Simulating gliders

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in collaboration with

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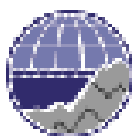
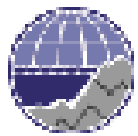
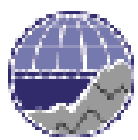


Outline

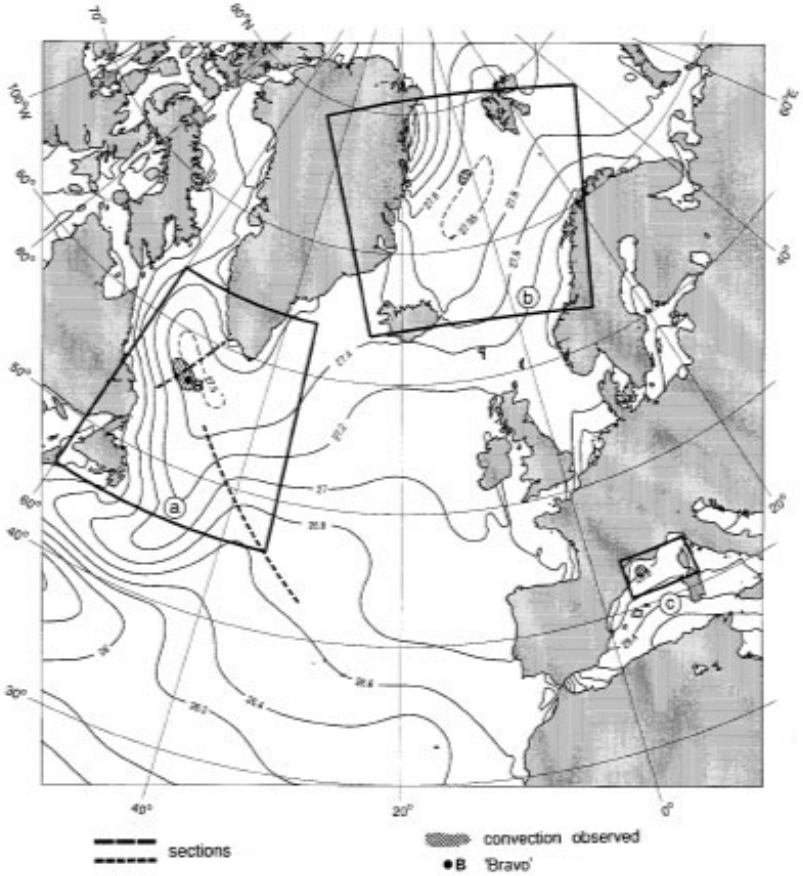


Why simulating?

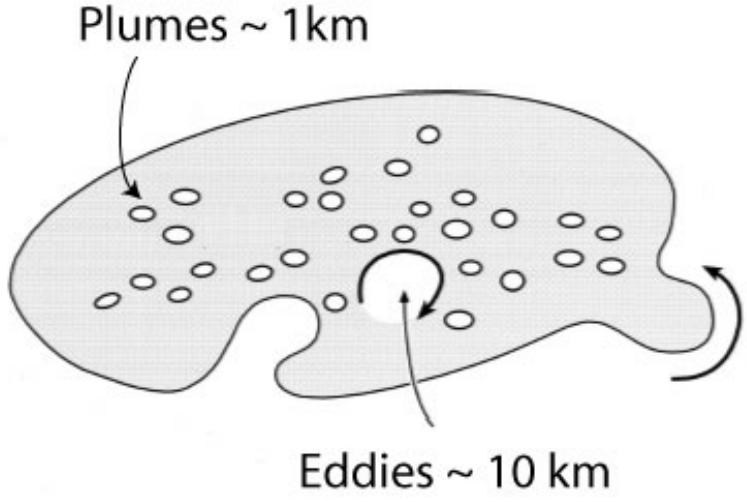
- No gliders out there yet,
- Examining observational capabilities,
- Evaluating sampling strategies.



Background



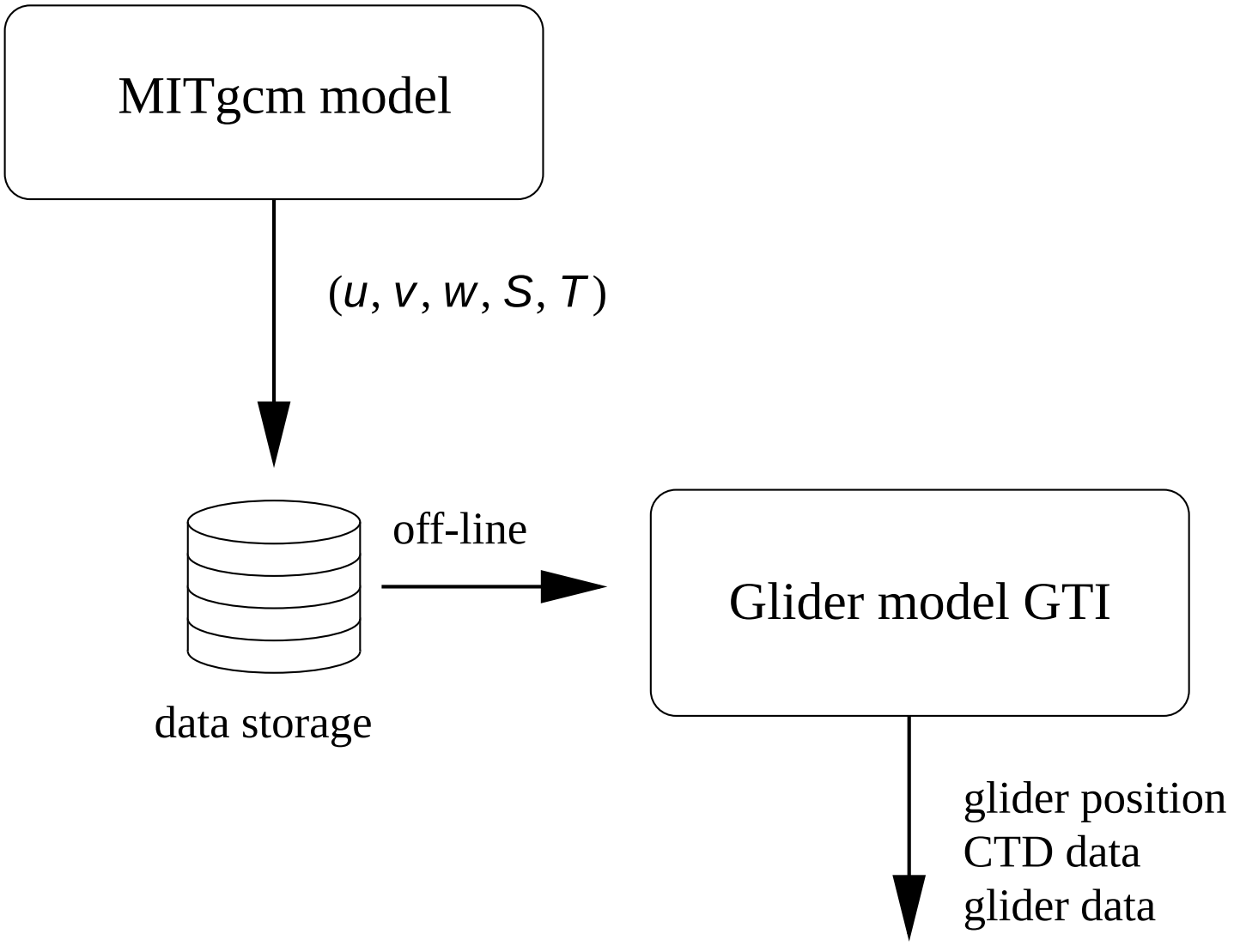
(Marshall & Schott, 1999)



(Marshall & Schott, 1999)

- Convective mixing

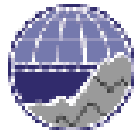
Model overview



MITgcm model highlights

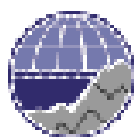
- non-hydrostatic,
- curvilinear grid,
- netcdf output,
- constant viscosity,
- freely available.

