Synthetic Satellite Imagery and Weather Prediction

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Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

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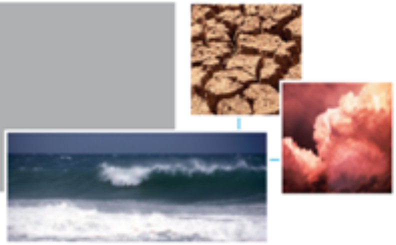
Introduction

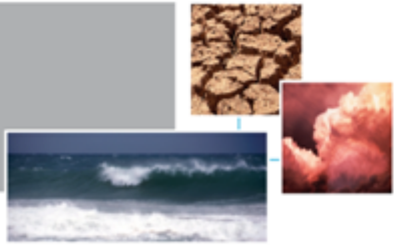


- Scheme initially designed for model evaluation
    - Direct comparison of model with satellite data
    - Test for radiative transfer and cloud fields
    - This is a model-to-satellite scheme (as opposed to satellite-to-product)
- Geostationary satellite data is perfect for regional scale NWP
    - large scale
- Compatible with regional models
- Numbers of pixels per grid square is (usually) large
    - available at least hourly
- Ties in with forecast output
- Synthetic imagery is a readily accessible summary of the model state
    - Forecasters trained to evaluate satellite imagery can apply same techniques to the model forecast imagery – synthetic imagery.

The model-to-satellite paradigm

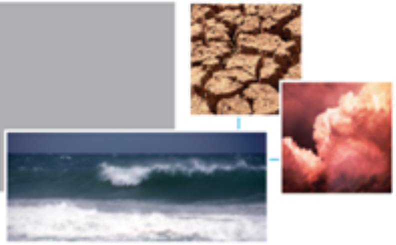
- Uses model's own radiative transfer scheme (or similar physically based code)
  - All the required fields are available
  - Tests model prognostic cloud fields – position, height, fraction
  - Tests cloud optical property parameterization
  - Tests radiative transfer assumptions – cloud overlap
  - Tests model surface properties
- Applied to every operational forecast every day

The synthetic imagery code



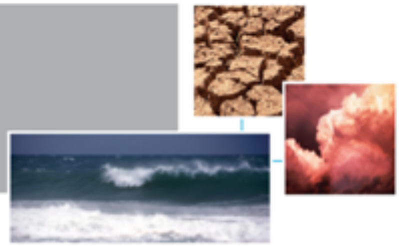
- Solves RT equation using parameterization-type code
  - Same physical assumptions as model
  - Takes account of spectral resolution function of specific satellite channel
- Original code based on Fels-Schwarzkopf RT parameterization in legacy models.
  - Simple band cooling to space emissivity approach
  - Spectral response added in 'on the fly'
    - Easy to add new satellite channels
    - Different formalism to UM so difficult to add in cloud assumptions
  - Restricted to emission channels
- SES version added by Zhian Sun
  - Same physics as UM
    - Easy to add in UM cloud property treatments
  - Requires spectral function to be pre-folded into band coefficients
  - Models scattering accurately
- Input model history files with cloud and thermodynamic fields

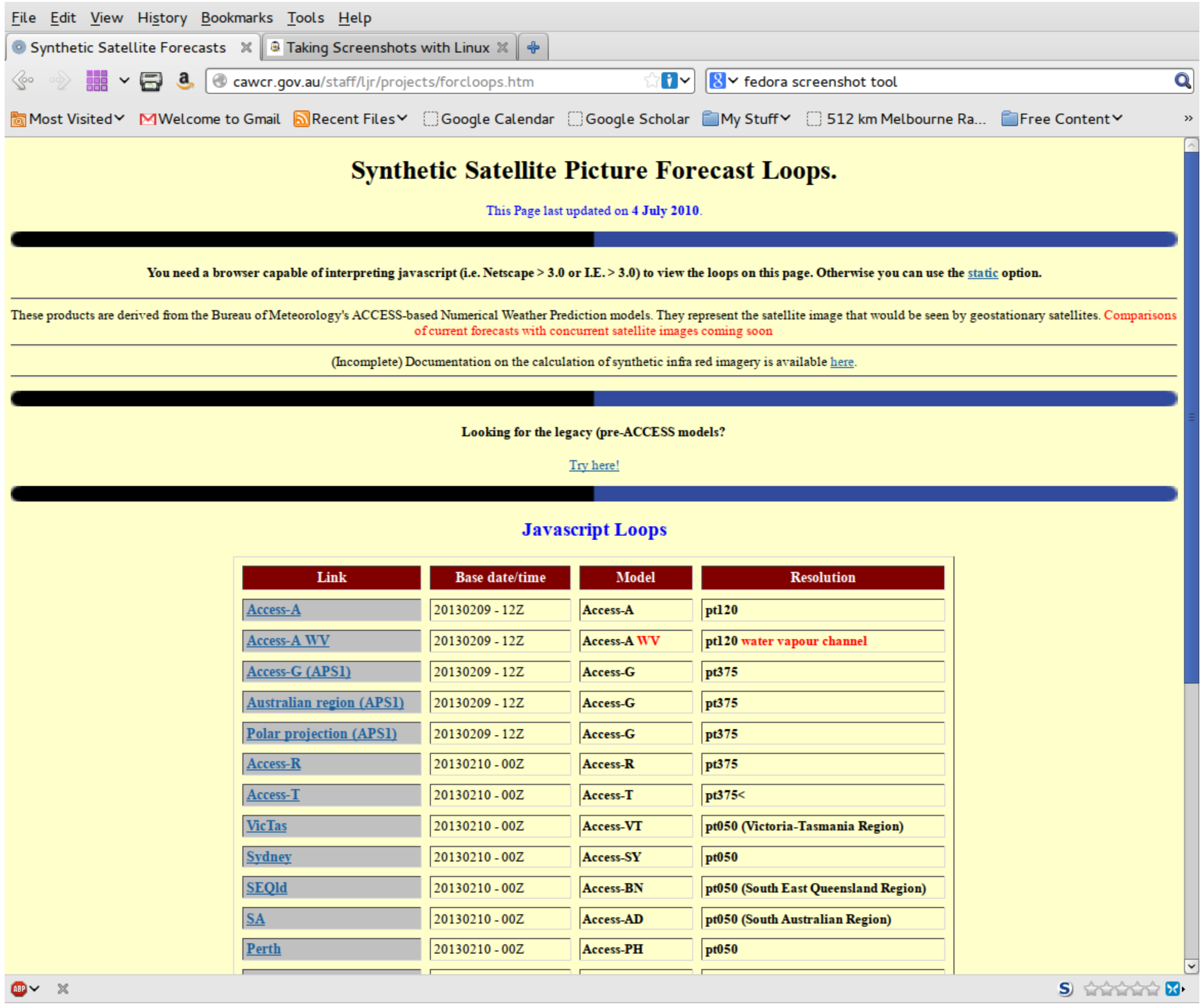
Current satellite channels in two stream code



Satellite	FY-2C	GOES-8/ 9/10	METEOSAT-5/6	MODIS	MTSAT-1R	MTSAT2	NOAA-7/8/9/ 10/11/ 12/14/15/16/1 7
Number of Channels	3	9	6	10	3	3	18
Number of bands	12	24	26	32	9	8	48
Satellite Channels	ir1 ir2 wv	ir1 ir2 wv	ir1 wv	27/28/ 29/30/ 31/32/ 33/34/ 35/36	ir1 ir2 wv	ir1 ir2 wv	Ch4 Ch5

My synthetic satellite imagery web page





File Edit View History Bookmarks Tools Help

Synthetic Satellite Forecasts | Taking Screenshots with Linux

cawcr.gov.au/staff/ljr/projects/forcloops.htm

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Synthetic Satellite Picture Forecast Loops.

This Page last updated on **4 July 2010**.

You need a browser capable of interpreting javascript (i.e. Netscape > 3.0 or I.E. > 3.0) to view the loops on this page. Otherwise you can use the static option.

These products are derived from the Bureau of Meteorology's ACCESS-based Numerical Weather Prediction models. They represent the satellite image that would be seen by geostationary satellites. Comparisons of current forecasts with concurrent satellite images coming soon

(Incomplete) Documentation on the calculation of synthetic infra red imagery is available here.

Looking for the legacy (pre-ACCESS models)?

Try here!

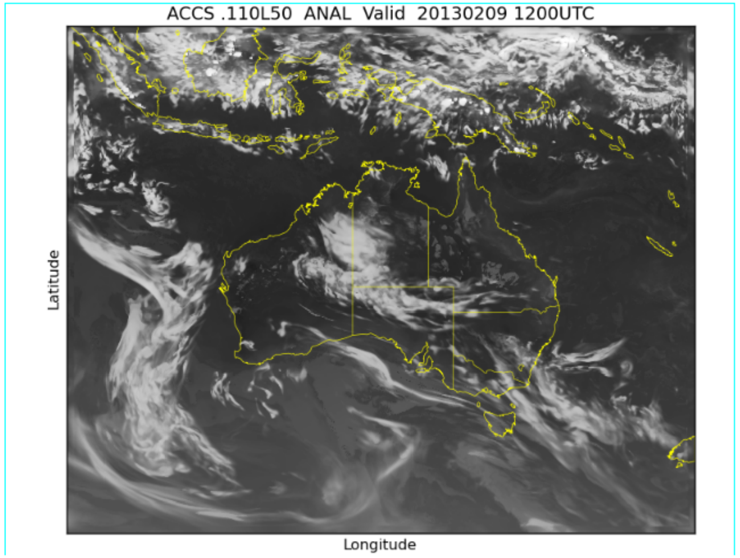
Javascript Loops

Link	Base date/time	Model	Resolution
Access-A	20130209 - 12Z	Access-A	pt120
Access-A WV	20130209 - 12Z	Access-A WV	pt120 water vapour channel
Access-G (APS1)	20130209 - 12Z	Access-G	pt375
Australian region (APS1)	20130209 - 12Z	Access-G	pt375
Polar projection (APS1)	20130209 - 12Z	Access-G	pt375
Access-R	20130210 - 00Z	Access-R	pt375
Access-T	20130210 - 00Z	Access-T	pt375<
VicTas	20130210 - 00Z	Access-VT	pt050 (Victoria-Tasmania Region)
Sydney	20130210 - 00Z	Access-SY	pt050
SEQld	20130210 - 00Z	Access-BN	pt050 (South East Queensland Region)
SA	20130210 - 00Z	Access-AD	pt050 (South Australian Region)
Perth	20130210 - 00Z	Access-PH	pt050

http://cawcr.gov.au/staff/ljr/projects/forloops.htm

- Requests led to setup for forecast guidance
  - Everyone knows how to interpret images
- Every operational forecast model
  - 0 and 12 UTC
- Process initiated at end of model run
  - Essentially real-time
- UNOFFICIAL
- UNSUPPORTED

