Predicting unobserved ocean filaments from altimeters

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10 days every 3 hours

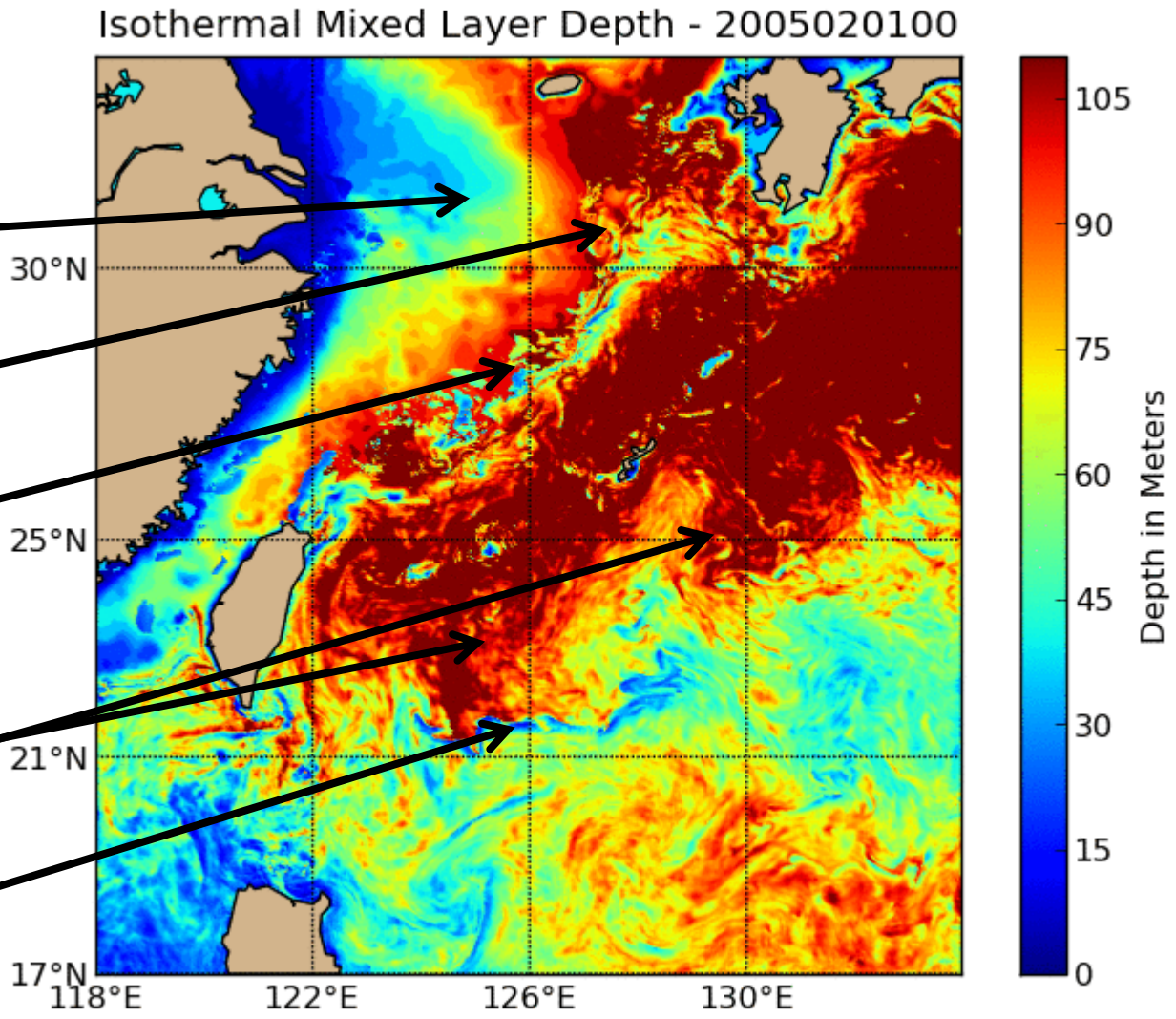
Tidal effects:

- Isothermal layer to the bottom on shelf
- Internal waves propagating onto the shelf
- Kuroshio sloshing

