



Ministério da
**Ciência, Tecnologia
e Inovação**



ANÁLISE DO ACOPLAMENTO SUPERFÍCIE-ATMOSFERA NA PRODUÇÃO DE PRECIPITAÇÃO


Resultados preliminares

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São José dos Campos - SP
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Introdução

- **Interações Superfície-Atmosfera:**

 **processo pouco compreendido** e uma grande **fonte de incertezas em modelos numéricos** (Betts, 2004; Koster et al., 2006; Seneviratne et al., 2010).

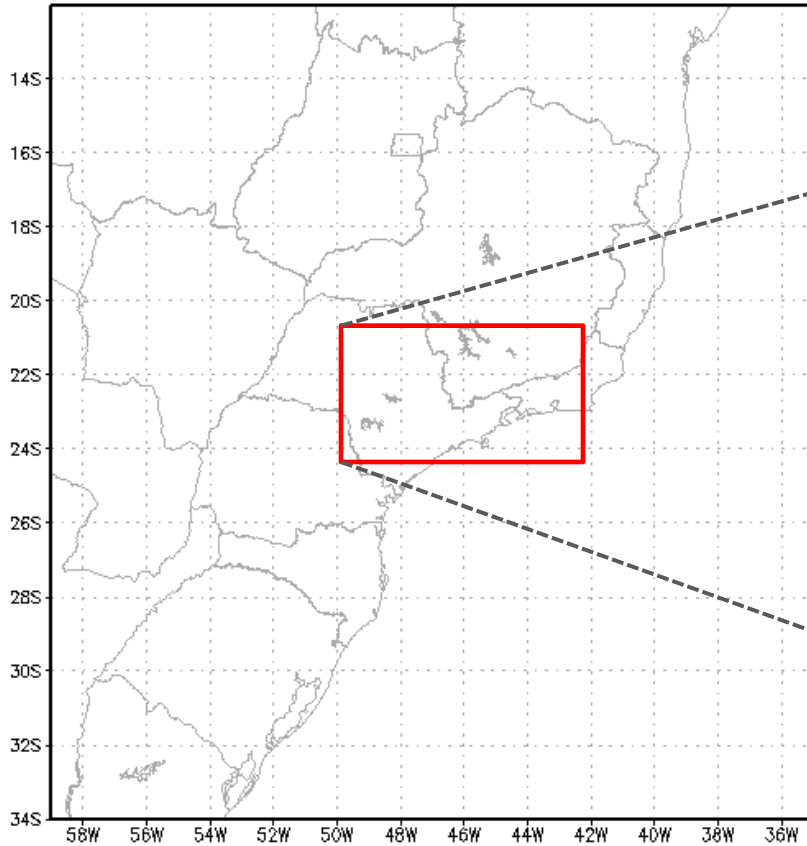
- Diante da falta de dados observacionais na escala dos processos de interação spf-atm, os **modelos numéricos em alta resolução espacial** se tornam uma ferramenta para estudo desses processos, o que também pode potencialmente melhorar as previsões de tempo e clima.

O **principal objetivo** deste estudo é analisar o efeito da força de acoplamento superfície-atmosfera no ciclo diurno dos fluxos de superfície e na produção de nuvens e precipitação, utilizando o modelo Eta em altíssima resolução.

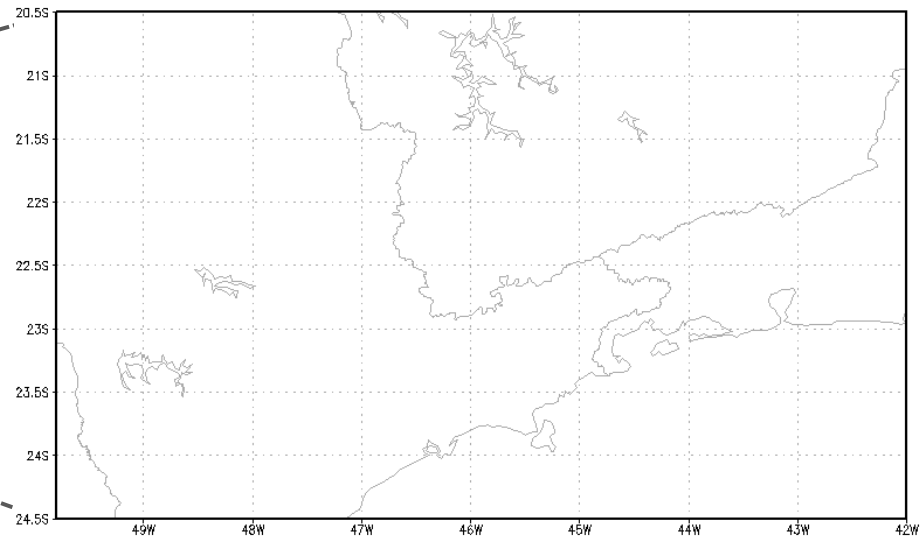
Metodologia

Área de estudo

Domínio 5 km
Modelo Eta - CFSR



Domínio 1 km

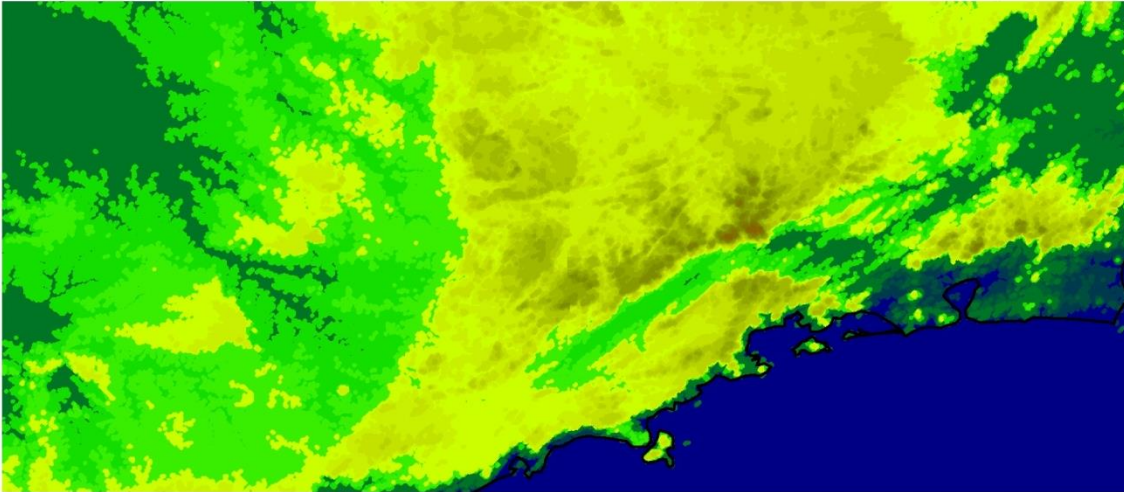


Características gerais do modelo Eta

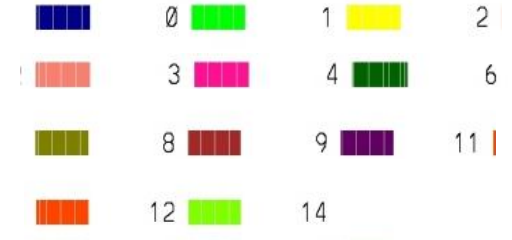
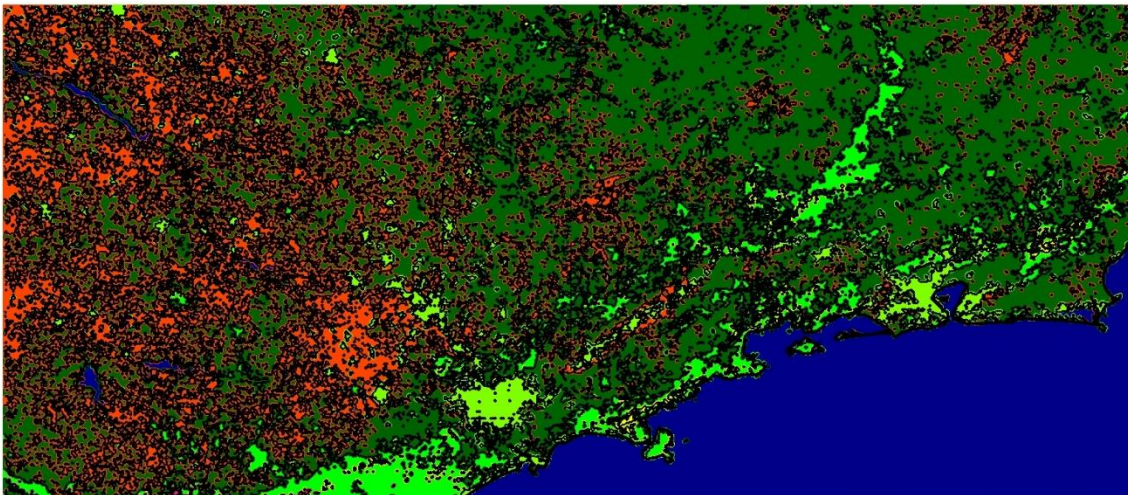
Característica	Descrição
Coordenada vertical	Coordenada Eta com refinamento do sloping steps (Mesinger et al. 2012)
Tipo de grade horizontal	Grade-E (Arakawa)
Tipo de grade vertical	Grade-Lorenz, primeiro nível em cerca de 20m.
Topografia original	USGS 90m
Ozônio	Média zonal climatológica
Turbulência	Mellor-Yamada (1982) nível 2.5 utilizando funções de estabilidade de Paulson (1970) na camada limite superficial
Radiação (curta/longa)	Calculada a cada hora. ROC (Lacis e Hansen, 1974) e ROL (Fels e Schwarzkopf, 1975)
Microfísica de nuvens	Ferrier et al. (2002)
Convecção ausente	
Esquema de superfície	NOAH (Ek et al. 2003)
Variáveis Prognósticas	T, q, u, v, ps, TKE e hidrometeoros das nuvens

Mapas de topografia e vegetação da região:

Topografia



Vegetação



Metodologia

Esquema de superfície NOAH

- Os fluxos de superfície de calor sensível (SH) e latente (LE) são calculados como:

$$SH = \rho C_p C_h |U| (\theta_s - \theta_a)$$

$$LE = \rho C_p |U| (q_s - q_a)$$

Onde:

ρ = densidade do ar

C_p = calor específico do ar à P constante

C_h = coeficiente de troca de calor e umidade

U = velocidade do vento

θ_s = temperatura da superfície

θ_a = temperatura no nível mais baixo de modelo

q_s = umidade específica superficial

q_a = umidade do ar no nível mais baixo do modelo

- Coeficiente de troca de calor/umidade à superfície utilizado na parametrização da camada limite superficial:

$$C_h = \frac{k^2/R}{\left[\ln\left(\frac{z_a}{z_{om}}\right) - \psi_m\left(\frac{z_a}{L}\right) + \psi_m\left(\frac{z_{om}}{L}\right) \right] \left[\ln\left(\frac{z_a}{z_{ot}}\right) - \psi_h\left(\frac{z_a}{L}\right) + \psi_h\left(\frac{z_{ot}}{L}\right) \right]}$$

Onde:

Z_{0m} = Comprimento de rugosidade momentum

Z_{0t} = Comprimento de rugosidade do calor (umidade)

k = constante de von Kármán

L = Comprimento de Obukhov

R = Estimado = 1,0. É a razão entre os coef. de transferência de quantidade de movimento e calor no limite neutro

z_a = altura de referência no interior da camada superficial

ψ_m e ψ_h = funções de estabilidade

- Os comprimentos de rugosidade de momento e de calor são utilizados para calcular C_h , com base na teoria da similaridade de Monin-Obukhov e são calculados de acordo com Zilitinkevich (1995). O termo C_{zil} controla a razão de z_{ot}/z_{om} .

$$z_{ot} = z_{om} \exp(-k C_{zil} \sqrt{R_e})$$

$$R_e = \frac{u_0^* z_{om}}{\nu}$$

Onde:

Z_{0t} = Comprimento de rugosidade do calor (umidade)

