Investigating Regional Climate Model - RCM Added-Value in simulating Northern America Storm activity

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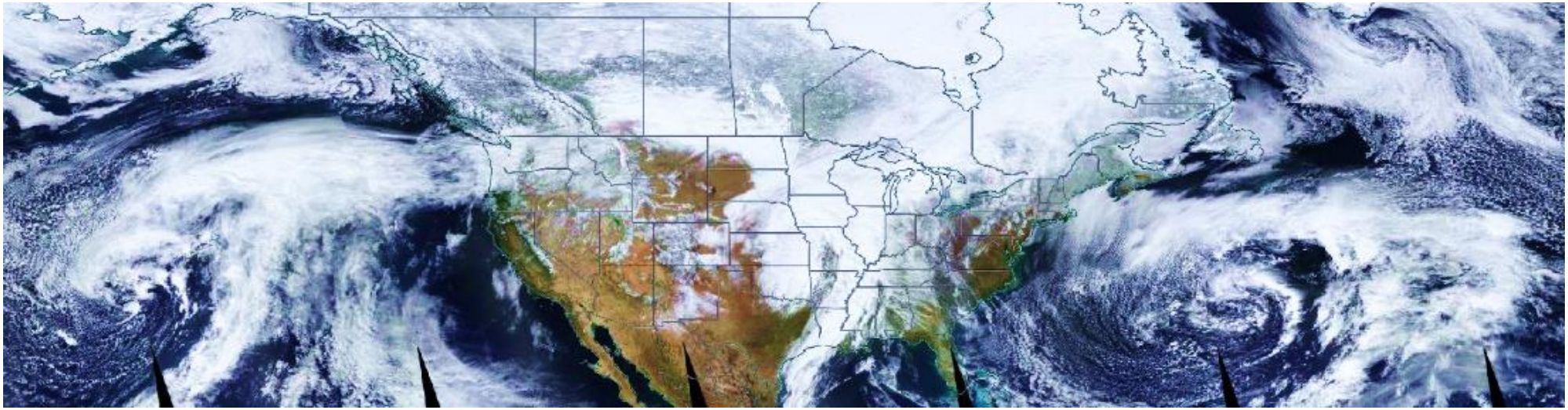
[2]*Recherche en Prévision Numérique, Environnement Canada, Montréal, Québec, Canada*



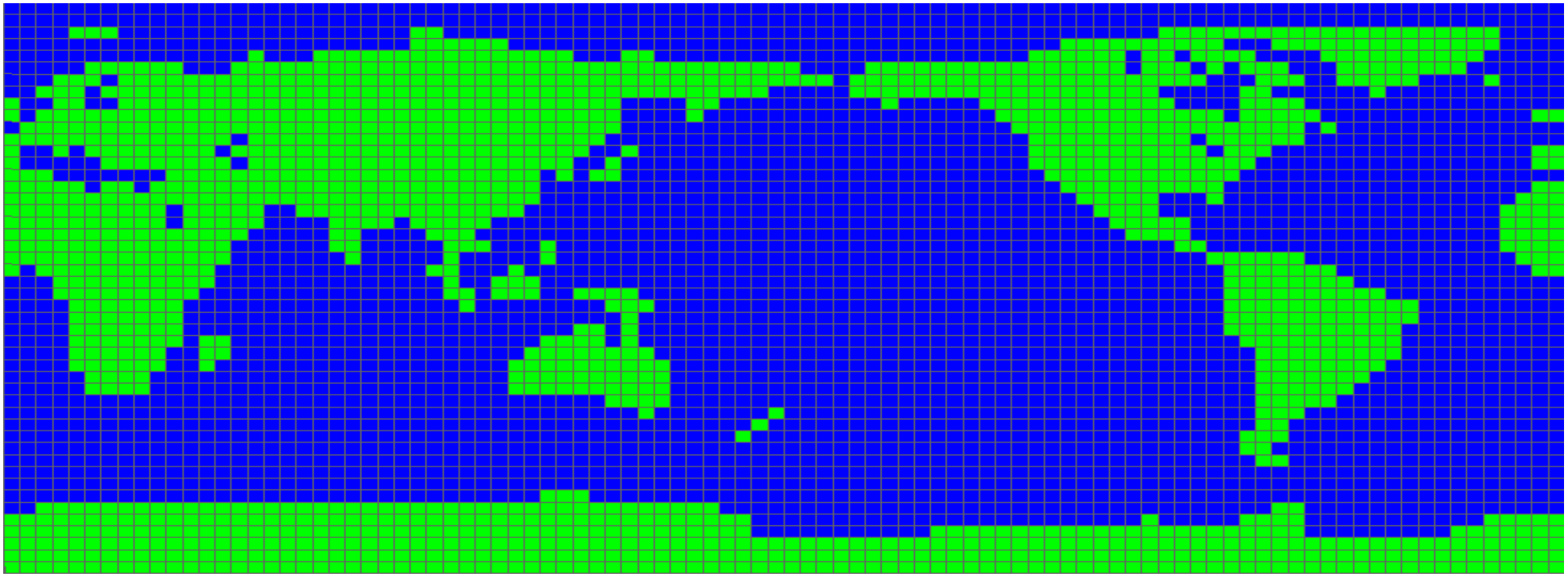
MODIS: 03-10-2013, https://worldview.earthdata.nasa.gov/

UQÀM

CENTRE ESCER
POUR L'ÉTUDE ET LA SIMULATION DU CLIMAT À L'ÉCHELLE RÉGIONALE

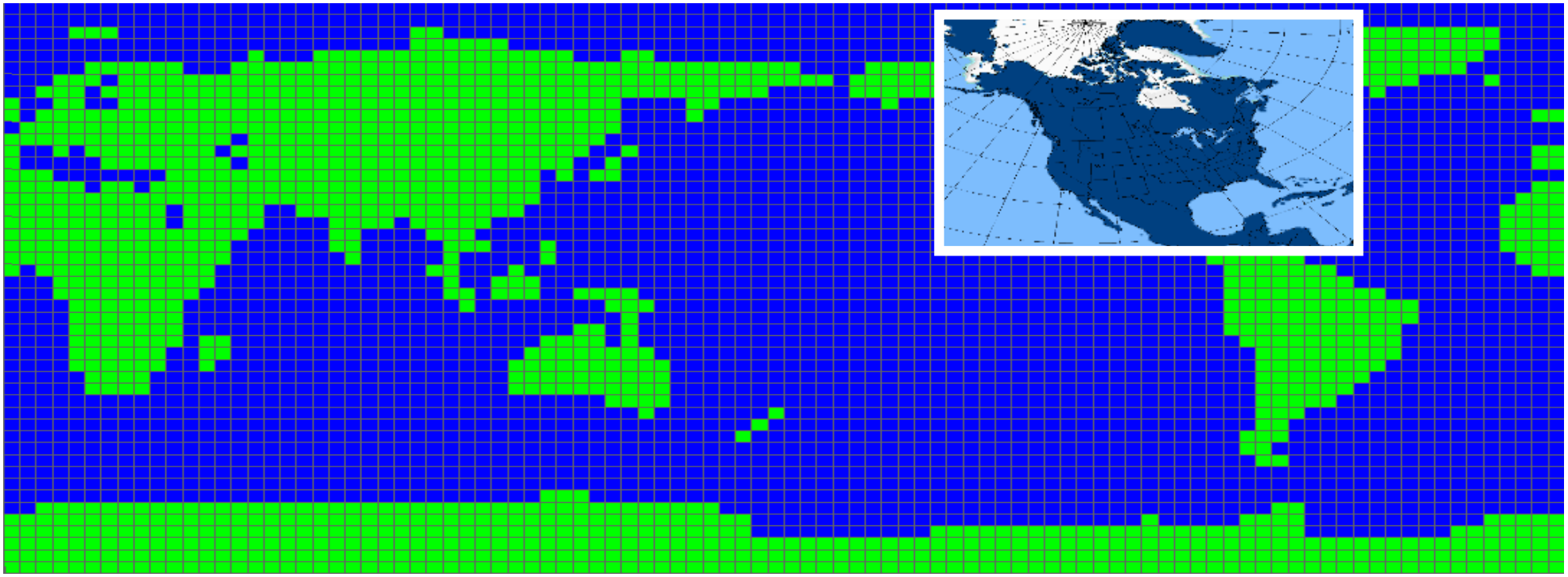
CNRCWP

Global / Regional Modeling



CanESM2 - Canadian Earth System Model version2 at horizontal resolution 1.9° (~200 km)

