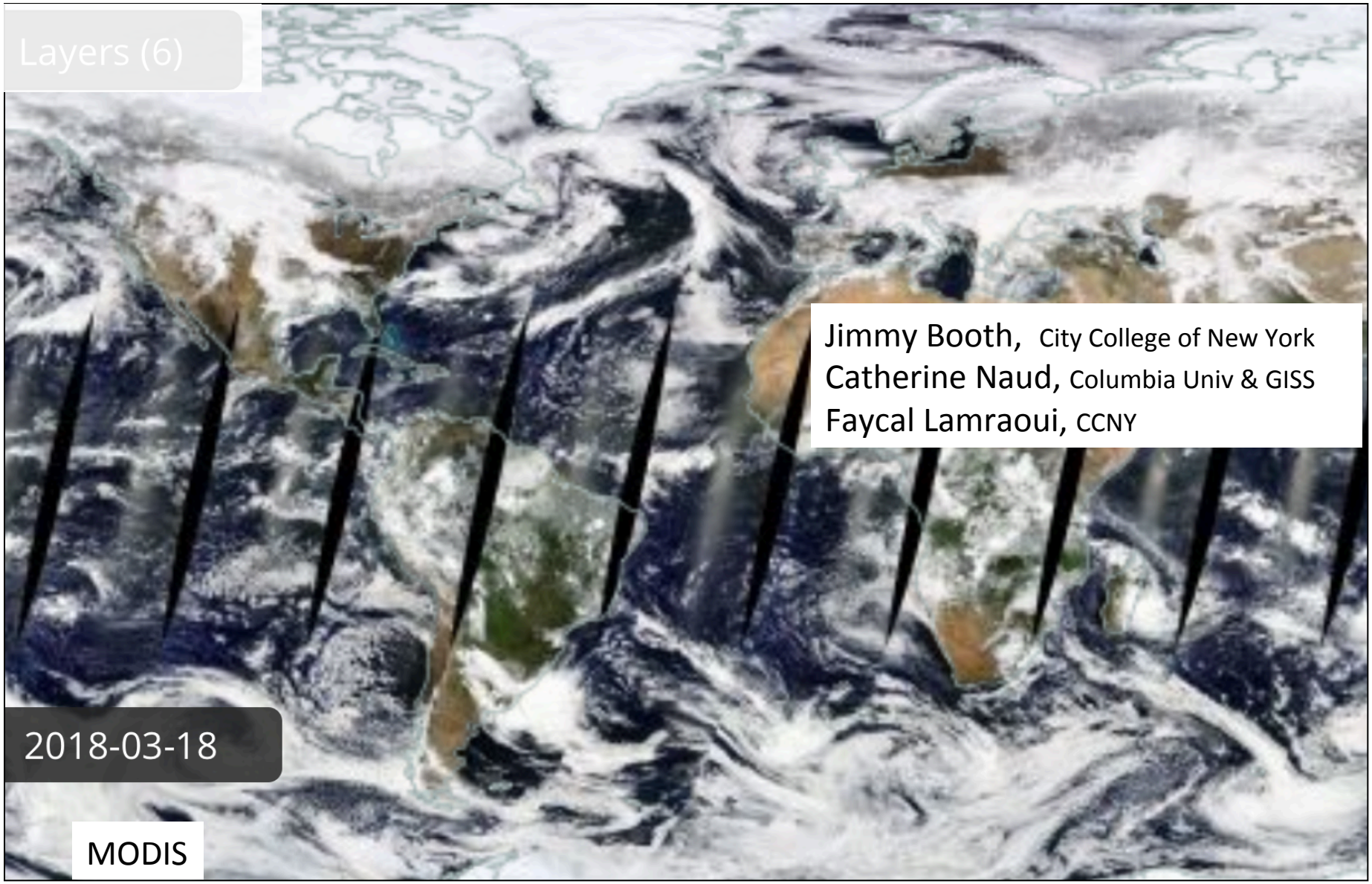
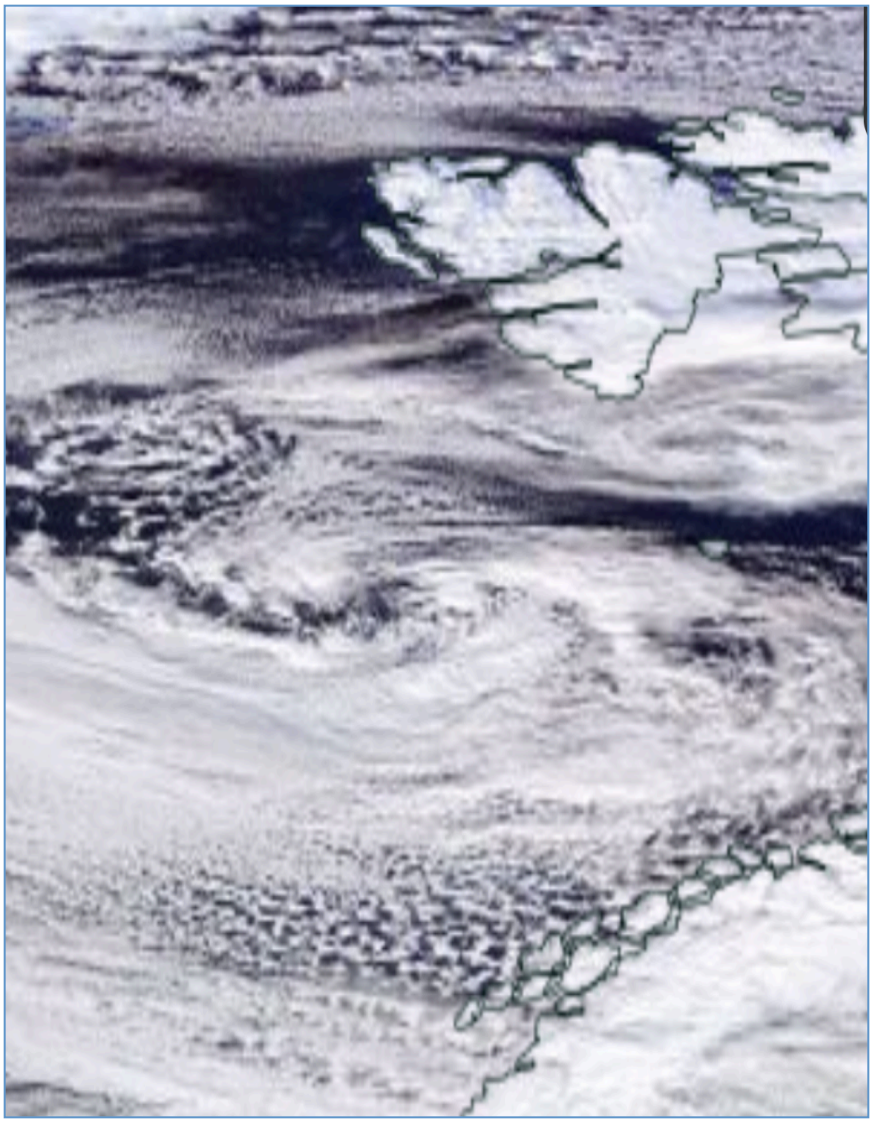
Comparing Synoptic Circulation and Low cloud properties during cold air outbreaks over the Gulf Stream, the ARM ENA Site, and Bear Island



