Using convection permitting simulations to study the intensity of extreme East Coast Lows

Alejandro Di Luca[1], Nicolas Jourdain[2], Daniel Argüeso[3] and Jason Evans[1]

[1]Climate Change Research Centre, University of New South Wales, Australia
[2]Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France
[3]School of Ocean and Earth Science and Technology, University of Hawai'i at Mānoa, US

NCAR workshop

Boulder, Colorado, US, September 2016

Motivation of the study

- Australian East Coast Lows (ECLs) are cyclones that either form or cross over the Tasman Sea adjacent to the Australian eastern seaboard (Speer et al., 2009).
- ECLs are responsible for much of the high-impact weather affecting the east coast of Australia including a large number of major floods, damaging winds and large ocean waves.
- For instance, Callaghan and Power (2014) identified major floods along coastal catchments in eastern Australia and found that about 60% were associated with ECLs.

Motivation of the study

- Australian East Coast Lows (ECLs) are cyclones that either form or cross over the Tasman Sea adjacent to the Australian eastern seaboard (Speer et al., 2009).
- ECLs are responsible for much of the high-impact weather affecting the east coast of Australia including a large number of major floods, damaging winds and large ocean waves.
- For instance, Callaghan and Power (2014) identified major floods along coastal catchments in eastern Australia and found that about 60% were associated with ECLs.

Key question

- How the intensity of the more intense systems may be impacted in the context of future climate changes ?

Motivation of the study

- Midlatitude cyclone's intensities has been shown to be sensitive to a variety of factors including :
  - **Large-scale environmental conditions** (e.g., static stability, strength of the horizontal temperature gradient) (e.g., Colle et al., 2013).
  - available **moisture** (e.g., Willison et al. 2015).
  - **lower boundary conditions (i.e., SSTs)** (e.g., Booth et al. 2012 ; Chambers et al., 2014)

Motivation of the study

- Midlatitude cyclone's intensities has been shown to be sensitive to a variety of factors including :
  - **Large-scale environmental conditions** (e.g., static stability, strength of the horizontal temperature gradient) (e.g., Colle et al., 2013).
  - available **moisture** (e.g., Willison et al. 2015).
  - **lower boundary conditions (i.e., SSTs)** (e.g., Booth et al. 2012 ; Chambers et al., 2014)

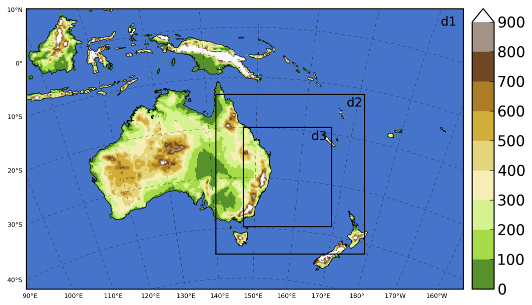
- however, the **role of moisture** on the development of the most intense ECLs is probably the one that can be better addressed using using very high-resolution simulations (e.g., Lackman et al., 2012 ; Marciano et al., 2015)

ECLs WRF ensemble

1. **Horizontal resolutions**
2. **Subgrid-scale processes**
3. **Historical environments**
4. **Future environments**

ECLs WRF ensemble

1. **Horizontal resolutions** simulations are performed using a triple nesting approach with grid spacings of 24 (d1), 8 (d2) and 2 (d3) km.



2. **Subgrid-scale processes**
3. **Historical environments**
4. **Future environments**

ECLs WRF ensemble

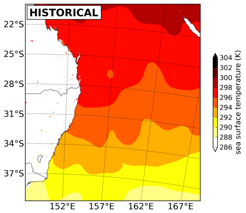
1. **Horizontal resolutions**
2. **Subgrid-scale processes** the ensemble includes different schemes to parametrized cumulus, surface/planetary boundary layer, radiation and microphysics processes.

