Some recent turbulence modeling at GISS Part 1

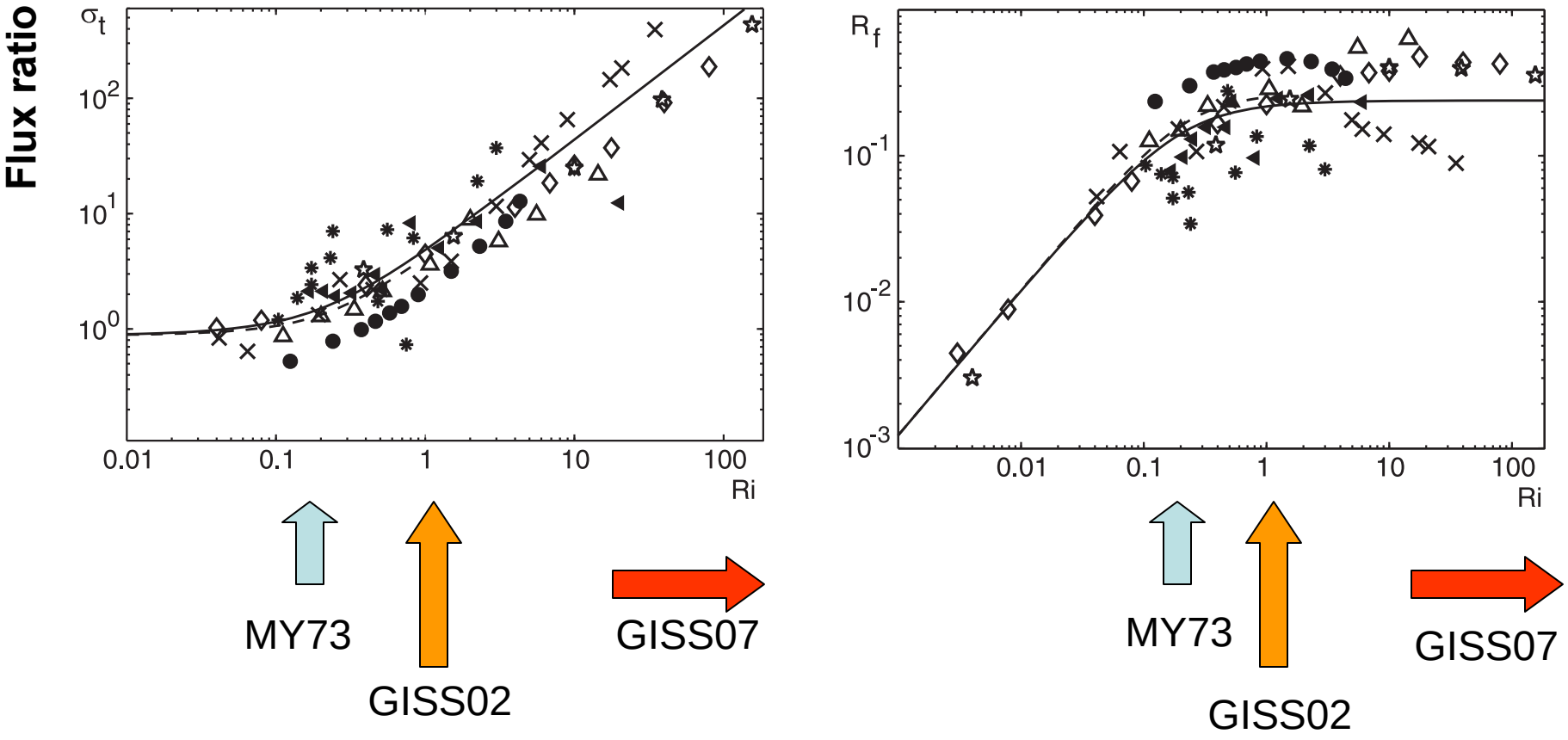
Ye Cheng

with V.M. Canuto and A. Howard

New model for stably stratified flow: prevents turbulence from dying too early by eliminating Ri(cr)