Jimmy Booth, City College of New York
Catherine Naud, Columbia Univ & GISS
Faycal Lamraoui, CCNY

What are the factors that impact CAO cloud variability at the **synoptic scale**?



MODIS image for Bear Island region, Mar. 18, 2018

A. Thermal Advection: $\vec{U} \cdot \nabla T$
(properties of air being advected)

B. Large-scale subsidence: ω_{500}

C. Surface Heat fluxes

D. Inversion strength

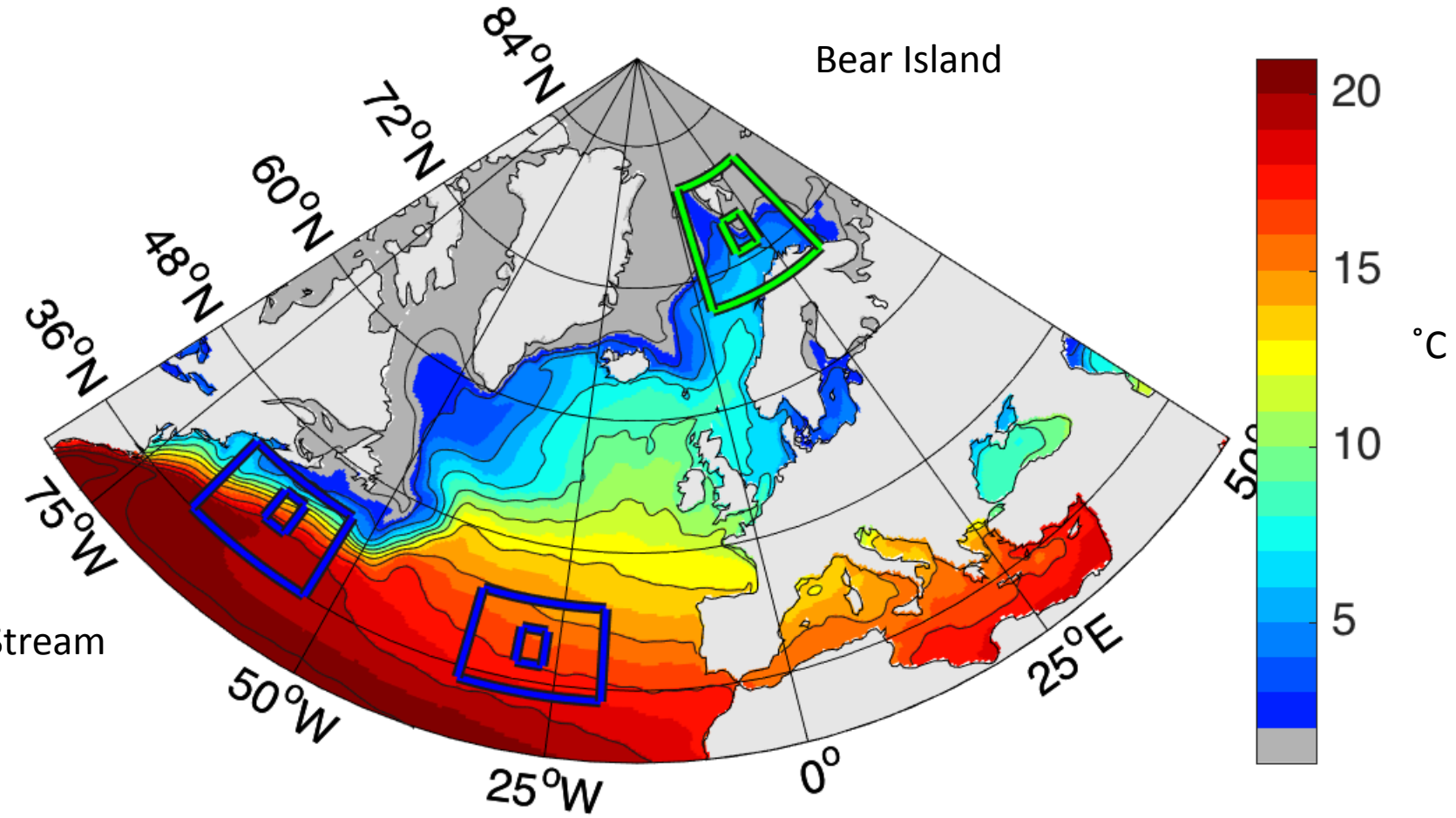
Perhaps, B and C set D?
Or D sets C?

