NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

Improving Weather and Climate Prediction Models Through the Super-Parameterization Approach

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Science Review
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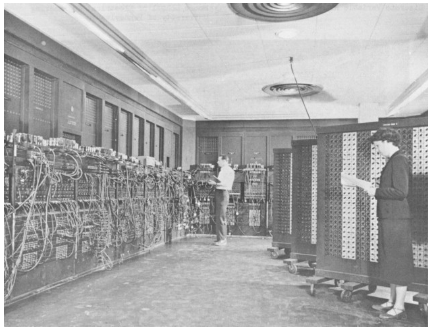
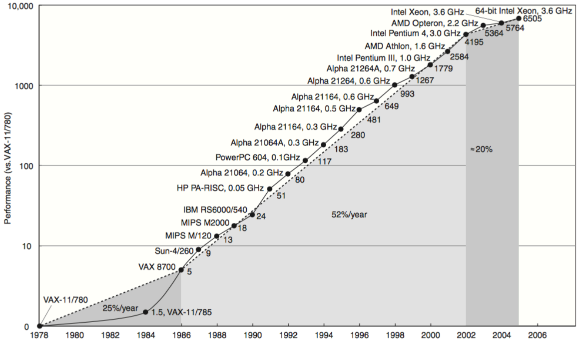
Motivation

The weather/climate modeler's lament:

The more things change, the more they stay the same

Since the 1980s: 1000-fold+ increase in both core speed and # or cores





Global model grid spacing: 1980s (400-km) → 2010s (50-km)

Yet many deficiencies remain: biases, missing transients (MJO), lack of spread, etc.

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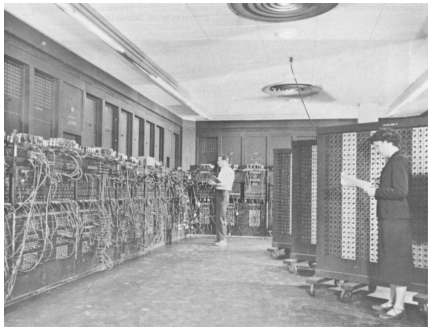

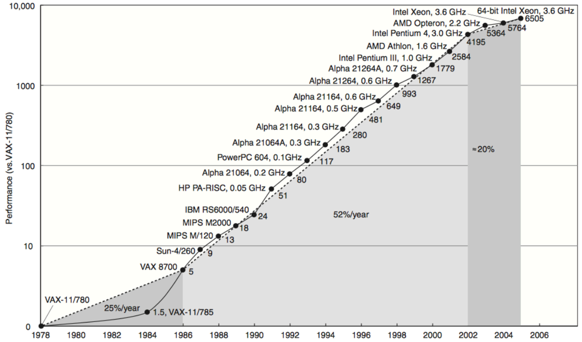

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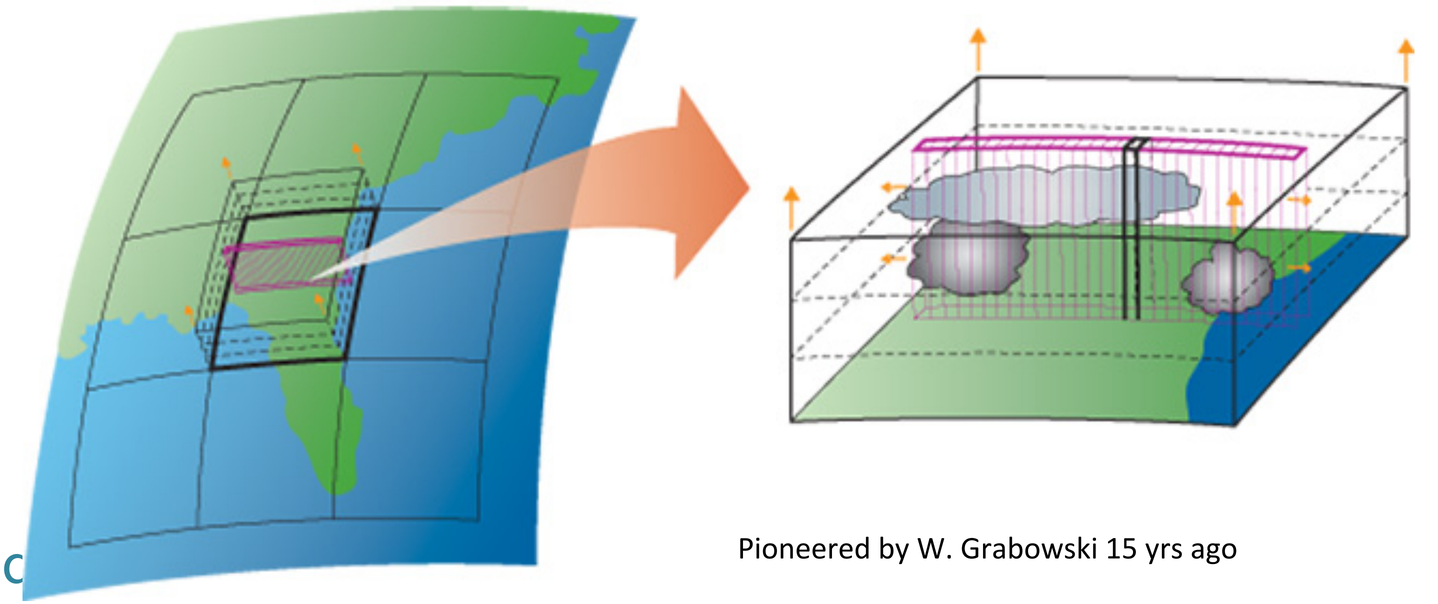
Parameterization is still the proverbial "thorn" in our side

