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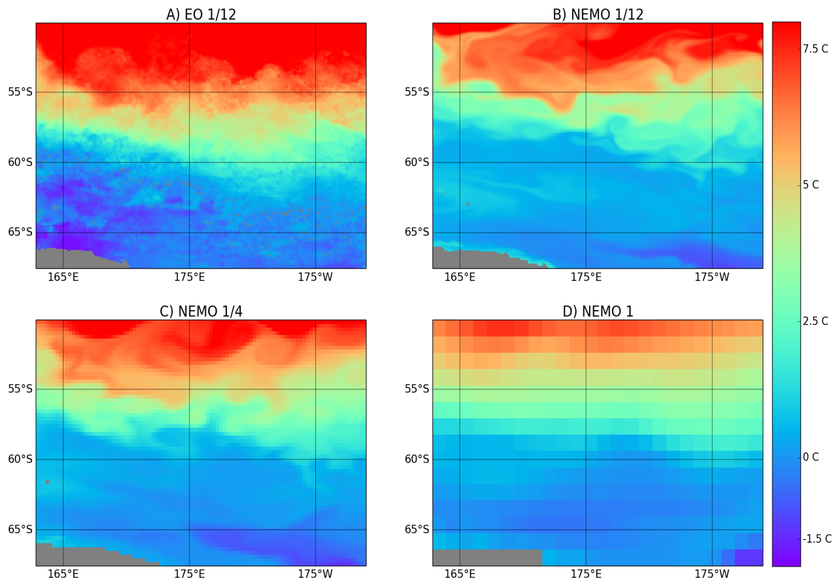
Listen to the ocean



Objectively determining oceanographic model resolution necessary to capture SST variability in the Southern Ocean

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Background

Observation: Scaling analysis often shows striking similarity of structures across large range of scales.