See also:
Fletcher et al. JCLIM 2016
McCoy et al. JCLIM 2017

*Here I am only talking about large-scale. Microphysics will also have a key role.

Regions used for this analysis

Sea Surface Temperature Climatology, for DJF, based on AVHRR



Gulf Stream
(GS)

East North Atlantic Site
(ENA)

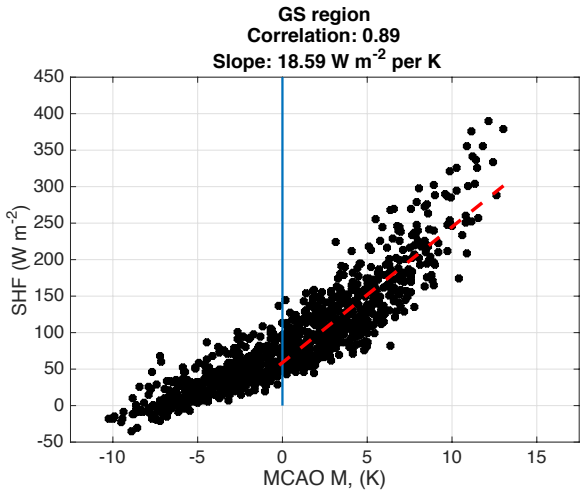
In all analyses, land is masked out

Start with what we expect: relationship between M and sensible heat flux (SHF)

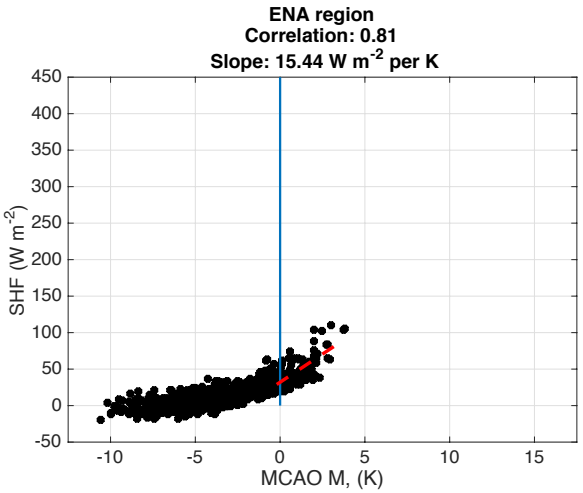
$M = \theta_{SKIN} - \theta_{850}$

$M > 0$: unstable

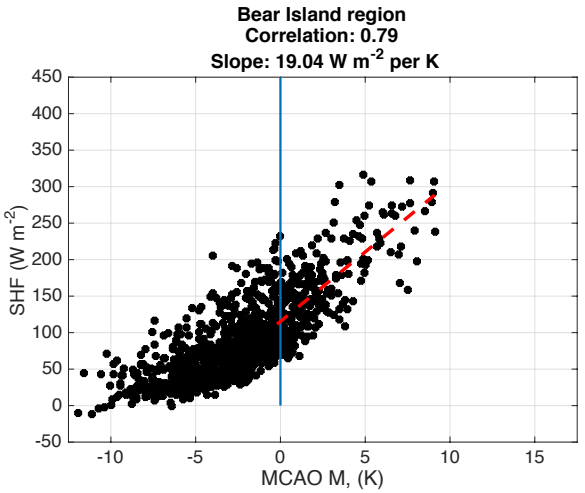
GULF STREAM



ENA SITE REGION



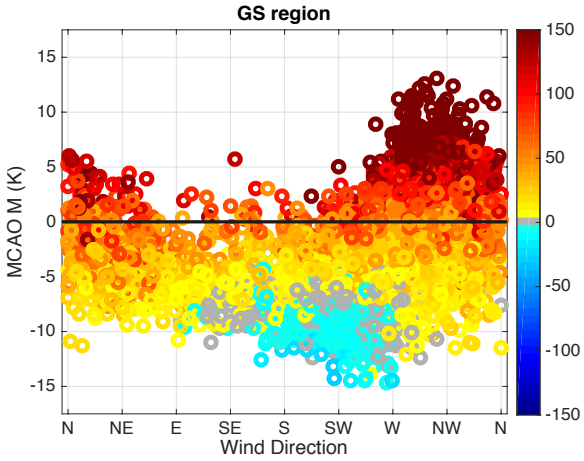
BEAR ISLAND

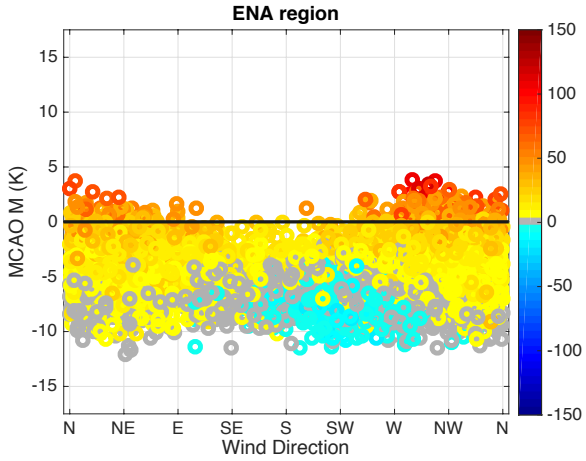


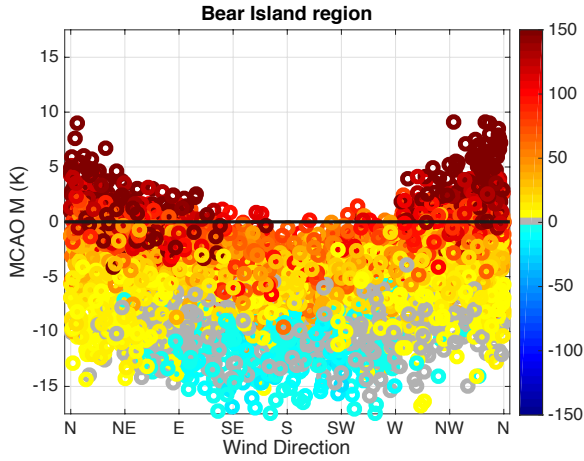
- The 3 regions have similar M/SHF relationships
- The distributions of M and SHF at the three regions are different
- For M > 0 there is a slight change in the slope of the linear relationship

What direction is the wind blowing during the CAOS?

