Observations of insects with weather radars in Australia

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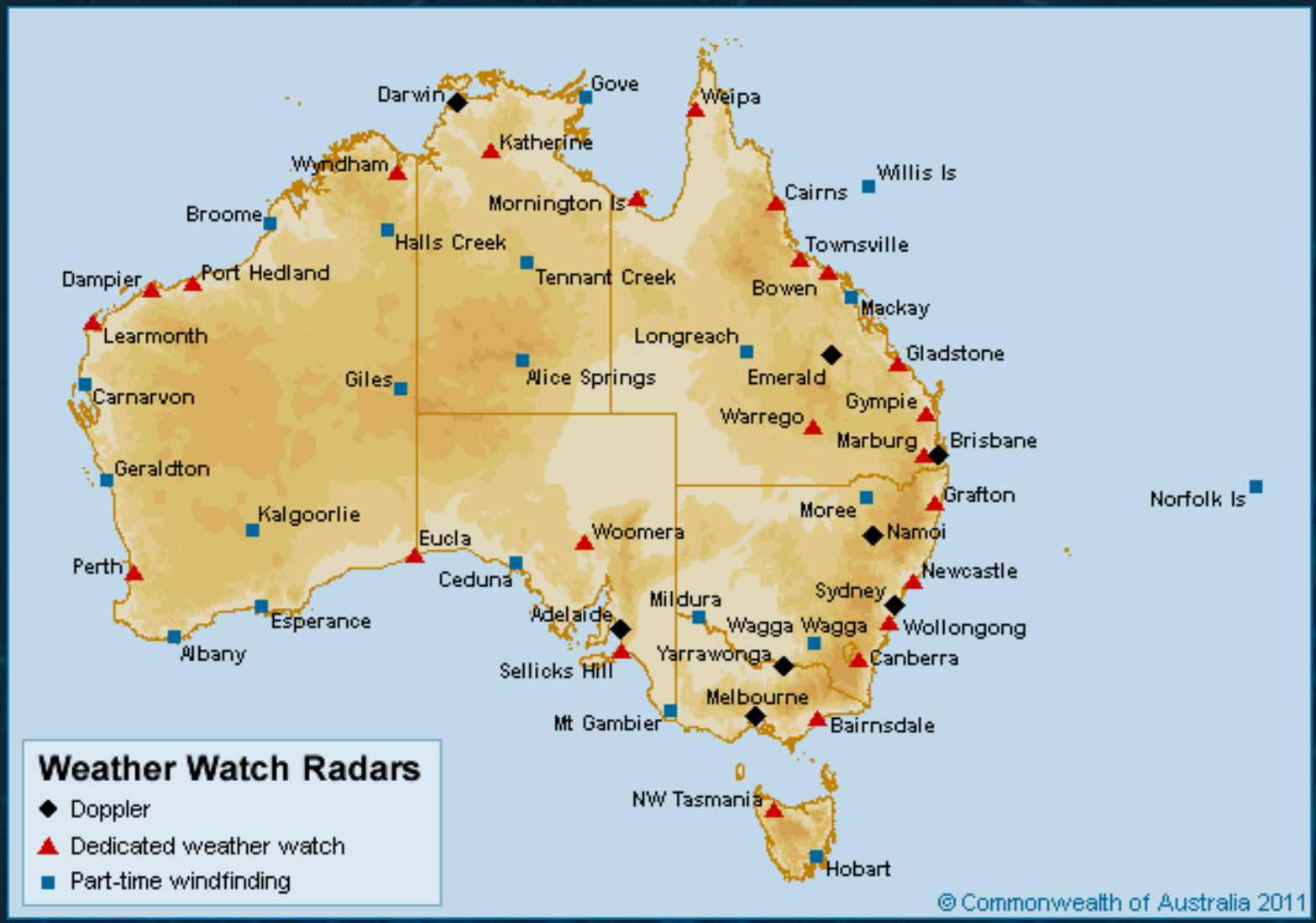
ENRAM 2014: Helsinki workshop.

Outline

1. Australia's weather radars
2. Insect echo on Doppler radars
3. Bird echo on Doppler radars
4. Target classifier
5. D-pol observations in Britain
6. Concluding remarks

1. Australia's weather radars



Quite a large network but mainly on northern coasts (cyclone watch) and around capital cities.

Australian Doppler radars

"Strategic Radar Enhancement Project"

- Scans 6 or 10 mins
- 0.5º to 32º elevation
- 250 or 500 m resolution
- 150 to 300 km range
- 1° or 2° beamwidth

