A Ceilometer-Derived Climatology of the Convective Boundary Layer Over Auckland


Sky View Photography (2019)

Hannah Marley

The University of Auckland

In collaboration with:

Jenny Salmond	School of Environment, University of Auckland
Kim Dirks	School of Population Health, University of Auckland
Lena Weissert	School of Chemical Sciences, University of Auckland
Ian McKendry	Department of Geography, University of British Columbia

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Boundary-Layer Meteorology
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RESEARCH ARTICLE

Check for updates

A Ceilometer-Derived Climatology of the Convective Boundary Layer Over a Southern Hemisphere Subtropical City

Hannah G. Marley[1] · Kim N. Dirks[2] · Ian McKendry[3] · Lena F. Weissert[4] · Jennifer A. Salmond[1]

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Contents

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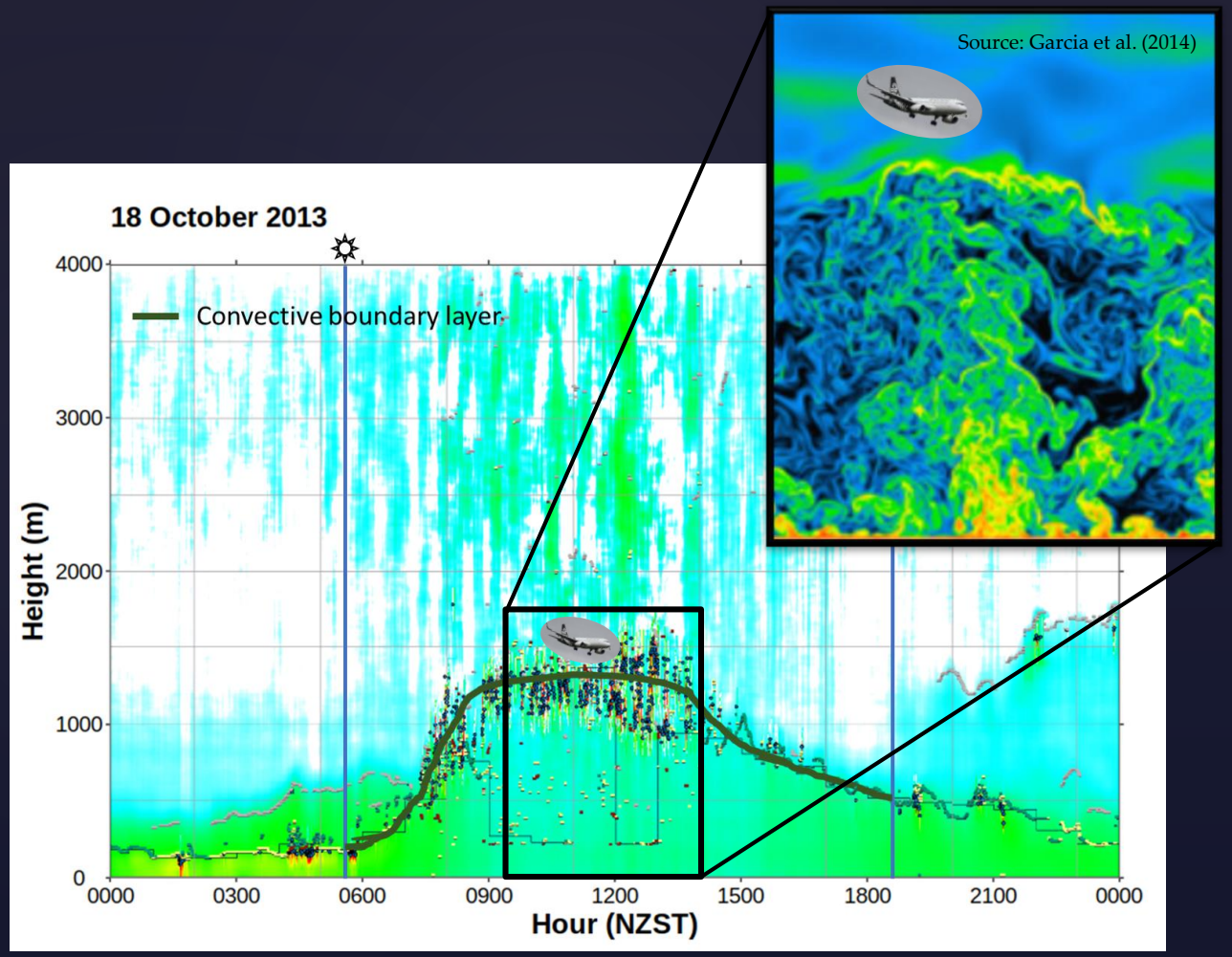
Background