Z_{0m} = Comprimento de rugosidade momentum

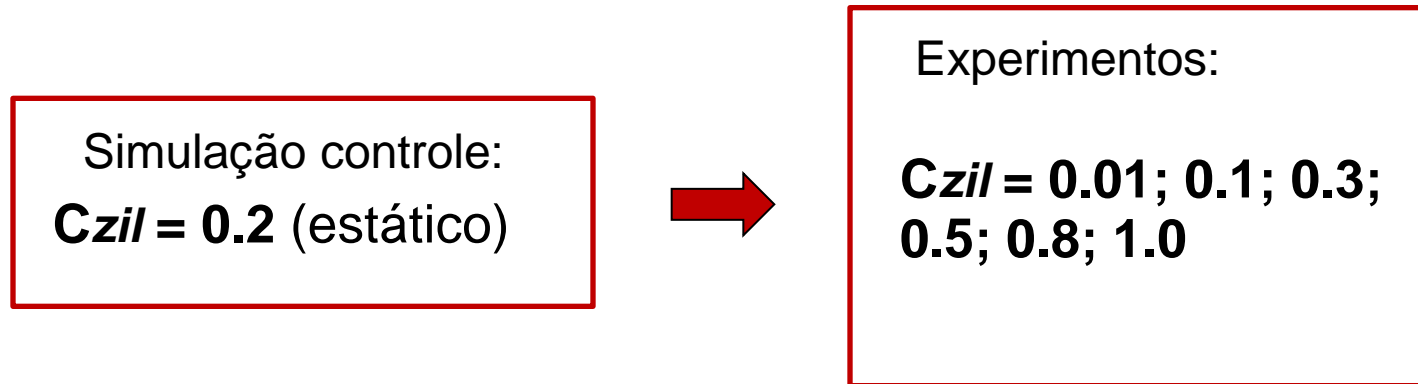
C_{zil} = Coef de Zilitinkevich

Re = Número de Reynolds

$k = 0,4$; constante de von Kármán

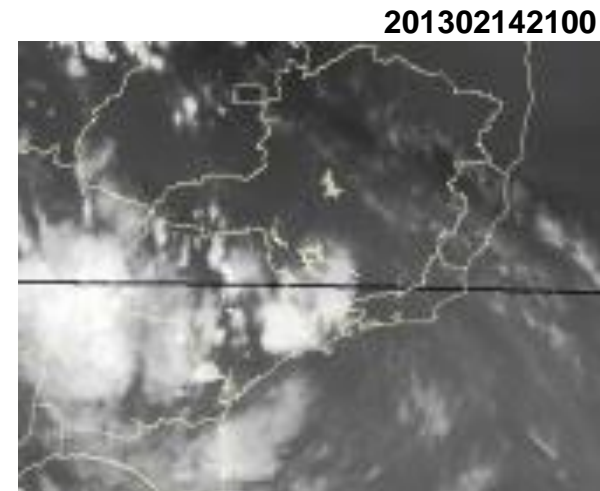
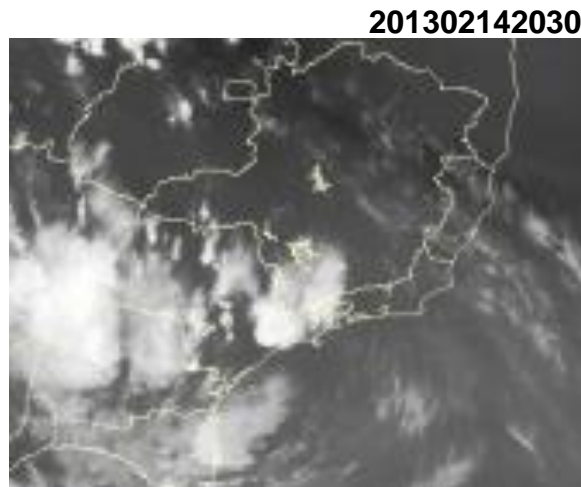
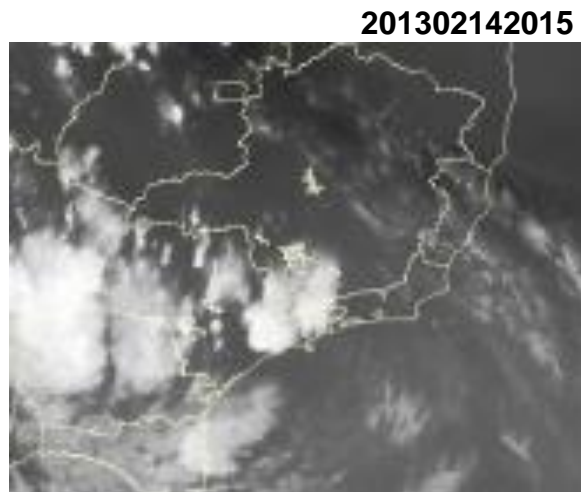
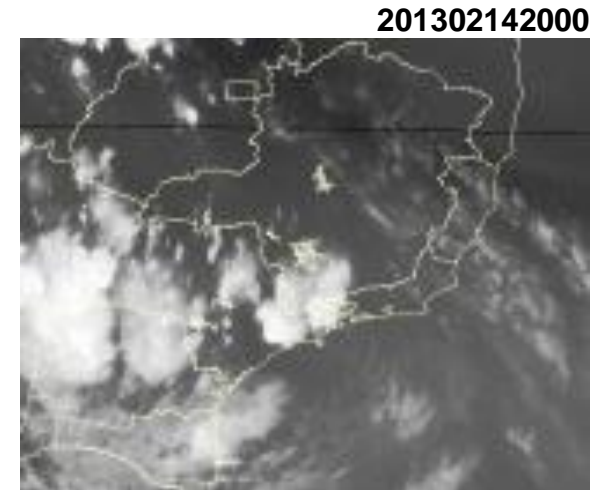
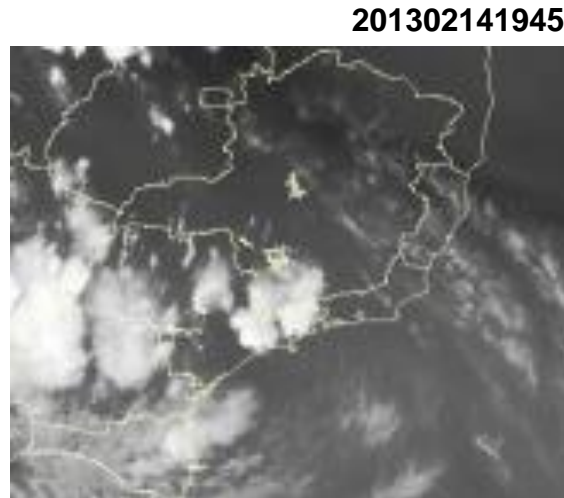
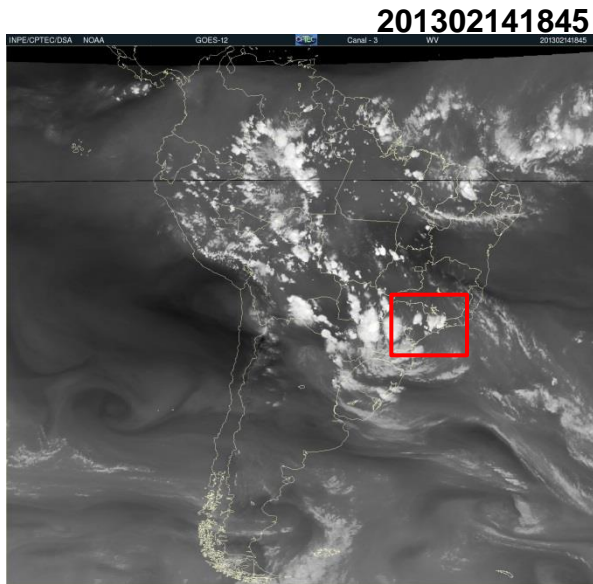
Alteração no coeficiente de troca à superfície

- Com o objetivo de investigar a influência do coeficiente de troca de calor e umidade à superfície no disparo da precipitação, o coeficiente (C_{zil}) que, indiretamente, determina a força de troca à superfície, foi alterado:



➡ Pretende-se por meio de modificações no coeficiente de troca à superfície, tentar melhorar a simulação dos fluxos de baixos níveis que irá impactar na simulação de nuvens e precipitação.

Caso 14 de fevereiro de 2013 – São Paulo-SP



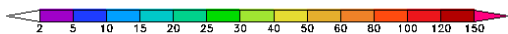
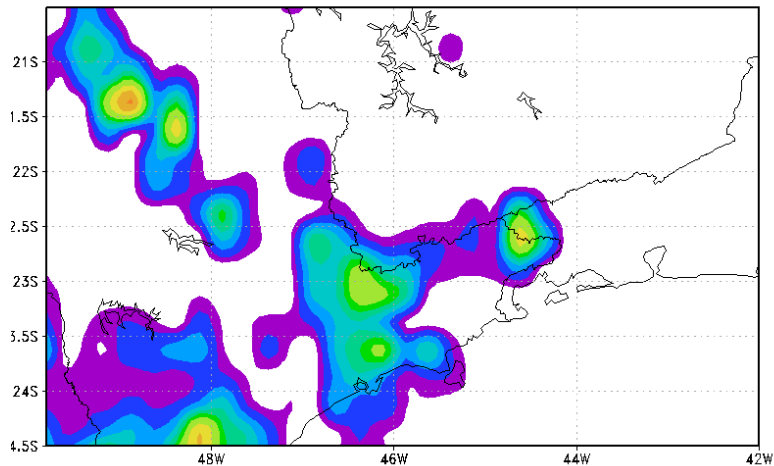
Boletim técnico CPTEC/INPE:

Data	Localização e análise meteorológica
14/02/2013	Tempestade de verão que atingiu SP ocorreu em situação bastante comum, sem a presença de um sistema de grande escala.

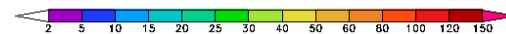
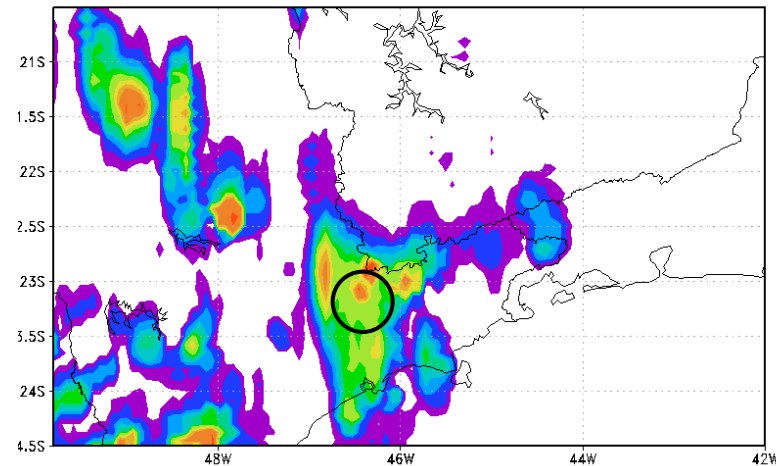
Resultados

Campos espaciais - Simulação Controle

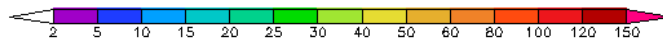
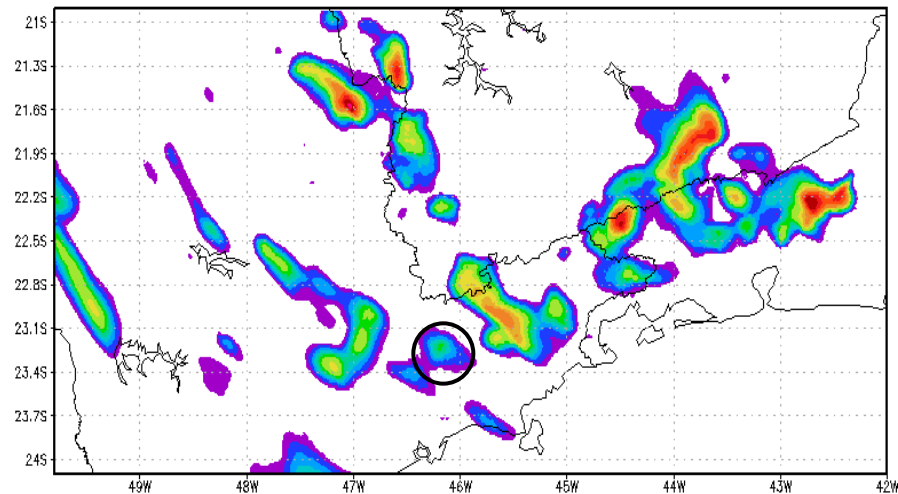
Precipitação Acumulada (mm/dia) do Modelo TRMM 20km
Período: 00Z14FEB2013-00Z15FEB2013



Precipitação Acumulada (mm/dia) CMORPH CMORPH 8km
Período: 00Z14FEB2013-00Z15FEB2013

