Numerical Modeling of Wildland Fire Behaviour under Foehn Winds in New Zealand

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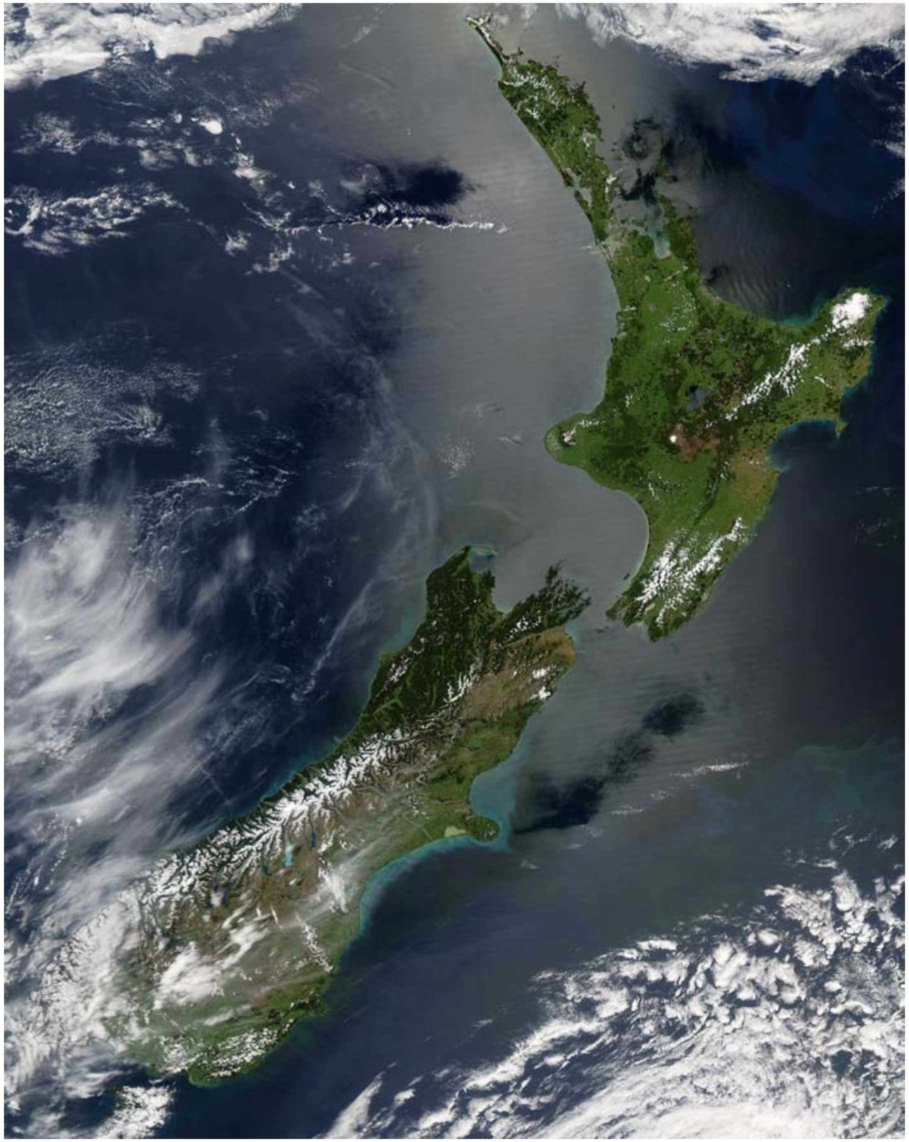
Introduction

- PhD Student at University of Canterbury, New Zealand
- Foehn winds in New Zealand:

Behaviour and characteristics

Importance for fire danger

- Work can be related to other areas affected by foehn winds
- Testing ground for the WRF-Fire modeling system

