Air-sea interaction at high-latitudes: A focus on the IPY

Ian Renfrew

With help from Nina Petersen, Alex Weiss, Emma Fiedler, Ian Brooks, Chris Fairall, Jeff Hare, Ola Persson

University of East Anglia

Motivation

The high-latitudes are:

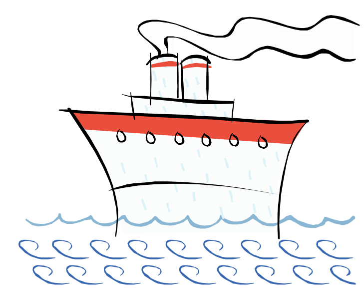
- Prone to high winds
- Cold
  - So low humidity
  - Dominated by sensible heat flux
- Often cloudy
- Influenced by sea ice
- Hard to access
- Important areas for atmosphere-ocean coupling

IPY Projects

- Aircraft-based
  - GFDex
  - BAS: MASIN and JASPER
- Ship-based
  - ASCOS
  - GasEx III
  - ICEALOT
- Multi-platform
  - OASIS

Aircraft vs. ship

- Platform independent of sea surface
- Flow distortion effects more uniform
- Quantity of data much lower
- Limited to U, T, q, CO_2,…
- Aircraft altitude
- Run choice needs consideration
  - 2 minutes ~ 12 km



Greenland Flow Distortion Experiment

- Greenland´s impact on local and downstream weather
- Low-level jets
- Mesoscale cyclones
- **Air-sea fluxes**
- Targeted observations

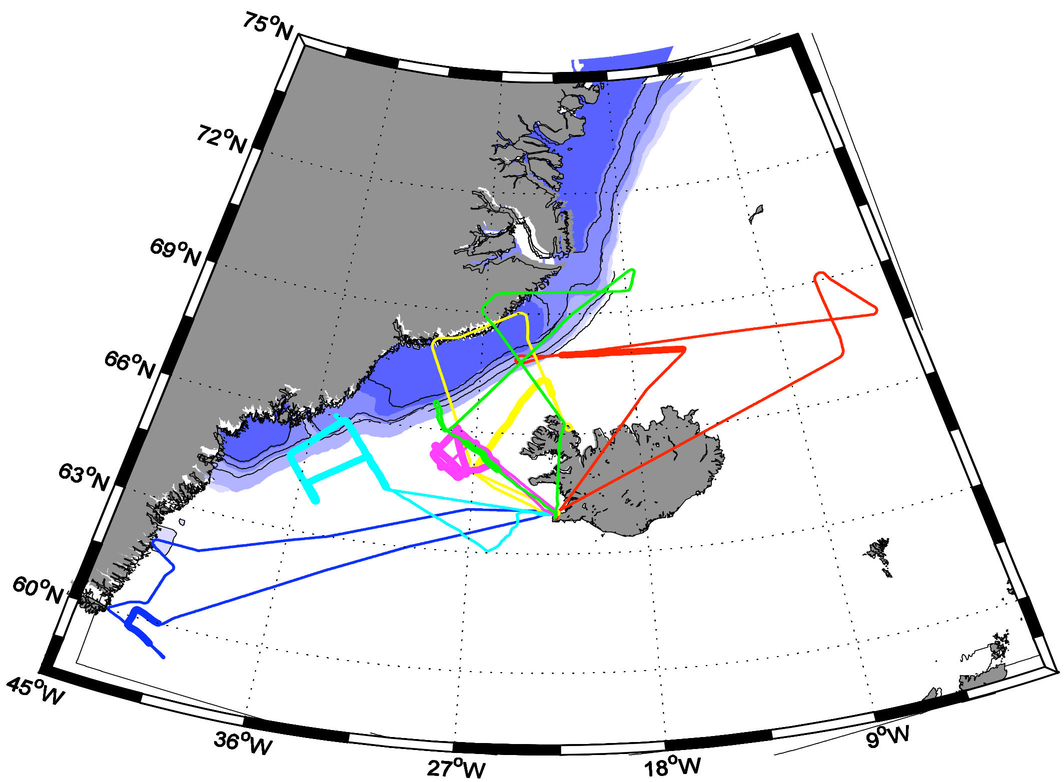
See Renfrew et al. Bulletin AMS, Sept. 2008

FAAM: Facility for Airborne Atmospheric Measurements

- 6 h endurance
- flight-level down to 30-40 m above sea level

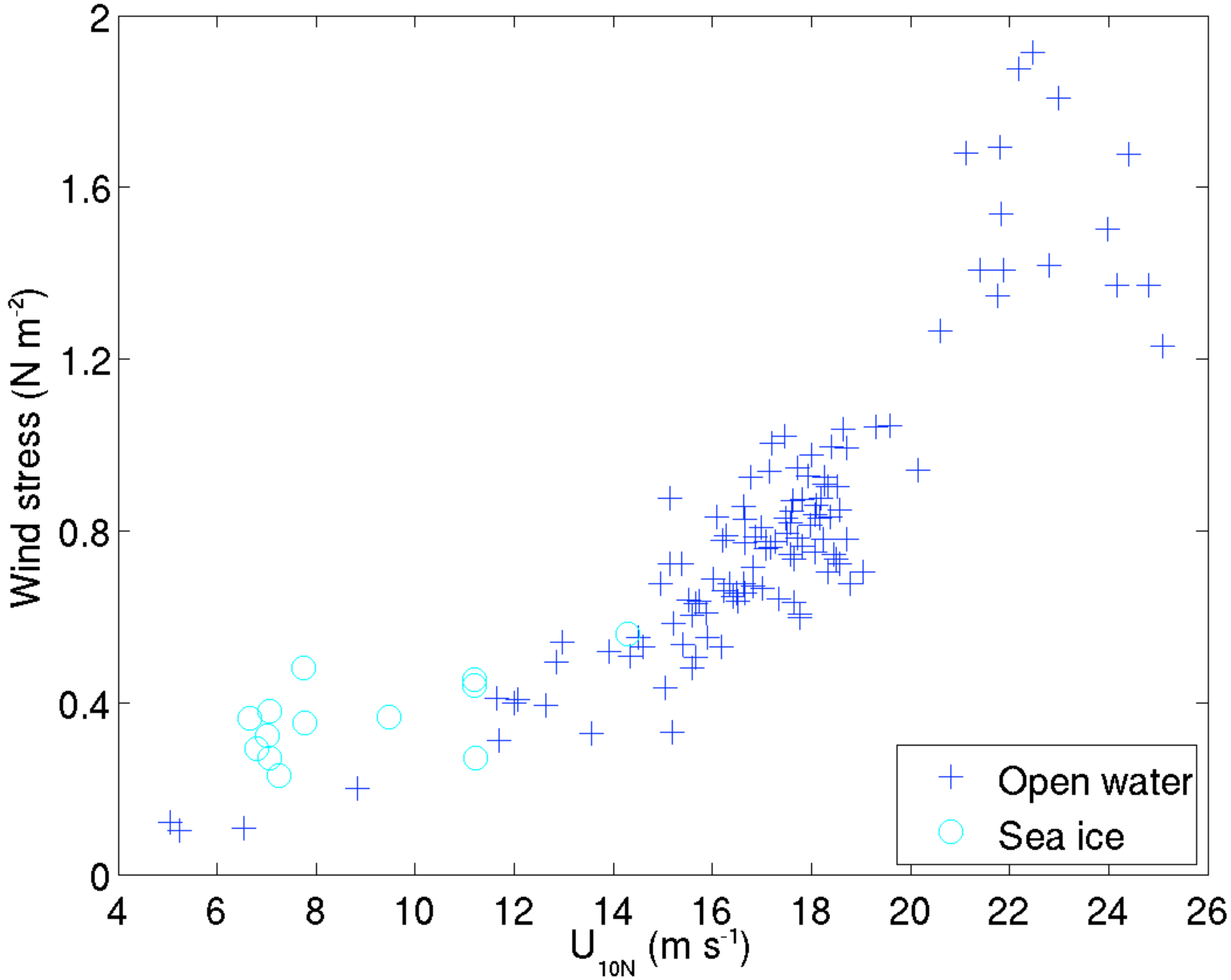
- *U,p*: a five-port pressure measurement system, 32 Hz
- *T*: Rosemount temperature sensor, 32 Hz
- *q*: Lyman-Alpha hygrometer, 64 Hz
- *SST*: Heimann radiometer, 4 Hz

Low-level flight legs

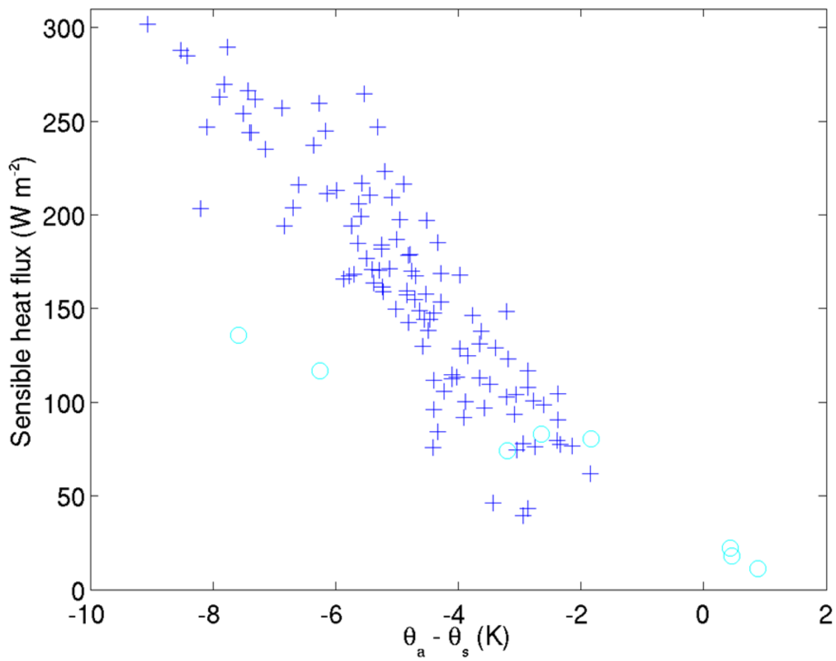


- 6 flights – 5 available for direct flux calculations
- 5 hours 22 min of high frequency data
- 145 runs
  - 131 over open water
- Altitude above the sea: 30-50 m

Wind stress

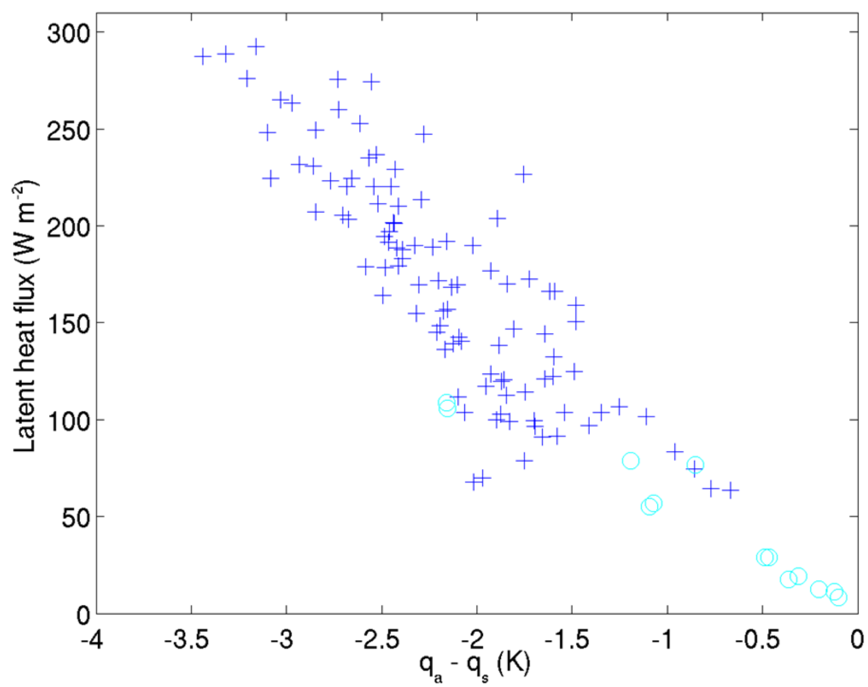


2
1.6
1.2
0.8
0.4
0
Wind stress (N m-2)
4
6
8
10
12
14
16
18
20
22
24
26
U10N (m s-1)
Open water
Sea ice



