



Heat flux and hydrography at the Main Endeavour vent field

*MGG seminar and Final Examination
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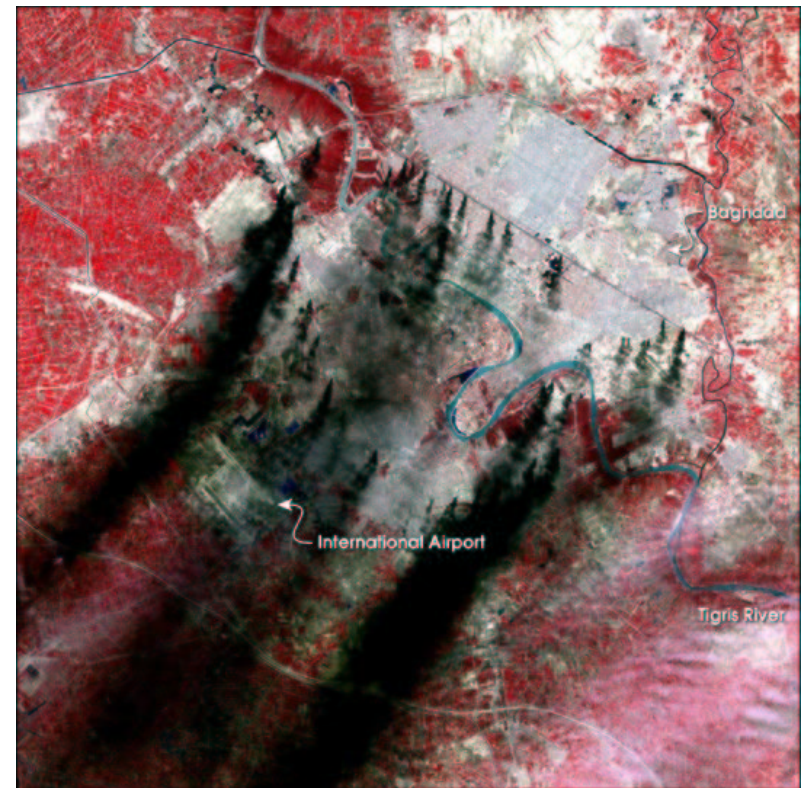
Motivation

Plumes in cross flow:

- Atmospheric →
- In the ocean

Plume flux & form implications:

- Crustal formation
- Ocean chemistry
- Habitat & dispersal
- Global heat budget



NASA Earth Observatory



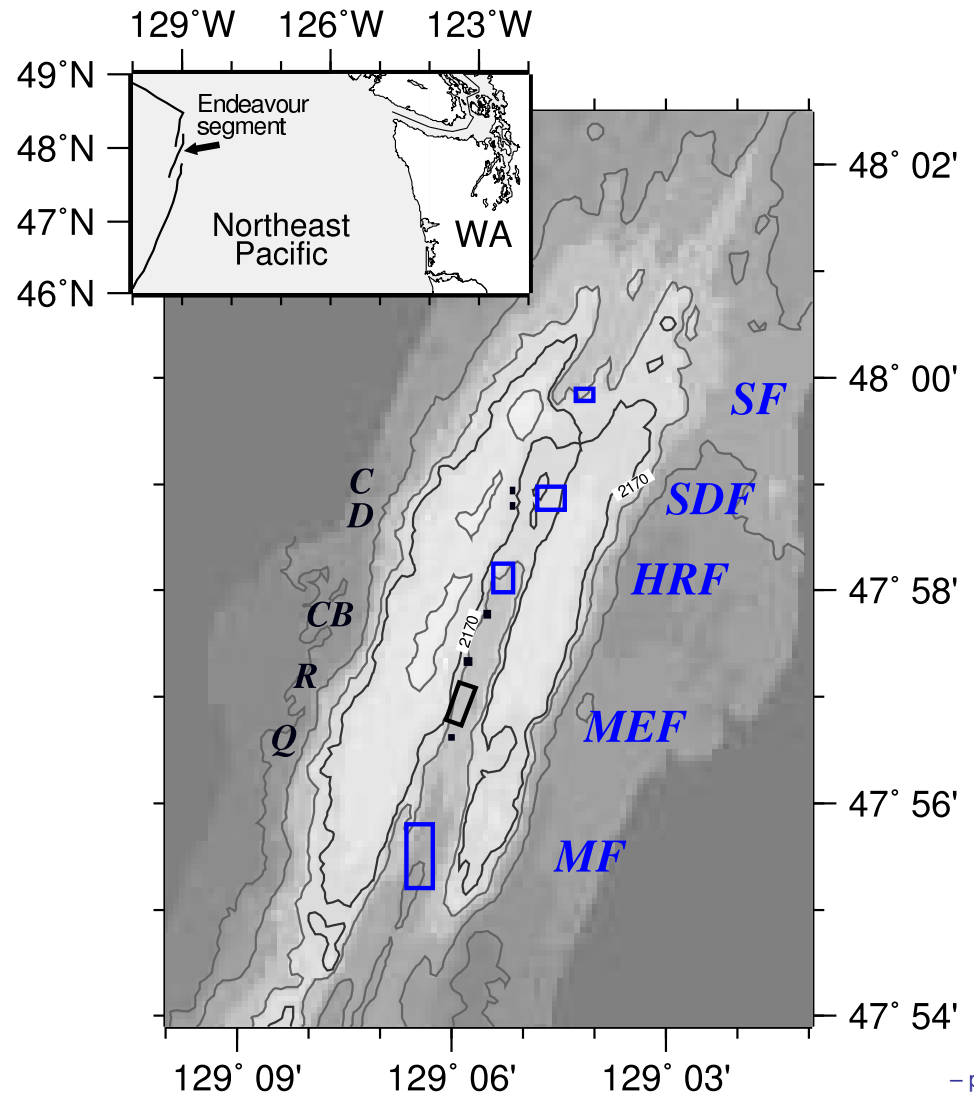
Outline (~45 minutes)

- (10) The Flow Mow study
- (10) Current results
- (5) Model results
- (10) Heat flux results
- (5) Conclusions
- (5) Acknowledgements

Flow Mow study site: Endeavour segment

Orientation:

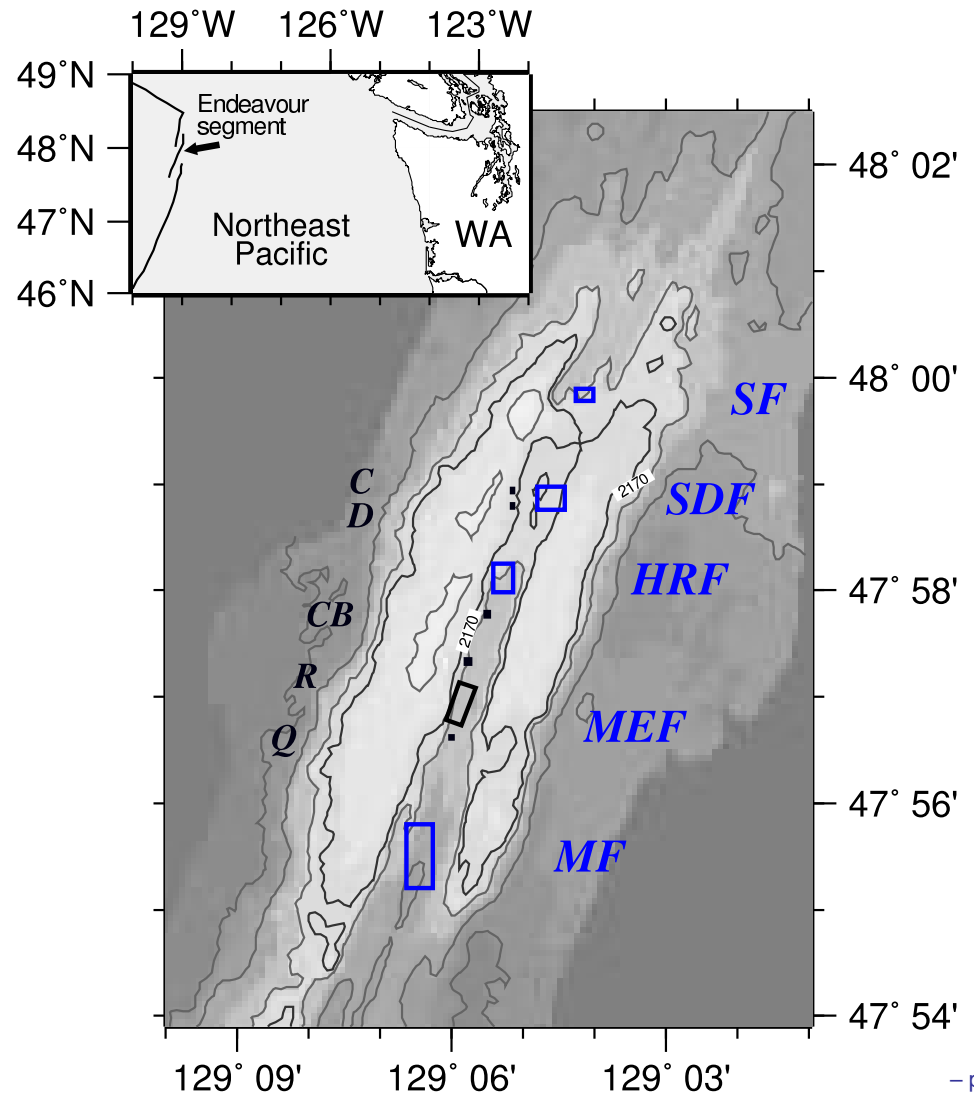
■ Start: $47^{\circ}54.5'N$



Flow Mow study site: Endeavour segment

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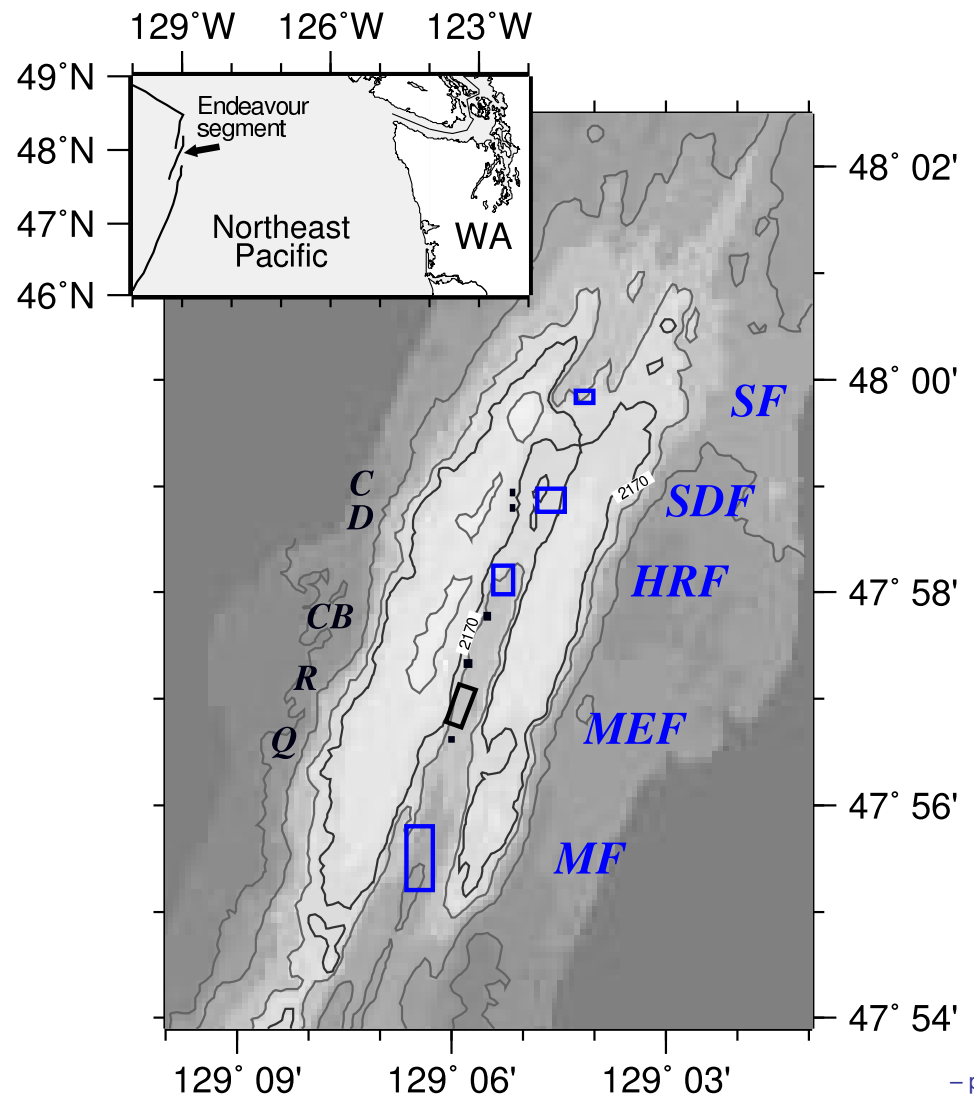
- Start: $47^{\circ}54.5'N$
- ~ 300 m relief;
crest ~ 2100 m



Flow Mow study site: Endeavour segment

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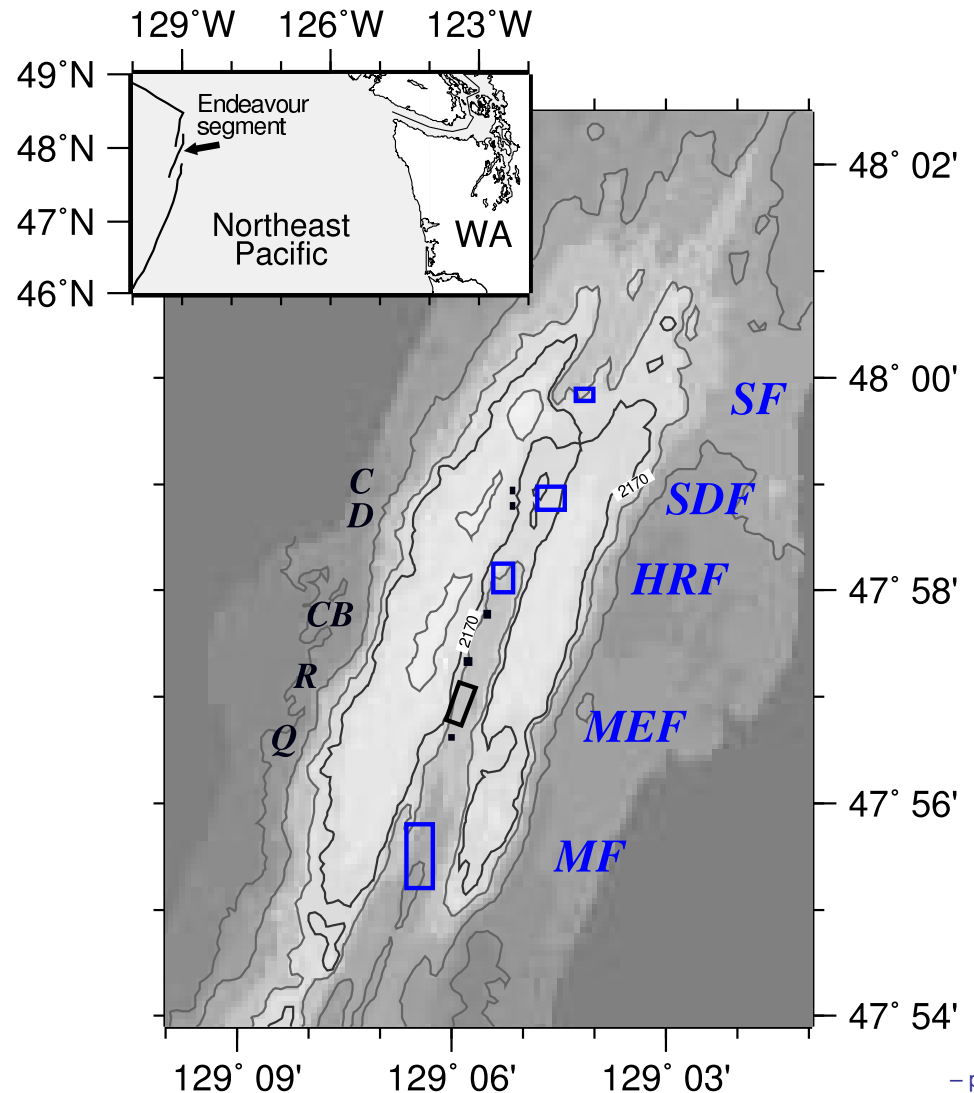
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- Valley 10 km
long, 1 km wide,
100 m deep



