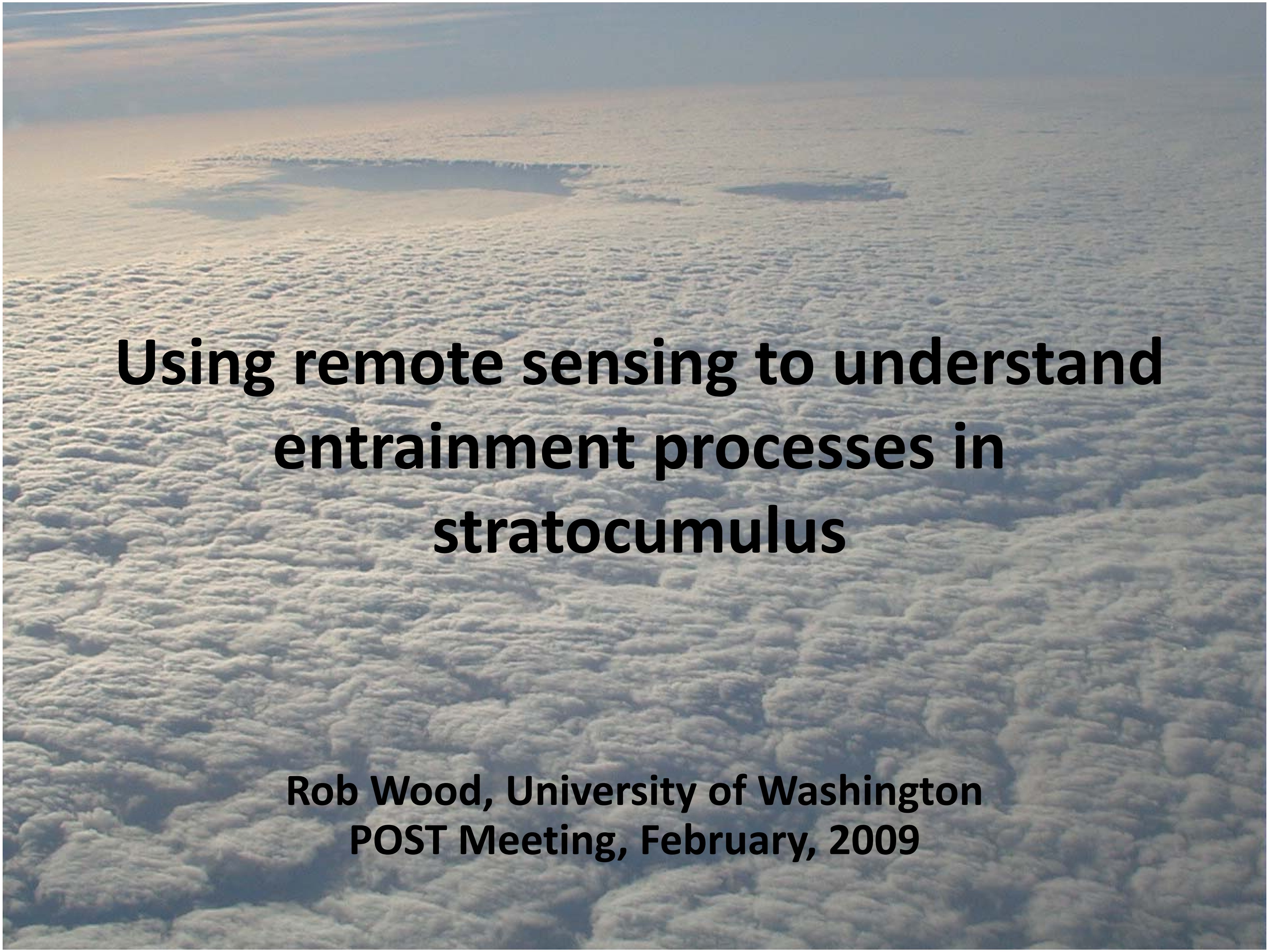


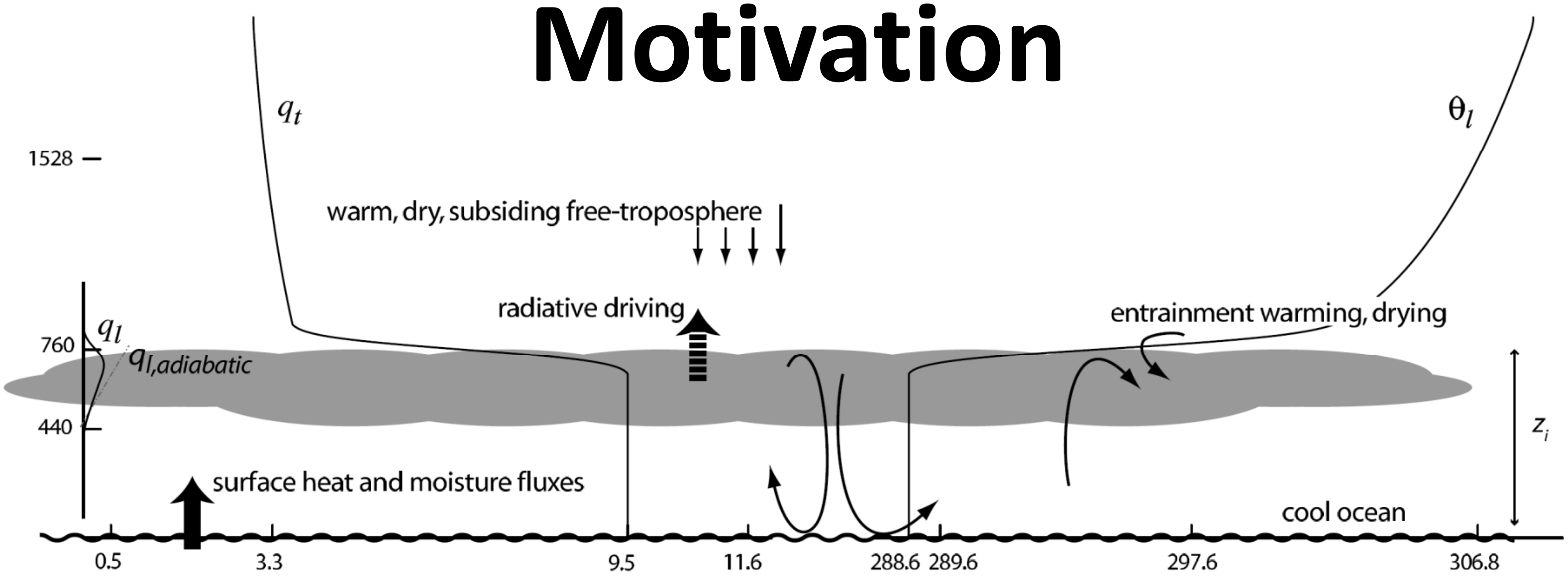
Using remote sensing to understand entrainment processes in stratocumulus

Rob Wood, University of Washington
POST Meeting, February, 2009