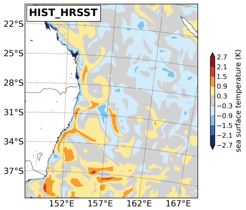
	CTL	CU	PBL	RAD	MPS
Microphysics	**WSM6**	WSM6	WSM6	WSM6	**Thomp.**
Longwave	**RRTM**	RRTM	RRTM	**CAM**	RRTM
Shortwave	**Dudhia**	Dudhia	Dudhia	**CAM**	Dudhia
PBL	**YSU**	YSU	**MYJ**	YSU	YSU
Cumulus	**BMJ**	**KF**	BMJ	BMJ	BMJ

3. **Historical environments**
4. **Future environments**

ECLs WRF ensemble

1. **Horizontal resolutions**
2. **Subgrid-scale processes**
3. **Historical environments** two environments using different SST fields.



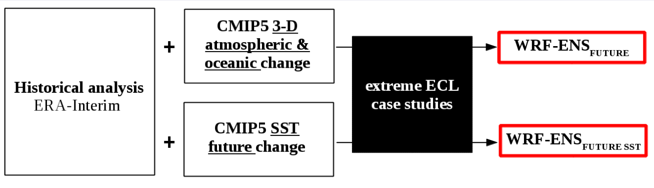


- **HISTORICAL** : low resolution SST directly from ERAI.
- **HISTORICAL HRSST** : high-resolution SST (0.1°) from the BRAN reanalysis.

4. **Future environments**

ECLs WRF ensemble

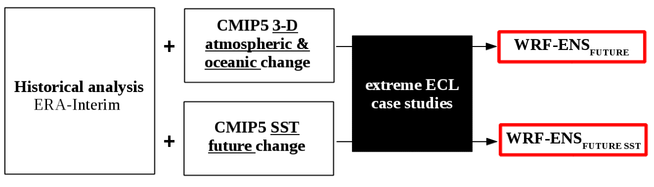
1. **Horizontal resolutions**
2. **Subgrid-scale processes**
3. **Historical environments**
4. **Future environments** two surrogate scenarios using the CMIP5 multi-model mean changes (RCP8.5 2080-2100 relative to 1990-2010).



- **FUTURE** :
  - includes future changes in all variables needed to run WRF (surface : T, V, U, SST, PSL, q ; 3-D : T, V, U, ϕ, q).
  - a total of 32 CMIP5 models were used to calculate the ensemble mean.

ECLs WRF ensemble

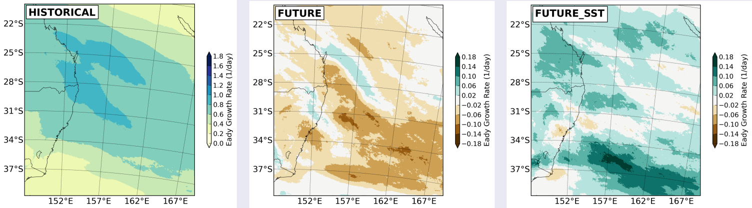
1. **Horizontal resolutions**
2. **Subgrid-scale processes**
3. **Historical environments**
4. **Future environments** two surrogate scenarios using the CMIP5 multi-model mean changes (RCP8.5 2080-2100 relative to 1990-2010).



- **FUTURE SST** :
  - includes future changes in SSTs only.
  - a total of 32 CMIP5 models were used to calculate the ensemble mean.

ECLs WRF ensemble

1. **Horizontal resolutions**
2. **Subgrid-scale processes**
3. **Historical environments**
4. **Future environments** Eady Growth Rate :



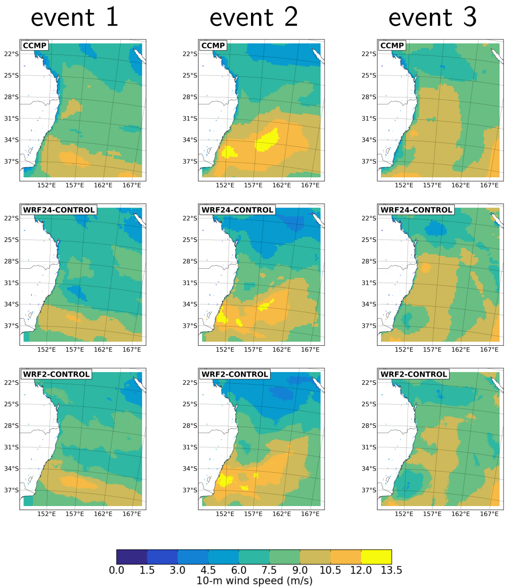
- **FUTURE** : $\downarrow$ vertical shear (i.e, $\downarrow \overline{\nabla T}$) and $\uparrow$ static instability
- **FUTURE-SST** : $\uparrow$ vertical shear (i.e, $\uparrow \overline{\nabla T}$) and $\downarrow$ static instability

