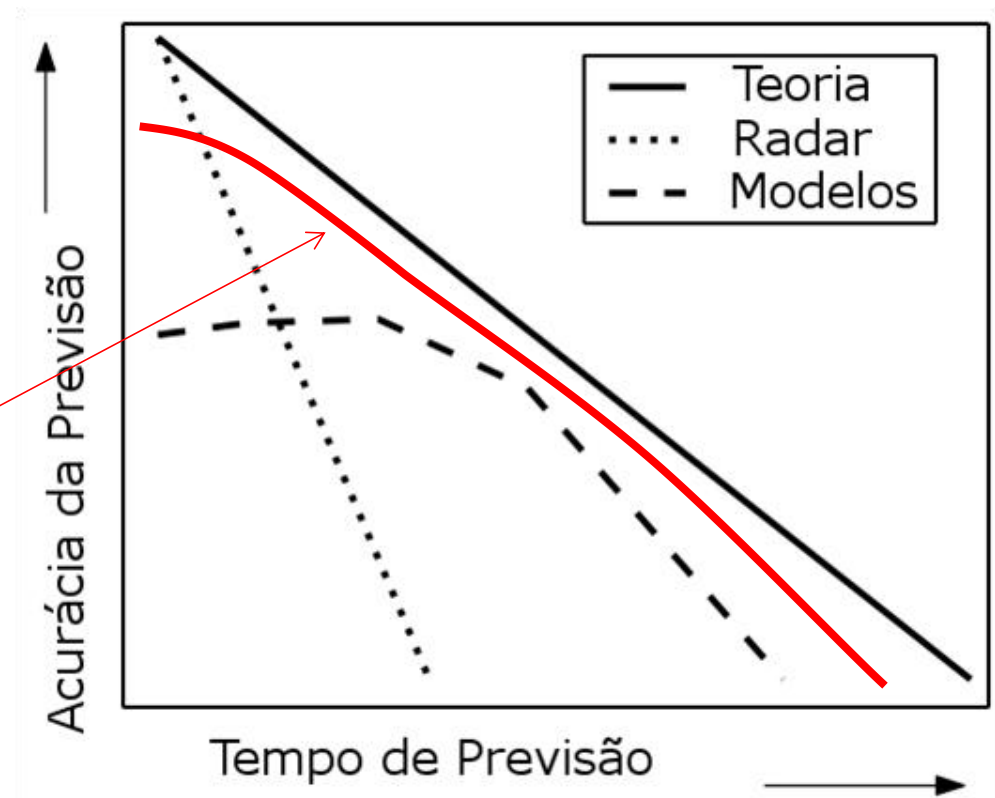


Assimilação de Dados de Radar

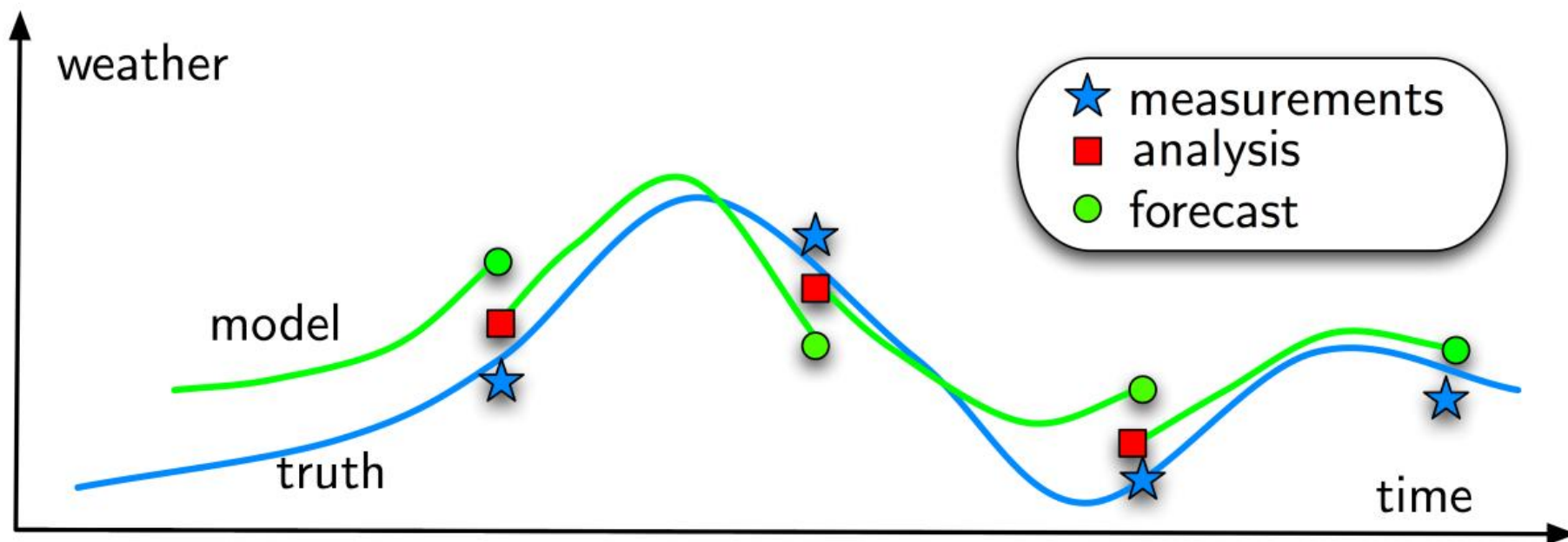
Éder Paulo Vendrasco

eder.vendrasco@inpe.br

Lin et al. (2005) – limitação dos modelos numéricos para previsão de curto prazo (inicialização da mesoescala).

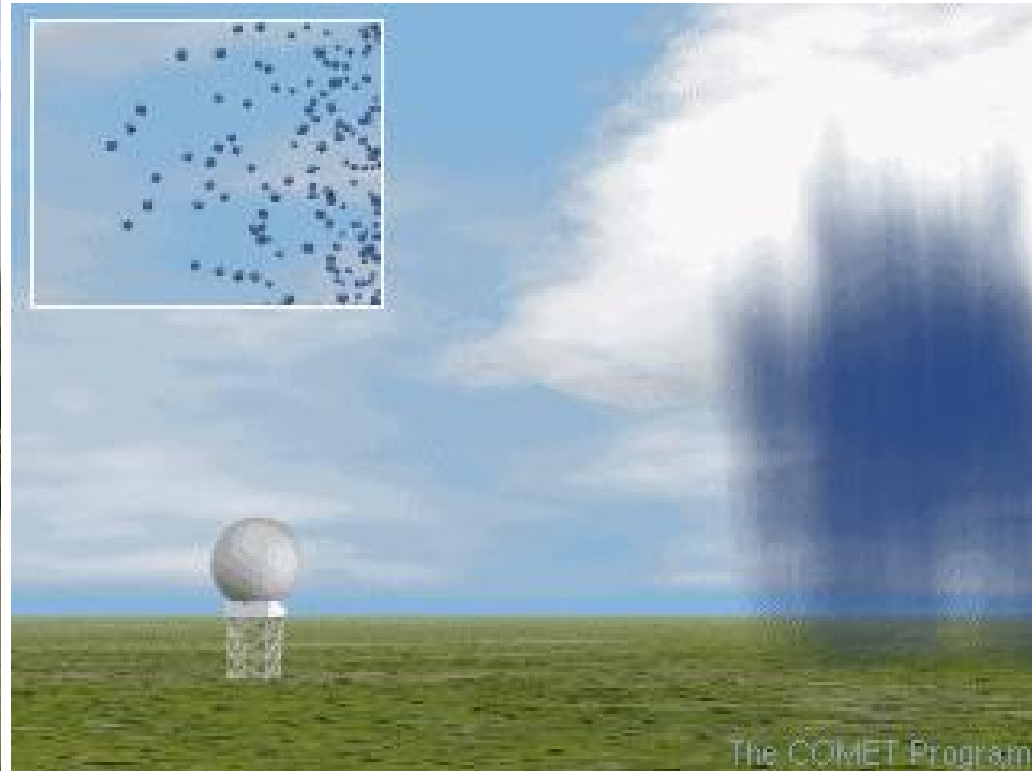


Objetivo da Assimilação
de dados de radar

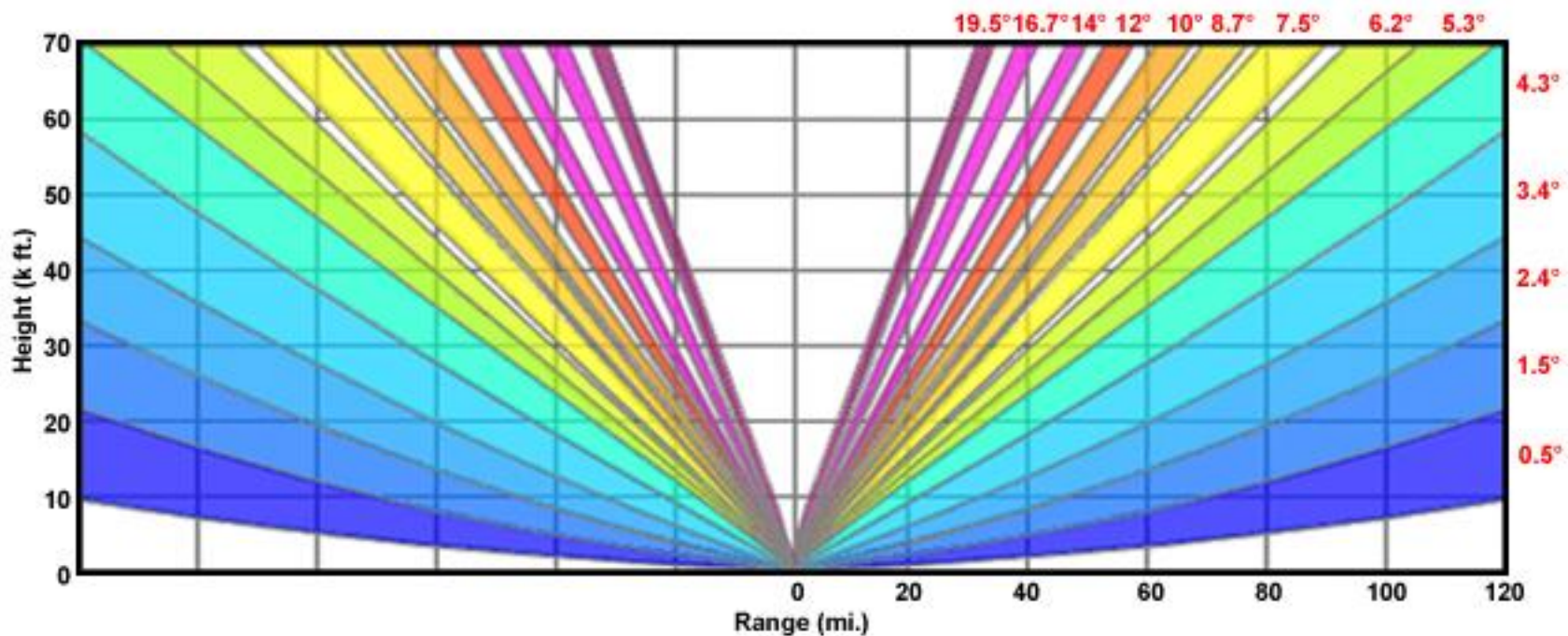


- Background e seus erros
 - Previsão
- Observação e seus erros
 - Observação com Radar

- Erros do modelo
 - Aproximações, parametrizações, discretização, etc...
- Interpolação/Representatividade
- Instrumento
 - Radar
 - Ecos de terreno, obstrução do feixe por alvos não meteorológicos, amostragem, atenuação, calibração, operador observação, etc.

