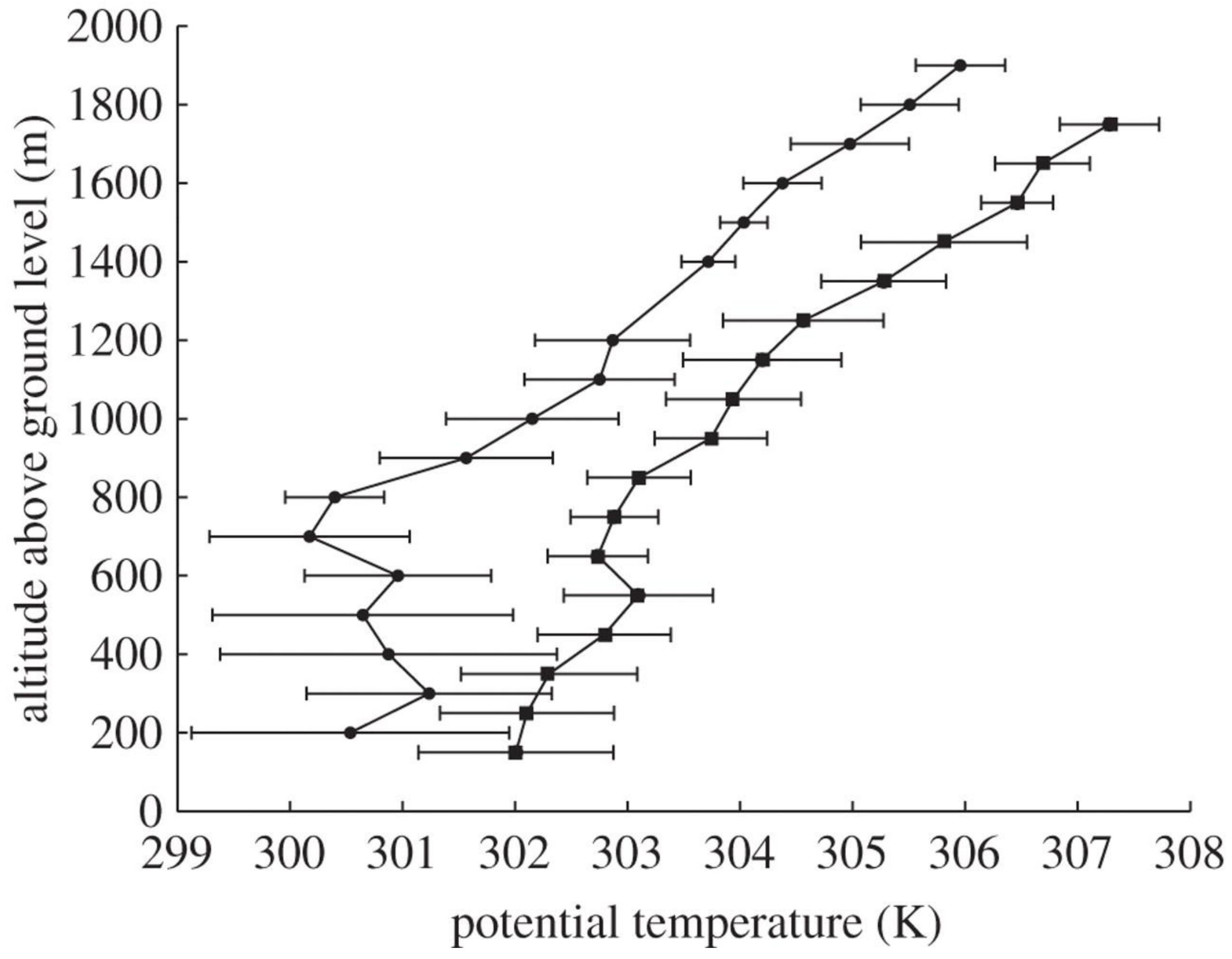
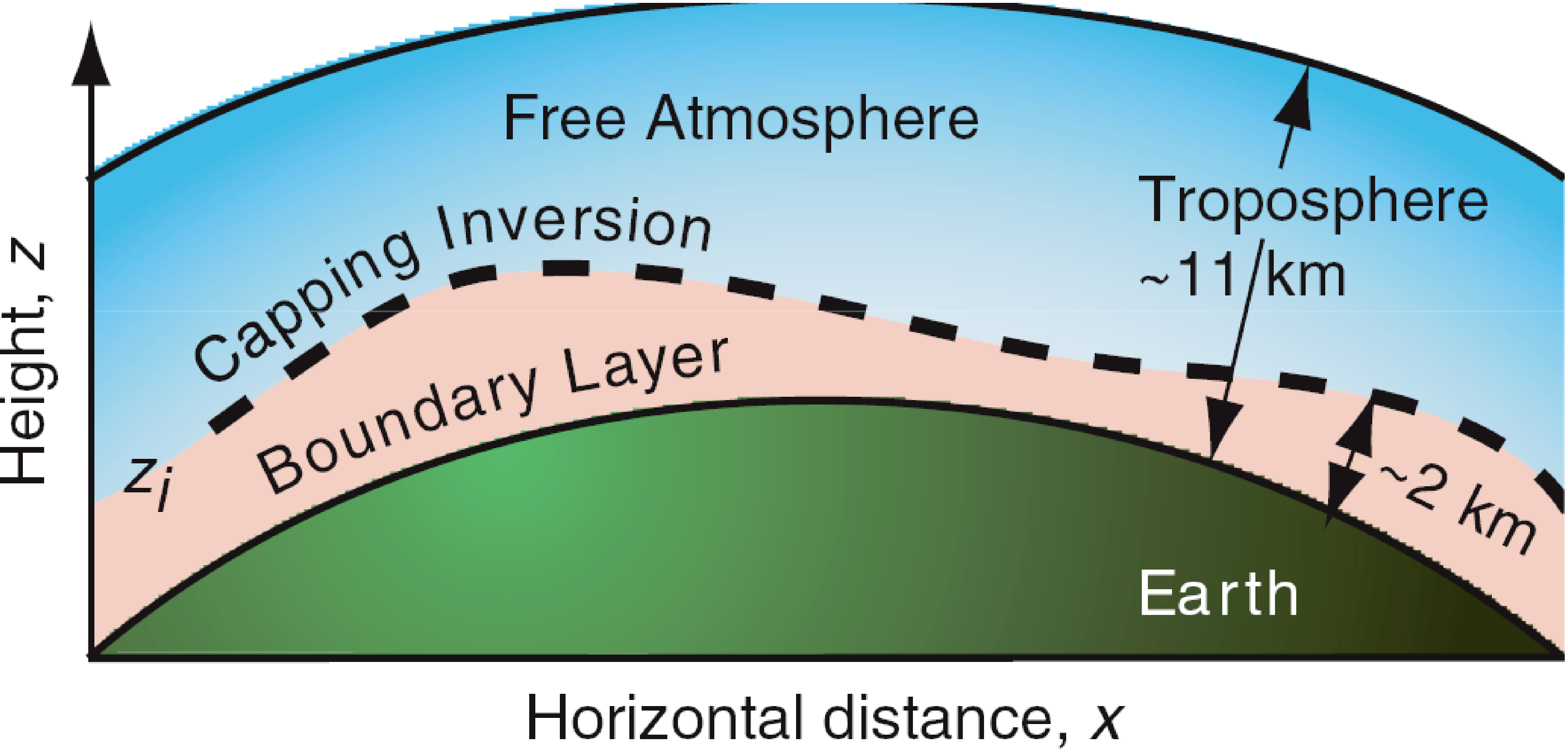
Mean vertical profiles of dry-bulb potential temperature over the rainforest (squares) and oil palm plantation (circles) landscapes from observations using the FAAM BAe146 research aircraft during OP3-III.

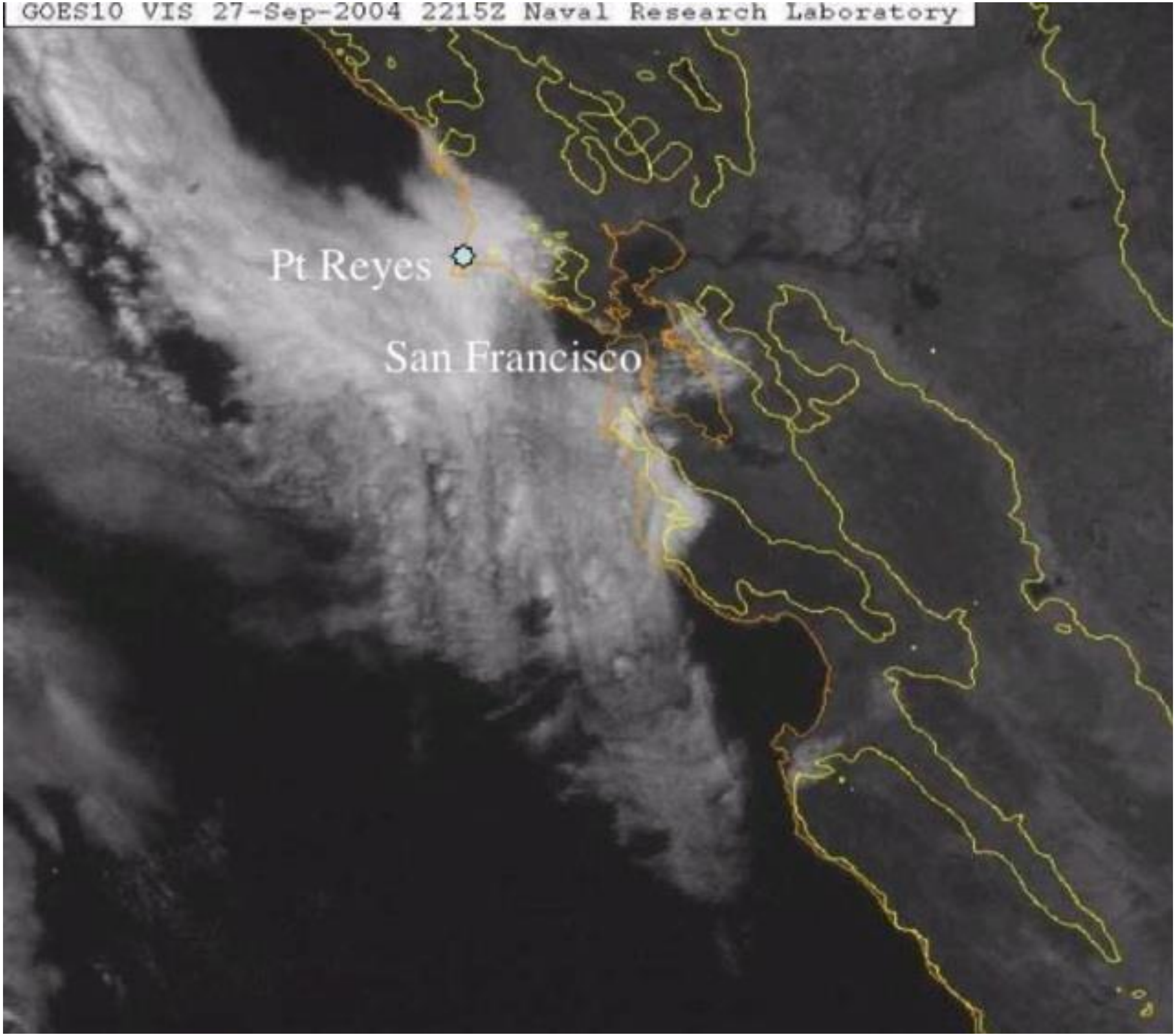


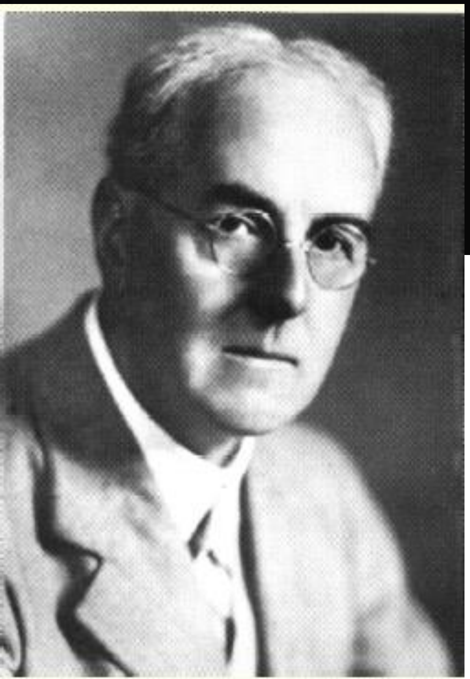
A. R. MacKenzie et al. Phil. Trans. R. Soc. B 2011;366:3177-3195


Free Atmosphere
Troposphere
~11 km
Capping Inversion
Boundary Layer
z_i
~2 km
Earth
Height, z
Horizontal distance, x

Stratus cloud deck

Photo by Ralph F. Kresge NOAA Central Library/NWS


GOES10 VIS 27-Sep-2004 2215Z Naval Research Laboratory
Pt Reyes
San Francisco



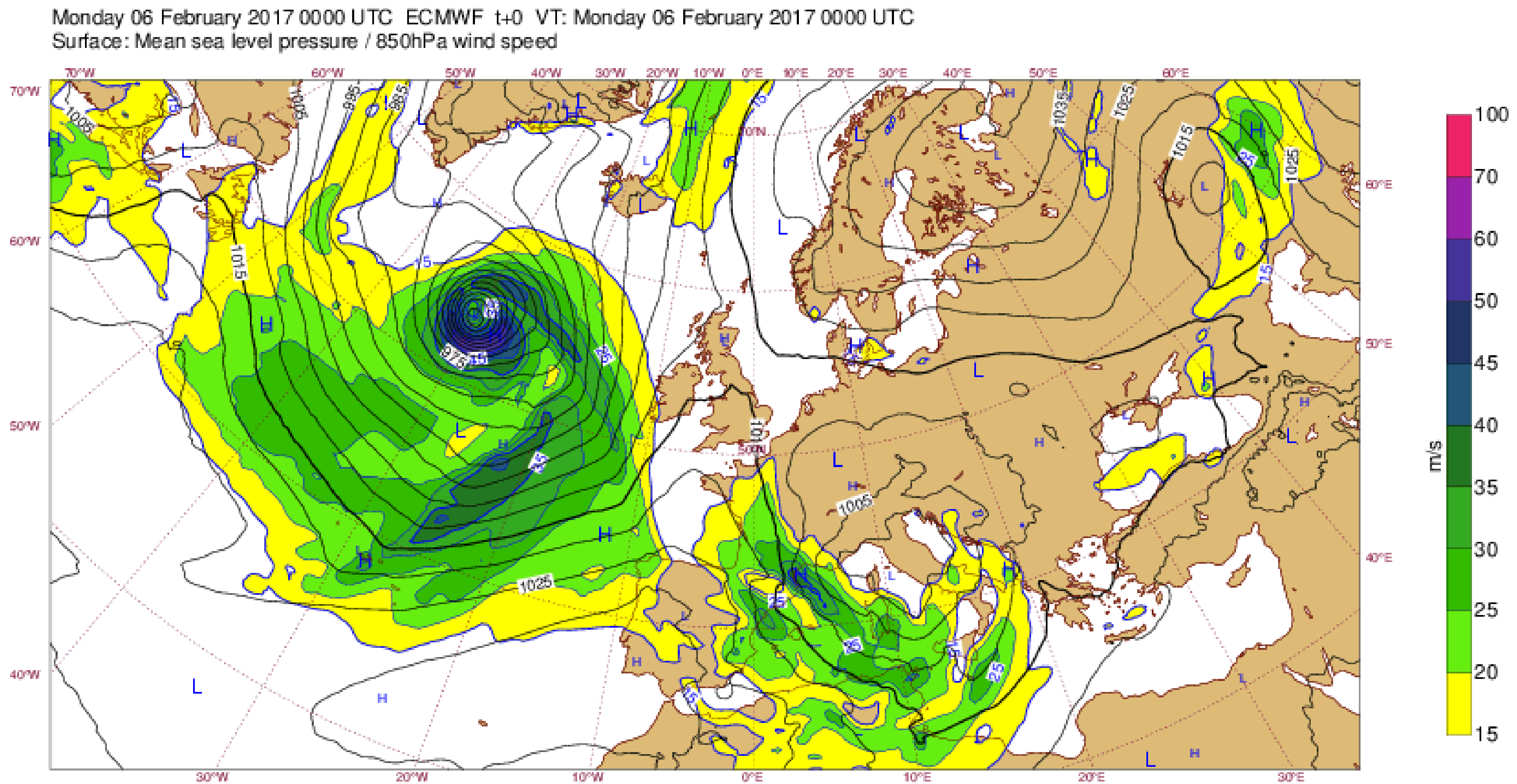
Big whirls have little whirls that feed
on their velocities,

and little whirls have smaller whirls,
and so on to viscosity

Lewis Fry Richardson

Le-bølger ved Hawaii. Kilde: NASA.