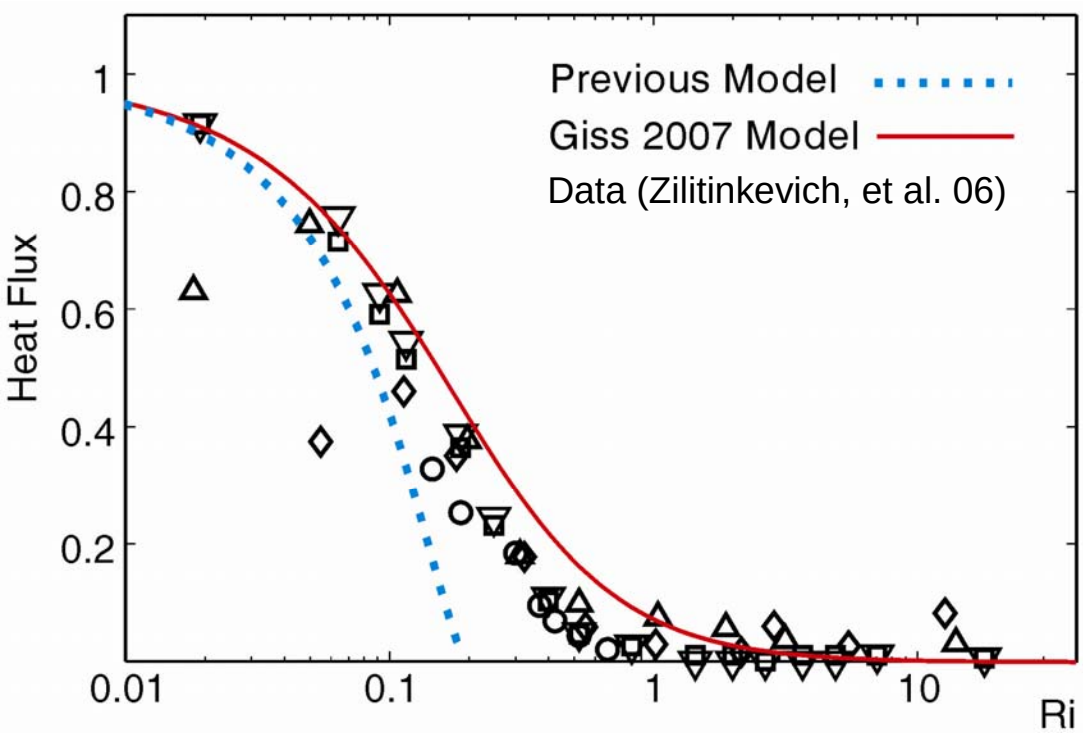
J. Atmos. Sci. , 2002, 2008.
GRL, 2008

Turbulence response to large scale forcing



$$\text{Large scale forcing}: \mathrm{Ri} = \frac{\text{stable buoyancy}}{\text{shear}}$$

Data (Zilitinkevich et al., 06)


Previous Model
Giss 2007 Model
Data (Zilitinkevich, et al. 06)
Heat Flux
1
0.8
0.6
0.4
0.2
0.01
0.1
1
10
Ri

Summary of ideas

- **Several time scales floating around in turbulence models**
- **Are they all constant multiples of each other?** **No**
- **A simple parameterization of one time scale yields much better results**

$$\tau_{p\theta} \sim \frac{\tau_{\varepsilon}}{1+Ri}$$

Some recent turbulence modeling at GISS
Part 2

Ye Cheng

with V.M. Canuto and A. Howard

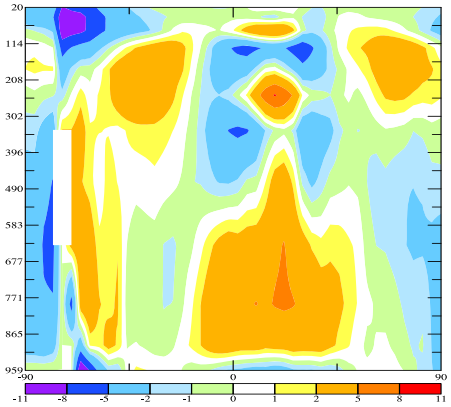
New model in unstably and stably stratified flows: includes non-locality via new 4th-order moments

J. Atmos. Sci. , 1994, 2001, 2002, 2005a,b

Unstable stratification

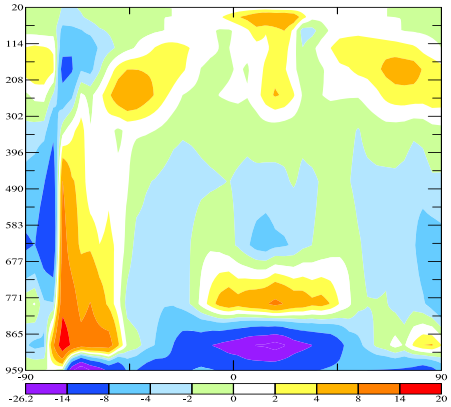
large eddies ⇨ non-local models

RH



Nonlocal-local

Could Cover



Nonlocal-local

Turbulence closure hierarchy

SOM

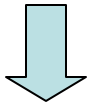
$$\frac{\partial T}{\partial t} = -\frac{\partial}{\partial z}\overline{w\theta}$$