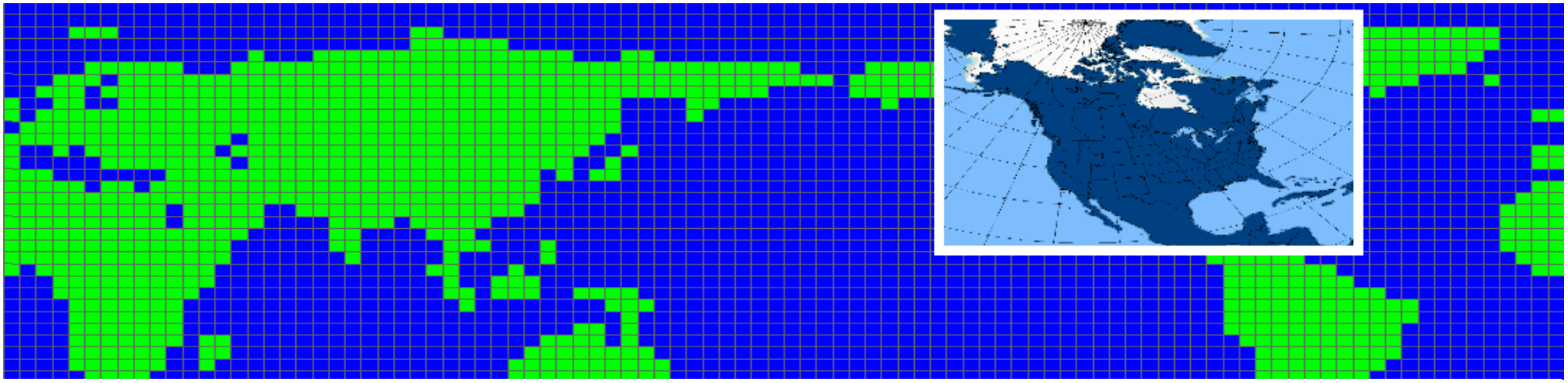
Global / Regional Modeling



CanESM2 - Canadian Earth System Model version2 at horizontal resolution 1.9° (~200 km)

CRCM5 – Canadian Regional Climate Model version 5 at 0.44° (~50 km)

Global / Regional Modeling



Specific Objectives

- Define a framework to use RCM simulation to approach extreme events
- Evaluate/Understand RCMs structural errors and Added-Value in simulating North America (NA) storm tracks
- Investigate future change in NA atmospheric storminess

Plan

1. Context and Motivation
2. Data and Methodology
3. Results
   - Seasonal mean characteristics
   - Storm serial clustering
   - Storm and precipitation
4. Conclusion and Future Work

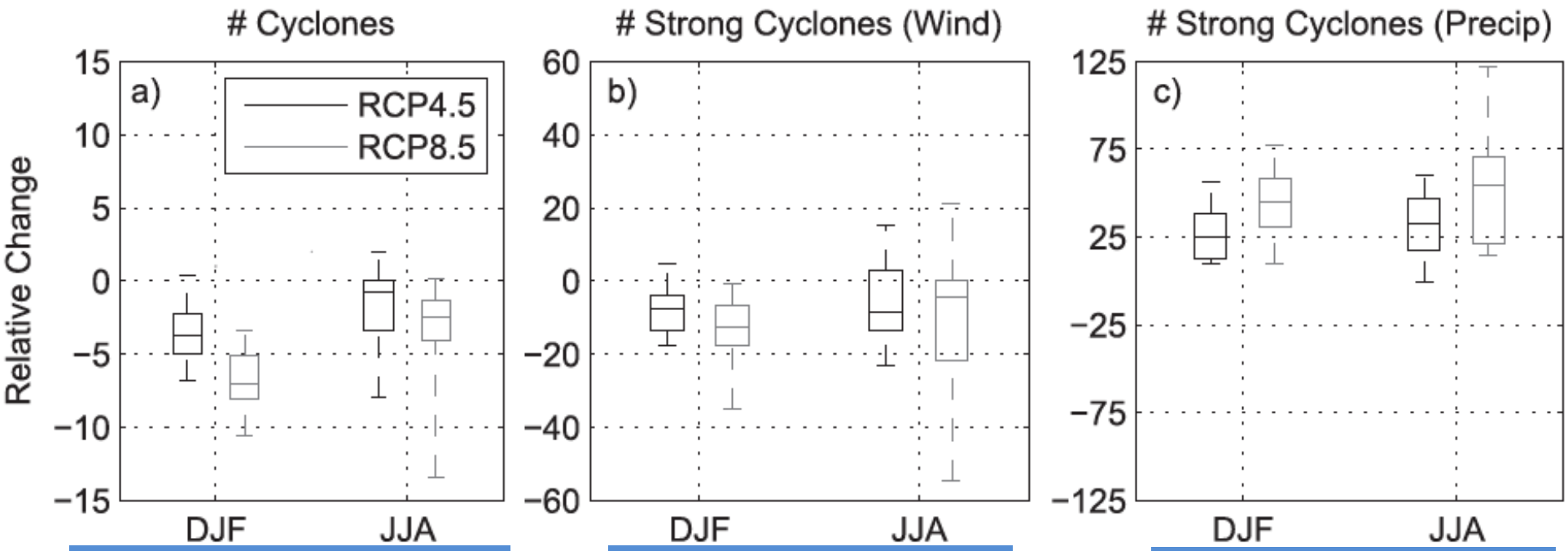
1- Context and Motivation

STORM ACTIVITY IN MID-LATITUDES:

- *The majority of extreme and severe weather events - heavy precipitation - snow storm - coastal waves and flooding are linked to Extra Tropical Cyclones (ETCs)*
- On a global scale: *the top 1% of daily extreme precipitation are coincident with ETCs in mid-latitudes (Pfahl and Wernli, 2012)*
- *Over the USA, 78% of the extreme precipitation events are caused by ETCs Kunkel et al. (2012)*
- *When clustered i.e. successive hits in small time window, ETCs are more devastating: Lothar and Martin over Europe 26-28 dec. 1999 were responsible for 140 lives and 19 B$ losses*

1- Context and Motivation

UNDER CLIMATE CHANGE (2070-2099)



Global ETCs # change

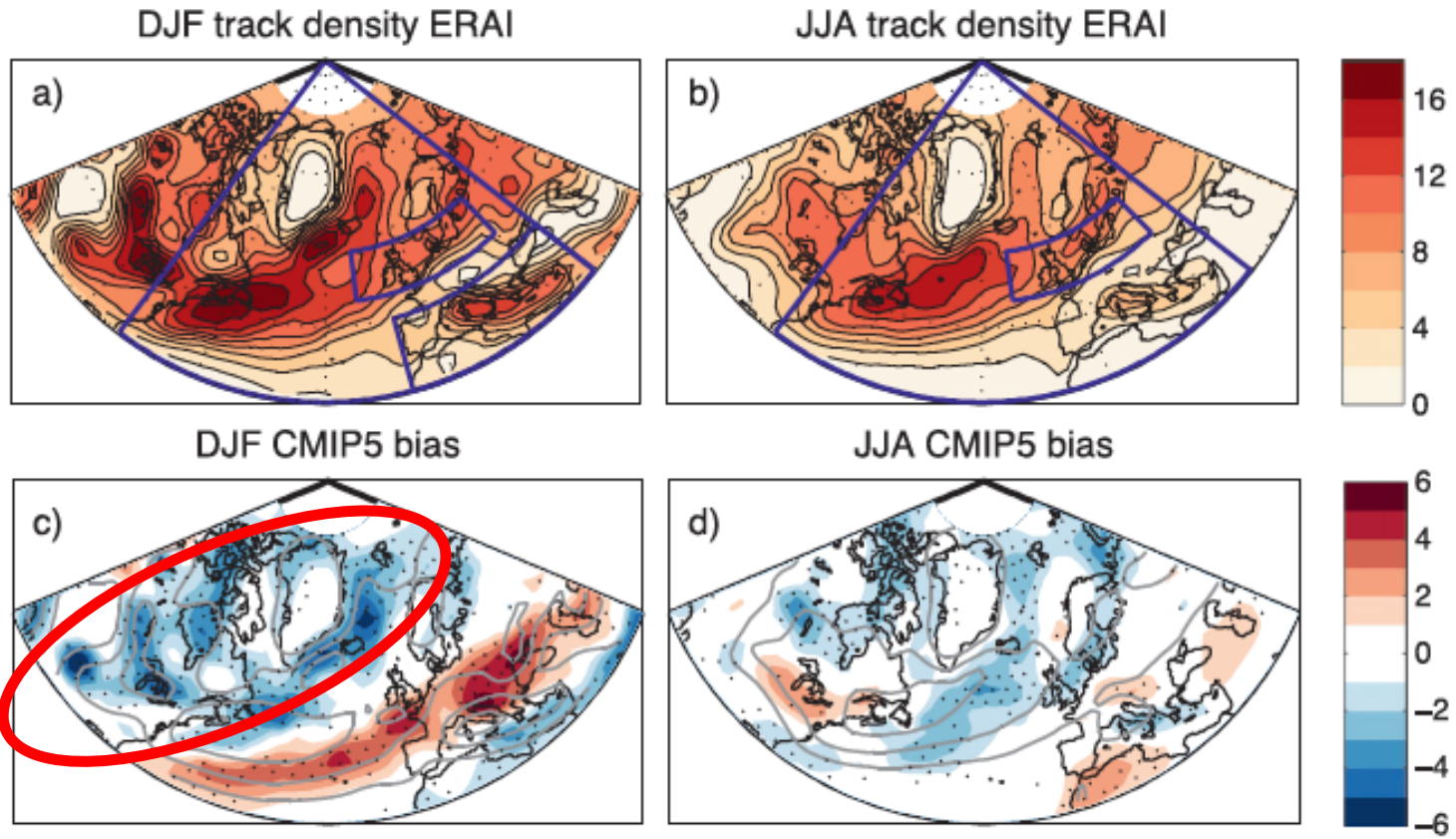
Atlantic ETCs # with strong winds change

Atlantic ETCs # with strong Rain change

Zappa et al. 2013

1- Context and Motivation

HOW SKILLFUL ARE GCMS RIGHT NOW? (1975-2005)



Continental Negative Bias

Zappa et al. 2013

1- Context and Motivation

Regional Modeling « could » help get a better picture

IMPROVED REGIONAL FEATURES:



- Over NA, topography is the most important forcing factor (Brayshaw et al. 2009)
- Smaller scales Temperature-gradients have a huge impact (Lakes effects)
- At T95 (~140 km), GCMs can only capture 60% of ETCs (Jung et al., 2006)

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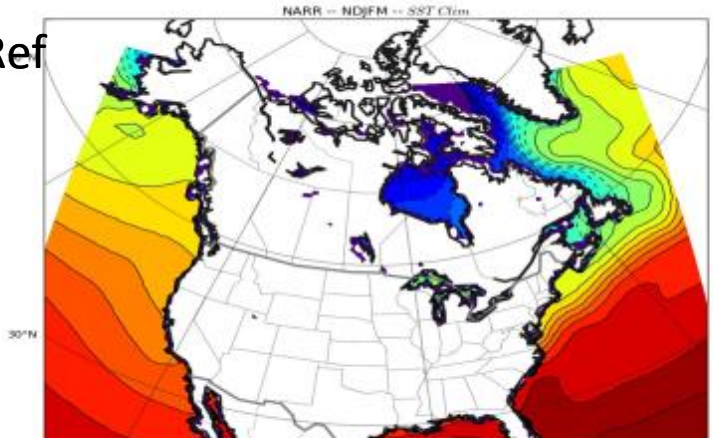
RCMs ARE DEPENDANT ON GCMs

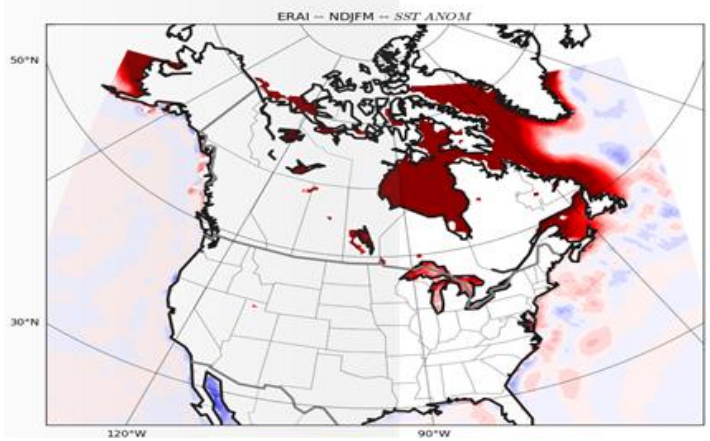
- Large dispersion in simulating large scale modes: ENSO – NAO
- Strong Sea Surface Temperature - SSTs (gradients and associated moisture) Biases

1- Context and Motivation

Strong Sea Surface Temperature (gradients and associated moisture) Biases

$REANA_0$-Ref





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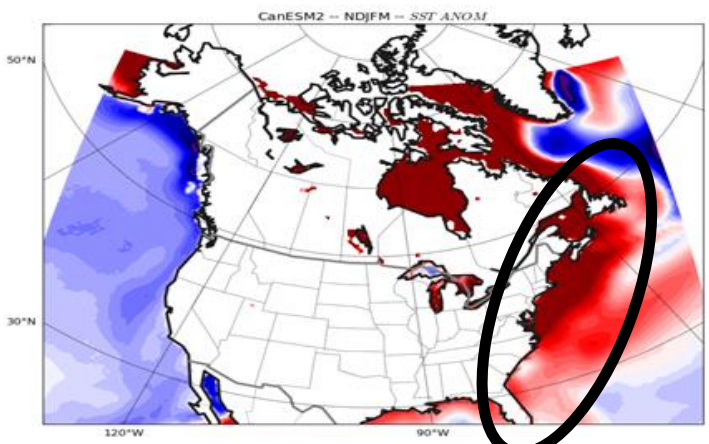
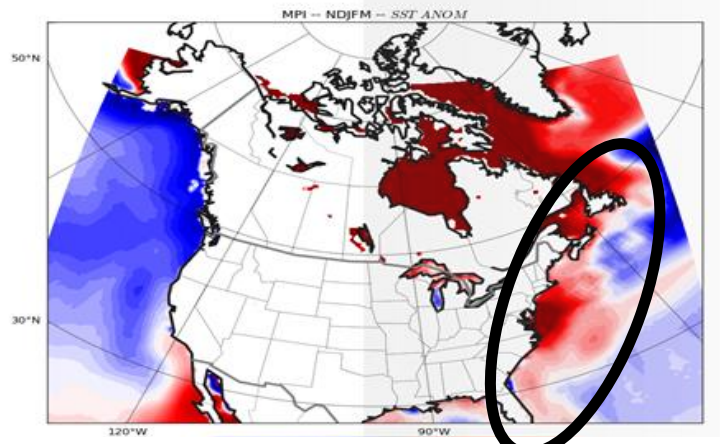
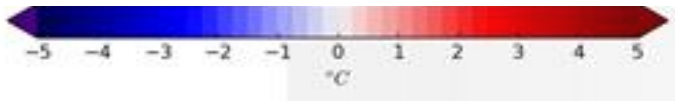
GCM_0-Pilot





GCM_1-Pilot



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2- Data and Methodology

Simulation Table (Winter NDJFM is considered)

Function	Simulation type	Simulation short name	Native Time/space resolution	Time Period/Domain	Climatological period
Reference	Regional Reanalysis	NARR	0.25°/3 hr	1979-2012/NA	1981-2010
Driving data	Global Reanalysis	ERAI	0.75°/6 hr	1961-2012/Global	1981-2010
	GCMs	CanESM2	1.9°/6 hr	1961-2005/ NA	1976-2005
		MPI-ESM	1.9°/6 hr	1961-2005/ NA	1976-2005
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Storm Tracking

→ Lagrangian Storm tracking method based on Sinclair (1997)

→ Use GZ1000 and UV-500 hPa Vorticity Threshold set to 2.5 CVU

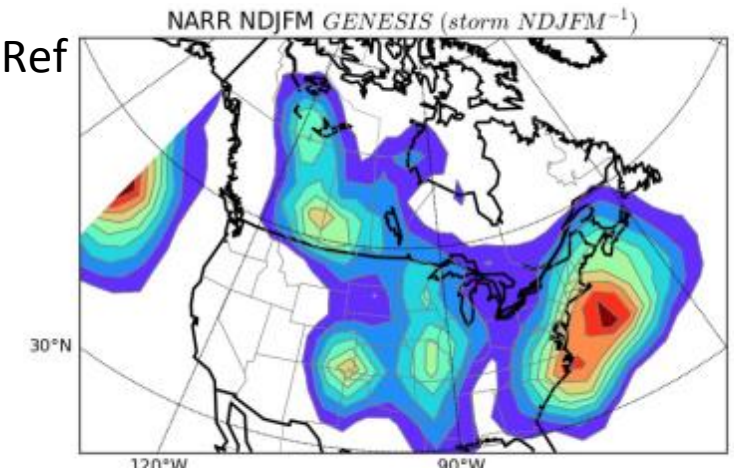
→ Data are all re-gridded to 100 km/3hr resolution

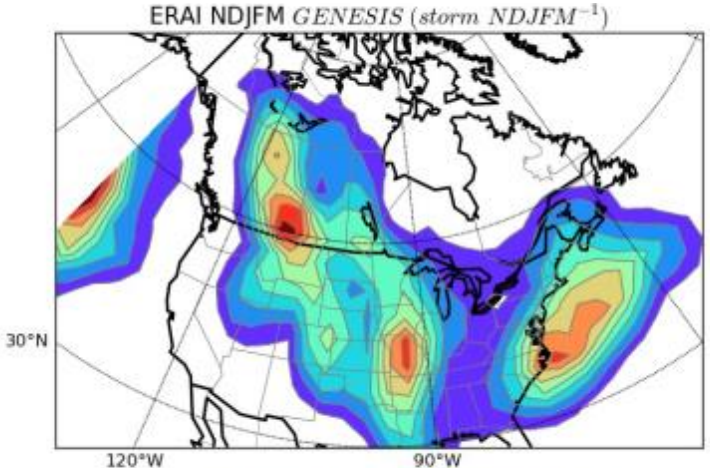
→ Storm Parameters retrieved: Occurrence – cyclogenesis – cyclolysis – Intensity

