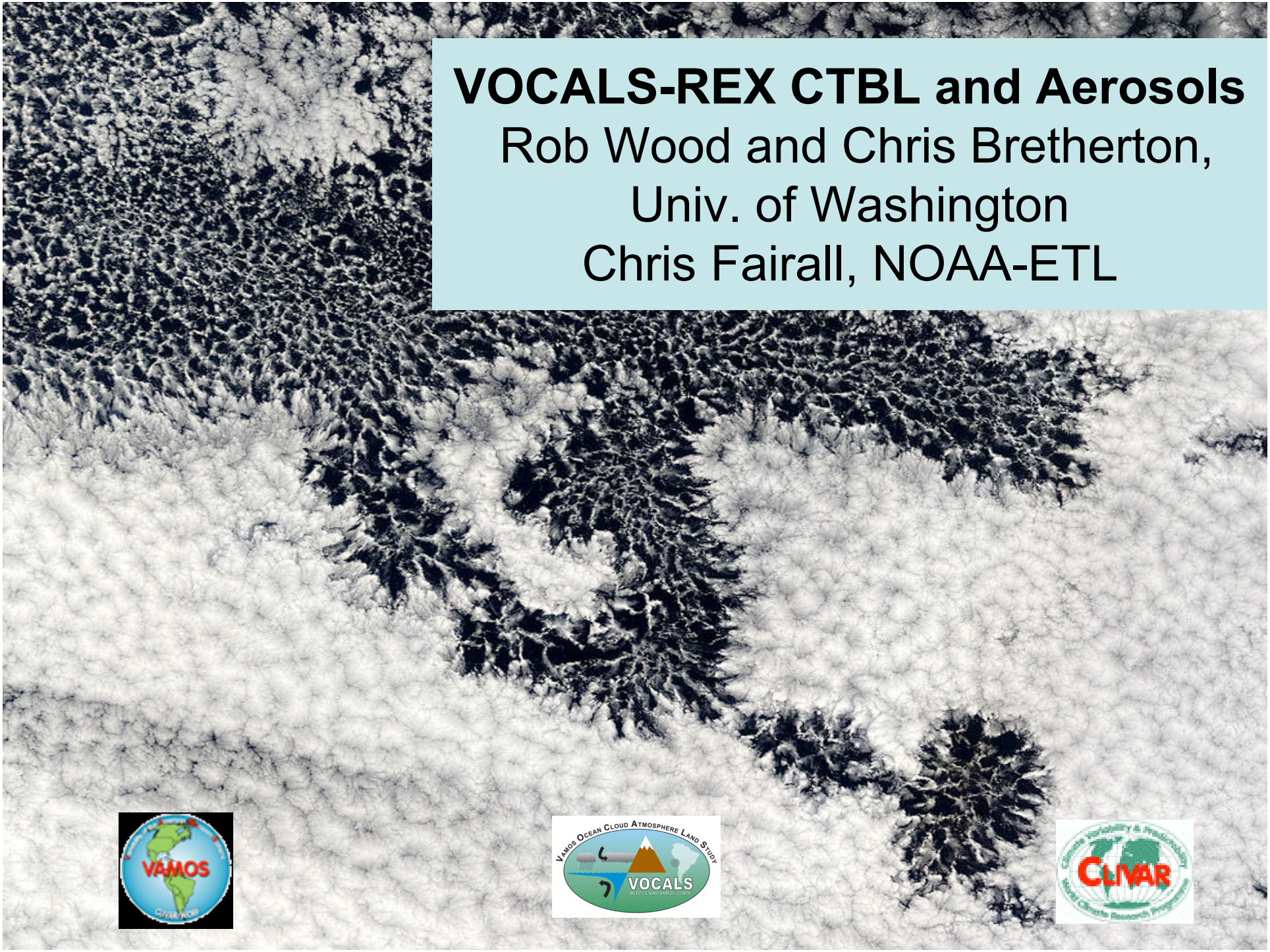
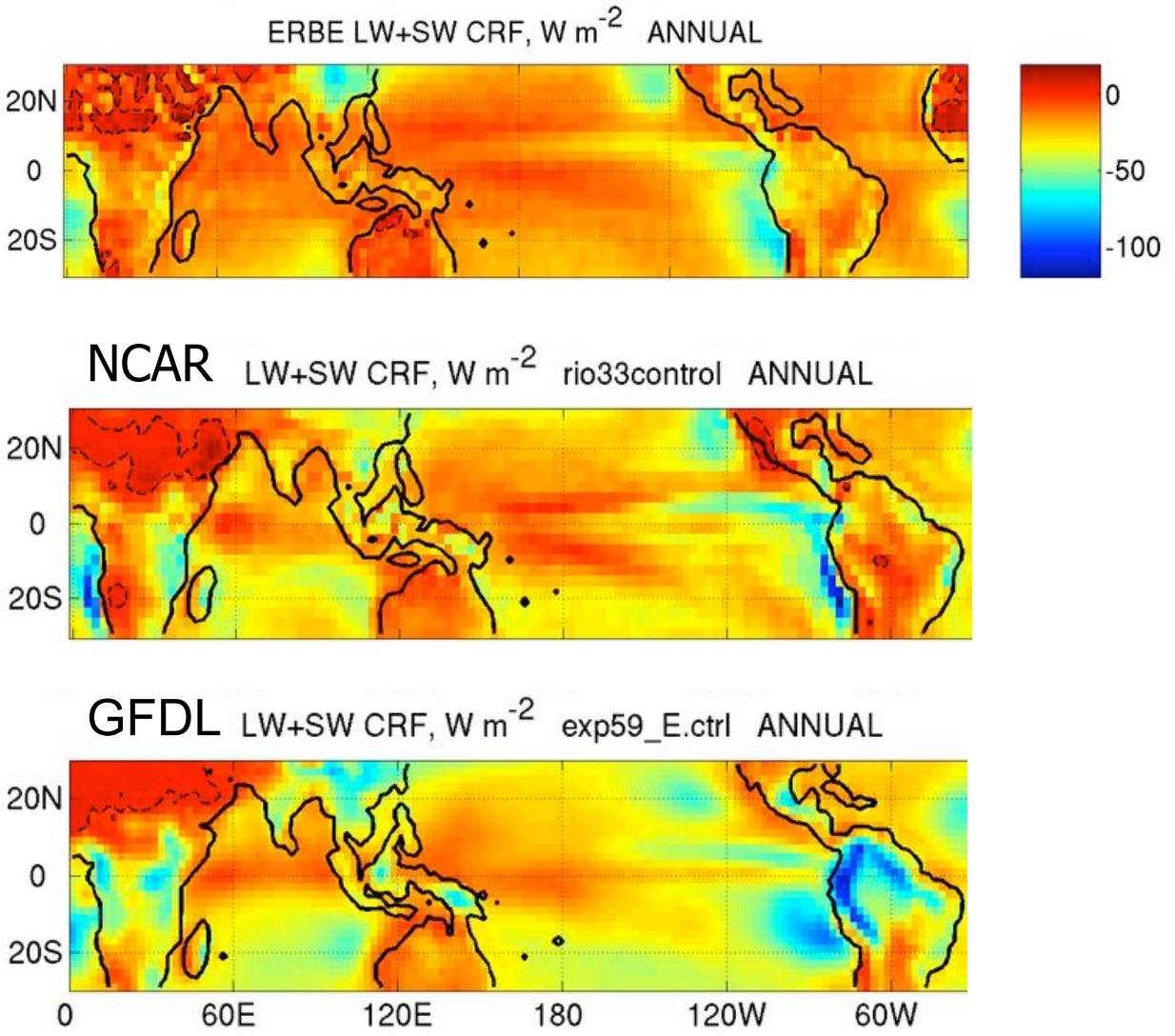


VOCALS-REX CTBL and Aerosols

Rob Wood and Chris Bretherton,
Univ. of Washington
Chris Fairall, NOAA-ETL

Current U.S. AGCM stratocumulus simulations

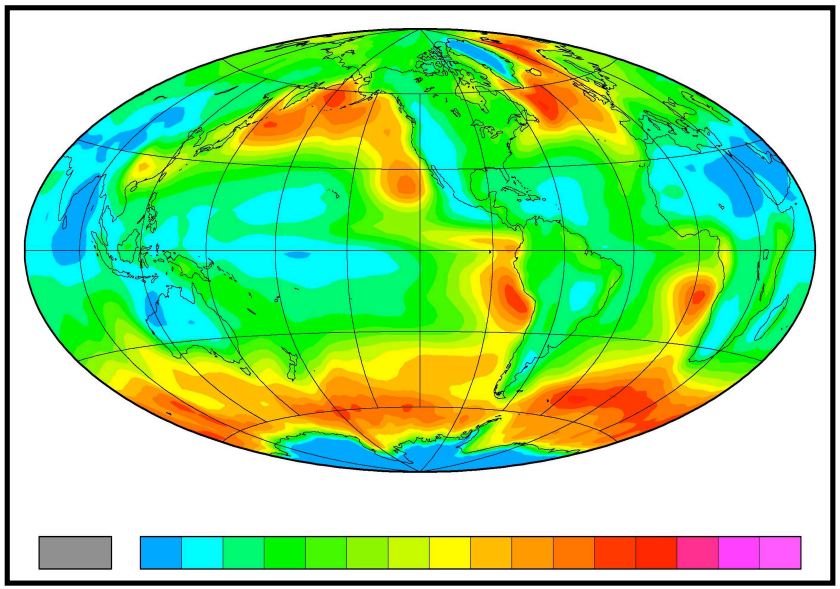


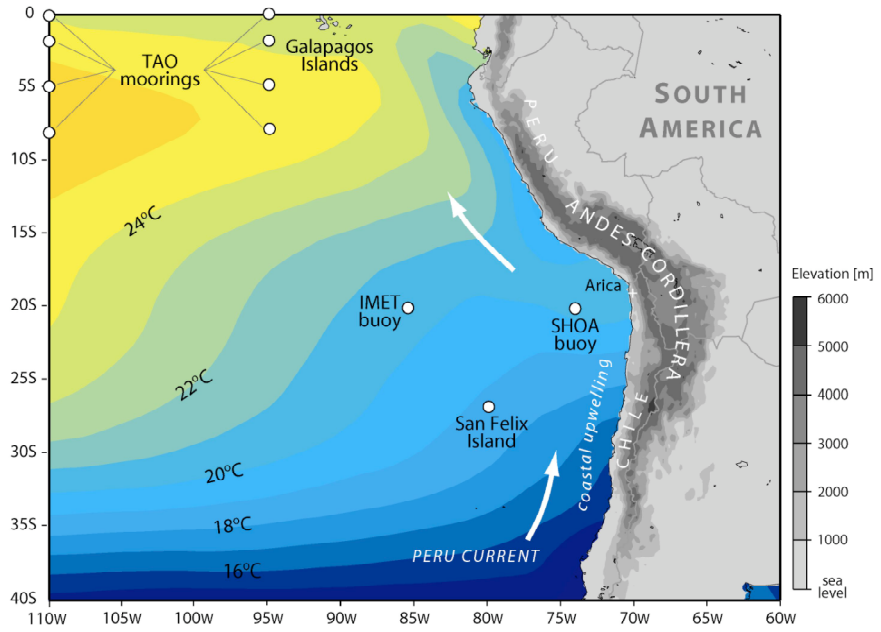
- Decent radiation
- Imperfect clouds
- Drizzle significant
- Cloud-aerosol feedbacks soon

(CPT, Wyant et al.2005; also note GCSS BLCWG)

