Heat flux and hydrography at the Main Endeavour vent field

MGG seminar and Final Examination May 8, 2003

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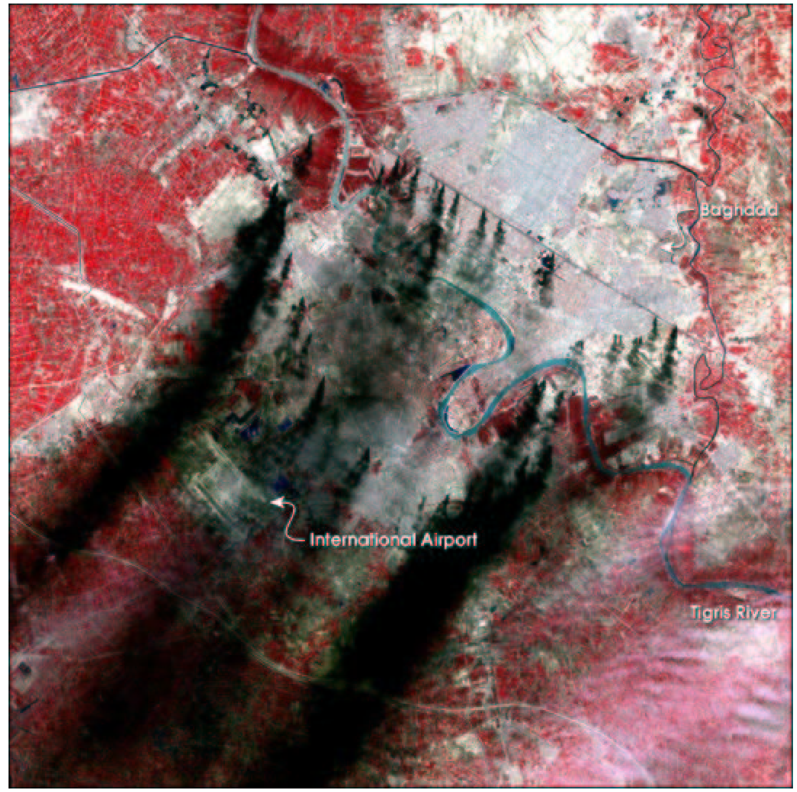
Motivation

Plumes in cross flow:

- Atmospheric ⟶
- In the ocean

Plume flux & form implications:

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



NASA Earth Observatory

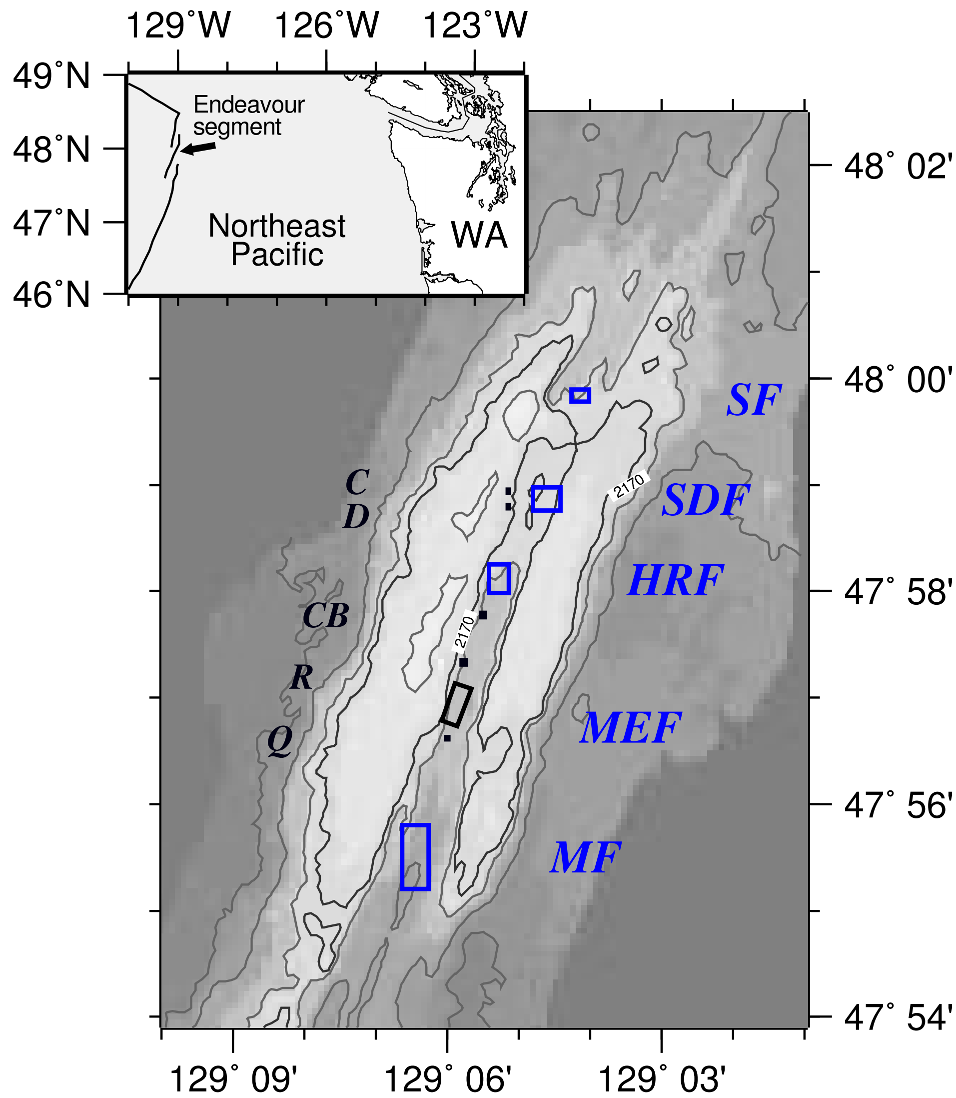
Outline (∼45 minutes)

- (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:

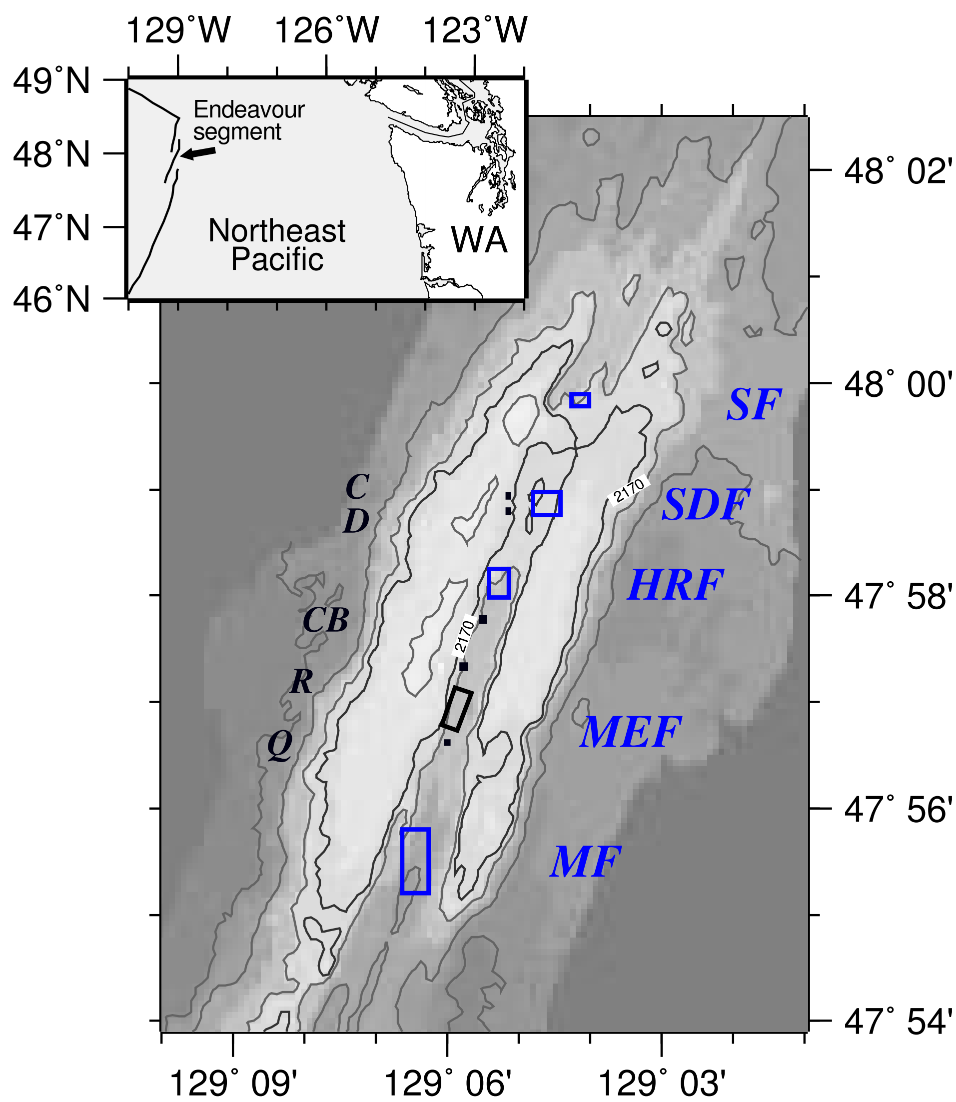
- Start: 47°54.5’N



Flow Mow study site: Endeavour segment

Orientation:

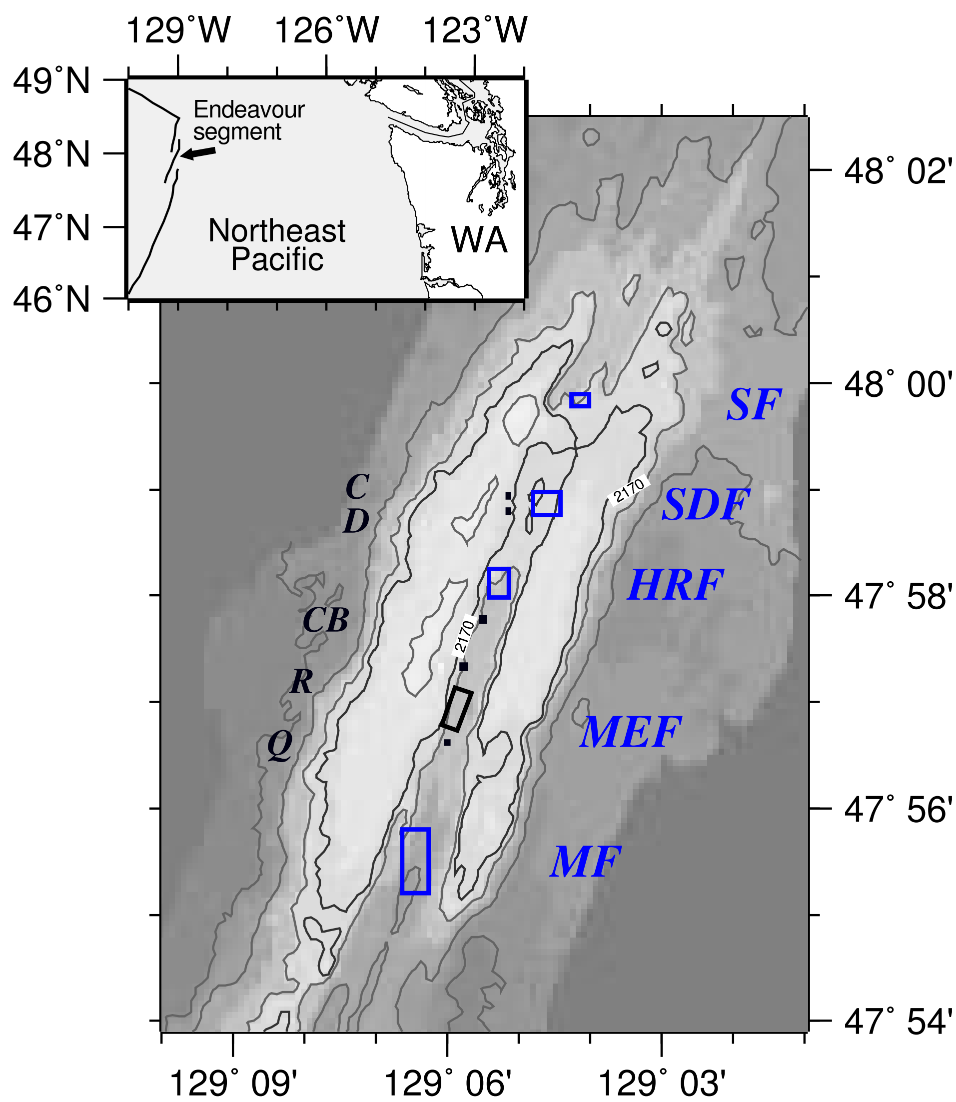
- Start: 47°54.5’N
- ∼300 m relief; crest ∼2100 m



Flow Mow study site: Endeavour segment

Orientation:

- Start: 47°54.5'N
- ~300 m relief; crest ~2100 m
- Valley 10 km long, 1 km wide, 100 m deep



Flow Mow study site: Endeavour segment

Orientation:

- Start: 47°54.5'N
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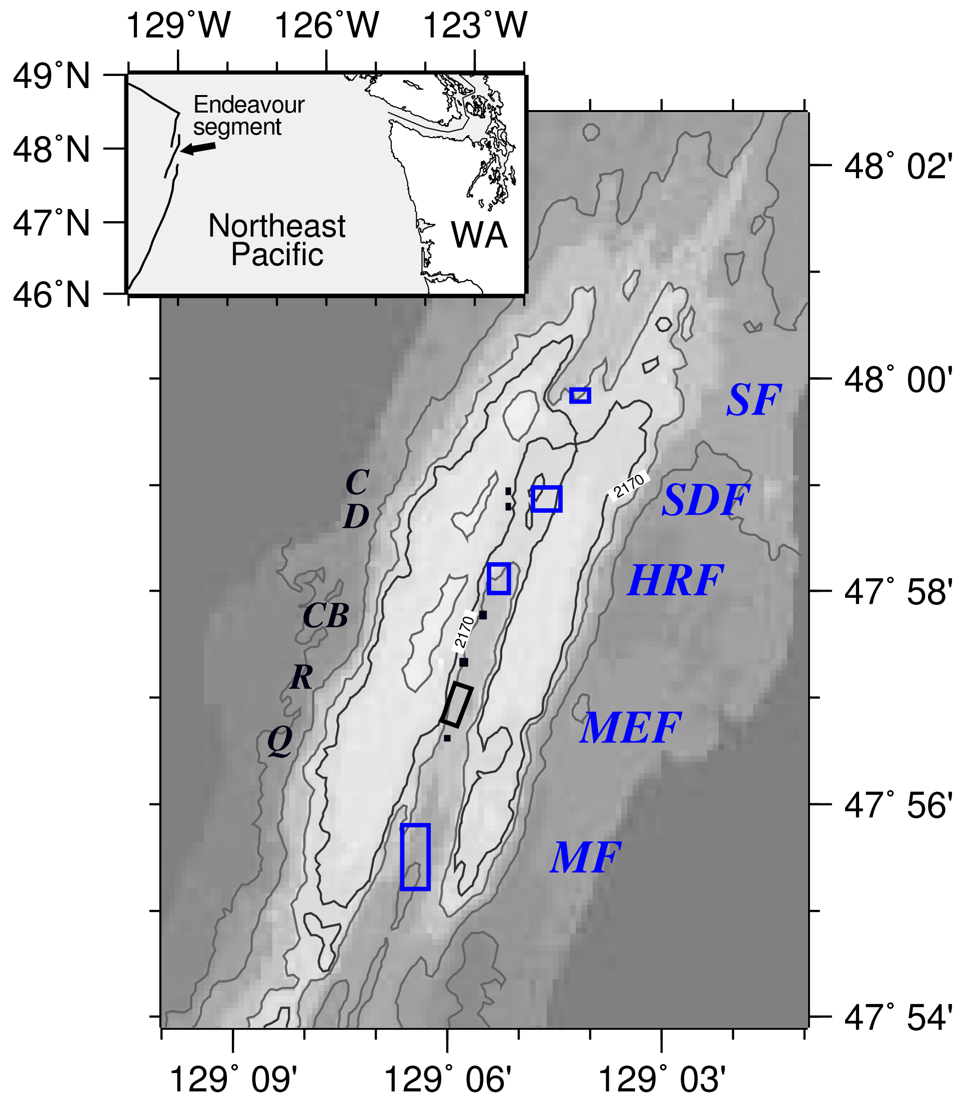
- Valley 10 km long, 1 km wide, 100 m deep
- Saddle ∼2170 m



Flow Mow study site: Endeavour segment

Orientation:

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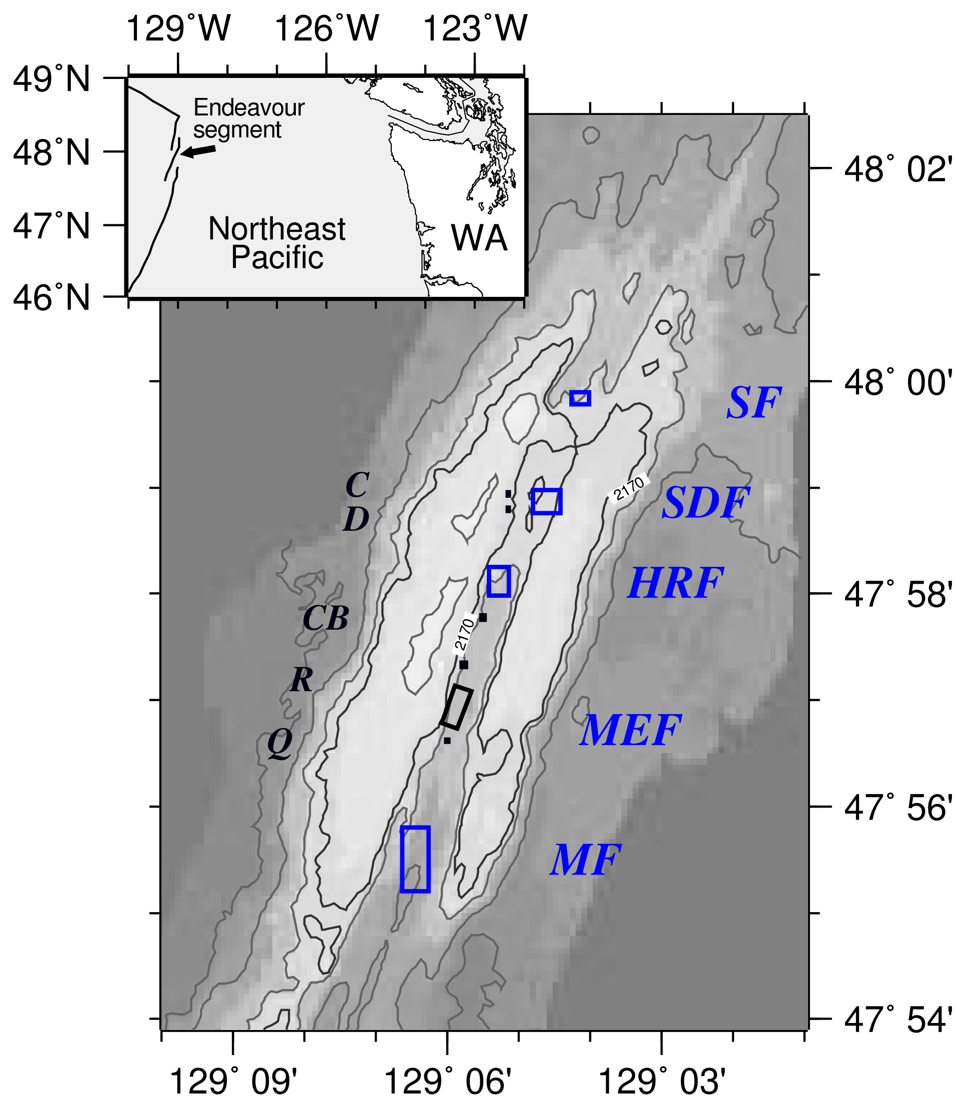
- Saddle ~2170 m
- Vent fields ~2 km spacing?



