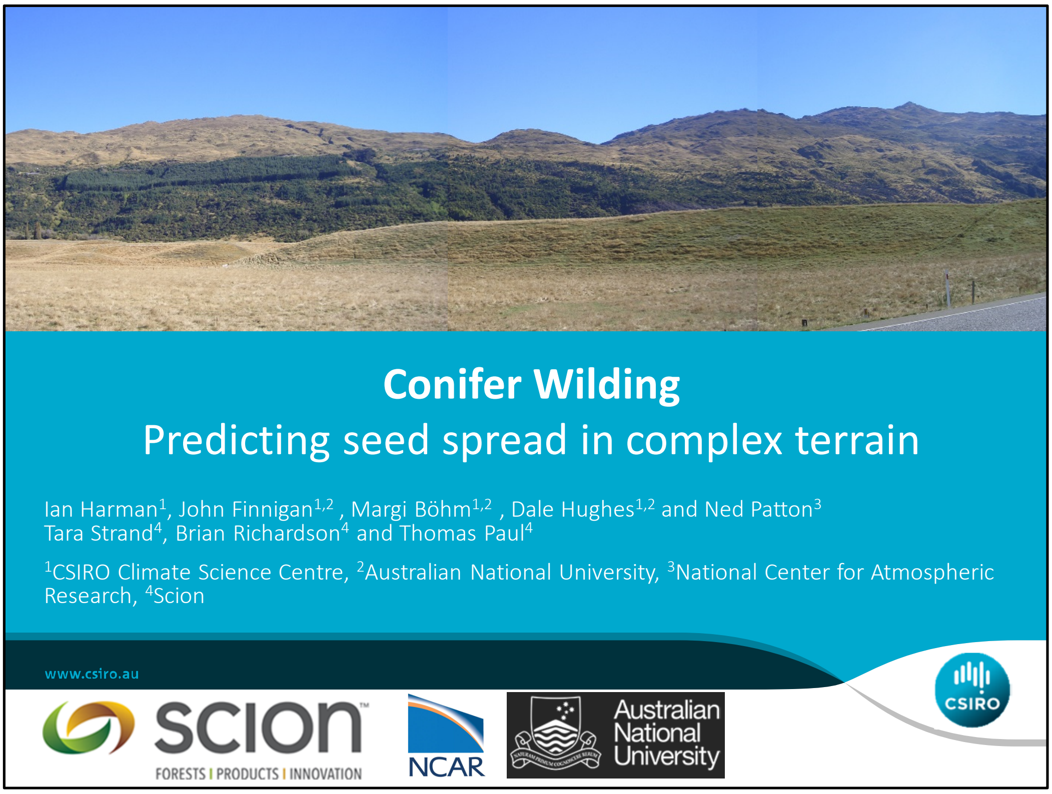
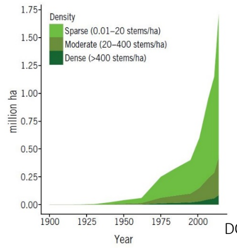


This presentation covers research carried out as part of the Winning against Wildings program. We'd like to thank all our collaborators and their host institutions as well as the funding agencies for this work (MBIE Winning against Wildings program, via Landcare NZ [Maanaki Whenua] and Scion).

Abstract: The invasive spread of conifers as a weed species has been identified as an increasing issue in New Zealand and national action has been deemed necessary. The Winning against Wildings programme is a multi-discipline effort across governments, communities, industry and research agencies to tackle the problem and identify new solutions. This presentation cover research that CSIRO, NCAR and collaborators at Scion have undertaken which aims to understand, and develop a predictive capability for, the airborne dispersal of seeds across complex landscapes. A brief overview of the three components to the project, and an illustration as to how this information could be utilised in Decision Support is provided.

IMPORTANT NOTE:
The material in this presentation has not undergone scientific peer-reviewed at this time (26/11/2020).

Introduction



DOC (2008)

Conifer Wilding in New Zealand is an issue of national importance with multiple implications for the environment and the economy

science aim: improve our understanding of the role of landscape complexity in determining the airflow, turbulence and seed transport.

practical aim: provide advice concerning preferred locations in the landscape for long-range seed dispersal (seed take off and deposition) so that management/monitoring can be targeted/prioritised

Mount Barker, Canterbury

In practice, a combination of 'rules-of-thumb' and simple models informed by observations will be needed in a Decision Support System

