Bridging the scales of the MABL for sea salt production estimates

John Park

Code 7542, U.S. Naval Research Laboratory, Marine Meteorology Division, Monterey, CA, USA

Hyungwon.park.ctr@nrlmry.navy.mil

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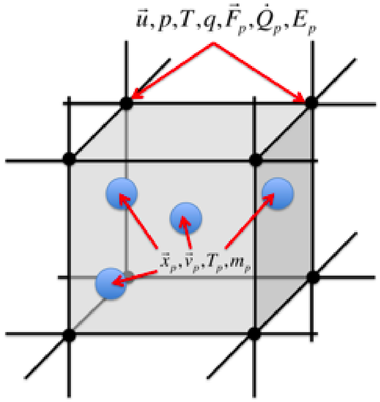
Reed Espinosa[GSFC], David Flagg[NRL], Livia Freire[USP], Chris Jackson[NOAA], Coda Phillips[CIMSS], Jeffrey Reid[NRL], David Richter[ND]

Takeaway message up front

Using numerical simulations (LES) we found that field-based sampling methods are unique in surface flux variability due to coherent roll structures within the marine boundary layer*.

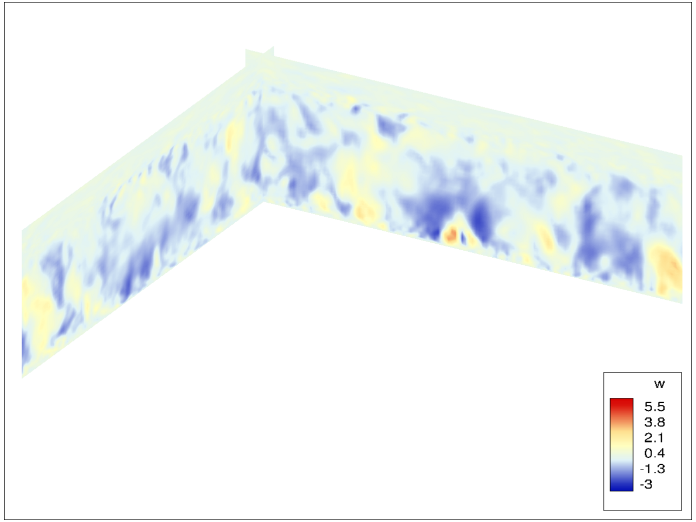
Schematic of a numerical simulation



Black nodes: Eulerian field air quantities (velocity, pressure, temperature, specific humidity, drag from particles, …)

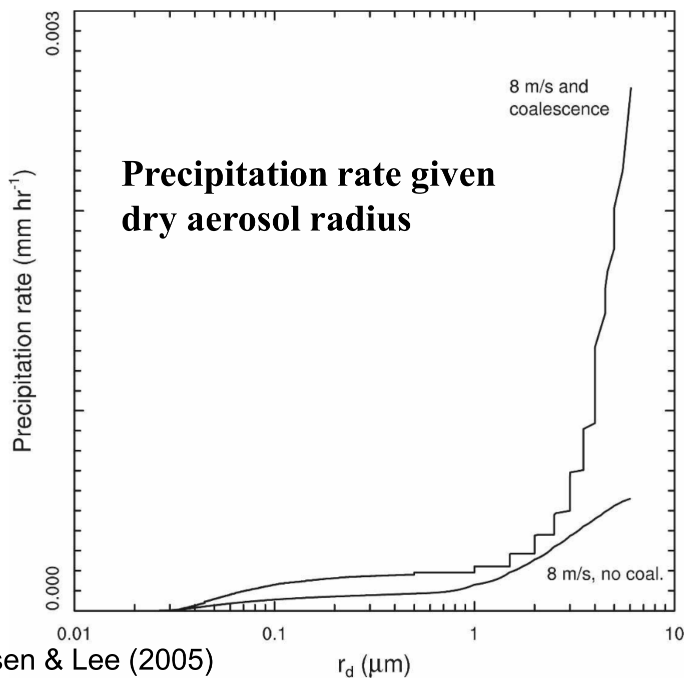
Blue circles: Lagrangian particle quantities (position, velocity, temperature, radius, mass, …)

Vertical velocity contours of a large eddy simulation with Lagrangian particles

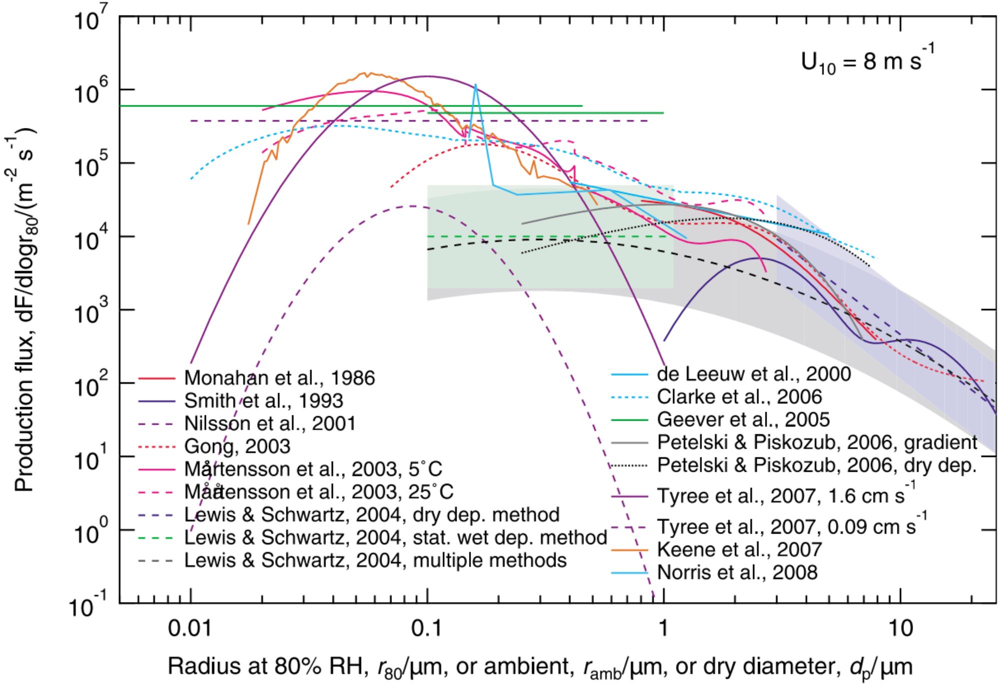


* Lots of contingencies…

Rationale: GCCN source flux variability



Jensen & Lee (2005)