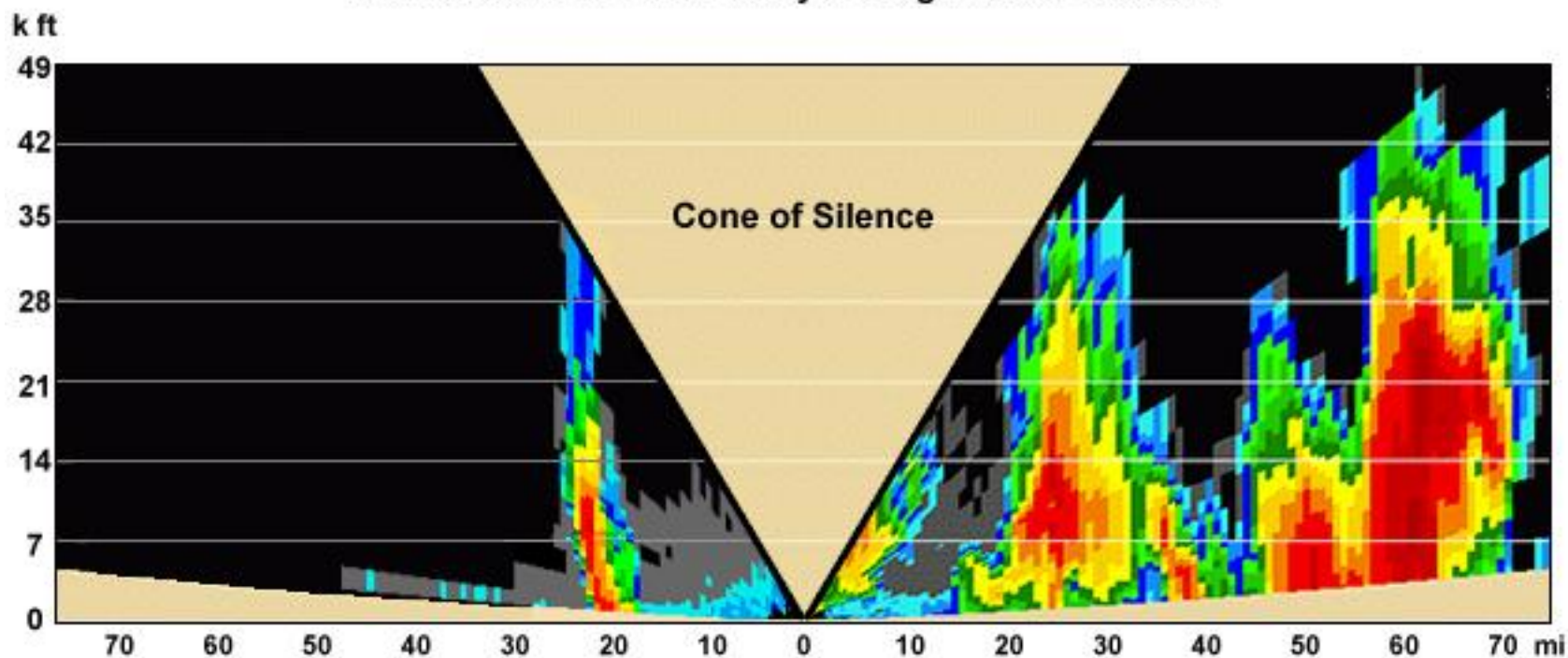


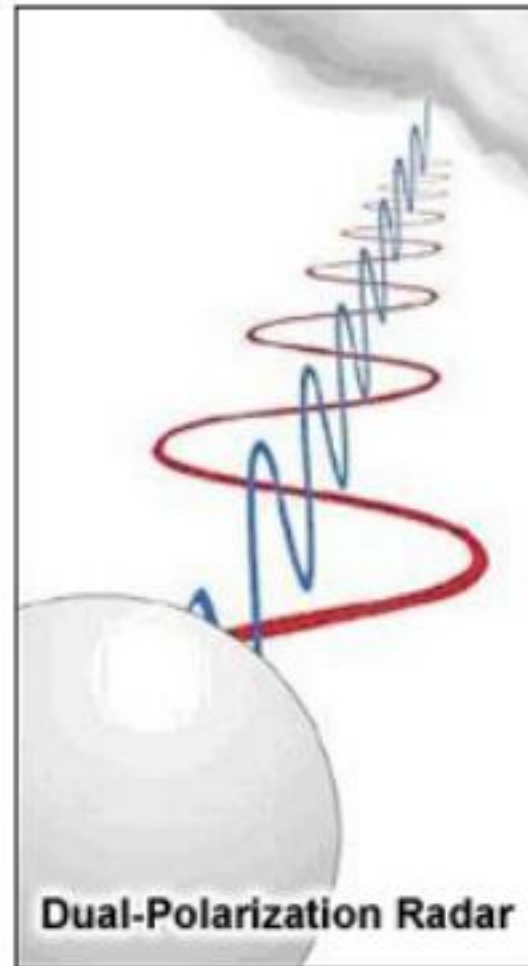
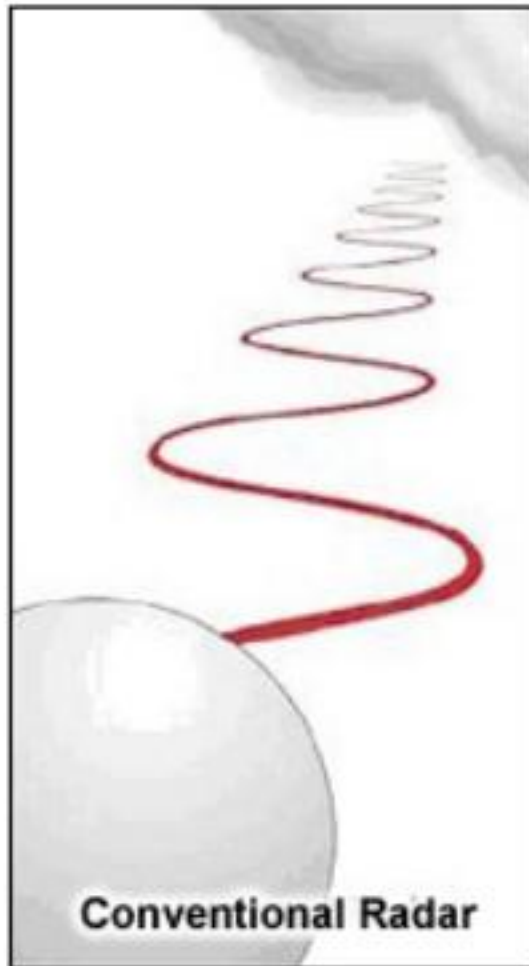
- Varredura do Radar



- Precipitação sobre o radar.

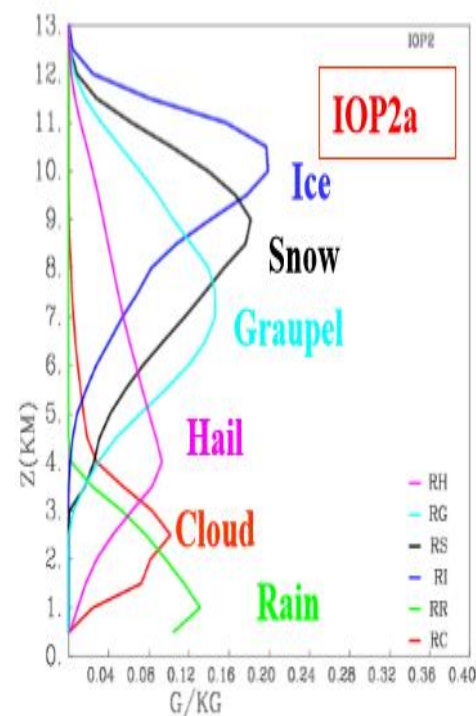
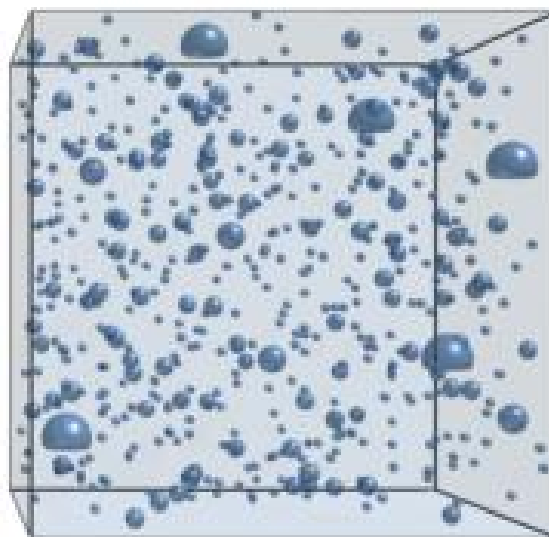
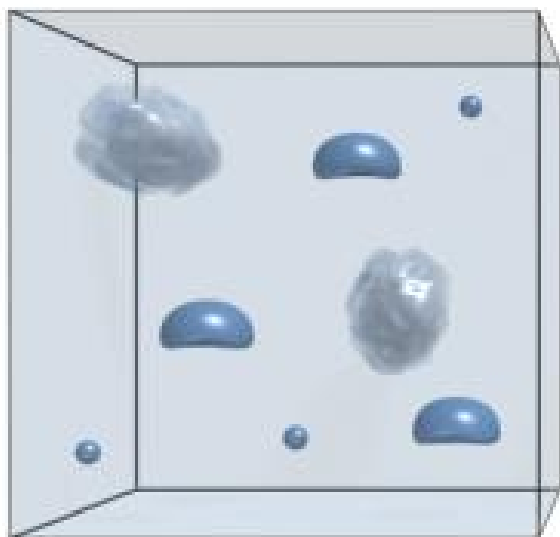
Cross-section of Reflectivity through Radar Location



