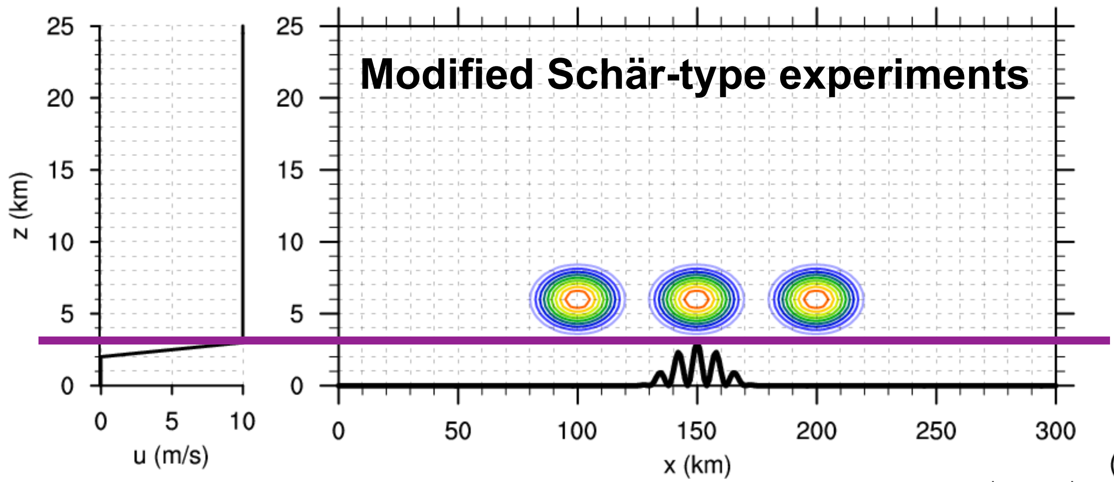
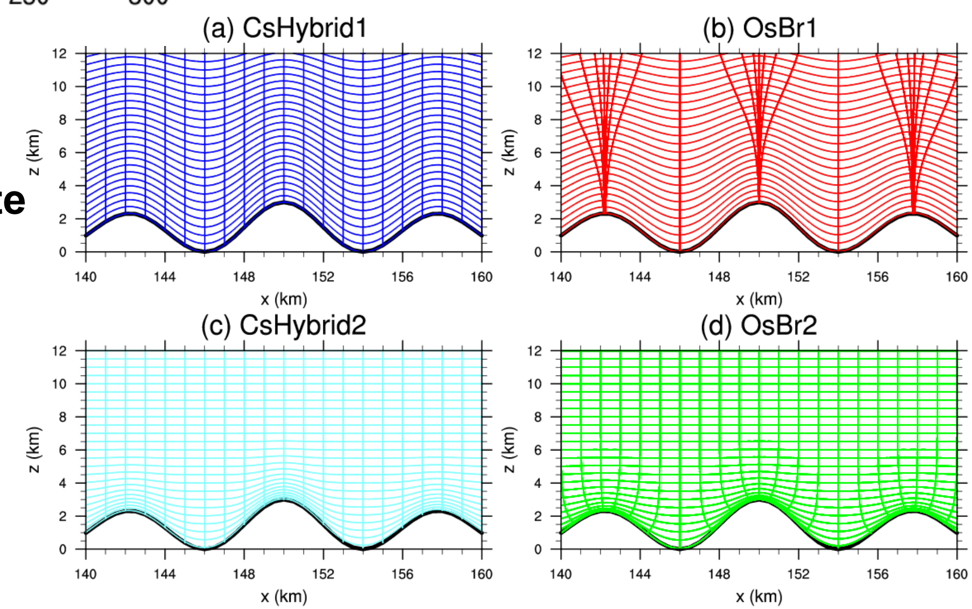
An Analysis of the Orthogonal Terrain-Following Vertical Grids on Reducing the Advection Errors in the Terrain-Following Coordinate

Yiyuan Li, Jinxi Li, and Bin Wang



- Move the tracer and the velocity right down to the top of the terrain

- Compare the results obtain by the ***hybrid*** and the ***orthogonal*** **σ-coordinate**
  - **Numerical solutions**
  - **Absolute errors**
  - **Root mean square errors (RMSEs)**



Conclusion

◆Through creating the **orthogonal and terrain-following vertical grids**:

- **Advection errors are reduce by 50% more** compared with the corresponding hybrid σ-coordinate

- **Shape of the tracer is preserved** at the end of the advection

More details are in the poster.