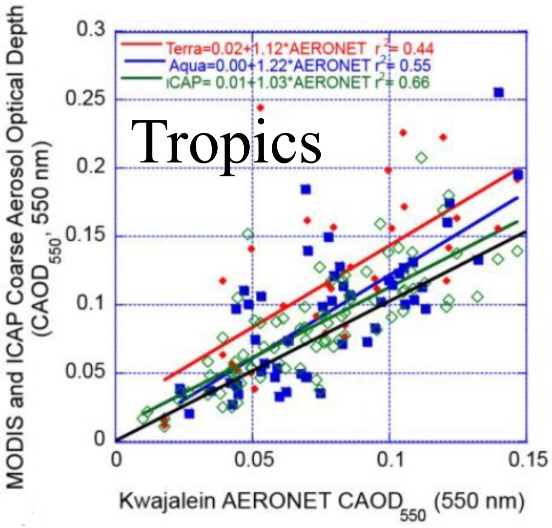


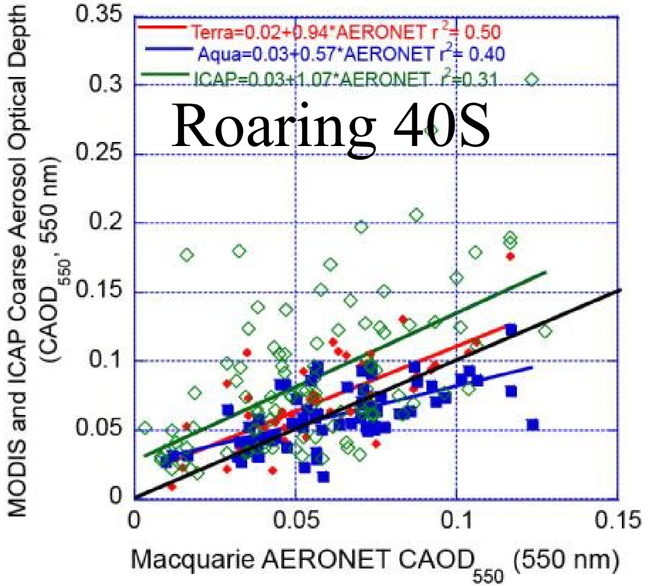
GCCNs accelerate the hydrological cycle for faster cloud precipitation, and leading to less condensed water in the atmosphere (Posselt et al. 2008, Jung et al. 2015)

Surface/production flux is orders of magnitude in variability, how can we constrain it?

Where do we go wrong?

Does the source function or the model representation of physical meteorology cause the wide range of model outcomes for high wind conditions and latitude?
With many source functions to choose from, how may we approach comparing output metrics?
How good can a source flux measurement even be? Is there physics or bias in different measurements? Can we even evaluate with AOD?

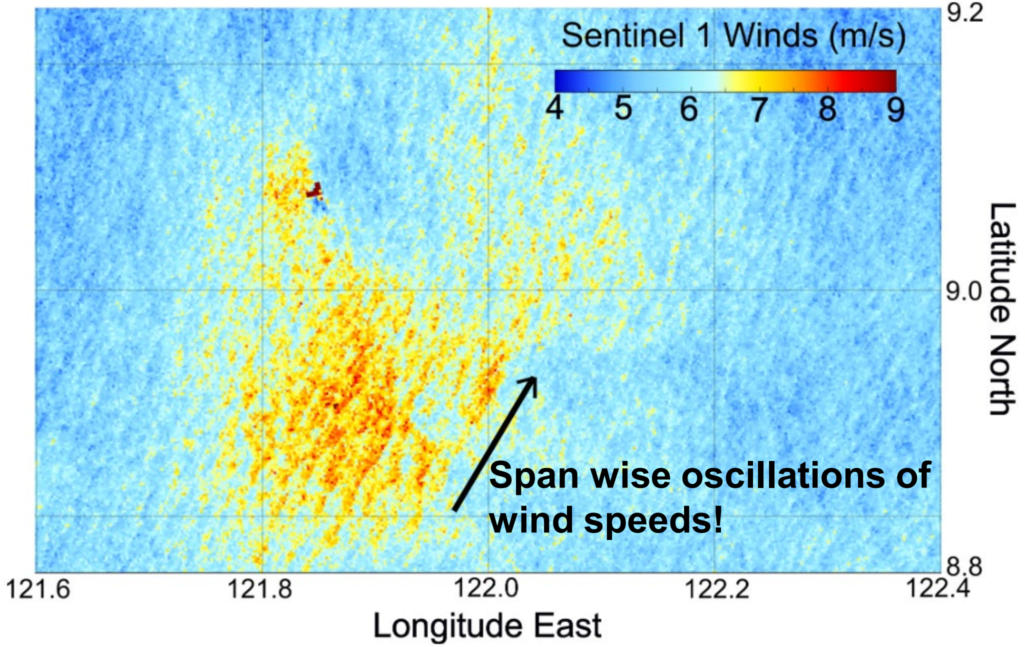


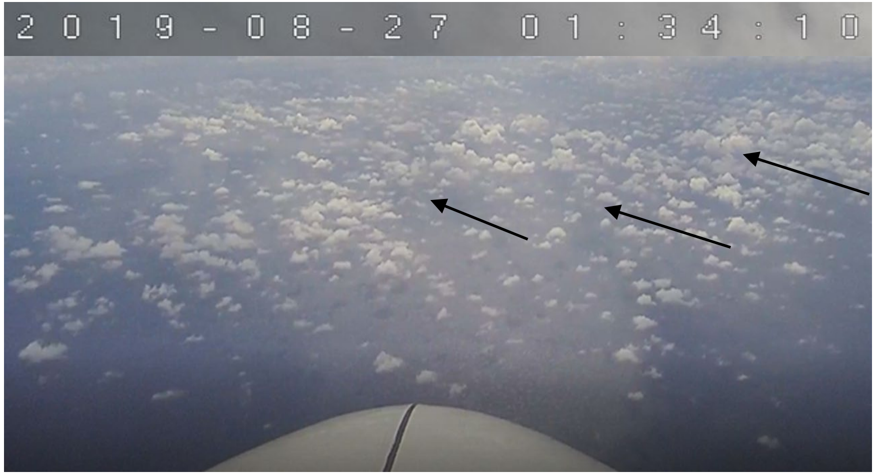


Observation of MBL roll features:

Feature occurrence for winds > 7 m/s

SAR imagery on the surface winds of the Sulu sea (09/01/2019), 250m resolution



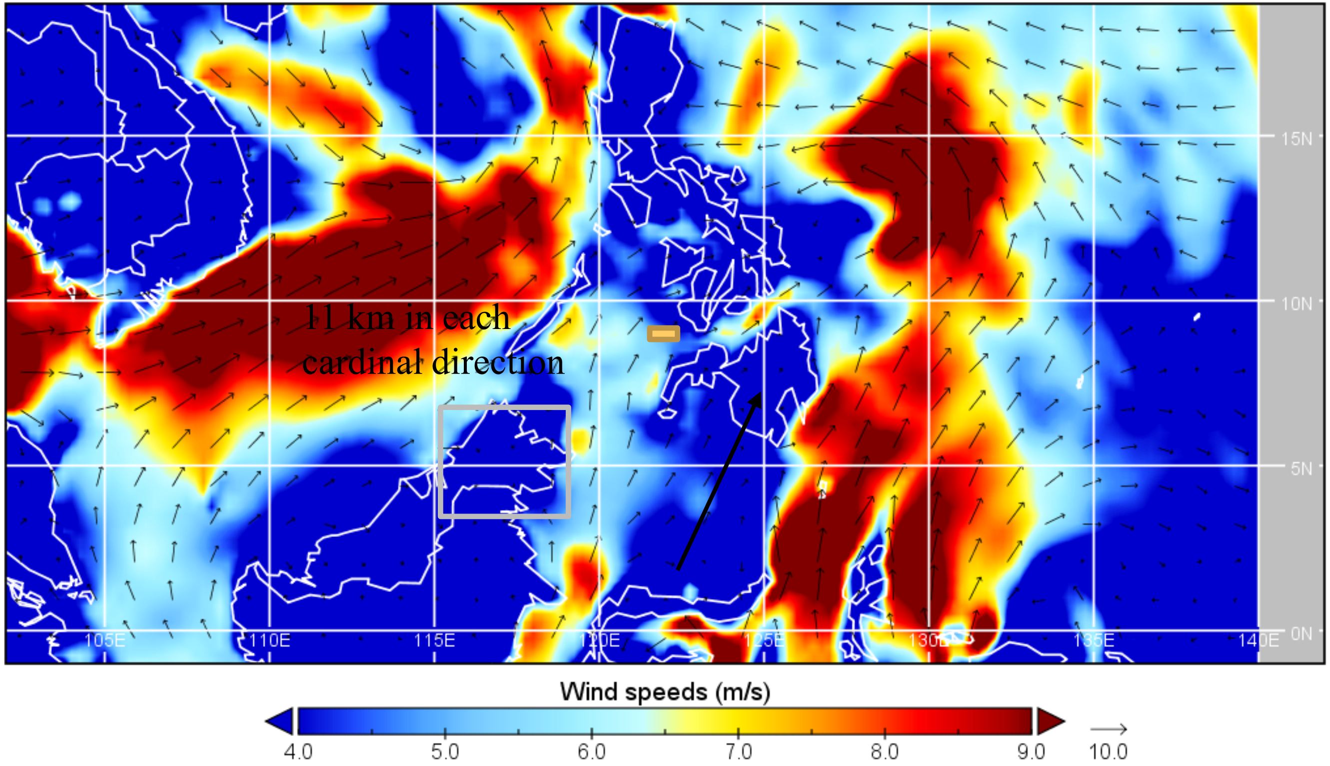


CAMP2Ex Forward-view

Sampling aerosol particles through heterogeneous turbulent fields (shown like these cloud distributions) will cause systematic bias if not sampled uniformly!

Horizontal wind speed comparisons

Horizontal wind-speeds of the Sulu Sea



Large scale models must parameterize smaller scale processes. What are the consequences of ignoring these roll-features observed on aerosol particle transport?

We have ongoing conversations of intermodel analysis with different teams/groups to accurately represent/capture smaller-scale turbulent structures