Loop for Access-A IR1 channel



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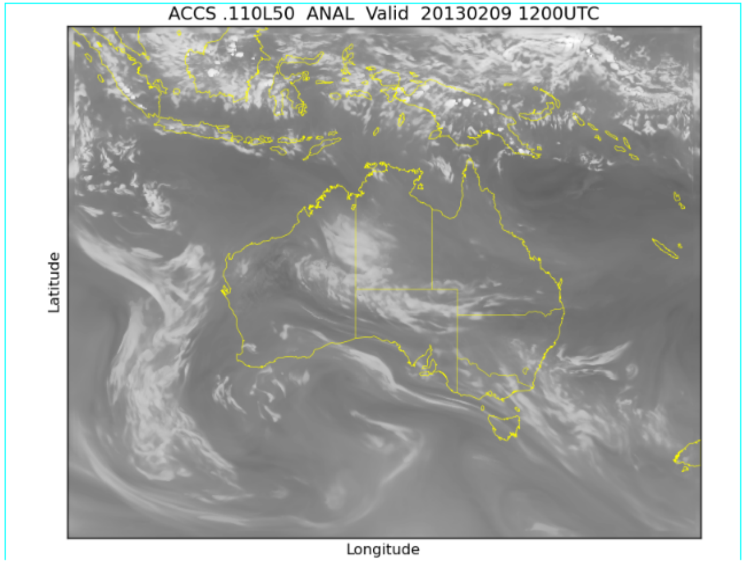
Loop for Access-A WV channel



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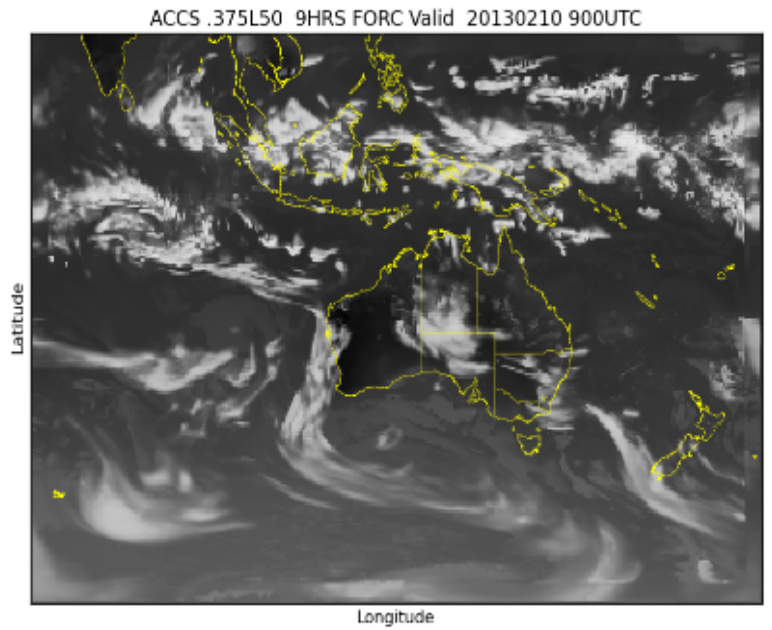
Loop for Access-R



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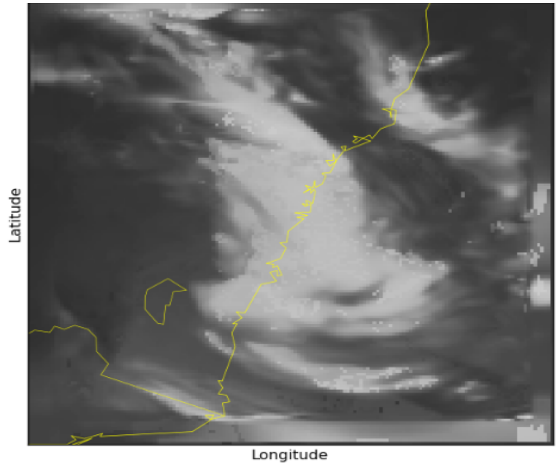

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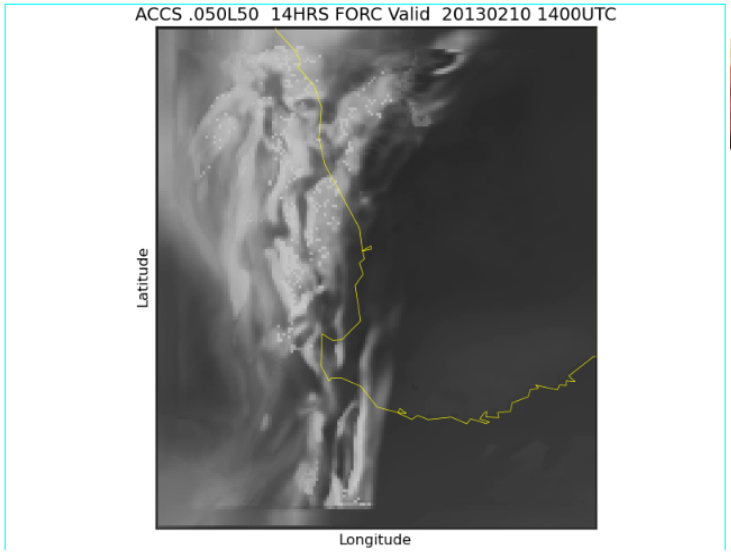
Loop for Access-PH



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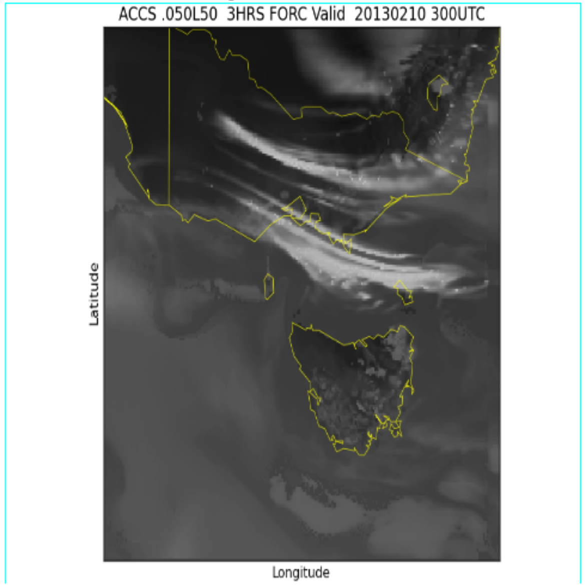
Loop for Access-VT/h3>



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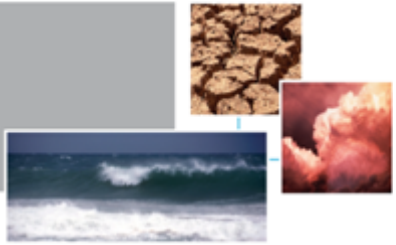
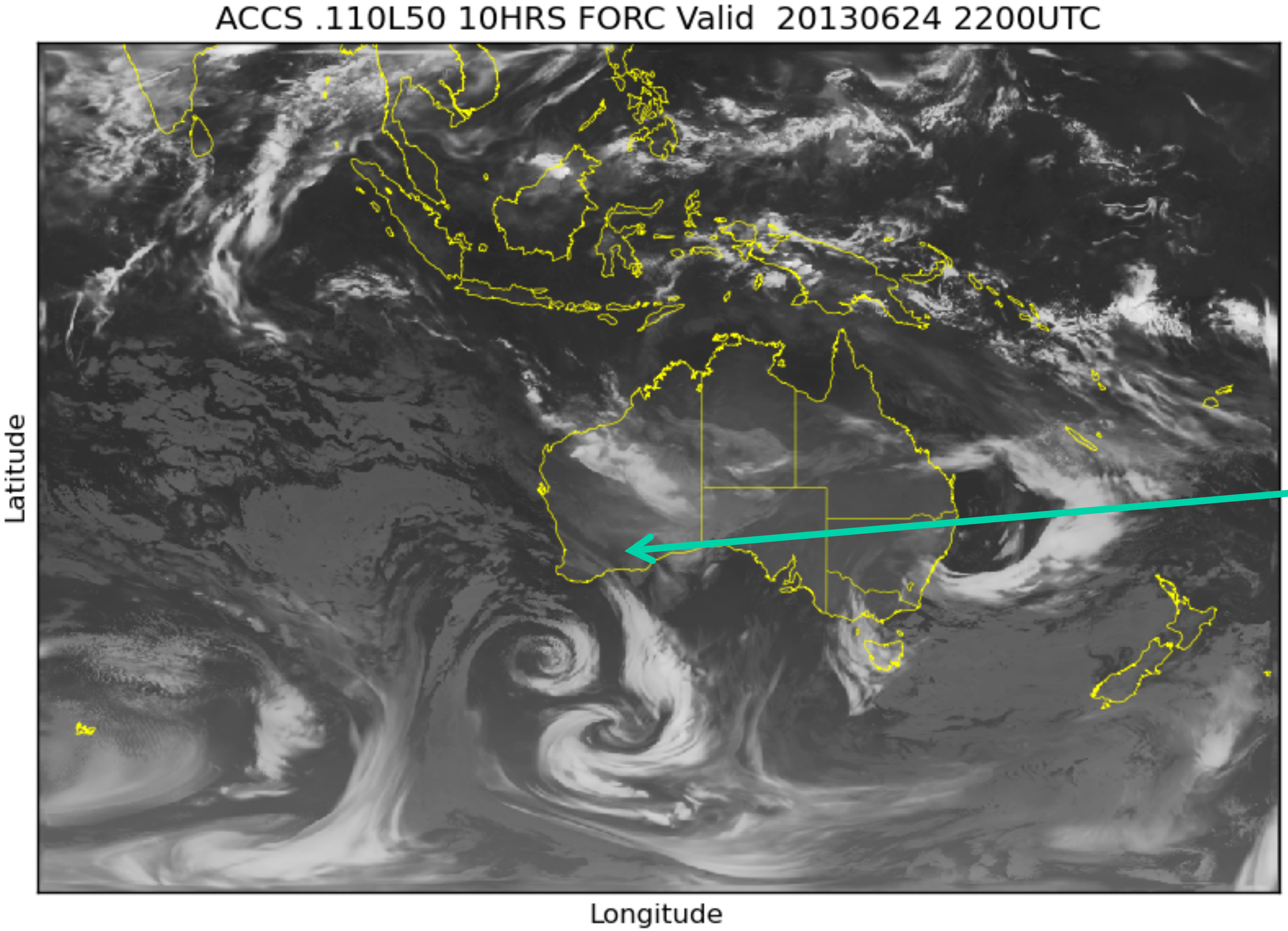
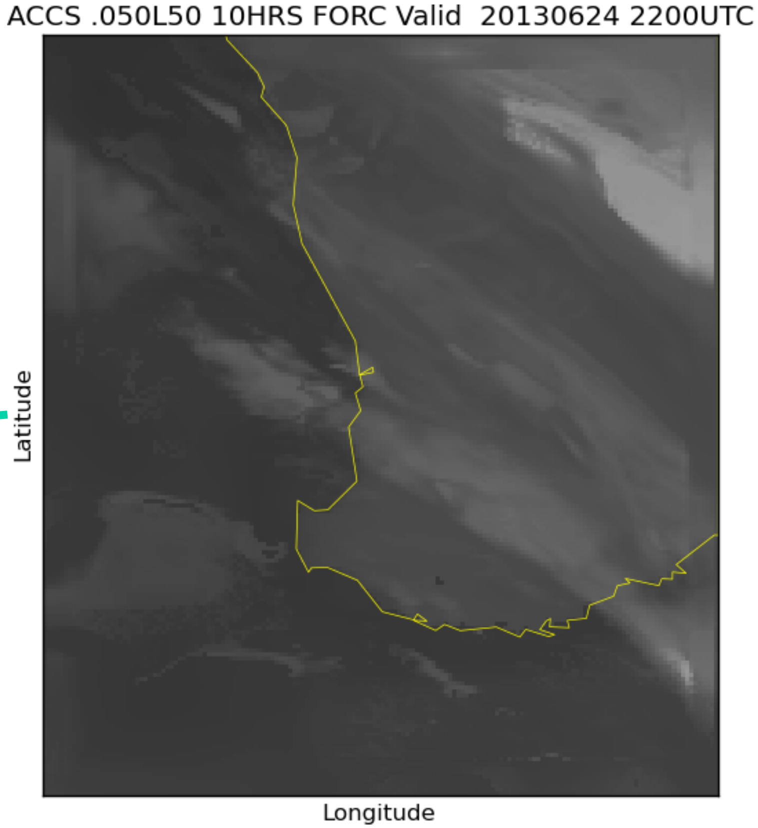
Regional models