Flow Mow study site: Endeavour segment

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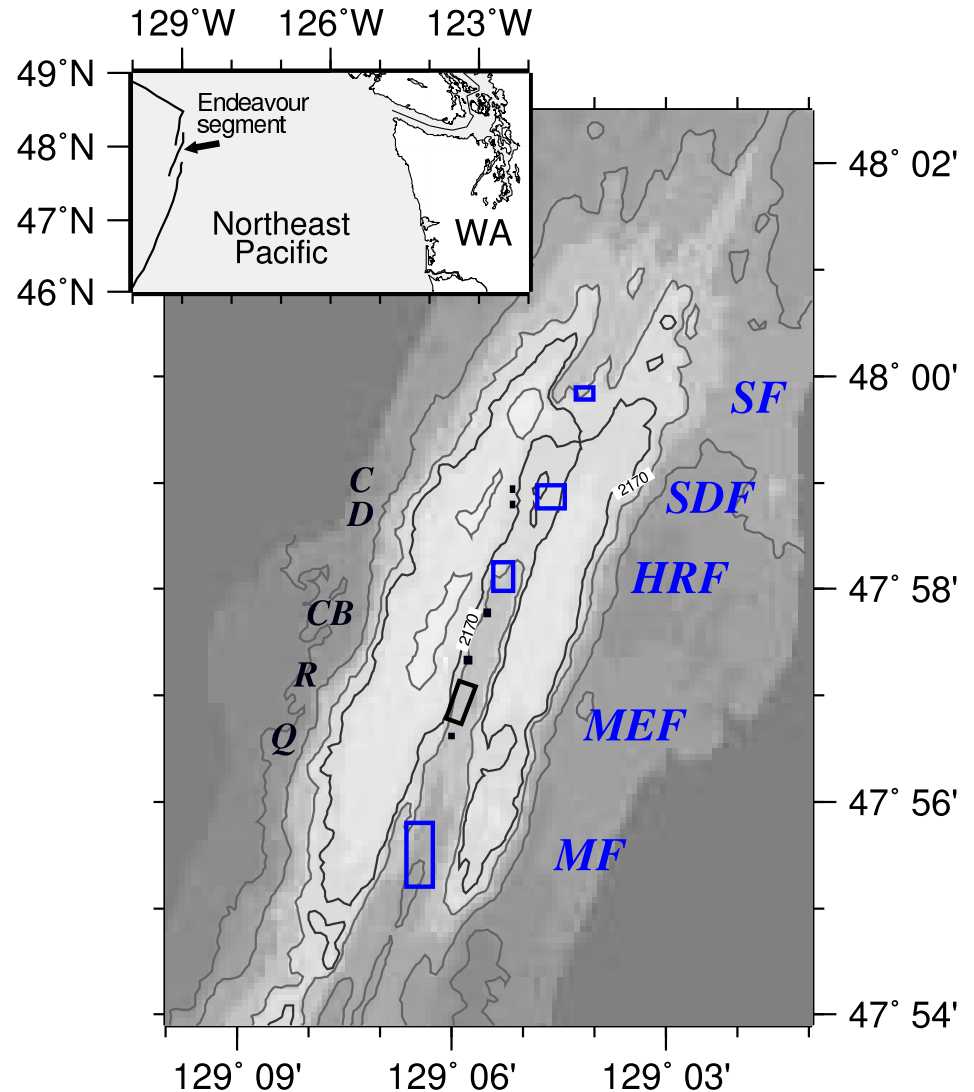
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Flow Mow study site: Endeavour segment

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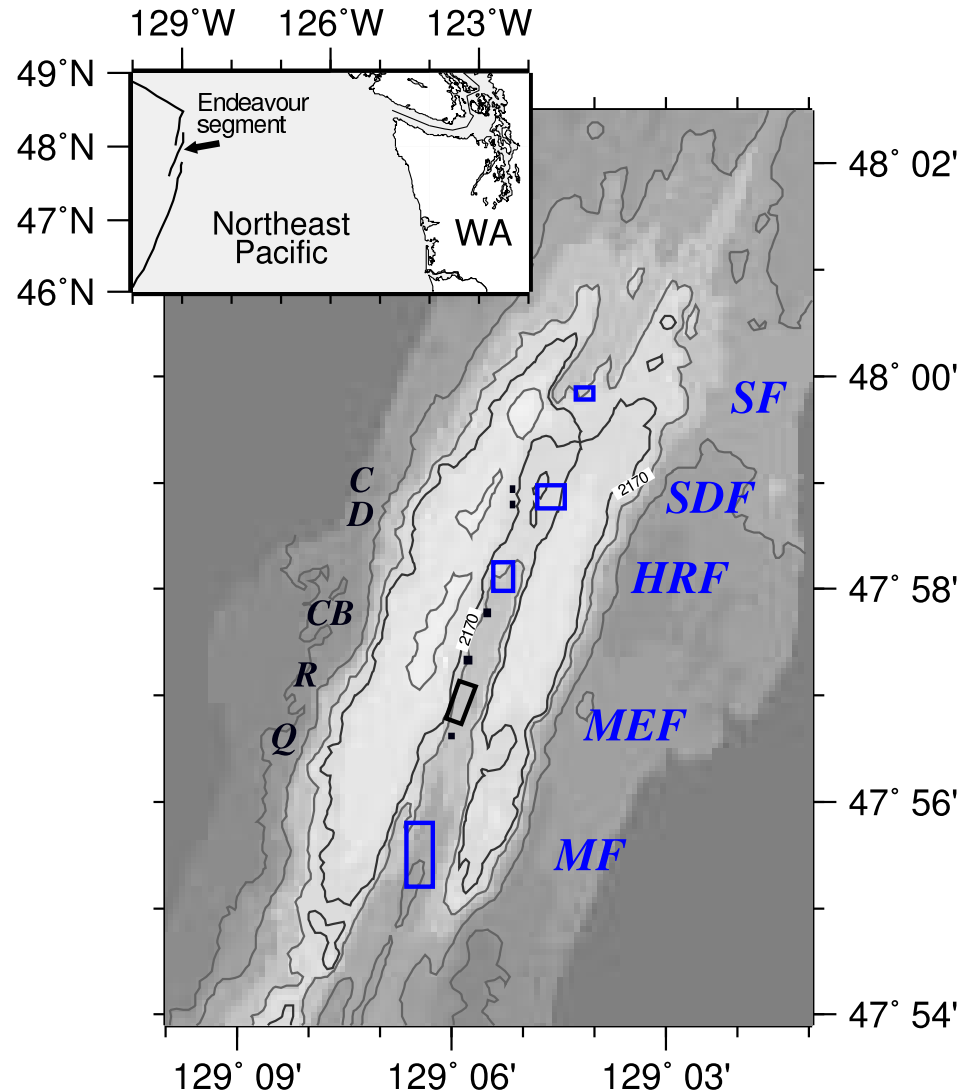
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- Vent fields
 ~ 2 km spacing?