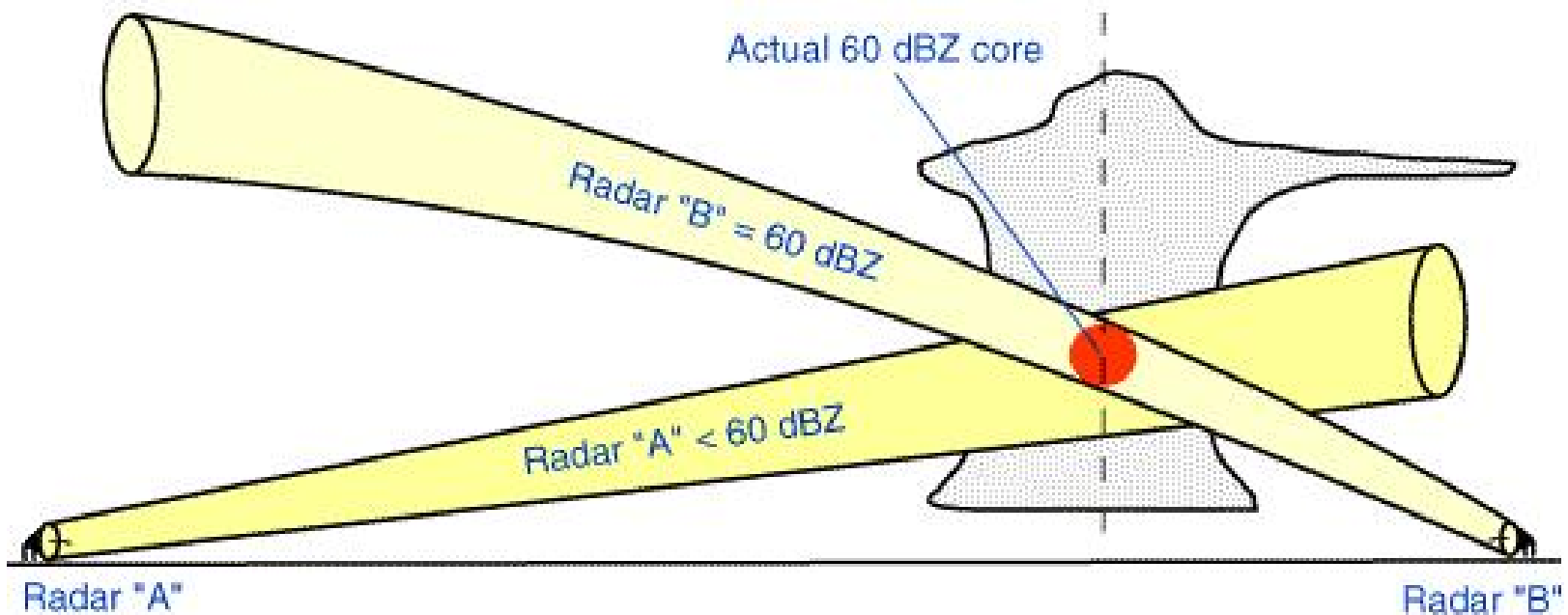


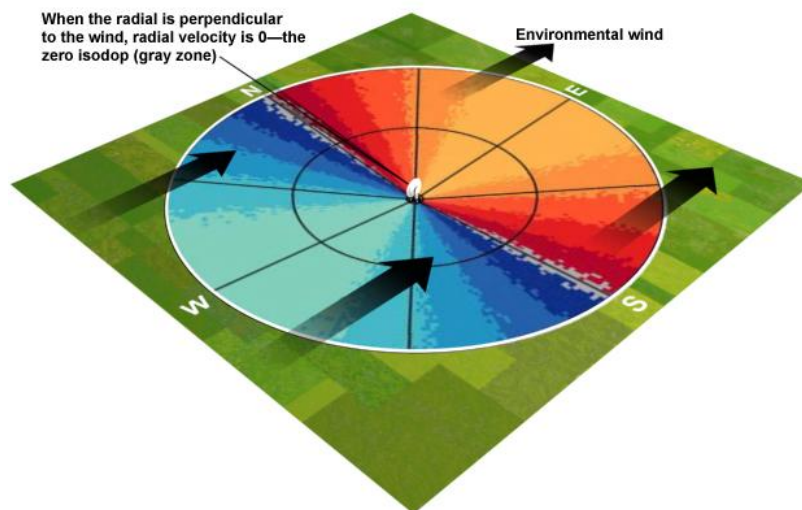
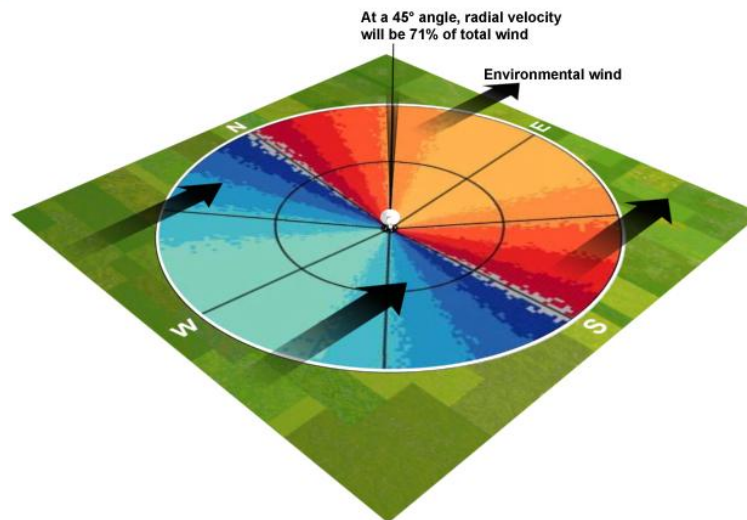
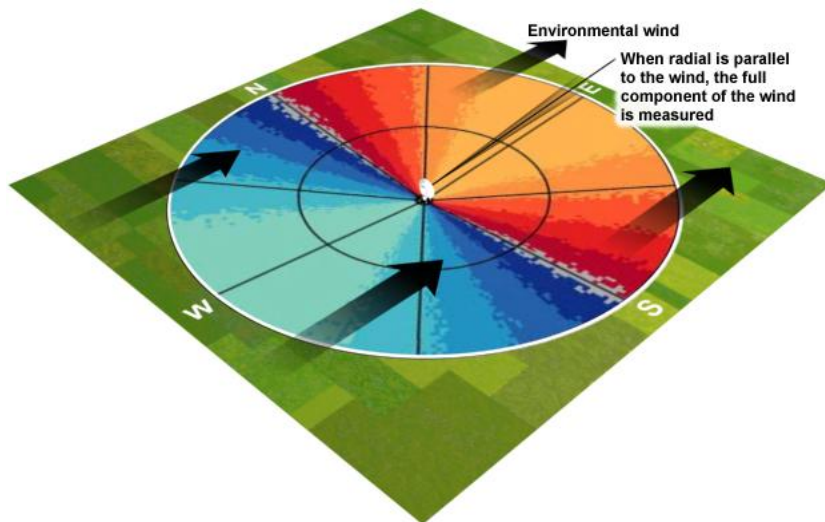
NOAA

- Ganho para a assimilação ao utilizar um radar de dupla polarização.



- Erro de preenchimento do feixe.
- Qual valor o modelo irá utilizar?





$0^{\circ} = 100\%$ - Parallel

$15^{\circ} = 97\%$

$30^{\circ} = 87\%$

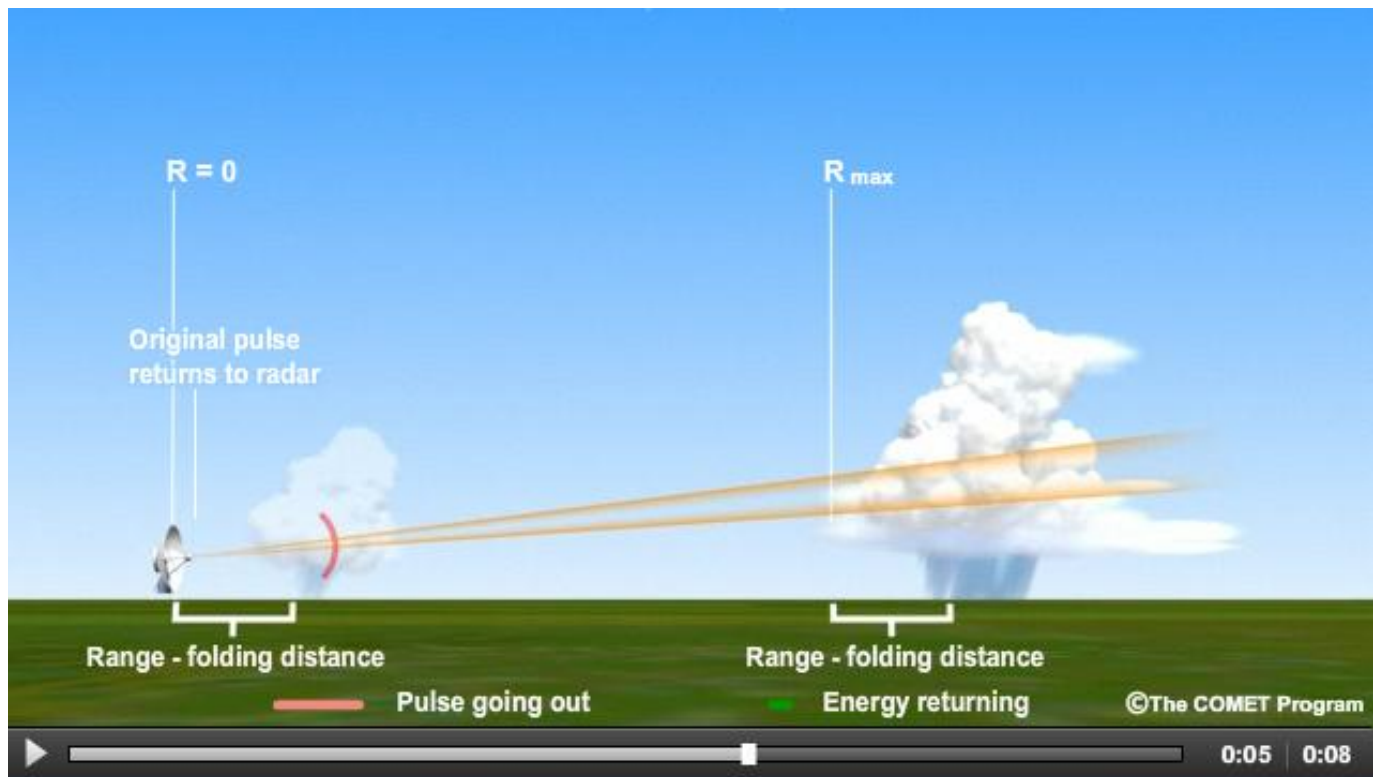
$45^{\circ} = 71\%$

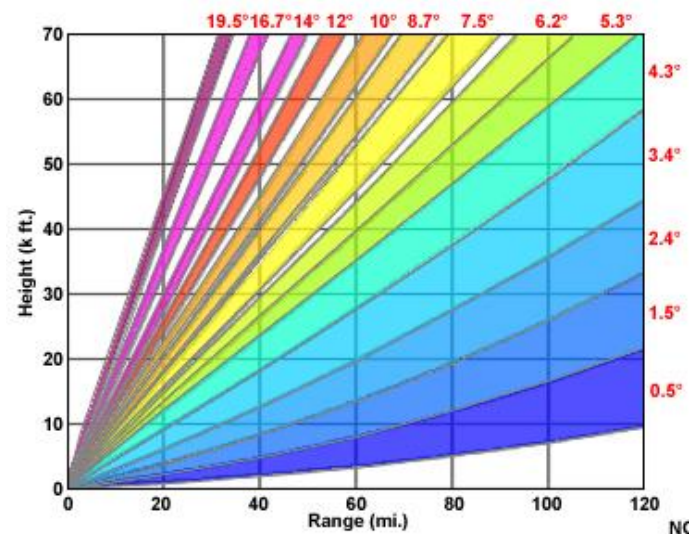
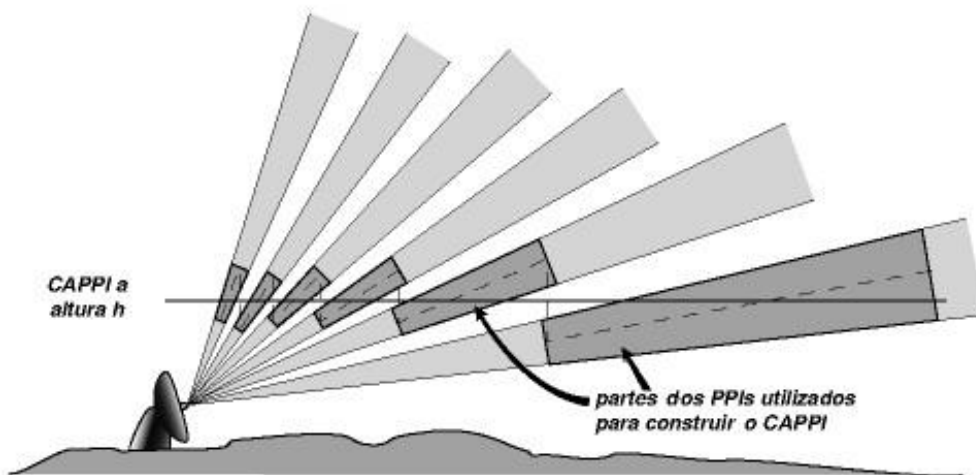
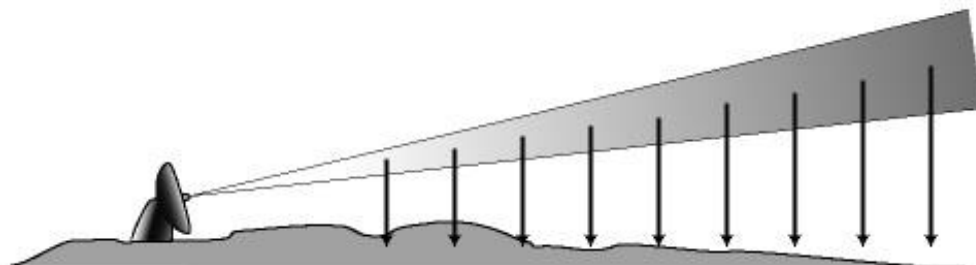
$60^{\circ} = 50\%$

