Healthcare Modelling for Pandemic Planning and Recovery

Michael O'Sullivan

Joint work with: Cameron Walker, Ilze Ziedins

University of Auckland

Summary of work from Te Pūnaha Matatini

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Te Pūnaha Matatini
Data ▪ Knowledge ▪ Insight

Ko Maungakiekie te maunga
Ko Waitemata te moana
Ko waka moana te waka
Ko Te Atatu te marae
Ko Airangi me Haina te iwi
Ko O'Sullivan te hapu

Ko Mike ahau

One Tree Hill is my mountain
Waitemata is my ocean
My waka (canoe) comes from over the sea
My community is Te Atatu
I am of Irish and Chinese descent
My family is O'Sullivan

I am Mike

Dr Michael O'Sullivan

Dept of Engineering Science
University of Auckland (UoA)

University of Auckland
- BSc (Hons), MPhil (Disc)

Stanford University alumni
- MS, PhD

President, OR Society of NZ

Theme Leader, Precision Driven Health

Investigator, Te Punaha Matatini

(Complex Systems)

Research/consulting in Operations Research and (Computational) Analytics for Health, Social Investment, Cloud Computing, Infrastructure Planning, Finance

University of Auckland/Te Pūnaha Matatini Researchers

Associate Professor Ilze Ziedins
Associate Professor of Statistics, University of Auckland

Associate Professor Cameron Walker
Associate Professor of Engineering Science, University of Auckland

Dr Mike O'Sullivan

Senior Lecturer in Engineering Science, University of Auckland

- Ilze, Cameron and Mike are all Associate Investigators with Auckland/Te Pūnaha Matatini
- Involved in the response to Covid-19 – translating disease spread into hospital/ICU admissio
- Have worked with Waitemata DHB and other DHBs previously
  - Surgery scheduling, CVICU planning, patient transit simulation, whole-of-hospital modelli

Te Pūnaha Matatini Researchers

Alex James
Associate Professor
College of Engineering
University of Canterbury

Audrey Lustig
Quantitative Ecologist
Manaaki Whenua/ Landcare Research

Mike Plank
Professor
School of Mathematics and Statistics
University of Canterbury

Rachelle Binny
Mathematical Modeller Wildlife Ecology and Management Team
Manaaki Whenua/ Landcare Research

Shaun Hendy
Professor
Department of Physics
University of Auckland

Nic Steyn
Researcher
Te Pūnaha Matatini

https://www.tepunahamatatini.ac.nz/?s=covid

(Some of) The Team

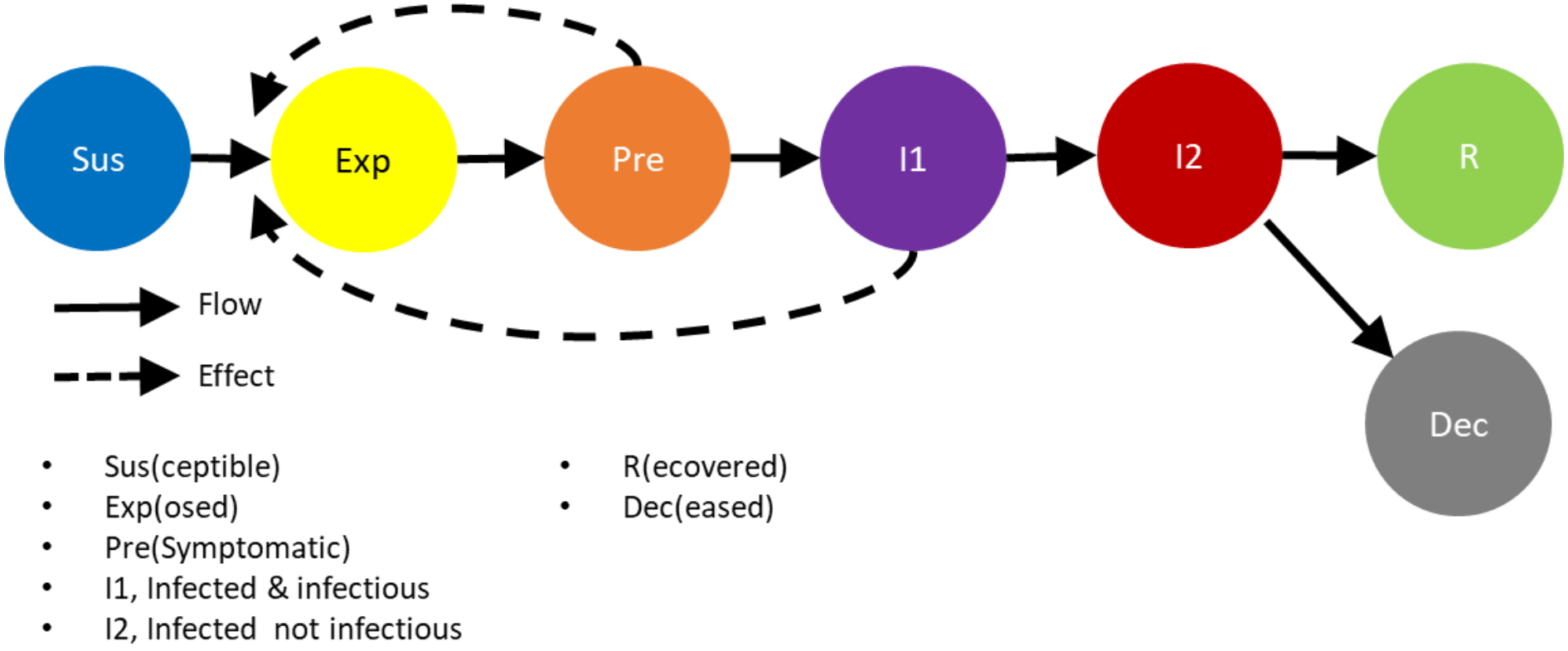
- Siouxsie Wiles
- Kate Hannah
- Giulio Dalla Riva
- Max Soar
- Andrew Sporle
- Dion O'Neale
- Emily Harvey
- Oliver Maclaren
- Adrian Ortiz-Cervantes
- Thomas Lumley
- Kevin Ross
- Pieta Brown
- Matt Parry
- Barry Milne
- Richard Arnold
- Krushil Watene
- Mick Roberts
- Genevieve Dawick
- Rebecca Priestley
- David Welch
- Suzie Greenhalgh
- Tahu Kukutai
- Melissa McLeod
- Kannan Ridings

Background

- New Zealand has followed a policy of “go hard and go early”.
- Early decision to aim for elimination of Covid-19 in New Zealand.
- NZ has had 2088 confirmed and probable cases (9 Dec), of whom 122 were hospitalized and 18 entered ICU.
  - Ministry of Health website, https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-case-demographics
- We were a very small part of a large team built and led by Shaun Hendy, mostly within Te Pūnaha Matatini
  - This talk gives very brief overview of some of the models of patient flow we developed, as part of the team built by Shaun Hendy. First case reported 28 February. By 26 March we are in lockdown.
- Detailed modelling of patient flow was not needed in the end.

Simple SEIR model of epidemic growth

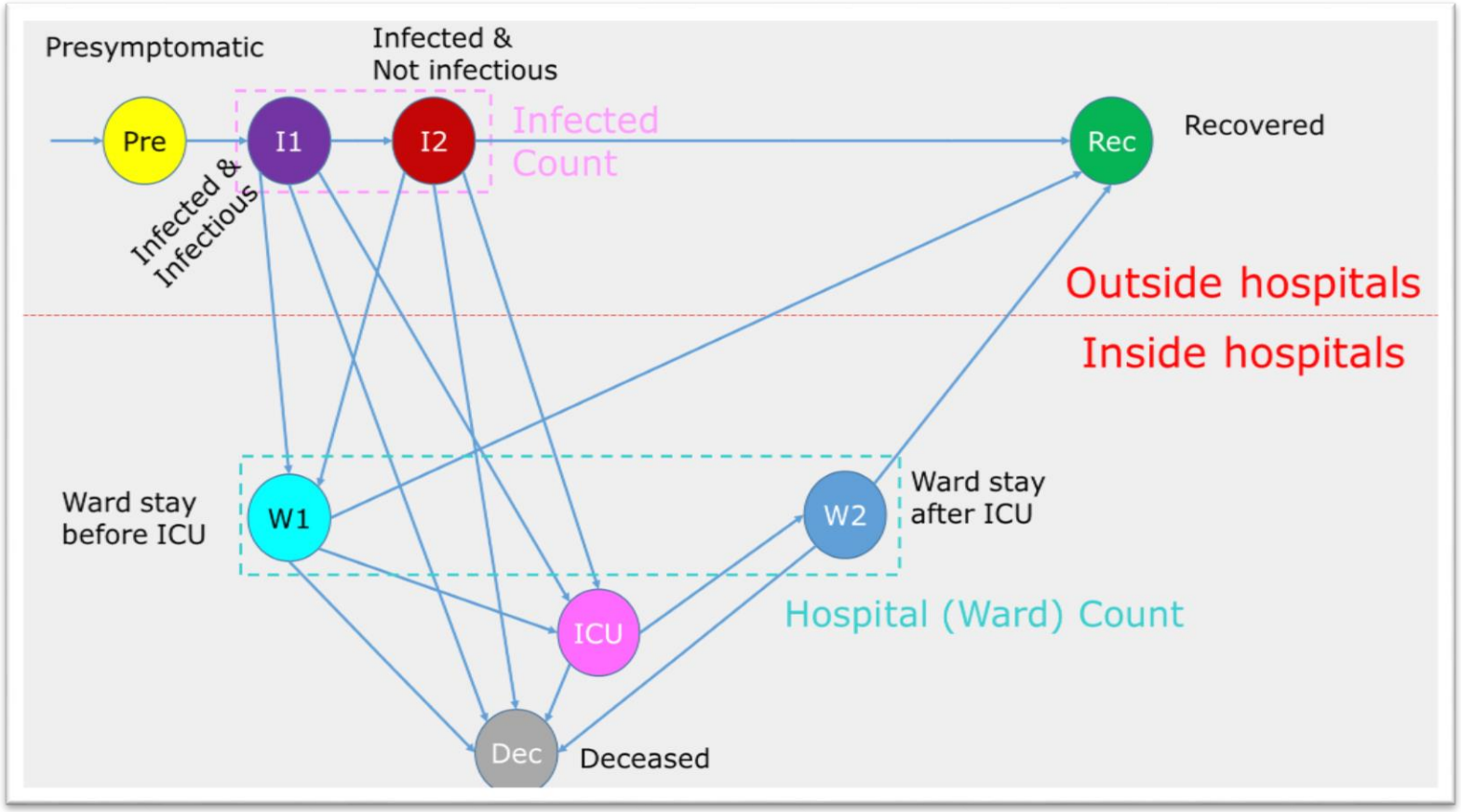
- Compartmental model, both deterministic and stochastic versions



- Based on original model from *Suppression and Mitigation Strategies for Control of COVID-19 in New Zealand* Alex James, Shaun C Hendy, Michael J Plank, Nicholas Steyn