X-axis indicates the direction wind is blowing from
Y-axis indicates $M = \theta_{SKIN} - \theta_{850}$
Color shows SHF (Wm-2)







At Gulf Stream and Bear Island, stronger fluxes, due to presence of land

Gulf Stream: CAOs mainly occur when winds are from the NW

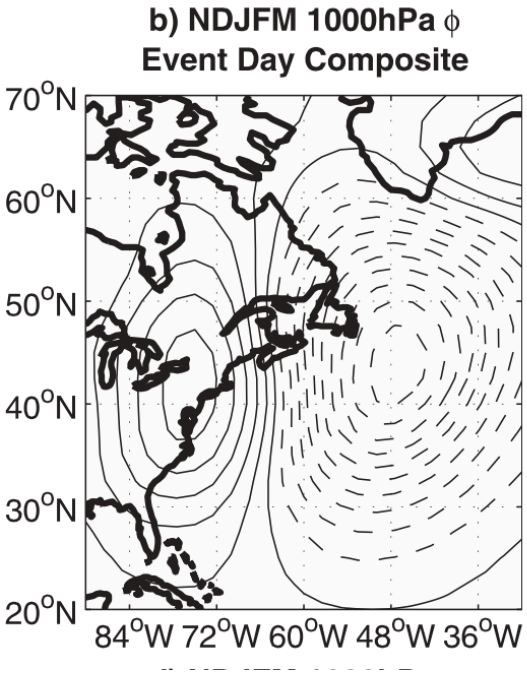
ENA: CAOs less frequent; occur when winds are from NW or NE.

Bear Island: CAOs occur when winds are from NW or NE

CAOs over the Gulf Stream: very strong link with extratropical cyclones

Composites of strongest fluxes out of ocean suggests CAOs occur as the cyclones exit the region.

- Shaman et al. 2010



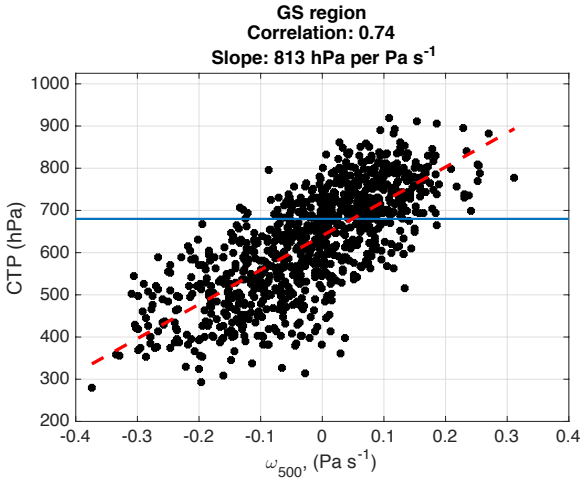
- Shallow convection in CAO
- Deeper cloud coincides with cyclone's cold front

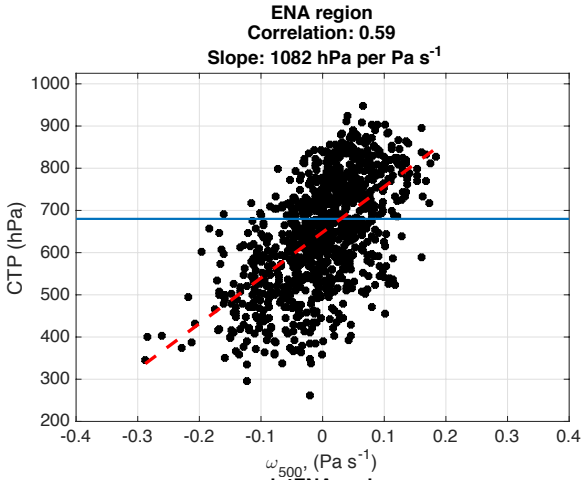
Synoptic-scale relationship between cloud top pressure (CTP) and vertical velocity at 500 hPa

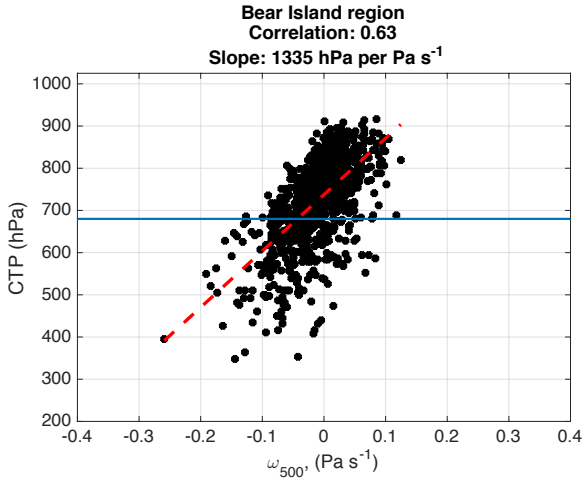
All 3 locations show the expected pattern:

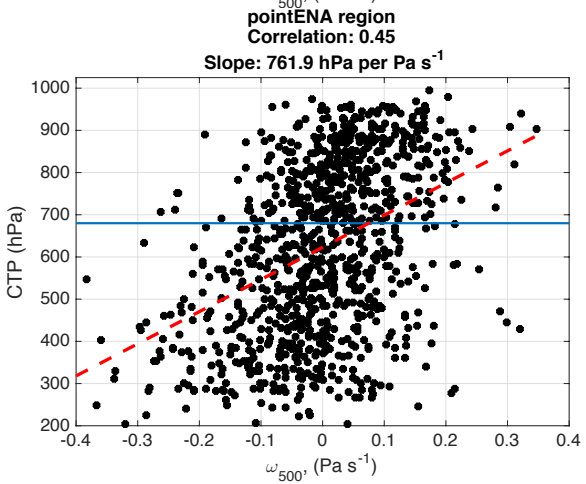
- high cloud tops in regions of ascent
- low clouds in subsidence regions

See also:
Remillard et al. 2012
Ghate et al. 2011









Strongest relationship for the GS, but signal remains at ENA and Bear Island.

For ENA, we compare results using synoptic and mesoscale averaging region, to point out how noise increases as we consider smaller scales.

Direct Link to Extratropical Cyclones?

For the dates of strongest CAOs we identify cyclone tracks within 2000 km of:

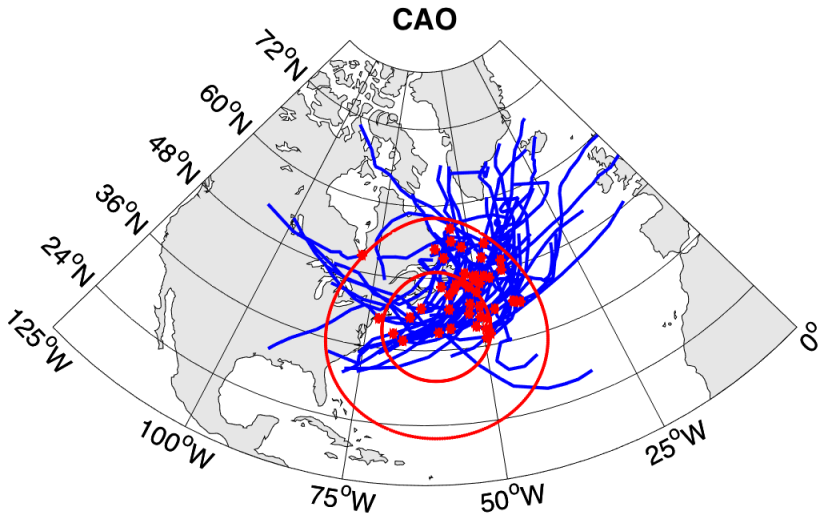
- Gulf Stream region (top)
- ENA region (bottom)

Red dots indicate location of the cyclone at the date of the CAO (+/- 12 hours).

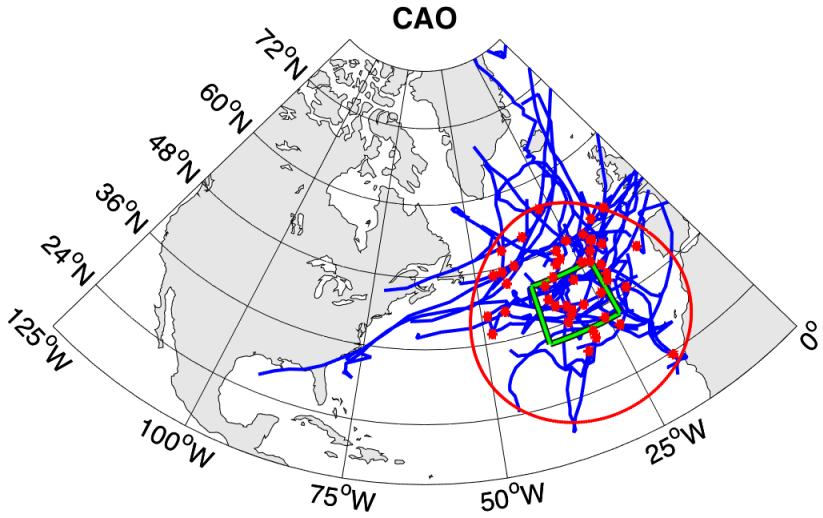
Can we do the same for Bear Island? Need to focus on polar lows.

Would it be useful to you all?