Flow Mow study site: Endeavour segment

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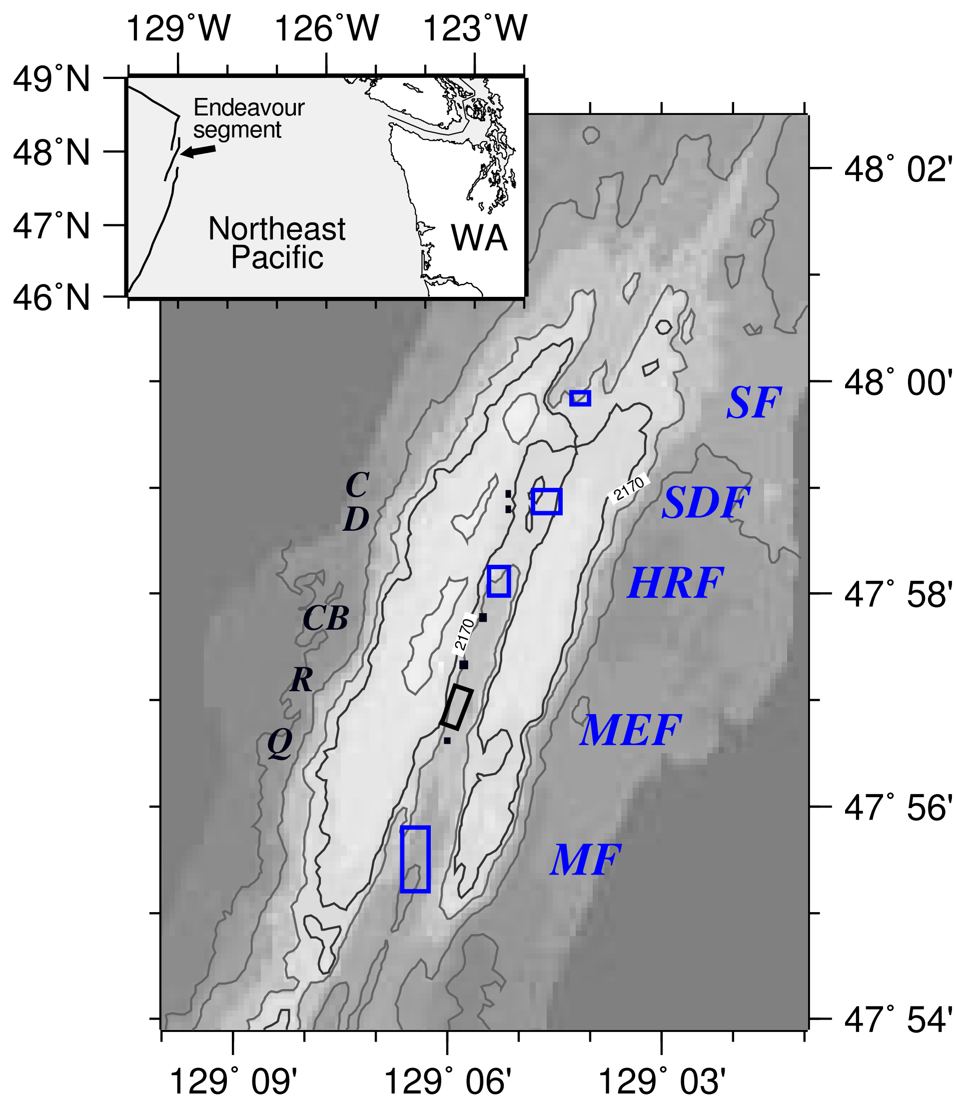
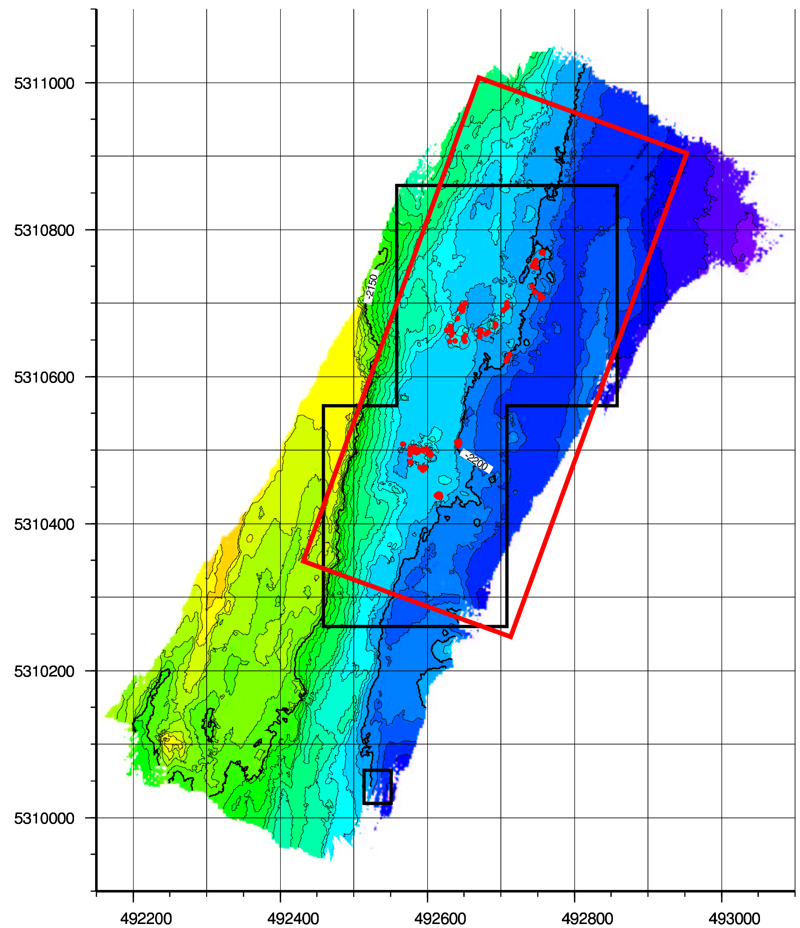


Main Endeavour vent field (MEF)

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

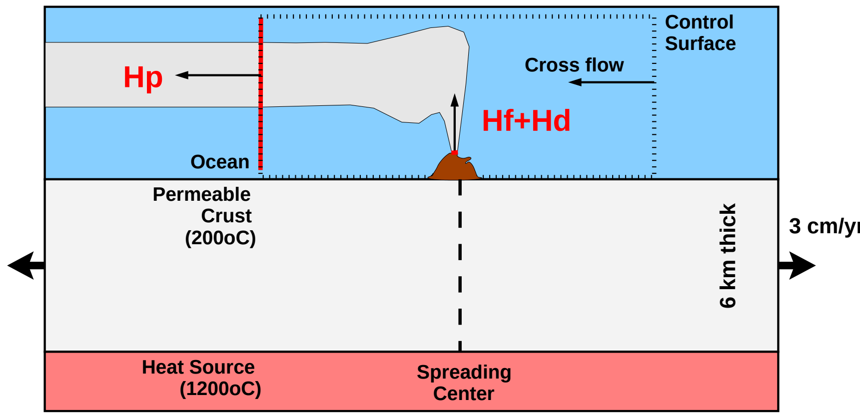


MEF heat flux puzzles

Power loss per km of ridge:

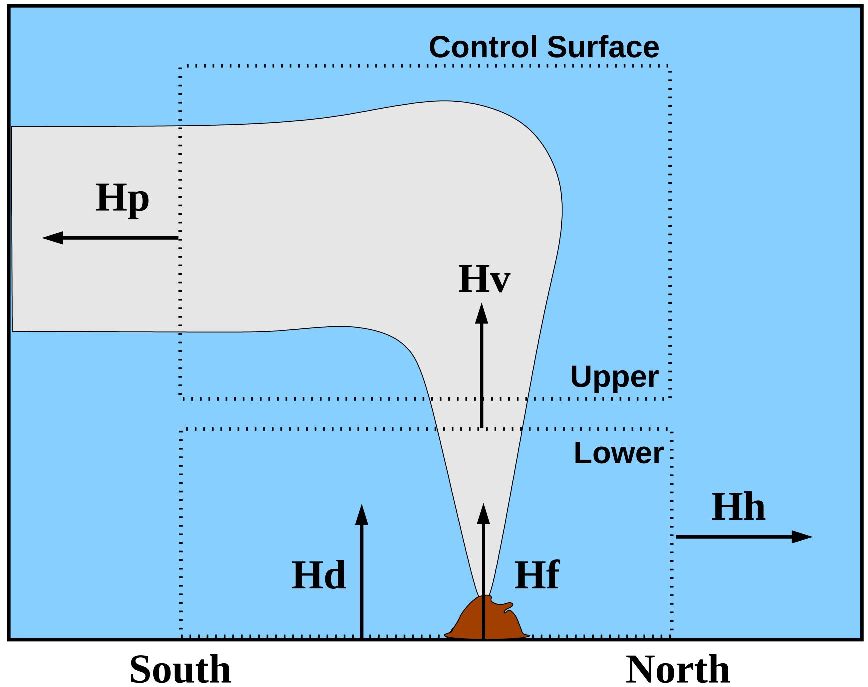
$$H_f + H_d \simeq H_R = Q_R(L_r + \int_{1200}^{200} c_r(T)dT) =$$