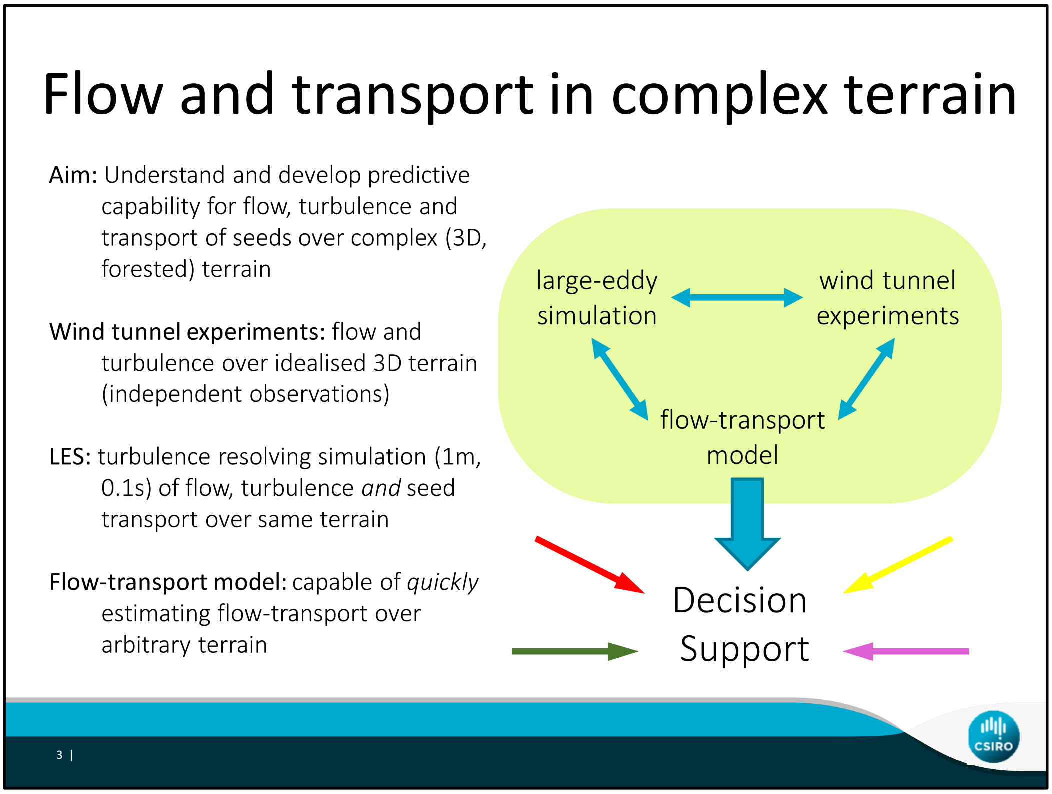
Our starting point for this work is that conifer wilding is an increasing issue in New Zealand and national action has been deemed necessary.

Conifers are spread primarily by the airborne transport of seeds. Fundamentally, seeds are carried by the wind - a typical seed will travel in the direction of the average wind at the time of release and over a distance controlled by the wind speed. However there is spread (dispersal) around this direction and distance when viewed across a collection of seeds released at the same time because there are fast fluctuations within the flow so different seeds experience different wind histories. It is the strength and scales of the turbulent eddies in the flow that controls the dispersal of the seeds – and turbulence also critical in determining any long range transport.

Most of the current scientific understanding of the processes involved in seed transport has focussed on the idealised case of flat terrain but over the last two decades there have been major advances in understanding how complex landscapes impact the flow, turbulence and transport.
… and it will not have escaped your notice that many regions of interest are not flat.

Consequently this project has two overarching aims: a science aim - and a more applied/practical aim. Both aims include accommodating the uncertainties that exist along the chain of scales that are important to the problem - from the largest weather scales down to the small seed/tree scales.

This talk will present an overview of the methodology used, some illustrative results, and a demonstration of how this project could be used within Decision Support.



In more detail: We aim to develop the understanding of, and to develop and validate a predictive capability for the flow, turbulence and transport of seeds across complex terrain.

We have started with the canonical case of gentle, but 3D, topography – as this was viewed as a key missing element in our understanding in the scoping phase of Winning against Wildings.

In order to achieve that we have undertaken research in three linked areas:

- First – we have completed two wind tunnel experiments over idealised 3D, circular (axisymmetric cosine to be precise) hills covered with a forest. These experiments provide high quality and independent data on flow and turbulence, in a controlled setting, as necessary to validate our other approaches. In particular, the controlled setting allowed us to observe the flow and turbulence at multiple locations across the landscape, certainly at many more locations than would be possible with a field experiment.

- Second, we have developed/enhanced a turbulence resolving simulation capability, also termed large-eddy simulation or LES, applied that to those same idealised hills, and then compared against the wind tunnel data. Turbulence resolving simulations directly solve the fundamental equations of motion at very high spatial (metres) and time resolutions (less than a second) – so can directly simulate turbulence.

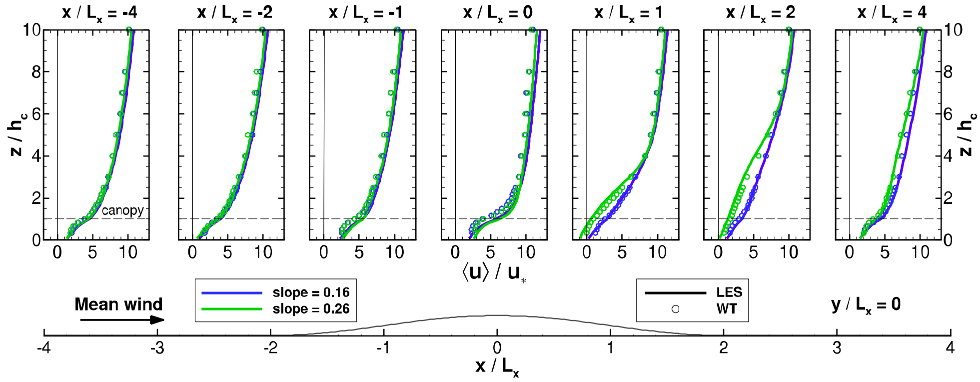
Importantly the LES can also be used to simulate the transport of seeds by the turbulent flow, and is flexible so that more complicated landscape and landcover configurations can be assessed. However LES is numerically intensive and can take weeks-months to run even on the very top-end high performance computers.

- Finally, we have formulated and coded an approximate-physics flow and transport model. This has the aim of rapidly estimating the flow and transport over arbitrary terrain. Results have been compared with the wind tunnel and large eddy simulations – the three-way comparison provides robustness to the overall methodology.

The ultimate aim is that insights, or even model capability itself, can be used as one input layer in a Decision Support system (alongside e.g. ecological, environmental/climate, social and/or management information)

Remember that turbulence is a critical component to the problem. While you can predict/estimate the statistical properties of turbulence, you can't predict the specifics as they apply to an individual seed. Similarly there is variability e.g. in seed shape – together these imply that results need to be probabilistic and/or risk-based.