Convective boundary layer

- A knowledge of the CBL depth is important for understanding & predicting weather, air quality, climate



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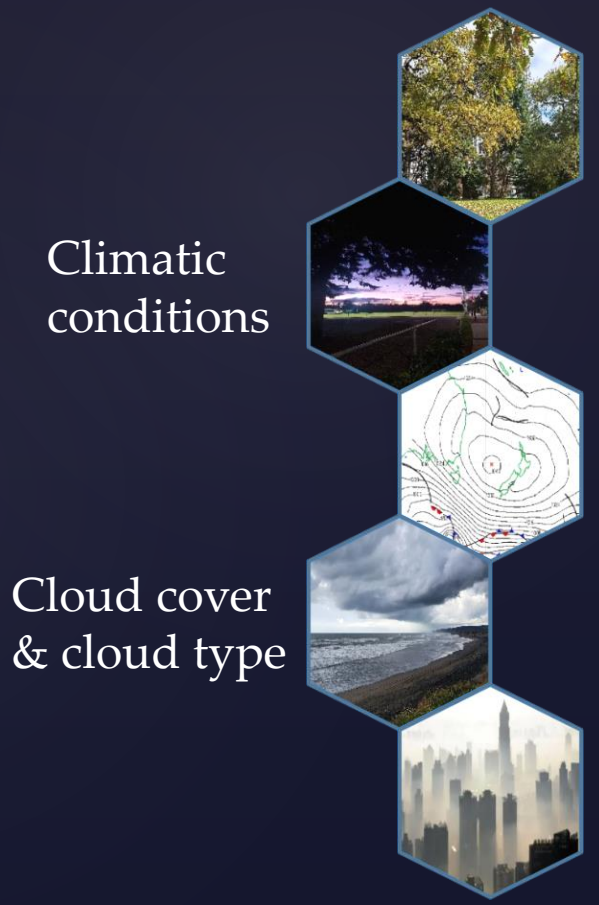
Background

Drivers of CBL depth variability

- Little consistency in the dominant driver of CBL depth variability identified between studies
- Drivers of variability interact in different ways at different locations
- Makes it difficult to accurately model the CBL depth



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Background

In the larger context of my PhD…

Auckland context:

First helpful to identify the dominant drivers of CBL variability

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Research Gap

Little consistency in the dominant driver of CBL depth variability identified between studies

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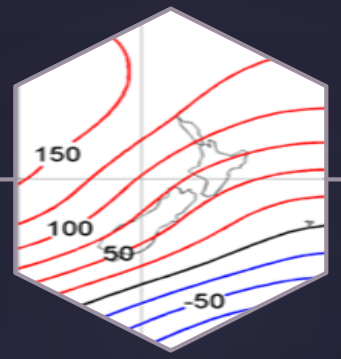
Research Objectives

To investigate relationship between the CBL depth & local meteorological variables



To investigate the relationship between the CBL depth and synoptic-scale weather types