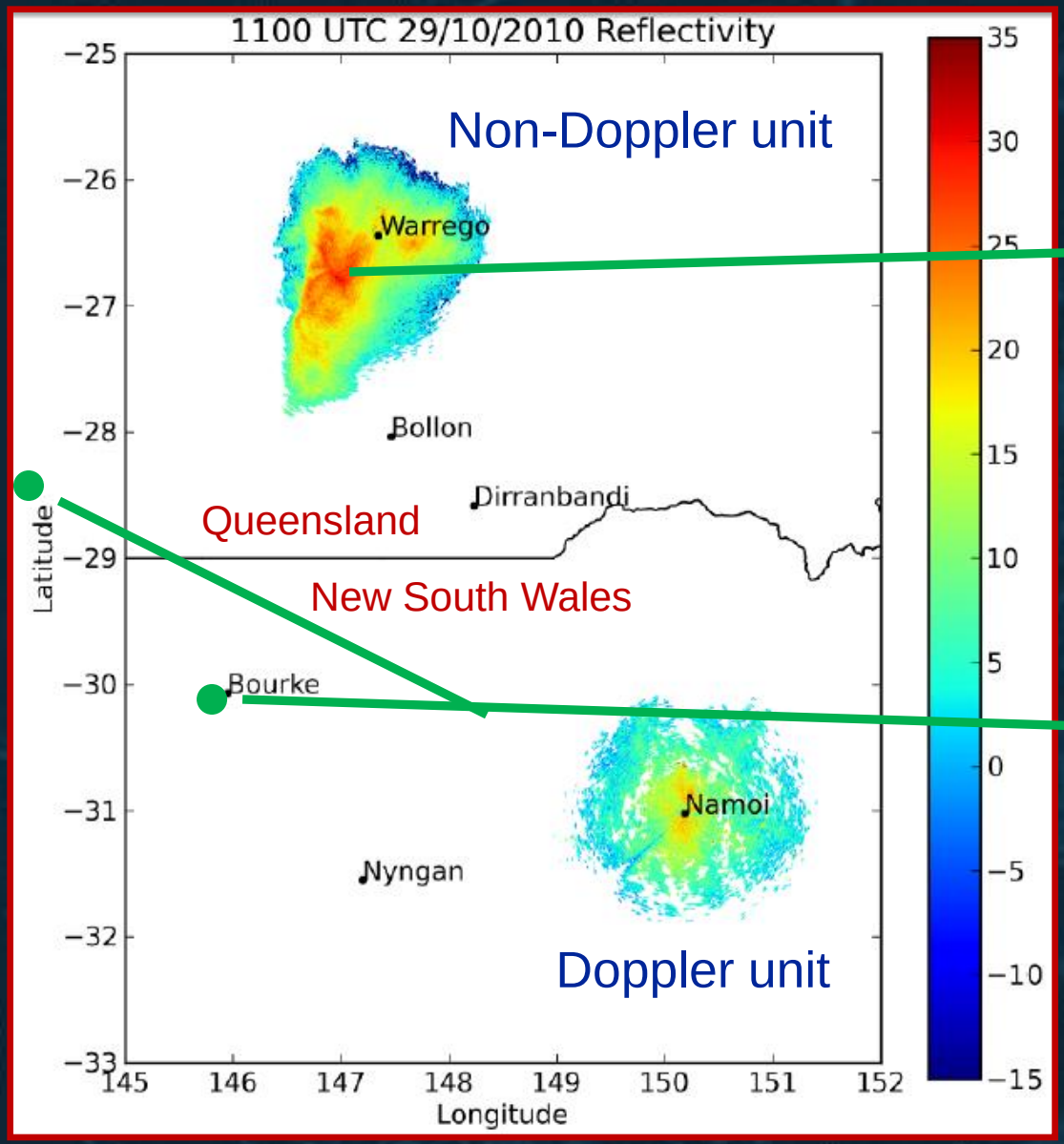
Yarrawonga

S-band preferred in tropics for better rain penetration

Dual-pol. research radars in Brisbane and Darwin

No additional DP radars currently proposed

2. Insect echo on Doppler radars



Patch due to concentration on ground

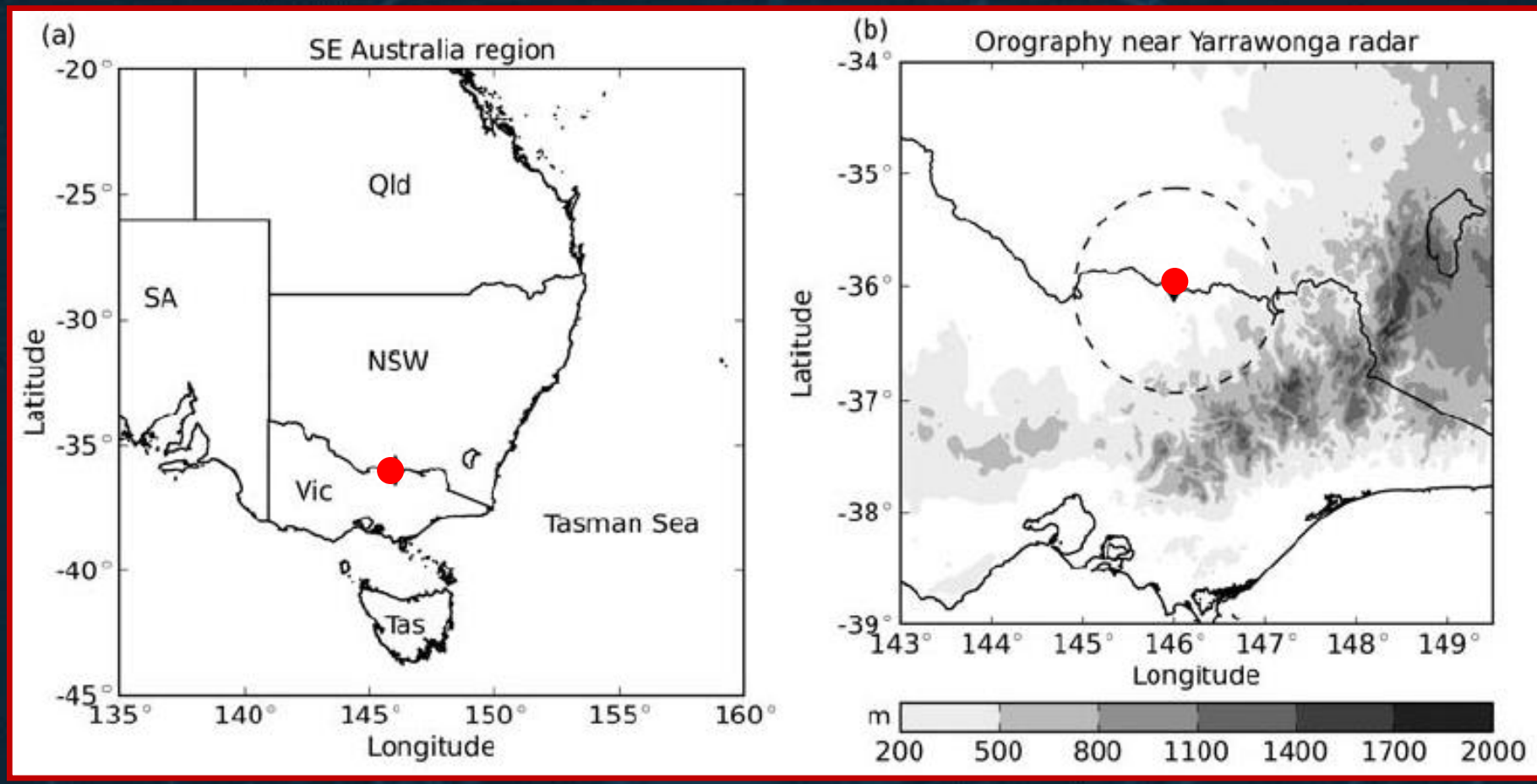
Echoes due mainly to locusts

Locations of UNSW Insect Monitoring Radars

21.00 h LST, 29 Oct 2010; elev. ~1º.

[From S.J. Rennie, 2012, *CAWCR Technical Report 055.* Bureau of Meteorology, Melbourne.]

Yarrawonga Doppler weather radar



C-band

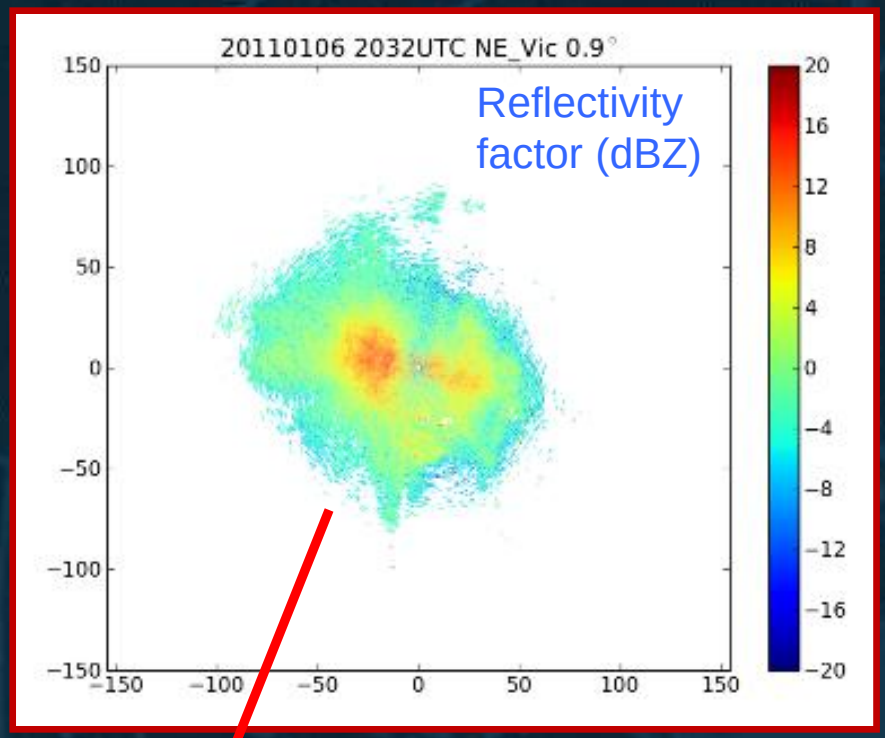
Inland site, little ground clutter, insects in all directions.

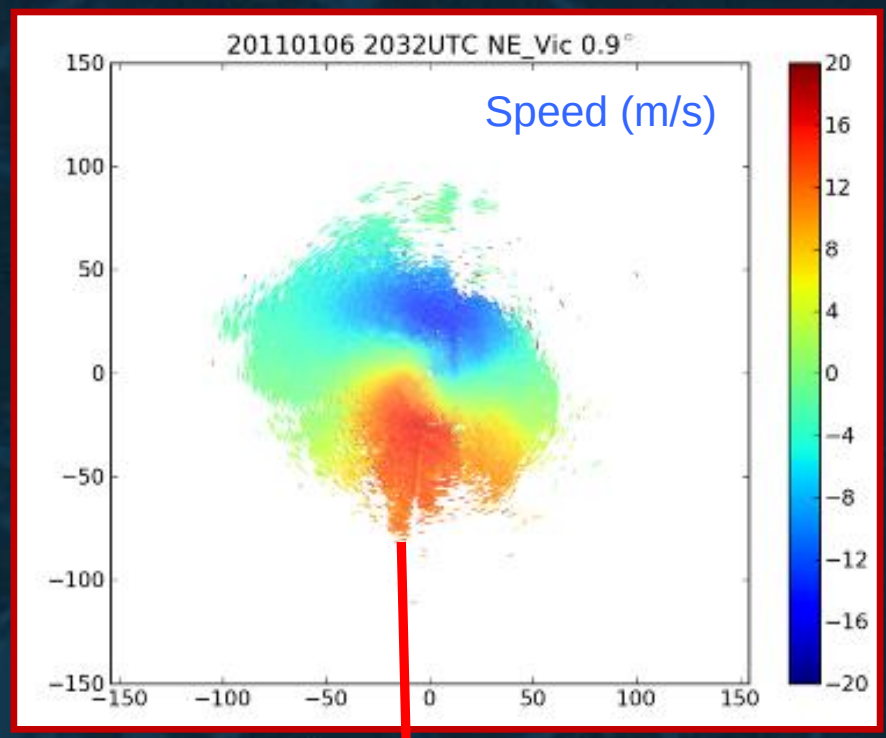
[From S.J. Rennie, 2014, *Meteorological Applications* 21:218-229.]

Insect echo at Yarrawonga

Reflectivity factor

Doppler velocity





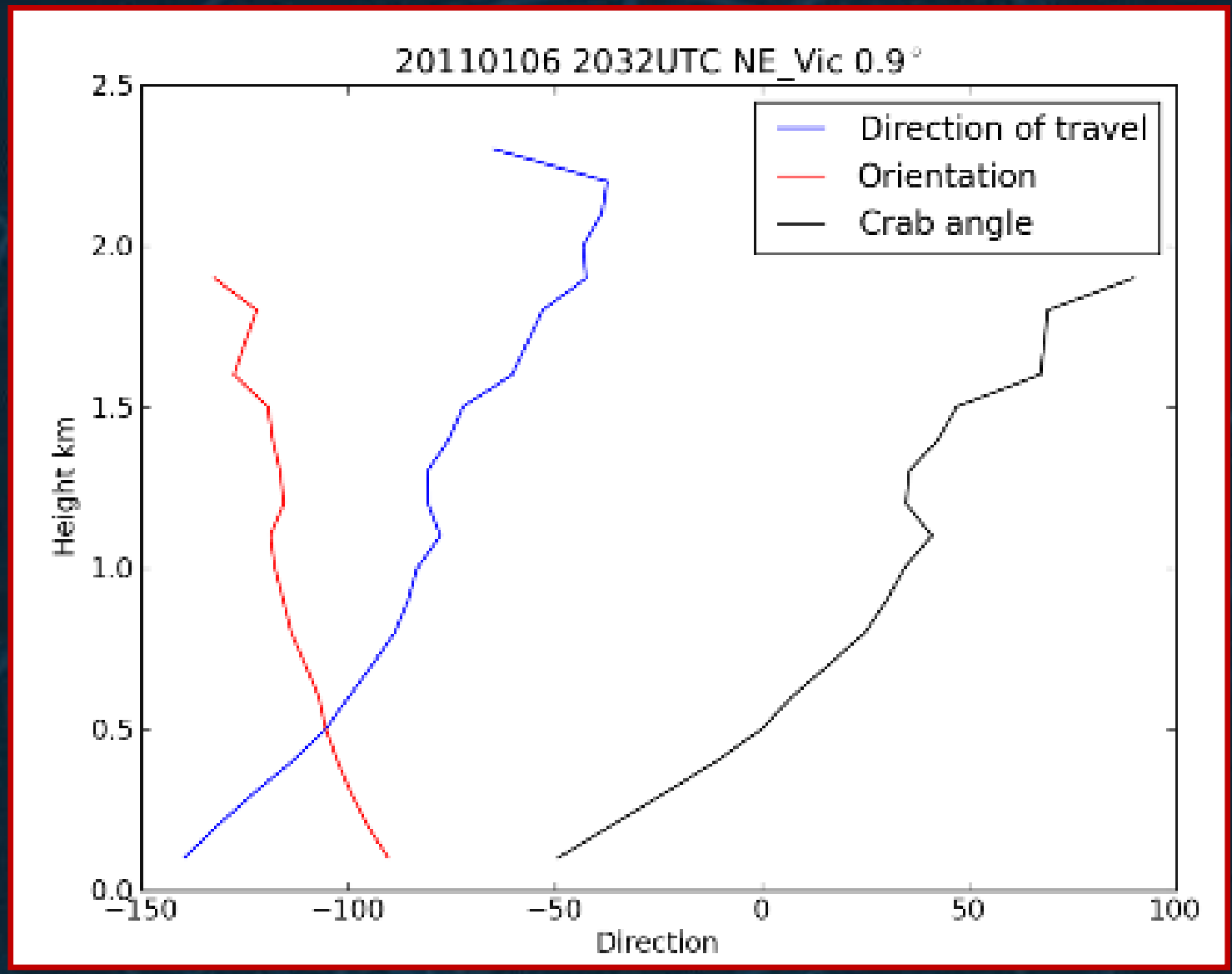
6 Jan 2011, 06.30 h LST; elev. 1º.