Synoptic scale (2-D) eddy



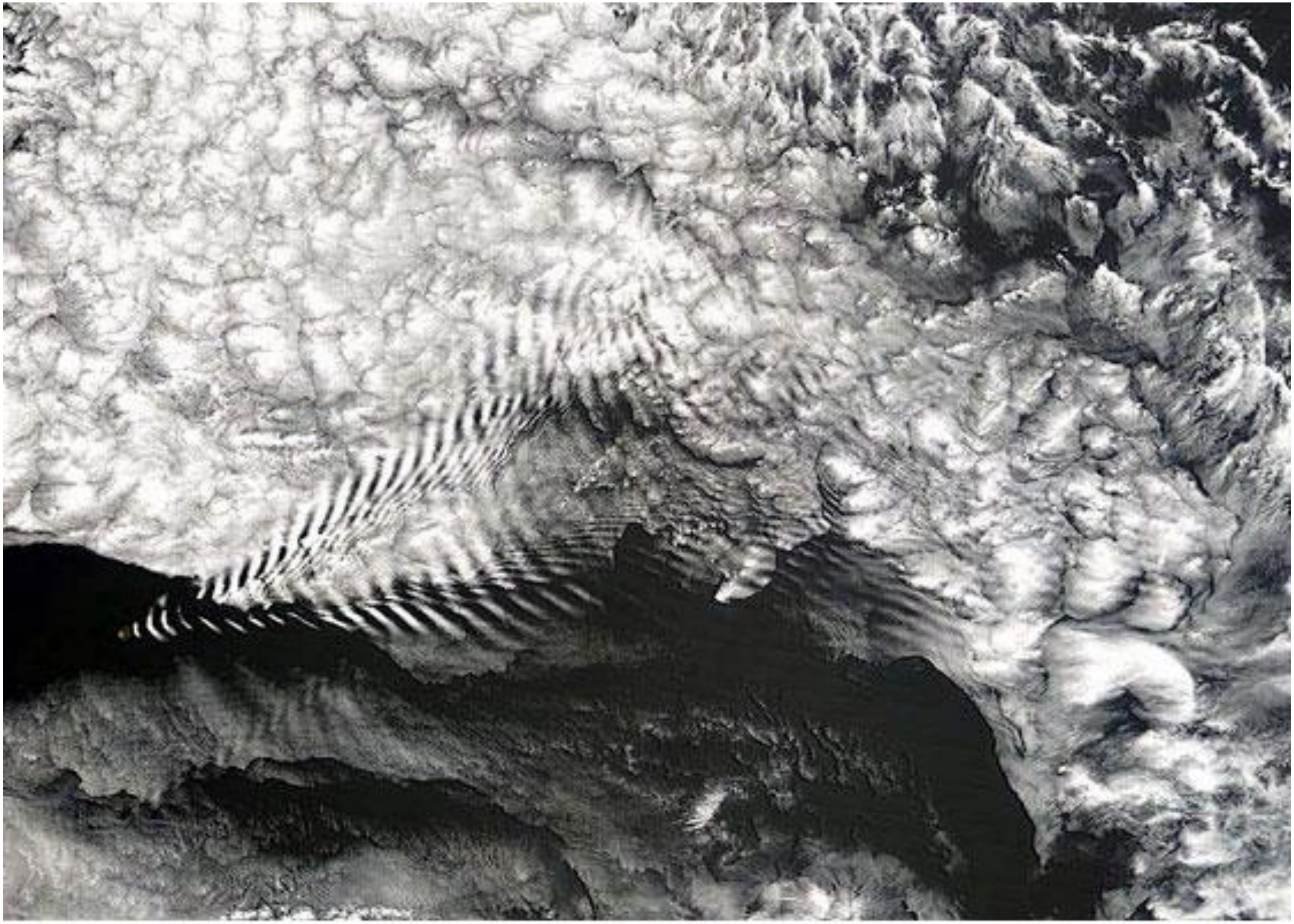
http://www.ecmwf.int/en/forecasts/charts/

Cumulus Cloud (convective eddy)

Turbulens i den frie troposfæren

Dannes ved vindskjær mellom to luftmasser

Turbulens ved vindskjær



NASA MODIS imagery. NASA still images generally are not copyrighted and may be used for educational or informational purposes.

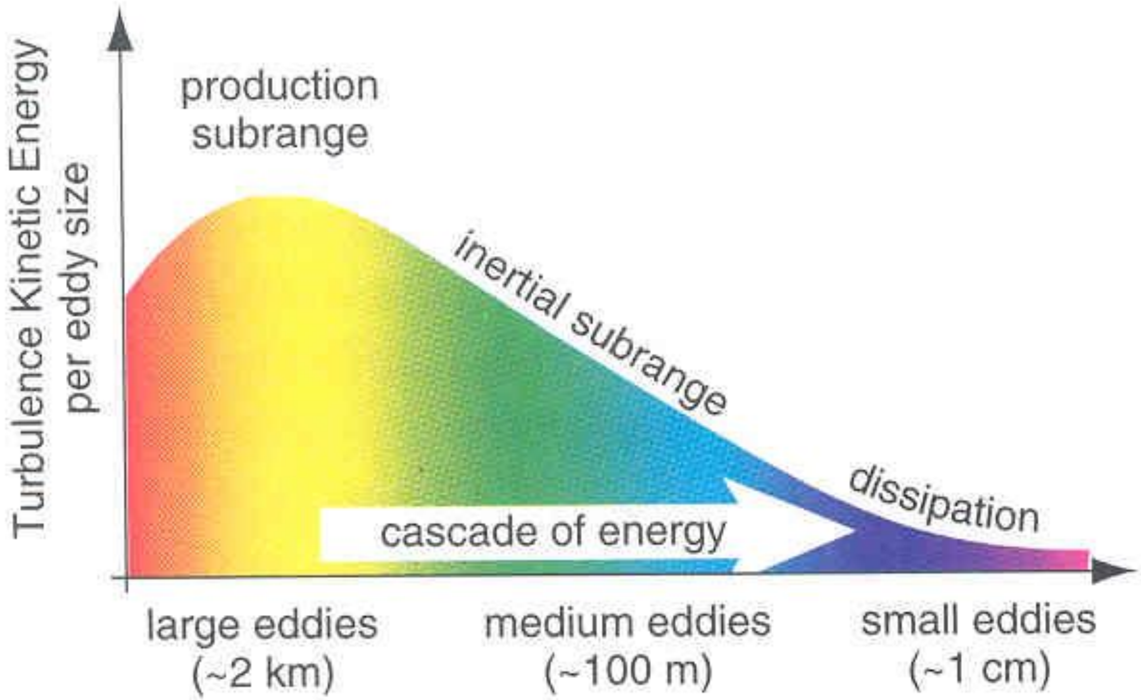
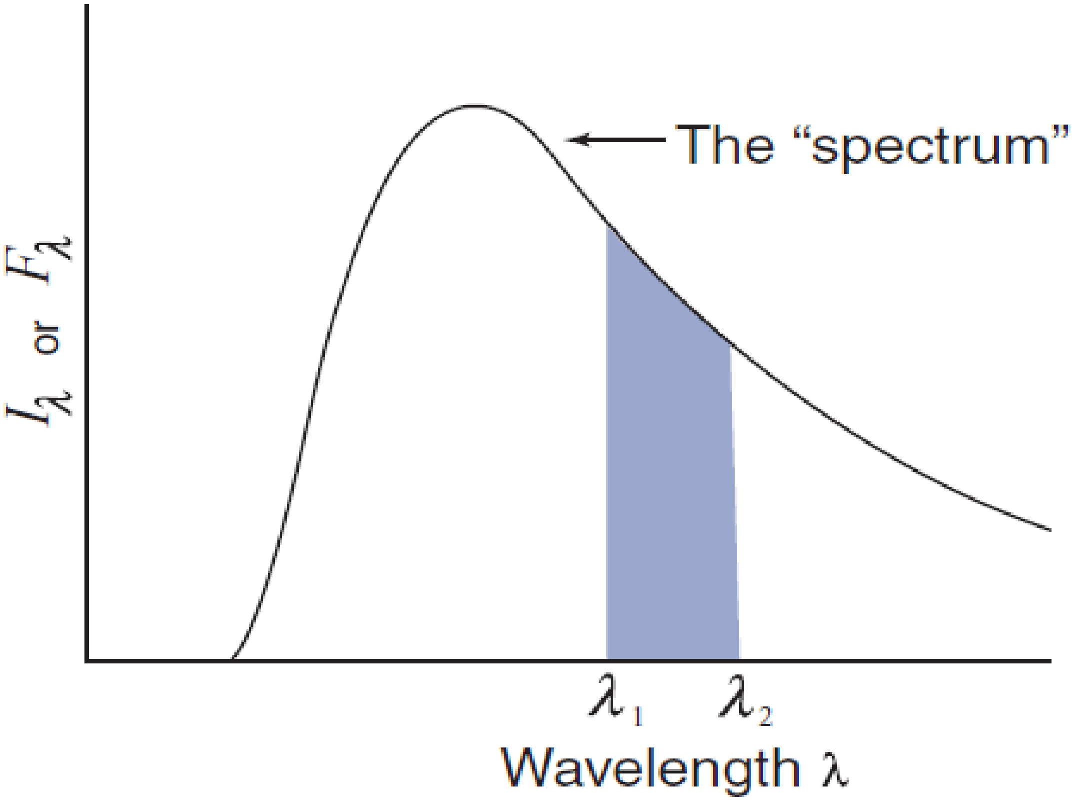


Fig. 9.5 The spectrum of turbulence kinetic energy. By analogy with Fig. 4.2, the total turbulence kinetic energy (TKE) is given by the area under the curve. Production of TKE is at the large scales (analogous to the longer wavelengths in the electromagnetic spectrum, as indicated by the colors). TKE cascades through medium-size eddies to be dissipated by molecular viscosity at the small-eddy scale. [Courtesy of Roland B. Stull.]



Tilsvarende som for stråling:
Også for turbulens er energien fordelt på "like" strukturer,
men med ulike størrelser

The Cryosphere Discuss., 9, 5775–5815, 2015
www.the-cryosphere-discuss.net/9/5775/2015/
doi:10.5194/tcd-9-5775-2015

The Cryosphere Discussions

Simulating the climatic mass balance of Svalbard glaciers from 2003 to 2013 with a high-resolution coupled atmosphere-glacier model

K. S. Aas[1], T. Dunse[1], E. Collier[2], T. V. Schuler[1], T. K. Berntsen[1], J. Kohler[3], and B. Luks[4]

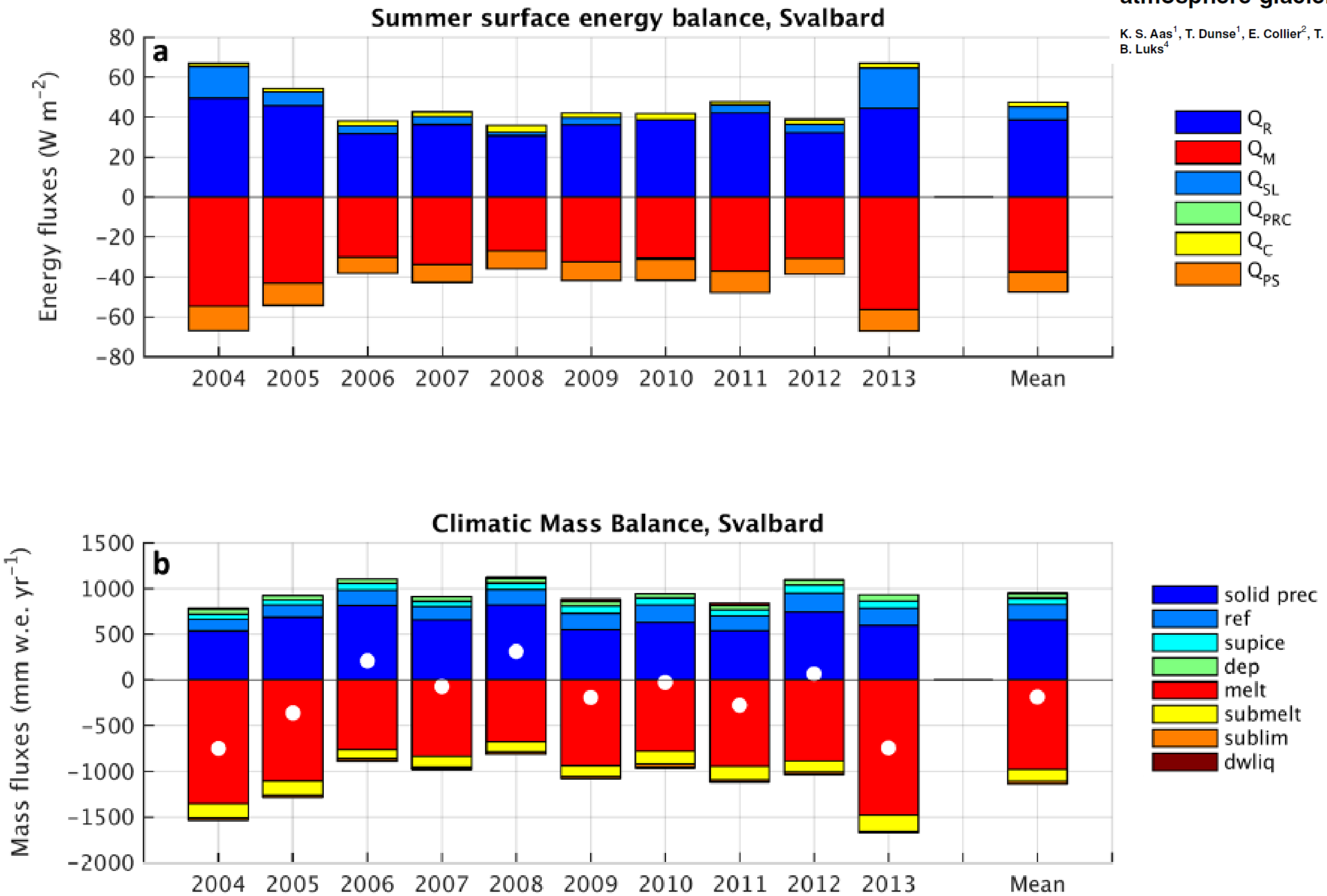


Figure 10. (a) Mean summer (JJA) surface energy balance fluxes. Q_R: net radiation, Q_M: melt energy, Q_{SL}: sensible and latent heat flux, Q_{PRC}: heat from precipitation, Q_C: ice heat flux and Q_{PS}: penetrating solar radiation. **(b)** Annual mass fluxes averaged over Svalbard. The resulting CMB is indicated by white dots.

Anemometer: Instrument for måling av vindstyrke og vindretning

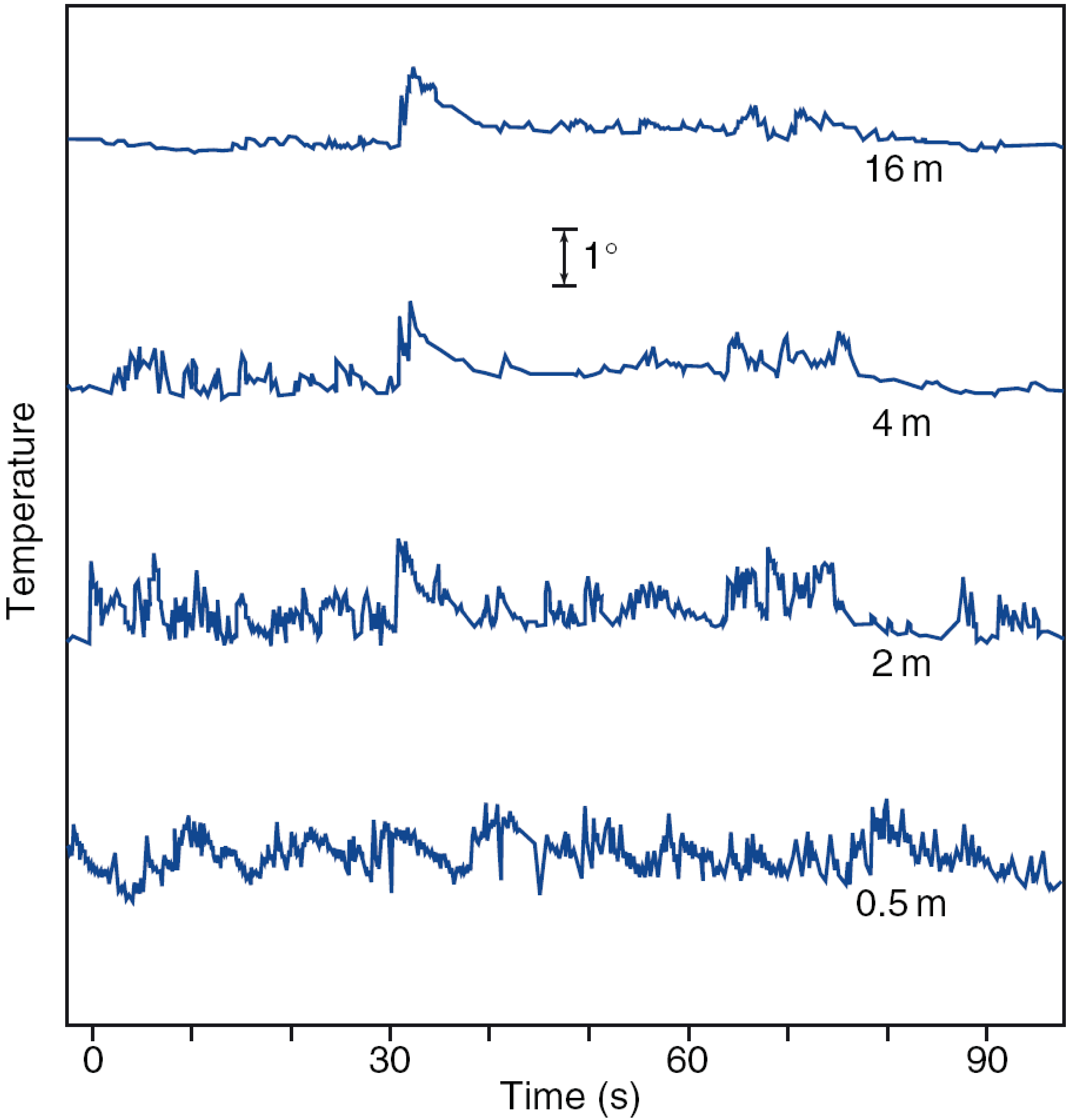
Standard anemometer:
Lite egnet for å måle turbulens.