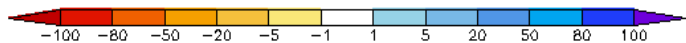
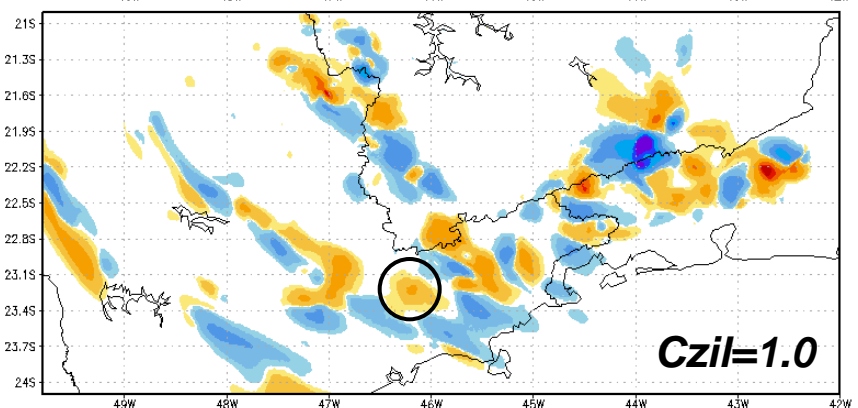
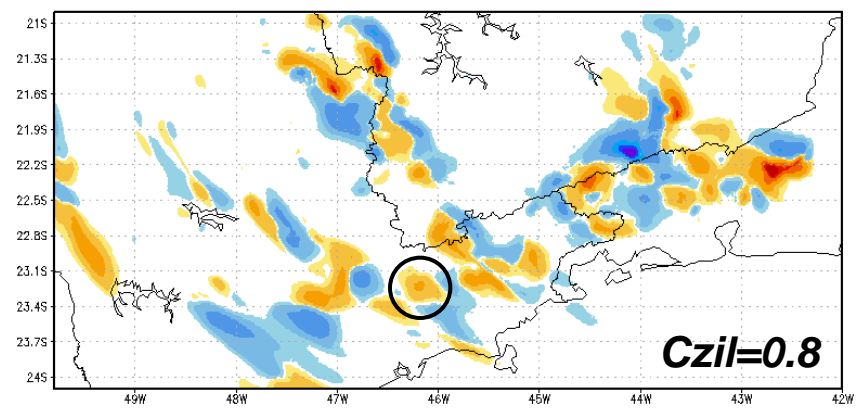
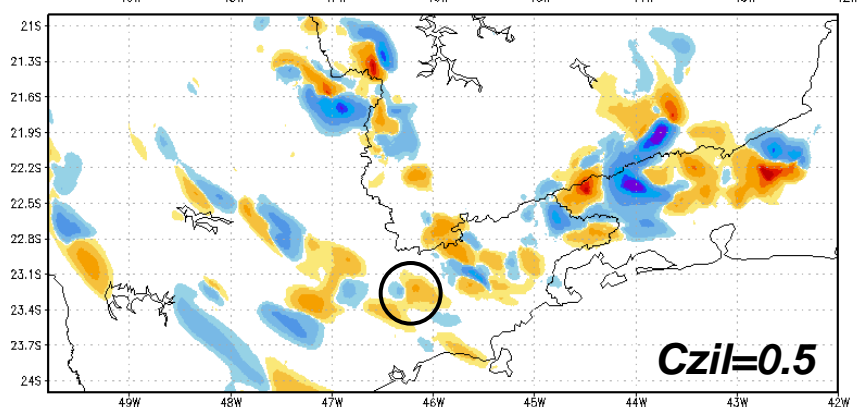
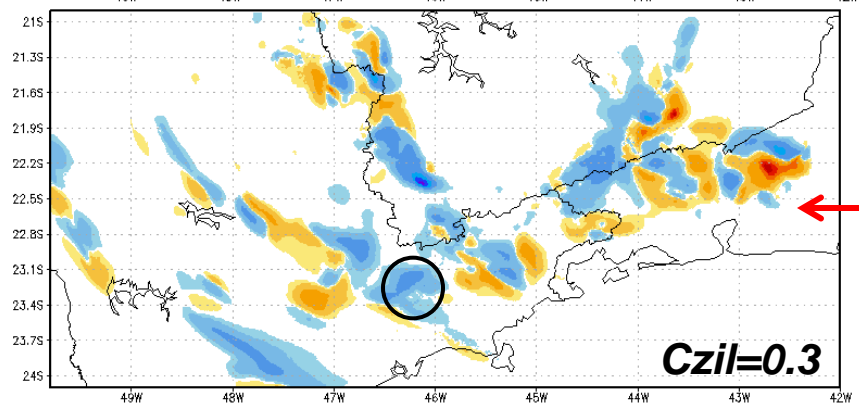
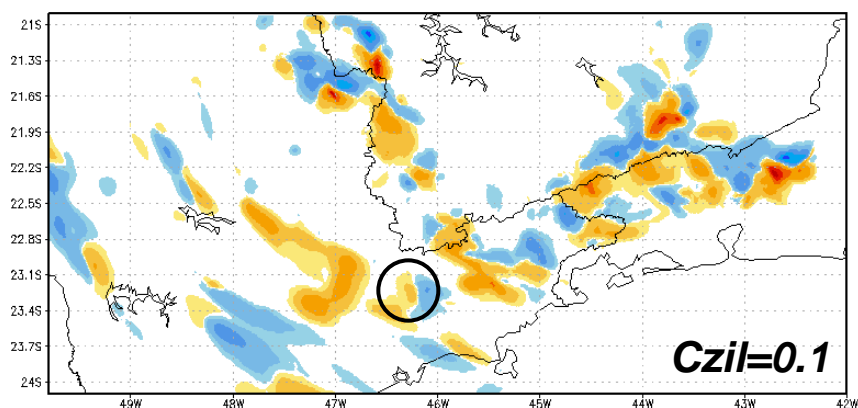
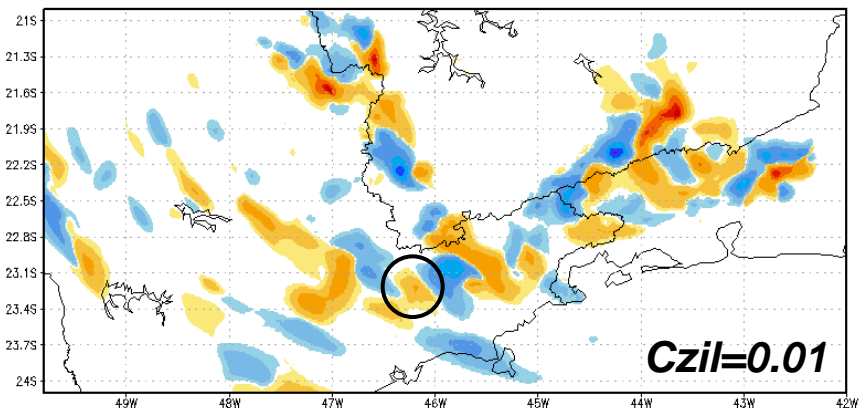


Precipitação acumulada (mm/dia) – Exp Controle
Período: 00Z14FEB2013-00Z15FEB2013



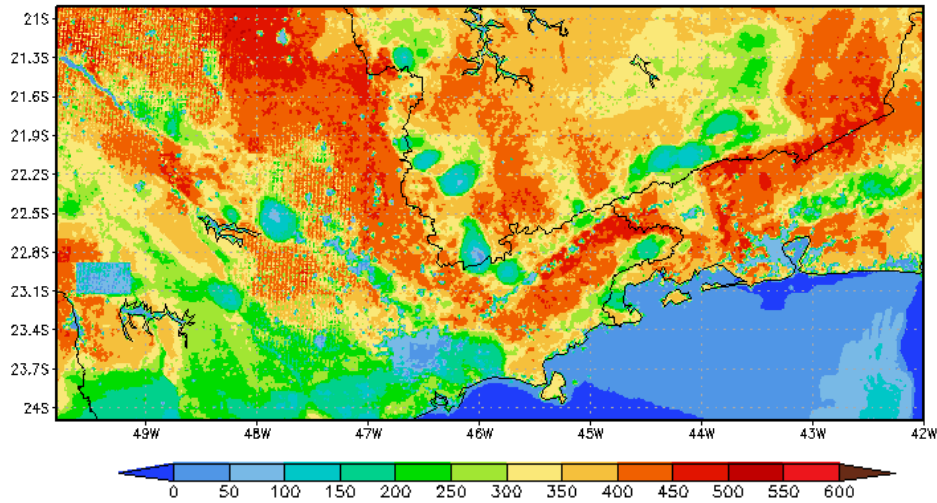
Campos de diferença da precipitação – Cntrl-Exp

Período: 00Z14FEB2013-00Z15FEB2013

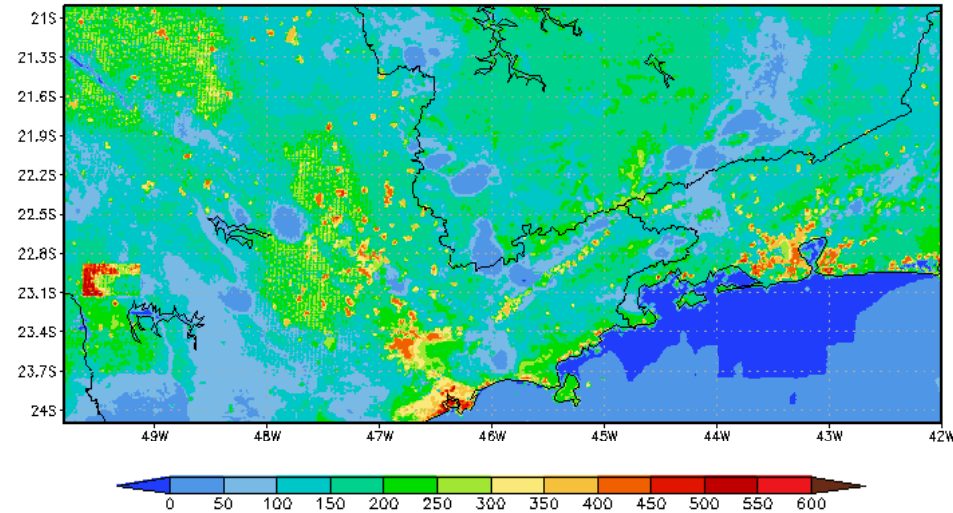


Campos espaciais - Simulação Controle

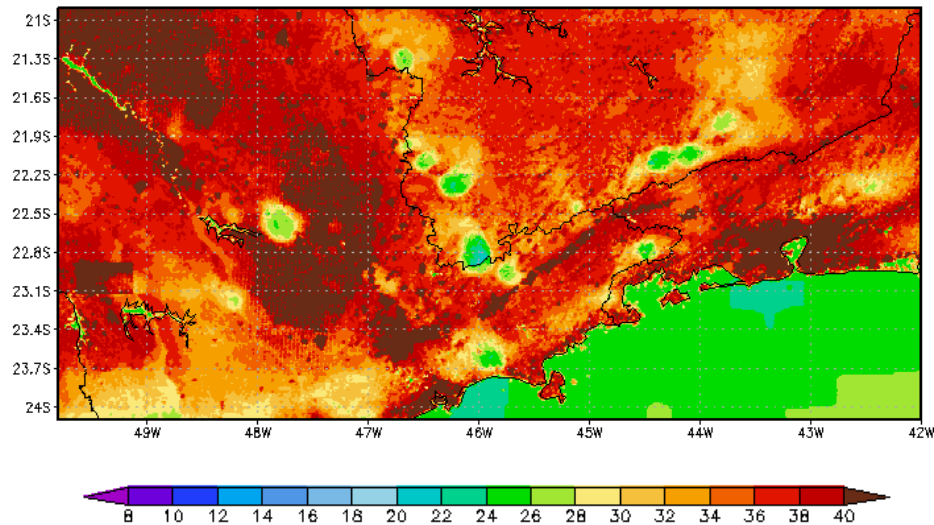
Sfc Latent Heat (w/m2) – 18Z14FEB2013



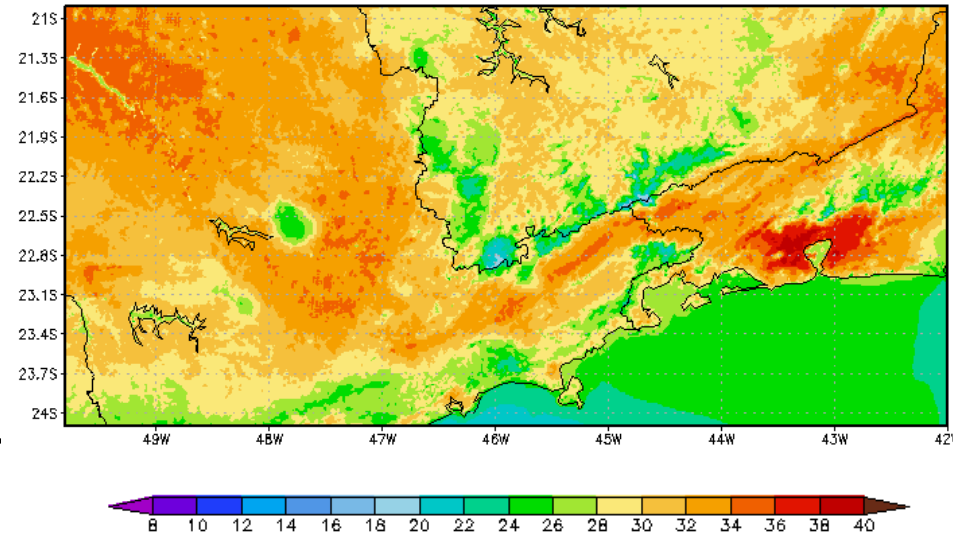
Sfc Sensible Heat (w/m2) – 18Z14FEB2013



Surface Temperature (C) – 18Z14FEB2013

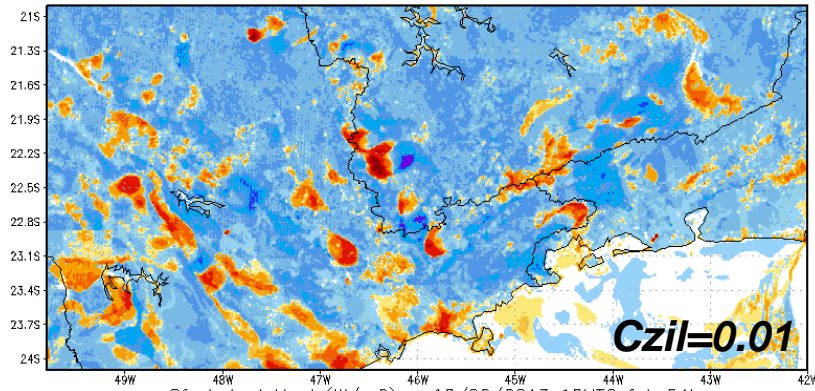


2 m Temperature (C) – 18Z14FEB2013

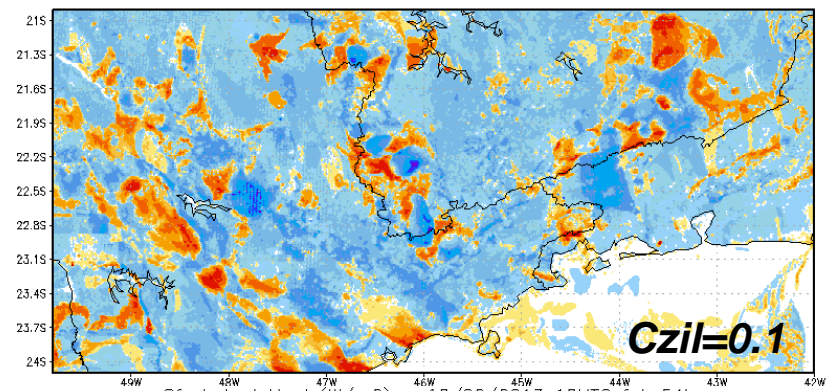


Campos de diferença de fluxo de calor latente – Exp-Cntrl

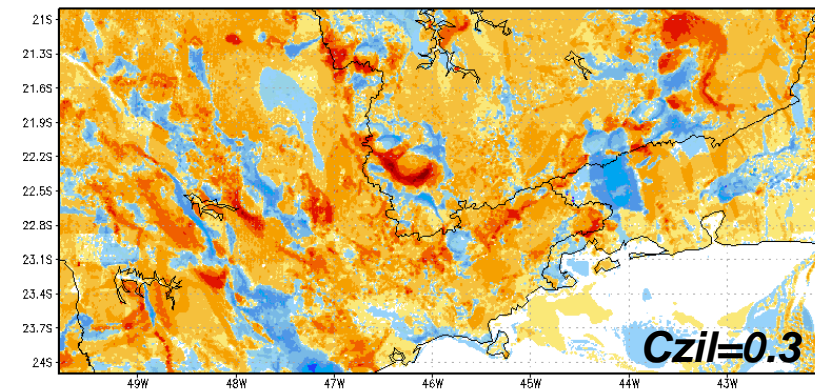
Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