10^1 cm

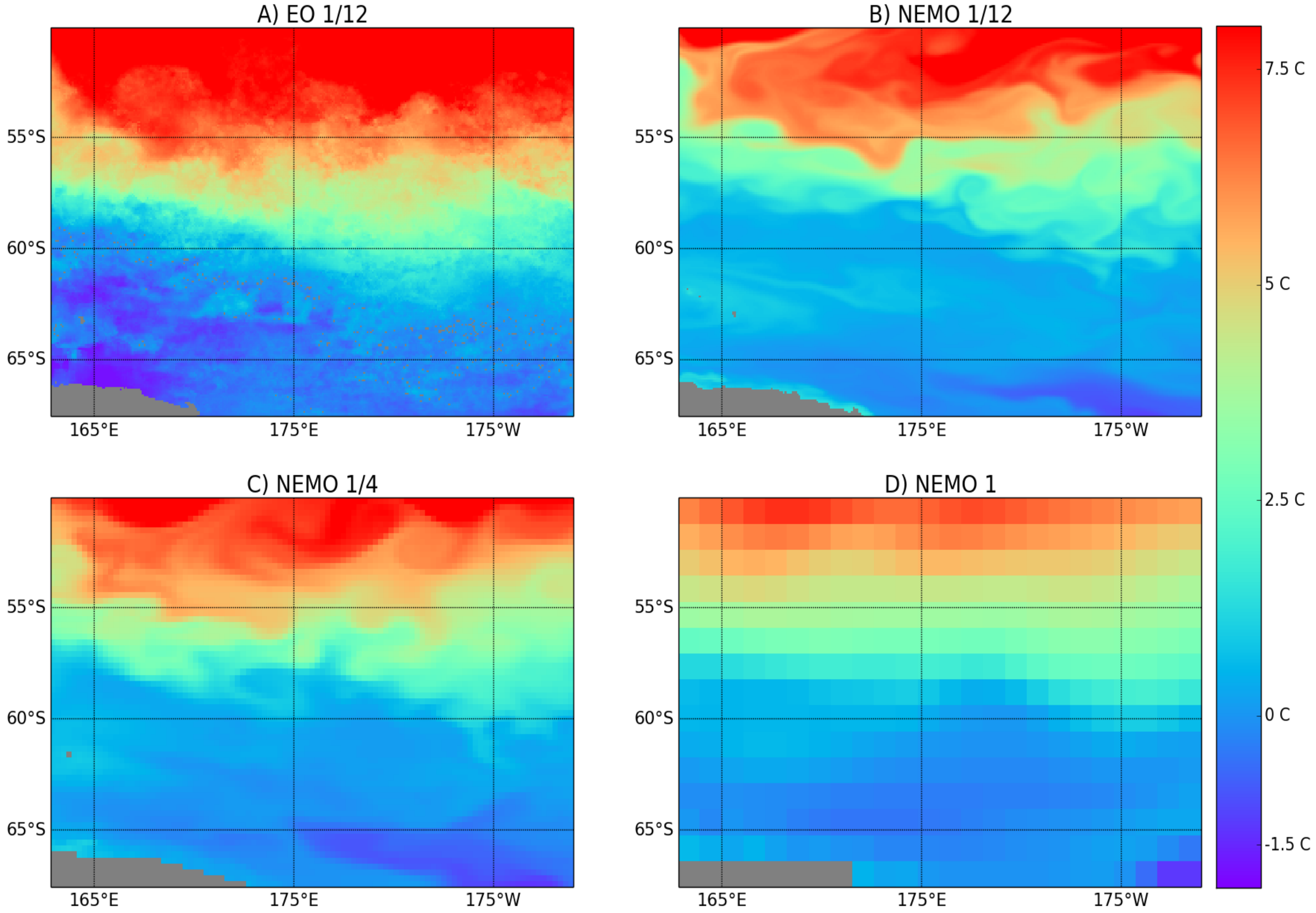
10^8 cm

10^{22} cm

Application: scaling analysis, based on fractals, powerful and insightful tool for making scale (inter)comparisons.

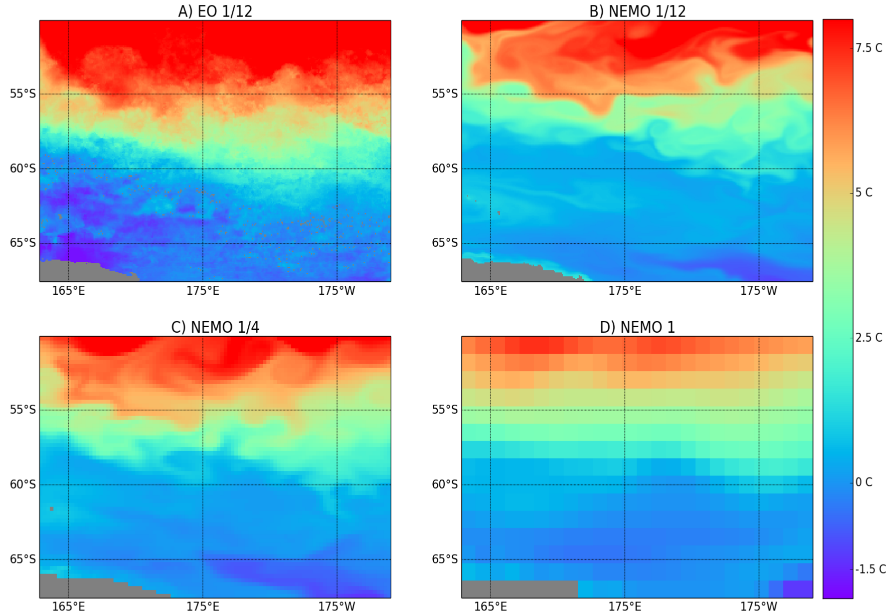
Outline

- How well do different model (NEMO ORCA) resolutions (1, 1/4, 1/12º) reproduce EO SST (1/12º) variability in the Southern Ocean?