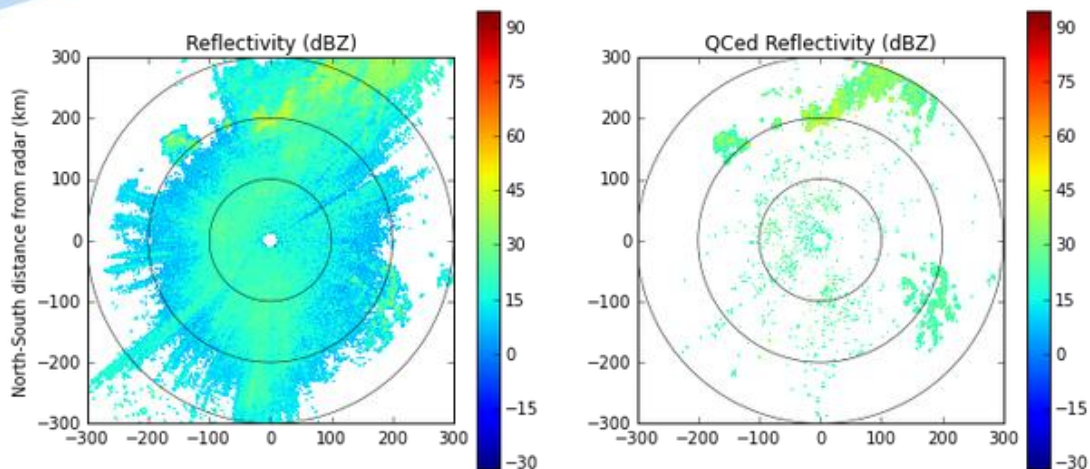
$75^{\circ} = 26\%$

$90^{\circ} = 0\%$ - Perpendicular

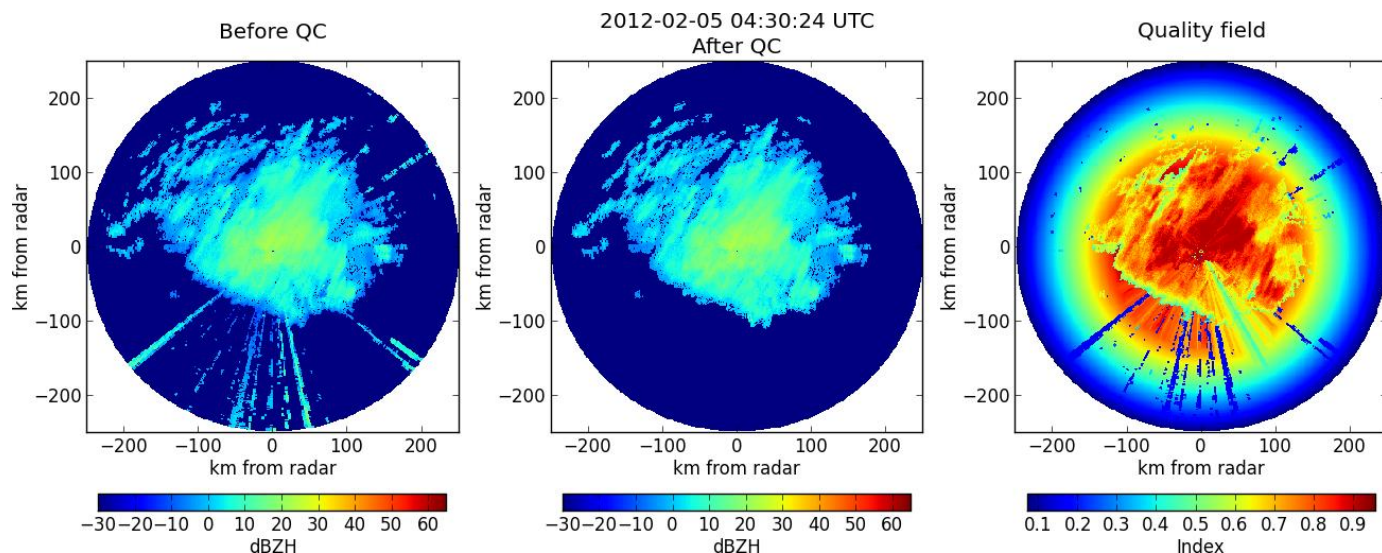
- Range Folding

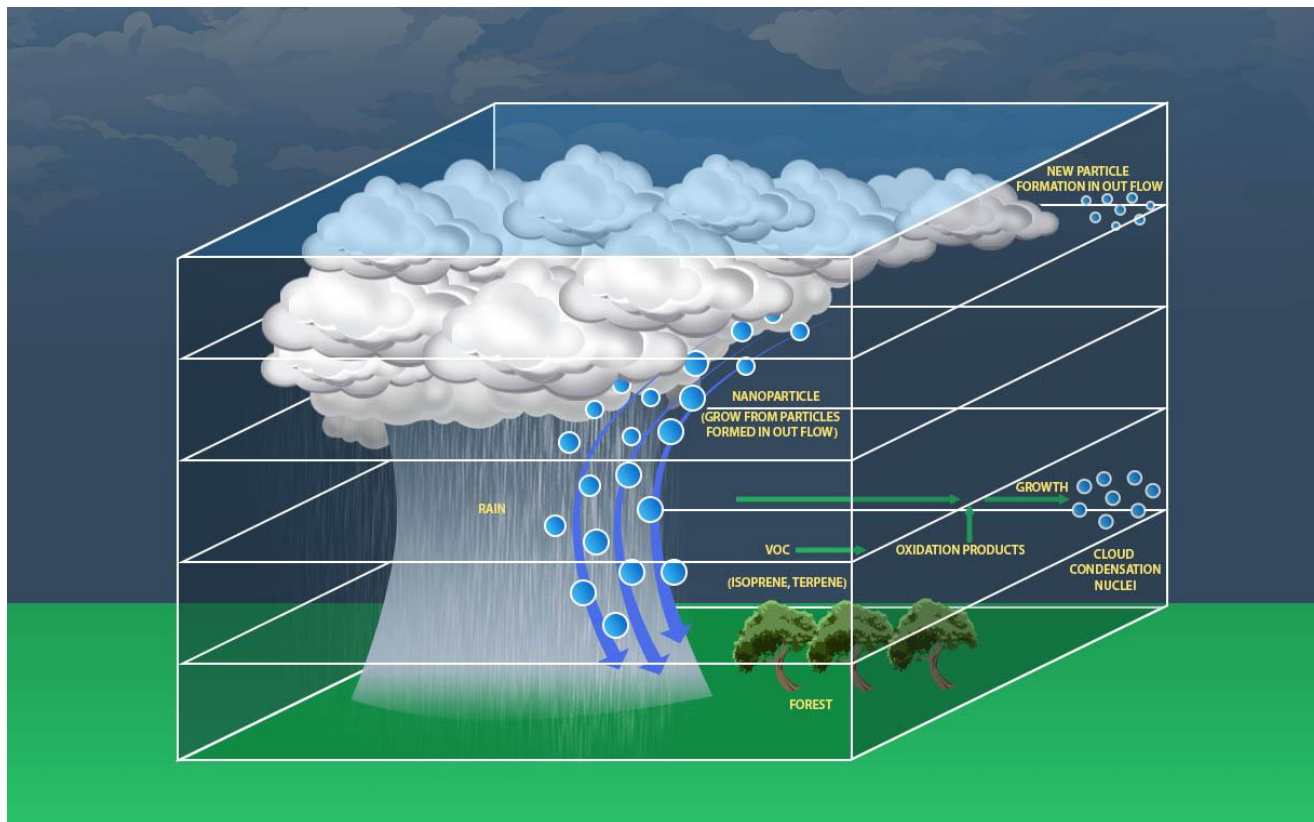




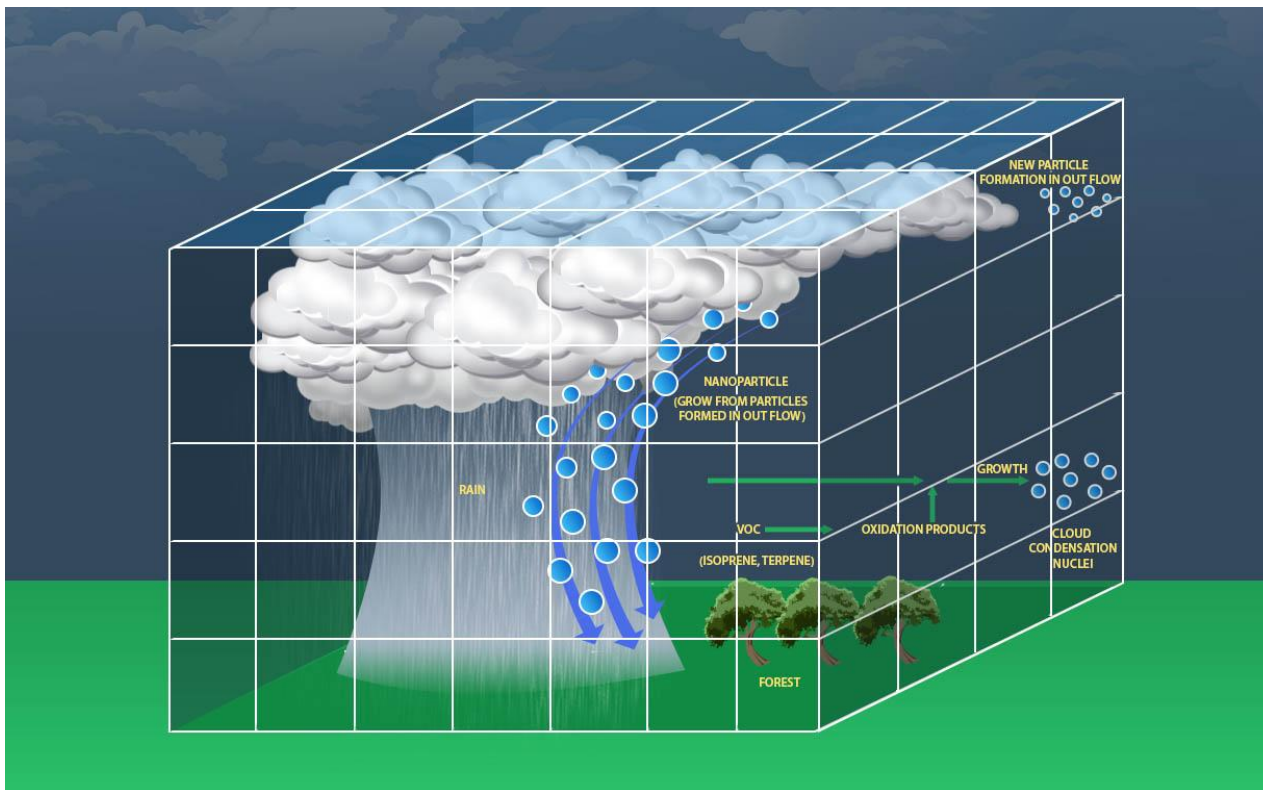


- Controle de Qualidade;
- Estimativa do erro.





$$Precipitation = F(\lambda, \phi) \cdot \vec{\nabla} \cdot q \vec{V}$$



Turbulência e microfísica das nuvens

Cloud resolving models (CRM)(3km-1km)

Large Eddy Simulation (LES) (dezenas/centenas de metros)

- Como e quais dados são assimilados?