Slightly asymmetrical, indicating ~NNE/SSW alignment

N–to–S movement

Resolution 1º x 250 m

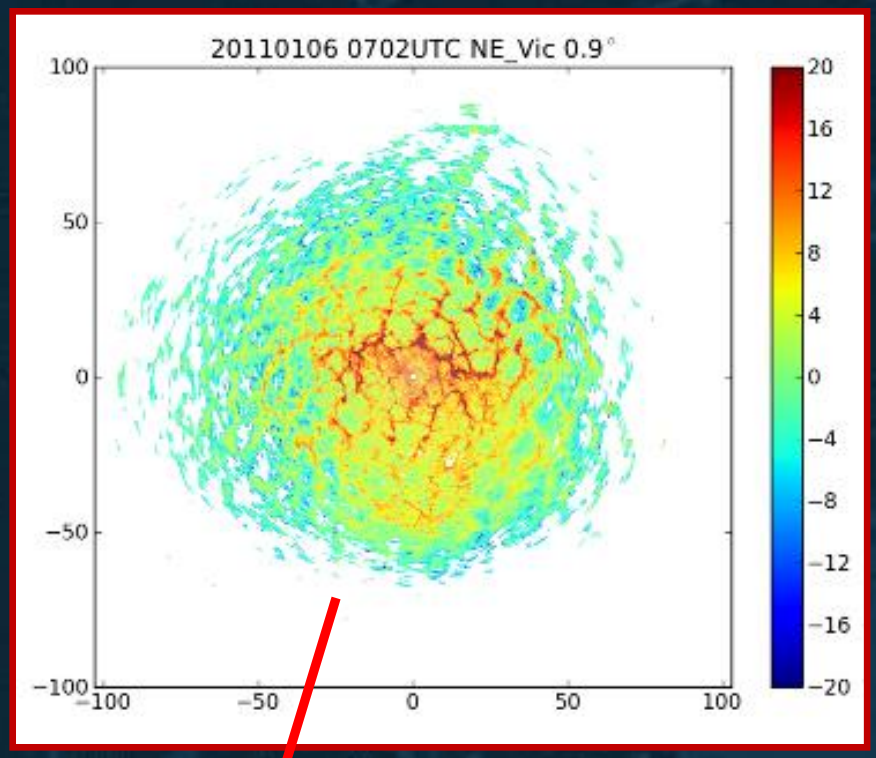
Profiles of direction of travel and orientation retrieved from PPI patterns.



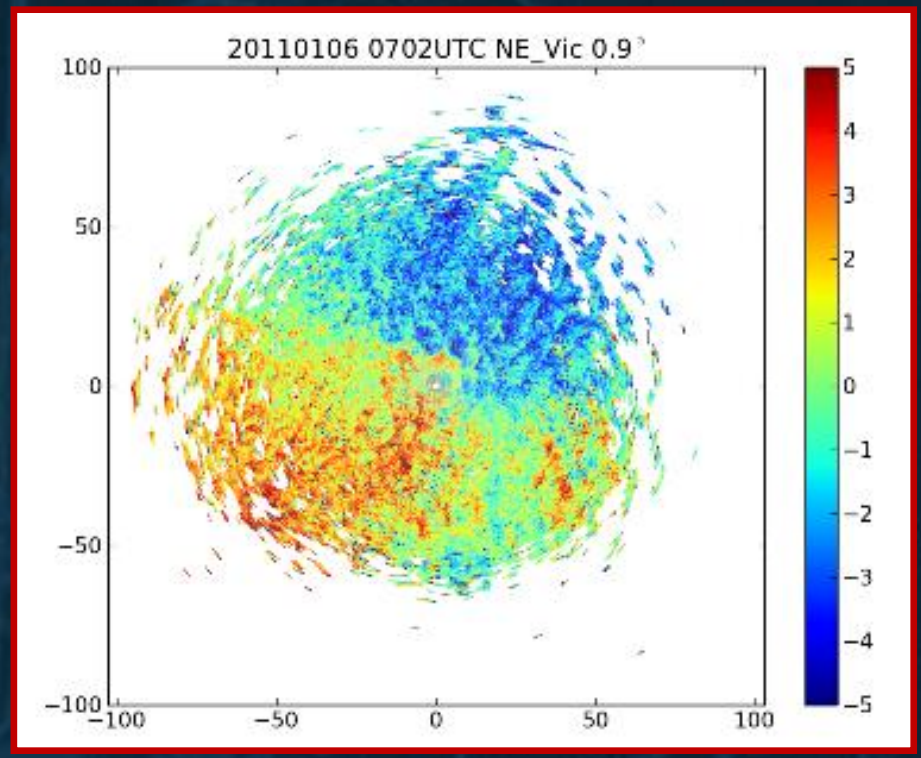
Yarrawonga, Vic, 06.30 h LST, 6 Jan 2001.

Daytime observations show convection

Reflectivity factor



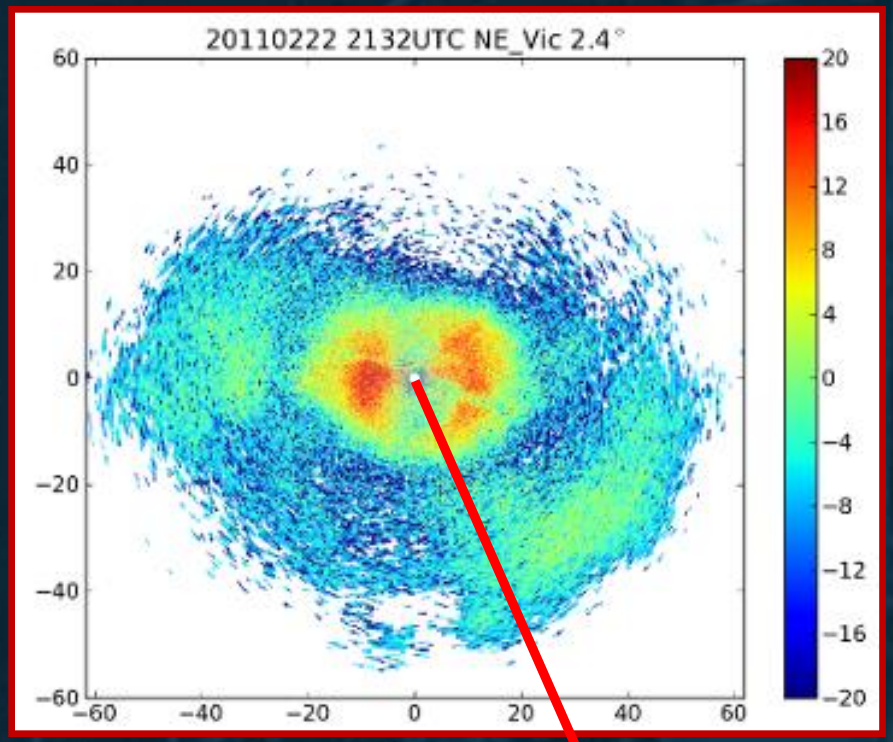
Doppler velocity

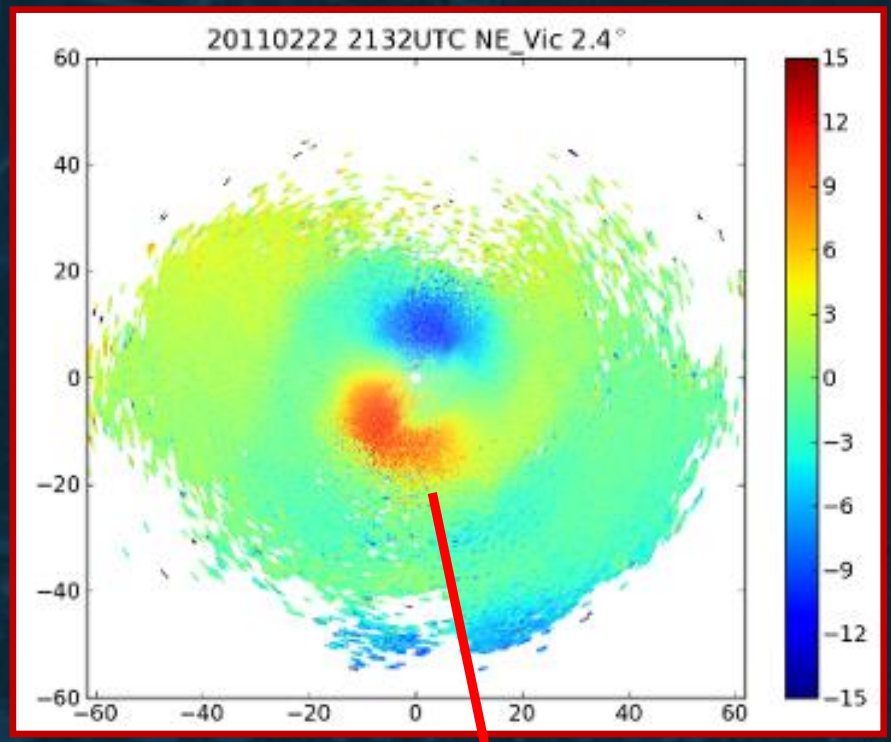


Yarrawonga, Vic, 17.00 h LST, 6 Jan 2001; elev. 1º.