Outline

- *What are the scales variability of **model input** SST drivers in order to determine the **resolution** required to adequately represent SST dynamics?*
  - *wind stress components*
  - *incoming shortwave radiation*
  - *surface heat flux to the atmosphere*
  - *bathymetry.*



Method

- Define SST variability at scale *L* as a horizontal spatial average (through spatial domain *x*) of **absolute differences in SST** at the points separated by scale *L*:

$$D_L = \langle |SST(x+L) - SST(x)| \rangle$$

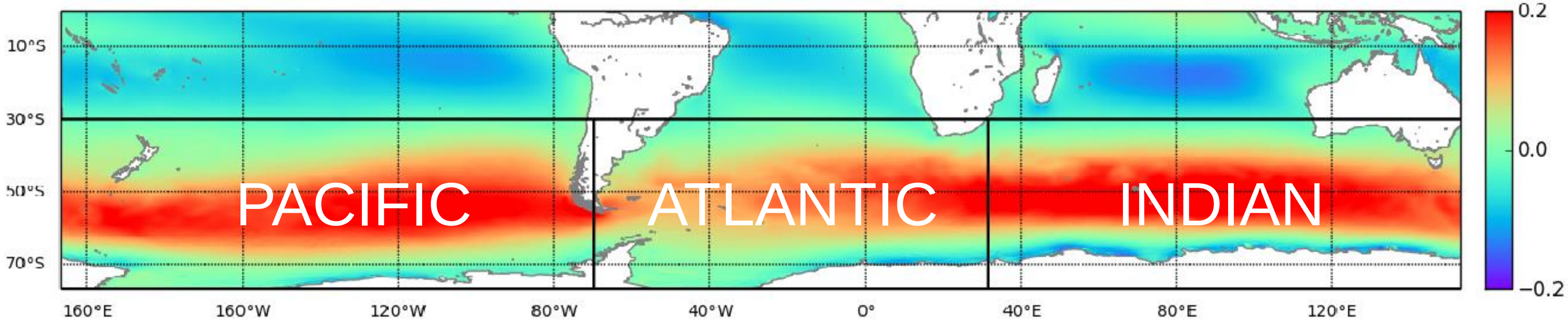
- Scale invariance implies this **scales as a power law**: L^H

- Observation: the SST fields analysed scale as piecewise power laws separated by a scaling break at L_0

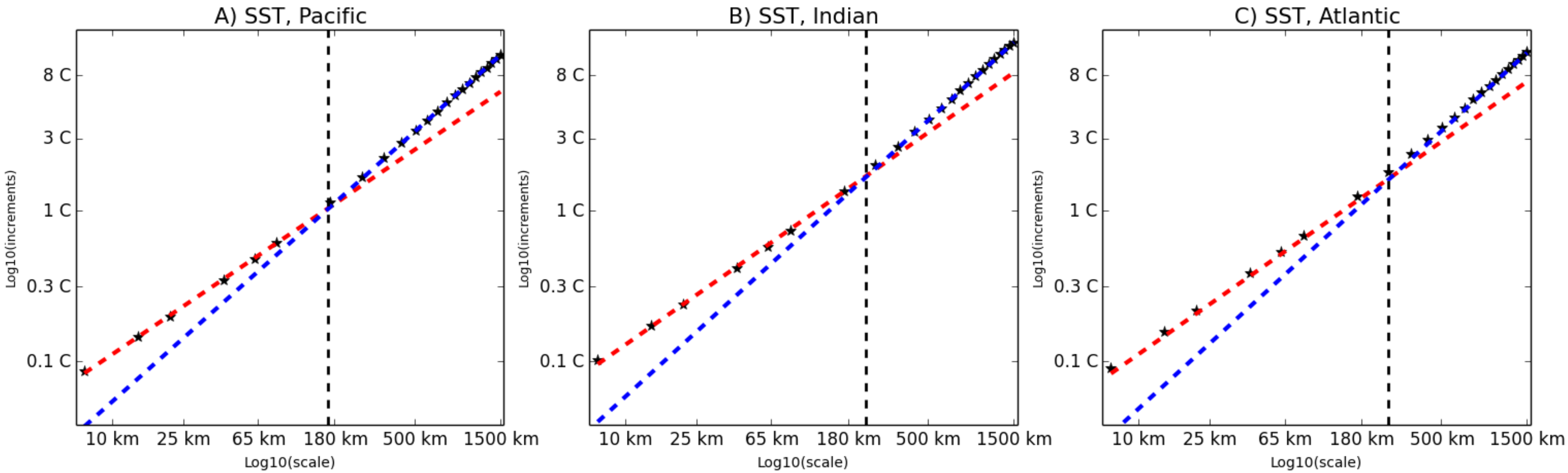
$$D_L = A.\left(\frac{L}{L_0}\right)^{H_1}, \quad L < L_0$$