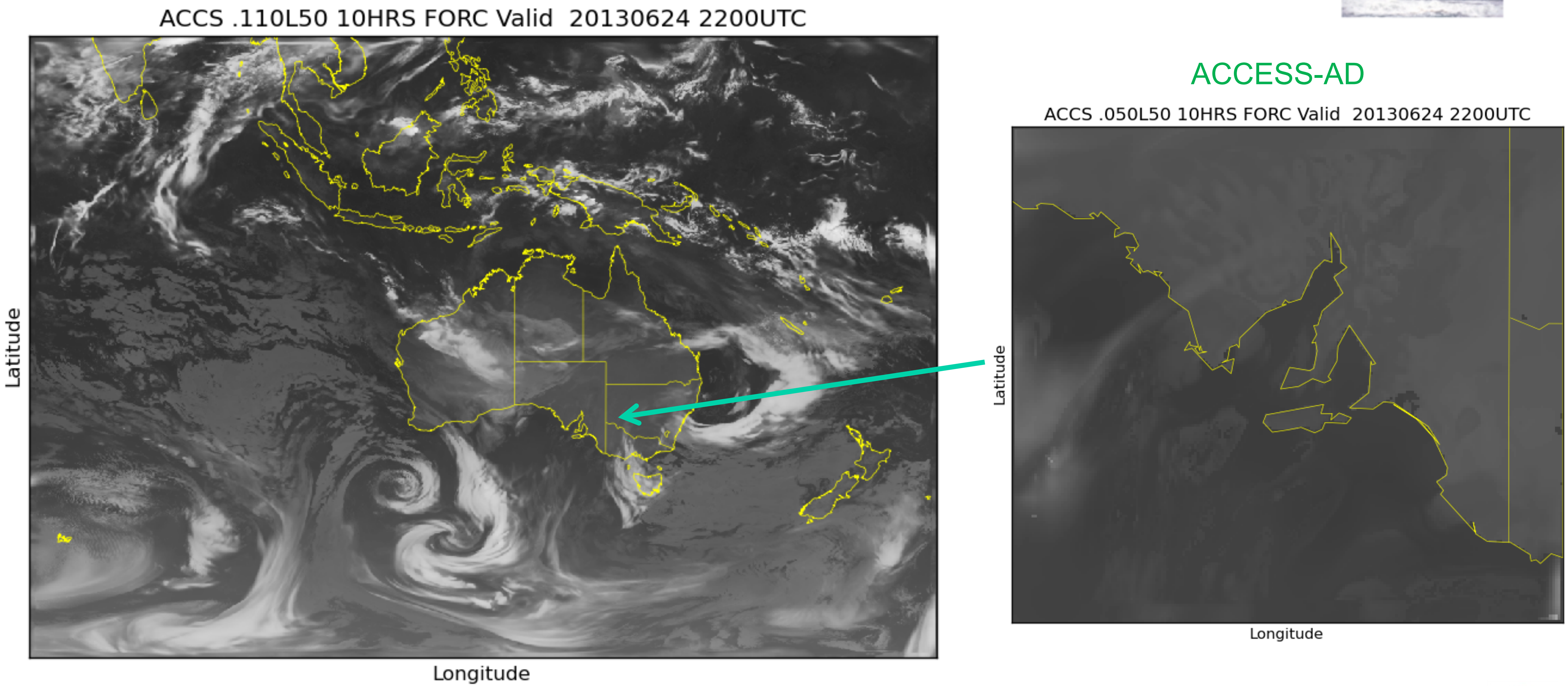




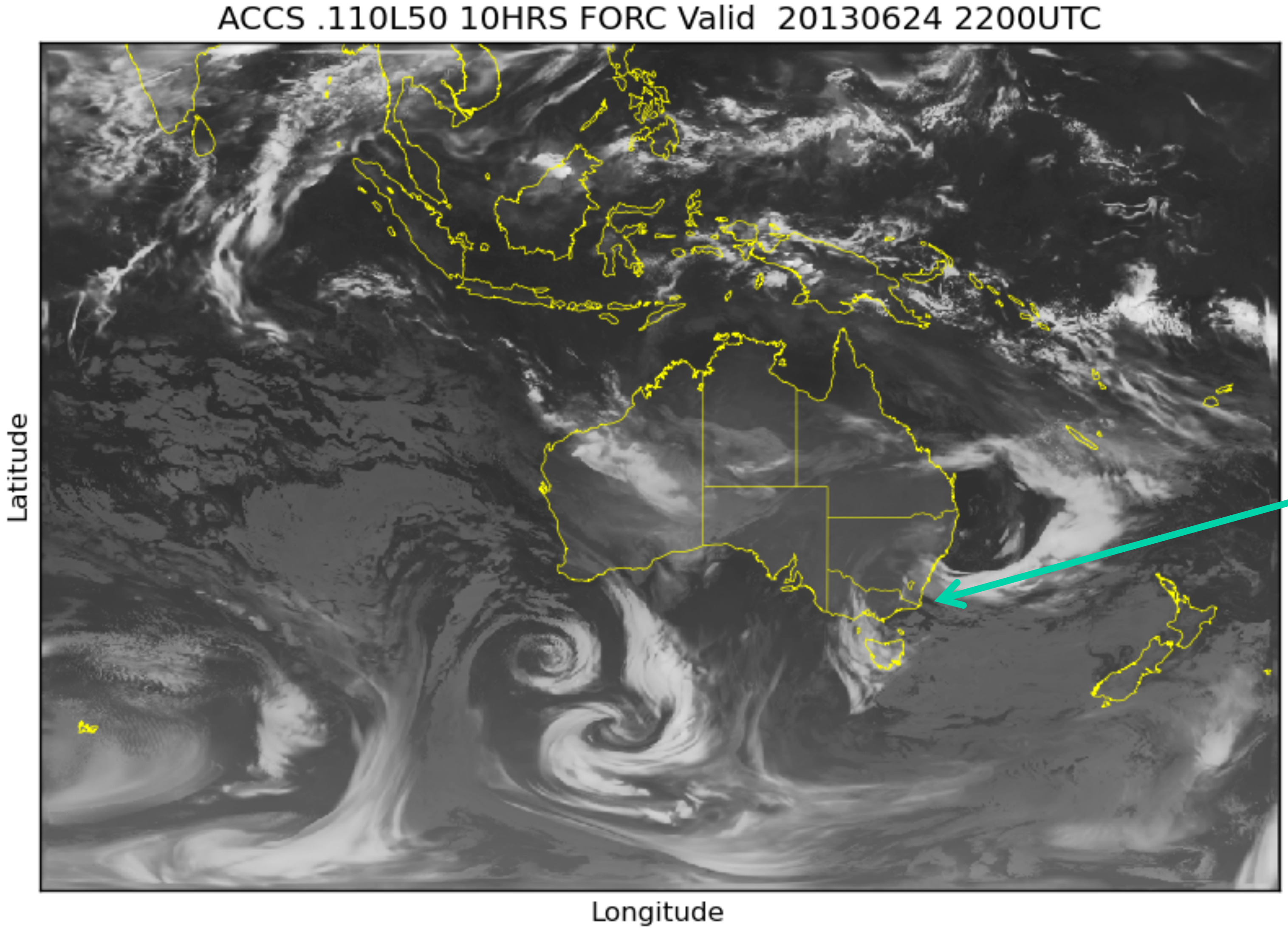
ACCESS-PH

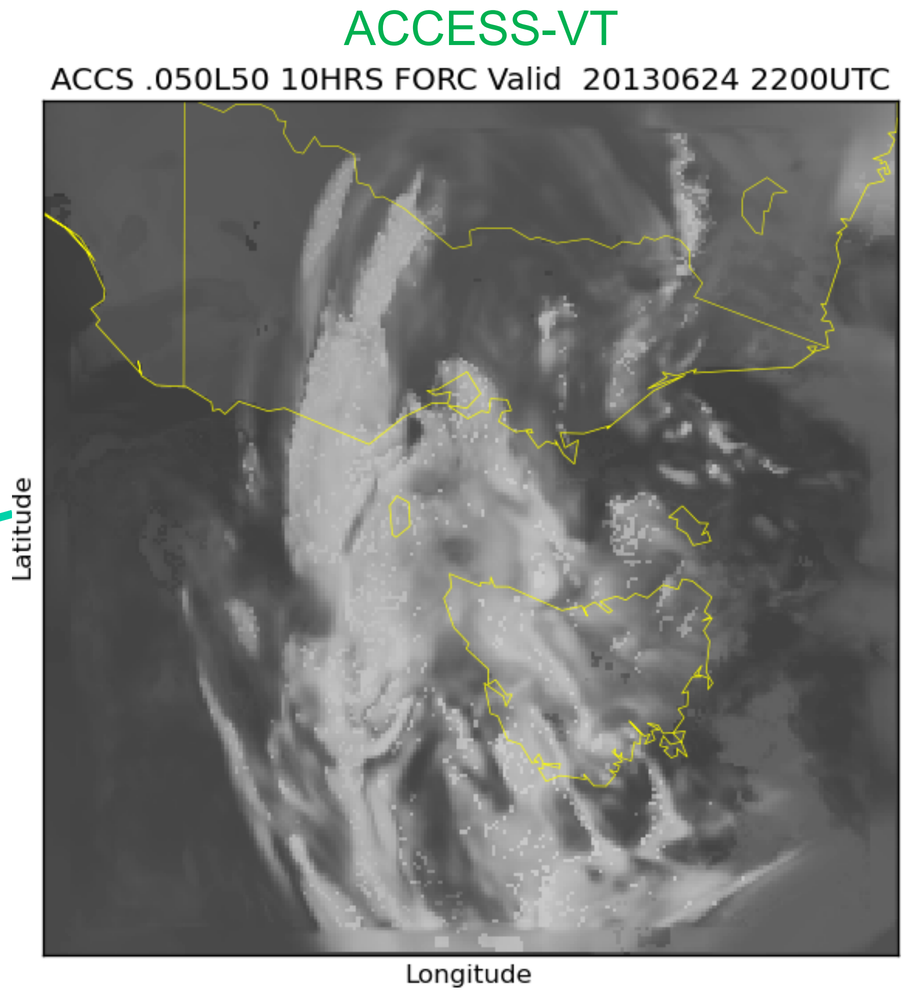


Regional models

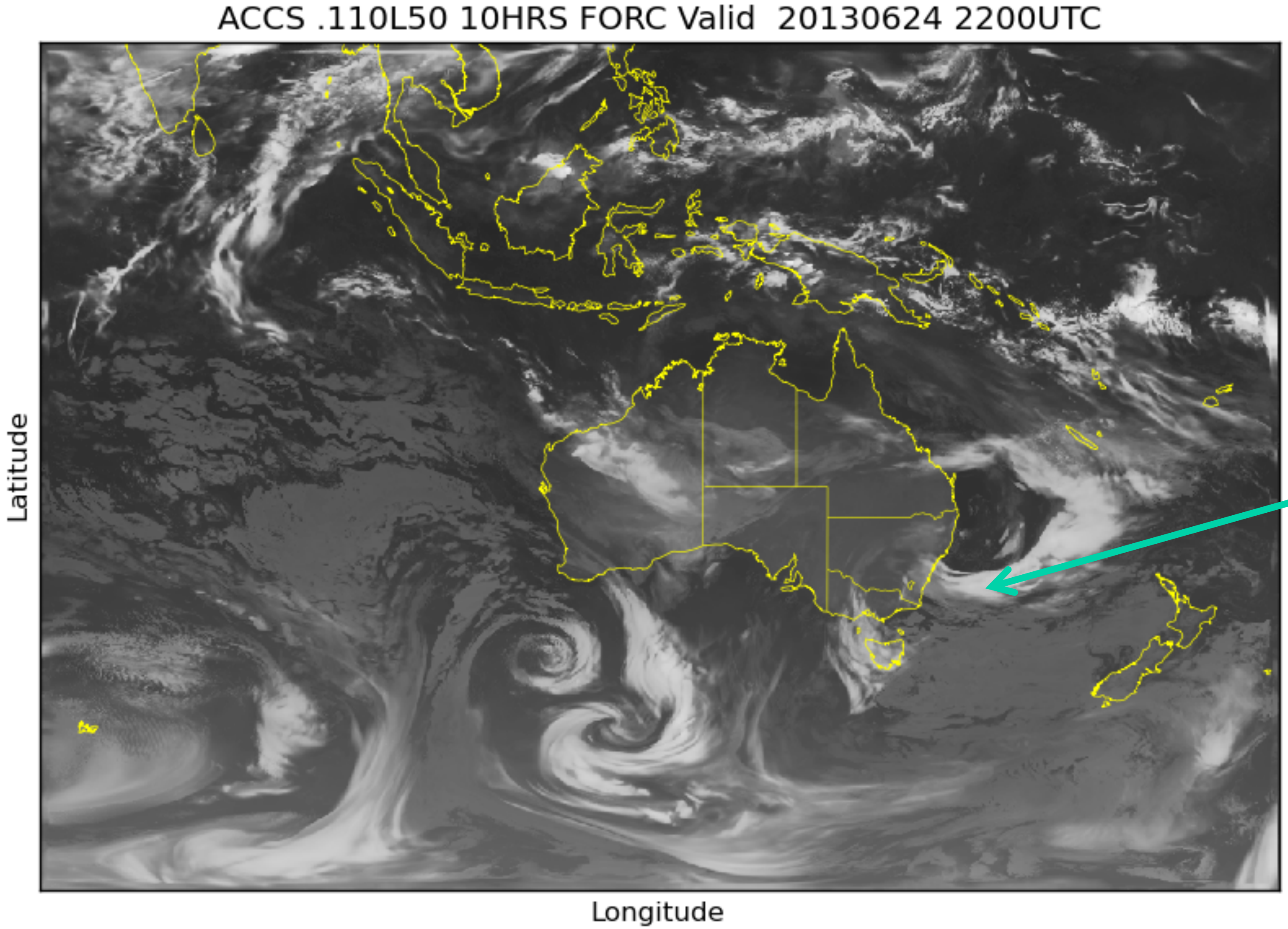