Minor diurnal heating effects

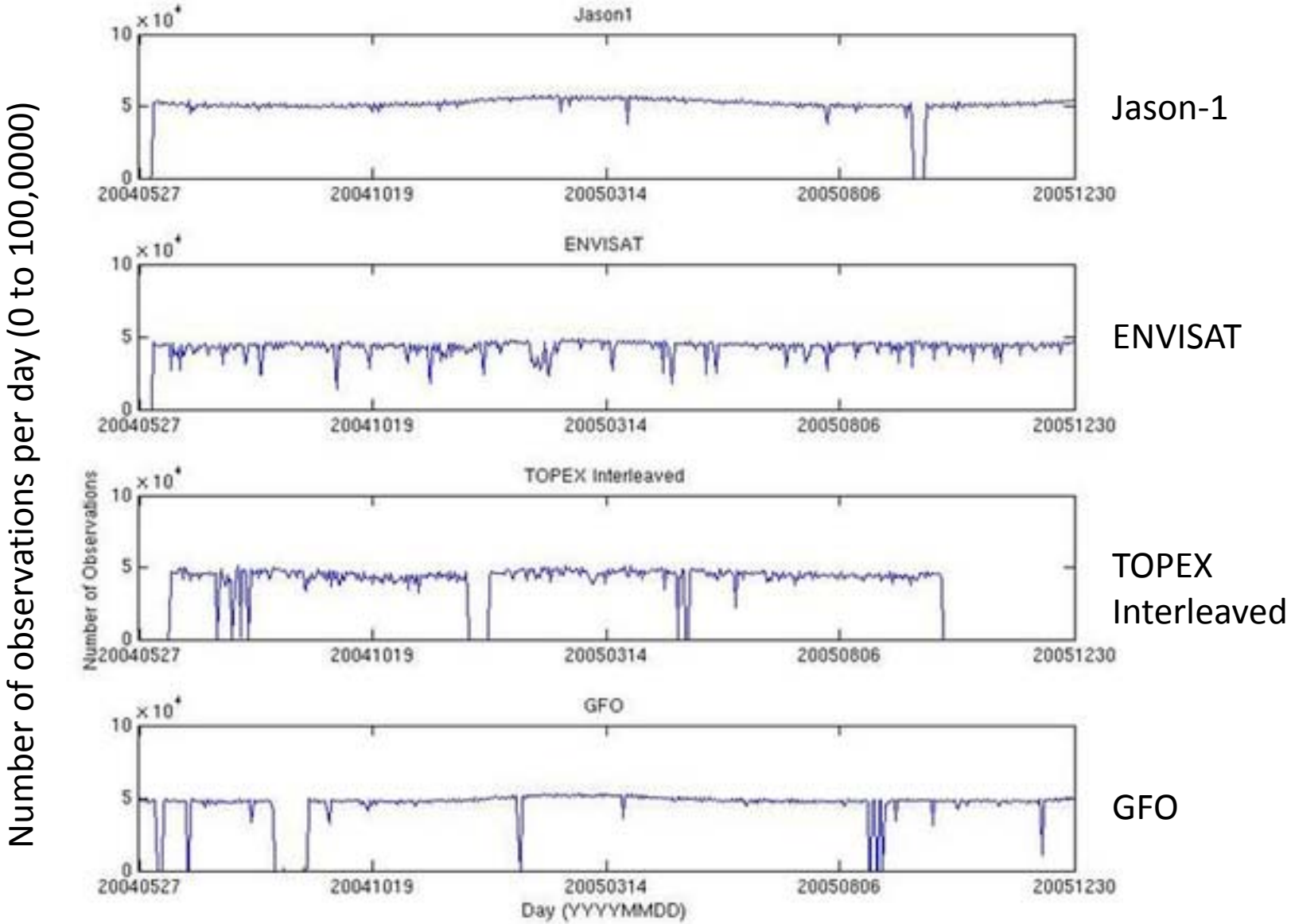
Deeper mixed layer in anticyclones

Most importantly, frontogenesis filaments



Jun 2004 – Dec 2005, 4 satellite altimeters available

Altimeter coverage



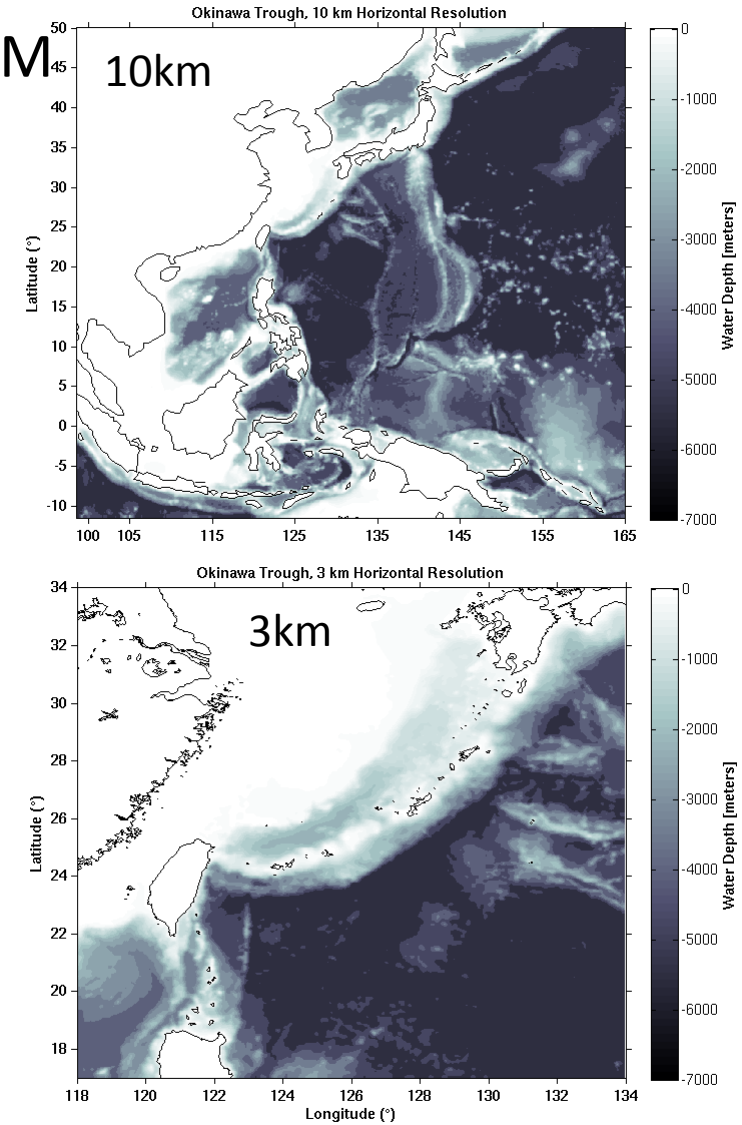
Jun 1, 2004 through Dec 31 2005

Model Experiment Details

- Jun 1 2004 – Dec 31 2005
- Boundary conditions from global 1/8°NCOM
- 10km resolution outer domain
- 3km resolution inner domain
- Assimilating all historical GODAE satellite and in situ data
- NOGAPS wind stress and bulk heat fluxes
- Output every 3 hours

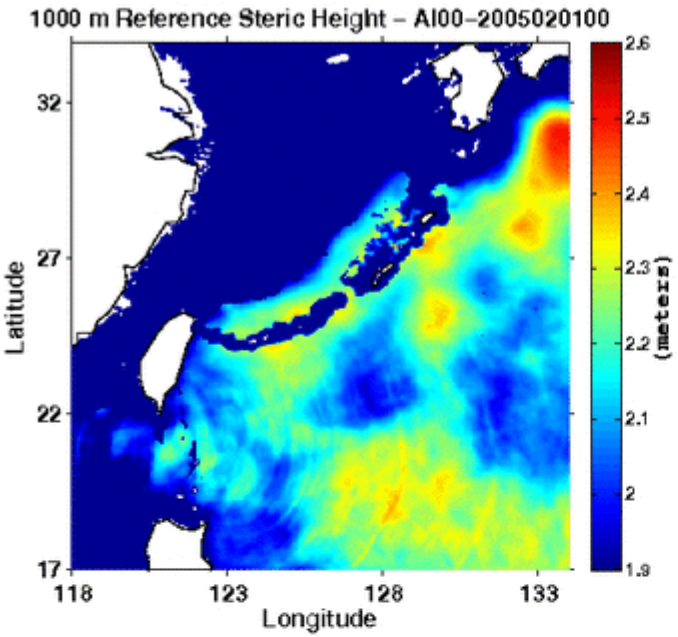
The interim 10km domain is very important for OSSEs so that high resolution domain boundary conditions match the global observing system capability

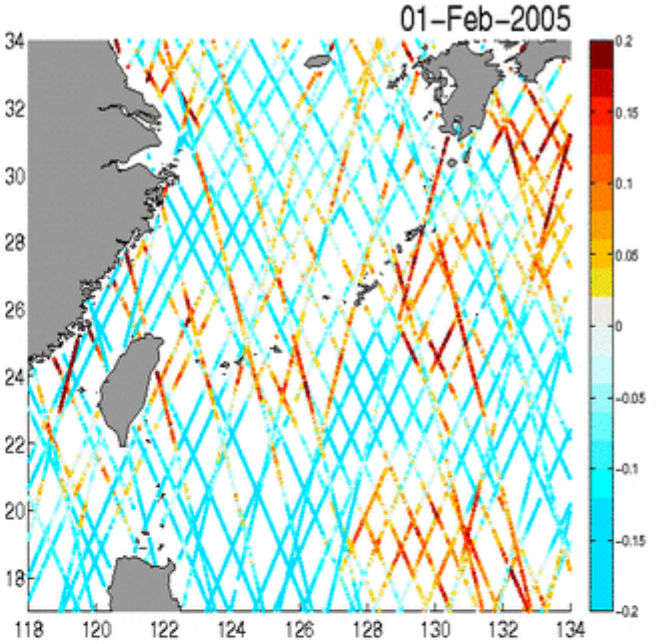
Bathymetry



Model State

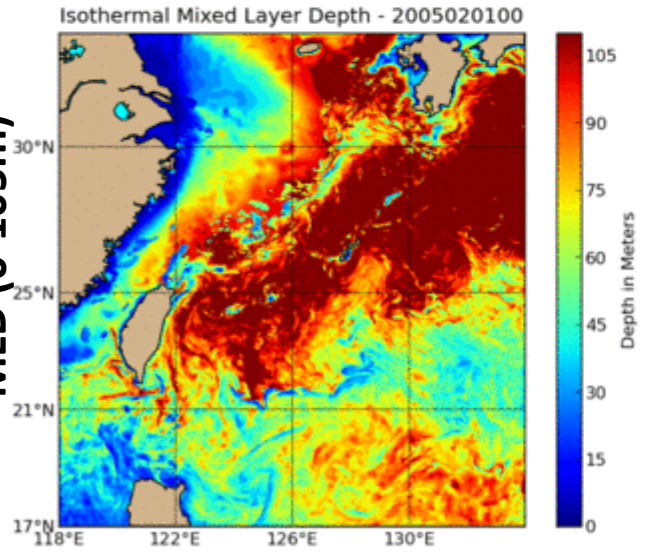
Steric Height (1.9 – 2.6 m)

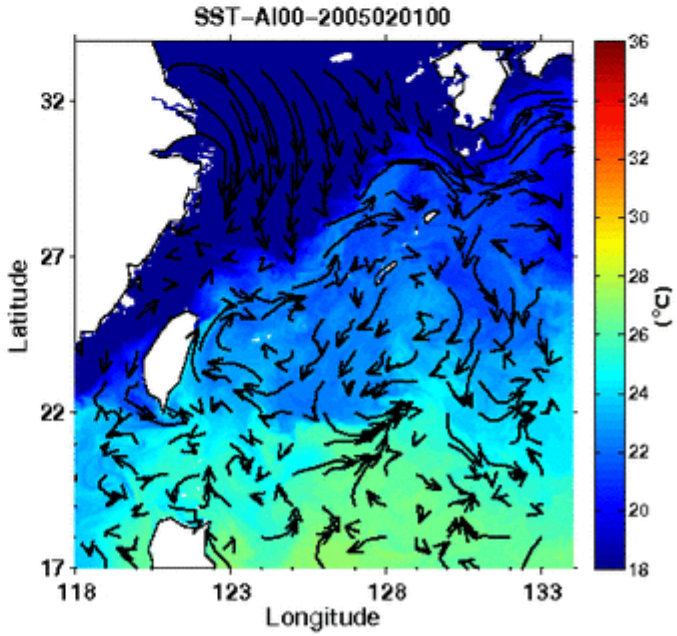




SSHA (-0.2 to 0.2 m)

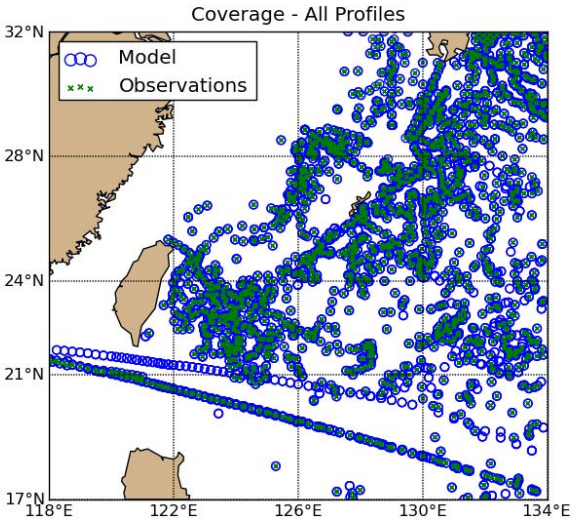
MLD (0-105m)