Reflectivity pattern almost circular – little evidence of orientation

Observations at higher elevation sometimes reveal layering





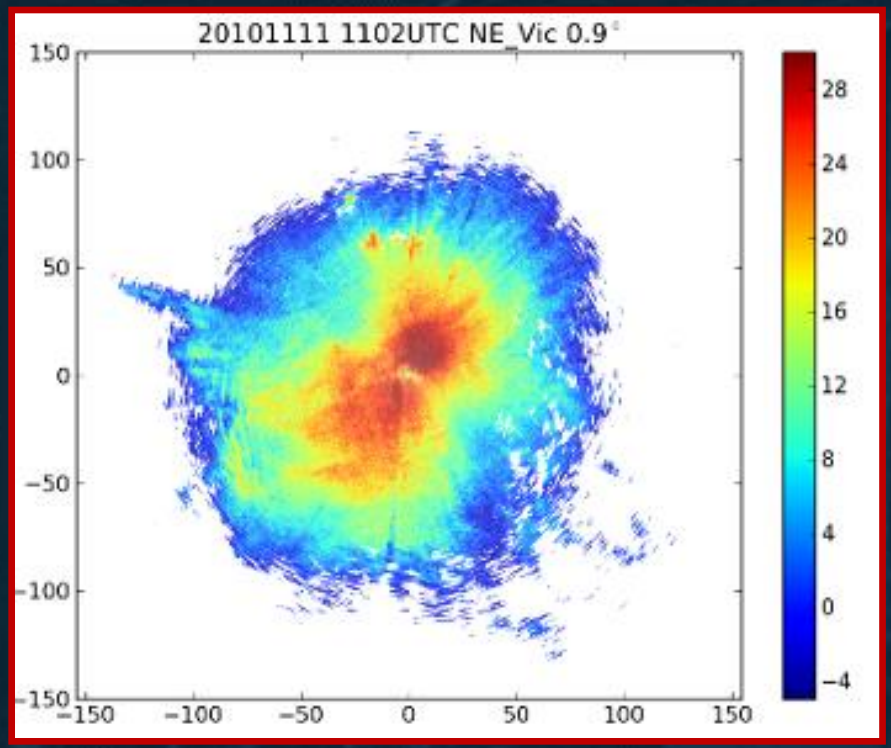
Yarrawonga, Vic, 07.30 h LST, 22 Oct 2011; elev. 2.5^{o}.

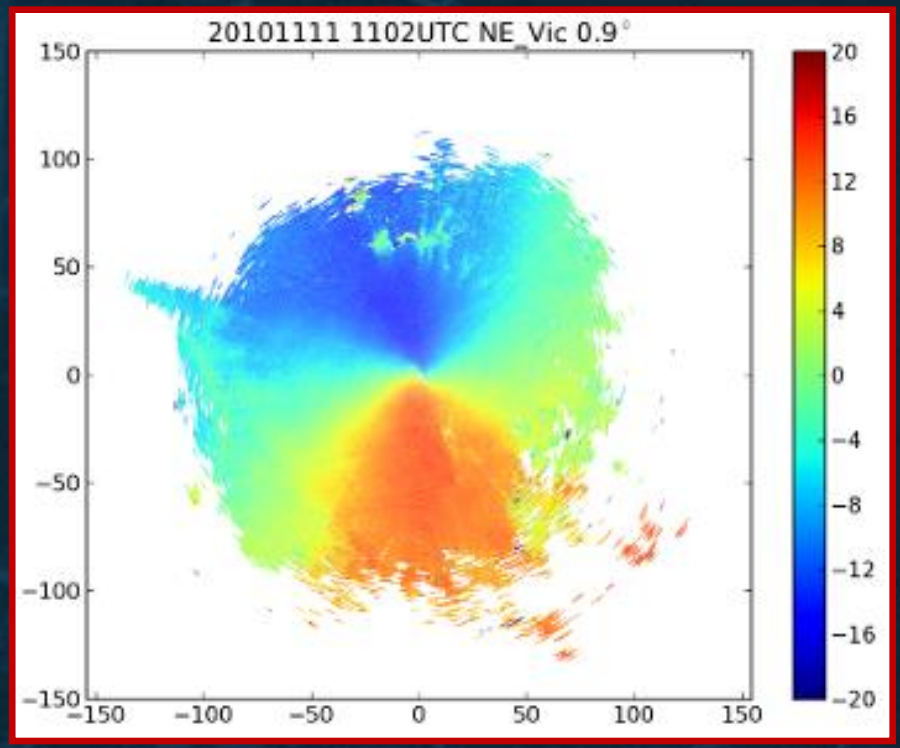
Movement N-to-S

Ring of intense echo indicates layer.

Stronger to E and W, indicating N/S orientation.

Locusts invade Melbourne!





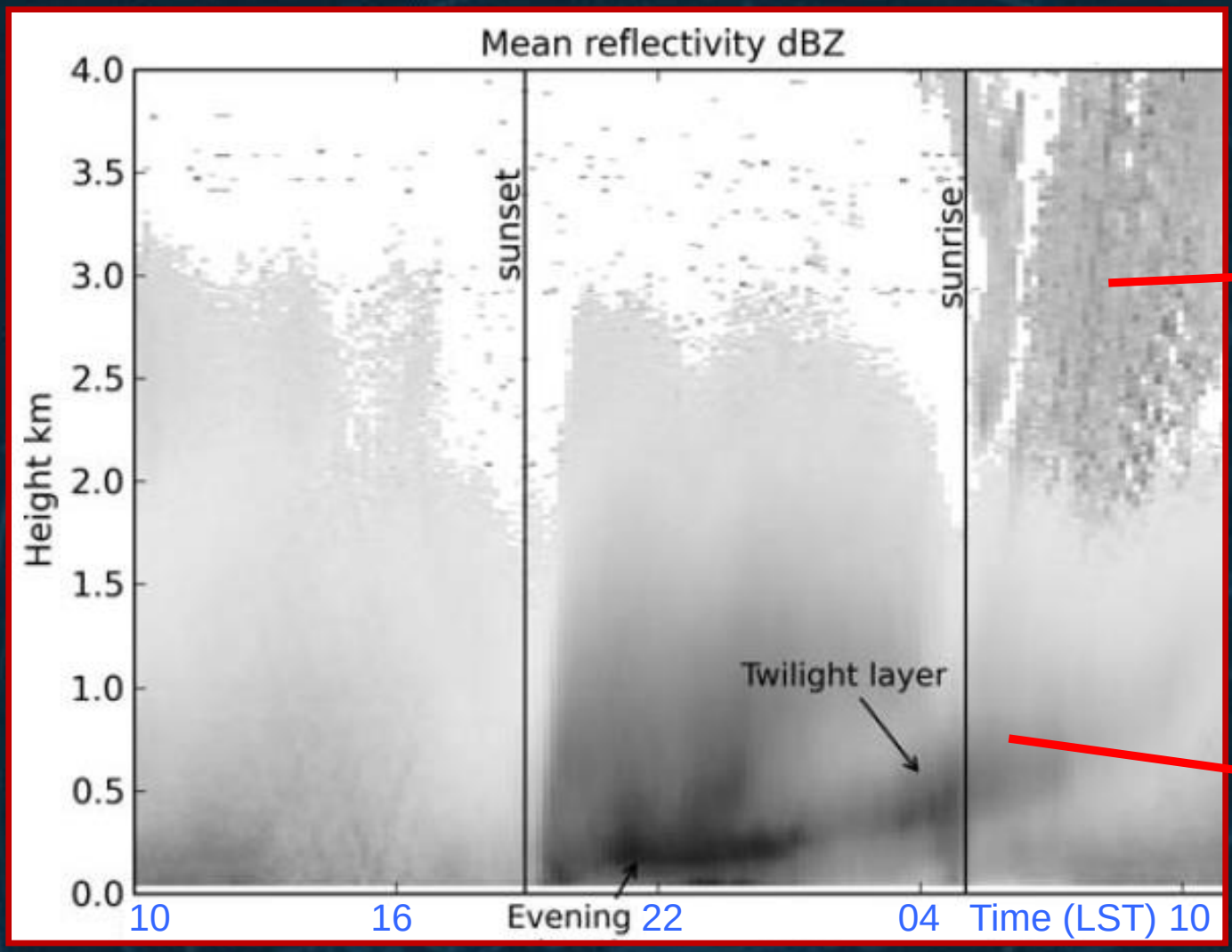
Yarrawonga, Vic, 21.00 h LST, 11 Nov 2010; elev. 1^{o}.

A particularly strong example. Locusts in the streets of Melbourne the following day!

Spur-throated locusts and Australian plague locusts

Note crab angle of ~45^{o}

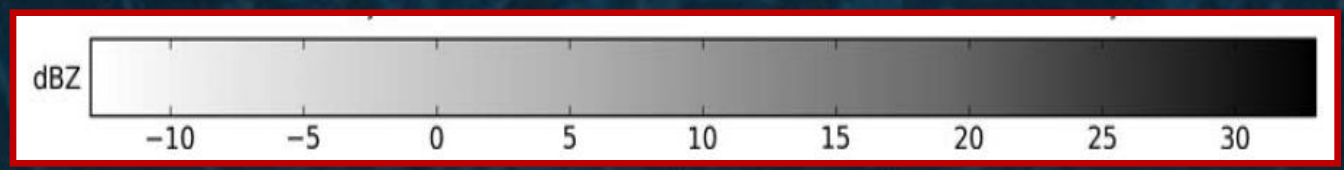
Diurnal development of reflectivity profile