TOM

$$\frac{\partial}{\partial t}\overline{w\theta} = -\frac{\partial}{\partial z}\overline{w^2\theta} + \cdots$$

FOM

$$\frac{\partial}{\partial t}\overline{w^2\theta} = -\frac{\partial}{\partial z}\overline{w^3\theta} + \cdots$$



Forever and ever

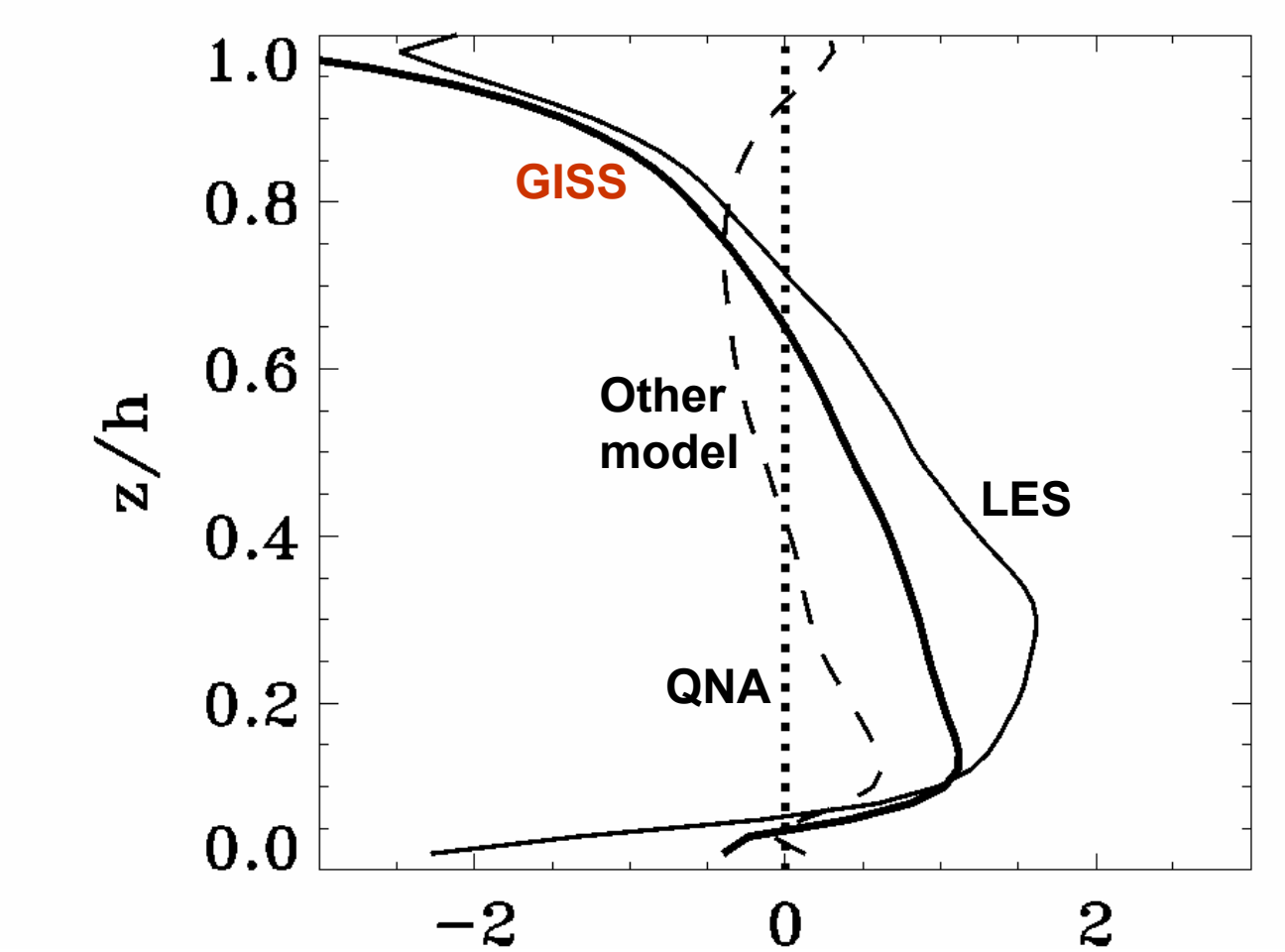
Previous FOM models: $\overline{w^3\theta} = \mathrm{QNA}$