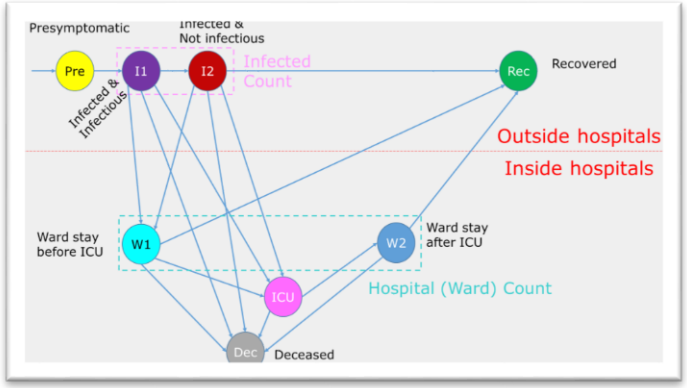
Effect on Health System

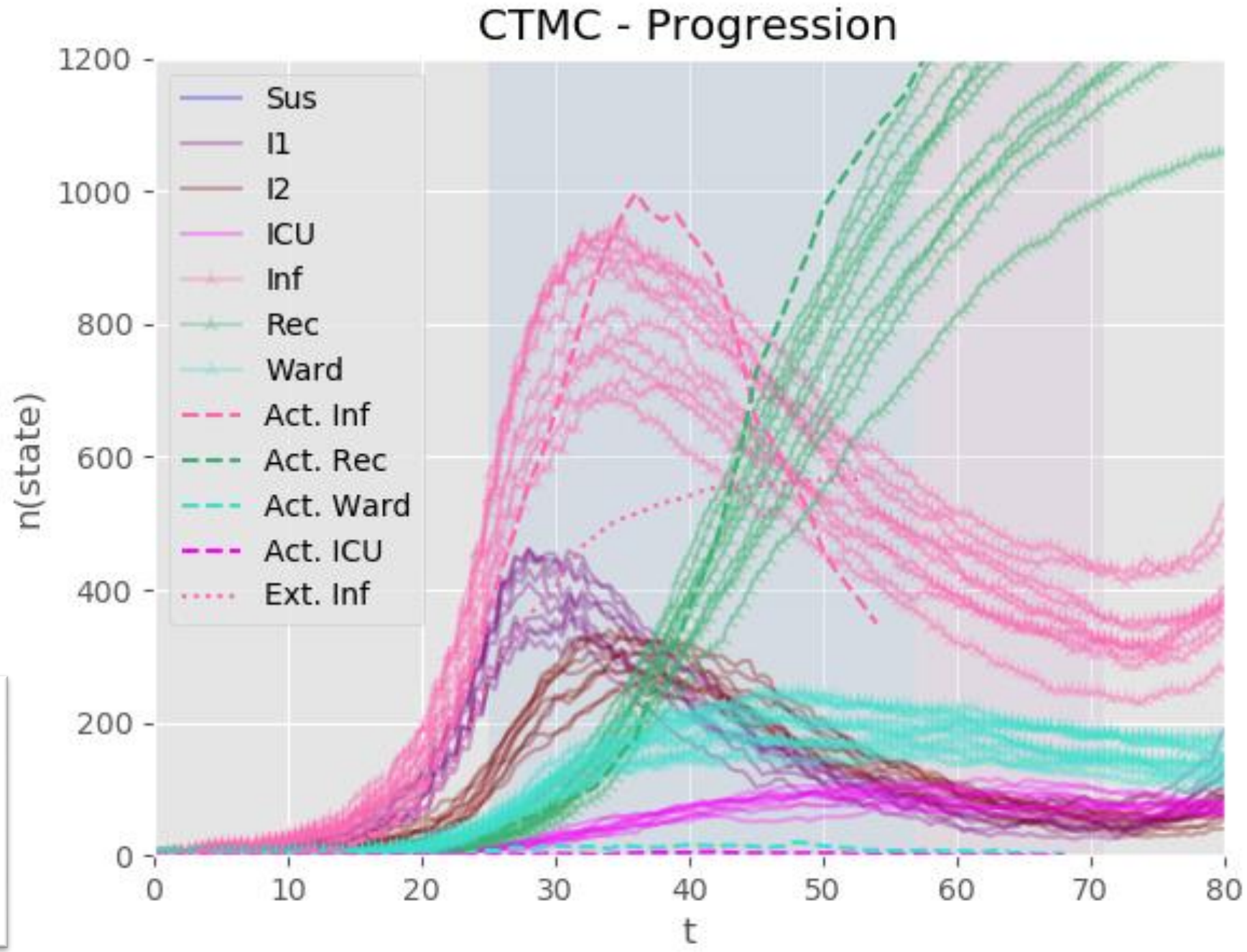
Compartmental model expanded (CTMC model)



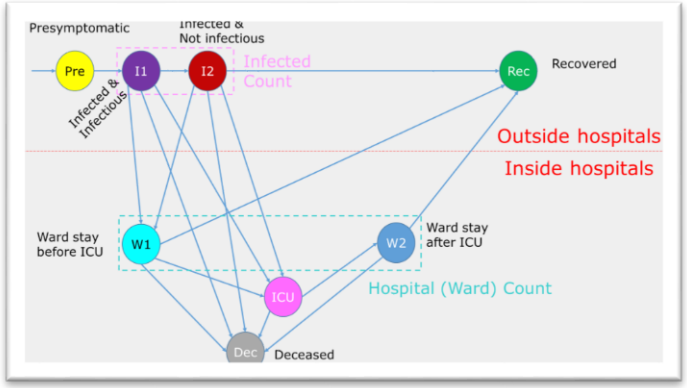
- W1 pre-ICU/ no ICU ward stay
- ICU stay
- W2, post-ICU ward stay
- R0, Recovered, unconfirmed
- Rec(overed), confirmed
- Dec(eased)

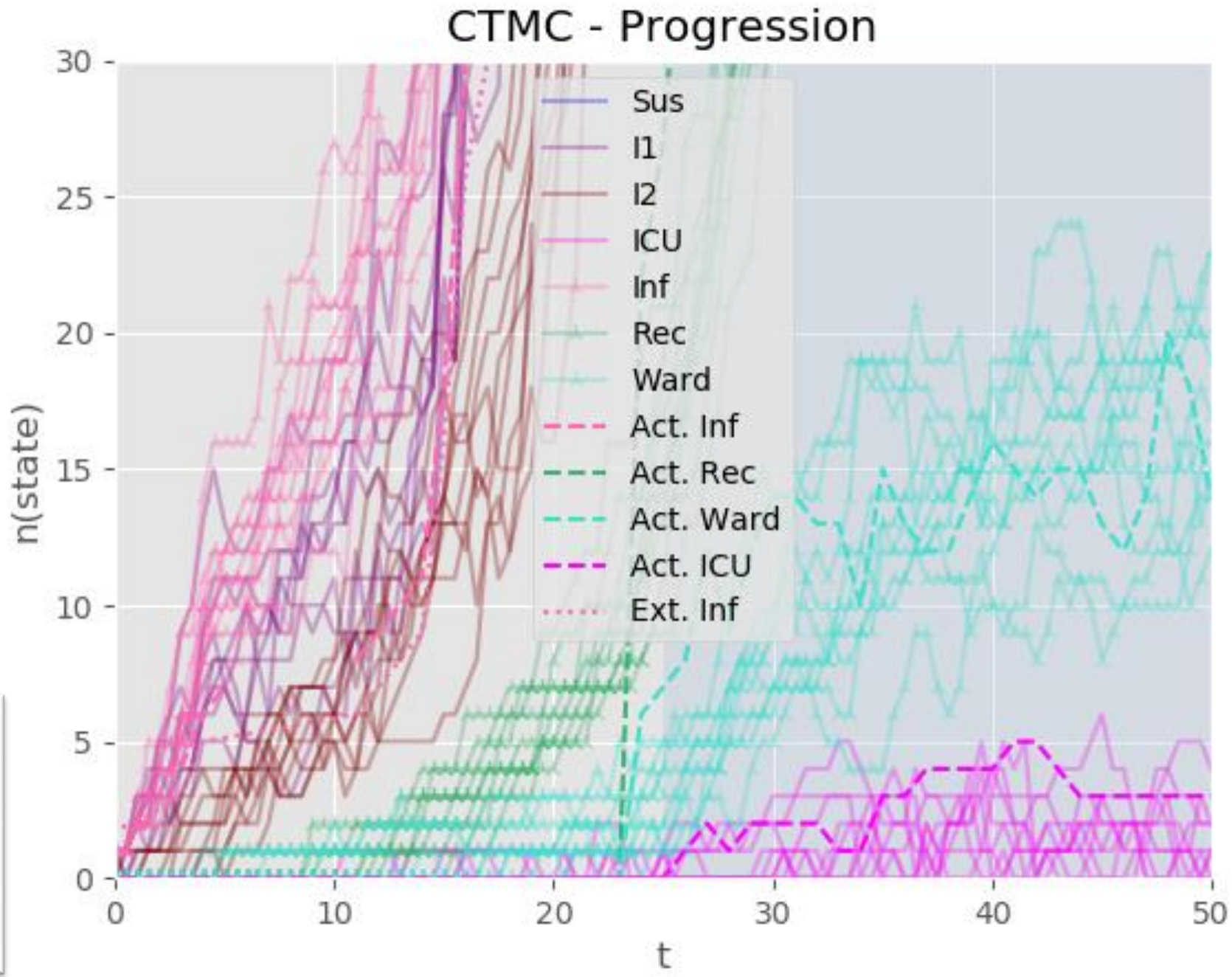
Effect on Health System





Effect on Health System



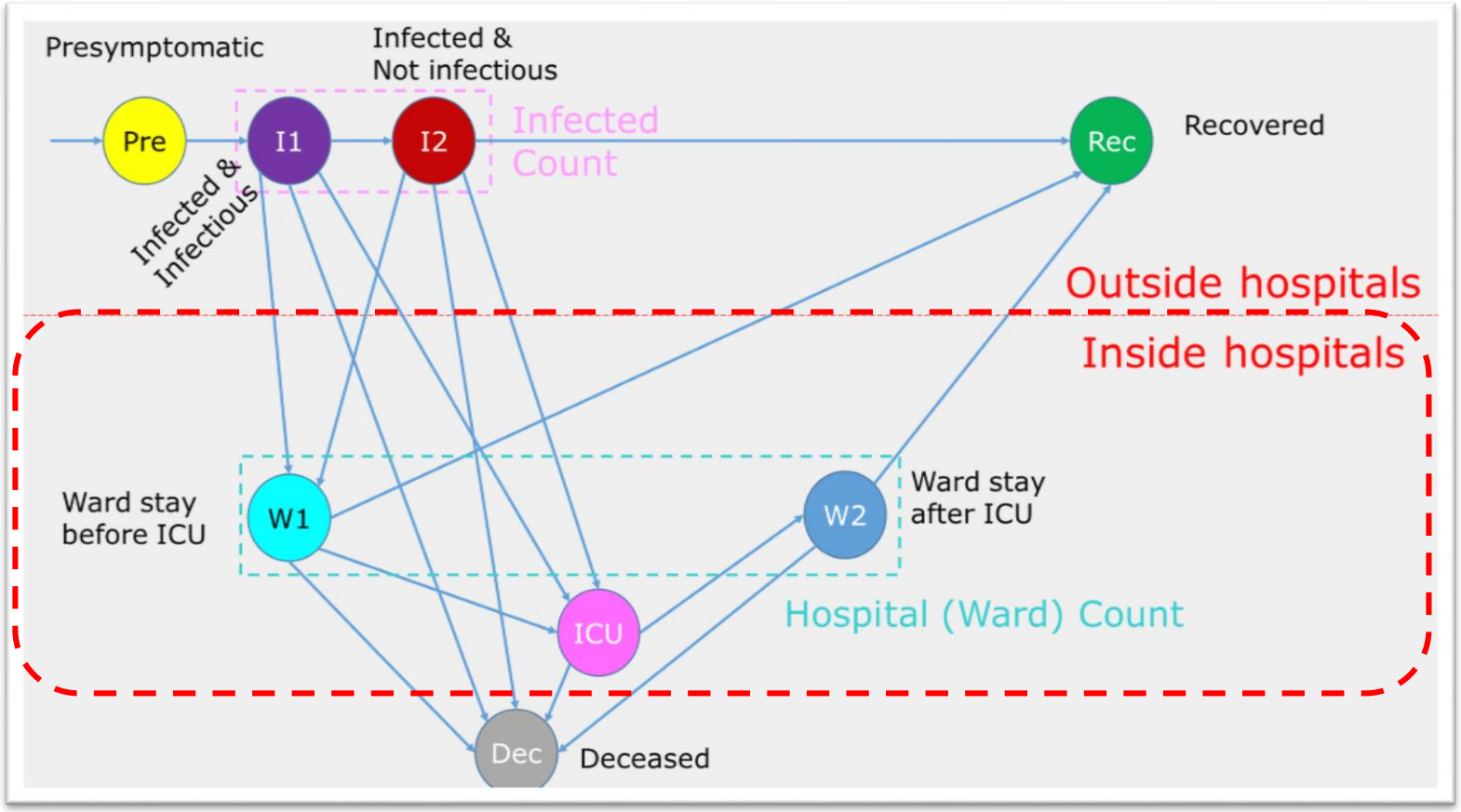


Extensions of basic model

1. Staff absence due to illness
2. More complex arrival process e.g. meshblock level spatial modelling of disease incidence.
3. More complex disease progression

