# A trajectory study to diagnose T◊S transport via the TTL

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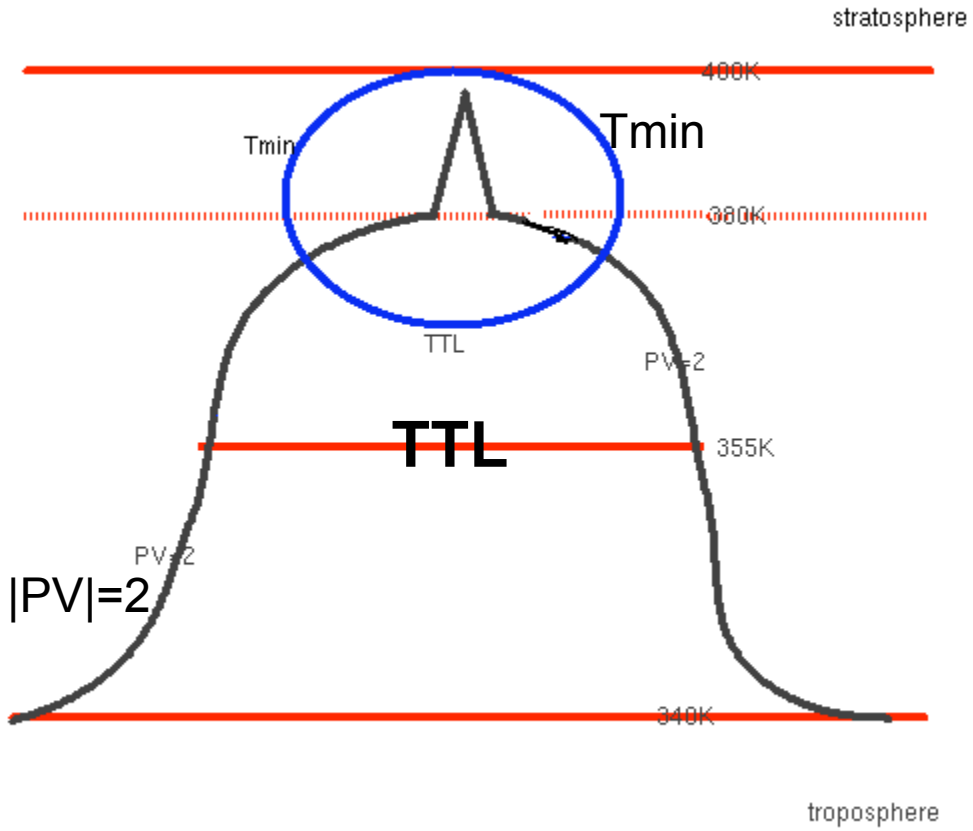
SPARC Data Assimilation Workshop

# Overview

- Method; Definition of Tropical Transition Layer (TTL)
- Path and transit time of air parcels traveling from T ◊ S through the TTL
- Minimum temperature evaluation to diagnose moist transport
- Seasonal differences in T ◊ S transport via TTL for air and moist
- Regional differences in T ◊ S transport via TTL for air and moist
- Conclusions

# Tropical Transition Layer (TTL)

Overworld




400K

Lowermost Stratosphere

355K; ~zero radiative heating

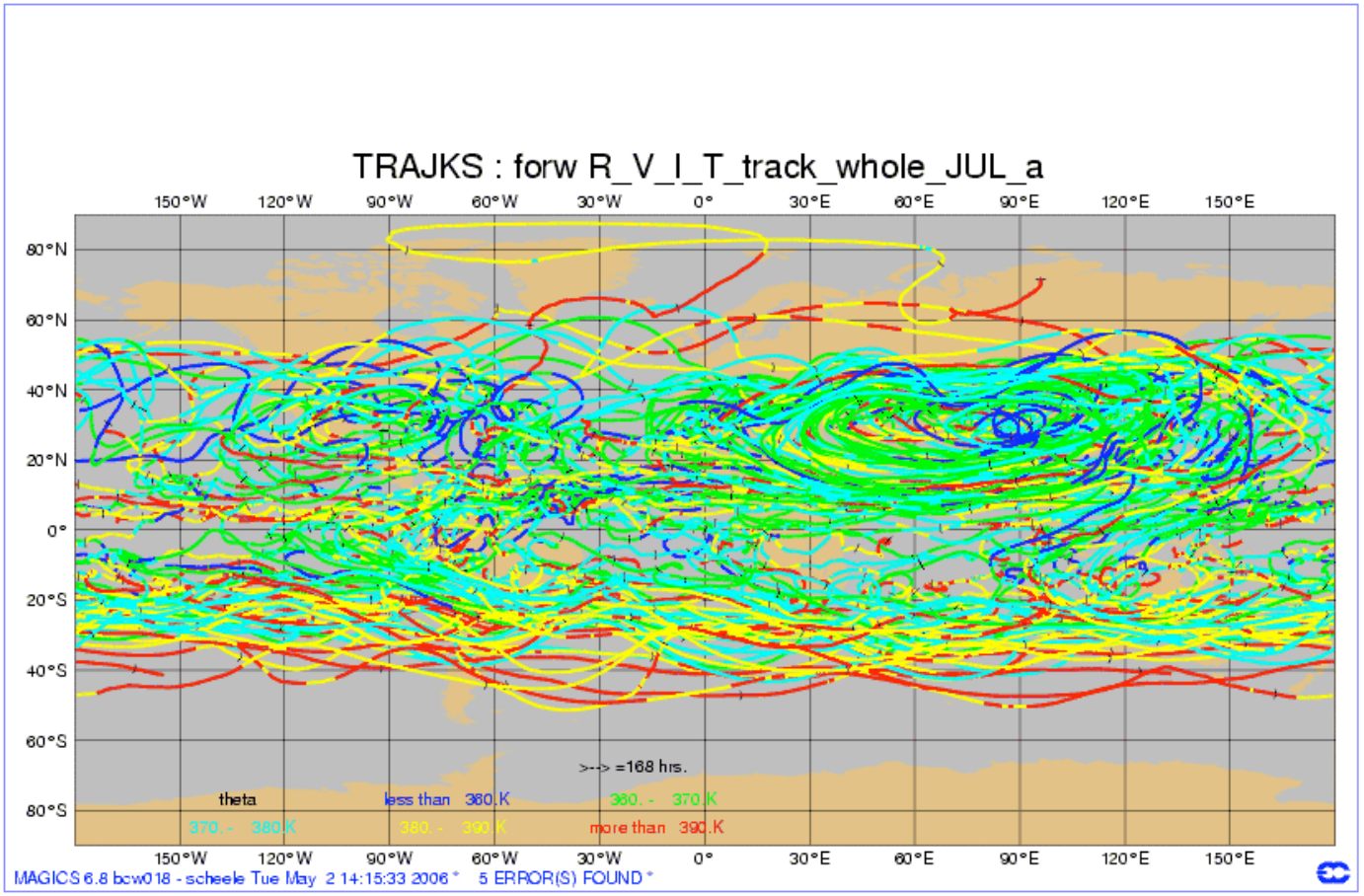
340K

Troposphere

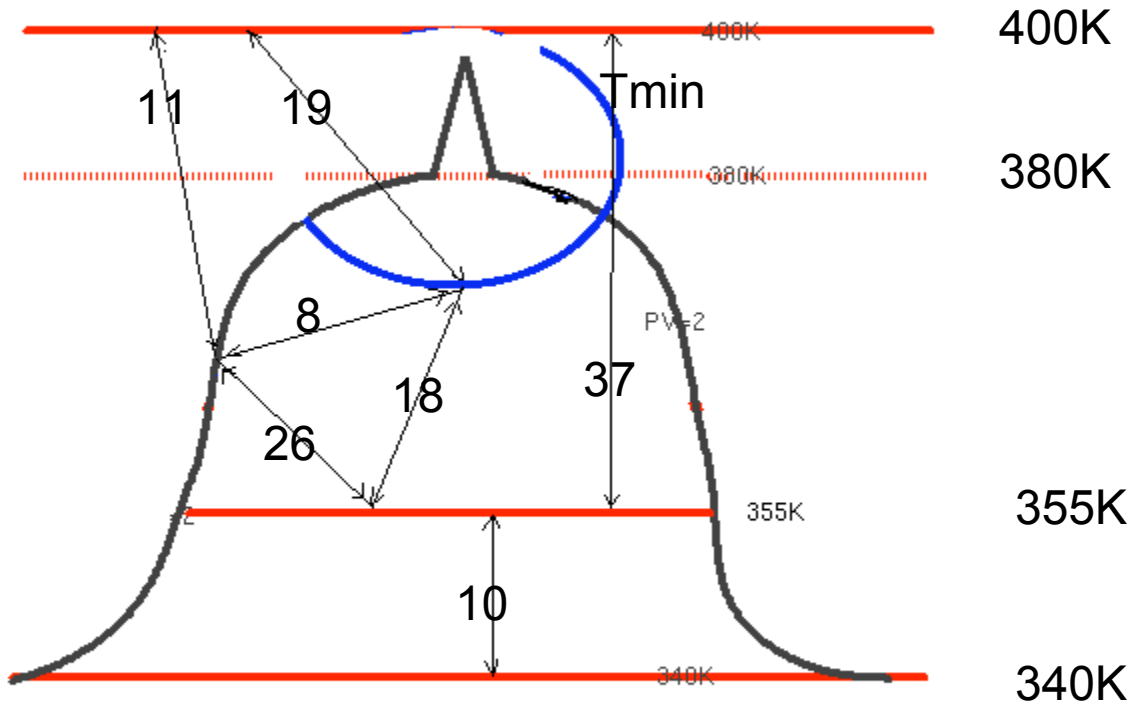
# Summary of Method

- Trajectories were started at 355 K (#54.696) globally
- For each month starting at the 15th day of the month
- 4.5 month forward and 1 month backward
- Using ECMWF OD analysis data for the year 2004
- Minimum temperature along the path evaluated (Lagrangian Cold Point)
- Selection criteria for T ◊ S transport via TTL:
  - Should originate from troposphere (<340K) within 30 days
  - Should arrive in the overworld (>400K) within 135 days
  - |PV| < 2 (#26.481) at 355 K: defined as TTL lateral boundary
- Total of #1.989 trajectories (3.6% of 54.696) to diagnose T ◊ S transport via TTL