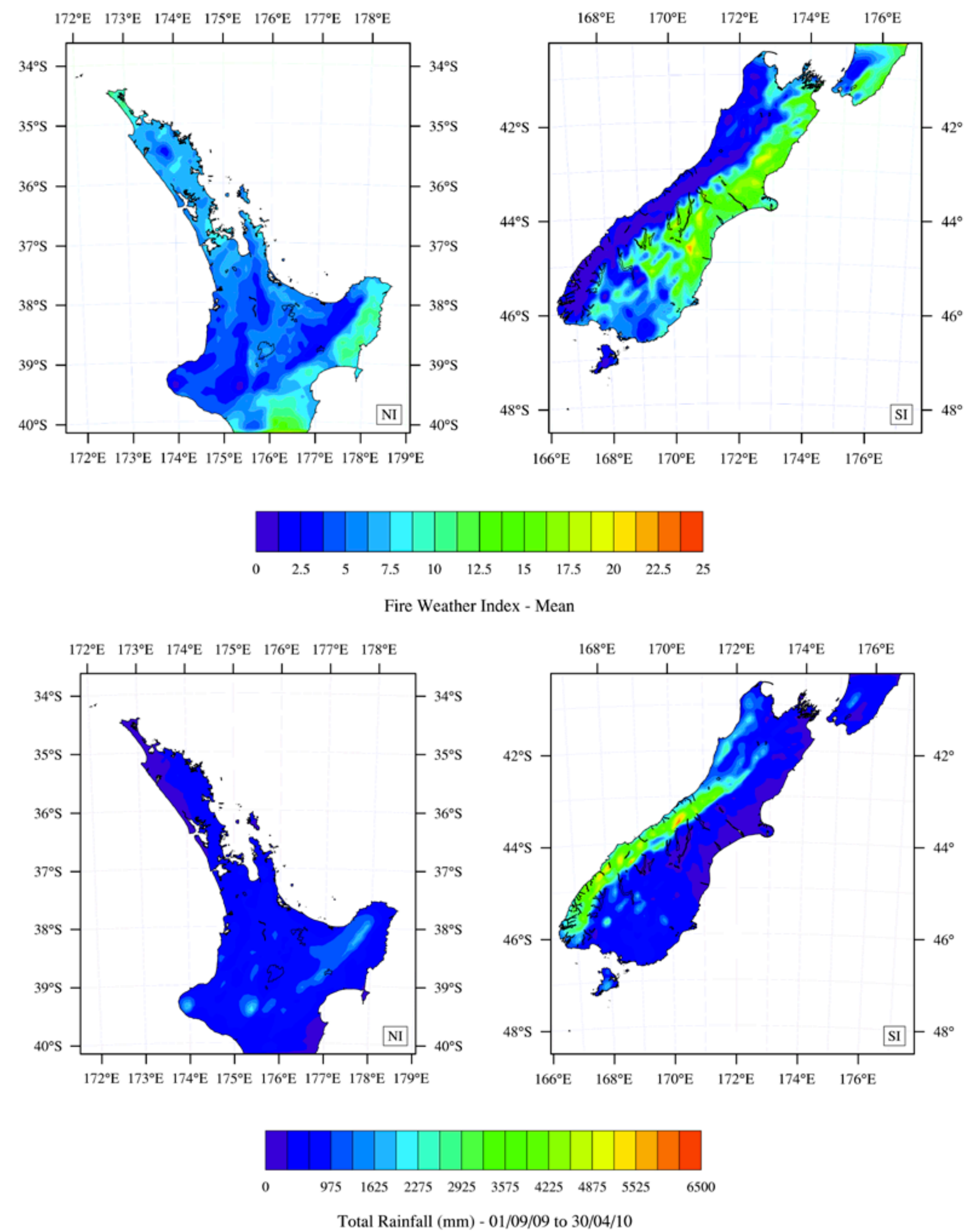


Fire Climate of New Zealand

- Complex climatic conditions:
  - Warm subtropical in the north
  - Cool temperate in the south
- Climate in particular dominated by:
  - Tasman Sea and Pacific Ocean
  - Mountains e.g. Southern Alps
- Mountain barriers to prevailing westerlies, divides country into regions of very different climates
- New Zealand experiences several thousand wildfires each year
- South Island's east coast has harshest fire weather
- NZ Rural Fire Agency use a modified Canadian Fire Weather Index used to quantify fire danger

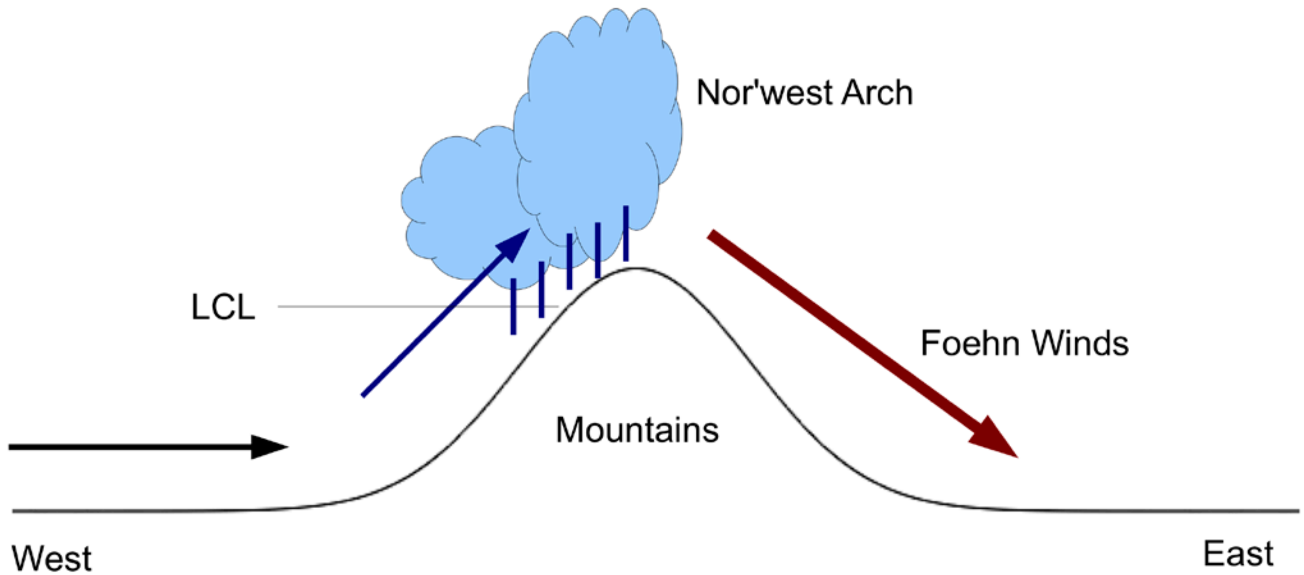
FWI

- FWI based on several weather variables:
  - Temperature
  - Rainfall
  - Wind speed
  - Humidity
- East coasts of mountain ranges have more severe fire weather:
  - Lee-side of mountains
  - Driest areas of NZ



Foehn Winds in New Zealand

- Canterbury Nor'wester
- Typically a pre-frontal mesoscale flow phenomenon
- Pressure gradient from west to east, divided by Southern Alps, flow from a northwesterly direction
- Orographic lifting causes heavy precipitation on west coast
- Dry air warmed adiabatically as it flows down slope
- Wind speeds at strong gale or even hurricane force