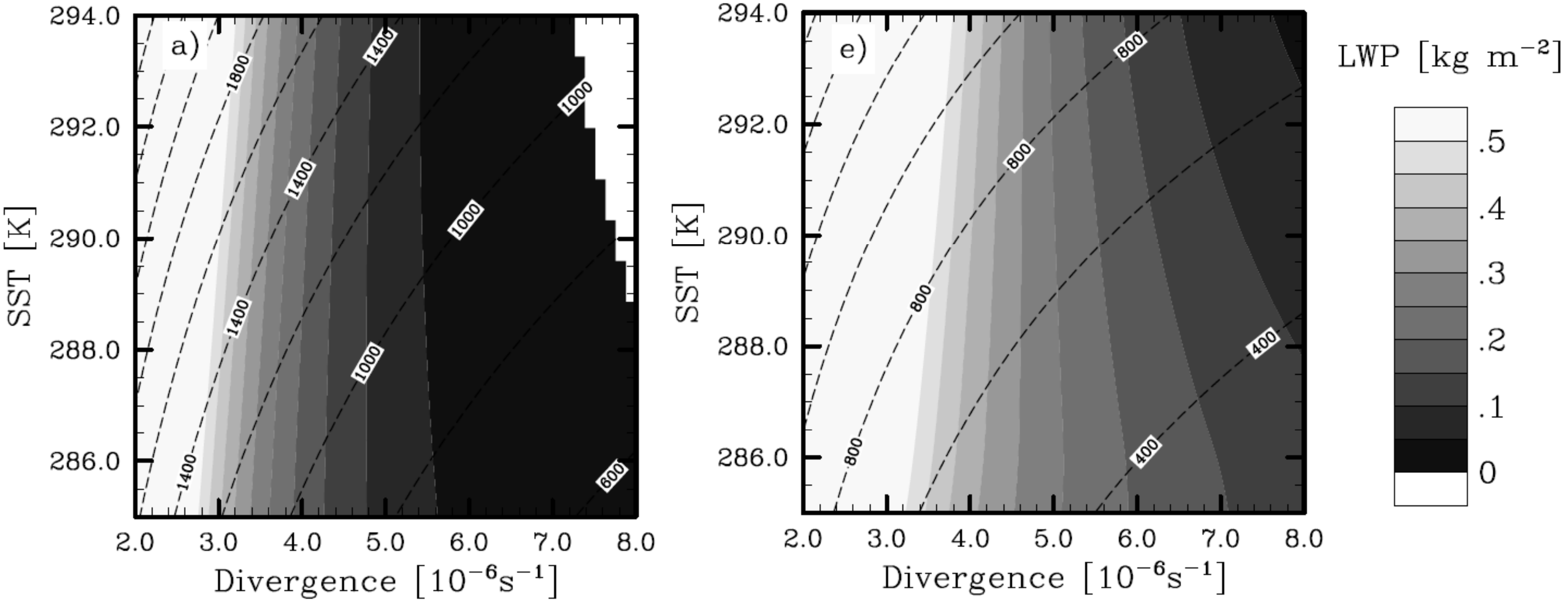
Outline

- Motivation
- MBL depth estimates
- Large scale forcings from satellite (humidity, surface divergence)
- Combination to estimate entrainment rate

Motivation



From Stevens (2002, 2007)