Radar Não Doppler¹

Radar Doppler^{1,2}

Radar Doppler Polarimétrico^{1,2,3}

PPI

CAPPI

Perfis Verticais

Refletividade¹

Velocidade Radial²

Refletividade Direcional³

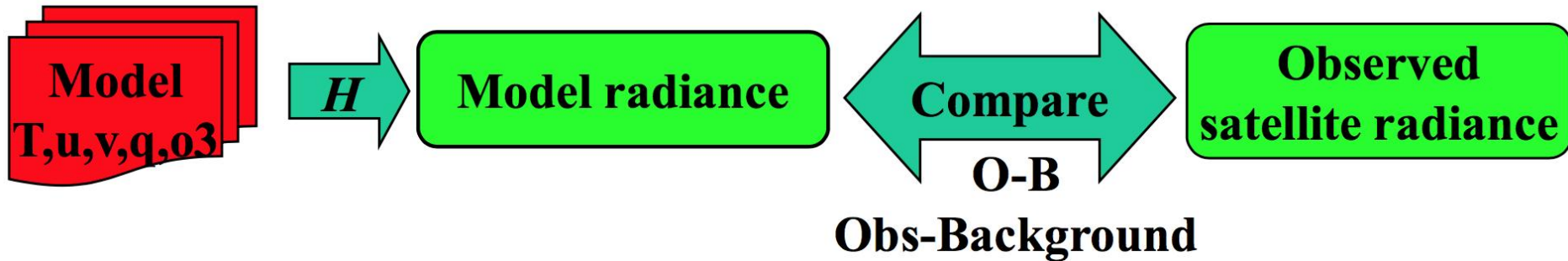
Hidrometeoros³
(tamanho e distribuição)

- O modelo contempla estas variáveis em suas equações prognósticas? O modelo sabe o que é **Refletividade**? E **Velocidade Radial**?
- Como eu comparo as variáveis do modelo com as variáveis do radar?

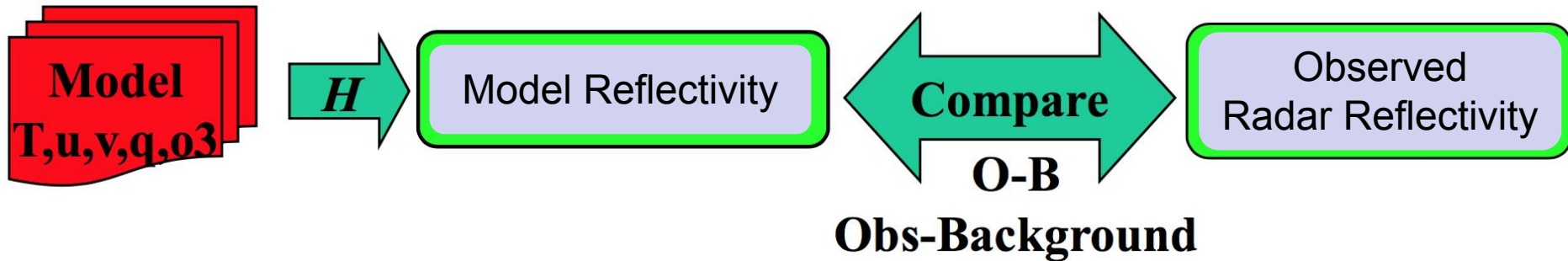


- Operador Observação (H)!
- "*Observações Equivalentes*" precisam ser calculadas para serem comparadas com as observações dos radares;
- H pode ser muito simples, como é o caso de assimilação de dados convencionais, sendo apenas um interpolador, ou...

- ... muito complexo!
- Ex: assimilação de radiâncias...



- ... muito complexo!
- Ex: assimilação de refletividade...



- Como relacionar variáveis do radar com as variáveis do modelo?

v_r - (u, v, w, q_r) Relation:

$$v_r = \frac{x - x_r}{r} u + \frac{y - y_r}{r} v + \frac{z - z_r}{r} (w - V_T(q_r)) \quad V_T = 5,4 \cdot \left(\frac{p_0}{\bar{p}} \right)^{0,4} \cdot (\rho q_r)^{0,125}$$

Z- q_r Relation (assume Marshal-Palmer DSD)

$$Z = 43.1 + 17.5 \log_{10}(\rho q_r) \quad \text{Sun and Crook (1997)}$$

Can also use empirical relations obtained by fitting with disdrometer data

Z- q_s and Z- q_h follow Gao and Stensrud (2012)

$$Z = 43,1 + 17,5 \cdot \log(1,0 \times 10^3 \text{LWC})$$

ou

$$Z = 3,63 \times 10^9 \text{LWC}^{1,75}$$

LWC = conteúdo de água líquida

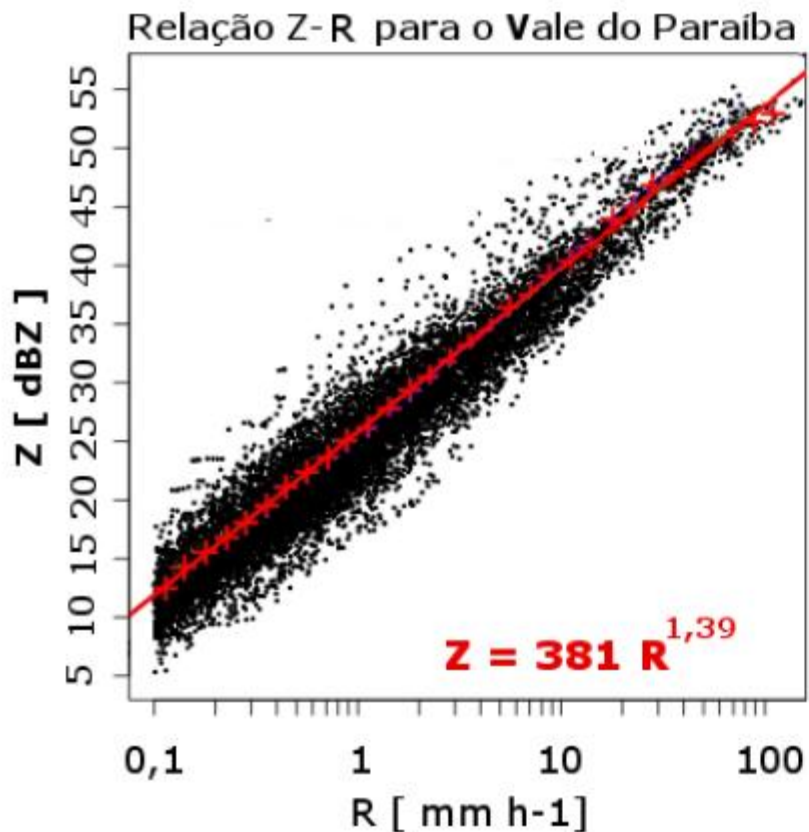
= densidade do ar seco \times a razão de mistura de água de chuva (q_r)

$$Z = a \cdot \text{LWC}^b$$

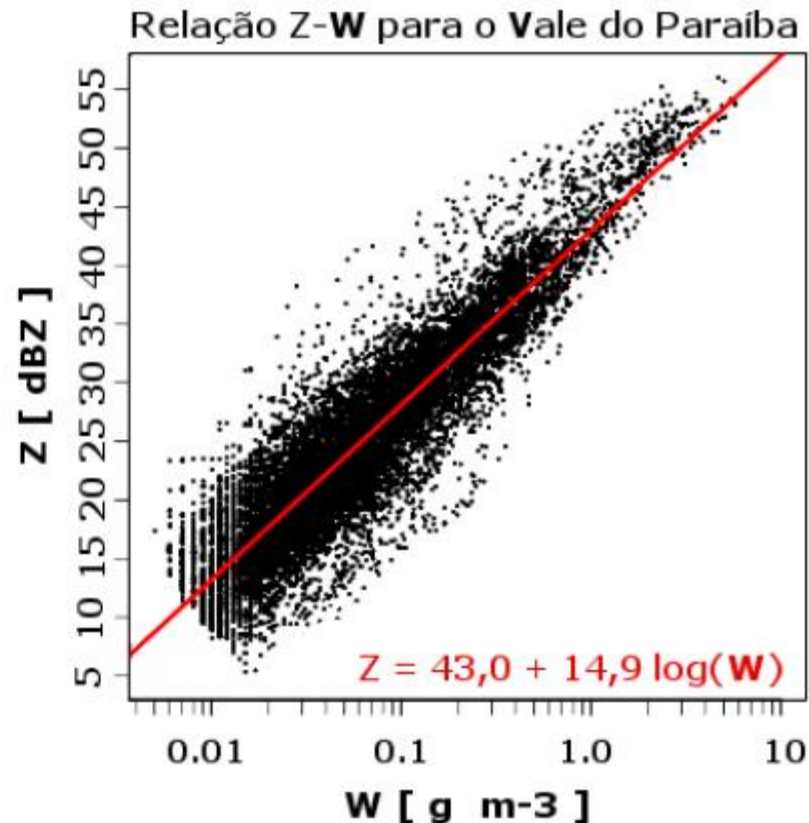
$$\text{LWC} = 1,0 \times 10^{-6} \cdot \frac{\pi}{6} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} \left(\frac{n_i}{v(D_i)} \cdot D_i^3 \right)$$

$$R = 3,6 \times 10^{-3} \cdot \frac{\pi}{6} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} (n_i \cdot D_i^3)$$

Onde F é o tamanho da superfície sensível do sensor ($F = 0,005 \text{ m}^2$), t é o tempo de amostragem dos dados ($t = 60 \text{ s}$), n_i é o número de gotas para cada classe de tamanho ($i = 1, \dots, 20$) no intervalo t , $v(D_i)$ é a velocidade terminal para o diâmetro D_i em $[\text{m s}^{-1}]$ (ver tabela 4.1) e D_i é diâmetro médio da gota na classe i em $[\text{mm}]$ (ver tabela 4.1).

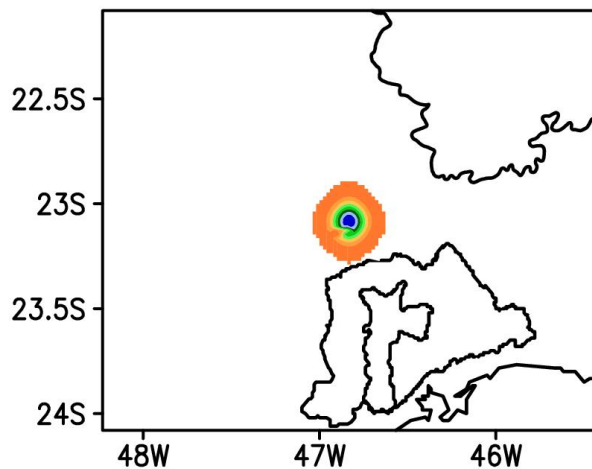


(a) Z-R

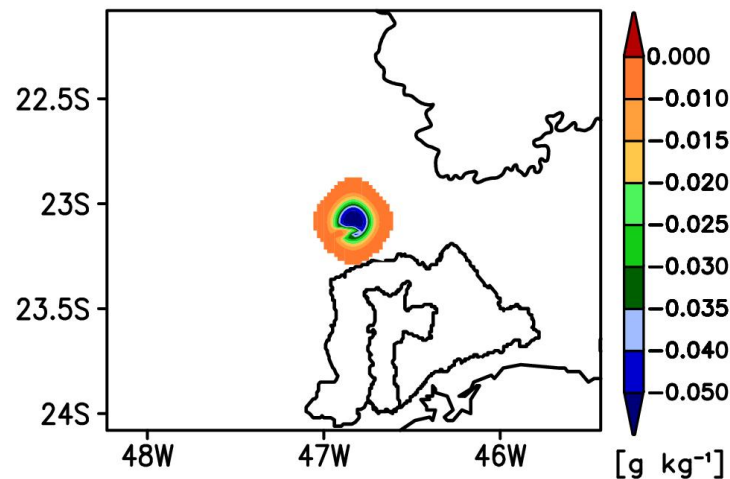


(b) Z-LWC

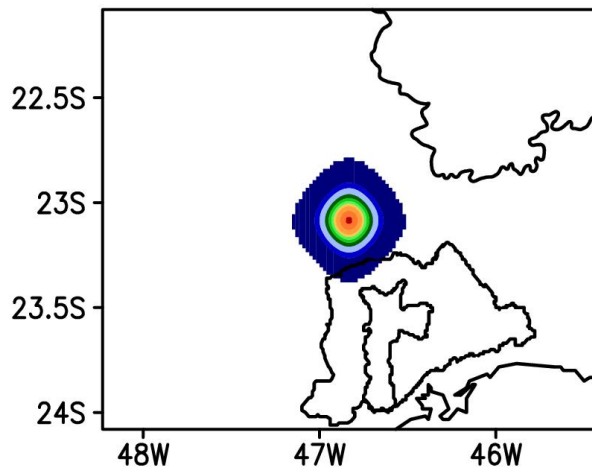
Eq. Original (10 dBZ)