Web: http://mitgcm.org

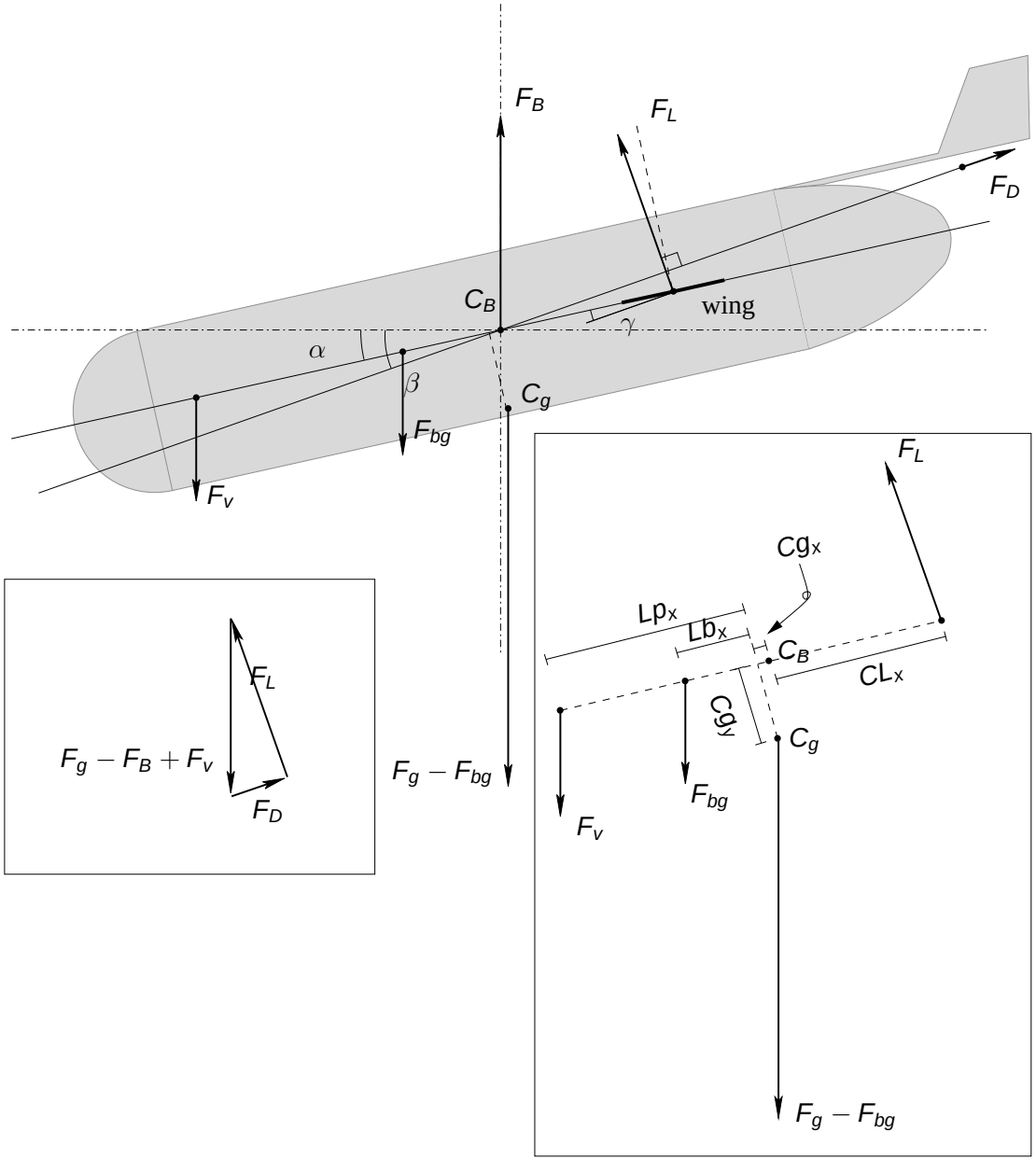


GTI model highlights

- considers all forces on glider,
- looks up in netcdf u, v, w using cubic interpolation,
- and T and S using tri-linear interpolation,
- user prescribed waypoints, gliding angles etc.,
- freely available from our website,
- C-code.



GTI model highlights



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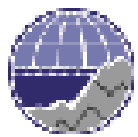
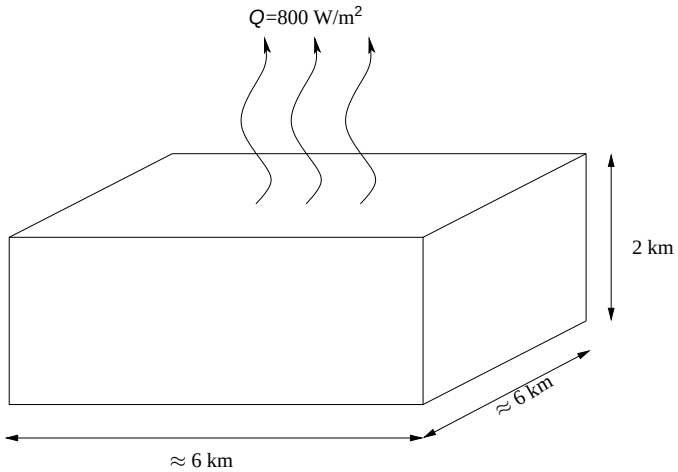
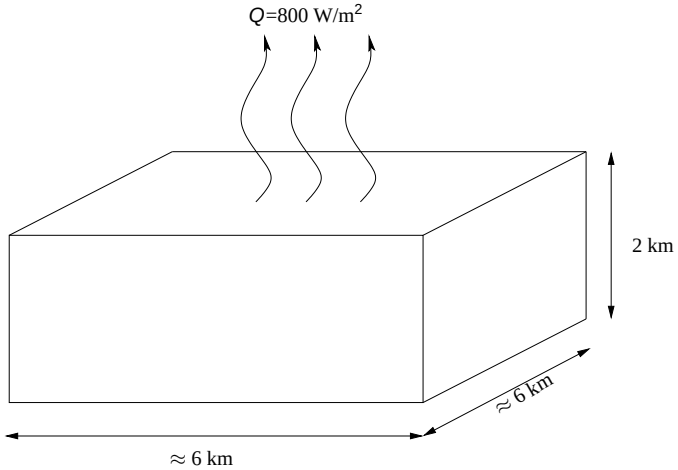
Web: http://www.noc.soton.ac.uk/omf/lmm/glider