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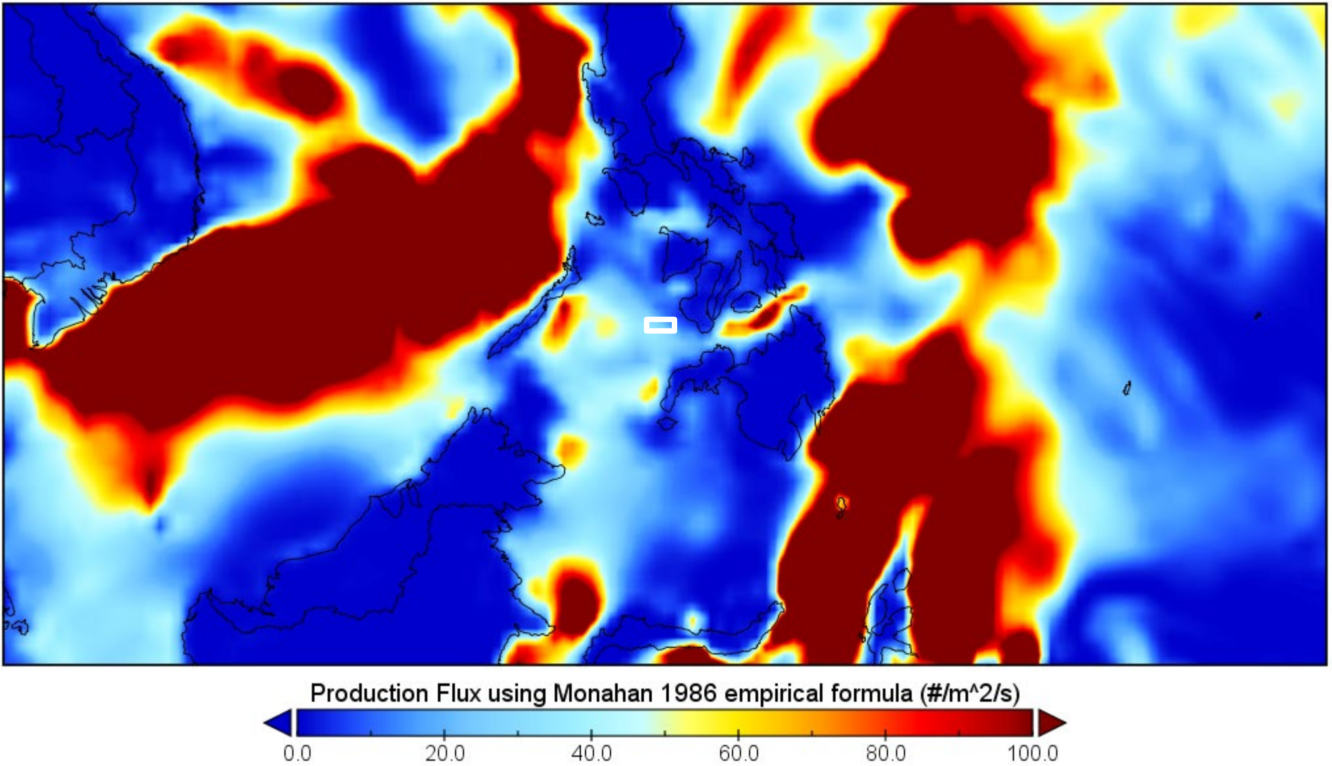
Aerosol generation scale comparison of satellites & models

Using Monahan 1986 relation for 5μm particles

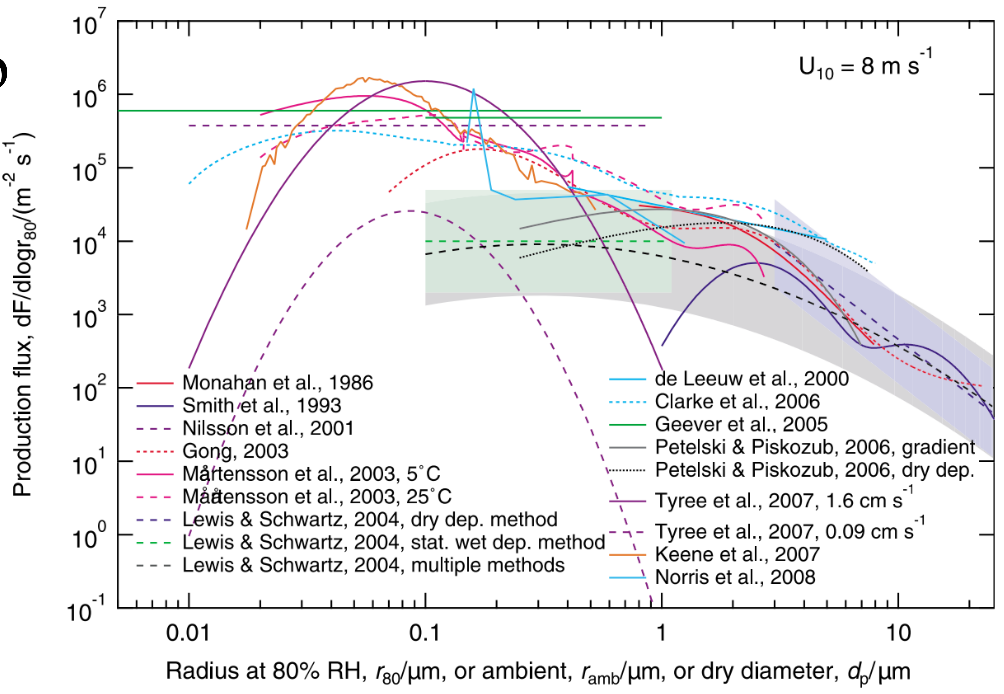


Large scale models must parameterize smaller scale processes. What are the consequences of ignoring these roll-features observed on aerosol particle transport?

Variation in production fluxes lead to systematic bias and uncertainty for aerosol-transport models

Questions summarized

- What is the range of variability in surface flux given *in situ* ship or aircraft measurements of aerosol particles and vertical velocity?
- How do roll features affect the sampling of aerosol particle fluxes?
- What measurement practices can aid in sampling representative aerosol fluxes?



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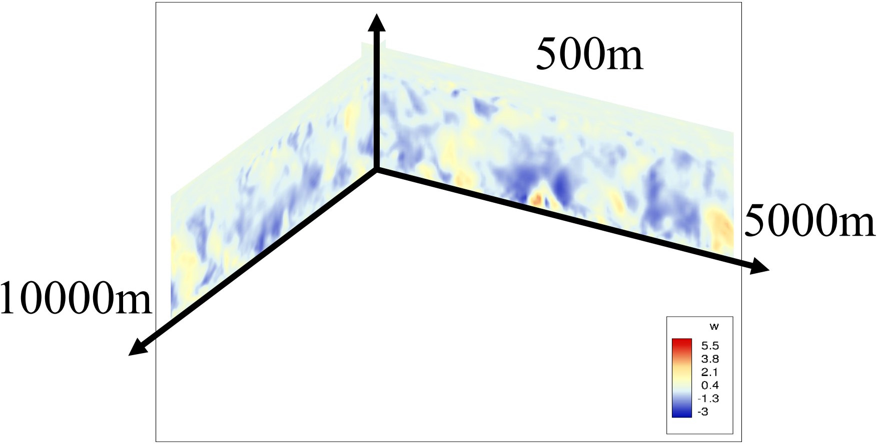
Numerical approach