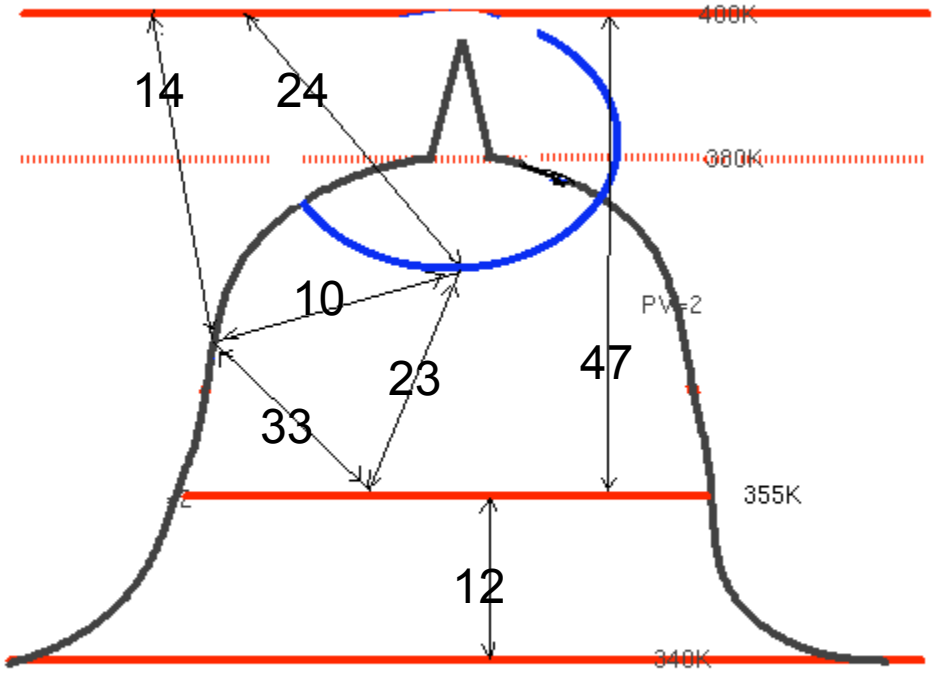
# Example tracks from 355 to 400K



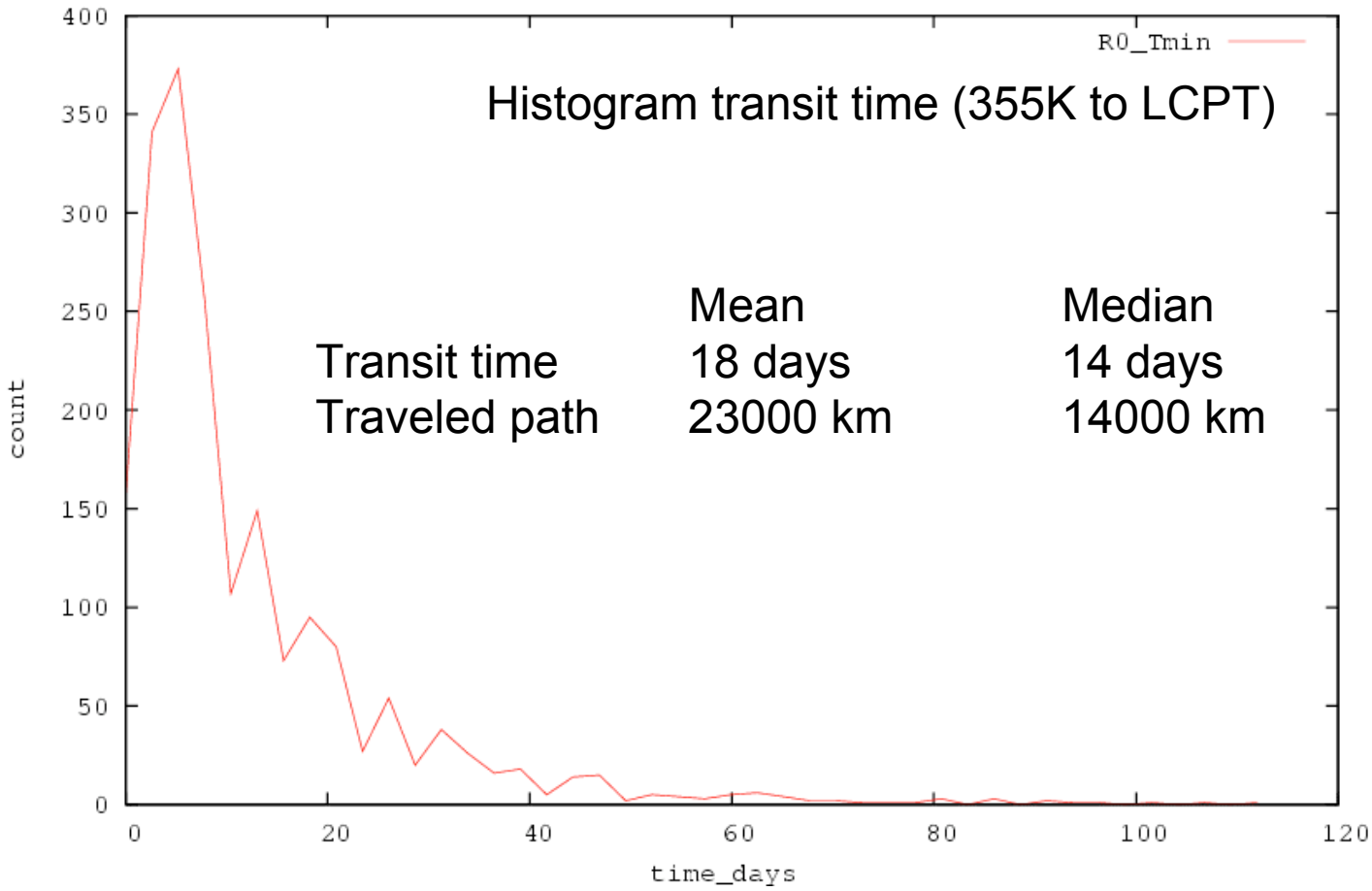
# Transit times (days)



# Traveled paths ($10^3$km)



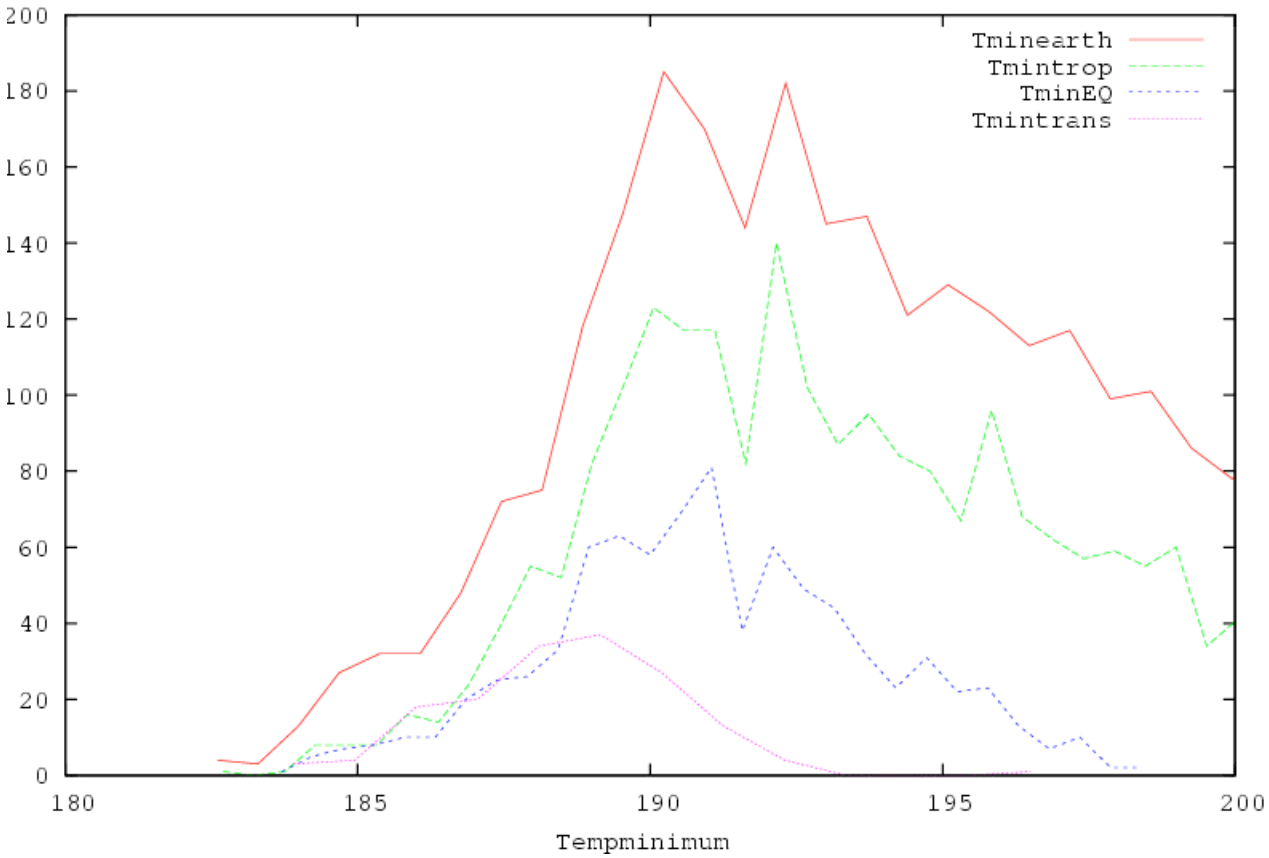
# Mean values vs. medians



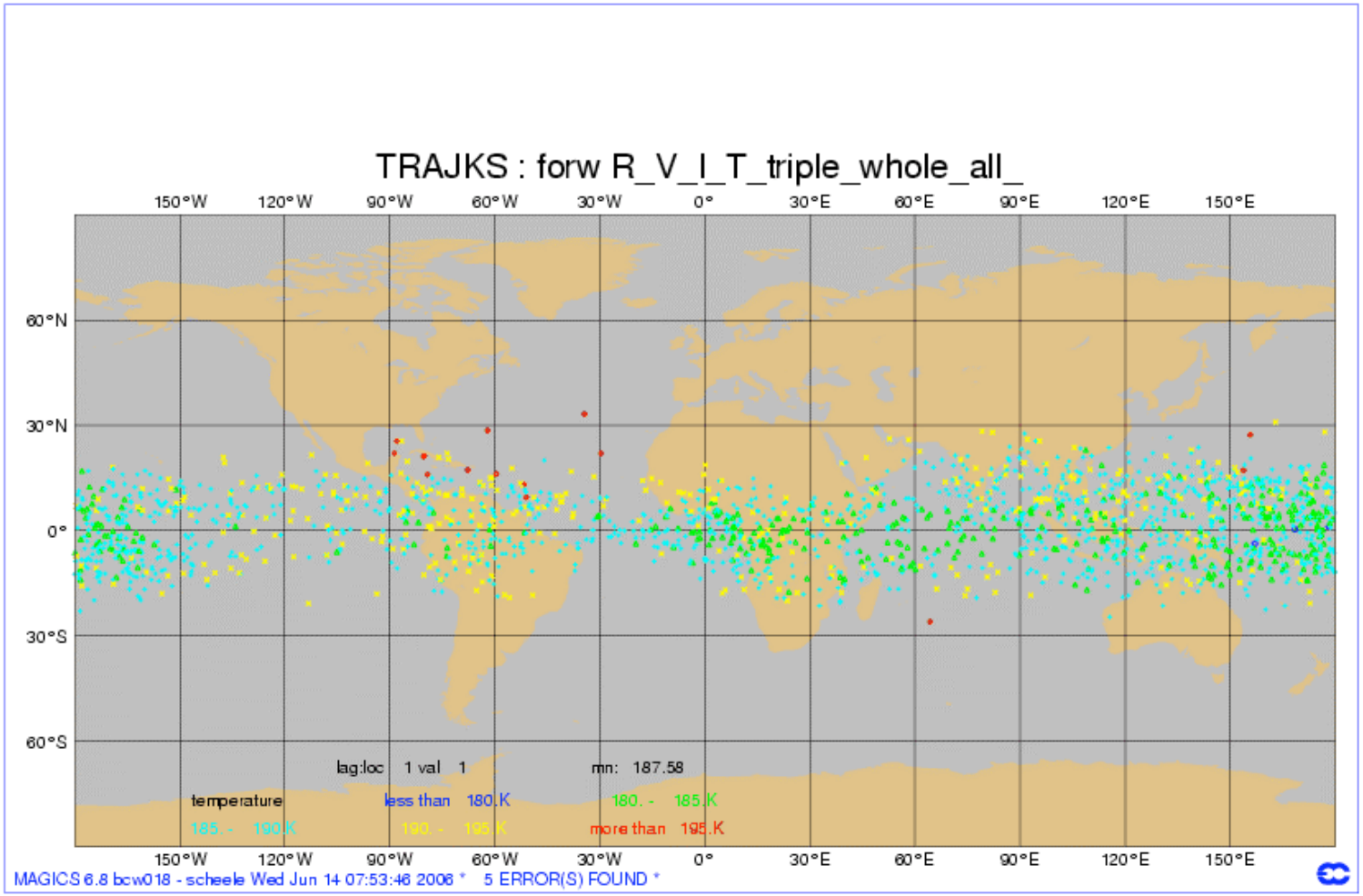
# Lagrangian Cold Point Temperature

(Fueglistaler et al., 2005)