Regional models

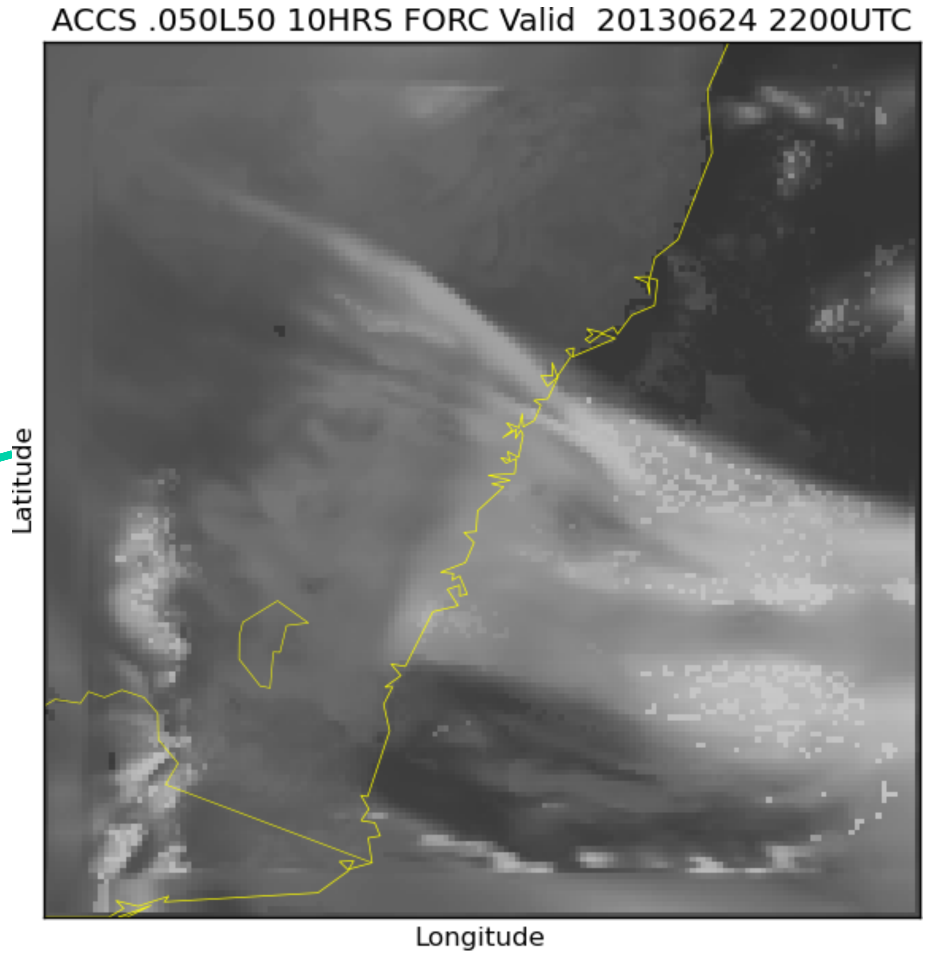




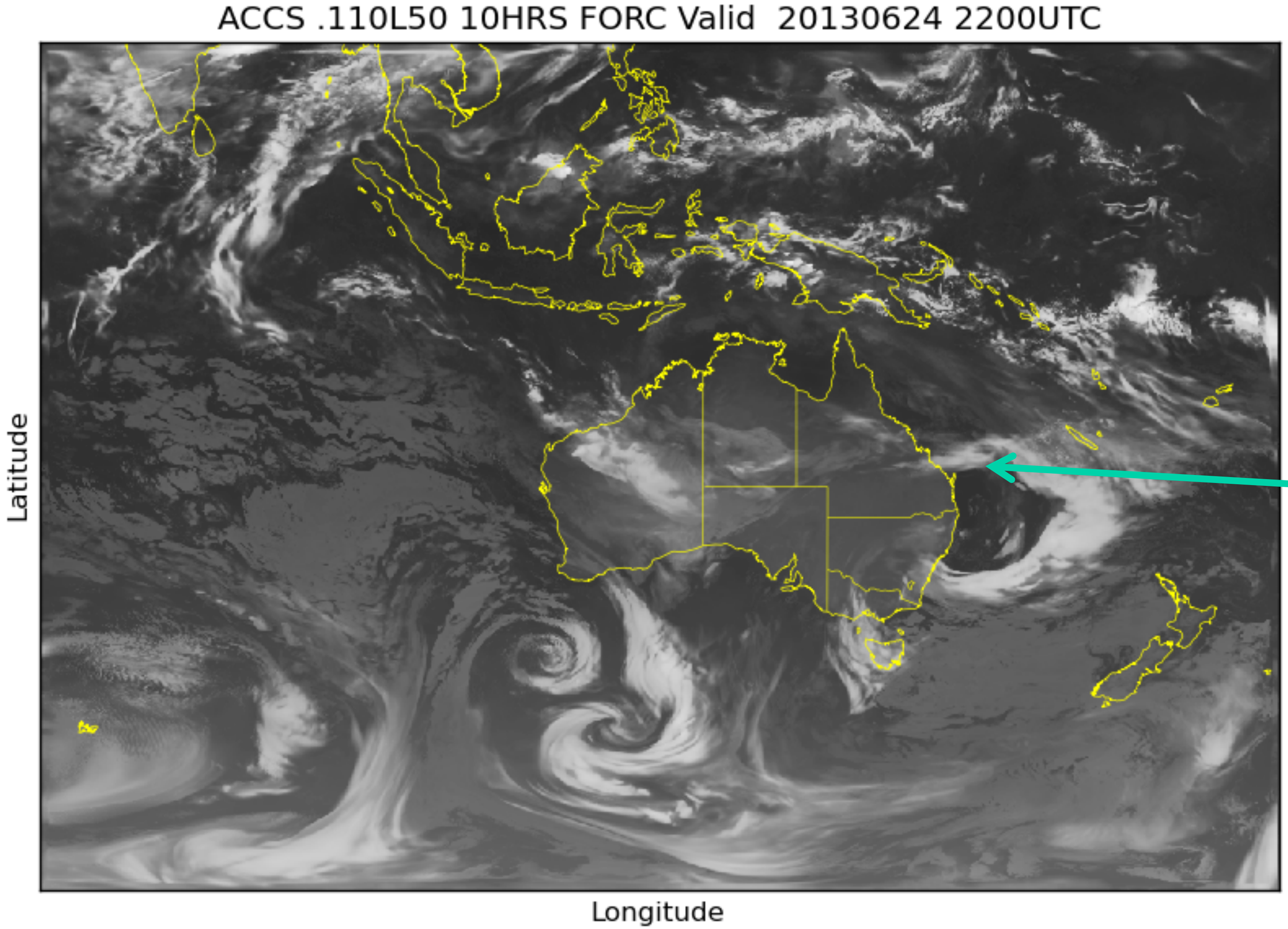
Regional models



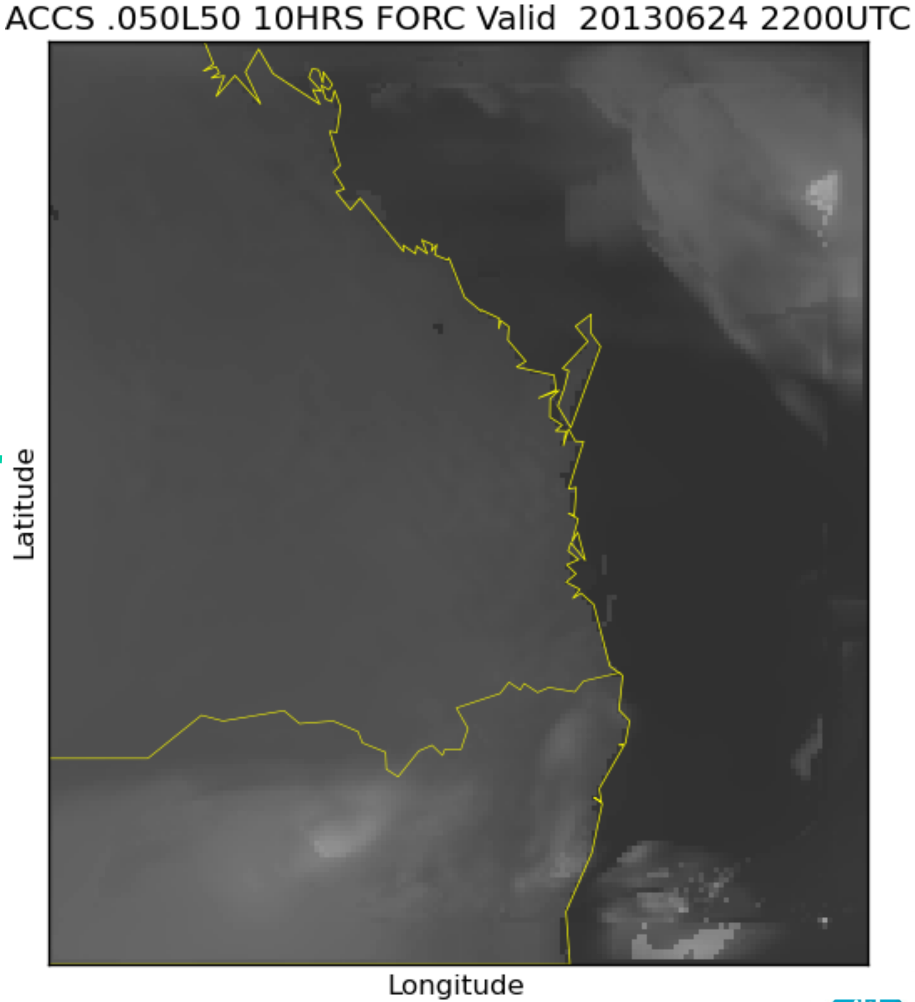
ACCESS-SY



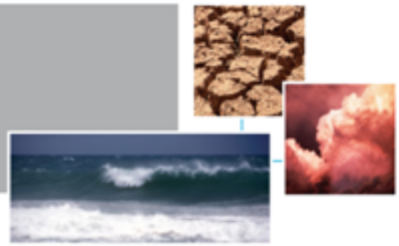
