Insight from other regions: Development of air quality forecasts for winter-time PM2.5 episodes occurring on multiple cities in south-central Chile

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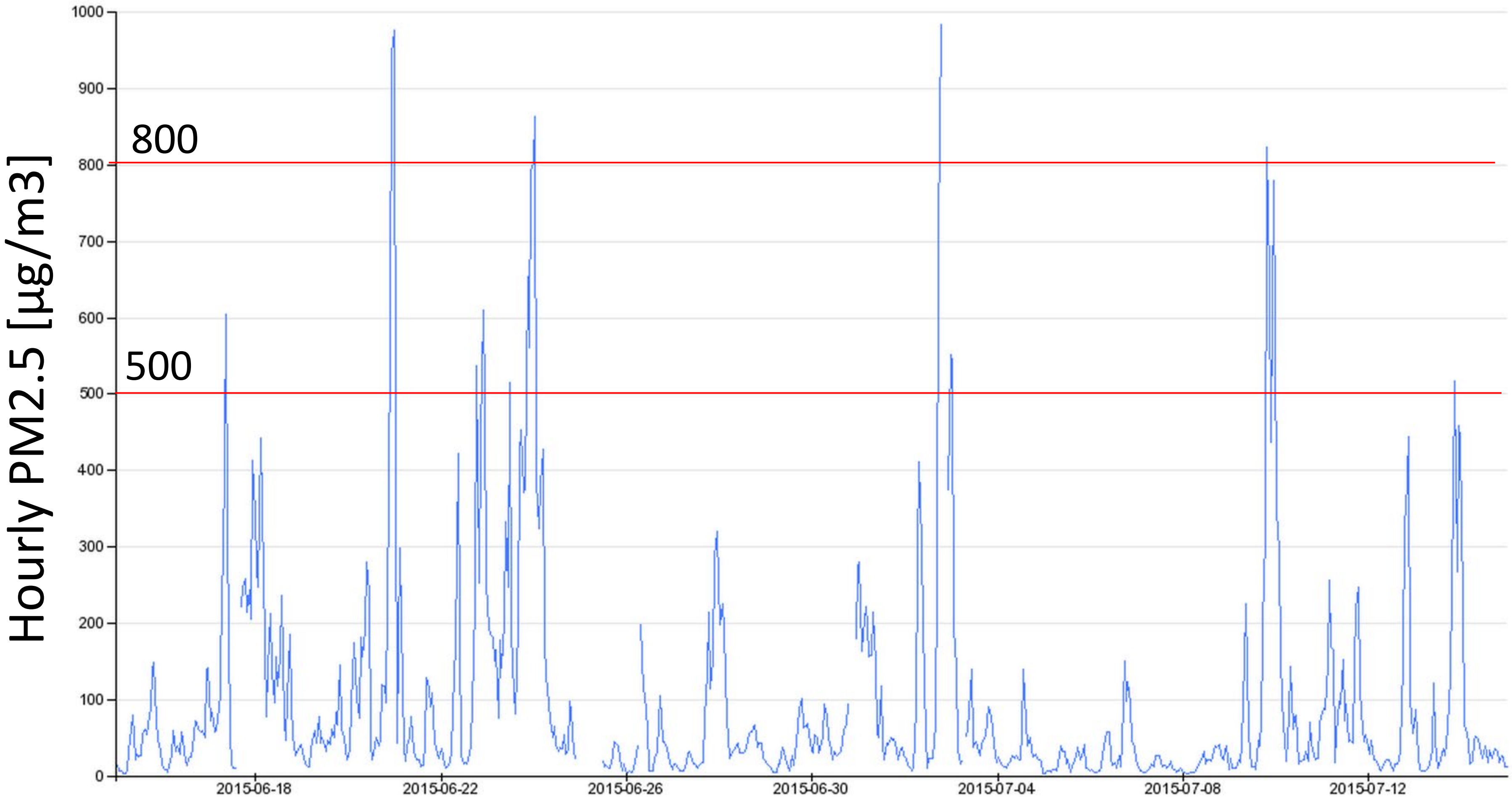
Trivia: What city is this and how big is it?



City: Osorno. Population: ~150k inhabitants

Severe PM2.5 episodes in south-central Chile

- Produced by a combination of:
  - Complex topography
  - Episodic meteorological conditions
  - Emissions due to anthropogenic activities

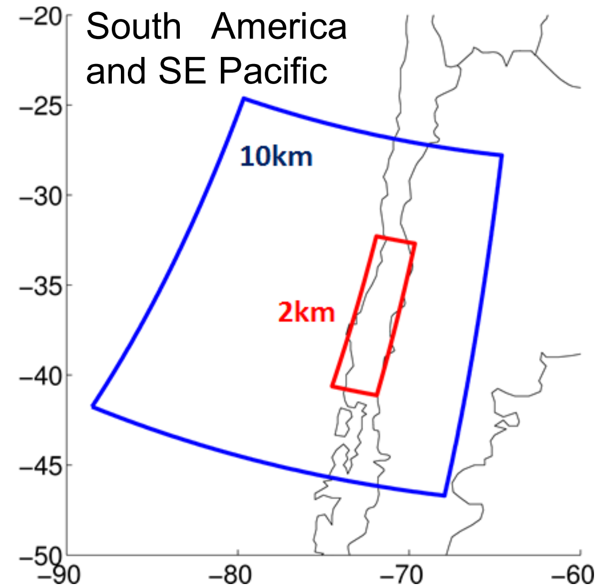
- Episodes are declared to warn the public and to try to reduce the impact by invoking temporary measures