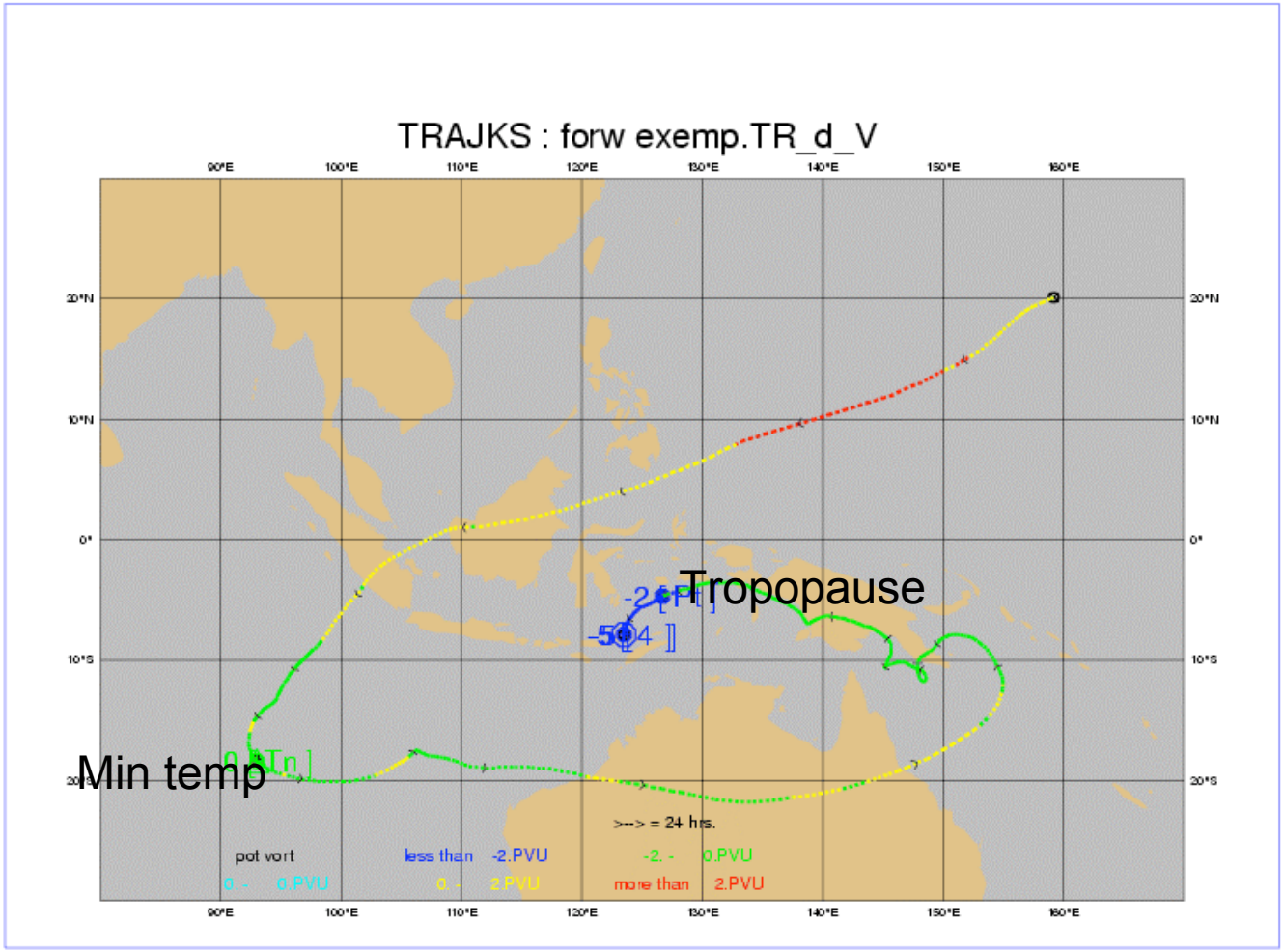
Red = global
Green = for |PV|<2 (TTL)
Blue = between 10S -10N
Purple = for selected trajectories: LCPT