3- Results: Winter storm cyclogenesis

Driving Data

REANA$_0$-Ref





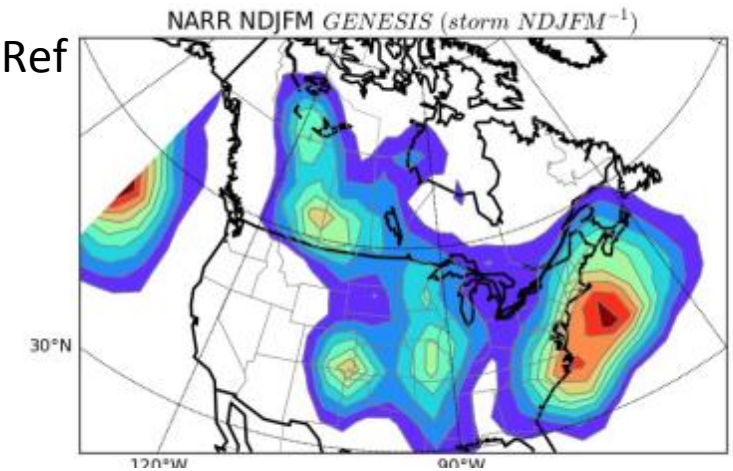
REANA$_1$-Pilot

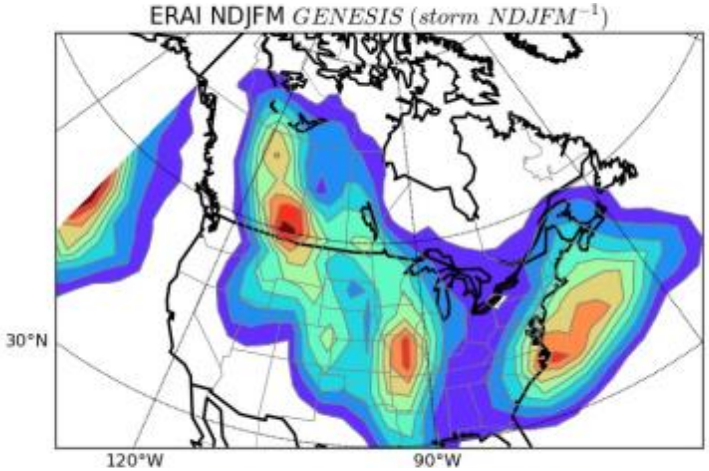


3- Results: Winter storm cyclogenesis

Driving Data

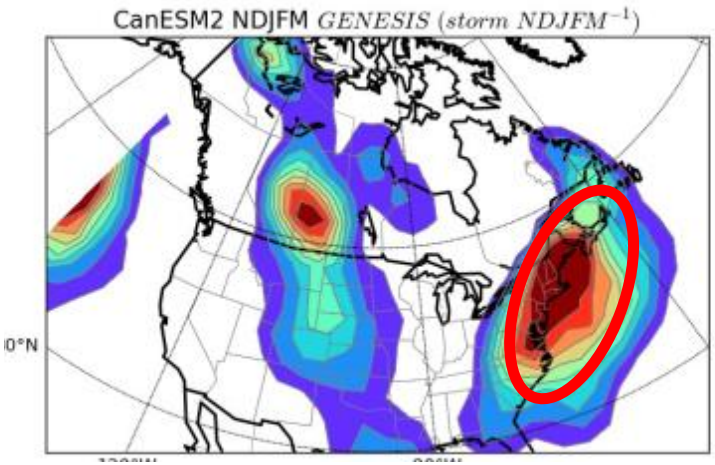
$REANA_0$-Ref

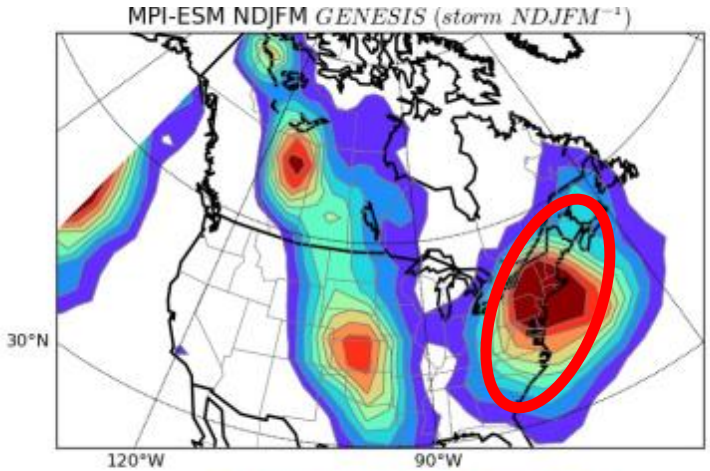




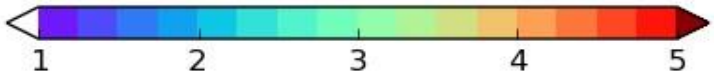
$REANA_1$-Pilot

GCM_0-Pilot





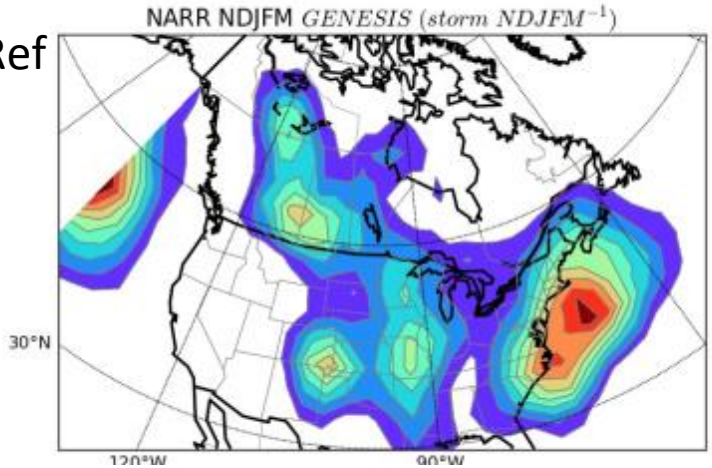
GCM_1-Pilot

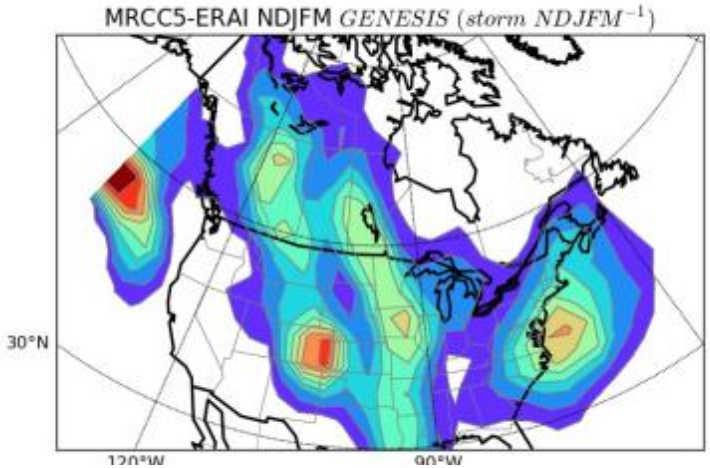


3- Results: Winter storm cyclogenesis

CRCM5 Data

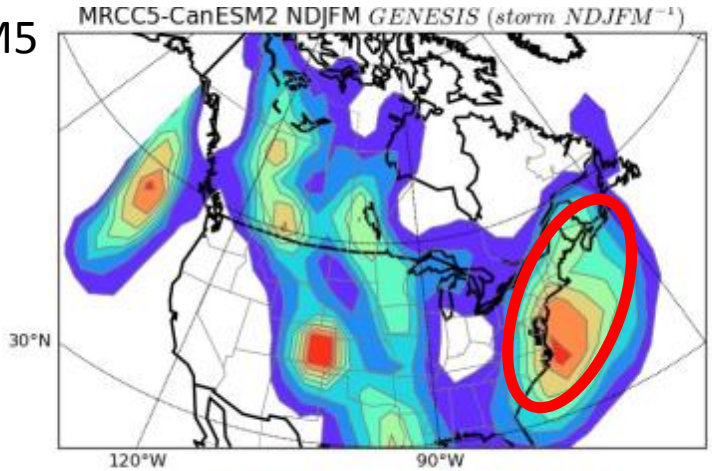
$REANA_0$-Ref

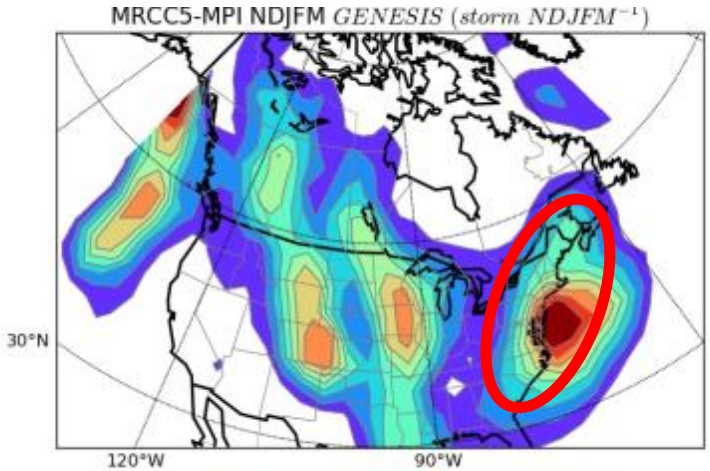




$REANA_1$-CRCM5

GCM_0-CRCM5





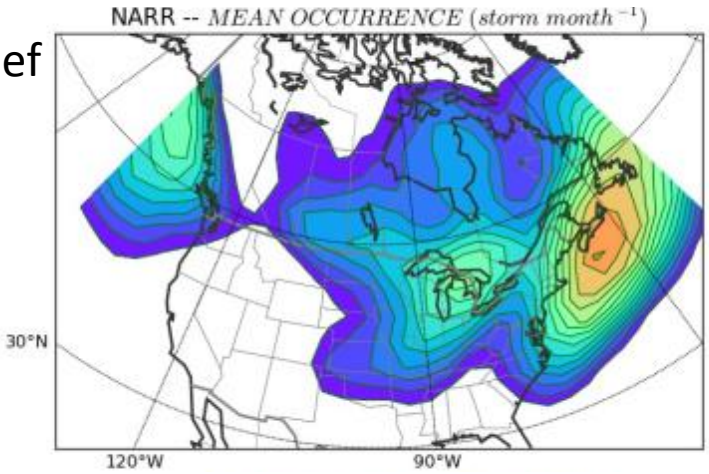
GCM_1-CRCM5

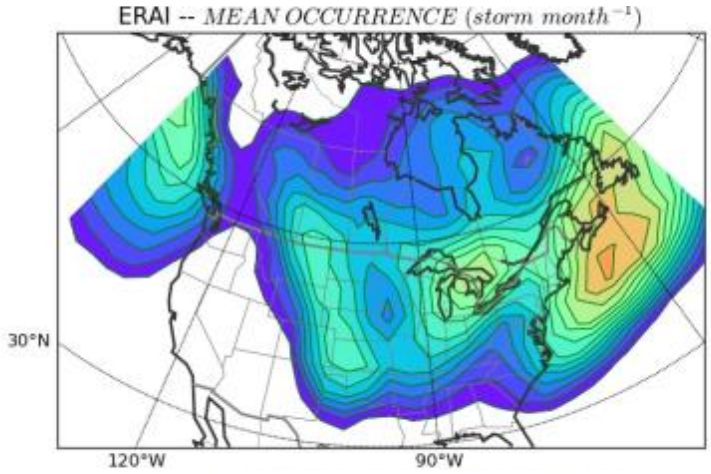


3- Results: Winter storm occurrence

Driving Data

REANA$_0$-Ref