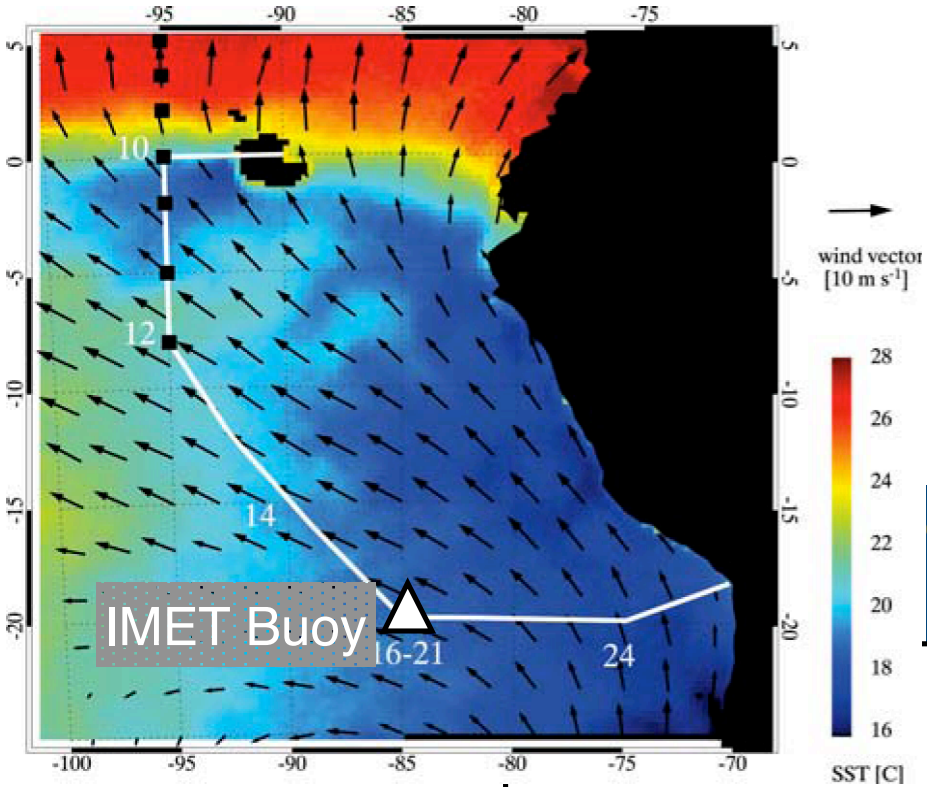
Why did EPIC/VOCALS get into SE Pacific stratocumulus ?

- Subtropical boundary-layer cloud errors in coupled climate models induce SST and circulation biases.
- The southeast Pacific (SEP) is the largest, cloudiest, cool-ocean region in the tropics, and a comparison to NEP.
- TAO and CLIVAR flux-reference buoys provide long-term SEP measurements, but overlying clouds poorly sampled.
- SEP buoy maintenance cruises provide opportunities for studying cloud-aerosol-dynamics interaction, indirect effect.



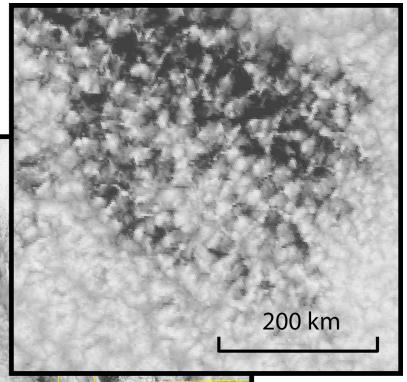


EPIC 2001-Sc



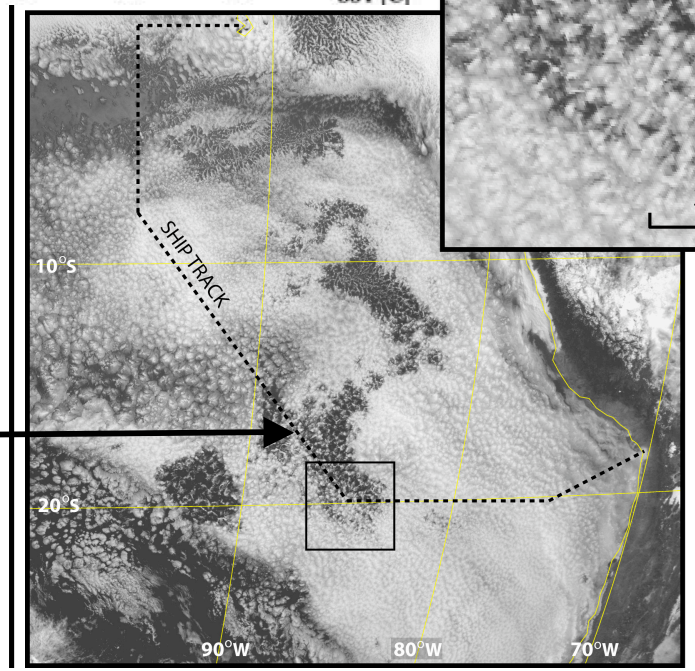
SST (TMI) & winds (Quikscat)

GOES Visible image

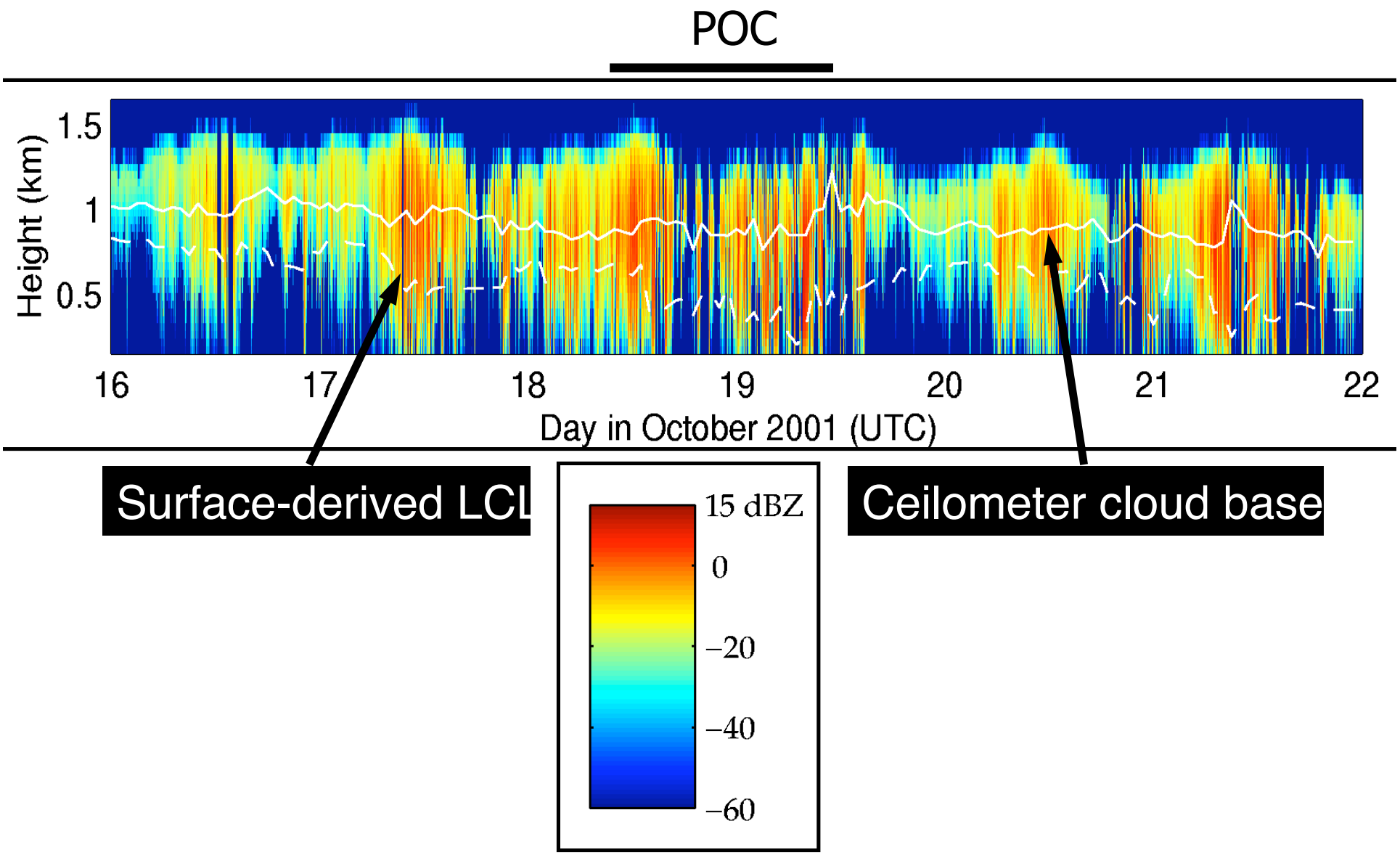


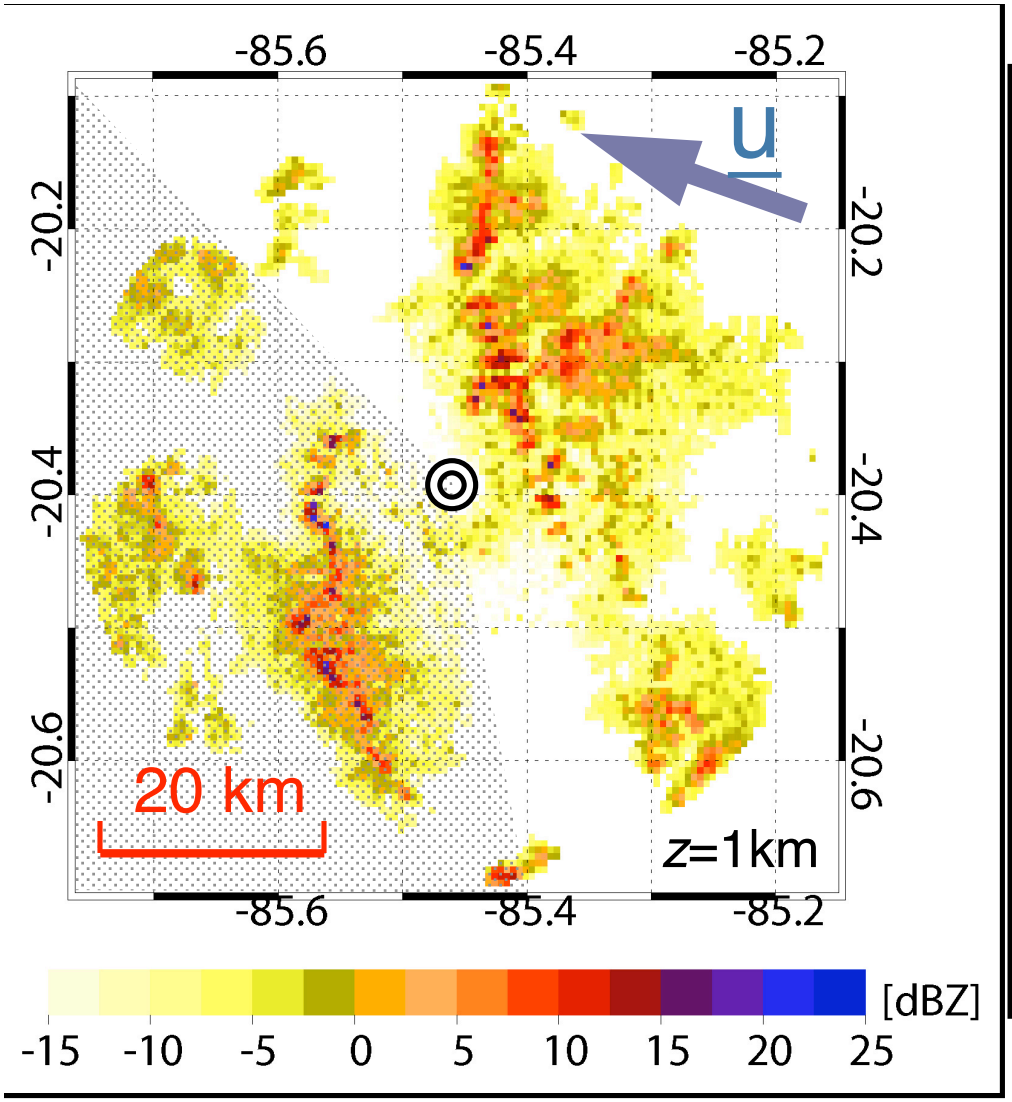
Showed power of ship-based obs. (sondes+NOAA-ETL radars, ceilometer, surf. flux)