Wind tunnel and LES



- wind tunnel and turbulence-resolving (LES) model agree on magnitude and locations of topographic impacts on flow and turbulence
- lee separation occurs at much lower slopes with a canopy than with bare soil or grass.

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Some illustrative results: Here we compare the wind tunnel experiments (markers) and LES (lines) results for vertical profiles of time-averaged horizontal wind at different locations along the centre line of our two idealised circular hills.

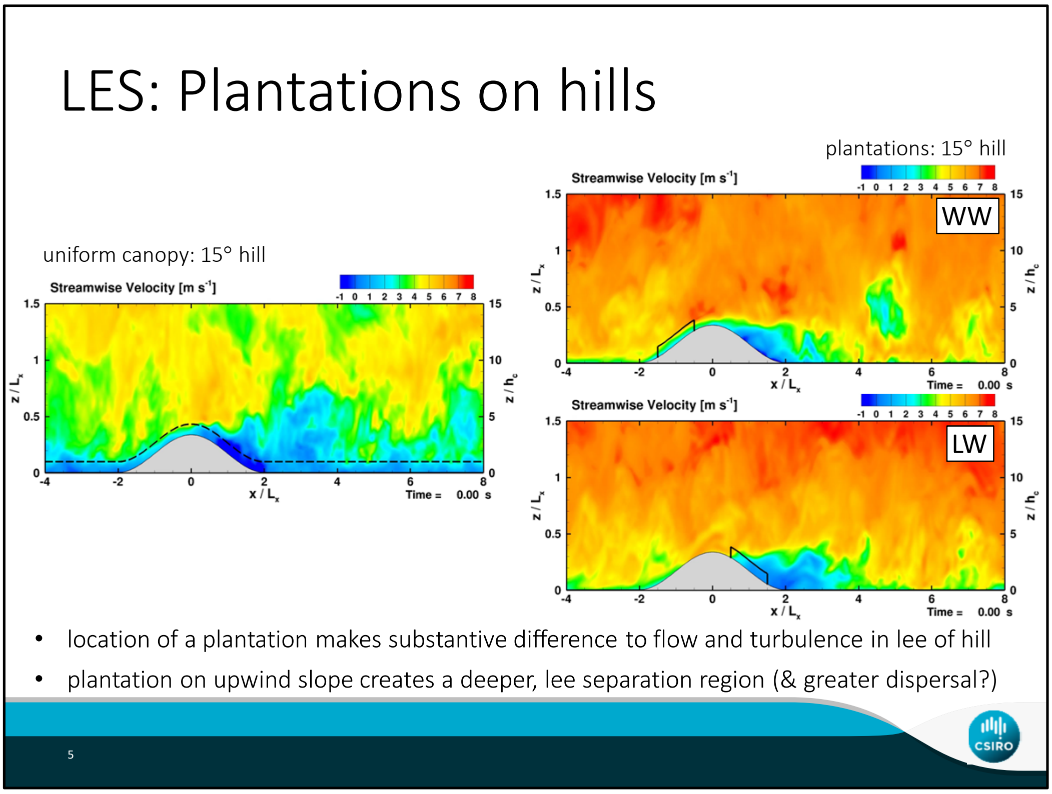
The two experiments are i) for a low slope hill (max slope 9 degrees) in blue and ii) a steeper slope hill (15 degrees) in green.

Overall, the LES and wind tunnel agree well on the magnitude and locations of the impact of the hill on the windflow – including the noticeable changes in the lee of the hills where the two cases are quite different.

We also note that the LES correctly simulates reverse (backwards) flow within the canopy on the lee of the steep hill (indeed, the LES data prompted us to go back and check that this does occur in the wind tunnel).

This reversed flow, and the associated deep wake region (see for the profiles at x/L=2), occurs with hills of much lower slopes if the surface is covered by a forest canopy than if covered by bare soil/grass.

Overall, our comparison so far has provided confidence in the capability of the LES to reproduce the wind tunnel cases – by inference, therefore, we have confidence in using the LES to assess the impact of more complex topography and also to assess seed dispersal.



As mentioned earlier, the turbulence resolving model is flexible and can simulate other landscapes and land cover configurations.
For example we can consider how the location of a plantation in a landscape would effect the flow, turbulence and hence transport of seeds.

In the presentation we showed movies of a vertical slice of the flow over the steep circular hill – here we show snapshots of a vertical slice (simulated) flow field along the centre line of the circular hill taken from the cases with the movies. On the left is the uniform canopy case that we showed previously, on the right we show two plantation cases (see the small white blocks). The upper panel has a plantation on the windward slope, the lower panel a plantation on the lee slope.

On these panels the colour scales are equal.

A key result is that the region of very high turbulence in the lee of the hills is substantively different – the windward plantation case has a deeper, longer and more intense turbulent wake than either the uniform canopy or leeward plantation case. We are still assessing the implications of this for seed dispersal.

The impact of the plantation on the flow and turbulence is quite sensitive to the location and size of the plantation relative to hill – for example other simulations indicate that WW plantations which sit lower down the hill slope do not result in the same extensive wake region (not shown).

Flow-Transport Model

Inputs

- terrain and land cover
- reference wind direction and speed (~30 min average, observed or NWP)
- seed release locations

→

Outputs

- time-averaged wind speed and direction across landscape
- measures of turbulence across landscape
- probability maps of deposition location for released seeds

Components

- approximate-physics flow model, incorporating canopies (originated with wind energy sector – Taylor, Hunt, Belcher, Finnigan, Harman developed from 1984 onwards)
- probabilistic WALD seed dispersal model with extensions for topography (Katul et al. 2005, Katul & Poggi 2012)
- development of theory so the models operate in three-dimensions

Utility: minutes-hours on standard home PC/laptop

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CSIRO

The remainder of this presentation will be focussed on the flow and transport model and its potential use.