“Super-parameterization” (SP): a promising alternative



Pioneered by W. Grabowski 15 yrs ago

Immec

- Based on first principles: F=ma, etc.
- Exploits chaotic CRM evolution
- Accounts for key subgrid interactions
- Embarrassingly parallel

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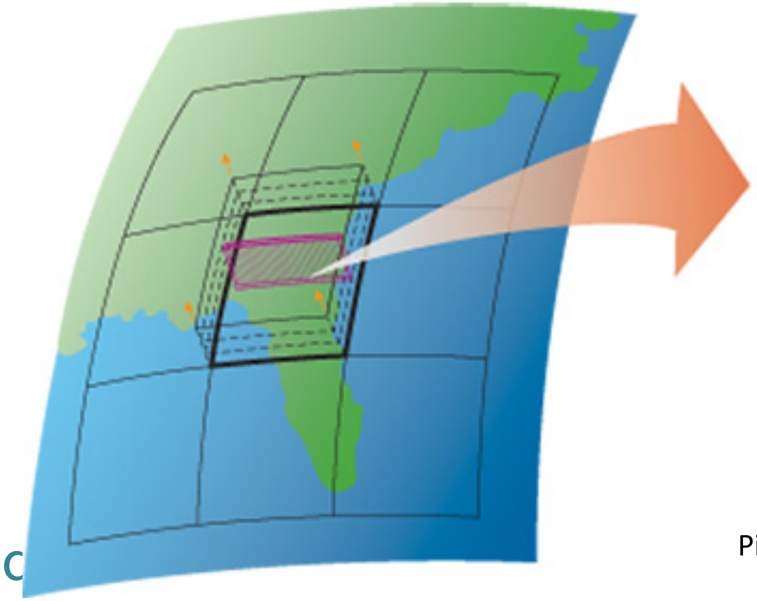

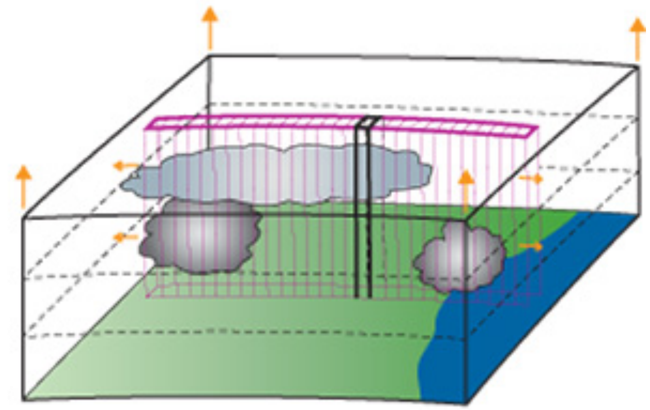

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} Simulation of tropical variability, especially the MJO, is greatly improved

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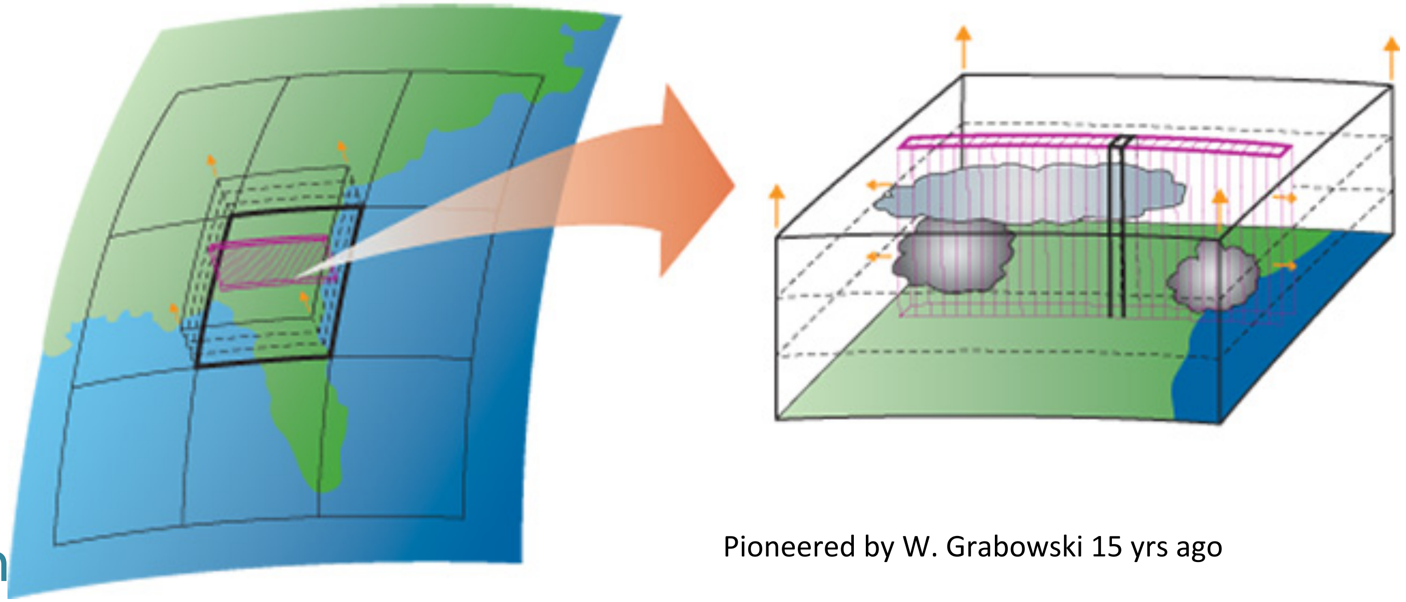