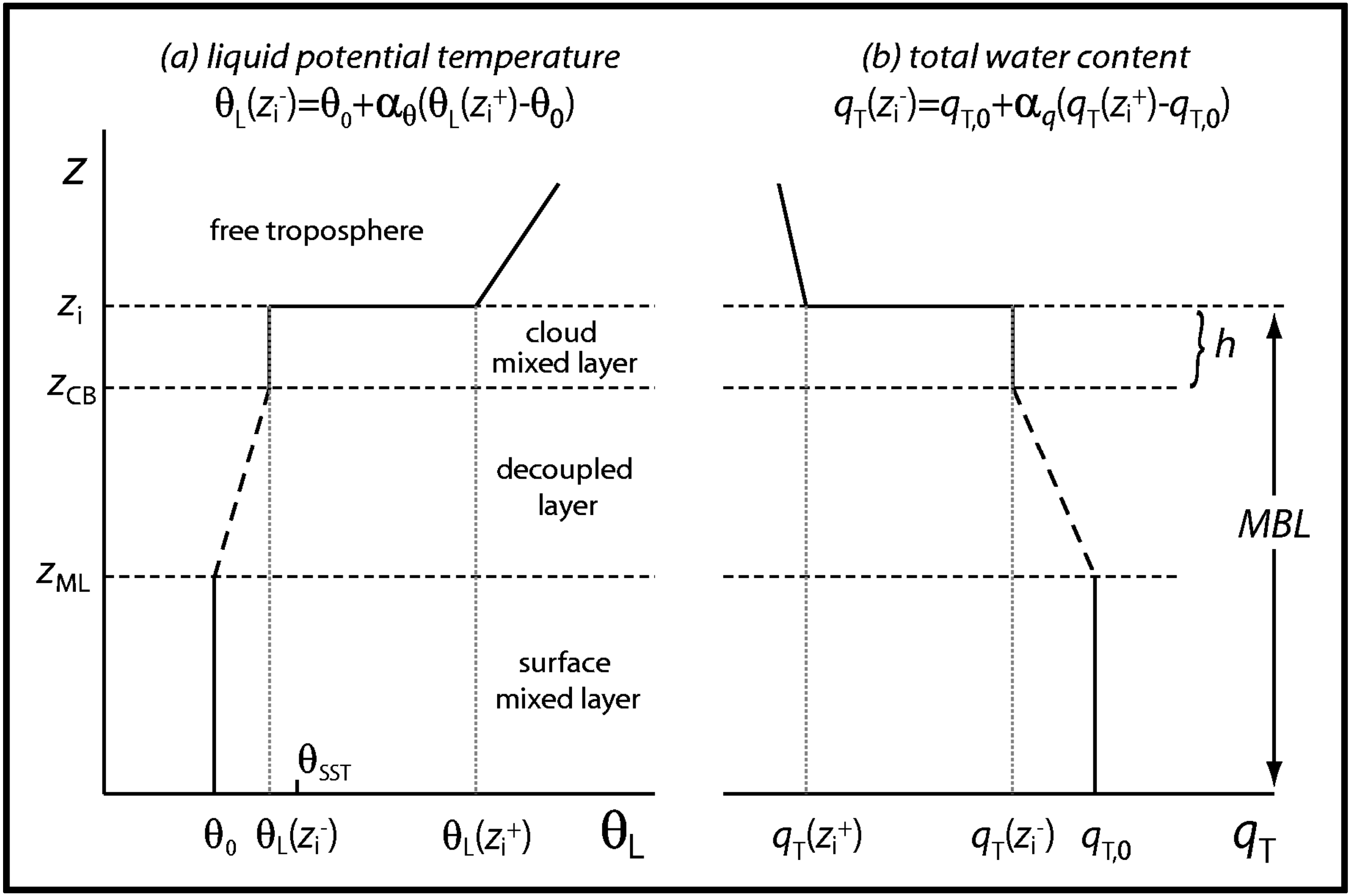
Entrainment efficiency = 1

Entrainment efficiency = 1/2

MBL depth, entrainment and decoupling

- Integrative approach to derive MBL and cloud properties in regions of low cloud
- Combines satellite remote sensing observations from MODIS/GOES and TMI/AMSR with reanalysis from NCEP and climatology from COADS
- Results in estimates of MBL depth and decoupling (and climatology of entrainment)