42 MW/km $\Longrightarrow 84$ 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

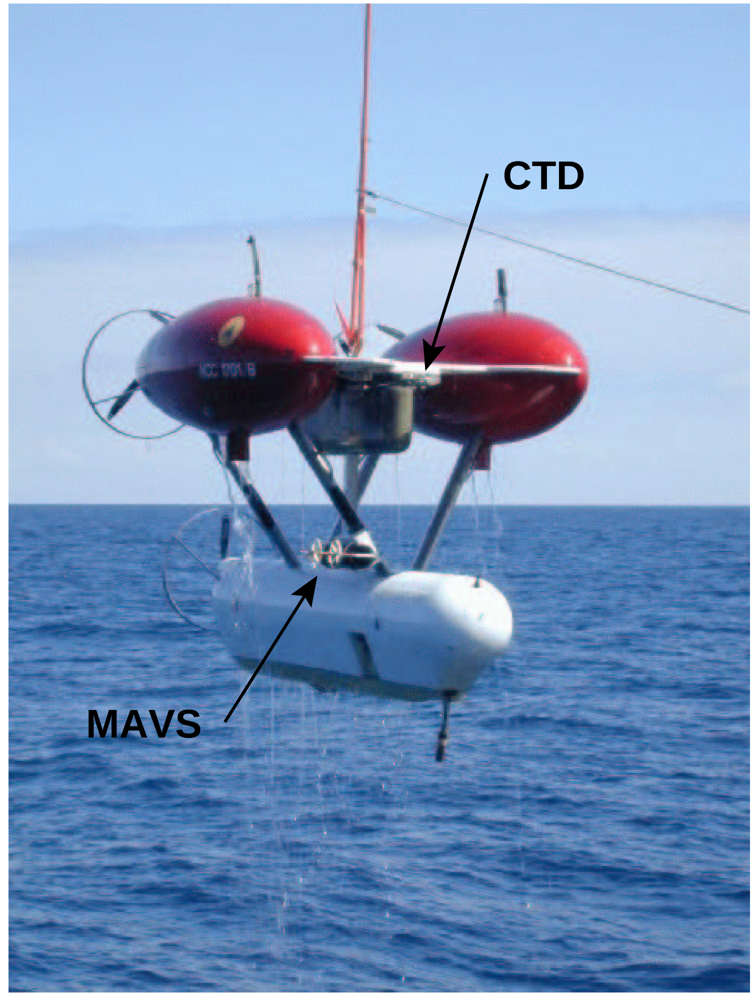
The “Flow Mow” control volume approach



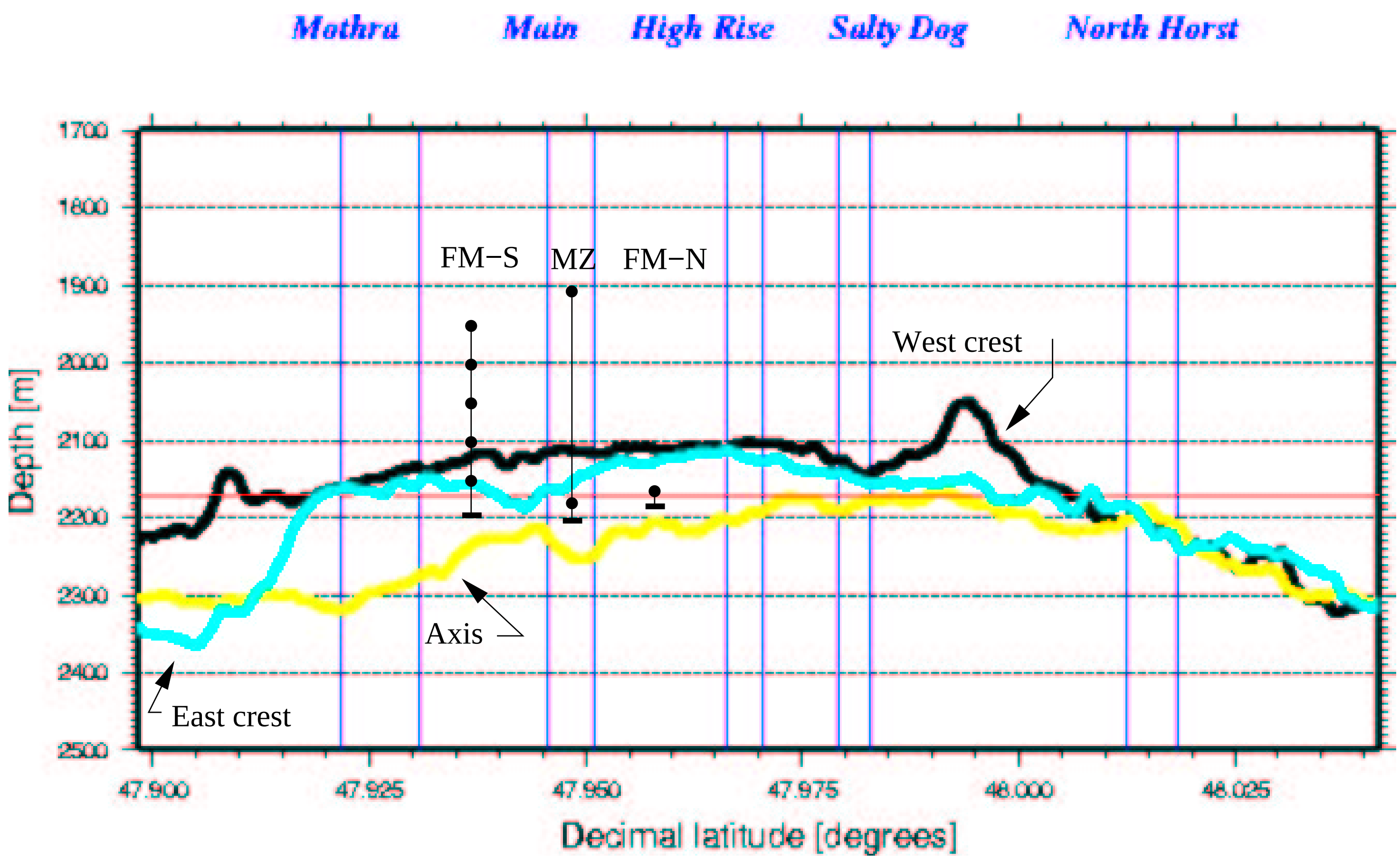
Net heat flux via *advection* through A:

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

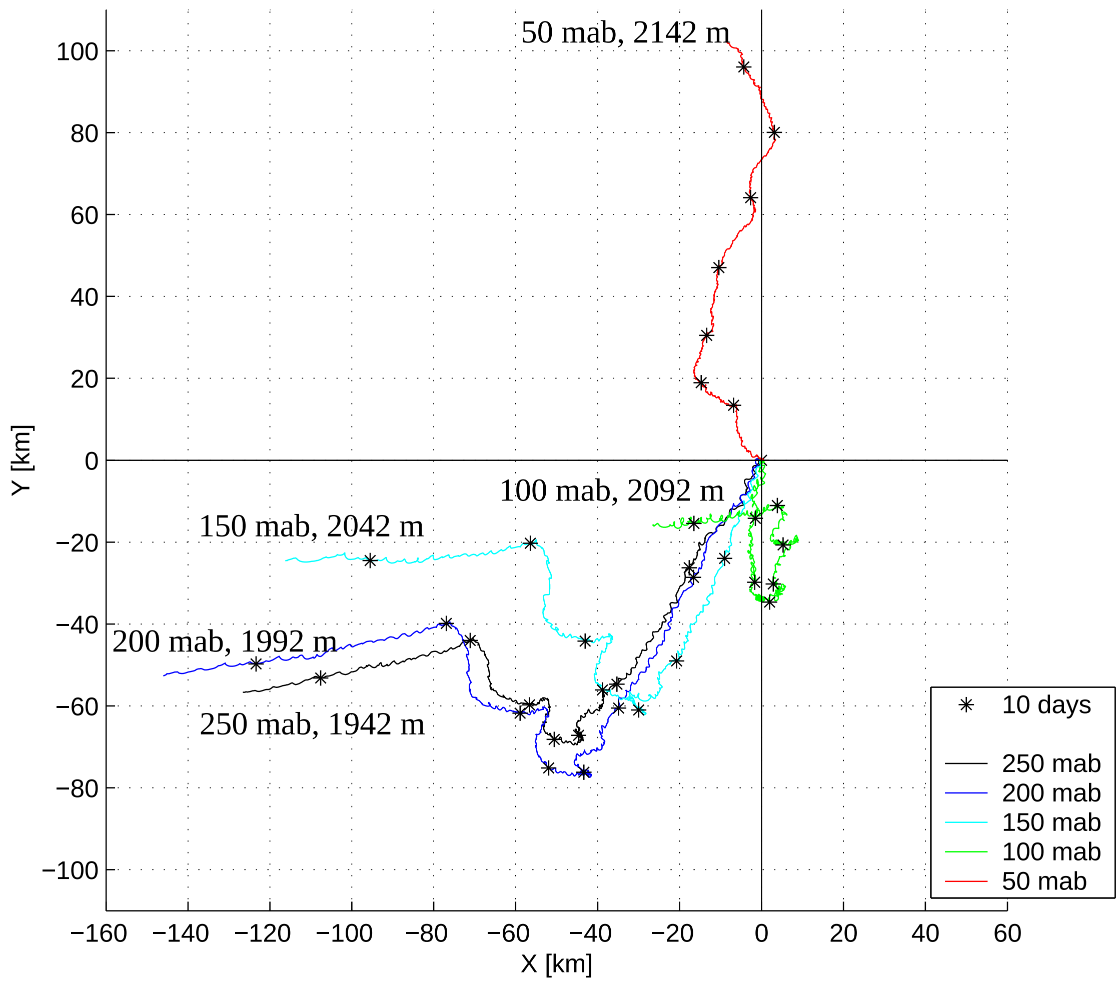
Instruments: CTD & ABE



Instruments: Current meters



Mean flow



50 mab, 2142 m
100 mab, 2092 m
150 mab, 2042 m
200 mab, 1992 m
250 mab, 1942 m
Y [km]
X [km]
100
80
60
40
20
0
−20
−40
−60
−80
−100
−160
−140
−120
−100
−80
−60
−40
−20
0
20
40
60
10 days
250 mab
200 mab
150 mab
100 mab
50 mab

Oscillatory flow over ridge

Δx_c

- $\sim$2.2 km above ridge
- $\sim$1.3 km in valley

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

- $\sim$2.2 km at 5 cm/s
- $\sim$0.5 km at 1 cm/s

Animation

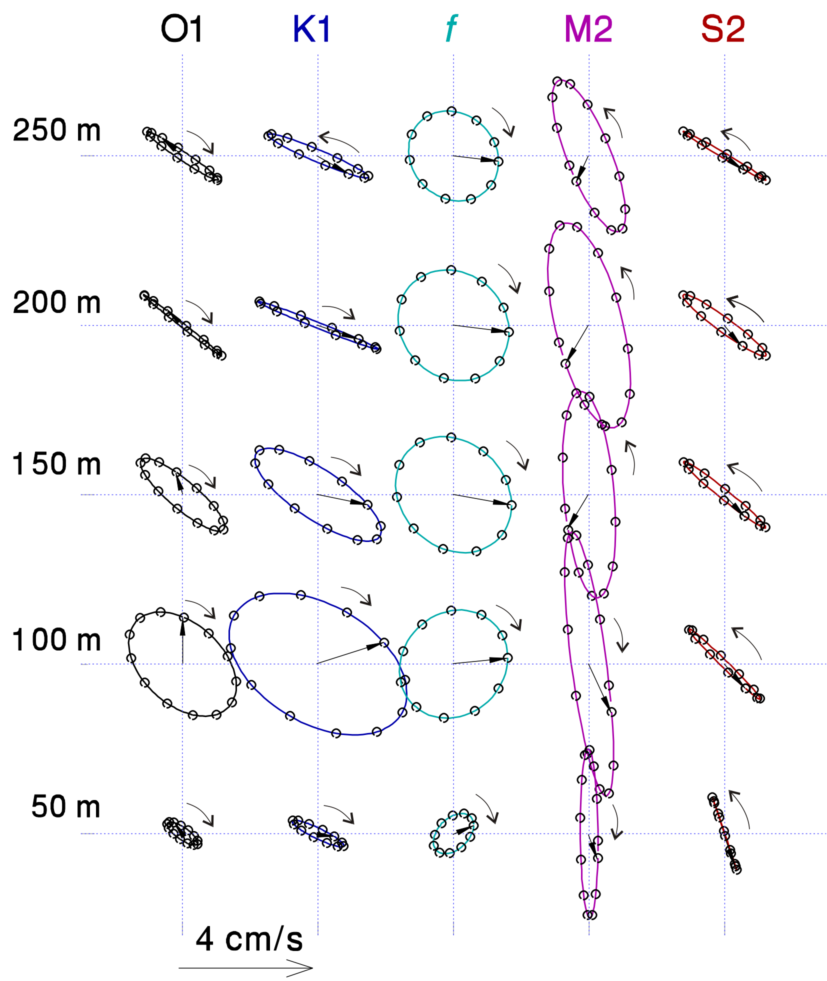
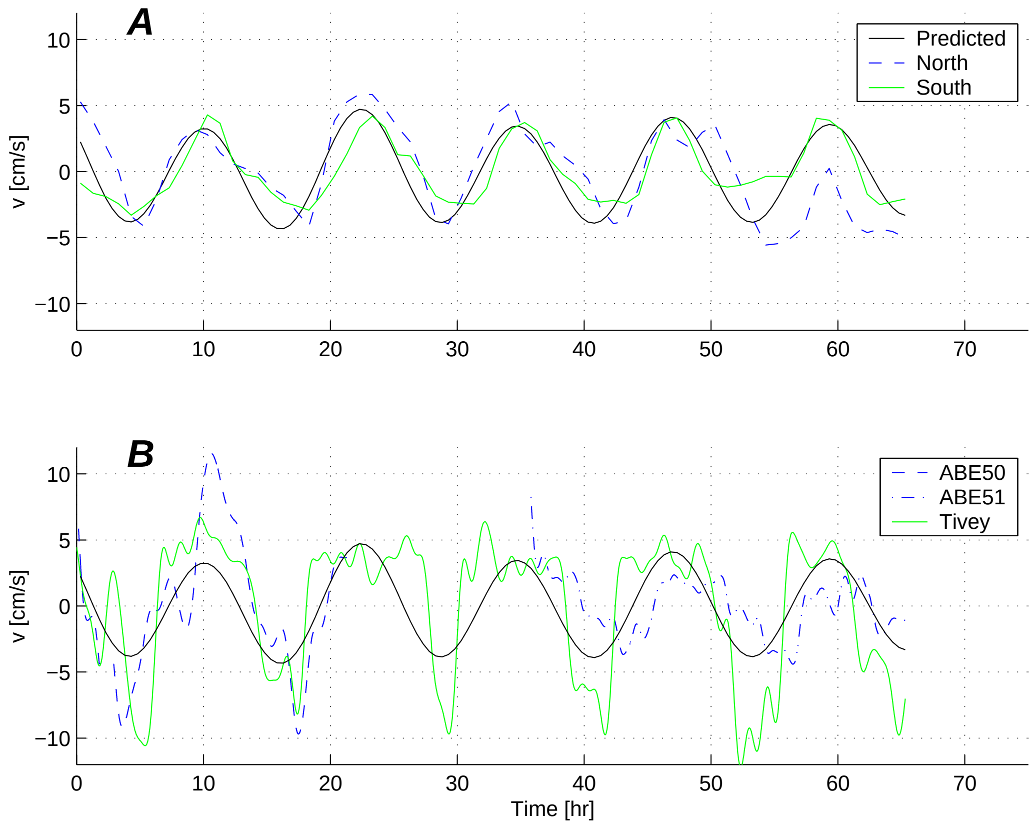