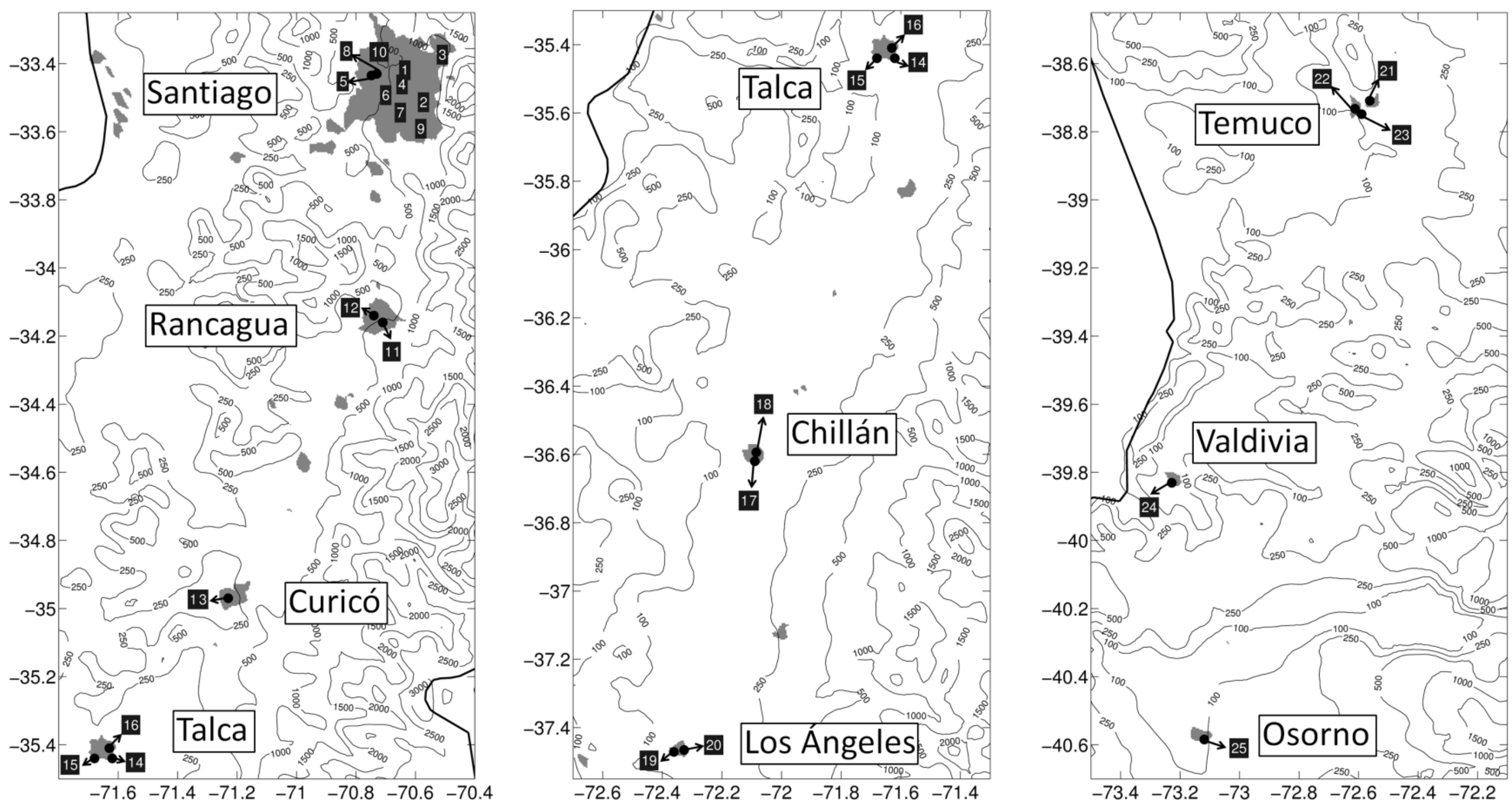
Santiago during en episode

Wood burning stoves in Temuco

Forecasting system

- WRF-Chem model at high spatial resolution to resolve met conditions, topography and emissions