ECLs WRF ensemble

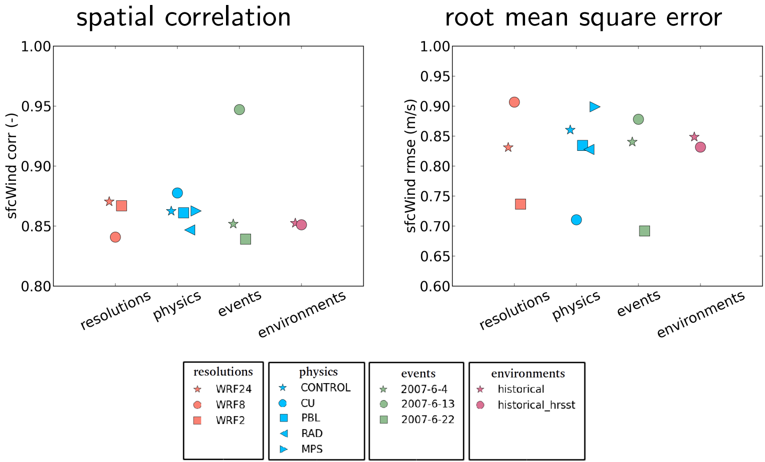
- All simultions are driven by the ERA-Interim reanalysis
- Spectral nudging is used to drive WRF24 (d01) simulation above the PBL and for $\lambda \geq$ 600km
- Same n° vertical levels (28) and land surface scheme (NOAH) for all runs
- Simulations are run for eight days
- Computational costs :
  - WRF24 : nx=289 ; ny=431 ; Δt=120 s (X)
  - WRF8 : nx=405 ; ny=435 ; Δt=40 s $\rightarrow$ 4X
  - WRF2 : nx=960 ; ny=1080 ; Δt=10 s $\rightarrow$ **100X**
- Available simulations so far :

	event1	event2	event3
historical	X	X	X
future (full CMIP5 change)	X	X	X
historical + HRSST	X		
future sst (SSTs CMIP5 change)	X		

Average wind speeds in observations and CONTROL runs

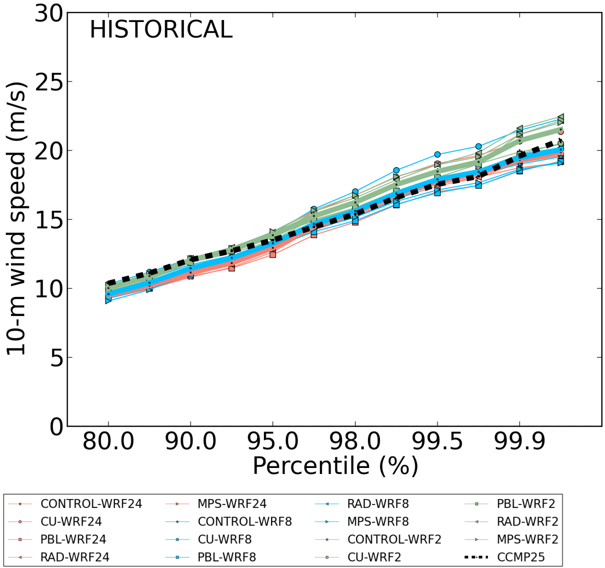


Wind speeds (against CCMP25 wind product)

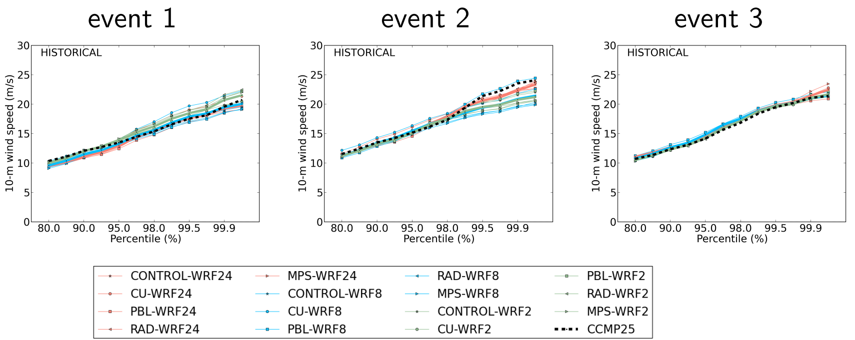


- WRF8 systematically poorer than WRF2/WRF24
- Alternative cumulus scheme (CU=KF) simulation performs better than the original (BMJ)
- Very smalll differences between low and high-res SST simulations