Regional models



ACCESS-BN



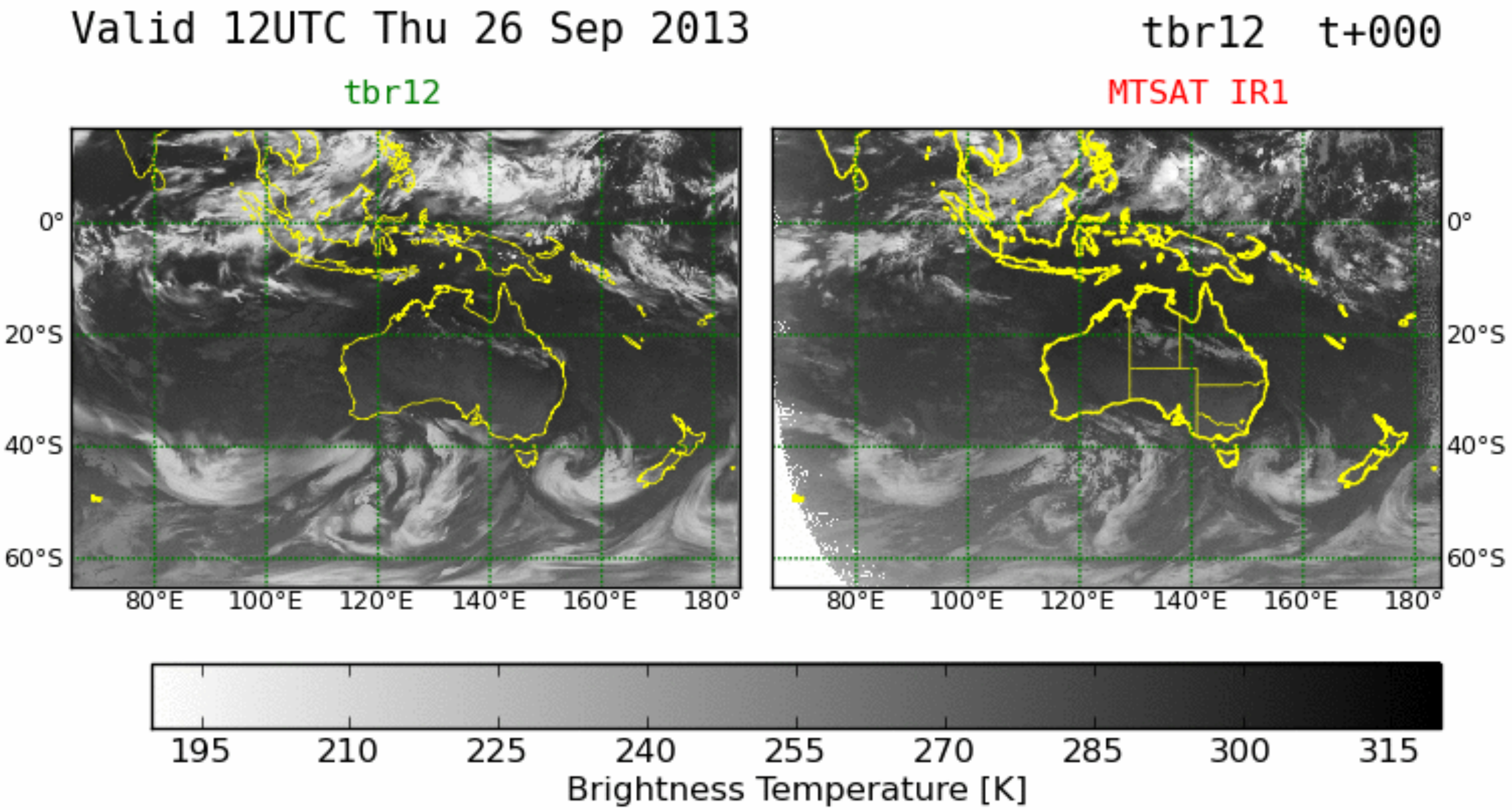
How can we compare the model and satellite data?



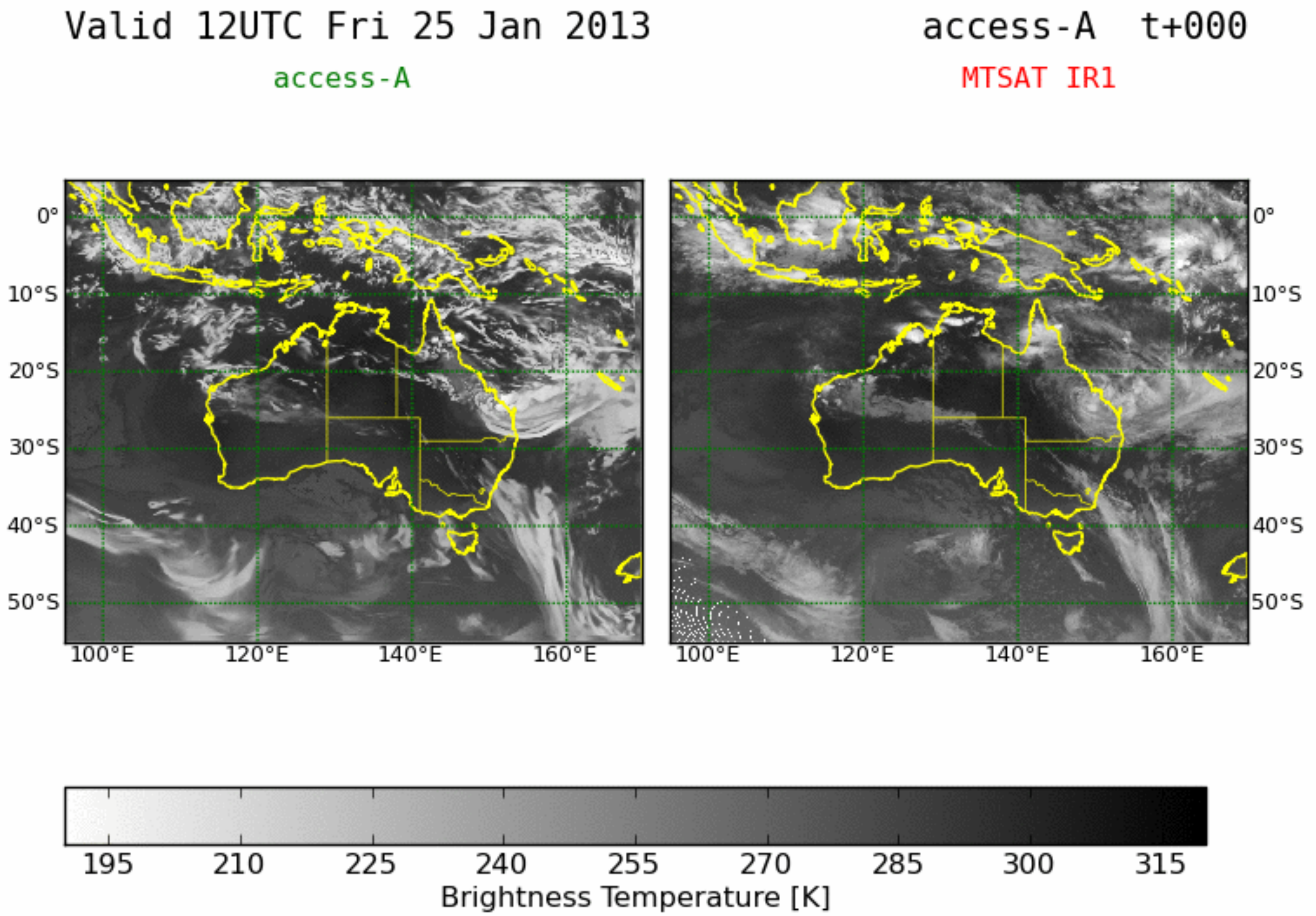
Depends on model grid resolution!