Rain

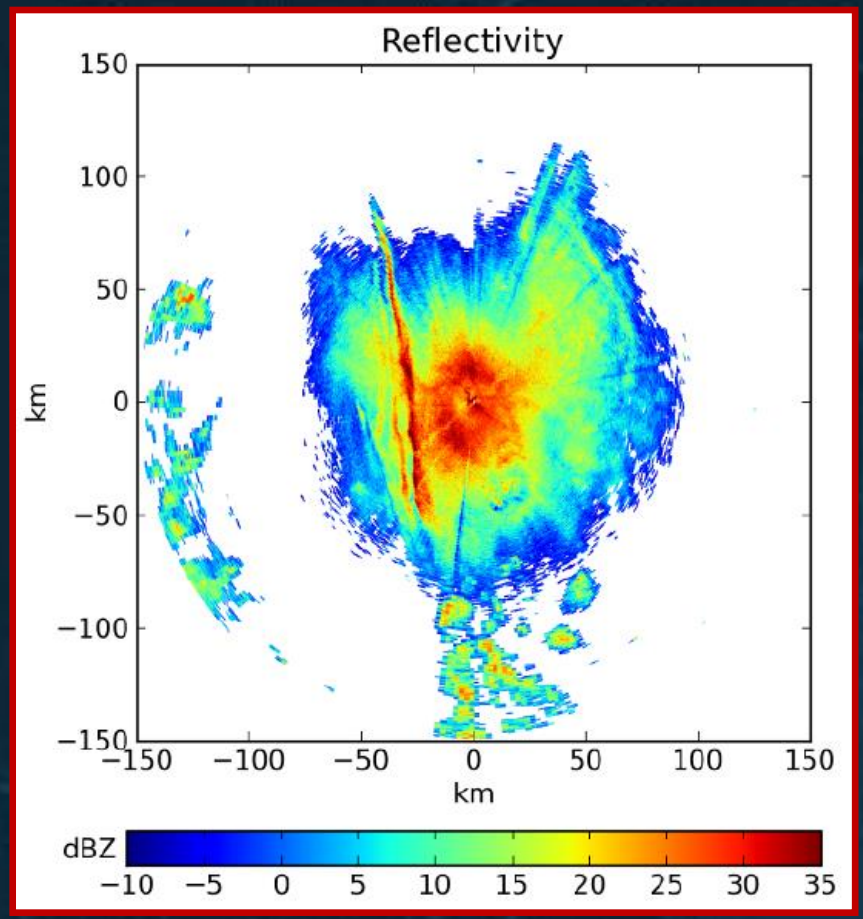
From 2° elevation scan

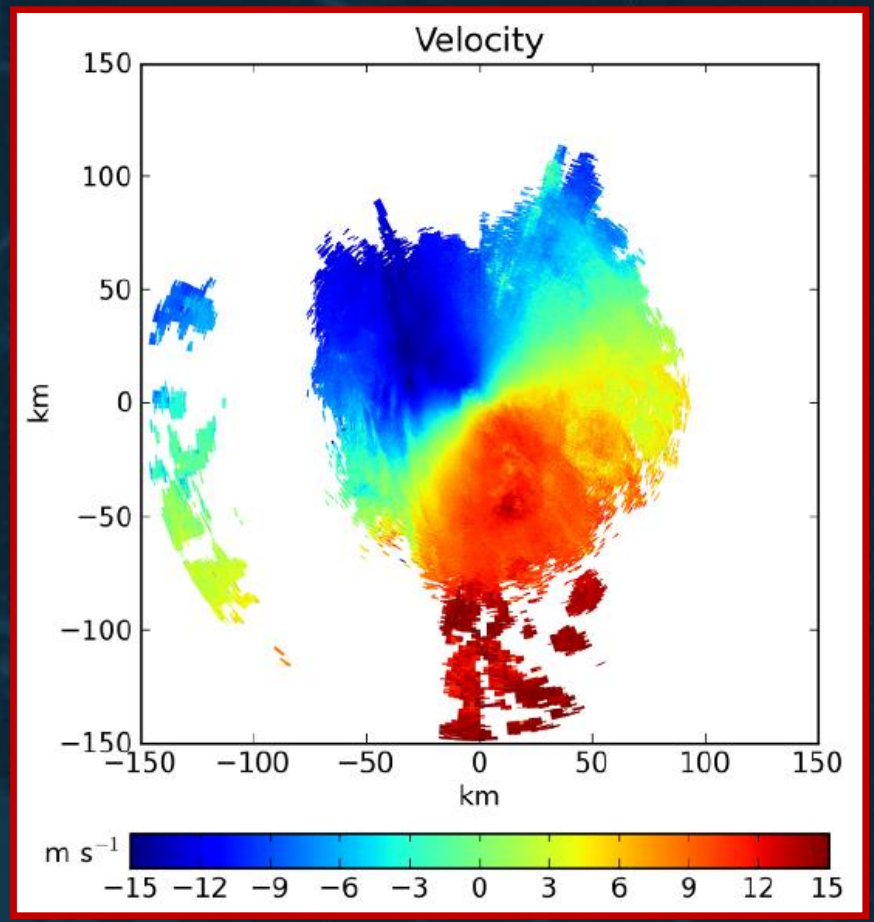
Insects



[From S.J. Rennie, 2014, *Meteorological Applications* 21:218-229.]

Insect echo revealing linear disturbance



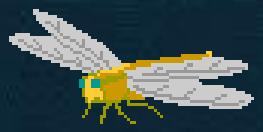


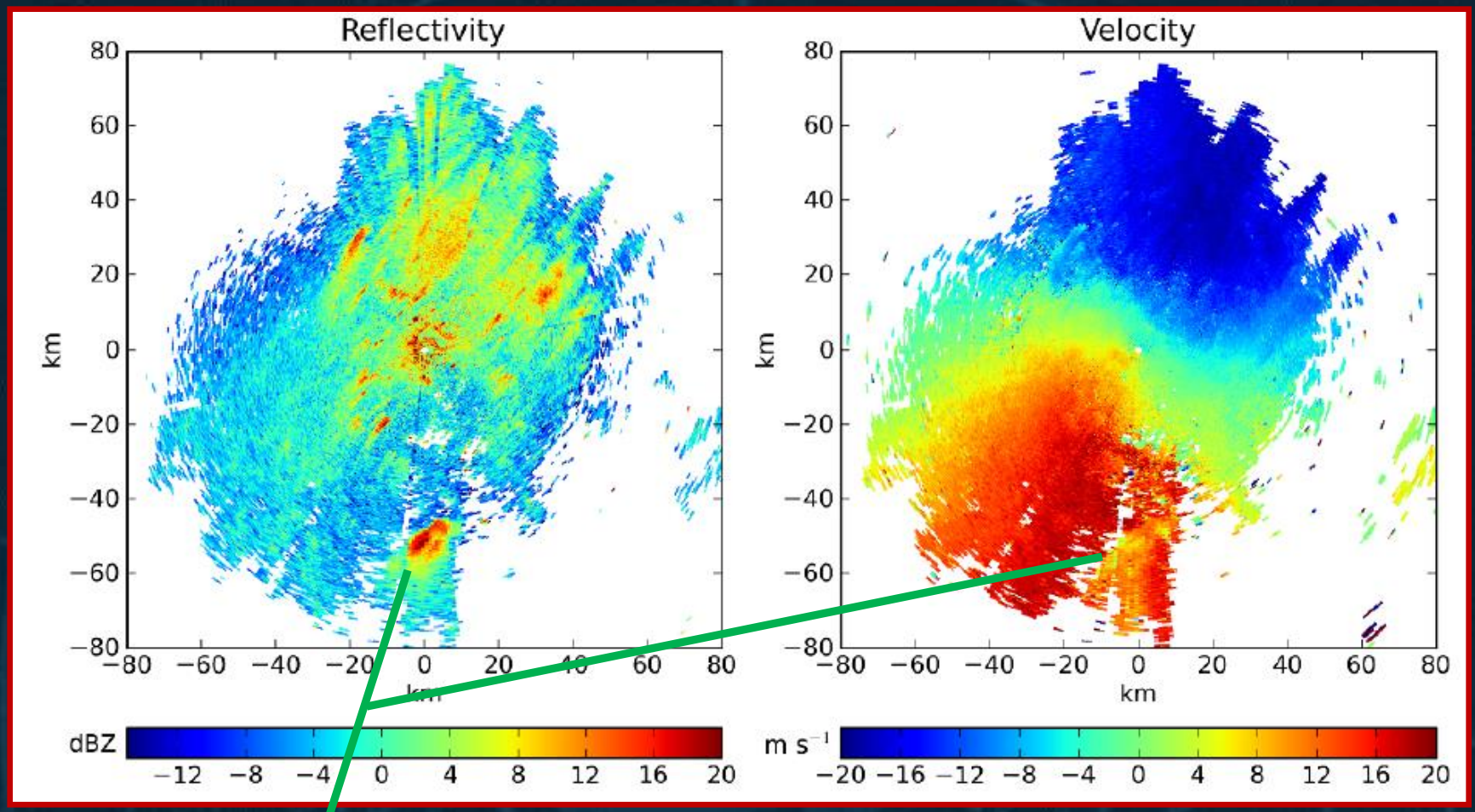
Yarrawonga, Vic, 00.15 h LST, 25 Nov 2010; elev. ~1º.

Line echo approached from W ahead of precipitation

Little effect on insect velocities, so probably a wave rather than a gravity current.