Hvorfor?

Ultralyd anemometer. Måler 3-D vind- og temperaturfluktuasjoner med høy frekvens.

Måler Dopplerforskyvning i 3-D med høy frekvens (≈100 Hz)

➔ kan beregne 3-D vind og temperatur med høy frekvens.


16 m
1°
4 m
2 m
0.5 m
Temperature
0
30
60
90
Time (s)

Samvariasjon mellom ulike variable i turbulensen (27 meter over bakken)

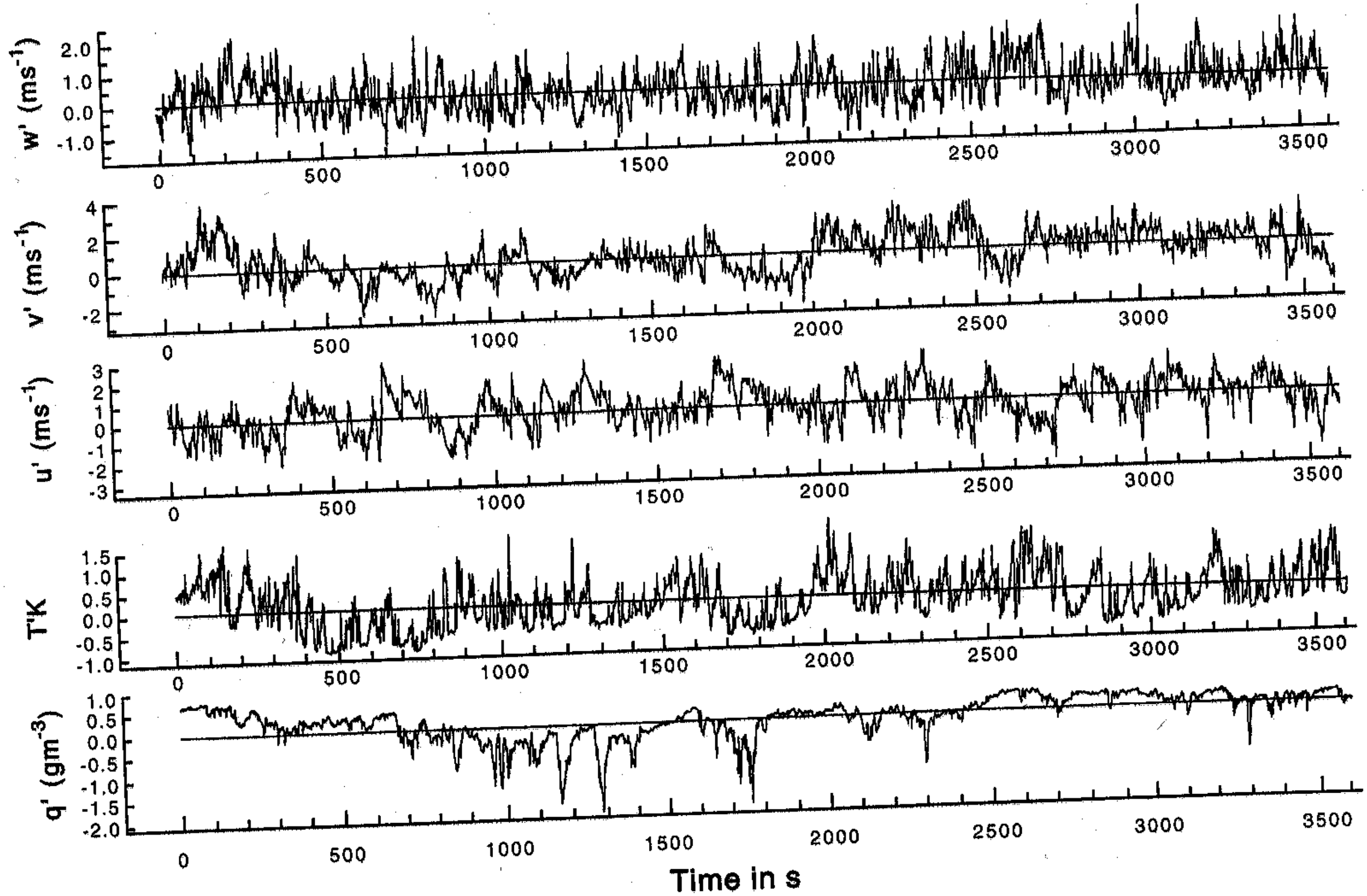
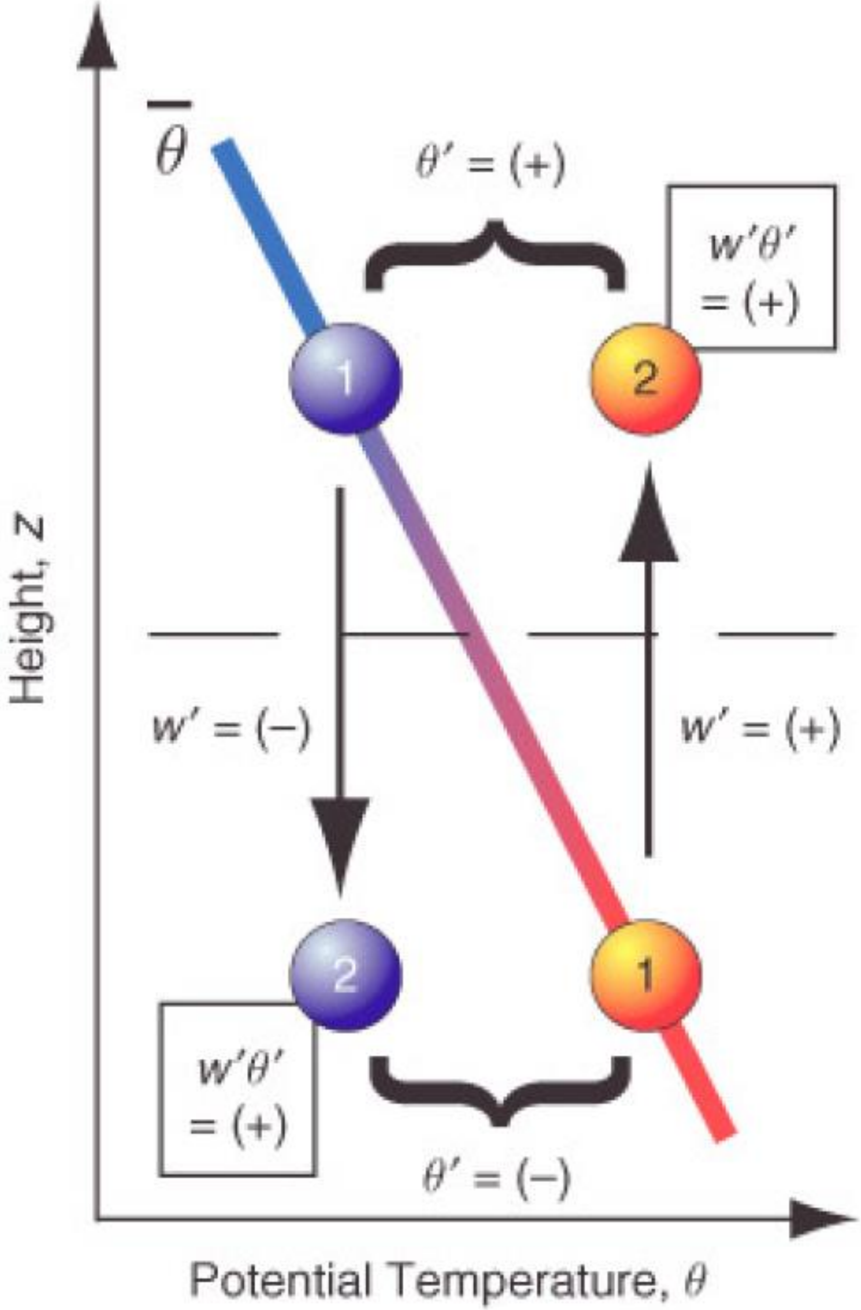
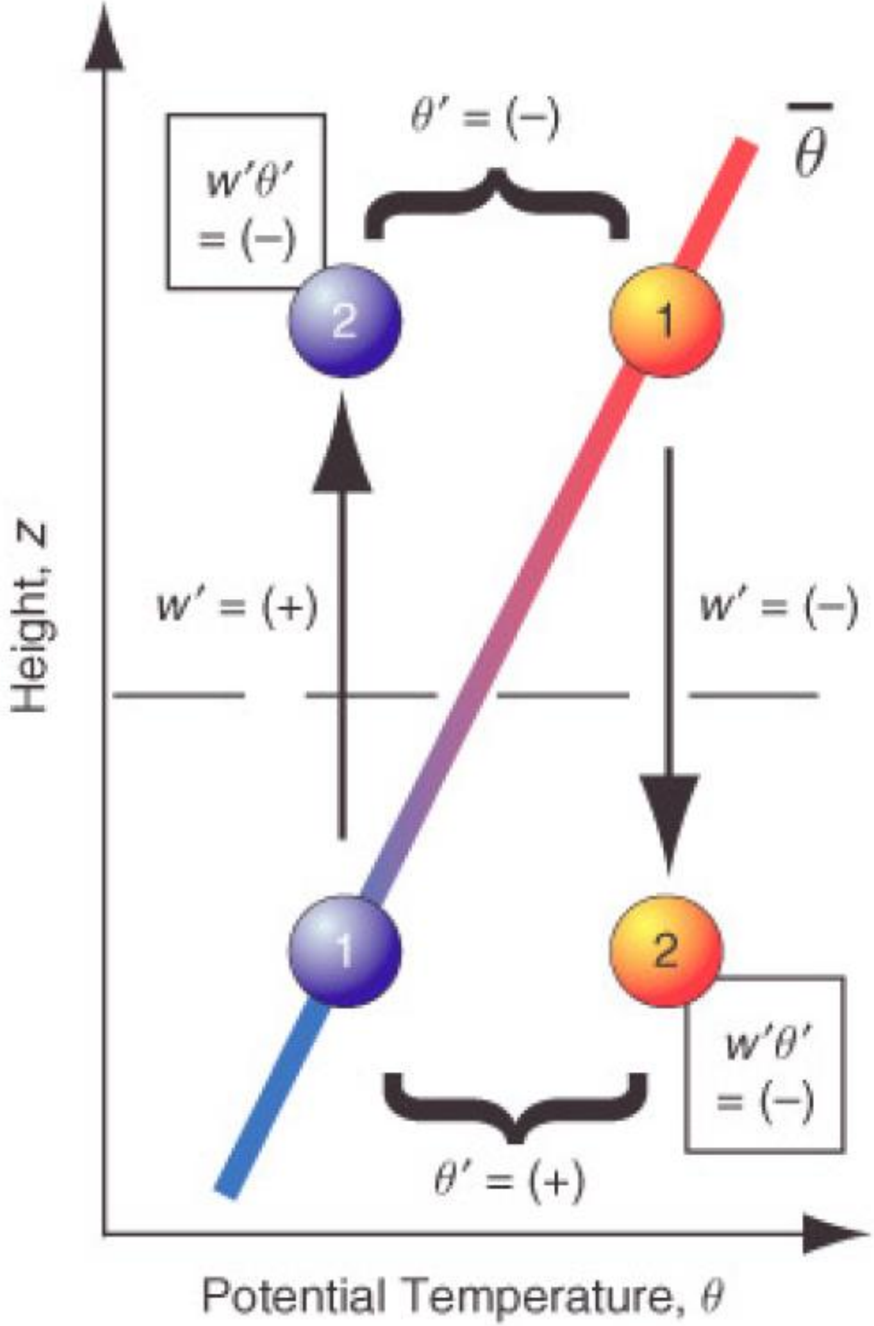


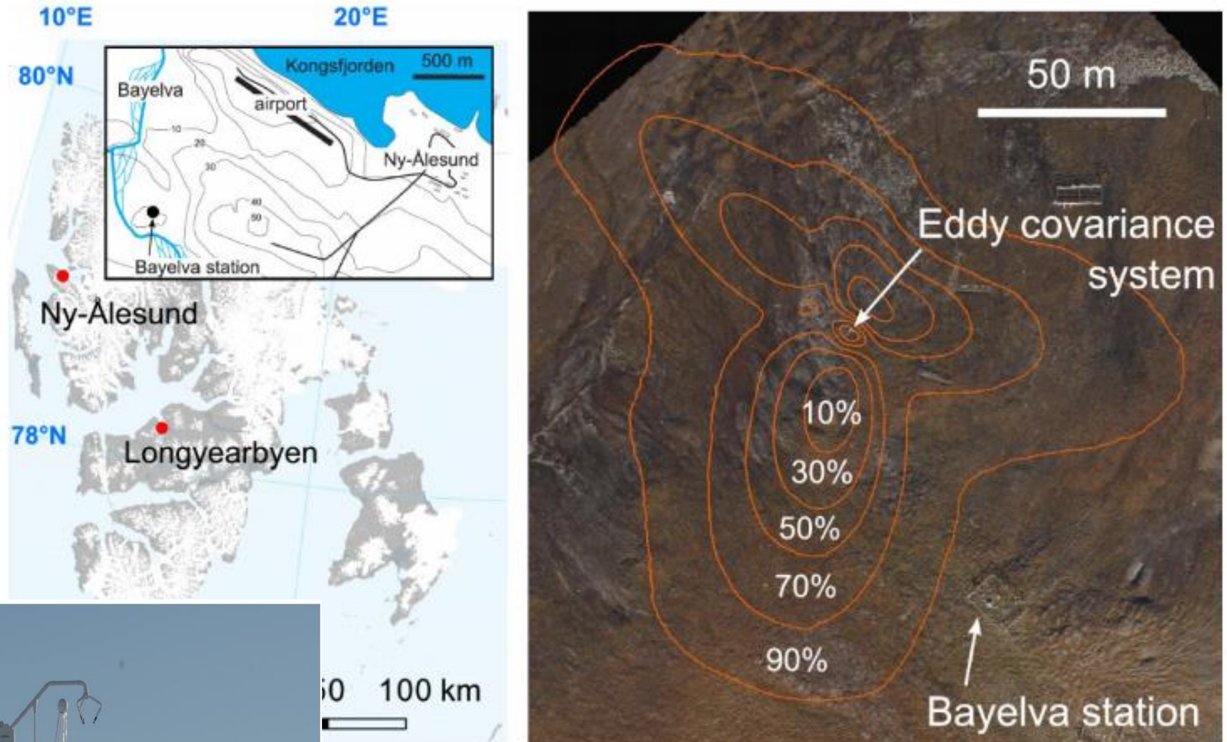
Figure 4.7 Measured time series of velocity, temperature, and absolute humidity fluctuations at a suburban site in Vancouver, Canada, during moderately unstable conditions. From Roth, 1990.



(a) Statically unstable: $\partial\overline{\theta}/\partial z < 0$.