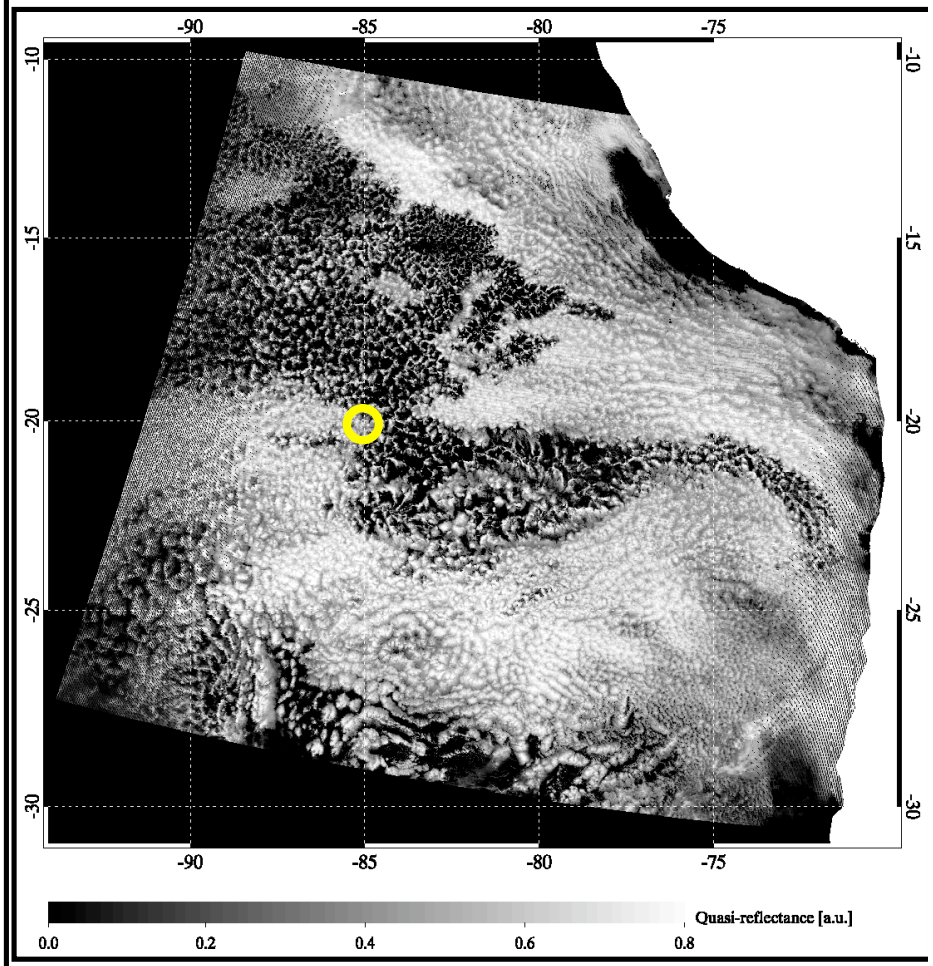
- Diurnal cycle & Andean forcing
- Cloud-drizzle-dynamics interactions and ‘pockets of open cells’ (POCs) ; possible aerosol link.



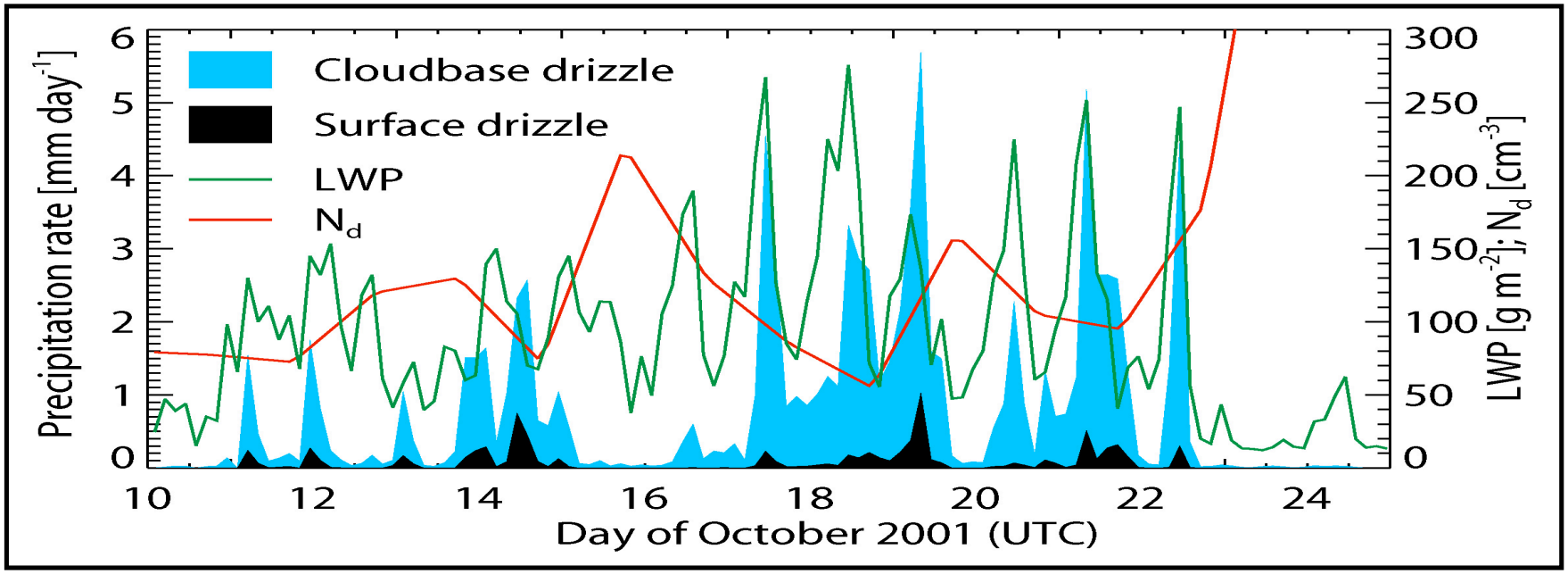
Diurnal cycle and drizzle

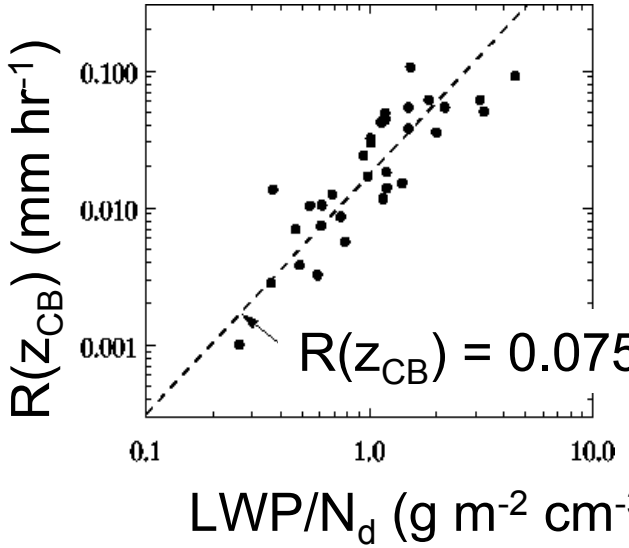



-85.6
-85.4
-85.2
-20.2
-20.4
-20.6
u
20 km
z=1km
[dBZ]
-15 -10 -5 0 5 10 15 20 25