3. Bird echo on Doppler radars



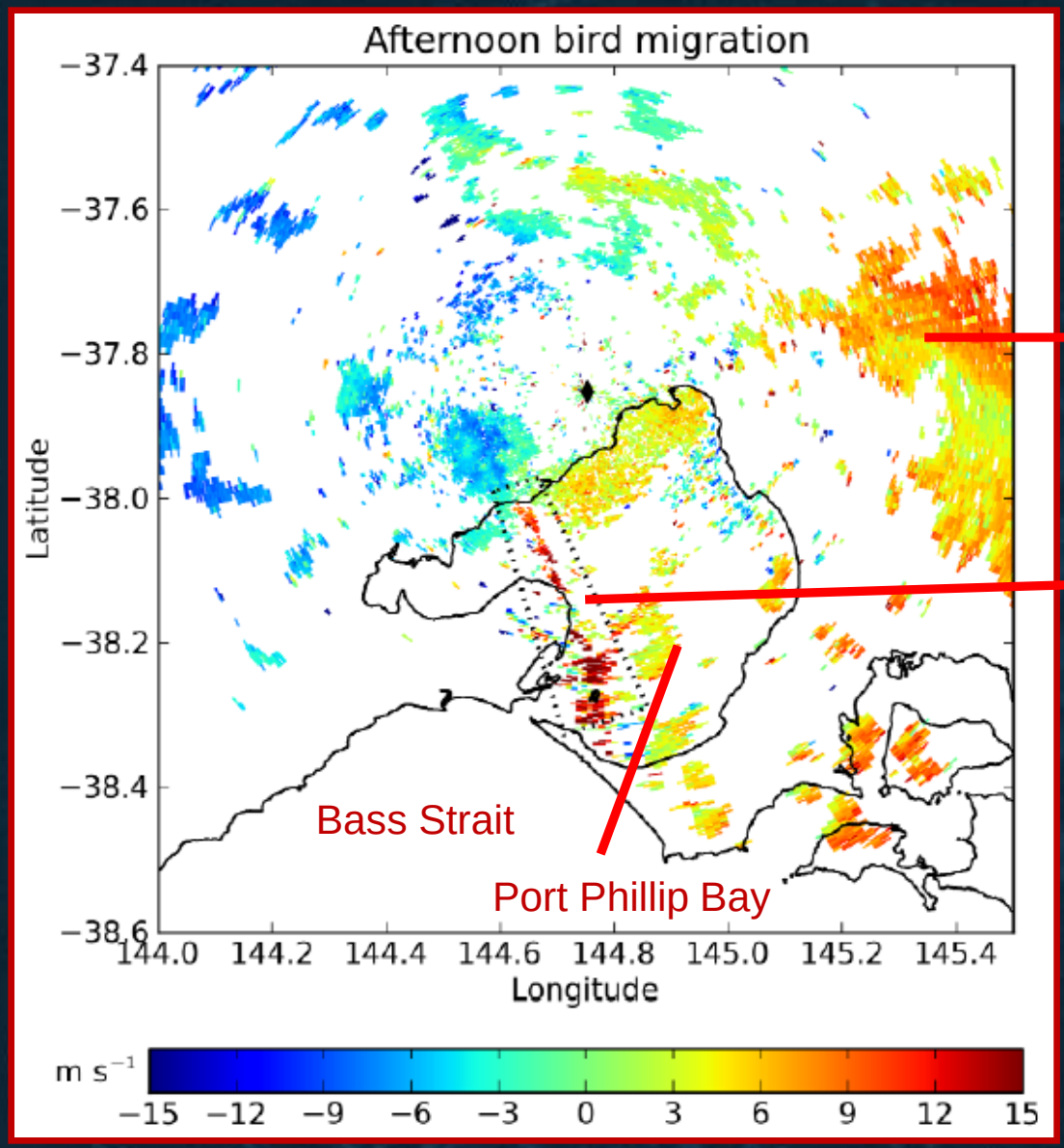


Yarrawonga, Vic, 04.30 h LST, 6 Jan 2011; elev. 1º.

Patch with different Doppler velocity

Dawn dispersal flights, probably waterbirds from roosts.

Birds streaming across bay



Doppler velocity

Precipitation echo

Gulls (?) streaming across bay from city

Widespread (broad-front) bird migration is not common in Australia

Melbourne, Vic, 15.30 h LST, 15 Sep 2011; elev. 0.5°.

4. Target classifier

The Bureau of Meteorology is interested in insect echo as source of information on wind profiles

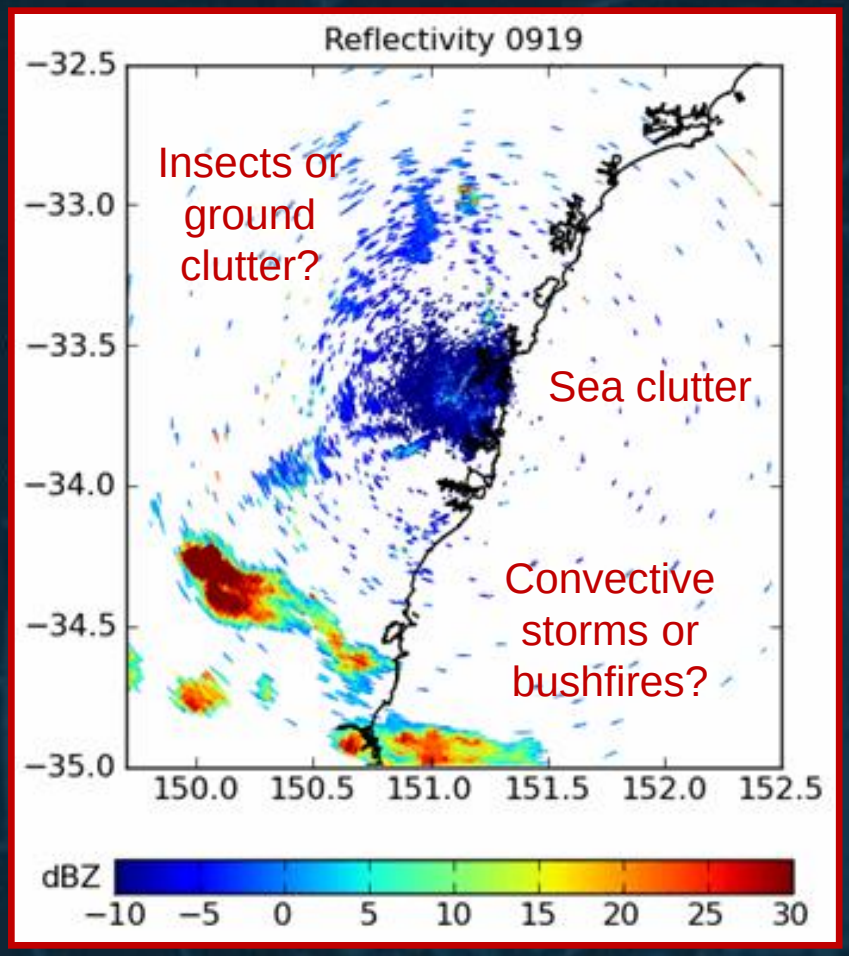
- Radial (Doppler) winds can be ‘assimilated’ into numerical weather prediction models, along with other meteorological observations (from balloons, surface stations, etc.).

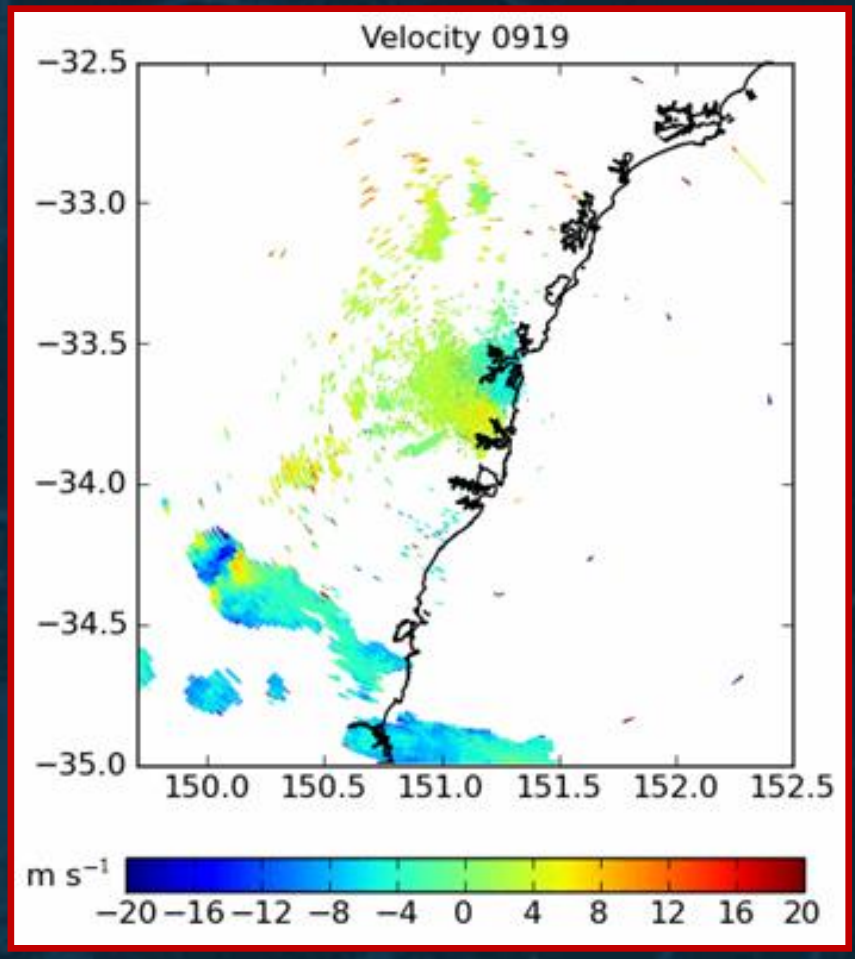
This will improve forecasts only if the winds are reasonably accurate

- Winds from precipitation echoes are unbiased: include them.
- ‘Winds’ from bird echoes will be false: exclude them.
- Winds from insects may or may not be significantly biased, depending on airspeed of insects and degree of orientation.

BoM is assessing whether insect ‘winds’ should be assimilated. It is also developing a target classifier to identify different target types.

Echoes from different sources have different characters





Terrey Hills (Sydney), NSW, 18 Jan 2012, elev. 1°.

[From S.J. Rennie *et al*., 2013, American Meteorological Society conference presentation.]

Echo classes

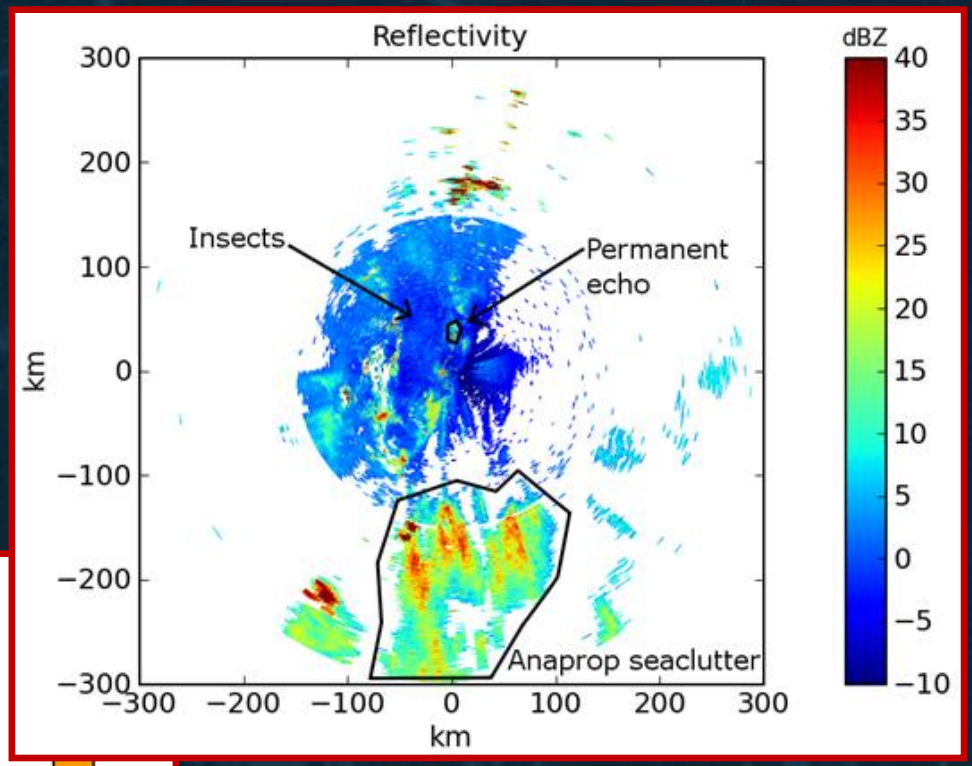
Classes	Abbrev.		
Convective precipitation	con	Precip	Use
Shallow convection	shc		
Stratiform precipitation	str		
Insects	ins	Clear air	Maybe use
Smoke	smk		
Chaff	chf	Clutter	Do not use
Birds/bats	brd		
Permanent ground clutter	pe		
AP ground clutter	gc		
AP sea clutter	ap		
Side-lobe sea clutter	sl		
2nd trip echo	2tp		