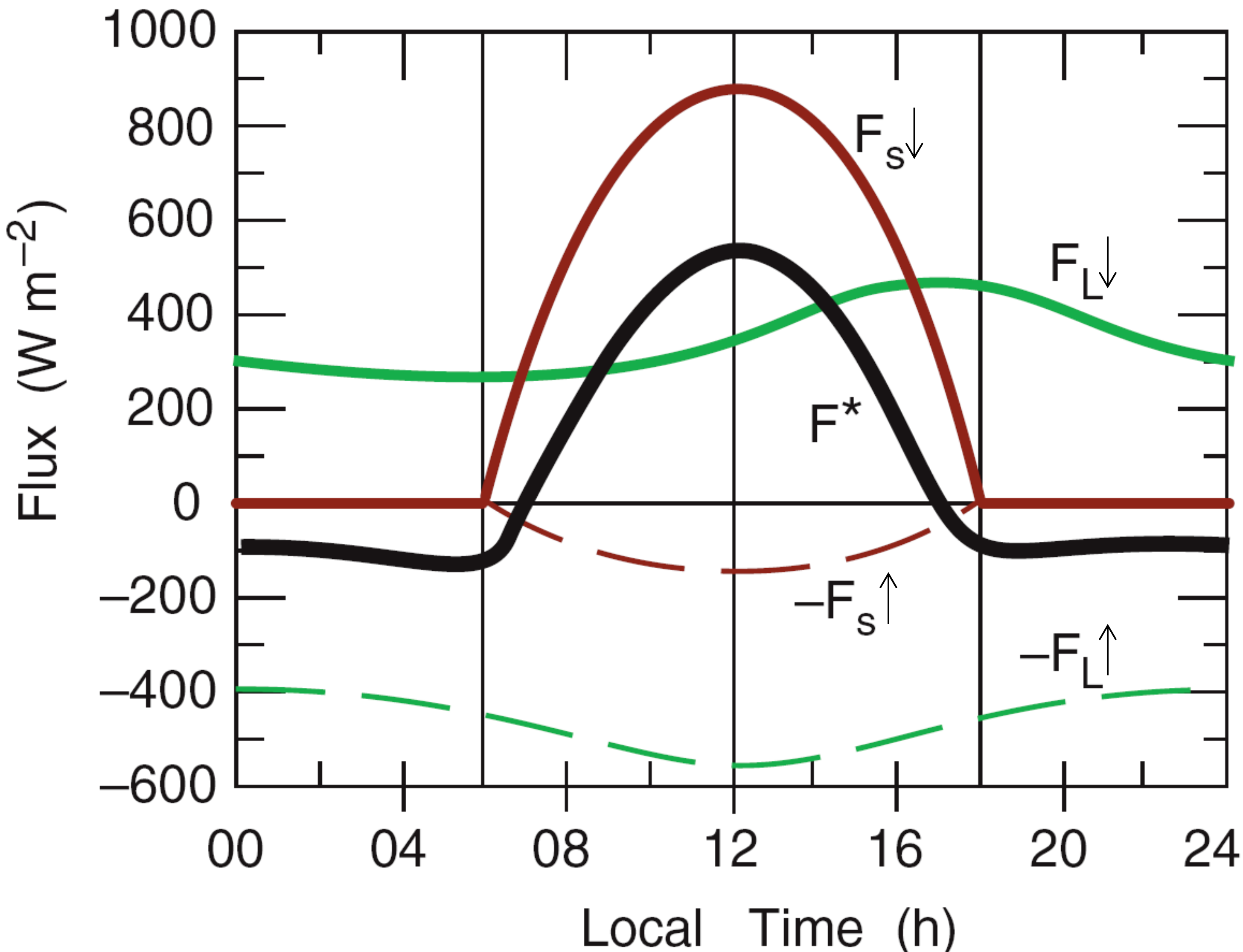


(b) Statically stable: $\partial\bar{\theta}/\partial z > 0$.

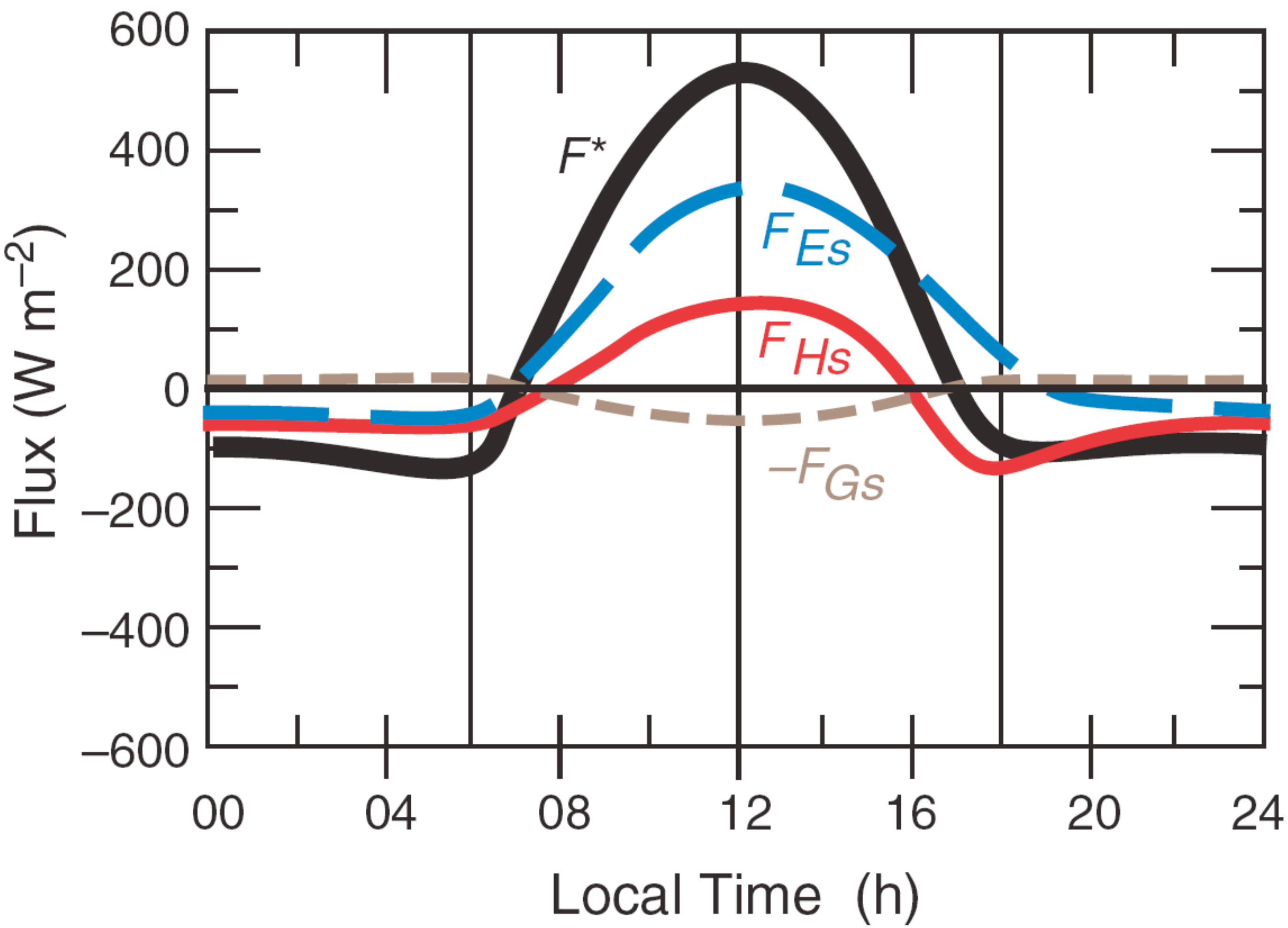


e system with a cumulative flux footprint (orange contours) depicted in the right panel. Leirhau-
intercepting the Bayelva climate station in the small left panel. Figure from Lüers et al. *(2014)*
in Westermann et al. *(2009).*

Eksempel på strålingsflukser til og fra bakken



Energiflukser til og fra bakkeoverflaten



F_{Es} : Latent varme
F_{Hs} : Følbar varme
F_{Gs} : Varme ned i bakken

Energibalanse ved bakken: $F^{*} = F_{Hs} + F_{es} + F_{Gs}$

Under hvilke forhold er F_{Gs} stor?

Global energibalanse

PROGRESS ARTICLE

NATURE GEOSCIENCE DOI: 10.1038/NGEO1580

Box 1 | Updated energy balance

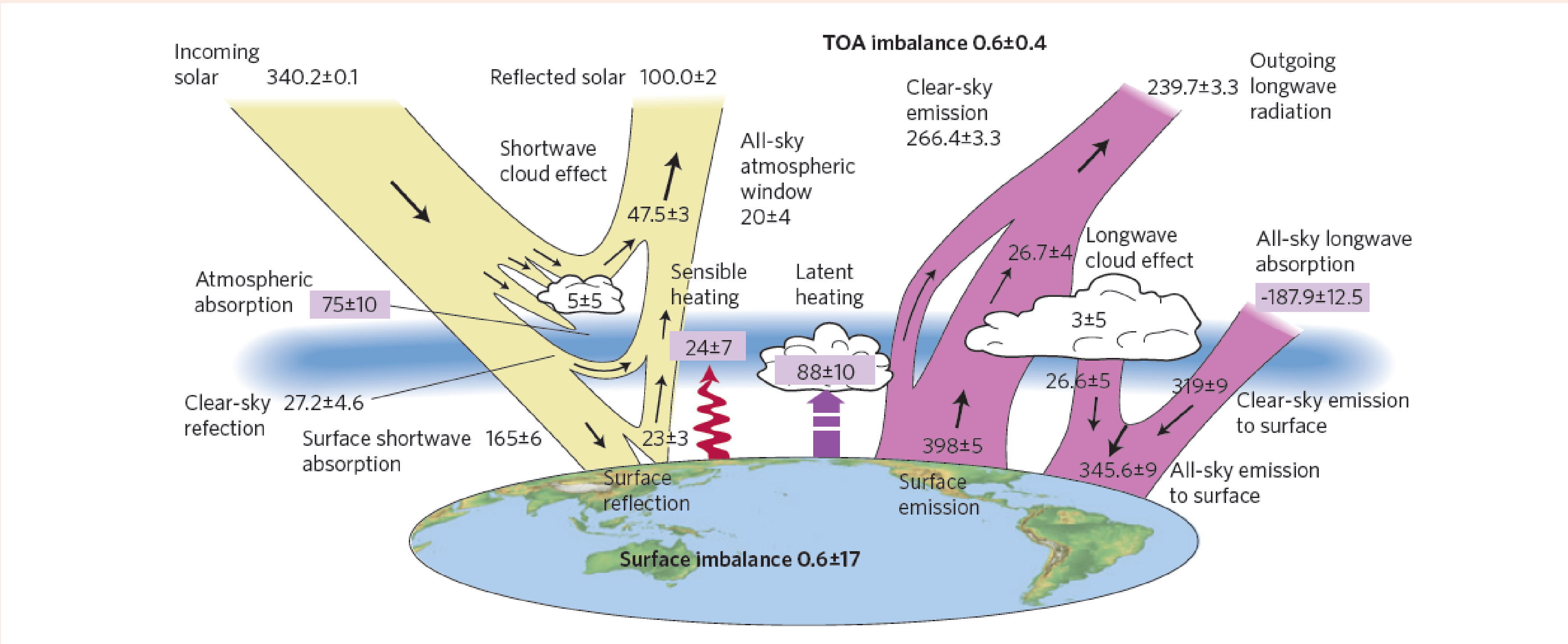
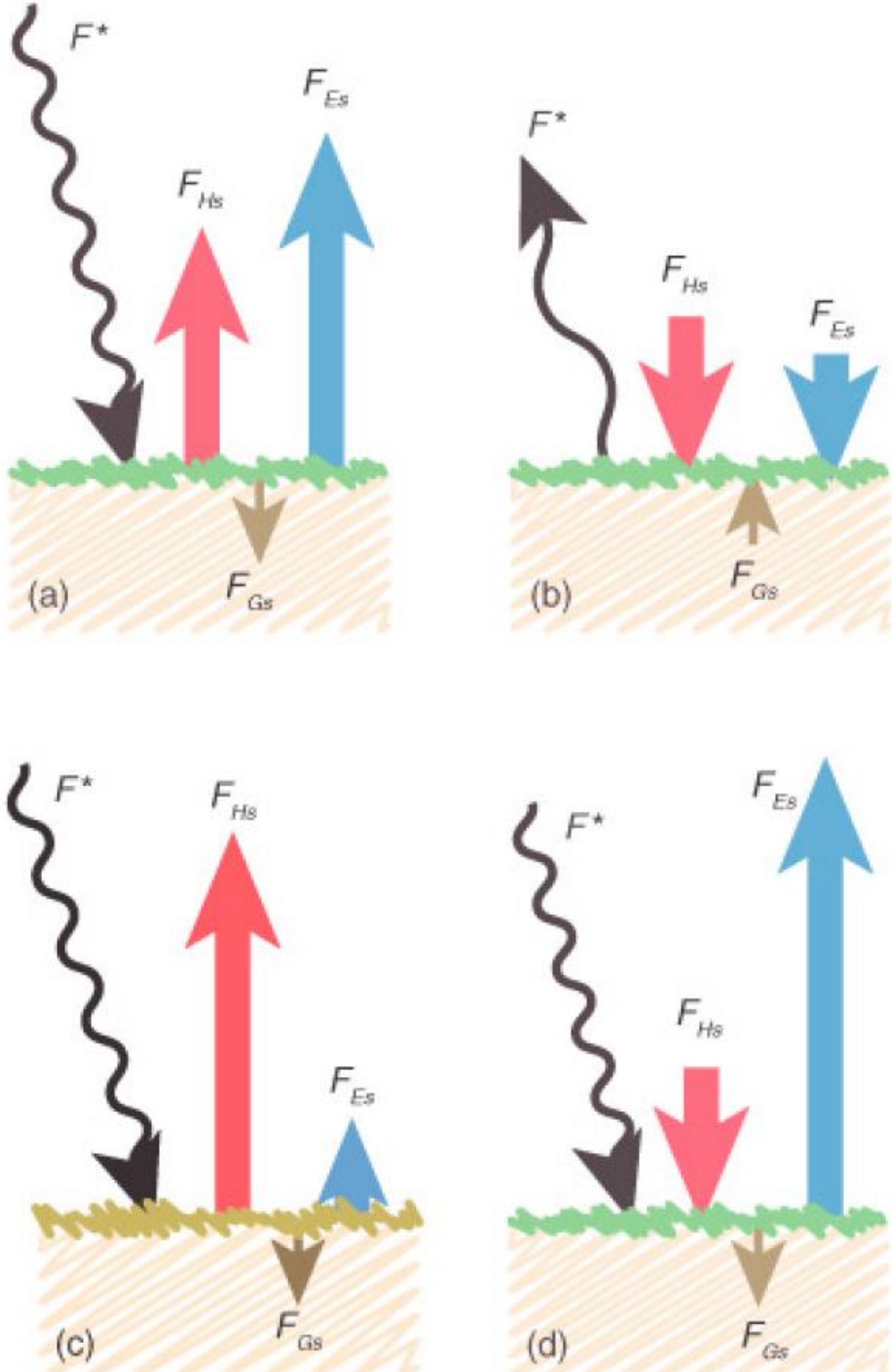


Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance.

Stephens et al., Nature Geos., 2012.