Sensible heat flux

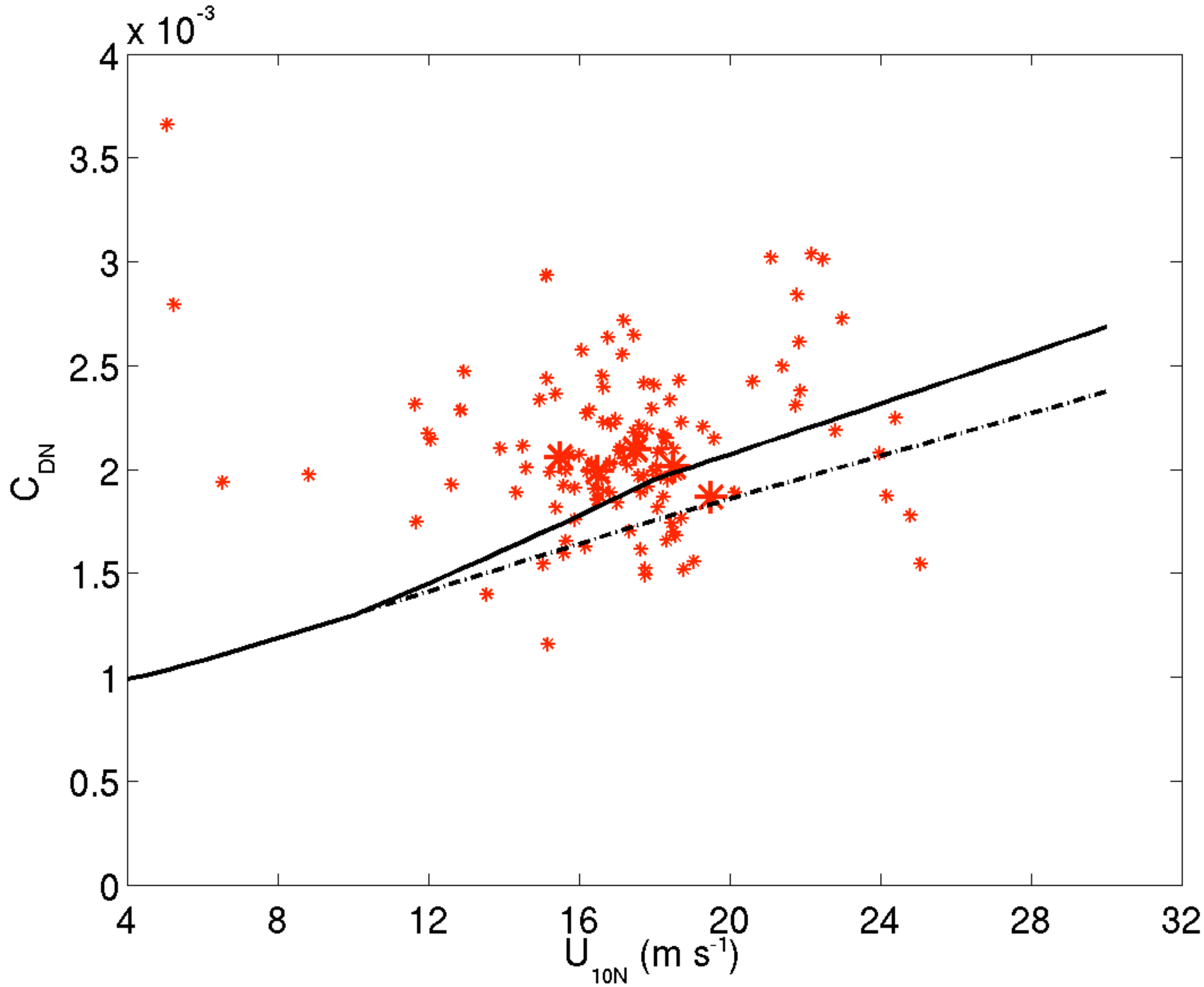
50-300 Wm^{-2}



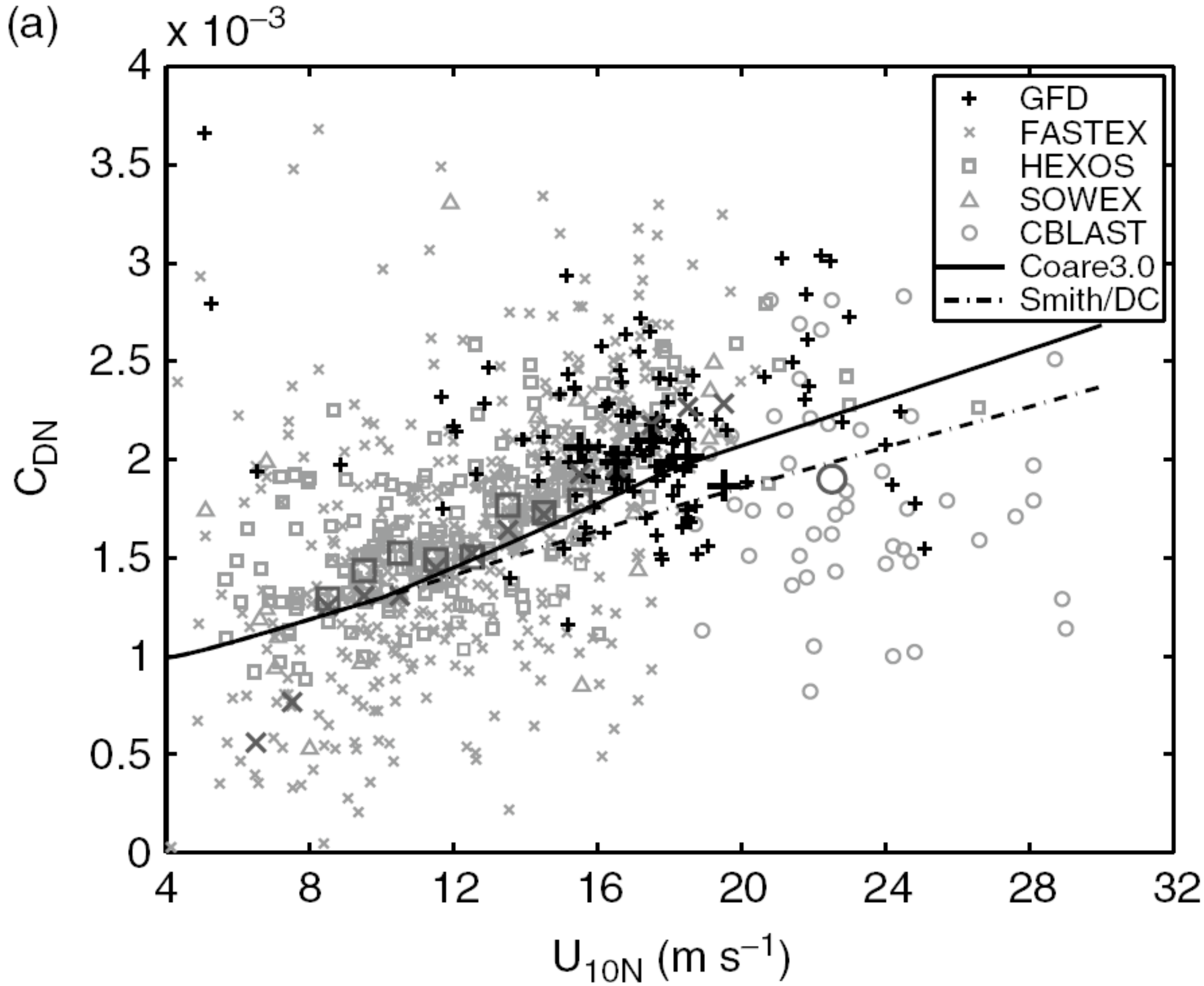
Latent heat flux

50-300 Wm^{-2}

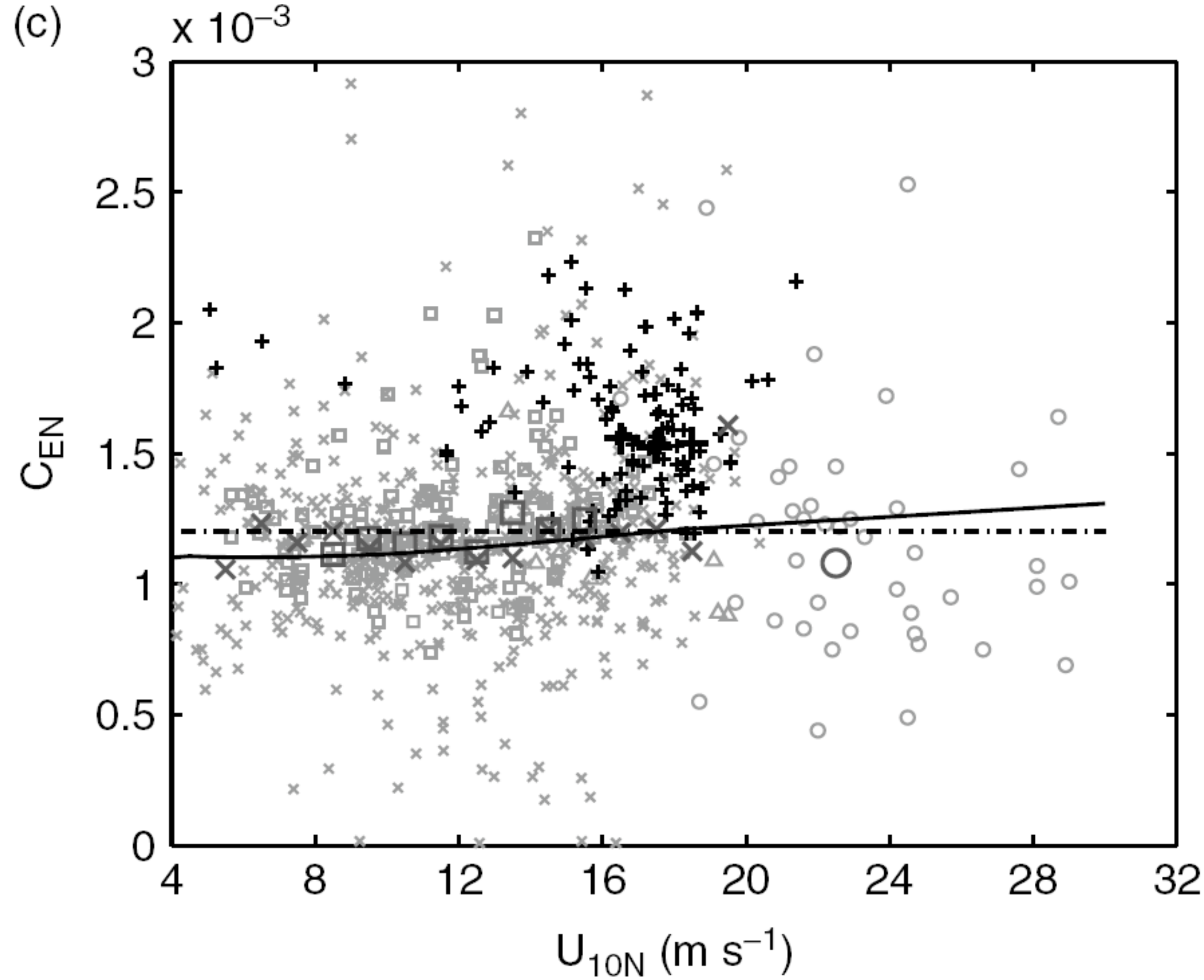
C_{DN} - momentum



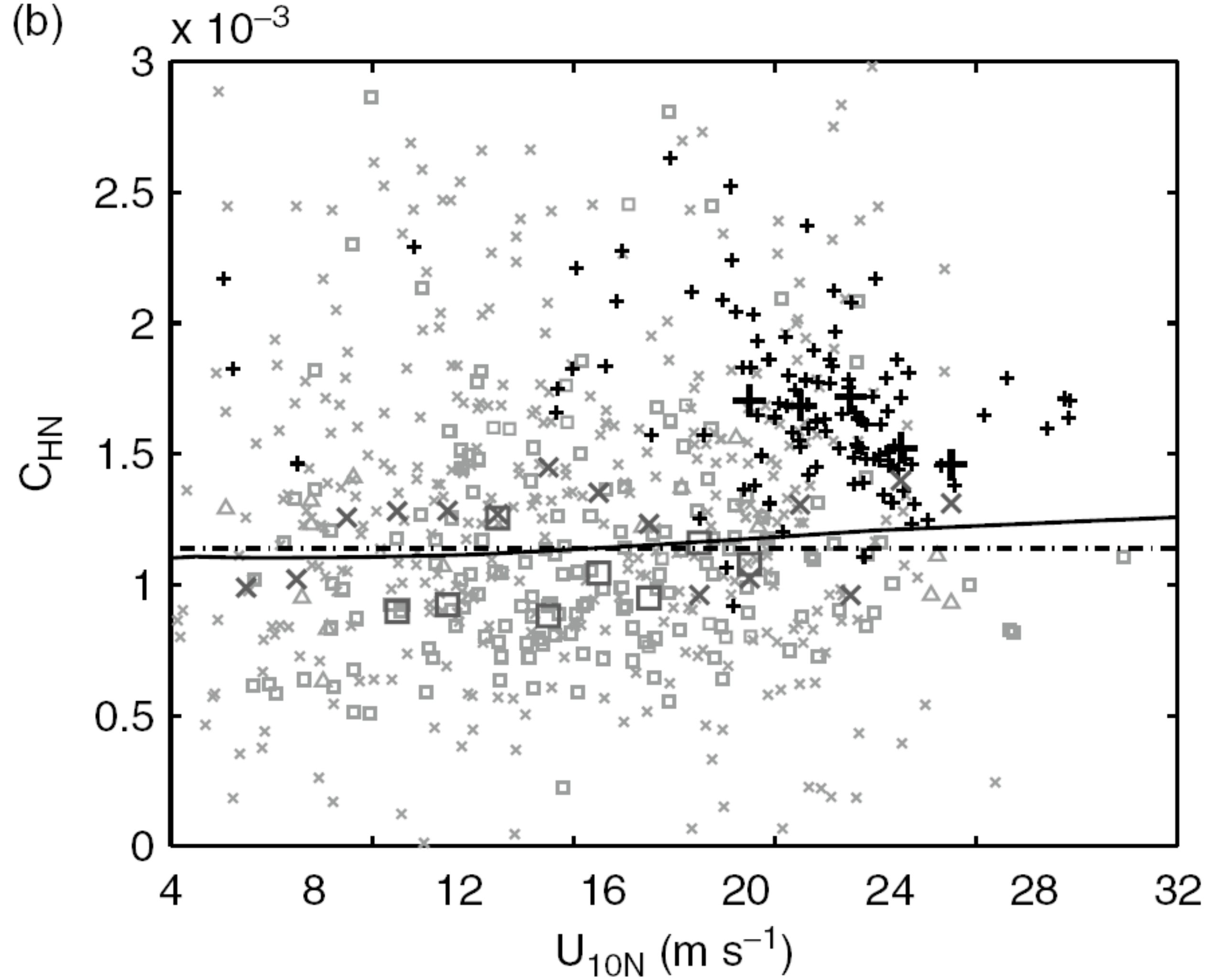
C_{DN} - momentum



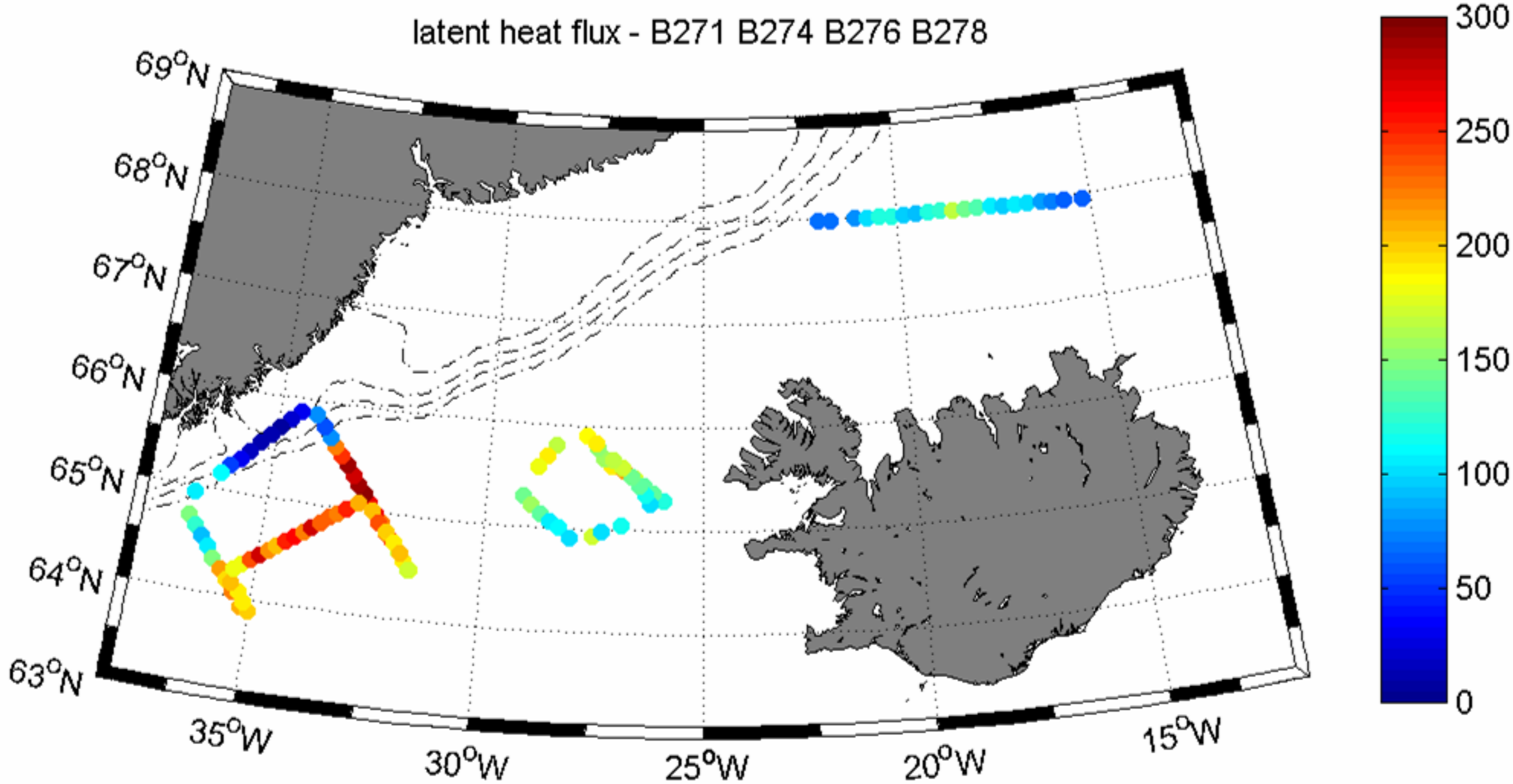
C_{EN} – latent heat



C_{HN} – sensible heat



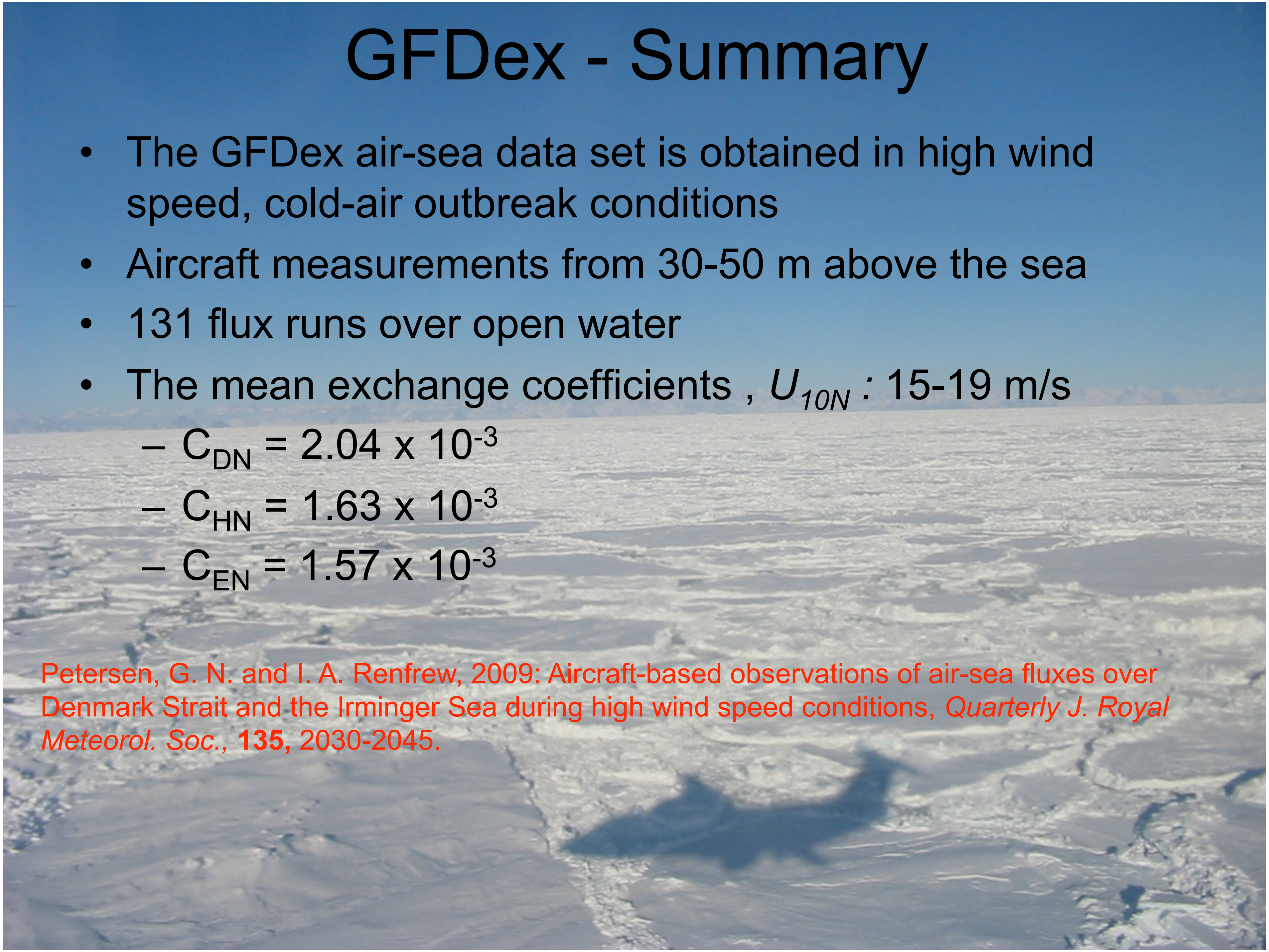
LH – spatial map



GFDex - Summary

- The GFDex air-sea data set is obtained in high wind speed, cold-air outbreak conditions
- Aircraft measurements from 30-50 m above the sea
- 131 flux runs over open water
- The mean exchange coefficients , U_{10N} : 15-19 m/s
  - $C_{DN} = 2.04 \times 10^{-3}$
  - $C_{HN} = 1.63 \times 10^{-3}$
  - $C_{EN} = 1.57 \times 10^{-3}$

Petersen, G. N. and I. A. Renfrew, 2009: Aircraft-based observations of air-sea fluxes over Denmark Strait and the Irminger Sea during high wind speed conditions, *Quarterly J. Royal Meteorol. Soc.,* **135,** 2030-2045.



Renfrew, I.A., G.N. Petersen, D.A.J. Sproson, G.W.K. Moore, H. Adiwidjaja, S. Zhang, and R. North, 2009: A comparison of aircraft-based surface-layer observations over Denmark Strait and the Irminger Sea with meteorological analyses and QuikSCAT winds, *Quarterly J. Royal Meteorol. Soc.,* **135,** 2046-2066.