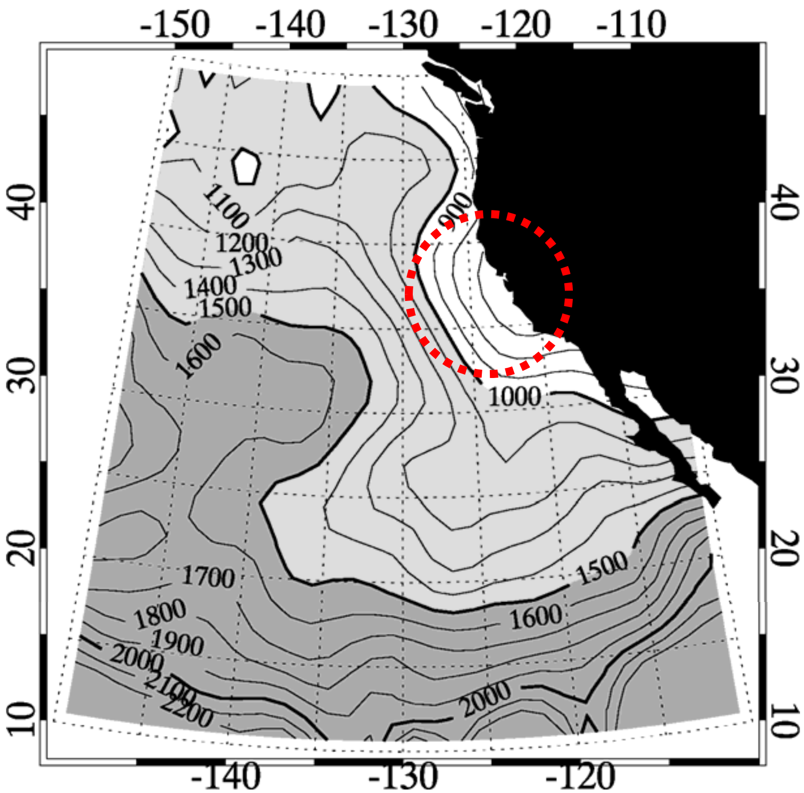
MBL structure



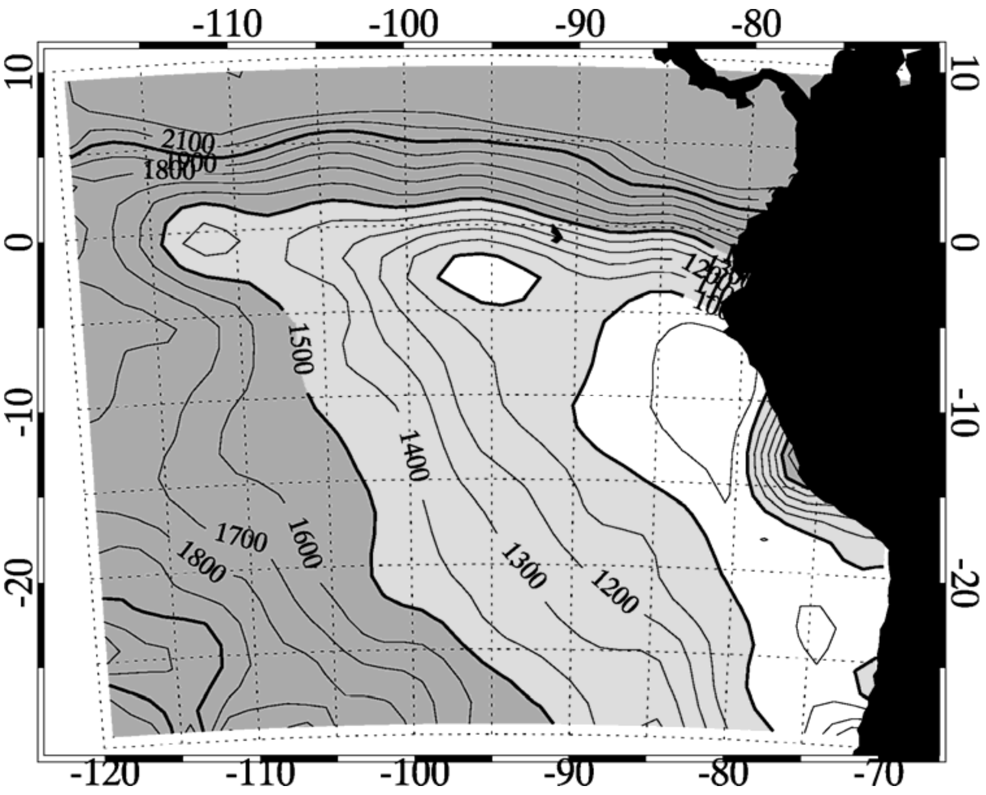
Methodology

- Independent observables: LWP, T_{top}, SST
- Unknowns: z_{i}, α_{q} $(= \alpha_{\theta})$
- Use COADS climatological surface RH and air-sea temperature difference
- Use NCEP reanalysis free-tropospheric temperature and moisture
- Iterative solution employed to resulting non-linear equation for z_i

Mean MBL depth (Sep/Oct 2000)