-90
-85
-80
-75
-10
-15
-20
-25
-30
Quasi-reflectance [a.u.]
0.0 0.2 0.4 0.6 0.8

Microphysics and drizzle production

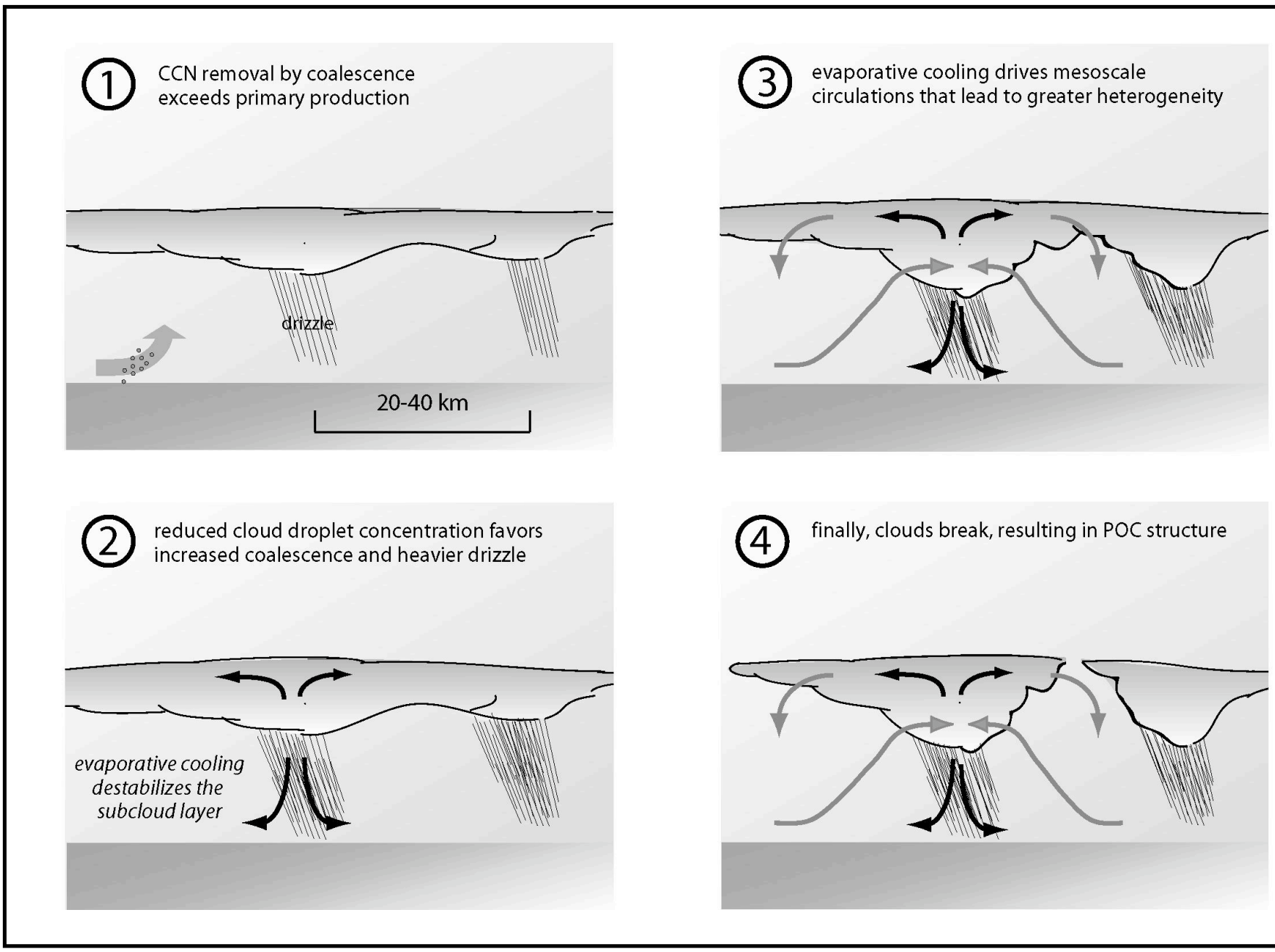


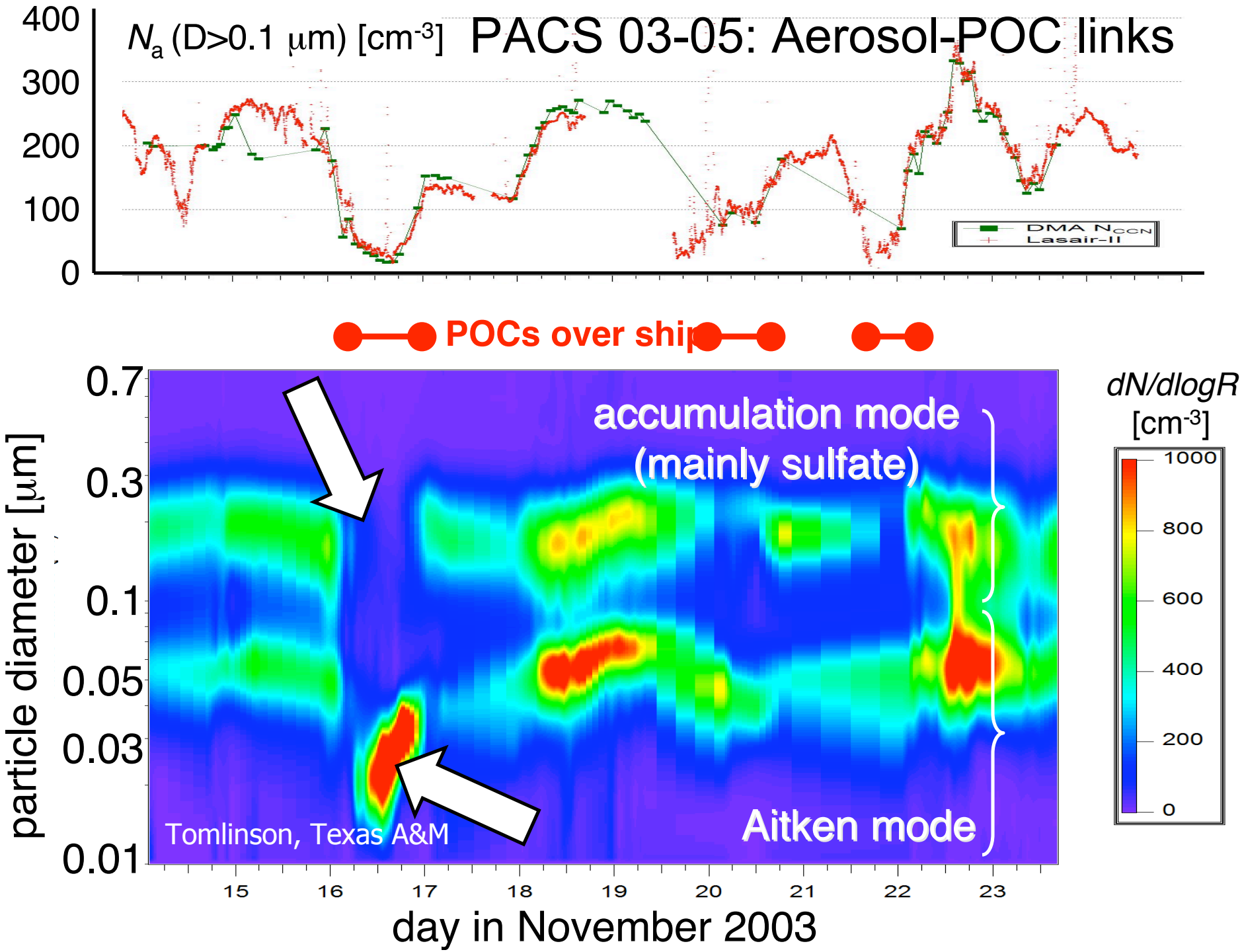


$R(z_{CB}) = 0.075(LWP/N_d)^{1.75}$

Results from EPIC 2001,
Bretherton et al. (2004)

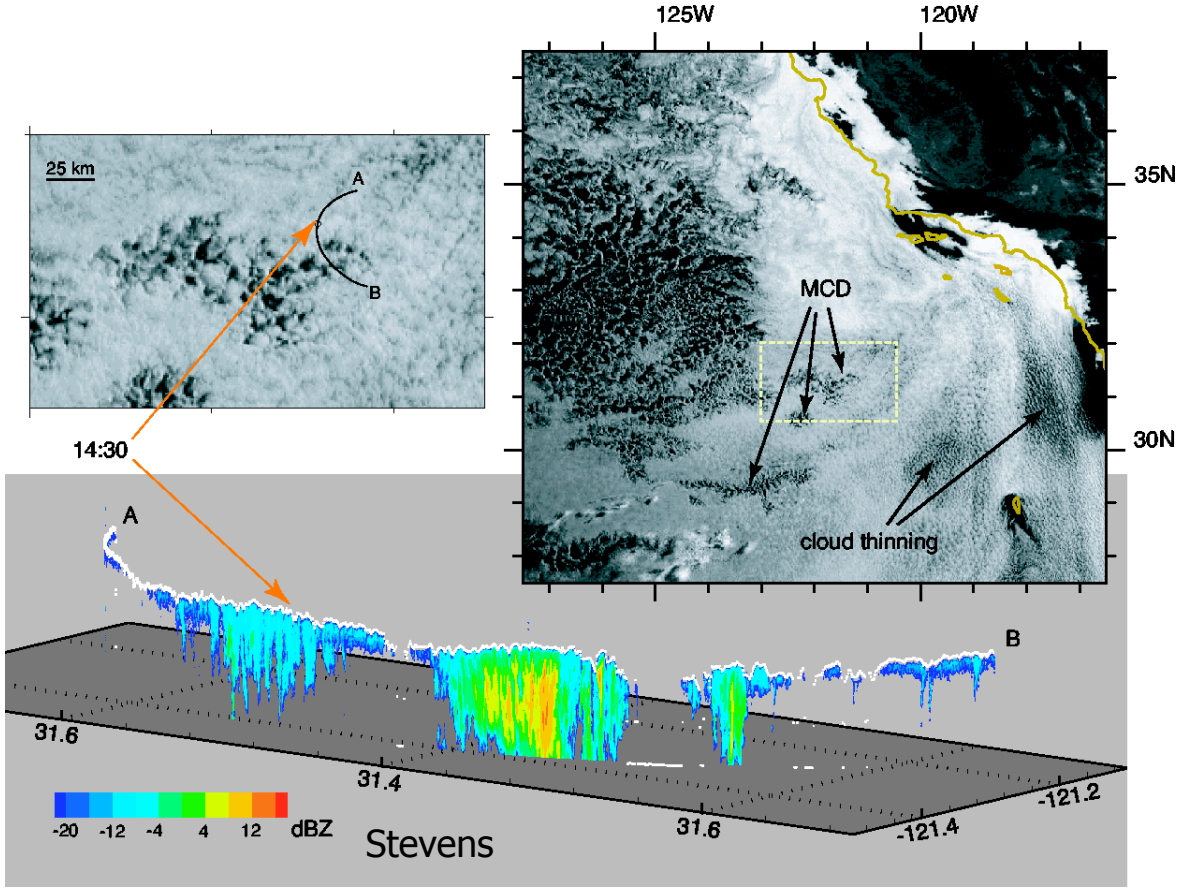
Conceptual model of open cell formation



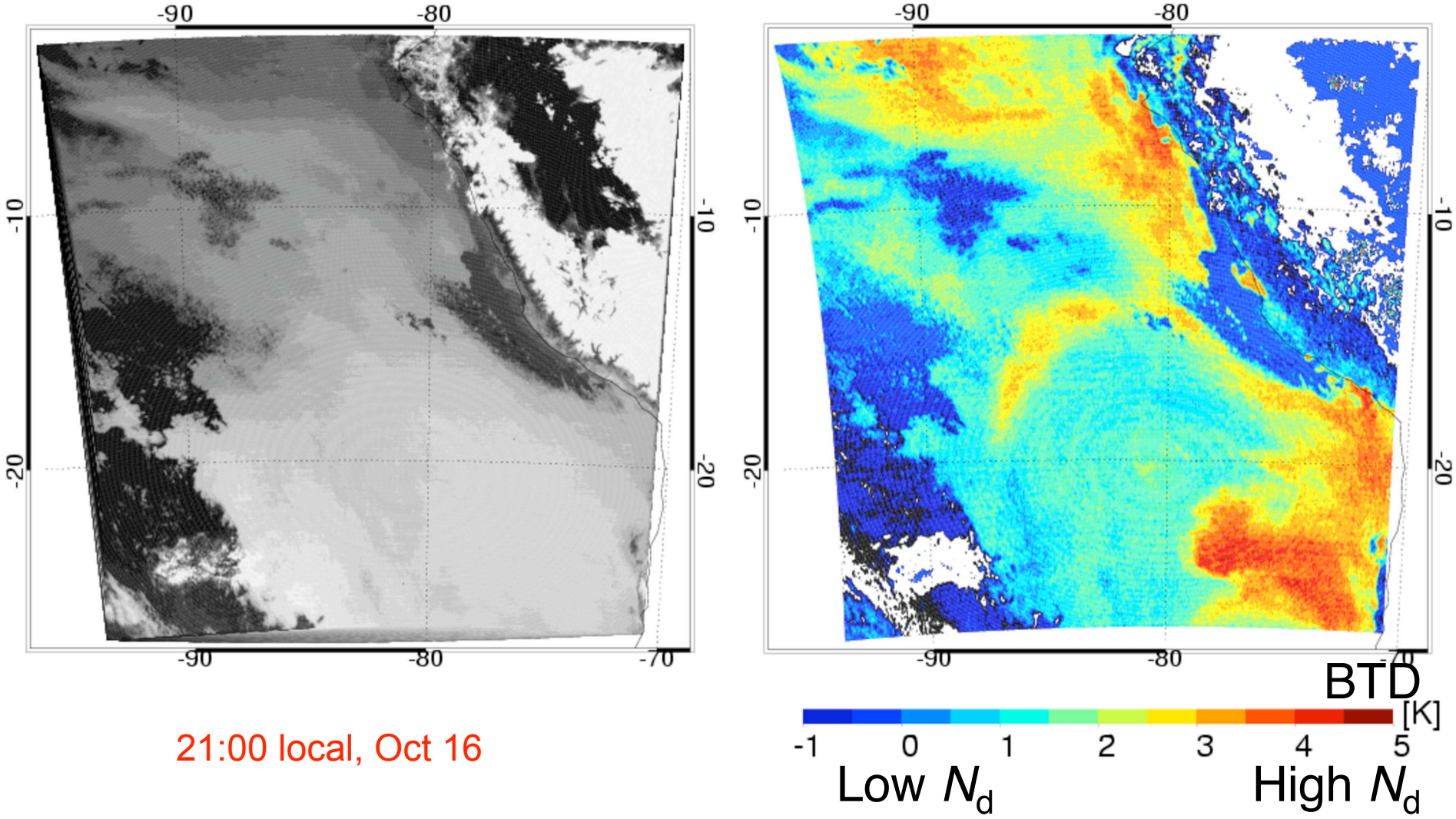

PACS 03-05: Aerosol-POC links
N_a (D>0.1 μm) [cm^{-3}]
400
300
200
100
0
DMA N_{CCN}
Lasair-II
POCs over ship
accumulation mode
(mainly sulfate)
Aitken mode
Tomlinson, Texas A&M
particle diameter [μm]
0.7
0.3
0.1
0.05
0.03
0.01
15
16
17
18
19
20
21
22
23
day in November 2003
dN/dlogR
[cm^{-3}]
1000
800
600
400
200
0

Synergy with NE Pacific cloud-aerosol studies

- Airborne (DYCOMS, Monterey CIRPAS): Smaller POCs, near-shore, diurnal cycle not sampled.
- AMF (Pt. Reyes): Long-term data but coastal.
- DYCOMS/EPIC joint POC paper (Stevens et al.2005)