Modelling Patient Pathways

- Patient pathway through hospital



The core inputs for these models include:

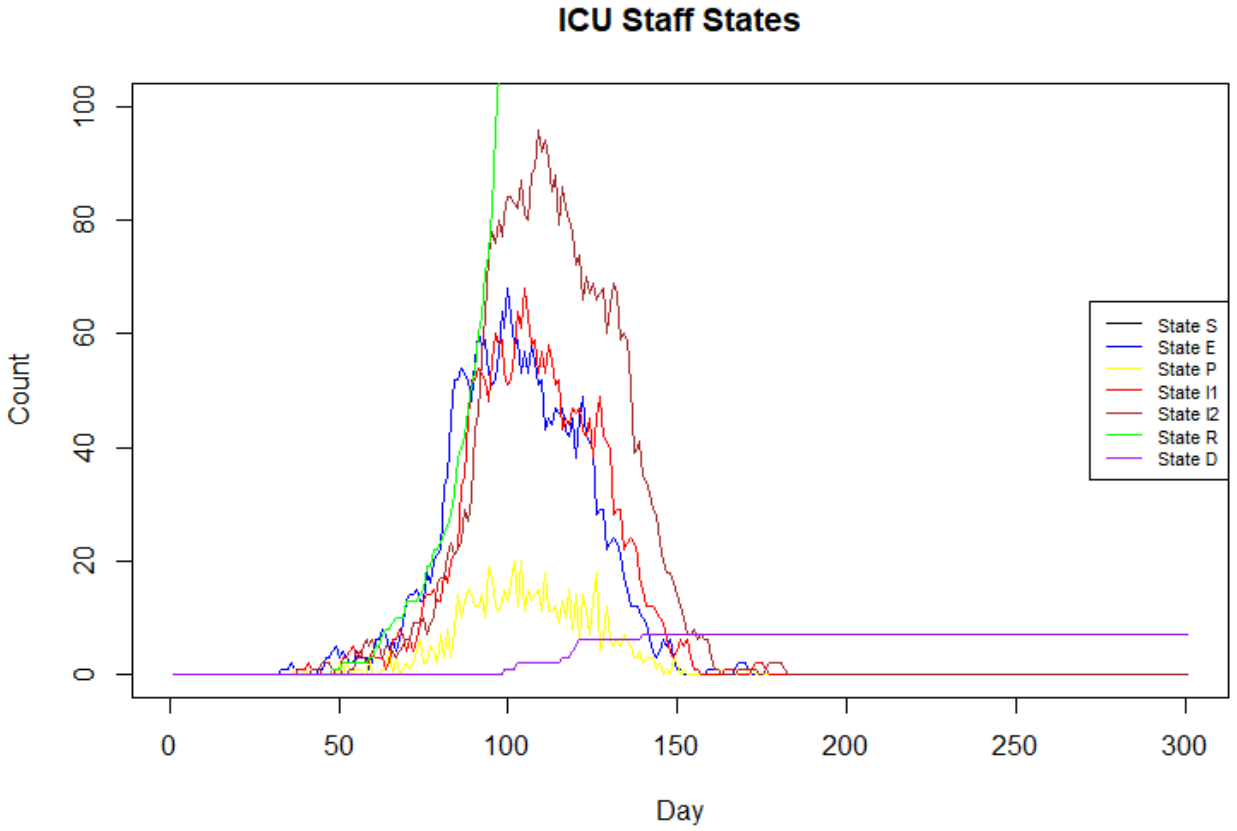
- Parameters as for CTMC, or, alternatively, entry rates to hospital/ICU
- Progression from ward to ICU to ward
- Length of stay in ward, ICU

Outputs for these models include estimates of:

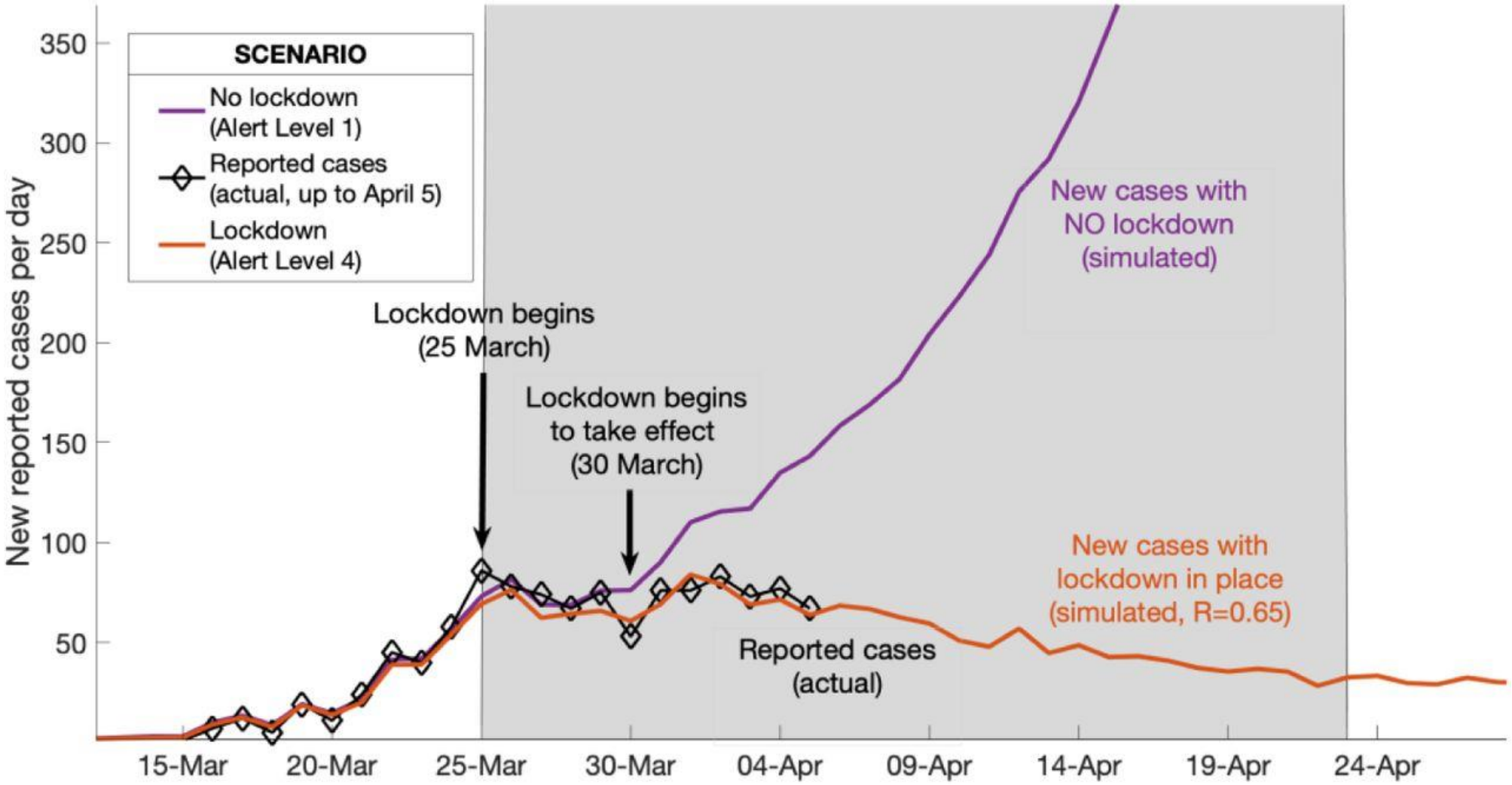
- Load on ICUs and Ward, and change over time

Including staff absences due to illness

- Daily admissions to hospital
  (from, for example, SEIR model)
  - Patients proportionally follow
    5 pathways with distributional LoS
    - ward -> discharge
    - ward -> ICU -> discharge
    - ward -> ICU -> ward -> discharge
    - ICU -> discharge
    - ICU -> ward -> discharge
- Each day ward and ICU staff can contract
  Covid-19 based on patient occupancy
  and number of infectious but non-symptomatic staff
  - Staff follow infection cycle
  - Bed availability reduced by staff unavailability
- ICU overflow to ward (deceased), affects staff/patient ratio in ward



Stochastic Model Based on Branching Process



A stochastic model for COVID-19 spread and the effects of Alert Level 4 in Aotearoa New Zealand
Michael J. Plank, Rachelle N. Binny, Shaun C. Hendy, Audrey Lustig, Alex James, Nicholas Steyn
medRxiv 2020.04.08.20058743; doi: https://doi.org/10.1101/2020.04.08.20058743

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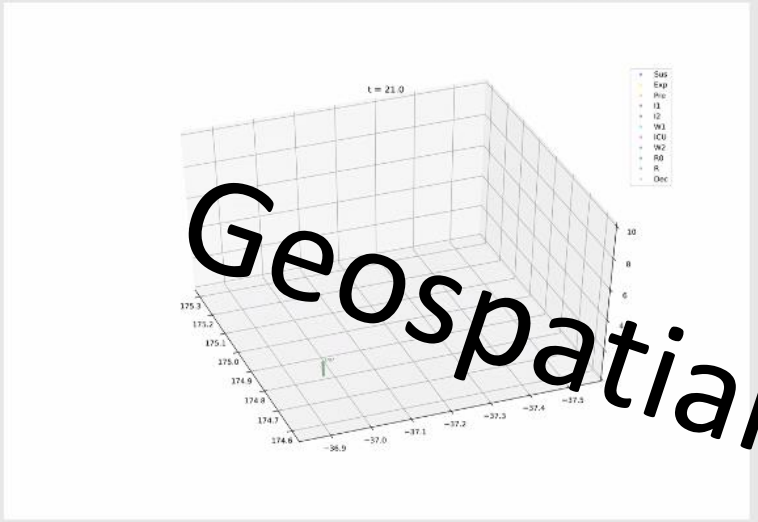

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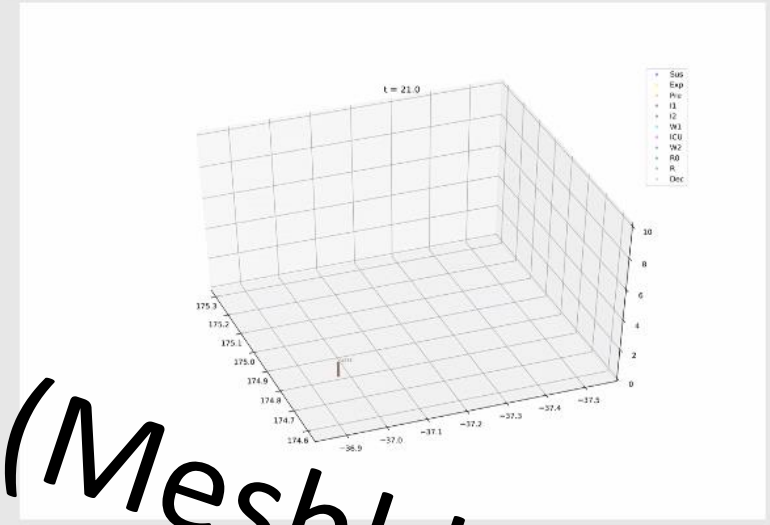