Large eddy simulation
with Lagrangian particles



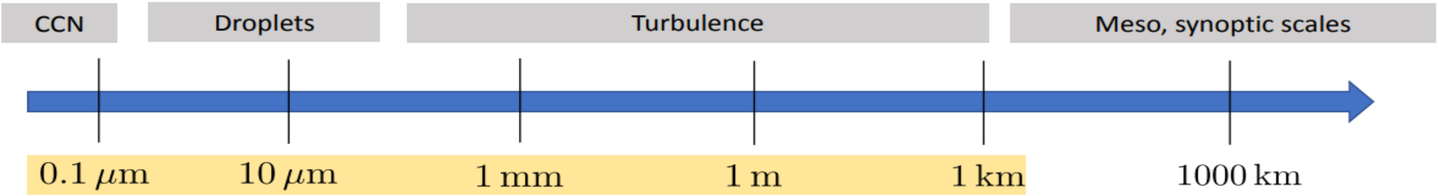
Representation of the cloud-free marine atmospheric boundary layer: a simplified approach

Unstable boundary configuration ($\Delta T = 1.5K$, $U_g = 10m/s$)

Prescribe persistent source of Lagrangian particles of two distinct sizes (10µm, 50µm) representing tracers and significant settling characteristics, respectively.

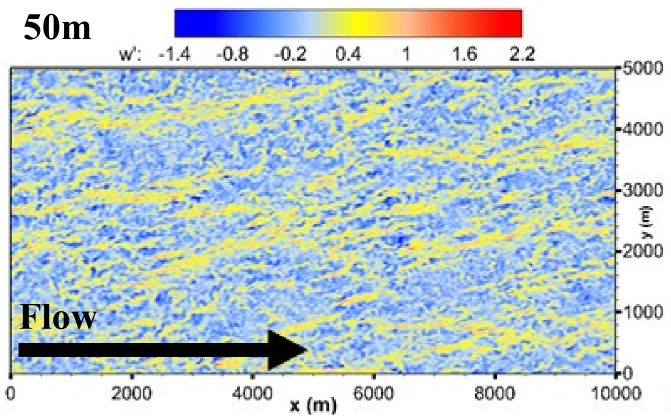
Aerosol particles

LES COAMPS NAAPS, ERA5



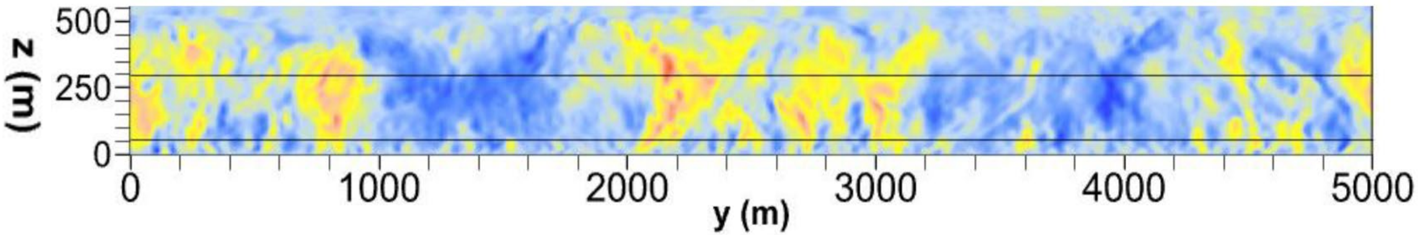
Increasing scales, as well as different processes!

Plane visualizations of LES vertical velocities



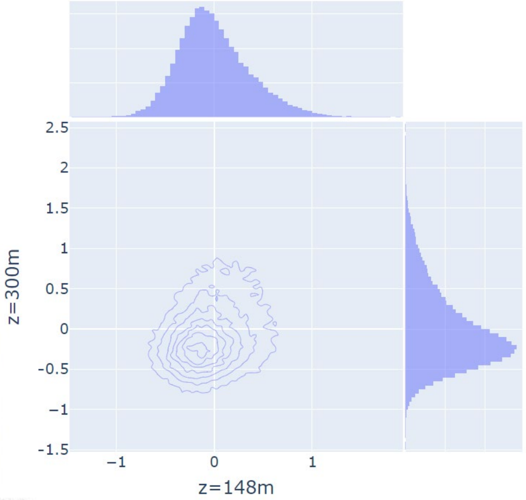
Top-down view of instantaneous vertical velocity contours. The panels are at 50m (left) and at 300m, for a inversion height at 500m. x is the streamwise direction (black arrows)

Spanwise oscillations of wind speeds



This configuration creates a heterogeneous field of turbulence, in accordance to Moeng & Sullivan 1994

Vertical velocity distribution between two heights

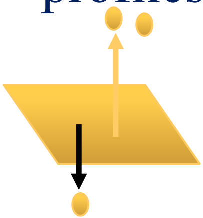


Calculations of flux

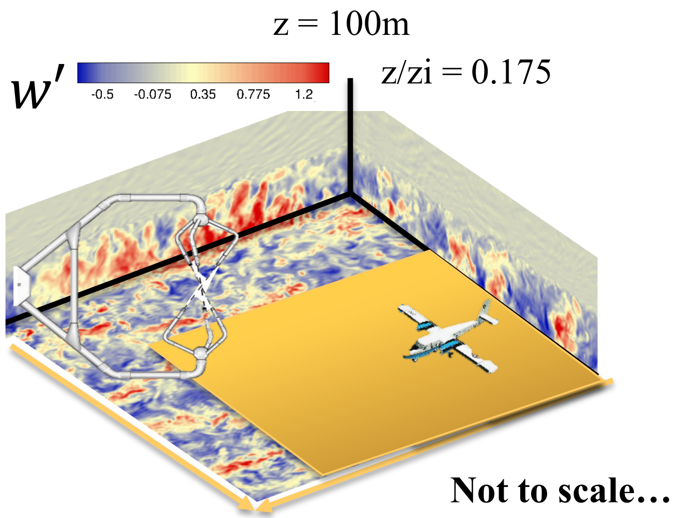
Horizontal 2-D planes (idealized)