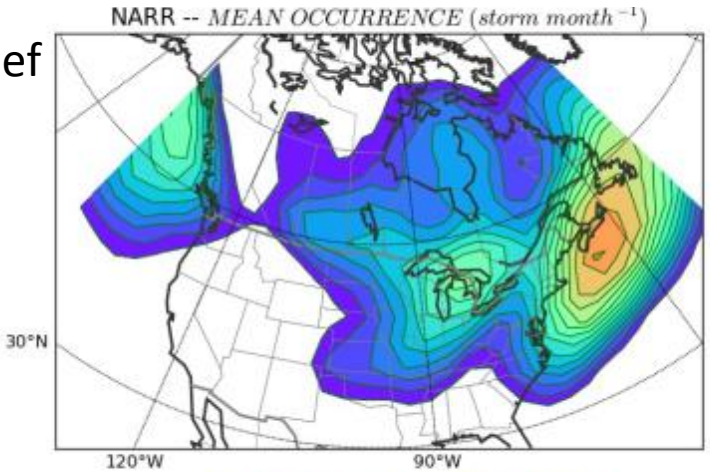
REANA$_1$-Pilot

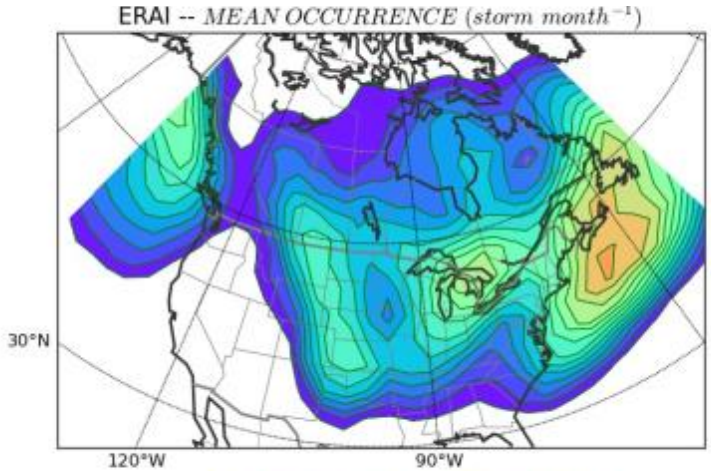


3- Results: Winter storm occurrence

Driving Data

$REANA_0$-Ref





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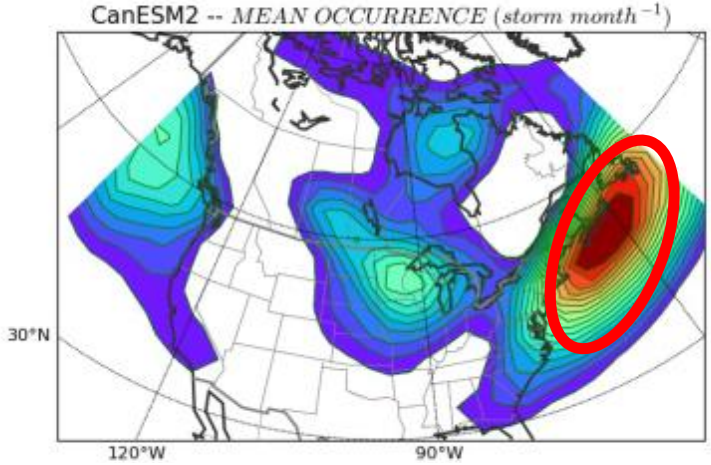
GCM_0-Pilot



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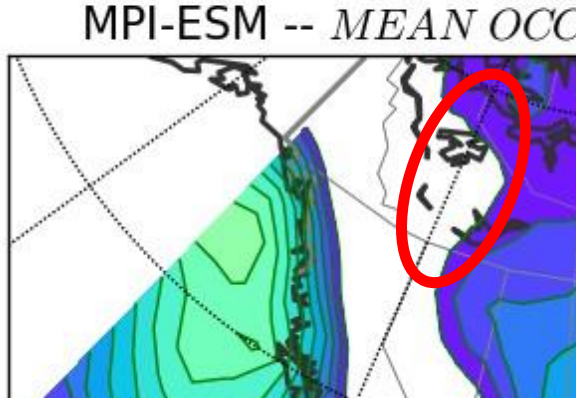
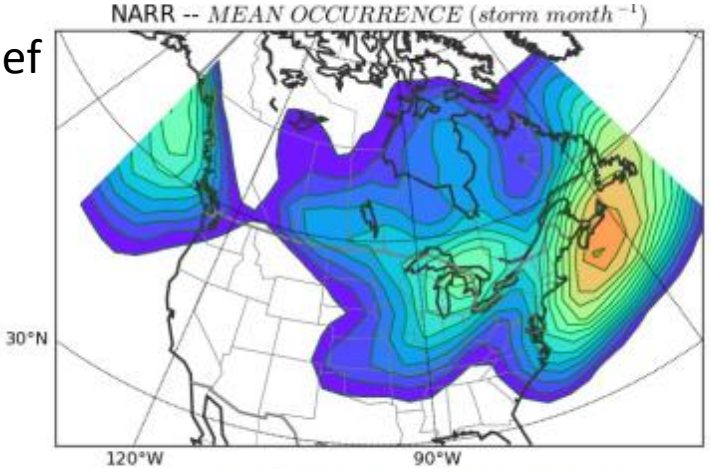


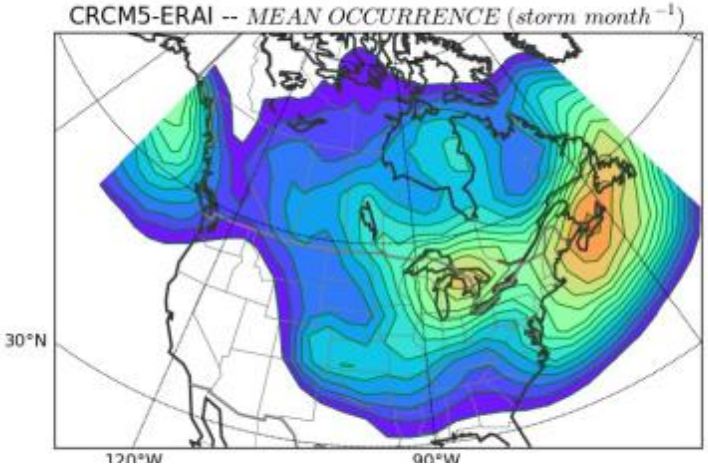


3- Results: Winter storm occurrence

CRCM5 Data

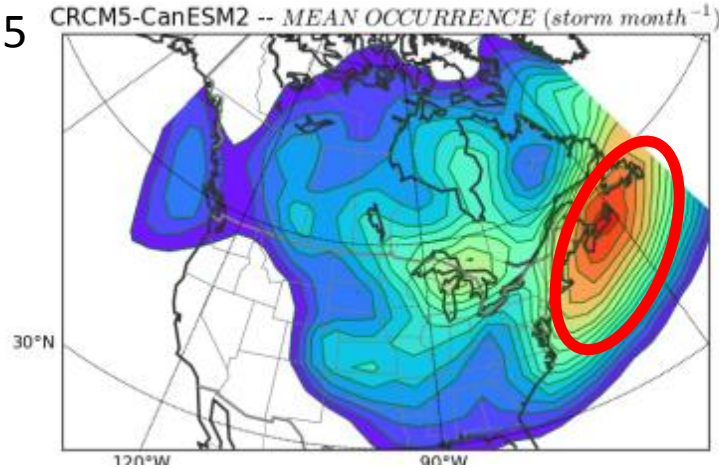
$REANA_0$-Ref

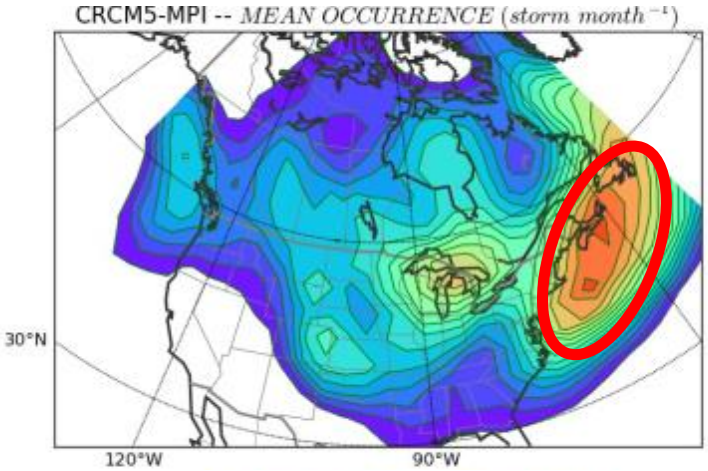




$REANA_1$-CRCM5

GCM_0-CRCM5





GCM_1-CRCM5



3- Results: Winter Storm Seriality

Short Notice: Storm monthly counts (occurrence) are compared to a 1-dimensional *Poisson process* using the dispersion parameter $\varphi = \frac{Var(N)}{E(N)} - 1$

