

# 地表-大気系の火星ダスト 循環

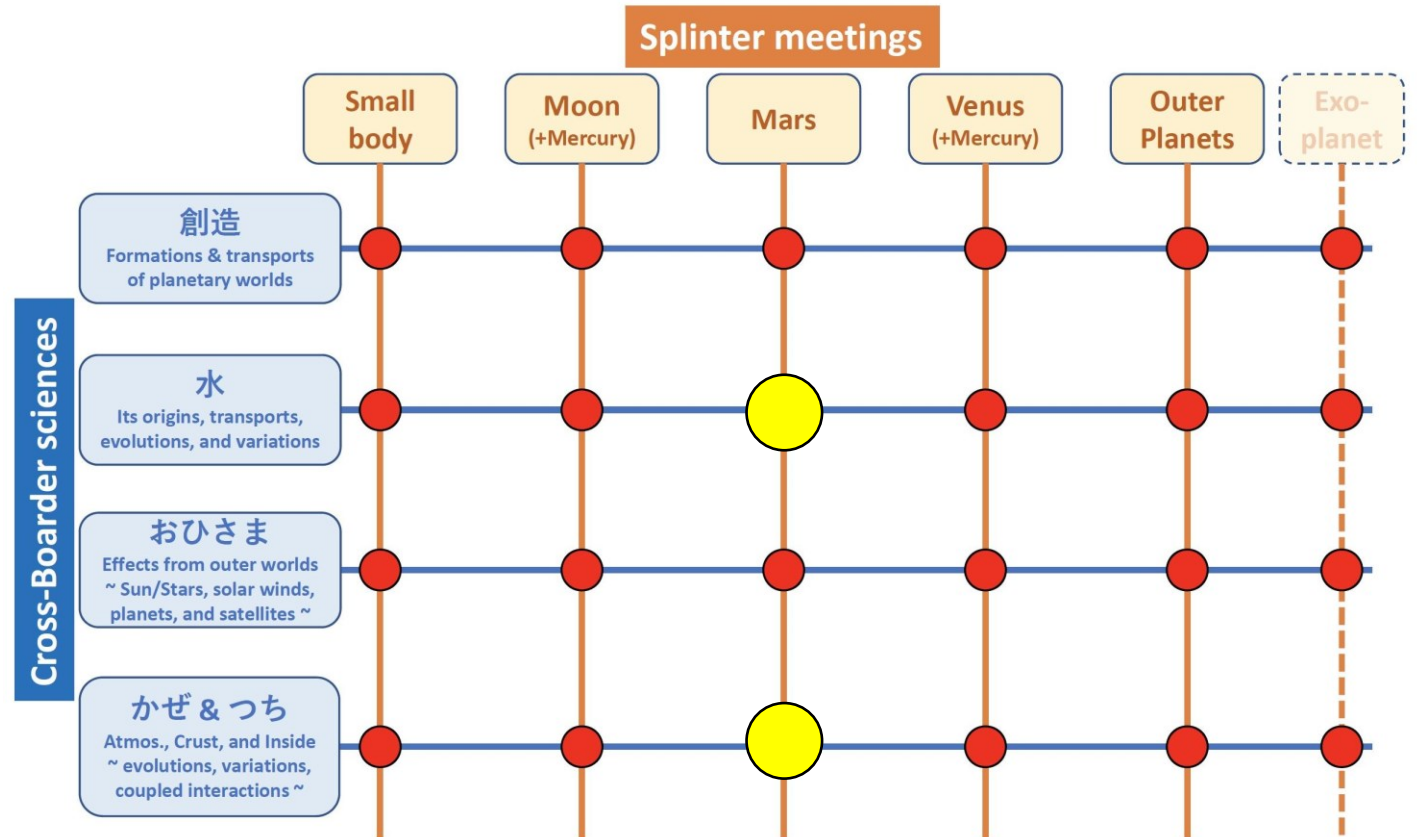
小郷原 一智 (おごはら かずのり)

京都産業大学

今日の位置  
づけ

# Focus of the Symposium 2022

Multiple Column x Low approach for Science requirement & Mission strategy



Making borderless teams and finding/investigating seeds for future explorations!

# 火星大気中 の熱源： ダスト

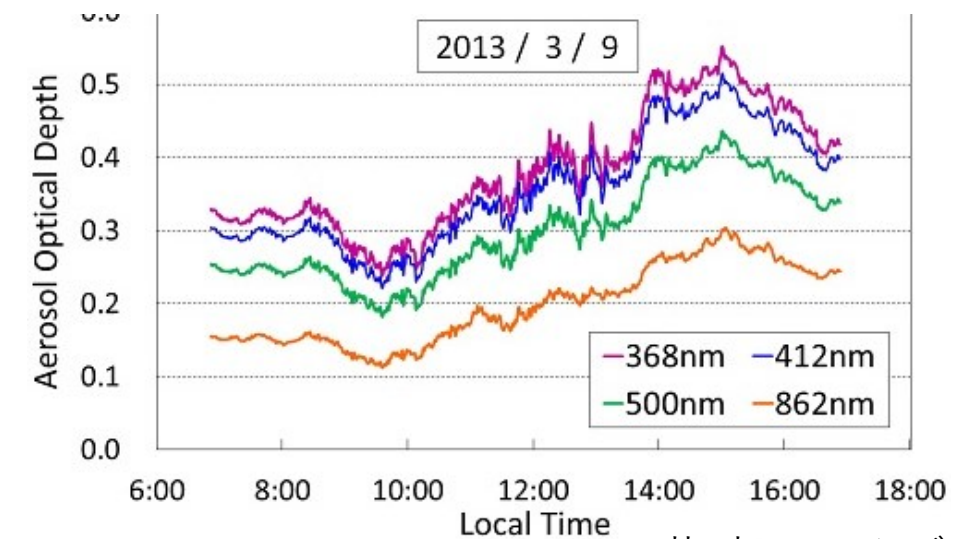
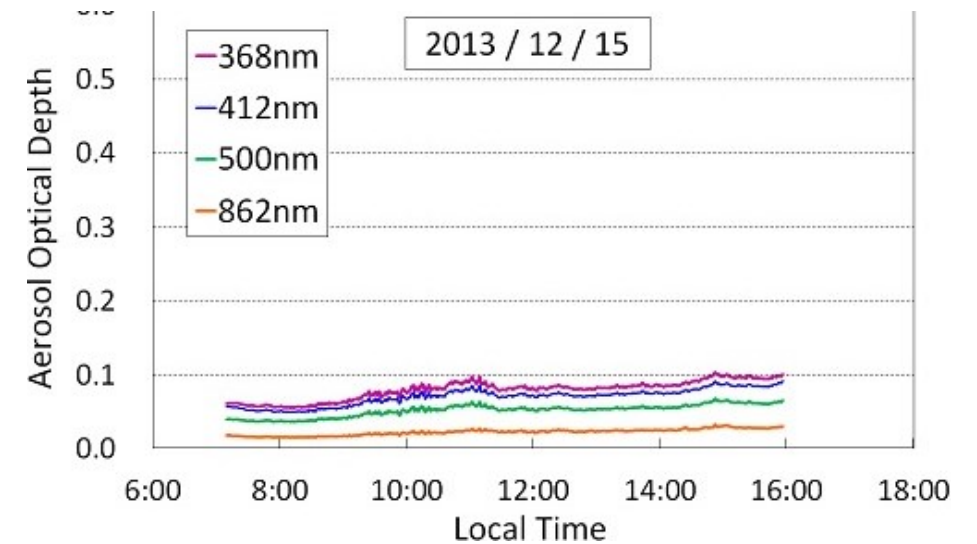
おひさまを浴びれば温まる，  
暗くなればじわじわ落ちる

Spiga et al. (2013)

Smith et al. (2001)

# 今の火星における ダストの役割

1. 地表の氷を隠す
2. 大気をそこだけ温める
  - →水蒸気の存在量上限を上げる
  - →上昇できる
  - →水その他の物質を効率的に上空に輸送する
3. 雲の生成を促す
  - 自らが地面に落ちるとともに水を地面に落とす



# ダストの時空間分布

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Heavens et al.

- 大気
  - 低緯度：
    - Detached layer (Heavens et al.,)
    - A storm
  - それ以外
    - B and C storms
  - 北半球の夏にダストが少なく (clear season) , 南半球の夏に多い (dusty season)
  - たまにGlobal dust storm (GDS) が発生するが、毎年とは限らない
  - GDSの開始季節も  $L_s=180-270$  くらいの幅がある

Smith et al. (2002)

# ダストの時空間分布

- 地面
  - GDS2001はHellas（1発目）とDaedalia（2発目）で形成された。
  - GDSが収まってみると，Hellasは明るく，Daedaliaは暗くなった
    - （曰はく）当該2地域からダストが取り除かれたが，GDS中にHellasにはダストが戻ってきた
  - GDSがなかった次のMYは，Hellasは暗く，Daedaliaは明るくなるセンス。
- 何らかの循環を示唆している。

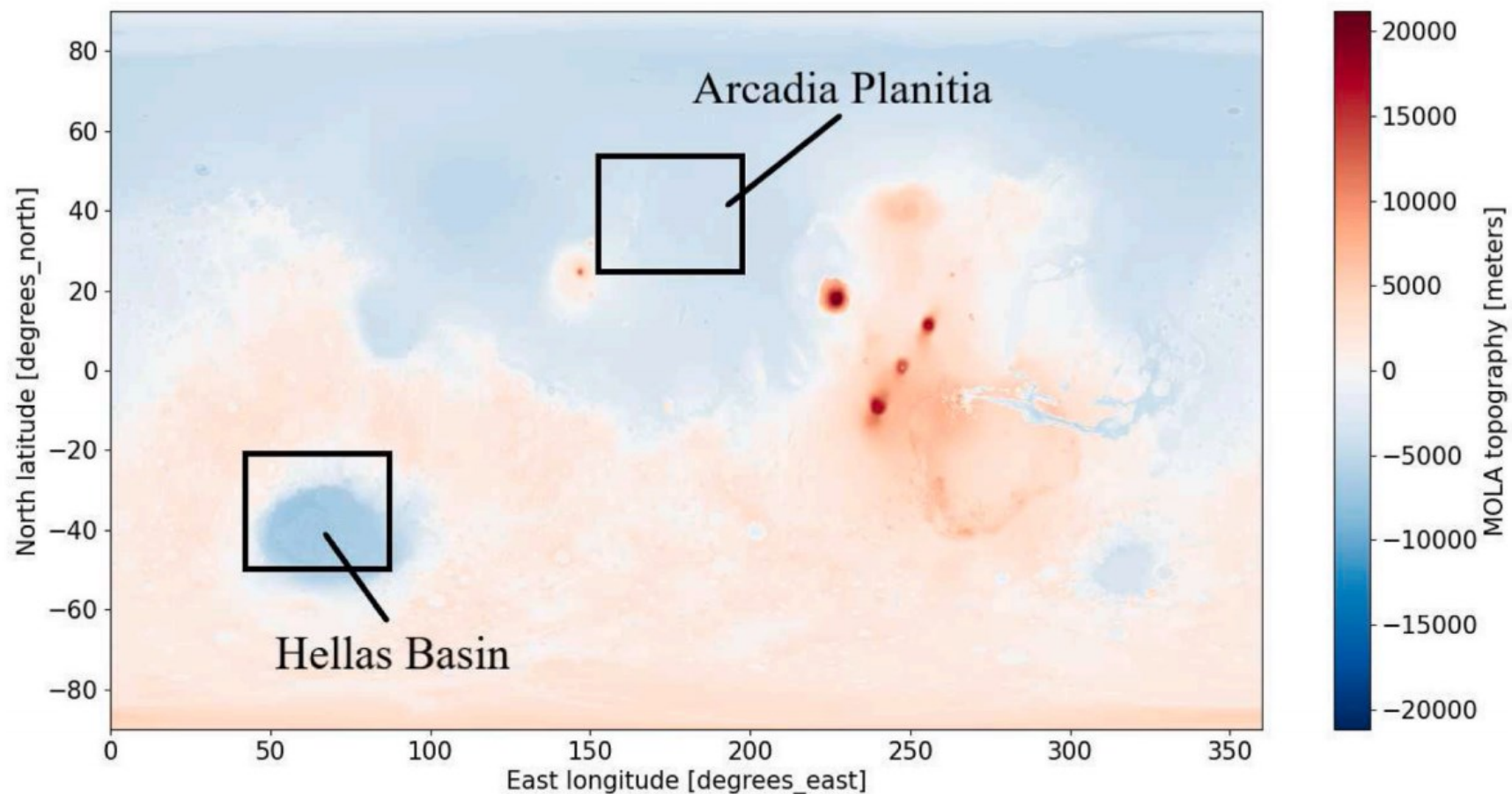
Szwast et al. (2006)

# 地表のダスト in GCM

- 無限のsurface dust (Newman et al., 2002b)
  - 毎年GDSが発生したり, 1発目が必ず同じ地域だったり
  - 観測されていない地域から発生したり
- 有限のsurface dust
  - 何年か後に枯渇し, 二度とダストストームが起こらない
  - 観測された地域から発生しない
- いろいろ難しいことが行われる (Newman & Richardson 2015)
  - ダストの多寡によって粗度が変わるよね
  - ダストが少なくなったら舞い上がらなくなるから, 臨界摩擦速度上げていいよね
  - 何十年か後には定常的なダストサイクルになるだろうから, そうなるようにチューンして問題ないよね