Flow Mow study site: Endeavour segment

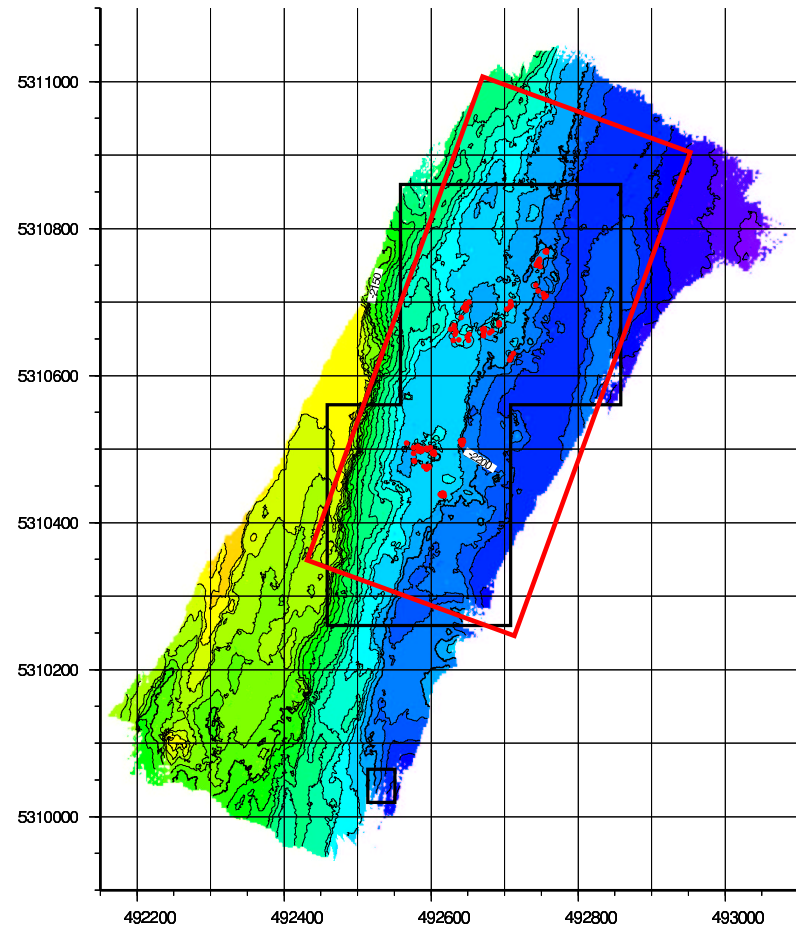
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 ~ 2 km spacing?



Main Endeavour vent field (MEF)

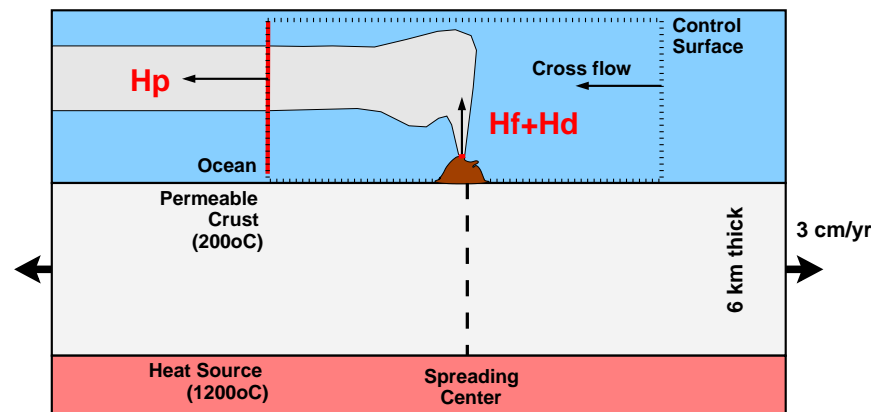
- Geology mapped very well
- 110 focused “smokers”
- Diffuse flow
- 300×700 m control volume
- Max rise height ~ 300 m



MEF heat flux puzzles

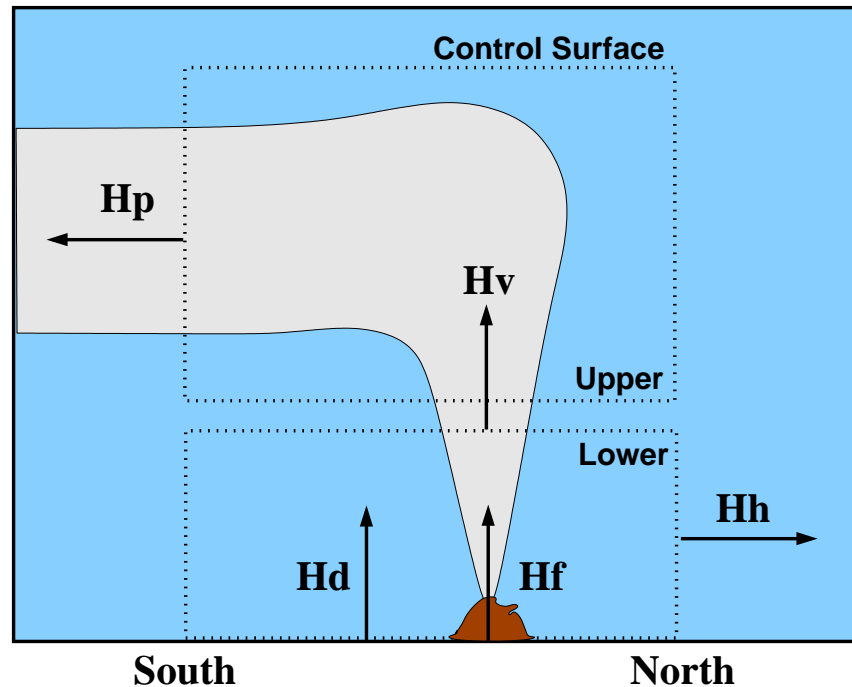
Power loss per km of ridge:

$$H_f + H_d \simeq H_R = Q_R \left(L_r + \int_{1200}^{200} c_r(T) dT \right) = 42 \text{ MW/km} \implies 84 \text{ MW MEF long-term mean}$$



Study	Estimate [MW]	Heat flux
Ginster et al., 1994	615 ± 120	H_f
Thomson et al., 1992	2500 ± 1525	H_p
Baker & Massoth, 1987	4250 ± 2750	H_p
Schultz et al, 1992	9000 ± 760	H_d