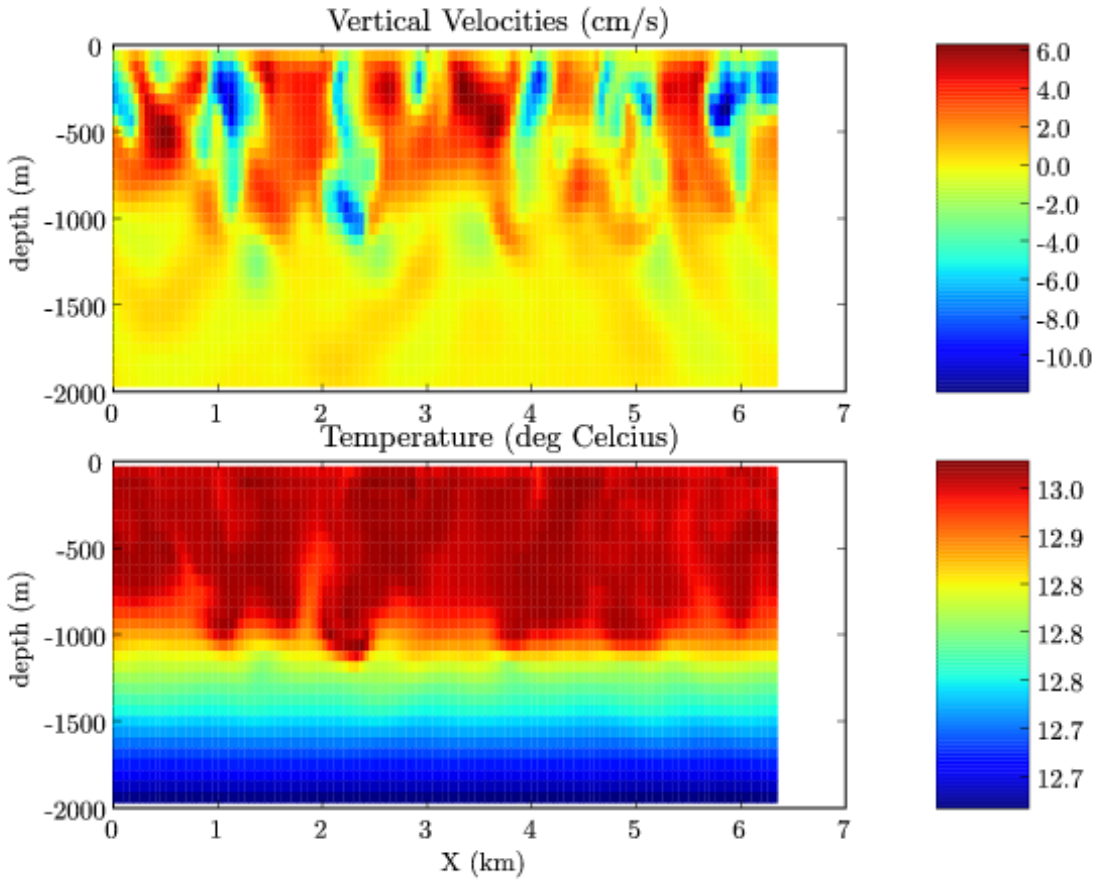


Model setup

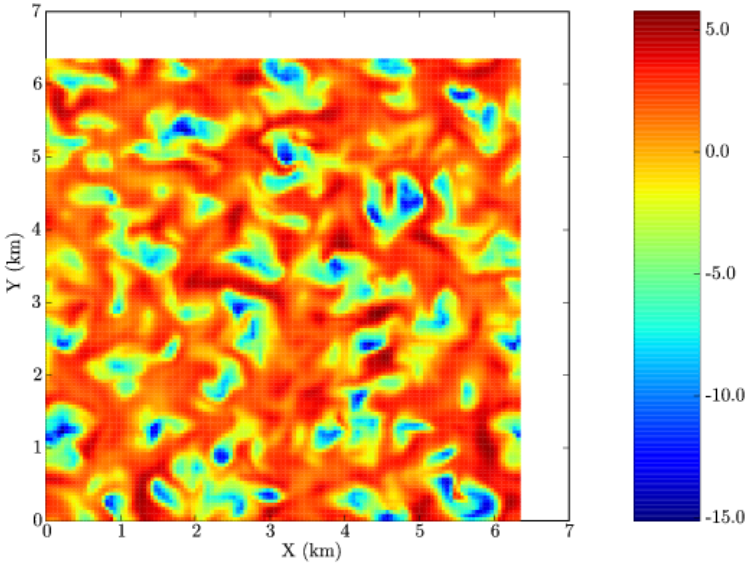


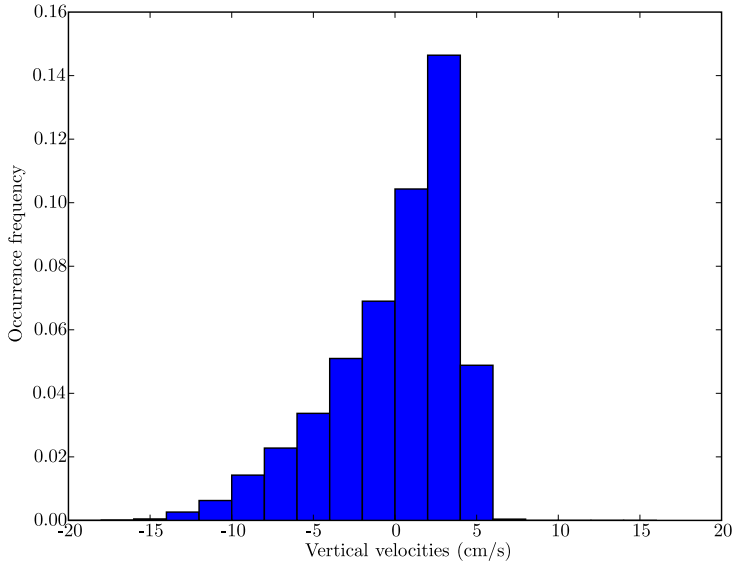
Model setup


Q=800 W/m²
2 km
≈ 6 km
≈ 6 km

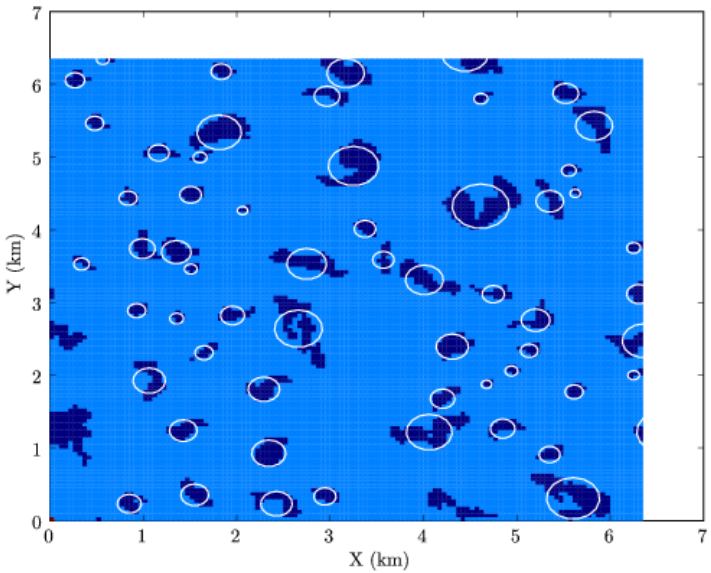

Vertical Velocities (cm/s)
depth (m)
0
-500
-1000
-1500
-2000
0 1 2 3 4 5 6 7
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
Temperature (deg Celcius)
depth (m)
0
-500
-1000
-1500
-2000
0 1 2 3 4 5 6 7
X (km)
13.0
12.9
12.8
12.8
12.8
12.7
12.7