- **Coarse resolution comparison of images**
  - Large domains show large scale cloud features (e.g. fronts, etc)
  - Eyeball assessment can be updated to image translation/transformation based metrics
  - Binning technique works (except for limb points) to put satellite data onto model grid
- **High resolution**
  - High computational cost implies smaller region and less oversight of large scale cloud structures
  - Maybe need to move to image quality metrics – texture, PDF’s etc
  - Binning technique fails because it assumes point-like pixels (ignore spatial weighting function)
    - Requires area conserving technique?

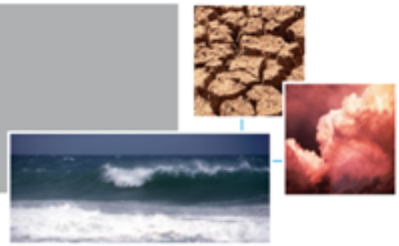
Australian Regional model



Access-A ex-TC Oswald 25th January 12UTC



Qualitative assessment



Tropics

Noisier

Too much cold cloud

Pass the squint test

Mid-latitudes

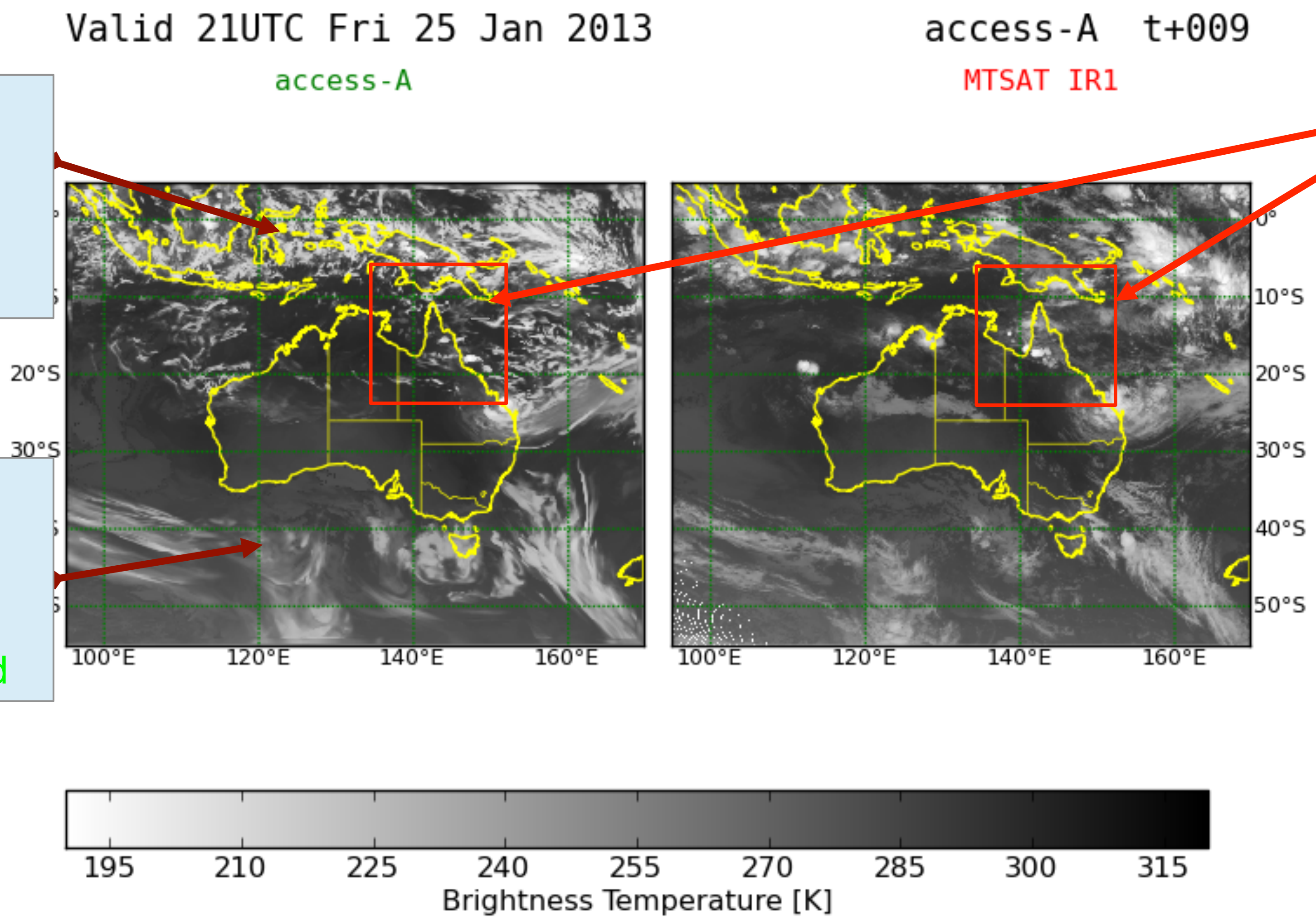
Smoother

Large-scales good

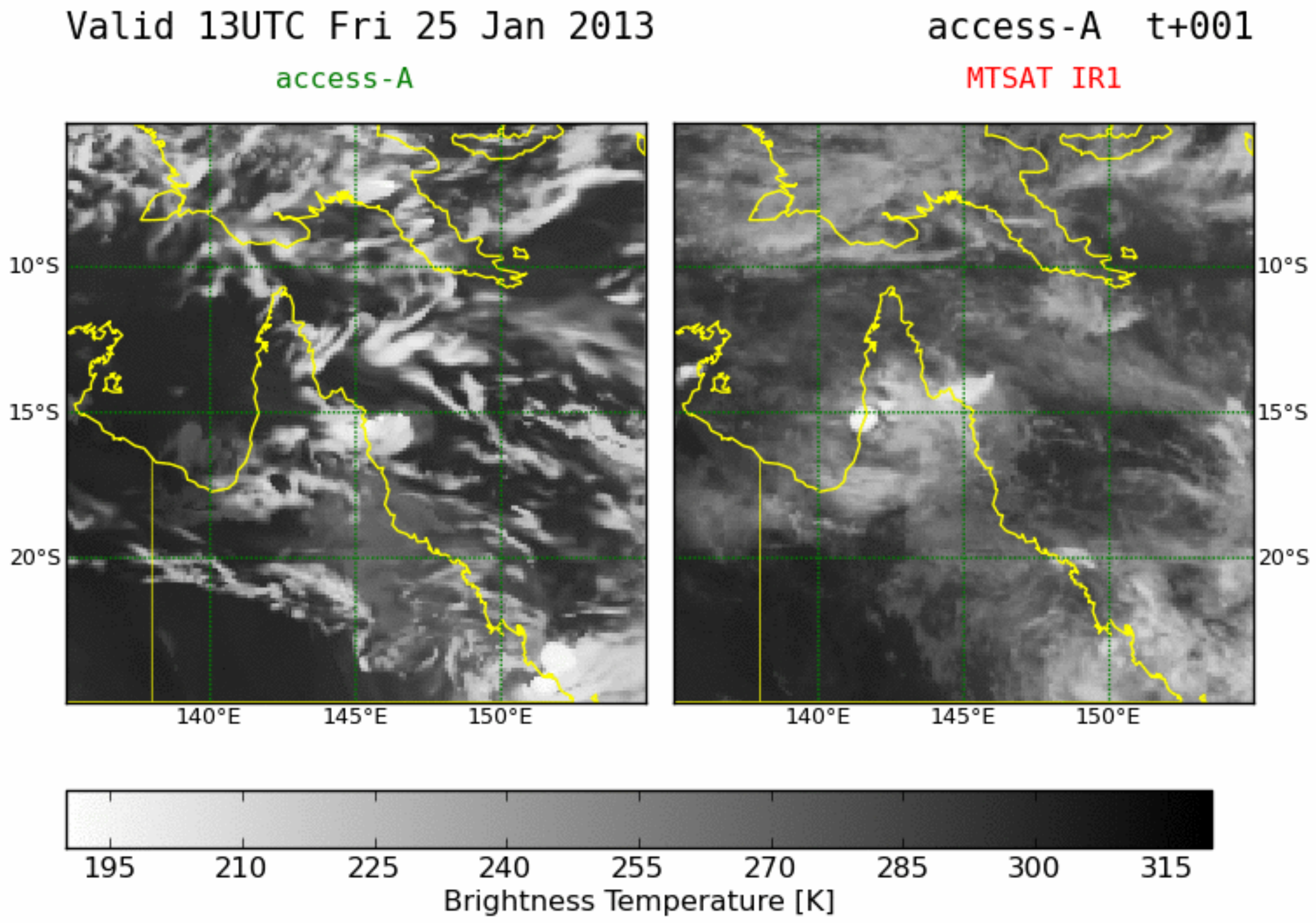
BT range good

Low cloud pretty good

Whoops!



Zooming in on a problem area



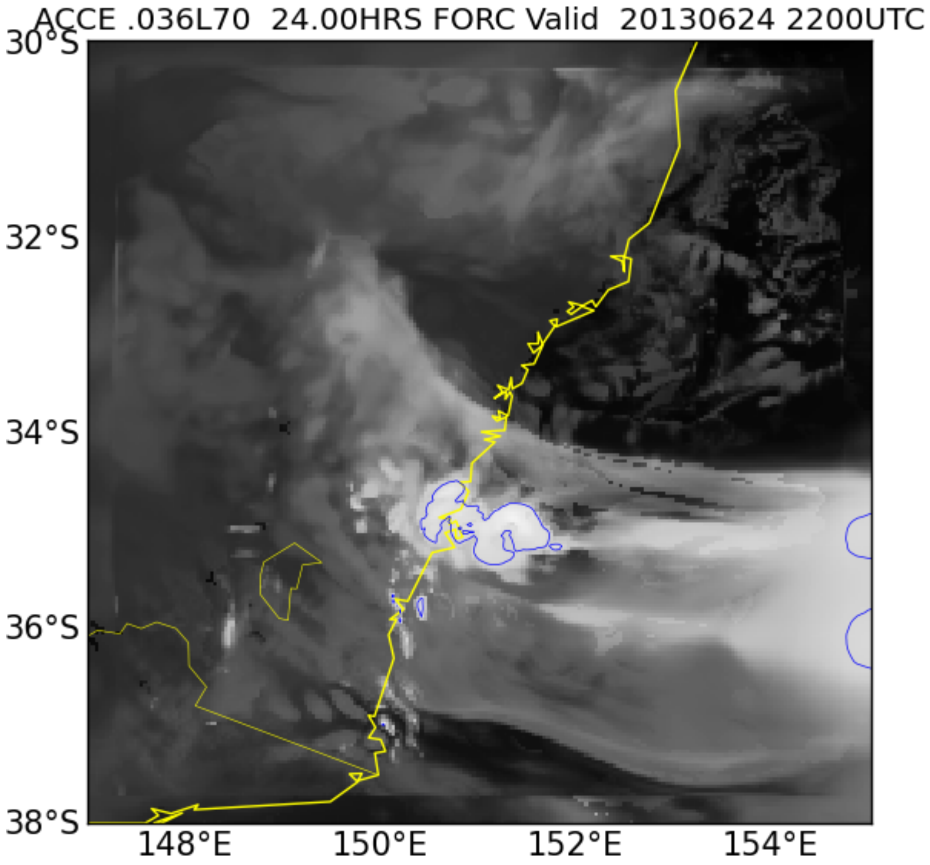
Highlights problems with convective parameterization and its link to cloud fields.