The idea of the FTM is to take readily available inputs-regional - wind speed and direction, topography (DEM) and land cover maps – and use these to provide outputs that are useful to inform our understanding and/or management strategies.

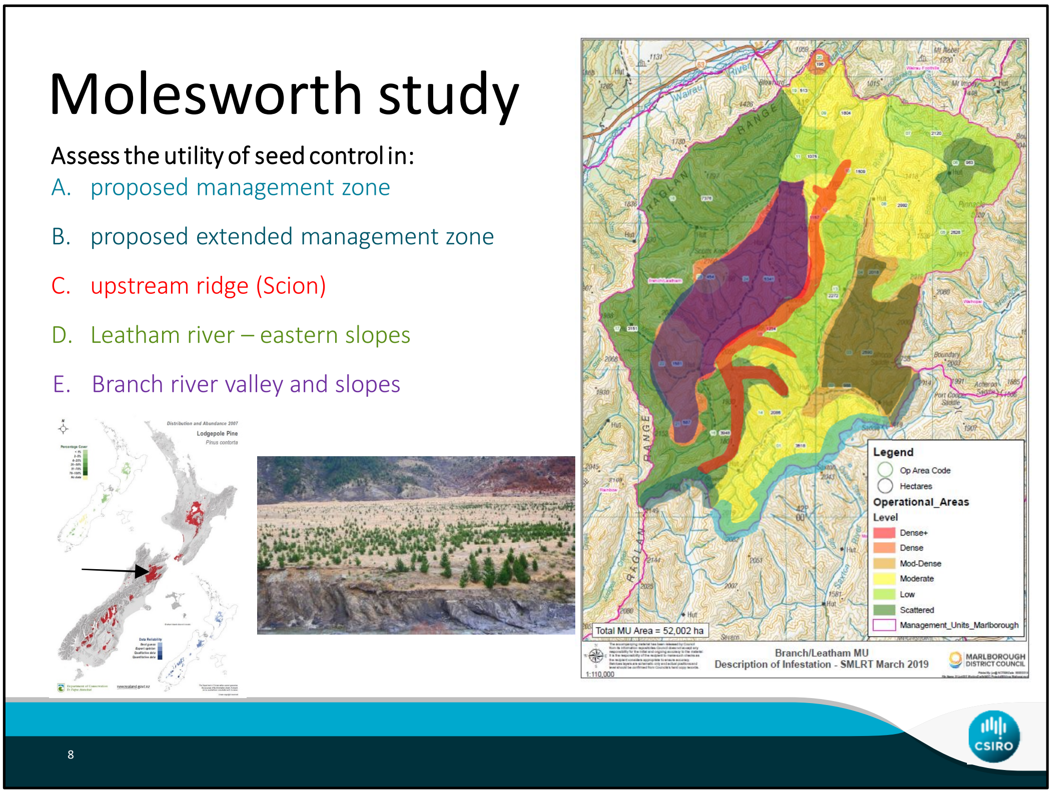
The model provides a static snap shot of the seed dispersal under a fixed wind speed, direction etc. – a more realistic climatology can be built up by compositing a set of these snap shots.

The FTM comprises two main components, each with a well-established science background:

- The flow part of the model consists of an approximate-physics approach established via the wind energy sector and involves 13-equations;
- the seed dispersal part utilises a probabilistic model called WALD which involves 5-equations to represent the dispersal kernel

As part of Winning against Wildings we have undertaken critical development work so that these models can operate in three-dimensions.

A key attribute of the FTM is that it is quick to run so many different scenarios can be compared.



We will demonstrate the FTM through a particular case: Molesworth station on the South Island.

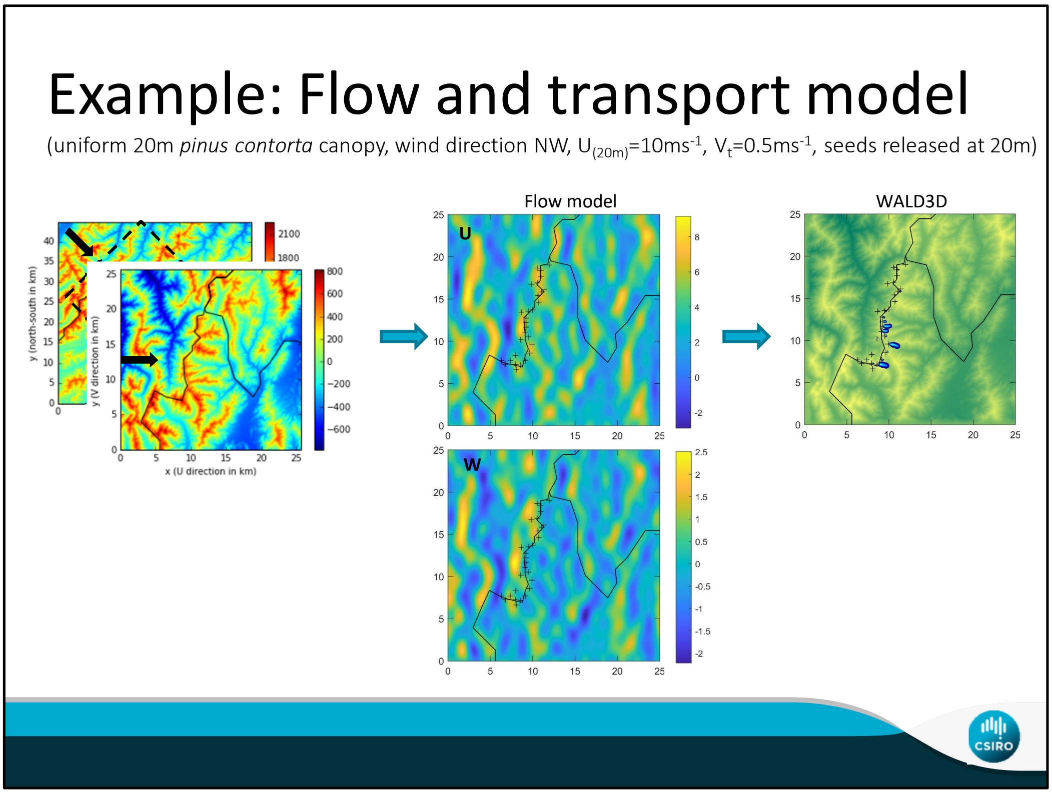
IMPORTANT NOTES: First, this analysis has been conducted in short time and in ignorance of the history of the site, including its management; and second, this case/site is pushing the current capability of the flow and transport model, which we are still actively developing.