$$D_L = A.\left(\frac{L}{L_0}\right)^{H_2}, \quad L > L_0$$

Regions of interest



- **EO SST magnitude of variability** (mean absolute differences in SST between points separated by a specific scale) scales between 7 – 100 km and 300 – 1500 km as two distinct power laws.



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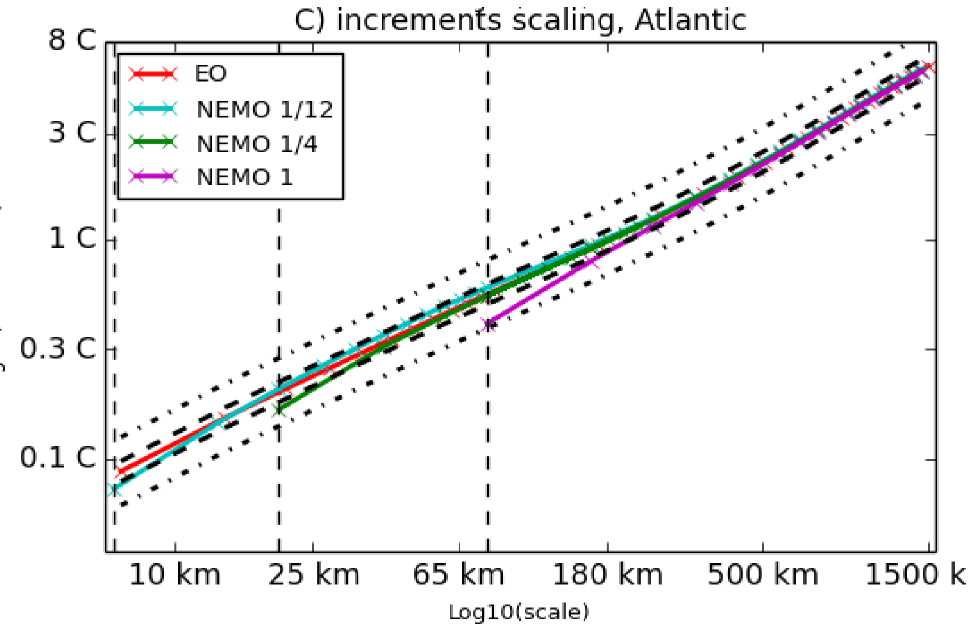
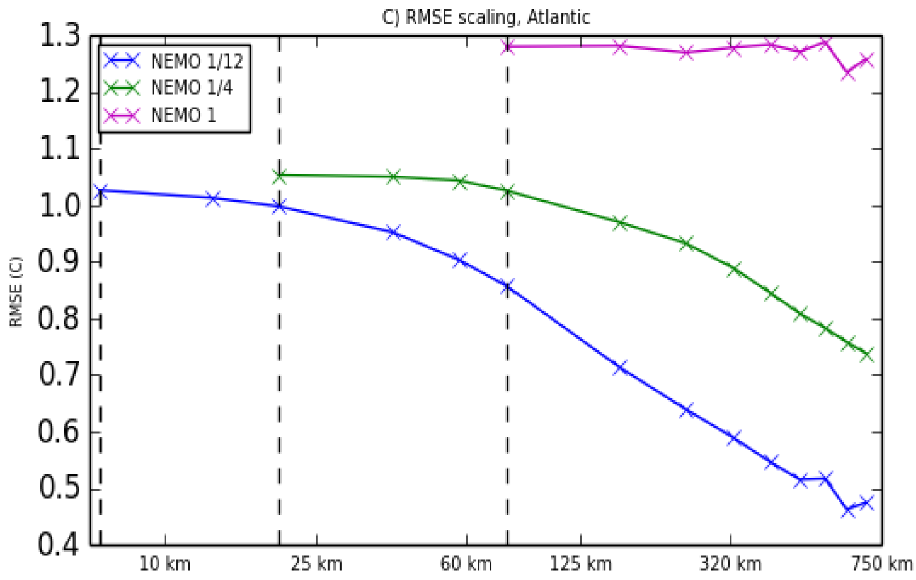
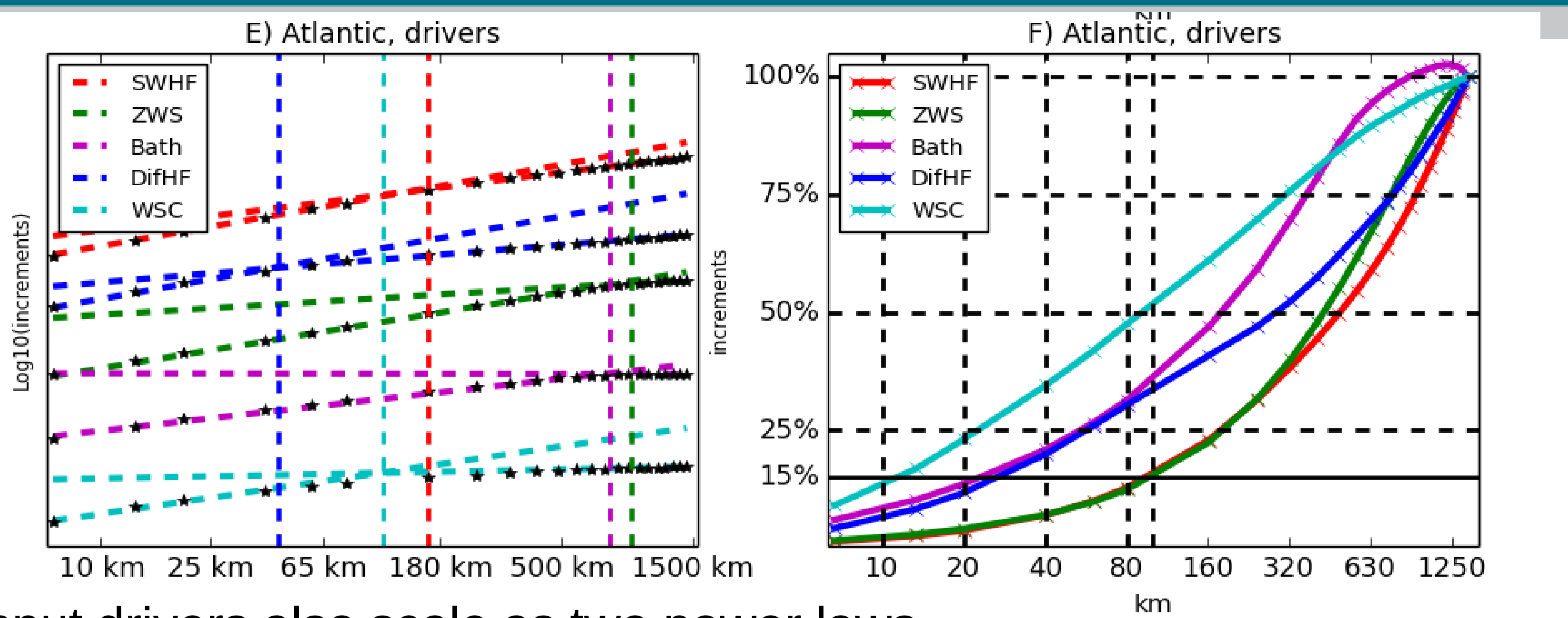
Model skill – SST variability and its spatial patterns (RMSE)





- Each model resolution matches the EO SST magnitude of variability within **10% from 4-5 times** the model resolution scale.
- **From approx 500 km** all model resolutions match the EO magnitude of variability within **3%**.
- Increasing model resolution has substantial impact how model represents spatial patterns of EO SST variability (RMSE) and this **impact grows with scale**.