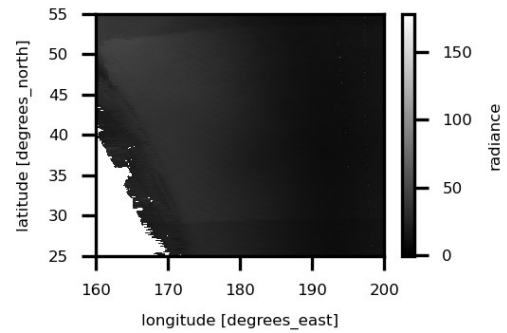
Newman et al., 2002b

地表と大気のコストがどれくらい活動的か知っていますか？

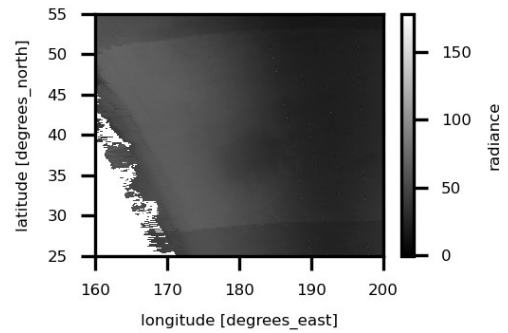




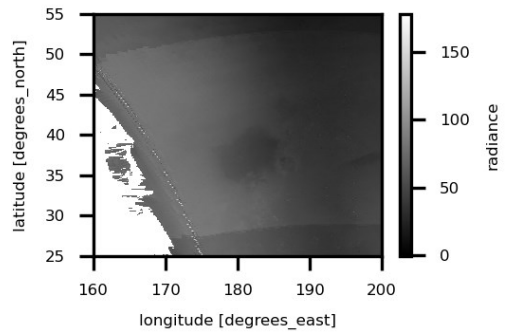
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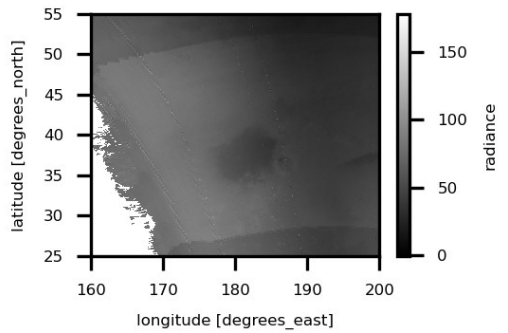
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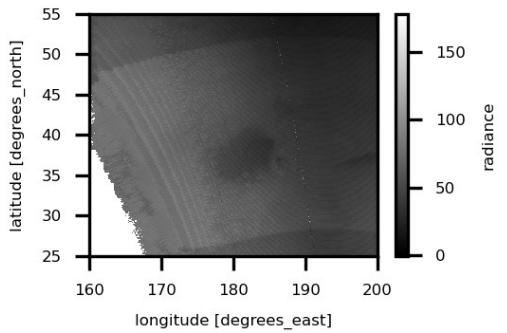
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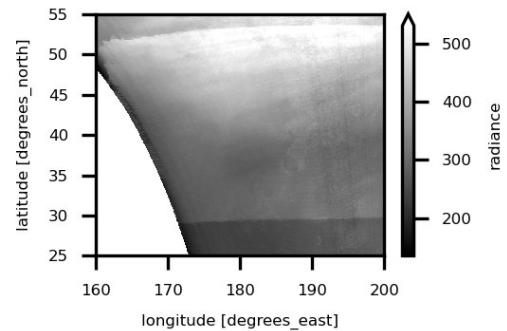
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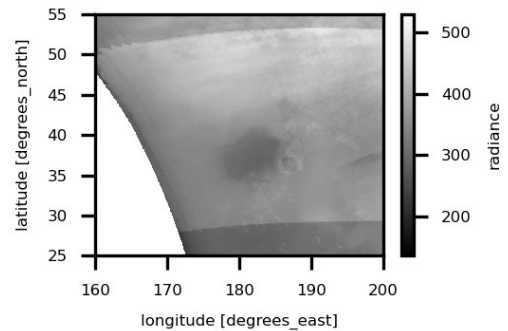
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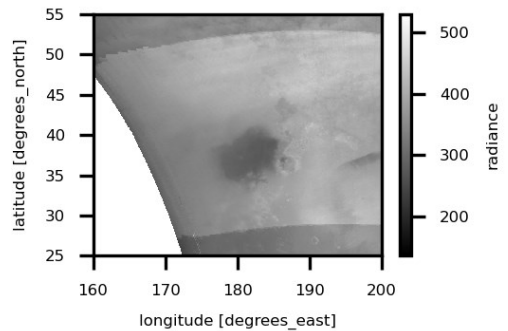
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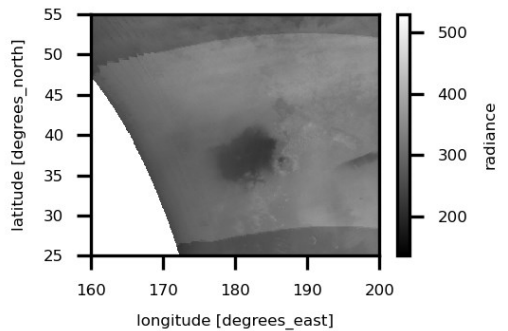
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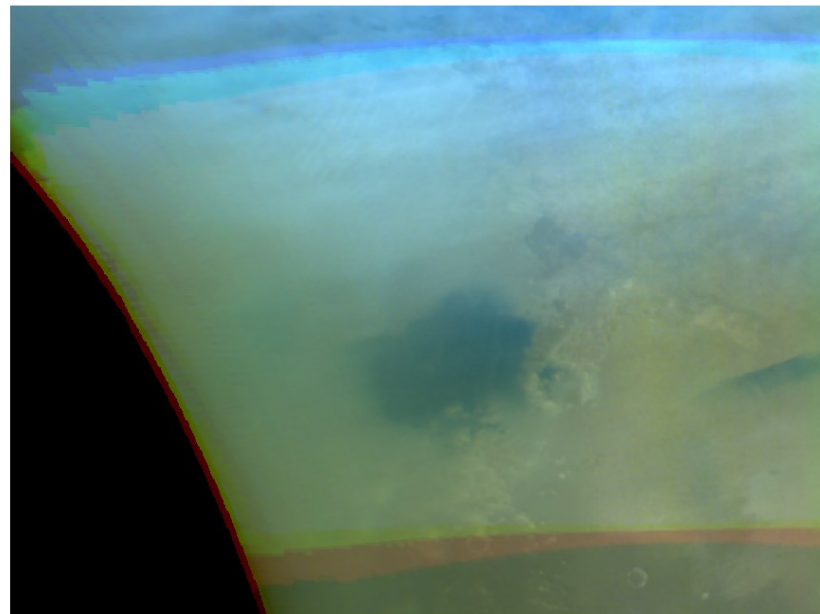
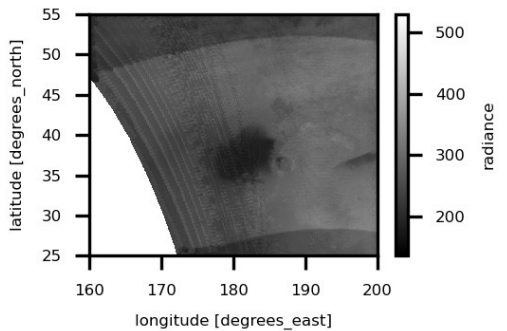
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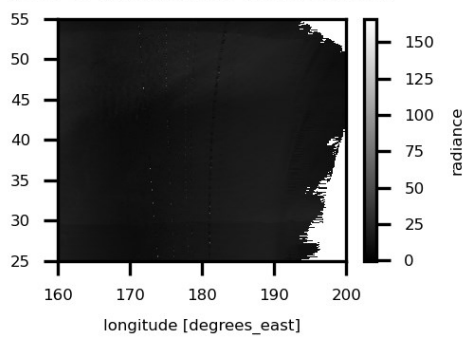


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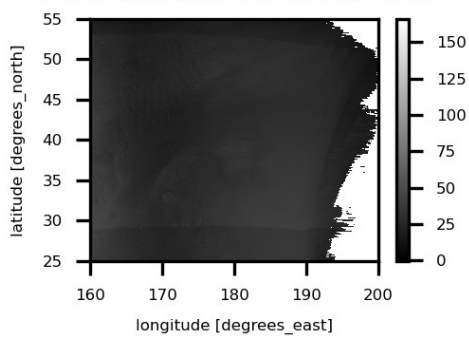


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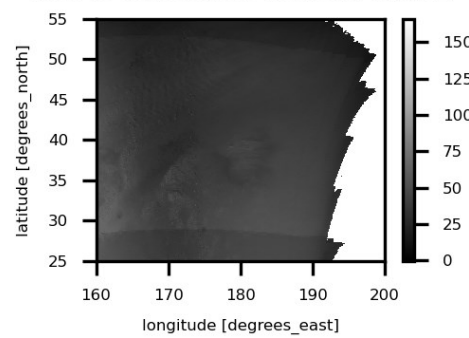
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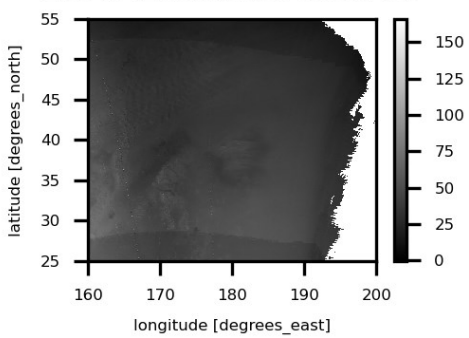
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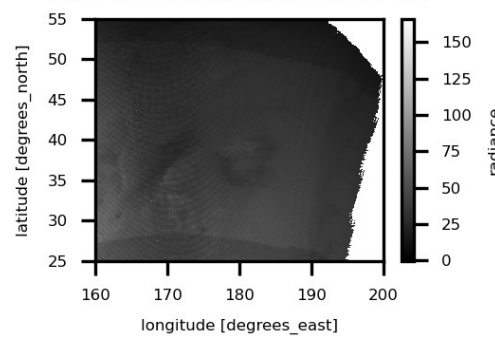
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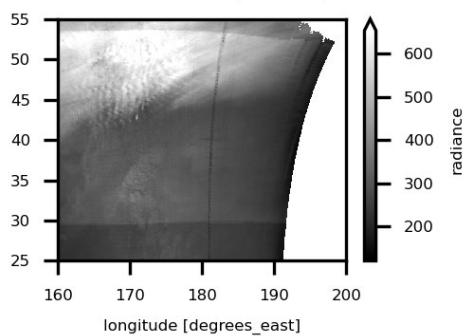
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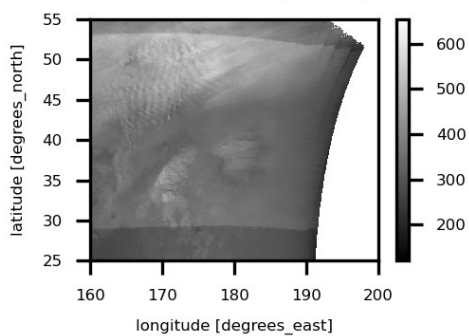
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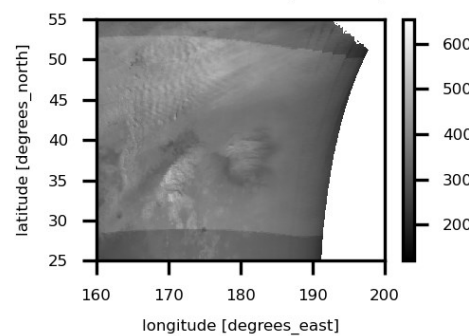
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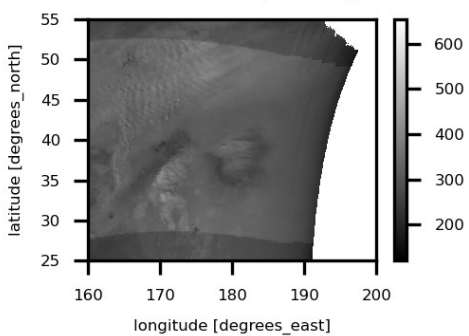
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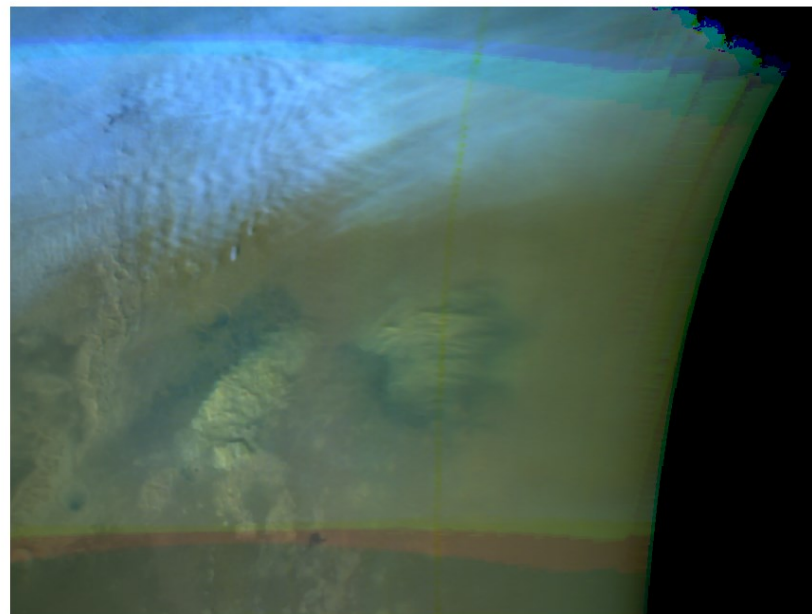
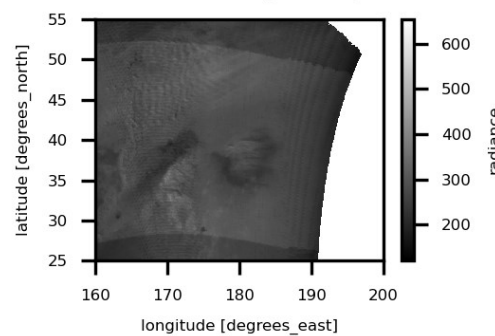
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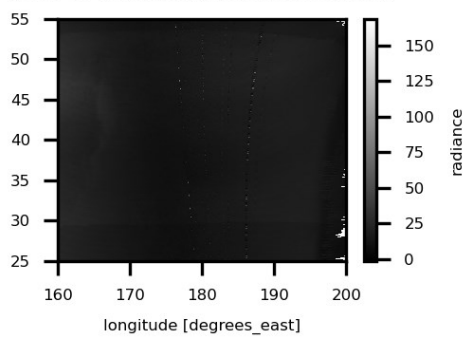


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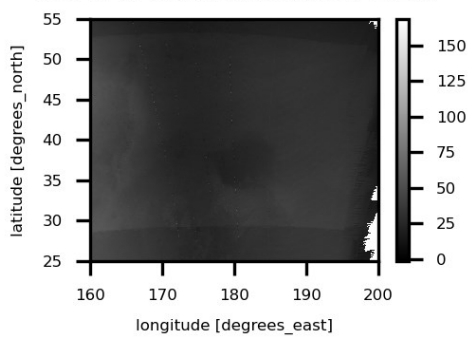


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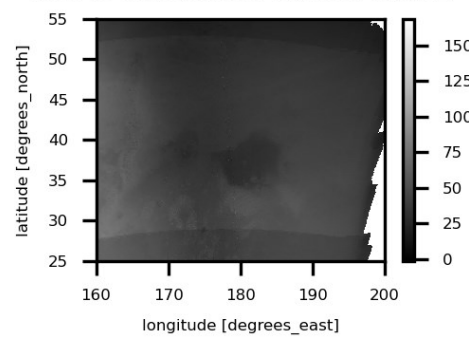
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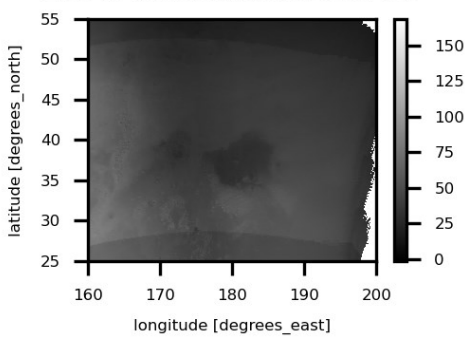
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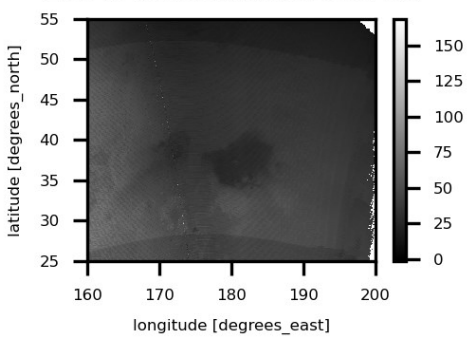
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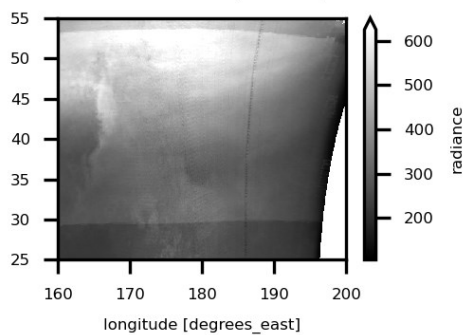
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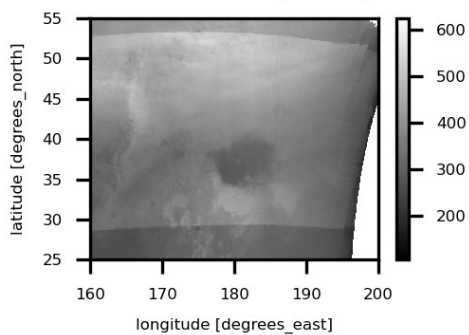
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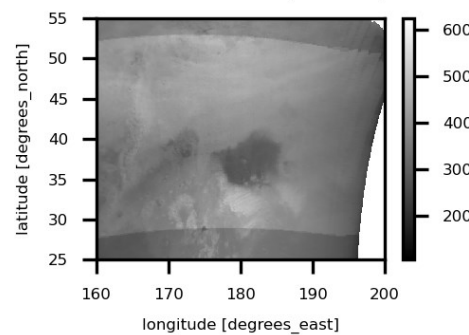
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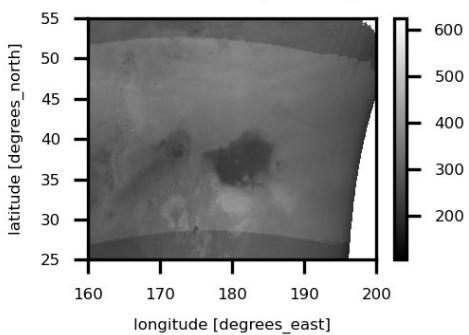
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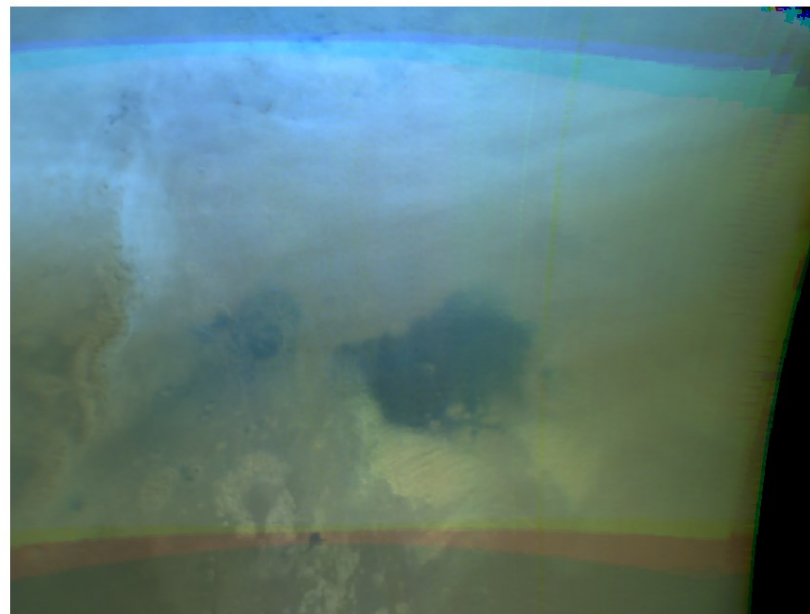
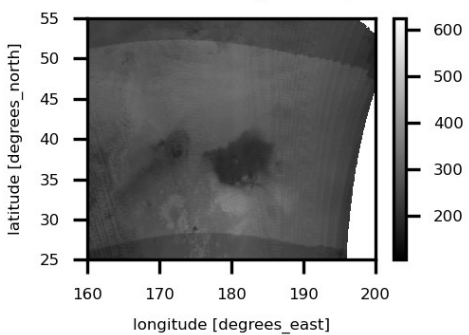
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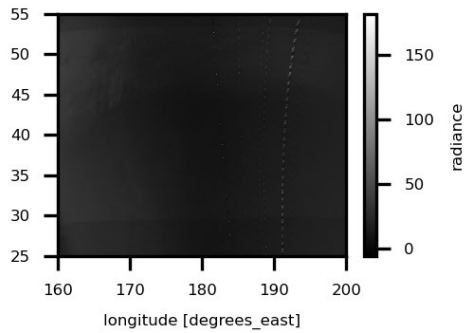