# Positions of experienced minimum temperatures

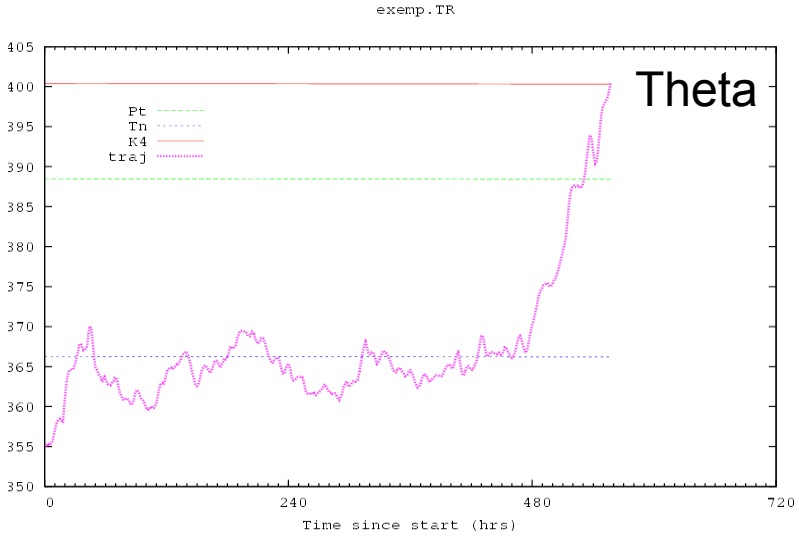


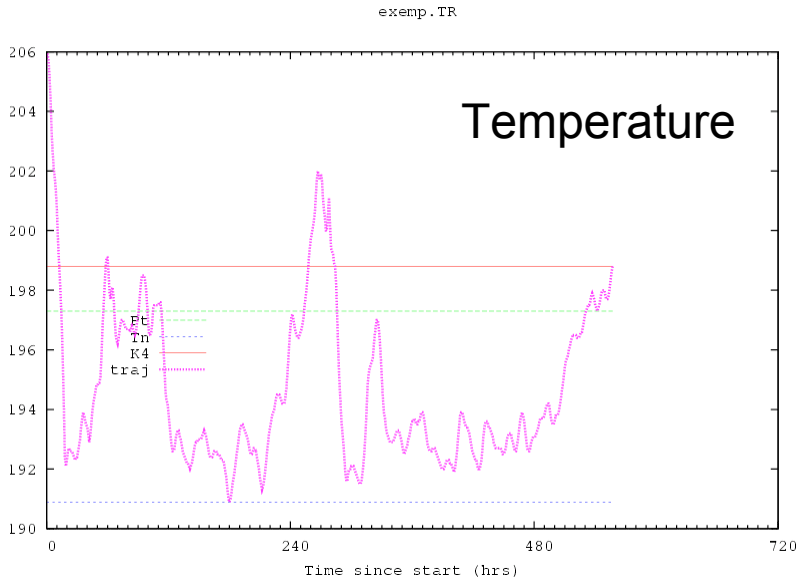
# Example #1

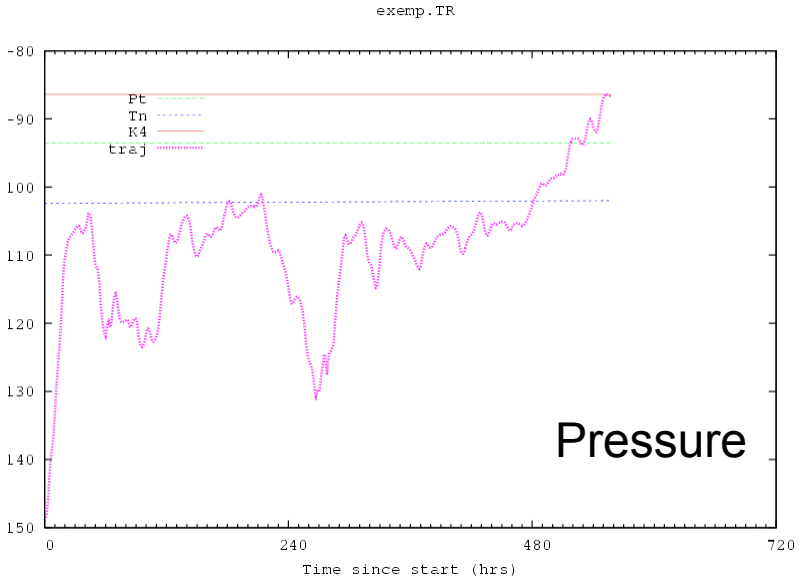


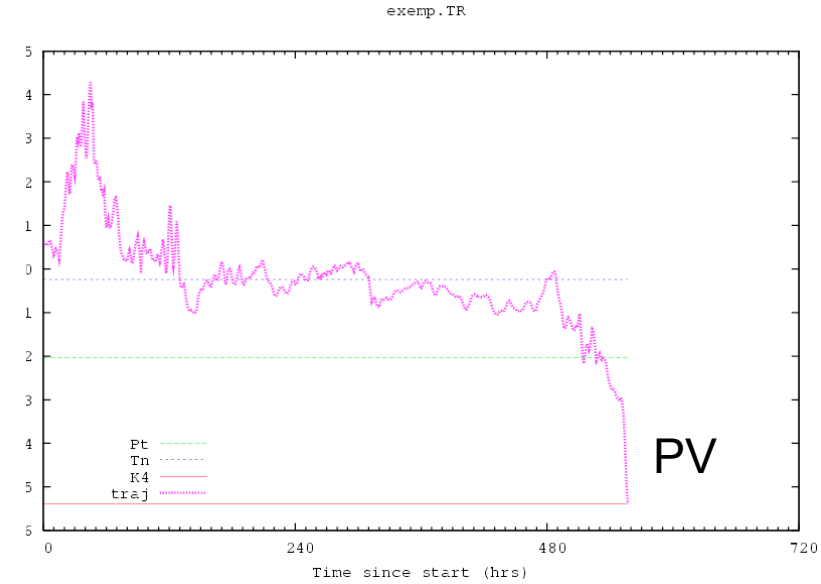

Started
15 August 2004

# Time-graphs of example #1 (Aug)

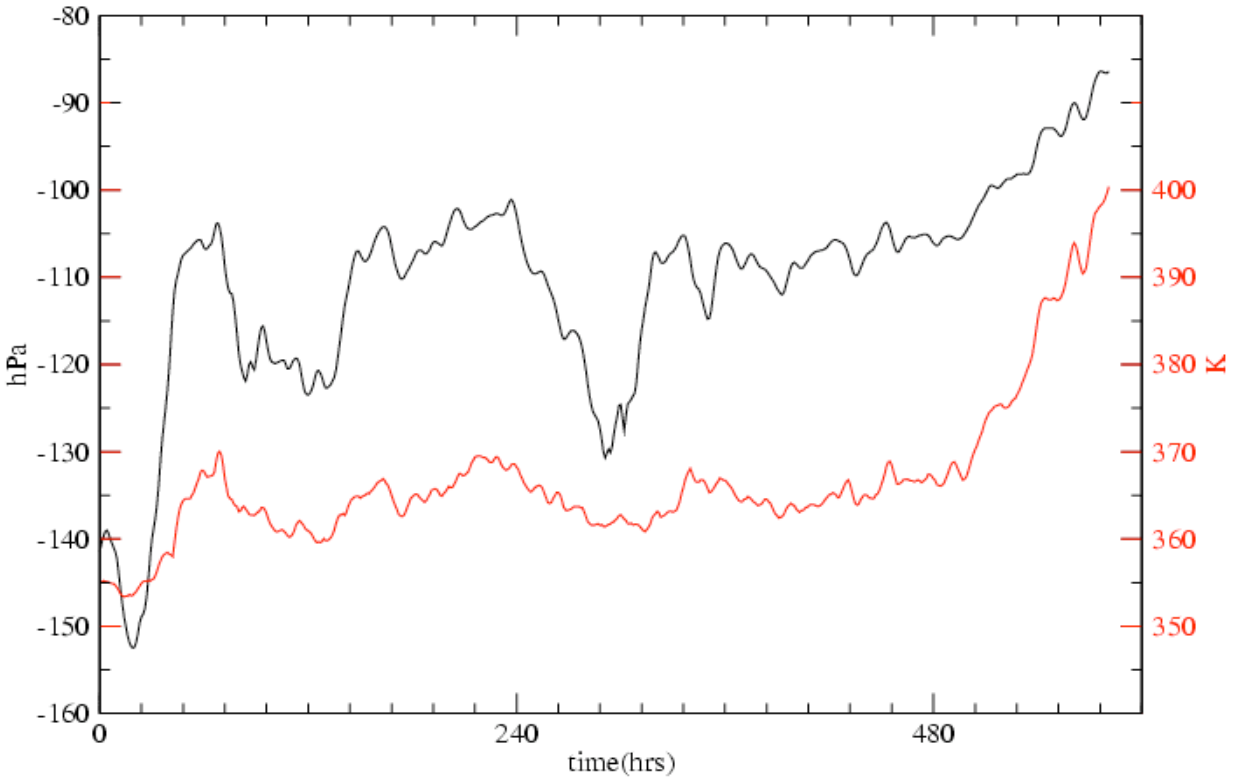


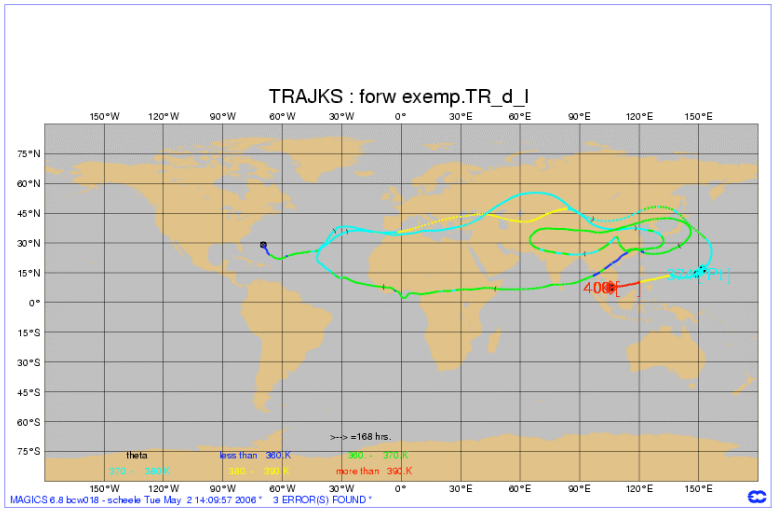



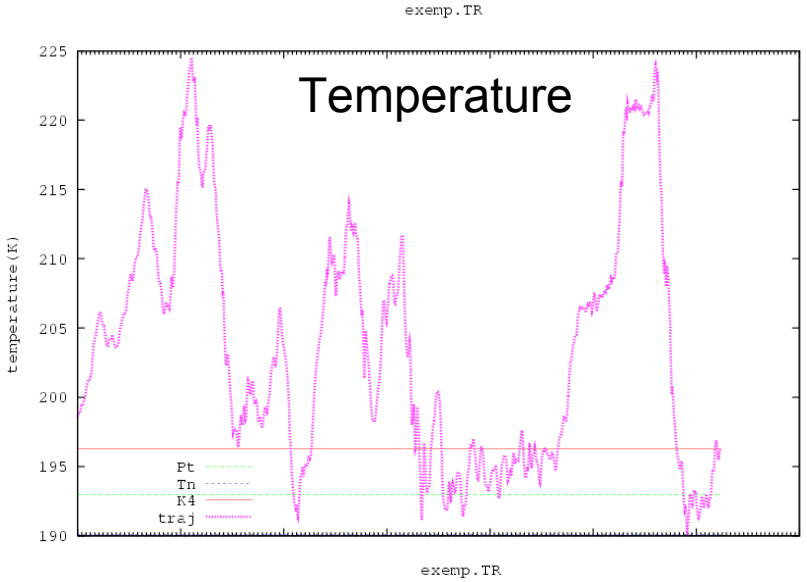



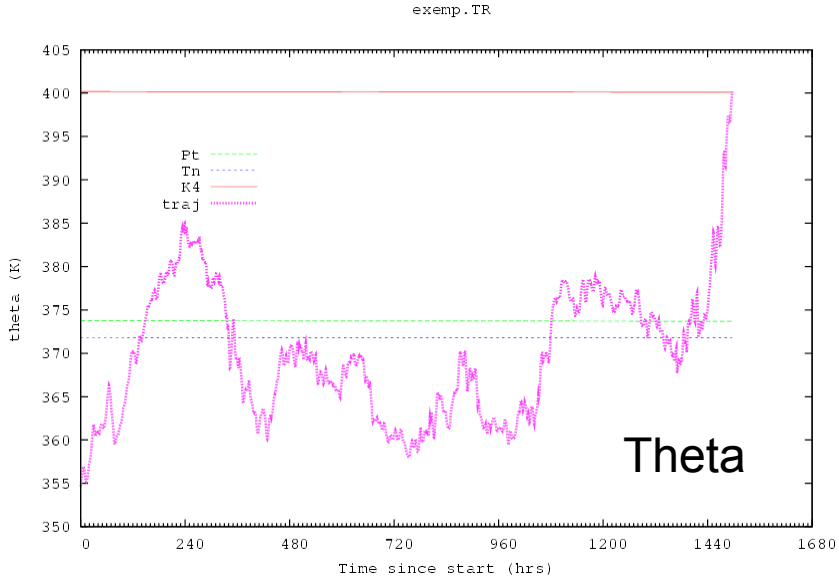
# Example #1:
# Pressure vs. Potential temperature