Wait for your comments and thank you!

Email: liyiyuan@mail.iap.ac.cn

Institute of Atmospheric Physics, Chinese Academy of Sciences
State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics

PDEs on the Sphere, 2014
Boulder, CO, USA

An Analysis of the Orthogonal Terrain-Following Vertical Grids on Reducing the Advection Errors in the Terrain-Following Coordinate

Yiyuan Li[1], Jinxi Li[1], and Bin Wang[1,2]
1. State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences,Beijing,China,100029
2. Ministry of Education Key Laboratory of Earth System Modeling, and Center for Earth System Sciences, Tsinghua University, Beijing, China, 100084

Introduction:

An orthogonal curvilinear terrain-following coordinate (OS-coordinate) was proposed by Li et al. (2013) to reduce the advection errors in the classic terrain-following coordinate (CS-coordinate). The OS-coordinate can smooth the vertical layers above the steep terrain as well as create the orthogonal and terrain-following grids in the vertical.

The idealized advection experiments implemented by Li et al. (2013) validated that the OS-coordinate can significantly reduce the advection errors in the high level above steep terrain. In this study, we further investigate the distinct effect of the orthogonal grids created by the OS-coordinate in term of the advection errors near the surface.

Experiments Design (Modified Schär-type Experiments):

- Wavelike terrain
- Tracer and the horizontal velocity are moved right down to the top of terrain
- Using the *OS-coordinate* and the *corresponding hybrid σ-coordinate*

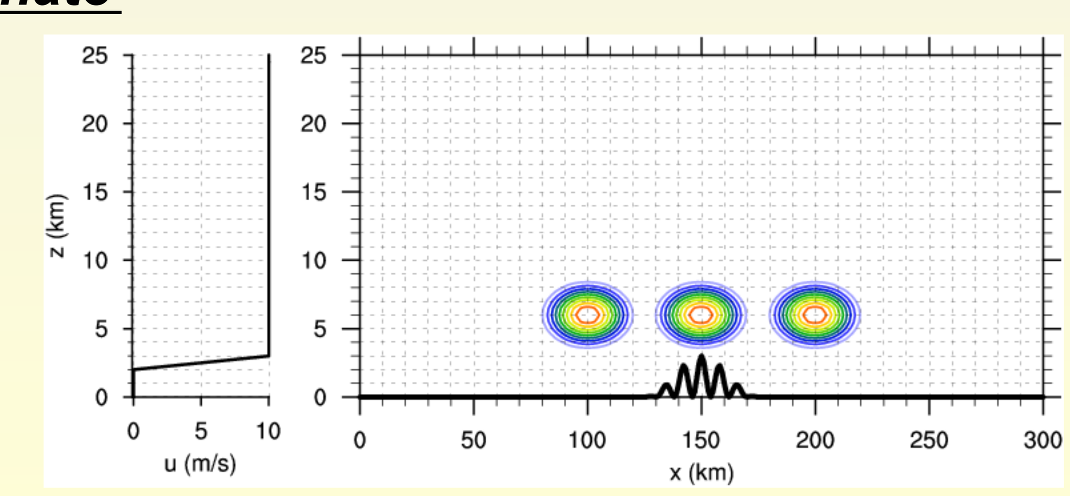


Figure 1: The modified Schär-type idealized 2-D advection experiments.