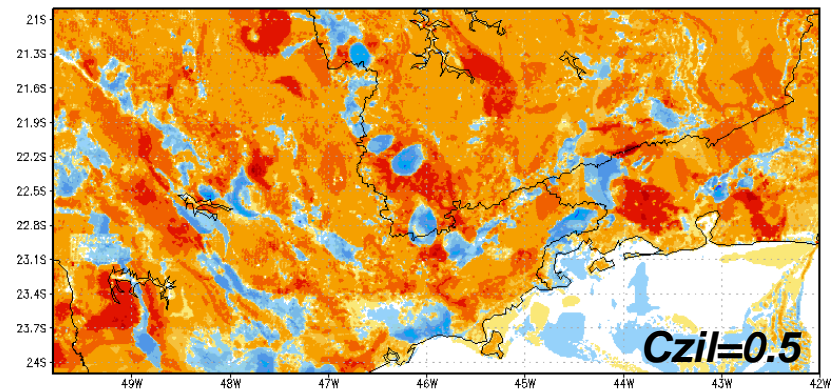
Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



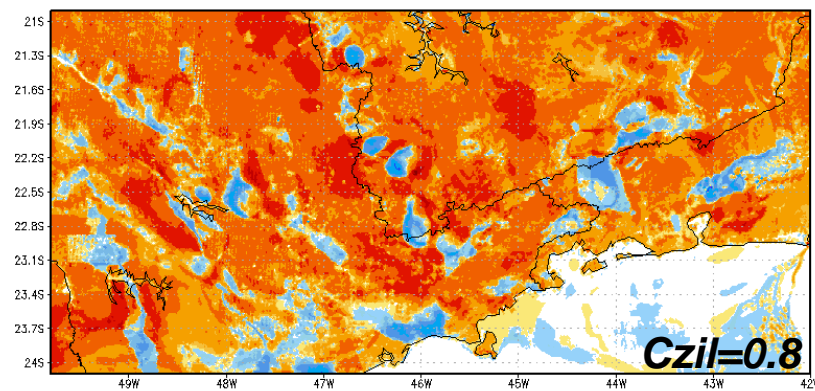
Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



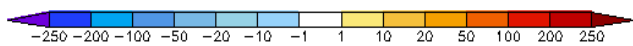
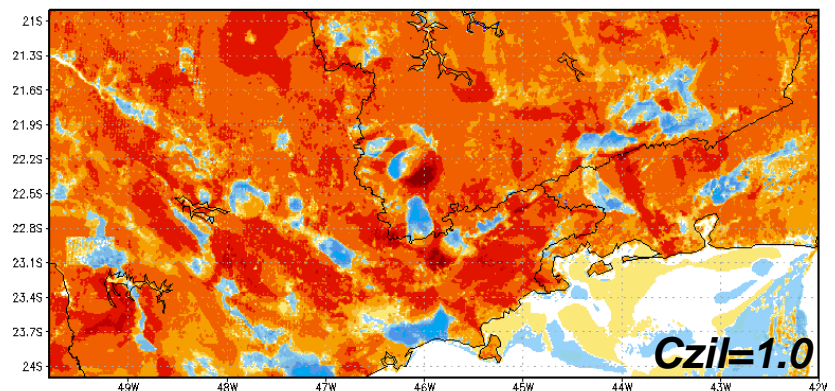
Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



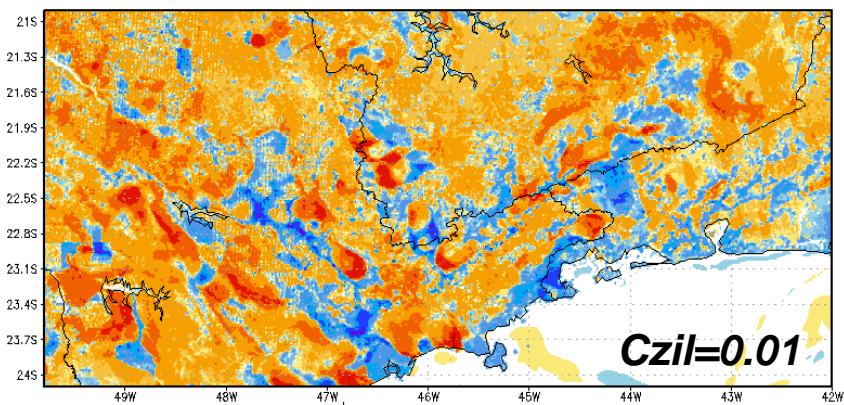
Sfc Latent Heat (W/m²) – 12/02/2013 12UTC fct=54h



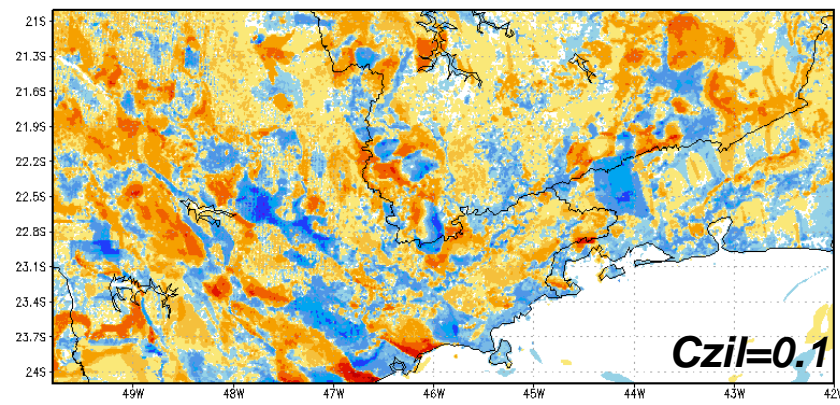
→ Em geral, o aumento do Czil levou a uma diminuição no fluxo de calor latente

Campos de diferença de fluxo de calor sensível – Exp-Cntrl

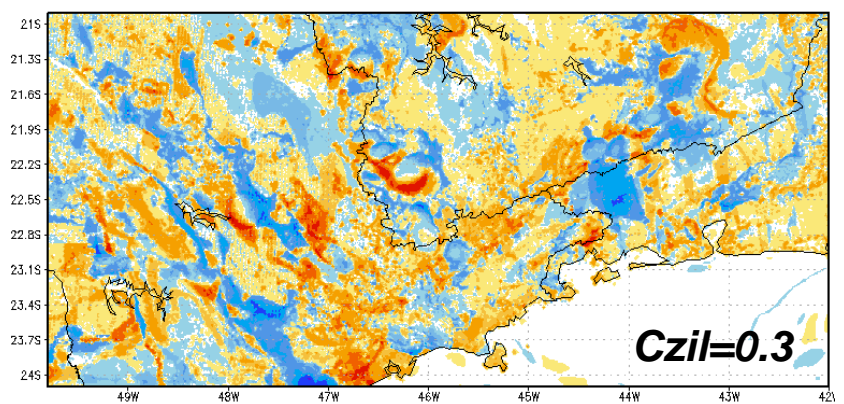
Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



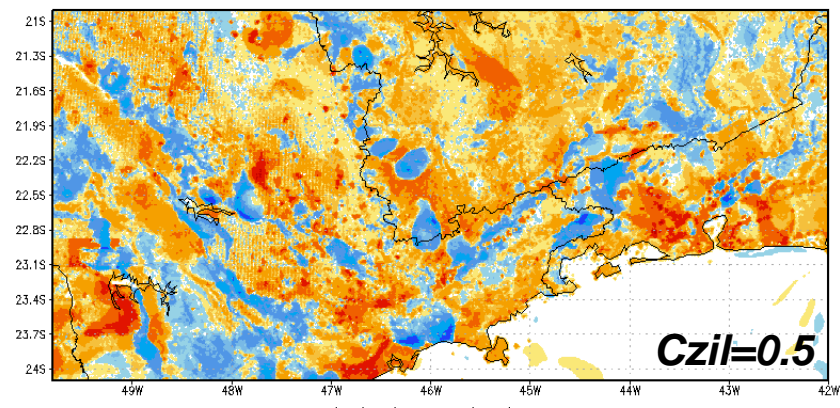
Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



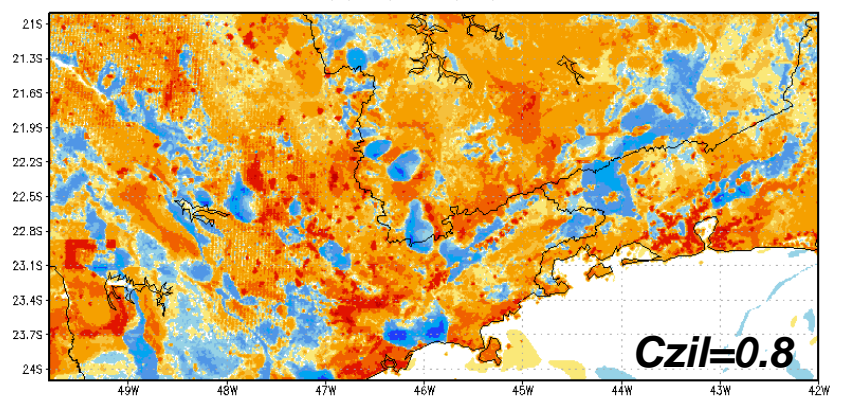
Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



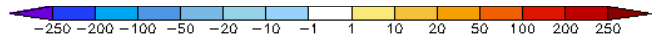
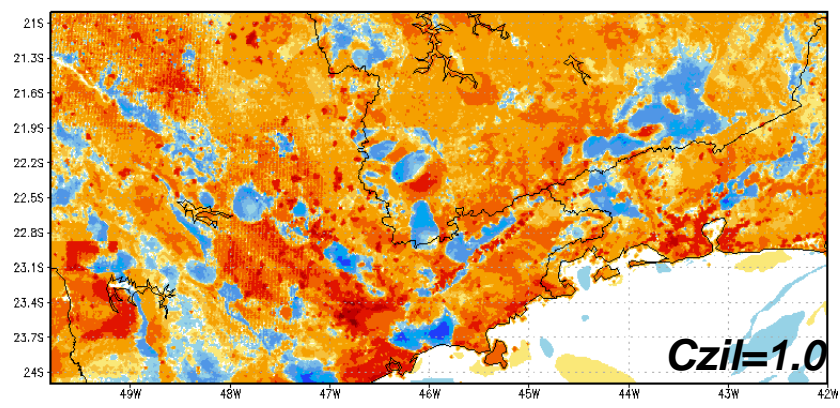
Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



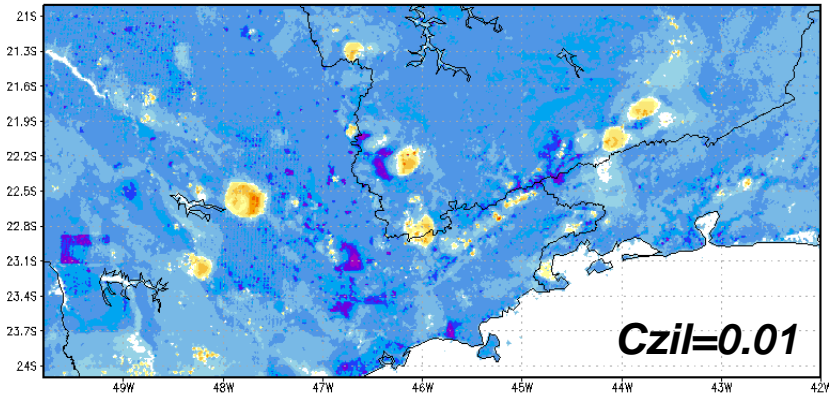
Sfc Sensible Heat (W/m²) – 12/02/2013 12UTC fct=54h



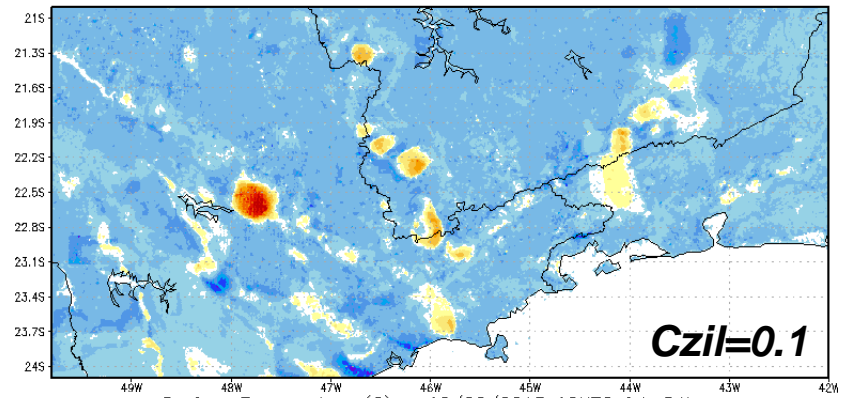
→ Em geral, o aumento do Czil levou a uma diminuição no fluxo de calor sensível