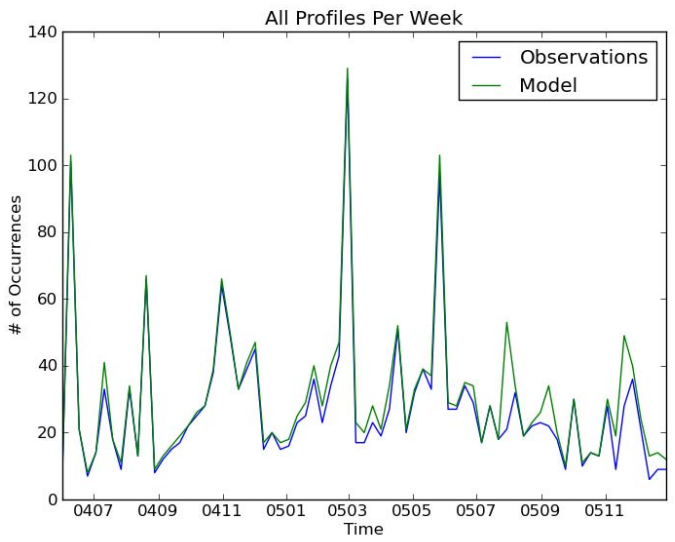




SST (18-36 degrees C)

MLD Performance

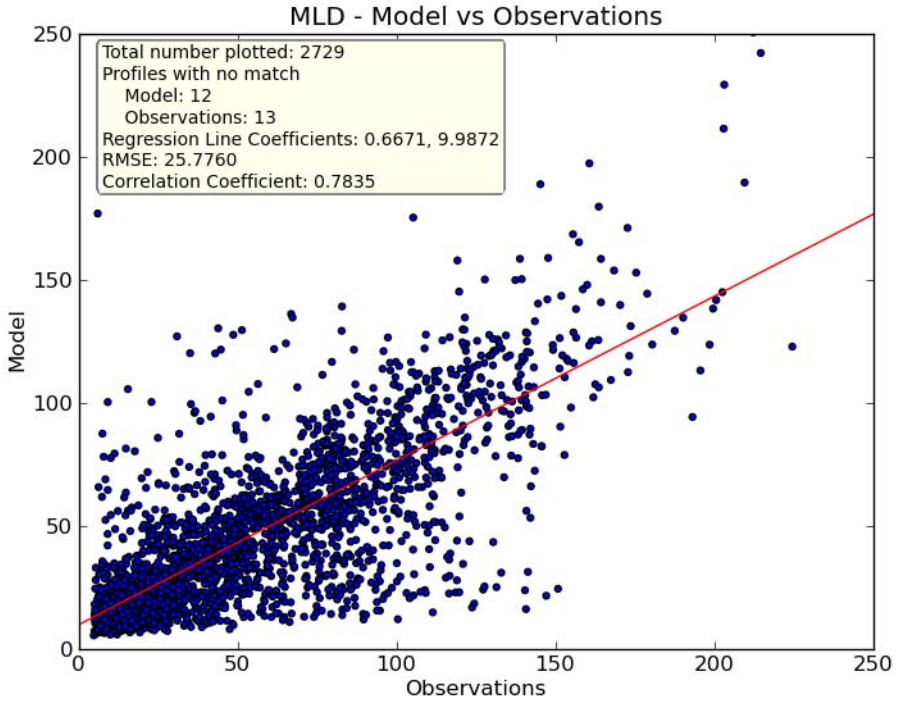




2729 profiles available for comparison

Many in situ profiles are quite noisy and thus removed

RMS = 25.8 m
CC = 0.78



Ageostrophic balance in fronts

$$fv_{gz} = b_x$$

The flow is assumed to be in thermal wind balance

$$\frac{D}{Dt} b_x = Q_{1x}$$

Q_1 Is a vector related to the substantial derivative of buoyancy

$$Q_{1x} = -u_{gx} b_x - v_{gx} b_y$$

From QG momentum and buoyancy

$$N^2 w_x - f^2 u_{a_z} = -2Q_1$$

$$N^2 \psi_{xx} - f^2 \psi_{zz} = -2Q_1$$

Streamfunction relation between vertical velocity and ageostrophic vertical gradients

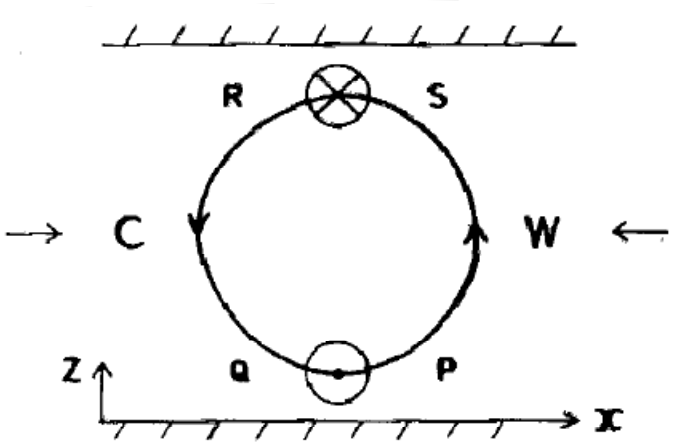


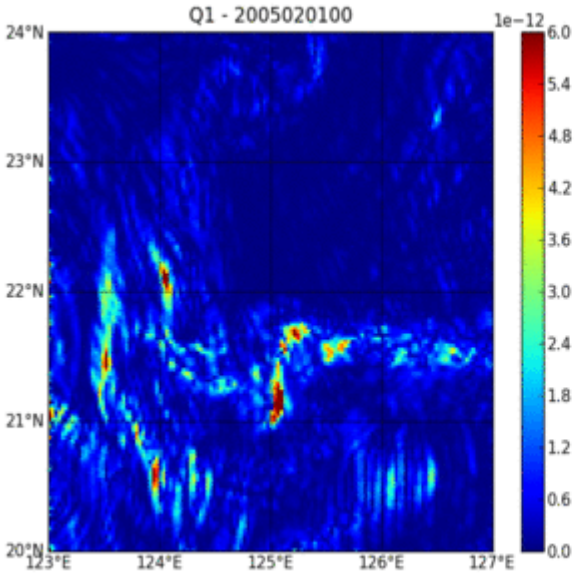
Figure 2 A frontogenetic situation in which a buoyancy gradient from heavy (*C*) to light (*W*) in thermal wind balance with a flow into the section at the top (⊗) and out of it at the bottom (⊙) is being increased by a large scale convergence in x indicated by arrows. The resulting ageostrophic cross-frontal circulation is shown by an arrowed streamline.

B.J. Hoskins, The mathematical theory of frontogenesis, Ann. Rev. Fluid Mech, 1982, 14, 131-151