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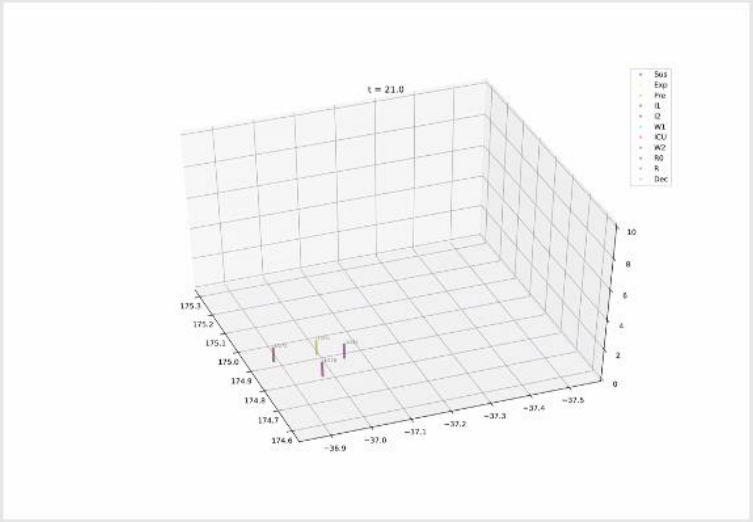

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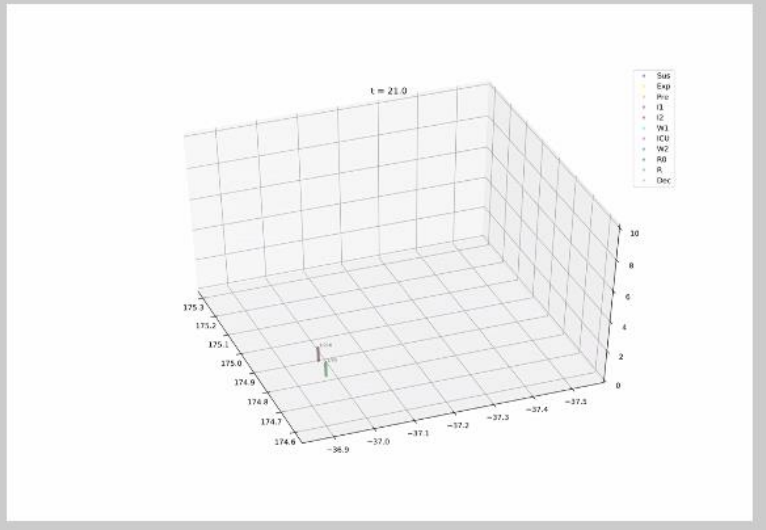

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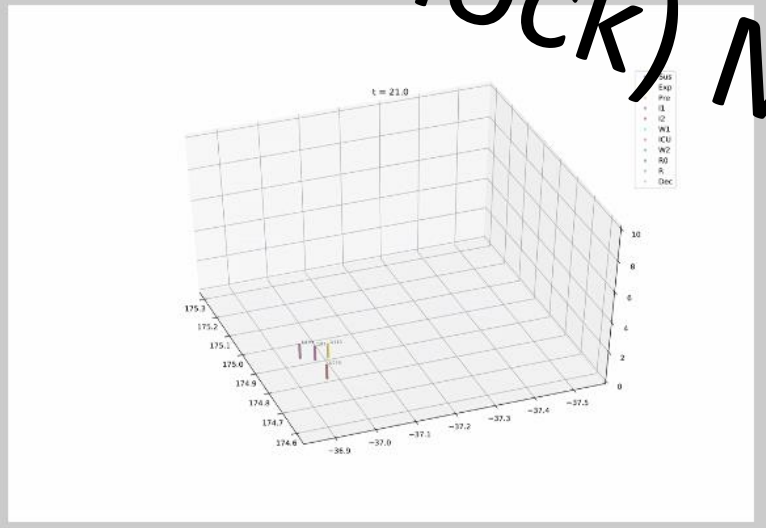

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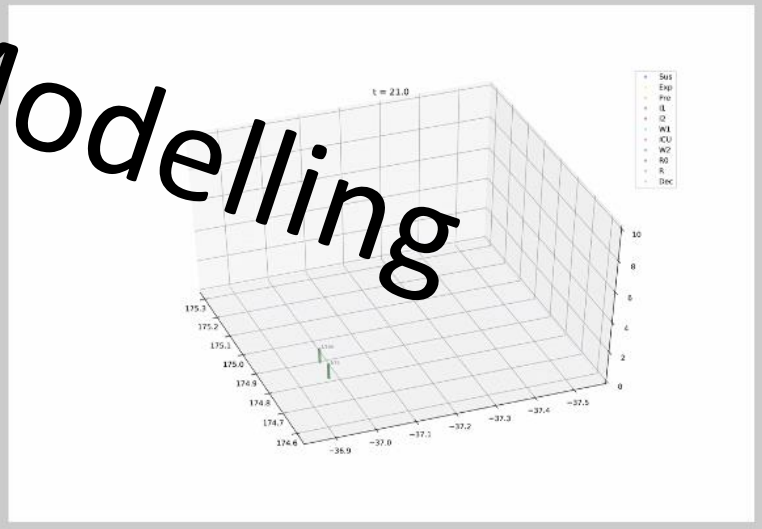

Geospatial (Meshblock) Modelling

Day 21, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

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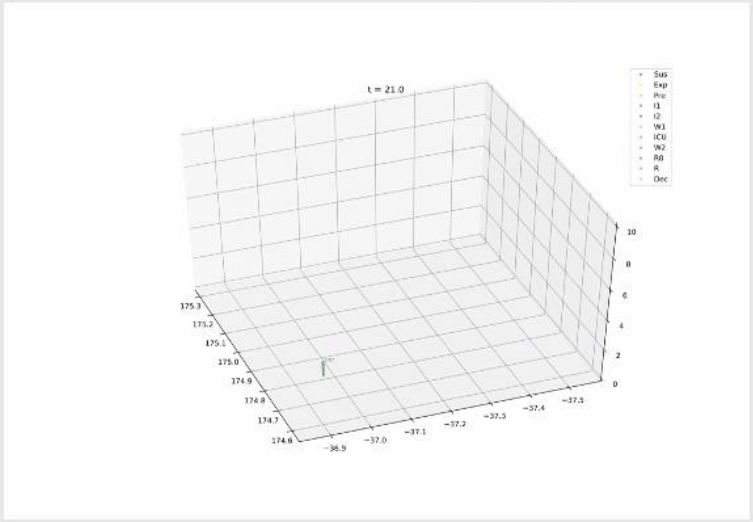

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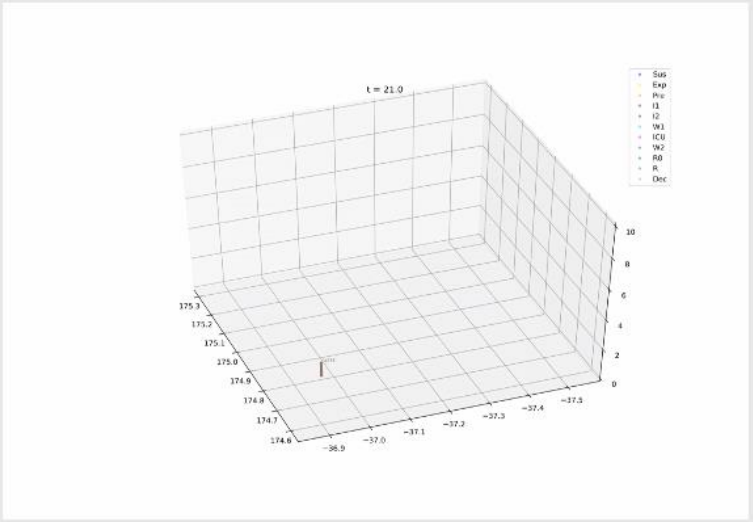

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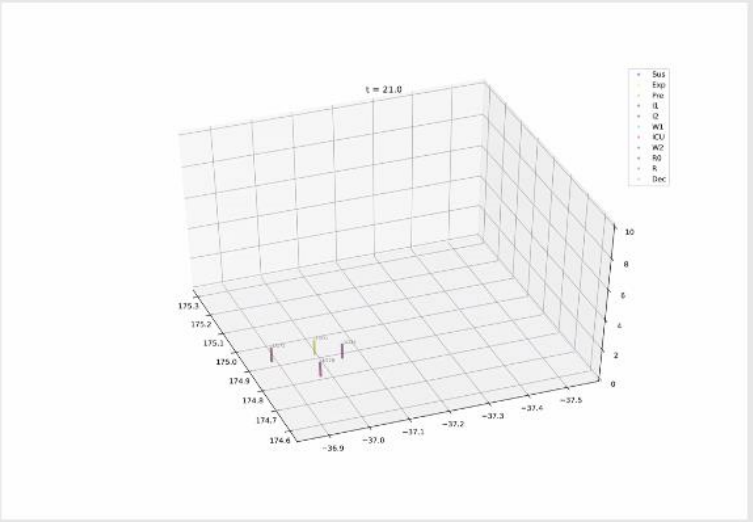

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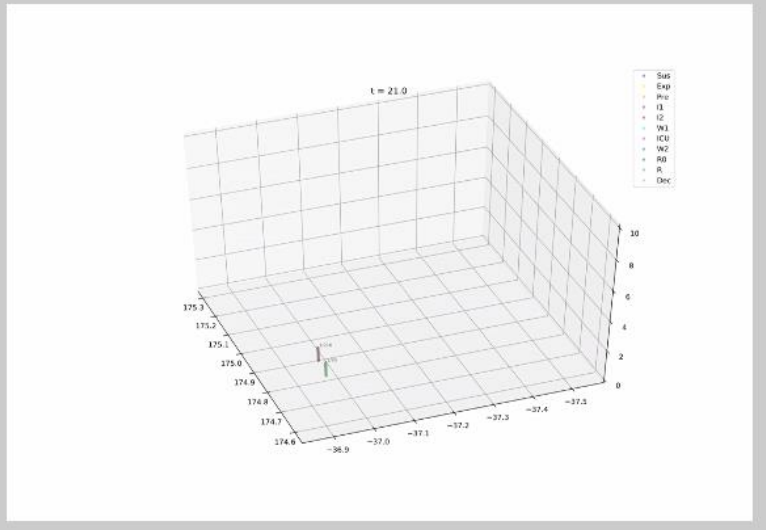

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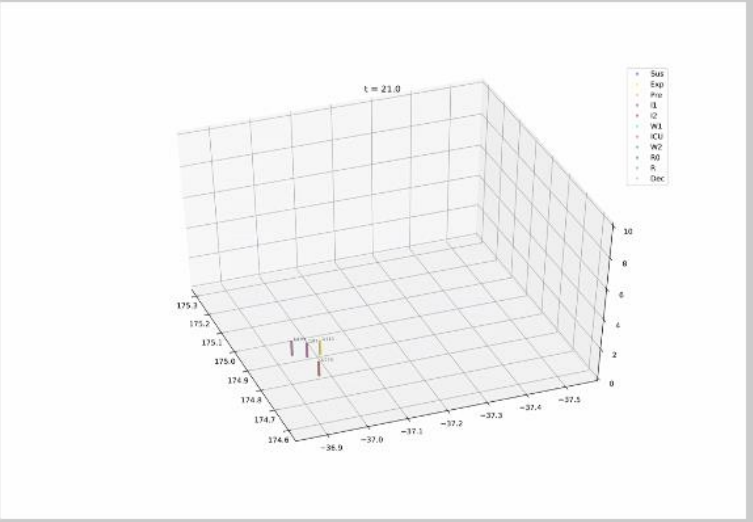