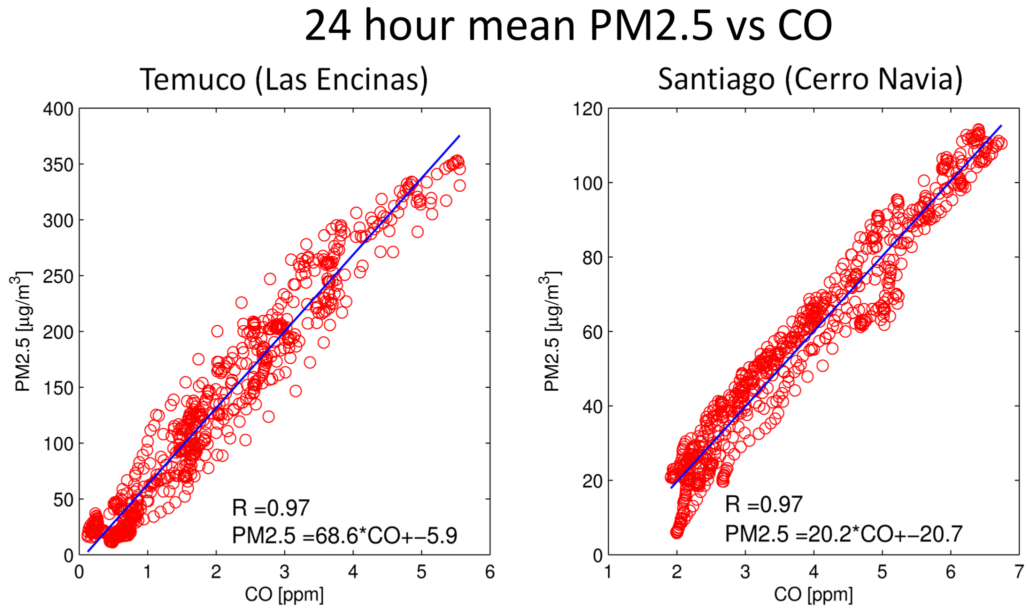




Saide et al., JGR 2016

PM2.5 modeling

- CO and PM are highly correlated during episodes

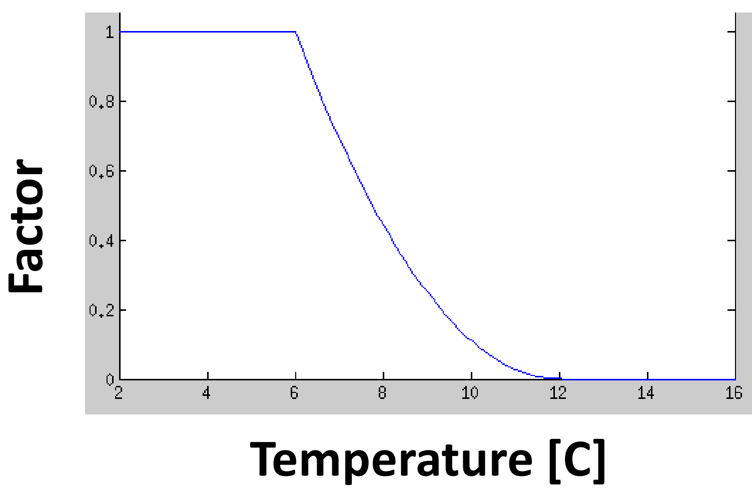


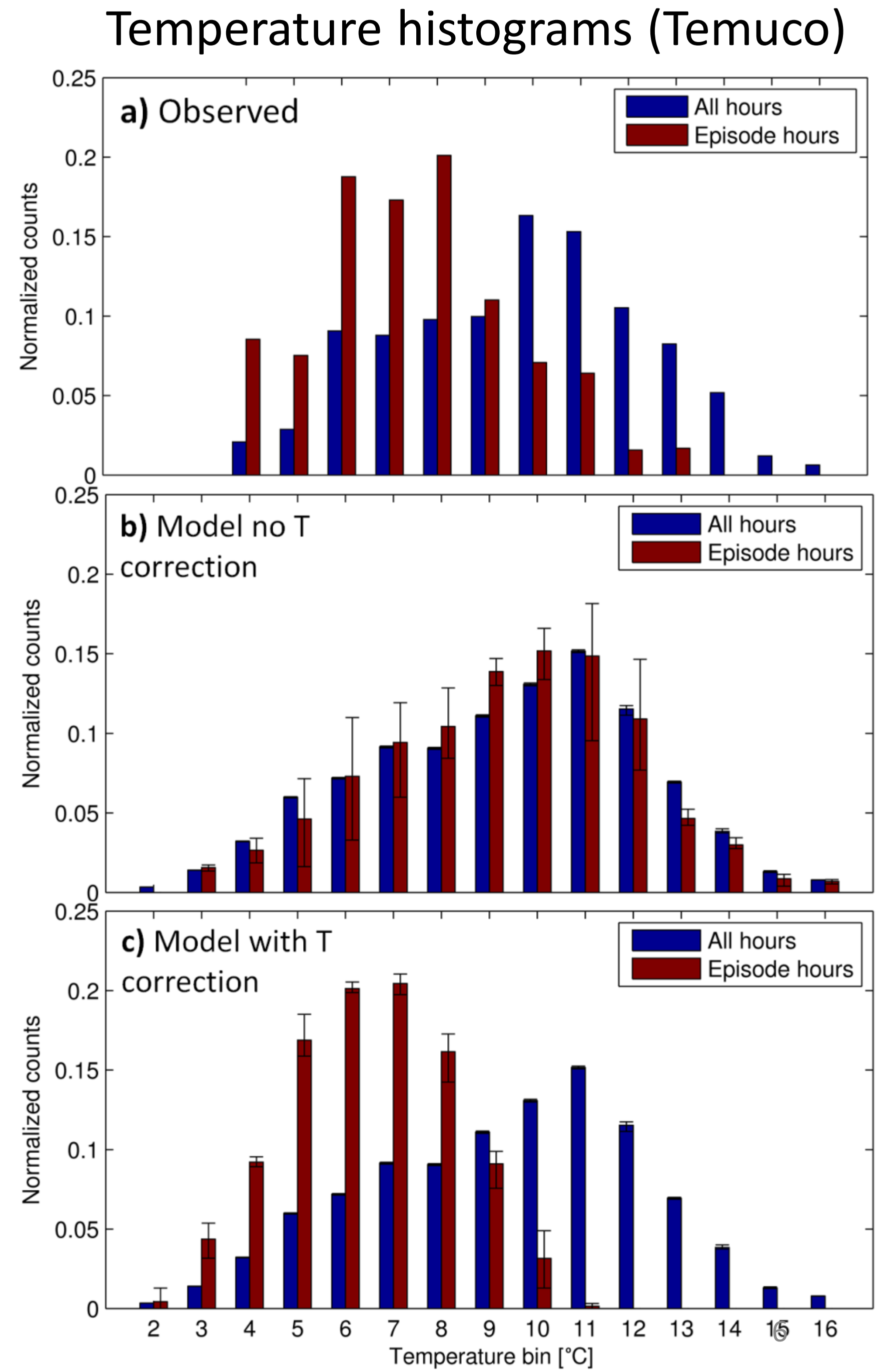
- Use CO tagged tracers ("traffic" and "wood burning stoves") and an empirically calibration for 2014
- The conversion factors are chosen to match observed episode statistics.
- Factors are introduced to include physical processes including % contribution of stoves by city, weekend effect, and temperature dependence

Saide et al., Atmos Env 2011
Saide et al., JGR 2016

Episode's Temperature dependence

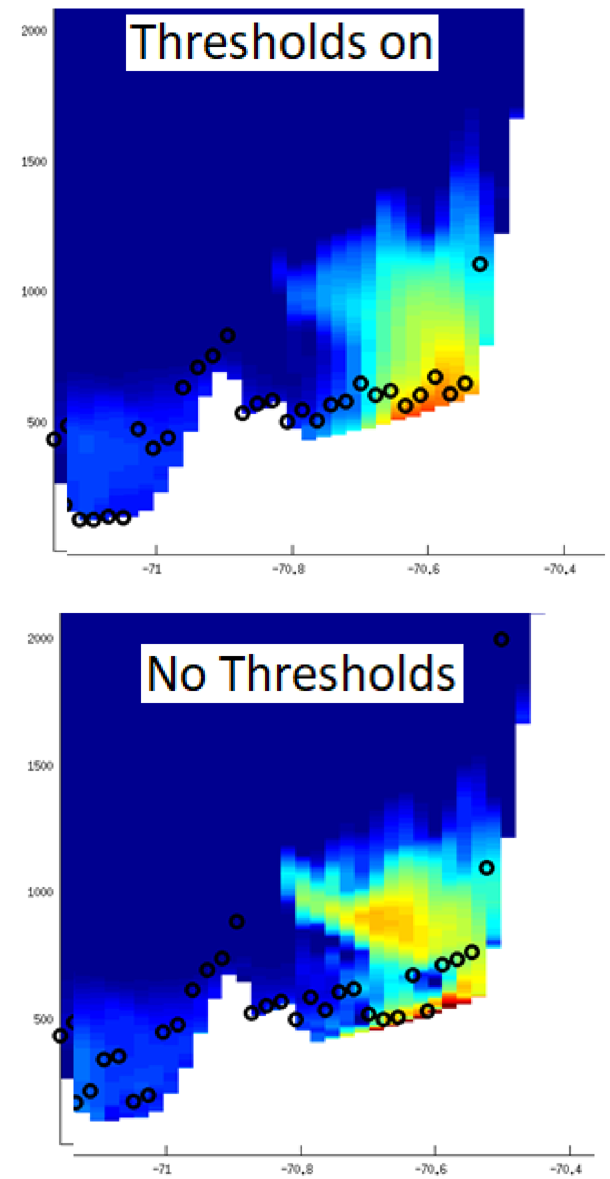
- Episodes associated to colder temperatures (statistically significant)
- This is due to emissions from wood burning stoves for heating
- Including temperature correction helps reproduce histograms





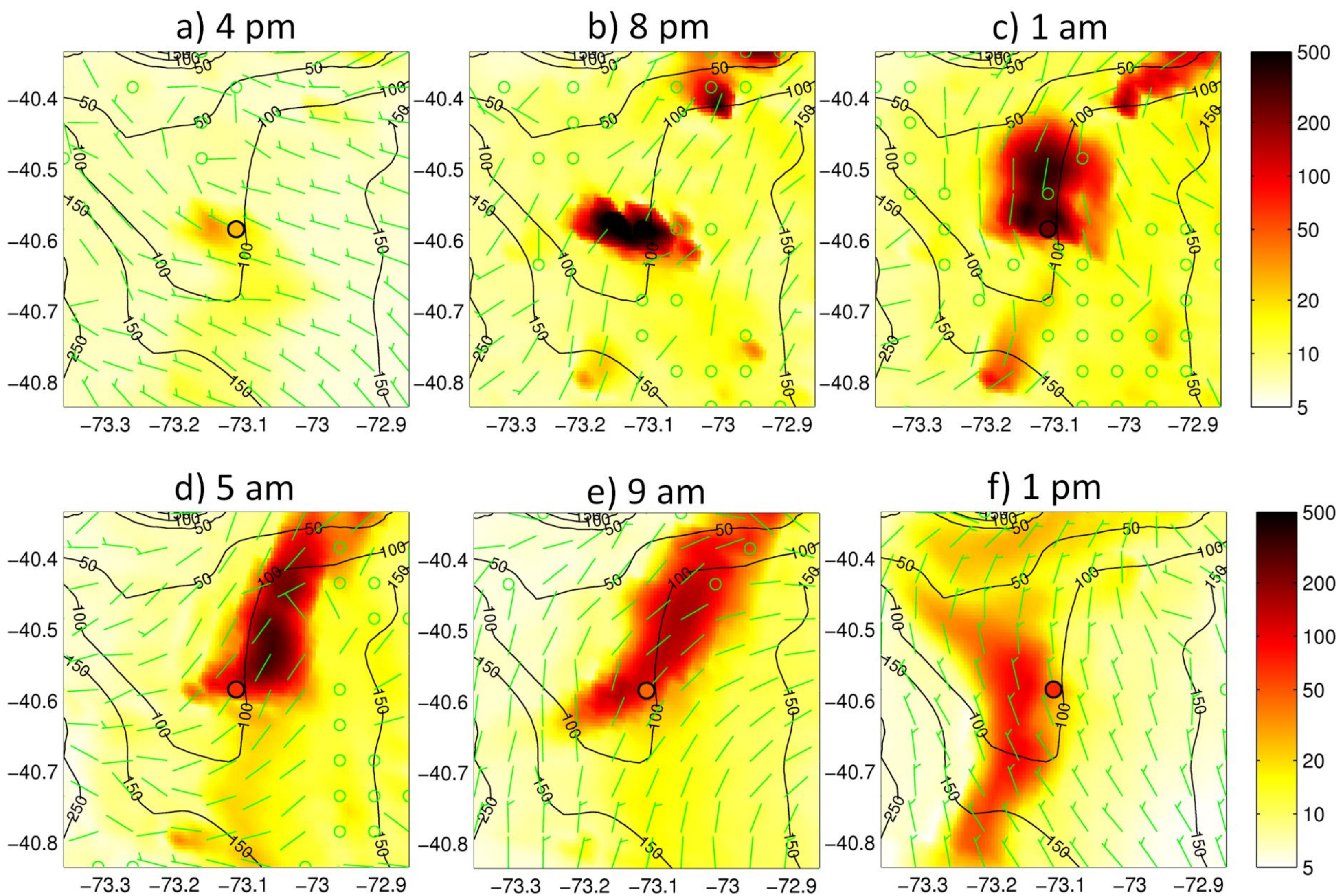
WRF-Chem configuration was tuned to resolve episodes