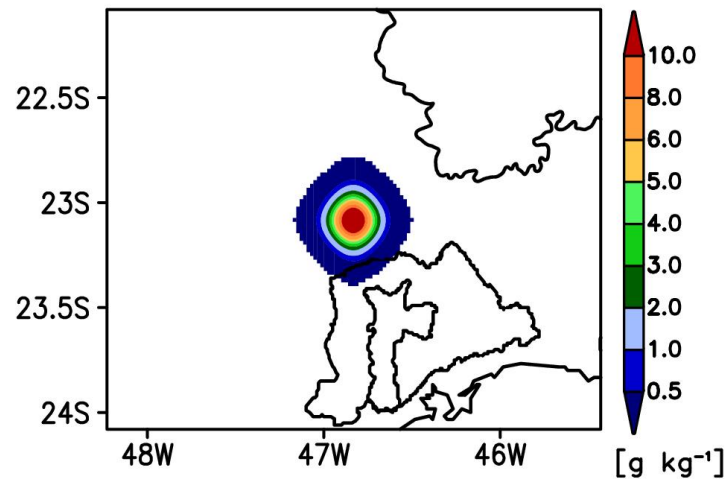
Eq. Nova (10 dBZ)



Eq. Original (60 dBZ)



Eq. Nova (60dBZ)



- Weather Research Forecasting model Data Assimilation system – WRFDA
 - Skamarock et al. (2008);
 - Barker et al. (2004); Sun e Crook (1997).
- Possibilidade de assimilação de dados de radar com 3D-Var e 4D-Var.

$$J = J_b + J_o + \underbrace{J_{v_r} + J_{q_r} + J_{q_v}}_{\text{For radar DA}} + J_{y1} + J_{y2} + \dots$$

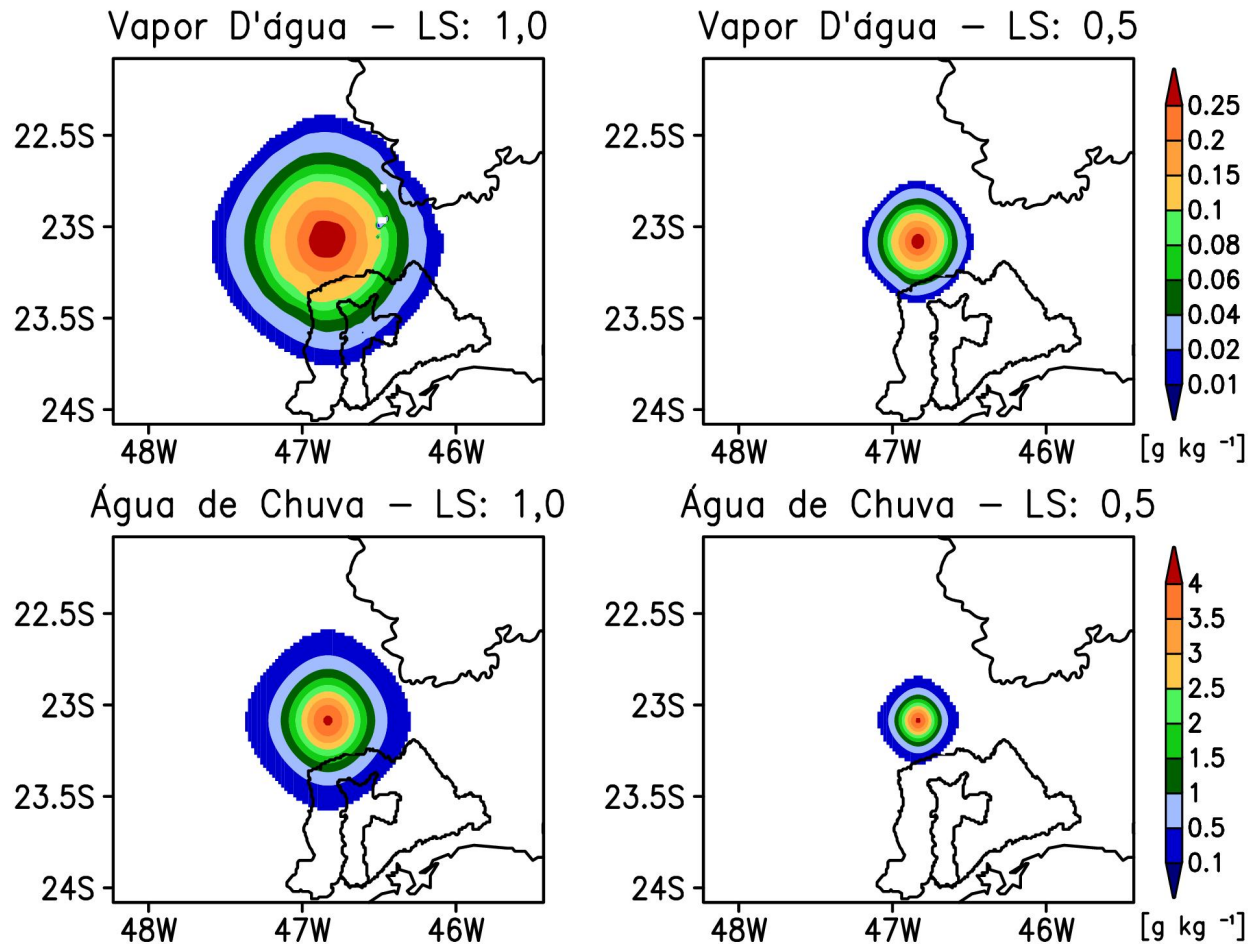
- Método NMC (Parrish e Derber, 1992);
 - Diferença de 12 h;

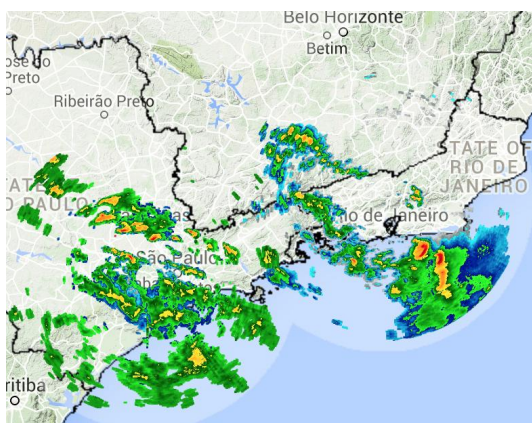
$$\mathbf{B} = \overline{\epsilon\epsilon^T} \cong \overline{\mathbf{x}'\mathbf{x}'^T}$$

- O método NMC é realmente bom para meu caso/região? Para assimilar radar?

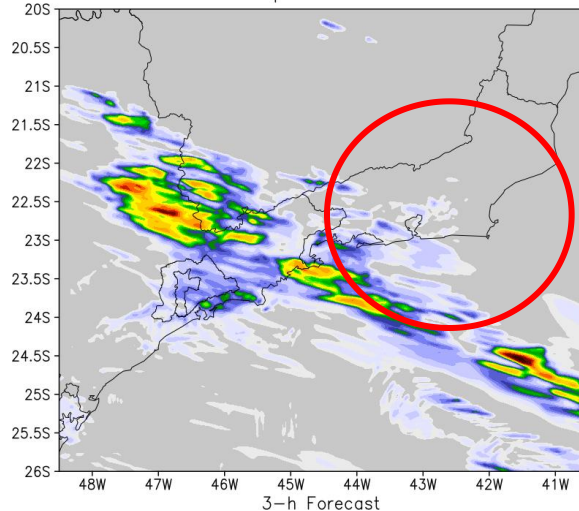
[Guo et al. (2007); Ming et al. (2009); Ha e Lee (2012); Tong et al. (2014).]

- Variance Scale - Length Scale

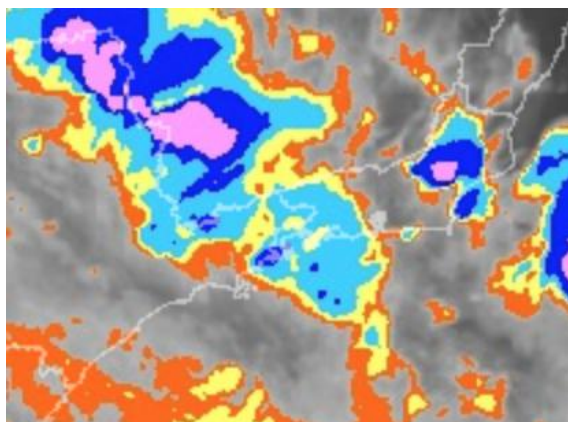
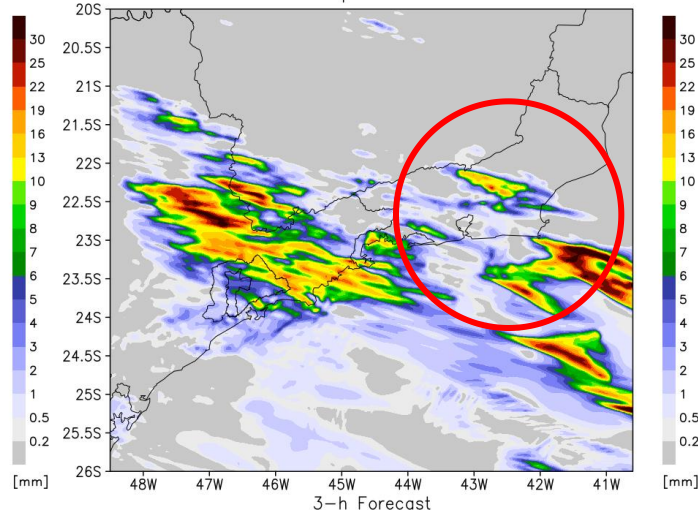




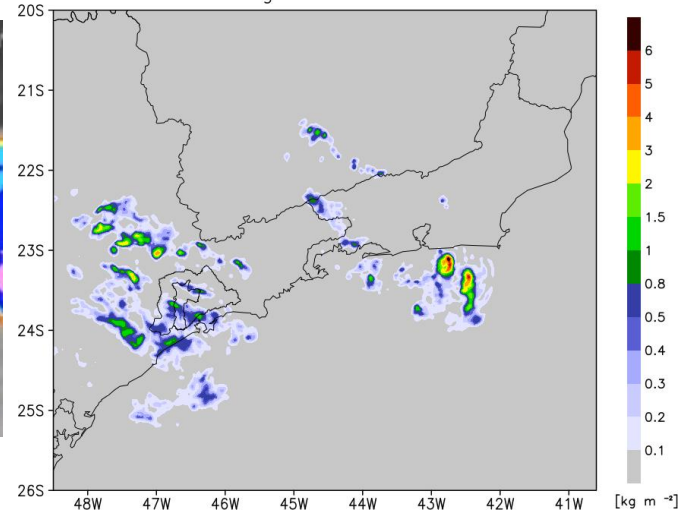
Surface Total Precipitation – without radar DA