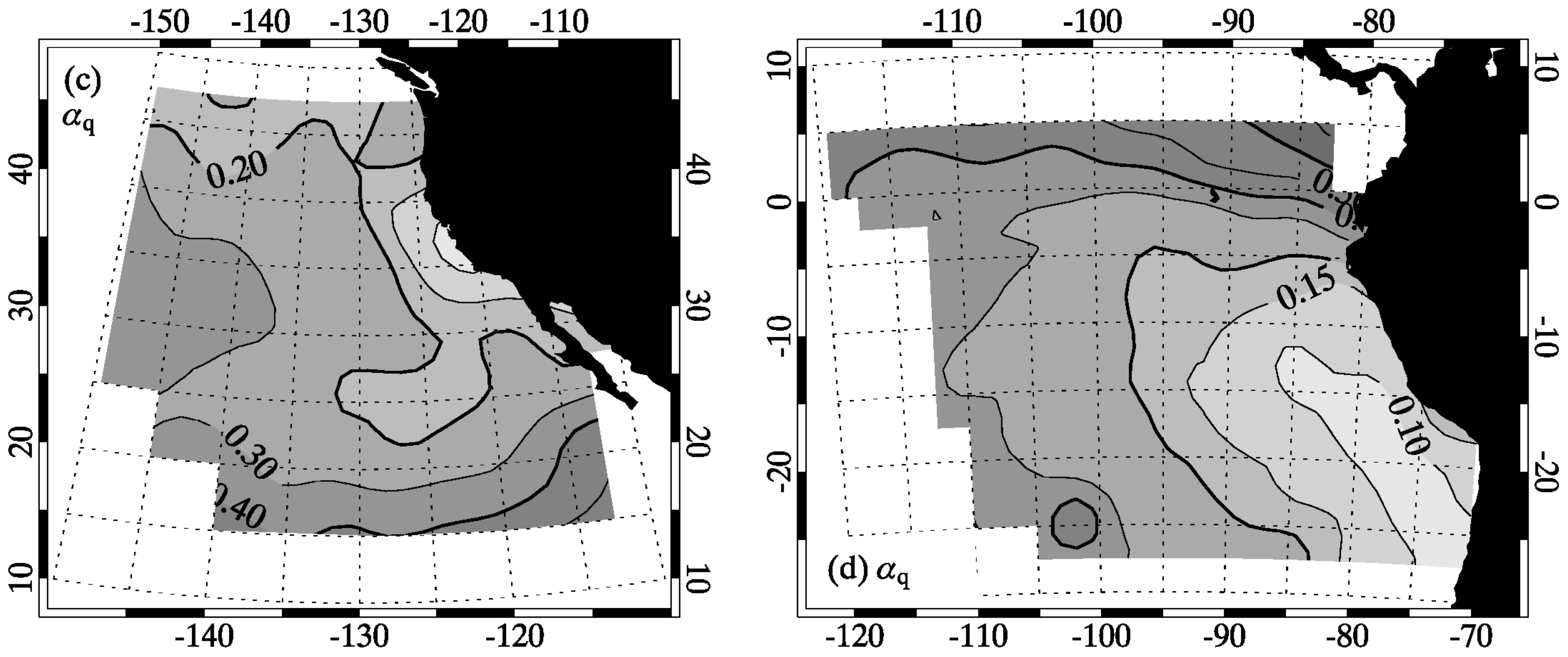


NE Pacific



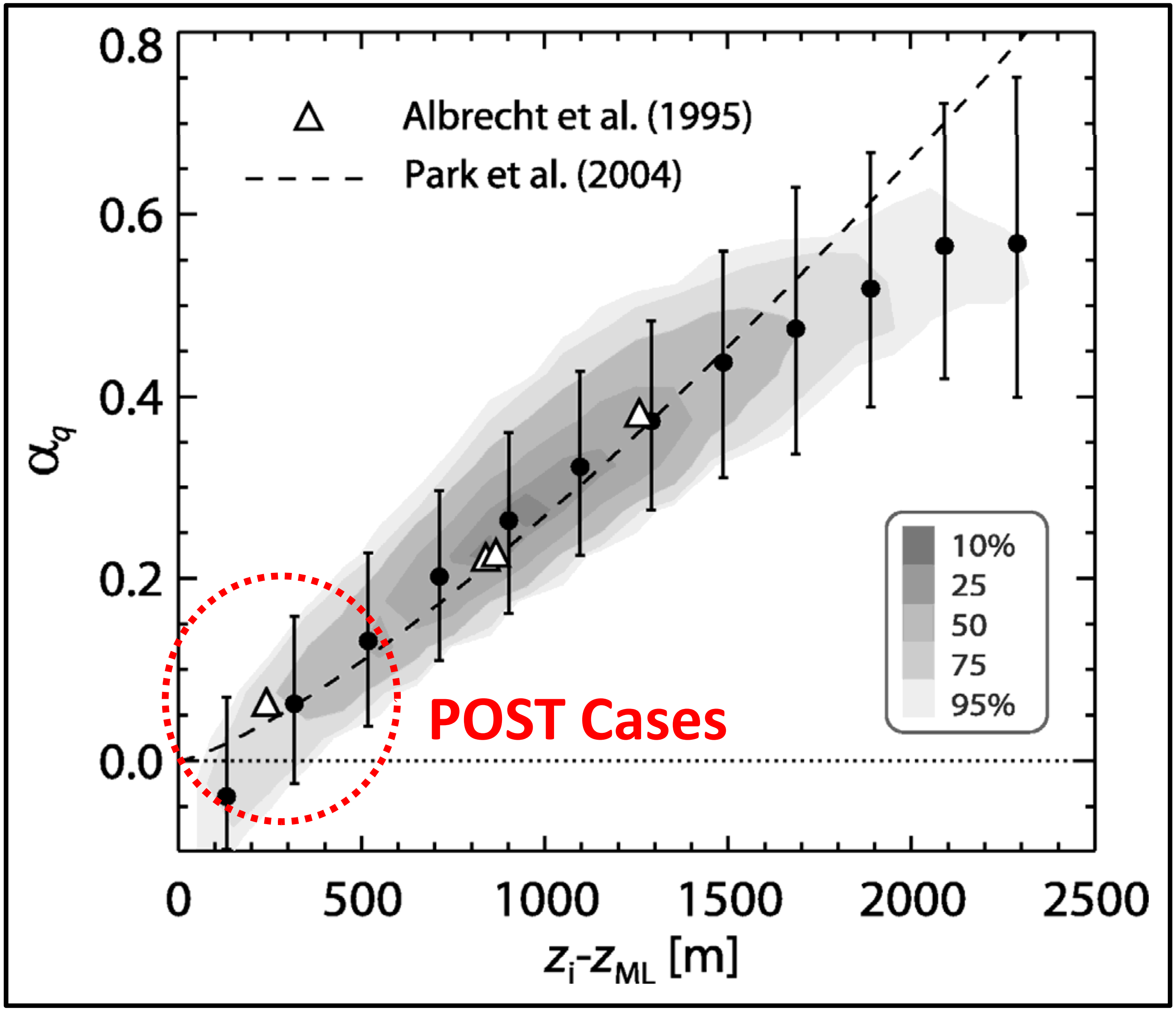
SE Pacific

Mean decoupling parameter α_q



Decoupling scales well with MBL depth

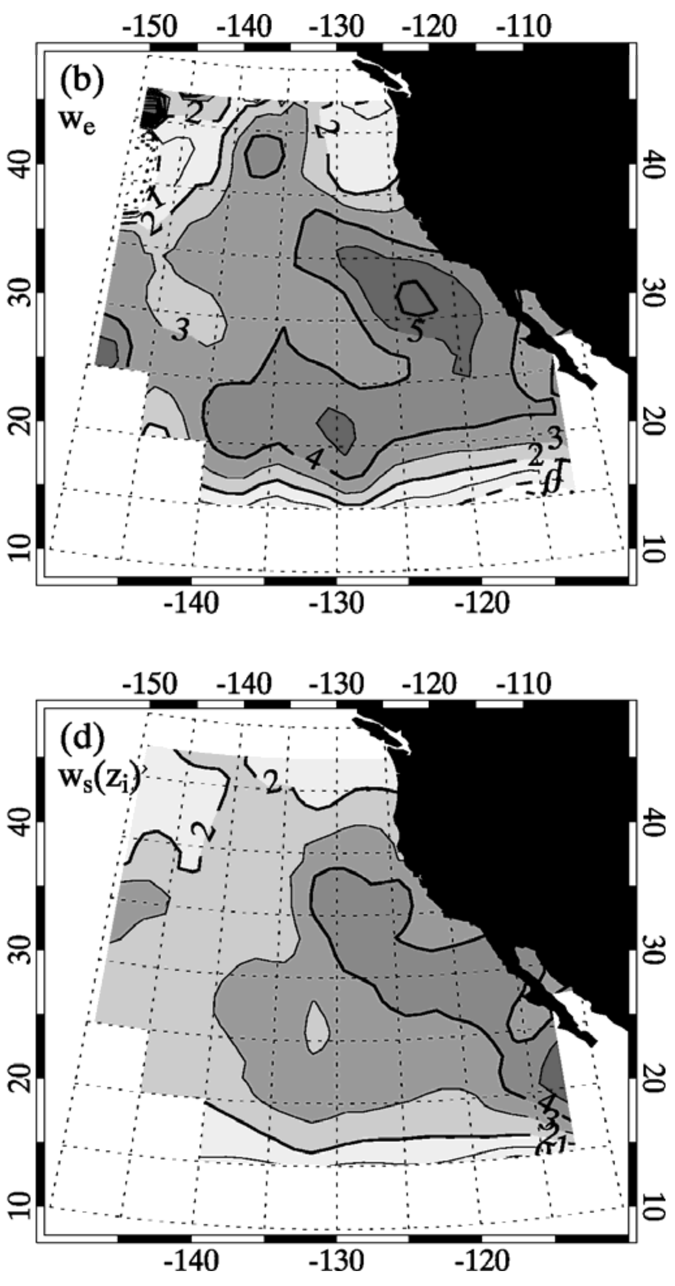
α_q VS Z_i-Z_{LCL}



Deriving mean entrainment rates

- Use equation: $w_e = \boldsymbol{u} \cdot \nabla z_i + w_s$
- Estimate w_s from NCEP reanalysis
- Estimate $\boldsymbol{u} \cdot \nabla z_i$ from NCEP winds and two month mean z_i