- No vertical diffusion thresholds for Chem
- No horizontal diffusion on the inner domain
- Sensitivity analysis was done for selecting vertical resolution (first two layers 10m thick, 6 levels below 100m), PBLH scheme (MYNN) and Meteorological Boundary conditions (GFS)

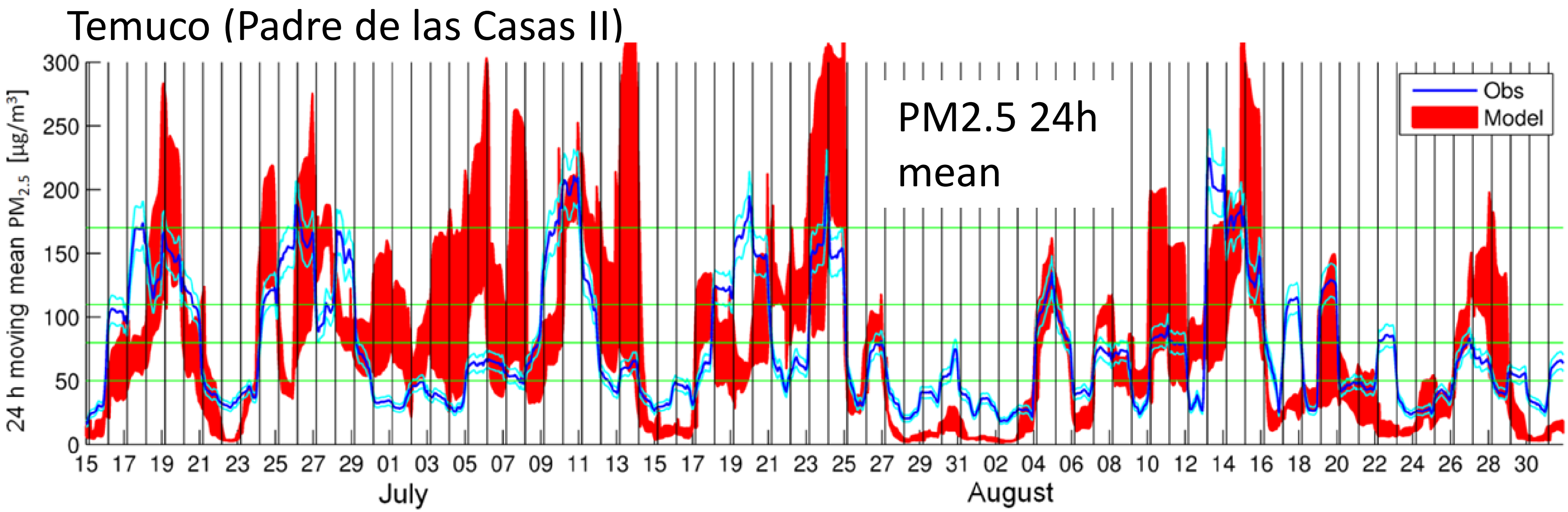


Saide et al., Atmos Env 2011

Episode evolution (Osorno)



Results



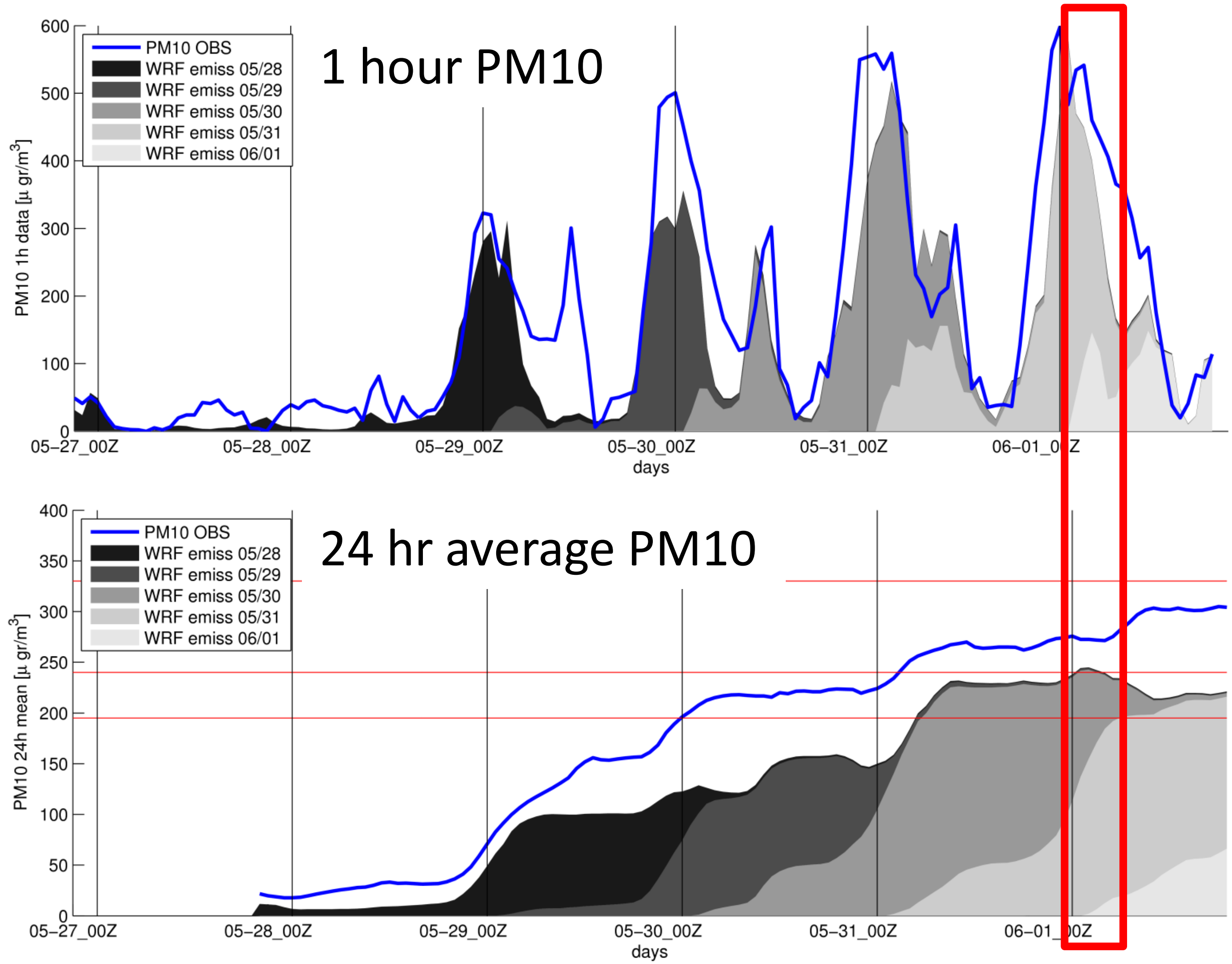
- Large variability within forecasts due to different meteorological initialization. Ensemble forecasting should be explored in the future
- Overall skill of 53–72% of episodes accurately forecasted which is generally better than persistence.