SST input drivers



- SST input drivers also scale as two power laws
- Split into three classes: scale **L which resolves 85% of their 1500 km variability**:
- 1) <u>large scale variability SST drivers</u> **L = 80 – 100 km**
  - wind stress, short wave incoming radiation
- 2) <u>medium scale variability SST drivers</u> **L = 20 – 40 km**
  - bathymetry, surface latent, sensible and longwave heat fluxes
- 3) <u>small scale variability SST drivers</u> **L = 10 – 20 km**
  - wind stress curl
- Fractals can determine the scale resolving 85% of large scale turbulent eddy SST variability (L ~ 3km).

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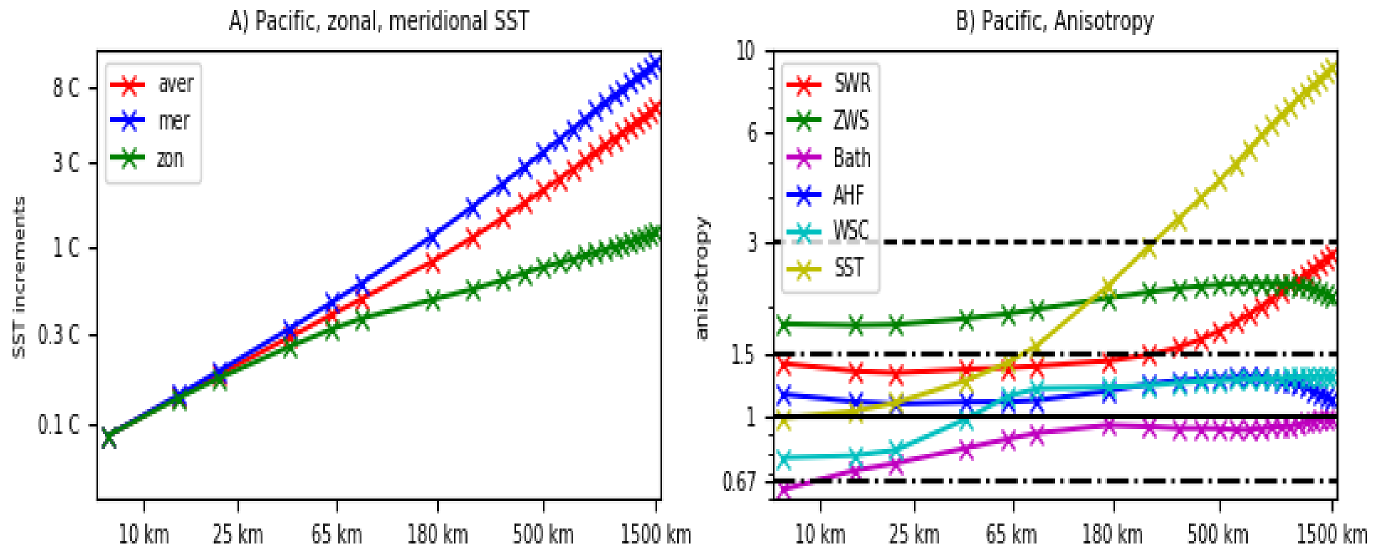
Anisotropy



- Two power law regimes associated with **SST horizontal anisotropy** (ratio of mean meridional to zonal increment).
  - SST is isotropic at scales < 50 km, but its anisotropy dramatically changes with scale and the anisotropy **meridional-to-zonal increment ratio is at 1500 km 9:1**.
- The large scale SST variability (above 300 km scale) is dominantly driven by **anisotropic drivers**:
  - the **wind stress** and **incoming short wave radiation**.
- The small scale SST variability (below 100 km scale) is dominantly driven by **isotropic drivers**:
  - the **turbulence** and to some extent also by the **wind stress curl** and the **heat exchange** with the atmosphere.

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Conclusions

- Scaling techniques derived from fractal geometry can provide a powerful way to:
- *1) analyse the skill of different resolution models,*
- *2) determine the desirable resolution scale for the model input drivers,*
- *3) explain the scales of dominant effect of model input drivers on model dynamical fields.*

Thank you