Cyclones for GS



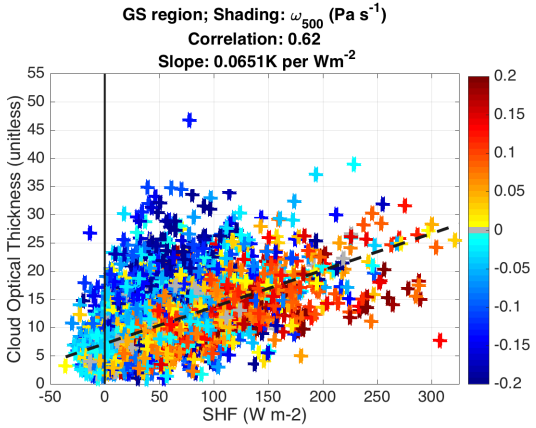
Cyclones for ENA

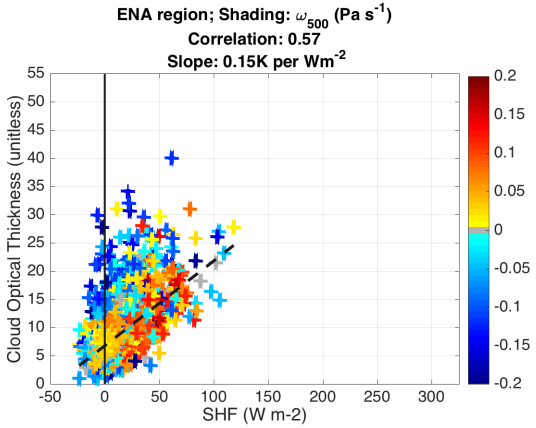


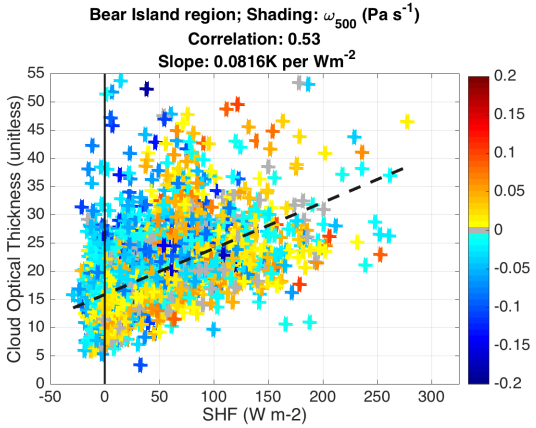
Synoptic-scale relationship between SHF, cloud optical thickness and vertical motion at 500 hPa

Top: all points with cloud fraction > 0.2
Bottom: as top, but subsidence regions

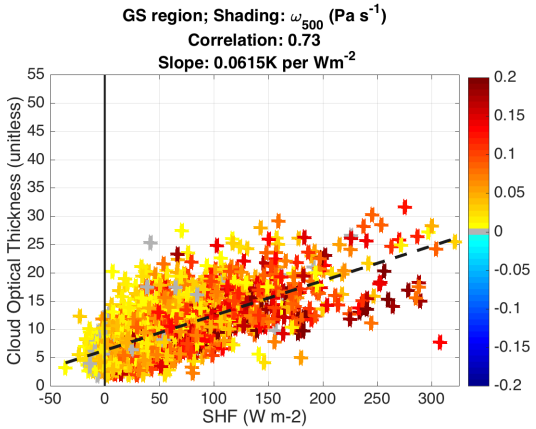
} Suggests SHF may influence cloud properties, in certain synoptic conditions.