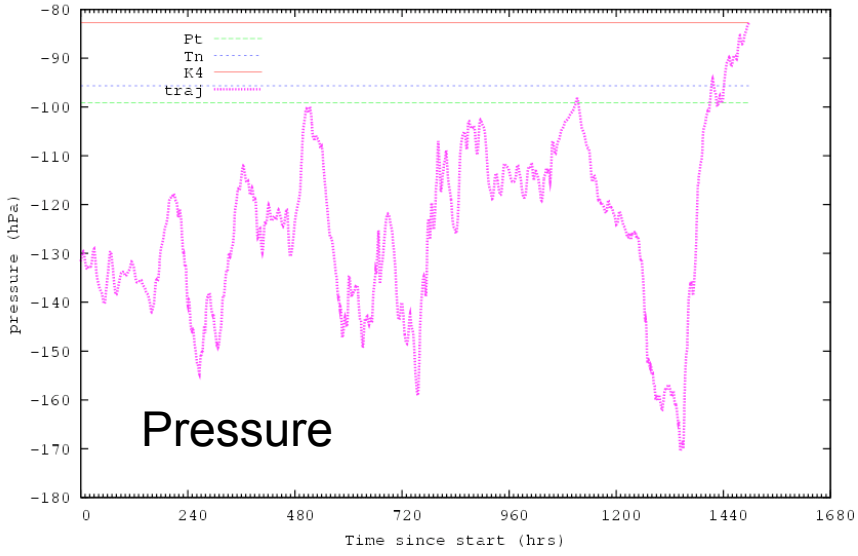


# Time-graphs of example #2 (Jun)

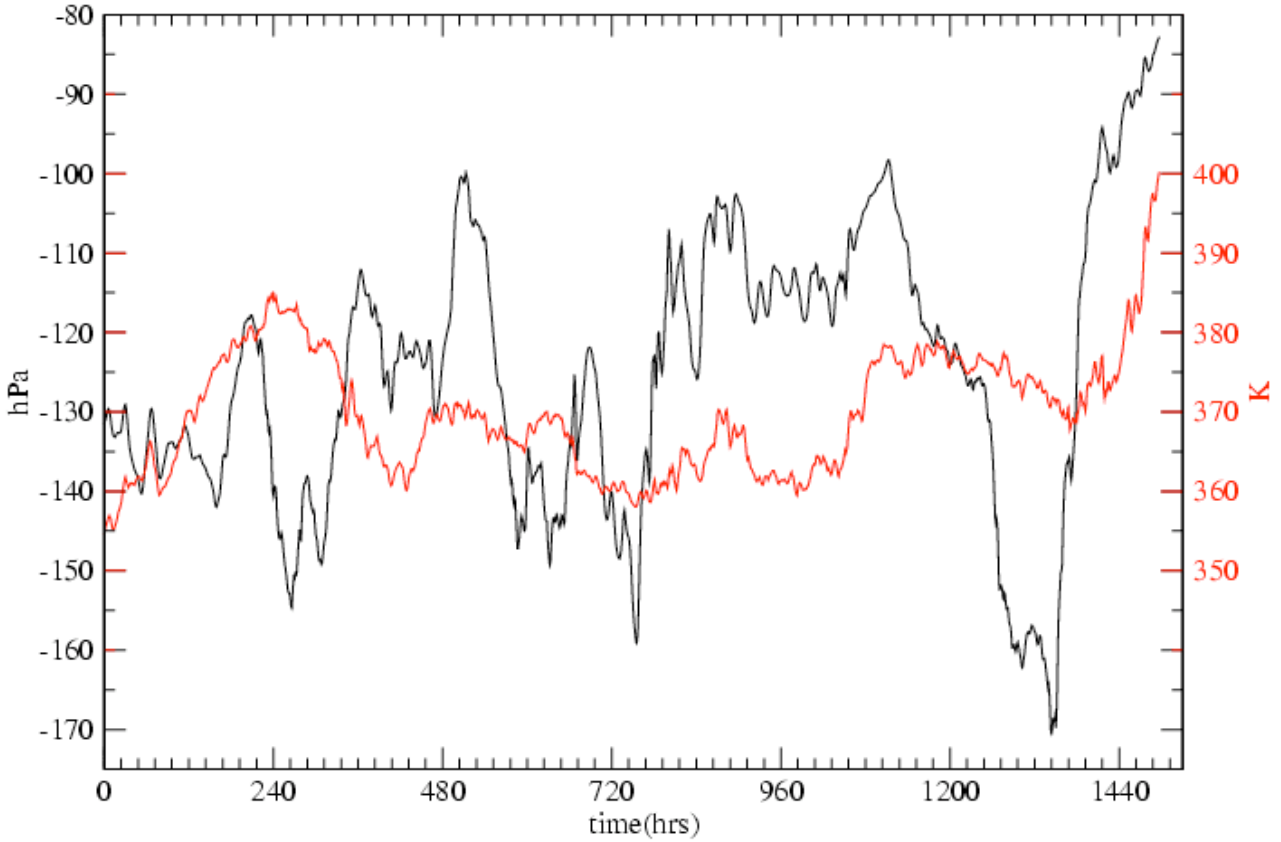


# Example #2:
# Pressure vs. Potential temperature



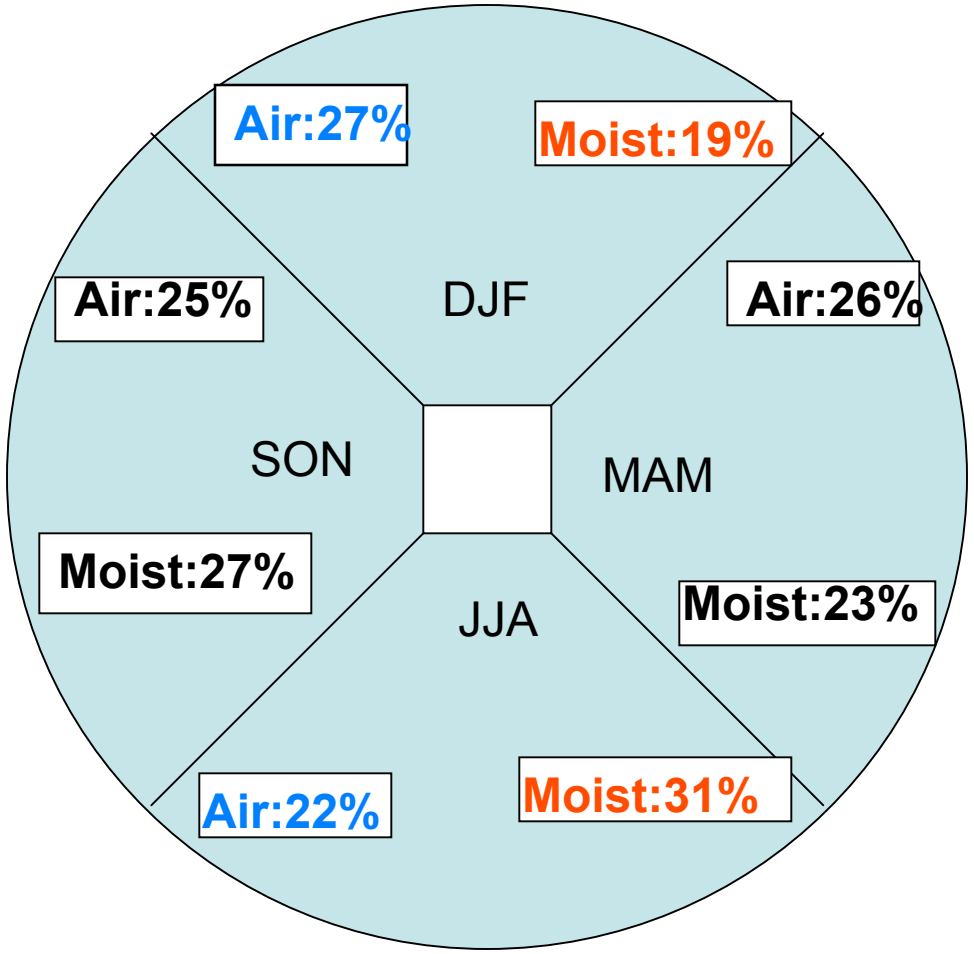
# Seasonal Variations in T◊S transport via the TTL

# Seasonal variation

| season | DJF | MAM | JJA | SON |
|---|---|---|---|---|
| #traj | 27% | 26% | 22% | 25% |
| Tmin | 185.7 | 187.0 | 190.2 | 188.5 |
| $Q_{sat}$(Tmin) | 1.16 | 1.45 | 2.28 | 1.80 |
| $Q_{sat}$ . #traj | 19% | 23% | 31% | 27% |
| Ptrop* | 95 | 98 | 106 | 100 |
| P(Tmin) | 89 | 93 | 98 | 94 |

*Ptrop = tropopause pressure, if defined as |PV|=2 or 380K

Air: Percentage of successful trajectories per season
Moist: Percentage contribution of Qsat(Tmin)-weighted trajectories per season

