Analysis of the Diurnal Cycle in RO Data Using Bayesian Interpolation

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Introduction

The diurnal cycle is relevant to climate because

(1) It serves as a test of climate models in the troposphere because of the timing of deep convection,

(2) It serves as a test of whole atmosphere models in the upper stratosphere because of vertical propagation of the solar tides, and

(3) It can be used to diagnose how under-sampling of the diurnal cycle biases climate data records.

Bayesian interpolation works by fitting data without over-fitting the data. There are several reasons to apply a Bayesian strategy to analyzing the diurnal cycle:

(1) Radio occultation (RO) data is globally but highly irregularly distributed with unknown implicit spatial and temporal resolution,

(2) It can explicitly model the diurnal (and semi-diurnal) cycles analytically, and

(3) It produces a complete error analysis useful for significance testing.

Bayesian Interpolation

Basis functions are spherical harmonics and sinusoids in diurnal cycle: longitude λ, latitude θ, and diurnal time τ. Diurnal time can be alternatively defined as local solar time or as UTC time, depending on final objective.

$$\phi_{lmn}(\lambda,\theta,\tau) = P_{lm}(\sin\theta)\,\mathrm{Re}\left[\left(a_{lmn}e^{i(m\lambda+n\tau)} + b_{lmn}e^{i(m\lambda-n\tau)}\right)\right]$$

Solution for most probable coefficients:

$$\mathbf{A} = \beta\phi'\phi + \alpha\mathbf{C}$$
$$a_{lmn}, b_{lmn} = \mathbf{A}^{-1}\phi'\mathbf{d}$$
$$2\alpha\chi^2 = n_{\text{coeffs}} - \alpha\,\mathrm{Trace}\mathbf{A}^{-1}$$

The regularizer C: $C_{lmn} = c\,l^{\mu}(l+1)^{\mu}\,n^{\nu}$

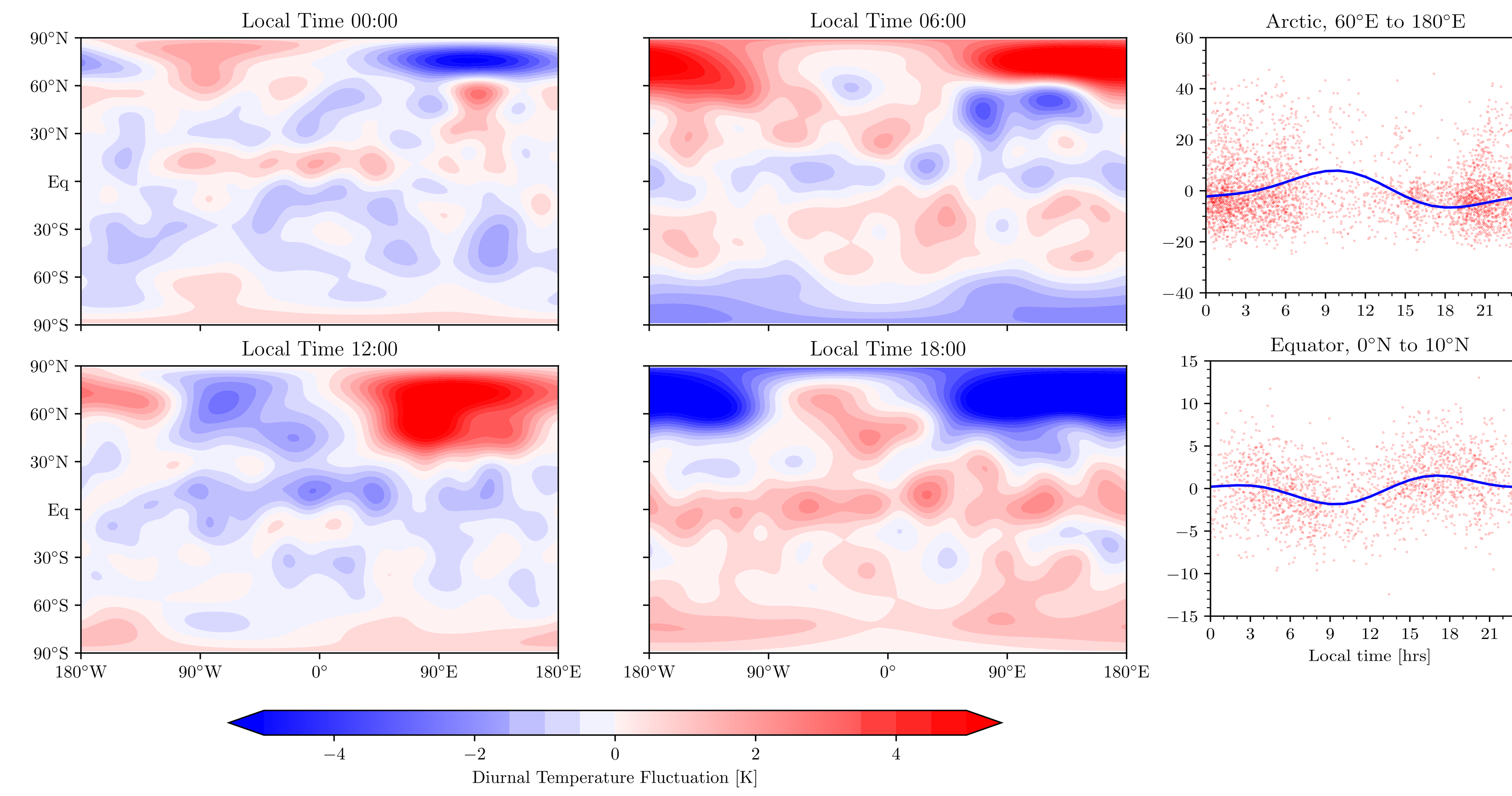
Condition	c	μ	ν
$l=m=n=0$	rMean	0	0
$l>0, m=n=0$	rMeridionalGradient	rSpatialExponent	0
$l>0, m>0, n=0$	1	rSpatialExponent	0
$l=m=0, n>0$	rHarmonic	0	rHarmonicExponent
$l>0, n>0$	rHarmonic	rSpatialExponent	rHarmonicExponent