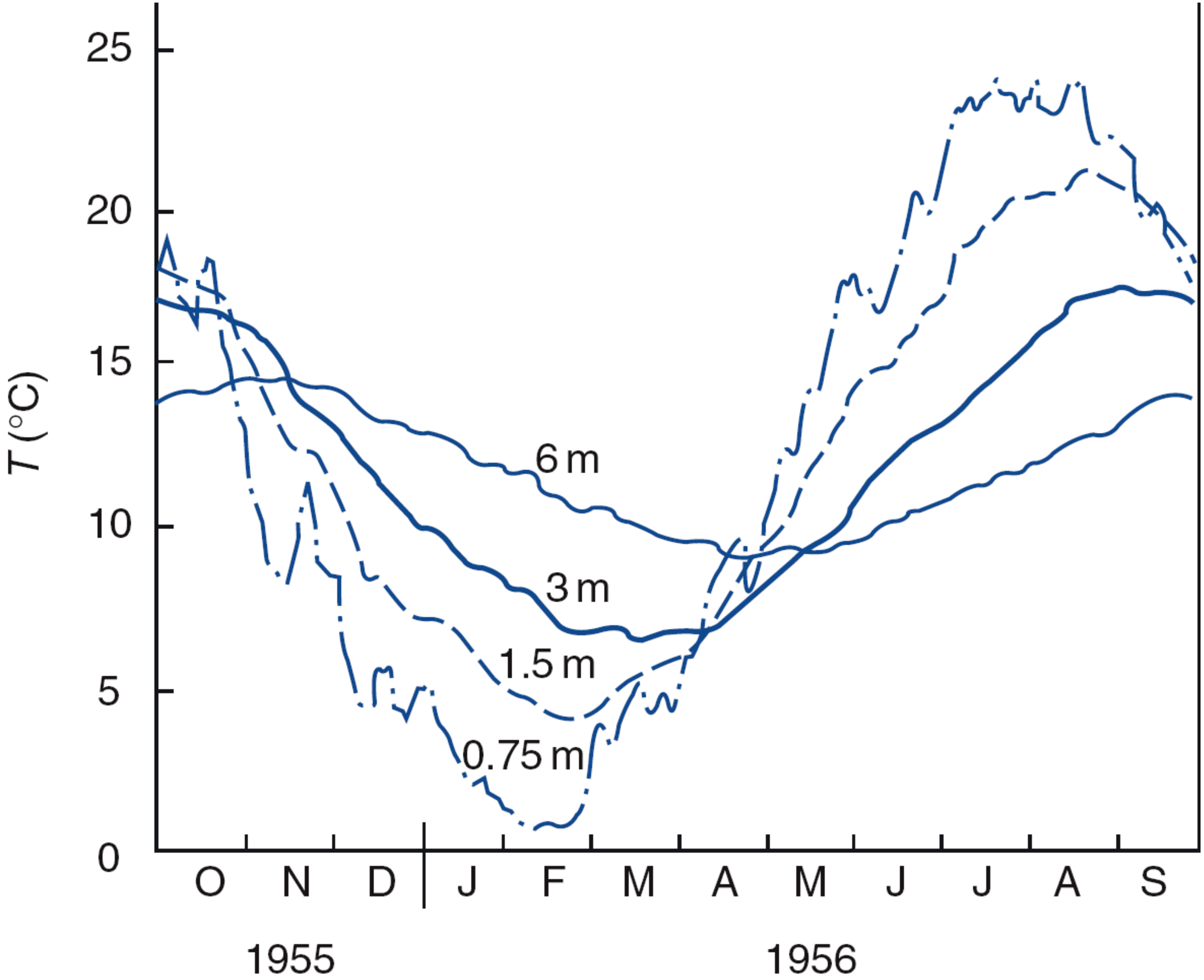


Hvilke forhold (tid og overflateforhold) som gir fluksene i a,b,c,og d

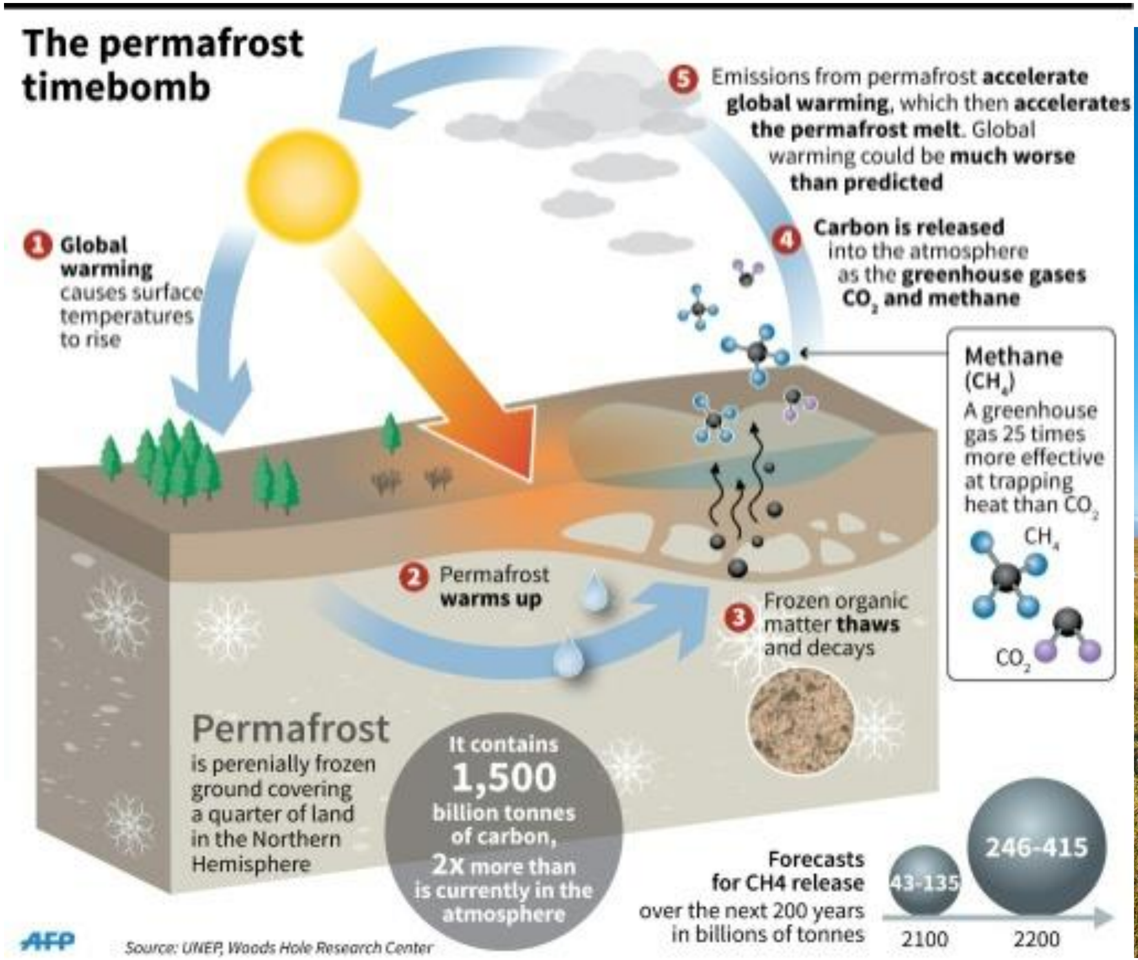
Bowen ratio: F_{Hs} / F_{es}

Tørr overflate: Høy Bowen ratio.

Temperaturvariasjon nedover i bakken.



Permafrost som tiner ➔ metanutslipp?



http://eesa.lbl.gov/spring-thaw-arctic-generates-pulses-co2-ch4-emissions/

Ultralyd anemometer. Måler 3-D vind- og temperaturfluktuasjoner med høy frekvens.

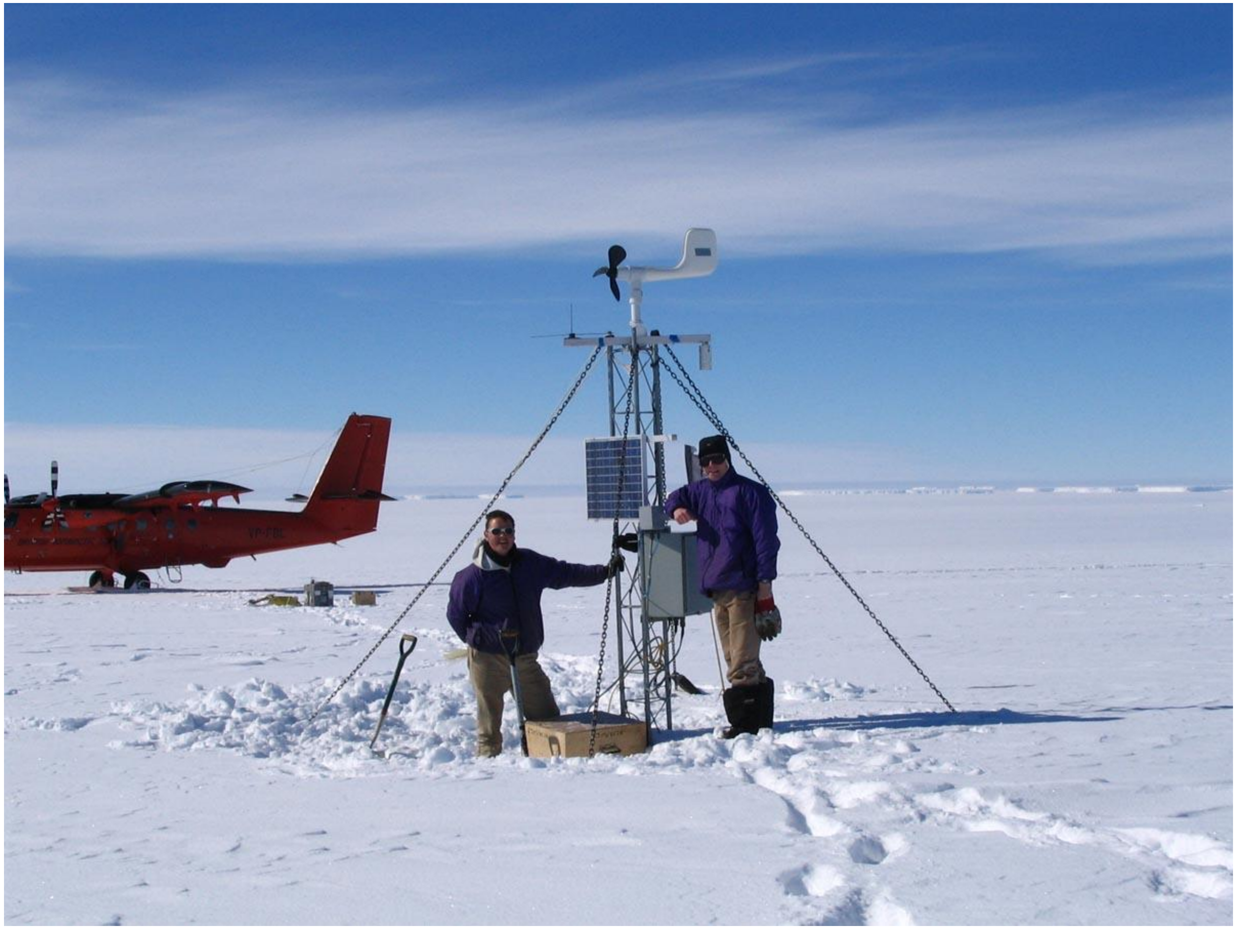
- ➔ Kan beregne turbulente flukser direkte ($\overline{w'\theta'}$)
- ➔ m/tilleggsutstyr : Også flukser av vann og sporstoffer

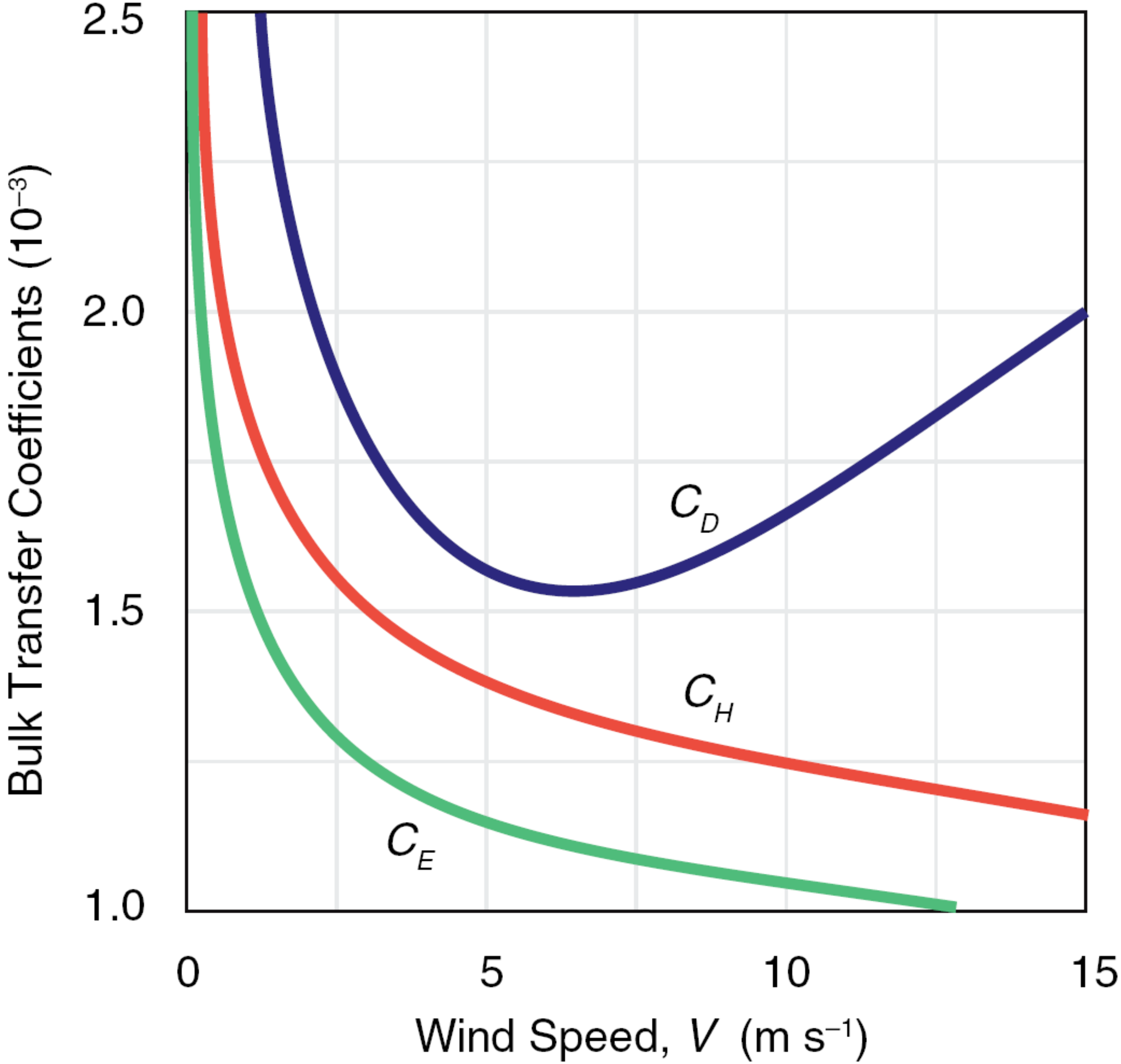
Alternativ: Automatiske værstasjon (jfr. Finse)

Gir (2m)

- Temperatur
- Vind (styrke og retning)
- Fuktighet

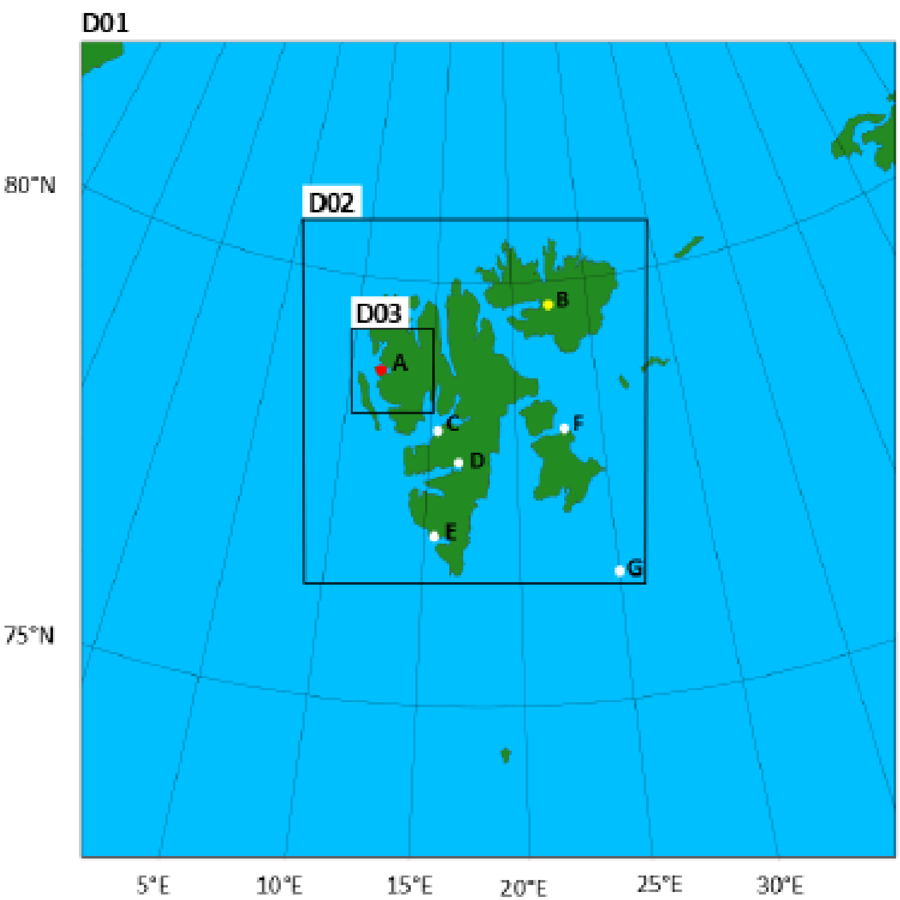
➔ Bruker bulk-formler for beregning av turbulente flukser





2.5
2.0
1.5
1.0
Bulk Transfer Coefficients (10^{-3})
C_D
C_H
C_E
0
5
10
15
Wind Speed, V (m s^{-1})

Kan vi bruke en værvarslingsmodell (her WRF) for å beregne energifluksene ved bakken (slik at de blir brukbare for f.eks. prediksjon av permafrost)?



G. 1. Map of WRF-domains with 9x9 km resolution (D01), 3x3 km resolution (D02)

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A Comparison between Simulated and Observed Surface Energy Balance at the Svalbard Archipelago

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Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany

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Department of Geosciences, University of Oslo, Oslo, Norway

(Manuscript received 26 March 2014, in final form 8 December 2014)

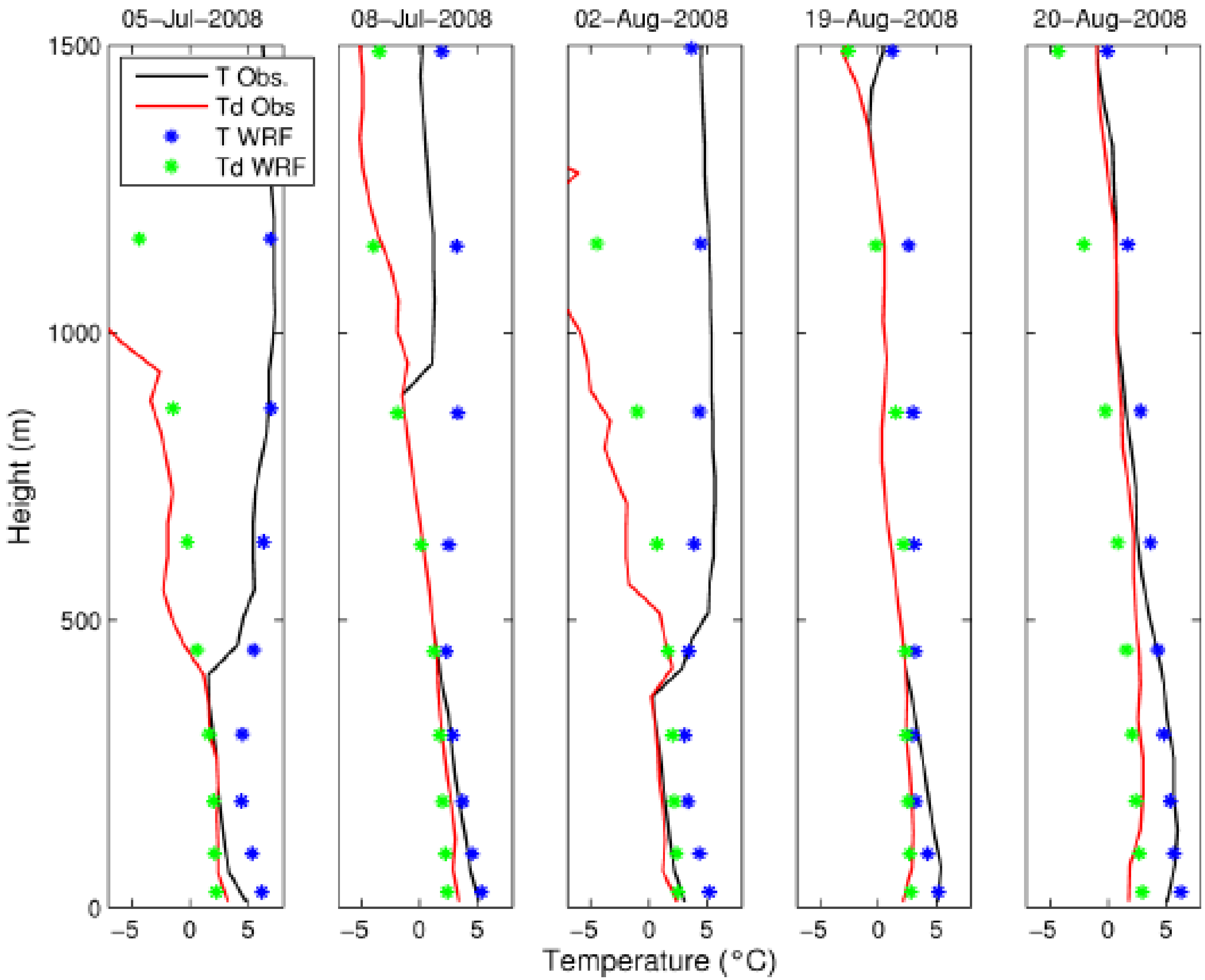


FIG. 3. Simulated temperature (blue *) and dew point temperature (green *) profiles for the five days with the highest LW_{in} bias during summer, together with corresponding profiles from radiosounding (solid lines) at Ny-Ålesund.