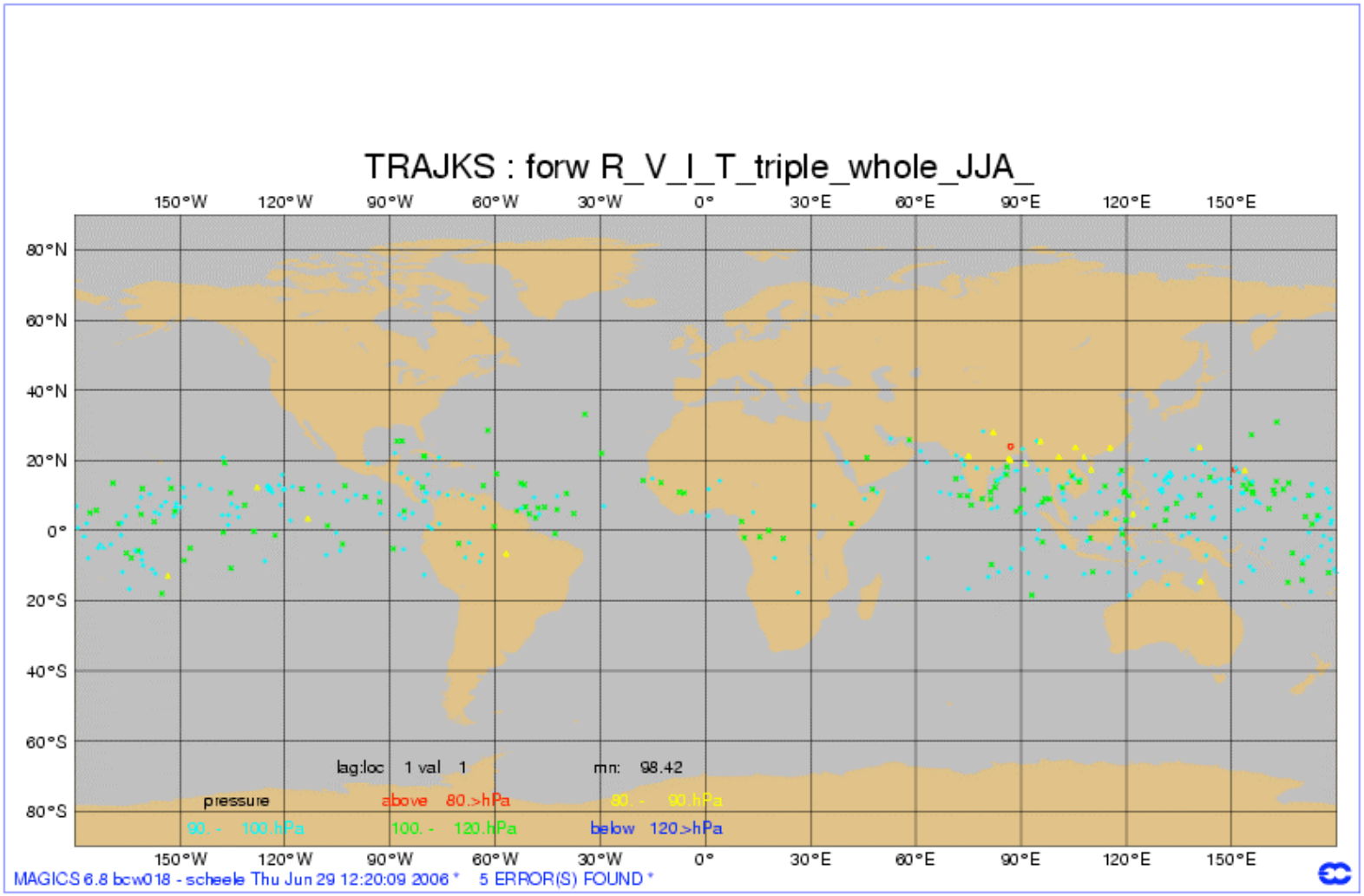


# Seasonal distribution, per hemisphere

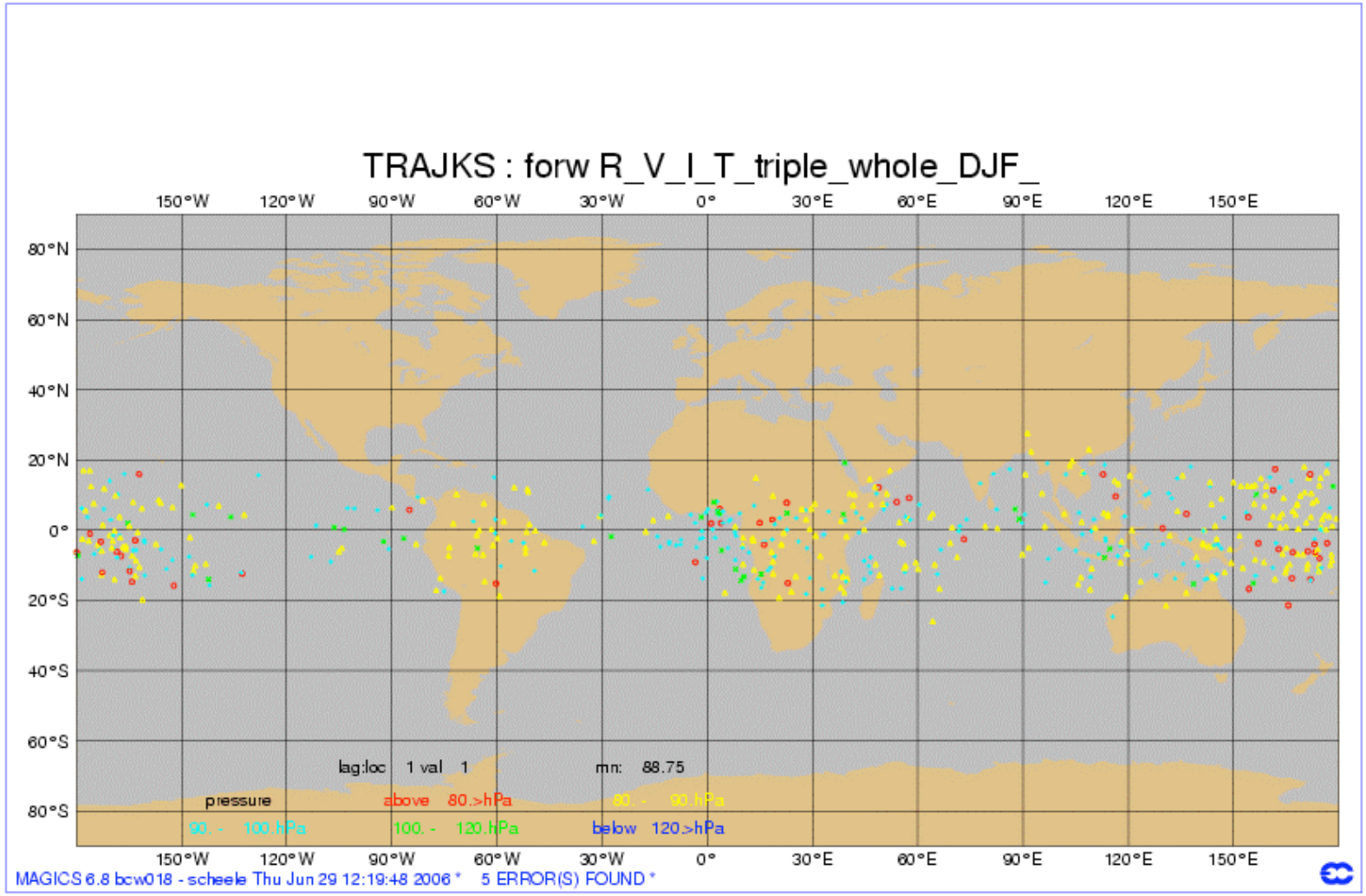
| | DJF | DJF | MAM | MAM | JJA | JJA | SON | SON |
|---|---|---|---|---|---|---|---|---|
| | SH* | NH* | SH | NH | SH | NH | SH | NH |
| #traj | 358 (18%) | 185 ( 9%) | 253 ( 13%) | 255 (13%) | 86 (4%) | 358 ( 18%) | 139 (7%) | 355 ( 18%) |
| Transit time to Tmin (days) | 18.2 | 18.7 | 14.4 | 16.4 | 14.5 | 18.2 | 27.2 | 19.7 |
| Path (Mm) | 22.4 | 26.4 | **16.9** | 20.7 | 18.2 | 21.8 | **34.3** | 23.6 |
| Dist (Mm) | 7.0 | 7.6 | 6.6 | 7.5 | 5.8 | 6.7 | 7.1 | 7.1 |
| Qsat(mg/kg) | 1.15 | 1.17 | 1.29 | 1.61 | 1.78 | 2.40 | 1.97 | 1.73 |
| Qsat(Tmin) weighted #traj | 410 (13 %) | 217 (7 %) | 326 (10 %) | 411 (13 %) | 153 (5 %) | 859 (26 %) | 274 (8 %) | 613 (19 %) |

*) NH :PV > 0.0 at 355 K;  SH: PV < 0.0 at 355 K

# Locations Tmin (JJA)

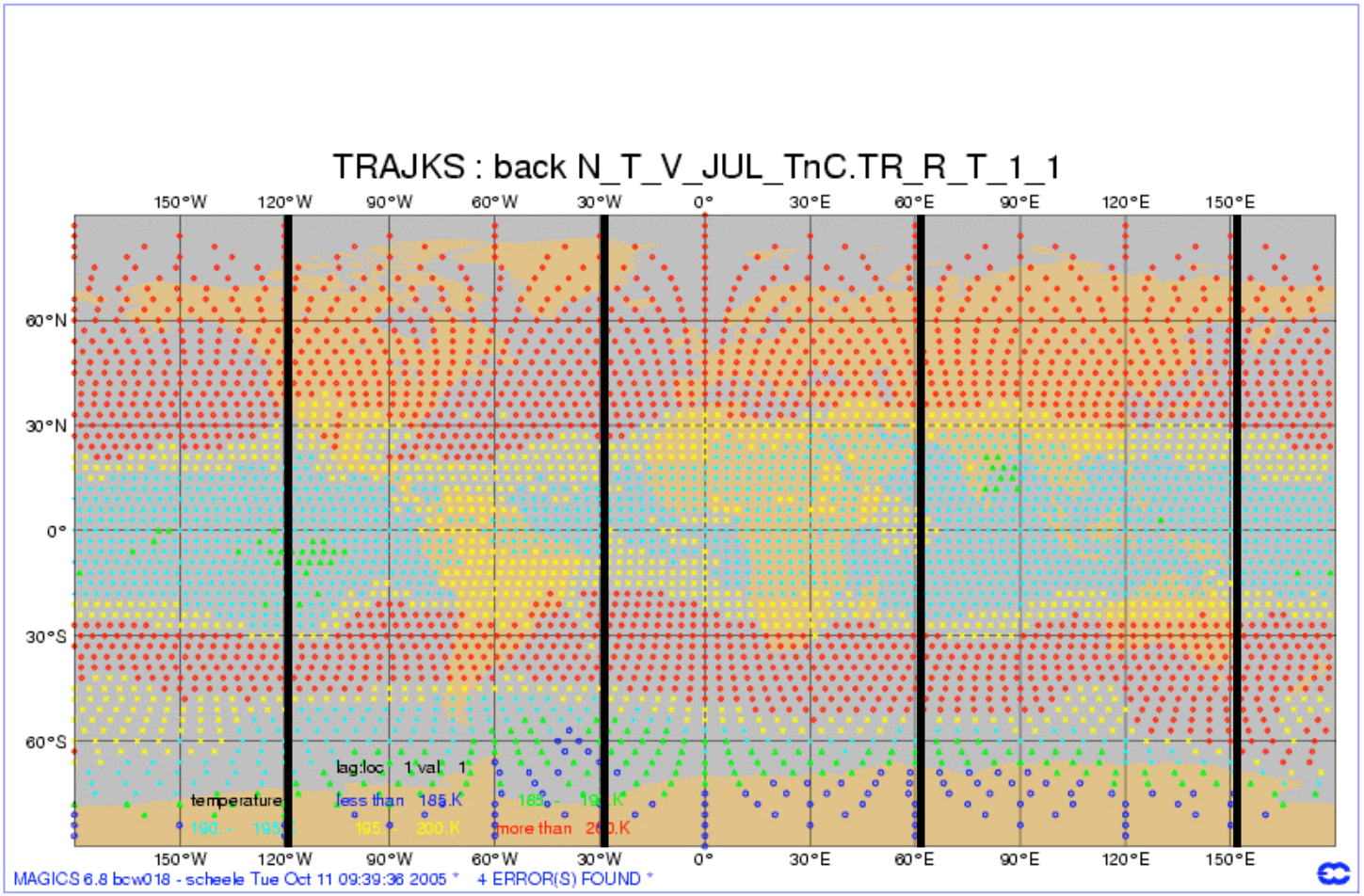


# Locations Tmin (DJF)



# Regional Variations in T◊S transport via the TTL

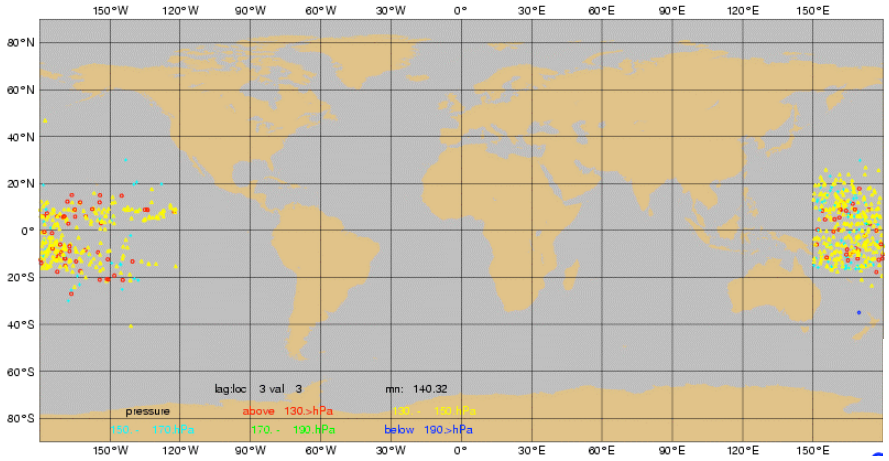
# Division into four regions



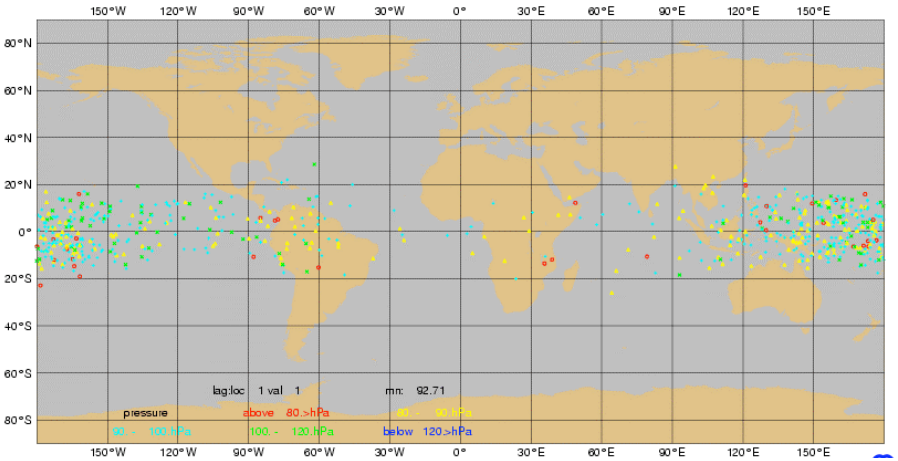

PAC AMR AFR IND PAC

# Locations: Pacific

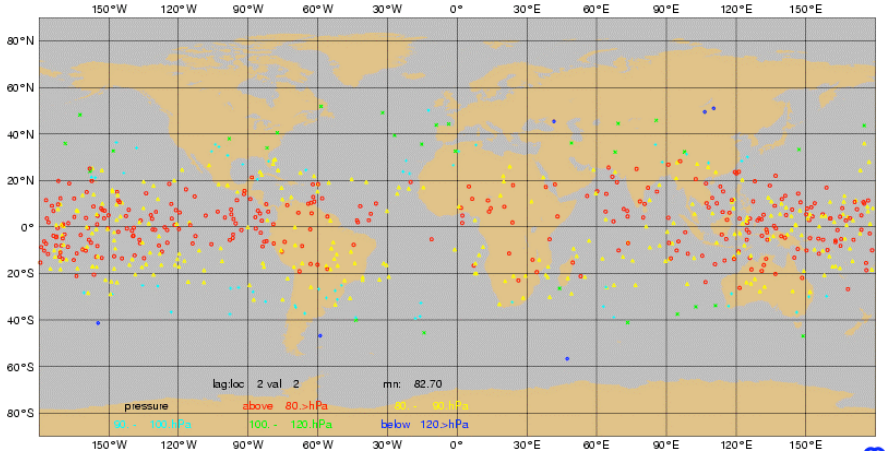
355K




Temperature minimum




400K



# Regional variations in Tmin and their effect (regions defined at **Tmin**)

| location | AFR | IND | PAC | AMR |
|---|---|---|---|---|
| #traj | 20% | 29% | 34% | 17% |
| Tmin | 187.1 | 187.7 | 187.3 | 189.7 |
| Qsat | 1.47 | 1.58 | 1.52 | 2.20 |
| Moist entr | 18% | 28% | 31% | 22% |