Problems:

- **Blow-up at typical forcing in unstable case**
- **Spurious oscillations in stable case**
- **Complicated**

GISS model addressed them at once

$$\frac{\partial}{\partial z}\left(\overline{w^3\theta} - \mathrm{QNA}\right)$$



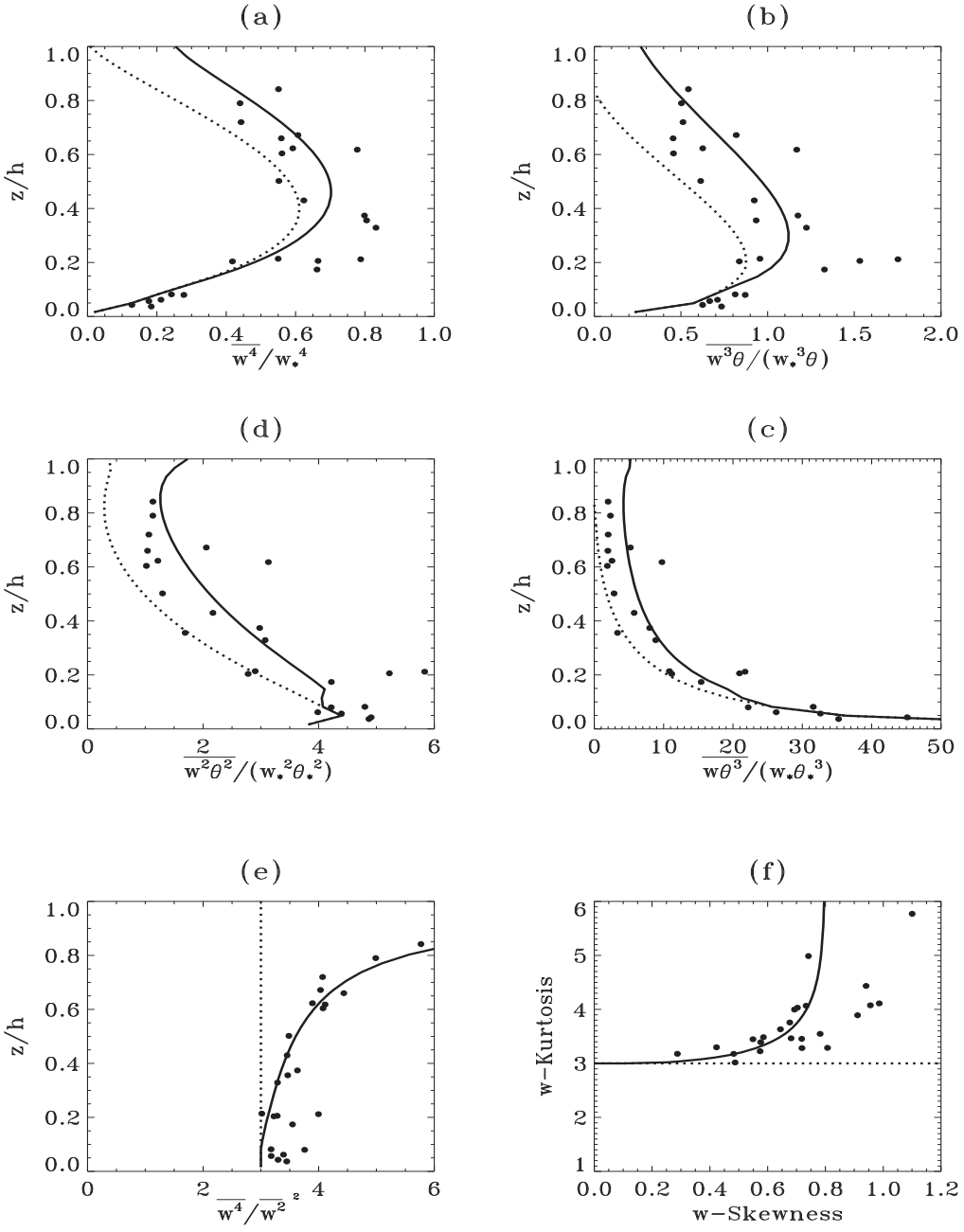


Fig.5

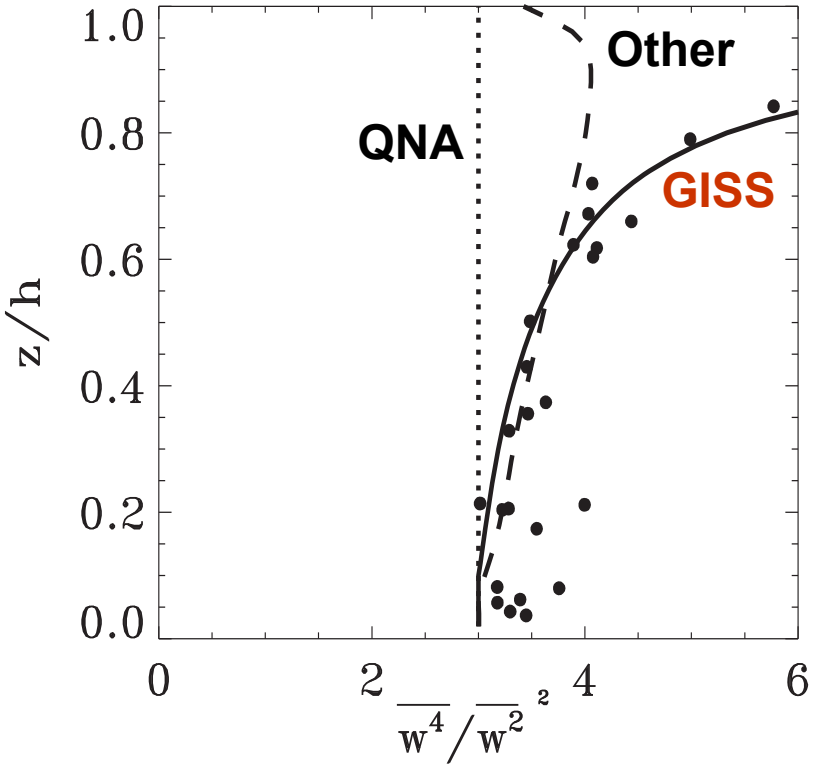
FOMs in PBL

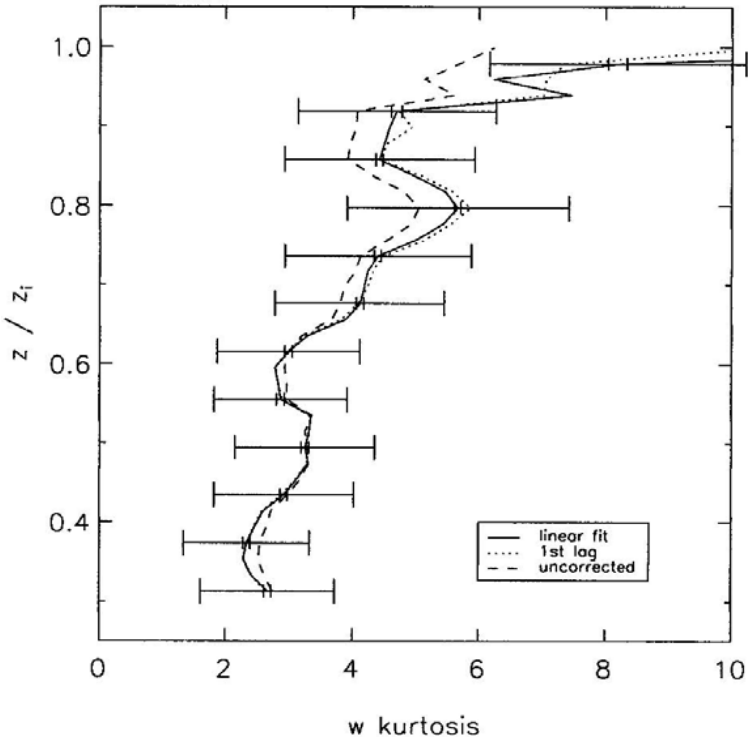
Dots: Aircraft data
(Hartmann et al., 1999)

Solid line:
New model

Dotted line: QNA

Velocity kurtosis $\overline{w^4} / \overline{w^2}^2$





New model (solid line)
Aircraft data (dots)

Lab measurements
Lenschow et al., *J. Atmos. Oceanic Technol.*, **17,** 1330-1347, 2000

Summary for non-local model

- A new way to formulate Non-QN FOMs
- TOMs damp more realistically in unstable case
- No spurious oscillations in the stable case
- Simpler than the QNA
- Future work: more accuracy and simplicity