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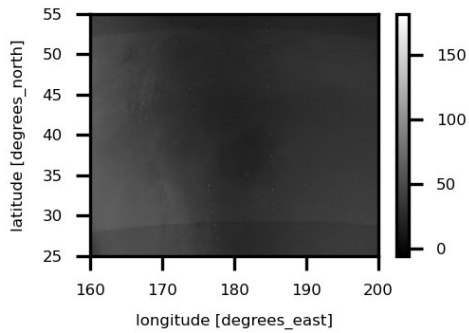


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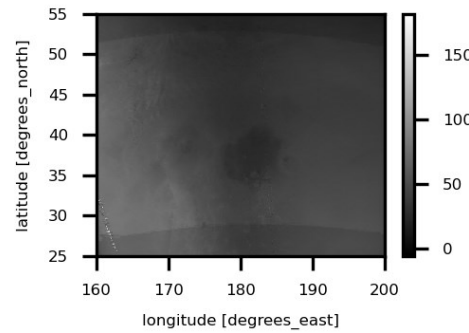
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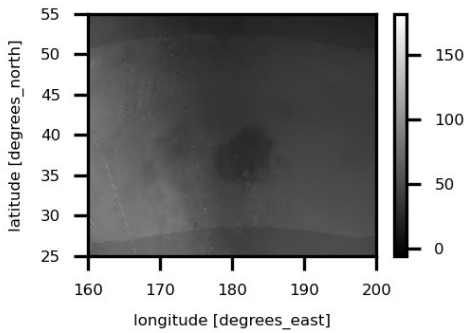
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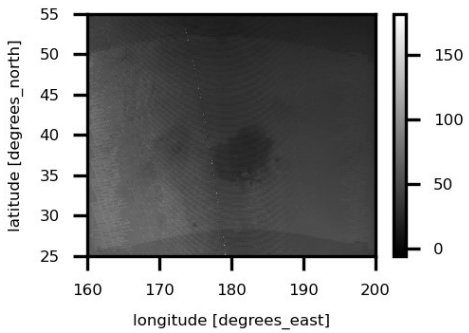
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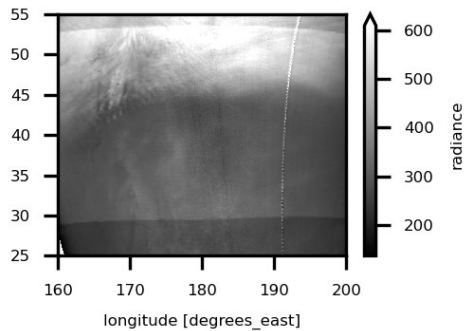
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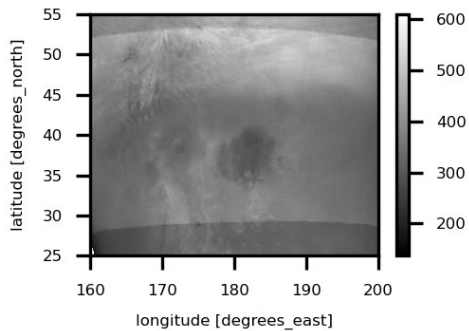
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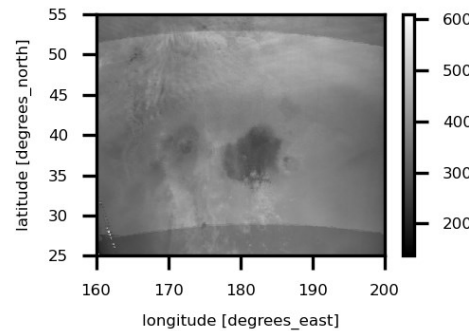
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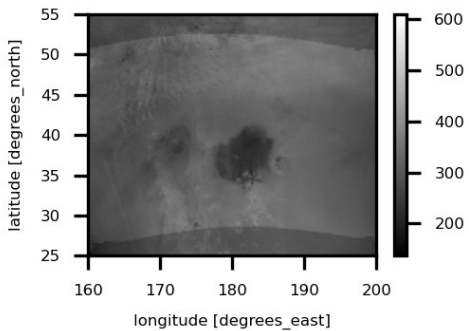
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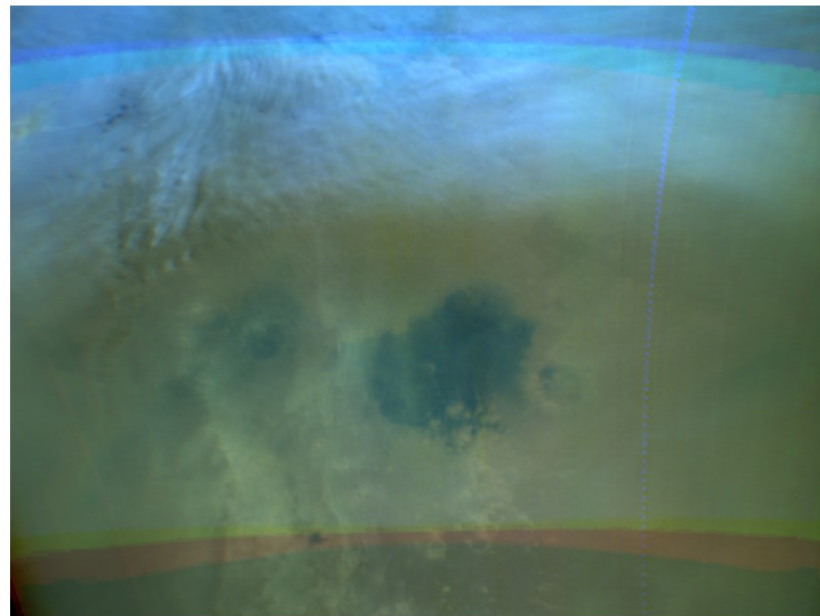
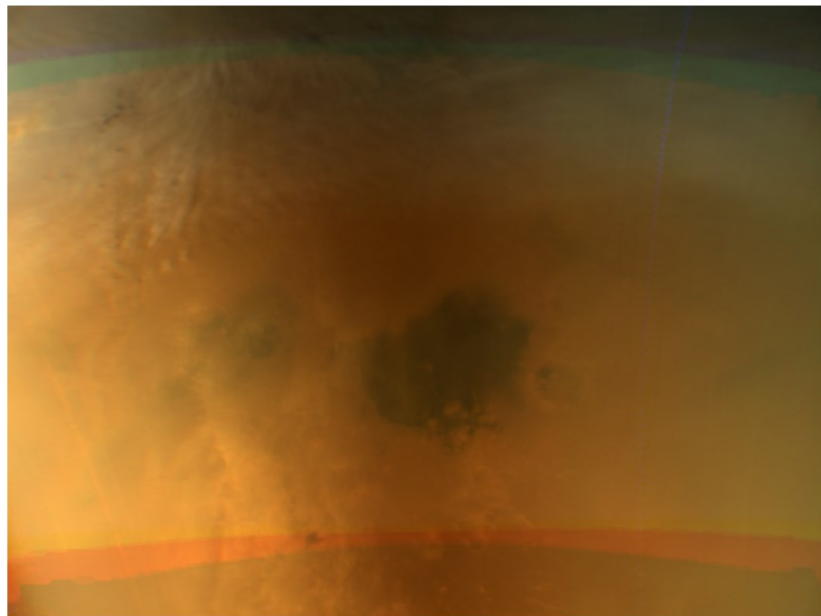
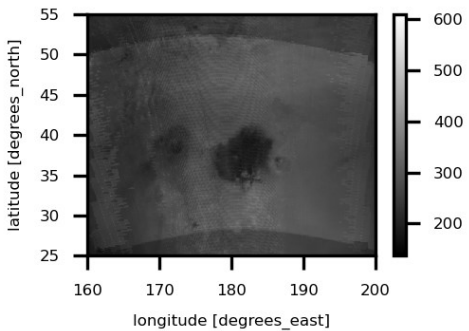
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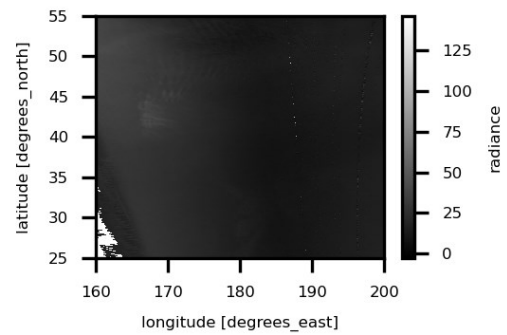


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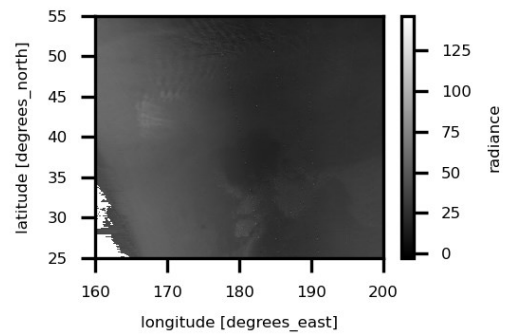


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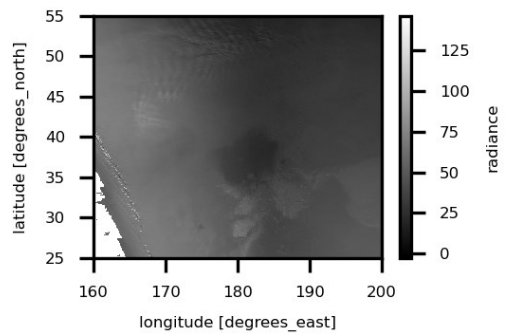
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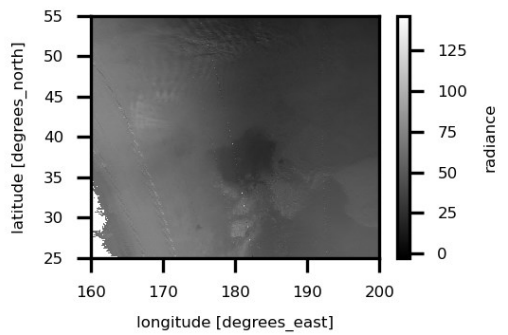
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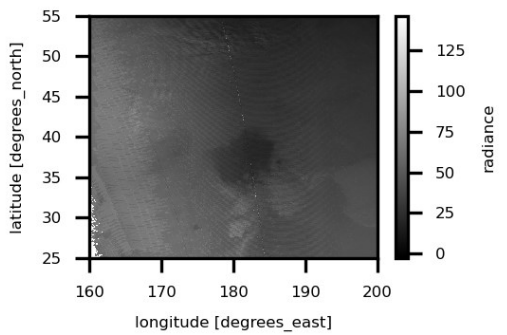
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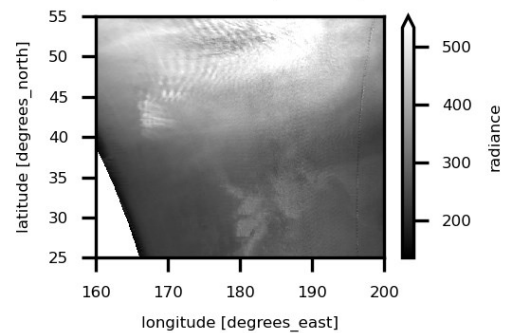
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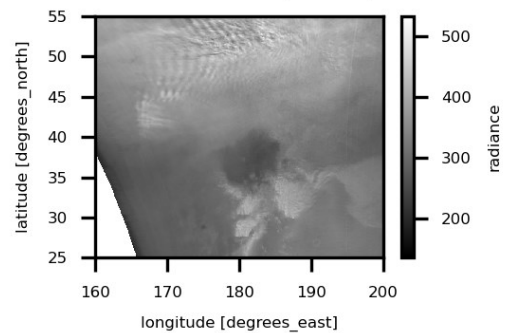
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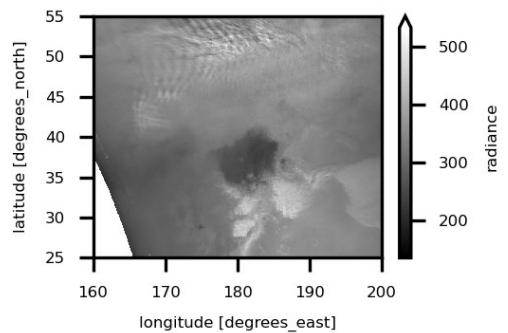
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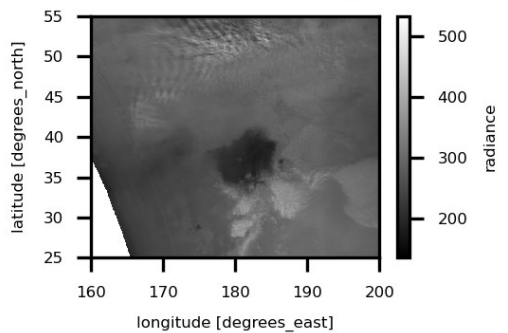
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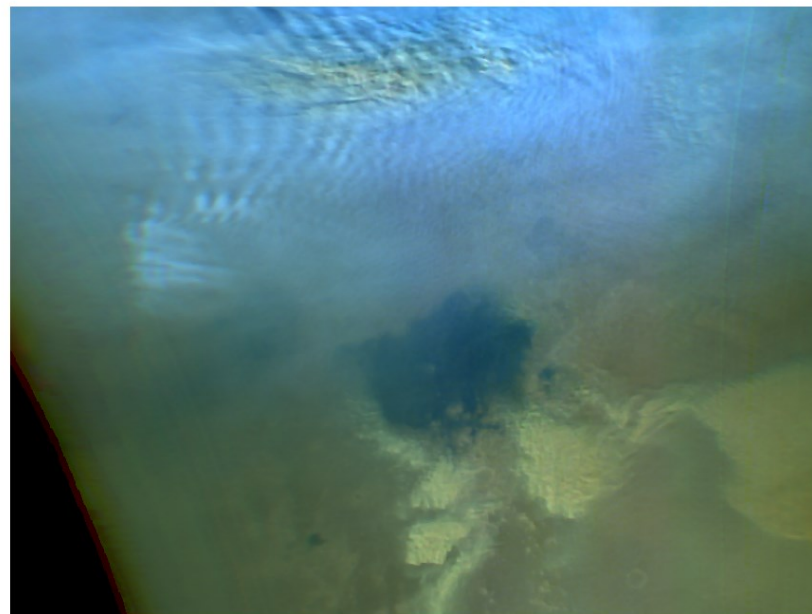
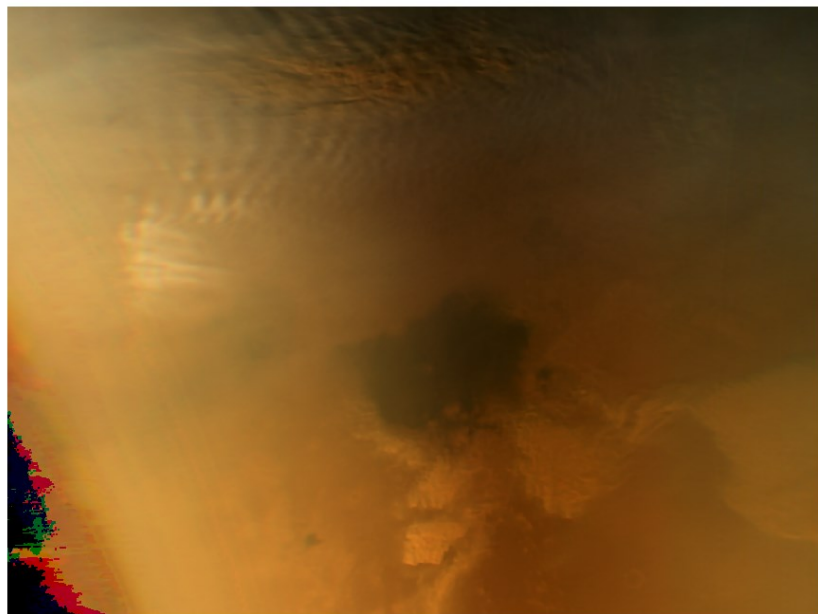
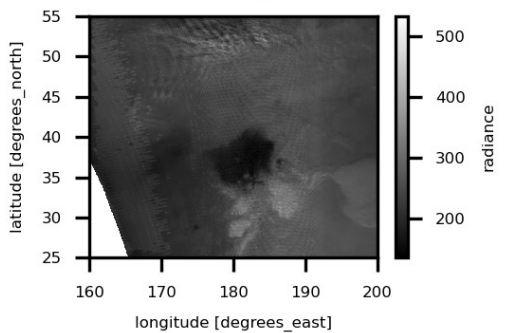
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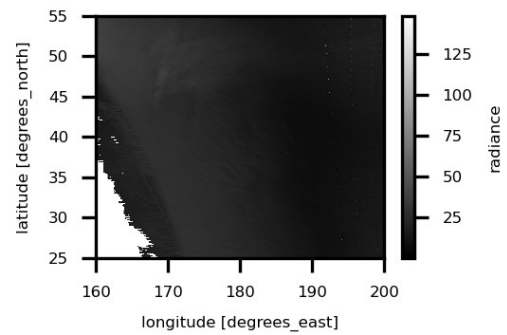