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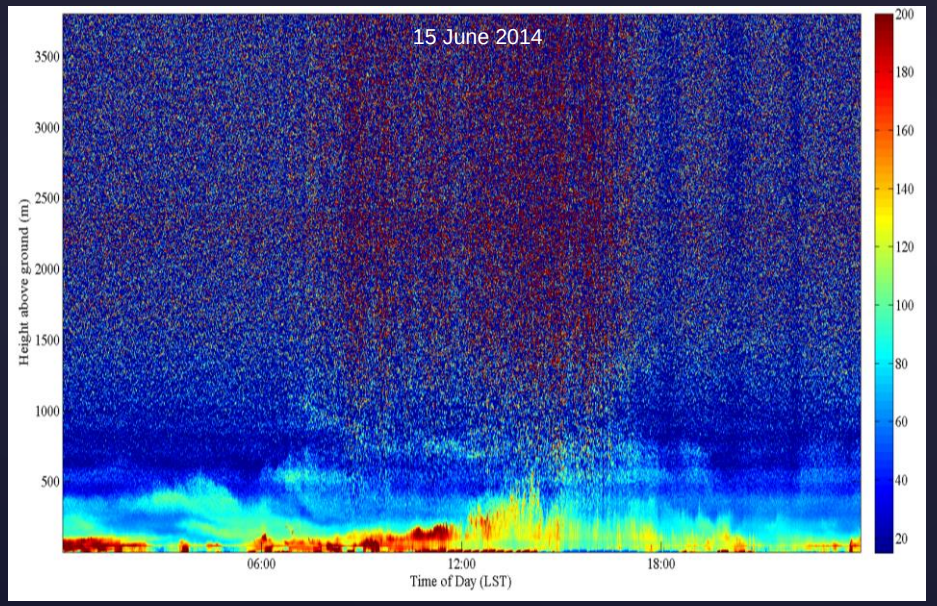
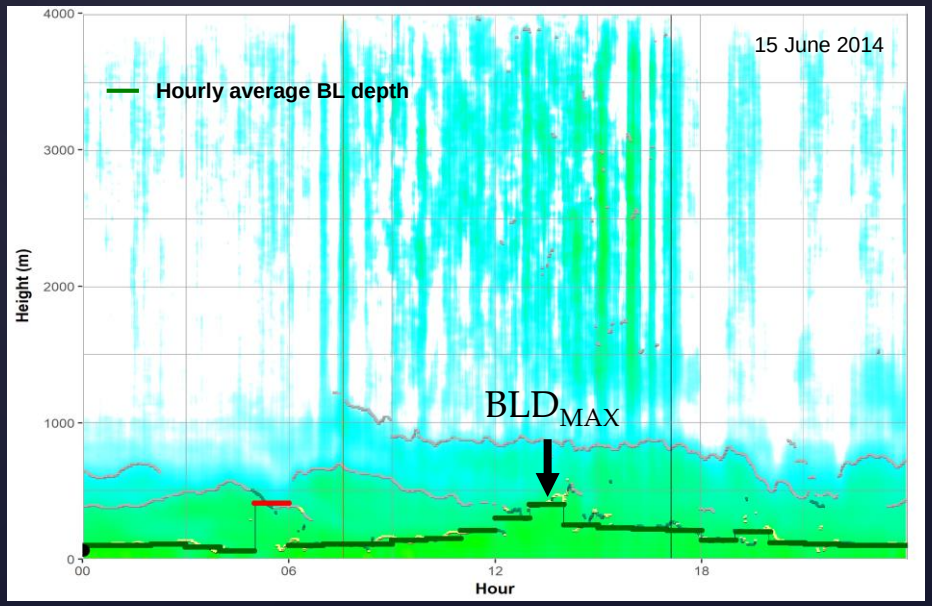
Data & Methods

Ceilometer (mini-lidar) used to retrieve BL depth estimates over the Auckland CBD for 2013 to 2015