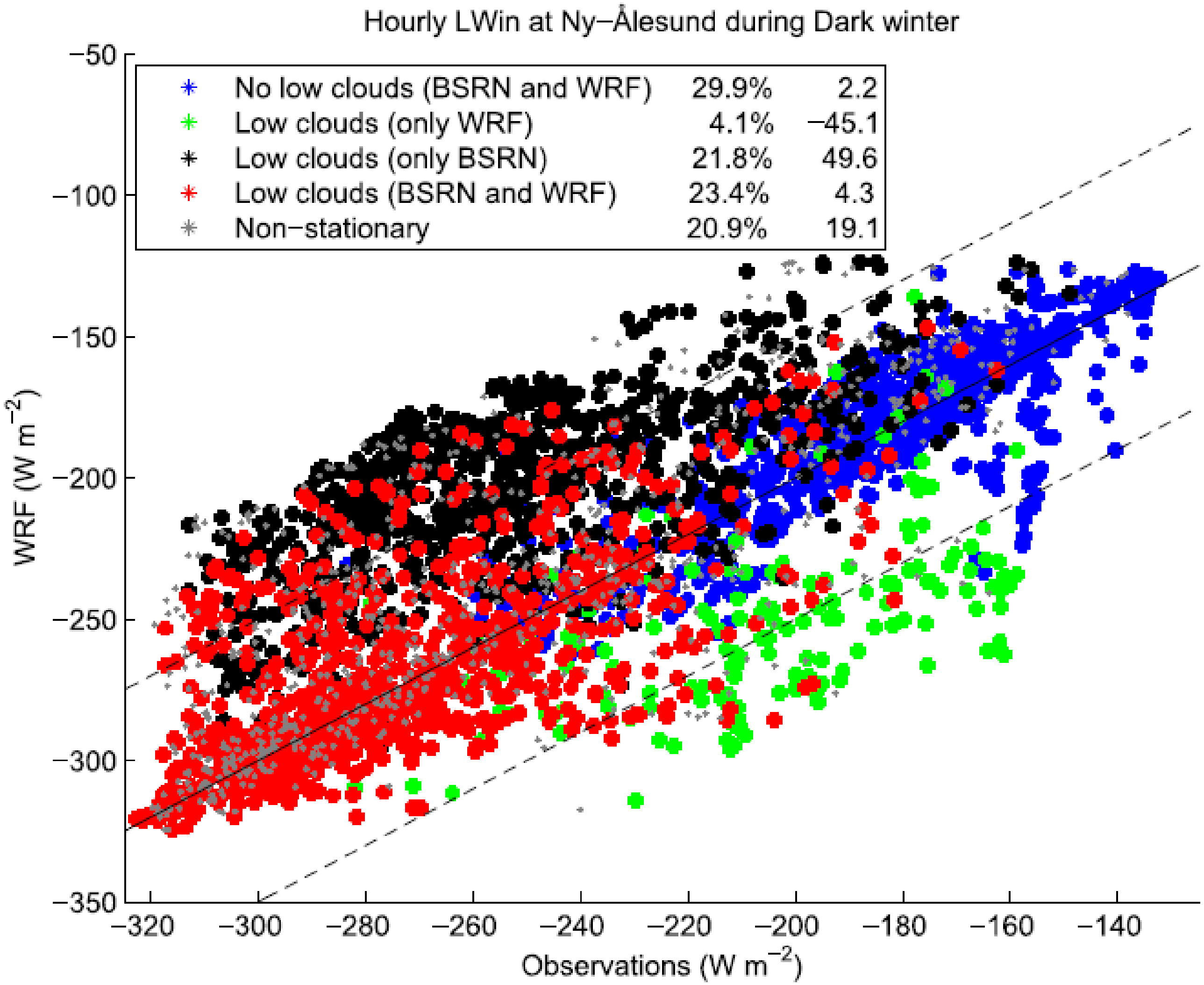


FIG. 6. Hourly observed and simulated LW_{in} ($W\,m^{-2}$) at Ny-Ålesund during dark winter period, with colors indicating the presence of low clouds (<3 km) according to ceilometer measurements (black), model (green), both measurements and model (red), or no low clouds in model or measurements (blue). Gray dots show data that are excluded because of nonstationary conditions in the ceilometer data. Frequency and average bias for each subset of data are given in the label. Clouds in the model are here defined as at least one layer having total condensed water content (cloud and precipitation) of more than $10\,mg\,m^{-3}$. Solid and dashed lines show the 1:1 line and $\pm 50\,W\,m^{-2}$, respectively.

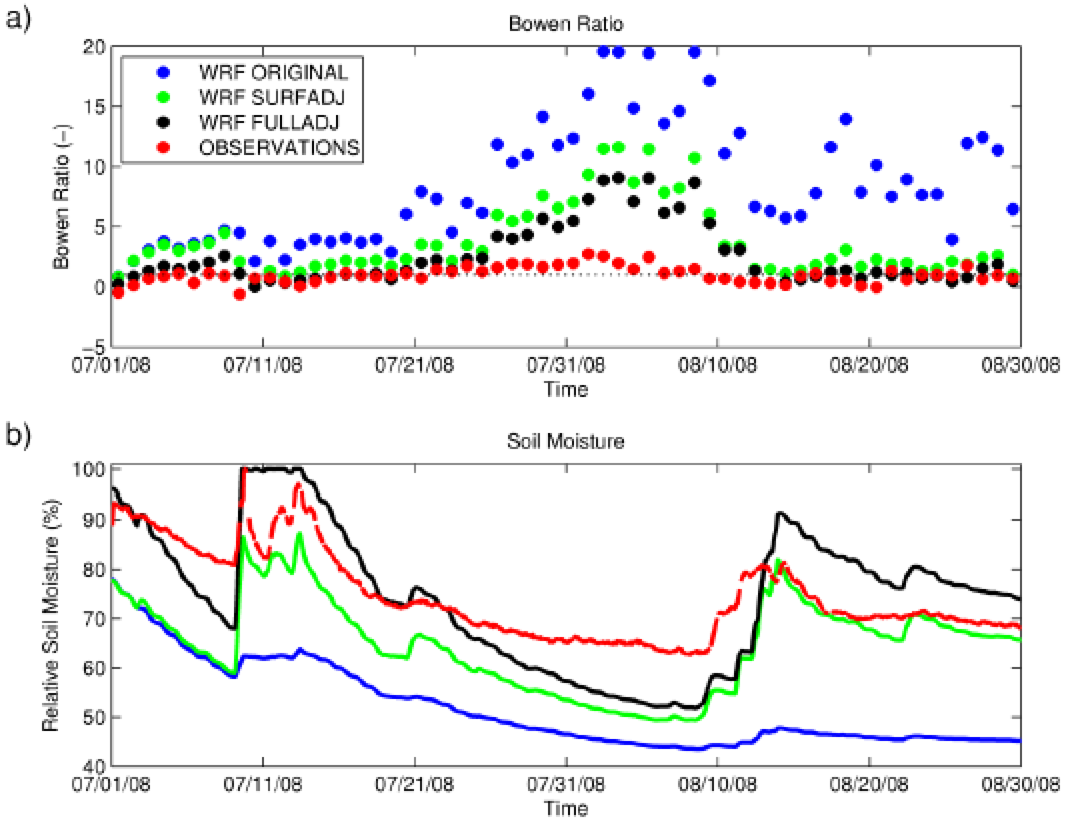


FIG. 4. a) Simulated and observed daily averaged BR and b) soil moisture relative to saturation at 0.05m depth in Bayelva for the entire summer period (July and August) from original WRF simulation (blue), modified surface runoff simulation (green), modified surface and underground runoff simulation (black) and observations (red). Saturation soil moisture in observations is assumed to be maximum measured value in this period.

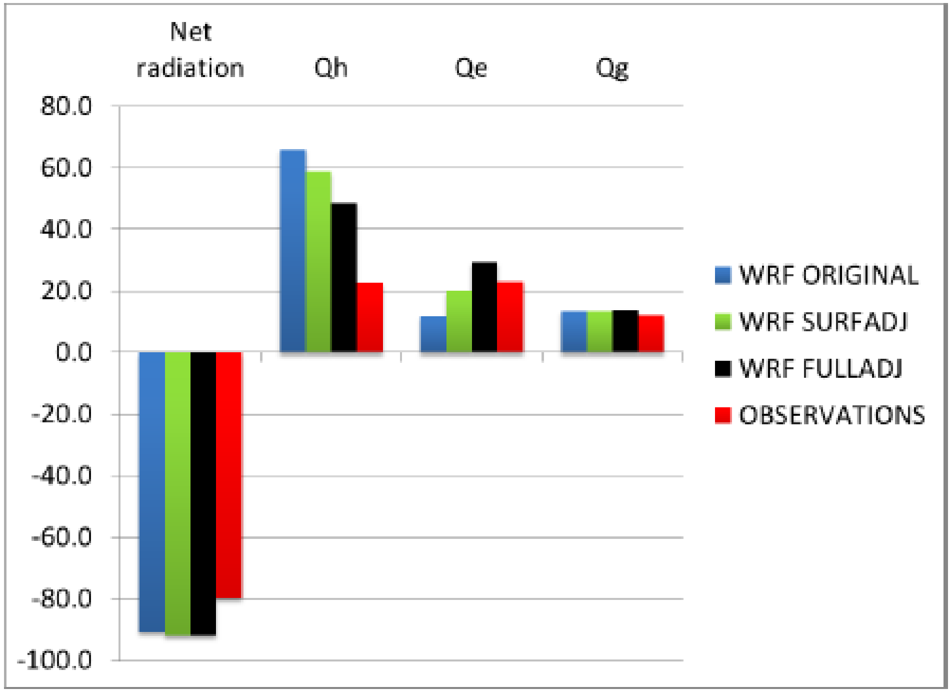


FIG. 5. Average SEB (W m^{-2}) during the summer period (July and August) from the original WRF model (blue), modified surface runoff simulation (green), modified surface and underground runoff simulation (black) and measurements (red).

