave observation from space
- Building of a global wave research community

WISE, 2006, Venice



Thank you