Surface Total Precipitation – with radar DA



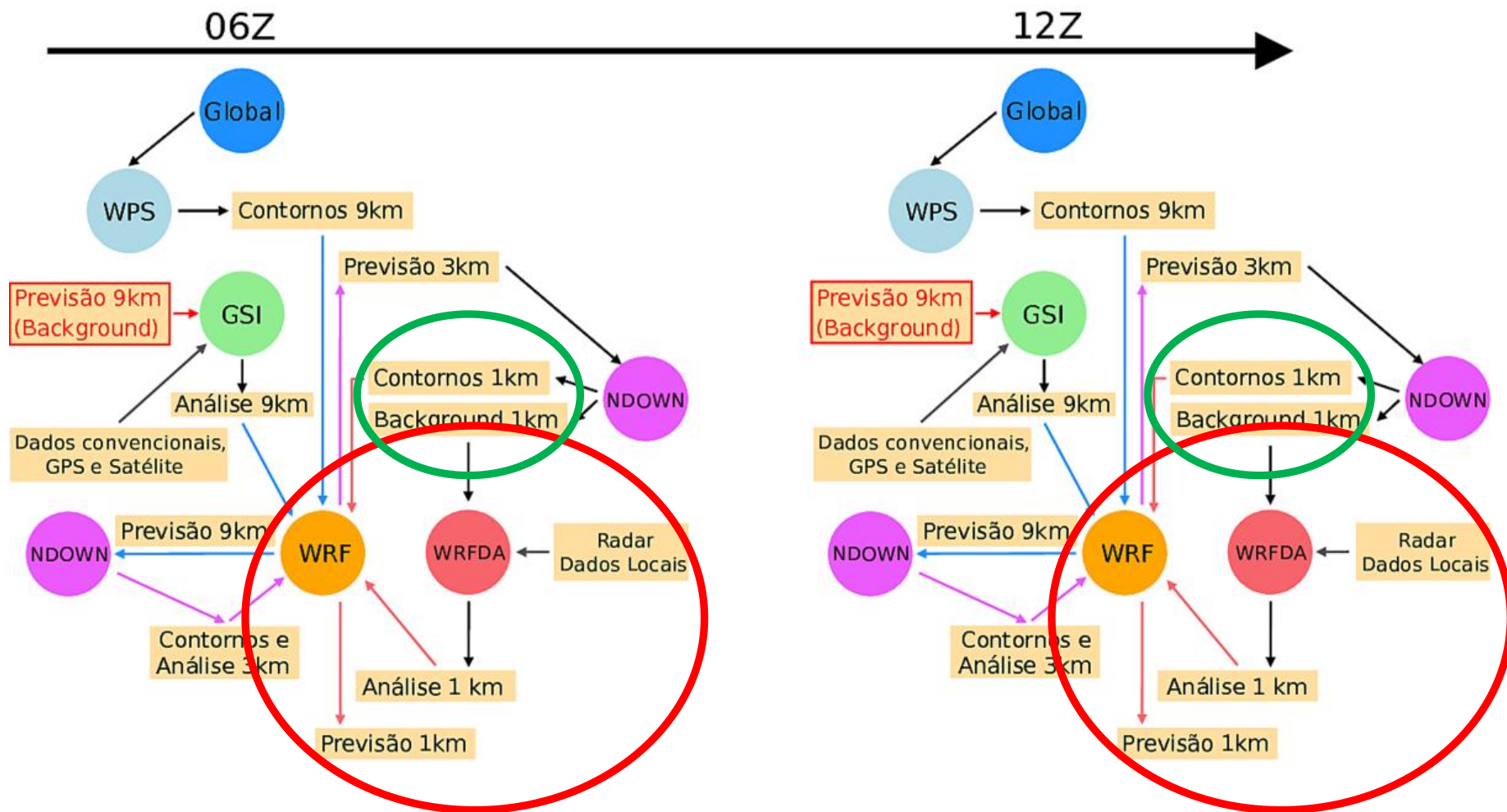
Total Column Integrated Rain – with radar DA



Jogos Olímpicos 2016

Assimilação de Dados
de Radar
São Roque e Pico do
Couto

- Sistema de Modelagem Local
 - WRF e WRFDA;
 - Condição de fronteira e inicial fornecida pelo CPTEC;
 - Assimilação de dados convencionais e não convencionais em toda a América do Sul;
 - Assimilação e dados de radar nos centros regionais.

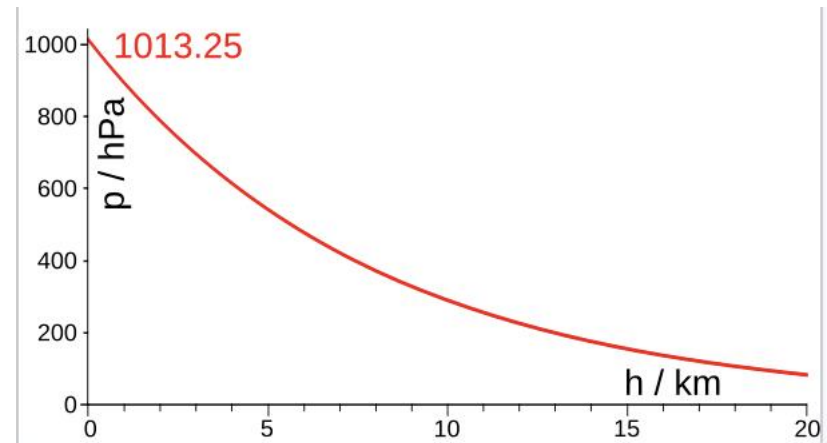


- **Implementation and Testing of Radar Data Assimilation Capabilities Within the Joint Effort for Data Assimilation Integration Framework With Ensemble Transformation Kalman Filter Coupled With FV3-LAM Model**
 - Jun Park, Ming Xue, Chengsi Liu

- Z from Multi-Radar Multi-Sensor (MRMS, Smith et al., 2016) 3D mosaic data and Level-II Vr data from WSR-88D radars are assimilated.
- Observation errors for Z and Vr are assumed to be 5 dBZ and 3 m s⁻¹, respectively.
- Z and Vr forward operators implemented in GSI (Labriola et al., 2021; C. C. Tong et al., 2020) are migrated into the Unified Forward Operator (UFO) module of JEDI

- The covariance localization radii are set to 18 km in the horizontal and 0.7 scale height in logarithmic p in the vertical

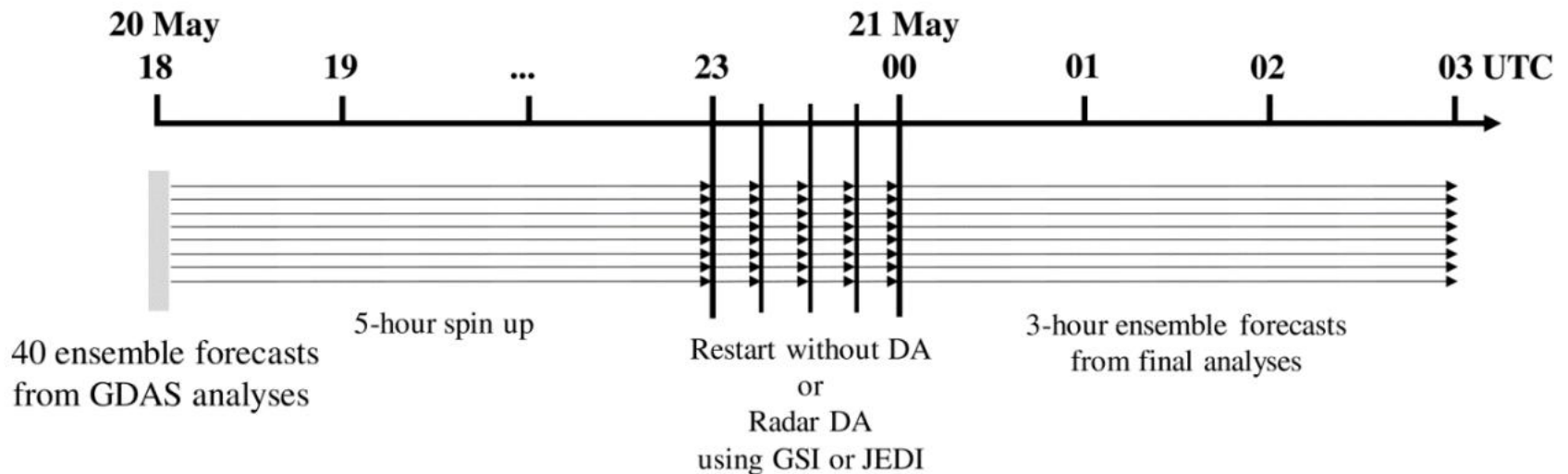
scale height is the increase in altitude for which the atmospheric pressure decreases by a factor of e



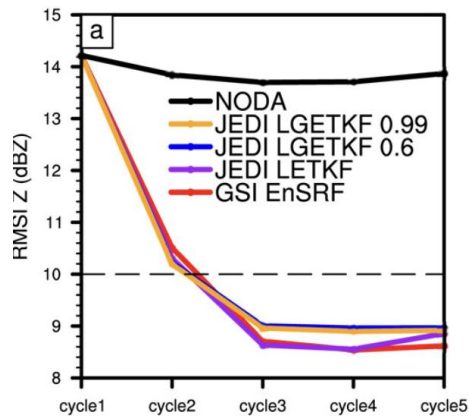
The earth atmosphere's scale height is about 8.5 km, as can be confirmed from this diagram of air pressure p by altitude h : At an altitude of 0, 8.5, and 17 km, the pressure is about 1000, 370, and 140 hPa, respectively.