References

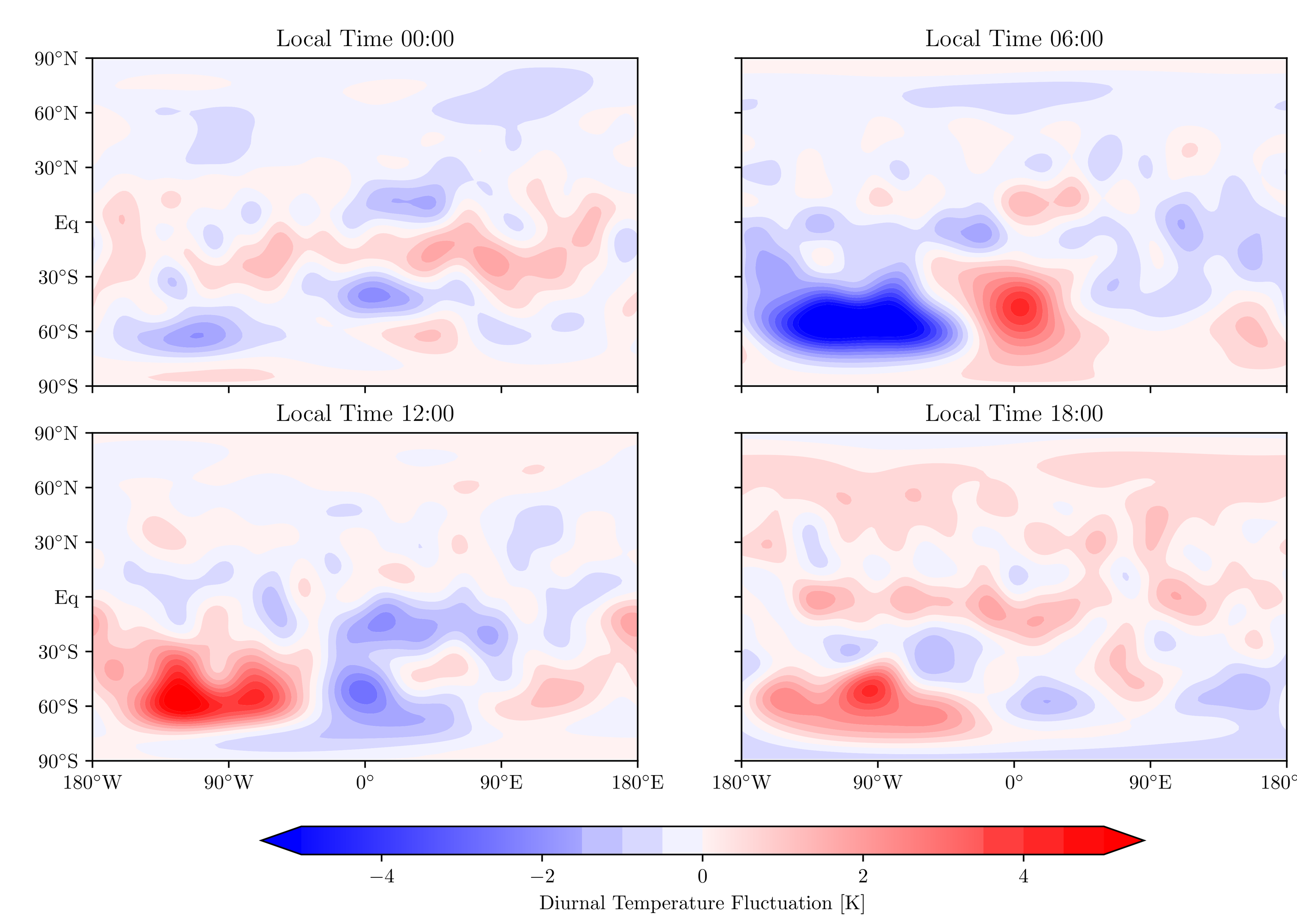
Leroy, S.S., 1997: Measurement of geopotential heights by GPS radio occultation. *J. Geophys. Res.,* **102** (D6), 6971–6986.