Next, the daytime maximum CBL depth (BLD_{MAX}) was calculated

- Important indicator as largest volume into which air pollutants mixed

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Data & Methods

1. Investigation of the relationship between the maximum CBL depth and local met variables

- Solar radiation
- Air temperature
- Wind speed

NIWA Taihoro Nukurangi Virtual Climate Station Network

- Soil-moisture deficit estimates

- Deseasonalised monthly mean anomalies calculated

- Linear regression analyses & statistical significance tests conducted

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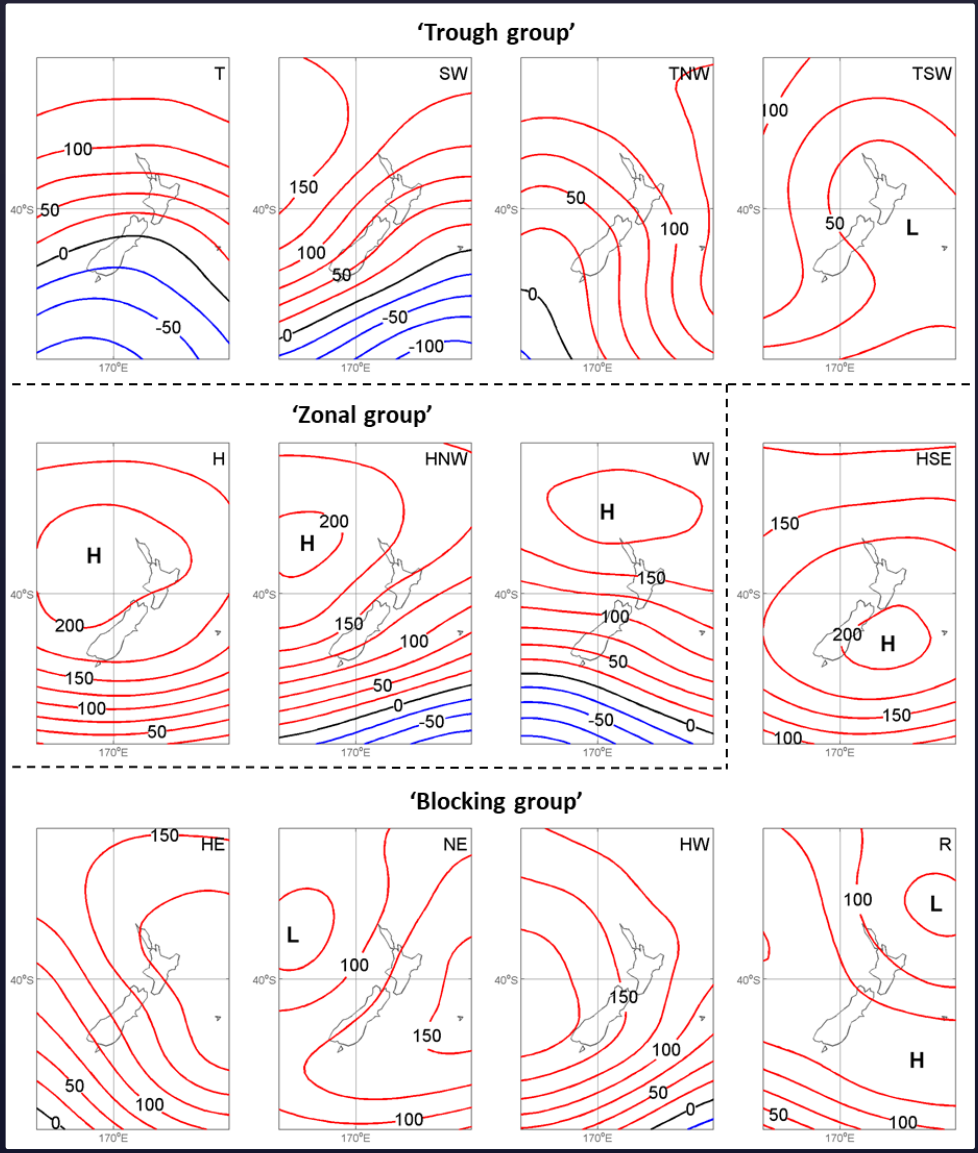
Data & Methods