⇒ PAC relatively most important for air and moist transport,

⇒ AMR highest Tmin; smallest #traj

⇒ AFR smallest contribution to moist transport

# Regional variations in Tmin and their effect (regions defined at **355K)**

| location | AFR | IND | PAC | AMR |
|---|---|---|---|---|
| #traj | 22% | 29% | 30% | 19% |
| Tmin | 187.6 | 187.6 | 187.4 | 188.5 |
| Qsat | 1.68 | 1.57 | 1.56 | 1.85 |
| Moist entr | 22% | 28% | 29% | 21% |

⇒ Marginal differences

⇒ PAC / IND somewhat more important for air / moisture transport

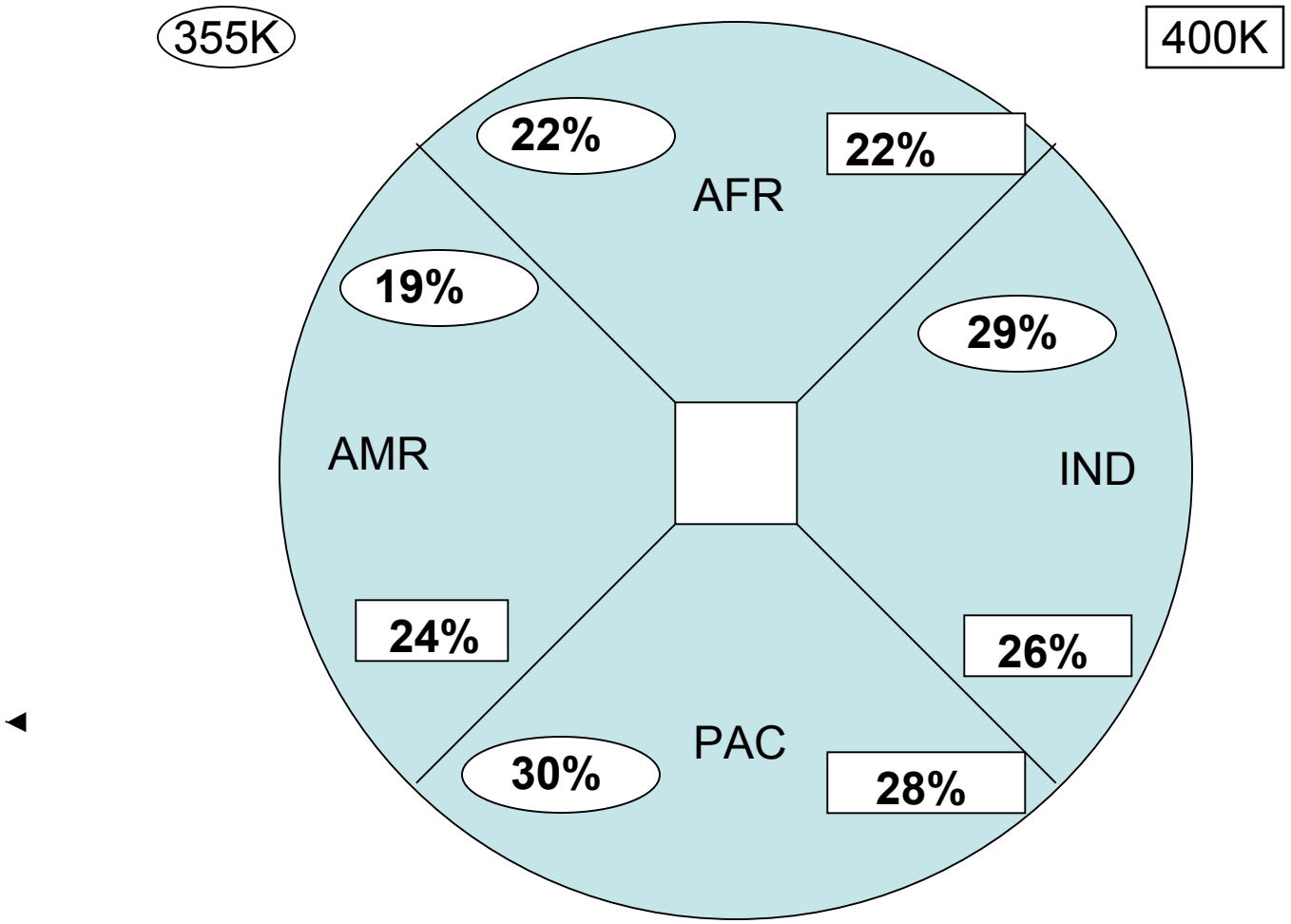
# Regional variations in Tmin and their effect (regions defined at **400 K** )

| location | AFR | IND | PAC | AMR |
|---|---|---|---|---|
| #traj | 22% | 26% | 28% | 24% |
| Tmin | 187.4 | 187.6 | 187.4 | 188.5 |
| Qsat | 1.55 | 1.59 | 1.59 | 1.84 |
| Moist entr | 20% | 26% | 27% | 27% |

⇒ Loosing regional signature

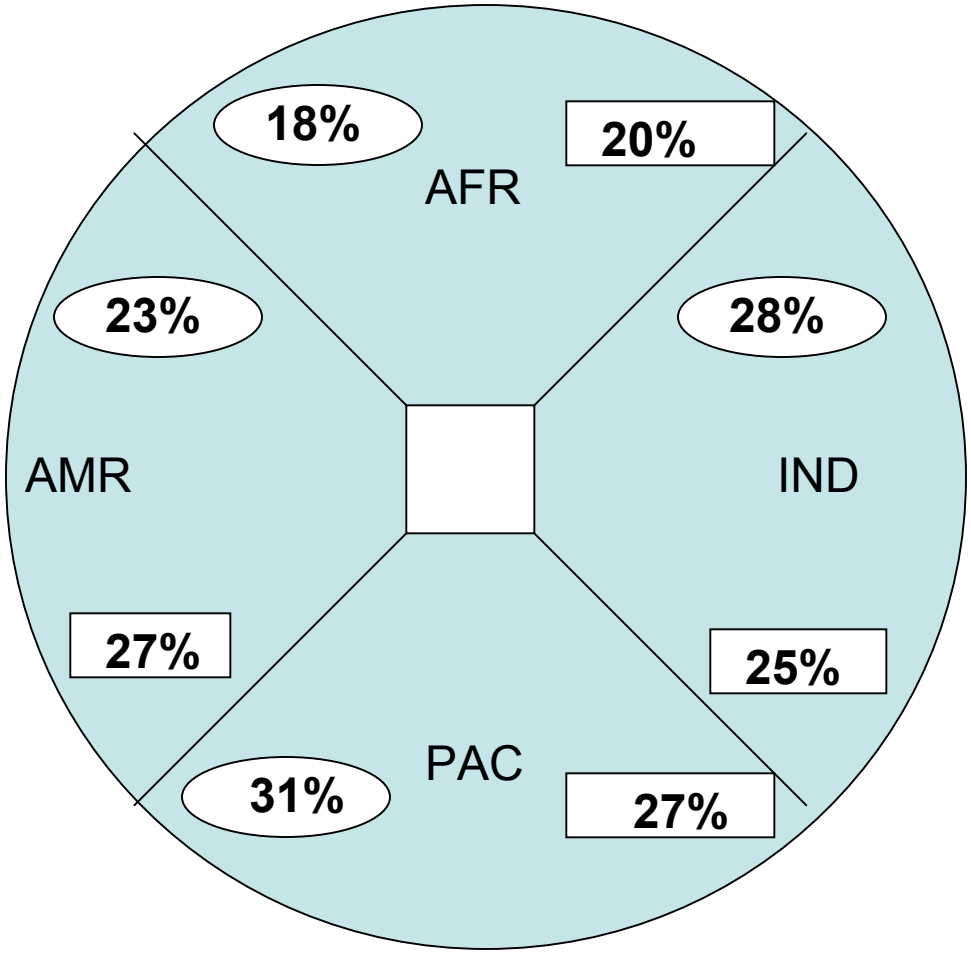
⇒ PAC / IND / AMR about equally important for moisture transport

# Air transport



# Moist transport

number of trajectories,weighted with Qsat(Tmin)



# Regional distribution, per hemisphere

| | AFR | AFR | IND | IND | PAC | PAC | AMR | AMR |
|---|---|---|---|---|---|---|---|---|
| | SH* | NH* | SH | NH | SH | NH | SH | NH |
| #traj | 200 (10%) | 203 (10%) | 193 ( 10%) | 384 (19%) | 325 (16%) | 350 ( 18%) | 219 (6%) | 355 ( 11%) |
| Transit Time to Tmin (days) | 17.6 | 16.7 | 18.0 | 18.2 | 18.0 | 18.6 | 23.0 | 17.9 |
| Path (Mm) | 20.3 | 20.5 | 20.5 | 24.3 | 22.5 | 24.5 | 28.6 | 19.8 |
| Dist (Mm) | 6.6 | 7.1 | 6.0 | 6.8 | 6.7 | 7.6 | 8.8 | 7.0 |
| Qsat(mg/kg) | 1.45 | 1.49 | 1.52 | 1.61 | 1.42 | 1.61 | 1.74 | 2.45 |
| Qsat-weighted #traj | 290 (9 %) | 303 (9%) | 293 (9 %) | 618 (19 %) | 461 (14%) | 563 (17%) | 200 (6%) | 536 (16 %) |