Our Scion colleagues posed questions concerning the utility of some proposed management strategies for Molesworth station – this management strategies involve aerial spraying over specific zones at and just over the border of Molesworth station with its neighbour (Branch-Leatham) to the north.

The FTM has been run so as to estimate the geographical ranges over which seeds released from trees in five regions could potentially spread – i.e. we are assessing the benefit of avoided wilding if such a management practice was applied. Of particular interest to Molesworth station are those locations in the landscape where any wilding seeds could potentially cross the boundary of the station.

The management strategies were
1. the ridge line that forms the northern boundary of Molesworth station (light blue region)
2. extensions along the boundary ridge line to the west and northeast (dark blue), and
3. the higher (upstream) ridgeline that separates the Branch and Leatham valleys (red)

… and then for reference we have also considered two regions with existing dense wilding concentrations located in the two river valleys.



Here we will step through the model for an illustrative but somewhat non-realistic example: windy conditions from the NW where the landscape is completely forested with 20m high pinus contorta (relatively light seeds)

The steps in the model are

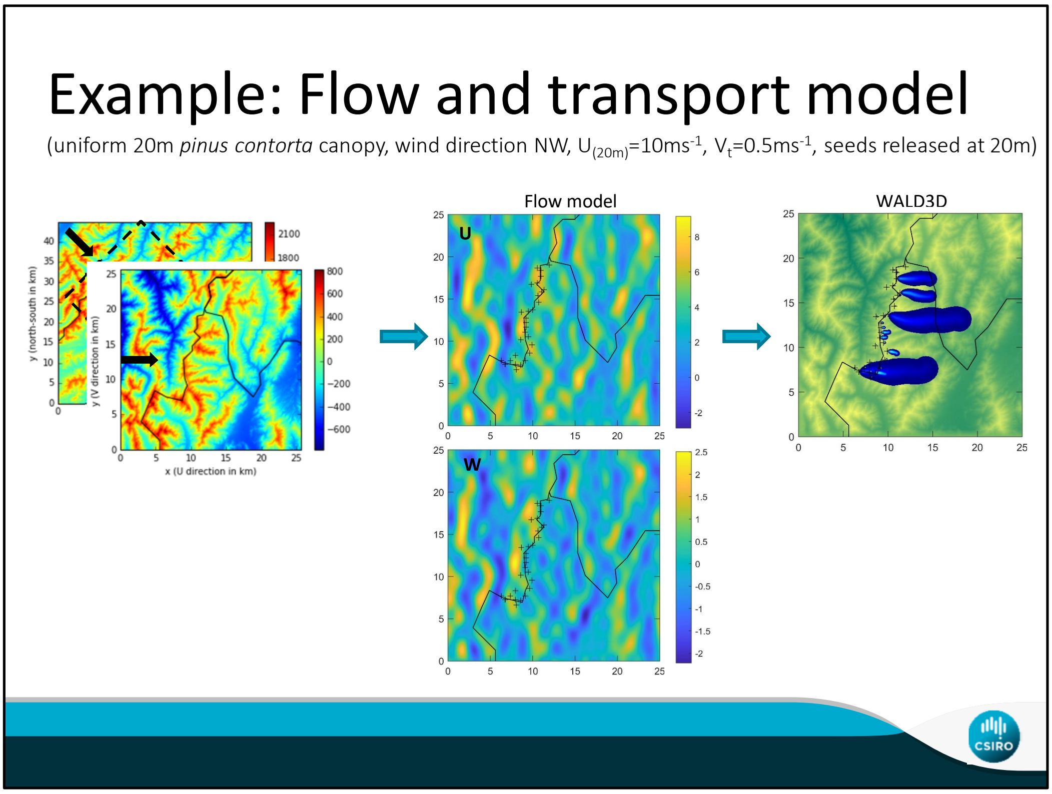
i) take a subset of the terrain and rotate so that the average wind flow is from left to right (the boundary of the station is marked by the thin black line to aid alignment of the audience) – left panel

ii) calculate maps of the averaged flow (in 3 directions) and the turbulence, across the landscape and at different heights above the ground – centre panels

iii) release seeds at prescribed locations in landscape (marked by crosses, in this case the proposed management region) and evaluate the probability map of where those seeds would land – right panel.

On the WALD panel the blue bubbles show the boundary within which 99.5% of the released seeds have landed on the ground, with the red-yellow-blue colours indicate a higher-to-lower probability of seed landing at that location. There is no allowance for bouncing, hitting other trees etc.