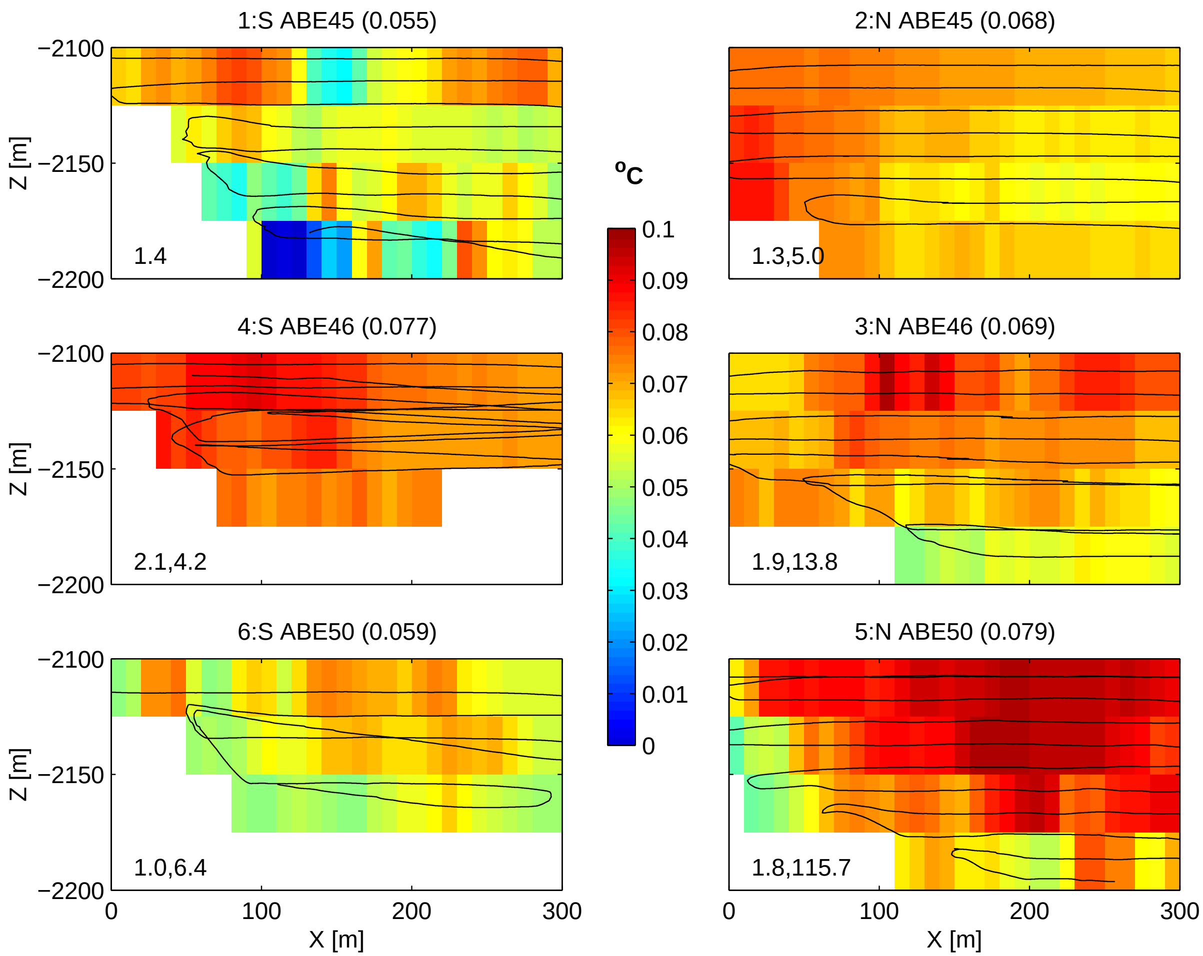
Figure courtesy Rick Thomson, IOS Canada