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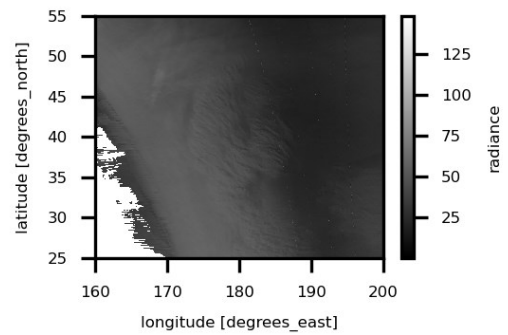


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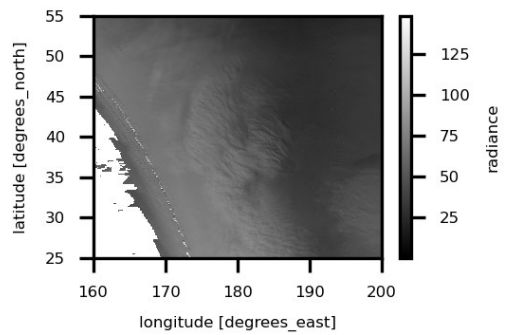
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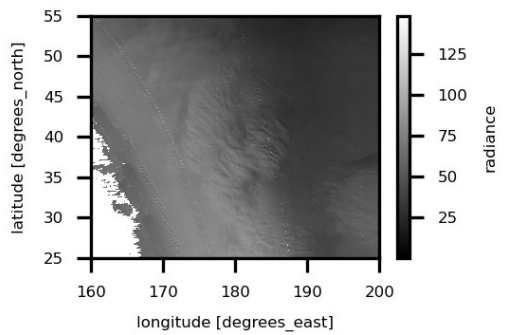
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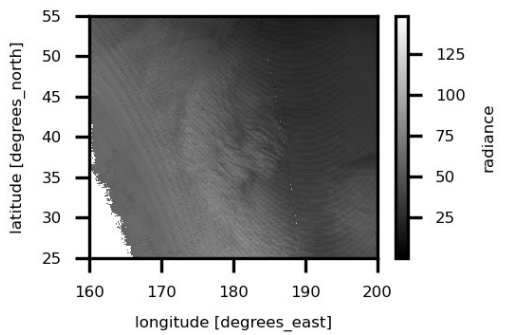
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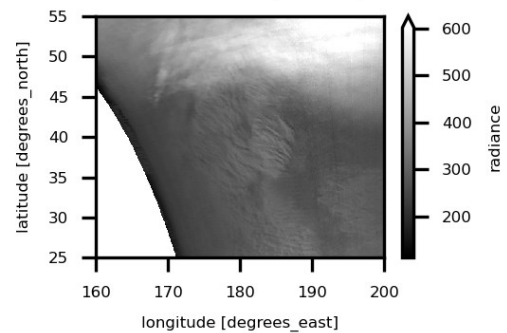
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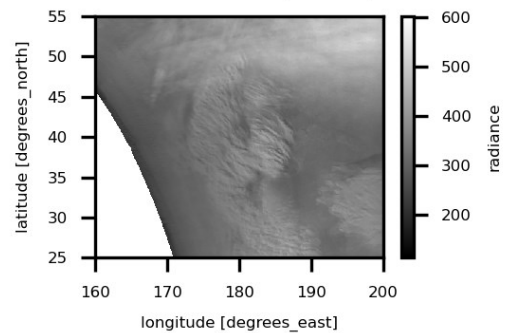
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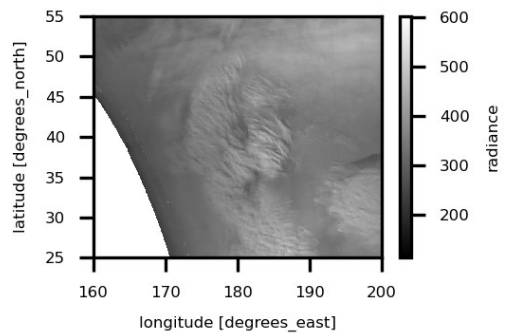
Corrected. BLUE (WR2015)



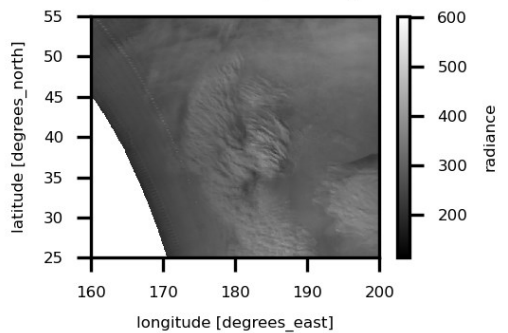
Corrected. GREEN (WR2015)



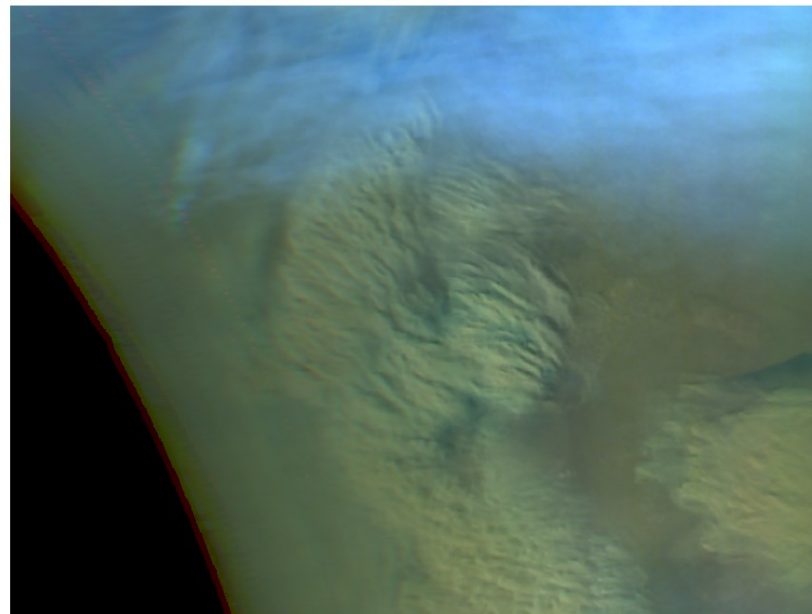
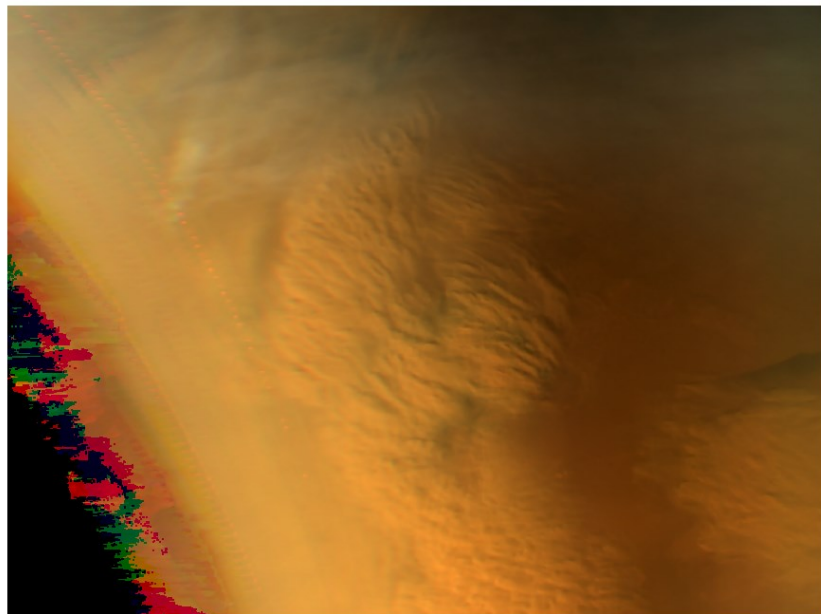
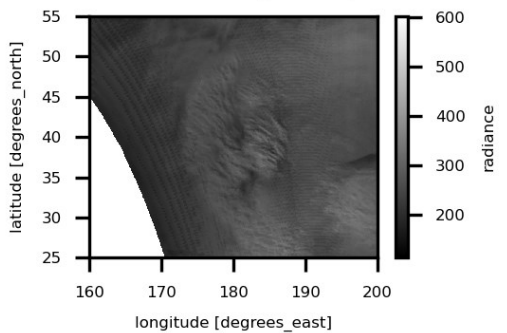
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

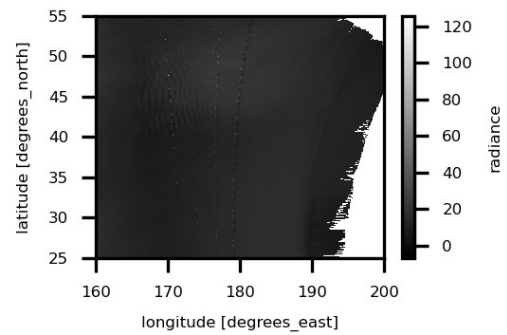


Corrected. NIR (WR2015)

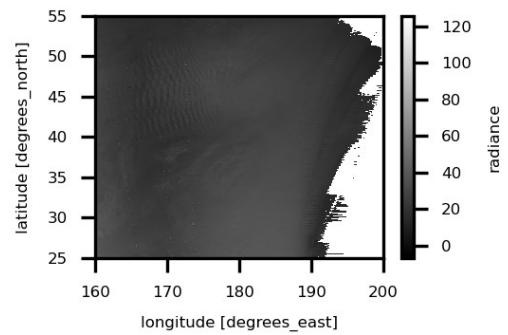


Ls : 322.6  
 time : 2009-08-17T00:55:18.472199936  
 orbit : 14329  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-17T00:55:18.472200+00:00

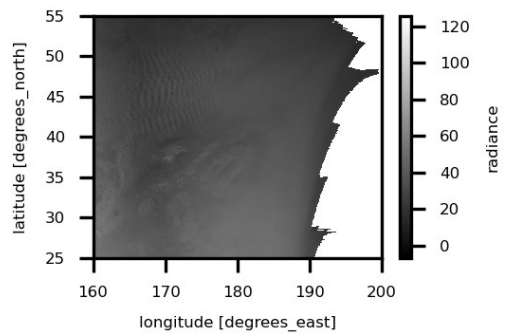
2009-08-18T03:06:10.017059968, BLUE



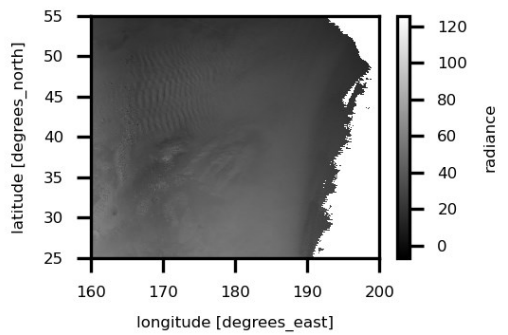
2009-08-18T03:06:10.017059968, GREEN



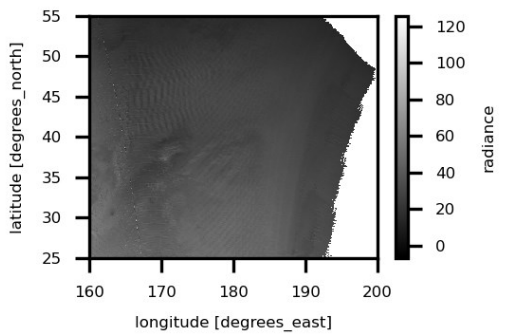
2009-08-18T03:06:10.017059968, ORANGE



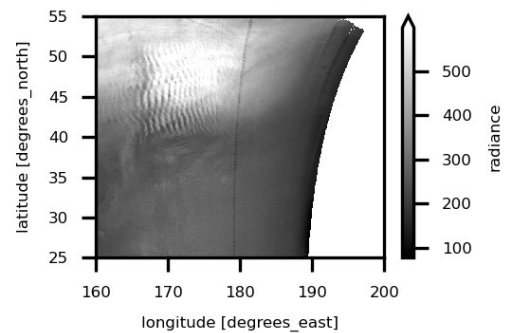
2009-08-18T03:06:10.017059968, RED



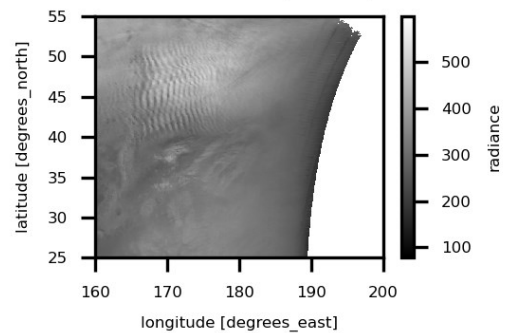
2009-08-18T03:06:10.017059968, NIR



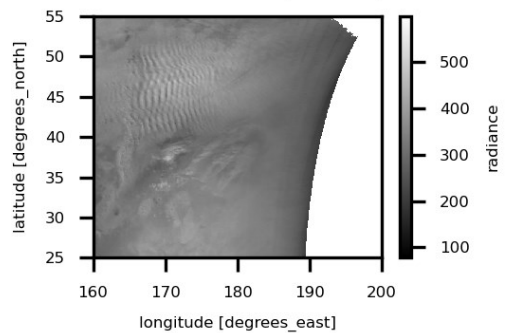
Corrected. BLUE (WR2015)



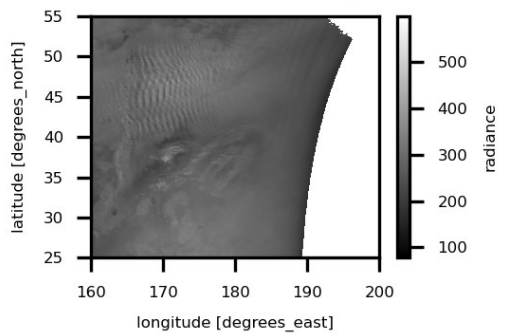
Corrected. GREEN (WR2015)