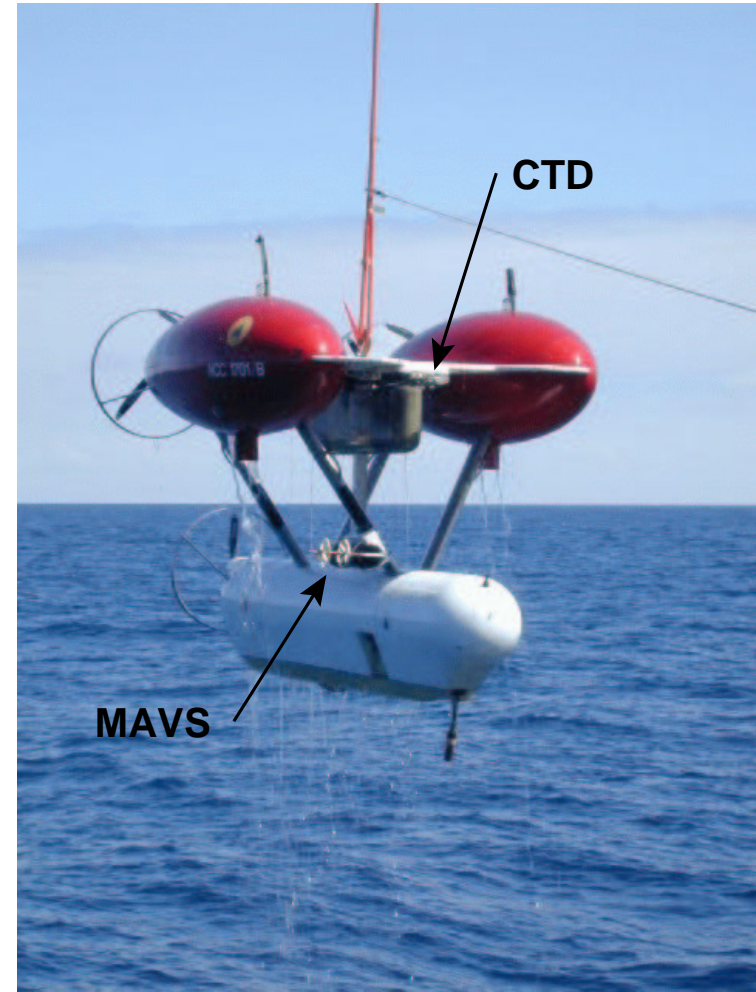
The “Flow Mow” control volume approach



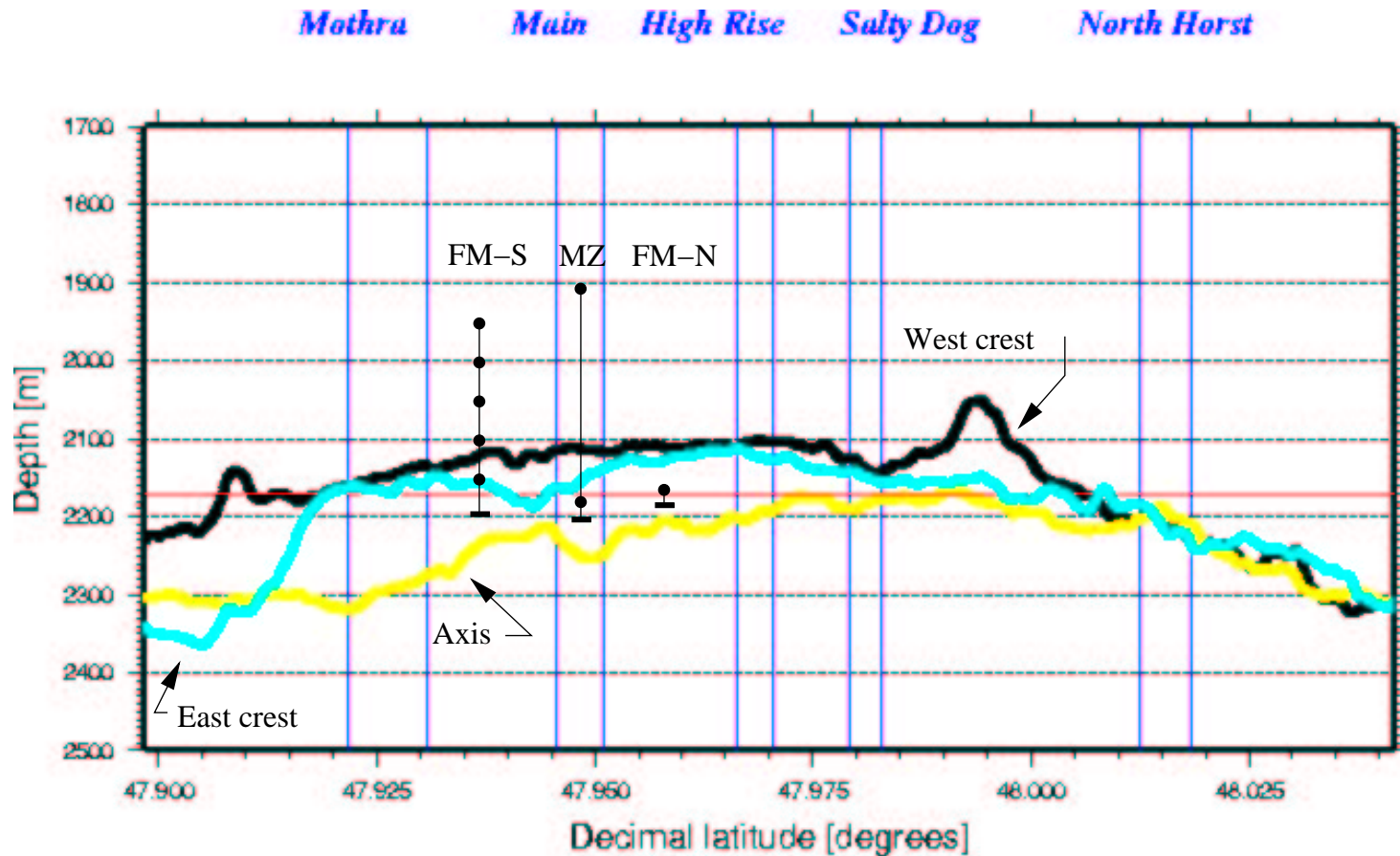
Net heat flux via *advection* through A :

$$\mathbf{H} = \int_A \rho c_p \theta \mathbf{u} \cdot \hat{\mathbf{n}} dA \simeq \rho c_p \sum_{i=1}^N \Delta_S \theta_i u_i \Delta A_i \simeq \rho c_p \overline{\Delta_S \theta} \bar{u} A$$