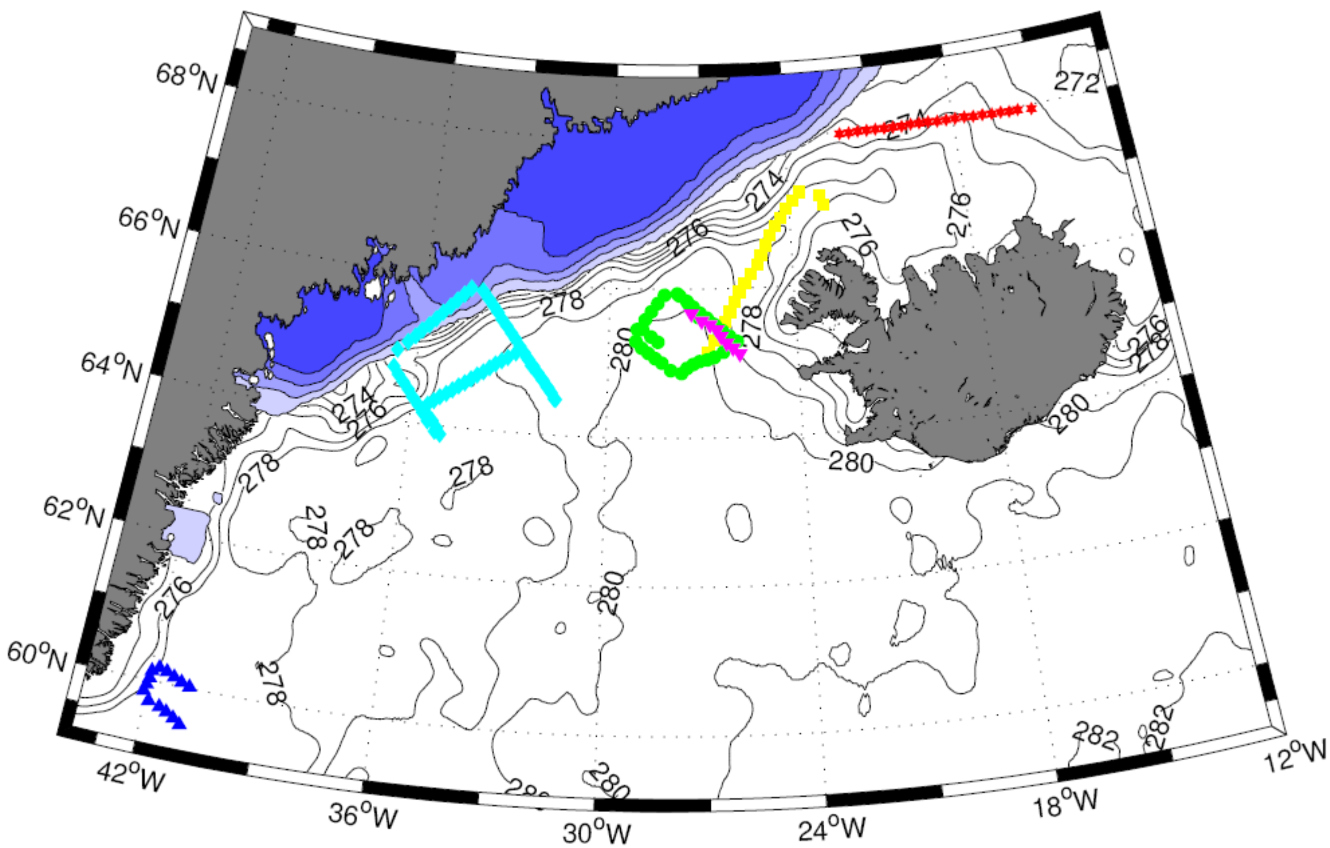
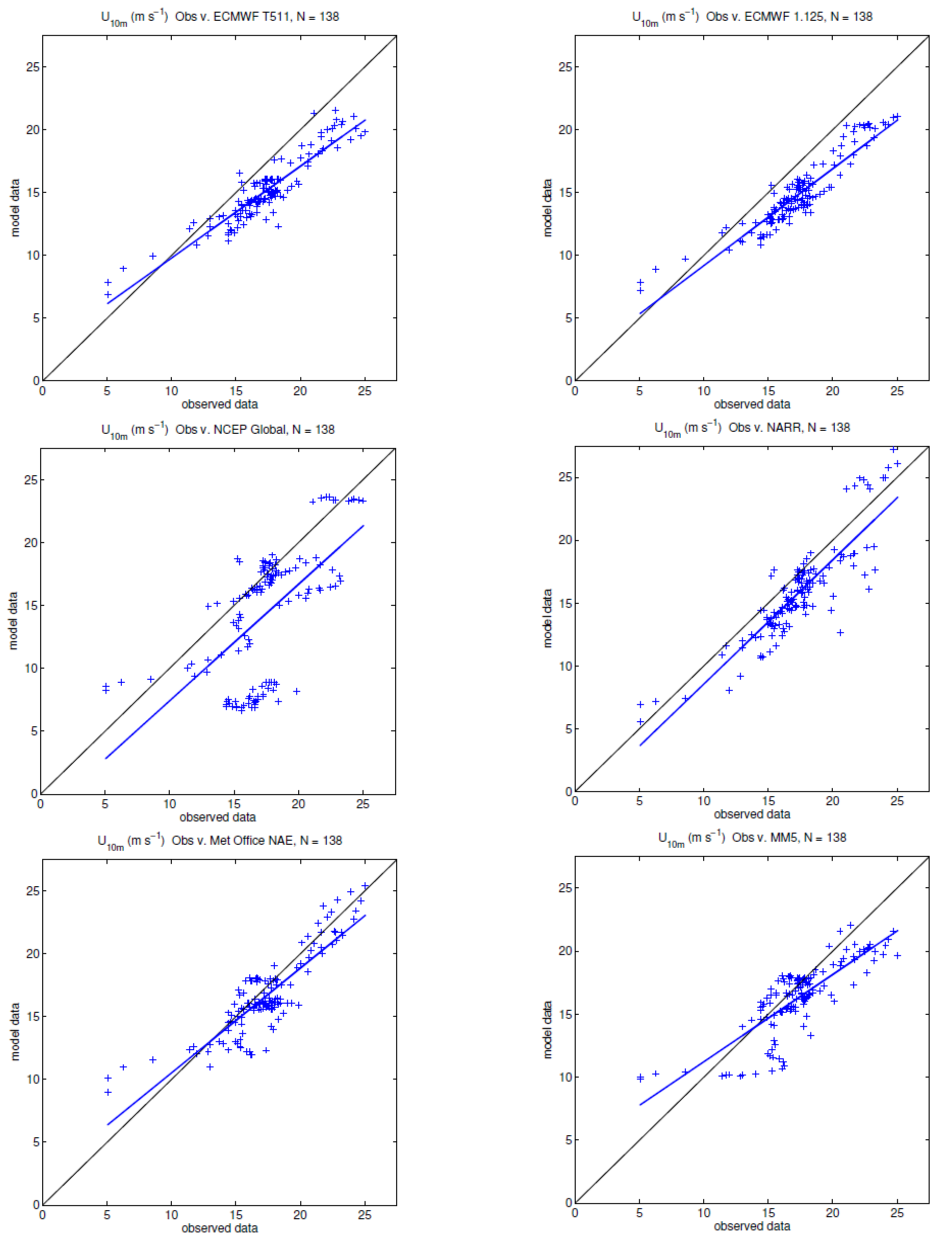
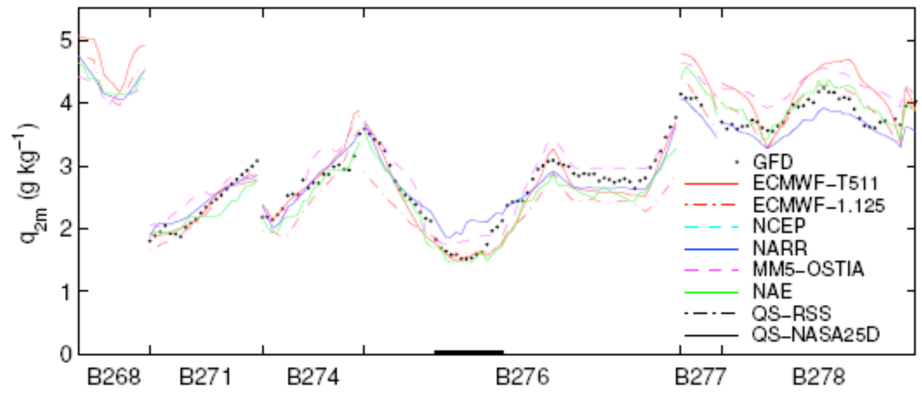
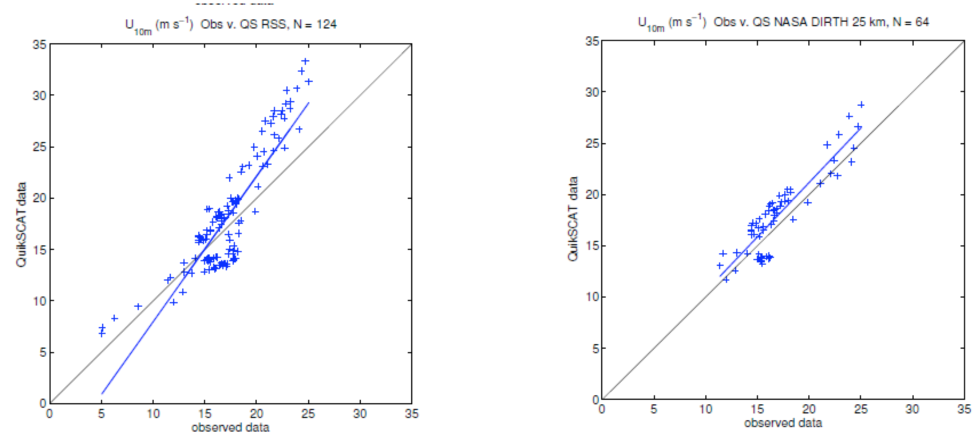
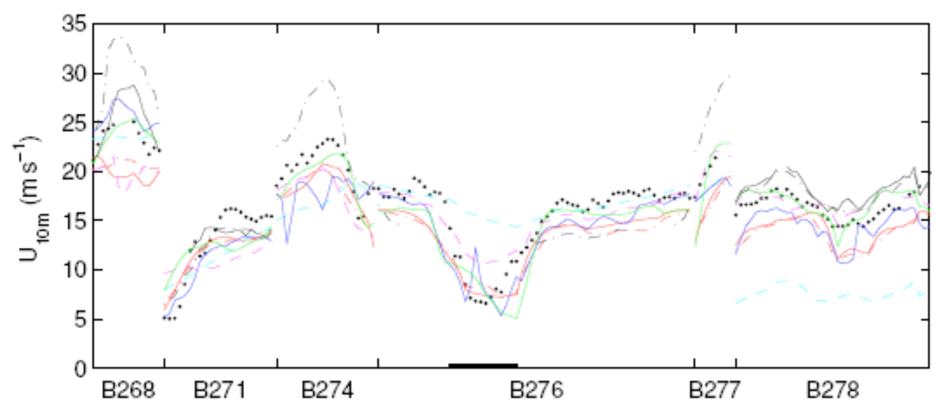


Figure 2 Locations of the observational database points. Data are from the low-level legs of flights B268 (blue triangles), B271 (red stars), B274 (yellow squares), B276 (cyan diamonds), B277 (magenta triangles) and B278 (green circles). Sea-ice concentration from the OSTIA data set on the 5 March 2007 is contoured at 20% intervals.


U10m (m s−1) Obs v. ECMWF T511, N = 138
U10m (m s−1) Obs v. ECMWF 1.125, N = 138
U10m (m s−1) Obs v. NCEP Global, N = 138
U10m (m s−1) Obs v. NARR, N = 138
U10m (m s−1) Obs v. Met Office NAE, N = 138
U10m (m s−1) Obs v. MM5, N = 138
model data
observed data

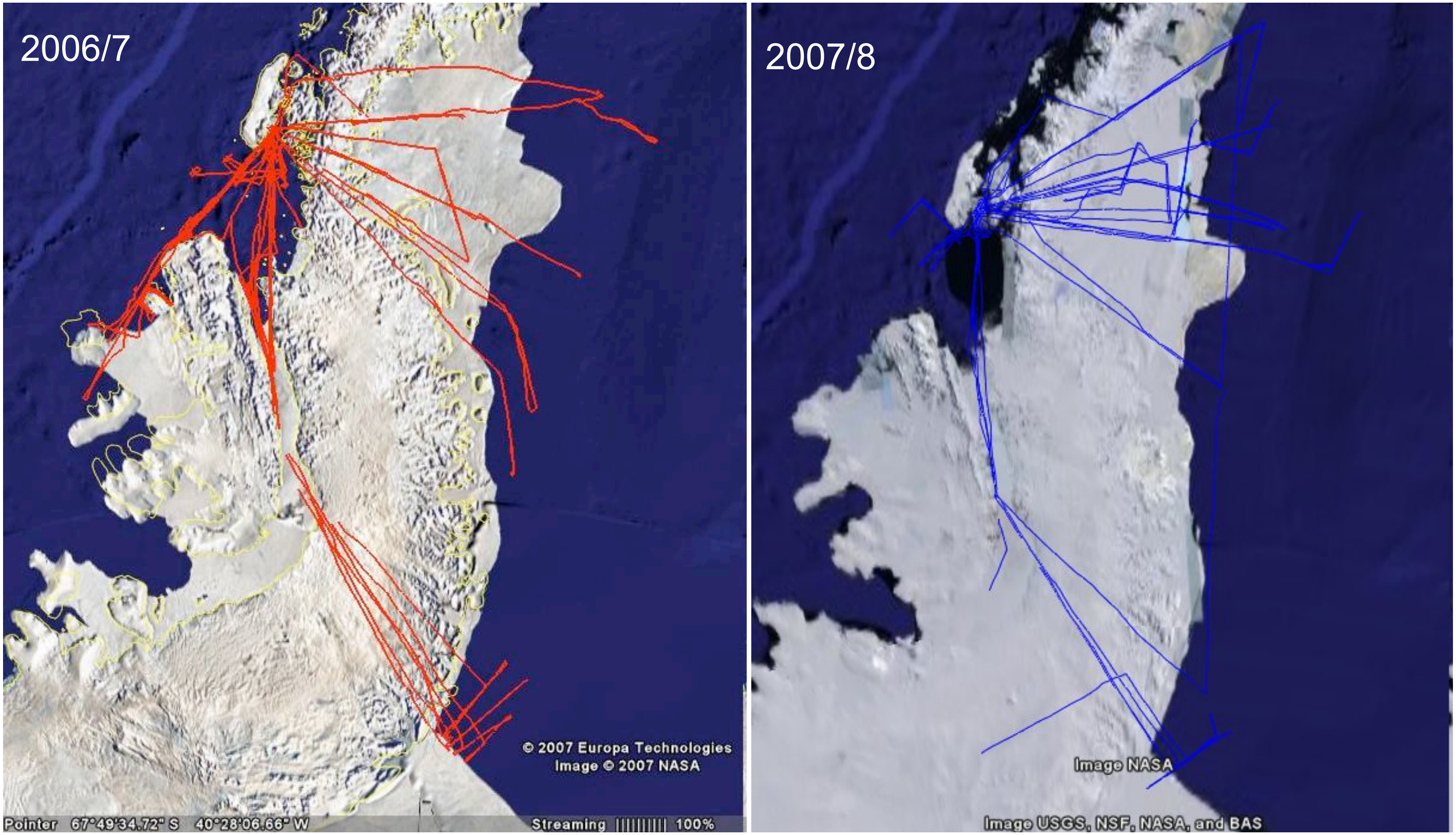

q2m (g kg−1)
GFD
ECMWF−T511
ECMWF−1.125
NCEP
NARR
MM5−OSTIA
NAE
QS−RSS
QS−NASA25D
B268
B271
B274
B276
B277
B278


U10m (m s−1) Obs v. QS RSS, N = 124
U10m (m s−1) Obs v. QS NASA DIRTH 25 km, N = 64
QuikSCAT data
observed data


U10m (m s−1)
B268
B271
B274
B276
B277
B278

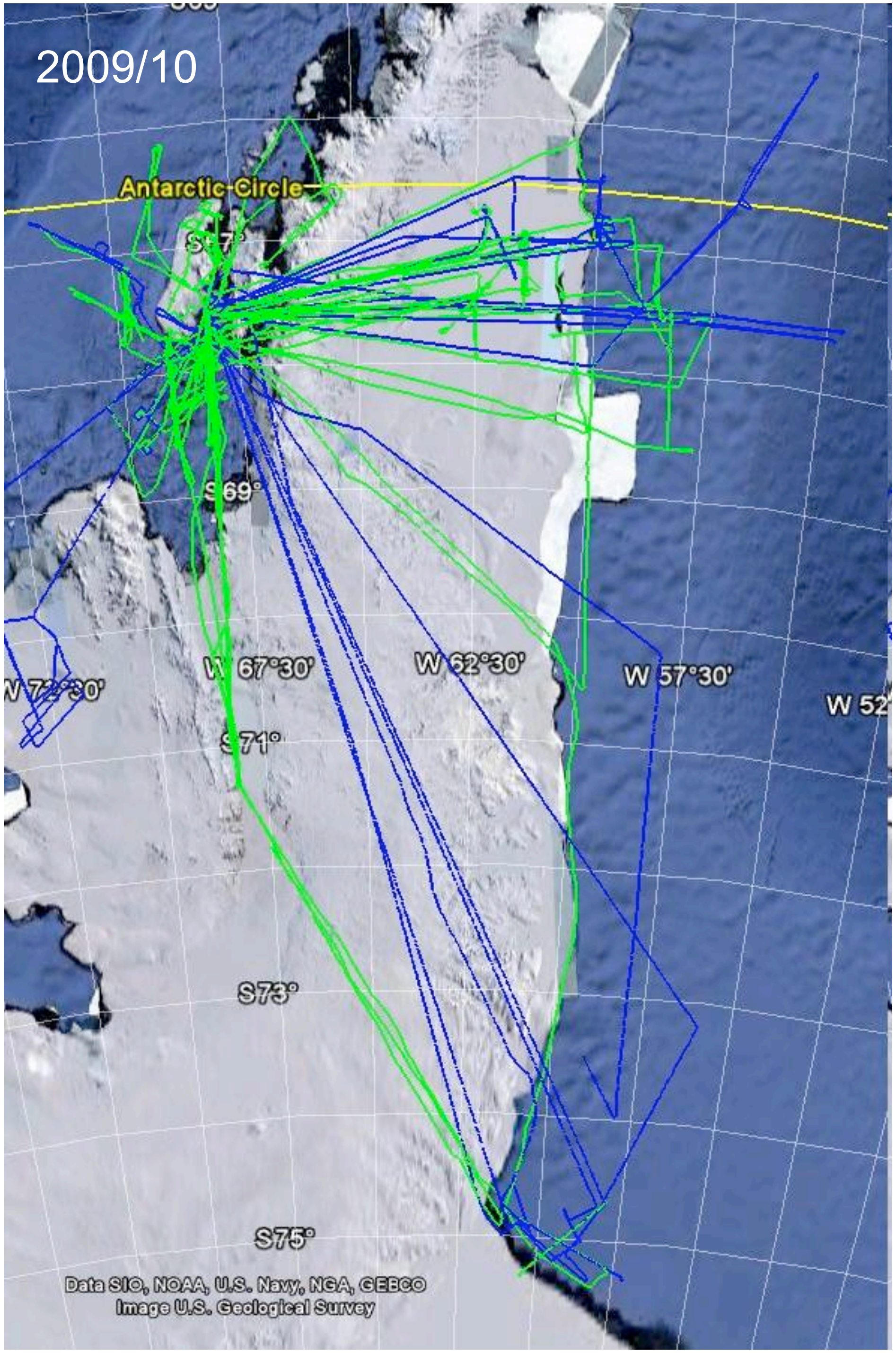
British
Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