Saide et al., JGR 2016

Emission influence on different days

- Episodes are declared to reduce emissions to avoid bad air quality

- 48 forecasts needed to declare episodes in advance



Saide et al., Atmos Env 2011

Forecasting for 2015

- System in place since 2015 pollution season
- Provided good guidance with similar skill as the 2014 calibration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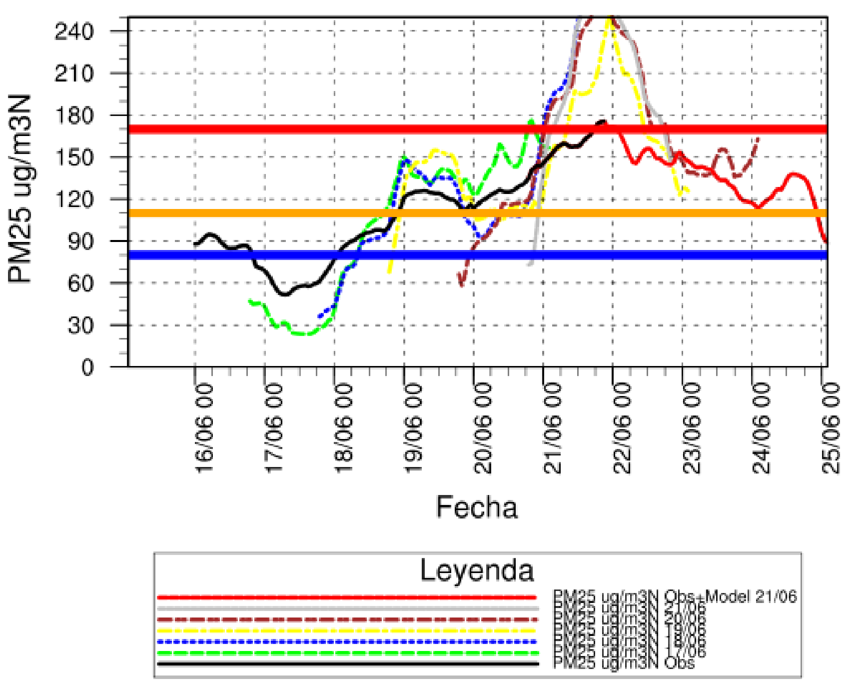
Horas críticas de aire tóxico presentan notoria reducción

Temuco y Padre Las Casas. Satisfacción en Medio Ambiente por el balance de la temporada tras finalizar alerta sanitaria.

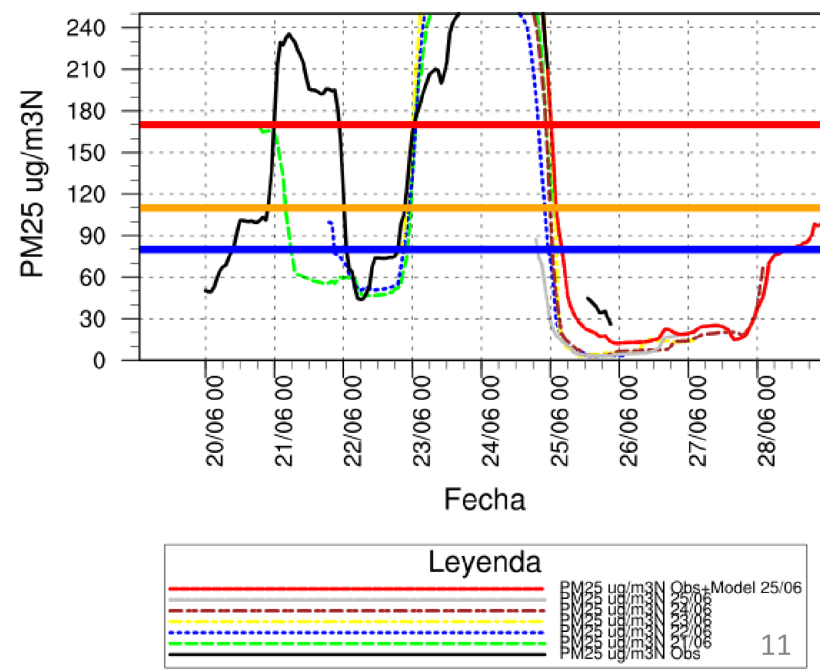
De 164 horas bajo niveles de emergencia ambiental en 2014 se disminuyó a sólo 29 entre el 22 de abril y el 30 de septiembre.

Mayo fue el mes con mayor cantidad de días de alta contaminación. Septiembre tuvo inusual comportamiento. *Págs. 2 y 3*