Oscillatory flow in valley



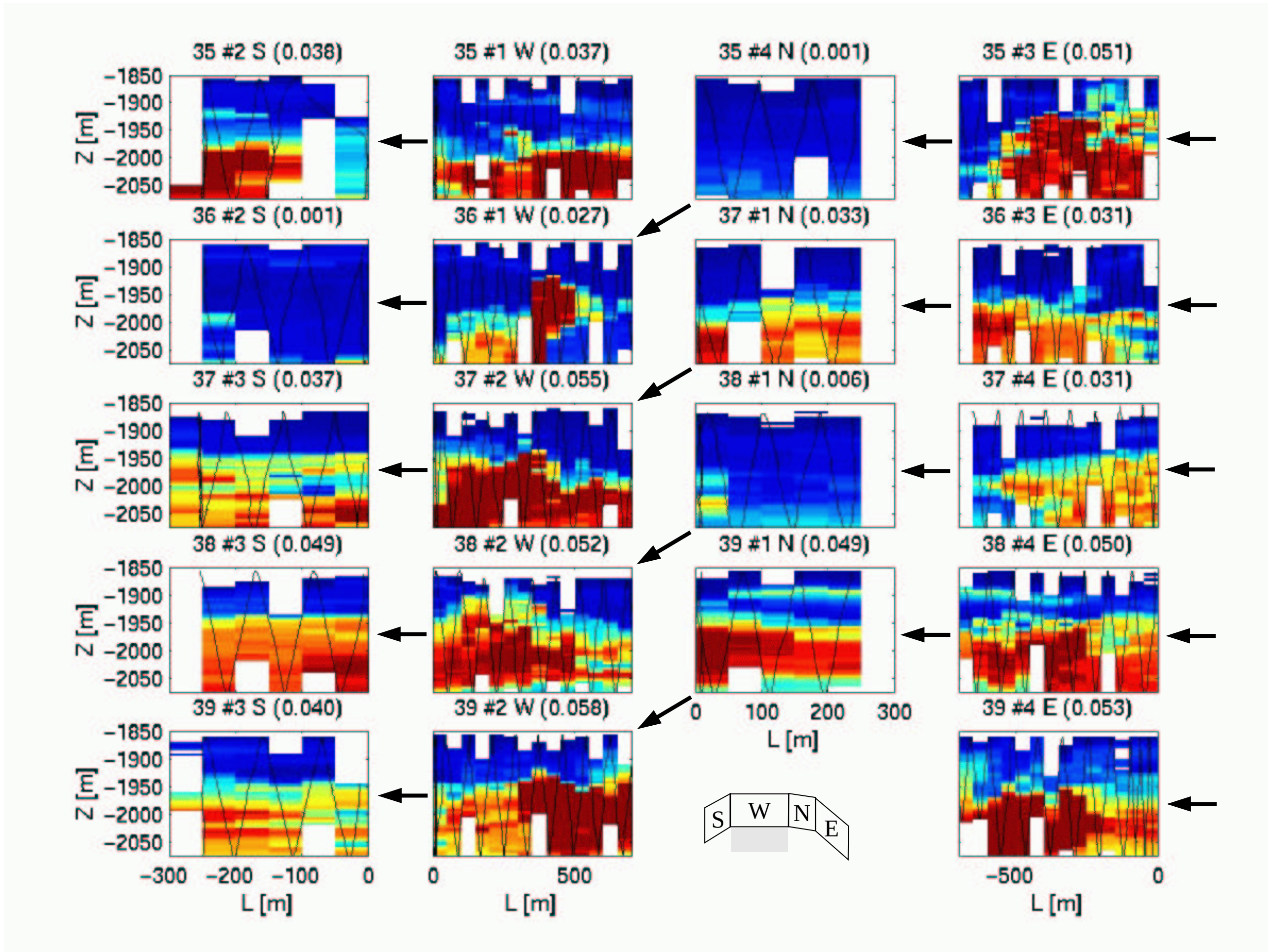
Animation

Hydrography and heat flux in the valley



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

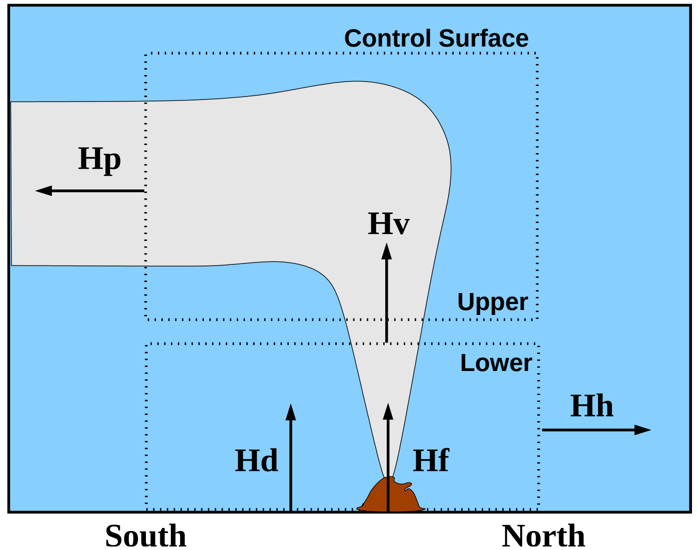
Hydrography and heat flux above the ridge



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

Lower heat flux budget:

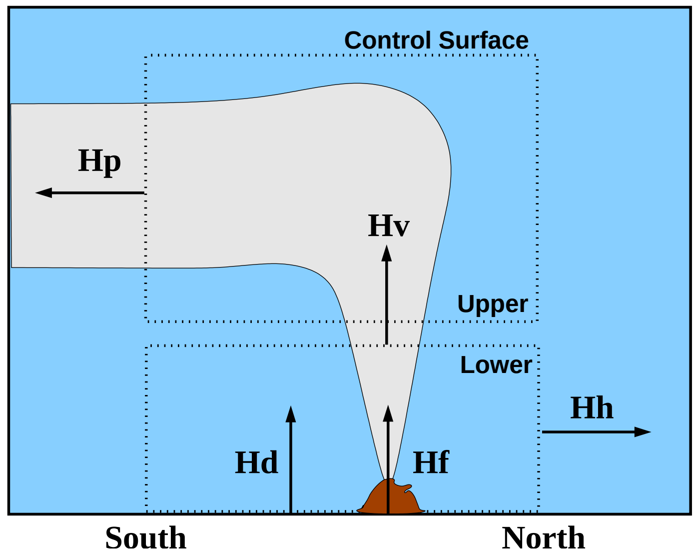
$$H_d + H_f = H_v + H_h$$



- $H_h = 80 \pm 37$ 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 ≃100:615≃1:6, rather than ∼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 $\sim$720 MW $\sim 10\times$ geologic mean of $\sim$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

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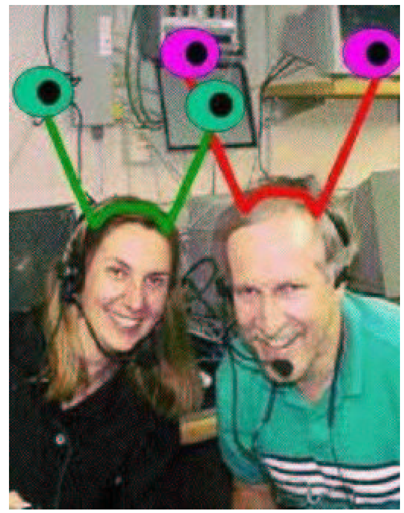

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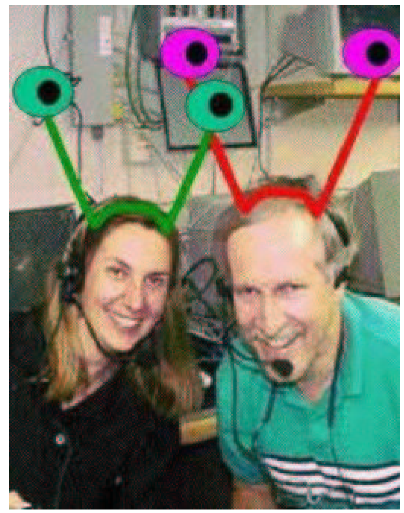

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- Supervisory committee members

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  Susan Hautala

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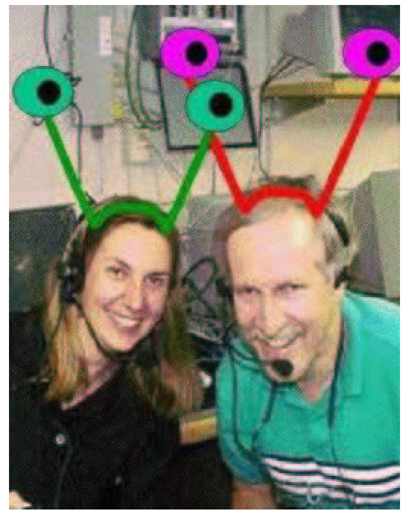

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  - Val, Leslie, Laura, Pete

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  - Val, Leslie, Laura, Pete
- Friends
  - *Many* kind friends
  - Fritz and Christian
  - Graduate compatriots

Questions?

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