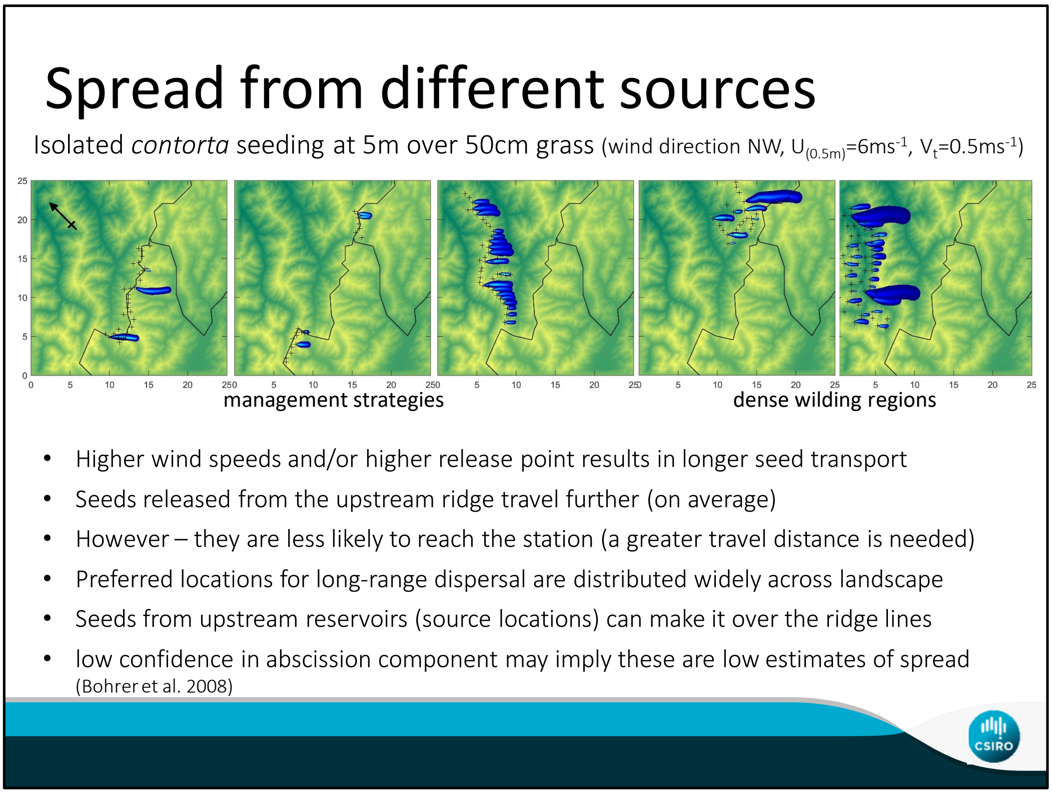
This example suggests that there’s not much to worry about – the predicted wilding spread is largely contained around the existing trees with few locations resulting in anything other than fringe spread.



Well actually – we deliberately held back some of the seed release locations from those results.

This shows the full result (4 extra seed release locations)

This immediately informs us that (according to the model at least) there are preferred locations in the landscape where long dispersal could/would occur and that seeds can travel substantial distances across/into Molesworth station.



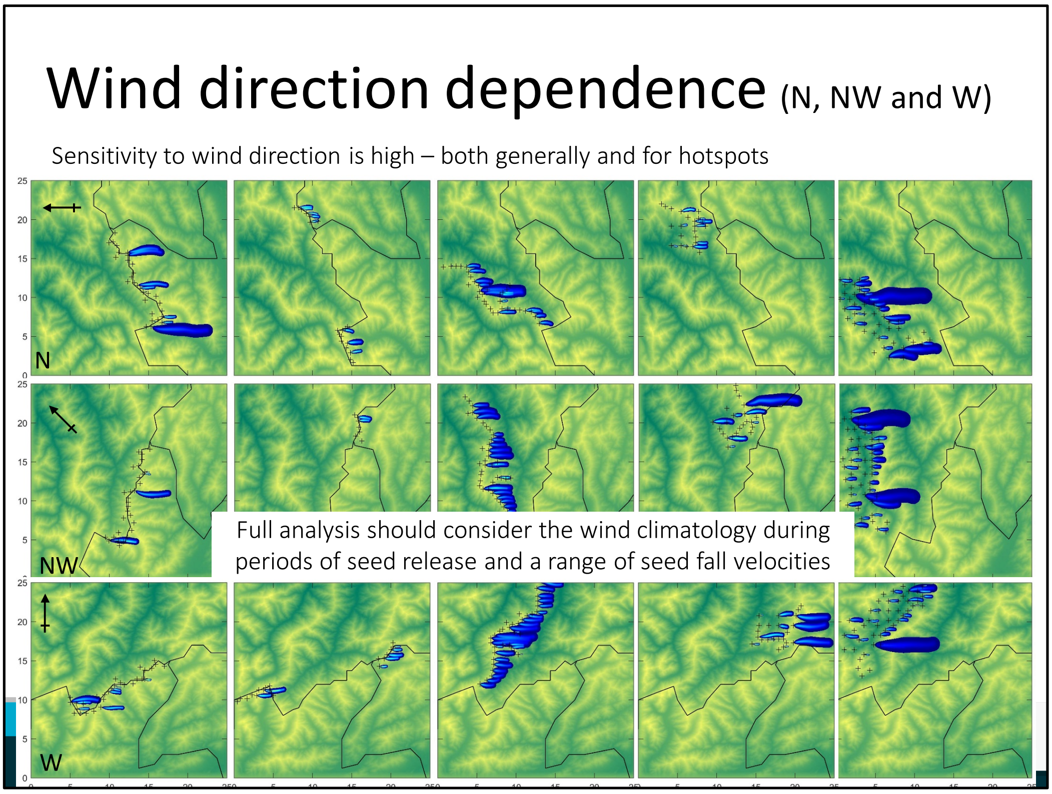
Those results were somewhat unrealistic – the landscape in Molesworth is not a uniform forest. Here we show the end result of a more realistic assessment: NW flow, 50cm grass cover, with isolated trees releasing seeds at 5m, still windy.