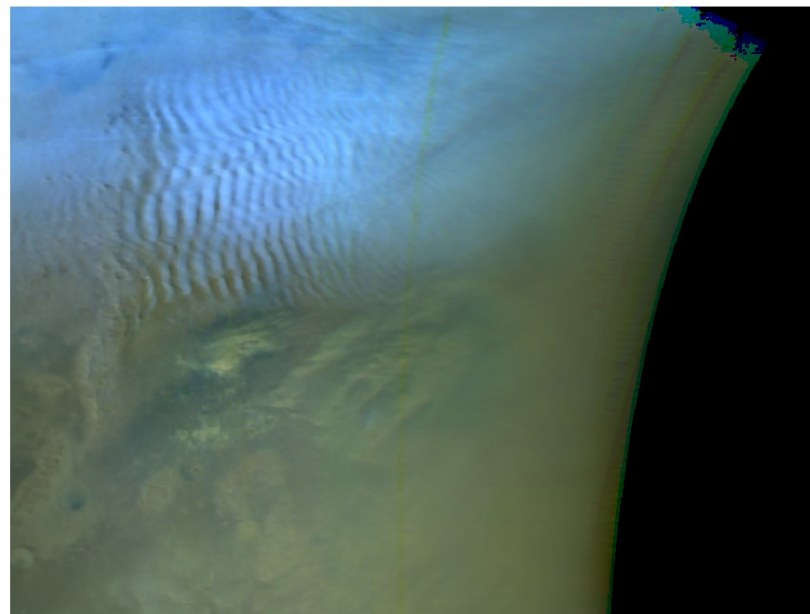
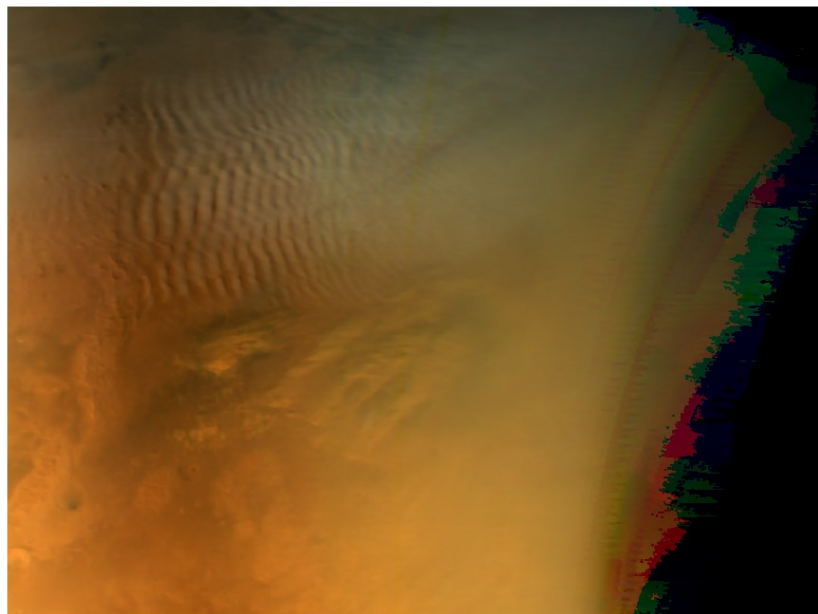
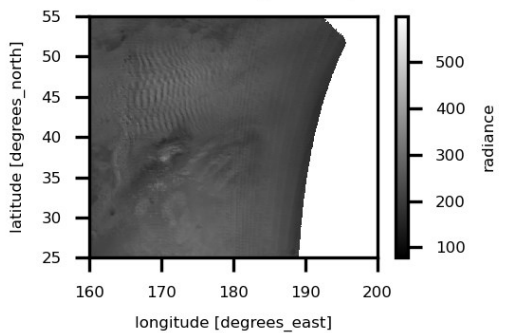
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

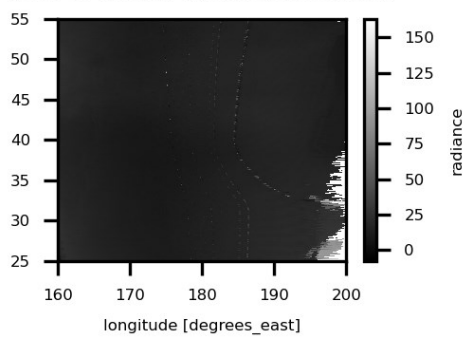


Corrected. NIR (WR2015)

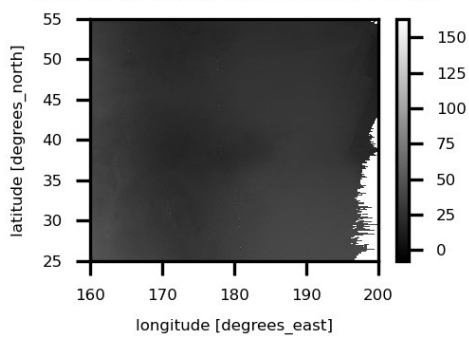


Ls : 323.2  
 time : 2009-08-18T03:06:10.017059968  
 orbit : 14343  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-18T03:06:10.017060+00:00

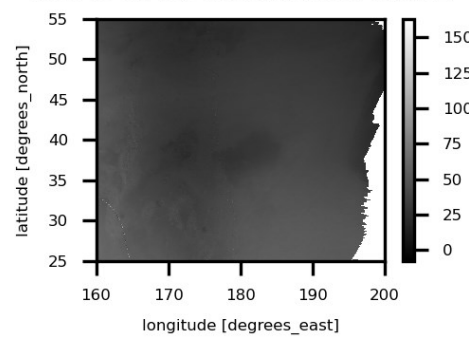
2009-08-19T03:24:46.890259968, BLUE



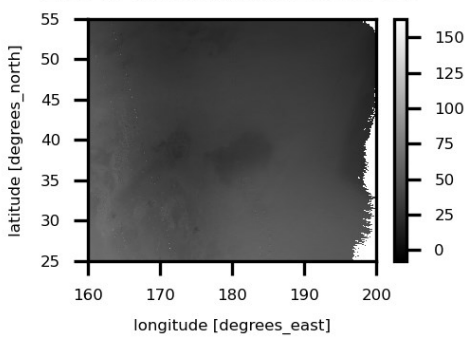
2009-08-19T03:24:46.890259968, GREEN



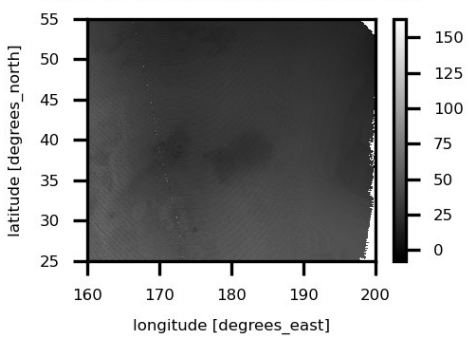
2009-08-19T03:24:46.890259968, ORANGE



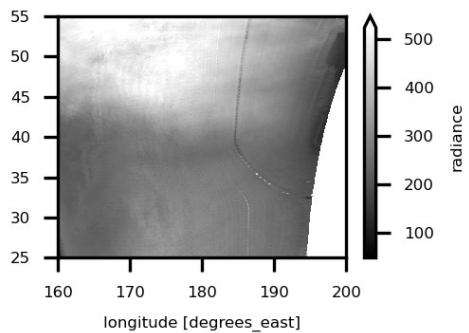
2009-08-19T03:24:46.890259968, RED



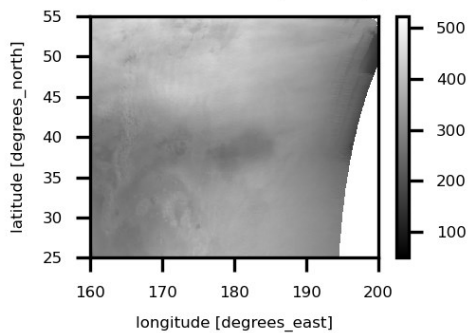
2009-08-19T03:24:46.890259968, NIR



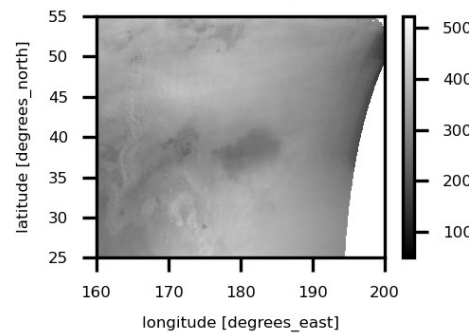
Corrected. BLUE (WR2015)



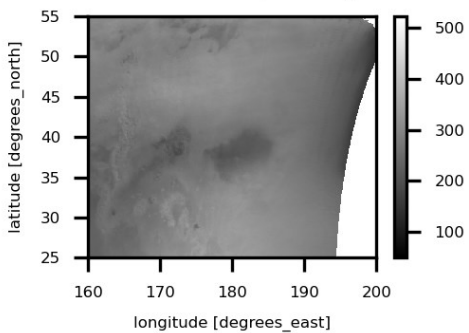
Corrected. GREEN (WR2015)



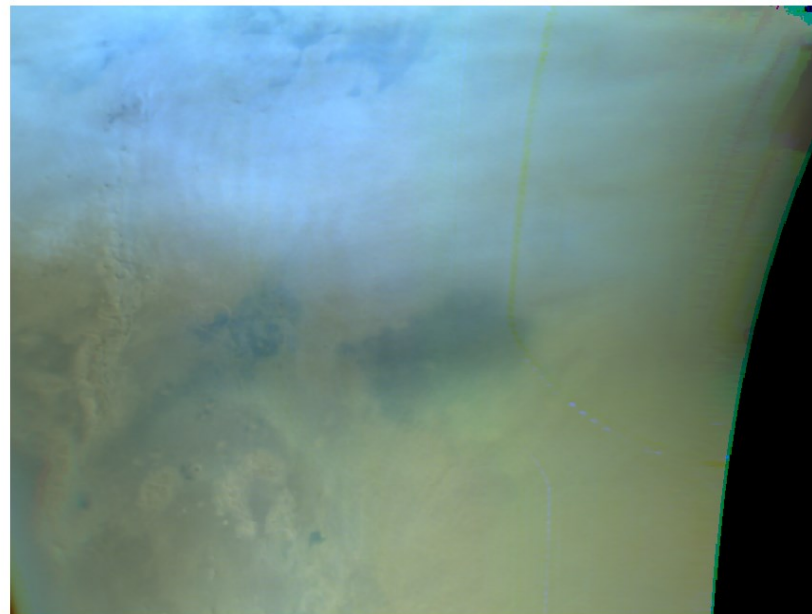
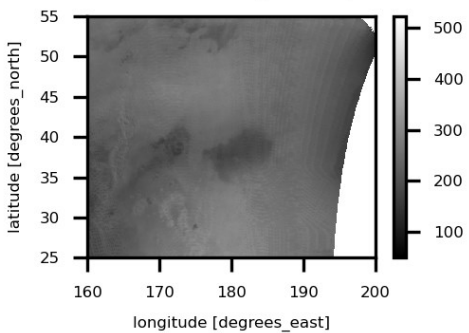
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)



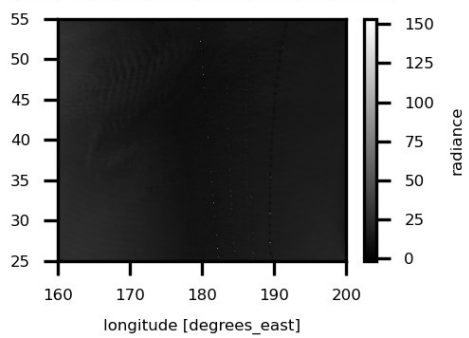
Corrected. NIR (WR2015)



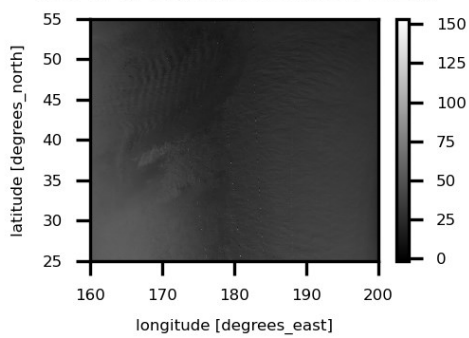
Ls : 323.8  
 time : 2009-08-19T03:24:46.890259968  
 orbit : 14356  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-19T03:24:46.890260+00:00



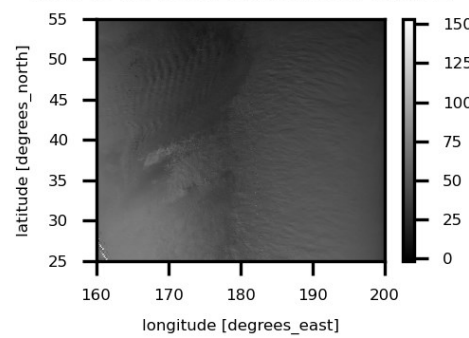
2009-08-20T03:43:23.560819968, BLUE



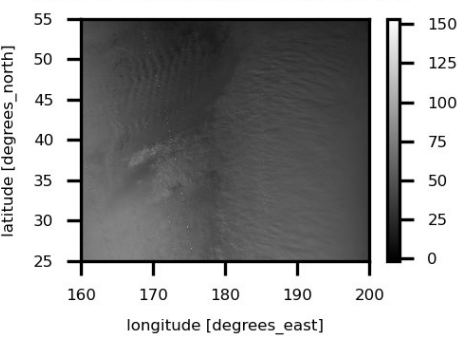
2009-08-20T03:43:23.560819968, GREEN



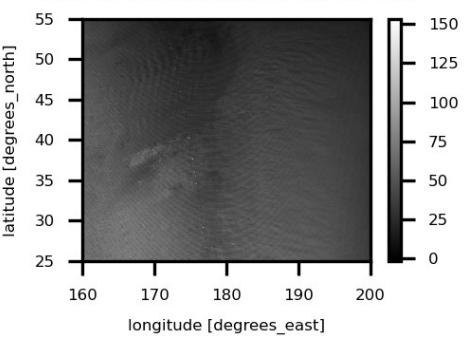
2009-08-20T03:43:23.560819968, ORANGE



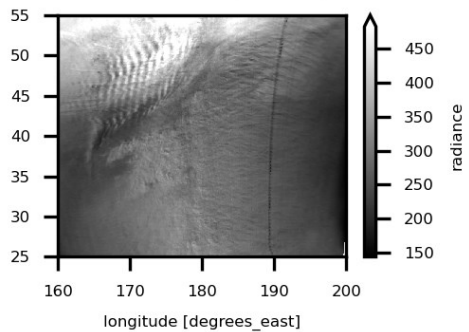
2009-08-20T03:43:23.560819968, RED



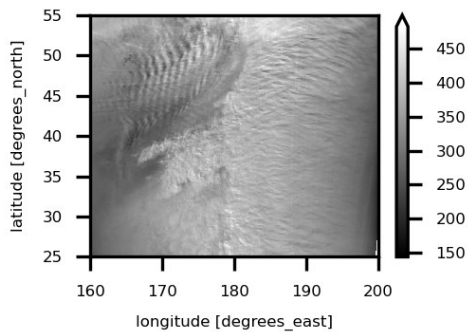
2009-08-20T03:43:23.560819968, NIR



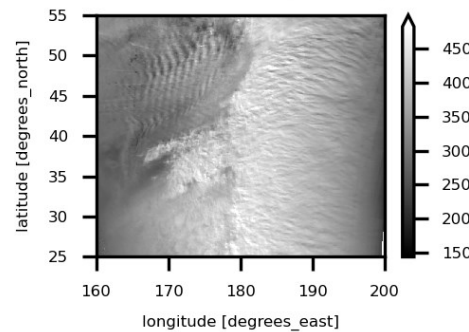
Corrected. BLUE (WR2015)



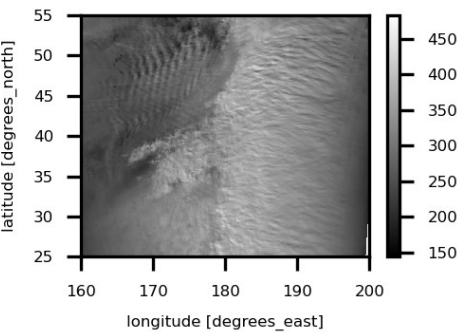
Corrected. GREEN (WR2015)