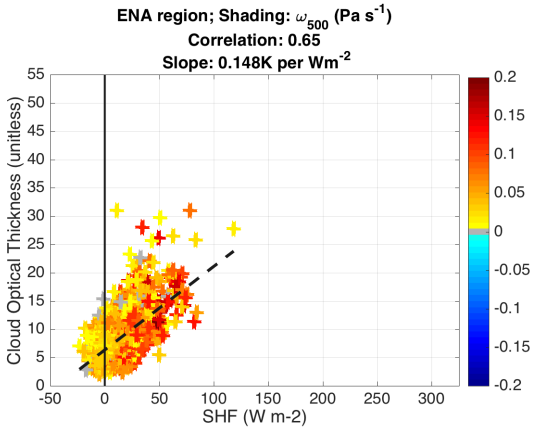


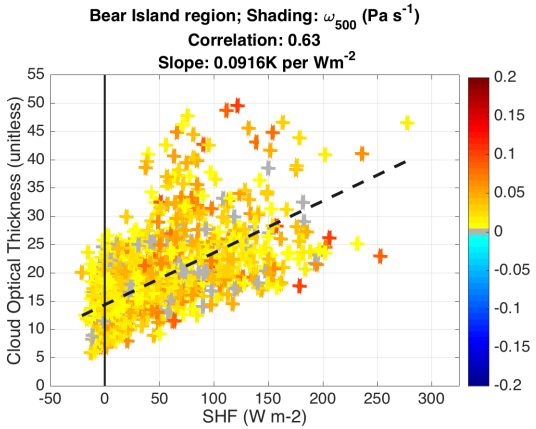




Pa sec^{-1}





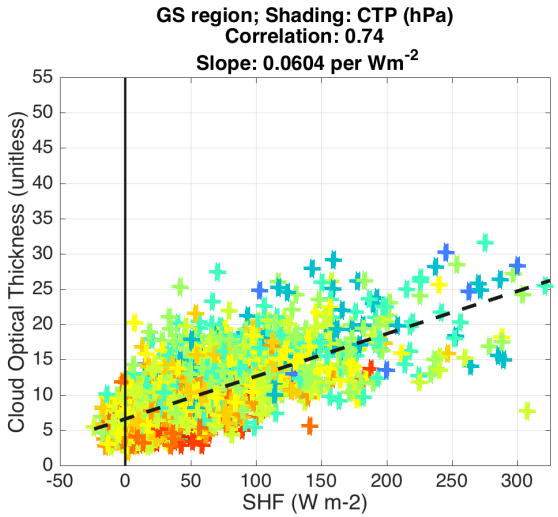


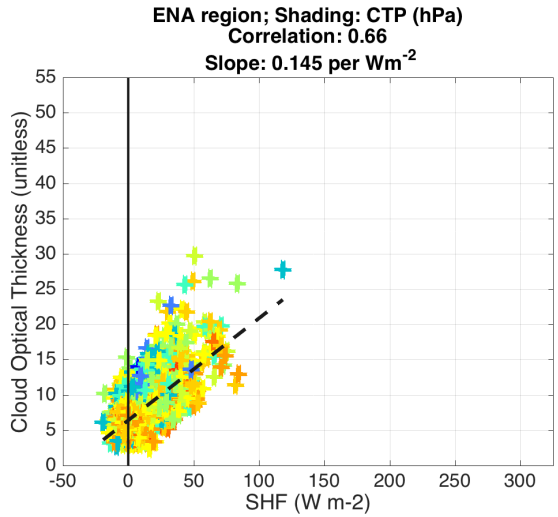
Pa sec^{-1}

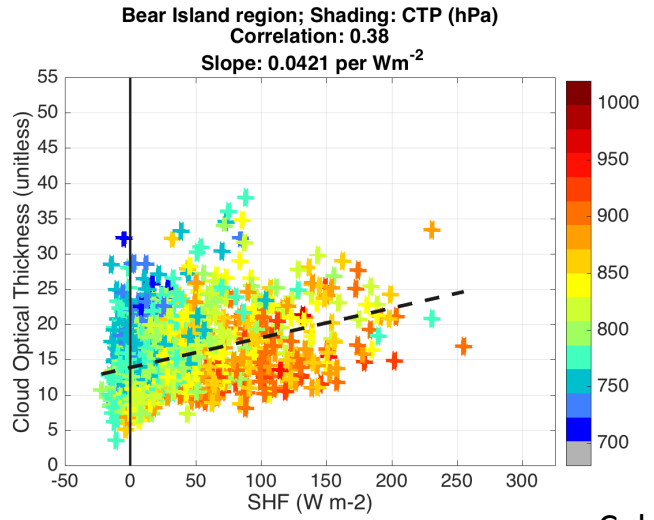
For the MODIS product I use, Tau at Bear Island is not calculated in winter. So this analysis considers the full year.

Synoptic-scale relationship between SHF, cloud optical thickness

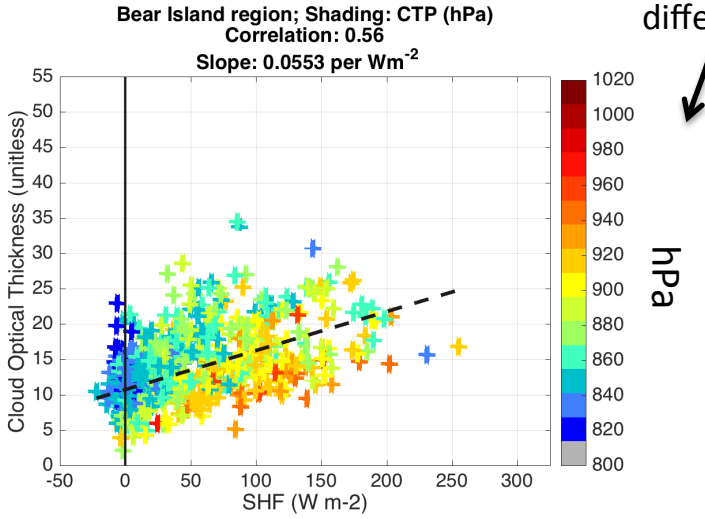
Subset of data for which: cloud fraction > 0.2
synoptic scale subsidence
CTP > 680 hPa (ISCCP low clouds)







Colorbar differs



Top row for GS and ENA, relationship between SHF and cloud optical thickness.

Bottom panel: shows Bear Island has a similar relationship for clouds with CTP > 800 hPa

our interpretation: SHF influences cloud thickness

Issue: CTP vs SHF differs for GS vs ENA and Bear

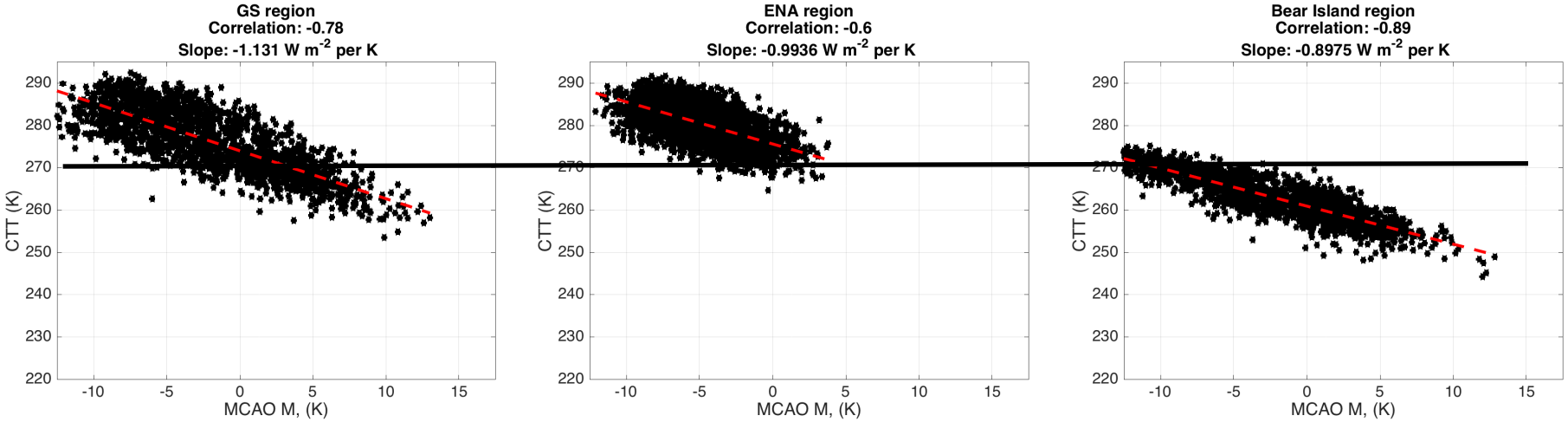
Synoptic-scale relationship between M and Cloud Top Temperature (CTT)

$M = \theta_{SKIN} - \theta_{850}$

$M > 0$: unstable

Low clouds only (CTP > 680 hPa), with synoptic-scale subsidence

Black line indicates T = 270 K, estimated threshold for supercooled liquid



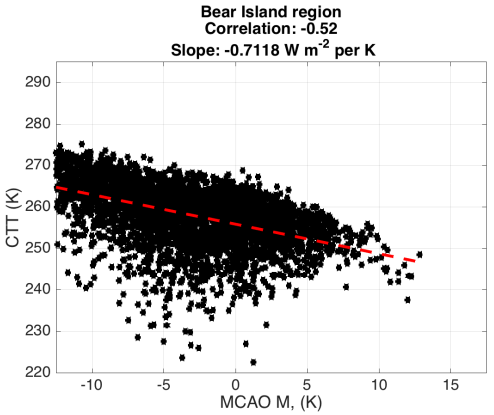
Robust linear relationship between M and CTT could be:

CAUSAL: Cloud response to lower-troposphere stability (perhaps through SHF?)

or,

CONSISTENT: Low-clouds are constrained to occur in specific conditions based on vertical stability, and as a result there appears to be a relationship with M

With no sorting



Summary

- Some of the properties of low-level clouds generated by cold air outbreaks have robust relationships with low-level atmospheric stability and surface sensible heat flux.