2. Investigation of the relationship between the maximum CBL depth and synoptic-scale weather patterns

Kidson Weather Types

- Standard synoptic classification system developed for the NZ region

Box-and-whisker analyses & statistical significance tests conducted

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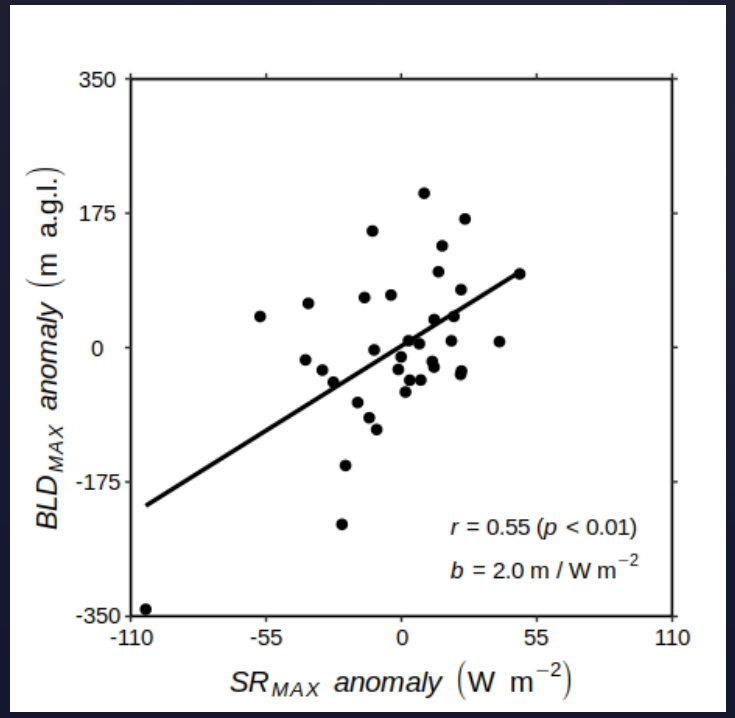
Key Results

Part 1: **Maximum CBL depth & local met variables**

CBL depth v Solar radiation – only statistically significant relationship:



Suggests that increased solar radiation is one of the key drivers of a deeper CBL at this site

Contrasts findings in Paris where no significant correlation between the CBL depth and solar radiation was found (when seasonality was removed) (Pal & Haeffelin, 2015)

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Key Results

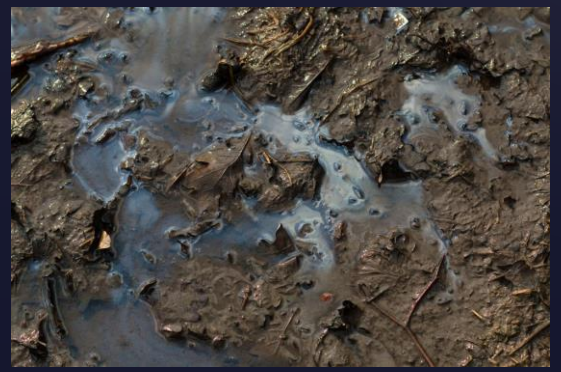
Part 1: **Maximum CBL depth & local meteorological variables**

- Soil moisture and wind speed are also known to influence this process

- Further investigation of this dominant influence of solar radiation on the CBL depth under:

1. Different soil moisture conditions

Wetter soil



Drier soil

2. Different wind conditions

Calmer

Windier

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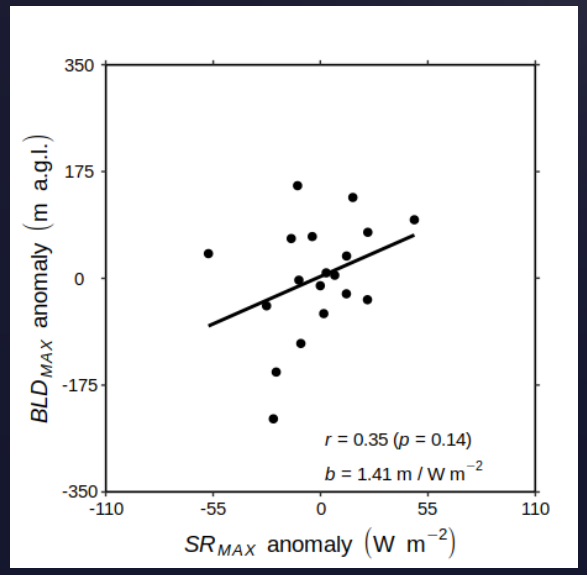
Key Results