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- Coarse GCM
- 2D geometry, Periodic BCs
- No convective momentum transport

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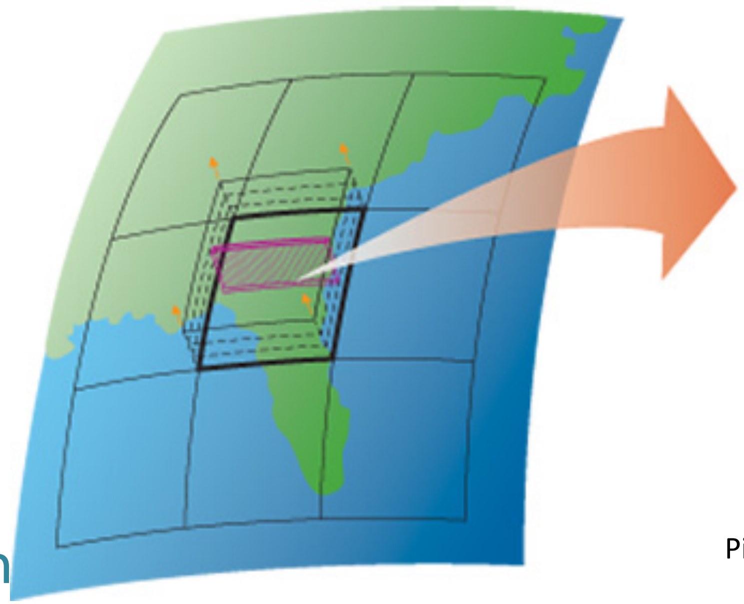

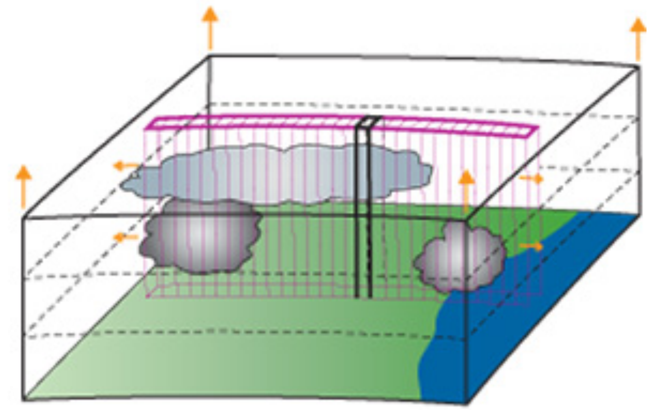

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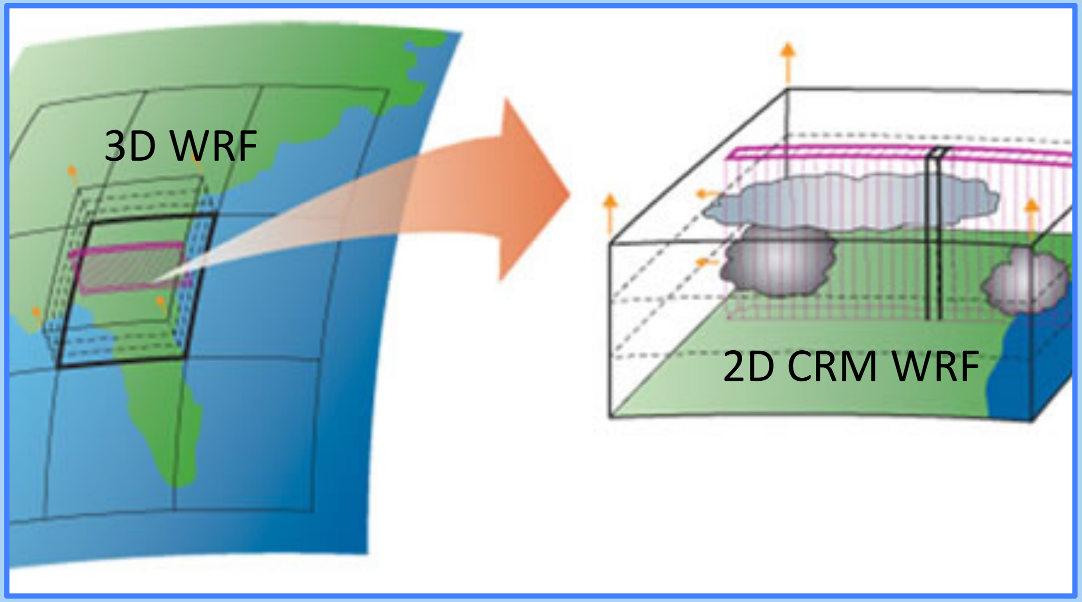
Mean-state biases are still a big issue… an opportunity for learning