*) NH :PV > 0.0 at Tn;  SH: PV < 0.0 at Tn

# Lagrangian Cold Point vs. [10S; 10N]-averaged minimum temperature

Year 2004

| | regions | | | | hemispheres | | seasons | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | AFR | IND | PAC | AMR | SH* | NH* | Earth year | DJF | MAM | JJA | SON |
| Tmin | 190.7 | 189.6 | 189.0 | 190.6 | 190.0 | 190.0 | 190.0 | 188.0 | 188.4 | 192.5 | 191.0 |
| Qsat | **2.64** | 2.23 | 1.95 | 2.59 | 2.39 | 2.34 | 2.35 | 1.75 | 1.82 | **3.23** | 2.60 |
| LCPT | 187.1 | 187.7 | 187.2 | 189.7 | 187.2 | 188.1 | 187.7 | 185.7 | 187.0 | 190.2 | 188.5 |
| Qsat LPCT | 1.47 | 1.58 | 1.52 | **2.20** | 1.51 | 1.73 | 1.64 | 1.16 | 1.45 | **2.28** | 1.80 |

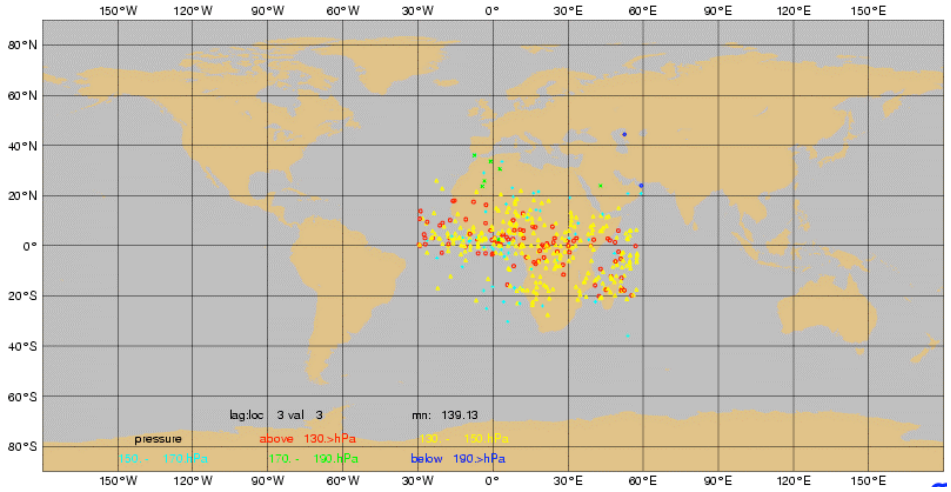
# Conclusions

- Seasonal and regional variability in Lagrangian T◊S transport has been quantified for the year 2004
- Tropical deep convection areas dominate TTL-entrance; large majority of air parcels in the TTL will not reach the overworld
- The path of an air parcel traveling from 340 K to the overworld (>400 K) via the 355K level in the TTL is by far not a vertical motion
- Air parcels typically travel long distances during 20-30 days before meeting their minimum temperature (LCPT); Afterwards air parcels rise (or fall) from the LCPT to 400K within another ~20 days
- T◊S moist transport is primarily determined by the LCPT; The number of successful trajectories is most relevant for tracers such as $CO_2$ / $CH_4$ / CO / …
- NH summer dominates moist transport but SH summer dominates tracer transport

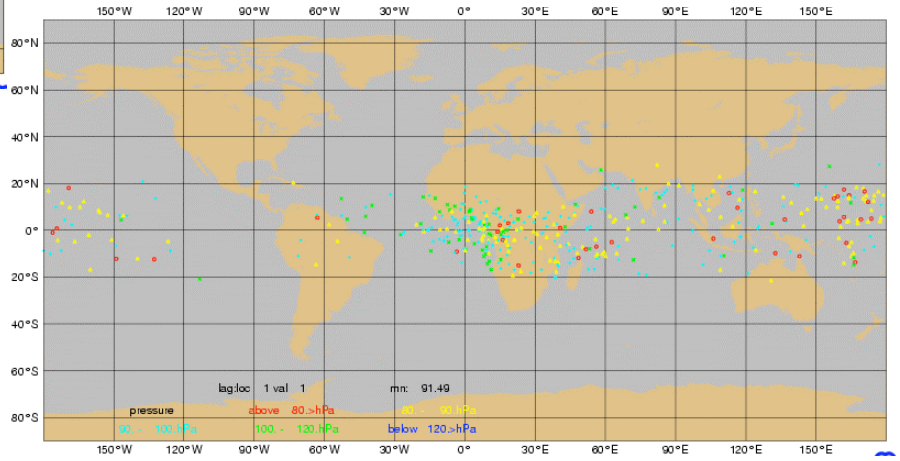
# Back up

# Locations: Africa

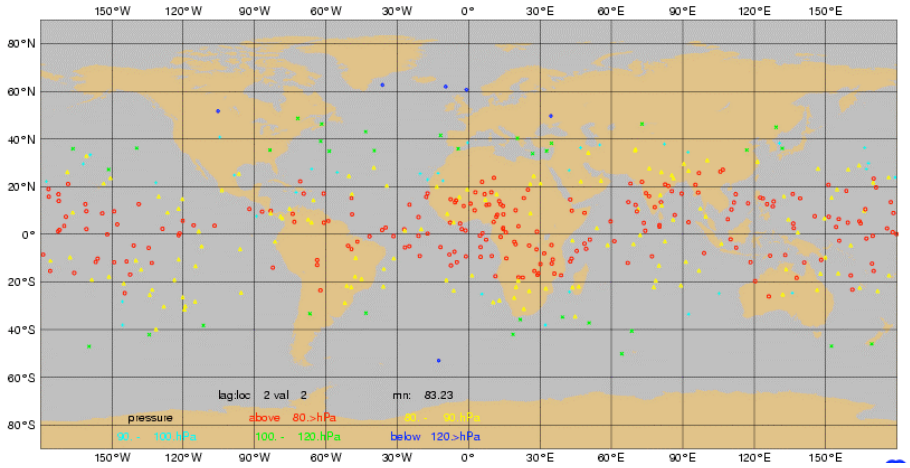
355K




Temperature minimum

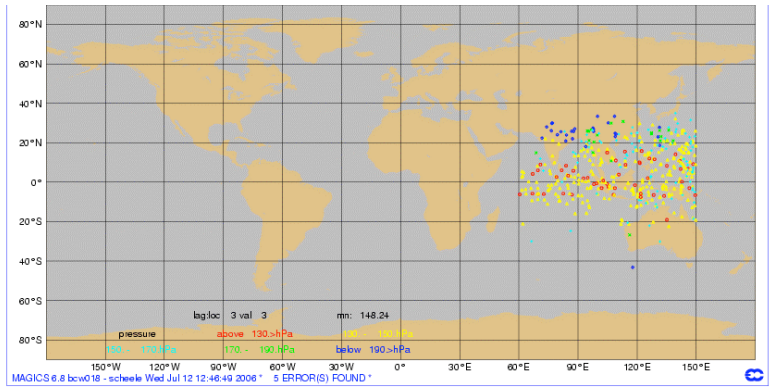



400K

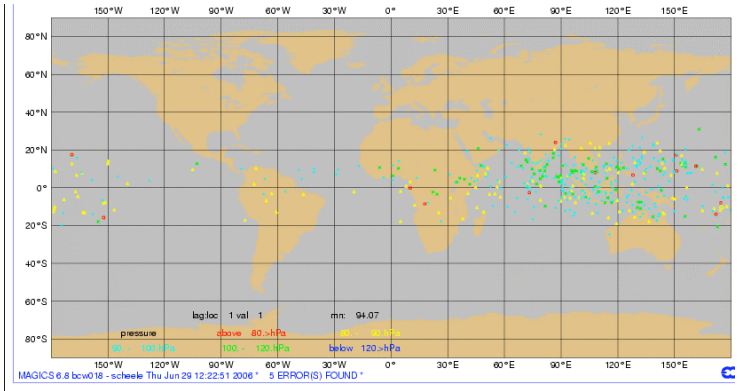


# Locations: Indian Ocean

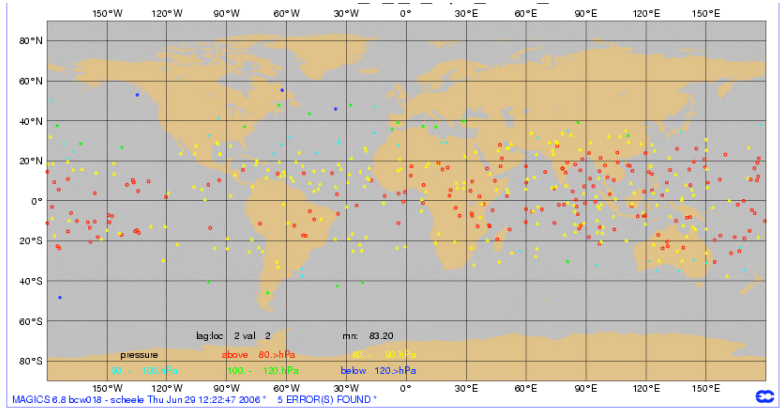
355K




Temperature minimum

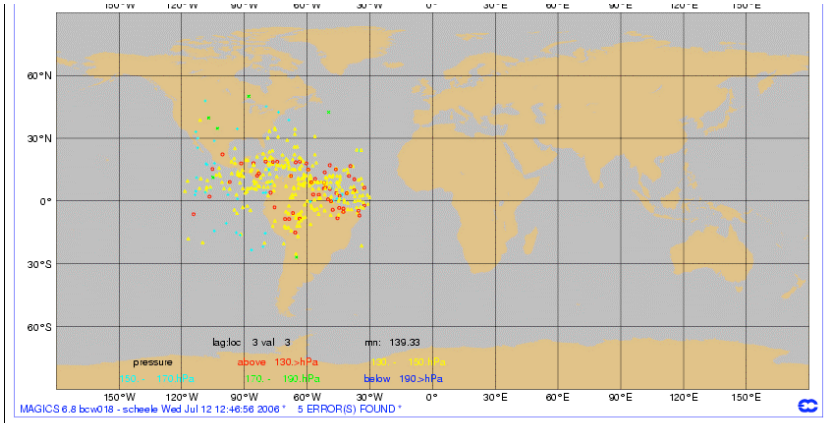



400K

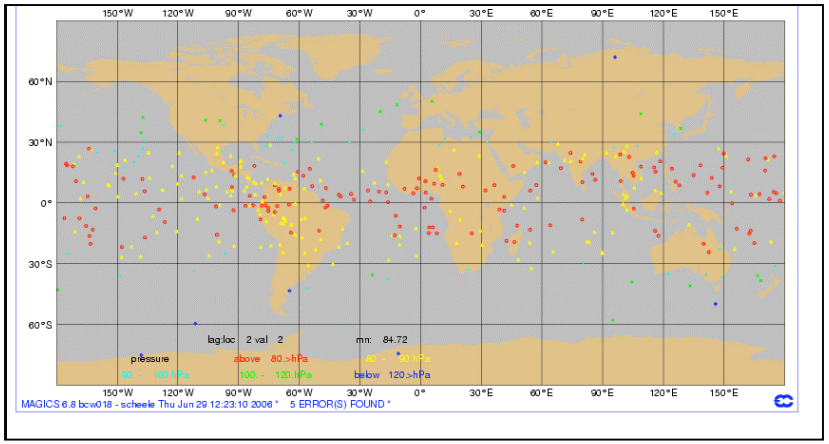


# Locations: America

355K




400K




Temperature minimum