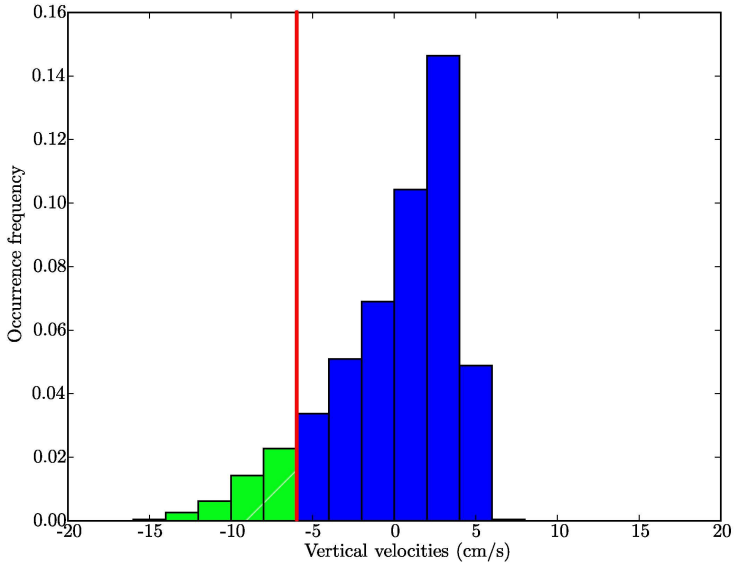
Plumes


Y (km)
X (km)
0
1
2
3
4
5
6
7
5.0
0.0
-5.0
-10.0
-15.0


Occurrence frequency
Vertical velocities (cm/s)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
-20
-15
-10
-5
0
5
10
15
20

Plumes


Y (km)
X (km)
0
1
2
3
4
5
6
7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0.00
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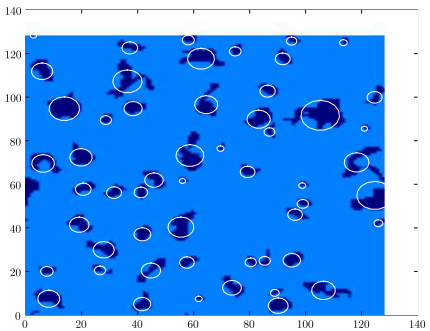
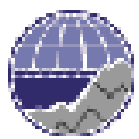
0.06
0.08
0.10
0.12
0.14
0.16
-20
-15
-10
-5
0
5
10
15
20

Some numbers...

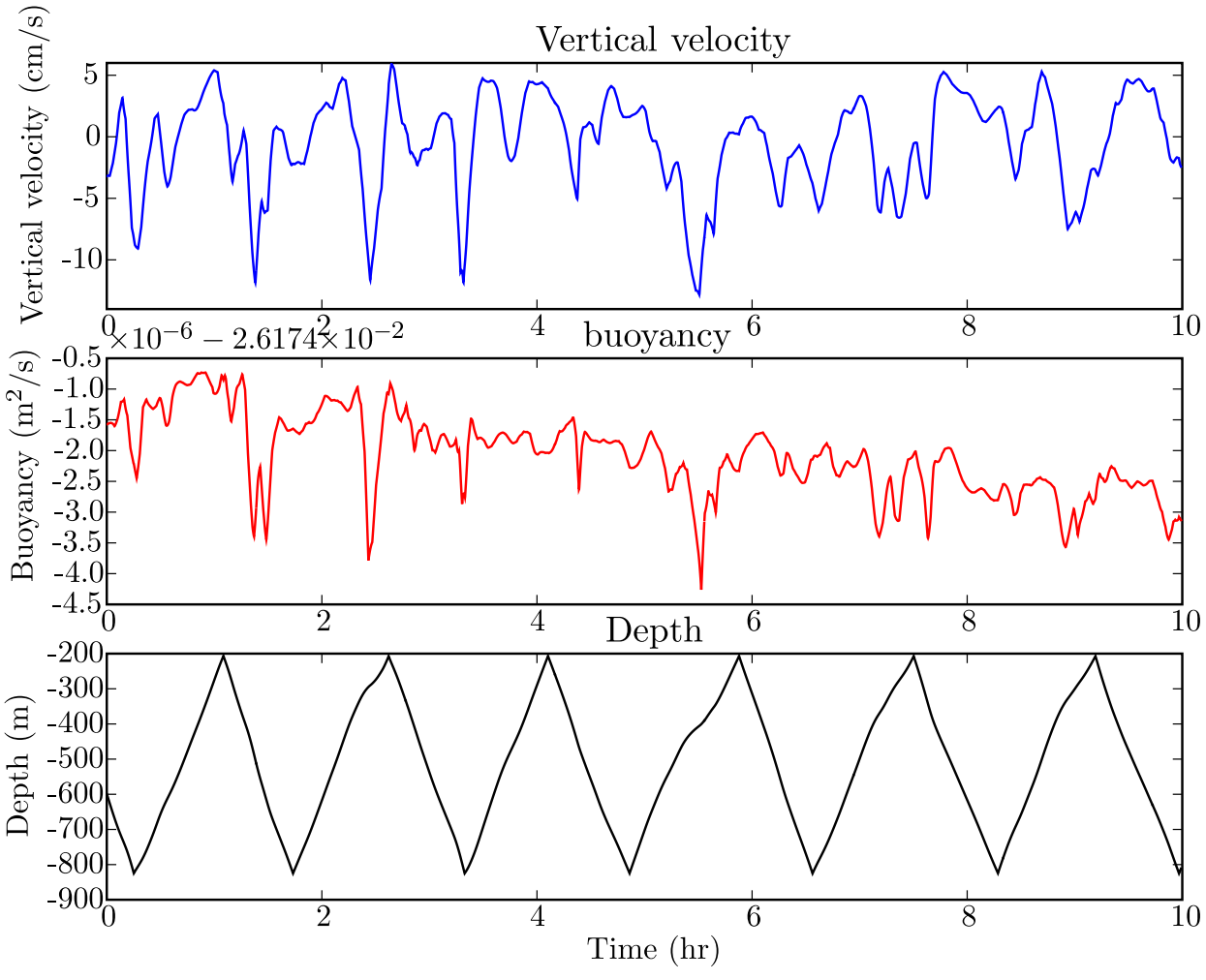


Plume density:	0.11	-
Average plume size:	$\approx$ 300	m
Number of plumes:	59	-
Averaged distance between plumes:	$\approx$2	km

Can we measure these numbers from glider data?