Emergency in Santiago

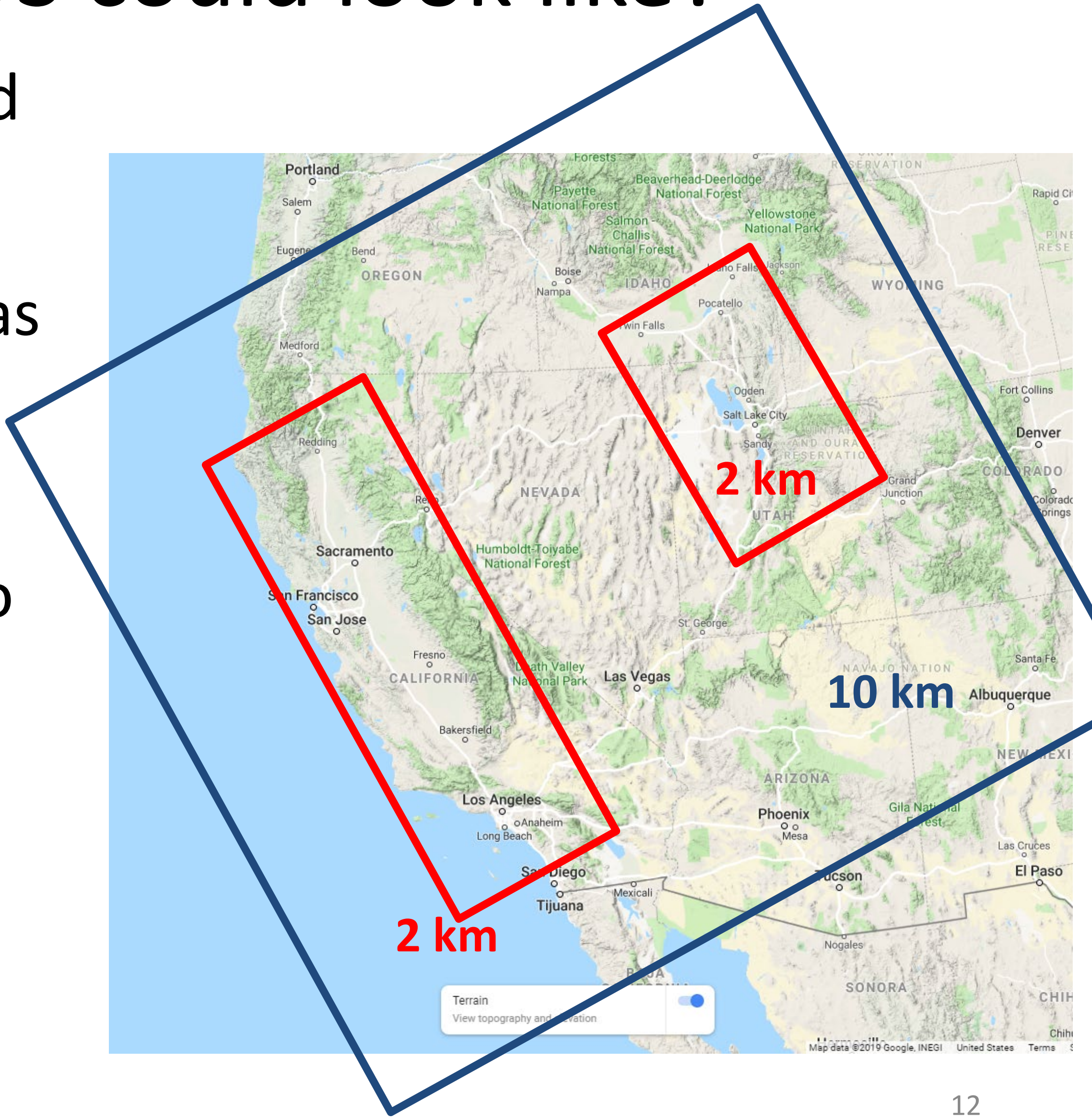


Emergency in Osorno



How would a forecasting system for AQUARIUS could look like?

- Two (or more?) nested domains to capture each sampling region
- Similar configuration as Chilean system to predict episode occurrence
- Ensemble forecasts to get a probabilistic forecast of episode occurrence
- Post-campaign simulations would be performed with full chemistry for analysis



Science questions

- Can a forecasting system developed for other regions predict winter-time air quality episodes in the western US?
- Does an ensemble system improve predictability?
- Once the accumulation of pollutants is properly modeled, can air quality models predict the chemical evolution during episodes?
- Can data assimilation of atmospheric constituents (AOD, CO, NO_2) help in the predictability of these events? Does the addition of geostationary satellites data play a role?

Previous work on data assimilation/inverse modeling: Saide et al., PNAS 2012; Saide et al., GRL 2014; Saide et al., GRL 2015a,b; Saide et al., JGR 2016; Saide et al., ES&T 2018;

Questions or comments?

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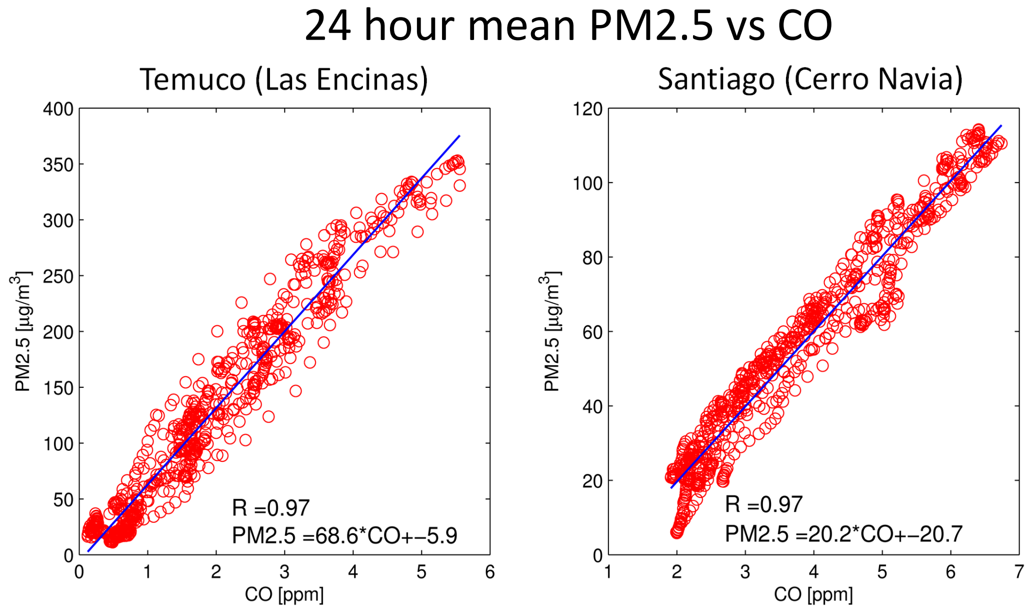
Supplemental slides

PM2.5 modeling



- CO and PM are highly correlated during episodes
- Use CO tagged tracers ("traffic" and "wood burning stoves") and an empirically calibration for 2014
- The conversion factors are chosen to match observed episode statistics.
- Factors are introduced to include physical processes

$$PM2.5_{t,s} = Tr\_to\_PM_s * A\_weekend_{t,s} * \dots$$

$$\left[F\_WB_s * A\_WB(T\_mean_{t,s}) * \left(\max_{i \in s \cup N_s} Tr\_WB_{t,i} \right) + (1 - F\_WB_s) * \left(\max_{i \in s \cup N_s} Tr\_T_{t,i} \right) \right]$$