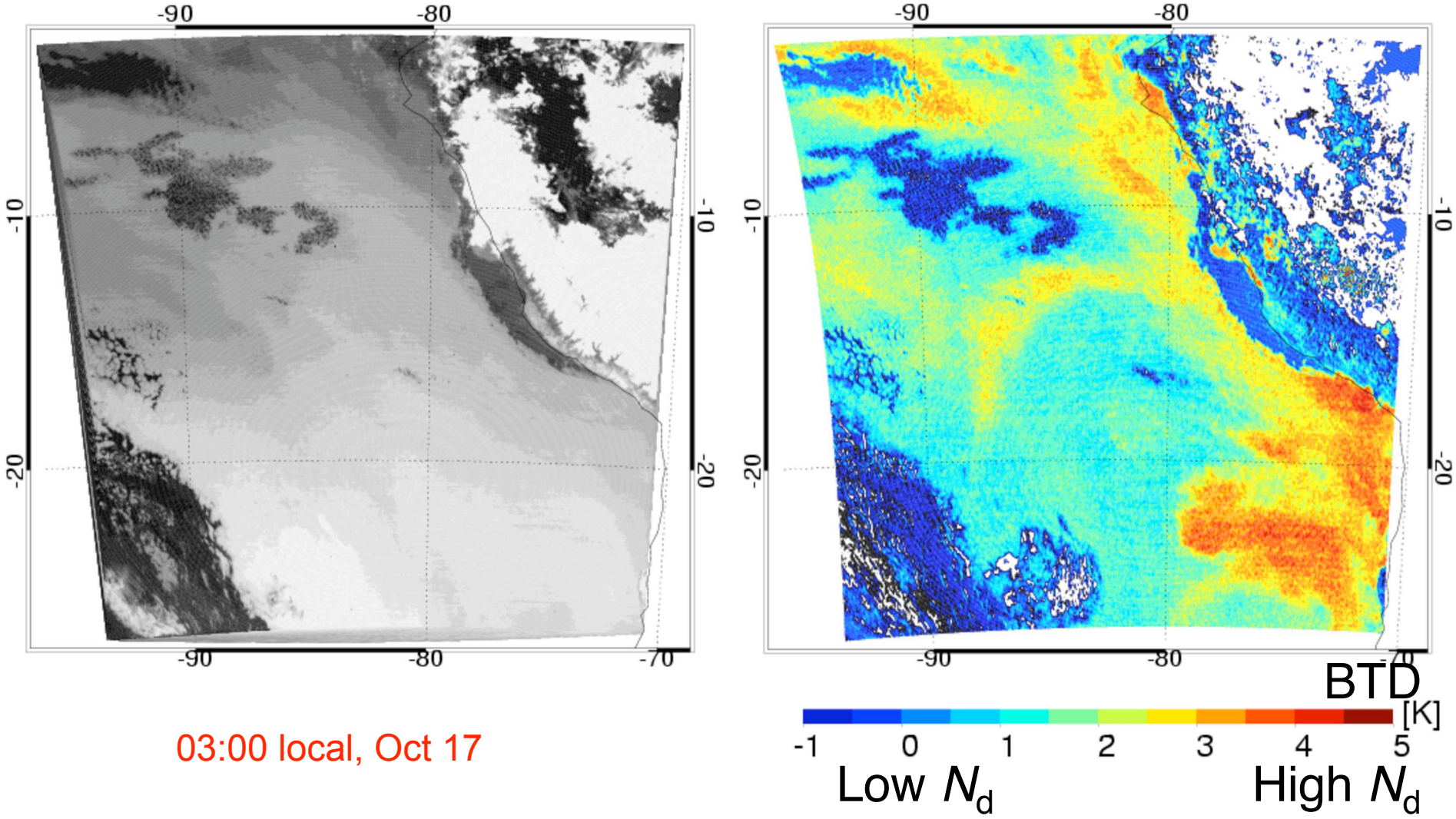


Satellite remote sensing of POCs
GOES IR (left) and 11-3.7 μm brightness temperature difference (BTD, right)



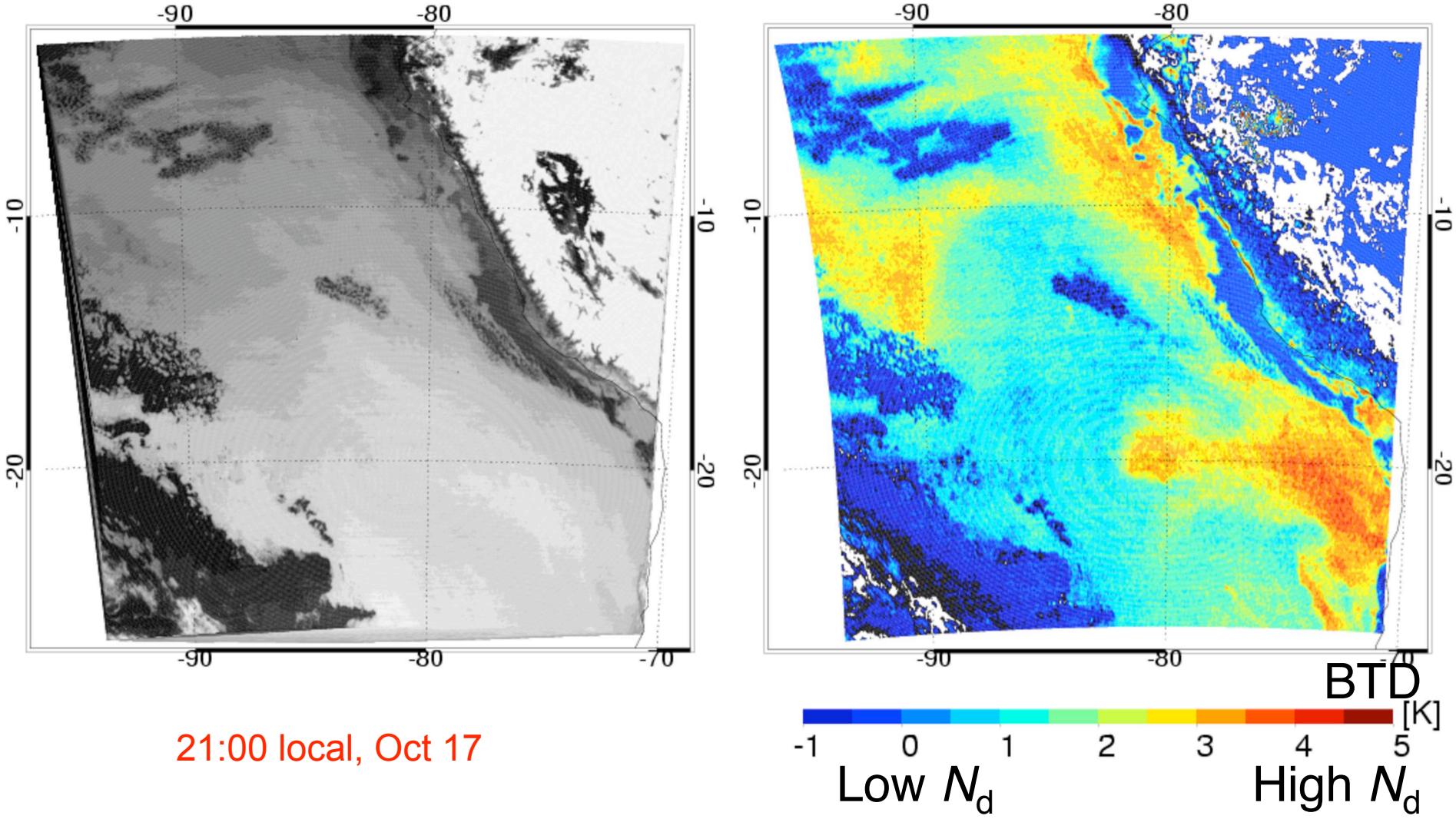
21:00 local, Oct 16

Satellite remote sensing of POCs
GOES IR (left) and 11-3.7 μm brightness temperature difference (right)



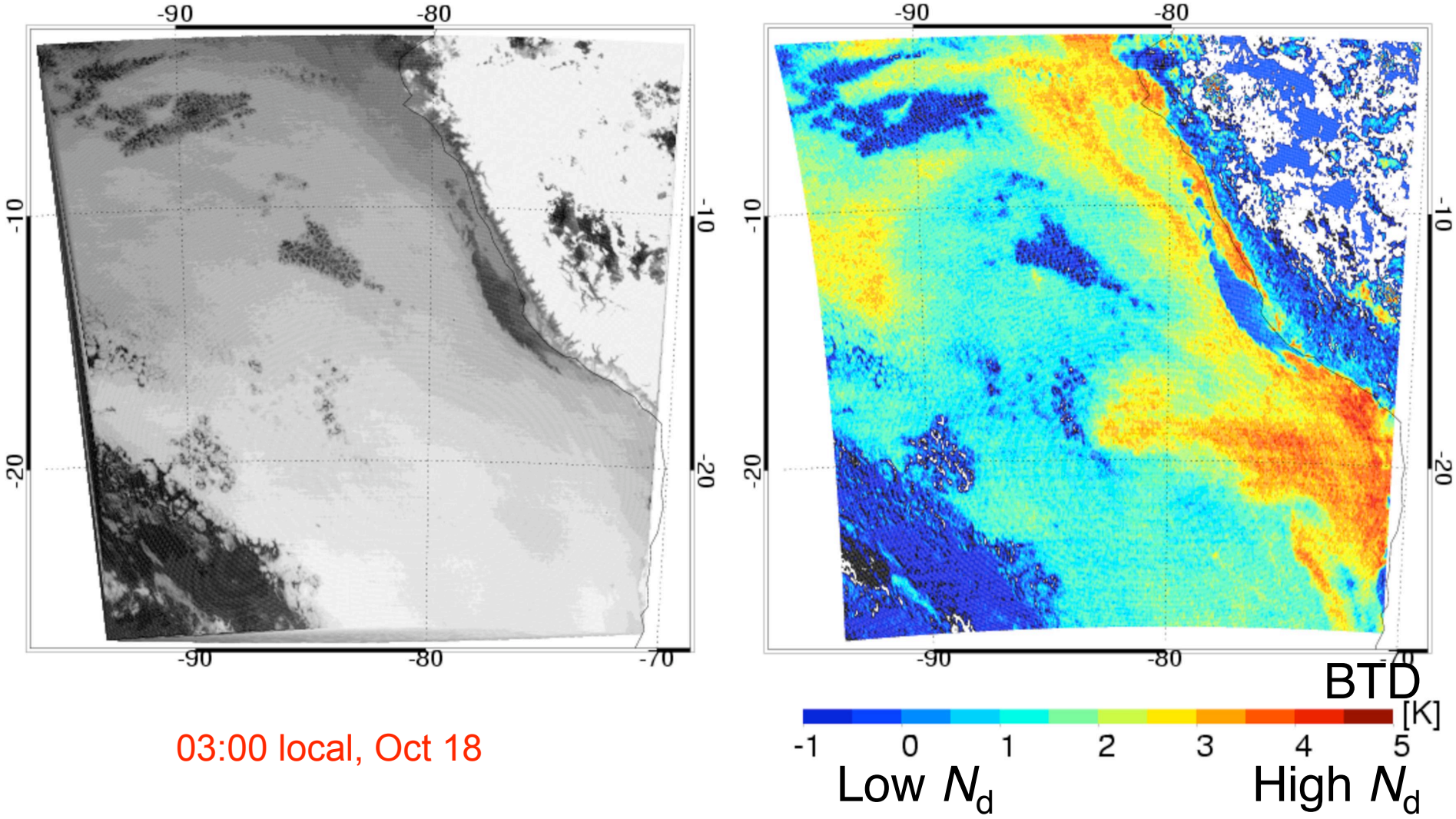
03:00 local, Oct 17

Satellite remote sensing of POCs
GOES IR (left) and 11-3.7 μm brightness temperature difference (right)