→ $\varphi = 0$: the counts are randomly distributed and therefore storm occurrences follow a homogeneous Poisson process

→ $\varphi \geq 0$: the process is more dispersive than a simple Poisson process and so cyclone occurrences are temporally clustered

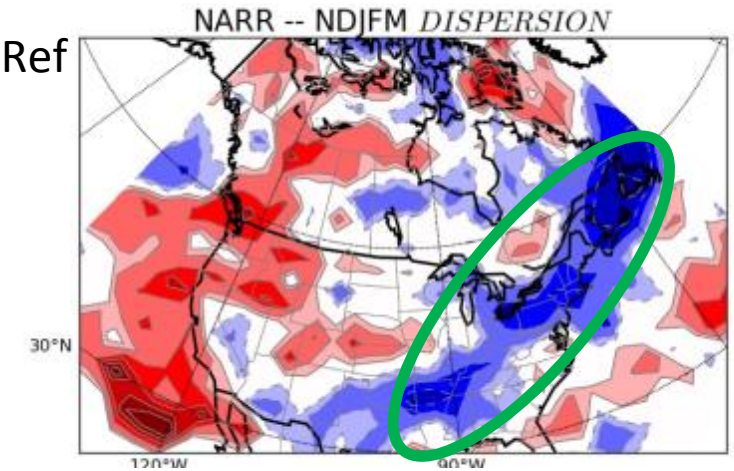
→ $\varphi \leq 0$: the process is under-dispersive and therefore cyclone transit at the given location tend to be a regular process.

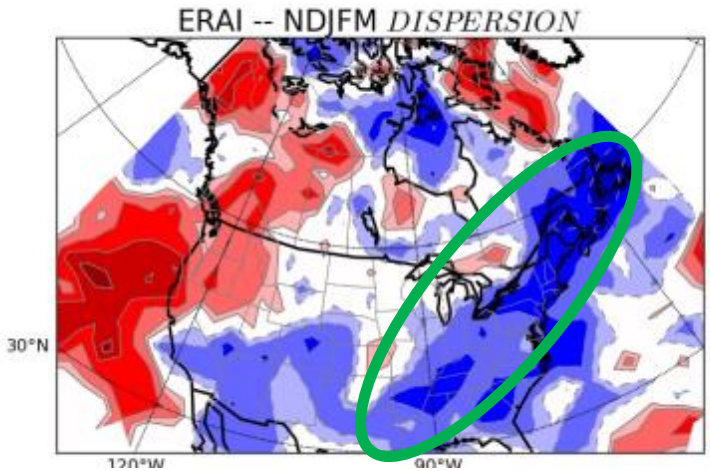
$$\varphi = \frac{Var(N)}{E(N)} - 1$$

3- Results: Winter Storm dispersion map

Driving Data

REANA$_0$-Ref





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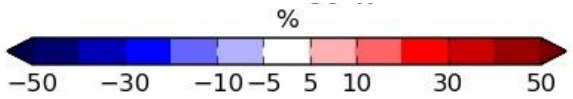
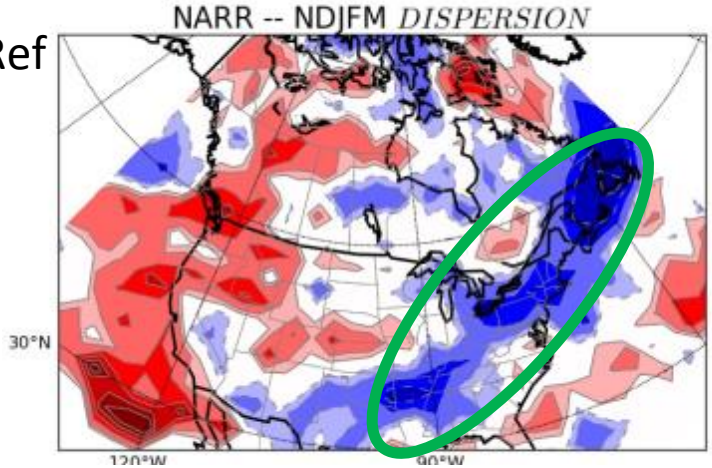


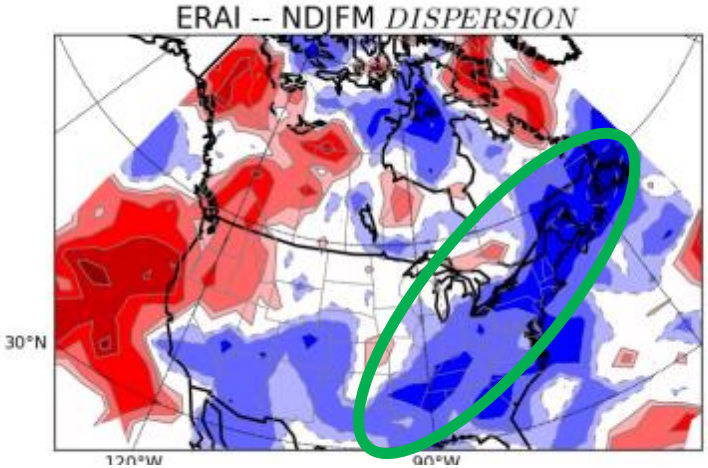
$$\varphi = \frac{Var(N)}{E(N)} - 1$$

3- Results: Winter Storm dispersion map

Driving Data

$REANA_0$-Ref





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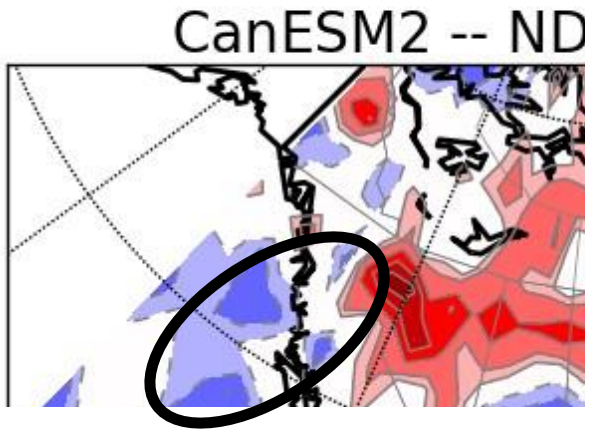
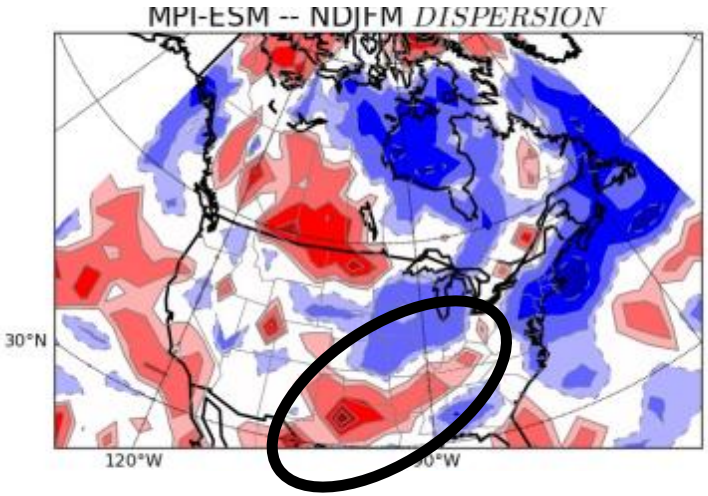
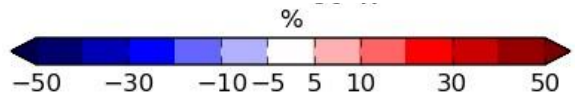
GCM_0-Pilot