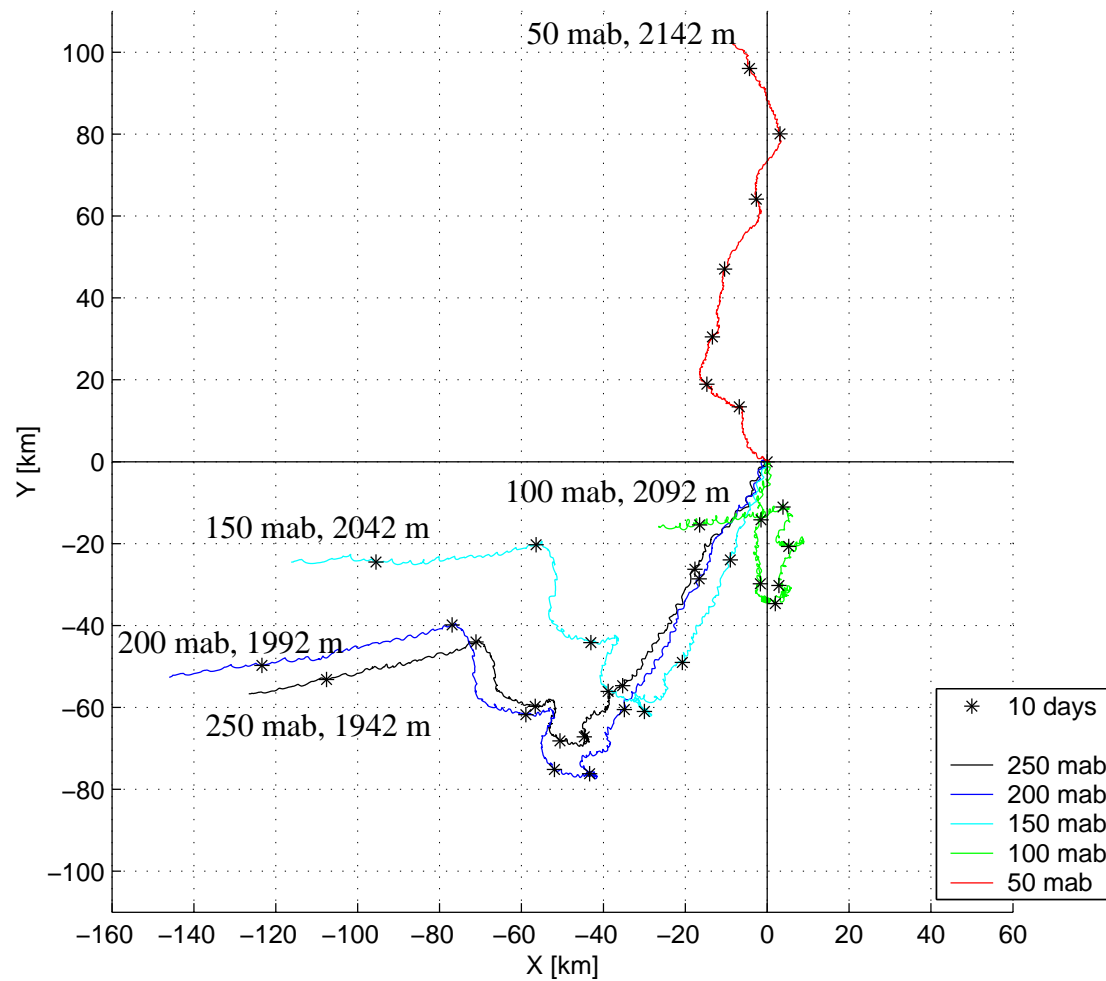
Instruments: CTD & ABE



Instruments: Current meters



Mean flow



Oscillatory flow over ridge

Δx_c

■ ~ 2.2 km above ridge

■ ~ 1.3 km in valley

$\Delta x_{\bar{u}}$ in 12 hr:

■ ~ 2.2 km at 5 cm/s

■ ~ 0.5 km at 1 cm/s

Animation

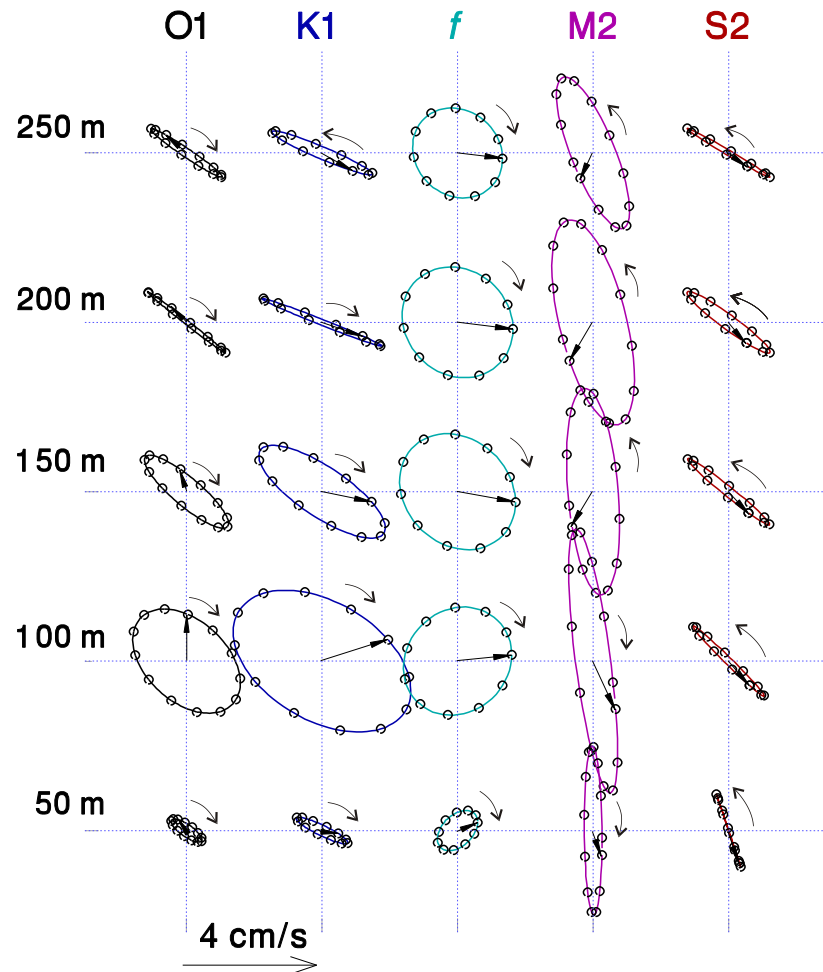
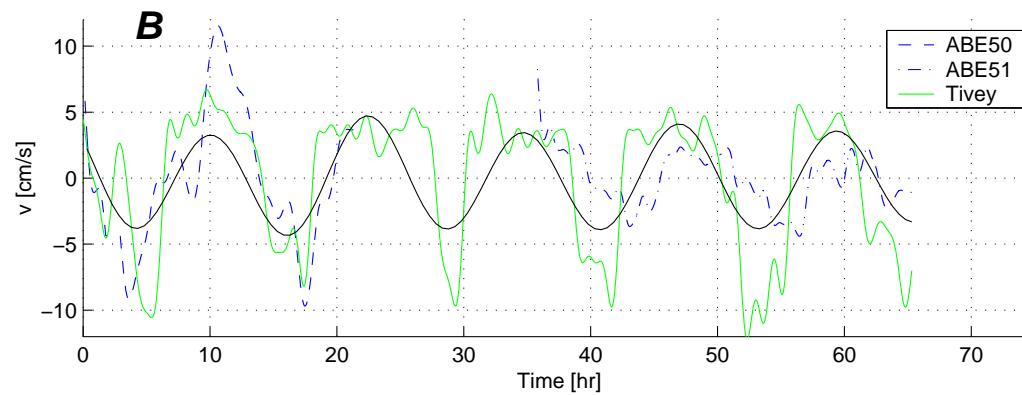
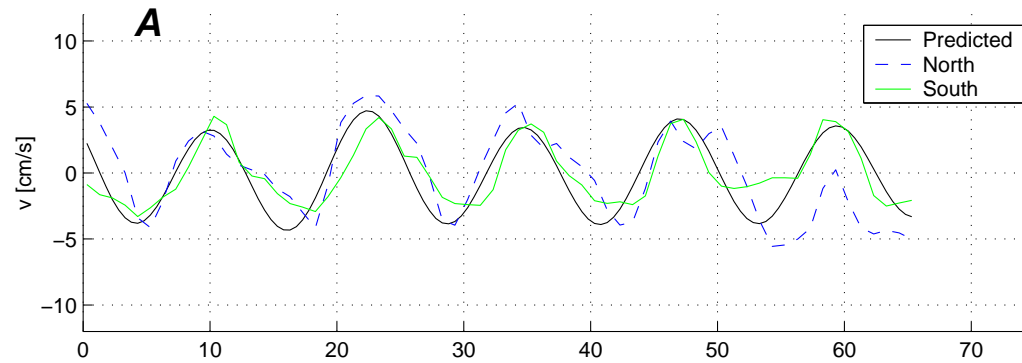