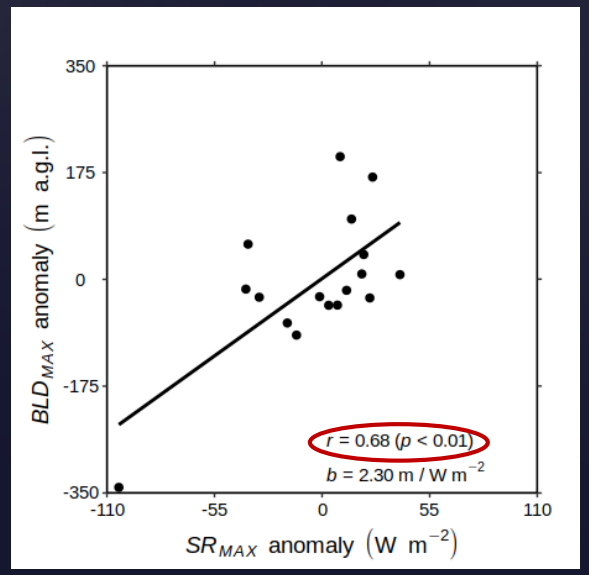
Part 1: **Maximum CBL depth & local meteorological variables**

1. Influence of soil moisture conditions on the relationship between the CBL depth and solar radiation

Wetter soil

Drier soil





A strong significant relationship was found under the dry soil regime

Indicates that the amount of incoming solar radiation has a greater influence on the CBL depth over Auckland when soils are drier

Possible reason: Drier soil conditions likely favour the partitioning of incoming solar radiation into sensible heat flux over latent heat flux

Which in turn promotes stronger convection and greater CBL growth

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Key Results

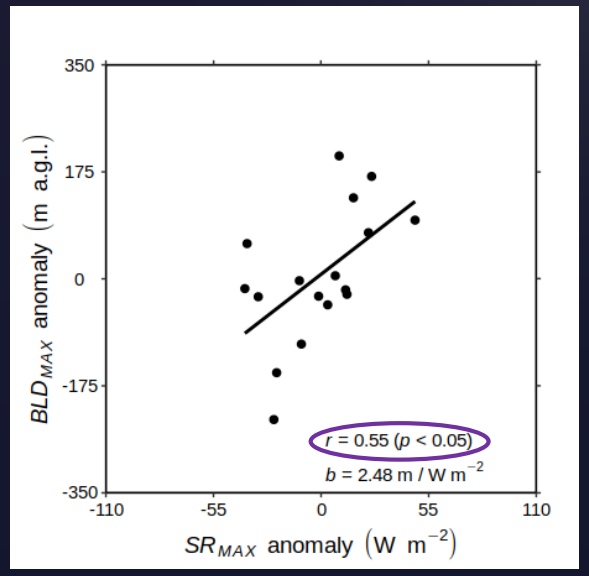
Part 1: **Maximum CBL depth & local meteorological variables**

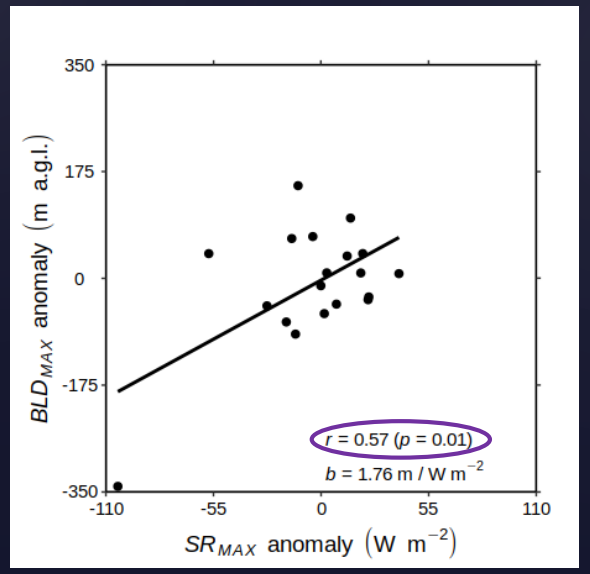
2. Influence of wind conditions on the relationship between the CBL depth and solar radiation