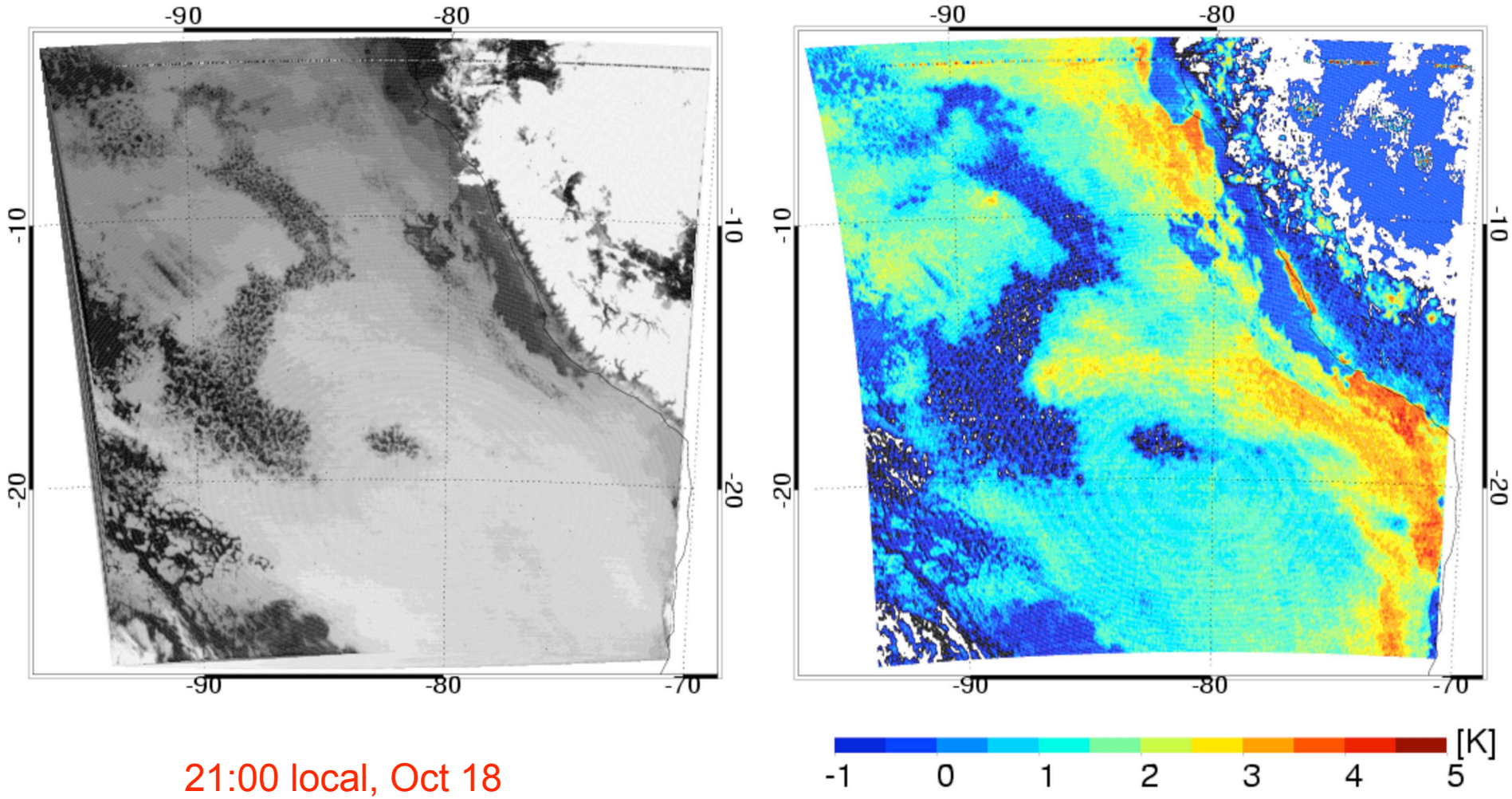
21:00 local, Oct 17

Satellite remote sensing of POCs
GOES IR (left) and 11-3.7 μm brightness temperature difference (right)



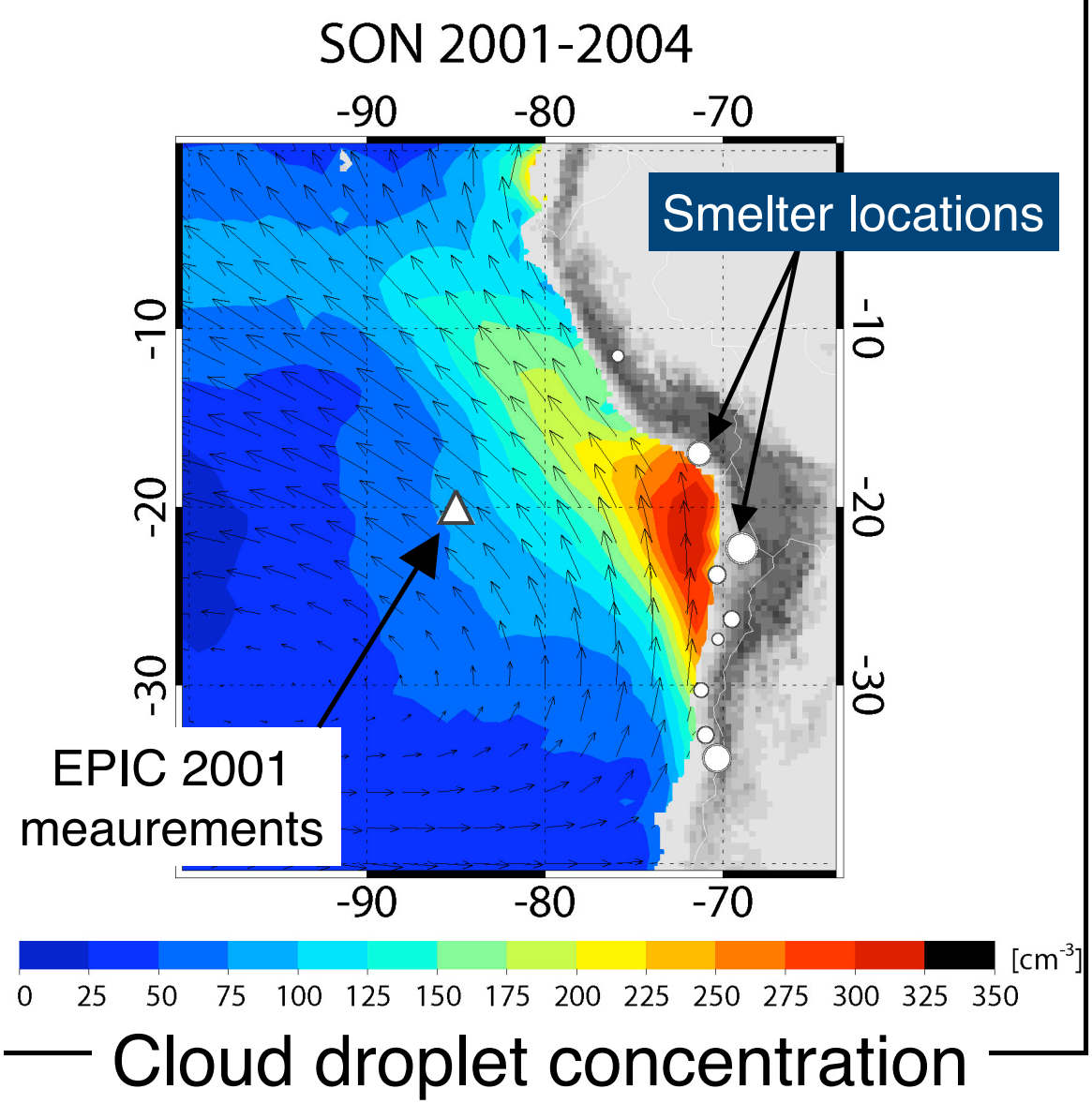
03:00 local, Oct 18

Satellite remote sensing of POCs
GOES IR (left) and 11-3.7 μm brightness temperature difference (right)



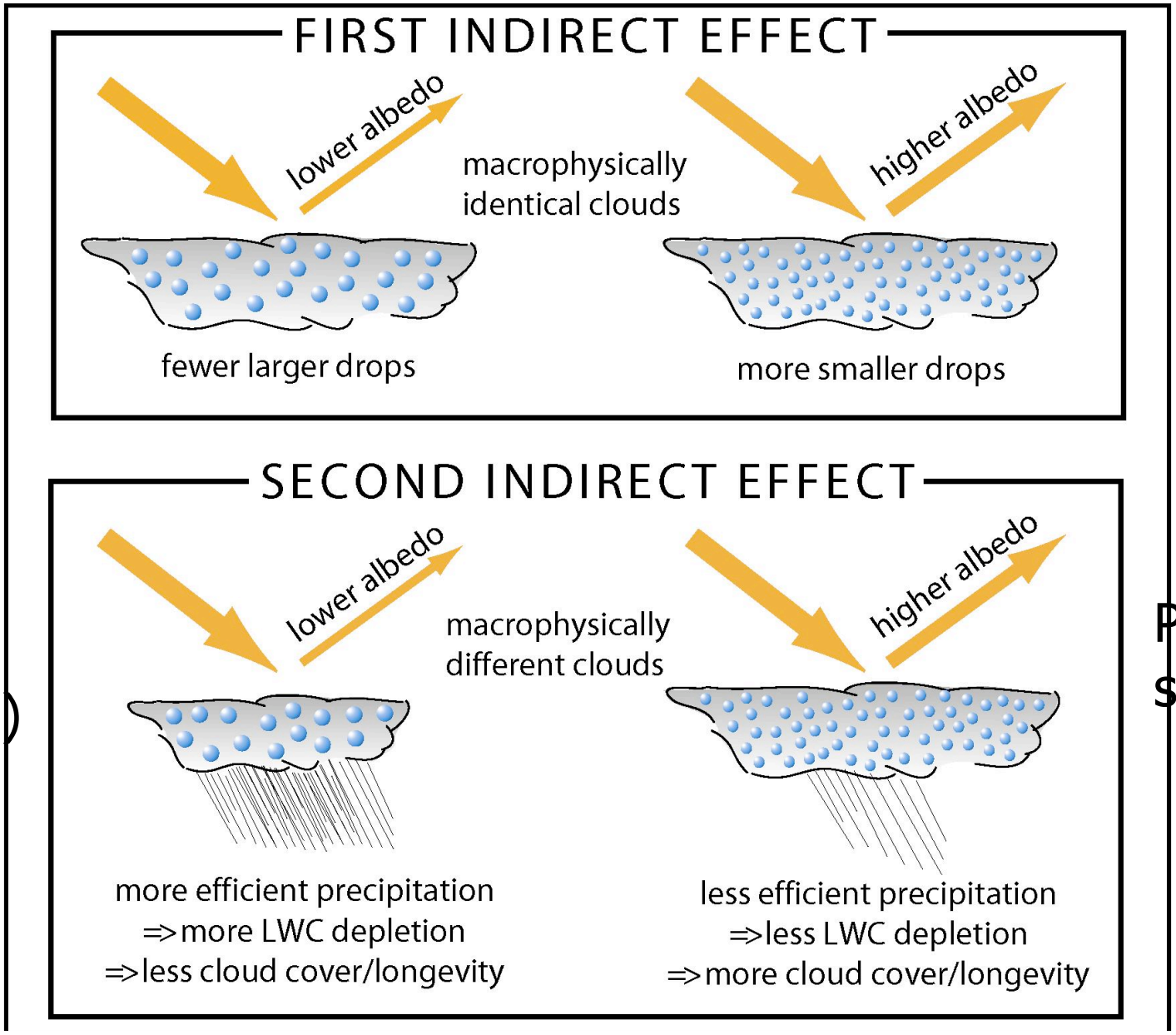
21:00 local, Oct 18

Aerosol sources in the SE Pacific



- Chile is world's largest copper producer
- Copper smelting SO_2 emissions from Chile (1.5 TgS yr^{-1}) comparable to total SO_2 emissions in Germany
- 90% of Chilean SO_2 emissions from seven smelters!
- Andes mountains prevents eastward transport
- Biogenic aerosol from coastal zone also important?
- Aerosol injected within PBL or entrained from above?
- MODIS effective radius retrievals unreliable in inhomogeneous cloud

Are anthropogenic aerosols suppressing POCs?



POC (clean)

Polluted solid Sc

What we think

- Daytime cloud thinning reduces SEP cloud albedo
- POCs lower cloud fraction/albedo
- Cellularity in POCs due to mesoscale circulations and ‘cold pools’ driven by evaporating drizzle.
- POCs initiate in early a.m. in uniform, aerosol-poor Sc.
- POCs self-maintaining by drizzle scavenging of aerosol.
- Smelter sulfate inhibits POCs, raises albedo near coast.
- Suggests large aerosol indirect effect in Sc regions.
- Target for AR5 GCMs incorporating aerosol indirect effects.

A combined aircraft-ship study can nail this down!