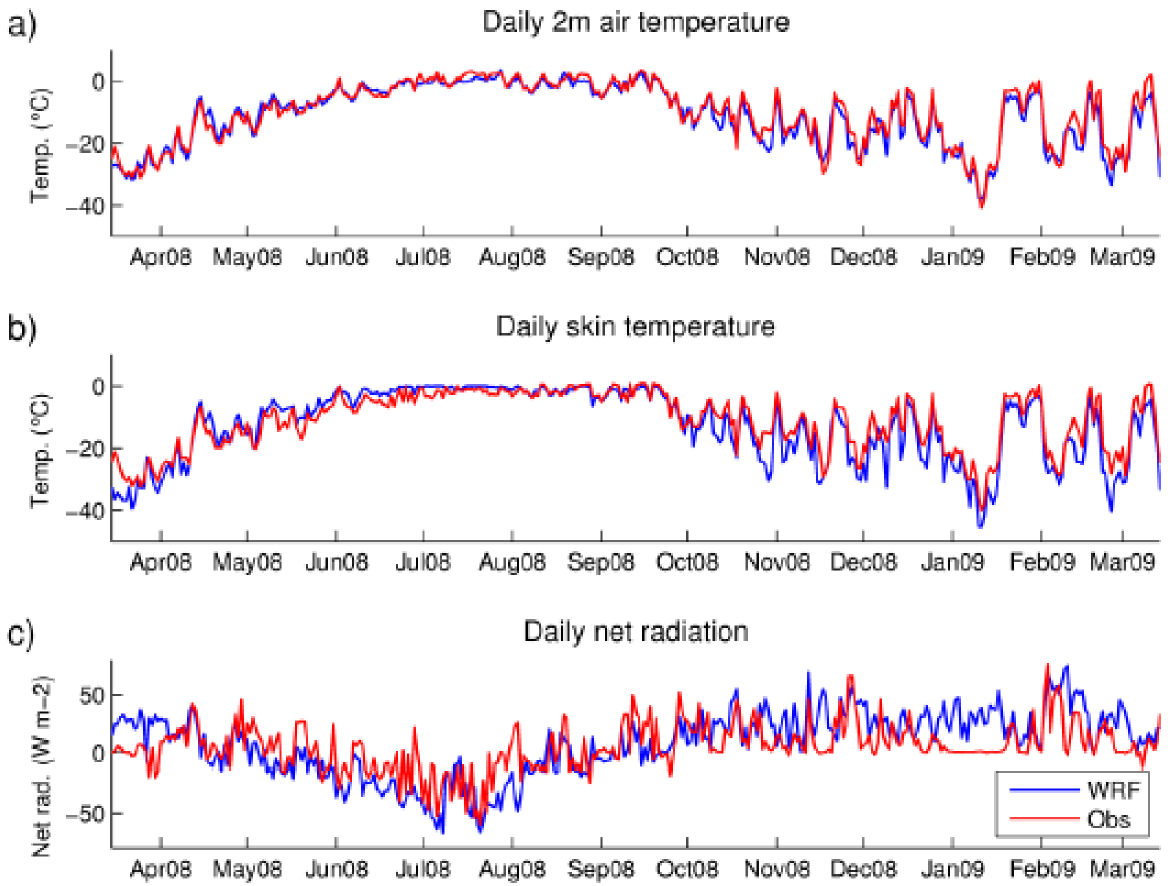
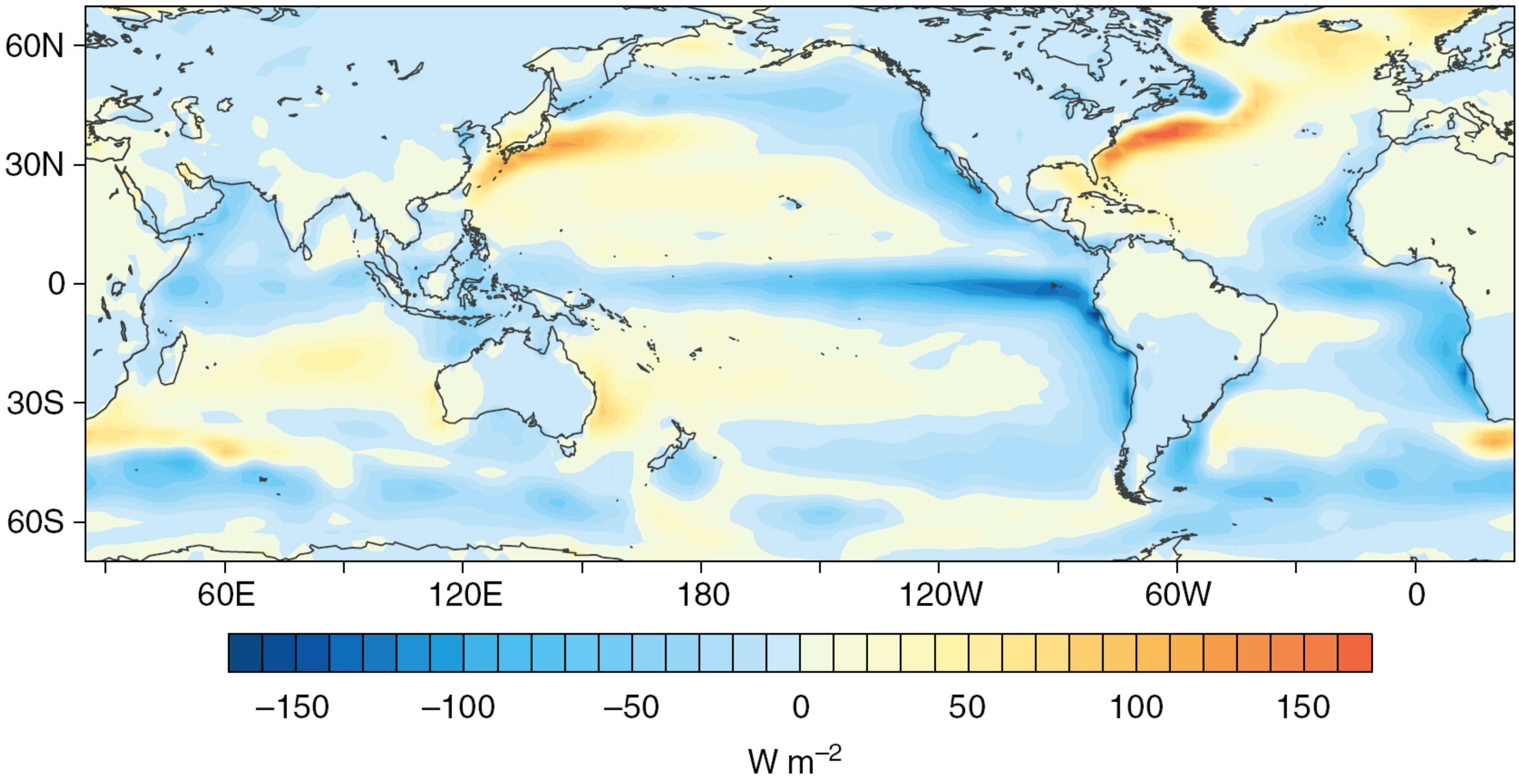
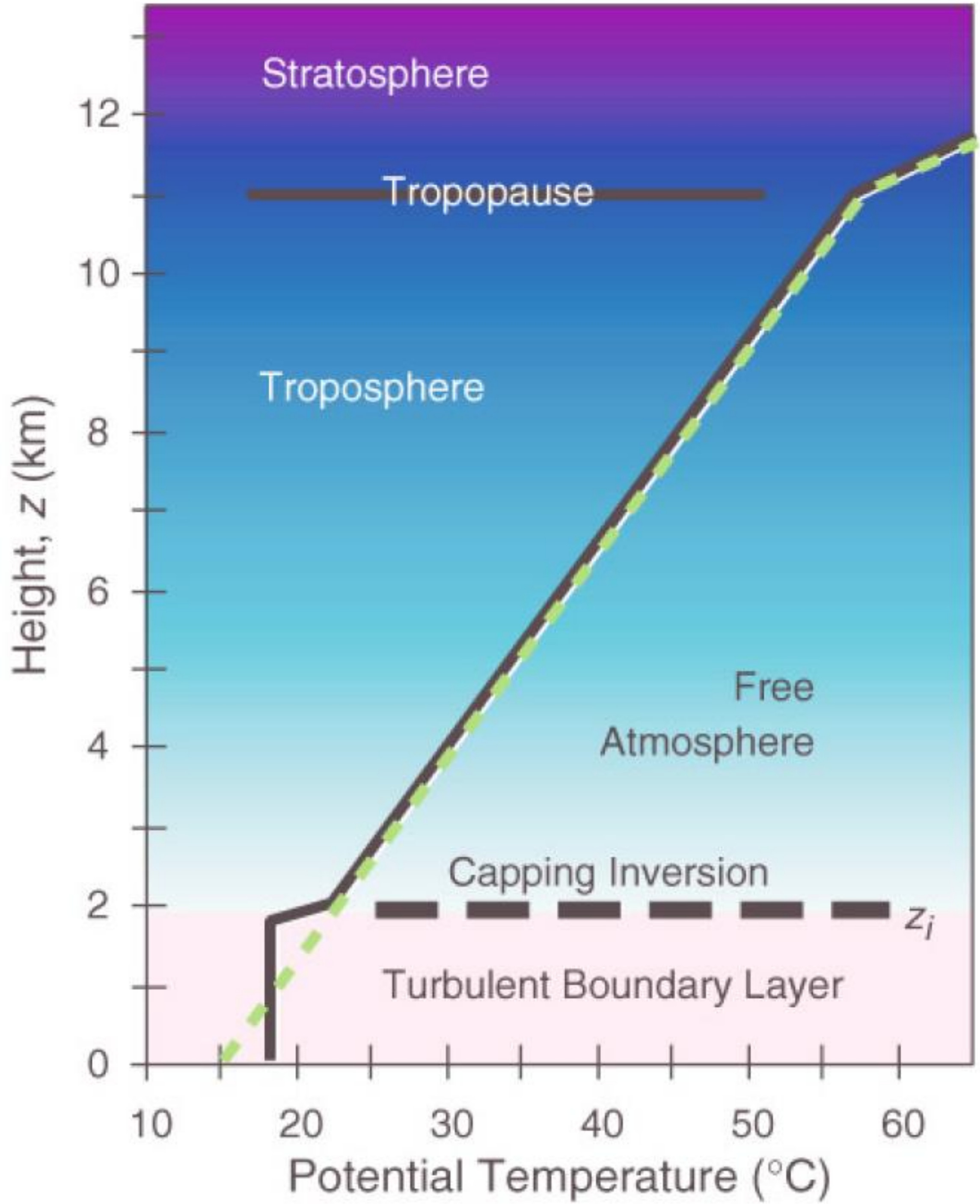


FIG. 9. Simulated (blue) and observed (red) daily averaged a) 2m air temperature (b) skin temperature and c) net radiation at Austfonna AWS for the entire simulation period.

Netto oppoverrettet energifluks ved bakken

Basert på re-analyser fra ECMWF 1958-2001



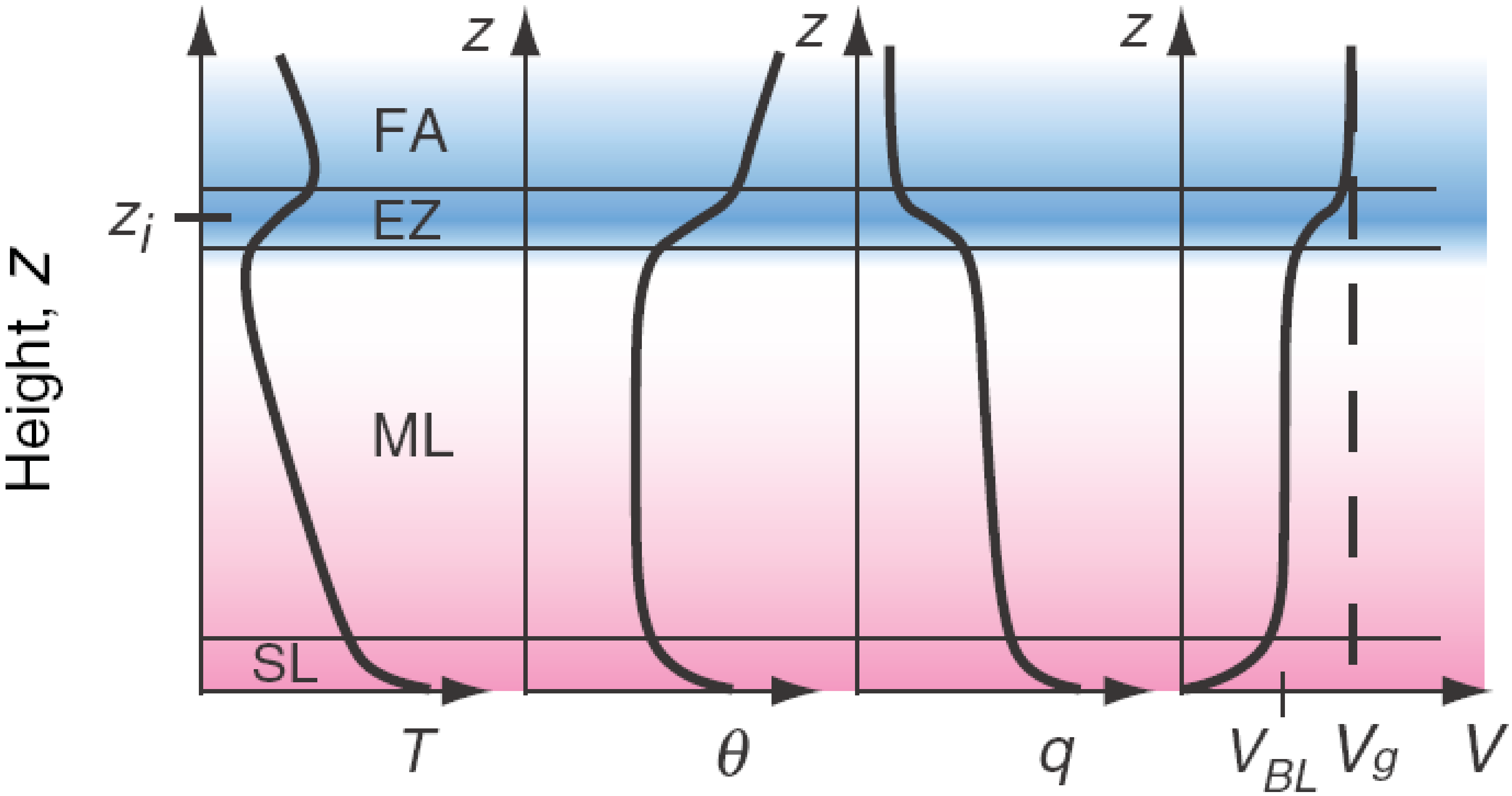

Stratosphere
Tropopause
Troposphere
Free
Atmosphere
Capping Inversion
z_i
Turbulent Boundary Layer
Height, z (km)
0
2
4
6
8
10
12
10
20
30
40
50
60
Potential Temperature (°C)