Significant moderate relationships exist under both wind regimes

Calmer

Windier





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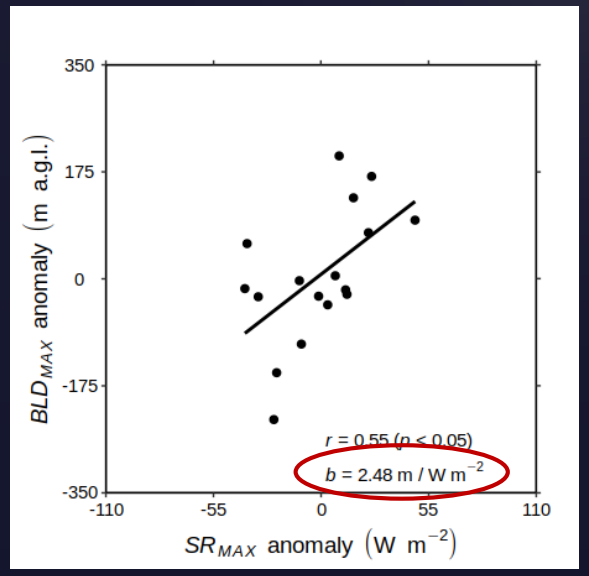
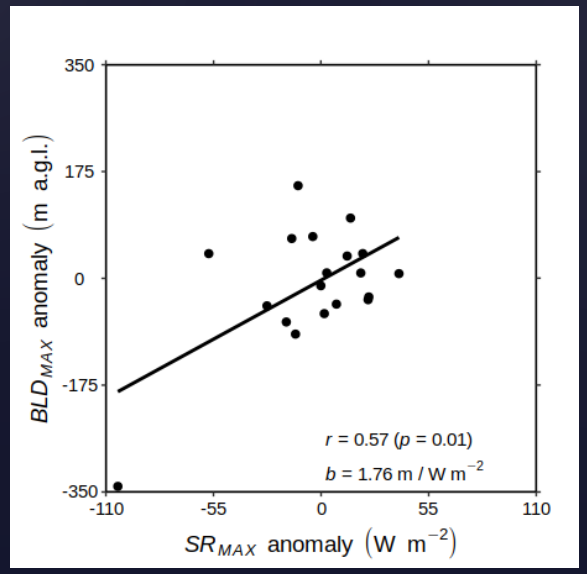
Calmer

Windier





Significant moderate relationships exist under both wind regimes

However, under calm winds, the maximum CBL depth is associated with a greater increase in depth with every 1 W m^{-2} increase in maximum solar radiation

Suggests more vigorous convection over the Auckland CBD may occur during calm winds

Possible reason: calm winds confine surface heat fluxes to the area rather than dispersing them via stronger winds