Numerical instrumentation

Theoretical flux-profiles



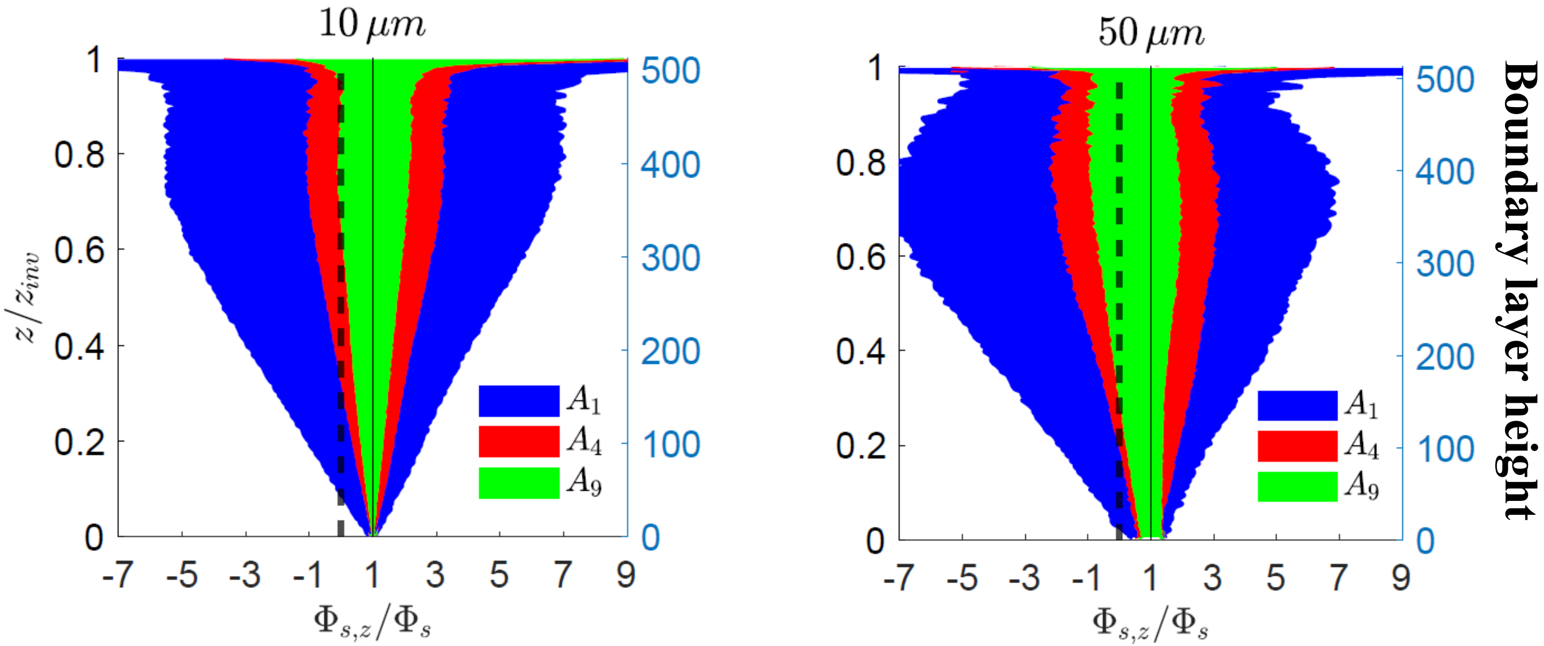
Positive turbulent flux!



- Do we get total convergence of sub-sampled turbulent flux in numerical simulations?
- How much sampling is required to achieve convergence between a measurement and its regional flux?

Surface flux (s.f.) variability

Colors represent s.f. variation based on height, sub-regional **areas**, and particle size



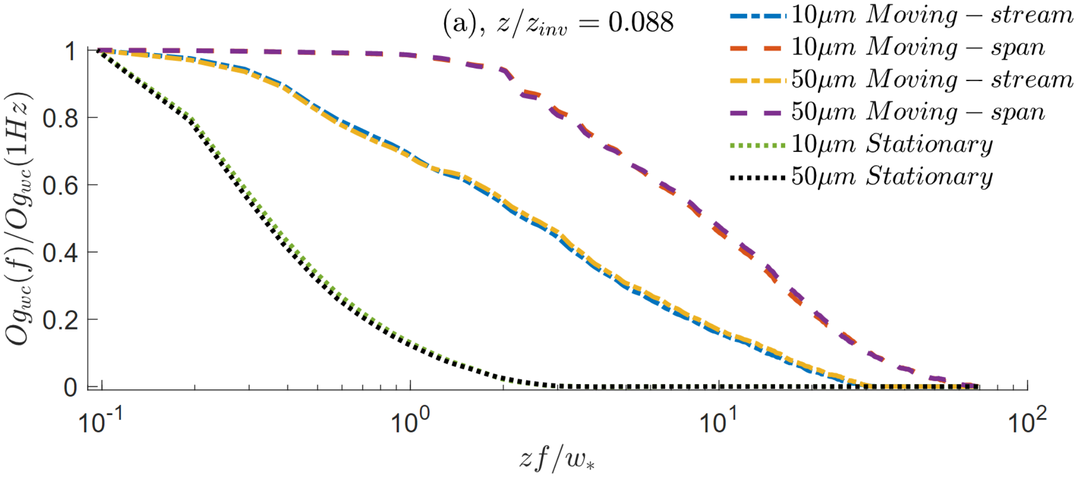
1 T_{eddy} worth of sampling (~14 minutes)

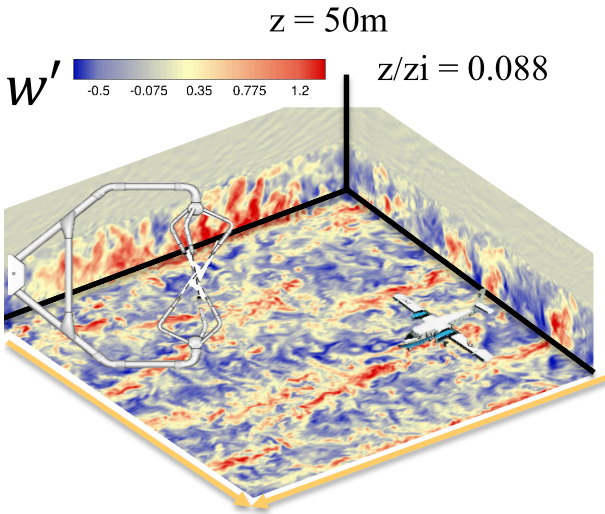
Even in an idealized flux sampling simulation, there exists variability in calculated surface fluxes!