Leroy, S.S., C.O. Ao, and O.G. Verkhoglyadova, 2012: Mapping GPS radio occultation data by Bayesian interpolation. *J. Atmos. Ocean. Tech.,* **29**, 1062–1074.

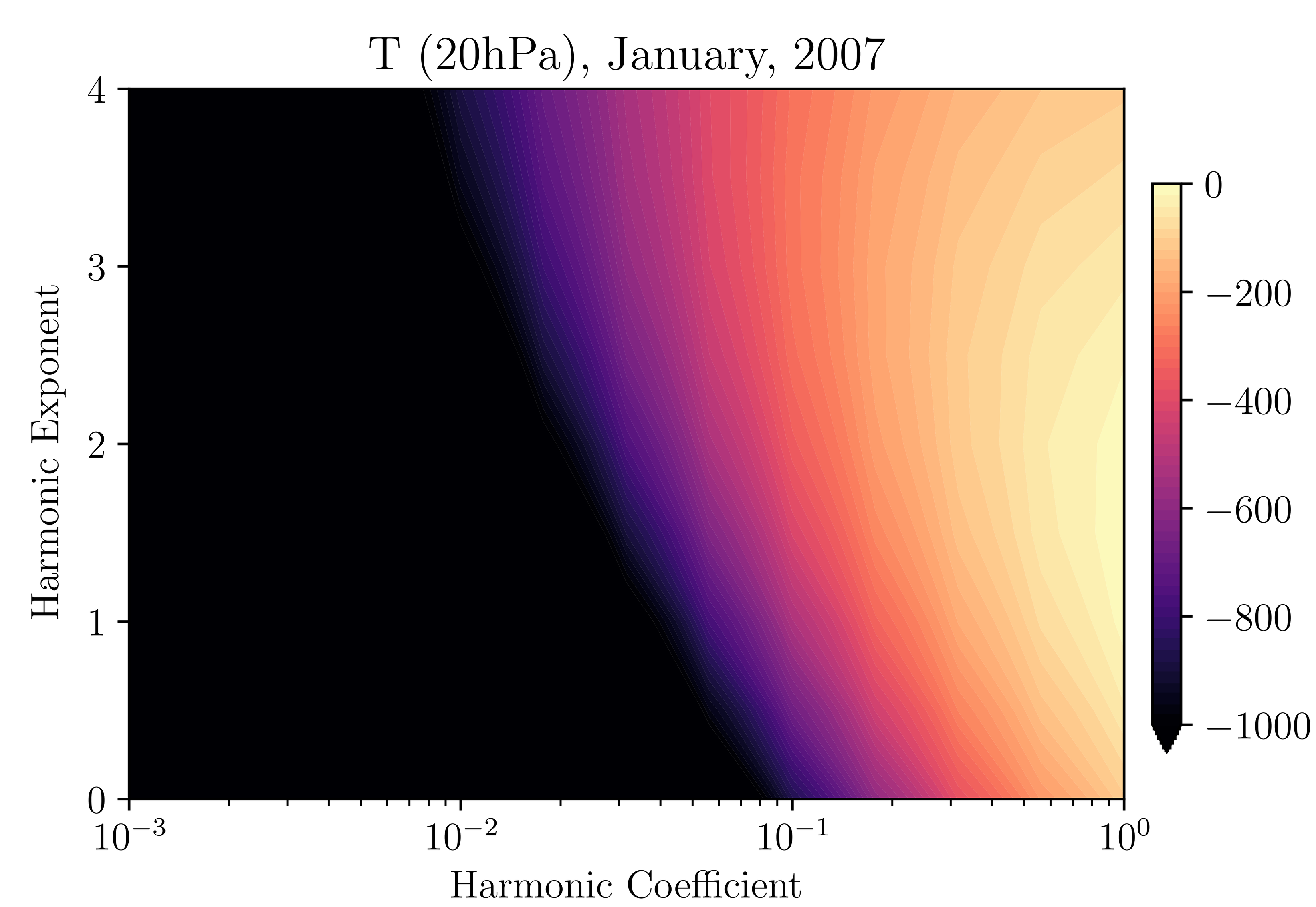
Diurnal cycle in temperature (20 hPa), COSMIC-1, January 2007
τ is local solar time



Diurnal cycle in temperature (20 hPa), COSMIC-1, July 2007



Probability of regularizer parameters



Findings

- Bayesian error analysis consistent with bootstrap error analysis (not shown).
- Standard (default) regularizer found objectively.
- *BayesianInterpolation package available from AER by license agreement.*