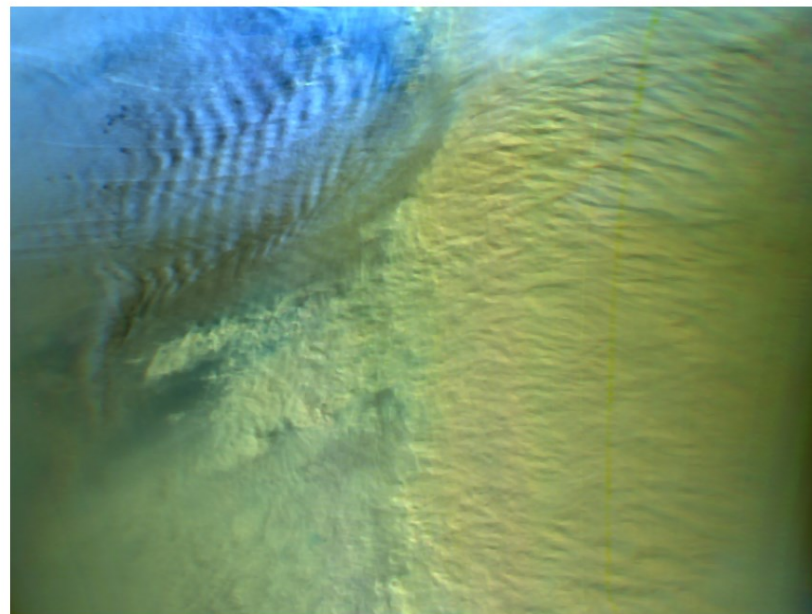
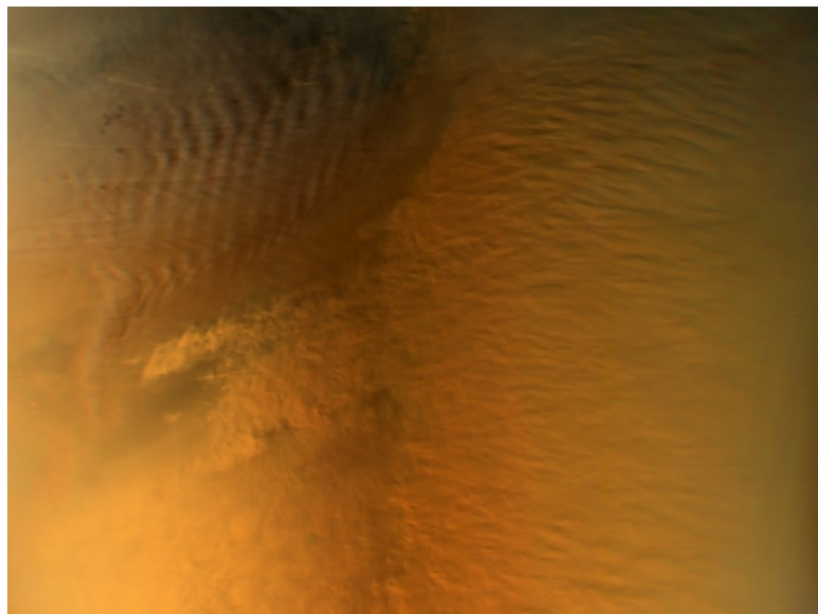
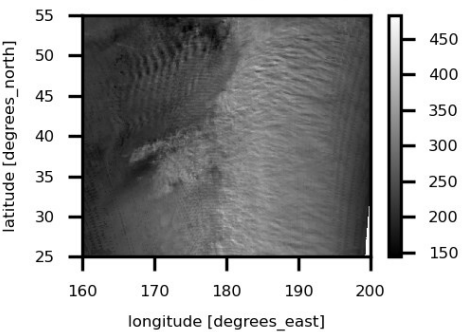
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

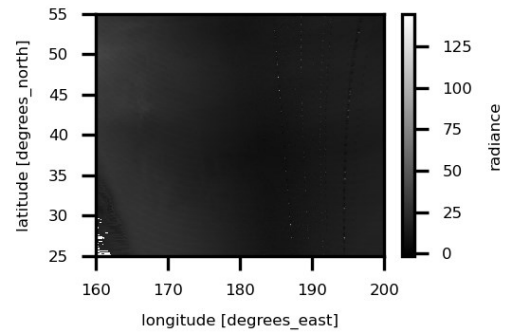


Corrected. NIR (WR2015)

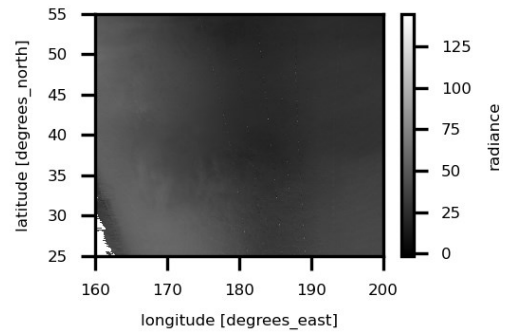


Ls : 324.3  
 time : 2009-08-20T03:43:23.560819968  
 orbit : 14369  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-20T03:43:23.560820+00:00

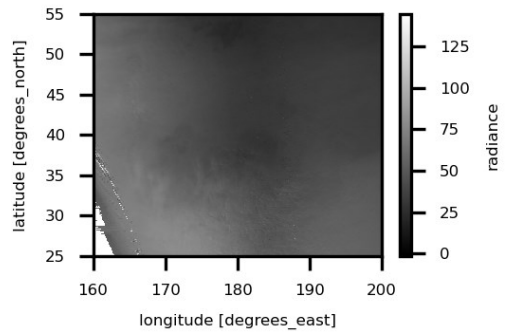
2009-08-21T04:02:04.528920000, BLUE



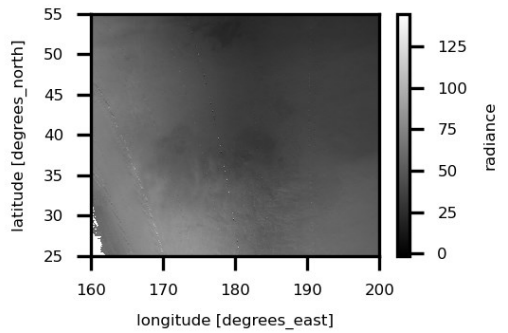
2009-08-21T04:02:04.528920000, GREEN



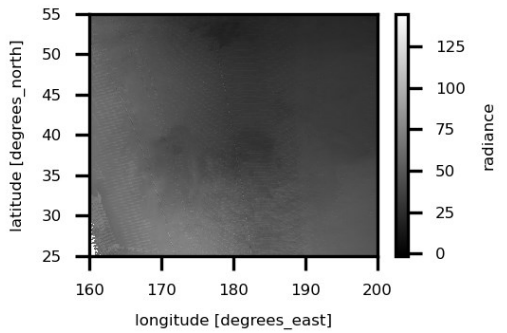
2009-08-21T04:02:04.528920000, ORANGE



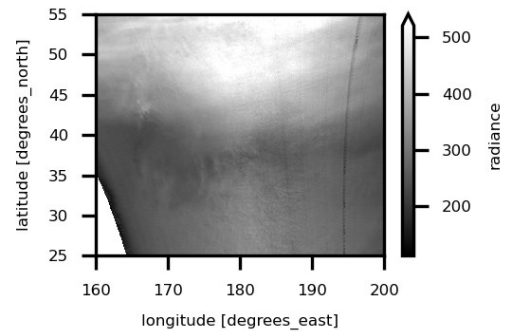
2009-08-21T04:02:04.528920000, RED



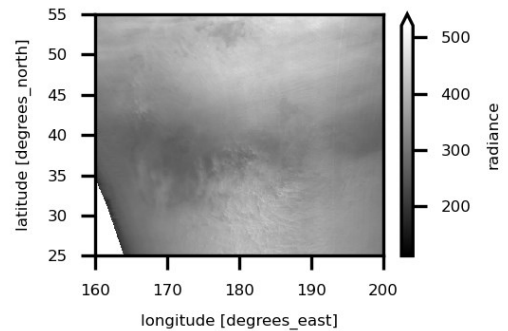
2009-08-21T04:02:04.528920000, NIR



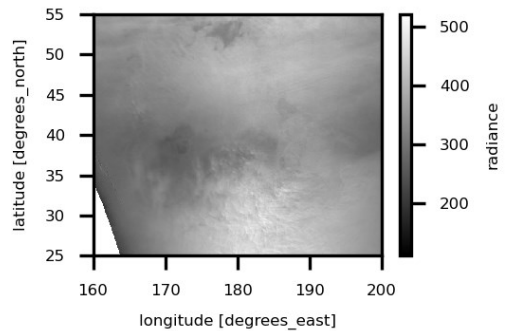
Corrected. BLUE (WR2015)



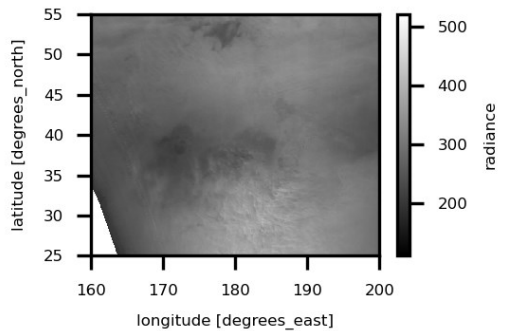
Corrected. GREEN (WR2015)



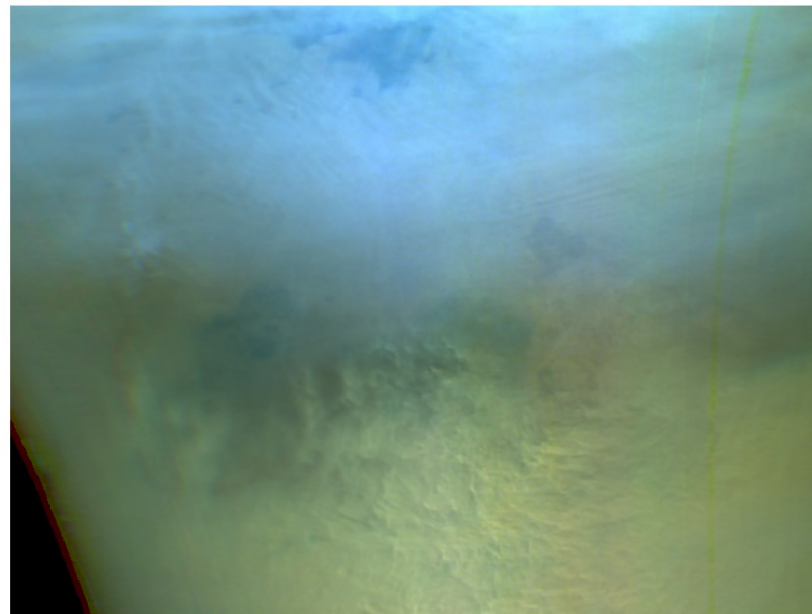
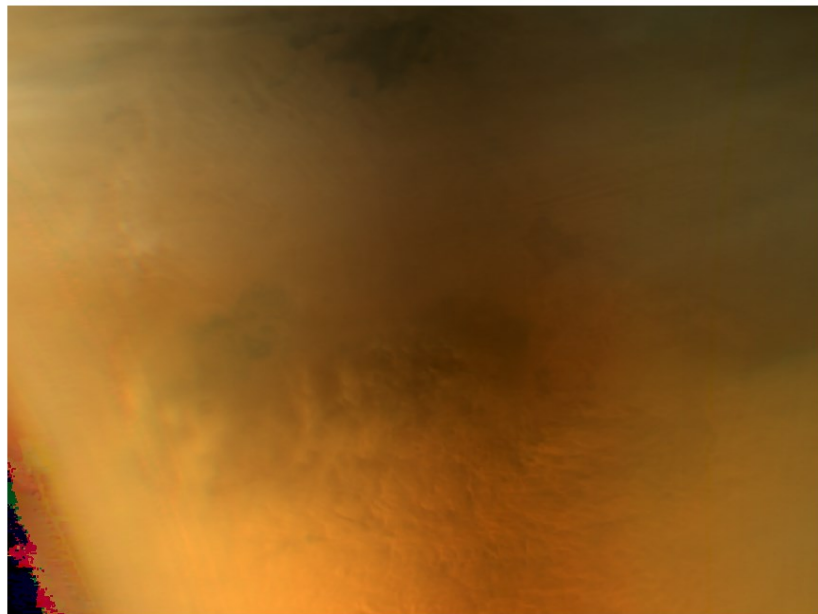
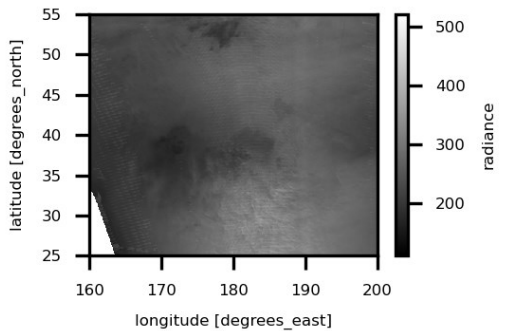
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

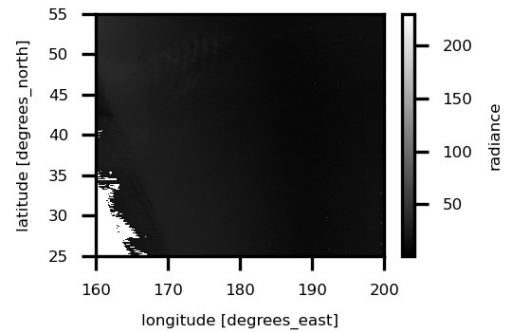


Corrected. NIR (WR2015)

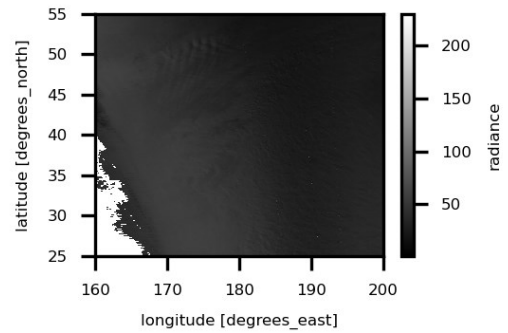


Ls : 324.9  
 time : 2009-08-21T04:02:04.528920000  
 orbit : 14382  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-21T04:02:04.528920+00:00

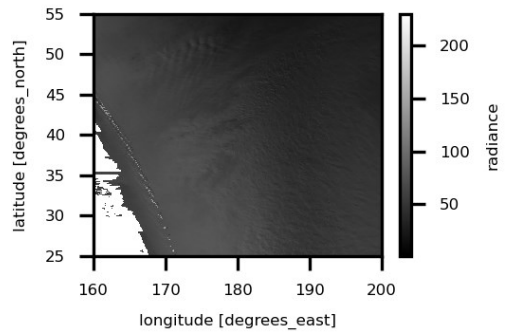
2009-08-22T04:20:45.977020032, BLUE



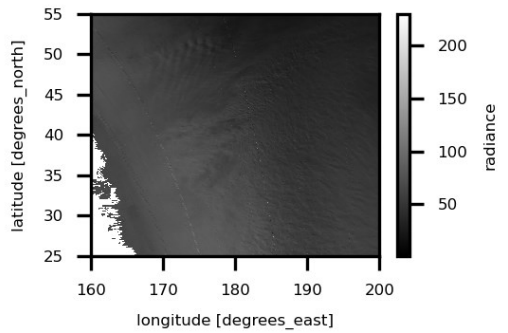
2009-08-22T04:20:45.977020032, GREEN



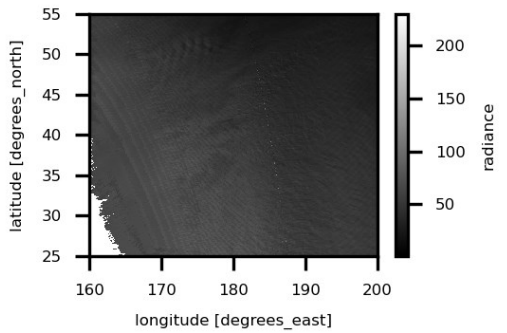
2009-08-22T04:20:45.977020032, ORANGE



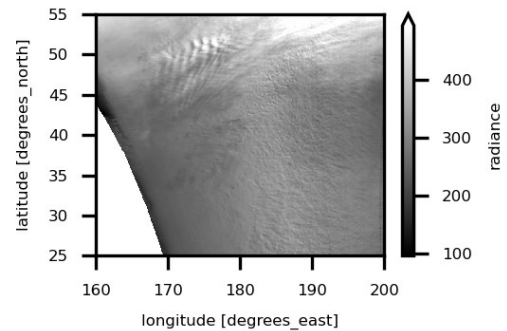
2009-08-22T04:20:45.977020032, RED



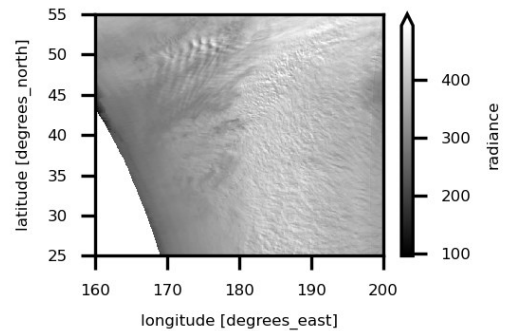
2009-08-22T04:20:45.977020032, NIR



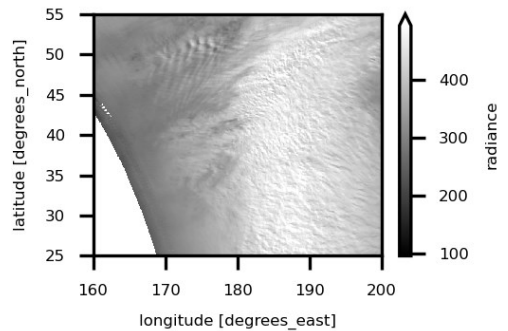
Corrected. BLUE (WR2015)