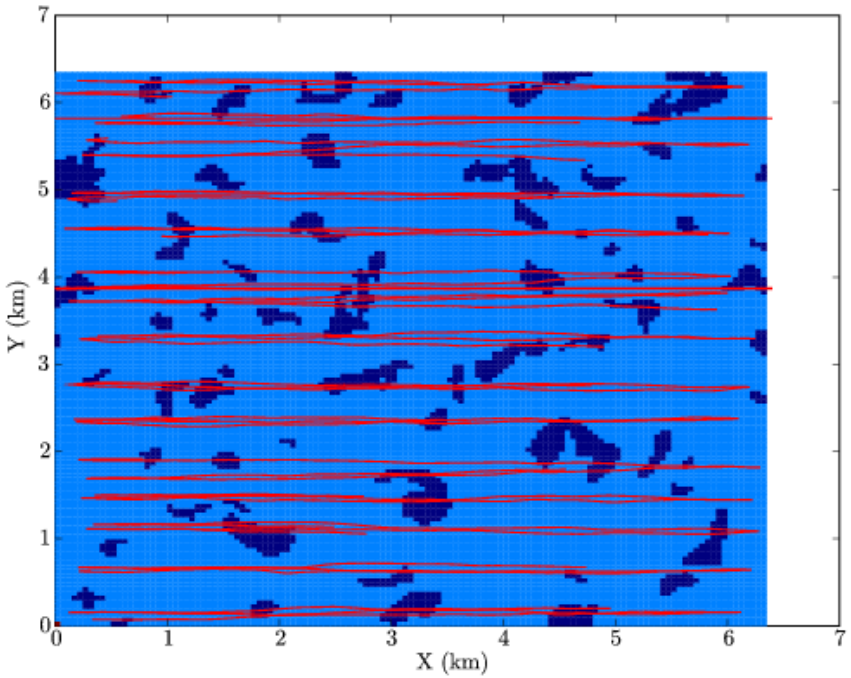


Glider time series...



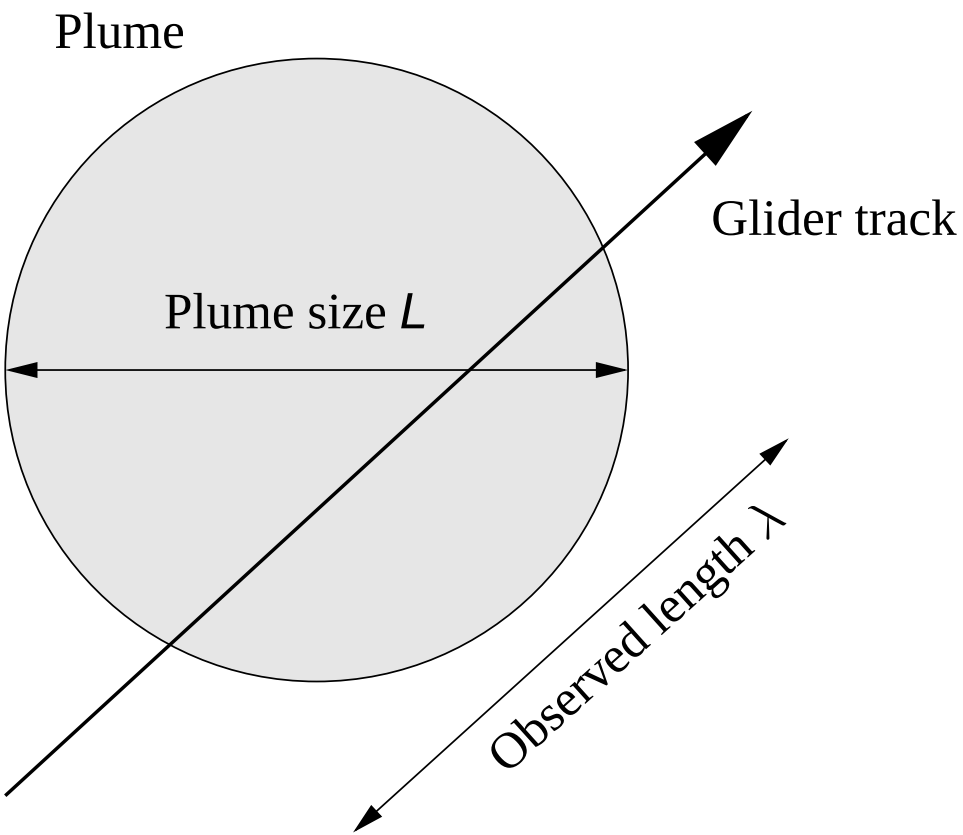
Plume density

Using 15 gliders:



Plume density MITgcm:	0.11
Plume density GTI:	0.11
# plumes MITgcm:	59
# plumes GTI:	67

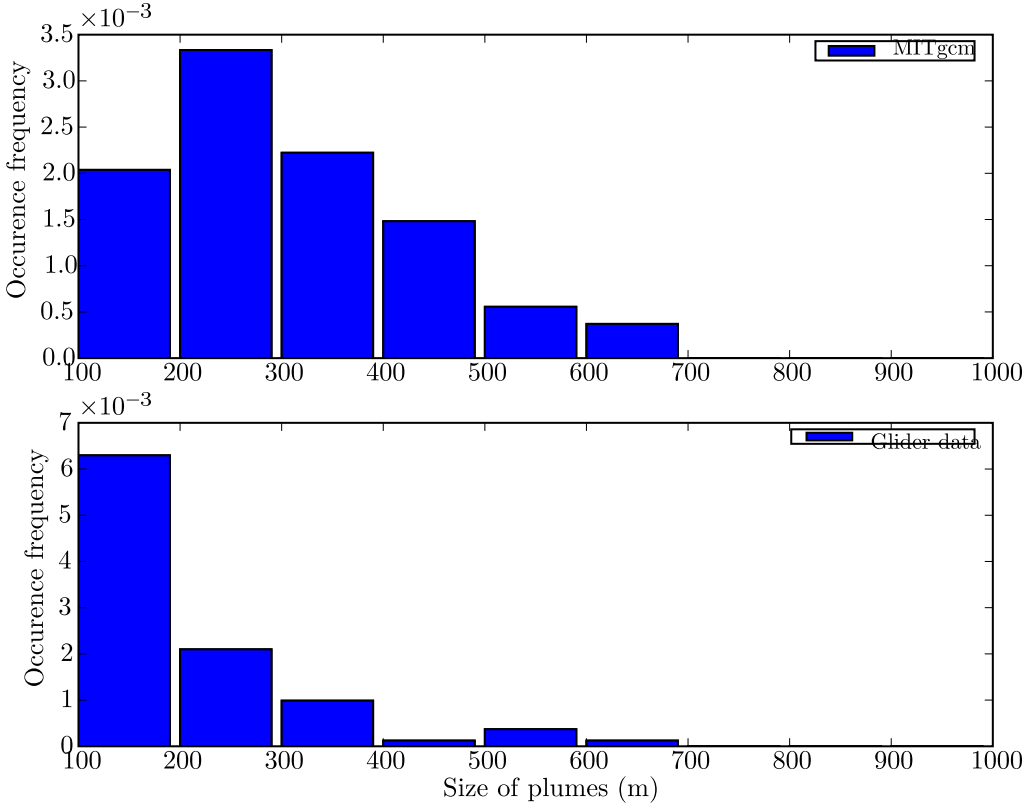
Plume sizes



Expected value observed length:

$$E(\lambda) = \frac{\pi L}{4}$$

Plume sizes

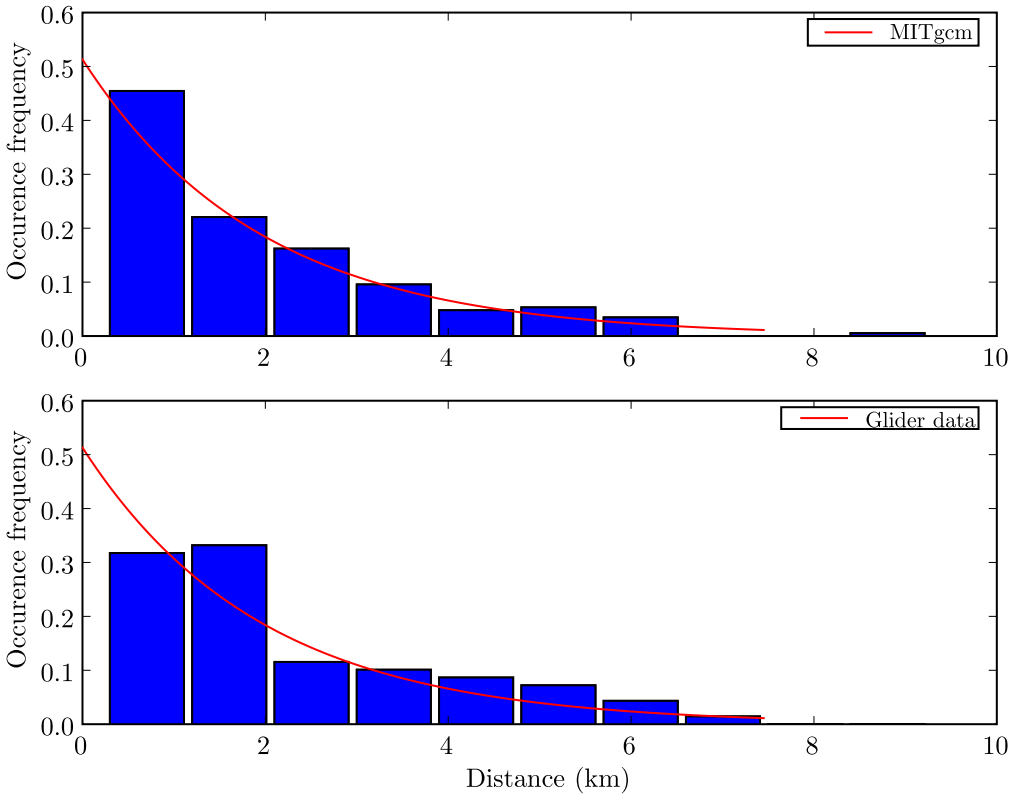


Average plume size MITgcm : 304 m

Average observed plume size GTI : 212 m

Average plume size GTI : 270 m

Plume–Plume distances

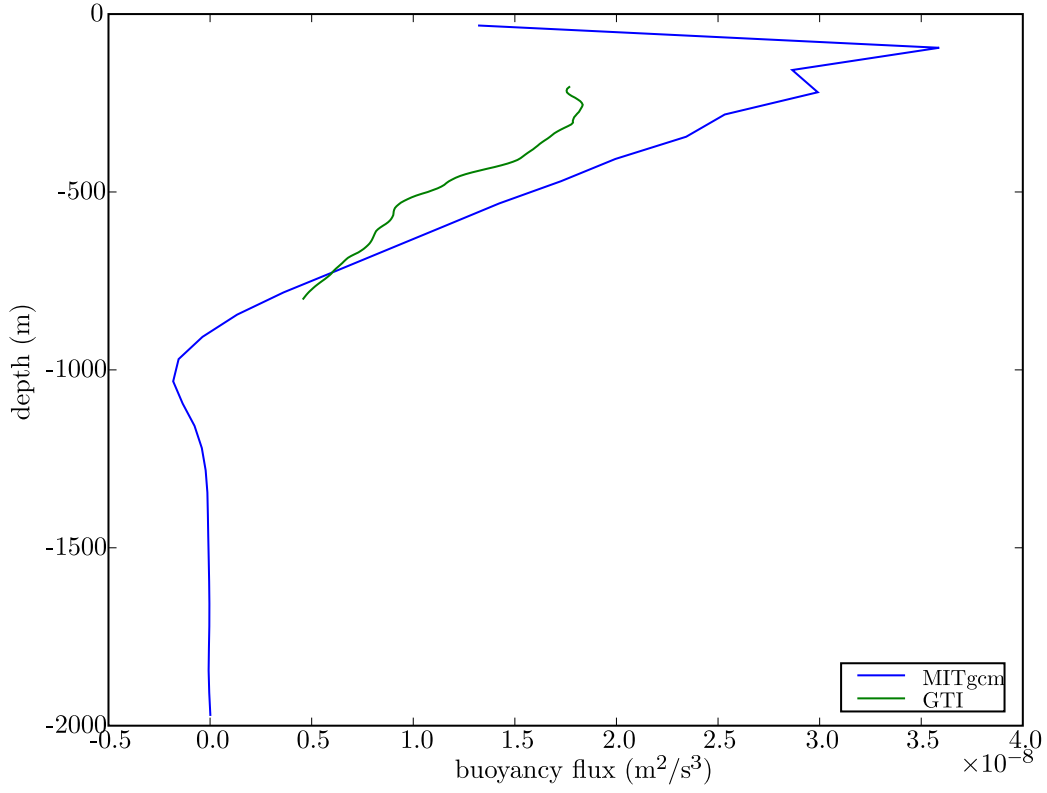


Average plume–plume distance MITgcm: 1.9 km

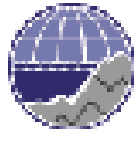
Average plume–plume distance GTI : 2.3 km

Buoyancy fluxes

Buoyancy flux = $\overline{w'b'}$



- Need many data to compute averages
- Need high quality estimates of vertical water velocities



Vertical velocity estimate

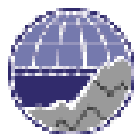
Vertical velocity of glider with respect to fixed reference frame:

$$w \approx \frac{1}{\rho g} \frac{\mathrm{d}P}{\mathrm{d}t}$$

which can be decomposed into:

$$w = w_{\text{glider}} + w_{\text{ambient water}}$$

What is w_{glider}?



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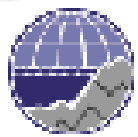
What is w_{glider}?

Optimally tuned glider dynamics model yields best estimate for vertical velocity from pressure fluctuations.