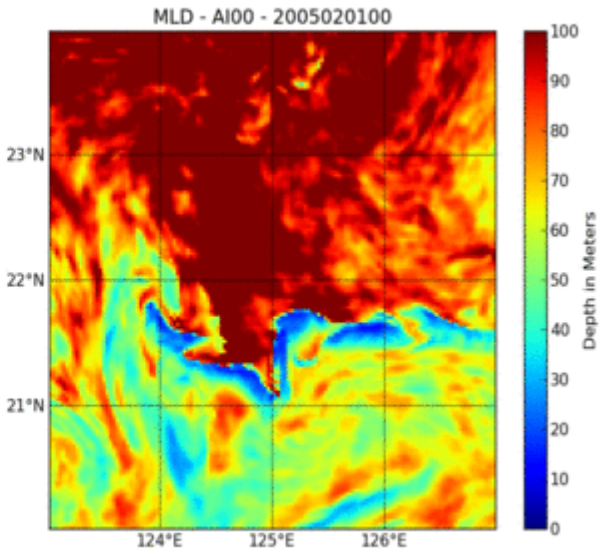
Q1 Related to MLD

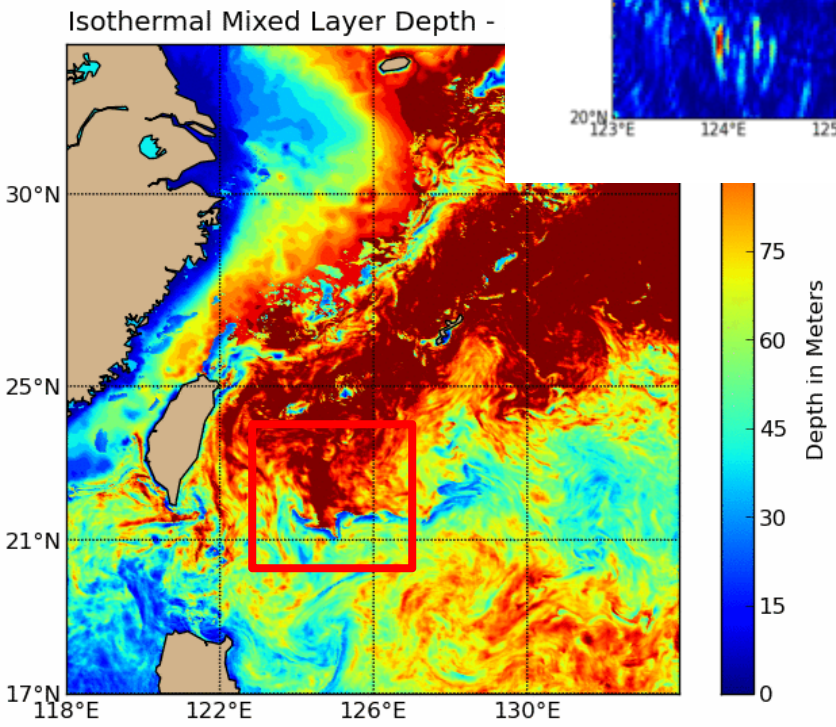
February 2005

Q1



MLD



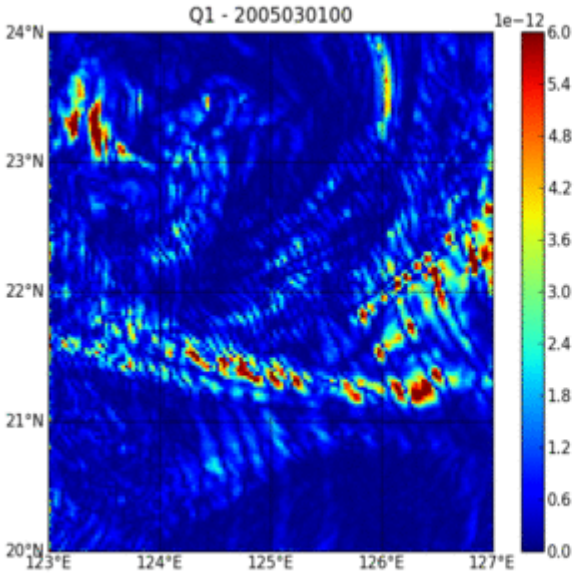


Areas of high Q1 are associated with frontogenesis
Resulting upwelling shallows the mixed layer

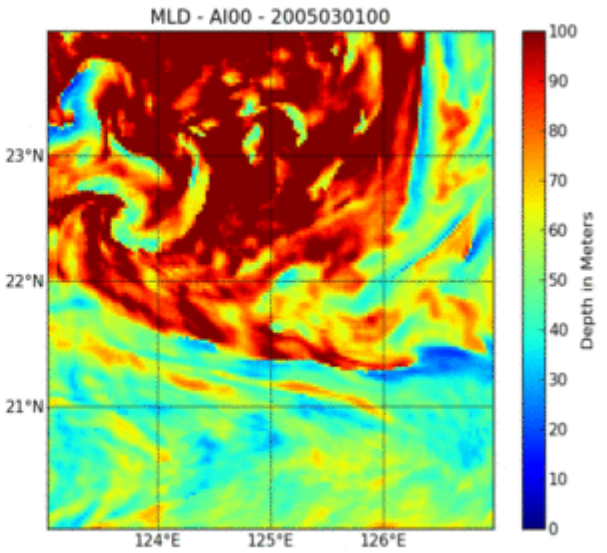
Q1 Related to MLD

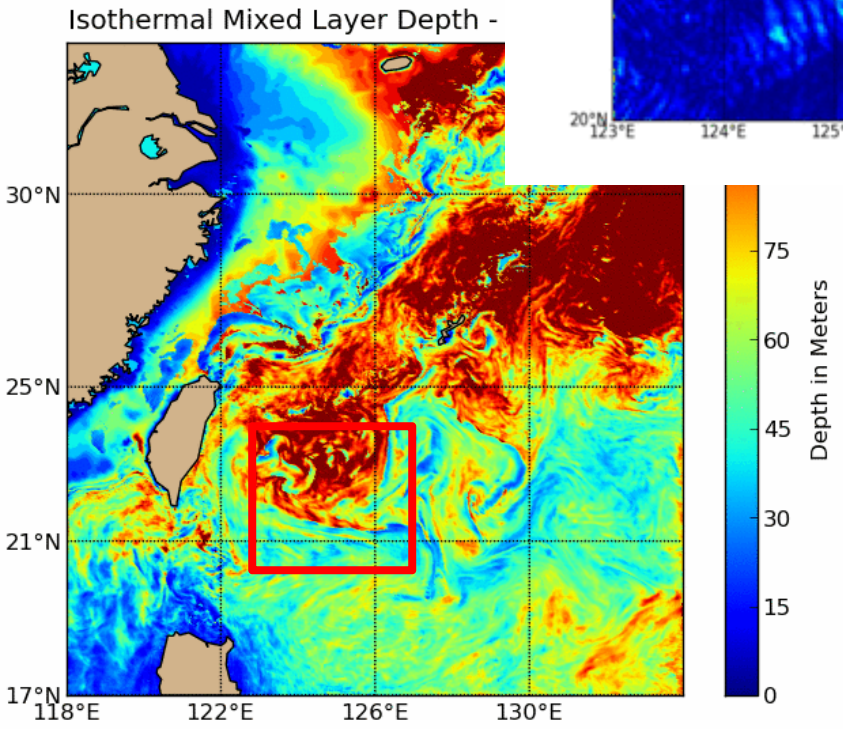
March 2005

Q1



MLD





Areas of high Q1 are associated with frontogenesis
Resulting upwelling shallows the mixed layer

Filaments

Are these features deterministic?

Can they be predicted?

Are they instability-generated processes?

OSSEs

- All inputs (surface forcing, boundary conditions) are identical except data assimilated
- All OSSEs run with initial condition at June 1 2004
- Nature run initial condition is from global model at June 1 2005
- Reproduction of the features shows they are predictable

Predictability

Are these features deterministic?

Can they be predicted?

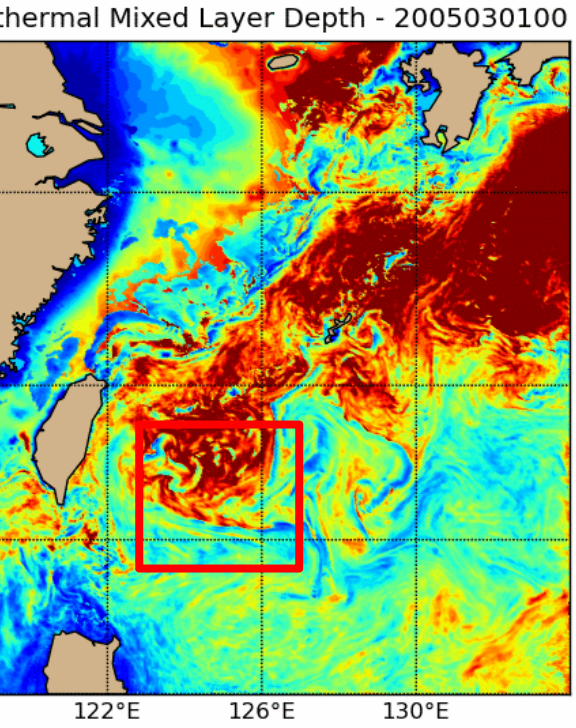
Are they instability-generated processes?