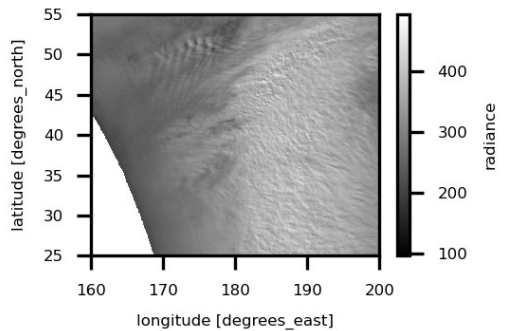
Corrected. GREEN (WR2015)



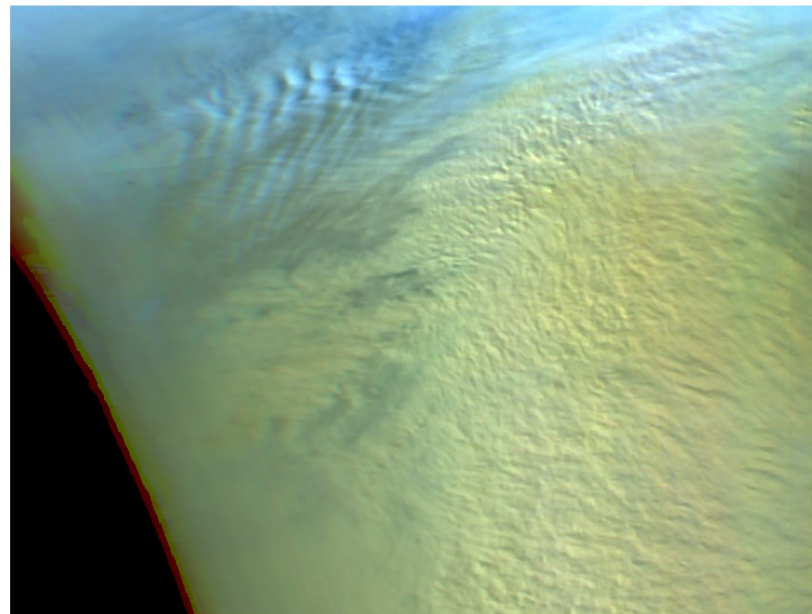
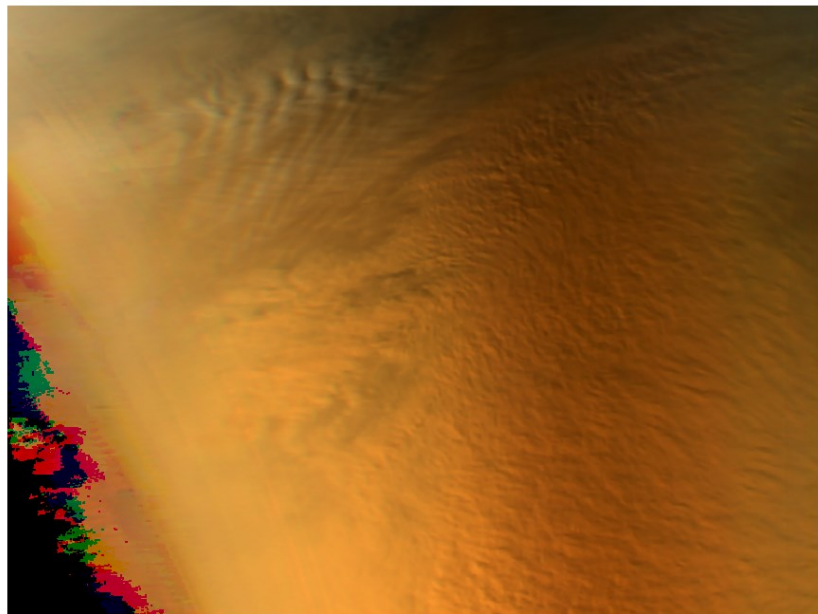
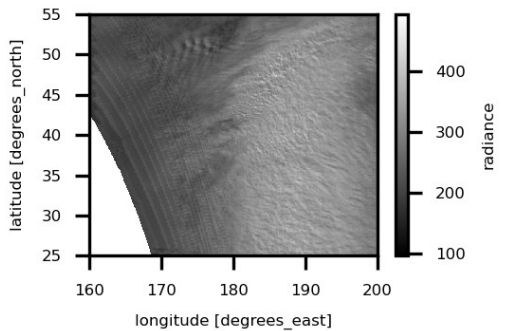
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

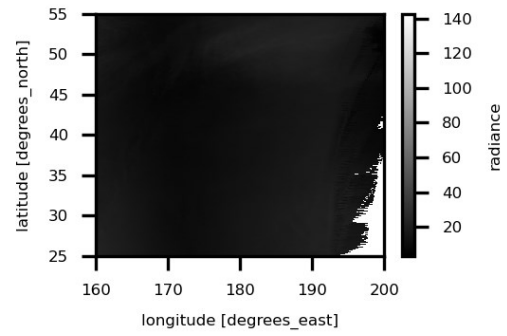


Corrected. NIR (WR2015)

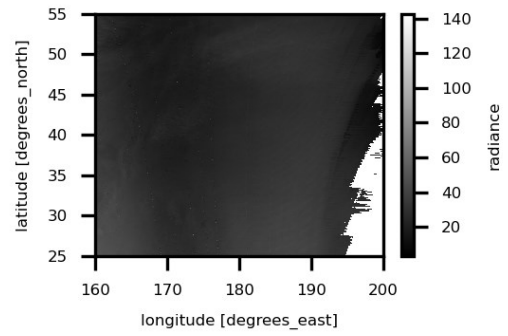


Ls : 325.5  
 time : 2009-08-22T04:20:45.977020032  
 orbit : 14395  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-22T04:20:45.977020+00:00

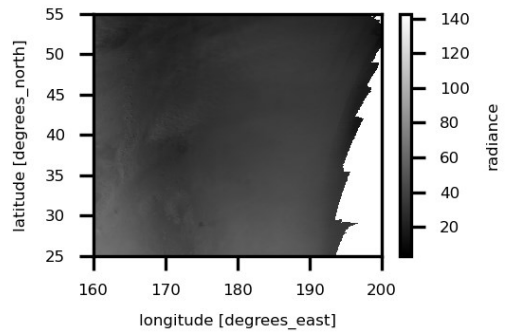
2009-08-24T06:50:32.697680000, BLUE



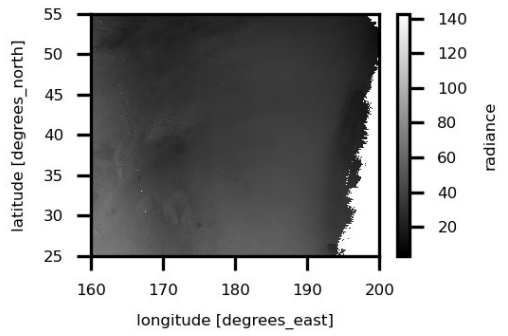
2009-08-24T06:50:32.697680000, GREEN



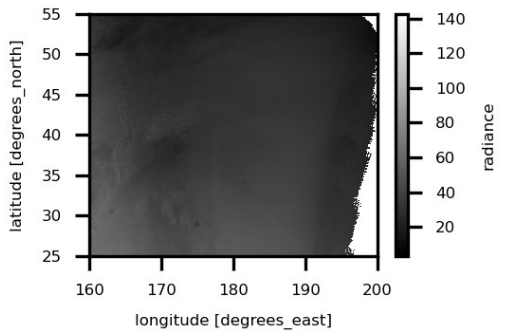
2009-08-24T06:50:32.697680000, ORANGE



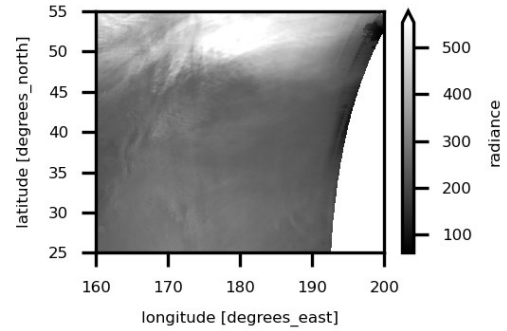
2009-08-24T06:50:32.697680000, RED



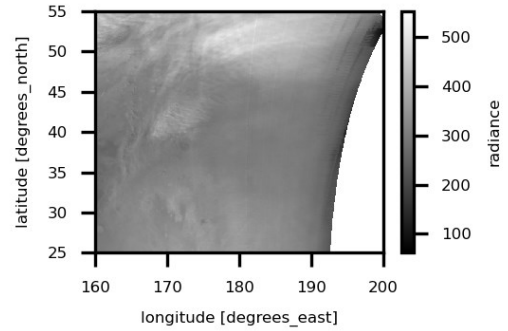
2009-08-24T06:50:32.697680000, NIR



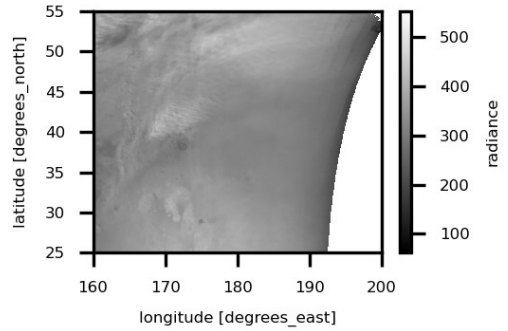
Corrected. BLUE (WR2015)



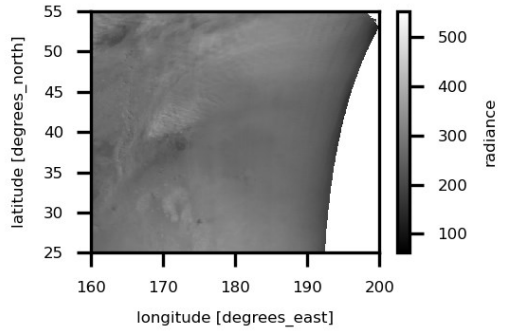
Corrected. GREEN (WR2015)



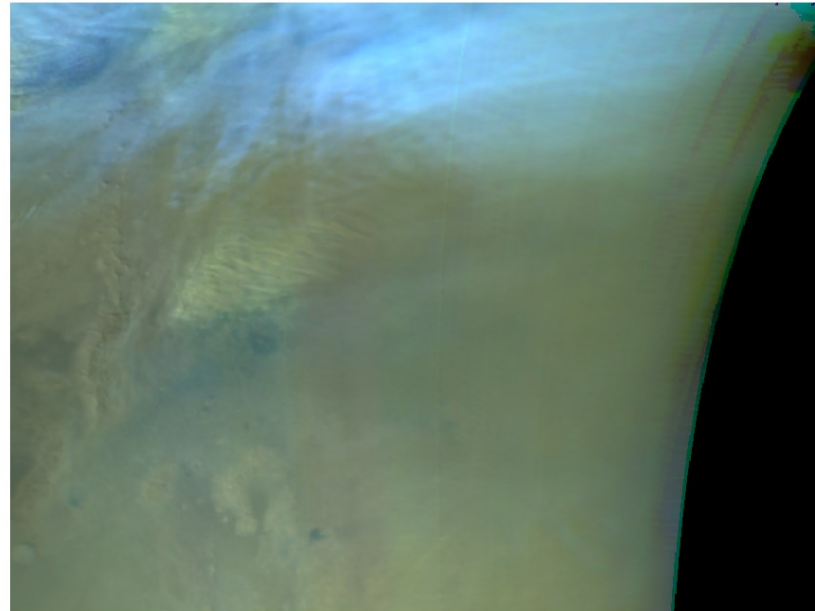
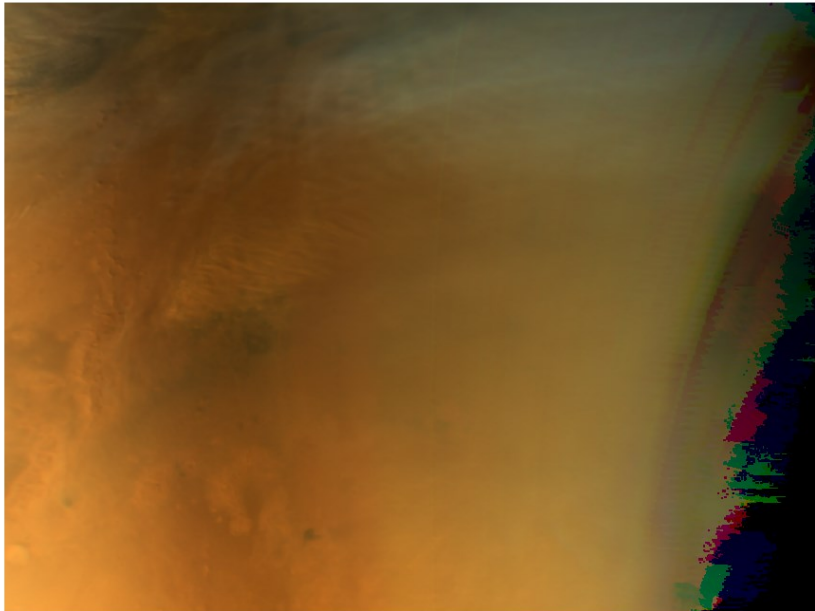
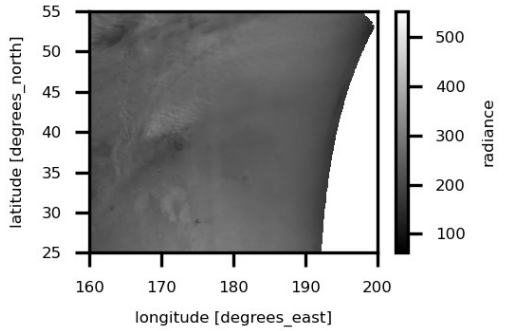
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)

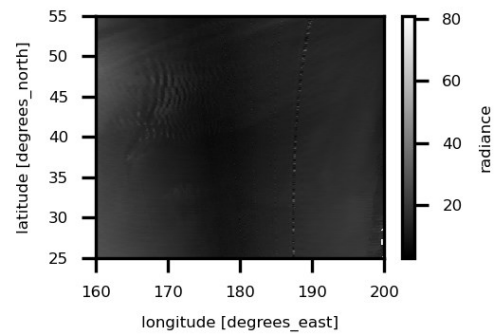


Corrected. NIR (WR2015)

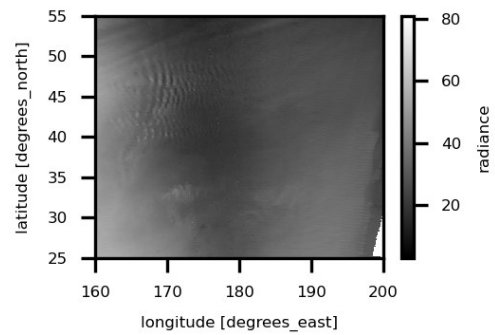


Ls : 326.6  
 time : 2009-08-24T06:50:32.697680000  
 orbit : 14422  
 today = 2021-11-16  
 option = -w 2 -o  
 obs\_date:  
 2009-08-24T06:50:32.697680+00:00