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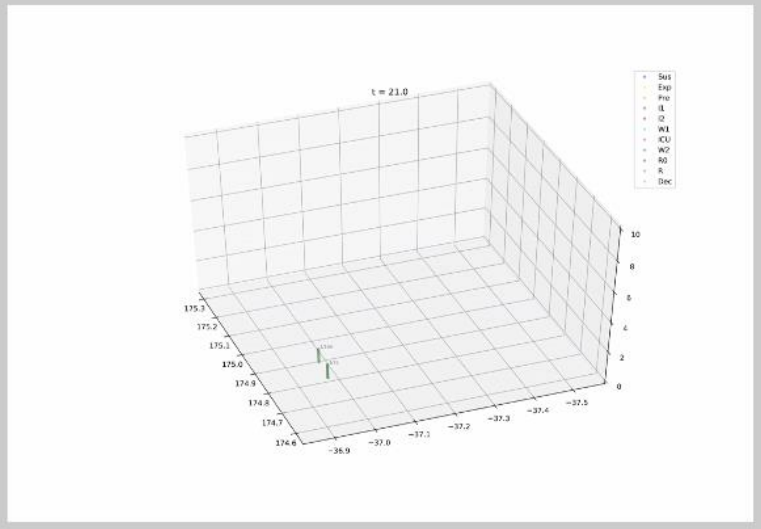
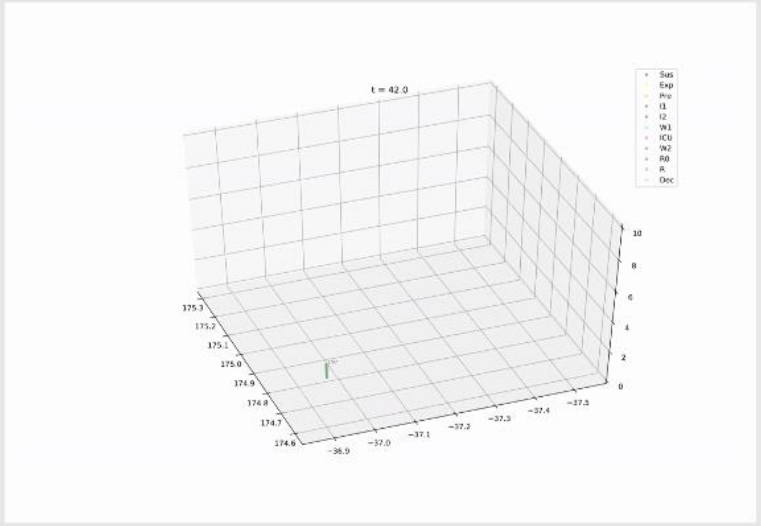


Day 21, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

Seeds = 1, 2, 4, 6, 9 (No spread)



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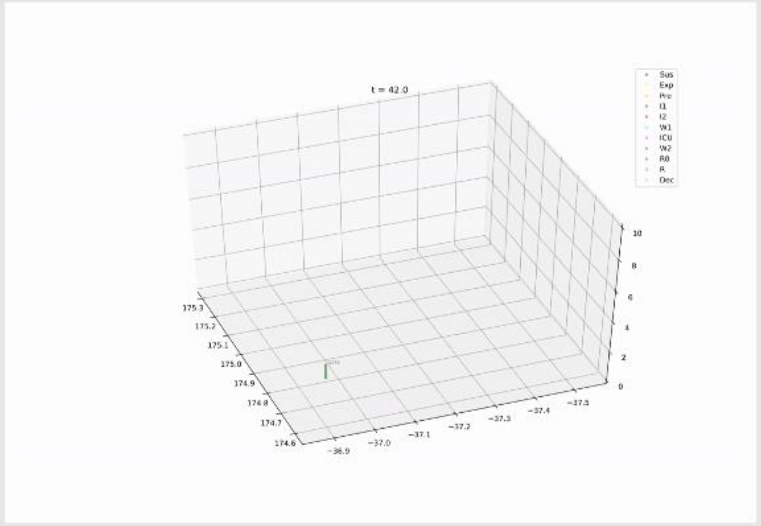

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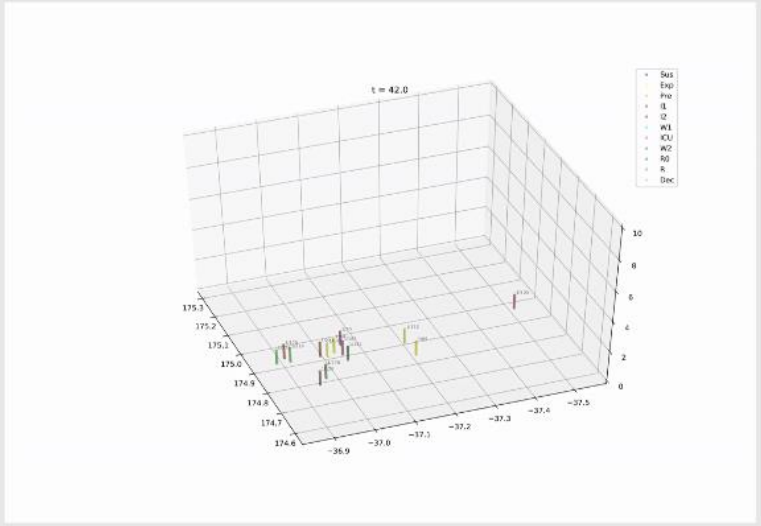

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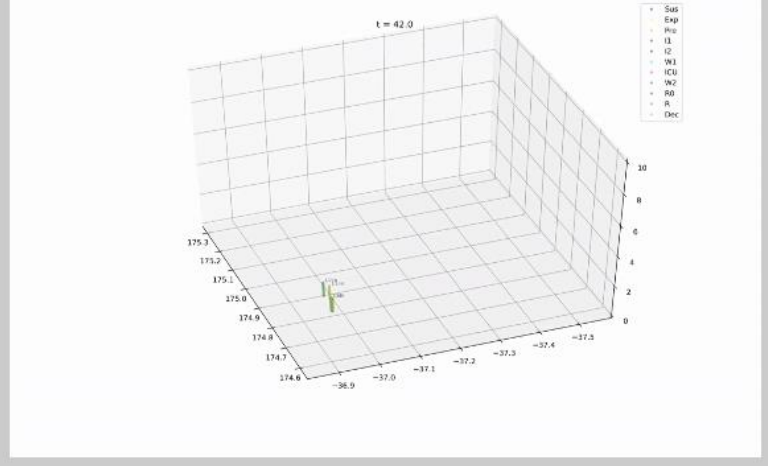

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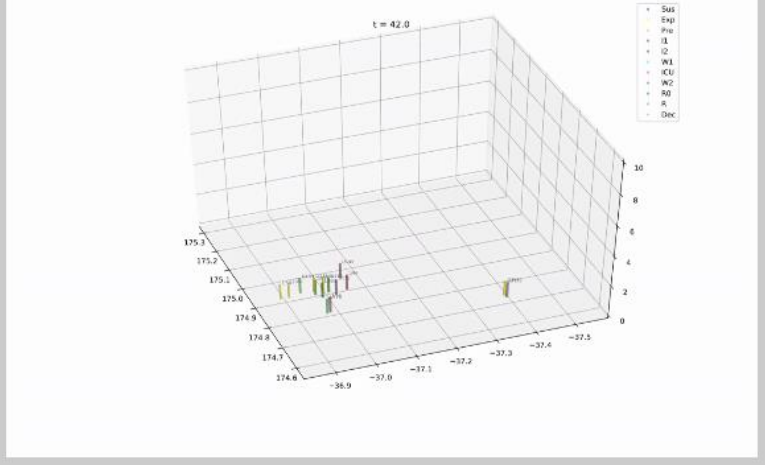

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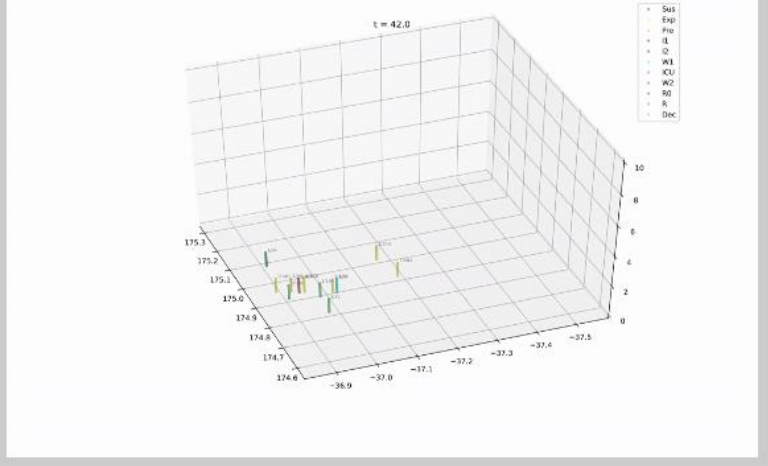
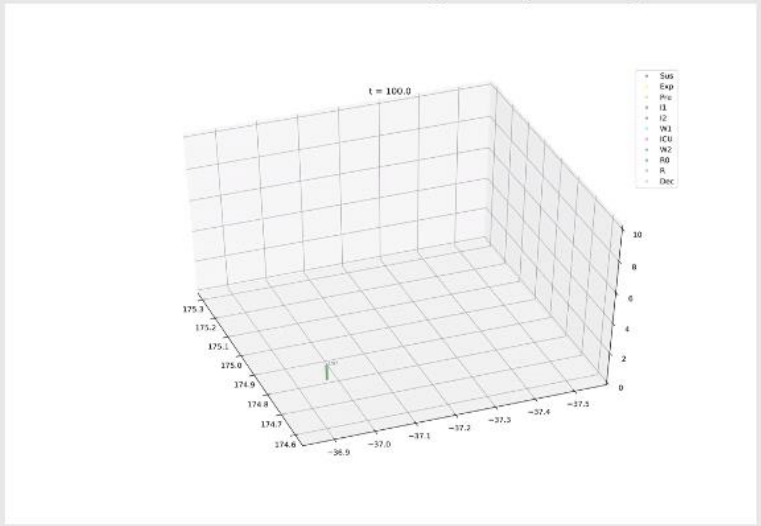


Day 42, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

Seeds = 1, 2, 4, 6, 9 (No spread)



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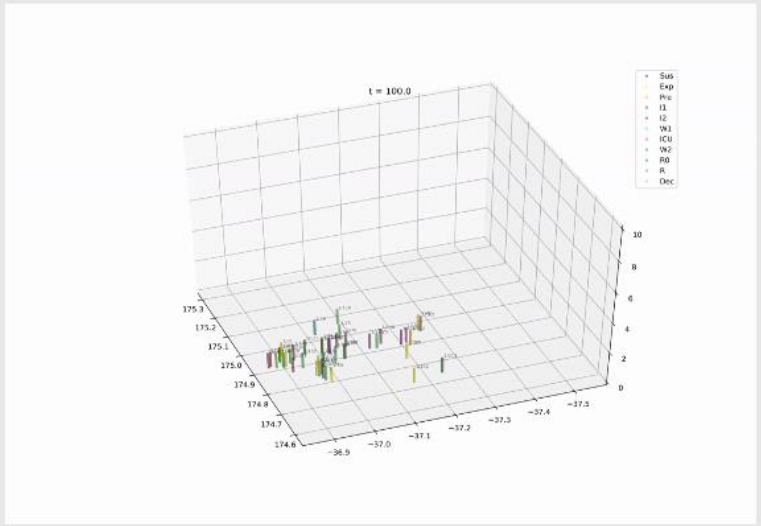

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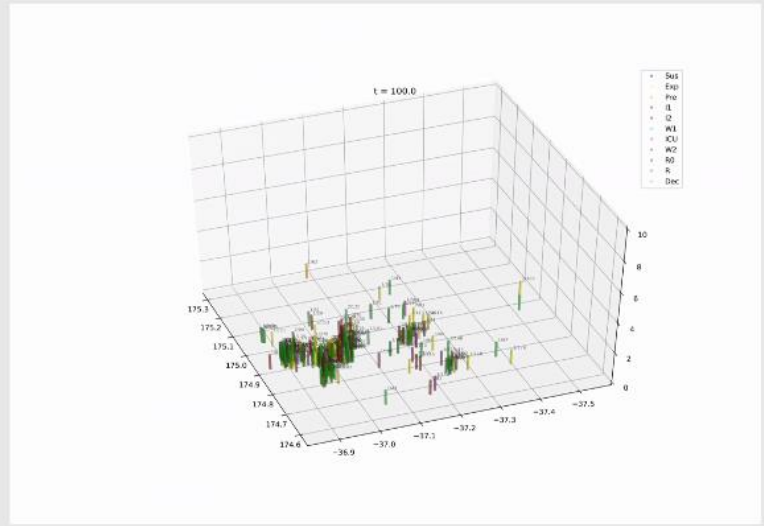