Campos de diferença de Temperatura da superfície – Cntrl-Exp

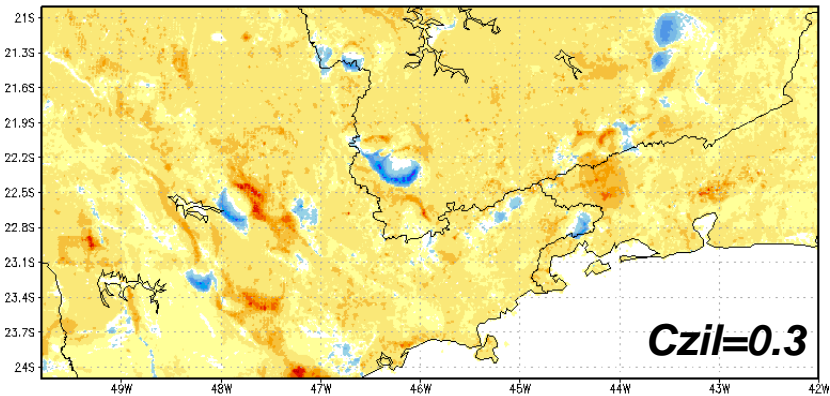
Surface Temperature (C) – 12/02/2013 12UTC fct=54h



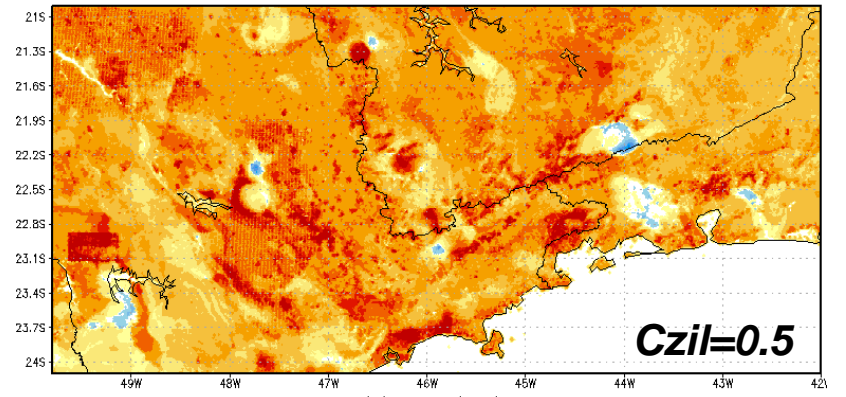
Surface Temperature (C) – 12/02/2013 12UTC fct=54h



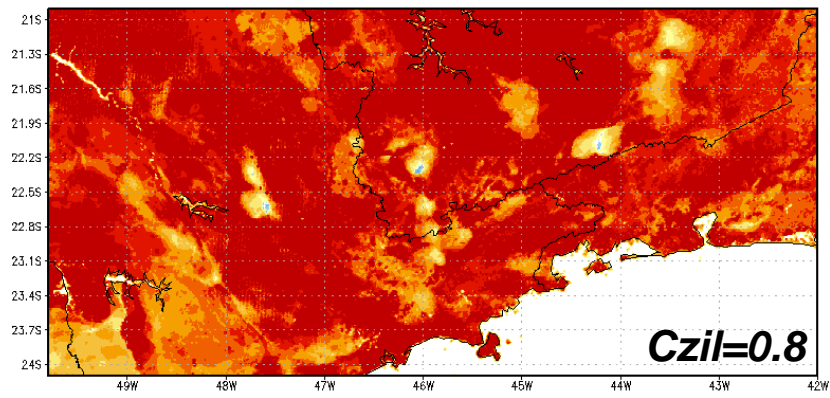
Surface Temperature (C) – 12/02/2013 12UTC fct=54h



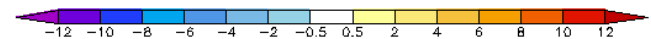
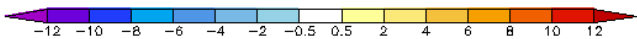
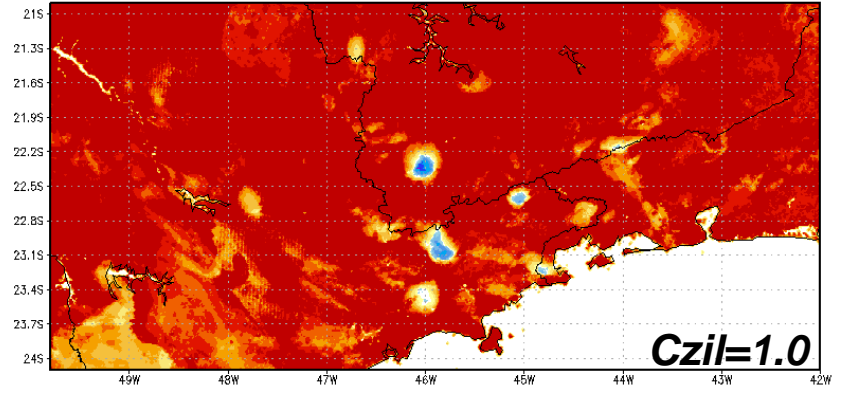
Surface Temperature (C) – 12/02/2013 12UTC fct=54h



Surface Temperature (C) – 12/02/2013 12UTC fct=54h



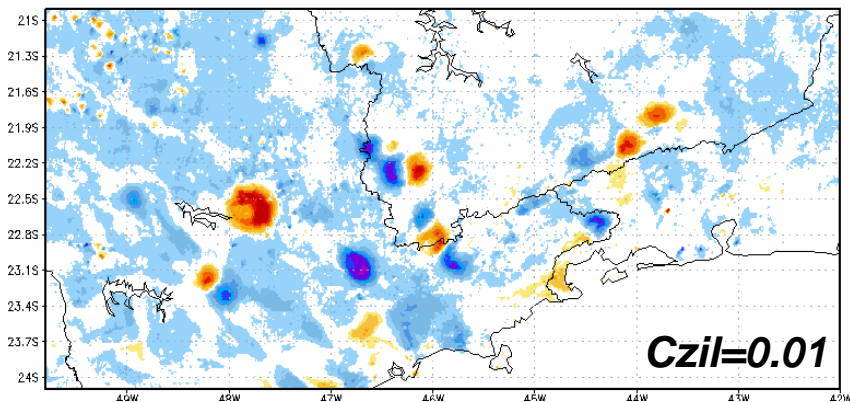
Surface Temperature (C) – 12/02/2013 12UTC fct=54h



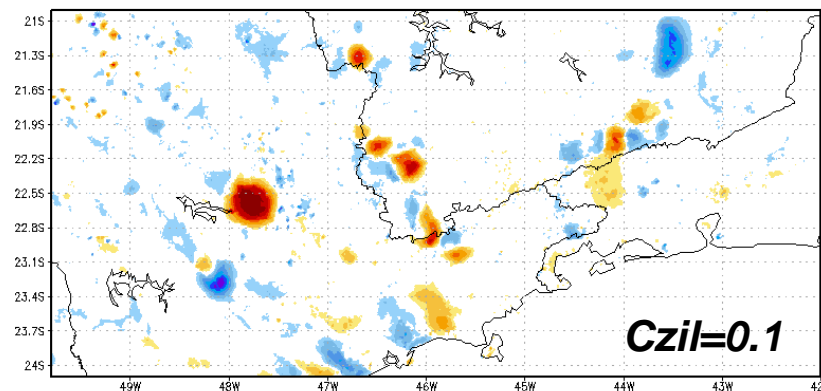
→ Em média, o aumento do Czil levou a uma diminuição na temperatura de sfc.

Campos de diferença de Temperatura a 2m – Cntrl-Exp

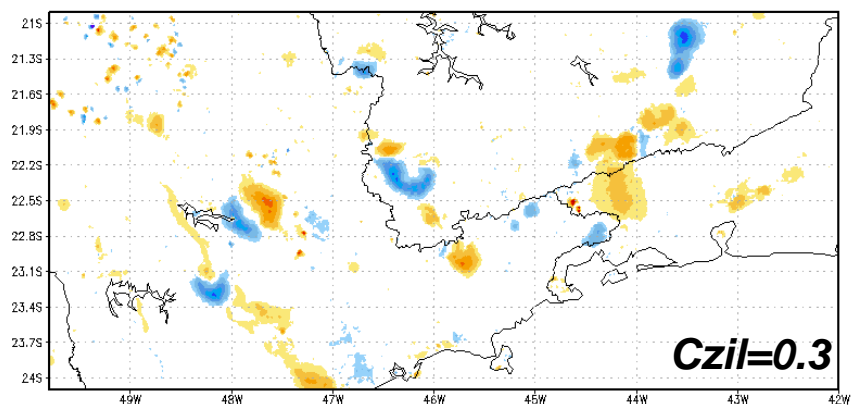
Temperature 2m (C) – 12/02/2013 12UTC fct=54h



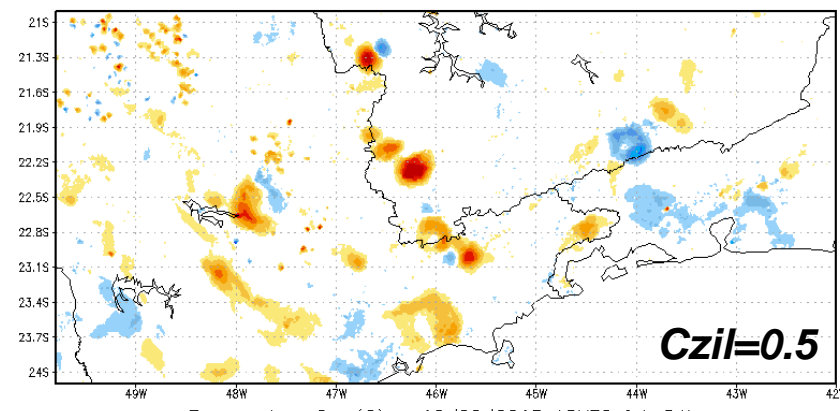
Temperature 2m (C) – 12/02/2013 12UTC fct=54h



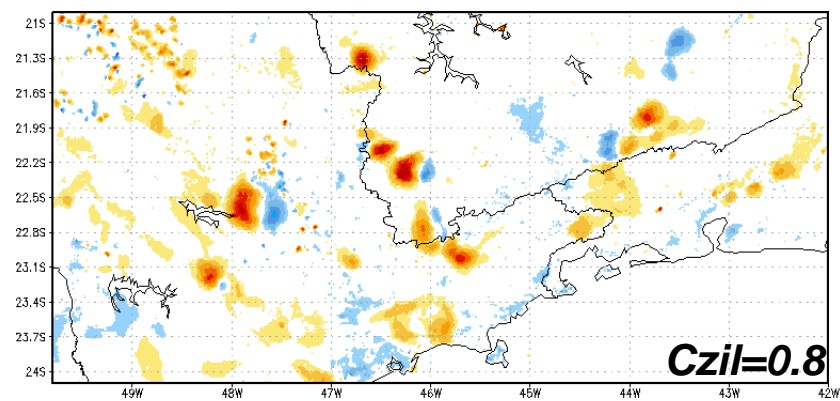
Temperature 2m (C) – 12/02/2013 12UTC fct=54h



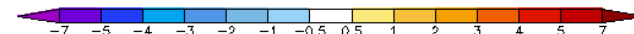
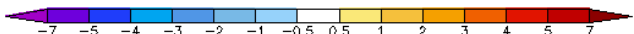
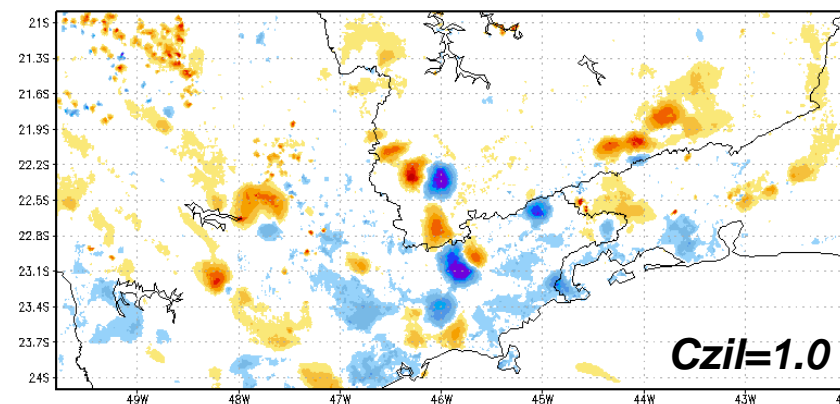
Temperature 2m (C) – 12/02/2013 12UTC fct=54h



Temperature 2m (C) – 12/02/2013 12UTC fct=54h



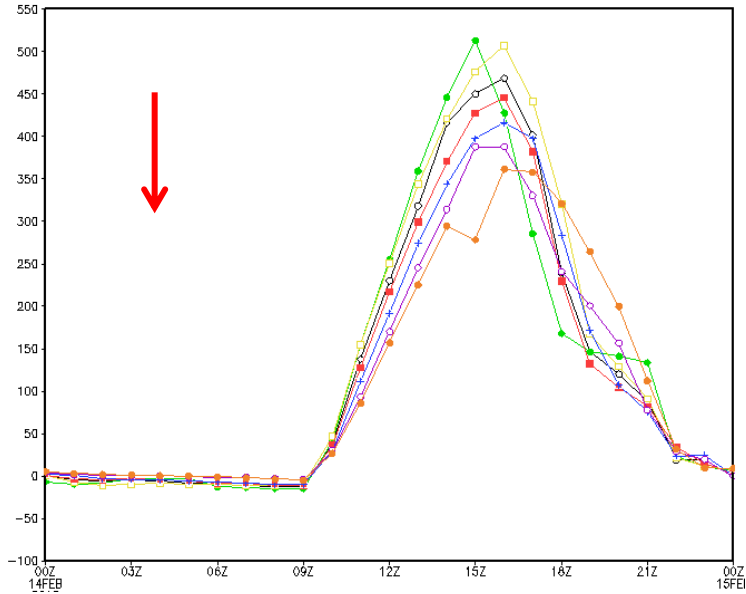
Temperature 2m (C) – 12/02/2013 12UTC fct=54h