GCM_1-Pilot

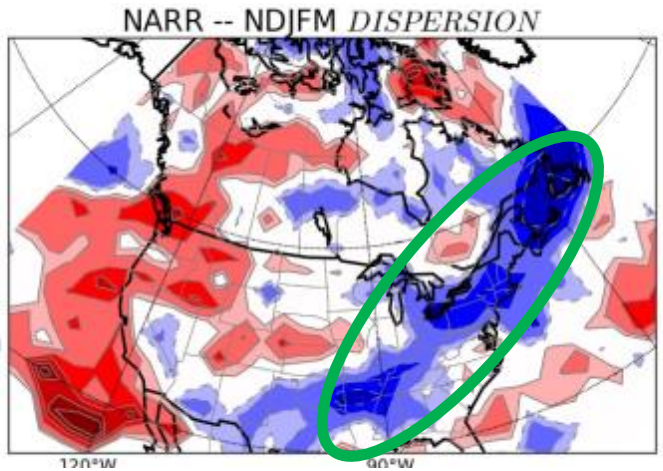


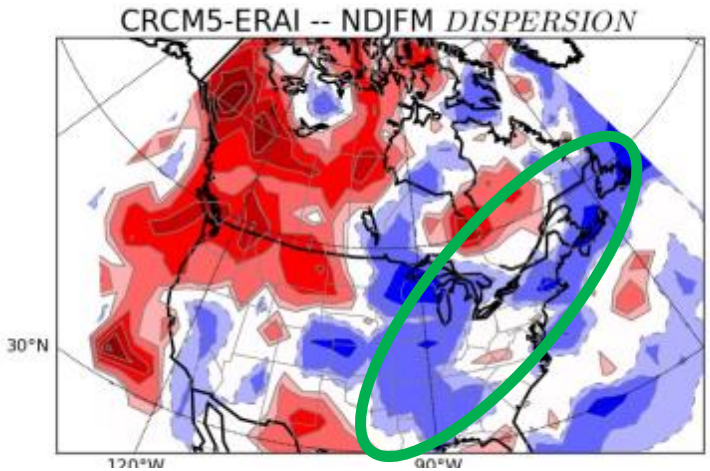
$$\varphi = \frac{Var(N)}{E(N)} - 1$$

3- Results: Winter Storm dispersion map

CRCM5 Data

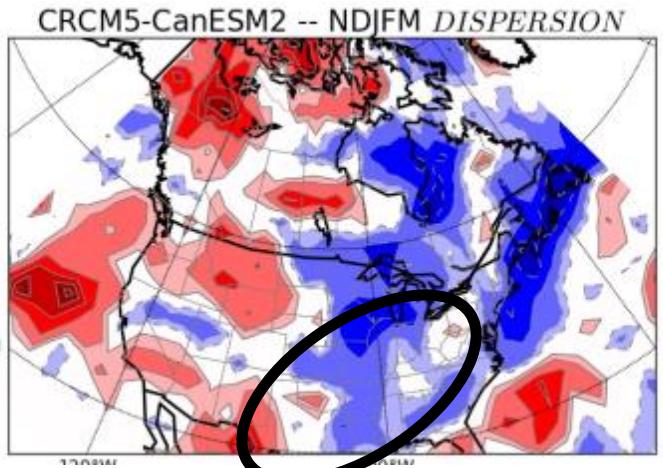
REANA$_0$-Ref

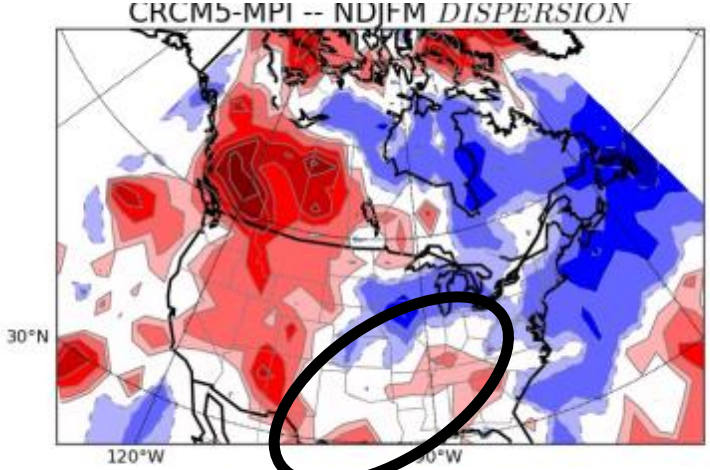




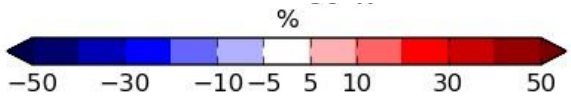
REANA$_1$-CRCM5

GCM$_0$-CRCM5





GCM$_1$-CRCM5



3- Results: Storms and precipitation

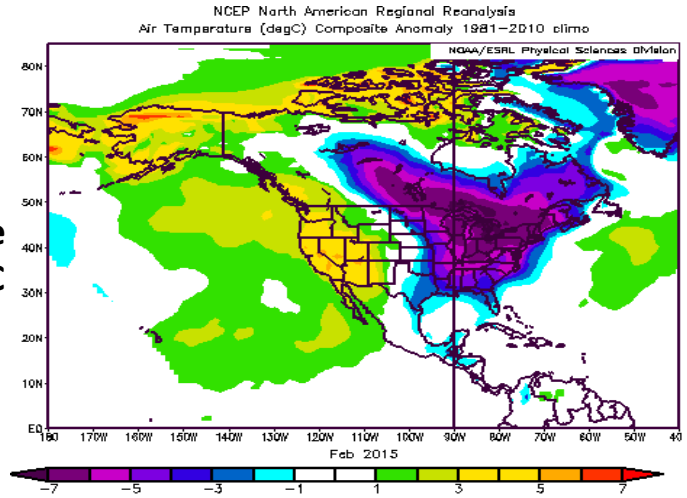
Example of last 2 winters (2015 – 2016)

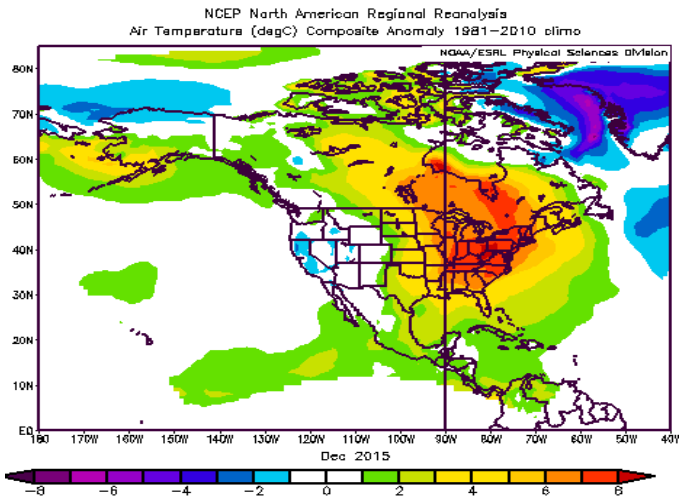
NARR reanalysis

Feb 2015

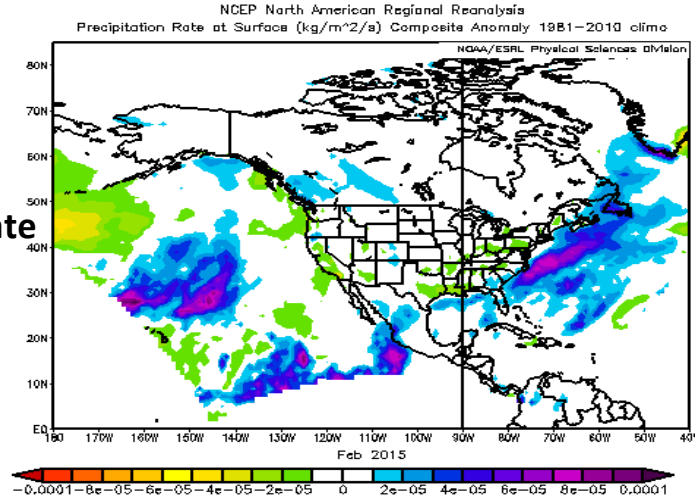
Dec 2015

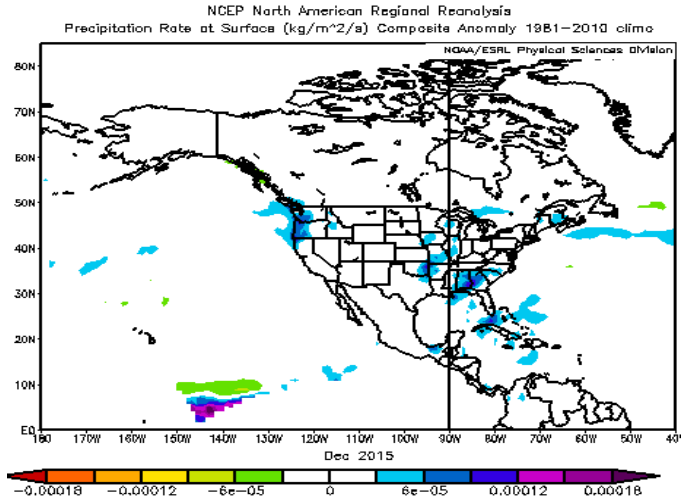
Temperature anomalies °C





Precipitation Rate anomalies (Kg m^{-2} s^{-1})





3- Results: Storms and precipitation

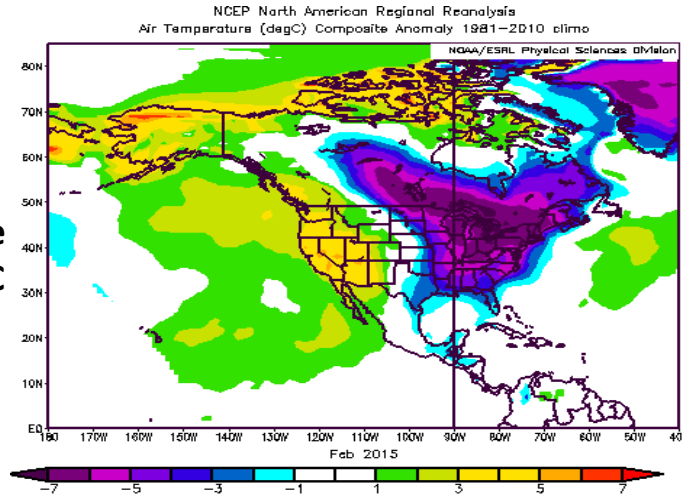
Example of last 2 winters (2015 – 2016)