Wind speeds (against CCMP25 wind product)

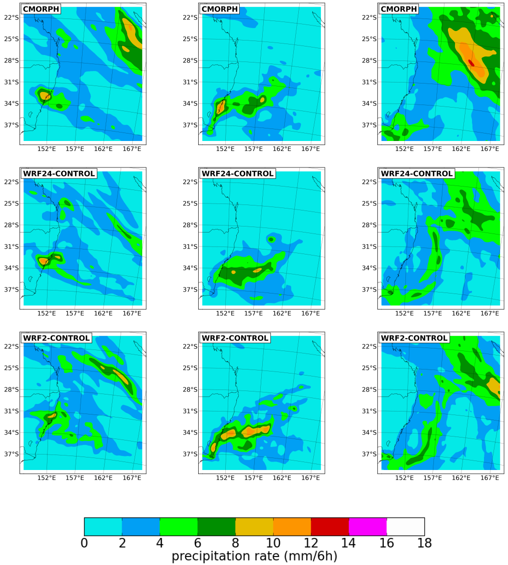


Wind speeds (against CCMP25 wind product)

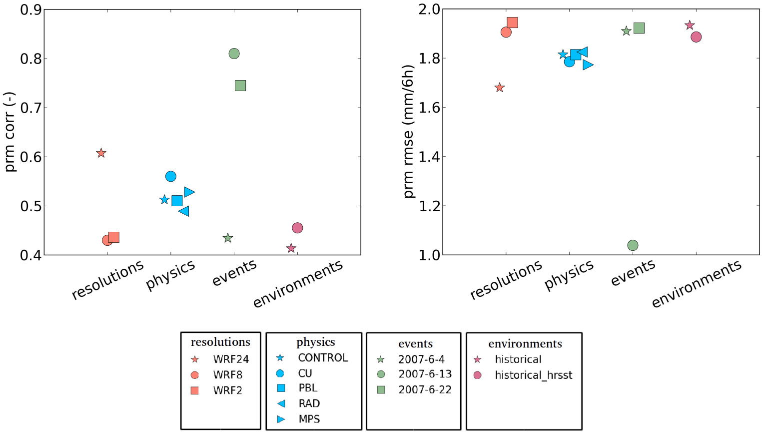


- Wind speed temporal/spatial distributions are well represented by all simulations, with little differences across resolutions/physics.

Precipitation (against CMORPH8 satellite observations)

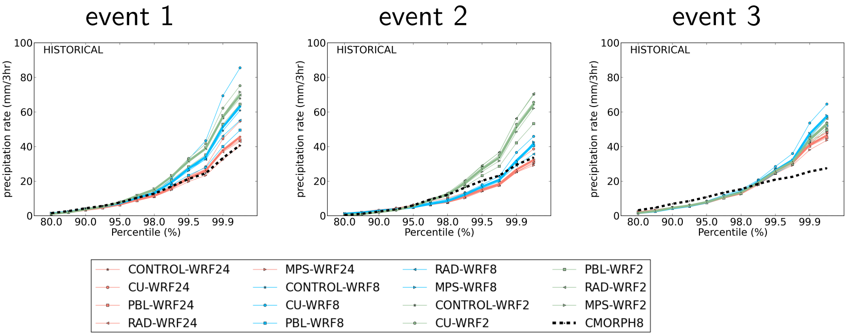


Precipitation (against CMORPH8 satellite observations)



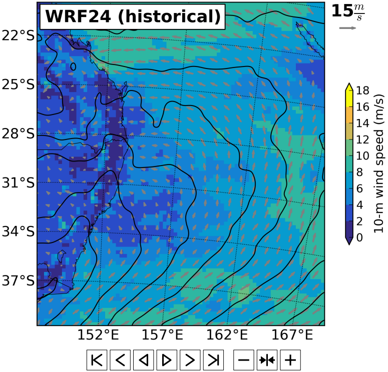
- WRF24 significantly better than WRF2/WRF8
- simulations using high-res SST show slightly better scores
- small differences across physics