The five panels here show the seed dispersal plumes from the 3 proposed management regions (left) and the 2 primary source regions (right). The background weather used here is similar to that previously so the leftmost panel can be sensibly compared to the previous slide. The underlying reasons for the difference between these and the previous results is the change in surface cover from trees to grass AND that the seeds are released at a lower height.

From this comparison we note that

- there are still locations in the landscape from which long range dispersal is simulated to occur – though these are fewer in number than in the previous illustrative but unrealistic example.
- of the three management strategies – seeds released by trees on the upstream ridge are expected to spread over a wider region – but, in this example, they do not get into the station area.
- seeds released from both the proposed, and proposed extended, management regions do impact Molesworth station.
- seeds from the two source regions can make it over the ridge lines – and there is (at least) one location from which seeds make it onto Molesworth station land.

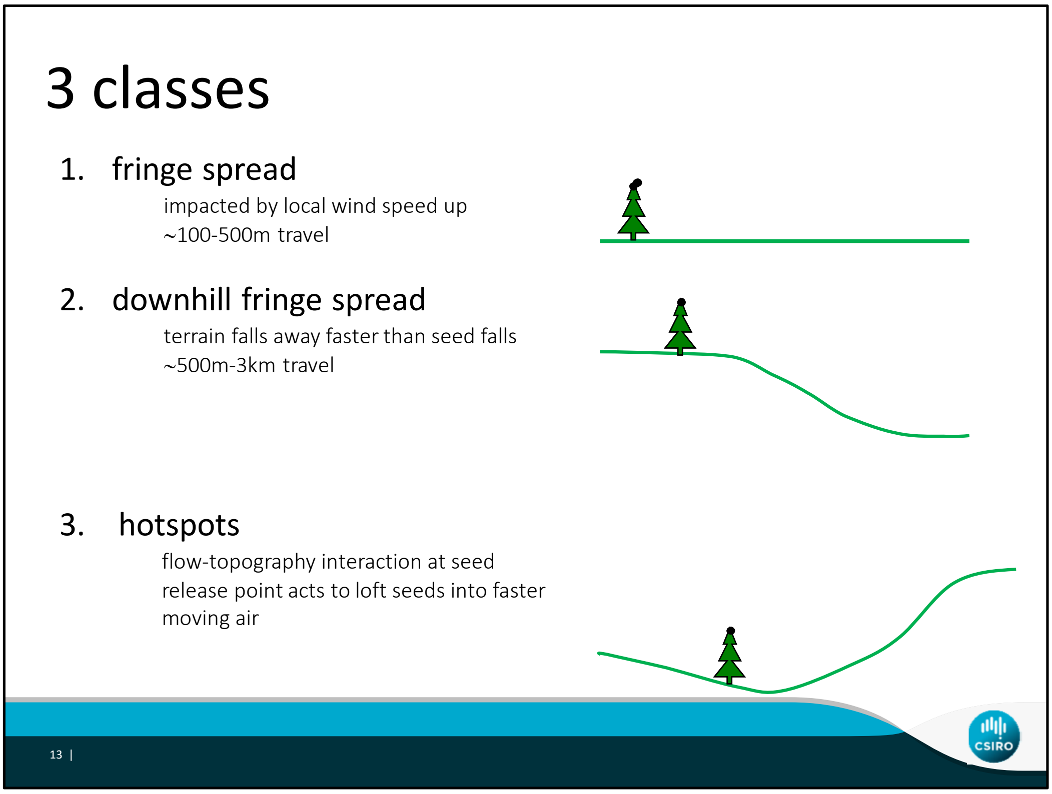
We should note that results from other researchers concerning the interaction between turbulence and seed abscission (which is not incorporated into this model yet) suggests that these results probably provide a low estimate of seed spread.



Of course – the weather provides variability in wind speed and direction – these panels provide a quick assessment of variability due to wind direction (from three prominent wind directions).

Overall these results provide similar information concerning the relative merit of the different management options.
Importantly however, the identified locations for long range seed spread (which we term hot spots) change with wind direction.
We also expect that more hot spots would occur with higher wind speeds.

A full analysis needs to consider the wind climatology during periods of seed release and address the uncertainty in seed fall velocities.



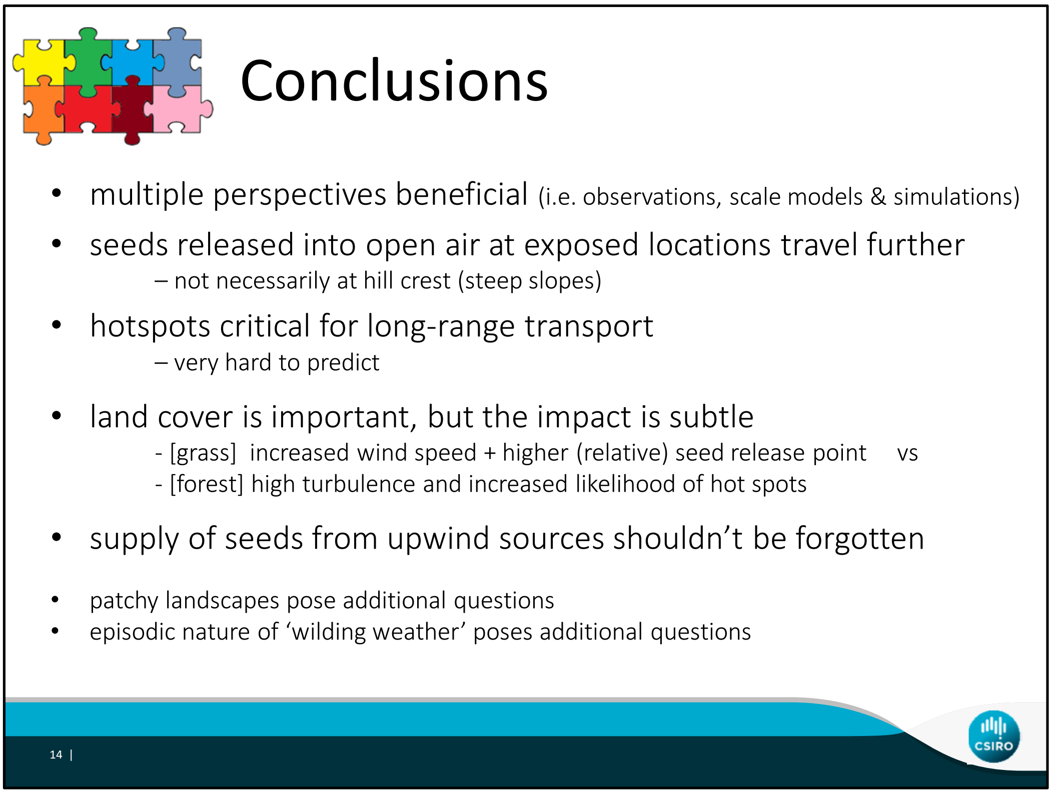
So we see from these results a marked dependence of the expected behaviour of seed dispersal on position of release in the landscape: Can we understand this further?