Aerosol flux convergence

An ogive curve computes how much aerosol flux (through the Cospectrum Co_{wc}) is captured given a reference frequency f_0: $Og_{wc}(f_0) = \int_{\infty}^{f_0} Co_{wc}(f)df$

Ogive curve from LES dataset





Aerosol flux is captured in different frequencies based on method of retrieval (critical for measurement differences from ships, buoys, aircraft, etc…)!

Theoretical flux-profile method

Vertical flux budget: The linearly decreasing ($-\beta z$) net surface flux Φ_s is equal to turbulent transport $-K_c \frac{d\bar{C}}{dz}$ and its gravitational settling $-w_s\bar{C}$.

(Nissanka et al. 2018)

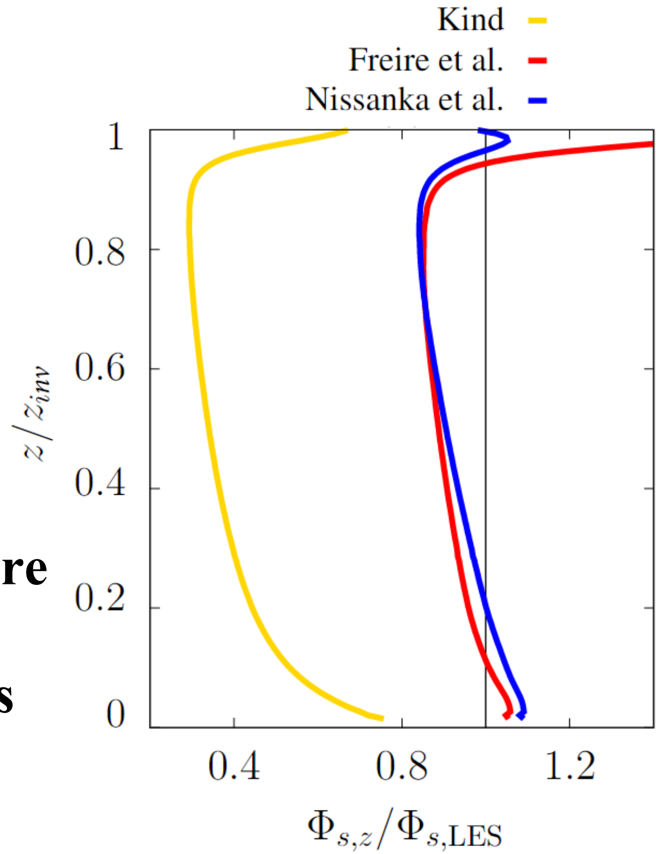
$$\Phi_s - \beta z = -K_c \frac{d\bar{C}}{dz} - w_s\bar{C}$$

What is the sensitivity of the N18 results with simulated instrumentation?

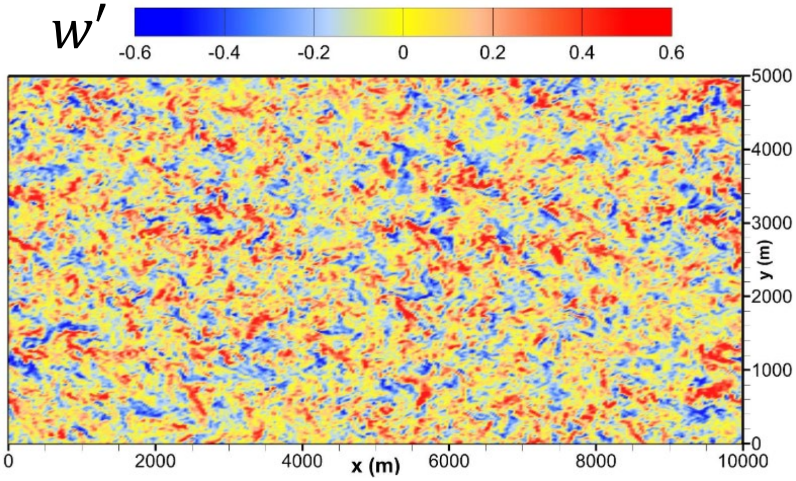
Extract LES data (i.e. horizontal average of concentration)

Solve for Φ_s in the vertical extent

Flux-profile methods are good (i.e. Freire and Nissanka), but requires high-fidelity of data.

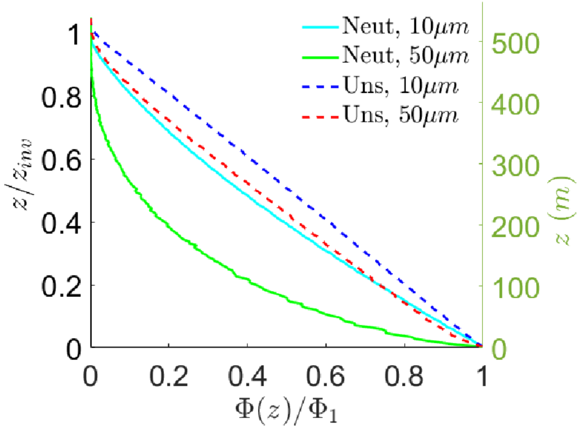


What about a different stability?