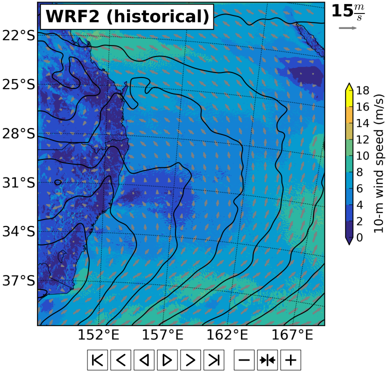
Precipitation (against CMORPH8 satellite observations)



Event 1 (Pasha Bulker ECL) trajectory (example)

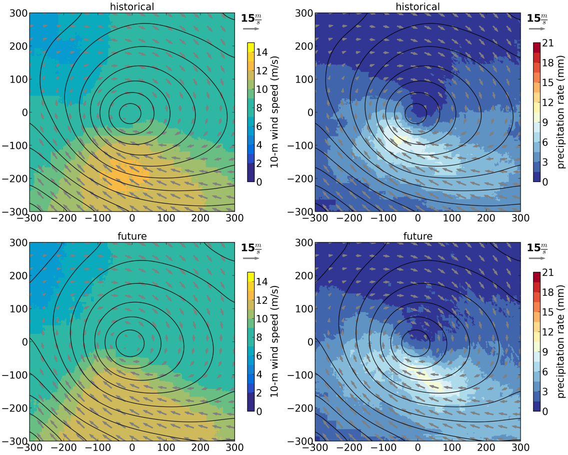
- An objective algorithm is used to identify and track lows



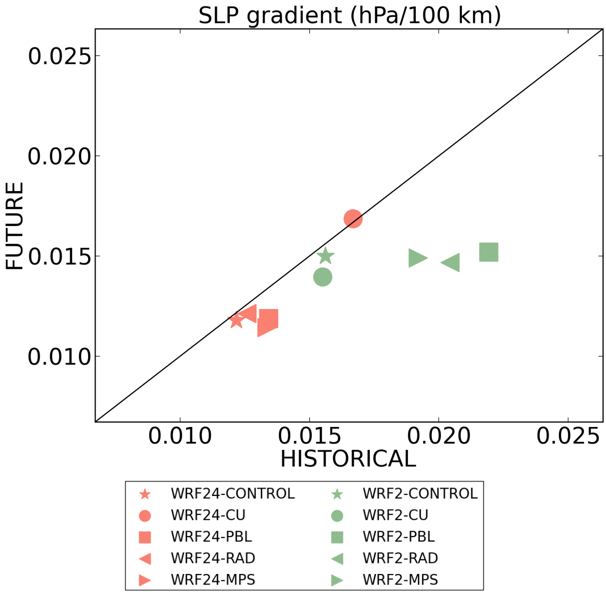


Historical and future cyclone's composites

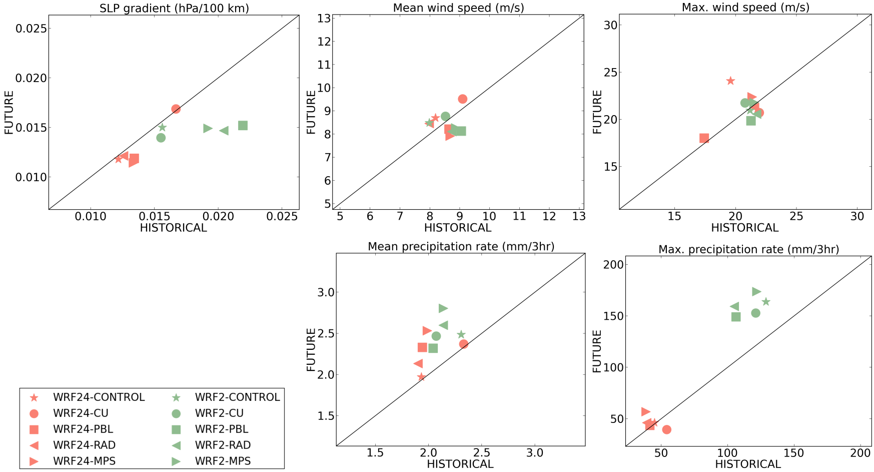
- Mean composites are calculated averaging fields (e.g., 10-m winds) relative to the center of all the identified lows