Aircraft – in-situ cloud microphysics, aerosol sampling
Ship – long time series in ‘clean’ and ‘polluted’ regimes
... ETL-enhanced Brown is going to stratus buoy anyway

VOCALS-REX atmospheric sampling

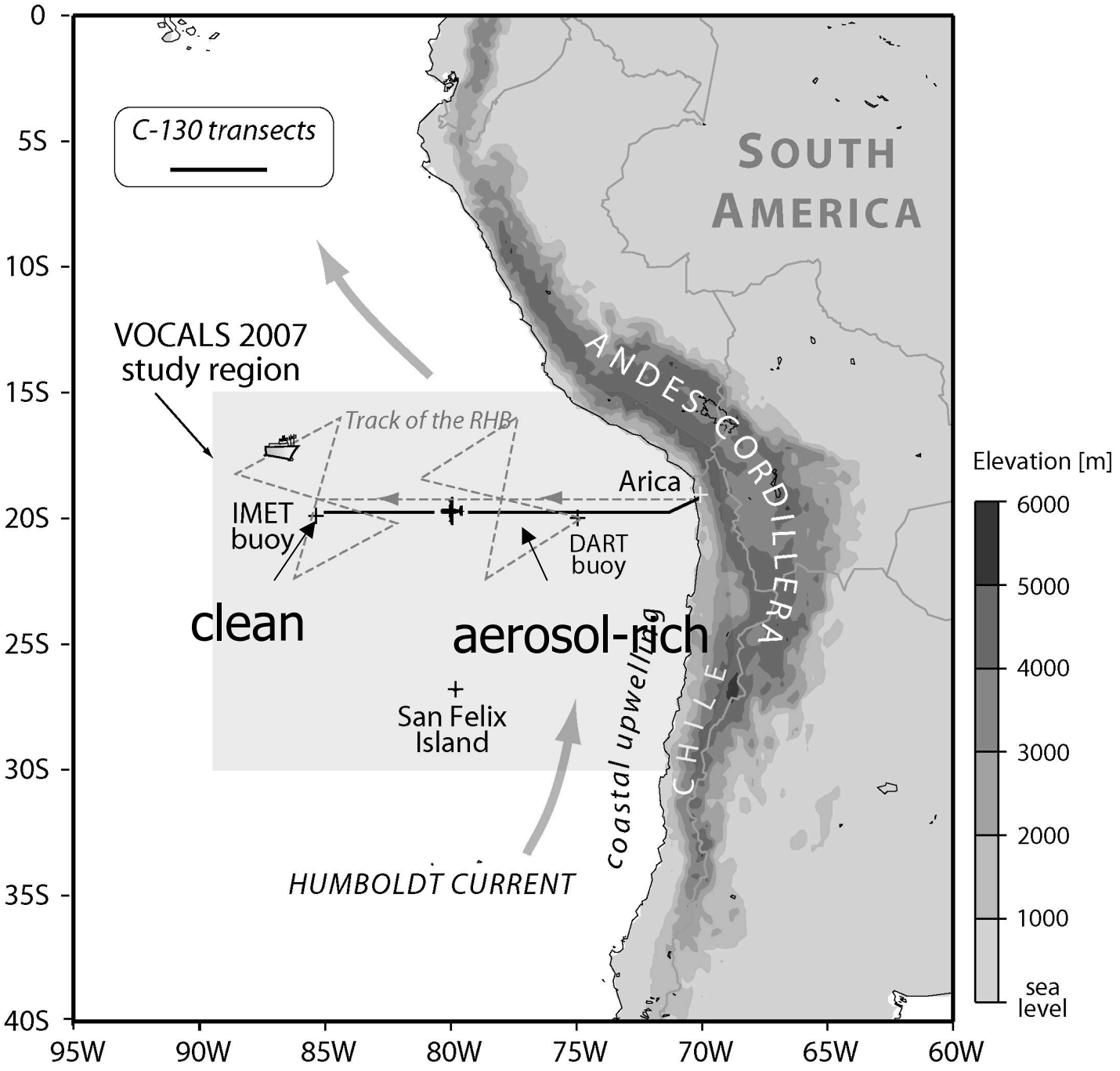
A combined ship-air strategy to sample cloud-aerosol-dynamics feedbacks and their surface impact across the large SEP systematic offshore gradient of aerosol concentrations.

1. What factors influence drizzle formation and POCs? Is aerosol the critical factor?
2. What are the aerosol characteristics, sources and sinks in the coastal and remote SEP?
3. Do satellite and ship-based retrievals of aerosol, cloud drop radius and drizzle agree with in-situ observations?
4. What is the relative importance of dynamical vs. aerosol variability in controlling SEP stratocumulus cloud cover?

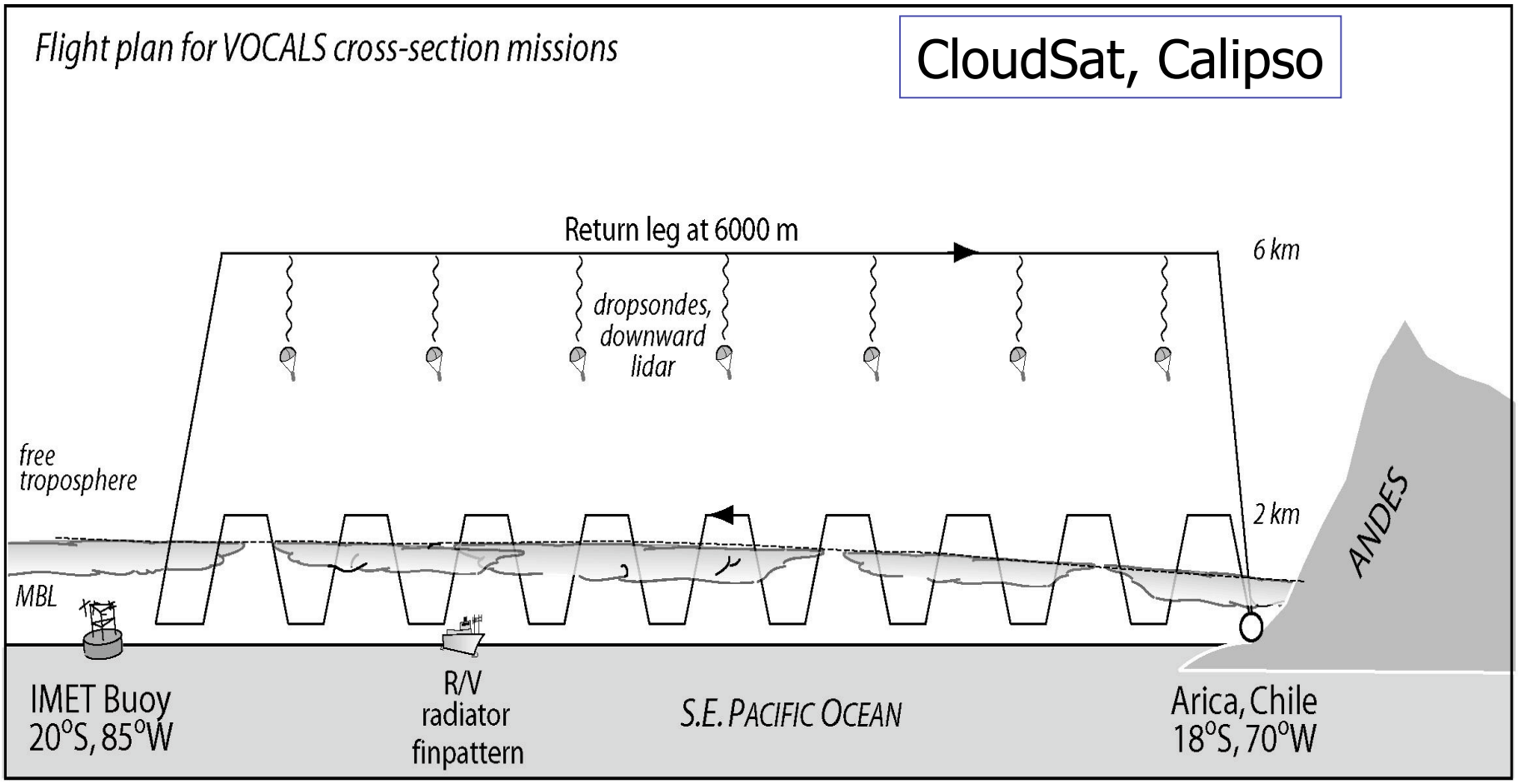
- This is part of a broader long-term VOCALS strategy including modeling, measurements of opportunity, and integrated data analysis.

Platforms

- NCAR C-130 (120 hrs; 30 days; Wood/Breth/Vali/Yuter):
  - In situ cloud, aerosol, turbulence sampling
  - Cloud radar/lidar/dropsonde survey
- Brown (43 days; Fairall)
  - ETL cloud radar/ceilometer/MWR/fluxes/met
  - Scanning C-band radar
  - Aerosols (ETL and/or Texas A&M).
  - Sondes.
- Possible externally funded add-ons
  - C-130 Aerosol/chemistry (Huebert/Bandy-SOLAS; $900K)
  - NOAA ‘coastal’ P-3 (Aeronomy lab – Feingold)
  - Aerosondes for POC-tracking (Esbensen; $300K+)

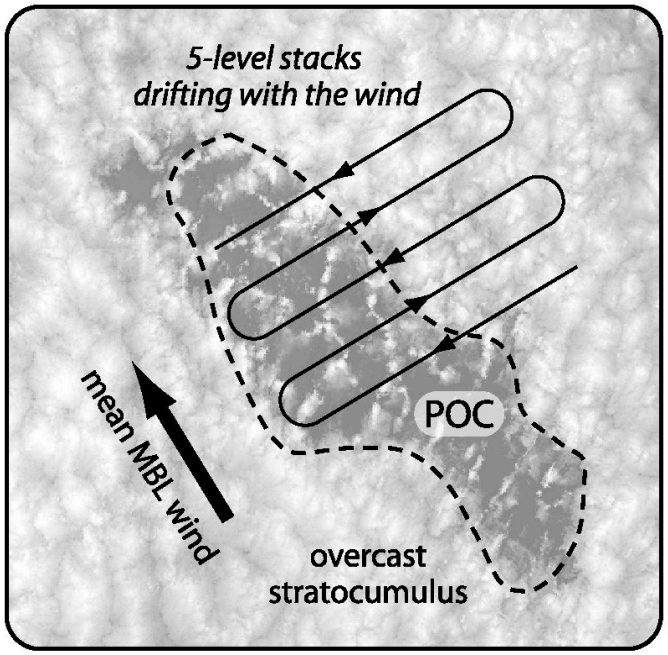

C-130 transects
SOUTH AMERICA
ANDES CORDILLERA
CHILE
VOCALS 2007
study region
Track of the RHB
Arica
IMET
buoy
DART
buoy
clean
aerosol-rich
San Felix
Island
HUMBOLDT CURRENT
coastal upwelling
Elevation [m]
6000
5000
4000
3000
2000
1000
sea
level
0
5S
10S
15S
20S
25S
30S
35S
40S
95W
90W
85W
80W
75W
70W
65W
60W

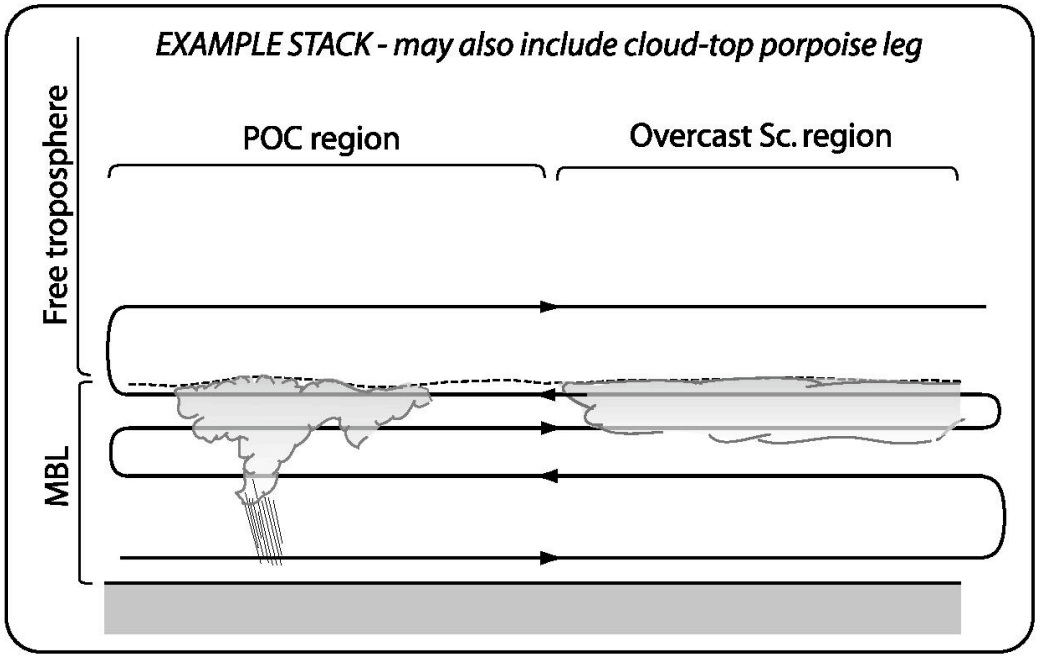
Cross-section flight plan



Flexibility for day or night A-Train underflights.