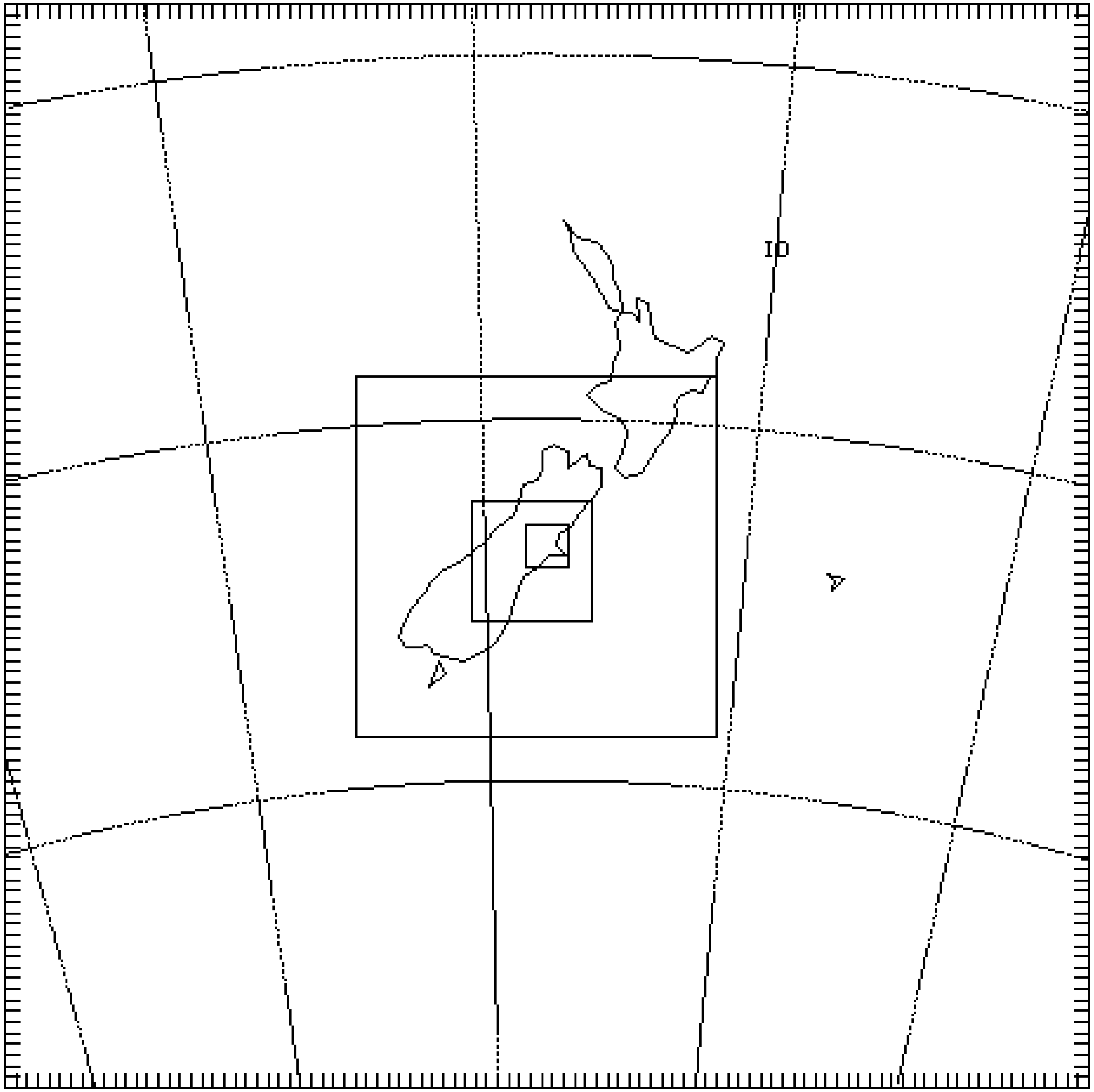
Foehn Wind Events

- Foehn events fairly common in spring/summer: numerous events to choose from
- Two events picked out as case studies:
  - 1st January 2010
  - 6th February 2011
  - Both chosen for their extreme pressure gradients
- Working with 1st January 2010:
  - Establish effective model setup
  - Use as a reference setup for future case studies
- Foehn wind events typically last 1-2 days, well suited to short high resolution WRF simulations

Modeling Setup, 01/01/10

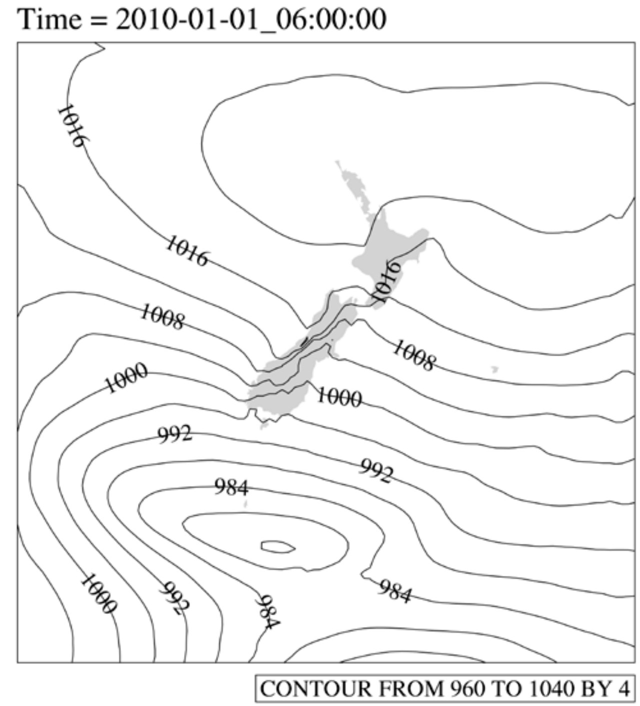
- WRF-ARW V3.2 and WPS V3.2
- Four square domains at following resolutions:
  - 33.75km, 11.25km, 3.75km, 1.25km
  - Two-way nesting enabled
- Total simulation time: 3 days (extend to 5 days)
- Number of possible setups tested
- NCEP FNL – initial conditions and nudging
- Planned improvements:
  - Improve SST representation, important for stability
  - Test further likely model setups