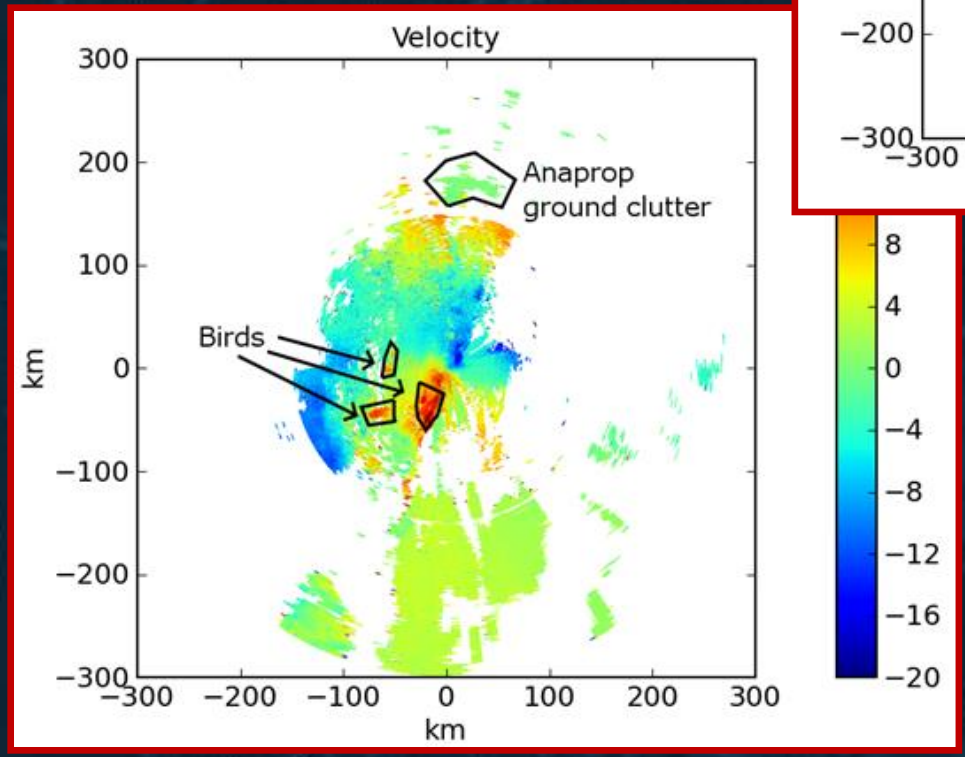
Identify using a ‘Naïve Bayesian Classifier’

Develop a training dataset to prime the NBC

Training dataset

Identified by expert using time series of elevation scans and all available *a priori* knowledge.





Terrey Hills, NSW,
3 Jan 2012, 09.50 h;
elev. 0.5^{o}.

Quantities used to classify echoes

Field	Description
DBZH	reflectivity
EHGT	echo top height to 4 dB
EHGT2	echo top height to −5 dB, where EHGT does not exist
WAVG	spectrum width from weighted average using adjacent beams
VTDL	vertical gradient of reflectivity
ZTEX[1]	variation of reflectivity in 2D kernel of 11×11
VTEX[1]	variation of velocity in 2D kernel of 15×15
SPIN[2]	change in sign of reflectivity gradient in 2D kernel of 19×19

'Texture'

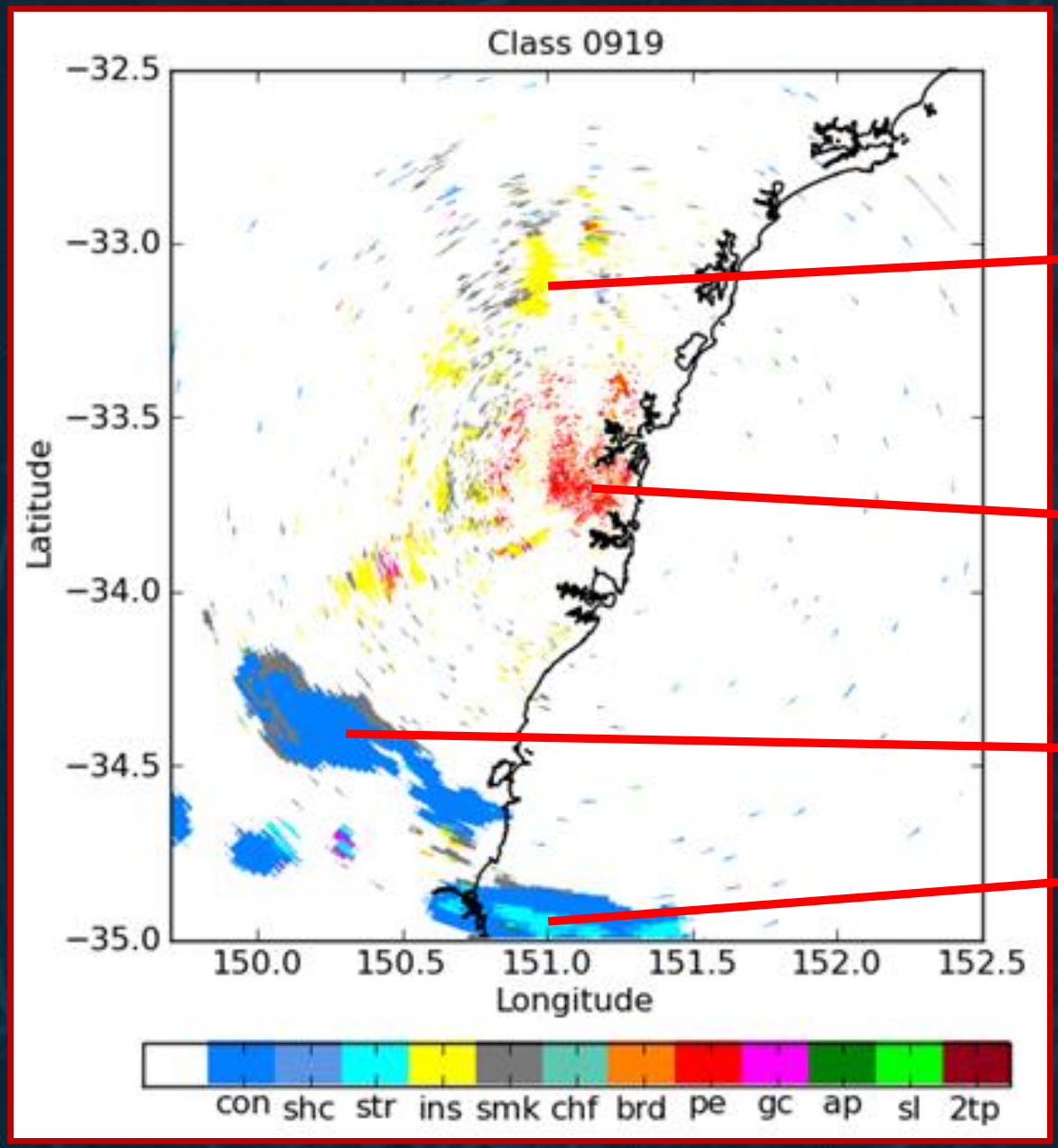
Limited as only reflectivity and velocity (and for a few units spectrum width) available.

Determine probability distribution functions and overlaps for each quantity

Set prior probabilities to incorporate *a priori* knowledge

- E.g. 0.4 for insects over land, but 0.0 over sea.
- Vary value for precip. according to current precip. forecast?

Classification output



Insects

Ground clutter

Conv. Precip.

Strat. Precip.

Terrey Hills, NSW, 18 Jan 2012, elev. 1º.

Conclusions - classifier

~85% of precipitation echo identified

Incorporating probability of precipitation from current forecast improves classifier performance