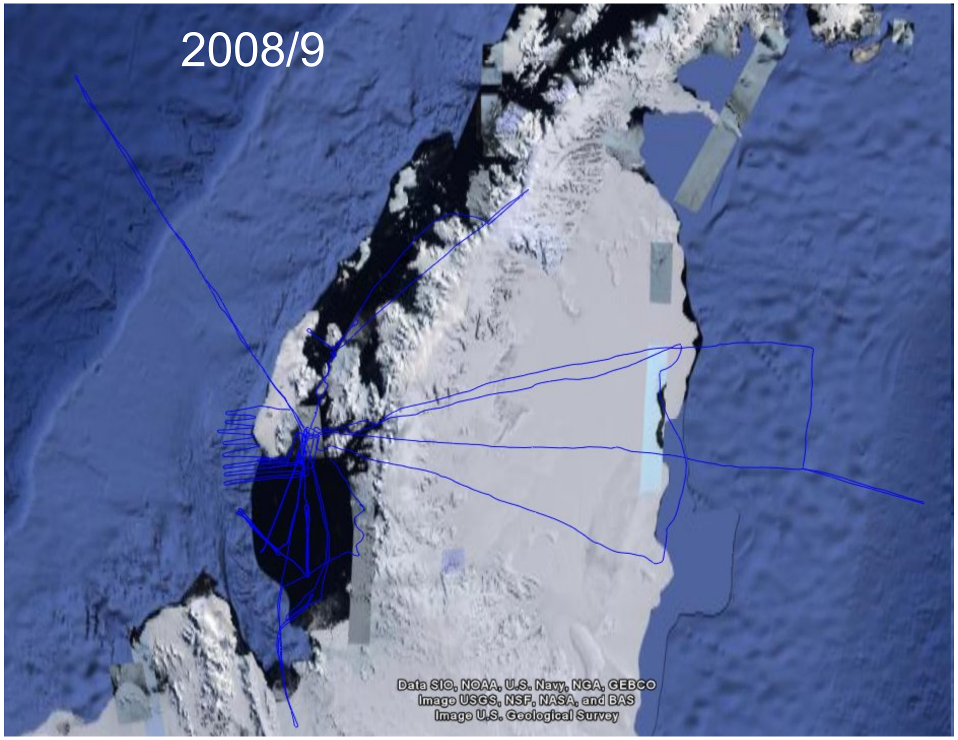
- MASIN
- Twin Otter
- BAT probe
- Fast T
- Radiation
- Heimann radiometer
- GPS



2006/7
© 2007 Europa Technologies
Image © 2007 NASA
Pointer 67°49'34.72" S 40°28'06.66" W
Streaming |||||||||| 100%
2007/8
Image NASA
Image USGS, NSF, NASA, and BAS

Green = BAS
Blue = AWI





Joint airborne boundary layer field experiment JASPER, Weddell Sea, Feb 2010

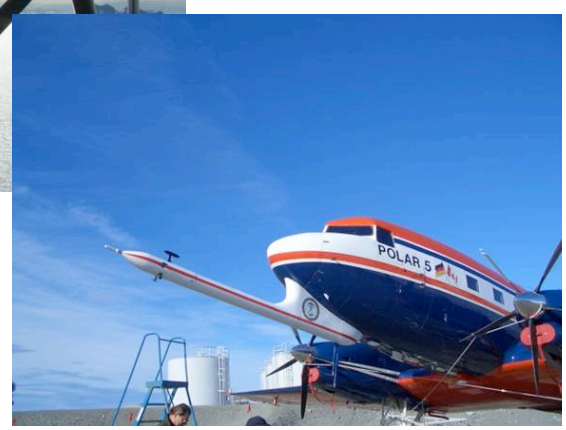
BAS, UK : A. Weiss, T. Lachlan-Cope, R. Ladkin

AWI, Germany: C. Luepkes, G. Birnbaum, J. Hartmann, W. Dierking

FMI, Finland : T. Vihma

Aircraft Instrumentation measure:

- Turbulent fluxes of sensible and latent heat, momentum, CO_2
- Short and longwave radition
- Cloud and aerosol parameters
- Surface parameters, i.e. surface temperature, roughness, freeboar
- Temperature, pressure, humidity, mean CO_2

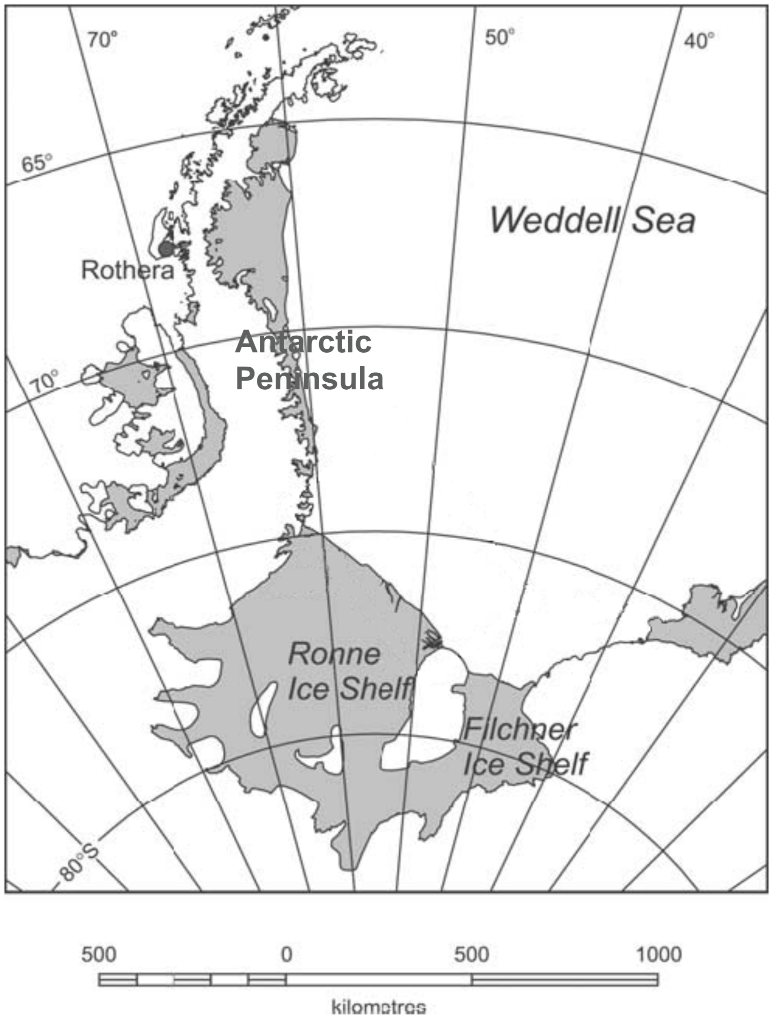


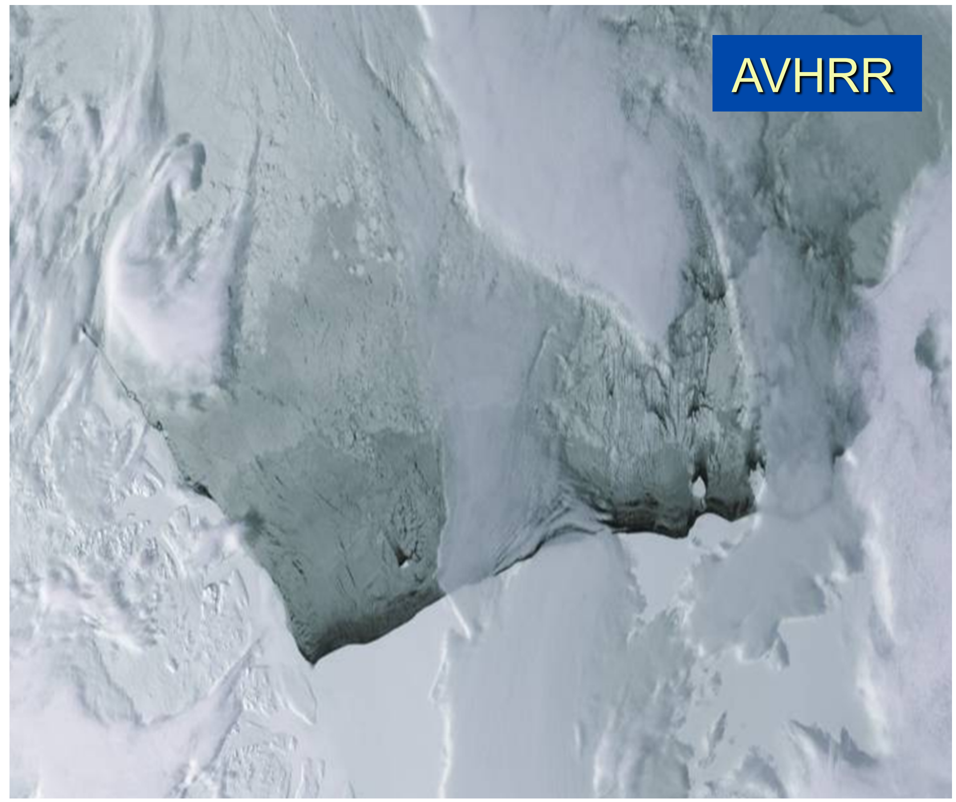
Some scientific goals of JASPER:

- Comparison of data from BAS and AWI aircraft set ups of boundary layer instrumentation
- Study of the atmospheric boundary layer in the Weddell Sea pack ice region and over ice shelfs
- Study of the boundary layer-cloud interactions and of cloud physics
- Study turbulent fluxes over leads and polynyas, e.g. in the Ronne Polynya area
- Study of radiation processes over sea ice and ice shelfs
- Validation and improvement of boundary layer models and parameterizations
- Validation of satellite data

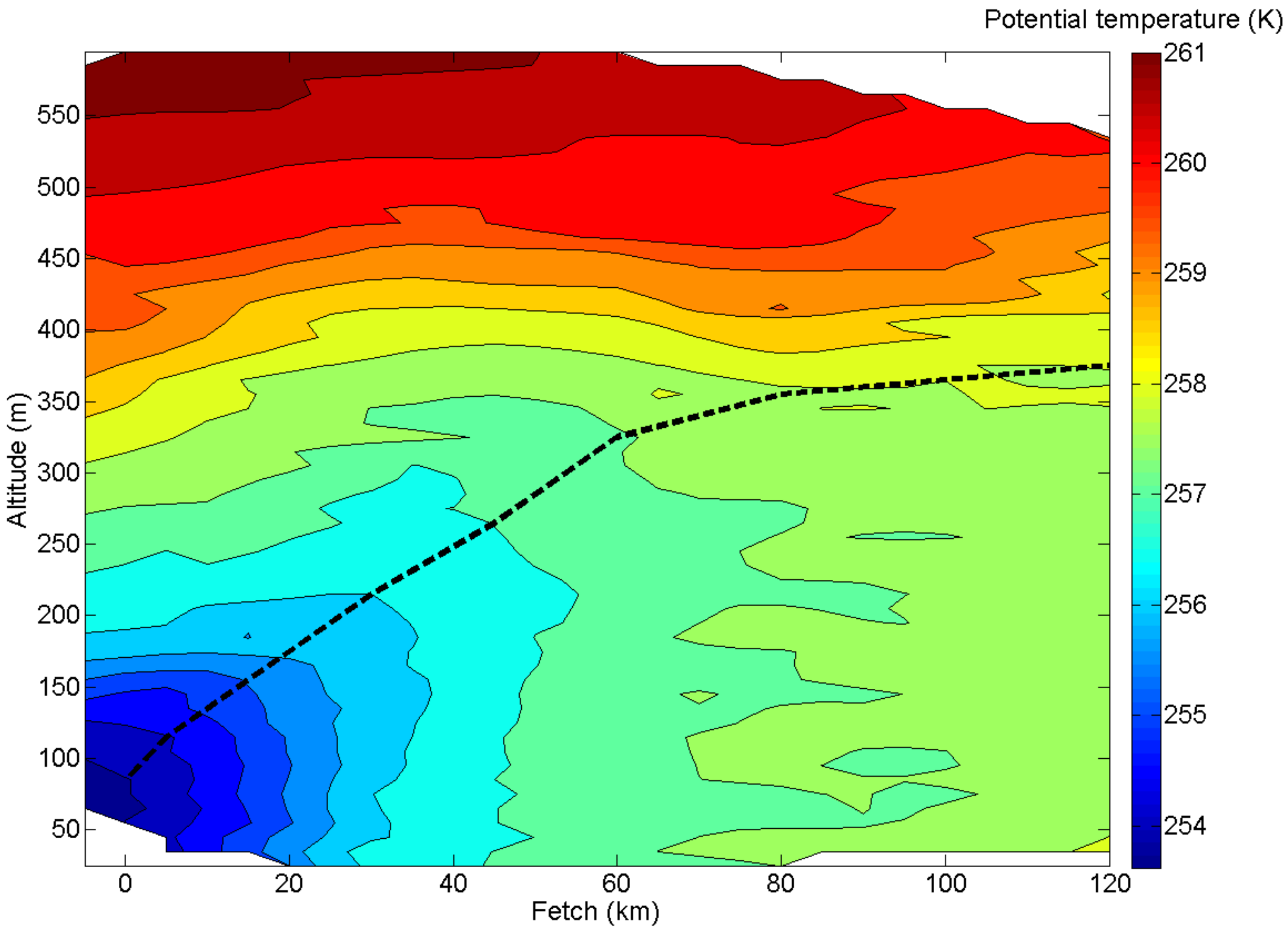
Air-sea fluxes over thin-ice polynyas

(Emma Fiedler)





CIBL structure

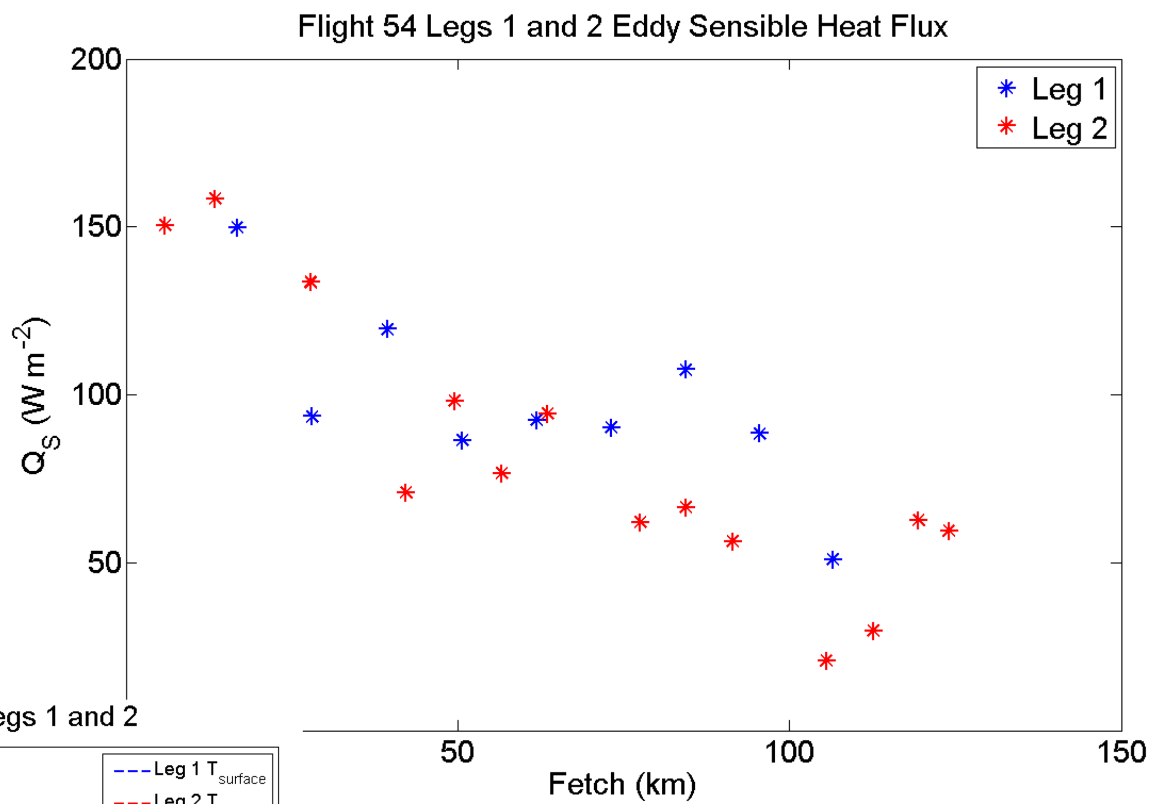


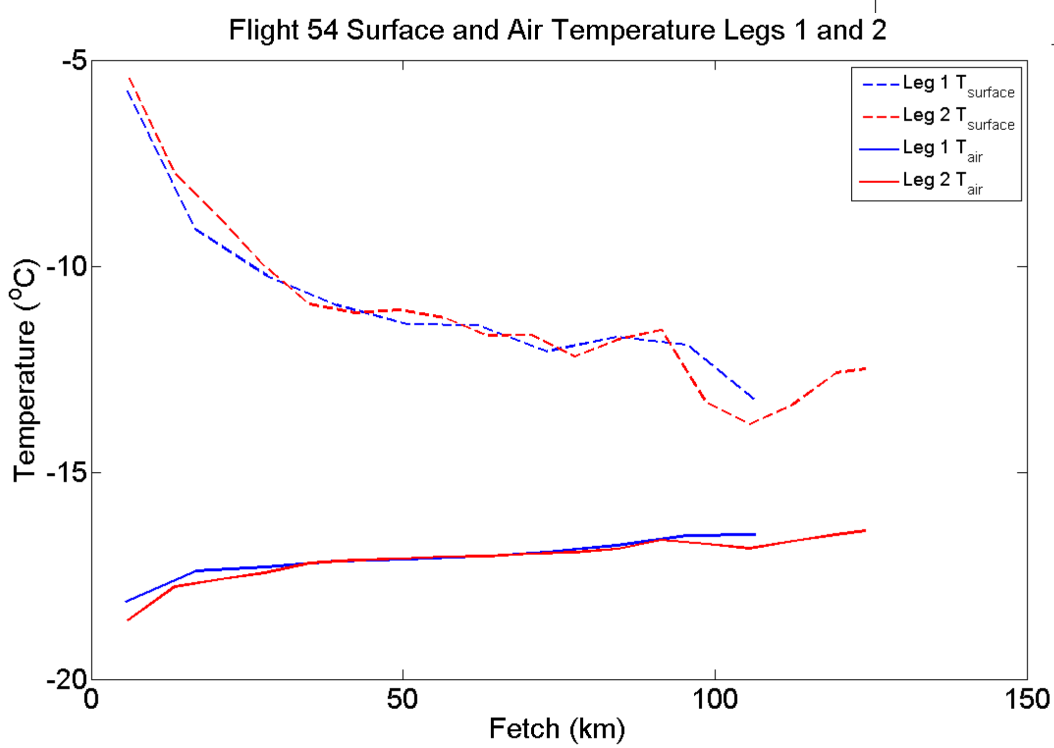
Results

Decrease in sensible heat flux with fetch due to reduction in air-surface temperature difference