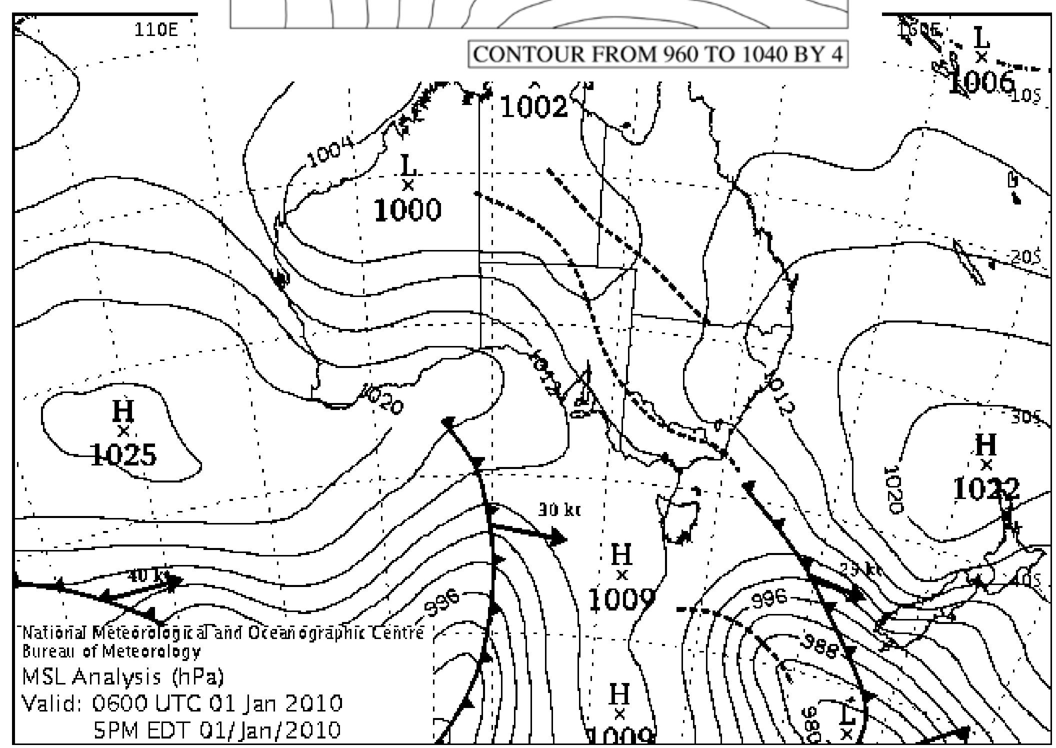
Modeling Setup - Domains



Synoptic Conditions

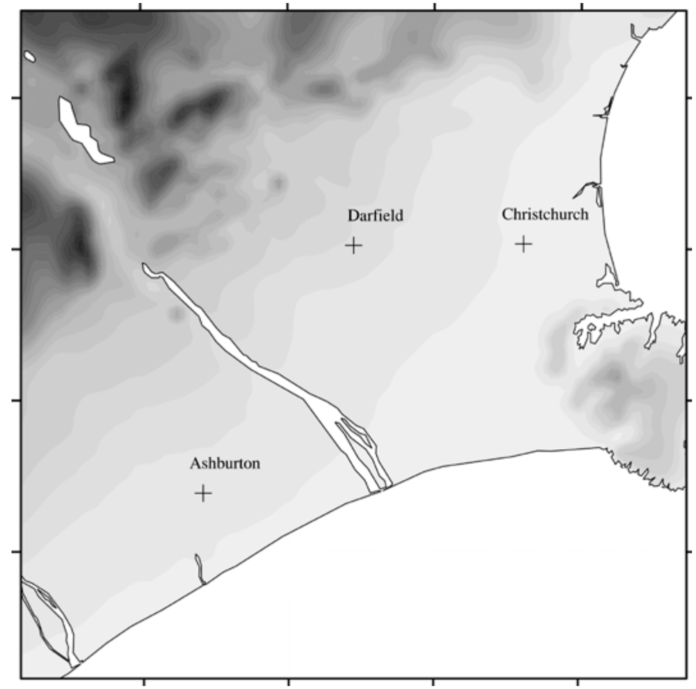
- NZ sandwiched between:
  - High pressure to the north
  - Low pressure to the south
- Pressure gradient of around 6-8hpa
- Lee-trough on east coast of South Island
- Preceded a cold front passage, typical of the Canterbury Nor'wester

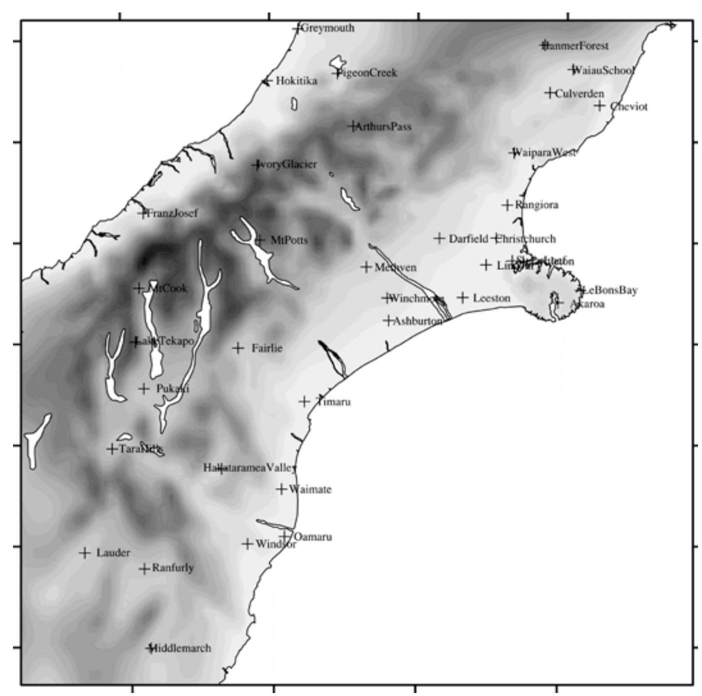




Observation Stations

- Three observation stations used:
  - Christchurch
  - Darfield
  - Ashburton
- Plans to investigate behaviour at additional stations:
  - West coast – precipitation
  - Flow characteristics in Otago (south of Canterbury)