Vertical Layers in All the Five Experiments:

- CS-coordinate (Cs)
- Two hybrid σ-coordinates (CsHybrid1, CsHybrid2)
- Two OS-coordinate (OsBr1, OsBr2)

Three Aspects of the Comparison:

- Results of the numerical solutions
- Absolute errors (AEs)
- Root mean square errors (RMSEs)

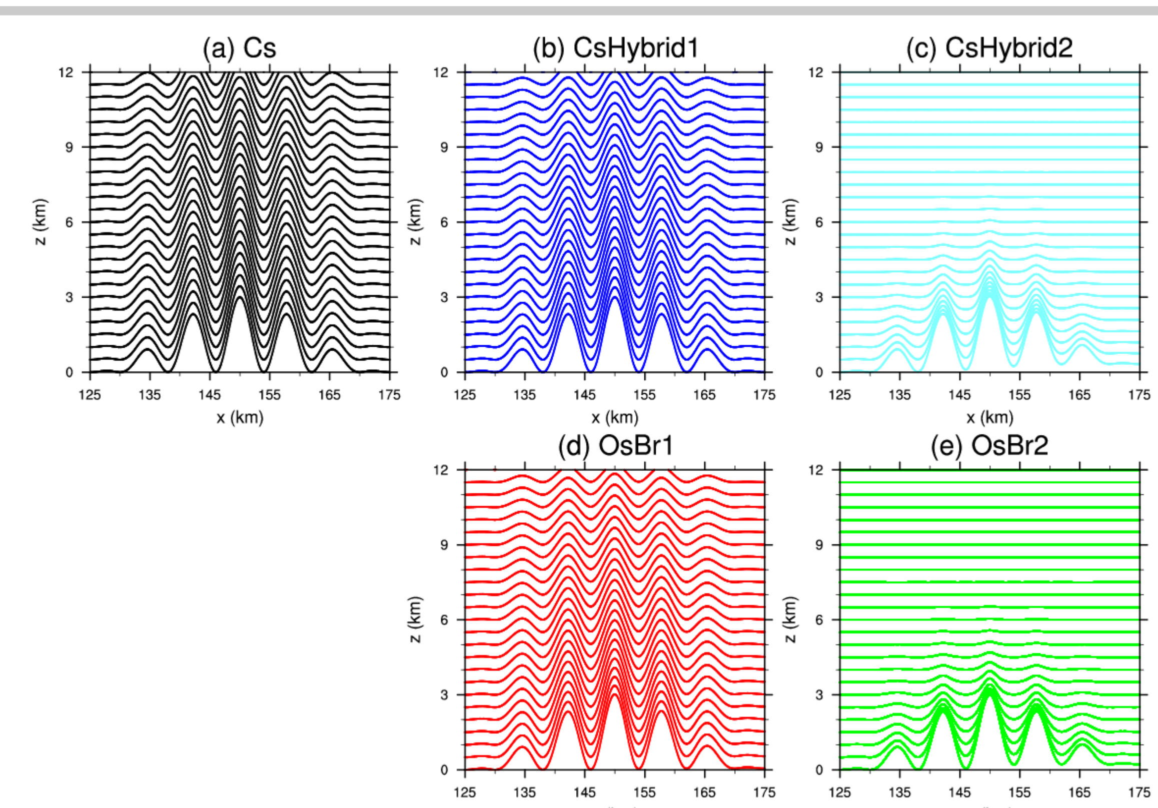


Figure 2: The vertical layers of all the five experiments.

CsHybrid1 and OsBr1 has similar vertical layers, which are *smoother* than those in Cs.

CsHybrid2 and OsBr2 has similar vertical layers, which are *much smoother* than those in Cs.

Result 1: Numerical Solutions

- In the OS-coordinate, the shape of the tracer are preserved at the end of the advection.
- The RMSEs in the OS-coordinate are much smaller than those in the hybrid σ-coordinate.