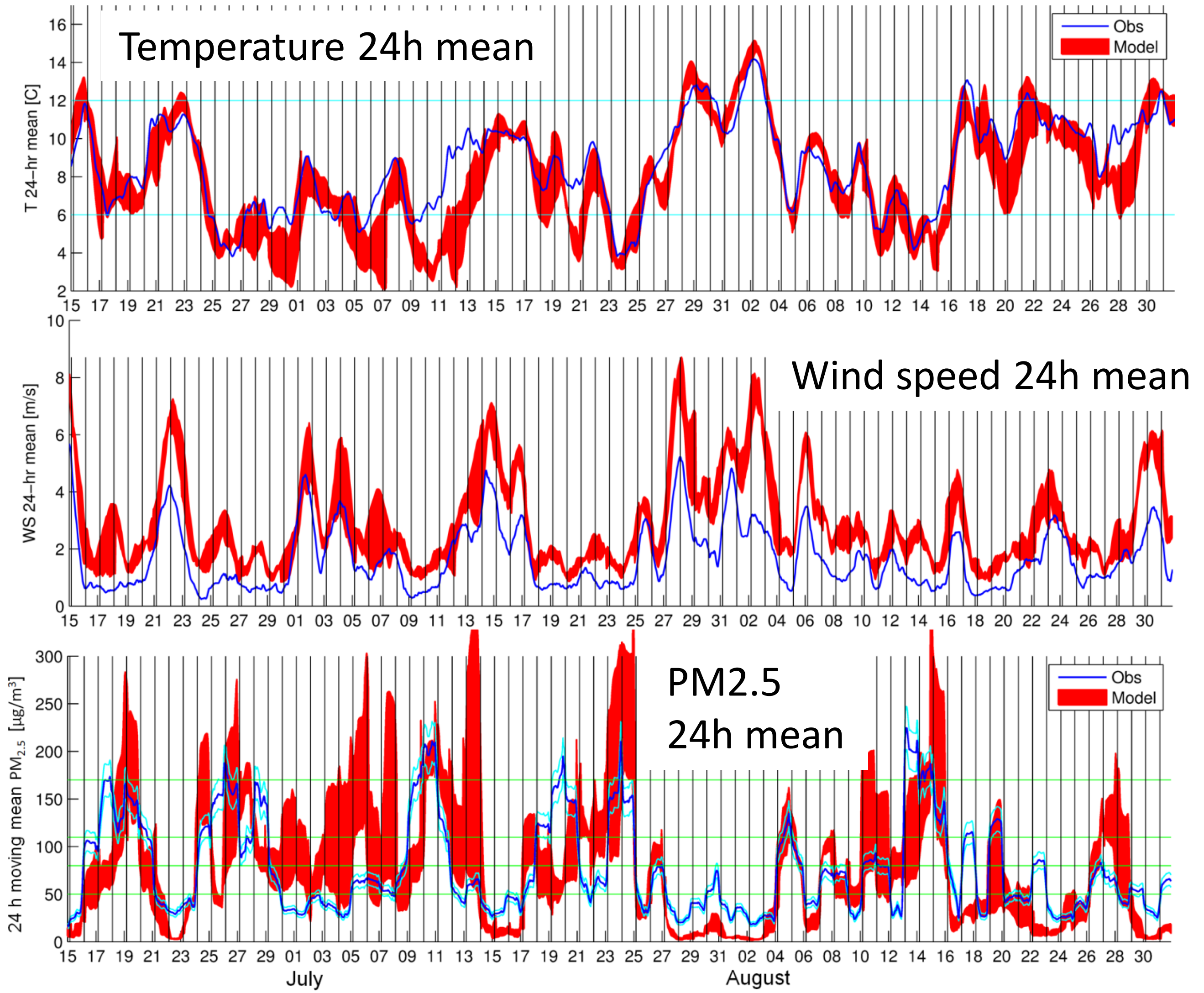
Weekend effect

- There were 137%, 34% and 38% more episodes on average for weekend days than for weeks-days in Santiago, Rancagua and Talca, respectively.
- Activity increases in Friday and Saturday nights, which generates episodes on Saturday and Sundays
- Inflation factors:
  - 1.4 for Santiago
  - 1.2 for Rancagua
  - 1.3 for Talca and Chillán
- Improvement in model performance:
  - 67% to 72% in Santiago
  - 64% to 69% in Rancagua
  - 57% to 63% in Talca
  - 63% to 67% in Chillan

Results

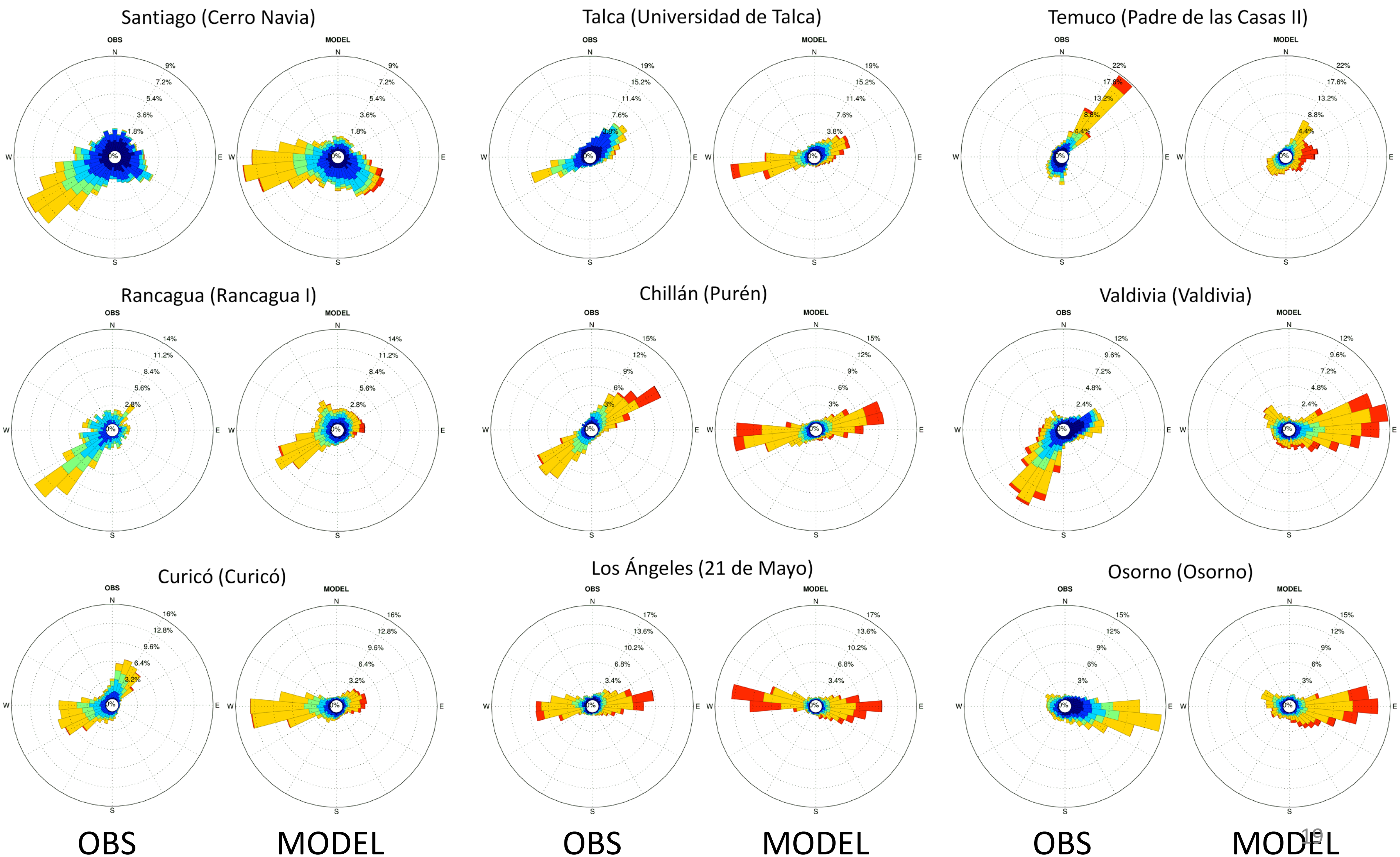
- Large variability within forecasts due to different meteorological initialization
- Variability in PM2.5 much larger than T and wind speed
- Ensemble forecasting should be explored in the future
- Overall skill of 53–72% of episodes accurately forecasted (61–76% for the best initialization) which is generally better than persistence.