- radar observations are assimilated every 15 min from 2300 through 0000 UTC

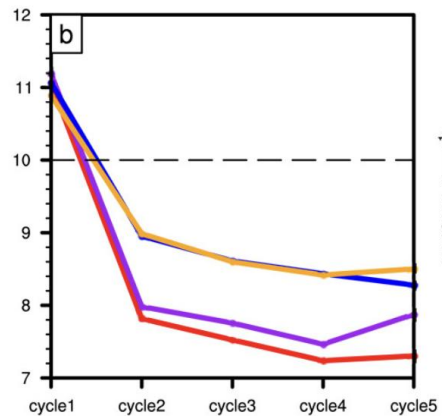
Case 21 May 2019



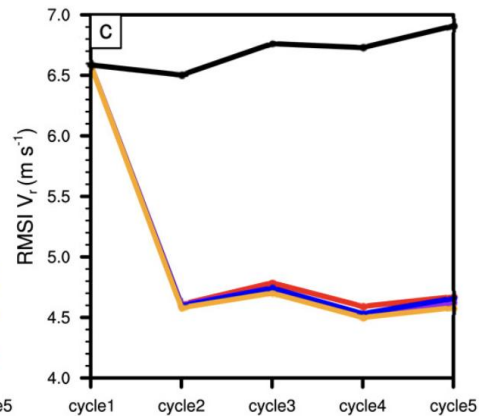
Background Forecast



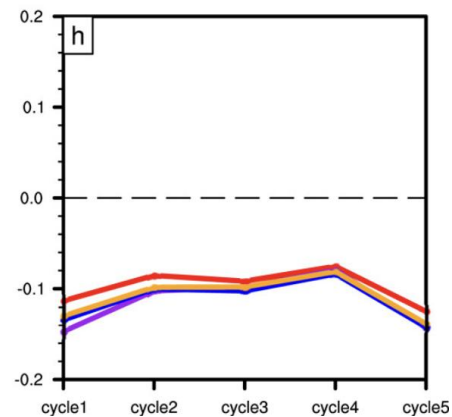
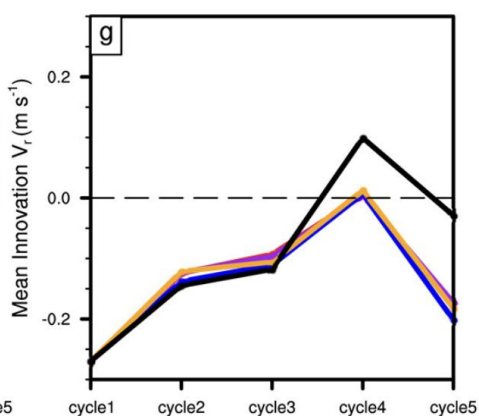
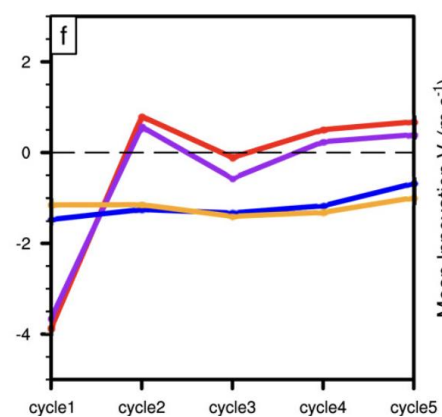
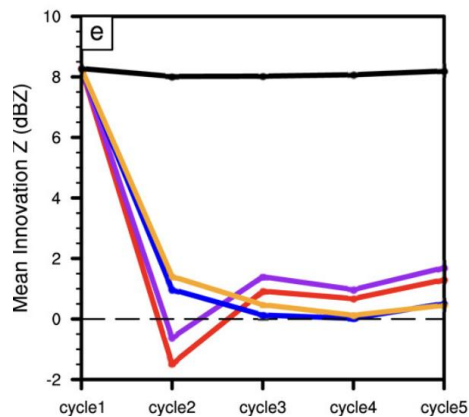
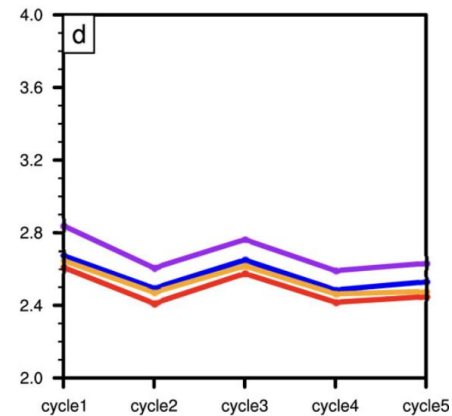
Analysis



Background Forecast



Analysis



JEDI LGETKF 0.99

JEDI LGETKF 0.6

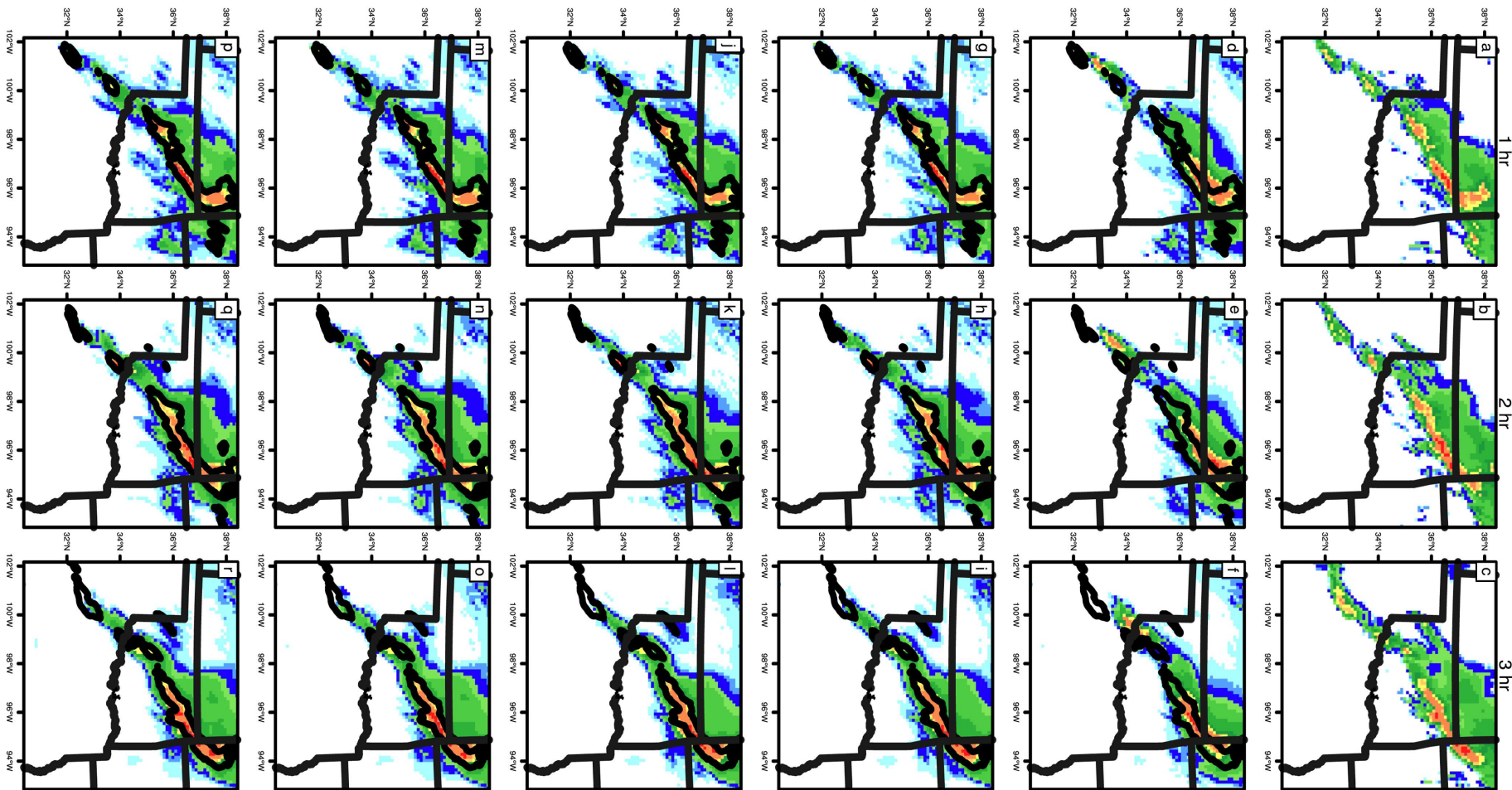
JEDI LETKF

GSi EnSRF

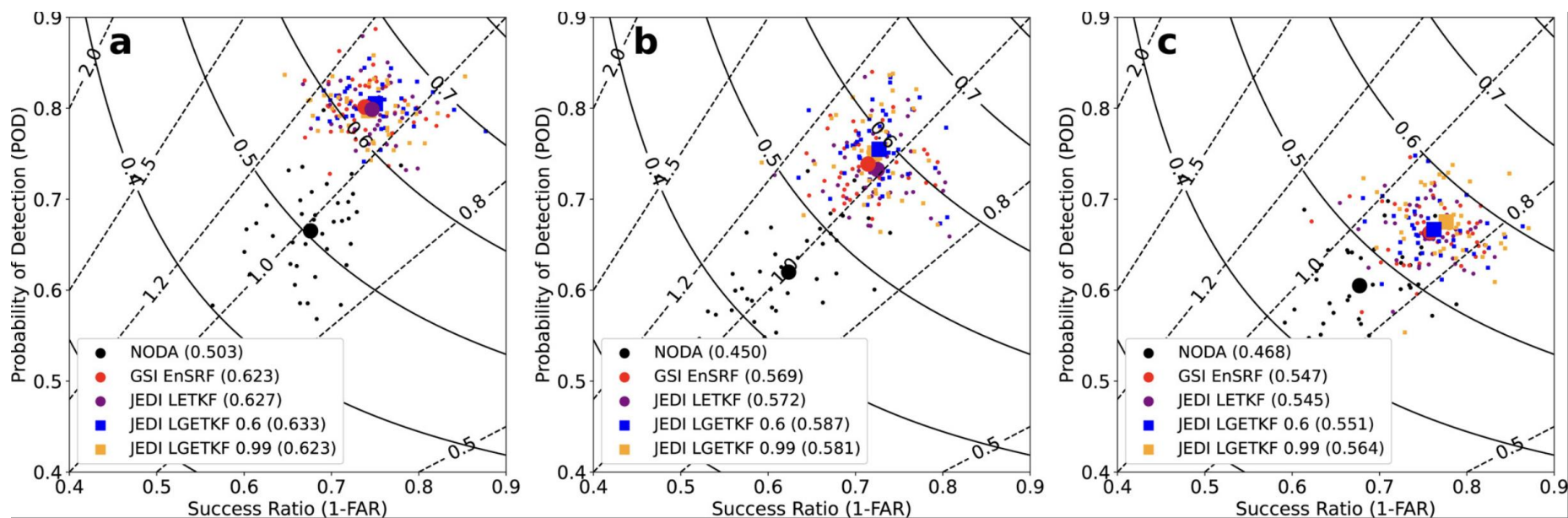
NODA

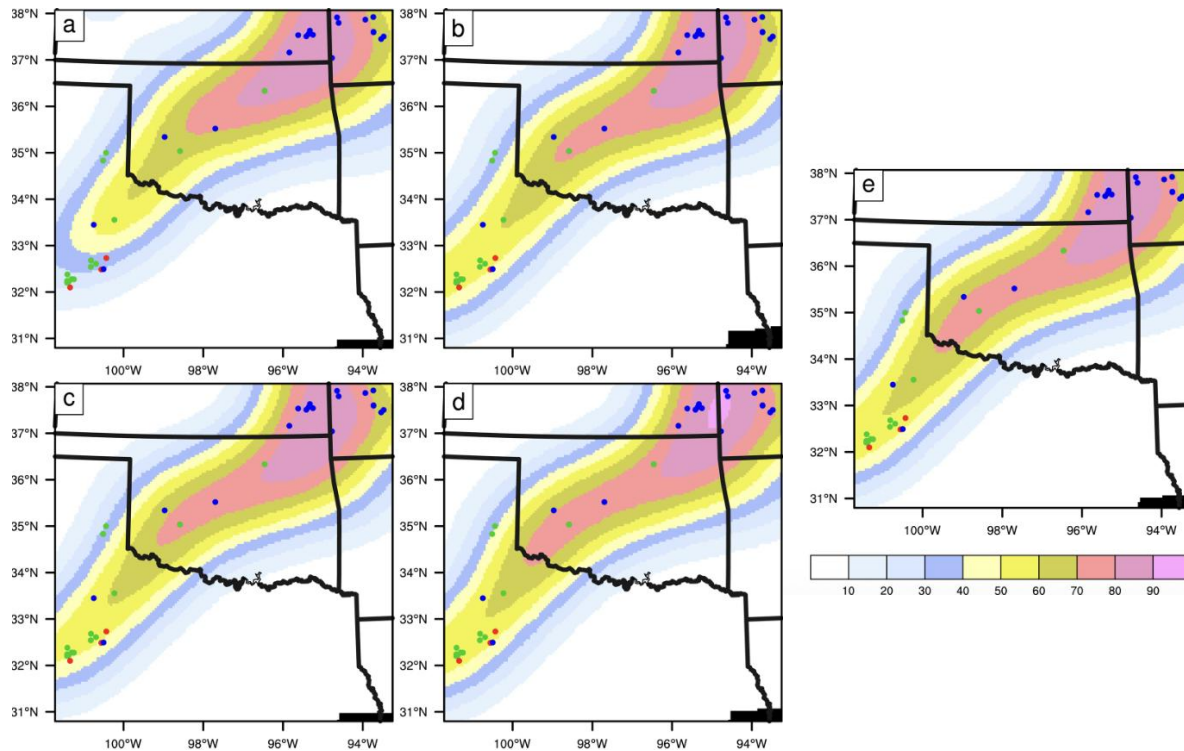
STAGE IV OBS

0.01 0.1 0.25 1 2 5 10 15 20 25 50 75 200 250



Performance diagrams of composite reflectivity of (a) 1-hr, (b) 2-hr and (c) 3-hr





Neighborhood maximum ensemble probability (NMEP) (%) of 3-hr maximum updraft helicity exceeding $75 \text{ m}^2 \text{ s}^{-2}$ for experiments (a) NODA, (b) EnSRF, (c) LETKF, (d) LGETKF.6, and (e) LGETKF.99. The SPC storm reports of high wind, hail, and tornado during the forecast period are represented with blue, green, and red circles, respectively.