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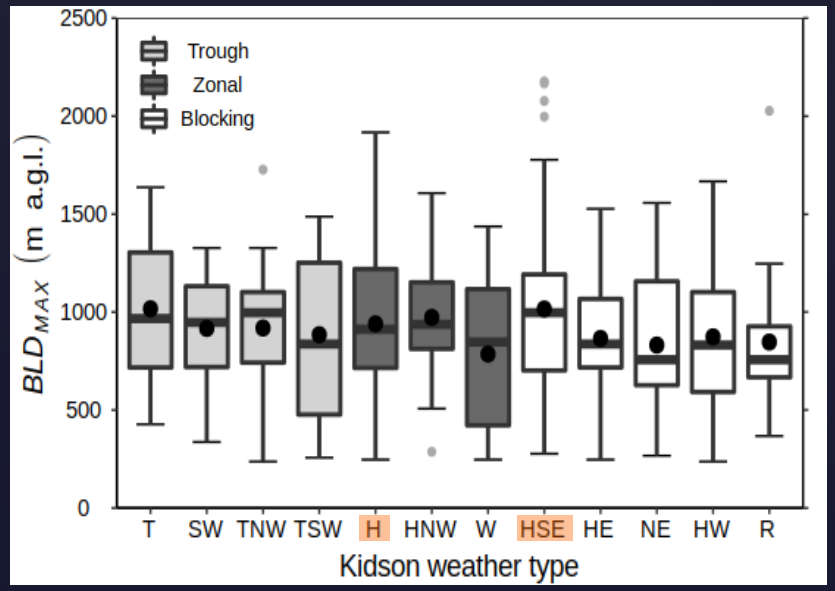
Key Results

Part 2: **Maximum CBL depth & Kidson weather types**



- H & HSE of interest – typically characterised by large, slow-moving anticyclones that result in descending air, stable conditions, and low wind speeds over Auckland

Interestingly, however, these weather types do not show a tendency for lower maximum CBL depth values

Significance tests also revealed that the maximum CBL depth was not statistically different between Kidson weather type

The lack of a relationship between the Kidson weather types and the the maximum CBL depth indicates that the Kidson classification system is not a strong determinant of the CBL depth

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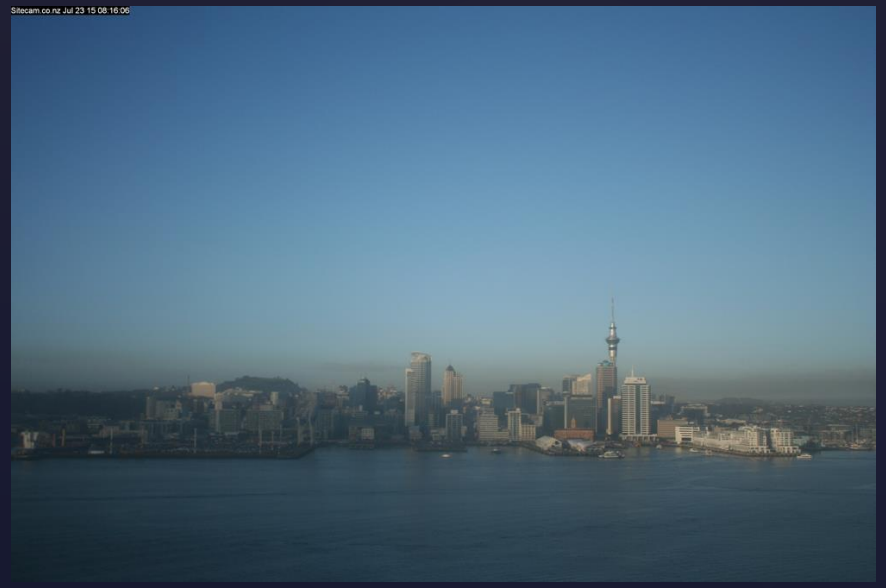

Previous research in Auckland has found it's more common for a brown air pollution haze to form when H & HSE weather types are present

BUT the haze was only observed to form on 20-25% of H & HSE days

Perhaps, the brown haze events that were observed to occur on the days with H and HSE weather types also happened to coincide with a shallow boundary layer…?

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Watch this space!

To find out what influence the BL has on brown haze formation over Auckland…

The Relationship Between Brown Haze, Atmospheric Boundary Layer Structure, and Air Pollution in an Urban Area of Complex Coastal Terrain

Hannah G. Marley[a*] • Kim N. Dirks[b] • Andrew J. Neverman[c] • Ian McKendry[d] • Jennifer A. Salmond[a]

Coming soon!!

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