Mean entrainment rates

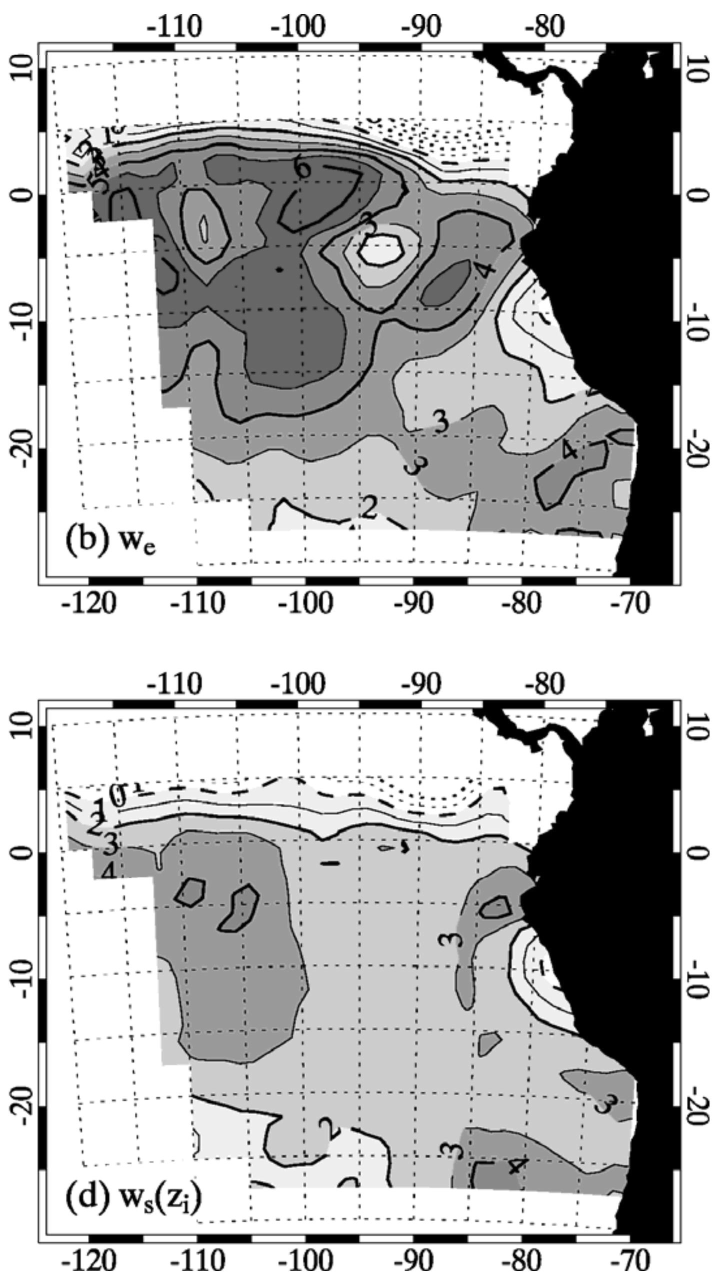


Entrainment rate [mm/s]

◀ NE Pacific

SE Pacific ▶

Subsidence rate [mm/s]



Summary of MBL depth work

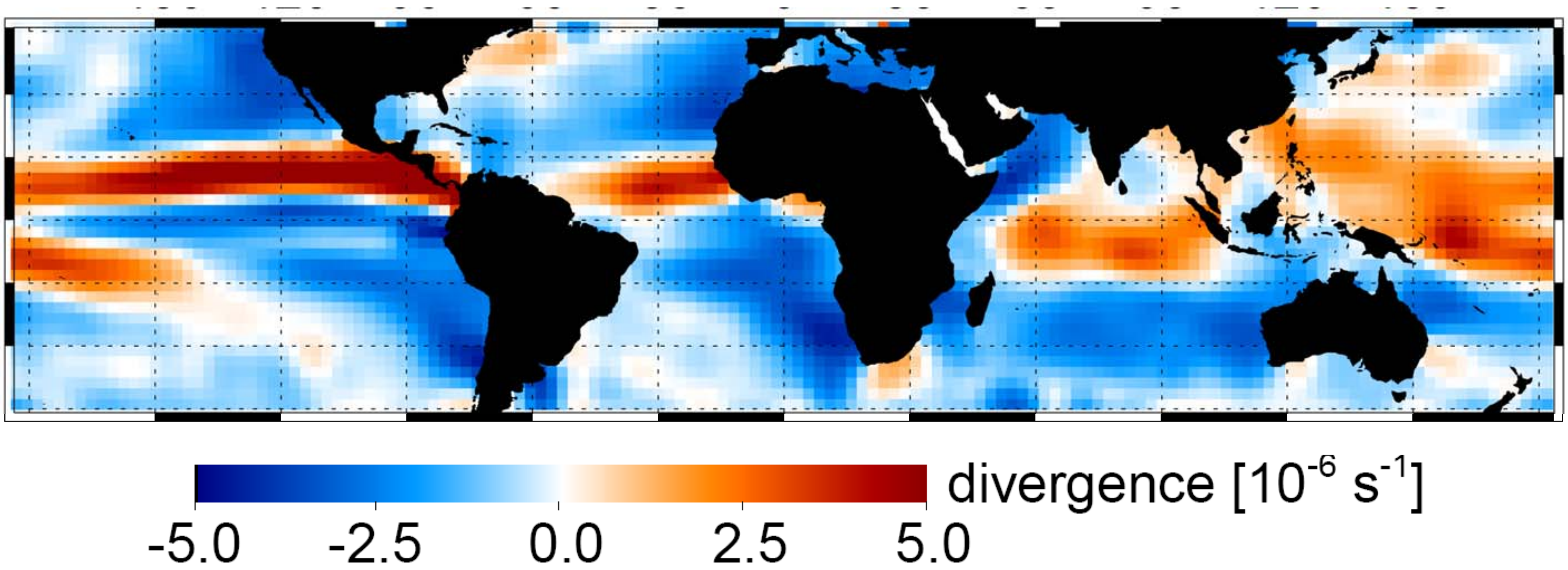
- Scene-by-scene estimation of MBL depth and decoupling
- Climatology of entrainment rates over the subtropical cloud regions derived using MBL depth and subsidence from reanalysis
- Decoupling strong function of MBL depth