OSSEs

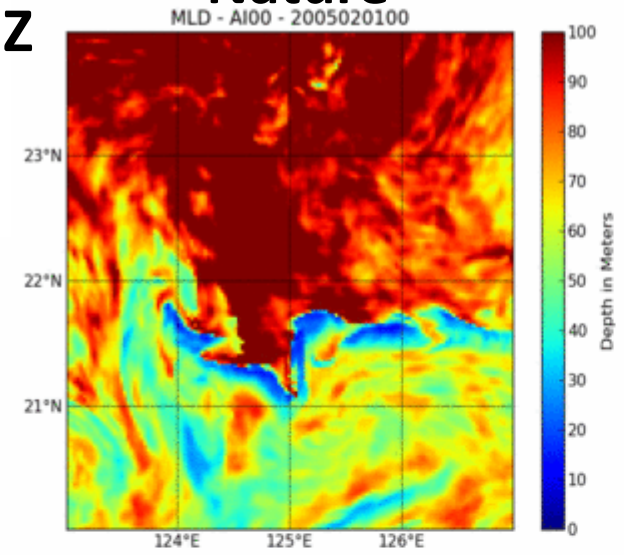
Exp ID	ALT Data	SST	other data
AI00	Jason GFO ENVISAT TPXI	on	Public (01 June 2005 initial conditions)
AI01	None	None	None
AI02	None	on	Public
AI03	Jason GFO ENVISAT TPXI	on	Public
AI04	Jason	on	Public
AI05	GFO	on	Public
AI06	Jason GFO	on	Public
AI07	ENVISAT	on	Public
AI08	Jason ENVISAT	on	Public
AI09	GFO ENVISAT	on	Public
AI10	GFO Jason ENVISAT	on	Public
AI11	GFO TPXI	on	Public
AI12	GFO Jason TPXI	on	Public
AI13	Jason TPXI	on	Public
AI14	GFO ENVISAT TPXI	on	Public
AI15	Jason TPXI ENVISAT	on	Public

Predictability

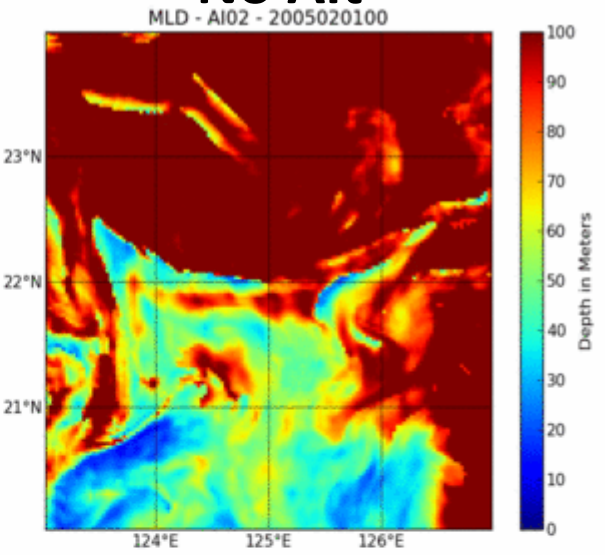
2005 Feb 1 03Z



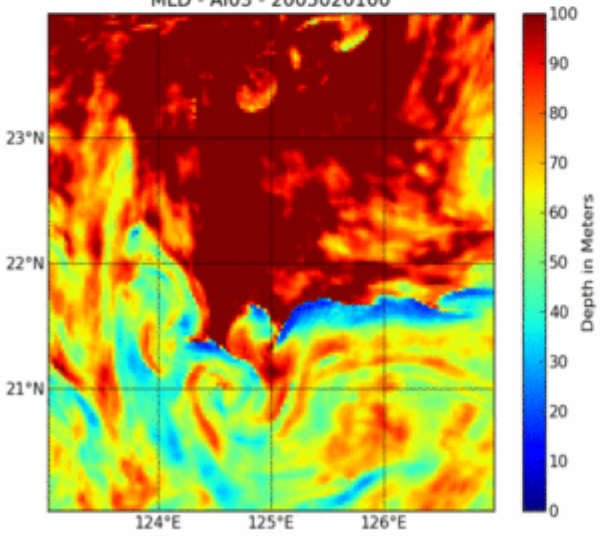
Nature



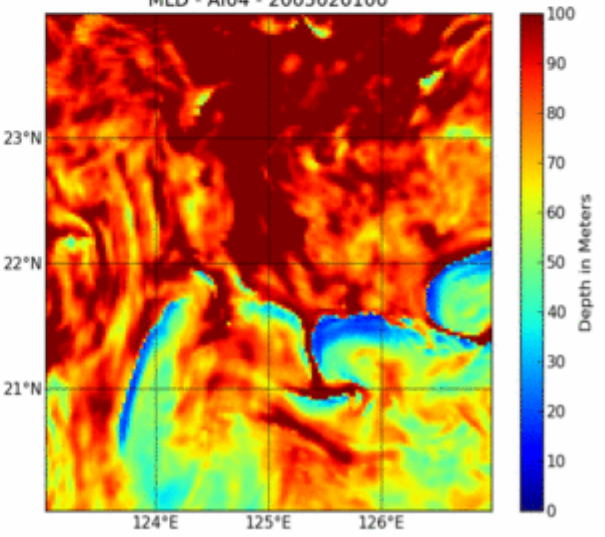
No Alt



All Alt

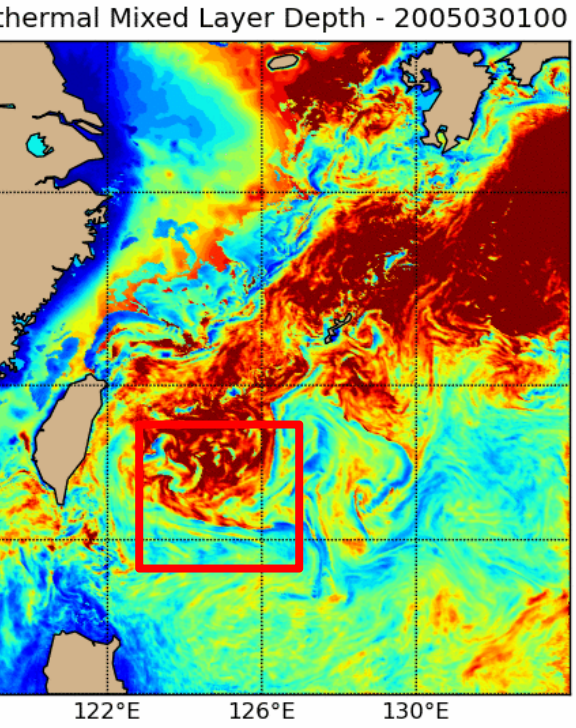


Jason-1

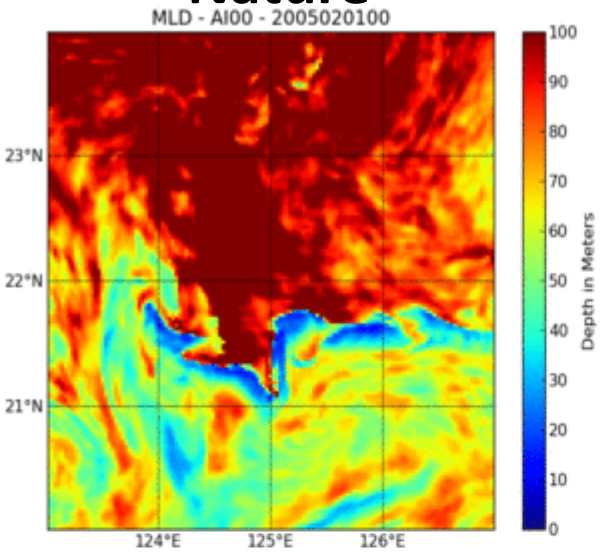


Predictability

2005 Feb



Nature



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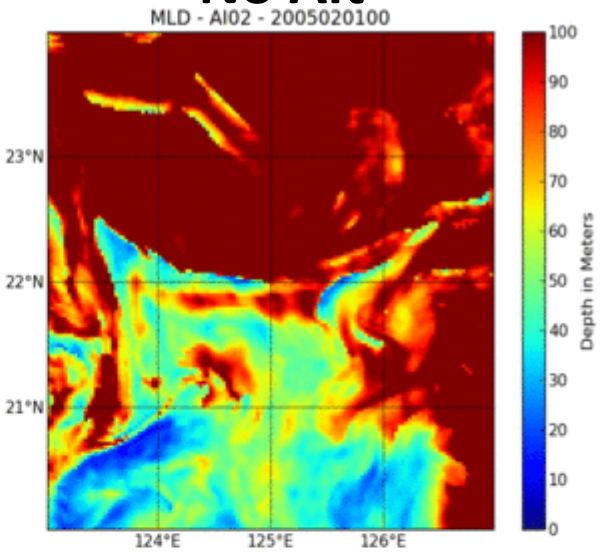
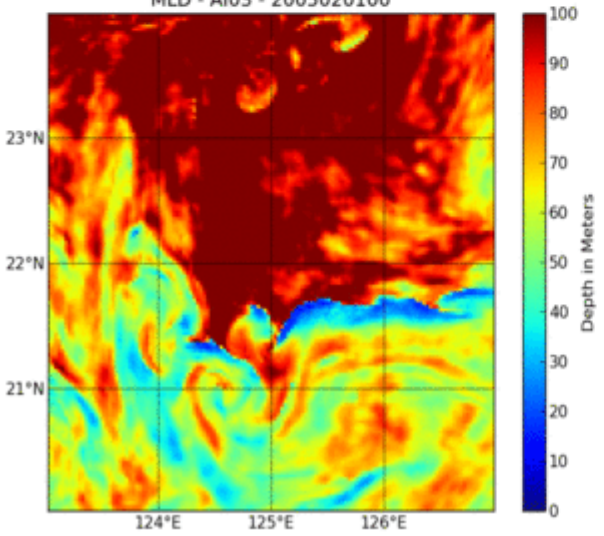
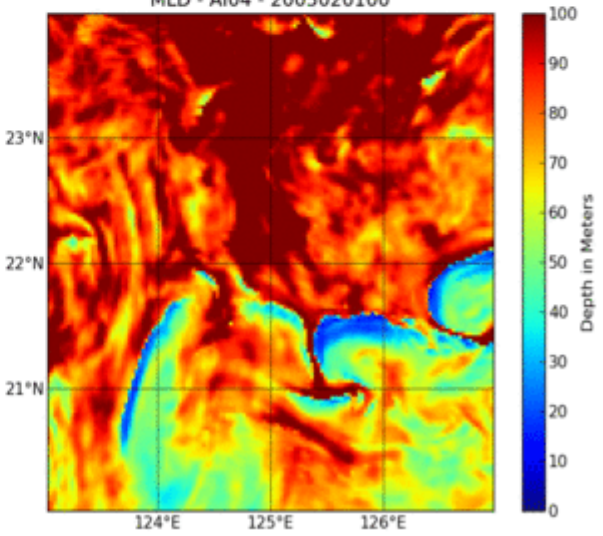