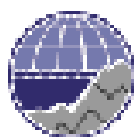


Tuning the GTI model

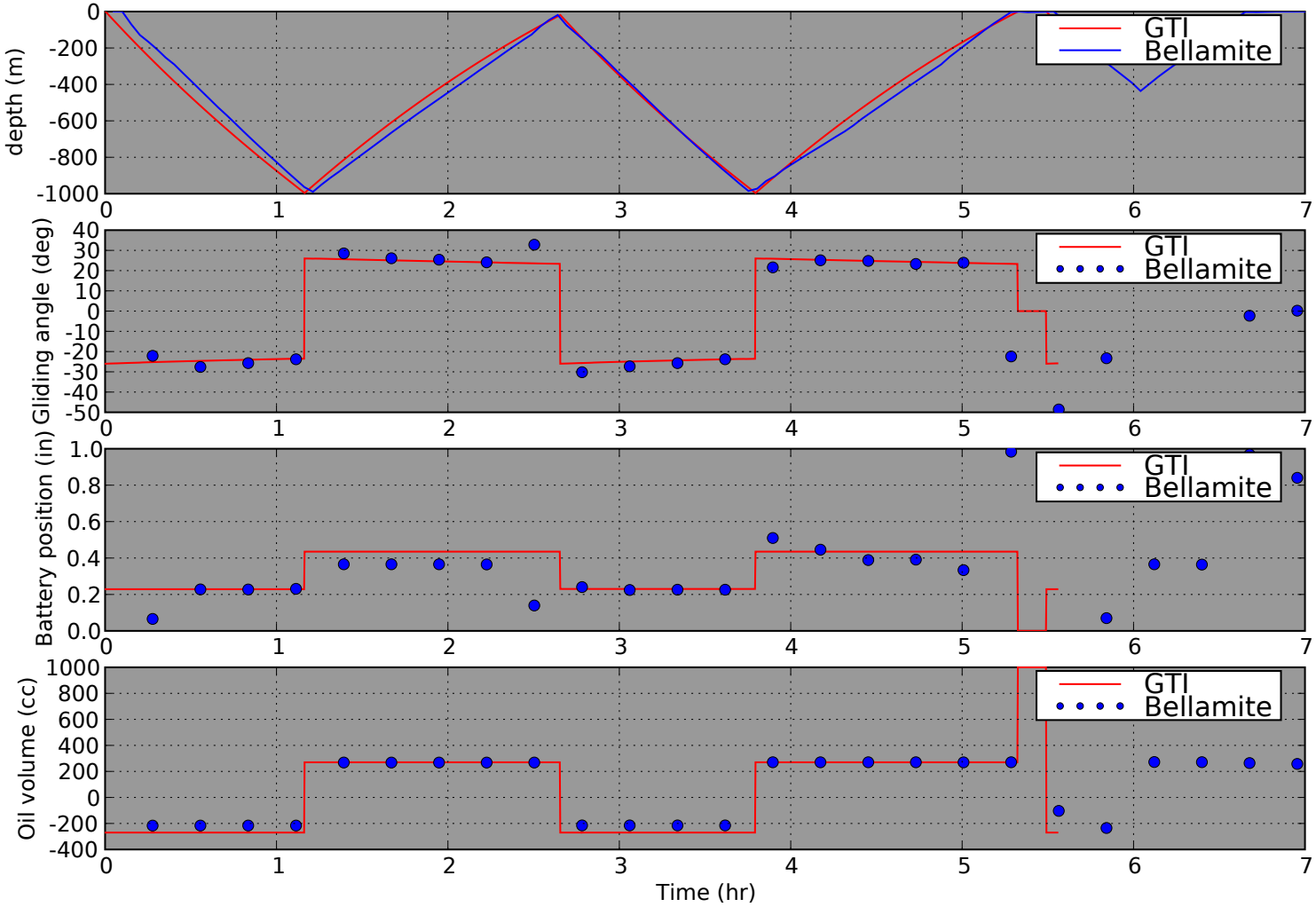
Comparing real glider data (*Bellamite* Mallorca trials April 2006) with GTI model:

Tuning paramters (short list):

- mass
- volume
- drag coefficients
- centre of mass(es)
- battery pack position
- ...



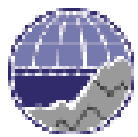
Data from GTI model and a mission from Bellamite



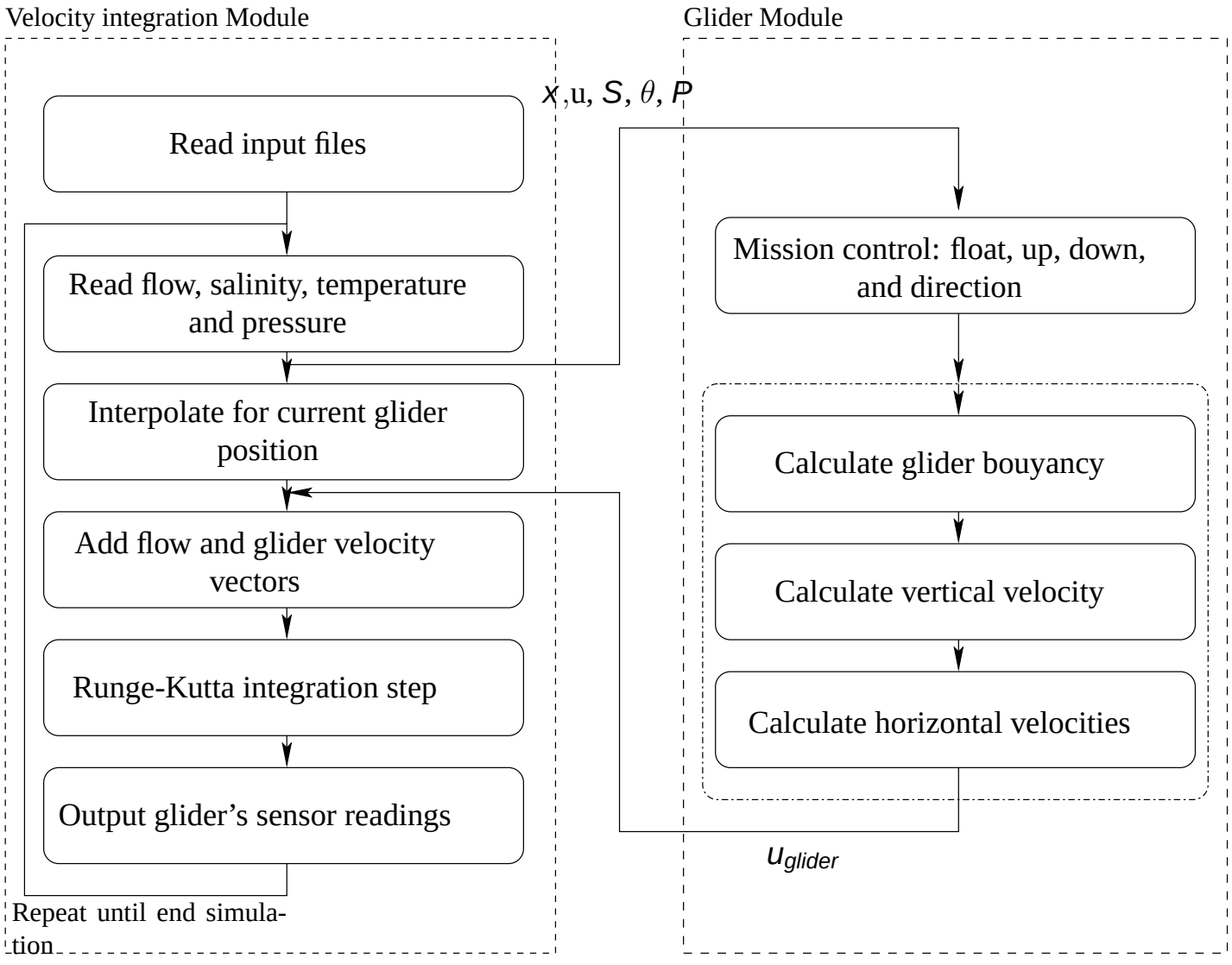
Conclusions

GTI:

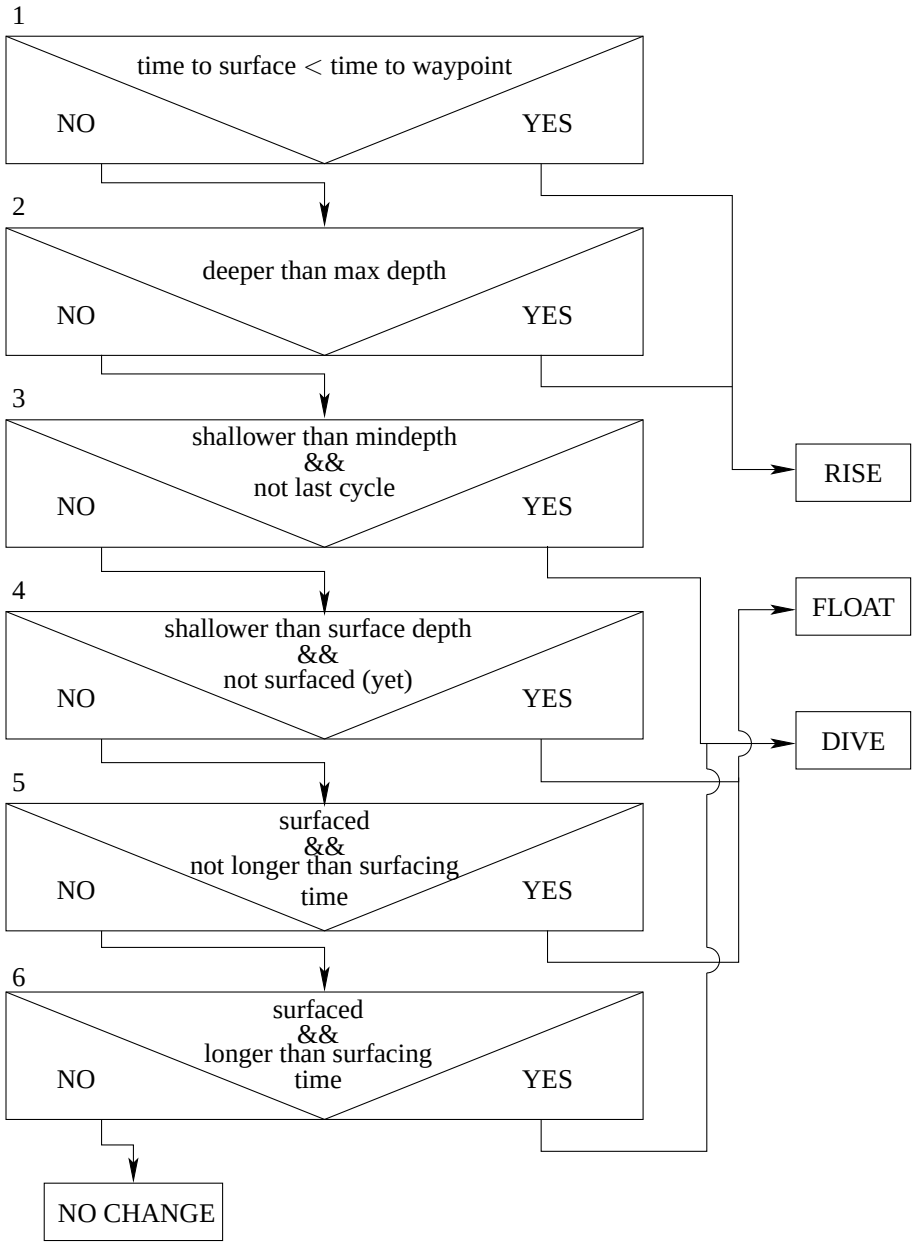
- Research tool
  - What to expect from glider data when flown in a convective area?
  - Evaluating sampling strategies.
- Tuning glider's dynamic model
  - Allows accurate as possible vertical flow velocity estimates.



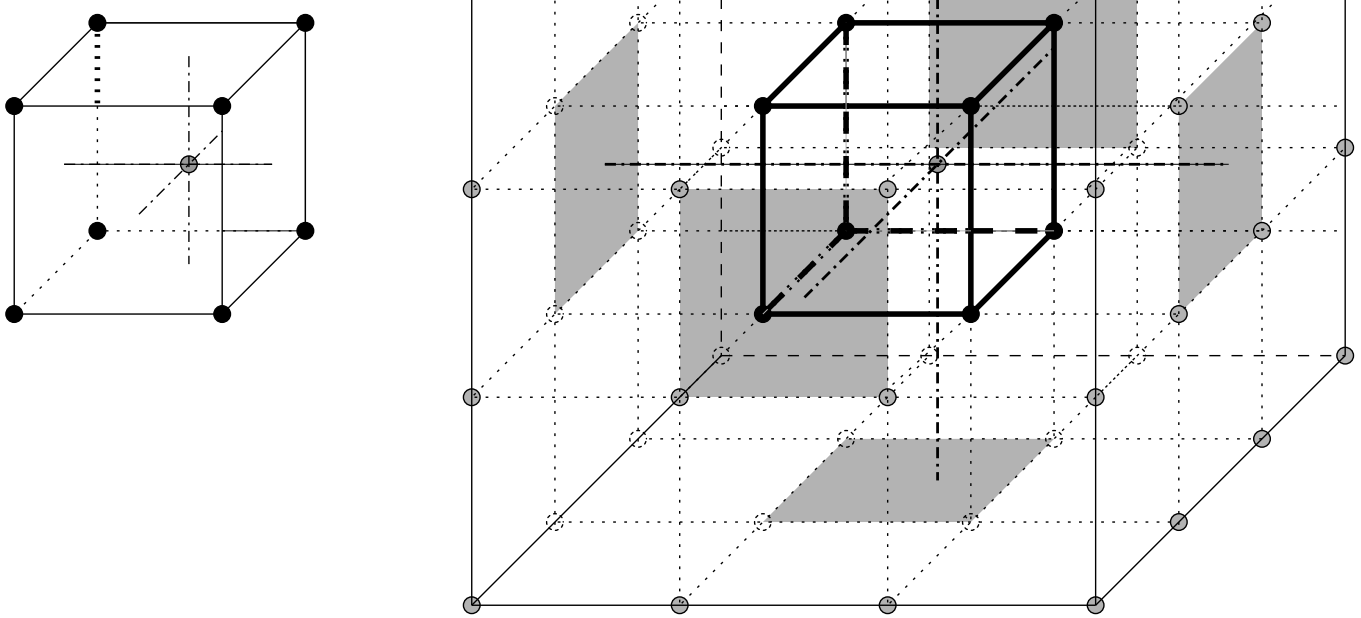
GTI model overview



GTI mission control



MITgcm data interpolation



The equations...

The vertical and horizontal components of the force balance:

$$F_g - F_B + F_v - \cos\beta F_L - \sin\beta F_D = 0$$
$$\cos\beta F_D - \sin\beta D_L = 0$$

The lift force (thin plate-shaped wings):

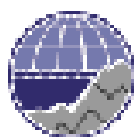
$$F_L = \pi\gamma\rho A_w U^2$$

The drag force F_D

$$F_D = \frac{1}{2} C_{dg}\rho A_g U^2$$

Torque balance:

$$\cos\alpha(F_g - F_{bg})Cg_x + \cos\alpha F_v Lp_x + \cos\alpha F_{bg} Lb_x$$
$$- \sin\alpha F_g Cg_y + \cos\gamma F_L C_{Lx} = 0.$$



The equations...

$$\gamma = \frac{C_{dg} A_g}{2\pi A_w \tan(\alpha + \gamma)}$$

$$\tan\alpha = \frac{(F_g - F_{gb})Cg_x + \cos^2\gamma C_{Lx}(F_g - F_B + F_v) + Lb_x F_{gb} + Lp_x F_v}{(F_g - F_{gb})Cg_y + \cos\gamma \sin\gamma C_{Lx}(F_g - F_B + F_v)}.$$

1. set $\gamma = 0$
2. calculate α
3. calculate γ
4. loop back to 2, unless converged.