- Discrete time step character
  - Oscillations in time
- Independent point profiles
  - Meso-scale structure not explicit
- Coupling to large scale cloud problematic

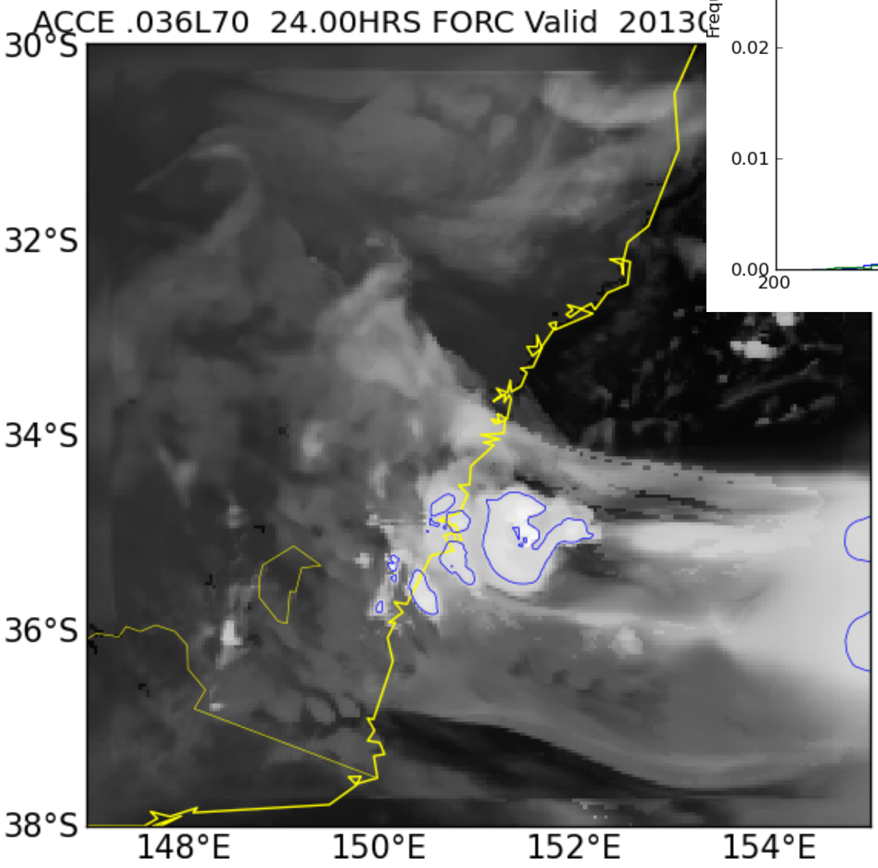
East Coast Low microphysics case study

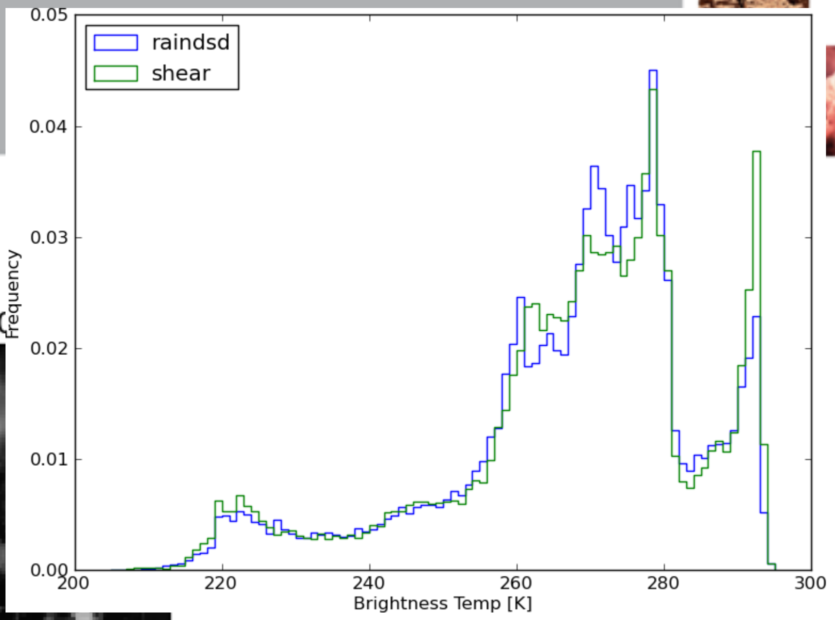
Collaboration with Charmaine Franklin and Holly Sims