Temuco (Padre de las Casas II)



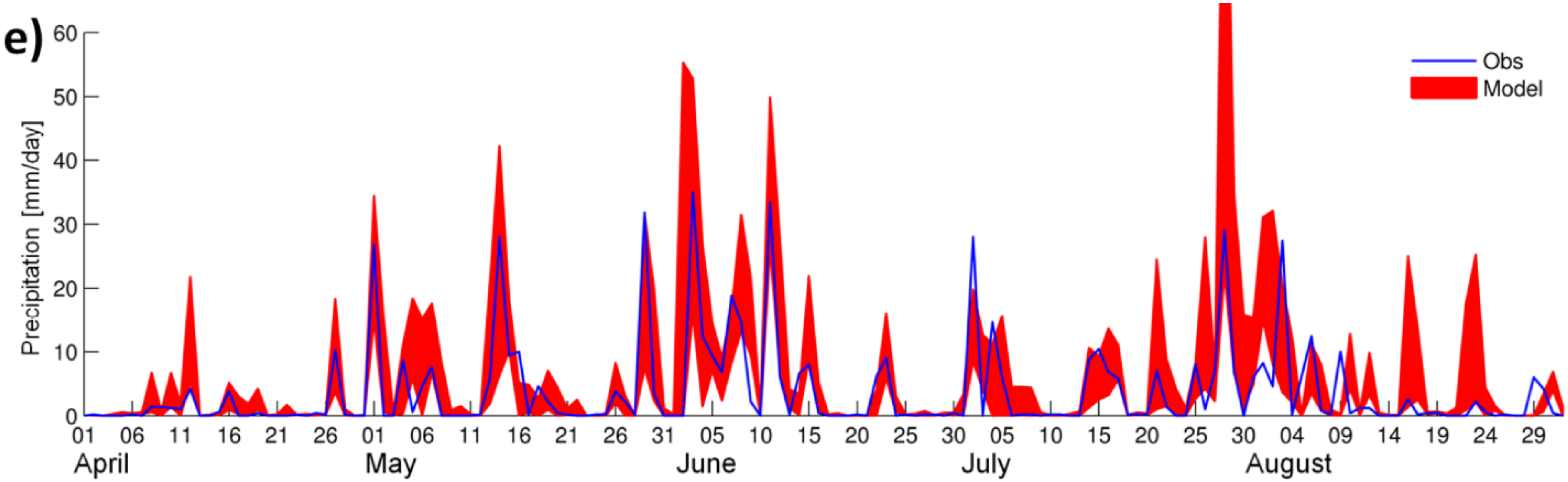
Saide et al., JGR 2016

Wind evaluation



Precipitation

Temuco Centro

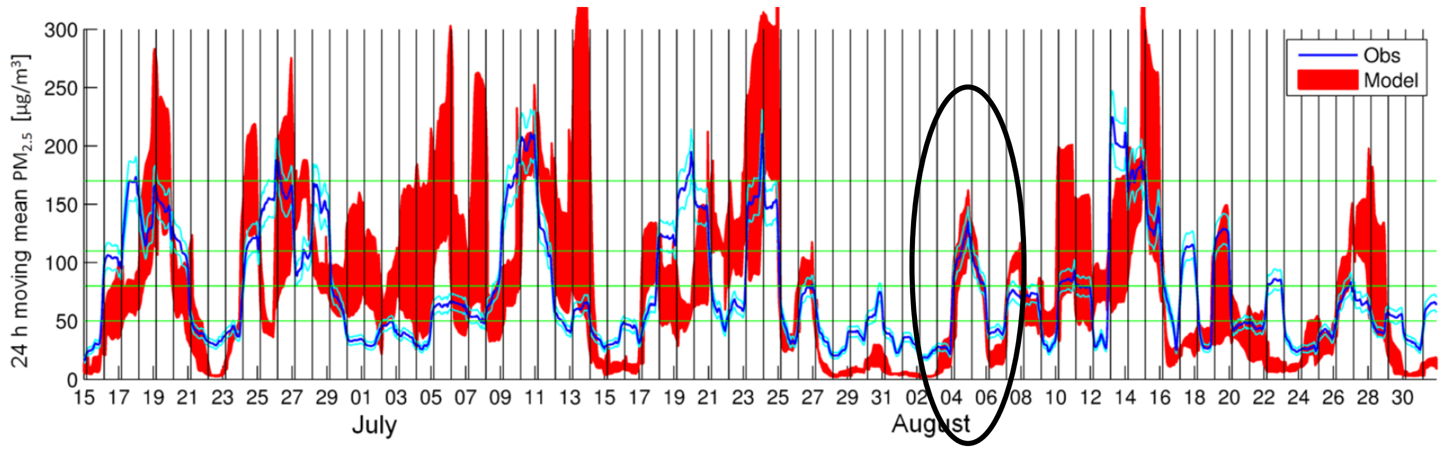


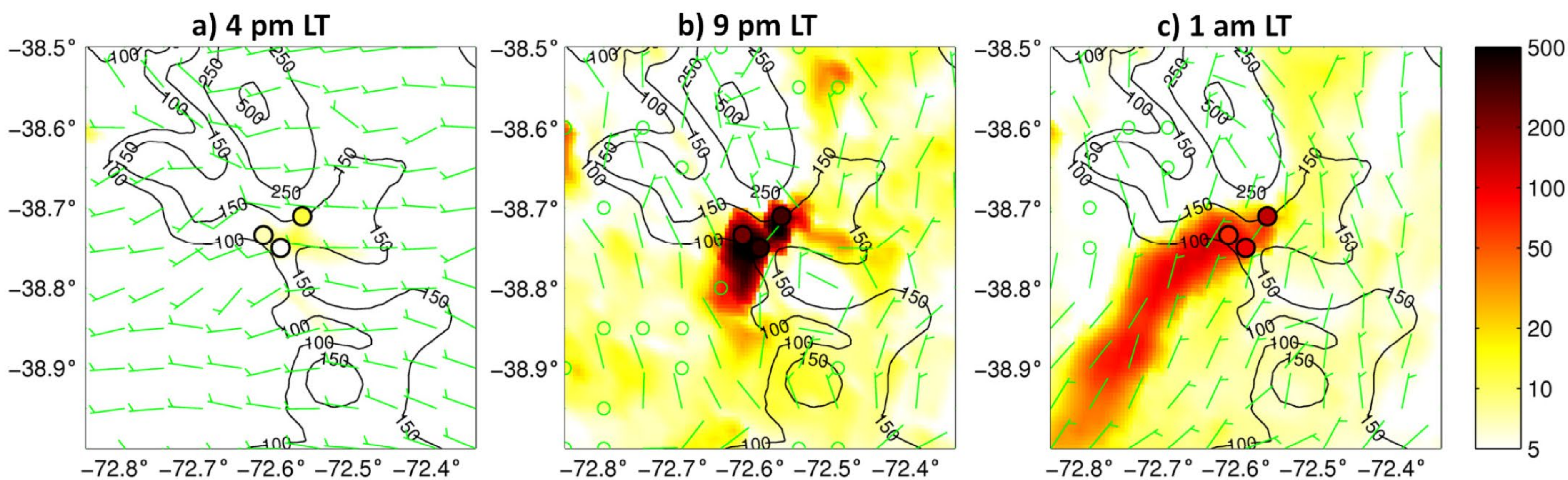
Forecast skill

- Forecasts one, two and three days in advance all have skill in forecasting
- Latest forecast no necessarily the best
- Forecast generally beat persistence

City	Station	Episode days (%)	% correct Episode Day 1	Day 2	Day 3	All	Pers
Santiago	Pudahuel	21%	63%	72%	69%	68%	56%
	Cerro Navia	30%	71%	69%	76%	72%	67%
Rancagua	Rancagua II	35%	68%	72%	68%	69%	64%
Curico	Curico	21%	61%	48%	48%	53%	42%
Talca	La Florida	38%	66%	64%	59%	63%	57%
Chillan	Puren	40%	65%	67%	62%	64%	65%
Los Angeles	21 de Mayo	33%	67%	67%	65%	67%	63%
Temuco	Museo Ferroviario	33%	73%	69%	71%	71%	64%
	Las Encinas	33%	68%	62%	68%	66%	64%
	Padre Las Casas II	38%	73%	71%	68%	71%	73%
Valdivia	Valdivia	31%	59%	61%	61%	60%	52%
Osorno	Osorno	38%	71%	64%	63%	66%	70%

Episode evolution (Temuco)





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