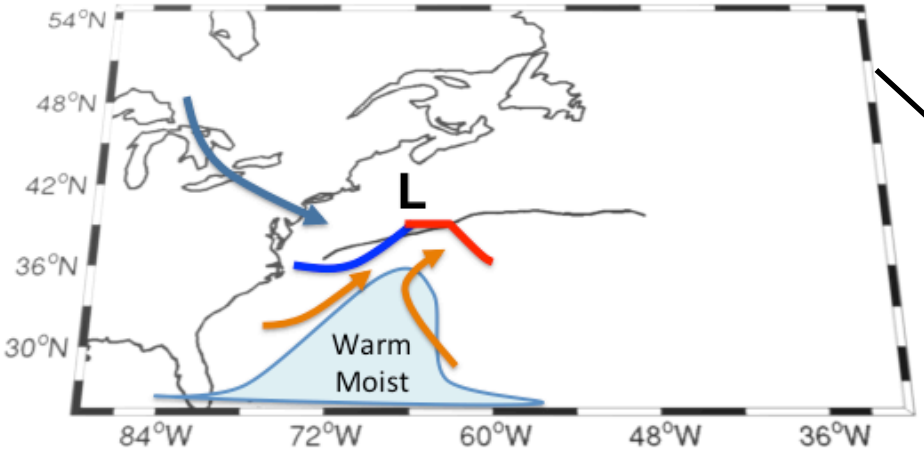
- The relationship may be coincidence, but our comparison for regions with different degrees of surface forcing suggest the need to investigate a causal relationship between surface forcing and variability in cloud characteristics.

- Differences in cloud/atmosphere relationships for the Gulf Stream, East North Atlantic , and Bear Island region are at least partially related to the strength of cold air advection at each region.

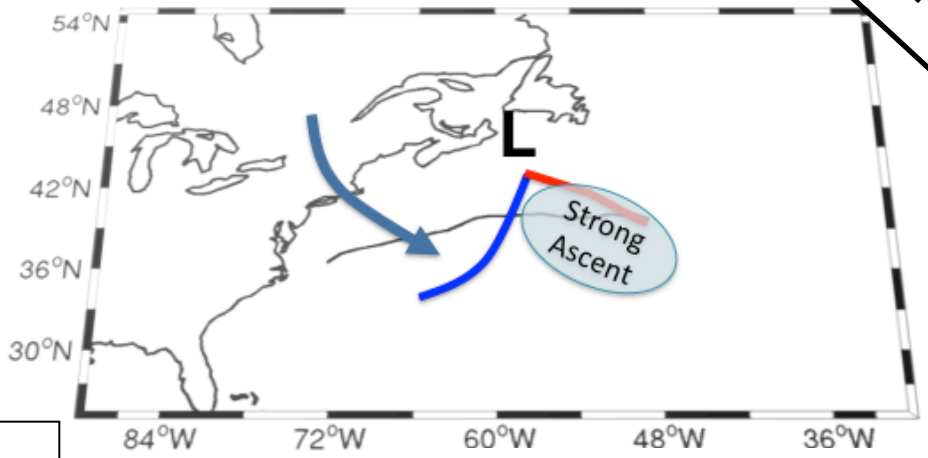
- For the ENA site, the lack of nearby land suggests a possible analog to the southern hemisphere. However, one difference is that ENA is often equatorward of the main storm track region.

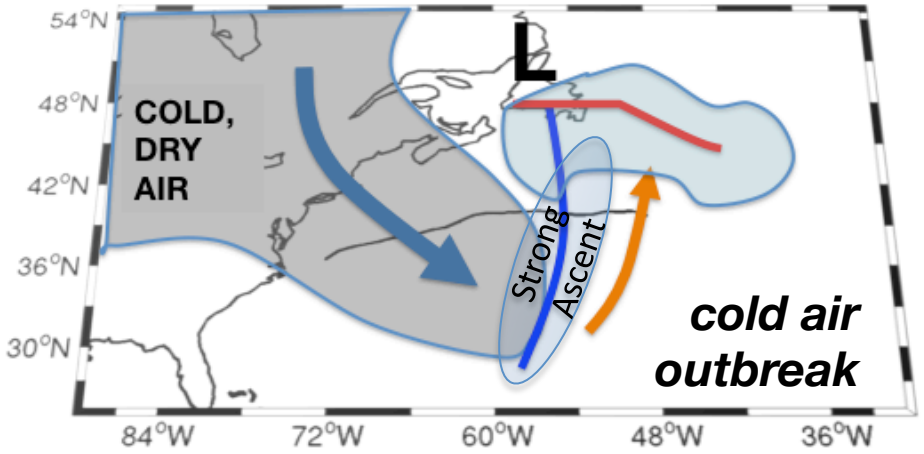
Follow-up or more info: Poster #69
Contact: jbooth@ccny.cuny.edu

SCHEMATIC FOR SYNOPTIC STORM OVER GULF STREAM



TIME





Light blue air mass corresponds to region of air in the warm conveyor belt.

Dark blue arrow corresponds to cold, descending air.