A new SP version of the WRF model (SP-WRF)



Unique capabilities:

» Can be run either regionally or globally
» Wide variety of bulk physics options
» Novel treatment of convective momentum transport (CMT)

SP-WRF (Tulich, JAMES 2015, in press)

A story of knowledge discovery with SP-WRF…

…or, how to simplify the game of Whac-a-Mole

PBL turbulence + surface fluxes

Cloud-radiation interactions

Convection closure/triggering

Entrainment/detrainment

Rain evaporation/downdrafts

A story of knowledge discovery with SP-WRF…

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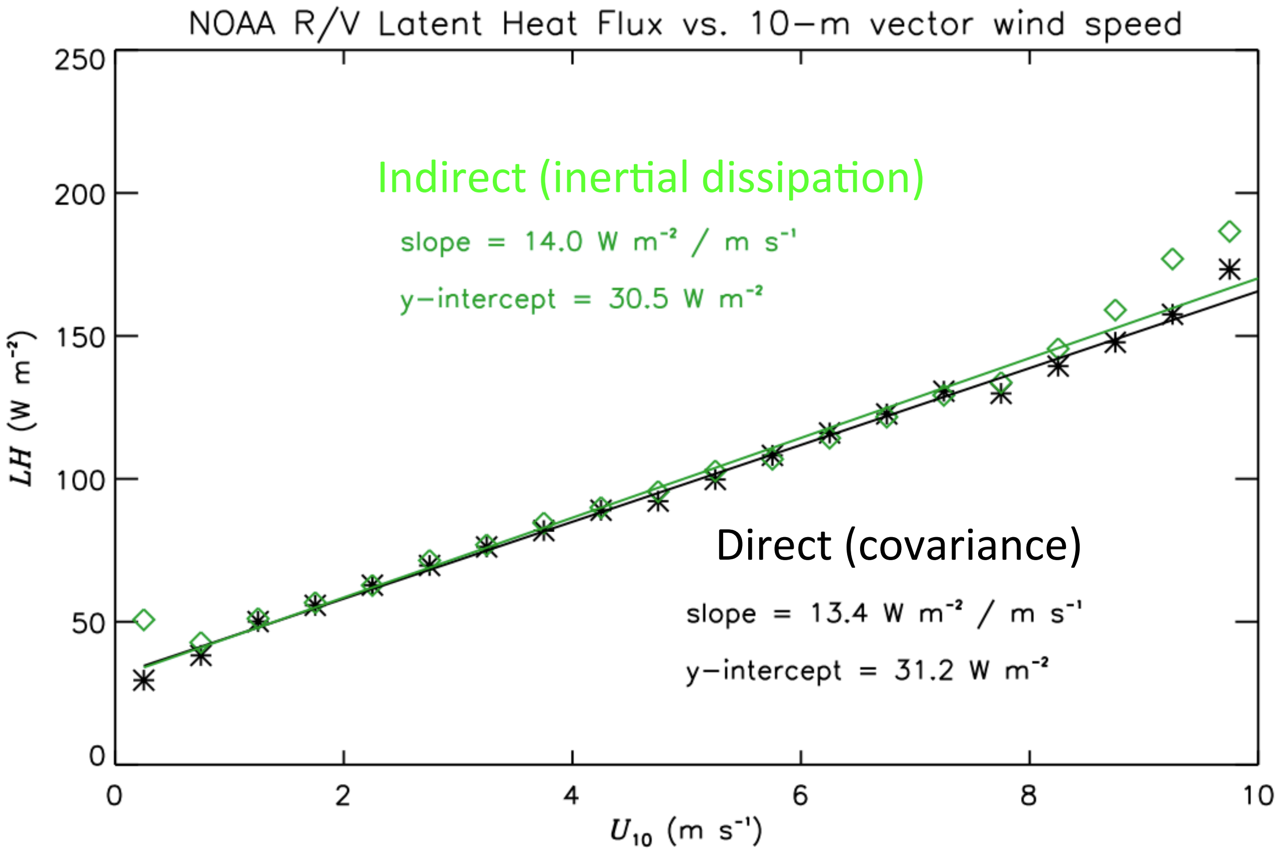
PBL turbulence + surface fluxes