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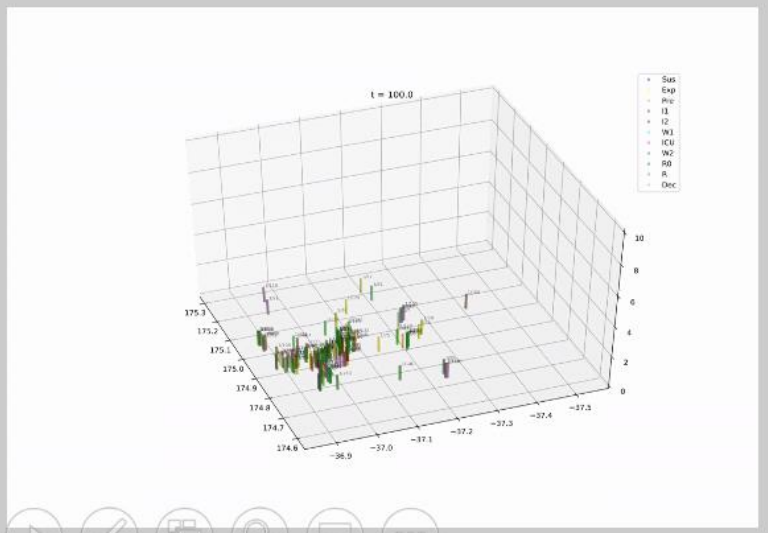

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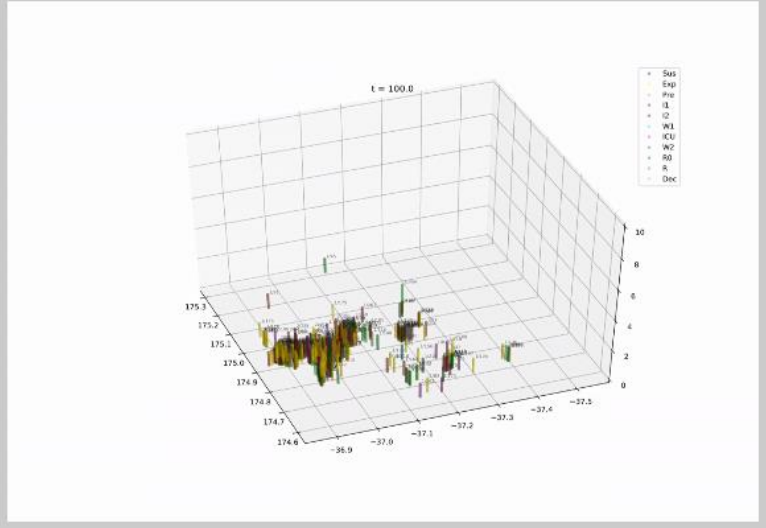

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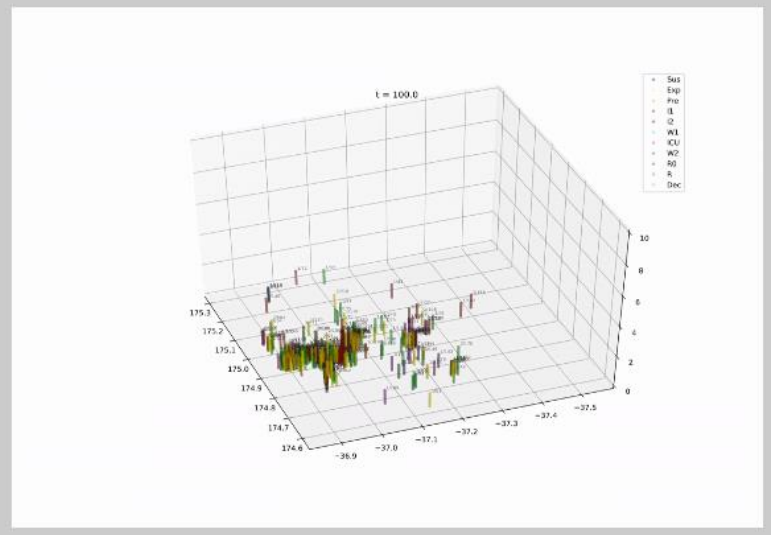
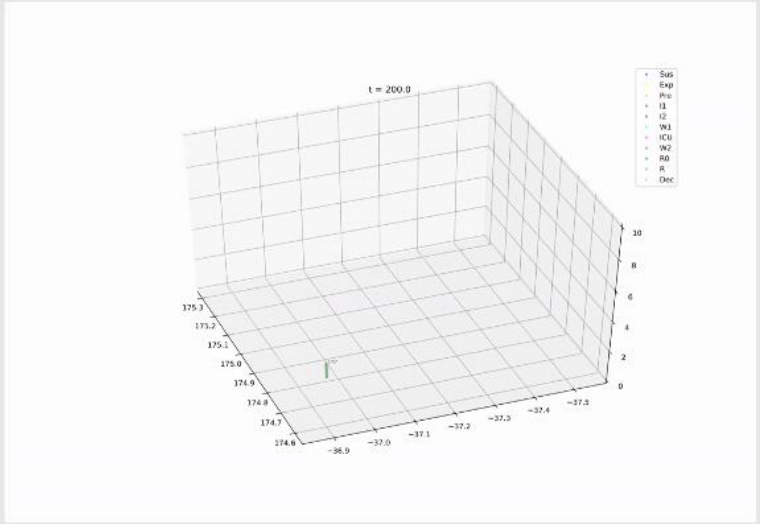


Day 100, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

Seeds = 1, 2, 4, 6, 9 (No spread)



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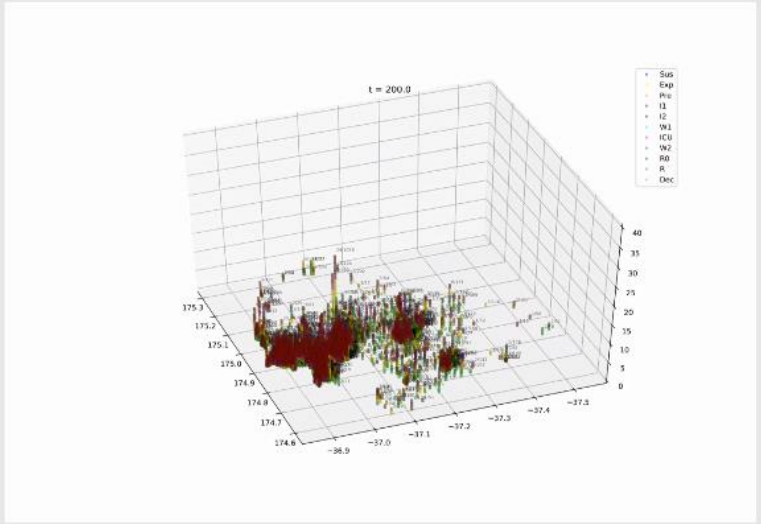

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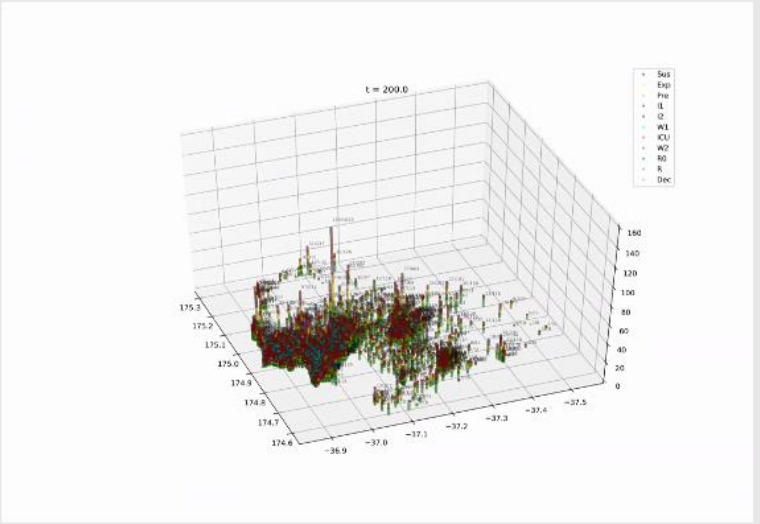

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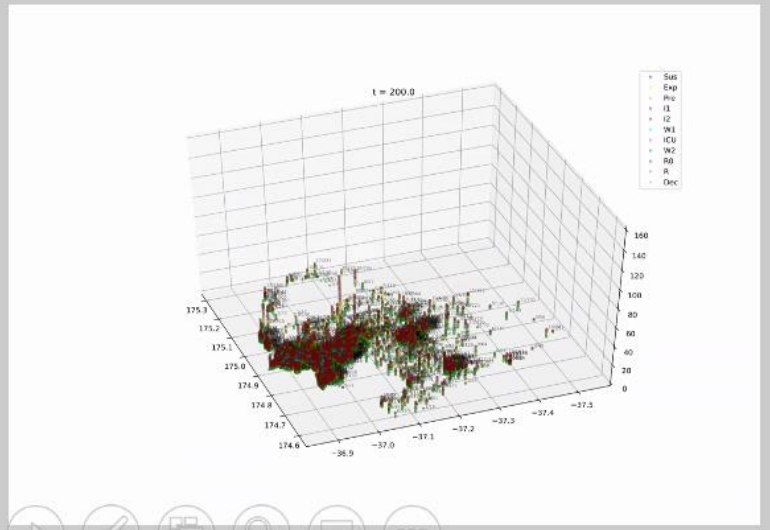

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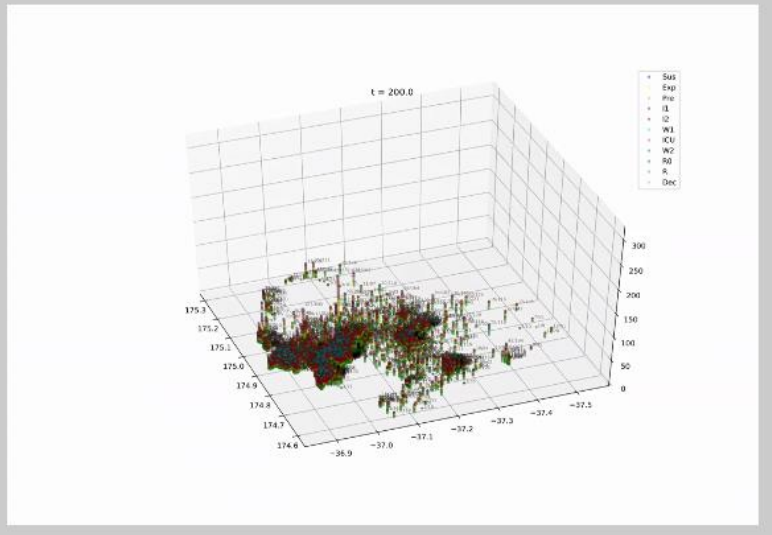