All Alt

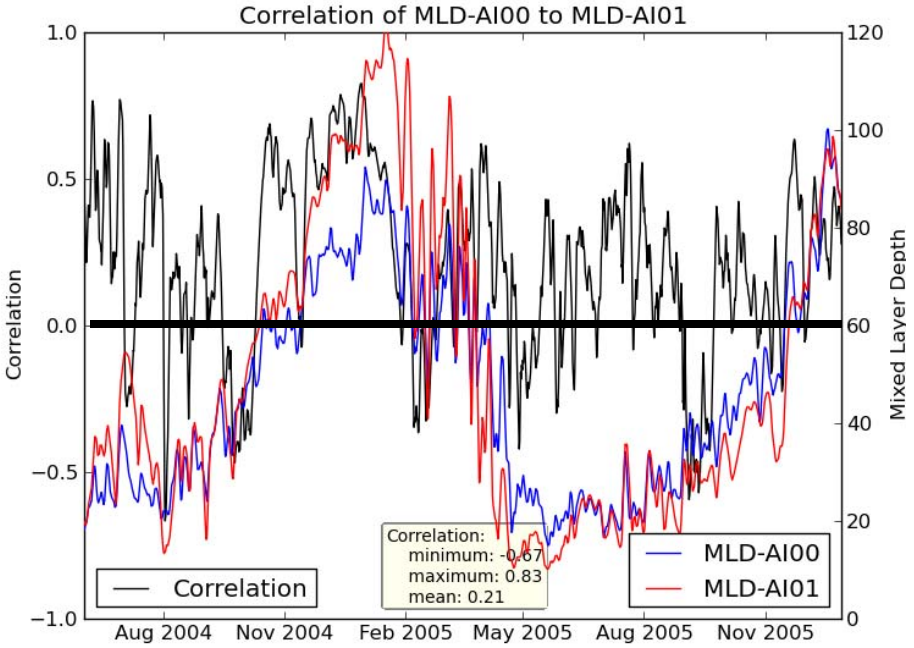


Jason-1

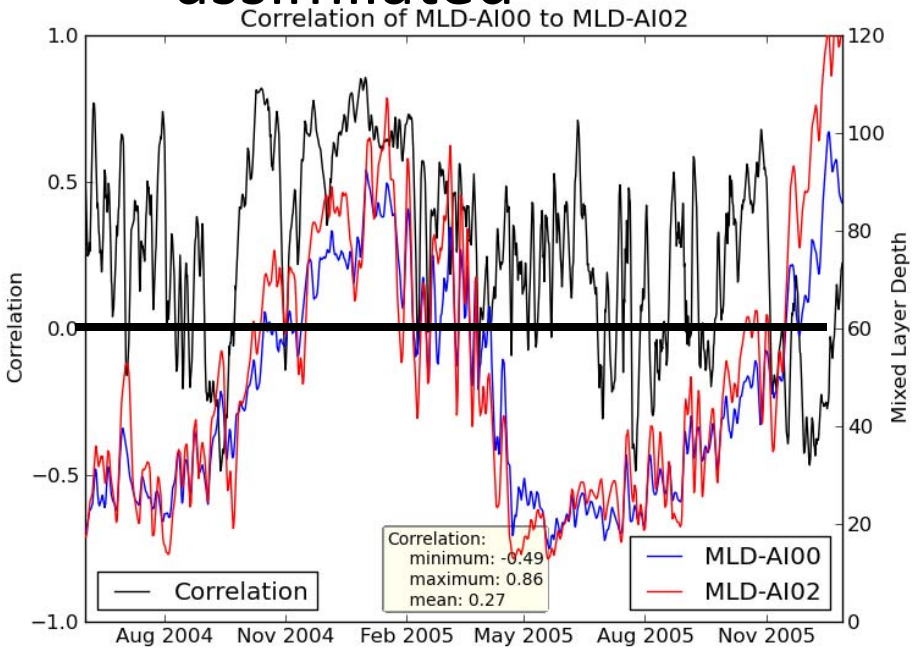


Predictability

No data assimilated



All data except ALT assimilated

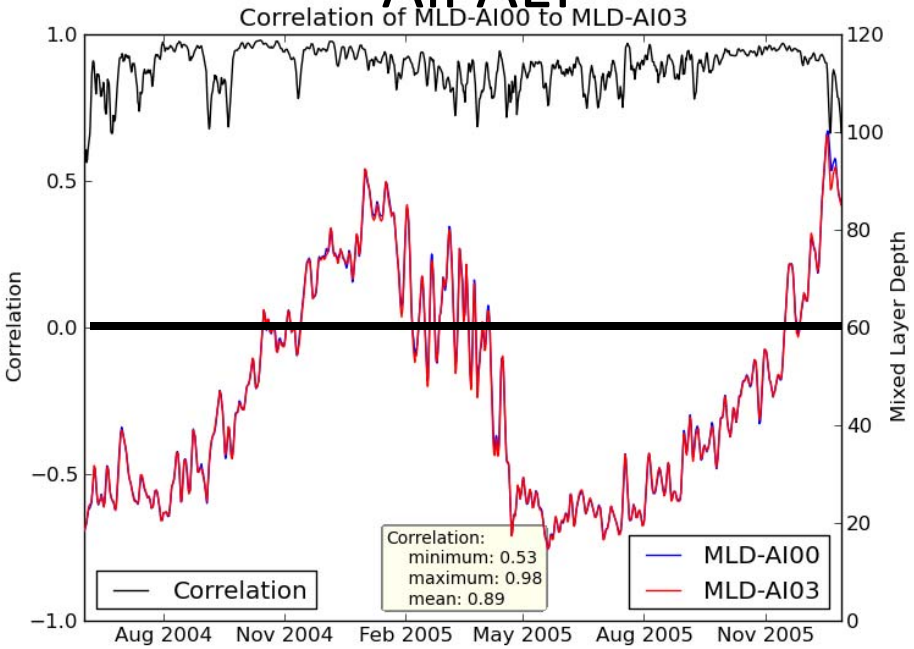


MLD Nature run

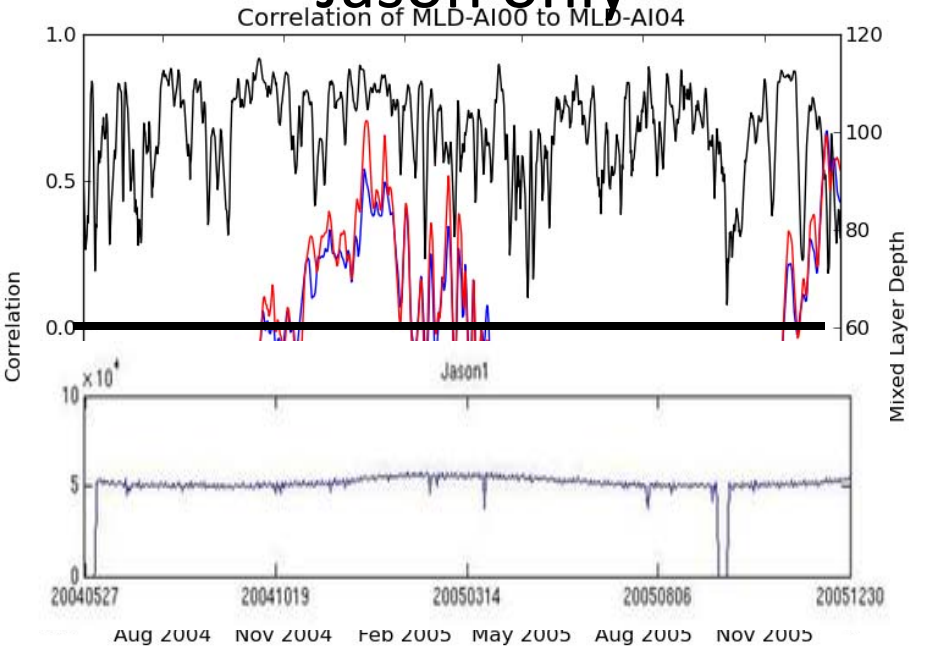
MLD OSSE run

Correlation

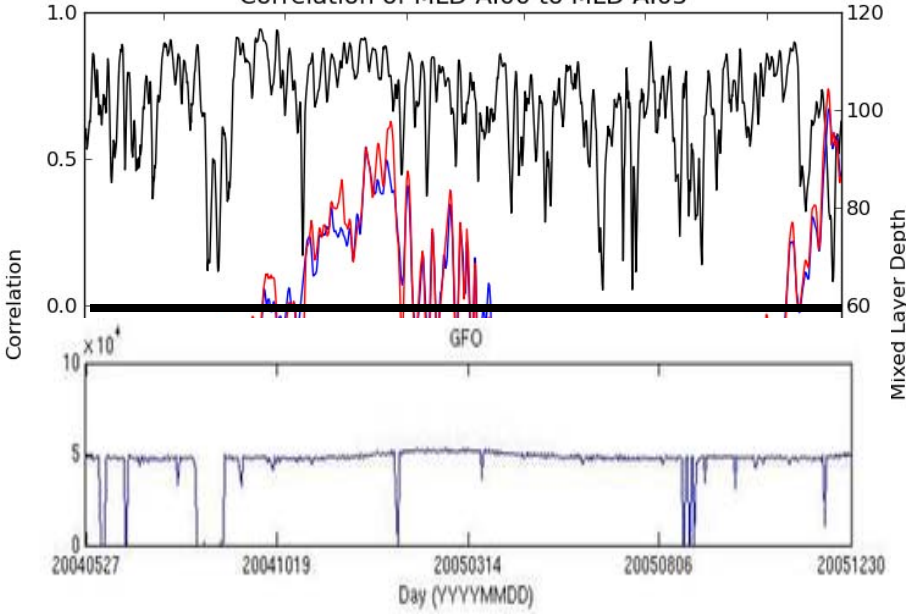
All ALT



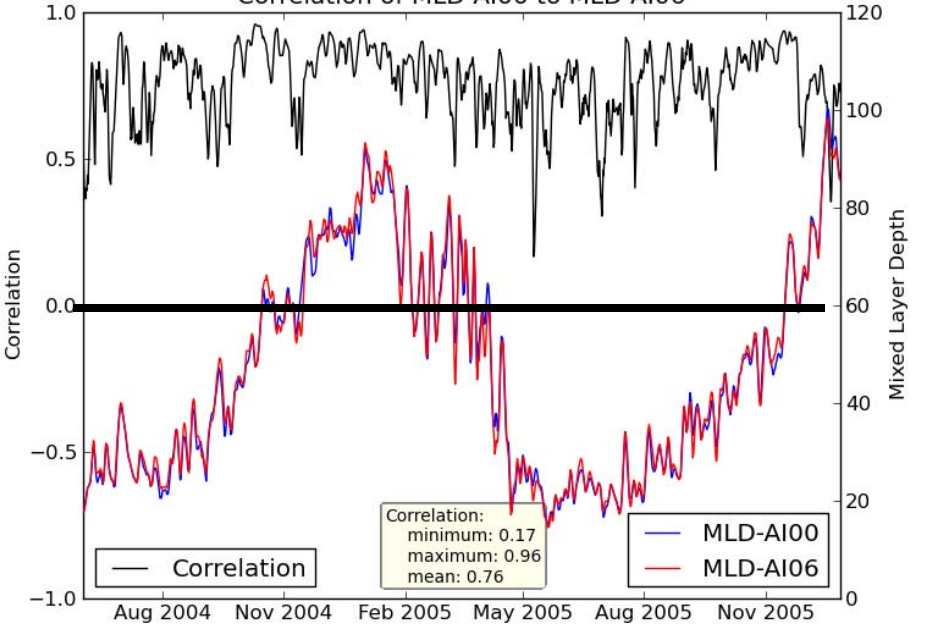
Jason only



GFO only



Jason+GFO



Predictability