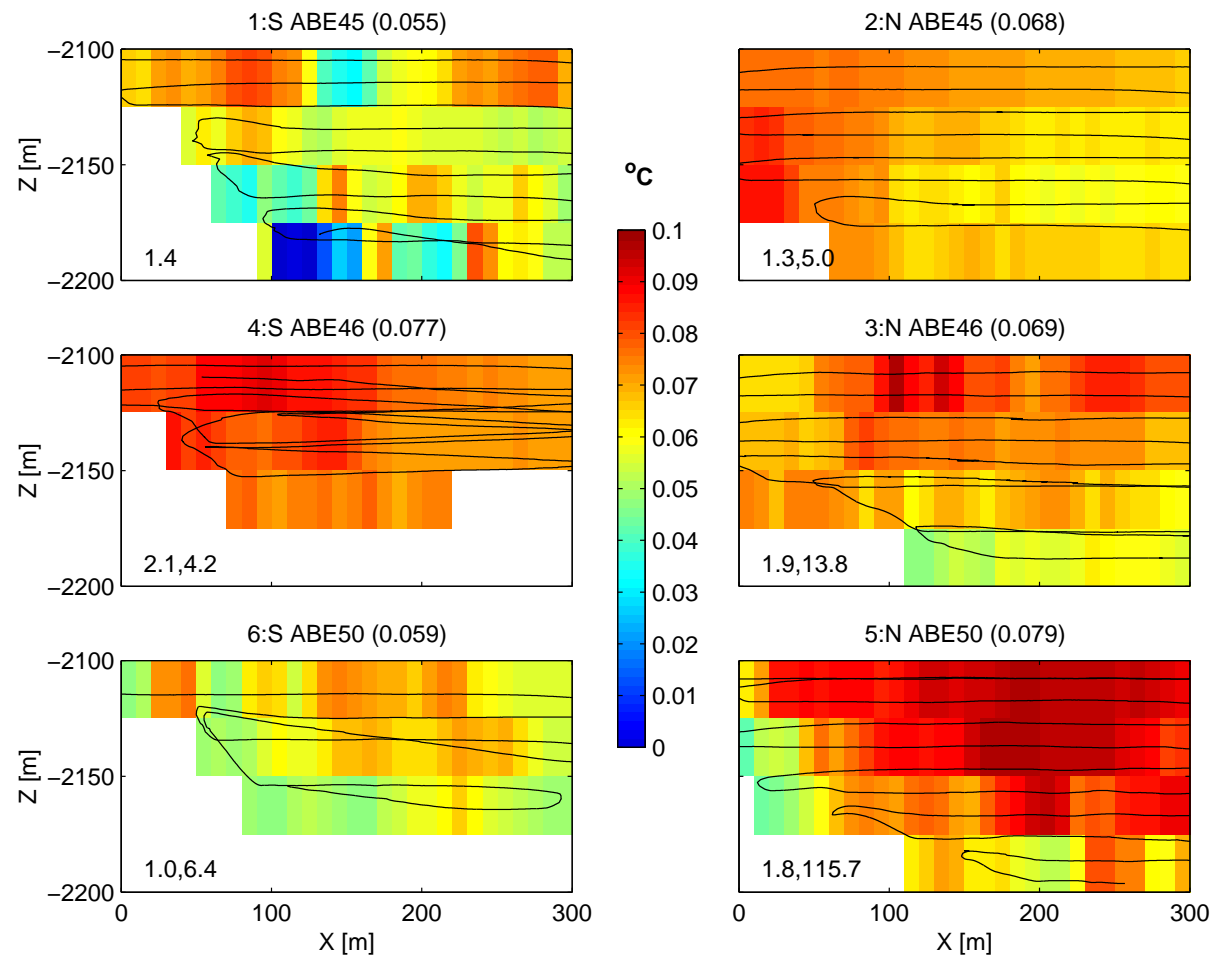
Figure courtesy Rick Thomson, IOS Canada

Oscillatory flow in valley



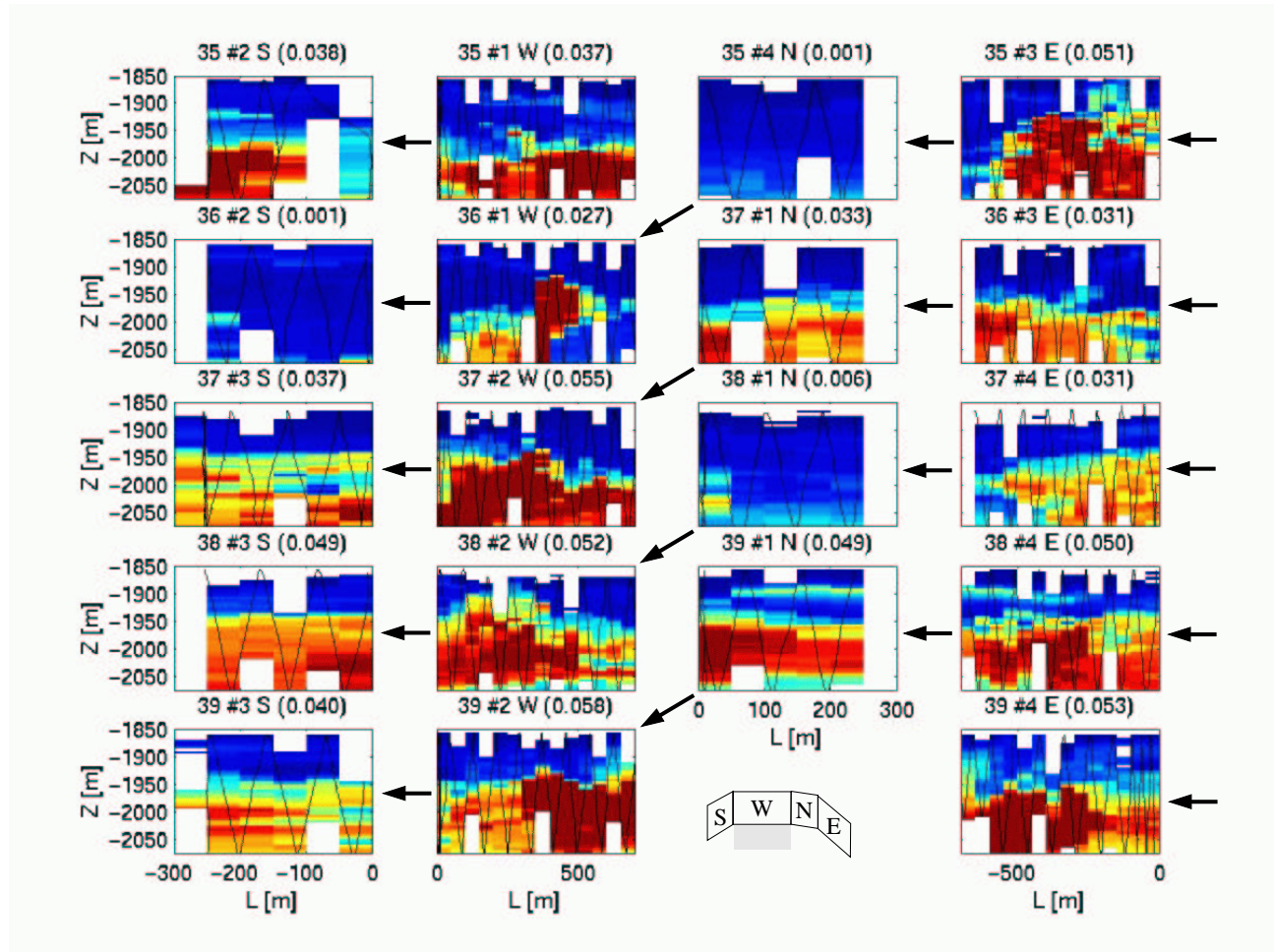
Animation

Hydrography and heat flux in the valley



$$H_h = \overline{H}_N + \overline{H}_S = \rho c_p \bar{u} A (\overline{\Delta\theta}_N - \overline{\Delta\theta}_S) = 80 \pm 37 \text{ MW (46\%, } \sim 50\%)$$