Cyclone's future changes : full CMIP5 changes

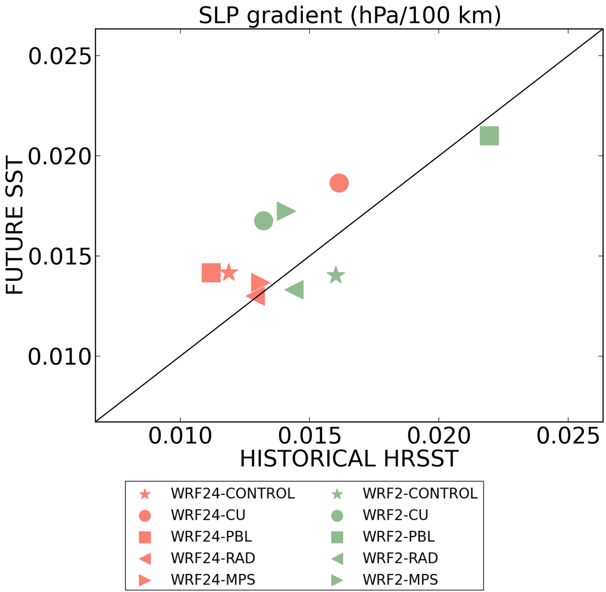


Cyclone's future changes : full CMIP5 changes

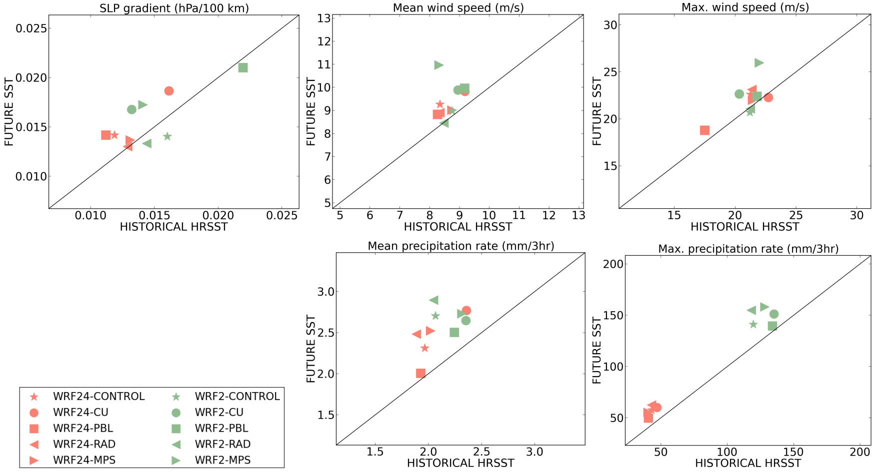


- Mean and maximum wind speed remain unchaged in the future
- Mean and maximum precipitation rates increase for most resolutions/physics

Cyclone's future changes : SST CMIP5 changes



Cyclone's future changes : SST CMIP5 changes



- Mean and maximum wind speed generally increase
- Mean and maximum precipitation rates increase for most resolutions/physics

Summary

- Mean and maximum precipitation rates increase systematically in the future scenarios (e.g., Marciano et al 2015), regardless of the resolution/physical scheme/future scenario considered.
- Future scenarios including full CMIP5 (3-D) changes tend to produce weaker cyclones and generally no changes in 10-m wind speeds.
- Future scenarios only including SST CMIP5 changes tend to produce somewhat stronger cyclones and a general increase in 10-m wind speeds.