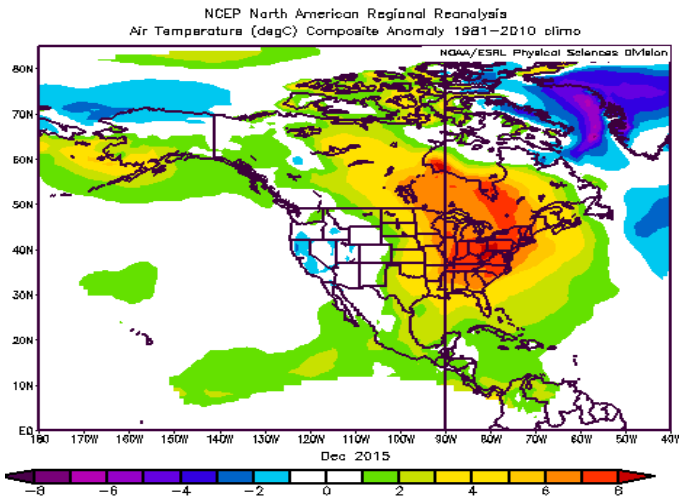
NARR reanalysis

Feb 2015

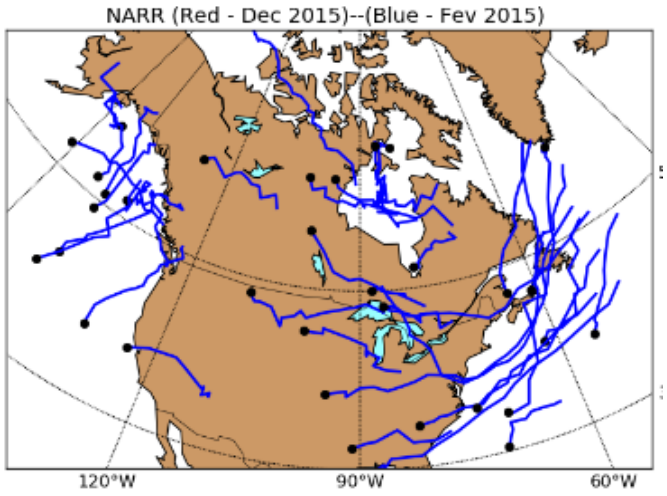
Dec 2015

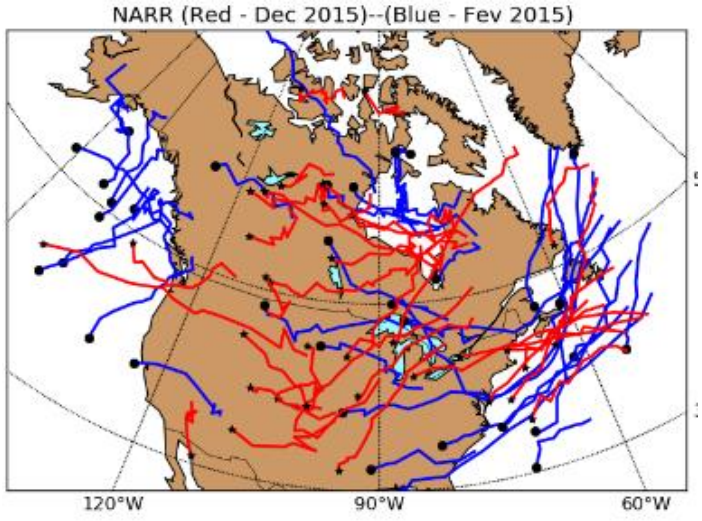
Temperature anomalies °C





Storm trajectories

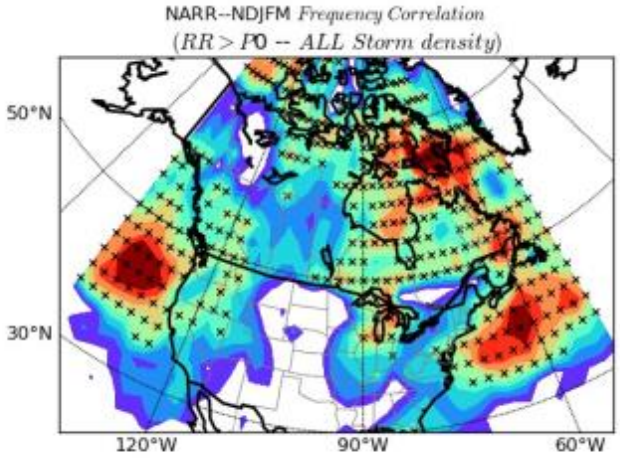




3- Results: Storms and precipitation

Winter Correlation: storm and rainy days

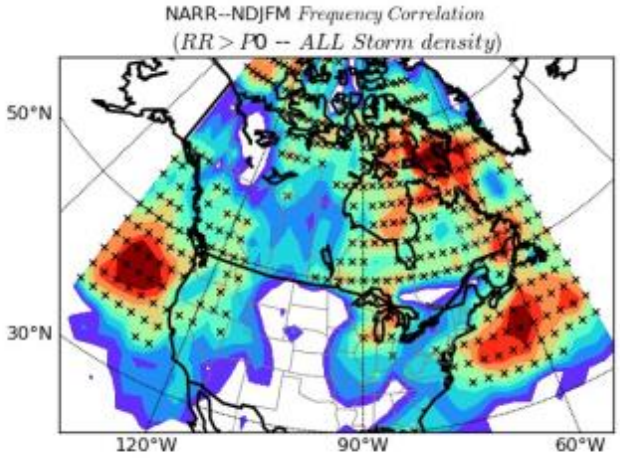
REANA$_0$-Ref

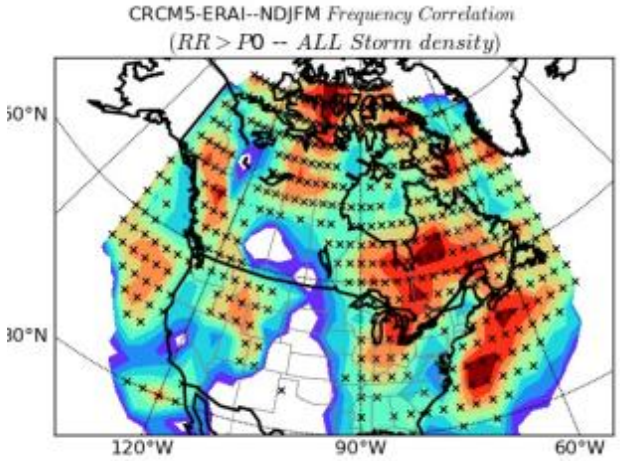


3- Results: Storms and precipitation

Winter Correlation: storm and rainy days

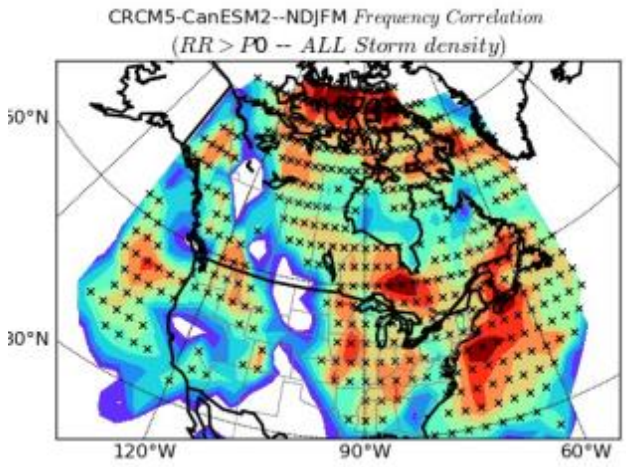
$REANA_0$-Ref

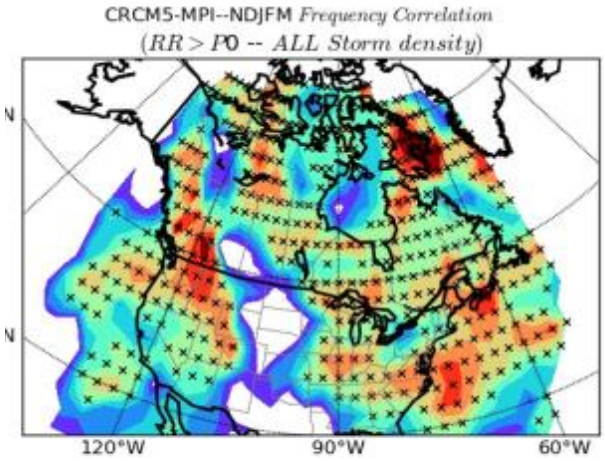




$REANA_1$-CRCM5

GCM_0-CRCM5





GCM_1-CRCM5

4- Conclusion - Future Work - Integration

Main results (Poan et al. 2016):

- Regional Reanalysis results are consistent with observed knowledge
- Topography resolution leads to differences in the 2 reanalyses
- GCM miss-capture storm regional features, mostly their continentality and the Atlantic development (SSTs – Land/sea contrast)
- Remarkable added-value: More continentality, East Coast structures (Western boundary current)
- Persistent Biases: Positive intensity and duration biases, Miss-representation of storm seriality (temporal variability)

Ongoing/Future work

- Storm spatial clustering and link with precipitation intensity/occurrence
- NA storminess in the future: RCP45 and RCP85 regional simulation analysis
- Investigate SSTs – land properties (topography, lake) - resolution impact on storm activity in the RCM

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Zappa G, Shaffrey LC, Hodges KI (2013a) The ability of CMIP5 models to simulate north Atlantic extratropical cyclones*. J Clim 26(15):5379–5396NA storminess in the future: RCP45 and RCP85 regional simulation analysis