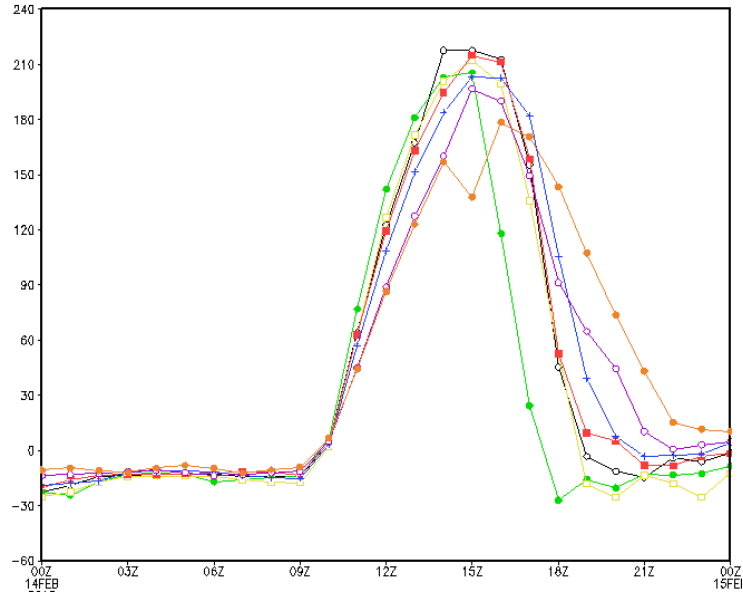
→ O aumento do Czil afetou de forma variada de uma região para outra.

Ciclo Diurno – Lat=-23.1; Lon=-46.8 - 00Z14feb2013

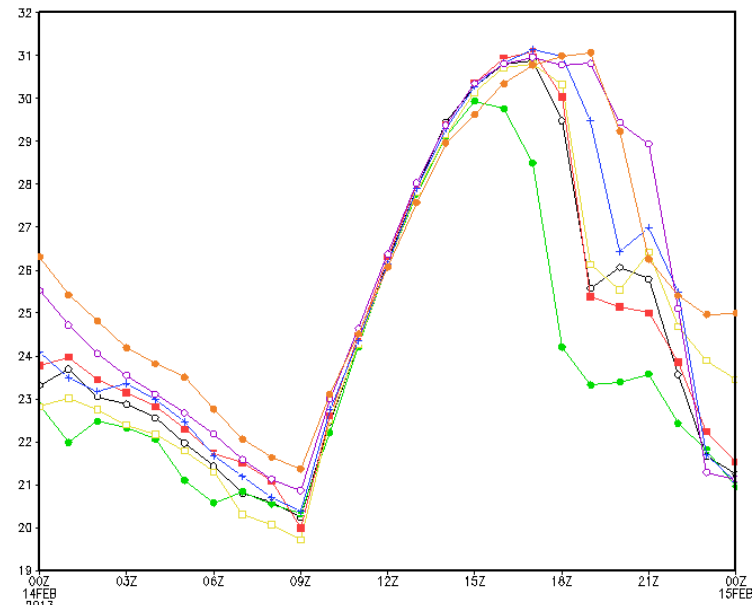
CLSF



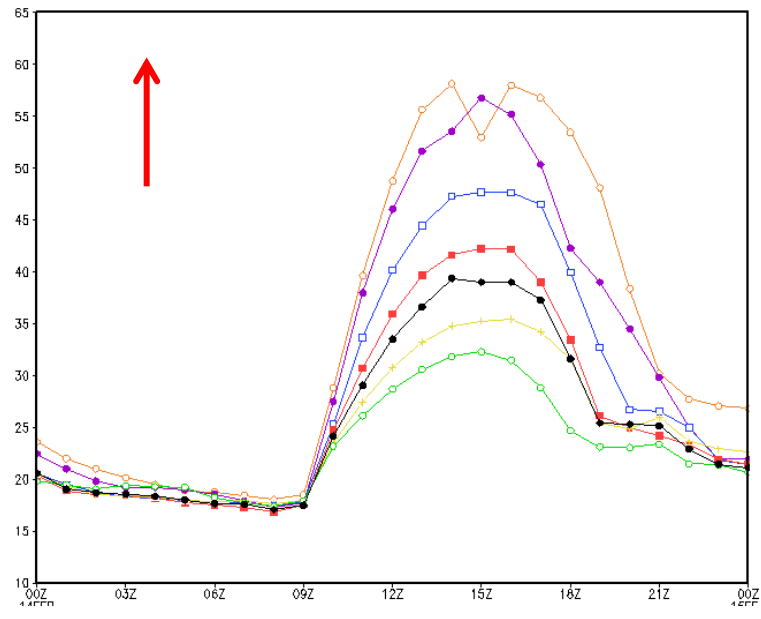
CSSF



TP2M



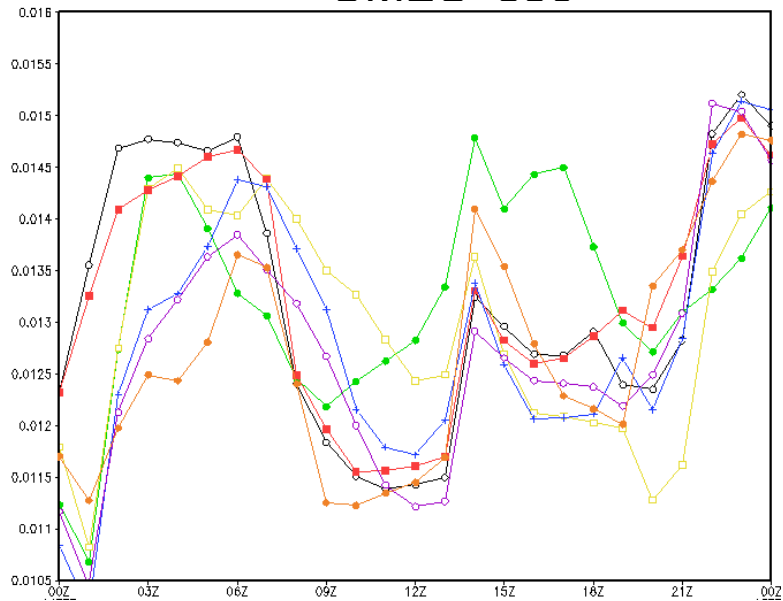
TSFC



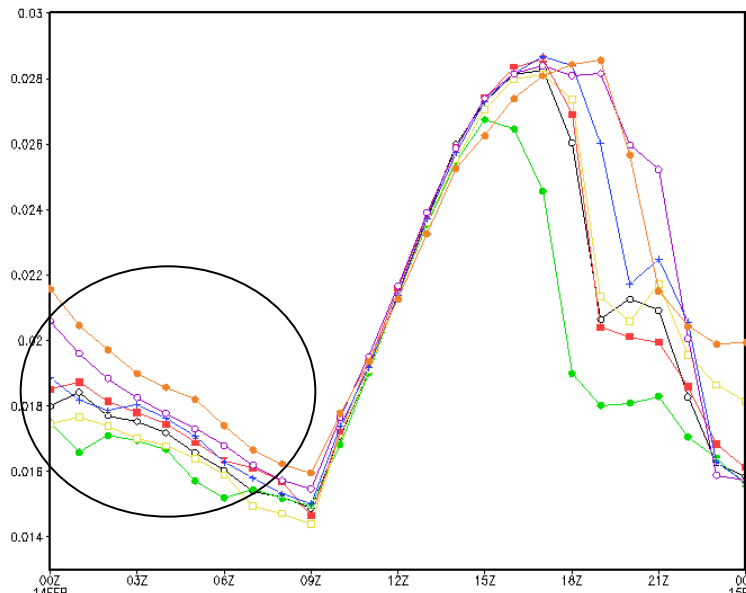
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- Czil=0.1
- Czil=0.3
- Czil=0.5
- Czil=0.8
- Czil=1.0