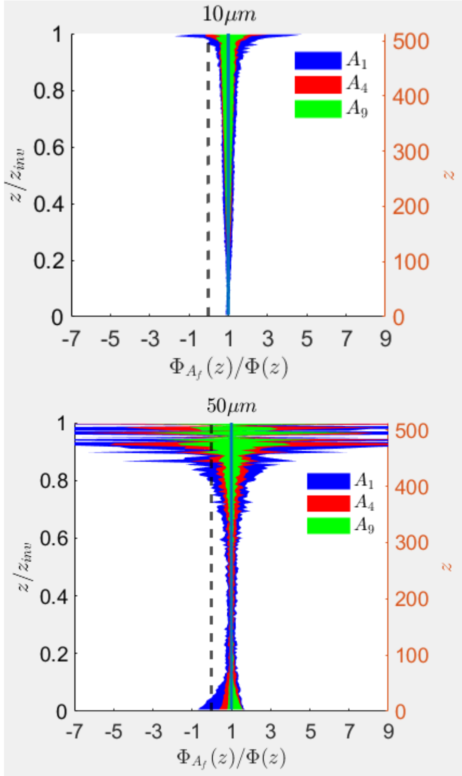


z = 300m, z/zi = 0.525

Sampled representative net fluxes result in less variation due to low vertical velocities



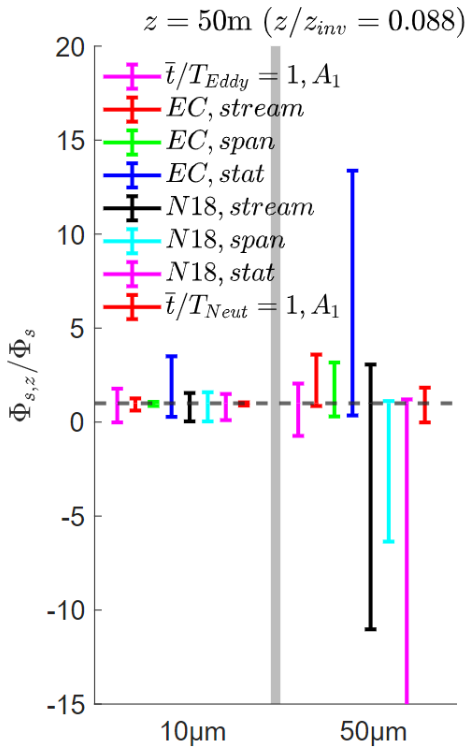
Neutral boundary layers lack convective structures, suggesting a good representative flux given a local sampling region…?



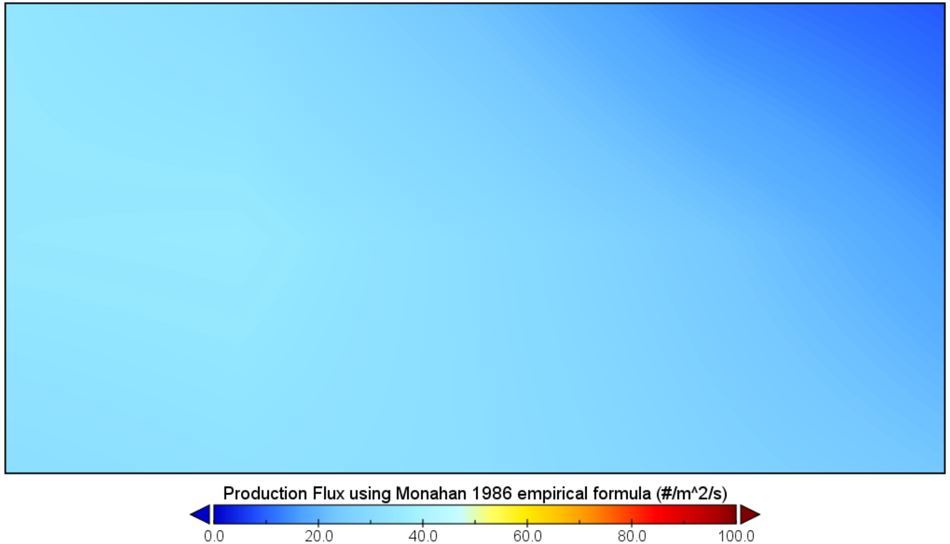
Compilation of techniques (Coupe de grace)

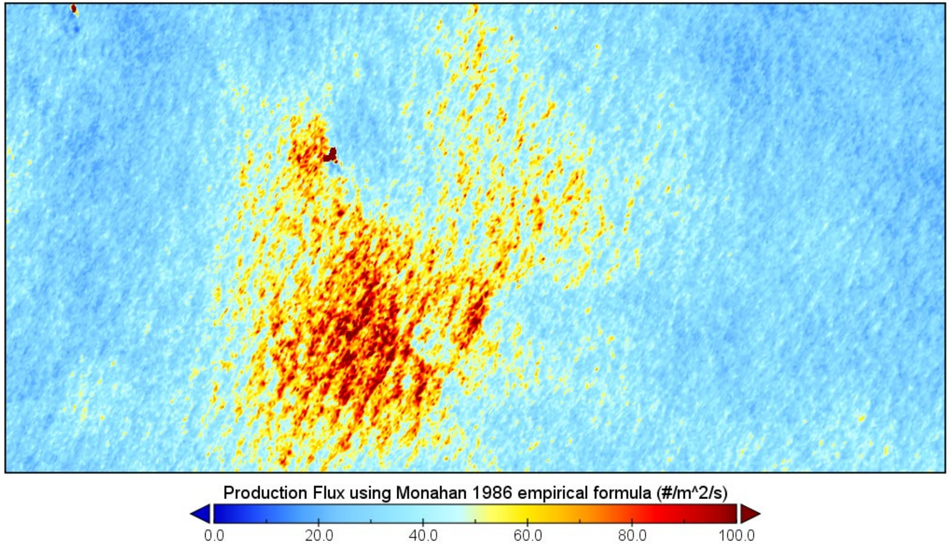
We aggregate all techniques to quantify the variability in the retrieved surface flux through aerosol particle size and boundary layer height

This baseline summary of different numerical approaches bounds the sampled surface flux in predictive range: informing global/mesoscale aerosol models



Conclusions





frequencies and associated temporal duration of sampling!

We want to quantify the important small-scale processes and parameterize them for the global/meso-scale models…

GCCNs (larger settling) cause greater aerosol flux uncertainty due to higher settling velocity