Are these features deterministic?

Can they be predicted?

Are they instability-generated processes?

OSSEs

Exp ID	ALT Data	SST	other data	Mean CC	Min CC	Max CC
AI01	None	None	None	0.21	-0.67	0.83
AI02	None	on	Public	0.27	-0.49	0.86
AI03	Jason GFO ENVISAT TPXI	on	Public	0.89	0.53	0.98
AI04	Jason	on	Public	0.66	0.07	0.92
AI05	GFO	on	Public	0.68	0.05	0.94
AI06	Jason GFO	on	Public	0.76	0.17	0.96

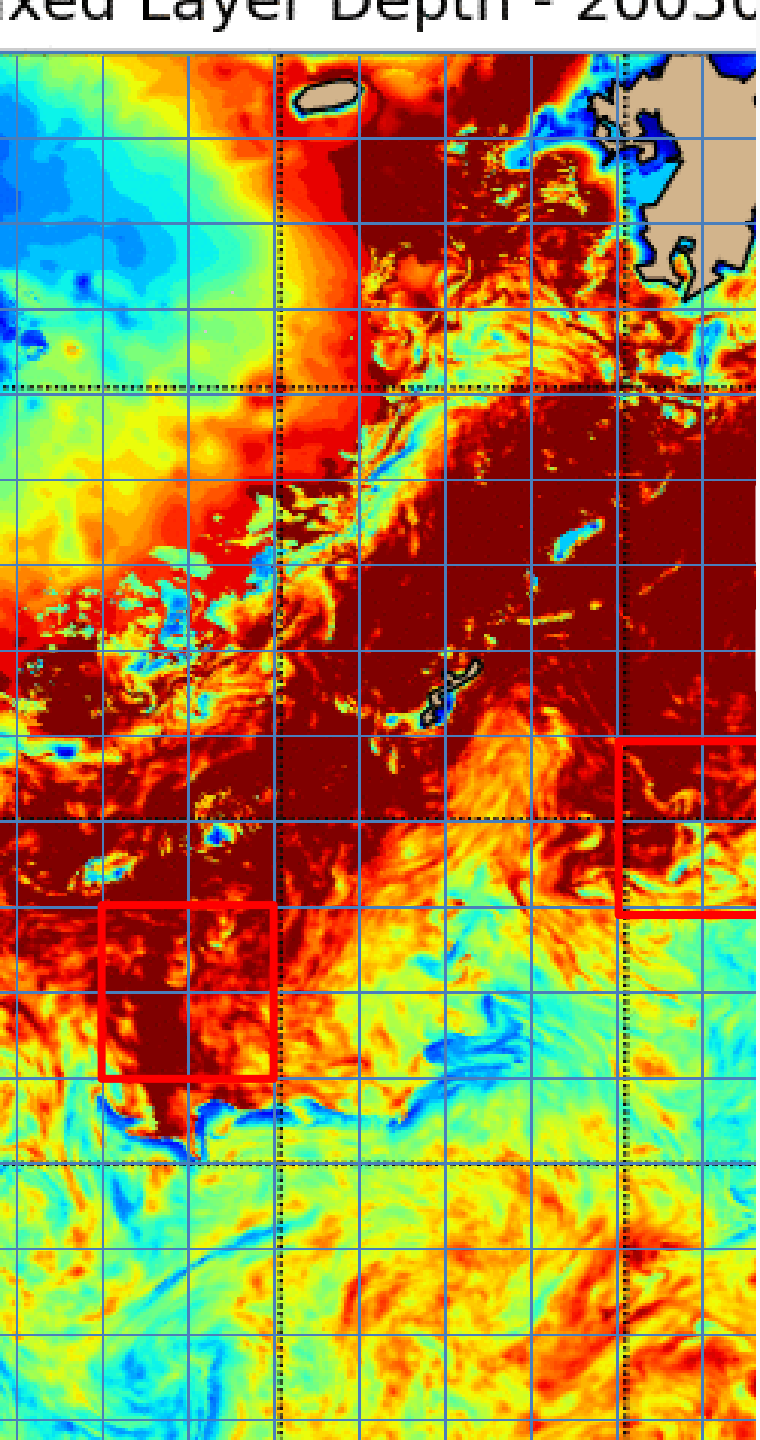
Noise floor correlation reduction by 0.08