Ciclo Diurno – Lat=-23.1; Lon=-46.8 - 00Z14feb2013

UMES 850

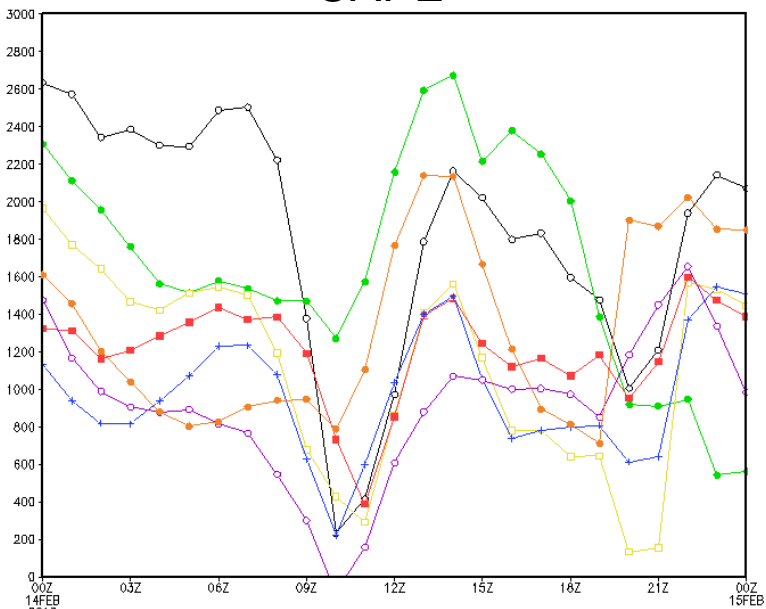


UMES2M

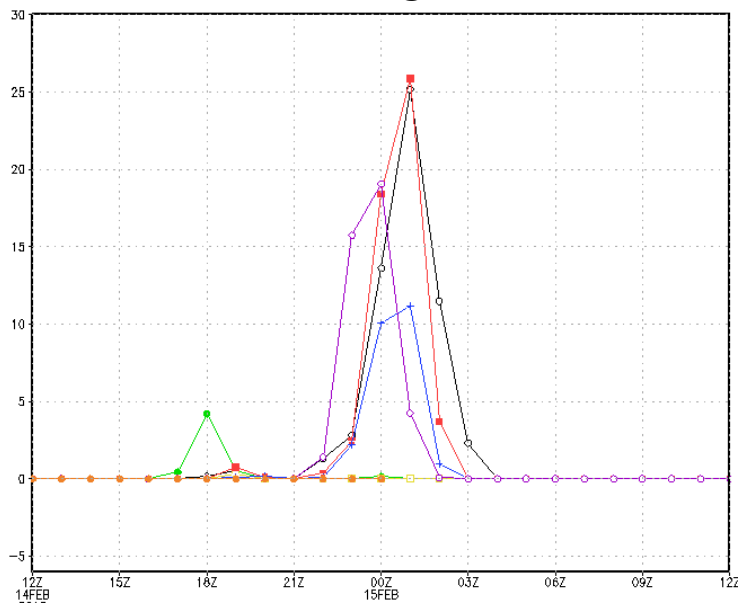


- Controle
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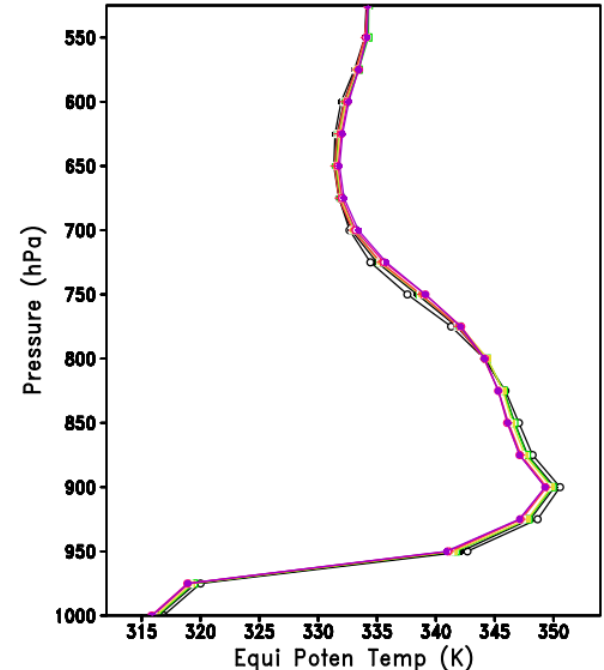
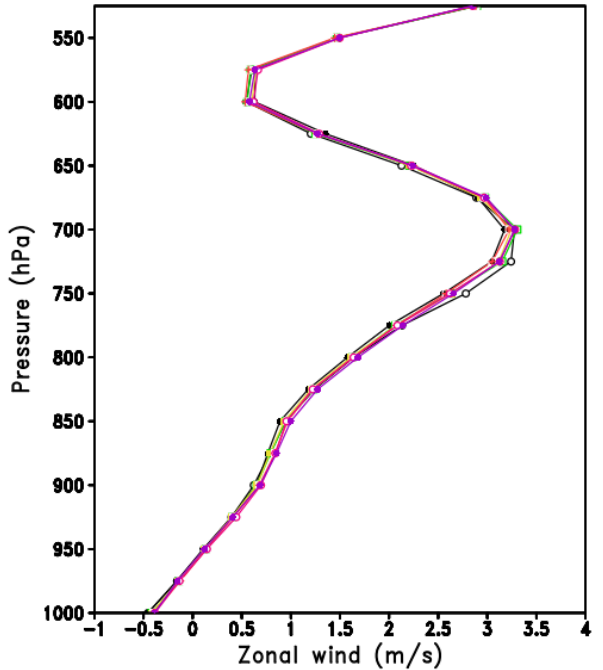
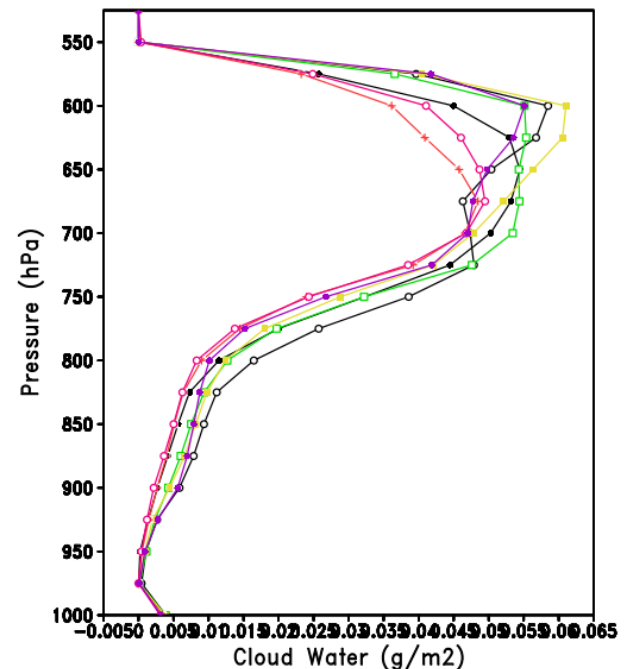
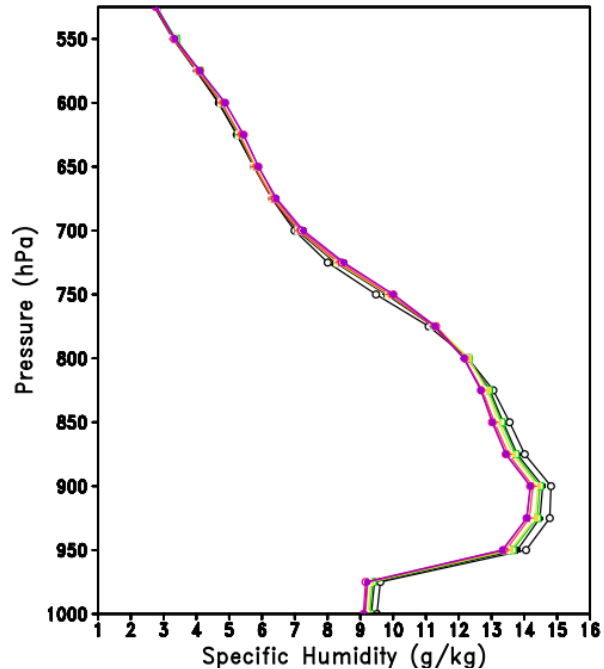
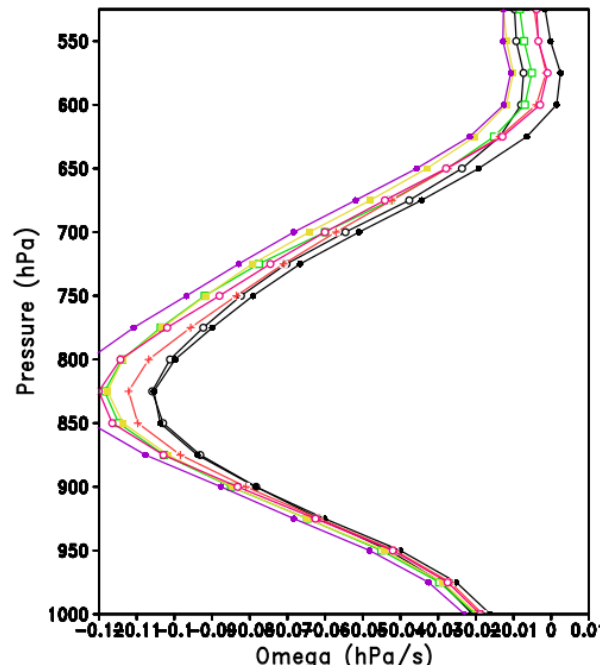
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PREC

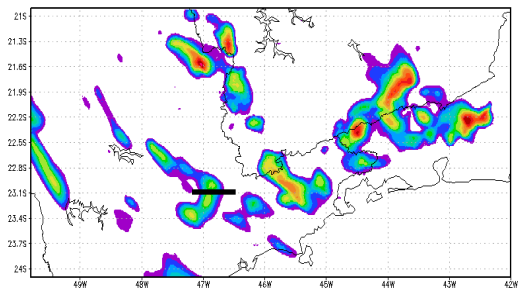
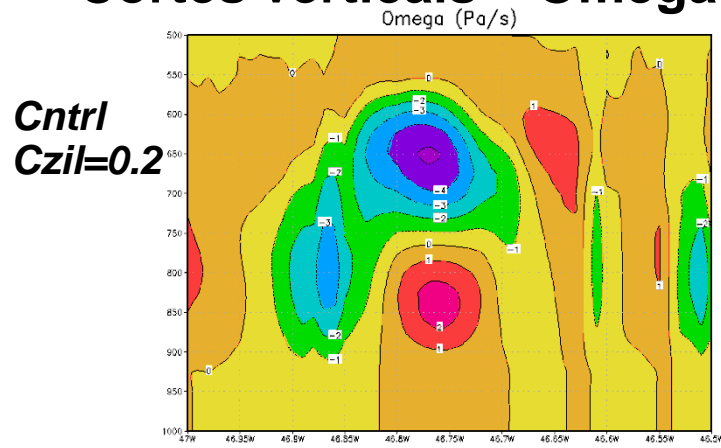


Perfil Vertical – Lat=-23.1; Lon=-46.8 18Z14feb2013

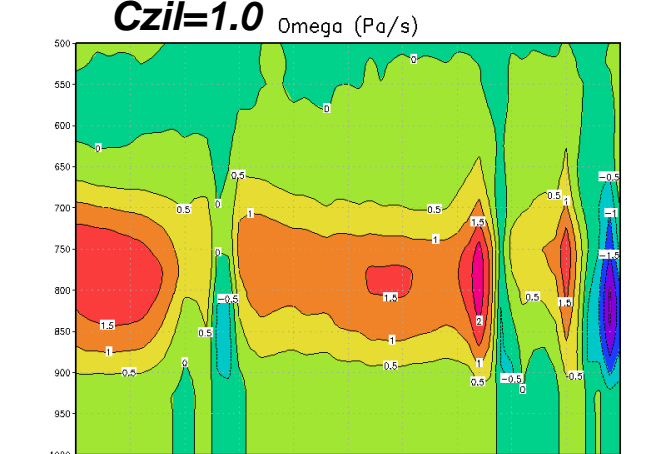
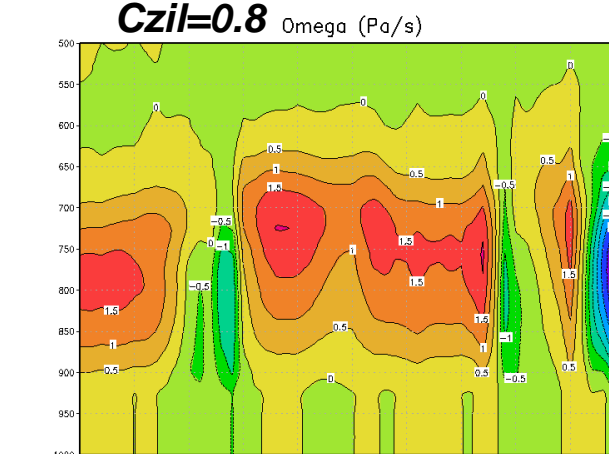
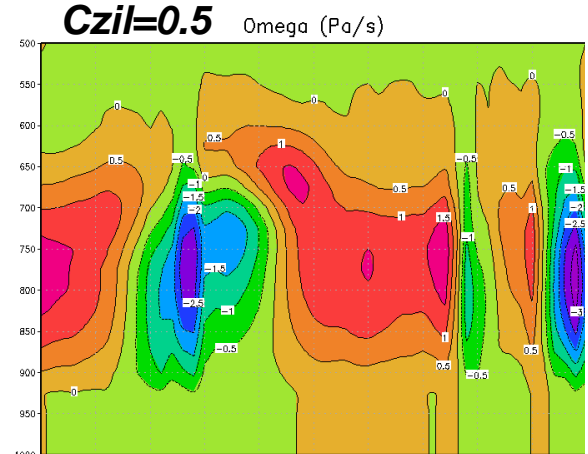
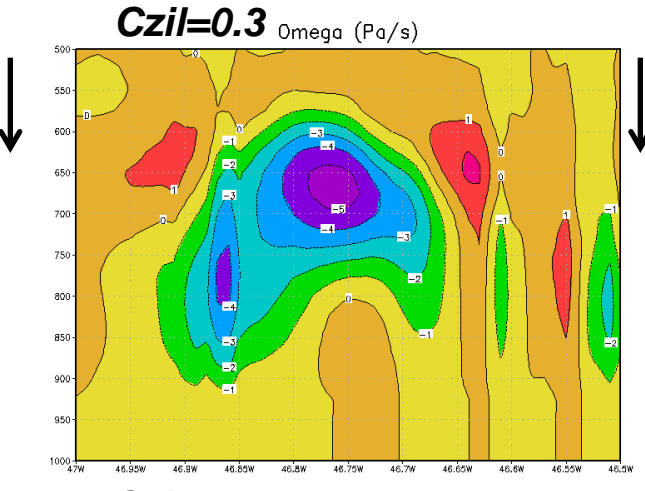
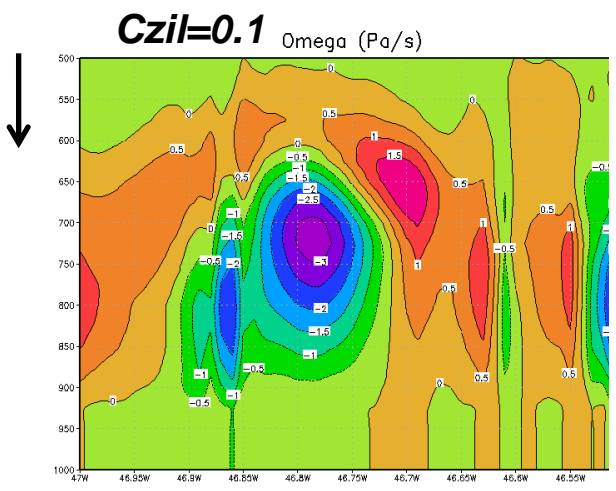
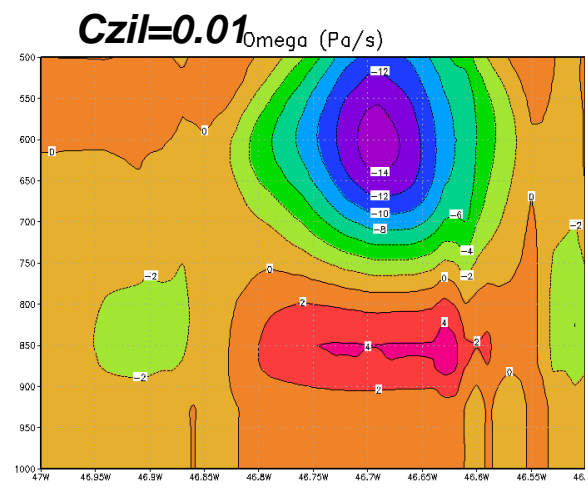


- Controle
- Czil=0.01
- - - Czil=0.1
- Czil=0.3
- Czil=0.5
- Czil=0.8
- Czil=1.0

Cortes verticais – Omega (Pa/s)

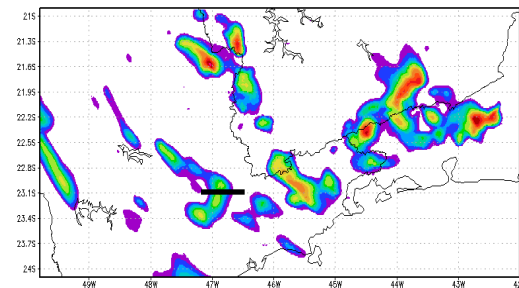
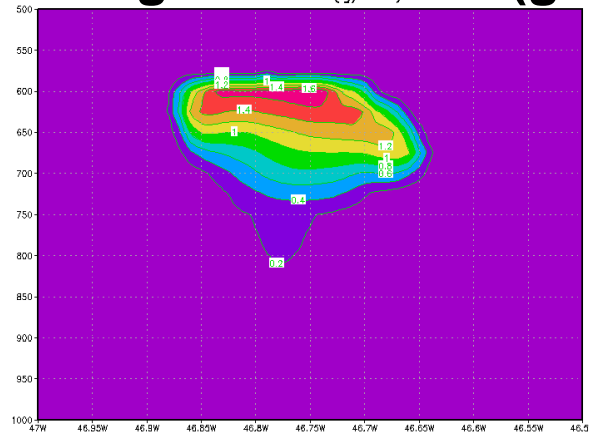