On further analysis it appears that the range of behaviour can be split into three broad classes:

1) fringe spread - impacted by any local terrain-induced wind variation (e.g. speed up).
2) fringe spread where the terrain falls away faster than the seed falls – also impacted by local terrain induced wind variations. The downhill slope allows seeds to travel further before landing. This class occurs from exposed slopes - not necessarily hill crests.
3) hotspots – from where long range transport is triggered.

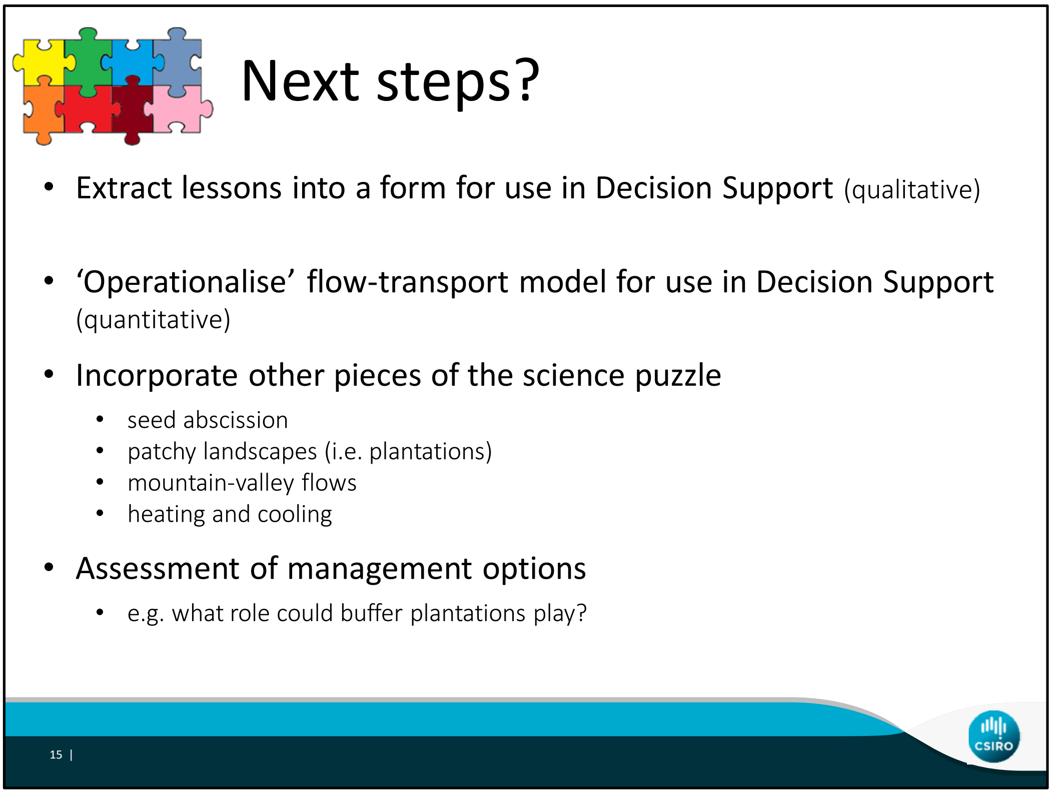
The key difference in the flow/turbulence at hotspot locations is a lifting of the seeds by the flow at/near their release points. This lifting moves the seeds into the faster moving air aloft, which can then carry the seed upwards against gravity. Seeds are always trying to fall under gravity - but this tendency can be countered by lift from upslope winds [with the lift force depending approximately on the square of wind speed so the lift is more likely to 'overcome' gravity if the winds speeds are higher and/or the seed is already well above the surface].

However, the insight gained by developing the flow-transport model is that predicting the hotspot locations is very sensitive to the landscape conditions – and is likely sensitive to the specifics of the model.



Conclusions from our work to date:

A comment on the 5th dot point: It is easy to focus on the proximal challenge – i.e. those wildings that are releasing seeds into a particular region of concern/management. However, in the longer term, a strategy that addresses/recognises all relevant seed sources is likely needed.



Next steps:

As part of 'Winning against Wildings' we aim to extract the lessons learned so far into a form that can be used (we term this qualitative information). This effort will include completing a more formal three-ways comparison between our wind tunnel, LES and FTM results as a means to provide the scientific rigour behind those lessons.

In the future there are a number of other areas for further work:

- work to operationalise the existing capability into a form that it could be used by the broader wilding community
- work to extend the capability of the flow transport model – we specifically addressed an area where the community understanding was weak, however there are many topics where additional insight would be valuable.
- specific work to assess the utility of management options, and
- efforts to validate/verify the models and their utility.

Thank you

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