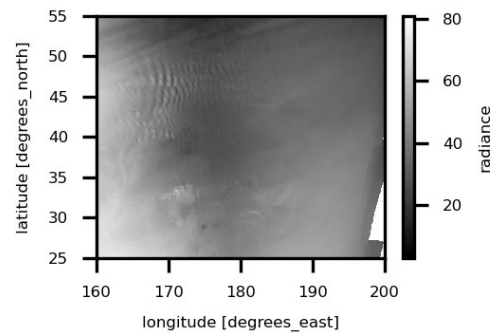
2009-08-25T07:09:15.726779968, BLUE



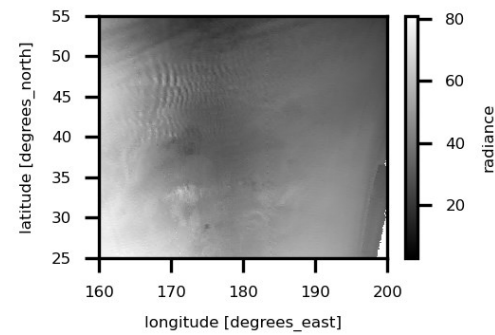
2009-08-25T07:09:15.726779968, GREEN



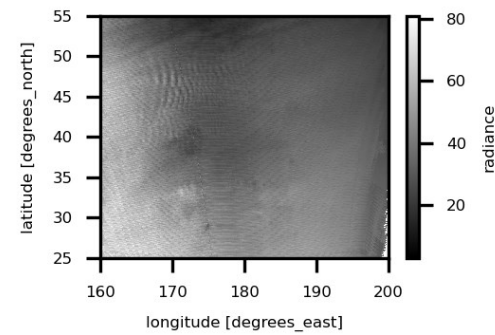
2009-08-25T07:09:15.726779968, ORANGE



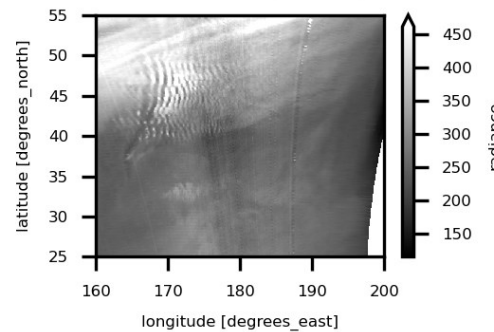
2009-08-25T07:09:15.726779968, RED



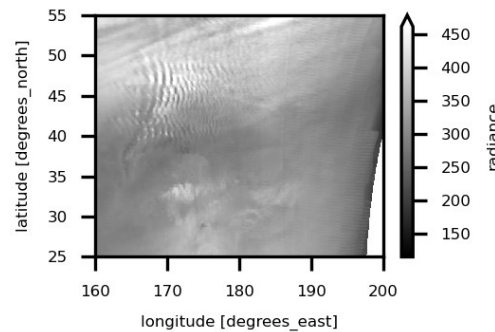
2009-08-25T07:09:15.726779968, NIR



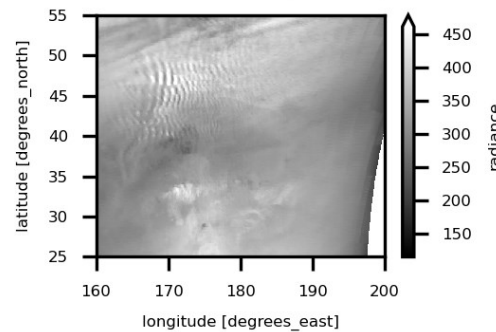
Corrected. BLUE (WR2015)



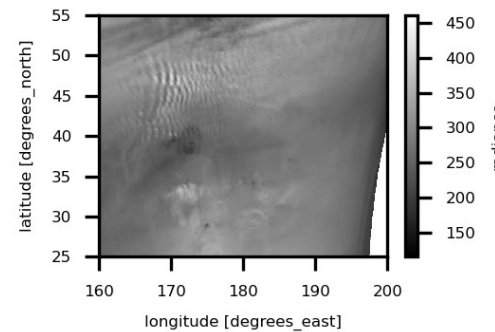
Corrected. GREEN (WR2015)



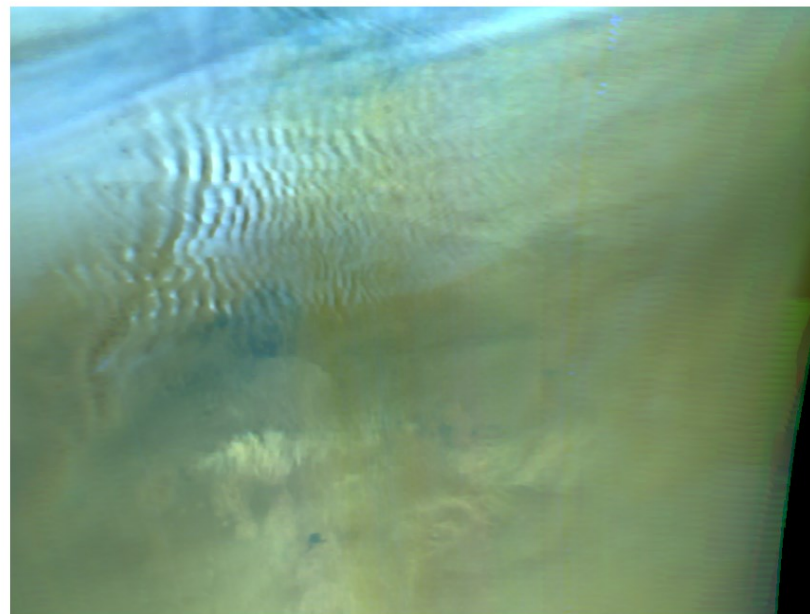
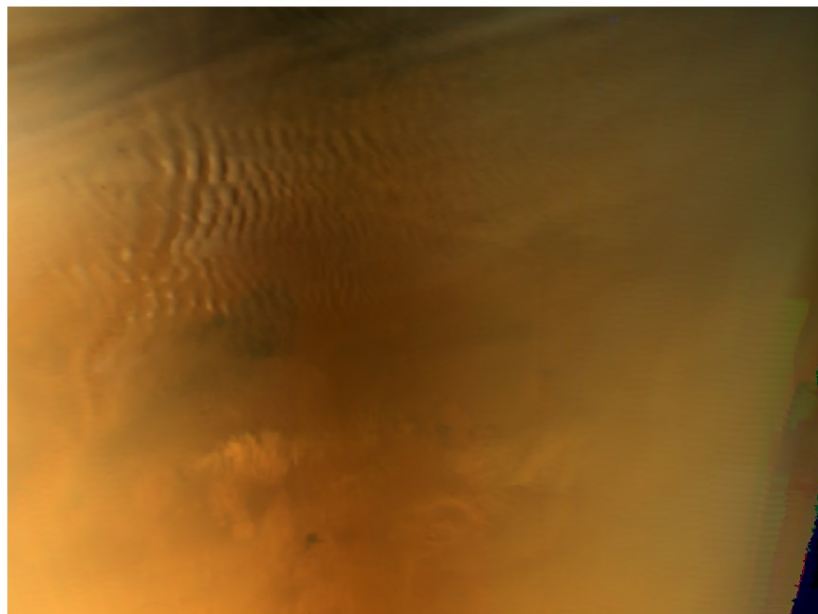
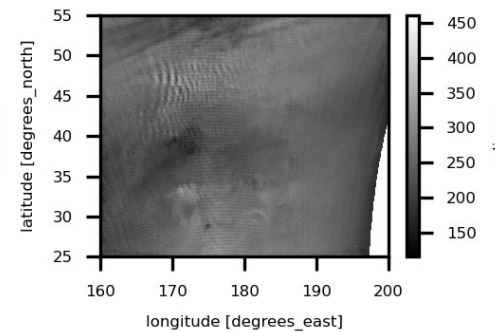
Corrected. ORANGE (WR2015)



Corrected. RED (WR2015)



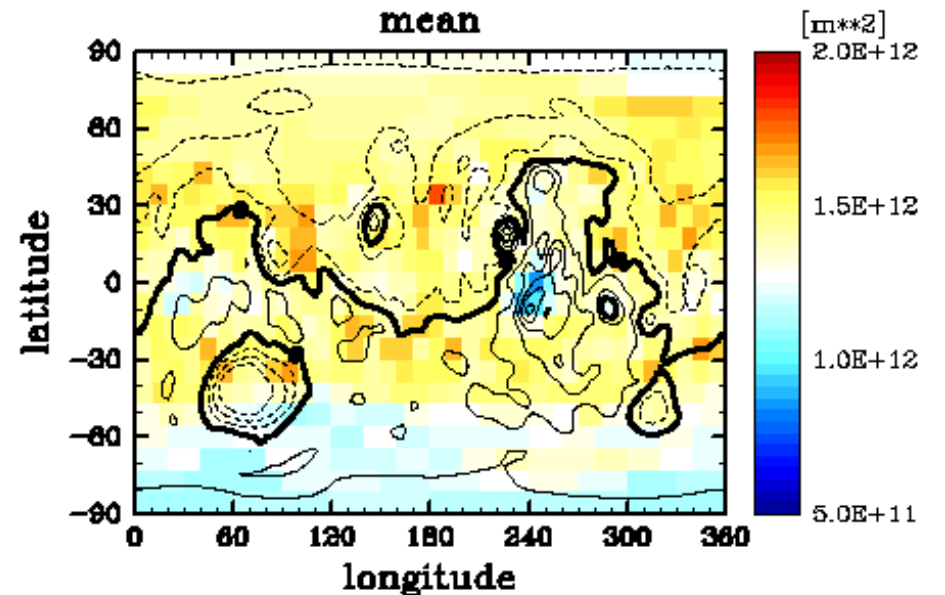
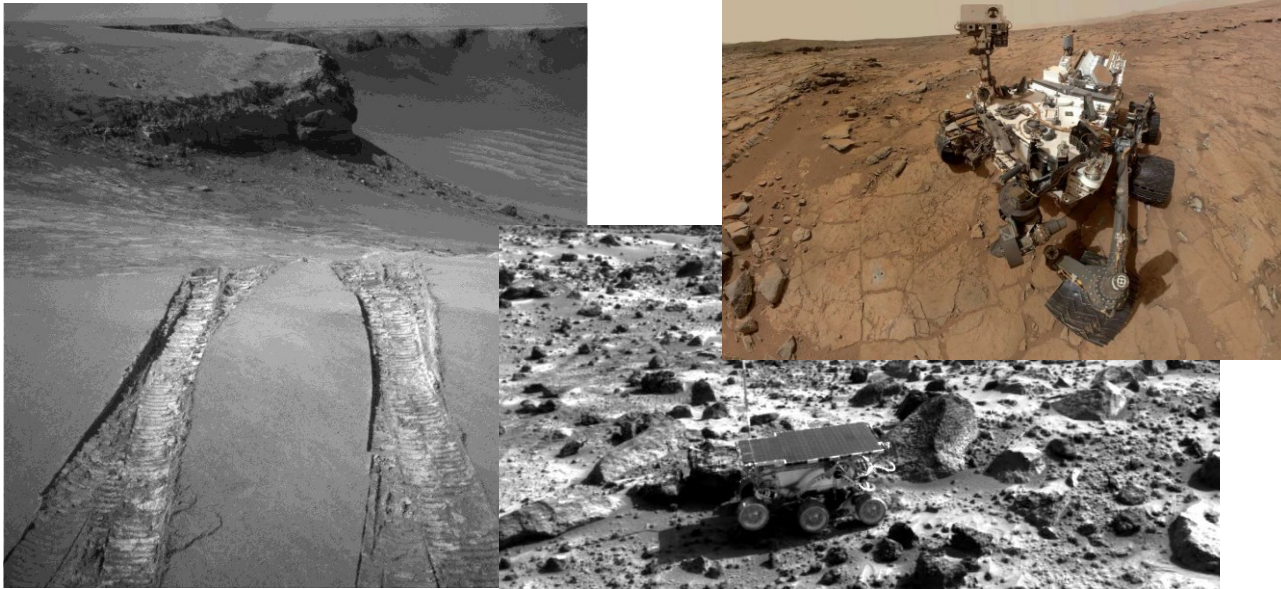
Corrected. NIR (WR2015)



Ls : 327.2  
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 today = 2021-11-16  
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 obs\_date:  
 2009-08-25T07:09:15.726780+00:00

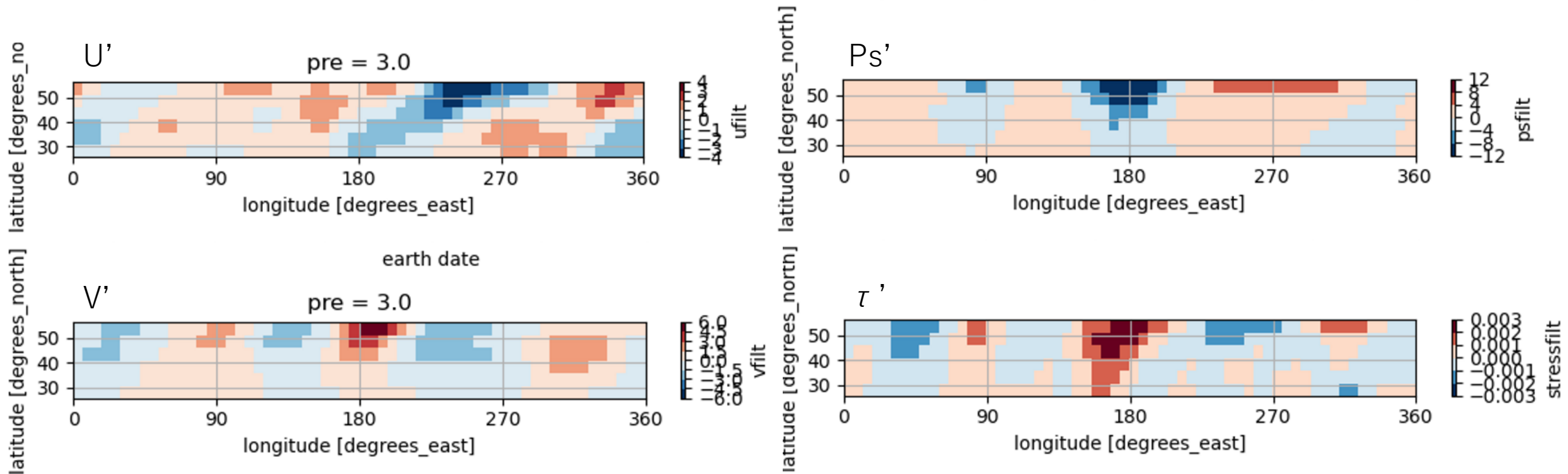
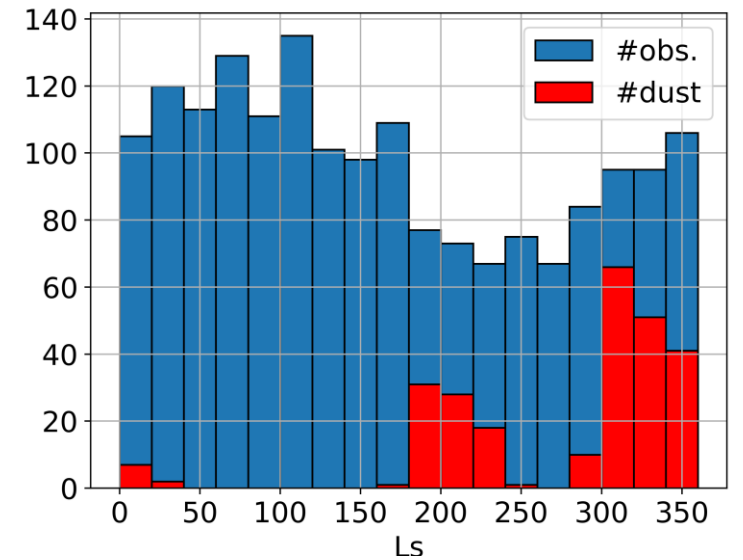
# 小さなスケールの巻き上げ過程

- GDSの前後差が派手なので興奮するが、日々の生活では、局所的に巻き上げ、局所的に落ちる、を繰り返すはず
- Local dust stormは数10km上空まで到達し、水などを効率的に上方輸送するだろうが、地面にダストがないことには始まらない。
- ダストストームにとって好ましい大気側の条件（大気が不安定とか、強風が吹きやすいとか、昼とか）と、地面側の条件（ダストが積もってる）とのANDが、観測されるダストストームの分布



# Arcadia平原のlocal dust storm

- 北半球中緯度の傾圧波動に伴って発生する
- 暖気側なのか，寒気側なのか，間なのか



# Local dust stormによる水の鉛直輸送

- 地表のダストと $H_2O$ の分布と同時に解かれる必要があるような
- Local dust stormを引き起こす現象のほうを研究する必要があるような
  - 仮定) 水の鉛直輸送に対するlocal dust stormの寄与が無視できない
  - 仮定) local dust stormは傾圧波動(前線含む)のせいで発生する
  - →それが弱まったらlocal dust stormは発生しにくくなるのであり、水の鉛直輸送効率が低下するはず

Ogohara et al.  
(2022)



# まとめ

- ダストは火星大気中の熱源で，大事です
- ダストストームが水を纏って上空に突き抜けていく可能性があります
- ダストストームの空間分布は，地表のダスト分布と，ダストの巻き上げを担う大気現象とのANDです
- ダストの巻き上げを担う大気現象，はまだ特定できていません
- 何が変わってもダストストームの頻度や空間分布は変わります
- もちろん，ダストストームによる水の鉛直輸送も変わります
- 難しいです