– CIBL warming

– surface temperature decrease





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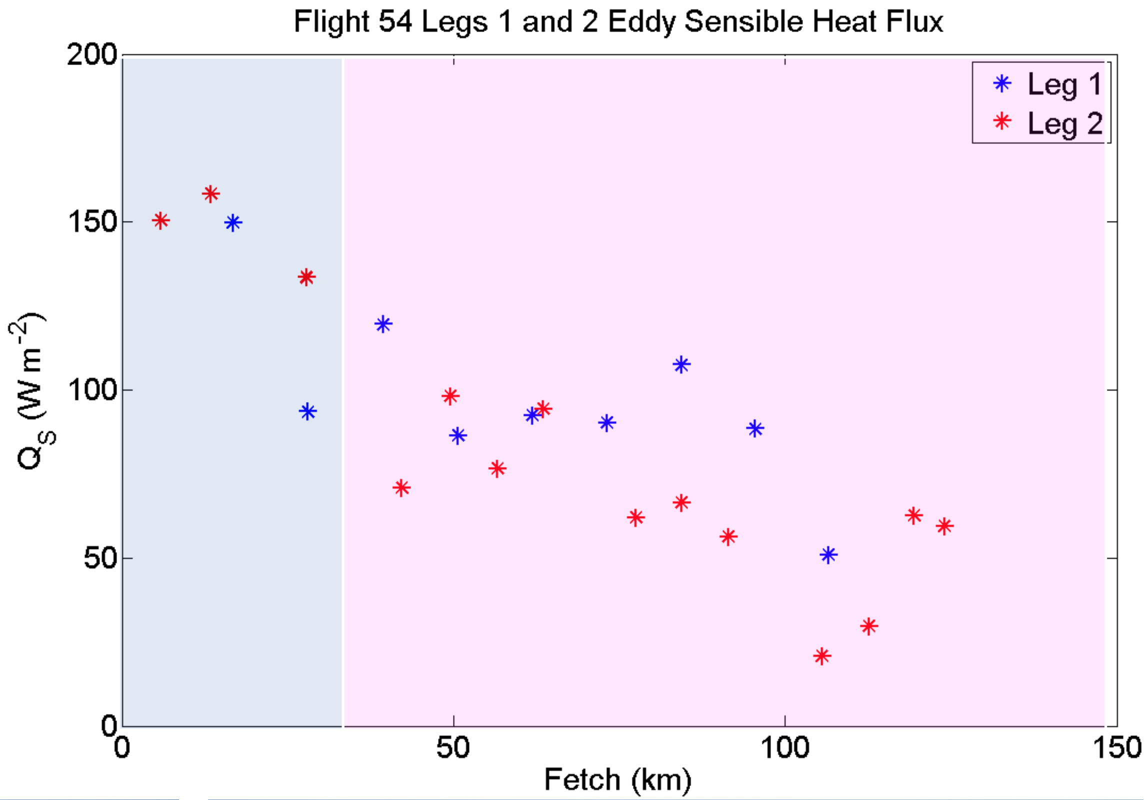
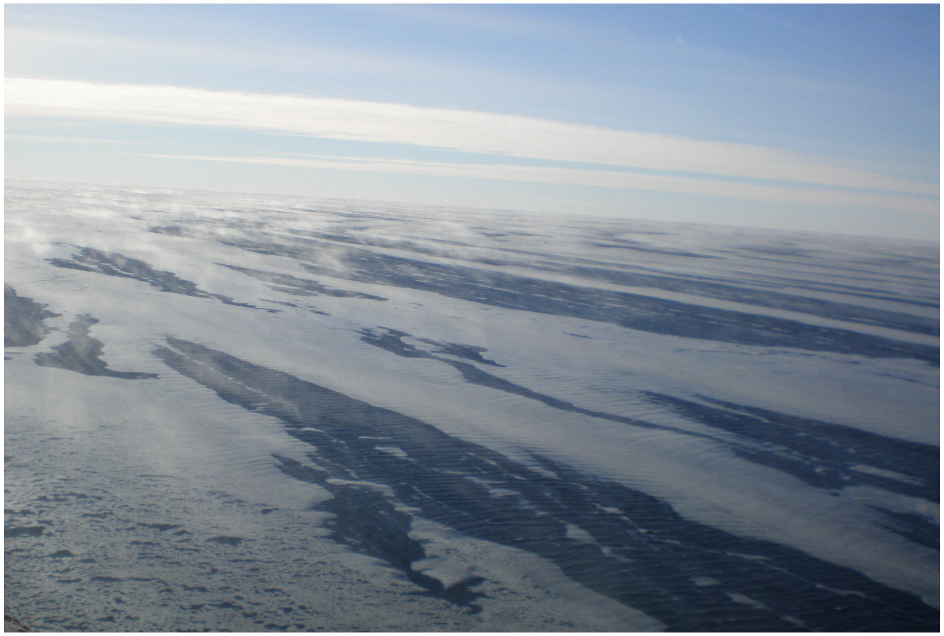
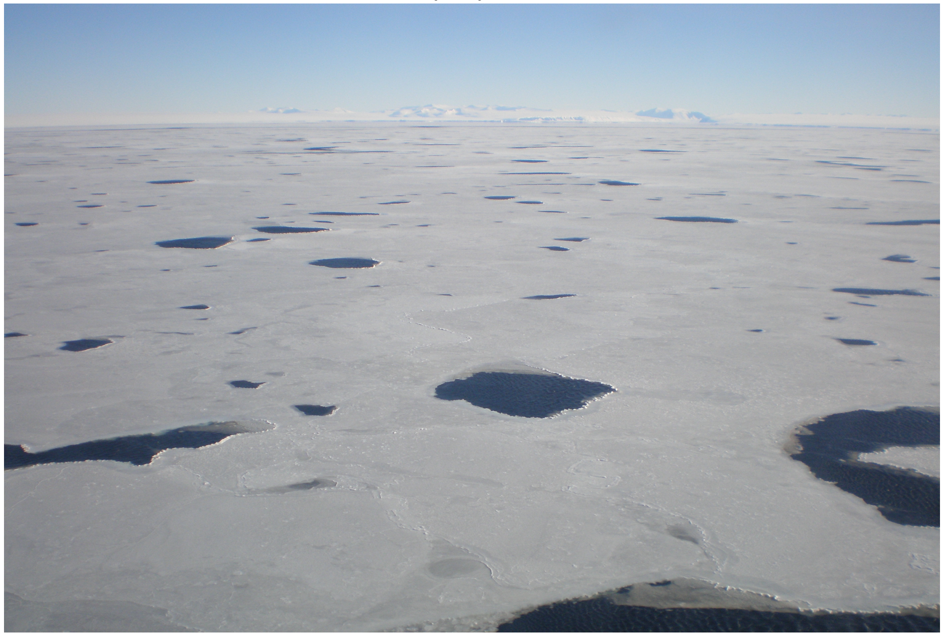
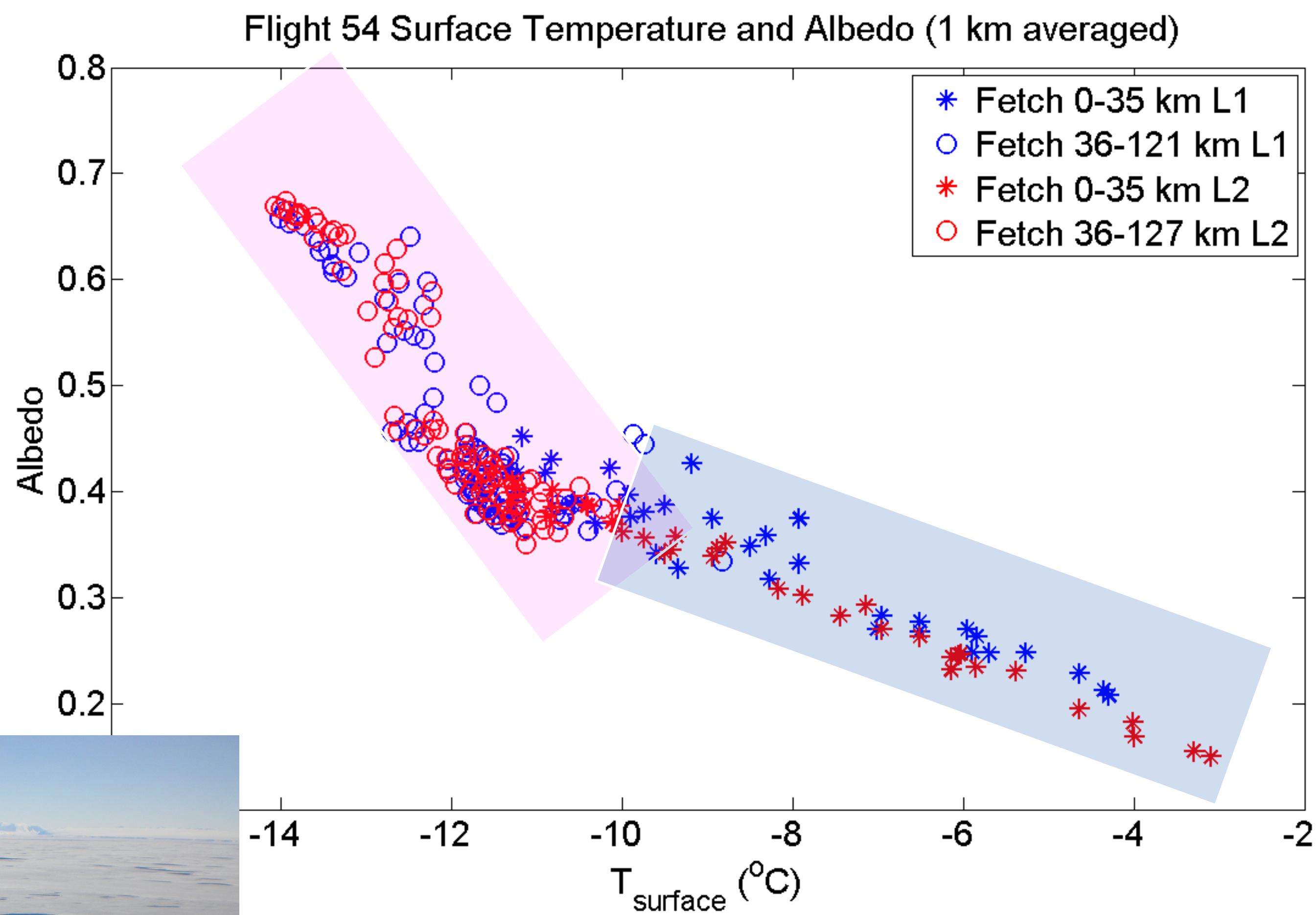
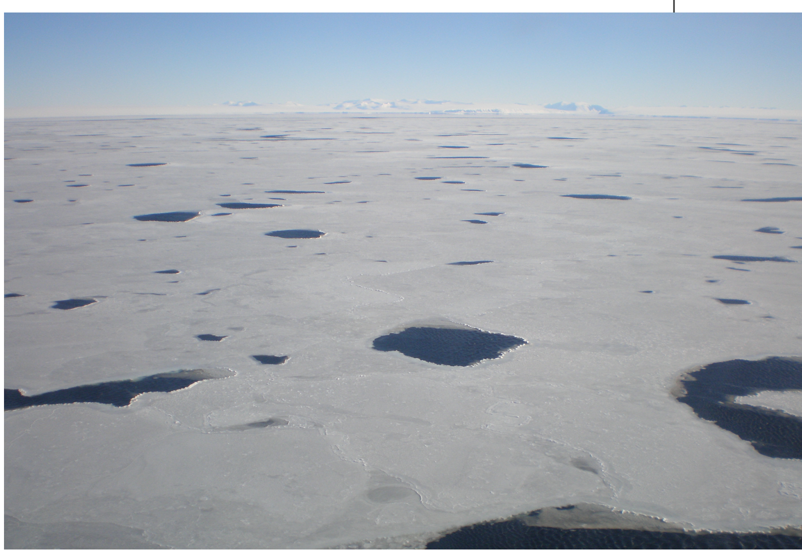
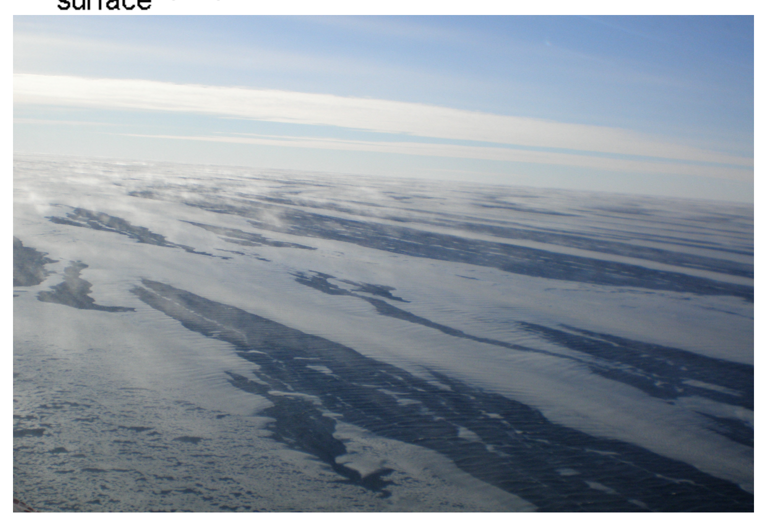







Flight 54 Surface Temperature and Albedo (1 km averaged)
Fetch 0-35 km L1
Fetch 36-121 km L1
Fetch 0-35 km L2
Fetch 36-127 km L2
Albedo
0.8
0.7
0.6
0.5
0.4
0.3
0.2
-14
-12
-10
-8
-6
-4
-2
$T_{surface}$ (^{o}C)





Transfer coefficients

Values from 15 m legs used only

Mean values same (flights 24 hrs apart)

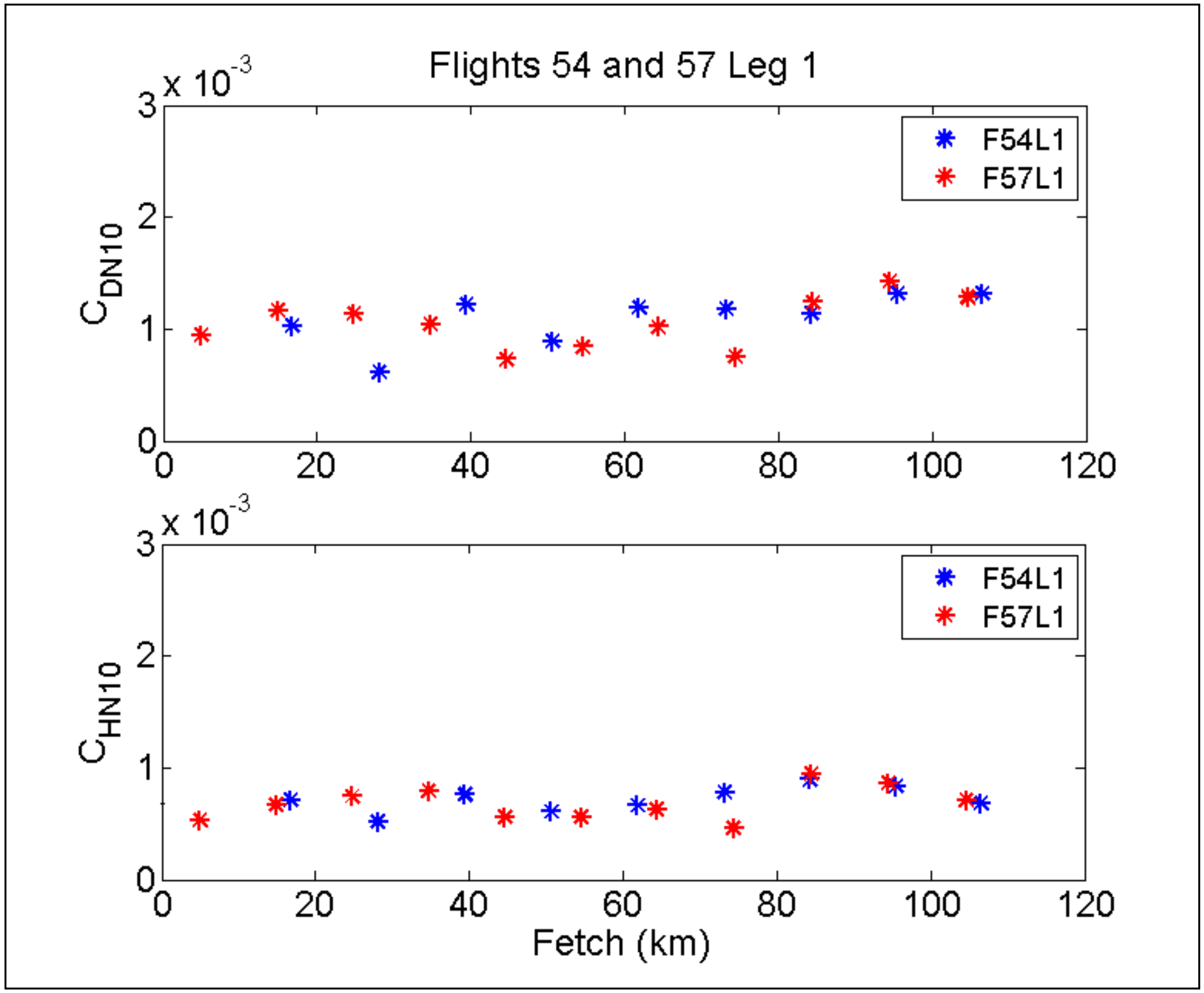
$C_{DN10} = (1.1 \pm 0.2) \times 10^{-3}$

$C_{HN10} = (0.7 \pm 0.1) \times 10^{-3}$

C_{HN10} lower than used in previous studies

Similar to heterogeneous sea ice $(0.8 \pm 0.2) \times 10^{-3}$

(Schröder et al., 2003)



Fiedler, E. K., Lachlan-Cope, T. A., Renfrew, I. A. and J. C. King (2009), Convective heat transfer over thin-ice covered coastal polynyas, J. Geophys. Res., *in revision*

IPY Projects

- Aircraft-based
  - GFDex
  - BAS: MASIN and JASPER
- Ship-based
  - ASCOS
  - GasEx III
  - ICEALOT
- Multi-platform
  - OASIS