Arguably, one of the least examined aspects of the parameterization problem

PSD has tremendous expertise concerning ocean surface fluxes



10 cruises during the 90's including COARE, JASMINE, and KWAJEX

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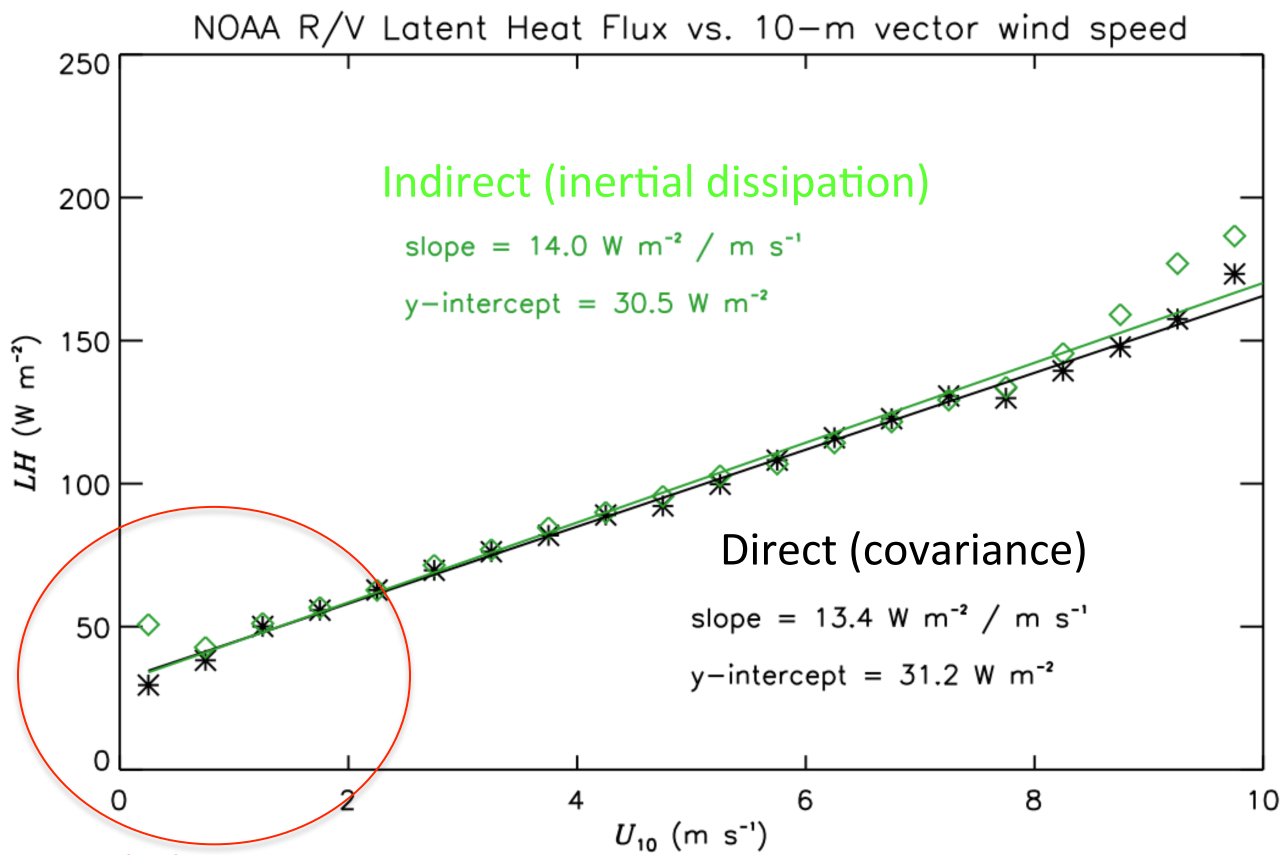

Critical observation:
Surface fluxes don't go to zero!

10 cruises during the 90's including COARE, JASMINE, and KWAJEX

Practical implications for bulk flux algorithms

$$LH = -(\rho L_v) C_q \Delta q U$$

$$\Delta q = q_a - q_{sfc}$$

$$U = \sqrt{u_a^2 + v_a^2 + V_g^2}$$

$$V_g^2 \stackrel{\text{def}}{=} \beta \left(\frac{g z_i B_{sfc}}{T_v}\right)^{1/3}$$