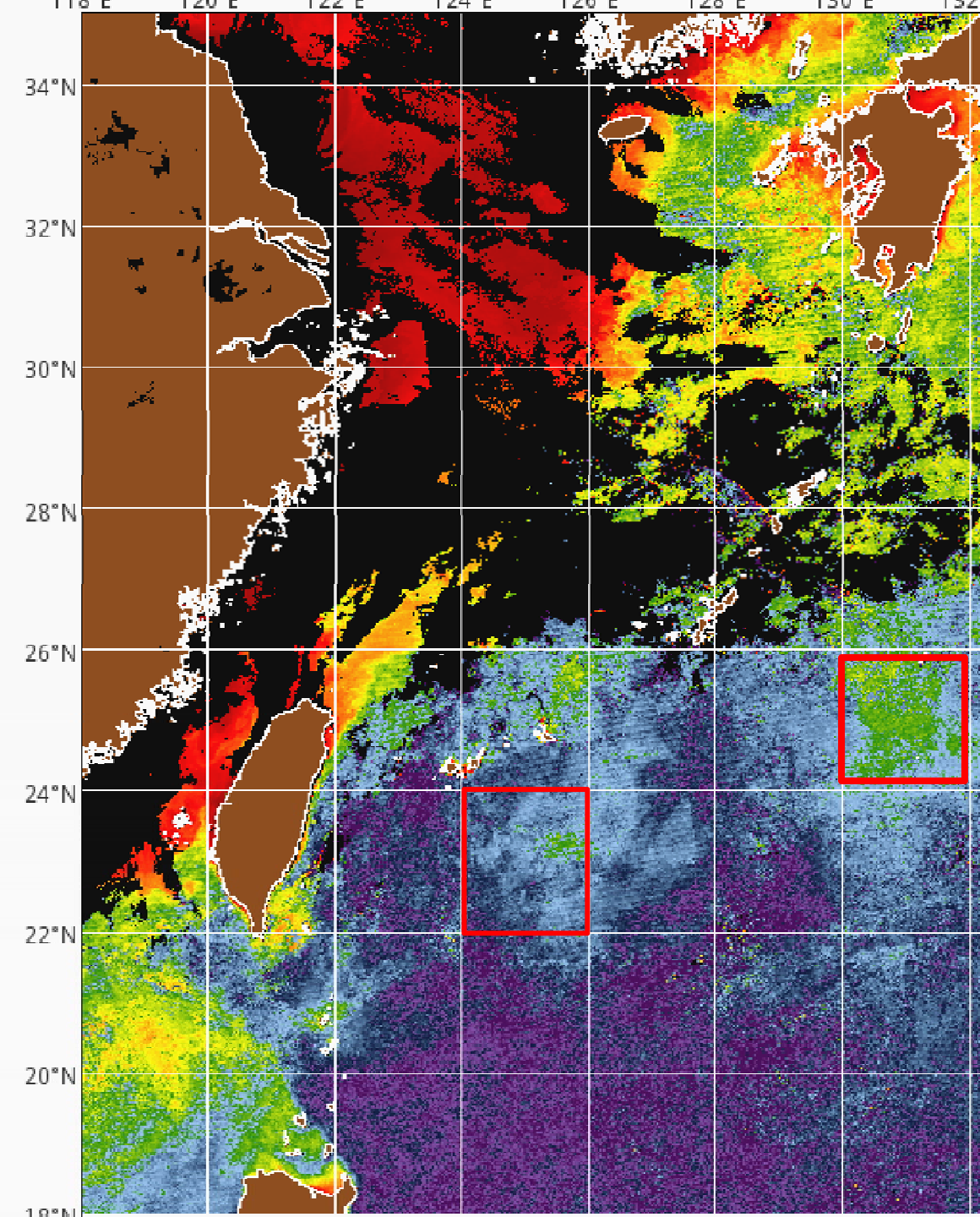
'Perfect OSSE' would correlate 0.92 to nature run

Conclusion

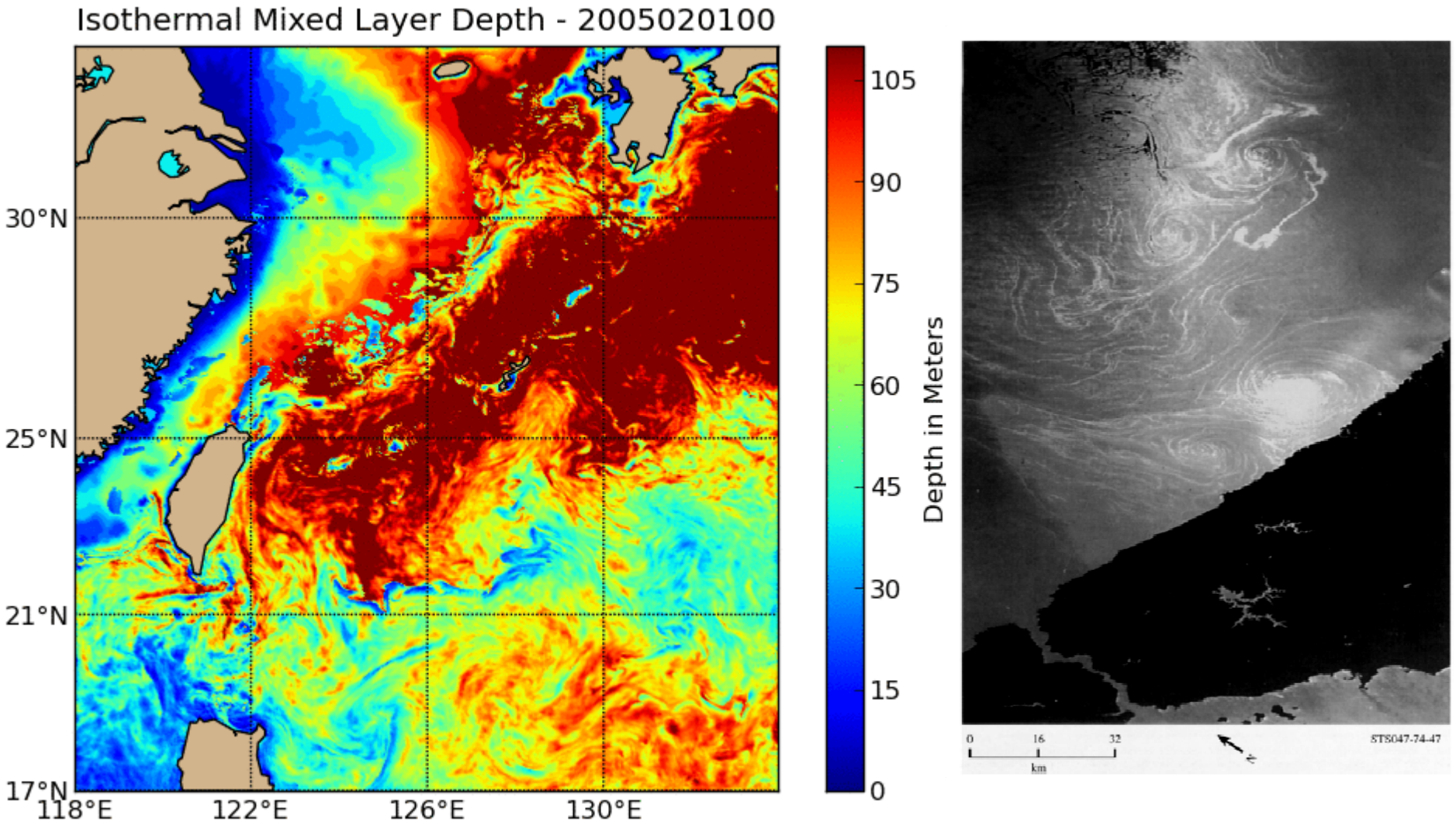
- **Unobserved frontogenesis filaments can be predicted**
- **They are deterministically connected to the mesoscale**
- **If the mesoscale is predicted, the fronts and associated filaments are predicted**

- **Verification in the real world is still necessary**
- **Prior data sets have not been sufficient and targeted observations will be needed**


ixed Layer Depth - 2003


34°N
32°N
30°N
28°N
26°N
24°N
22°N
20°N

Questions?


Isothermal Mixed Layer Depth - 2005020100
30°N
25°N
21°N
17°N
118°E
122°E
126°E
130°E
105
90
75
60
45
30
15
0
Depth in Meters
0
16
32
km
STS047-74-47