Plans for POST

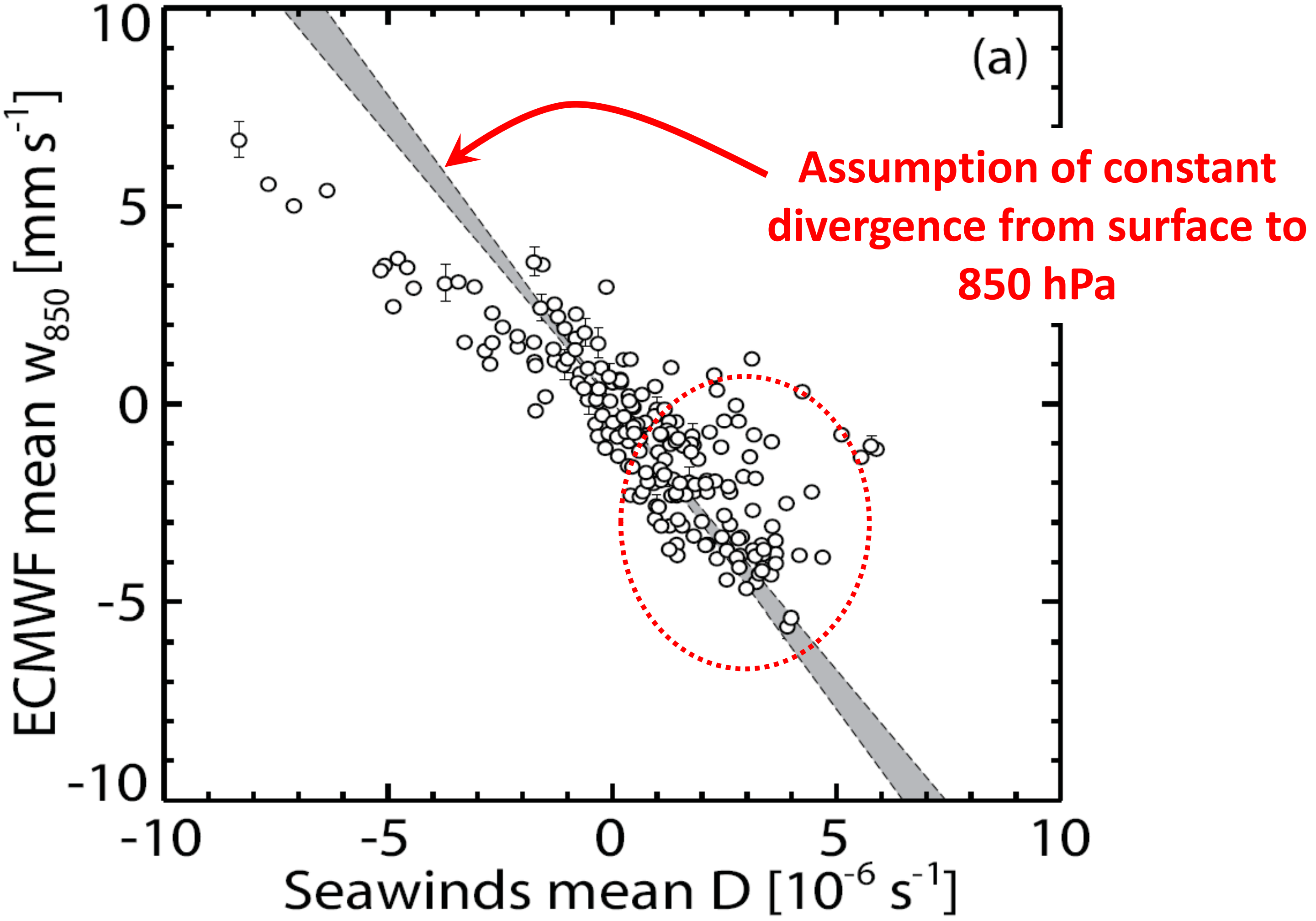
- Use of Quikscat winds to constrain subsidence rate

$$D(z) = \frac{du}{dx} + \frac{dv}{dy} = -\frac{dw}{dz}$$

$$w(z) = \int_0^z D(z)dz$$



QuikScat divergence and ECMWF vertical wind at 850 hPa



Assumption of constant divergence from surface to 850 hPa

Approach

- Use 3-day mean Quikscat divergence estimates (and NCEP analyses), together with 3-day mean GOES cloud top temperatures, to estimate entrainment rates
- How do these entrainment rates vary over time? Is the temporal variability statistically significant/robust?
- Do satellite entrainment rates agree with those from aircraft?

Diurnal vs. synoptic variability (MM5)

Diurnal amplitude equal to or exceeds synoptic variability (here demonstrated using 800 hPa potential temperature variability) over much of the SE Pacific, making the diurnal cycle of subsidence a particularly important mode of variability