ARCTIC SUMMER CLOUD OCEAN STUDY 2008

OBJECTIVES

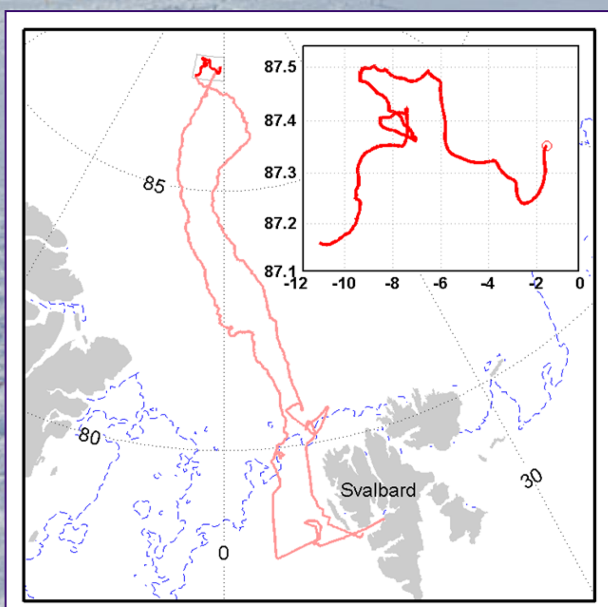
- To characterize the processes controlling arctic stratus clouds
- To determine the role of marine biochemistry as a source of aerosol (CCN & IN)
- To determine strength of turbulent mixing between surface and cloud
  - Role of surface forcing
  - Role of cloud forcing
- Characterize radiation-turbulence interactions in optically thin arctic clouds
- Determine microphysical properties of arctic stratus
- CCN-cloud radiative forcing relationship for optically thin stratus

The on-ice science team

ASCOS is a highly interdisciplinary project involving:

- Meteorology
- Remote sensing
- Aerosol physics & chemistry
- Gas-phase chemistry
- Marine bio-chemistry
- Physical oceanography

Coordinated with 5 NASA DC8 flights over the surface site



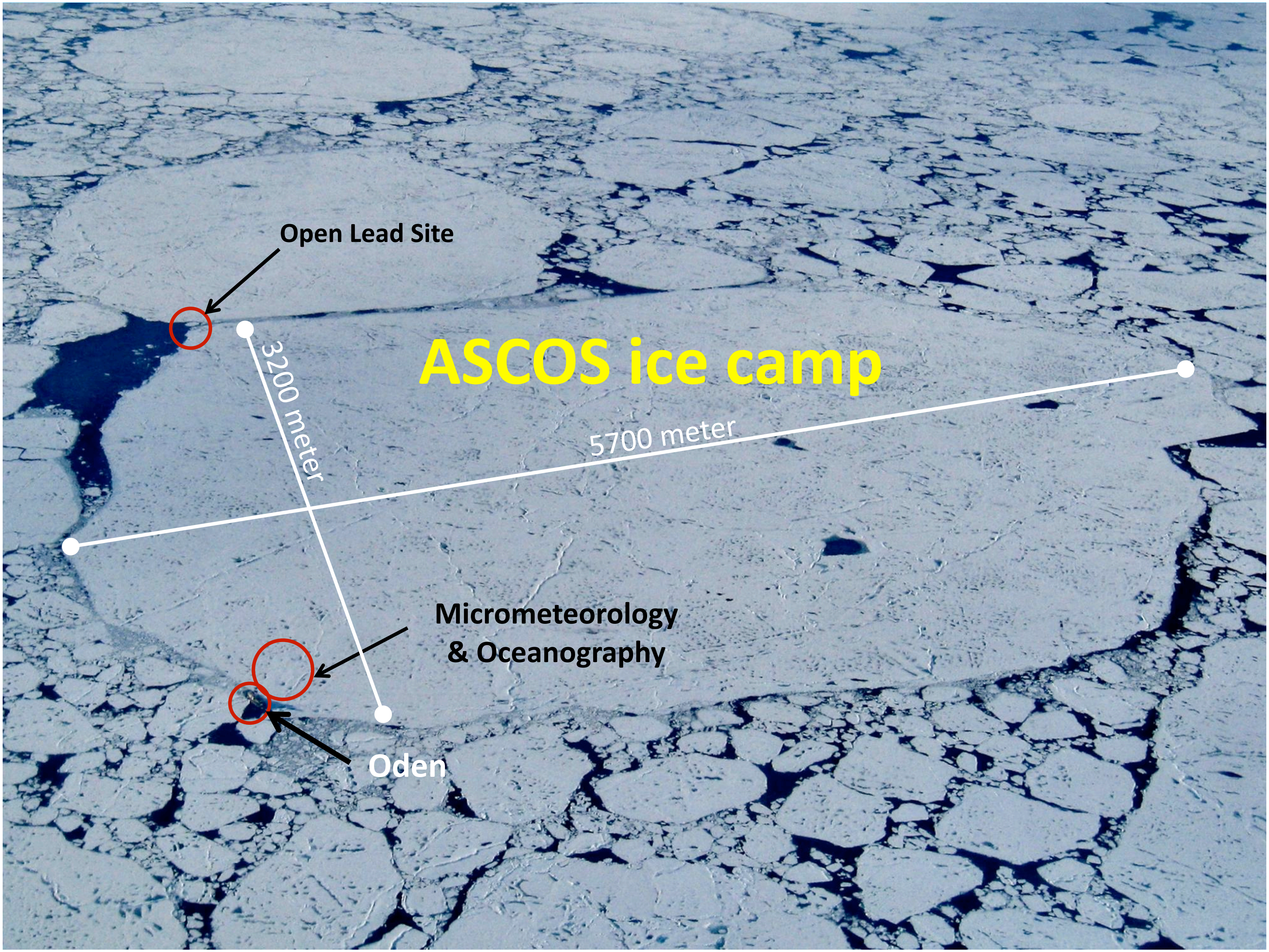
ASCOS – based on Icebreaker Oden

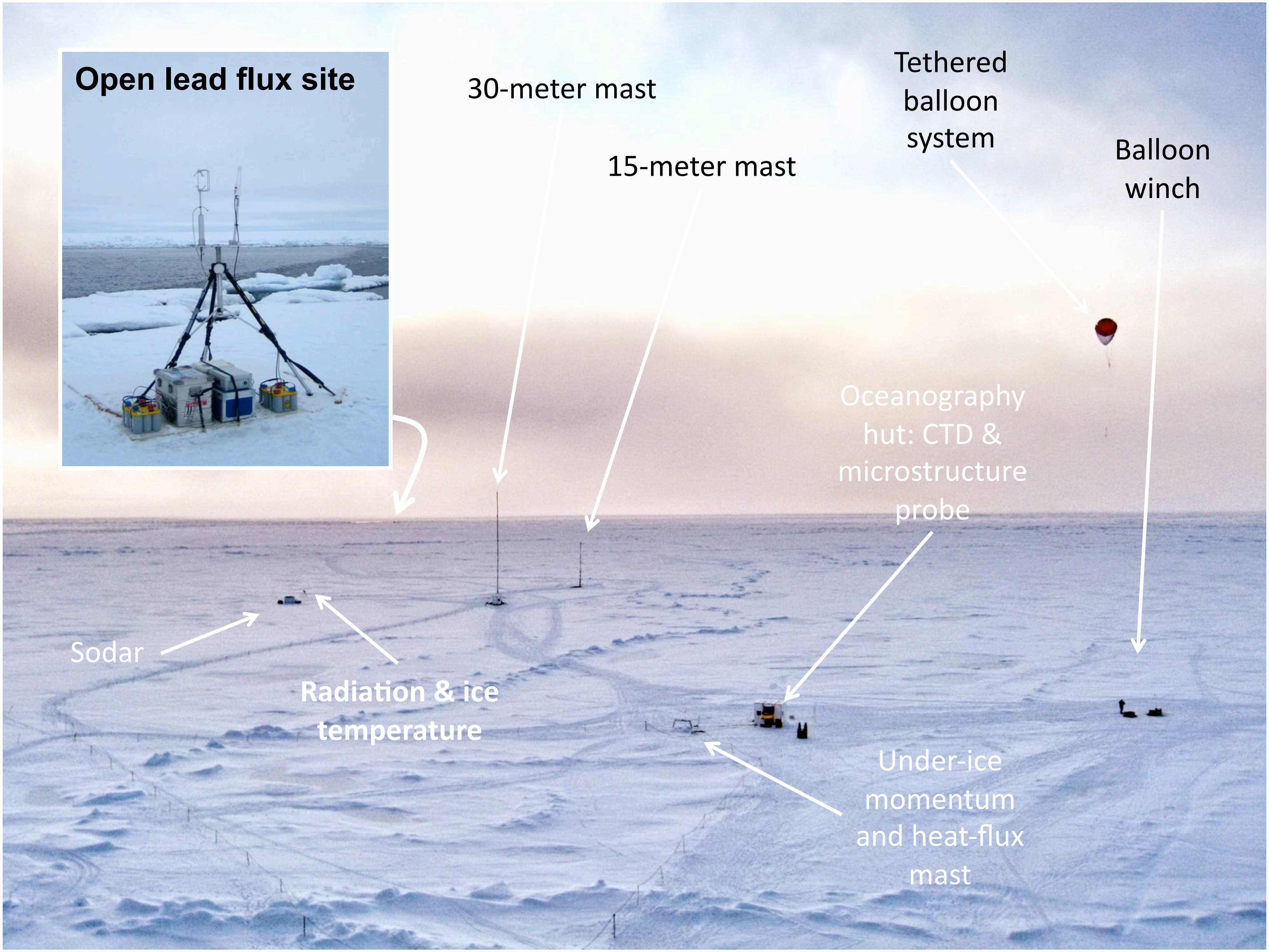
Cruise: July 31 – Sept 10 2008

Ice drift: August 12 – Sept 2

ASCOS Micrometeorology

Ian Brooks, Cathryn Birch (Leeds)
Thorsten Mauritsen (Max Planck Institute for Meteorology)
Joe Sedlar, Michael Tjernström (Stockhom University)
Andreas Held (University of Bayrueth)
Ola Persson (NOAA)


Open Lead Site
ASCOS ice camp
3200 meter
5700 meter
Micrometeorology
& Oceanography
Oden

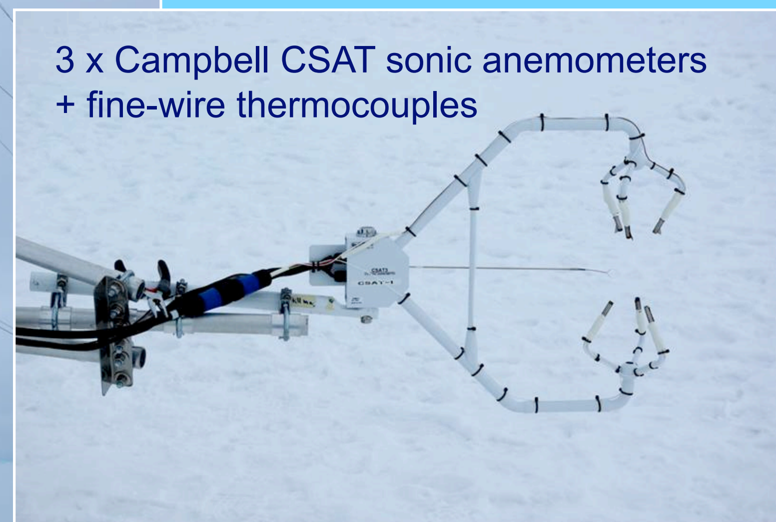


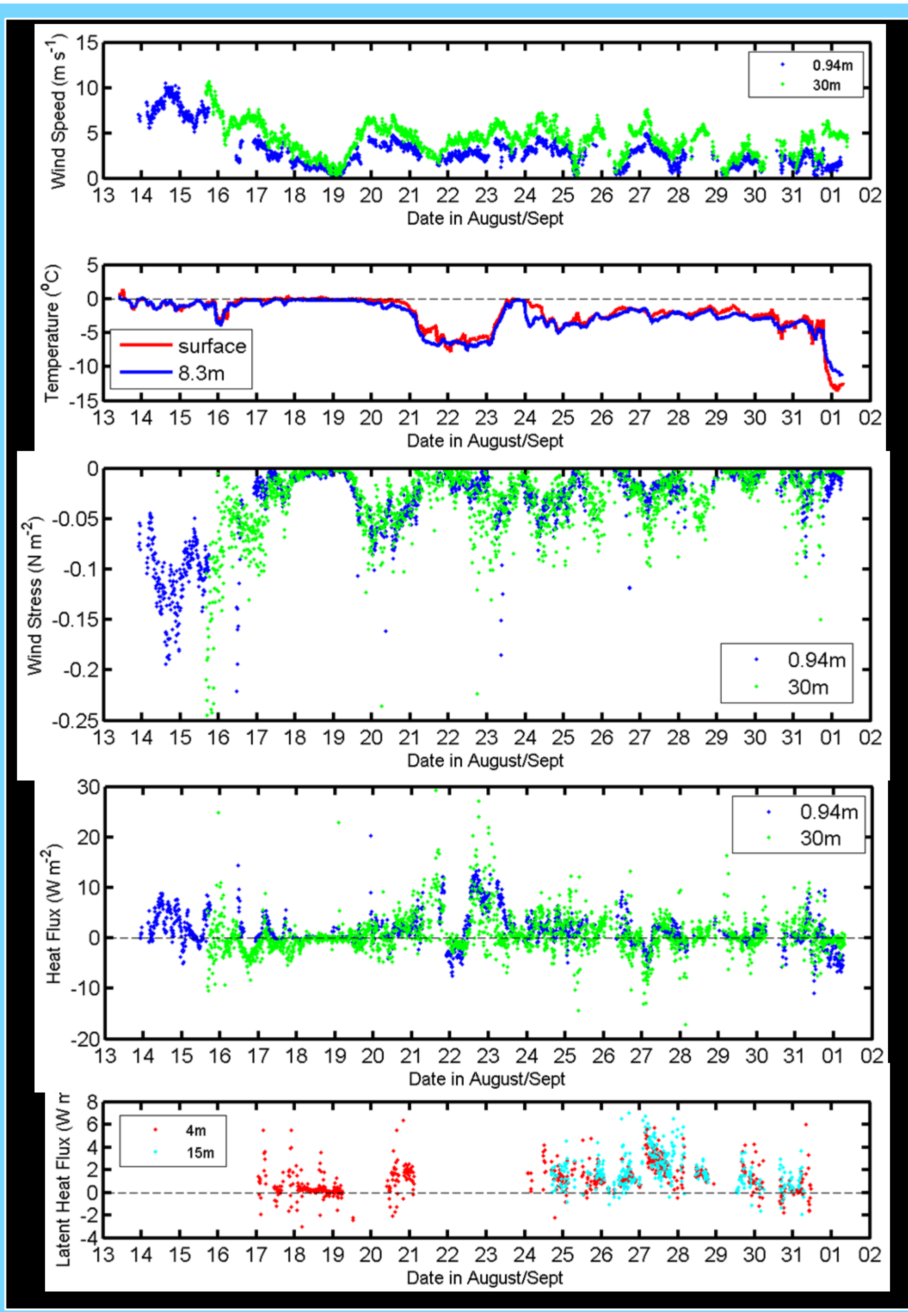
Open lead flux site
30-meter mast
15-meter mast
Tethered balloon system
Balloon winch
Oceanography hut: CTD & microstructure probe
Sodar
Radiation & ice temperature
Under-ice momentum and heat-flux mast


Turbulence/micrometeorology masts
15 m mast

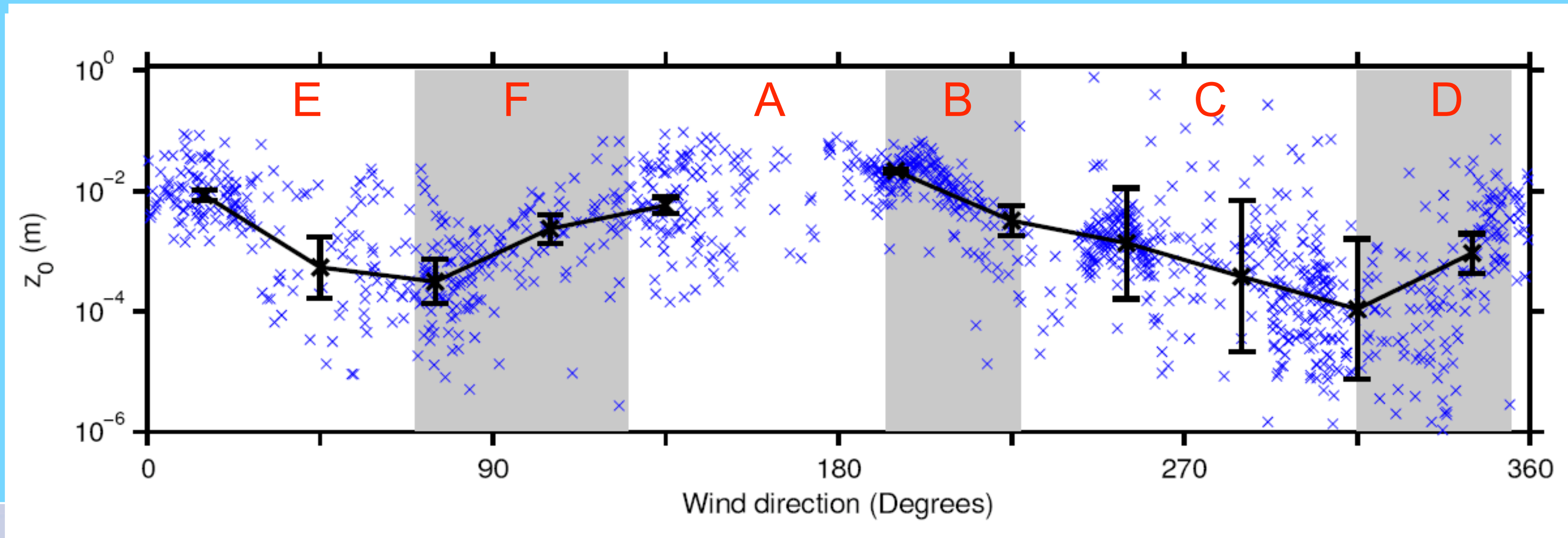

1 Metek Sonic anemometer @30m
30 m mast

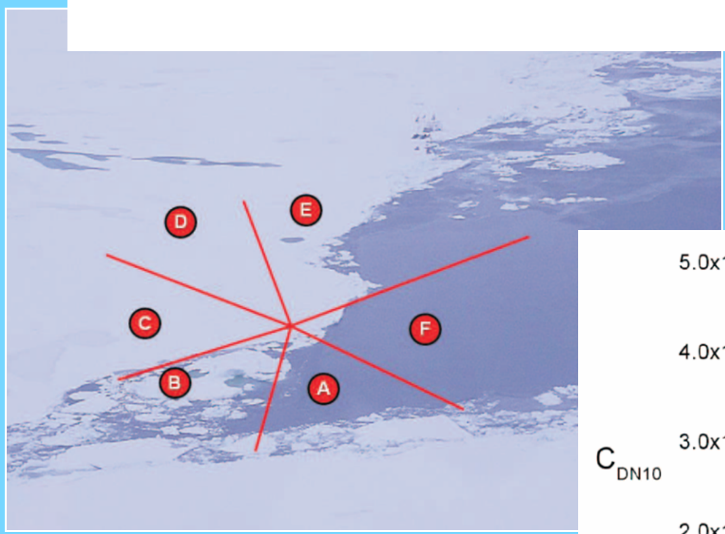

Mean T & RH
2 x Gill R3 sonic anemometers
+ LiCOR LI-7500 H_2O/CO_2 sensor


3 x Campbell CSAT sonic anemometers
+ fine-wire thermocouples

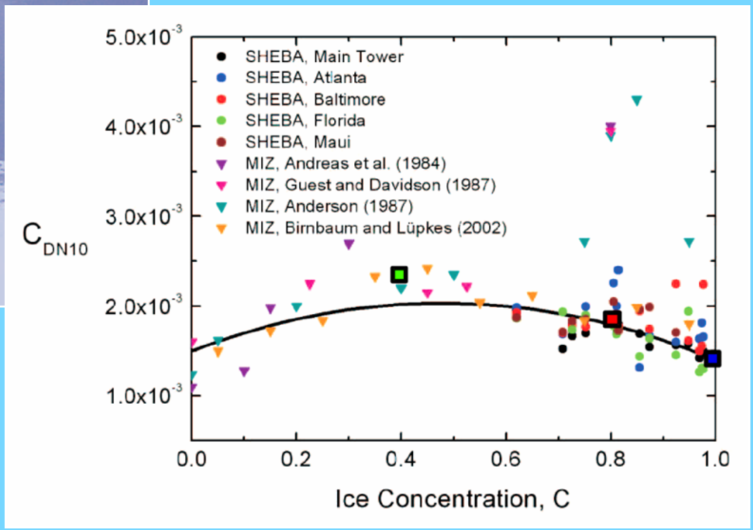


Time series of windspeed, air- and ice-surface temperature, wind stress, sensible heat flux, and humidity flux for the ice-drift.