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"Gustiness" wind speed

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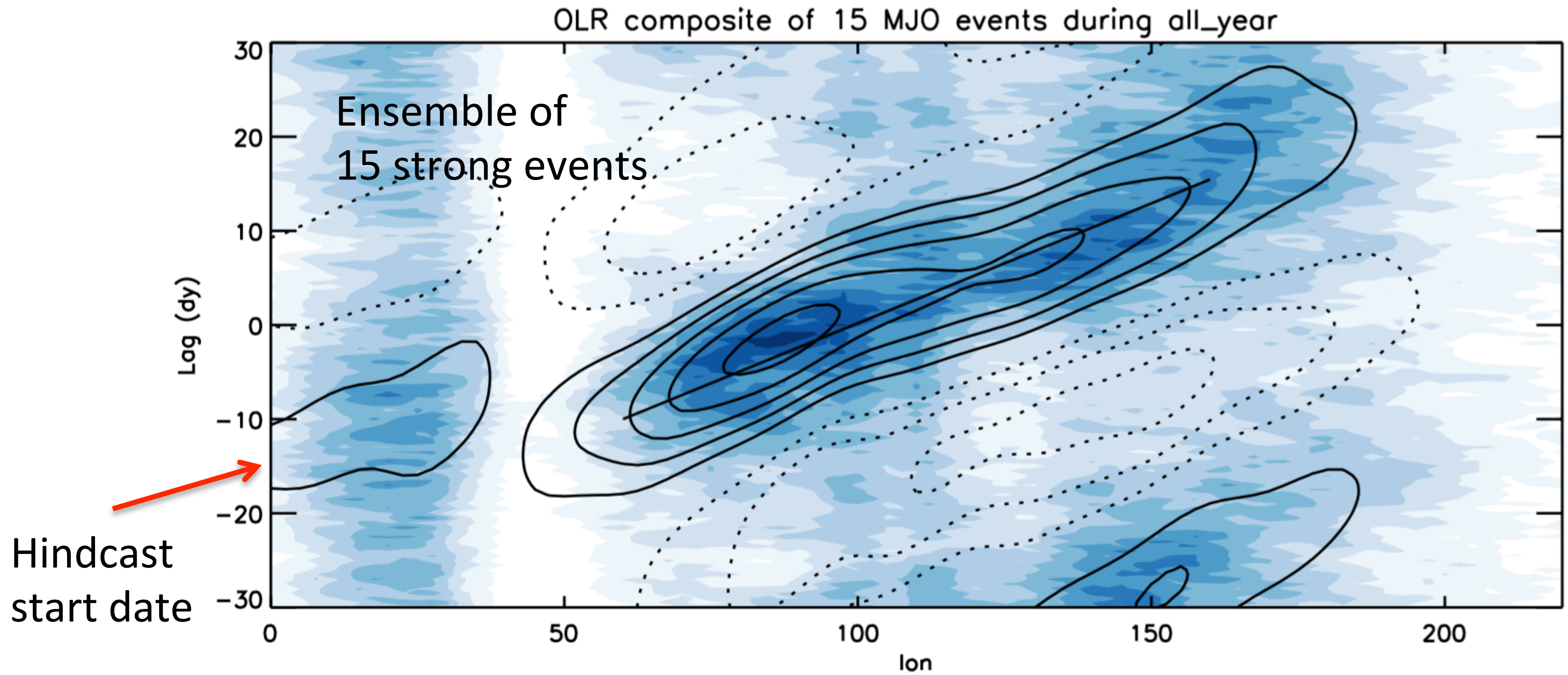
COARE3.0 algorithm uses Deardorff velocity

But what is the appropriate choice of gustiness for use in models?

- Gustiness strength in nature increases with spatial scale $E(k) \sim k^{(-5/3)}$
- Models often have steeper E(k) curves near grid scales
- Systematic model biases can lead to steepening of the LH vs U relationship ($C_q \approx$ constant)

The assumed strength of gustiness matters importantly in SP-WRF

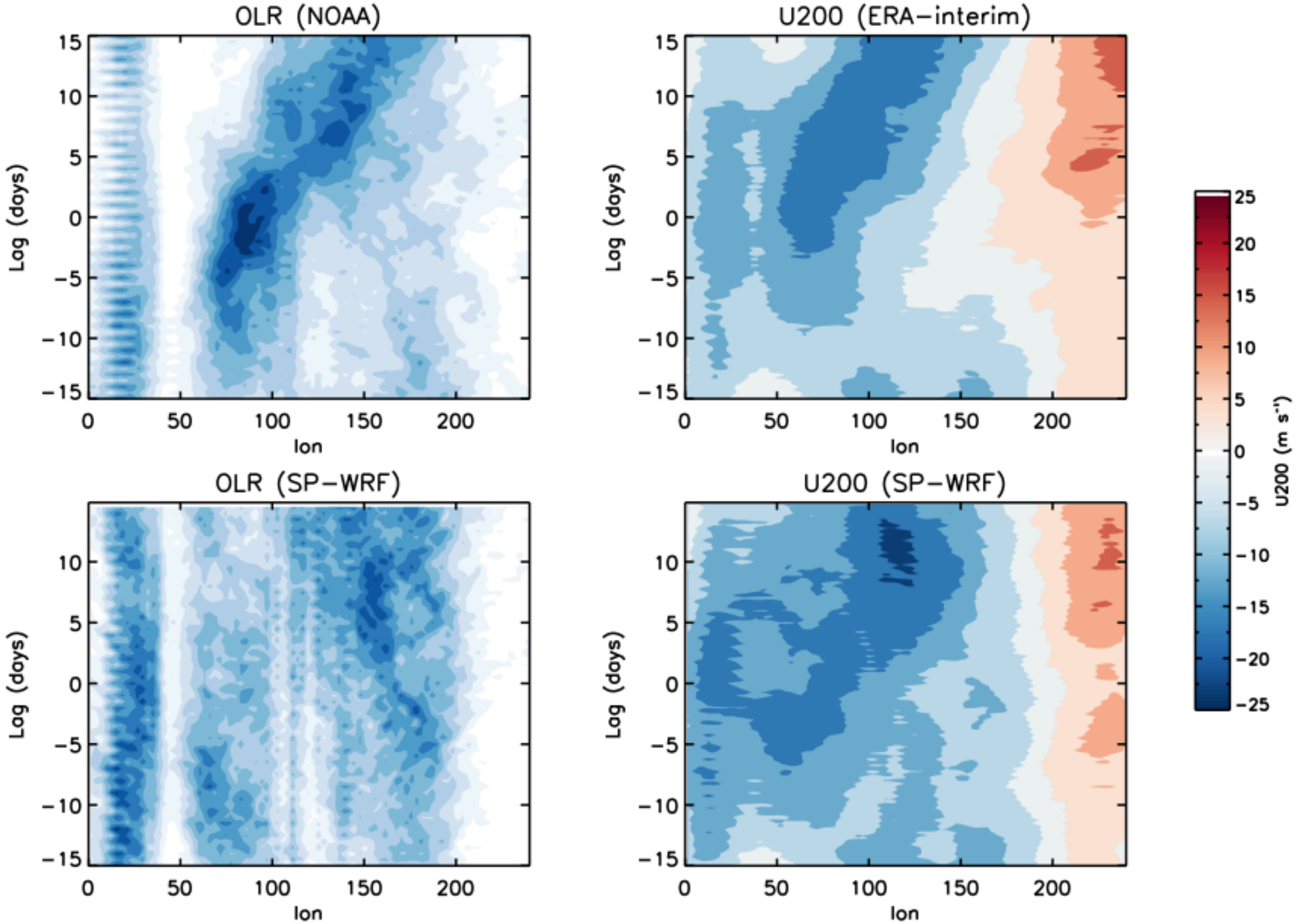
in the context of MJO hindcasts:



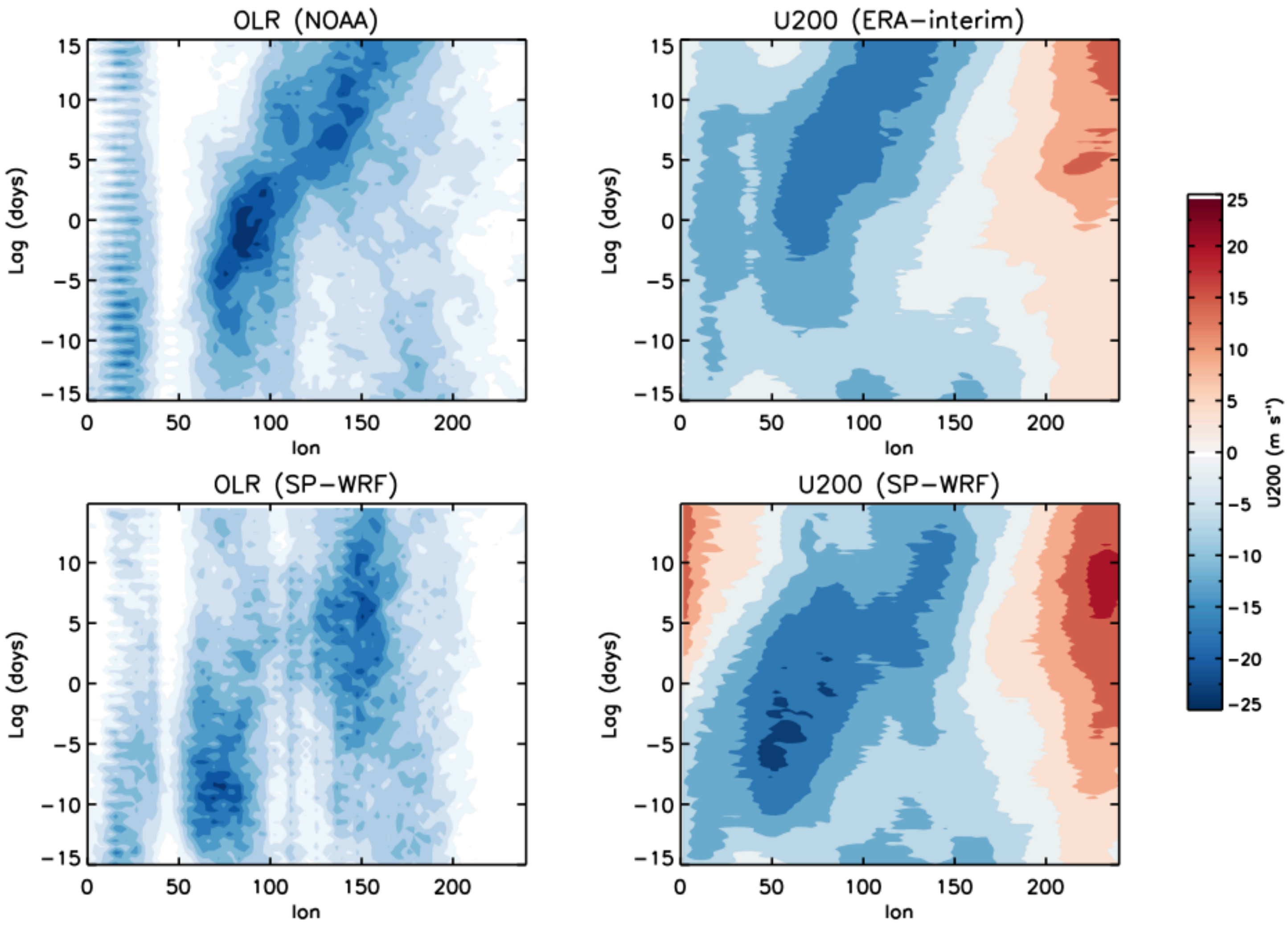
Experiment details:

- 2.8x2.8 deg. global
- Initialized from ERAI
- Time-varying SSTs

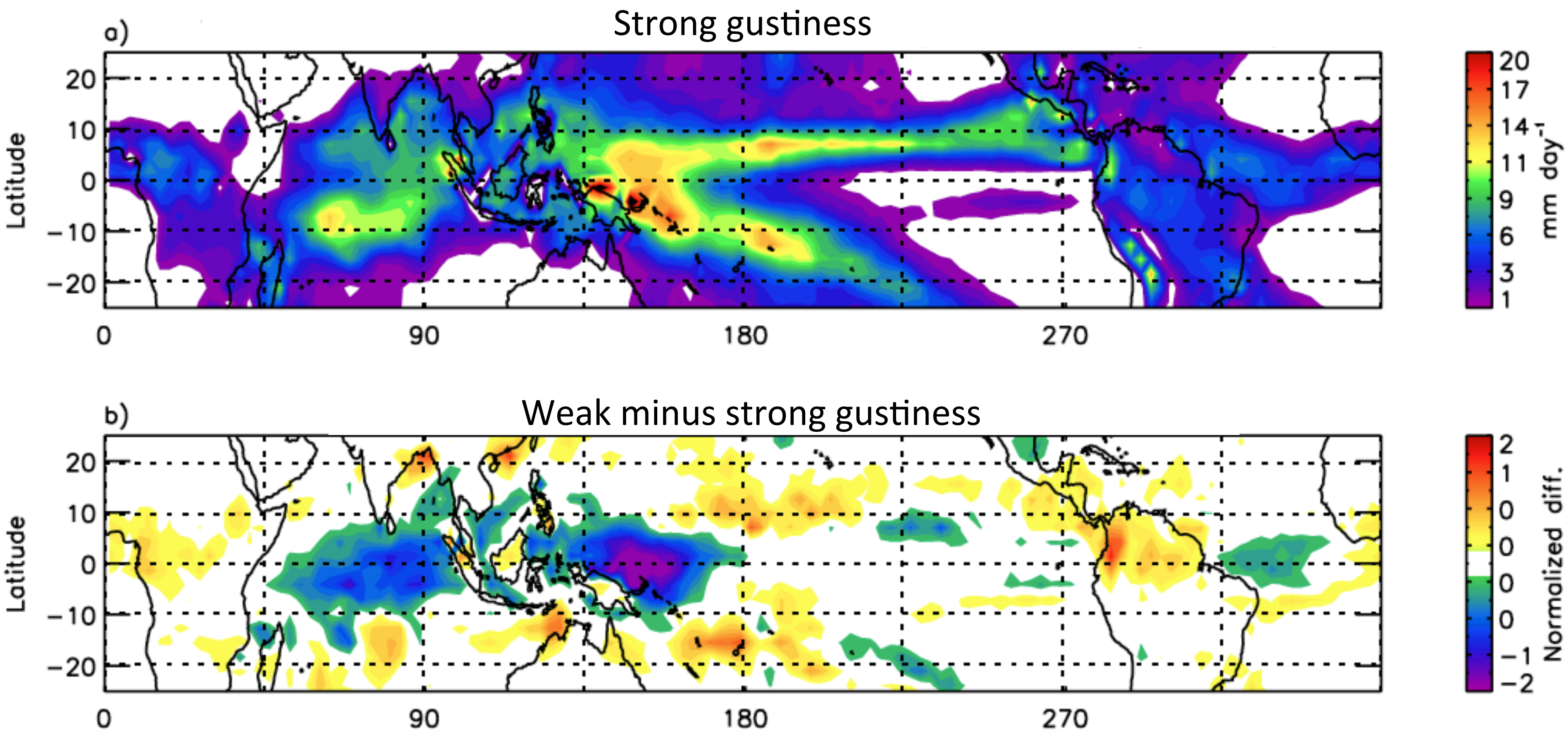
Ensemble-mean SP-WRF hindcast (“weak” gustiness)



Increasing the gustiness brings out the MJO!



Changing gustiness also leads to time-mean rain differences



Summary and Conclusions

- SP-WRF is unique and versatile tool that we are using to inform the broader modeling community (future plan: knowledge transfer to in-house operational version of GFS)
- Model also helping to improve our physical understanding of the weather/climate system (MJO, ITCZ, etc.)
- Story from today illustrates the diverse range of skills and knowledge that are brought together within PSD