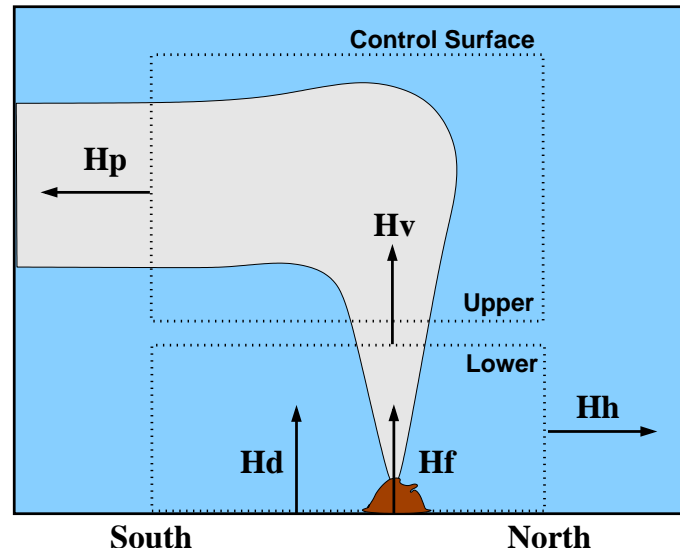
Hydrography and heat flux above the ridge



$$\overline{H_{qs}} = 442 \pm 213 \text{ MW. Max } H_{qs} \simeq +2000 \text{ MW}$$

Lower heat flux budget:

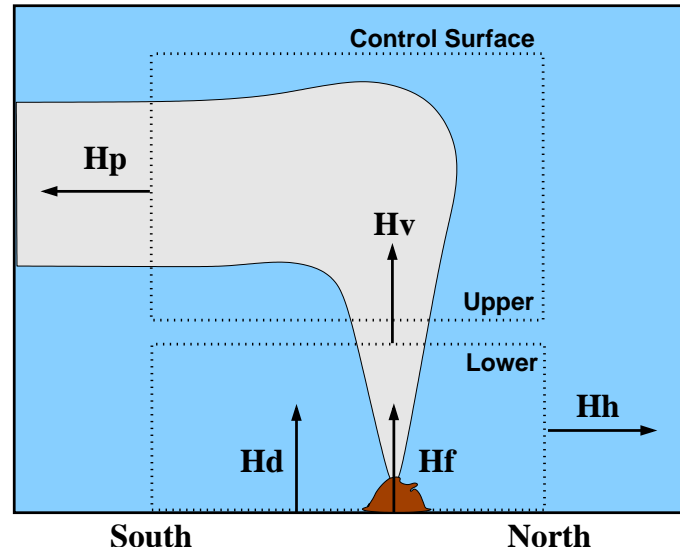
$$H_d + H_f = H_v + H_h$$



- $H_h = 80 \pm 37$ MW, $H_v = 640 \pm 115$ MW, $H_f = 615 \pm 120$ MW
- $H_d \simeq 105$ MW versus 9000 ± 760 MW (Schultz et al, 1992) and ~ 150 MW (Johnson et al, 2002)
- Partitioning of heat flux between sources:
 $H_d:H_f \simeq 100:615 \simeq 1:6$, rather than $\sim 10:1$

Upper heat flux budget:

$$H_v = H_p \simeq \overline{H_{qs}}$$



Study	Estimate [MW]	Heat flux
Stahr et al, 2003	640 ± 115	H_v
Veirs et al, 2003	442 ± 213	$\overline{H_{qs}}$
Thomson et al, 1992	2500 ± 1525	H_p
Baker & Massoth, 1987	4250 ± 2750	H_p
Rosenberg et al, 1988	3000 ± 2000	H_p

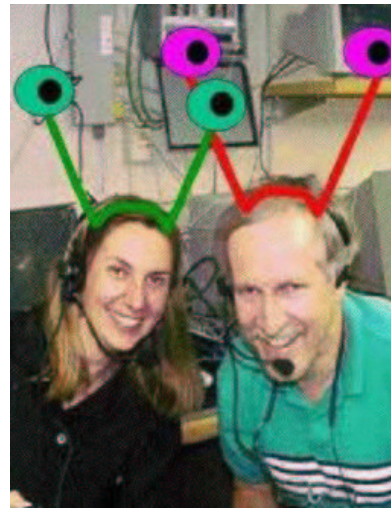


Conclusions

- Net heat flux at MEF is ~ 720 MW
 $\sim 10\times$ geologic mean of ~ 82 MW
- MEF $H_d:H_f \sim 1:6$, rather than 10:1
- Expect multidirectional flow above ridge
(high heat flux variance & $\Delta x_c = 2.2$ km)
- When oscillatory currents disperse plumes,
use a control volume to calculate *net* flux
- Expect rectilinear tidal flow and mean inflows
in valley (Sea Breeze hypothesis)

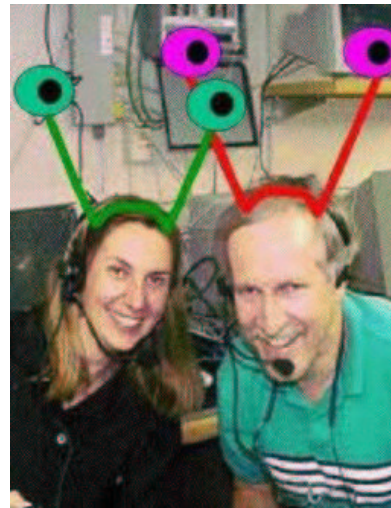
Acknowledgements

■ Russ McDuff



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- Russ McDuff
- Bill Lavelle



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- Supervisory committee members

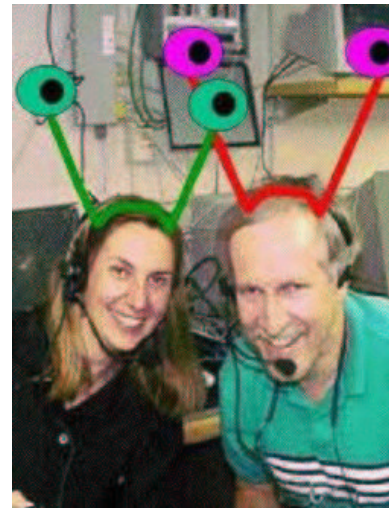
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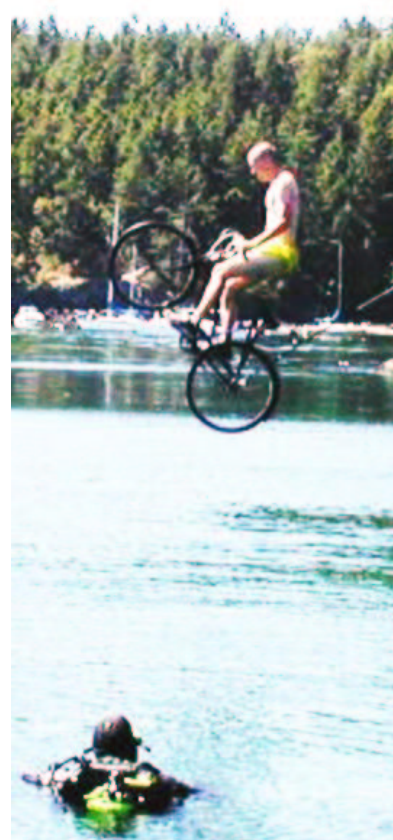
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- Family
 - Annie Reese and Mila
 - Val, Leslie, Laura, Pete



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 - Will Wilcock
 - Stephen Porter
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 - Val, Leslie, Laura, Pete
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 - Many* kind friends
 - Fritz and Christian
 - Graduate compatriots



Questions?



Daniel McDuff, Whistler cornice (*photo credit: Mark McDuff*)