FA: Free Atmosphere

ML: Mixed Layer

EZ: Entrainment Zone

SL: Surface Layer



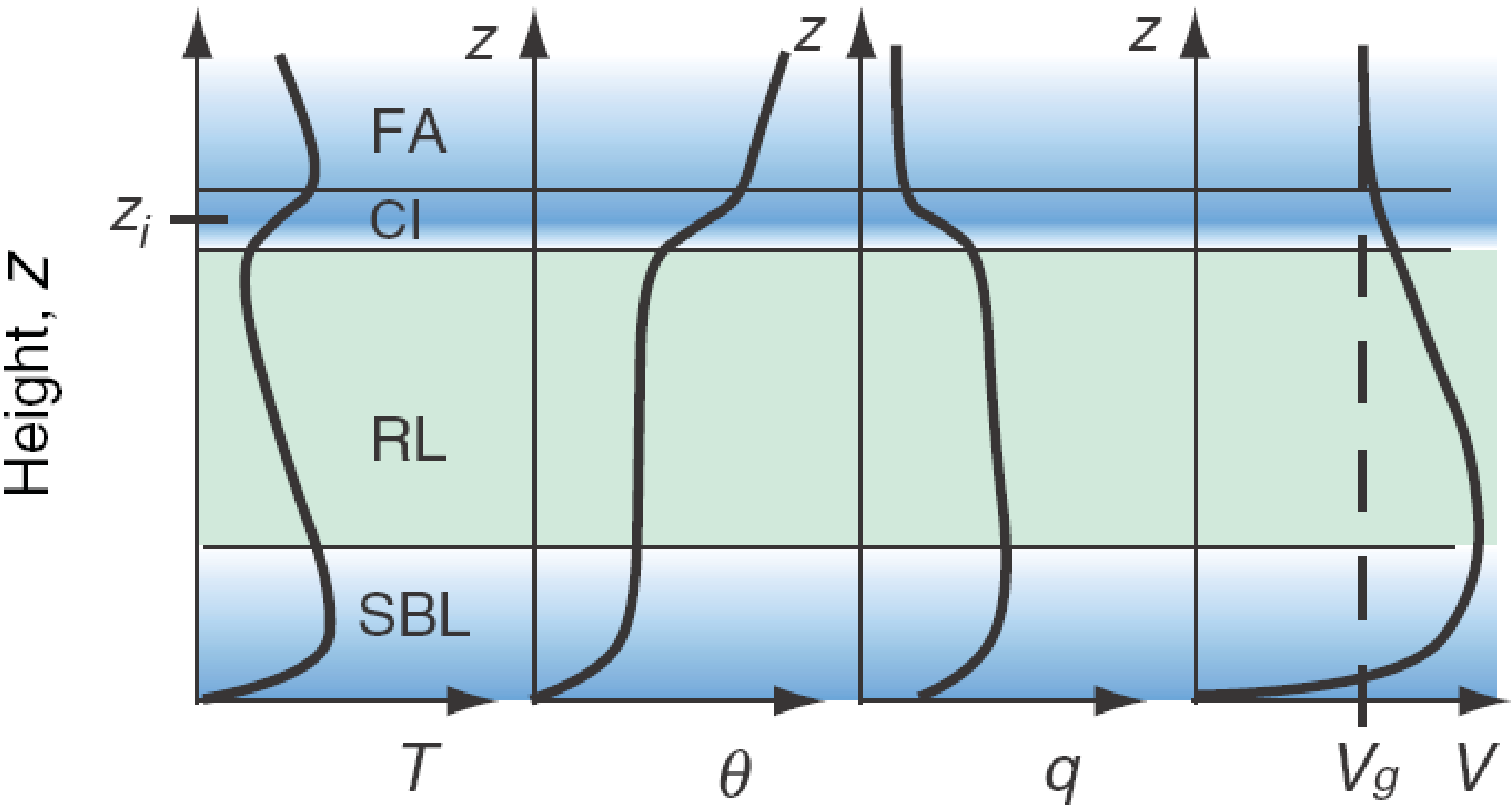
(a) DAY

FA: Free Atmosphere

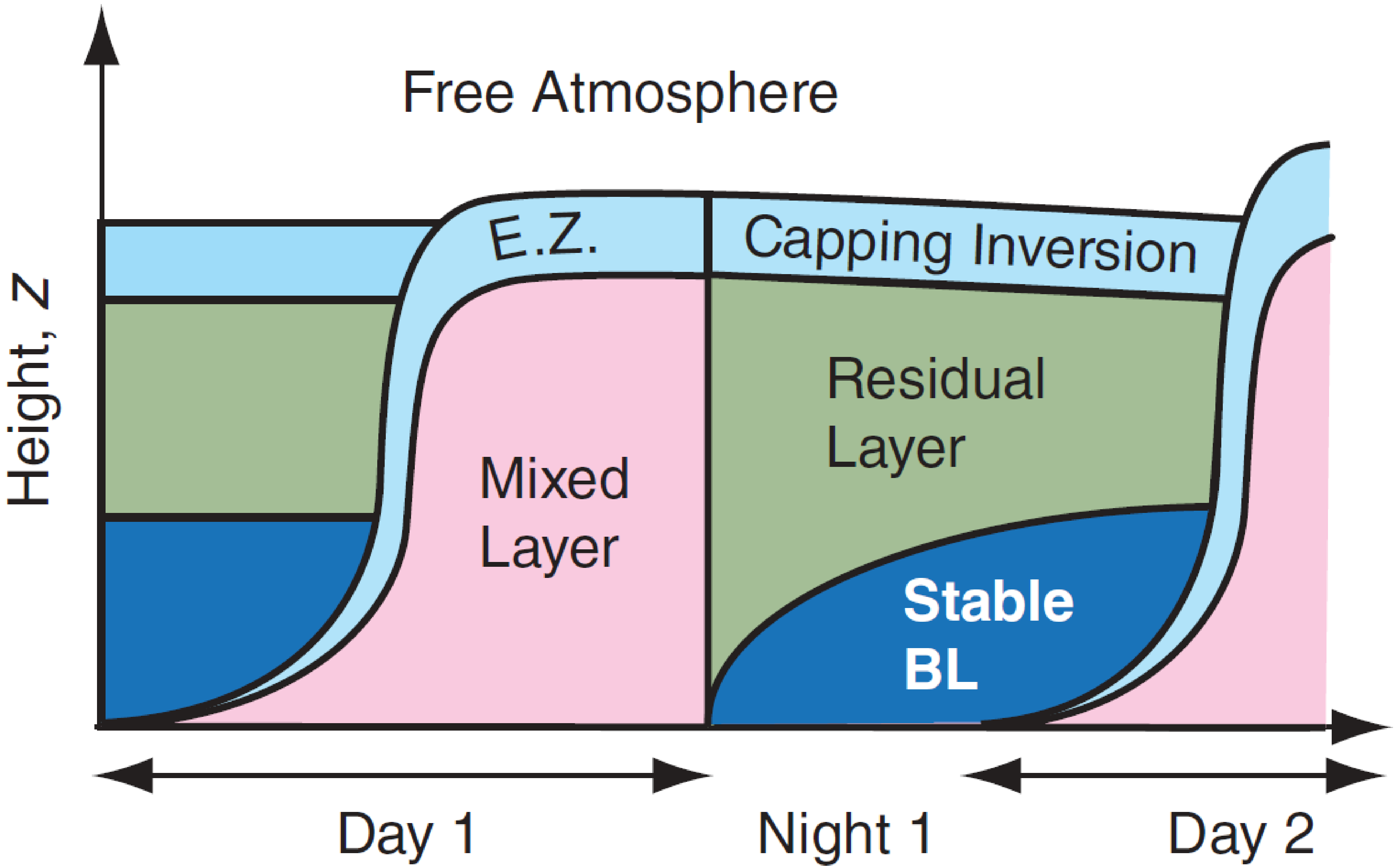
RL: Residual Layer

CI: Capping Inversion

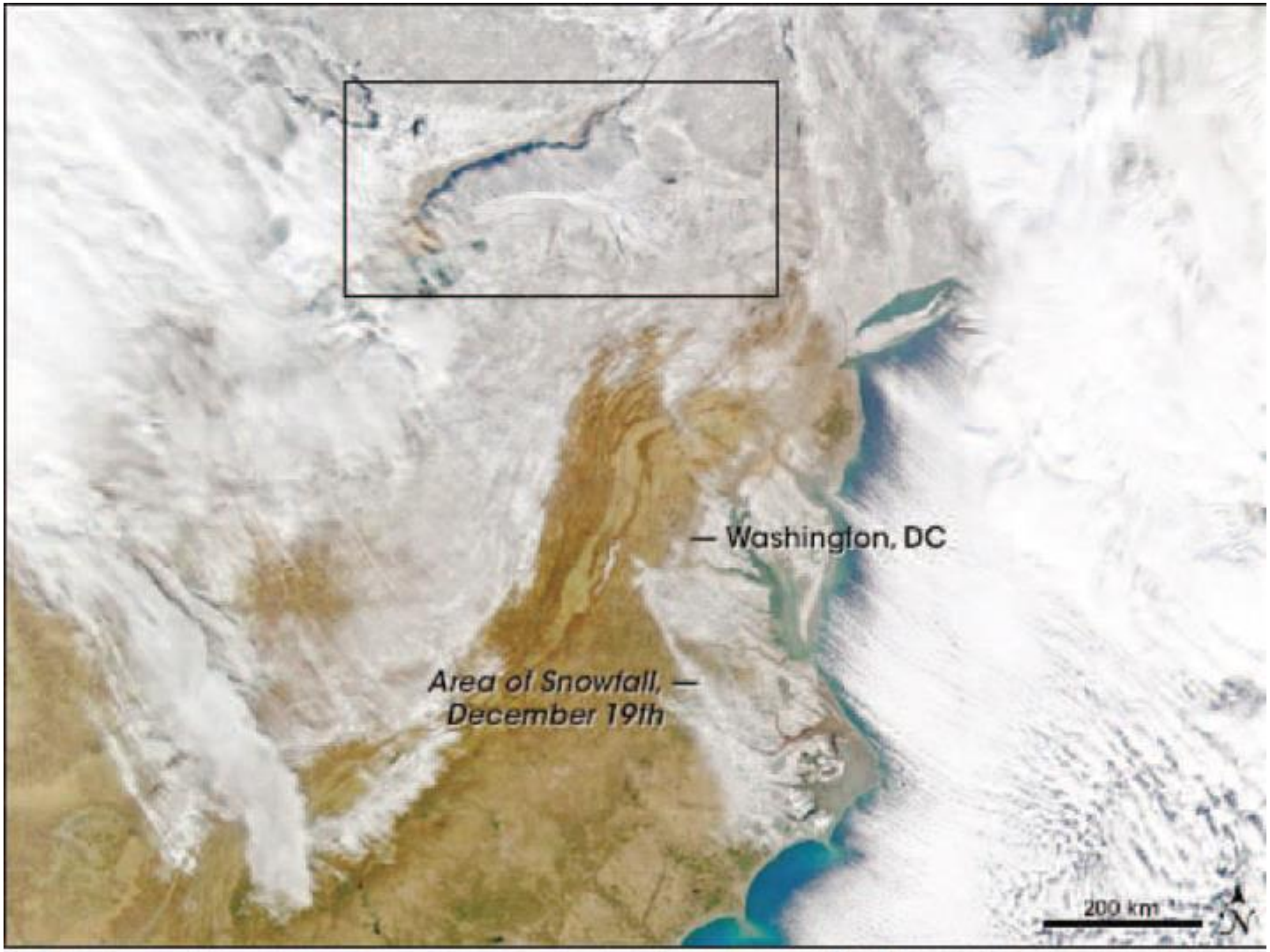
SL: Stable Boundary Layer



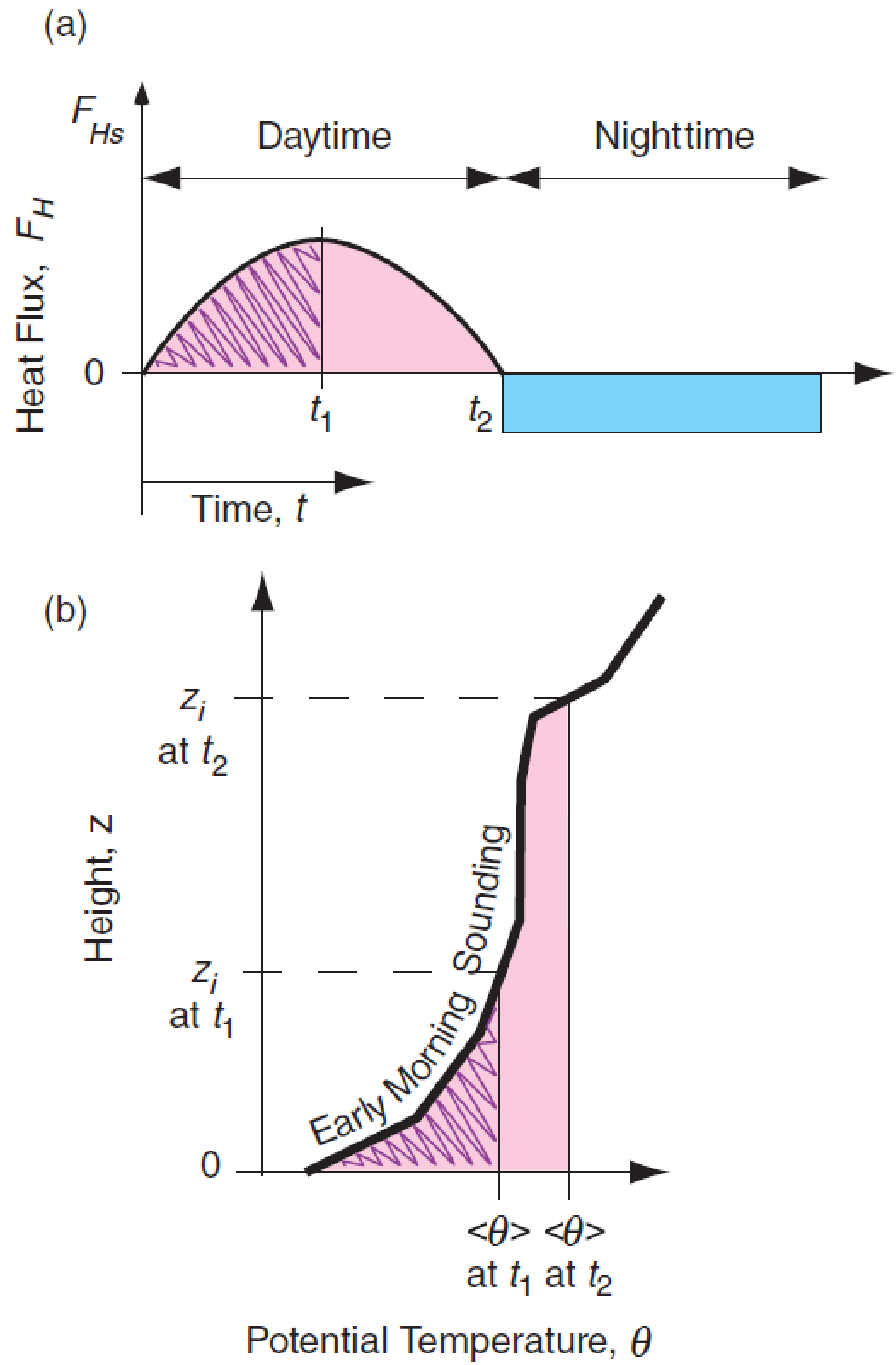
(b) NIGHT


Free Atmosphere
Height, Z
E.Z.
Capping Inversion
Residual
Layer
Mixed
Layer
Stable
BL
Day 1
Night 1
Day 2

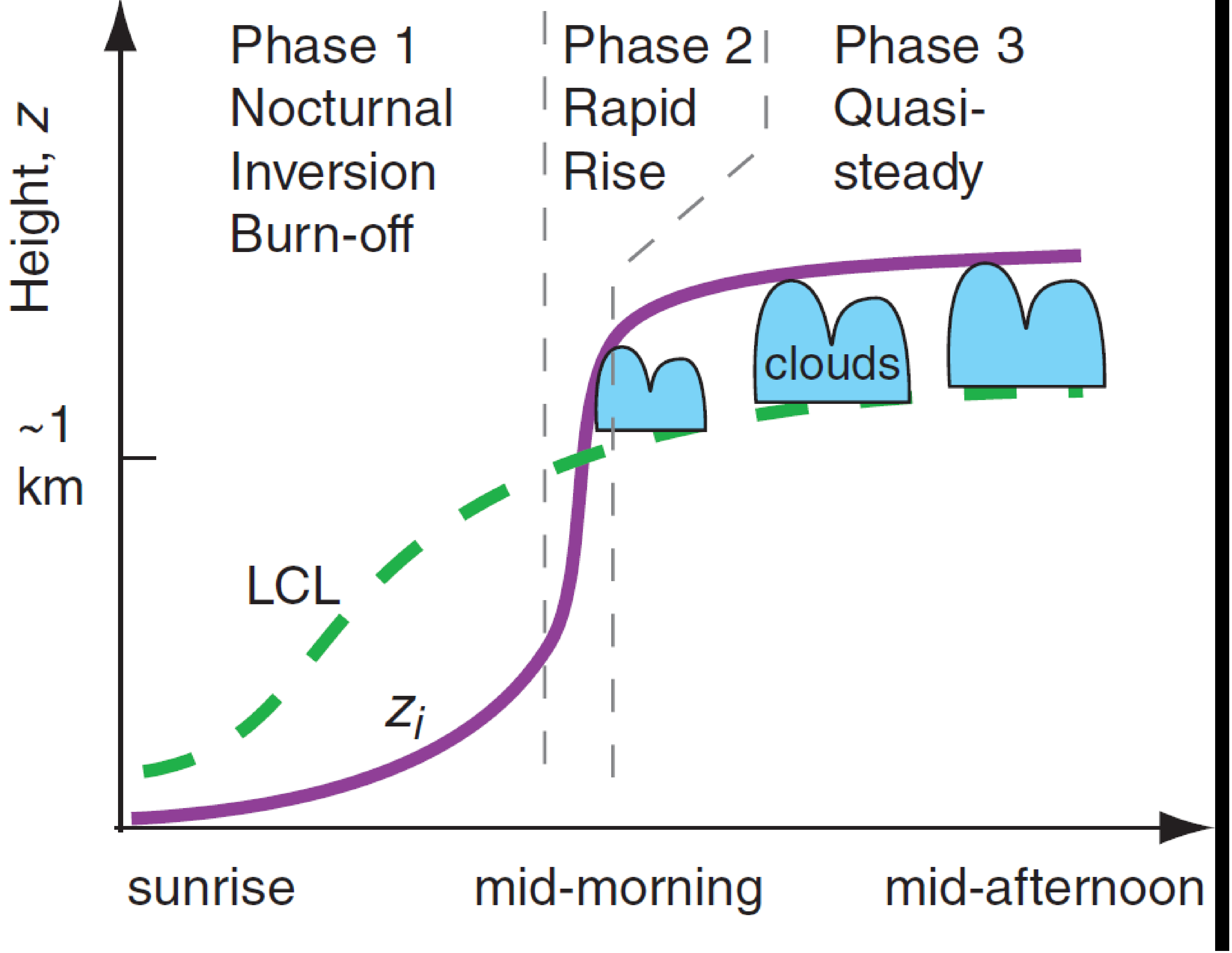
Overflateflukser ➔ Ekstremvær



- Kald arktisk luft fra NV ut over isfri Lake Ontario
- Kraftig fluks av følbar og latent varme fra sjøen til atmosfæren
- ”Skygater” dannes parallelt med vinden ➔ mesoskala nedbørsystemer
- Kraftig snøfall: Mer enn 1 meter med snø



(a)
F_{Hs}
Daytime
Nighttime
Heat Flux, F_H
0
t_1
t_2
Time, t
(b)
z_i at t_2
Height, z
Early Morning Sounding
z_i at t_1
0
<θ> at t_1
<θ> at t_2
Potential Temperature, θ


Height, z
~1 km
Phase 1
Nocturnal
Inversion
Burn-off
Phase 2
Rapid
Rise
Phase 3
Quasi-
steady
clouds
LCL
z_i
sunrise
mid-morning
mid-afternoon

Kan vi endre turbulensforholdene i grenselaget og dermed temperaturen på bakken?

nature climate change

LETTERS

PUBLISHED ONLINE: 29 APRIL 2012 | DOI: 10.1038/NCLIMATE1505

Impacts of wind farms on land surface temperature

Liming Zhou[1]*, Yuhong Tian[2], Somnath Baidya Roy[3], Chris Thorncroft[1], Lance F. Bosart[1] and Yuanlong Hu[4]

Økning i bakketemperaturen om natten der det er vindmøller.

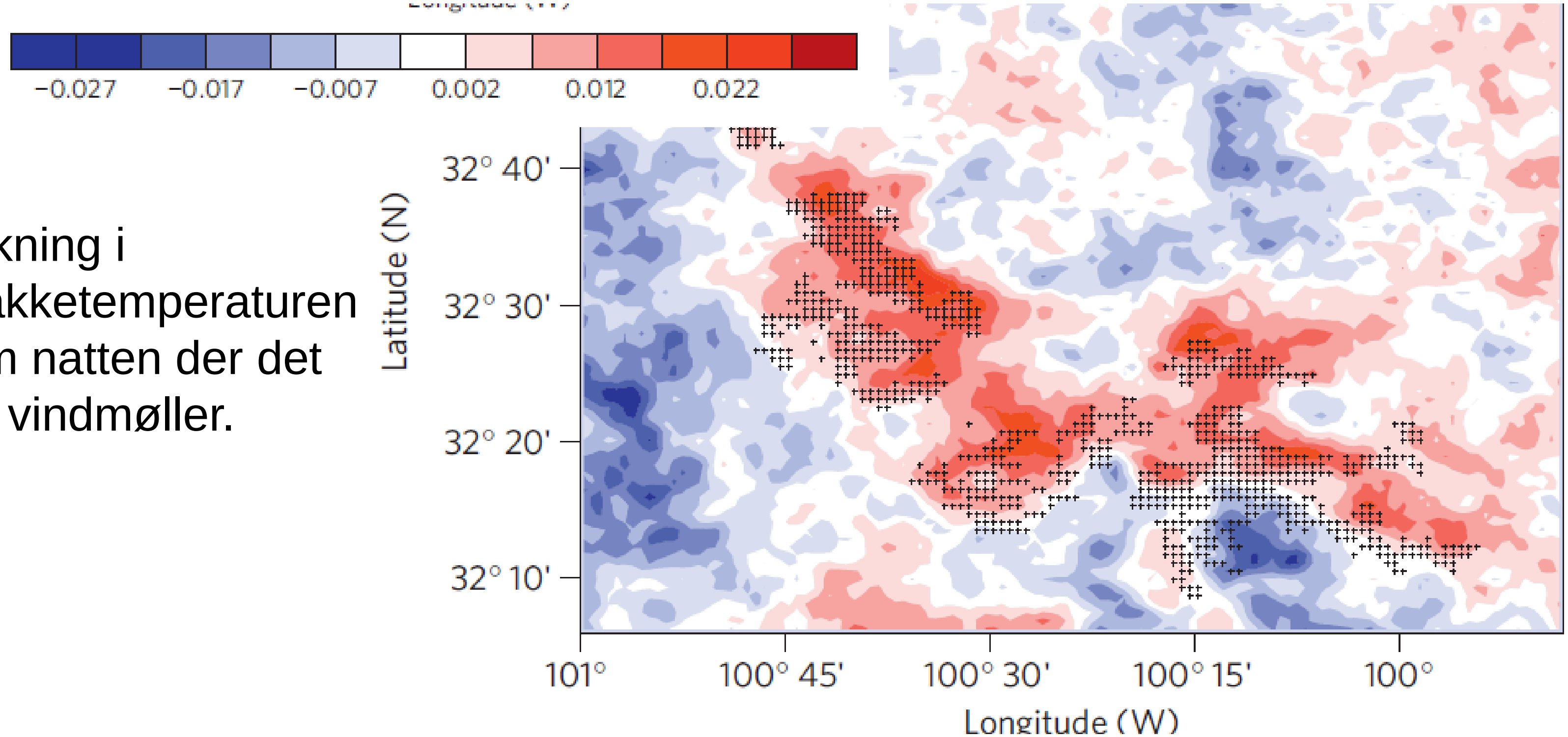


Figure 2 | MODIS JJA night-time LST and daytime shortwave-albedo differences for the period of 2003–2011. a,b, LST differences (°C): 2009–2011 minus 2003–2005 averages (**a**) and 2010 minus 2003 (**b**).