Summary

- Mean and maximum precipitation rates increase systematically in the future scenarios (e.g., Marciano et al 2015), regardless of the resolution/physical scheme/future scenario considered.
- Future scenarios including full CMIP5 (3-D) changes tend to produce weaker cyclones and generally no changes in 10-m wind speeds.
- Future scenarios only including SST CMIP5 changes tend to produce somewhat stronger cyclones and a general increase in 10-m wind speeds.
- Results were based on a few events so we should be very cautious about these conclusions
- Particularly for the WRF8 and WRF2 simulations, internal variability is still important

References

- Callaghan and Power, 2014, Aust. Meteorol. Oceanogr. J., 64, 183–213.
- Chambers and coauthors, 2014, Meteorol. Atmos. Phys., 125, 1–15.
- Colle and coauthors, 2015, Current Clim. Change Rep., 1, 125-143.
- Di Luca and coauthors, 2015b, J. Clim., 28, 9530-9549.
- Knutson and coauthors, 2008, Nat. Geo., 1(6), 359-364.
- Lackmann, 2013, J. Clim., 26, 4688–4709.
- Marciano and coauthors, 2015, J. Clim.
- Willison and coauthors, 2015, J. Clim., 28, 4513-4524.

THANKS FOR YOUR ATTENTION !

QUESTIONS ? COMMENTS ?

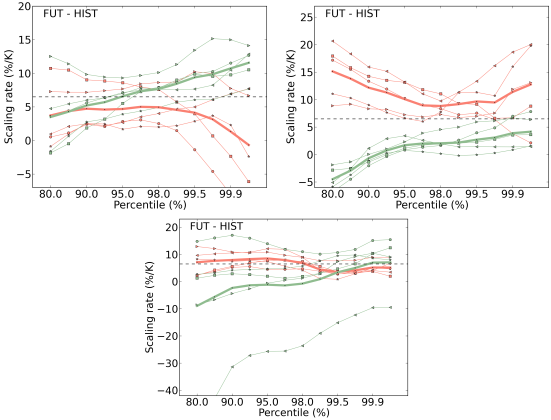
Cross-calibrated, multi-platform (CCMP) wind data

- $\Delta x \sim 25$ km ; $\Delta t \sim 6$ hours ; between -78 and 78 deg.
- Uses a variety of surface wind datasets from different sensors and satellites.
- Satellite winds (e.g., QuikSCAT) has been calibrated using more than 10 years of buoy measurements.
- First guess analysis : from ERA-40 between 1987 and 1998 ; from the operational ECMWF analysis from 1999.
- Probably better to after 1999 to avoid some possible smoothing coming from the low-resolution ERA-40 product.

	Available	Calculated
SSM/I	Microwave radiometer sensor	wind speed
TMI	Microwave radiometer sensor	wind speed
AMSR-E	Microwave radiometer sensor	wind speed
SeaWinds	Scatterometer	wind speed and direction
QuikSCAT	Scatterometer	wind speed and direction

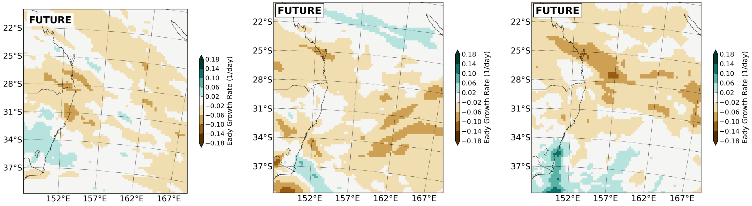
Precipitation scaling

FUTURE :

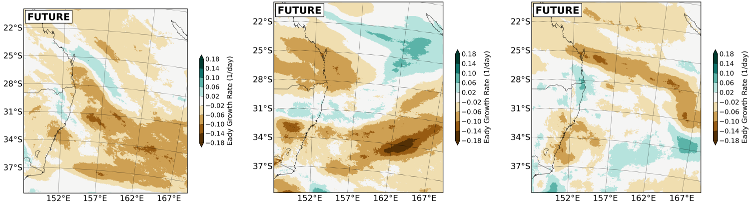


EGR for other events

WRF24 :

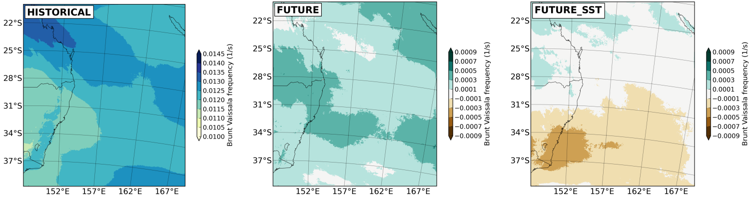


WRF2 :



EGR decomposed

Brunt Vaissala frequency :



Vertical shear :