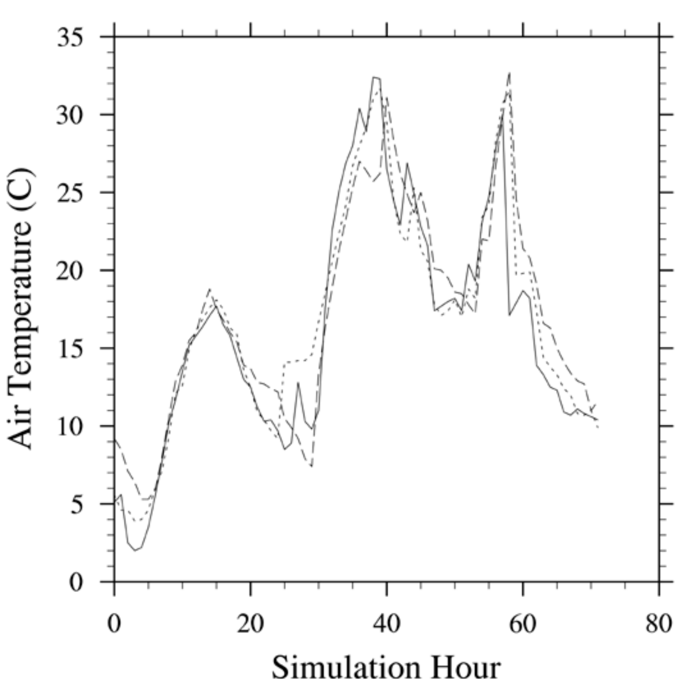


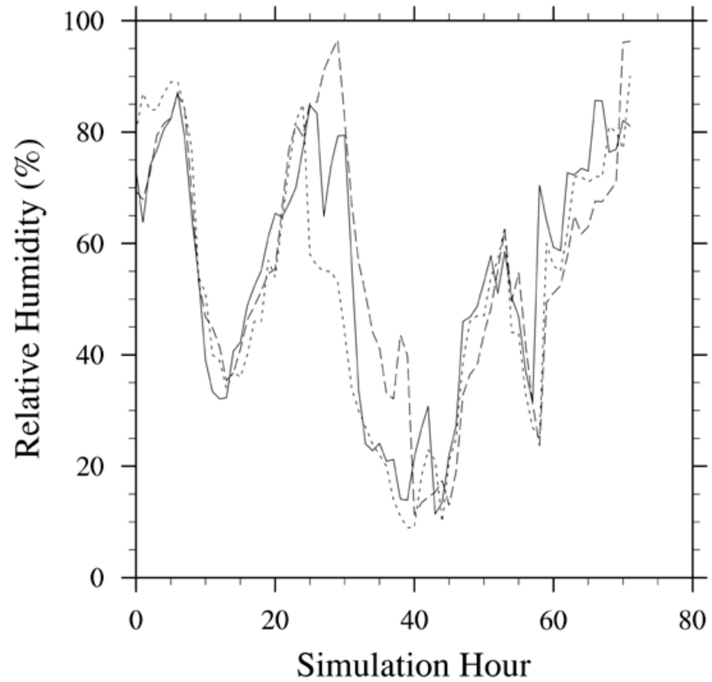


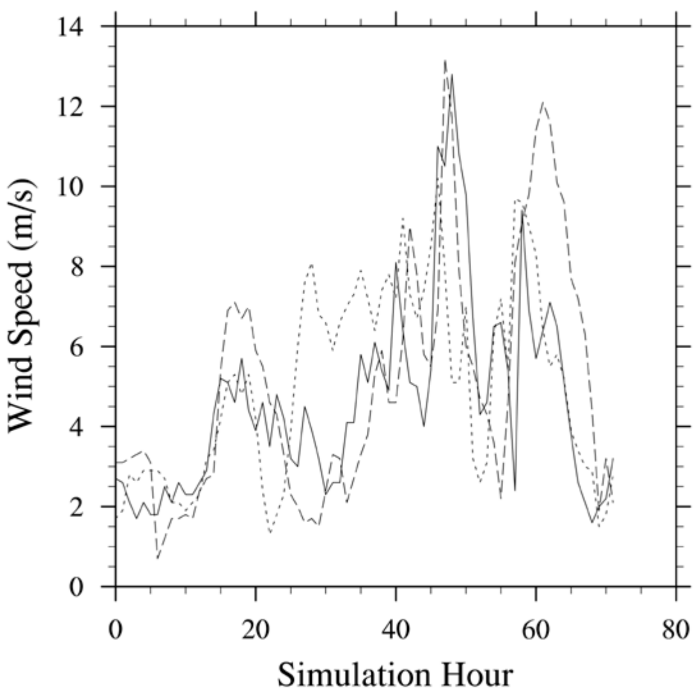
Mesoscale Conditions

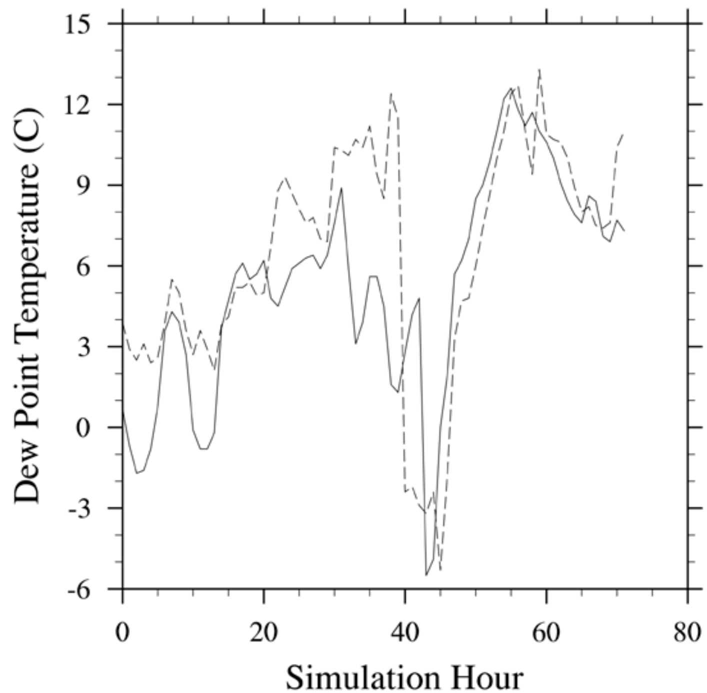
- Foehn conditions start about 6am, 01/01/10
- Weather conditions @ 4pm, 31/12/09
  - Air temperature approx. 18C
  - Relative humidity approx. 40-50%
  - Wind speed about 10mph from SW direction
- Weather conditions @4pm, 01/01/10:
  - Air temperature approx. 30C
  - Relative humidity approx. 10-15%
  - Wind speed approx. 40mph from NW direction
- Mean daily maximum air temperature for Christchurch in January: 22.5C

Mesoscale Conditions - Timeseries









Mesoscale Conditions

- Heavy precipitation on west coast via orographic lifting, up to 250mm in 10 hours
- Air warms adiabatically as it descends, warmer on lee side due to loss of moisture

Rapidly increases local fire danger:

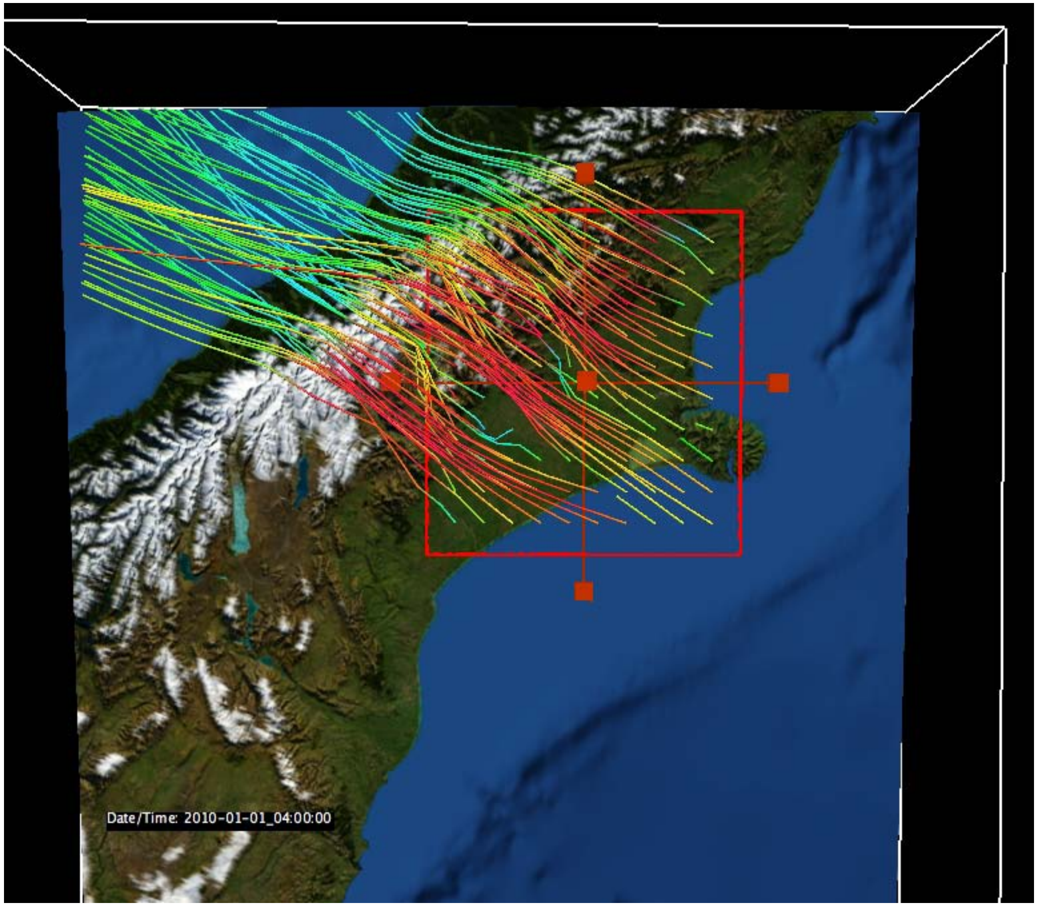
Increased air temperature

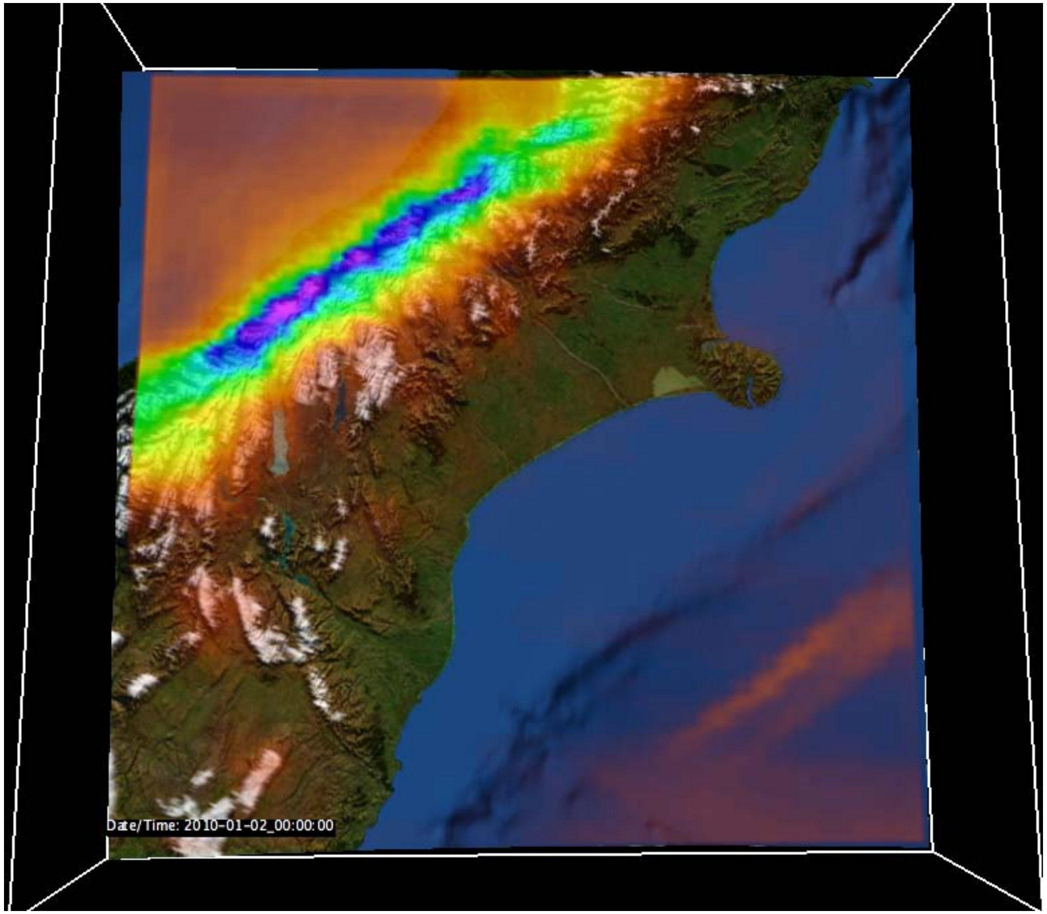
Decreased relative humidity

Increased wind speed

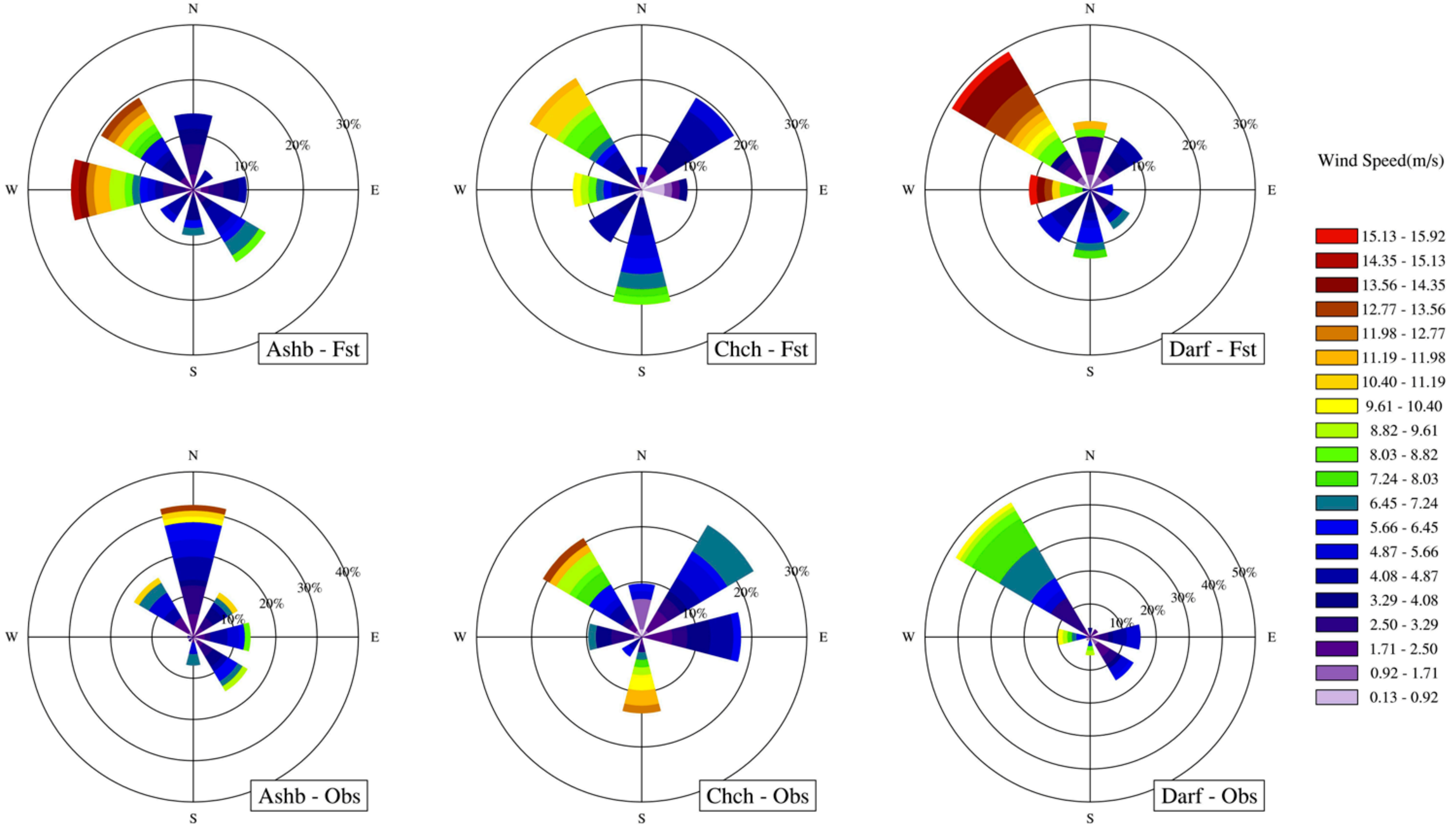
Wind direction change close to 90 degrees

Flow and Precipitation





Wind Rose Plots



Motivation for use of WRF-Fire

- What impact do these foehn winds and other mesoscale phenomenon have on fire behaviour?
- WRF-Fire physics package used to simulate semi-idealised surface fires:
  - Surface fire spread model
  - Two-way fire-atmosphere interactions
- Ignite fire prior to onset of foehn winds, investigate possible impacts on fire behaviour

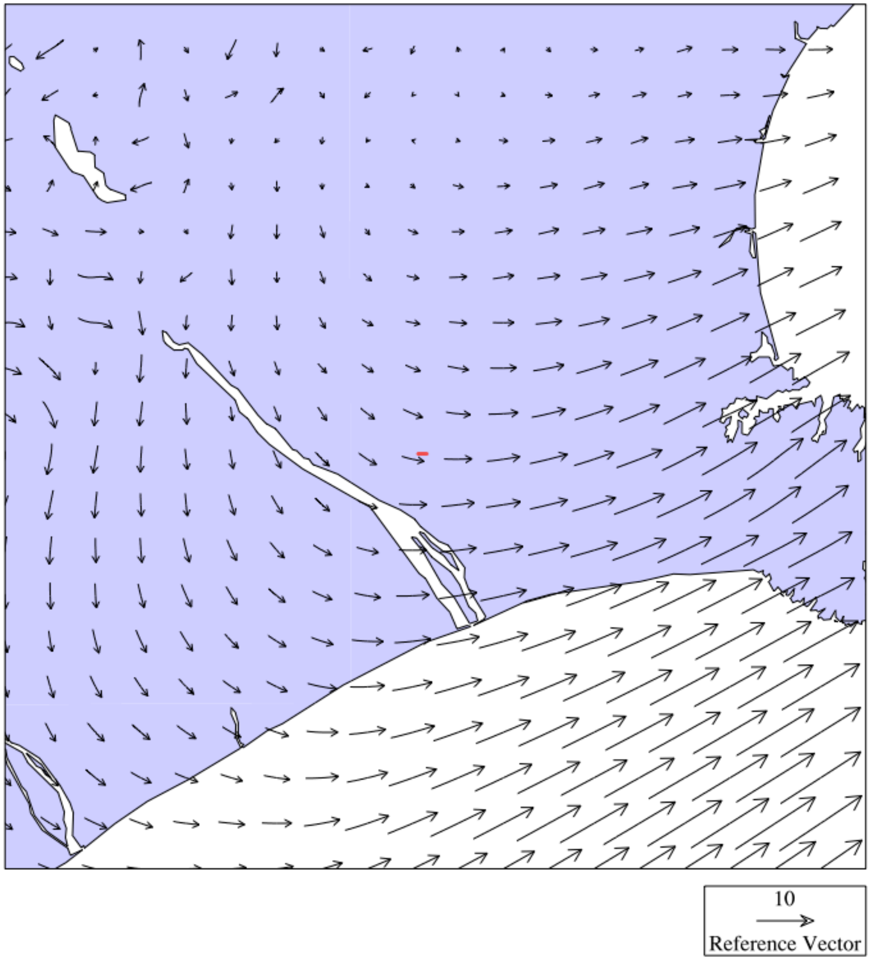
WRF-Fire Setup

- Fire model uses 2d surface grid as a subgrid of lowest atmospheric grid
- Two additional high resolution static datasets:
  - Topography (SRTM 90m data)
  - Fuel Category (idealised uniform fuel)
- Fuel type can be changed e.g. grass, trees
- Fire spread rate calculated via Rohtermal:

$$R = R_0 + \Phi_W + \Phi_S$$

- Choose time, location and size of fire

WRF-Fire Modeling - 2



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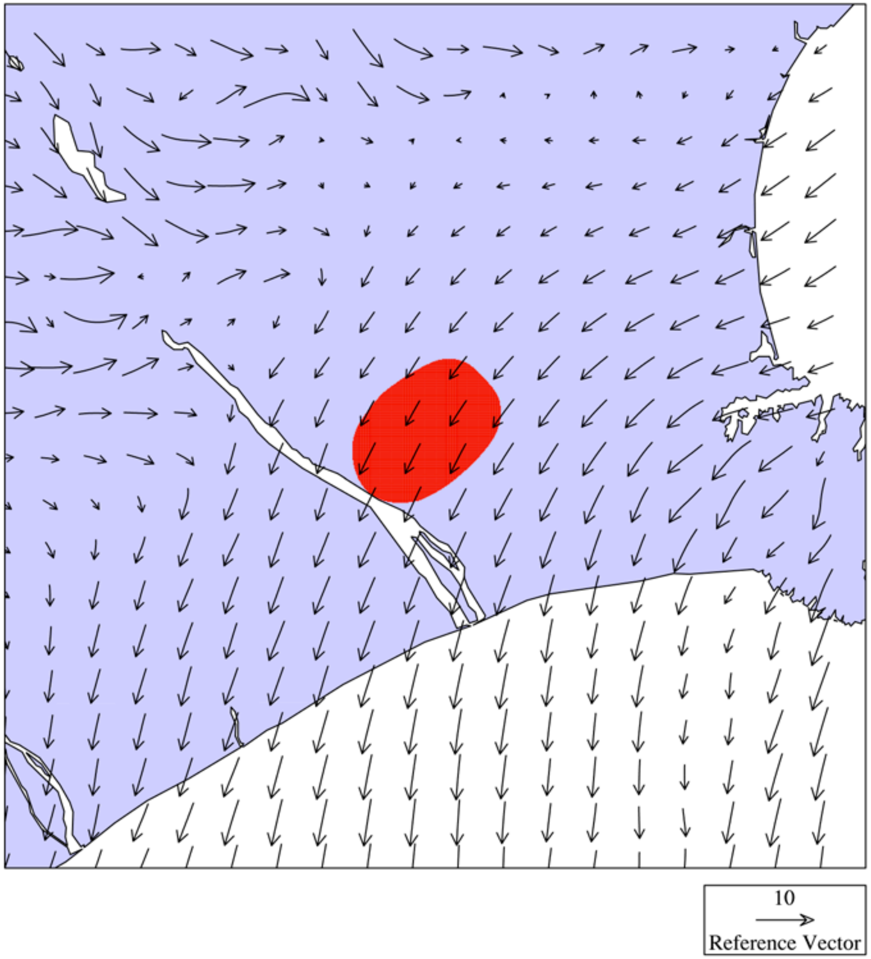
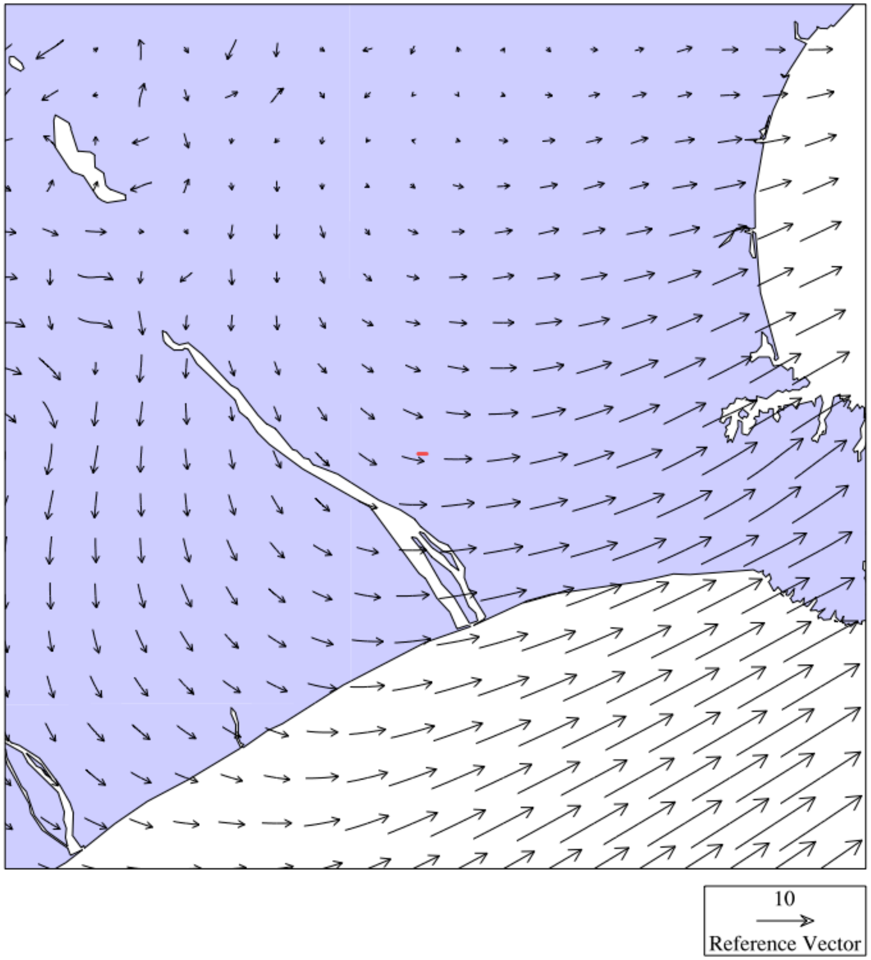


WRF-Fire Modeling - 2



Conclusions

- WRF has been used to simulate a foehn wind event in New Zealand at high resolution
- Model nicely captures the synoptic and mesoscale conditions of a foehn wind:
  - Strong lee-side dry winds and warm temperatures
  - Heavy orographic precipitation
- Further work needed on aspects of simulations:
  - SST representation could be improved
  - More realistic fuel representation
  - Improved fire modeling