POC-sampling missions
(repeated flights to an evolving POC if possible)





Satellites or optional aerosondes for diurnal cycle sampling

Atmospheric Platforms-‘Skeleton plan’ costs

NCAR C-130 ($450K/3yrs - NSF)

120 flight hrs	$805K – deployment pool)
120 dropsondes	$215K – deployment pool)
SABL lidar (EOL)	$90K – NSF
Wyo. cloud radar	TBD

PI UWyo: $300K/3yrs + UWash: $450K/3yrs

Brown (supplemental above ‘annual’ 18 day CPPA stratus cruise)

4xdaily sondes + NOAA-ETL + aerosol	$100 K
C-band radar (Yuter)	$60K subcontract – NSF
PI ETL analysis:	$300 K/3yrs – NOAA

Optional ETL ship profiler $50K

Total out-of-pocket NSF-ATM = $900 K

NOAA = $450 K

Deploy. pool = $1015 K

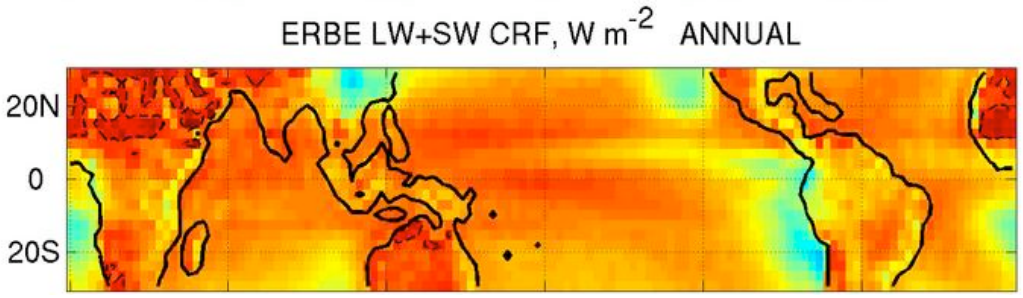
VOCALS-REX atmospheric payoffs

- Better characterization of aerosol indirect effect in stratocumulus as needed for IPCC AR5 models.
- Improved fundamental understanding of POC formation, maintenance, surface flux effects.
- Better characterization of both natural and anthropogenic aerosol sources in SEP.
- In-situ validation of A-Train drizzle (CloudSat) and daytime/nighttime cloud droplet size/LWP retrievals (MODIS) for stratocumulus.
- Unique dataset for testing regional models of diurnal/synoptic variability in/above CTBL.
- Context for interpreting long-term stratus buoy surface flux data.

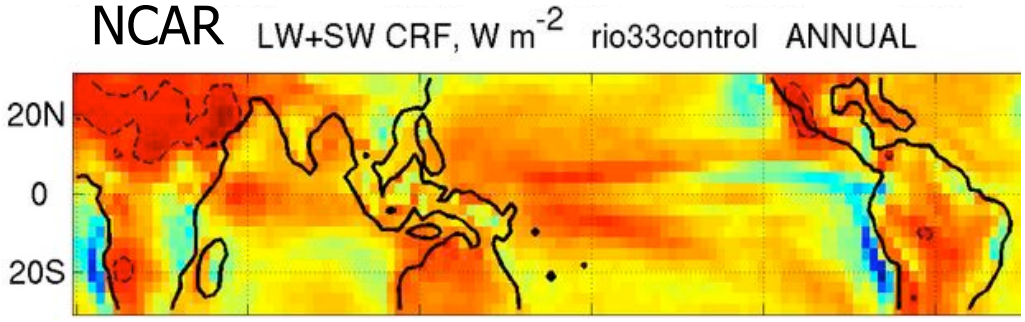
VOCALS GOAL

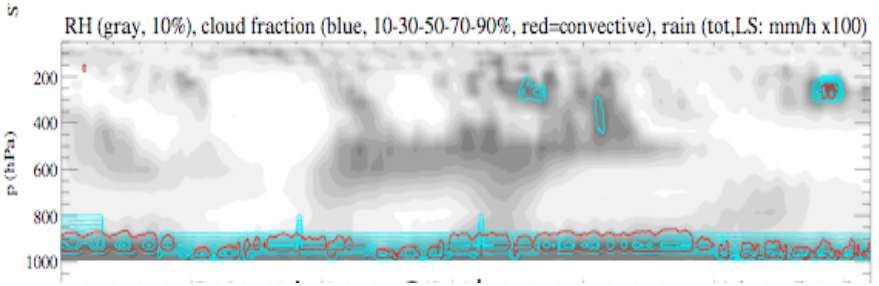
Better understand, simulate, and predict the Southeast Pacific cool-ocean climate regime and its interactions with the larger-scale coupled ocean-atmosphere-land system on diurnal to interannual timescales.

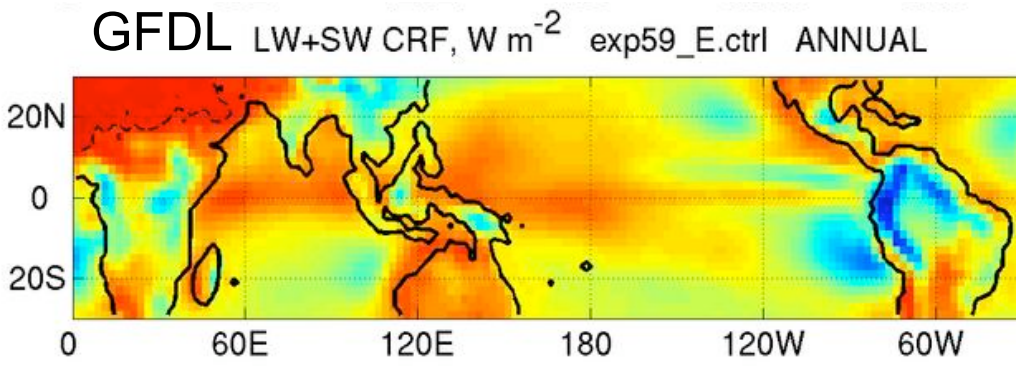
Current U.S. AGCM stratocumulus simulations



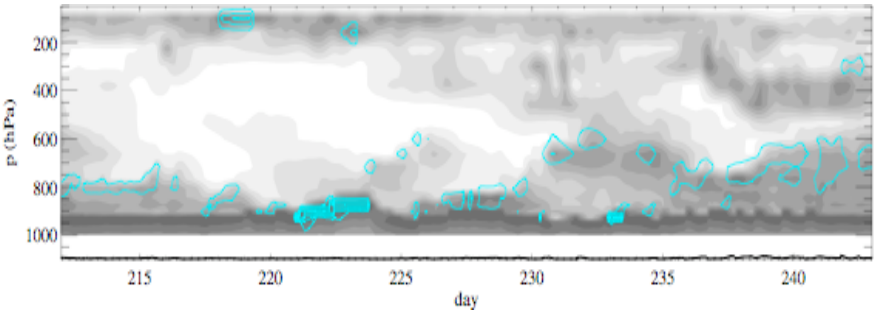
- Decent radiation
- Imperfect clouds
- Drizzle significant
- Cloud-aerosol feedbacks soon





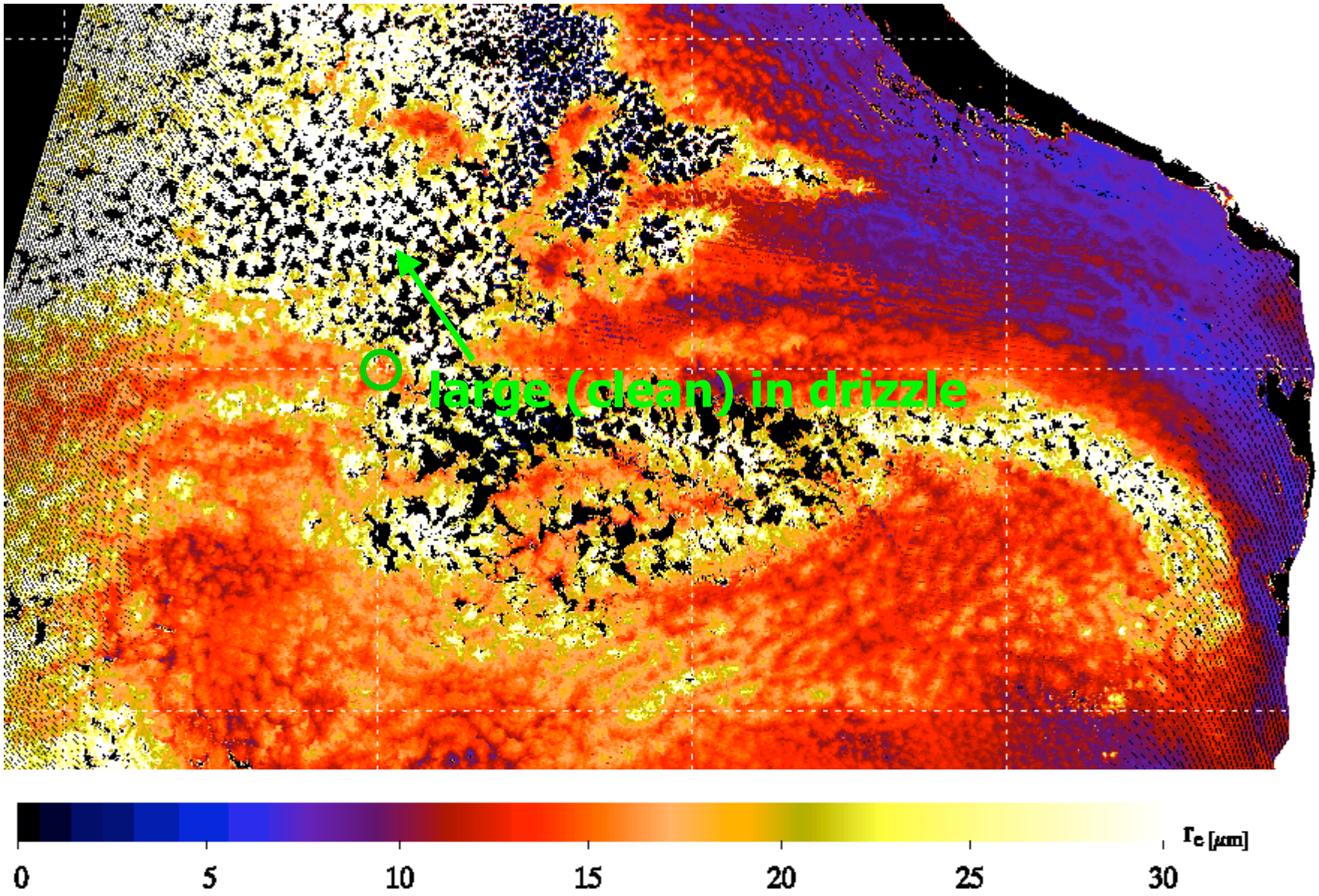


A model month at 20S 85W



(CPT, Wyant et al.2005; also note GCSS BLCWG)

MODIS-derived cloud droplet radius excessive in broken cloud



Global cloud droplet concentration estimates (MODIS satellite, annual mean 2001-2004)