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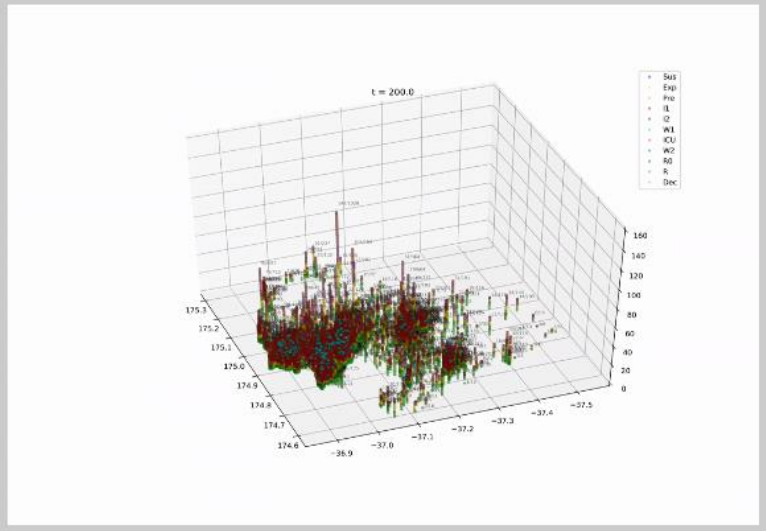
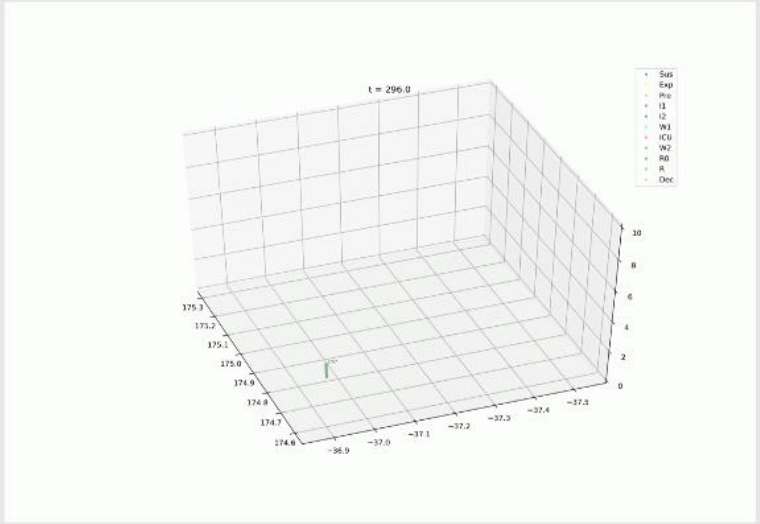


Day 200, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

Seeds = 1, 2, 4, 6, 9 (No spread)



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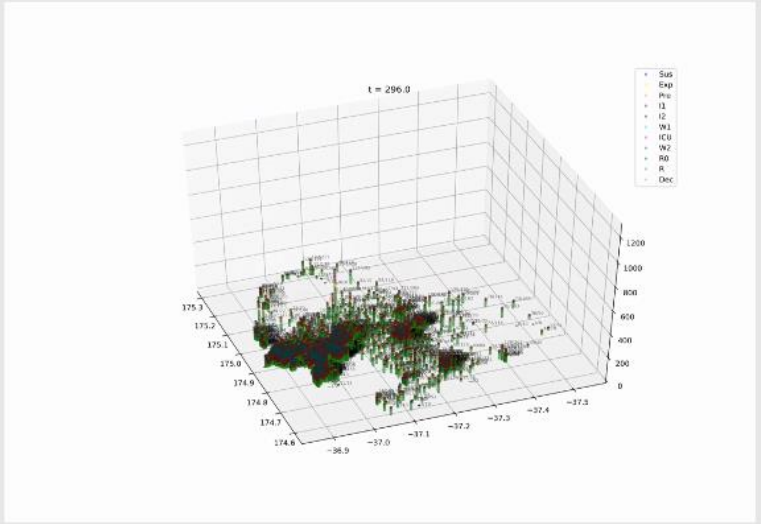

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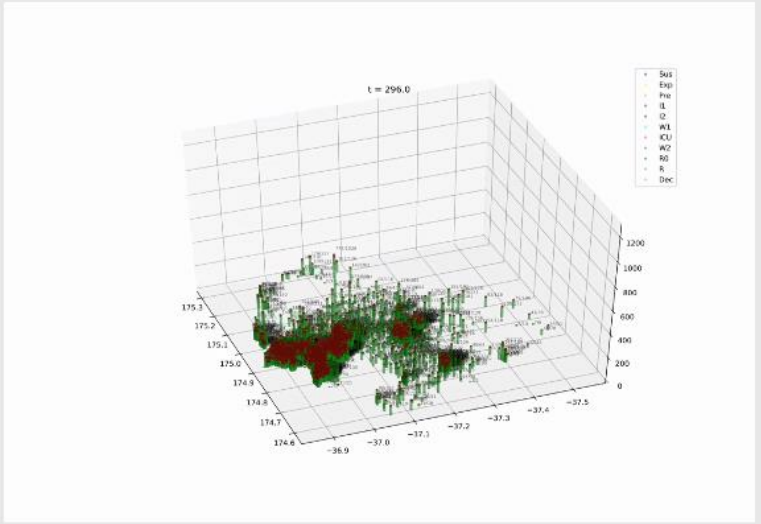

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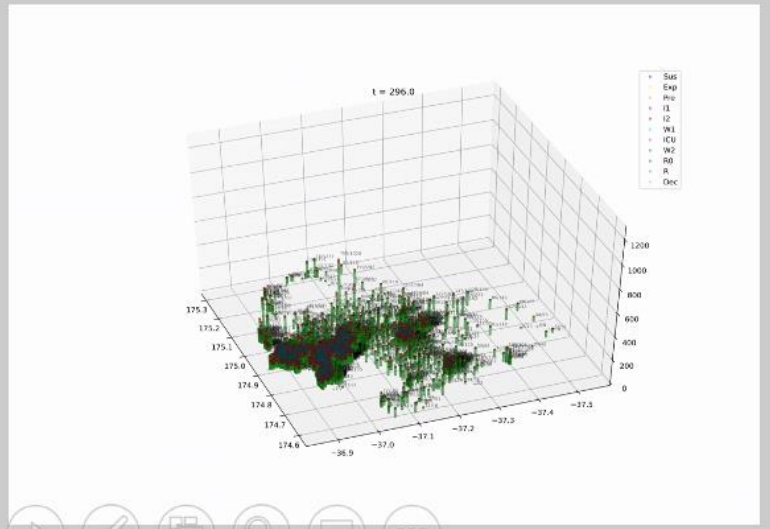

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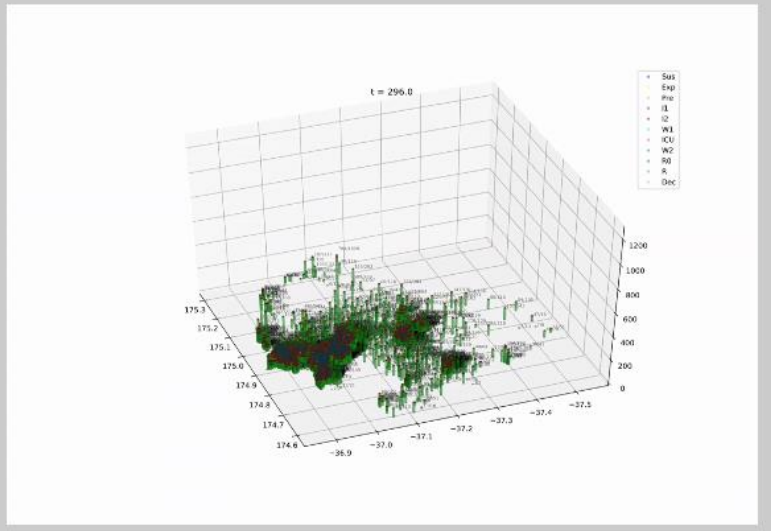

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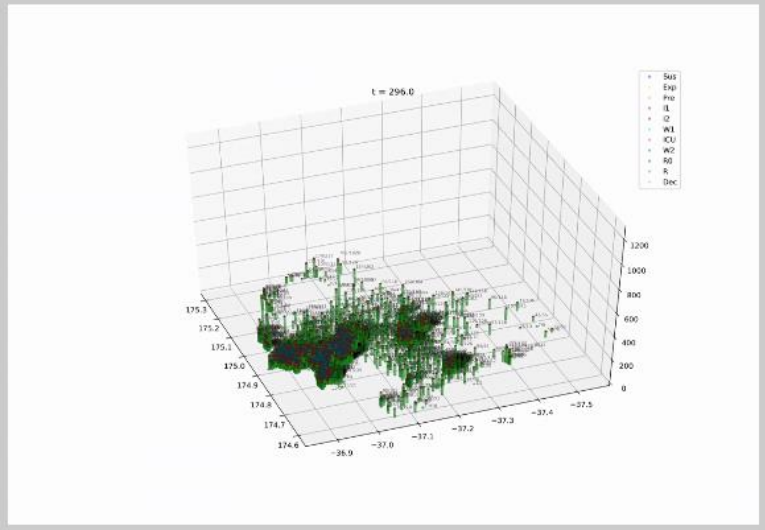
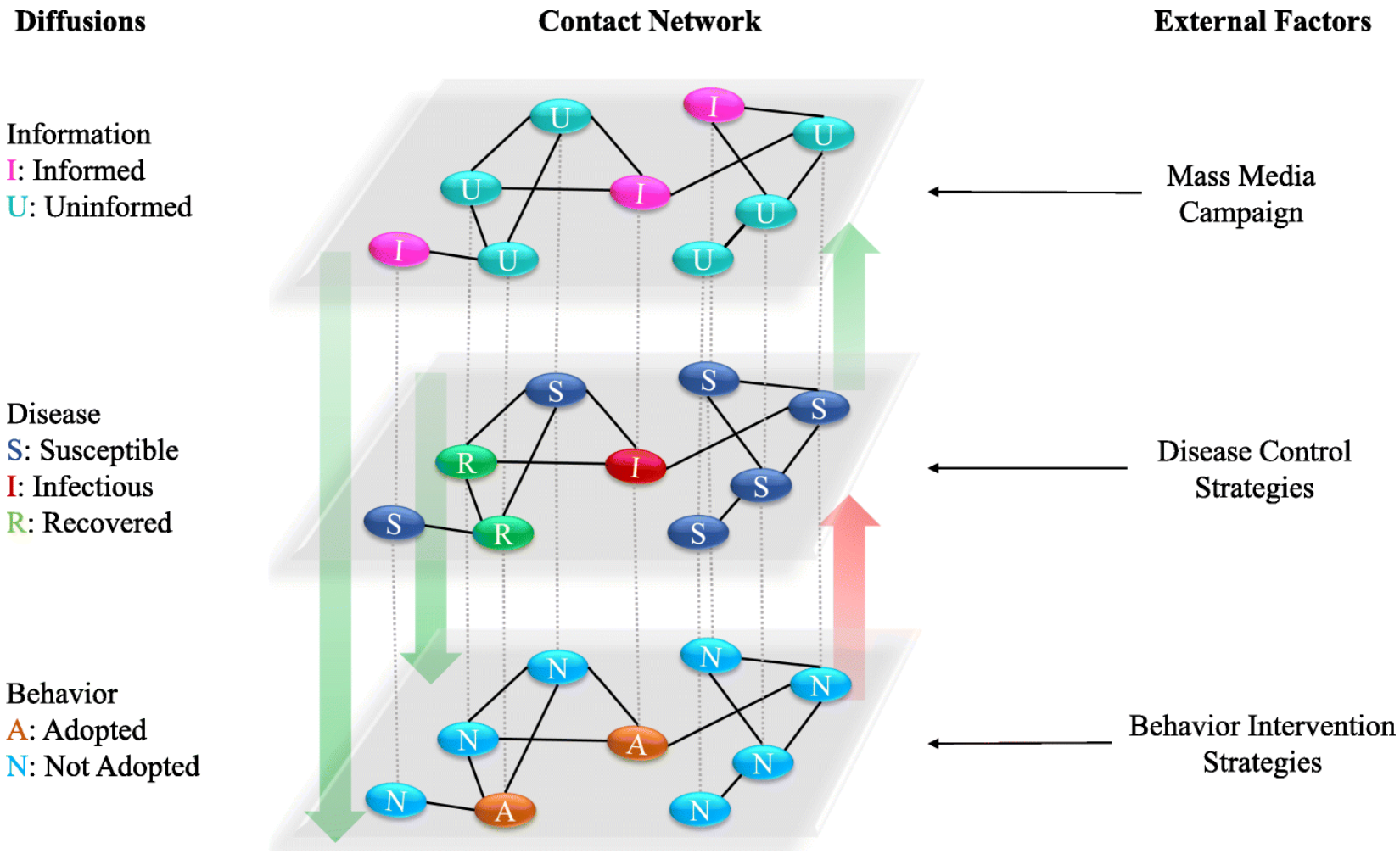