Lat = -23.1
Lon = -47 -46.5



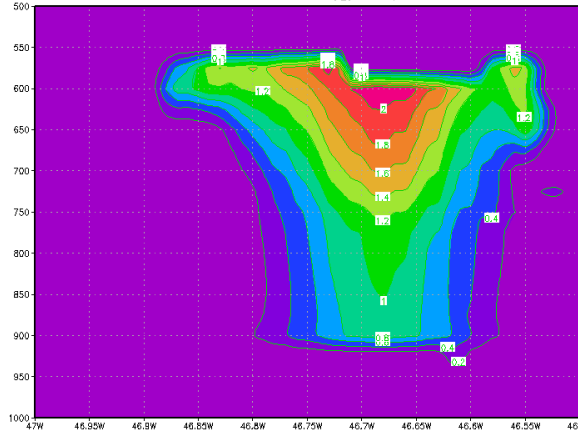
Cortes verticais – Água da nuvem (g/m²)

Cntrl
Czil=0.2

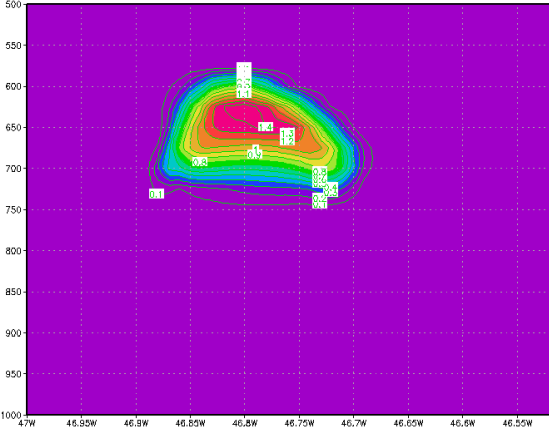


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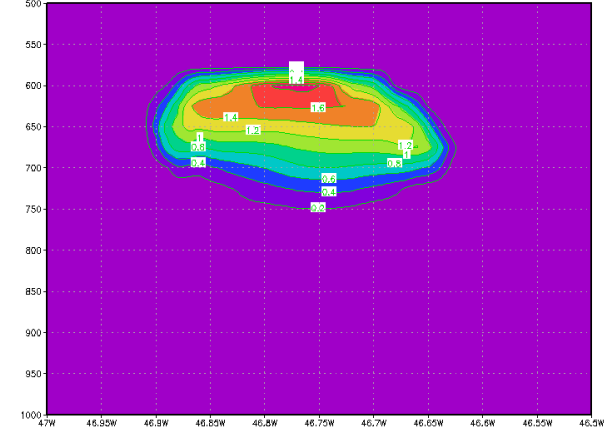
Czil=0.01 Cloud Water(g/m²)



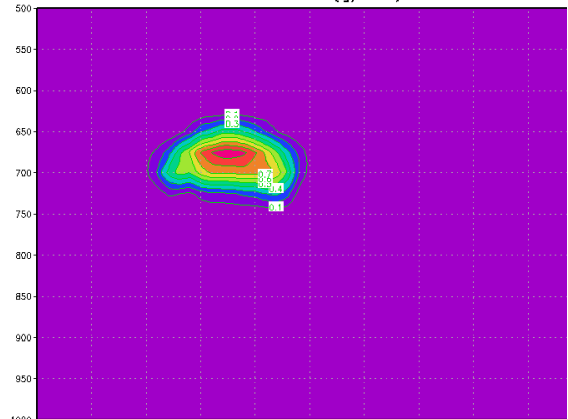
Czil=0.1 Cloud Water(g/m²)



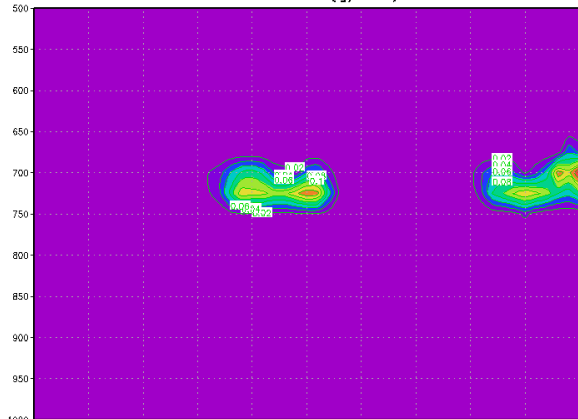
Czil=0.3 Cloud Water(g/m²)



Czil=0.5 Cloud Water(g/m²)



Czil=0.8 Cloud Water(g/m²)



GES

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Conclusões

- O coeficiente C_{zil} altera indiretamente os fluxos de superfície bem como as condições das camadas atmosféricas próximas a superfície.
- Em geral, o aumento no valor do coeficiente C_{zil} aumenta os fluxos de calor latente, de calor sensível e a temperatura na superfície.
- A diferença nos campos de temperatura a 2m e precipitação teve um comportamento variado com o aumento do coeficiente C_{zil} .
- O aumento do coeficiente altera tanto a quantidade quanto a localização da precipitação produzida.
- Para o caso de chuva que ocorreu em SP, o valor $C_{zil}=0.3$ apresentou os melhores resultados, considerando que houve um aumento na precipitação produzida.

Análises futuras:

- Testar um C_{zil} dinâmico, variando em função da altura de vegetação.
- Comparação com dados observacionais.

Obrigada!

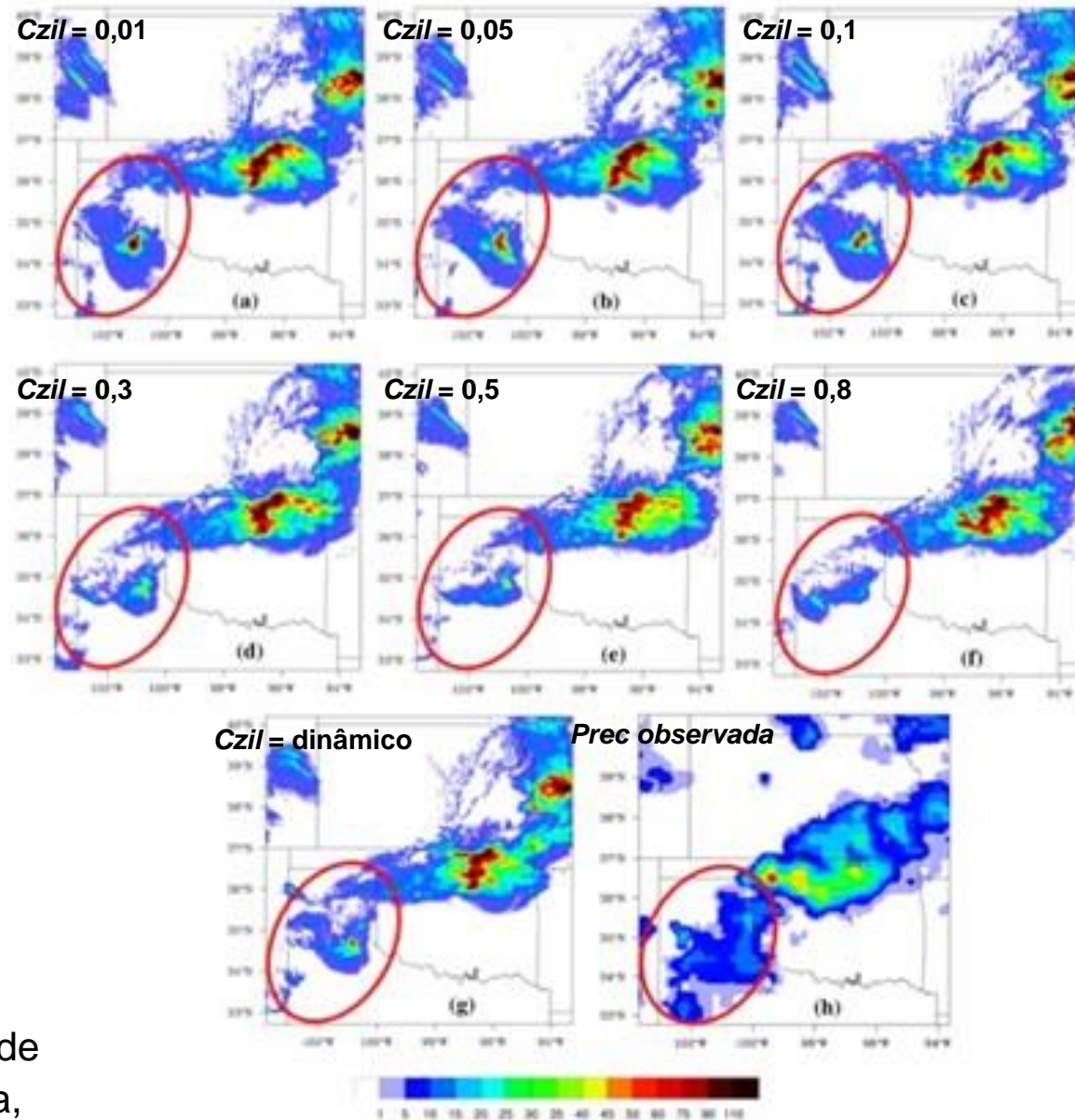
daniela.rodriques@cptec.inpe.br

Revisão Bibliográfica

Coeficiente de troca

Zheng et al. (2015):

- Investigaram o impacto do acoplamento spf-atm sobre a convecção e precipitação
- Modelo WRF com 3 km
- Resultados destaca que um $Czil$ constante não afeta a localização geral, mas apenas a amplitude da precipitação simulada.
- O $Czil$ dinâmico melhora tanto o padrão como a localização da precipitação simulada.
- Os resultados com o coeficiente de acoplamento dinâmico mostraram melhorias na simulação dos fluxos de superfície e do estado da atmosfera,



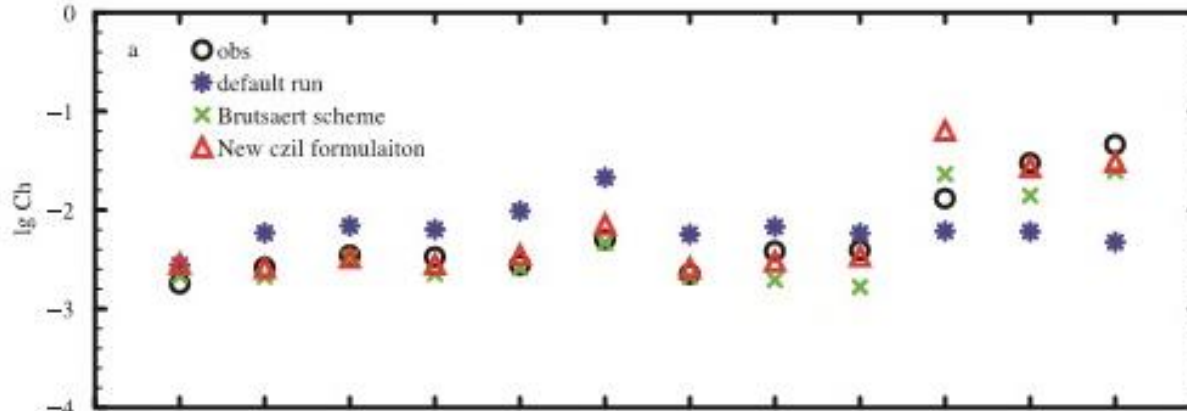
Revisão Bibliográfica

Coeficiente de troca

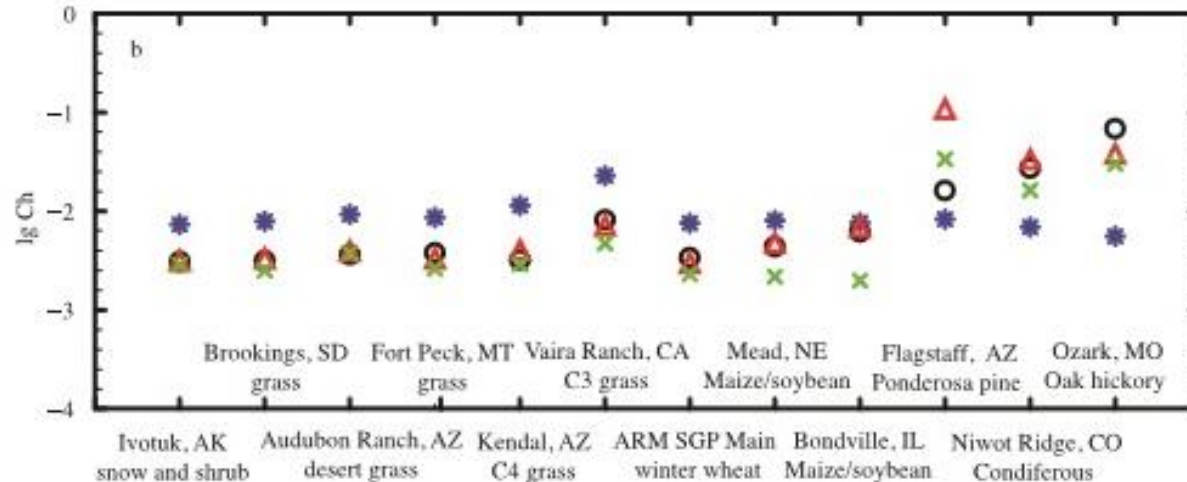
Chen e Zhang (2009):

Valores médios de Ch :

Primavera



Verão



- Dados observados de longo prazo do *AmeriFlux*
- Qual a força de acoplamento spf-atm para diferentes coberturas de spf?

Experimento controle

Noah: $C_{zil} = 0,1$



- **Subestima** Ch para florestas
- **Superestima** Ch para culturas e gramas

Nova formulação Δ :

$$C_{zil} = 10^{(-0.4h)}$$



Este estudo destaca o papel crucial do tratamento correto dos processos de troca à superfície em modelos acoplados de tempo e clima.