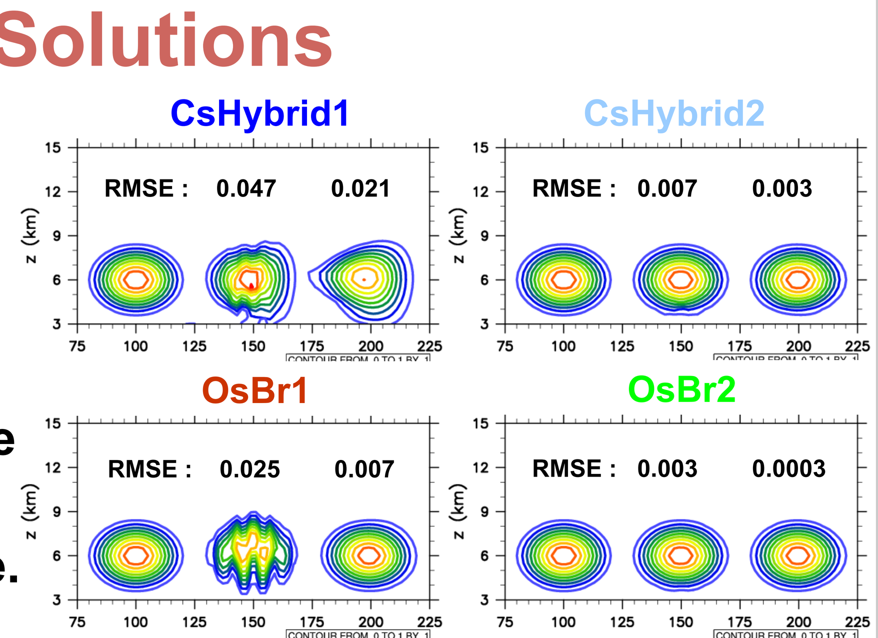


Figure 3: The numerical solutions of hybrid σ-coordinate and the OS-coordinate.

Result 2: Absolute Errors

- In the OS-coordinate, the Maximum of AEs are reduced by about 50% compared with those in the hybrid σ-coordinate

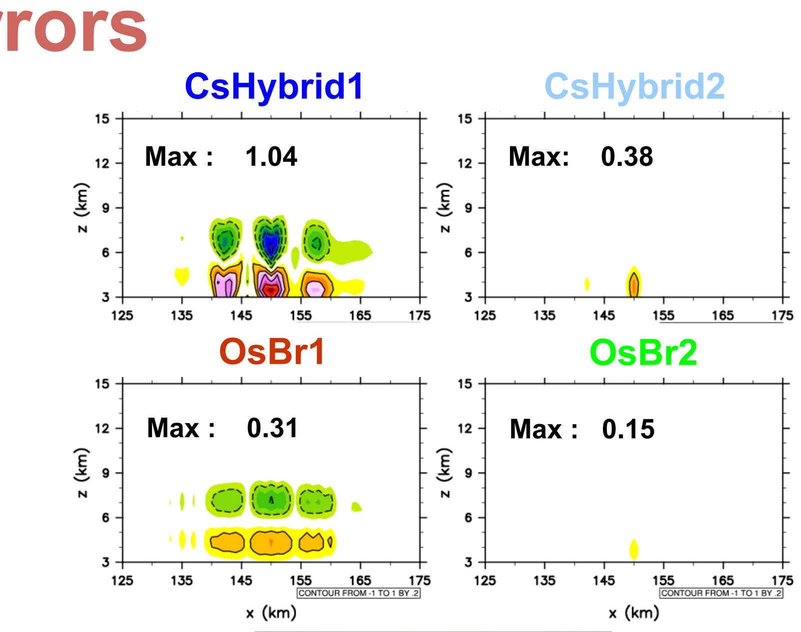


Figure 4: The absolute errors of the advection in each experiment over the top of the terrain.