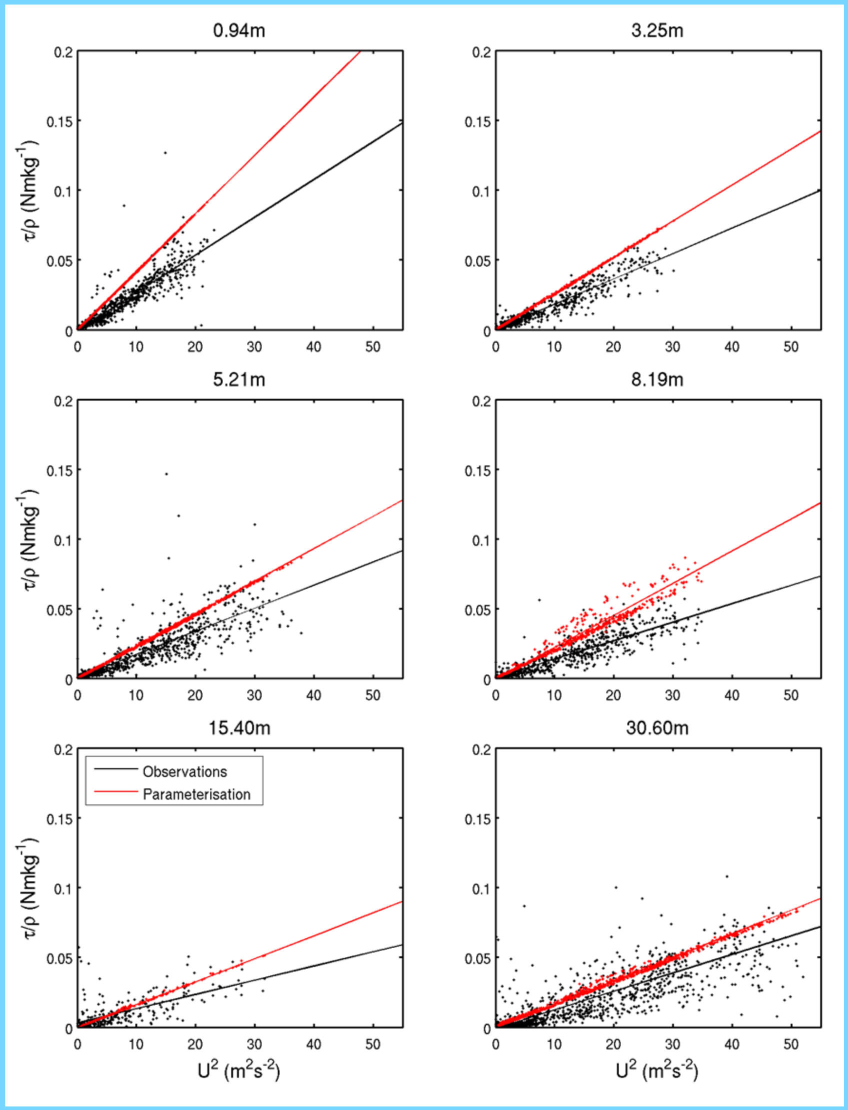




ASCOS Estimates of z_0 and C_{DN} are in close agreement with SHEBA parameterisation as function of ice concentration.



SHEBA bulk flux parameterisation comparison



- SHEBA parameterisation run using values of z_0 calculated from observations at each measurement height
- Wind directions over ice floe only
- Gradient of lines is equal to transfer coefficient
- Parameterisation overestimates transfer coefficient even when using observed z_0

ASCOS Papers

Using data from AOE2001 experiment:

Birch, C. E., I. M. Brooks, M. Tjernström, S. F. Milton, P. Earnshaw, S. Söderberg, P. O. G. Persson, 2009: The performance of a global and mesoscale model over the central Arctic Ocean during late summer. J. Geophys. Res. 114, D13104, doi:10.1029/2008JD010790.

ASCOS papers submitted:

Sedlar J.; M. Tjernström; T. Mauritsen; I. M. Brooks; C. E. Birch; M. Shupe; A. Sirevaag; P. O. G. Persson; C. Leck, 2010: A transitioning Arctic surface energy budget: the impacts of solar zenith angle, surface albedo and cloud radiative forcing. Climate Dynamics, (submitted)

Mauritsen, T., J. Sedlar, M. Tjernström, C. Leck, M. Martin, M. Shupe, S. Sjögren, B. Sierau, P. O. G. Persson, I. M. Brooks, E. Swietlicki, 2010: Arctic aerosol indirect effects. Science (submitted)

Gas Ex III (CO_2 focus)

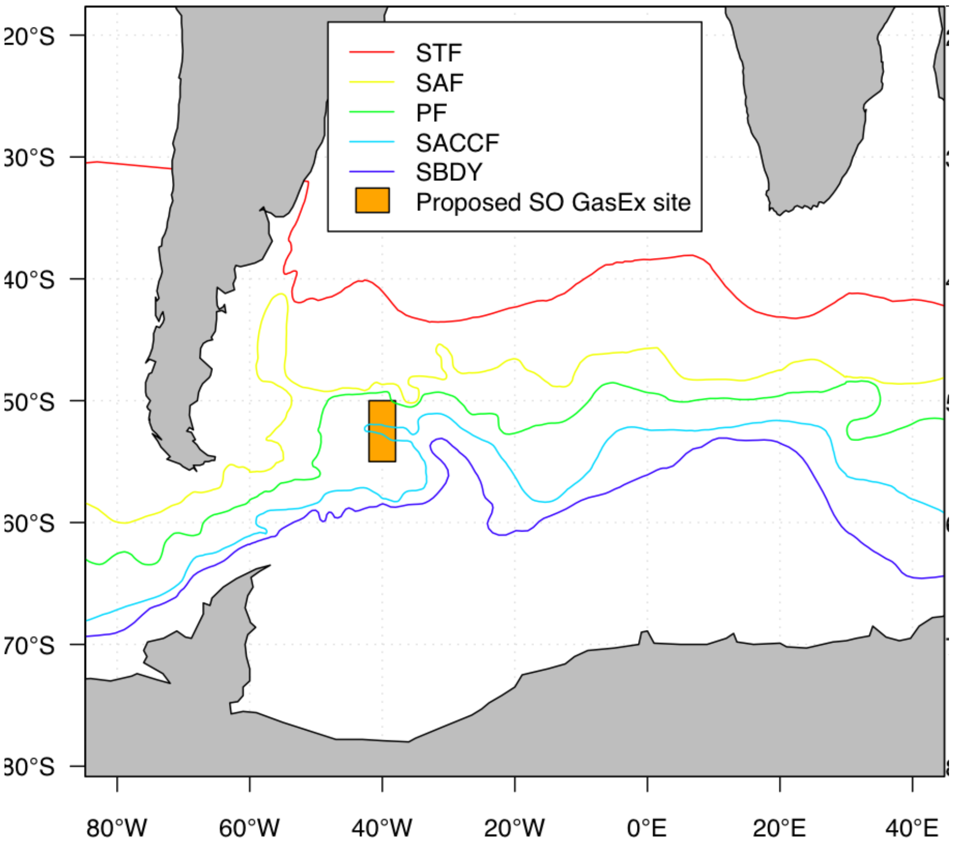
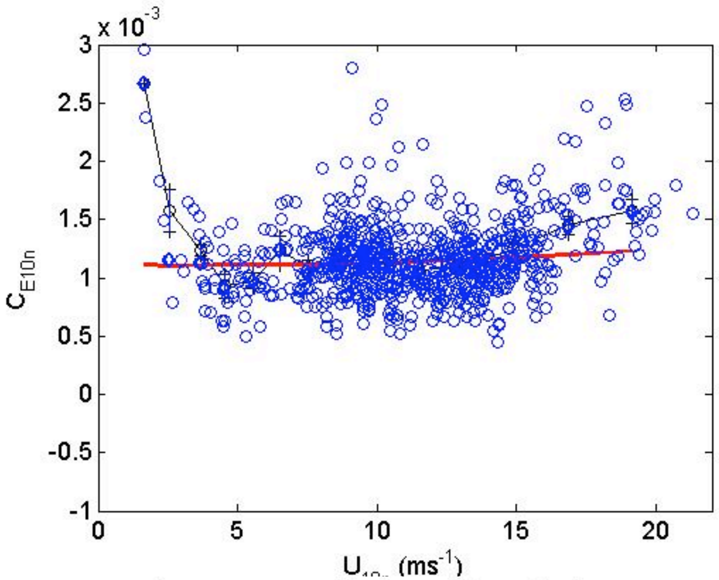
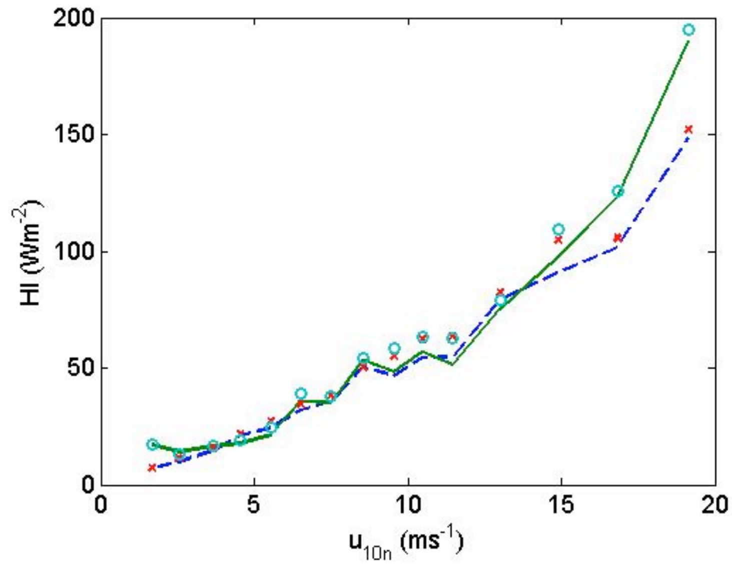
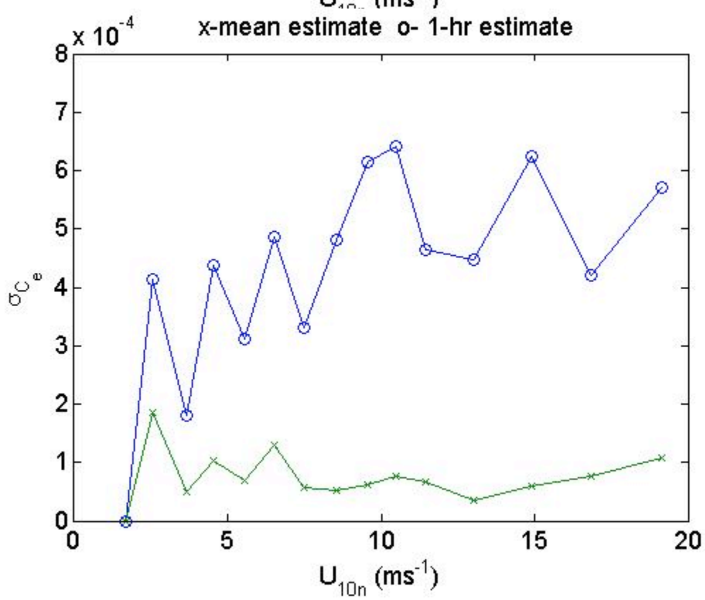


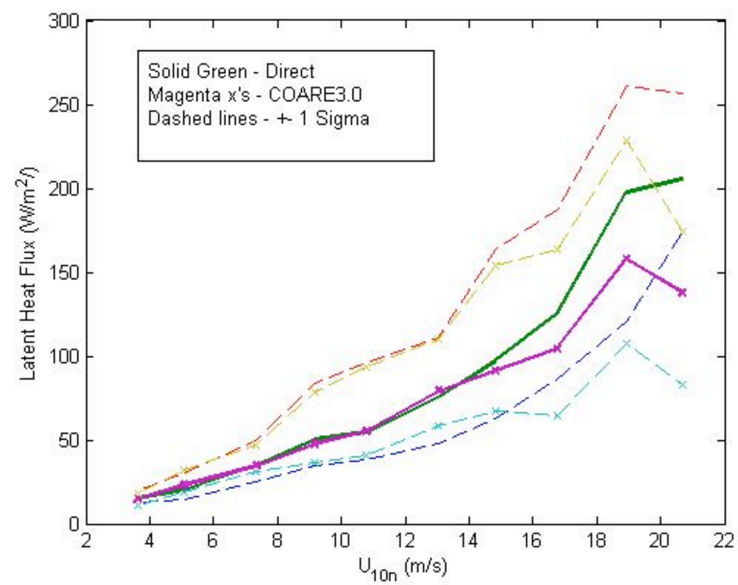
Figure 1. Cluster of sonic anemometers, fast humidity sensors, and mean T/RH sensors on the jackstaff of the NOAA Ship Ronald H. Brown for GASEX-3. The PSD sonic is in the center. The sleeved fast-sample LI-7500 is the unit on the right with the large blue ventilation tube. The two open path units are on the left. Each sonic is mounted to its own motion-measuring system.