Day 296, Level 2, R0 = 1.49 (rest of NZ), 2.533 within meshblocks

Multilayer Networks

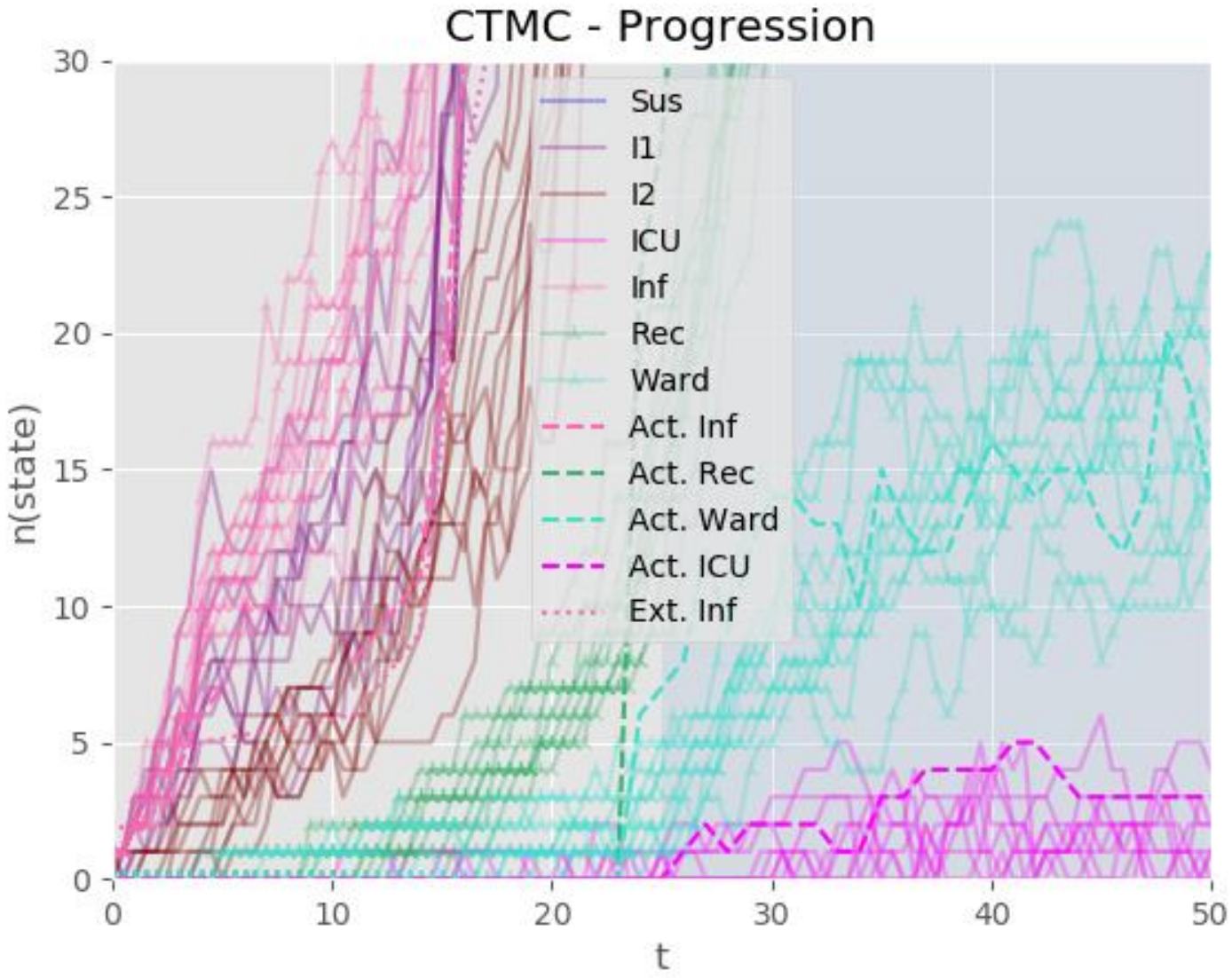
Harvey, Emily, Oliver Maclaren, Dion O'Neale, Adrian Ortiz-Cervantes, Frankie Patten-Elliott, Steven Turnbull, Demival Vasques Filho, and David Wu. "Network-based simulations of re-emergence and spread of COVID-19 in Aotearoa New Zealand."



Hammoud, Z., Kramer, F. Multilayer networks: aspects, implementations, and application in biomedicine. Big Data Anal 5, 2 (2020). https://doi.org/10.1186/s41044-020-00046-0

Models (thankfully) were not really used

- Single most important observation was that any growth would quickly overwhelm the capacity of our ICUs and Ward
- NZ has relatively low number of ICU beds per 100,000 inhabitants



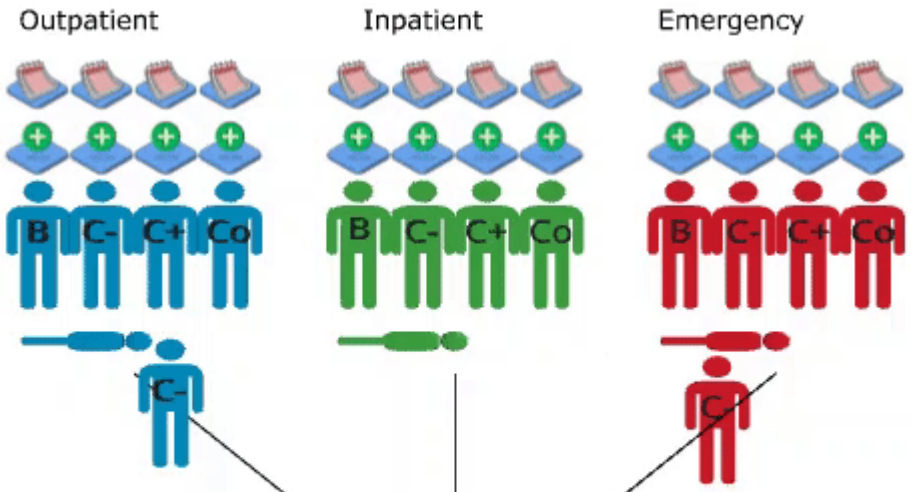
Recovery from Pandemics

- Clearing backlog of diagnoses and procedures missed during lockdown.
- This includes:
  - surgical scheduling
  - nurse rostering
  - matching flow through surgery with available capacity in ward

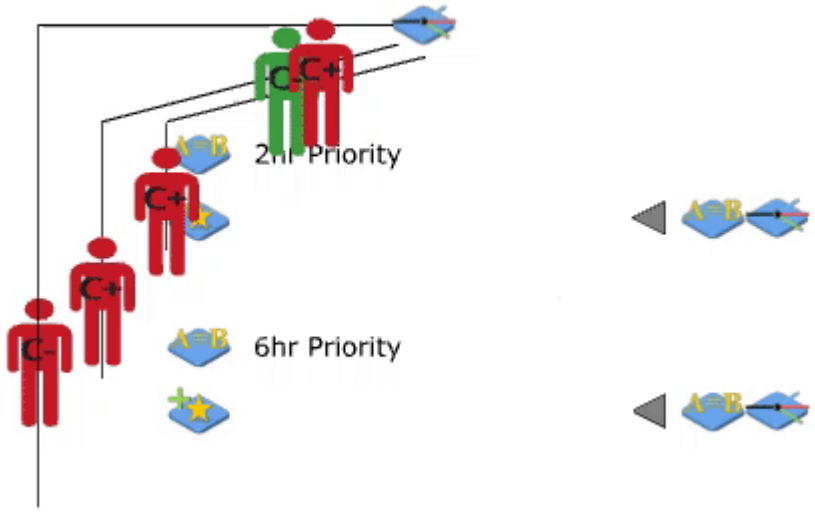
Theatre 1 - Morning Session	2020-07-09	08:30-12:30		
ID	Procedure	Start/Finish	Priority	Days waiting
344	Procedure - type 1	08:30-09:30	2	176
346	Procedure - type 1	09:56-10:56	2	168

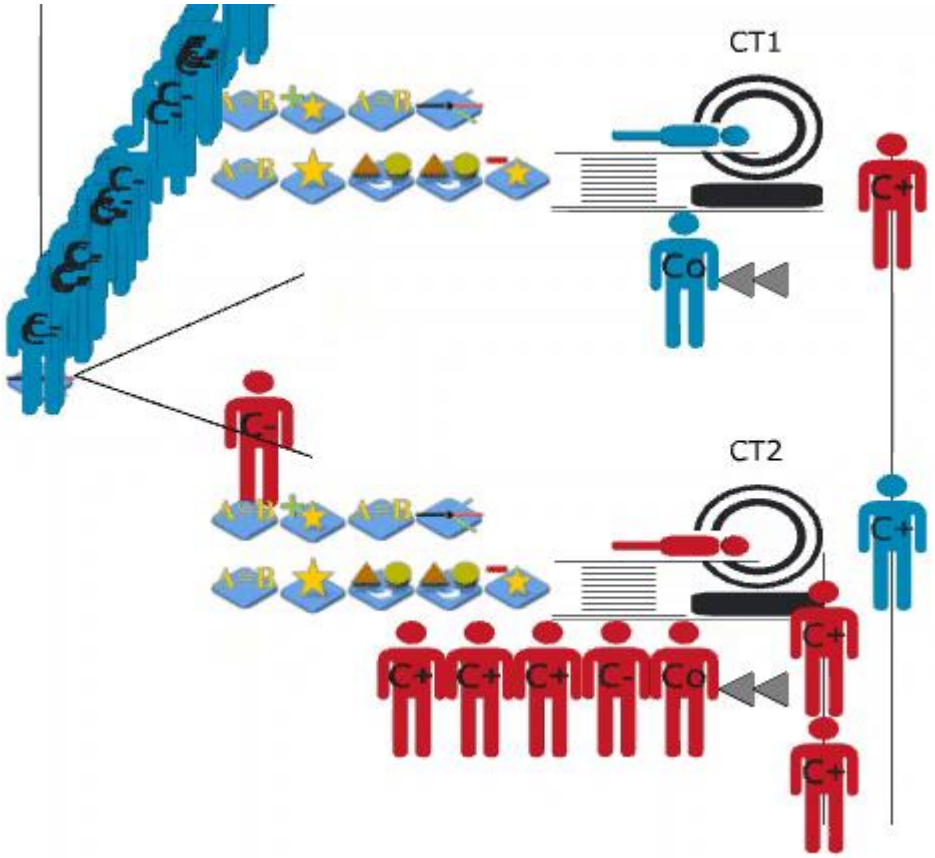
Theatre 2 - All Day Session	2020-07-09	08:30-17:00		
ID	Procedure	Start/Finish	Priority	Days waiting
10	Procedure - type 2	08:30-09:30	3	233
69	Procedure - type 3	09:56-12:26	2	162
348	Procedure - type 1	12:52-13:52	2	126

Recovery from Pandemics



- Pathway modelling
- Simulation





Bottom Line

- Modelling is a very useful planning tool for pandemics
- Modelling is **also** very useful for the recovery from pandemics
- Modelling can be performed very quickly by large-ish teams working together
- It would be **better** if modelling was used for planning outside of pandemics (BAU) and was ready for pandemics

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THANKS!