SHEAR



RAINDSD

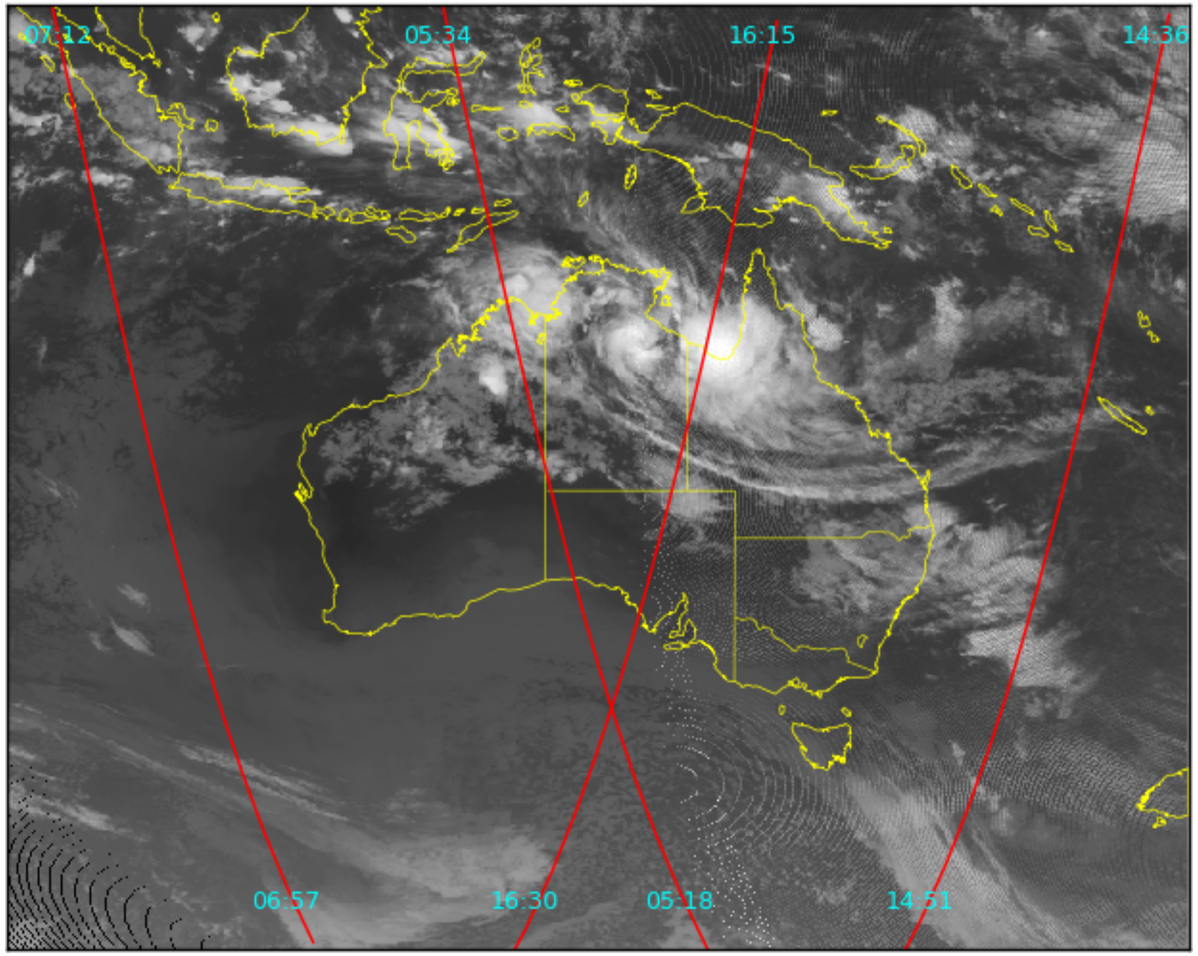




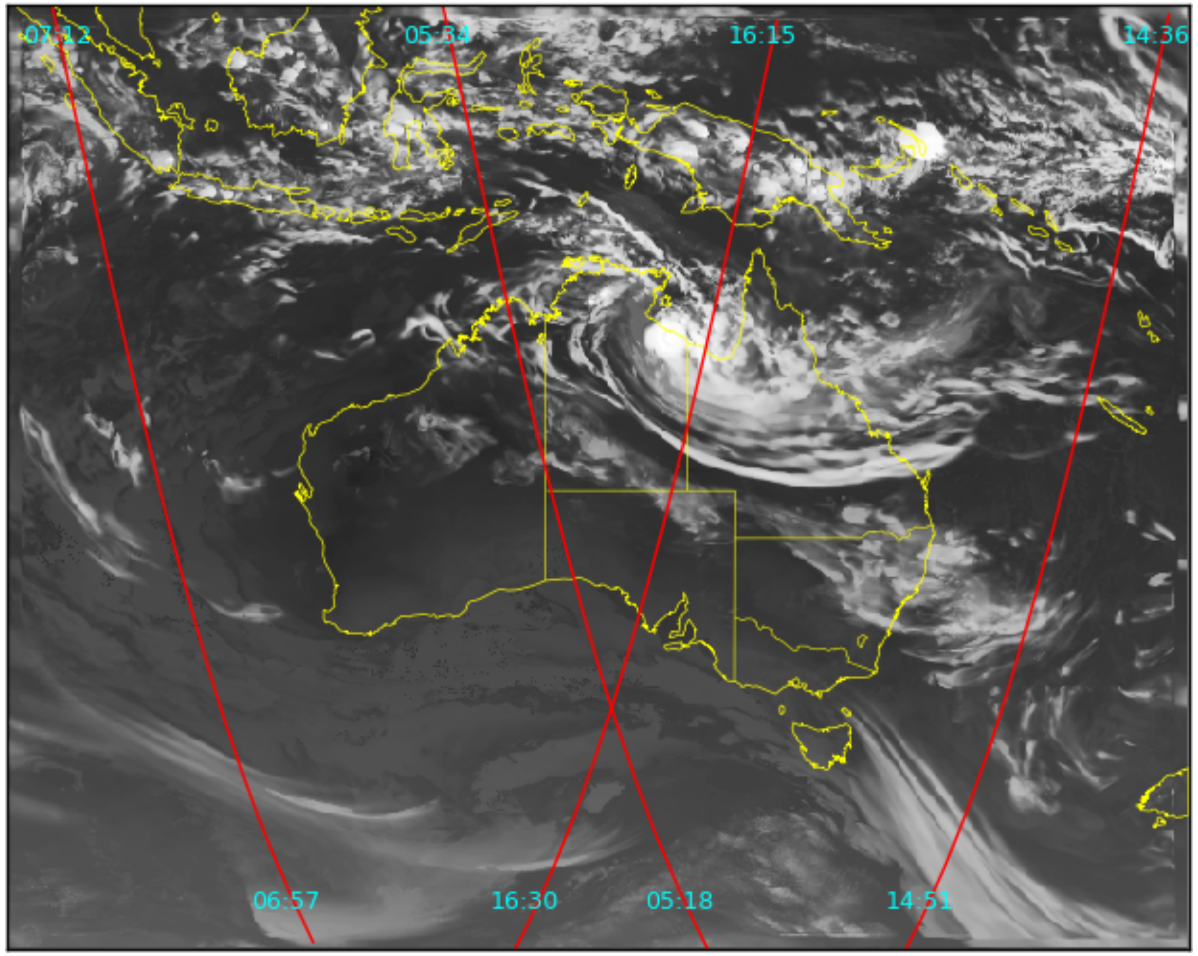
Use of other satellites

Collaboration with Alain Protat, Stuart Young and Michael Whimpey

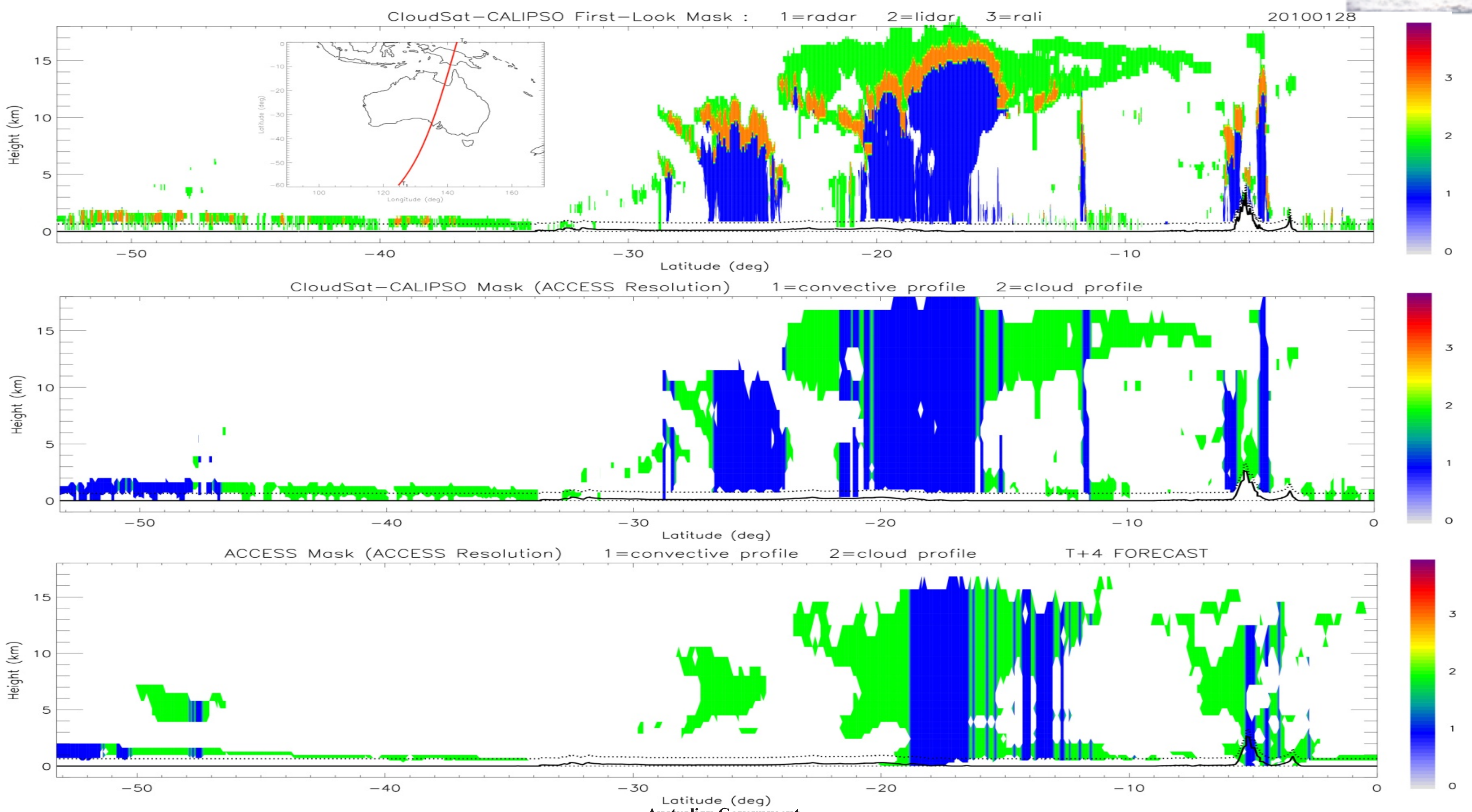
CloudSat/CALIPSO 28 Jan 2010 MTSAT



CloudSat/CALIPSO 28 Jan 2010 T+4 FORECAST



The C-C & ACCESS Cloud Masks



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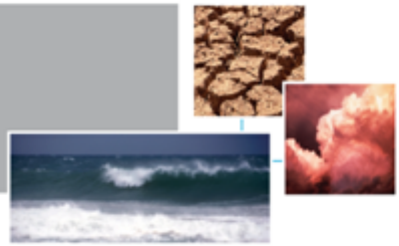
Courtesy: Stuart Young

Limitations of the technique



- Relies on model's description of cloud
  - i.e. assumed droplet size distributions, crystal shape and orientation
    - Impacts channel sensitivity
  - Sub-grid scale horizontal inhomogeniety not describable
    - i.e cloud shadowing, texture effects etc
  - Vertical resolution of model
    - Cloud overlap assumptions
- Time of model validity vs scan time of satellite
  - Satellite scan time ~ 30 minutes cf cloud structure lifetime
- Limb saturation
- Break down of independent profile and parallel plane assumptions
  - Need for 3D radiative transfer for resolution < 10km?
- Channel sensitivity to aerosols

Future Work

- Code changes
  - **Add in all more current geostationary and polar orbital satellites**
  - **Microwave channels**
  - **Add in alternative Radiative transport algorithms**
    - 4 stream, DISORT, 3D code, RTTOVS, CRTM etc
- Compile statistics for access-A/R/R12 for 2 – 3 years
  - **Apply image based algorithms to identify features etc**
    - Frontal speed/intensity
    - Convection presence/timing/intensity
    - Texture analysis
- Look at sensitivity of other channels
- More case studies
- Use of translation operator to modify model forecasts
  - **Translation operator defined by synthetic imagery to real satellite image**
  - **Use to correct cloud related variables (e.g. solar surface radiation, frontal position etc)**

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ESM

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Thank you

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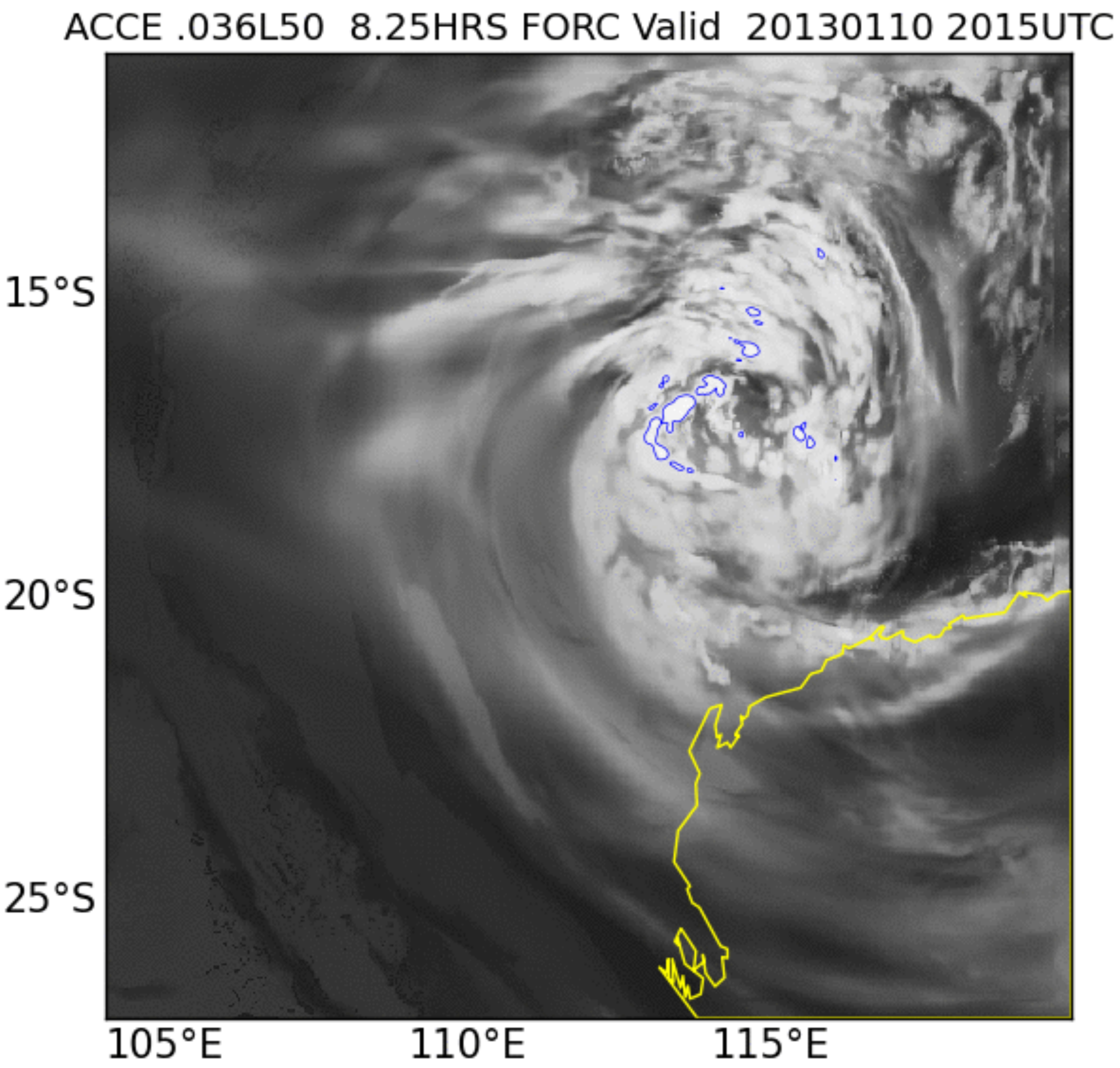

Courtesy of the high impact weather team in WEP/CAWCR

- 4km
- 15 minute slices
- Contour 200K