GASEX-III Humidity Flux Analysis Examples

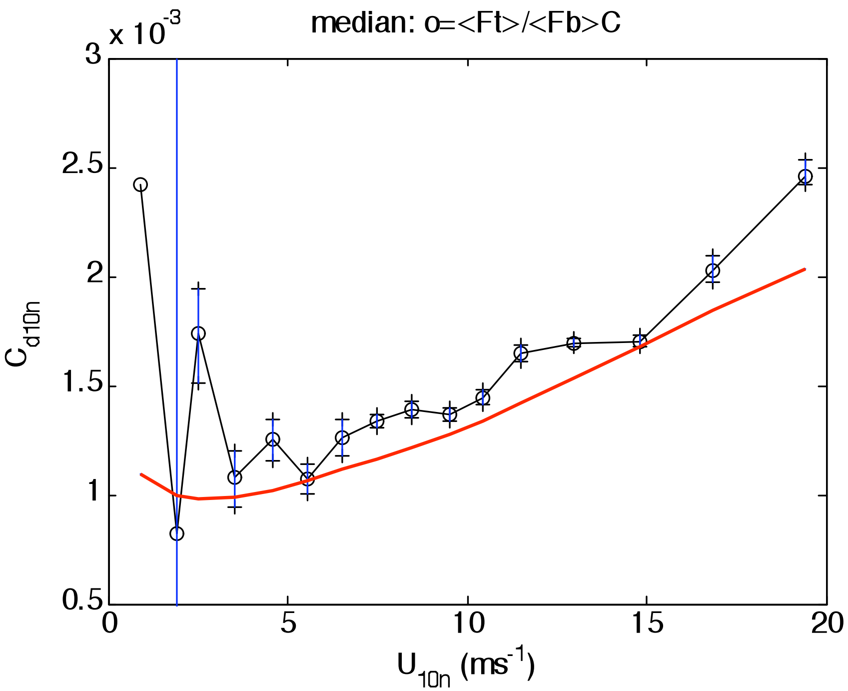


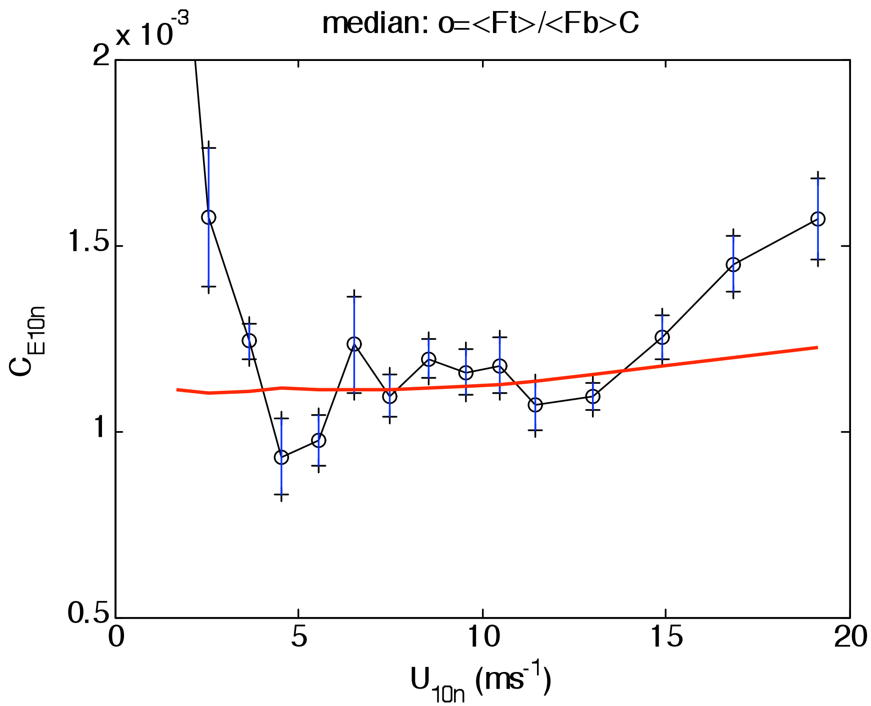






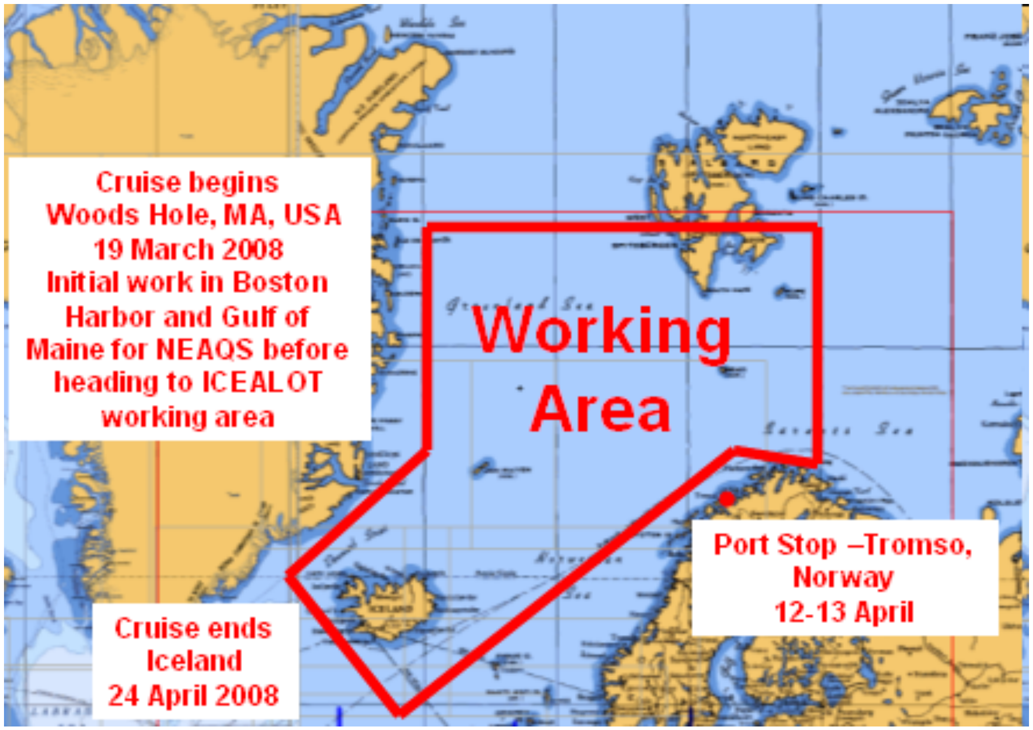
GASEX-III Bulk Transfer Coefficient Results





Turbulent transfer coefficients as a function of 10-m neutral wind speed. Solid red line is the COARE algorithm. The circles (with 1-sigma median limits) are the flux-weighted transfer coefficients. Left panel is the momentum coefficient; right panel is the latent heat coefficient.

ICEALOT
International Chemistry Experiment in the Arctic LOwer Troposphere



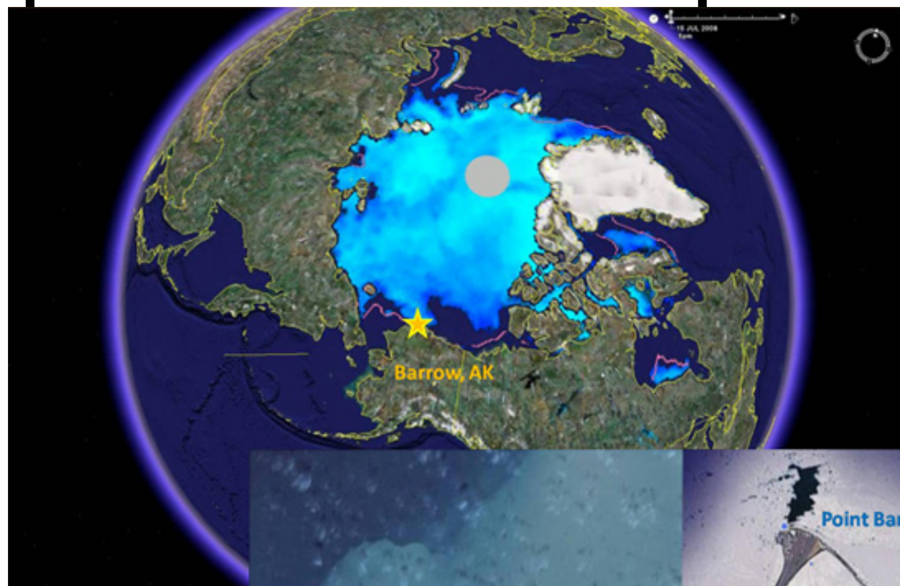
As part of POLARCAT, NOAA will undertake a research cruise in an ice-free region of the Arctic during March and April of 2008. The study area will include the Greenland, Norwegian, and Barents Seas.

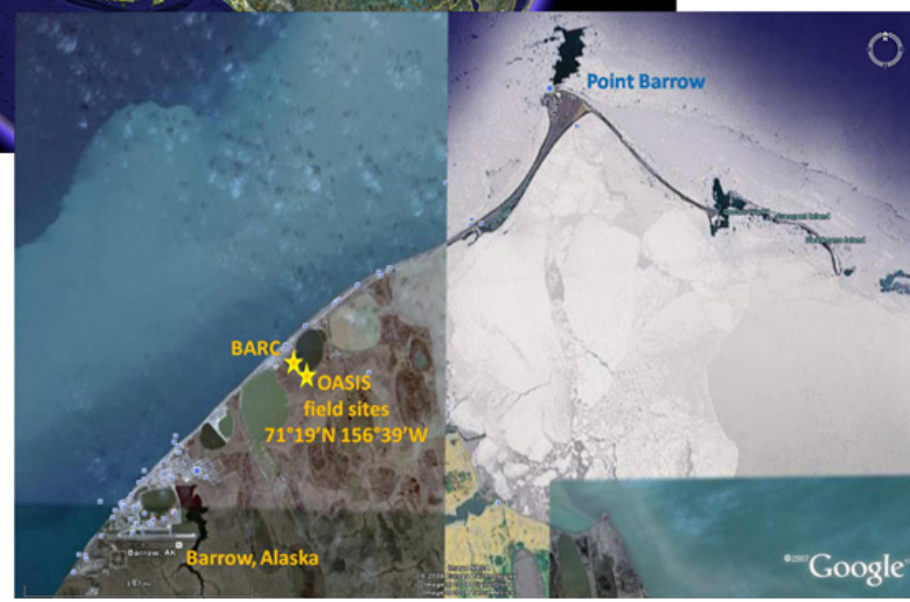
Scientific issues to be addressed include springtime sources and transport of pollutants to the Arctic, evolution of aerosols and gases into and within the Arctic, and climate impacts of haze and ozone in the Arctic.

OASIS

Ocean - Atmosphere - Sea Ice - Snowpack

The international multidisciplinary program studies chemical and physical exchange processes between the title reservoirs. It focuses on their impact on tropospheric chemistry and climate, as well as on the surface/biosphere and their feedbacks in the Arctic.





Links

- GFDex http://lgmacweb.env.uea.ac.uk/e046/research/gfdex/index.htm
- BAS- MASIN http://www.camracers.org.uk/masin/
- ASCOS http://www.ascos.se/
- GasEx III http://so-gasex.org/
- ICEALOT http://saga.pmel.noaa.gov/Field/icealot/
- OASIS http://www.oasishome.net/

Quality control

- Follows French et al. (2007), Drennan et al. (2007)
  - power spectra
  - linear cumulative summation of the covariances
  - cospectra of the covariances
  - ogives

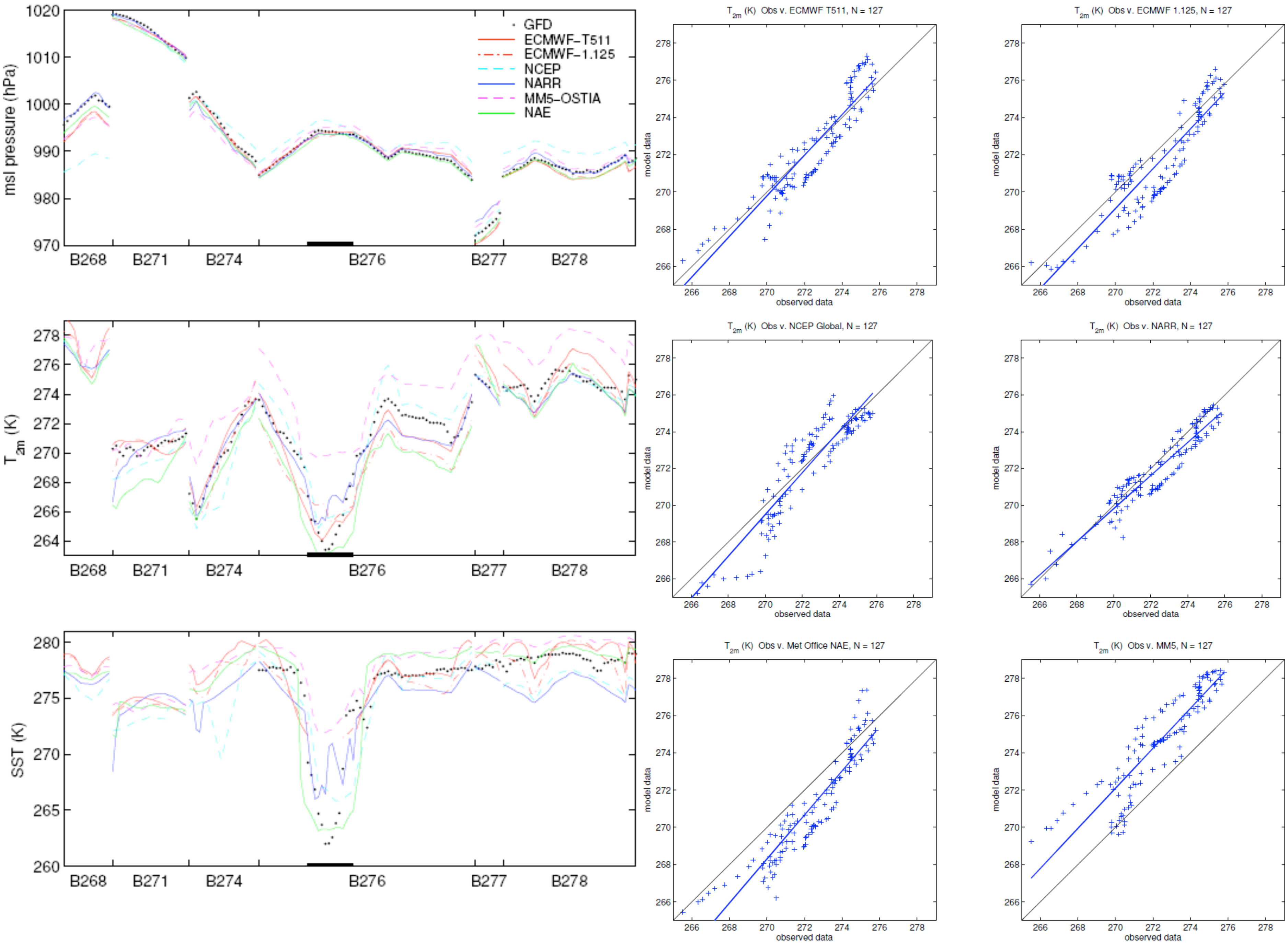
131 flux runs over ocean

⇒ 120 accepted for wind stress

⇒ 109 for sensible heat flux

⇒ 102 for latent heat flux

COARE3.0 review noted only 133 & 85 from 7000 h of momentum & latent flux obs for U > 15 m s^{-1} in ETL database



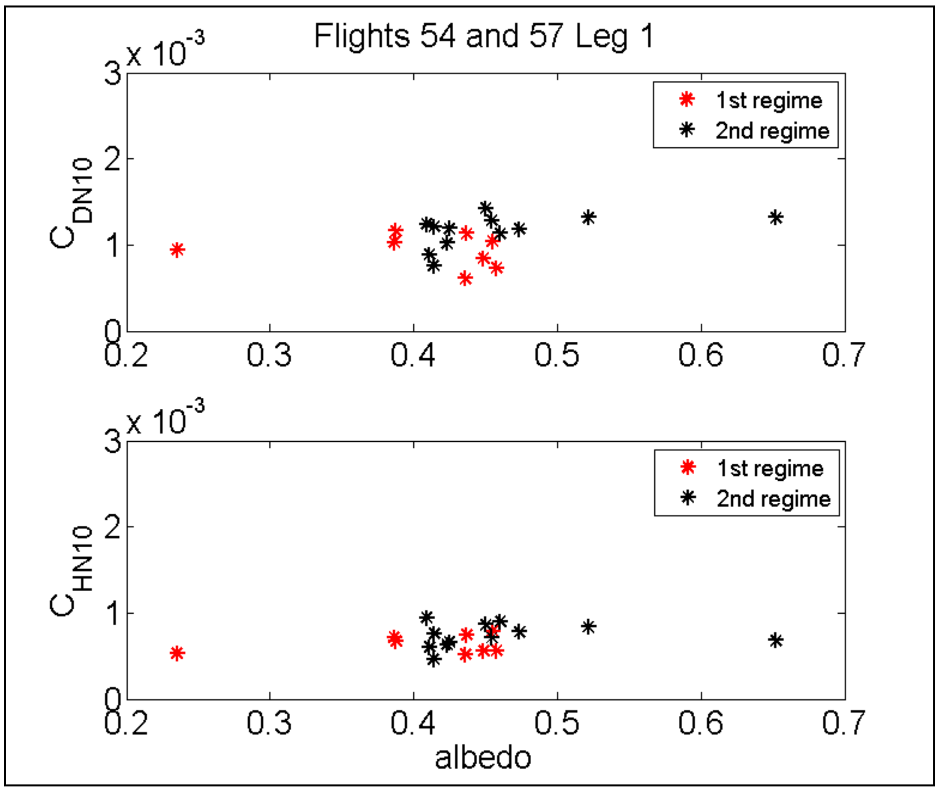
GFD
ECMWF–T511
ECMWF–1.125
NCEP
NARR
MM5–OSTIA
NAE
msl pressure (hPa)
T2m (K)
SST (K)
B268
B271
B274
B276
B277
B278
T2m (K) Obs v. ECMWF T511, N = 127
T2m (K) Obs v. ECMWF 1.125, N = 127
T2m (K) Obs v. NCEP Global, N = 127
T2m (K) Obs v. NARR, N = 127
T2m (K) Obs v. Met Office NAE, N = 127
T2m (K) Obs v. MM5, N = 127
model data
observed data

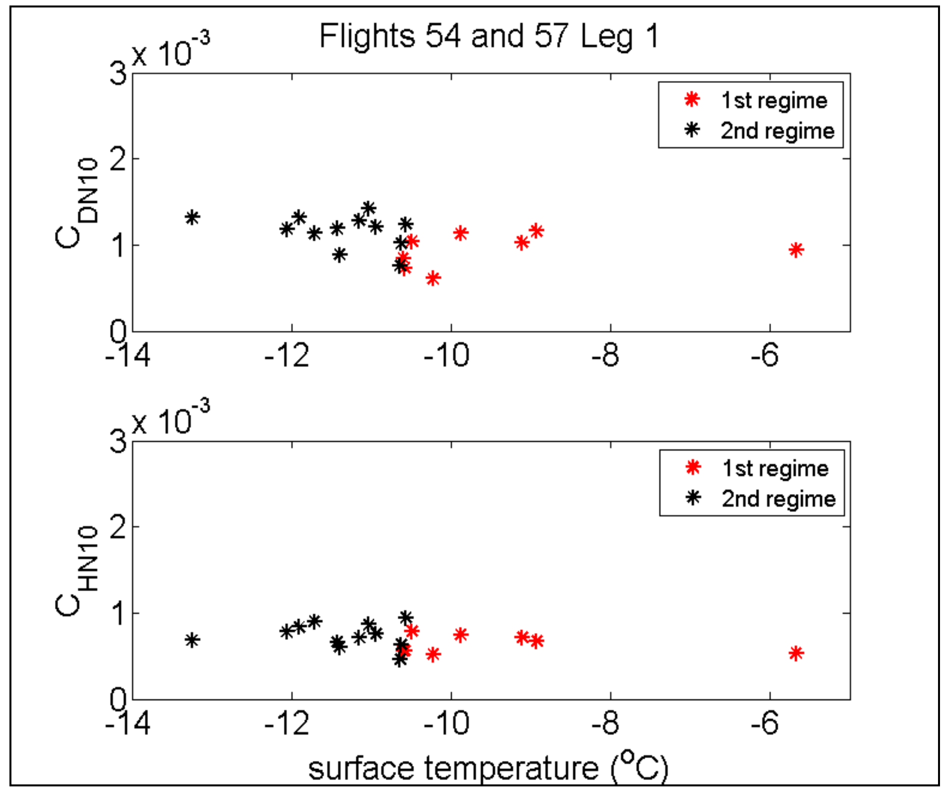
GFDex Comparison Conclusions

- To simulate the high winds associated with extratropical mesoscale weather systems, such as tip jets, barrier flows and polar lows, a model resolution of order 20 km is necessary but is not sufficient; as appropriate ABL and surface flux parameterizations are also crucial.
- In regions relatively close to the sea-ice edge, the current generation of NWP models still have problems in accurately simulating ABL temperature and humidity,
  - *perhaps being unable to transit from stable to unstable conditions quickly enough?*
- An accurate prescription of the SST is essential.
- The use of surface turbulent fluxes from NWP models is not recommended without an investigation of the surface flux algorithm used and validation against observations.

Is there a variation with surface characteristics?

Relationships between C_D & C_H with albedo and $T_{surface}$





Fiedler, E. K., Lachlan-Cope, T. A., Renfrew, I. A. and J. C. King (2009), Convective heat transfer over thin-ice covered coastal polynyas, J. Geophys. Res., *in revision*

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(www.interscience.wiley.com) DOI: 10.1002/qj.534

RMetS
Royal Meteorological Society

Editorial
The Greenland Flow Distortion Experiment

- Case studies
  - Obs & dynamics of an easterly tip jet
  - Obs & modelling of a Greenland lee cyclone
  - Barrier flows & wakes around Greenland
- Climatological studies
  - A climatology of westerly tip jets
- Targeted Observations
  - Impact assessment in collaboration with Met Office
- Air-sea interaction:
  - Turbulent flux observations
  - Comparison of obs & NWP models
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