Identification of clear air echo for assimilation appears feasible

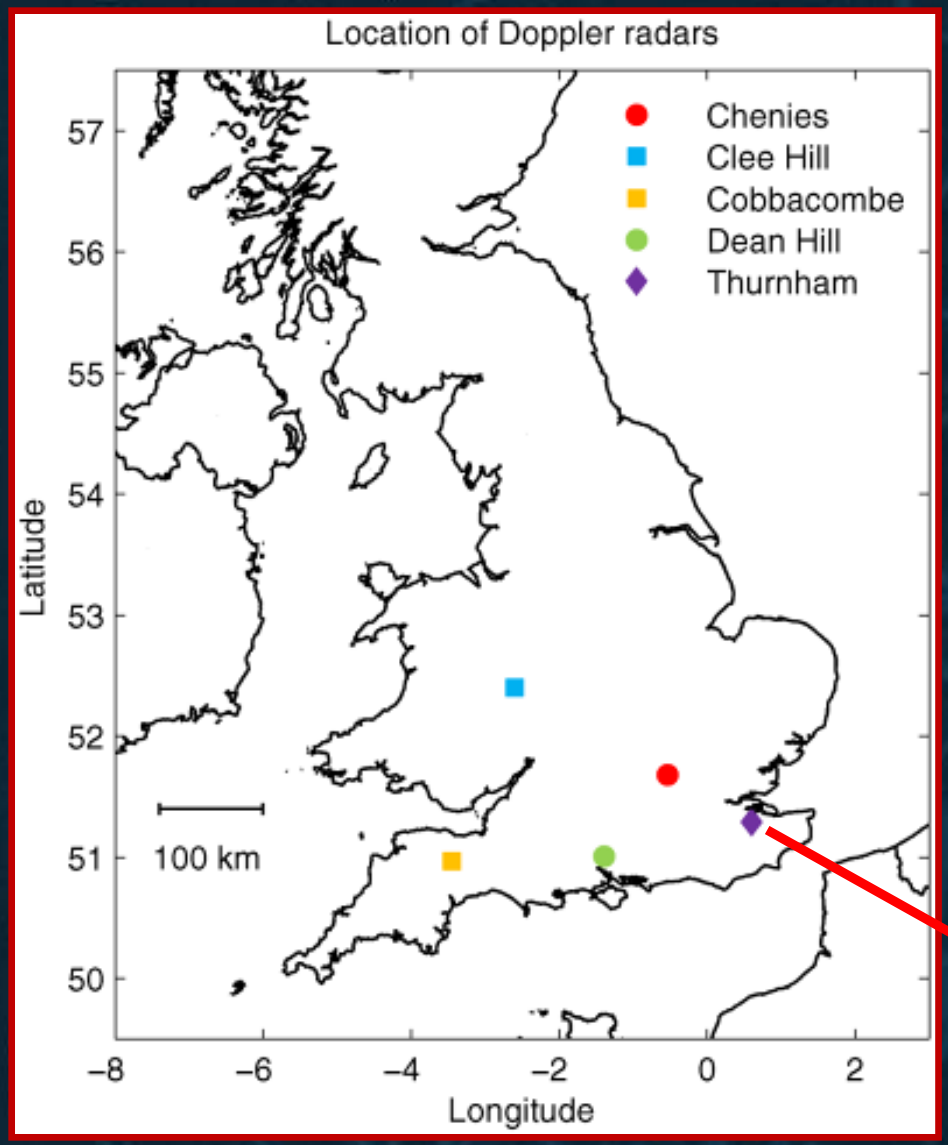
Main contaminants anaprop clutter, chaff, and smoke remain hard to distinguish but occur infrequently.

Little broad-front bird migration so clear-air echo mainly due to insects

- Bird/bat echoes usually dispersal flights at dawn and dusk
- Discriminate by local variations in reflectivity and velocity

Bird-insect discrimination less of a challenge than elsewhere

5. D-pol observations in Britain



In ~2007:-

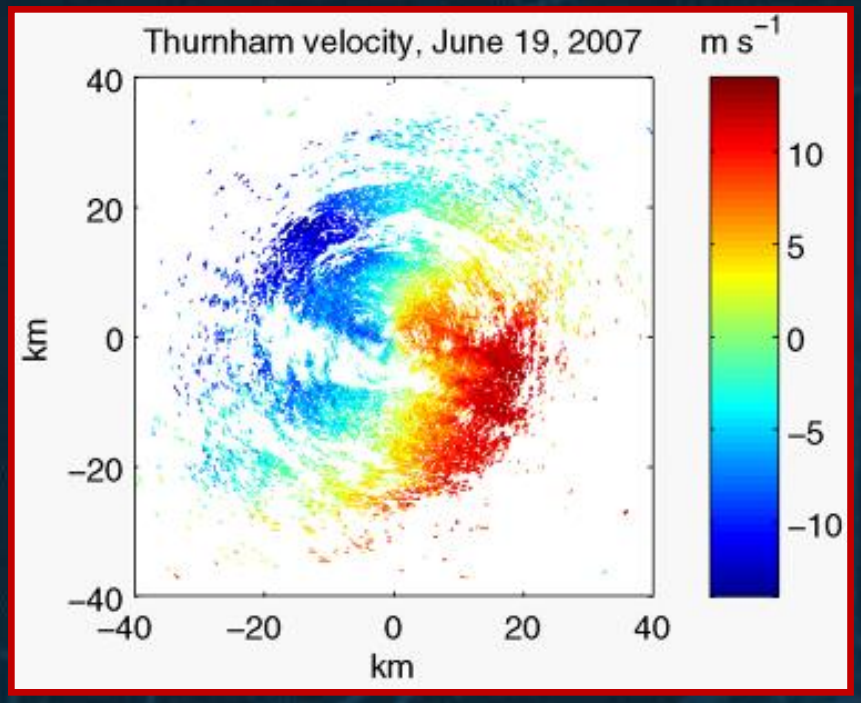
4 S-pol Doppler weather radars (C-band, operational).

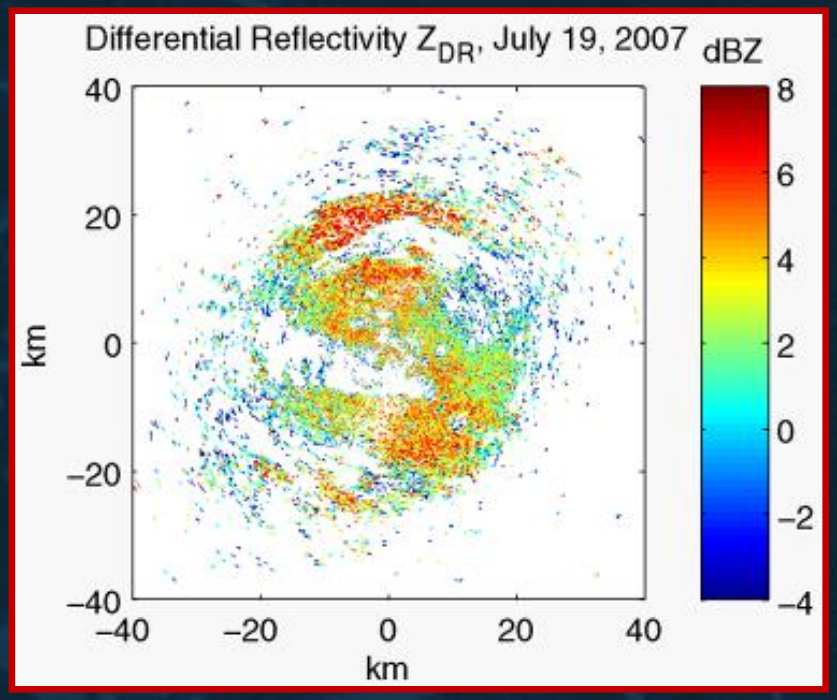
1 D-pol unit (Thurnham) (C-band, research).

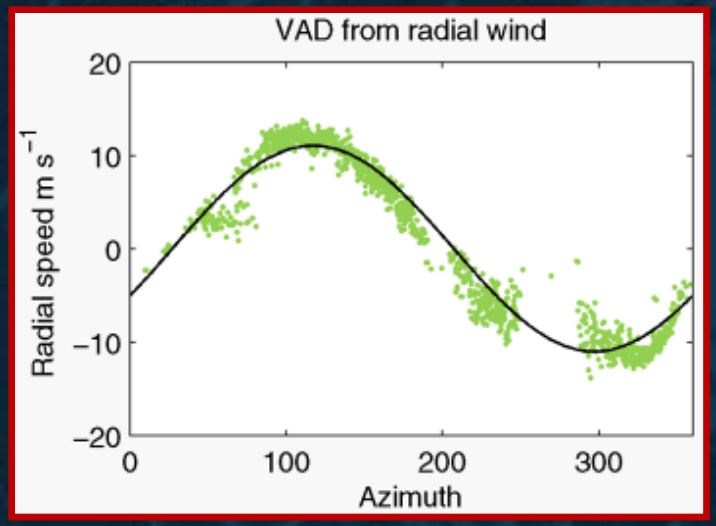
Main objective of research effort: prediction of extreme rainfall events (flood risk).

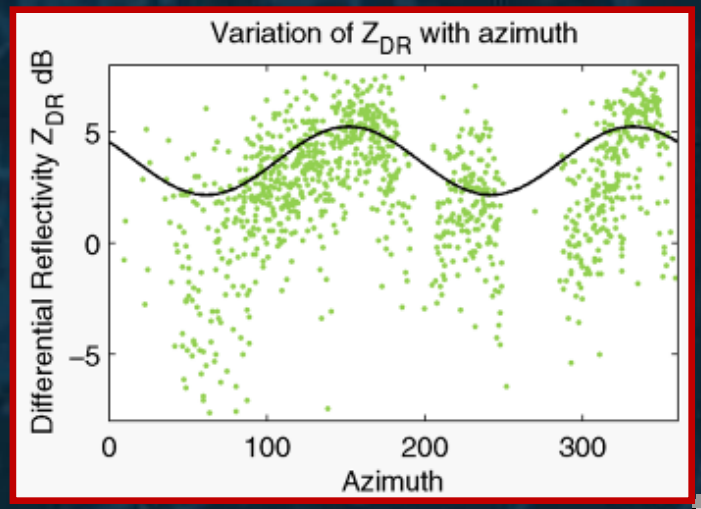
Thurnham

Insect echo detected during summer









Use Z_{DR} variation to infer orientation

6. Concluding remarks

Insects in the aerosphere, and insect echo on radars, are widespread in Australia and occur through much of the year.

- Warm climate, extensive rangelands and agricultural plains.
- Insect echo especially evident in the inland plains where insect migration is often intense and topography produces little clutter

Broad-front bird migration hardly occurs

- Bird echo is mainly from dispersal flights at dawn and dusk

Weather surveillance radars are mostly located near the coasts where insect migration patterns are poorly known

- No prospect of WSR coverage of locust outbreak area in far inland

Main interest is assimilation of clear-air winds into numerical weather forecasts

Publications

Rennie, S.J. 2012. Doppler weather radar in Australia. *CAWCR Technical Report 055*. Bureau of Meteorology, Melbourne.

Rennie, S.J., Illingworth, A.J., Dance, S.L., & Ballard, S.P. 2013. the accuracy of Doppler weather radar wind retrievals using insects as targets. *Meteorological Applications* 17:419-432.

Rennie, S.J. 2014. Common orientation and layering of migrating insects in southeastern Australia observed with a Doppler weather radar. *Meteorological Applications* 21:218-229.

Rennie, S.J., Curtis, M., Peter, J.R., Seed, A.W., & Steinle, P.J. 2014. Training the Ancilla Naïve Bayesian Classification System to provide quality control for weather radar data. *CAWRC Technical Report 073*. Bureau of Meteorology, Melbourne.

Acknowledgments

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- ENRAM and UNSW supported AD's travel to the meeting.