Result 3: RMSEs

- In the OS-coordinate, the RMSEs are reduced by about 50% more compared with those in the hybrid σ-coordinate

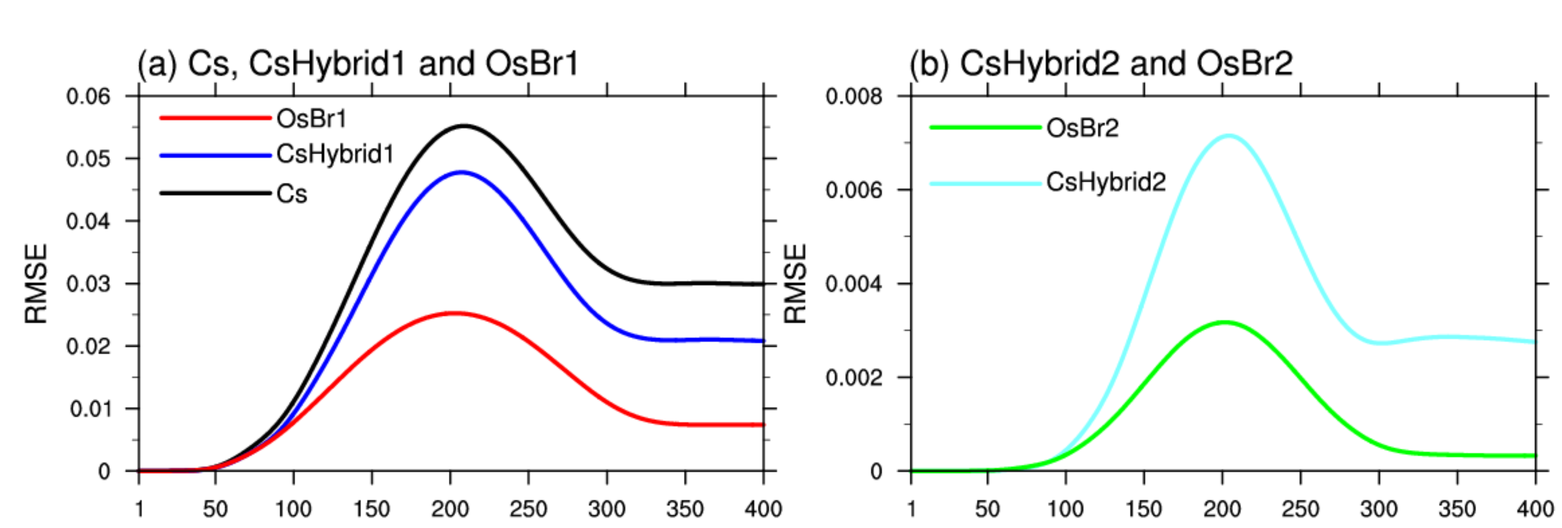


Figure 5: The RMSEs of the advection in each experiment.

Table 1: The RMSEs reduction by the OS-coordinate.

Experiments	RMSEs		RMSEs reduction by the OS-coordinate	
	average	maximum	average	maximum
CsHybrid1	0.029	0.048	47.5%	47.2%
OsBr1	0.012	0.025		
CsHybrid2	0.0029	0.0072	63.5%	55.7%
OsBr2	0.0011	0.0032		

Conclusion:

- The OS-coordinate can reduce the advection errors compared with the corresponding hybrid σ-coordinate through its orthogonal and terrain-following vertical grids:
  - Reducing the RMSEs by 50% more;
  - Preserving the shape of the tracer at the end of the advection.

References

- Li, Y., Wang, B., and Wang, D.: An orthogonal curvilinear terrain-following coordinate for atmospheric models, Geosci. Model Dev. Discuss., 6, 5801-5862, doi:10.5194/gmdd-6-5801-2013, 2013.
- Schär, C., Leuenberger, D., Fuhrer, O., Lüthi, D., and Girard, C.: A new terrain-following vertical coordinate formulation for atmospheric prediction models, Mon. Wea. Rev., 130, 2459-2480, 2002.

Email: liyiyuan@mail.iap.ac.cn